Snohomish Basin 2060 Scenarios: Adapting to an Uncertain Future

Decision Support for Long Term Provision of Ecosystem Services in the Snohomish Basin, WA

March 2013

A project of the Urban Ecology Research Laboratory, University of Washington, Seattle with funding provided by the Bullitt Foundation

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FORWARD

The Snohomish Basin Scenarios (SBS) aim to support critical decisions for maintaining ecosystem functions in the Snohomish Basin in the long term despite irreducible uncertainty. The Project, led by the Urban Ecology Research Lab in partnership with a team of regional experts, aimed to develop and assess hypotheses about the future trajectories of ecosystem service provision in the basin by characterizing the uncertainty associated with alternative future baseline conditions. The project culminated in four scenarios presenting unique and surprising sets of future conditions. Together the four scenarios are intended to provide decision-makers with essential information for testing, monitoring, innovating and prioritizing policies in light of potential opportunities and challenges that future conditions may present. Project lessons are translated into six areas of support for making decisions under uncertainty. Scenario planning provides a systematic approach to 1) focus on system resilience rather than controlling change, 2) redefine the decision context and framework, 3) challenge our assumptions about future conditions, 4) highlight risks and opportunities that prompt creative solutions, 5) monitor warning signals of regime shifts, and 6) identify robust decisions under uncertainty.

We hope this project and report will contribute to the transformation of institutional frameworks and long term decision making in the basin towards a more resilient and anticipatory approach to maintain natural capital in the long term. To everyone who has collaborated along the way, and to all of you who are inspired to collaborate to ensure the basin a healthy future, we thank you.

Urban Ecology Research Lab

How can the Snohomish Basin Scenarios help decision makers shift the attention towards resilience?

Resilience is the capacity of a system to tolerate disturbance without shifting into a qualitatively different state that is controlled by a different set of processes. Resilience theory leans on four assumptions about the nature of coupled social-ecological systems: complexity, change, diversity, and uncertainty. At times, maintaining or enhancing the resilience of one sub-system comes at the cost of the resilience of another. Planning decisions may involve important tradeoffs that cannot be eliminated, but rather explicitly addressed in a negotiation process by various basin stakeholders. The SBS Science Team developed a set of questions to guide planners and decision makers in the complex task of assessing alternative strategies towards maintaining system resilience.

How can the Snohomish Basin Scenarios help decision makers redefine the decision framework?

A key step of developing future scenarios is to define the problem and identify the diversity of basin actors and their views. Their unique lenses stem from the diversity of values, backgrounds, and experience. The scenario building process explores shifts in decision context and tradeoffs associated with shifts in power domains (actors), problem conceptualization (information), political attention (priorities) and innovations (substitutable actions) that divergent strategies may imply. An expanded decision context helps explore strategies that are generally more 1) equitable, 2) flexible, 3) proactive, and 4) anticipatory in character.

How can the Snohomish Basin Scenarios help decision makers challenge assumptions about the future?

Scenarios focus on the 'irreducible uncertainty'- future changes that diverge from past observations. Based on the interactions of variable trajectories of multiple drivers, scenarios explore hypothetical boundary conditions beyond the scope of assumptions of predictive models. Scenarios are extremely powerful when combined with predictive modeling. Scenarios also require linking multiple social and ecological models in an integrated framework. Using the expanded boundary conditions set by the divergent scenarios, integrated models can help 1) test hypothesized trajectories and interactions; 2) refine potential relationships and feedback among variables; and 3) assess potential impacts of hypothesized futures on ecosystem services and human wellbeing. Scenarios are not an alternative to models but rather a complement to them, expanding the boundary conditions of predictive models and providing a systematic approach to deal with i uncertainties in assessing alternative strategic actions.

How can the Snohomish Basin Scenarios help decision makers highlight risks and opportunities?

One of the fundamental objectives of scenario planning is to explore the interactions between multiple critical uncertainties supporting otherwise overlooked future conditions. Scenarios attempt to highlight risks and opportunities of plausible future conditions by looking at divergent trajectories. The four Snohomish Basin scenarios describe futures where economic, social and ecological drivers vary greatly; testing regional worldviews about what is appropriate and certain. Our hypothesis is that exposing multiple divergent scenarios to planners and decision makers supports a more creative process for imagining solutions. For example, to one decision maker the growth in recreational activity in the basin may pose new pressures through the spread of invasive species, the higher market value of wildland

homes and increased carbon emissions through day-trips. However, another decision maker may see this trend as a new revenue source and a source of increased public attention and volunteering efforts.

How can the Snohomish Basin Scenarios help decision makers anticipate potential system shifts?

Scenarios help illuminate warning signals that could allow decision makers to anticipate potential regime shifts and change their strategies in a timely and effective manner. Robust strategies are effective under divergent futures, but adaptive strategies support effective action under specific conditions – depending on how the future changes. Critical sensitivities refer to potential thresholds or irreversible conditions with significant implications for multiple ecosystem services and diverse stakeholders. The most pervasive sensitivities in the basin include snowmelt, lowland productivity, and economic diversity. Multiple strategies can facilitate reduced impacts from earlier snowmelt - from upland snowpack reservoirs to lowland wider riparian and estuary buffers. The management of the basin's lowlands, including floodways, agricultural valleys, urban corridors and salmon habitat represents significant overlap and divergence of stakeholder values. Decisions over the management of these lands over the next decade will likely determine the course of the basin over the next half century. Lastly, the future of the basin highly depends on the future of aerospace engineering for its role in its economic stability. While several diverse economic sectors including the medical industry, outdoor recreation and service sectors are at play, conditions in the basin would shift dramatically depending on the actions of few key players.

How can the Snohomish Basin Scenarios help decision makers identify robust decisions?

Scenario planning aims to support decision making under uncertainty by providing a systematic approach to assess the robustness of alternative strategies under a set of plausible future conditions. The SBS explore divergent future conditions that can emerge from the interaction of uncertain trajectories characterizing a major vs. a minor potential climate change (magnitude and variability) and diverse trajectories of change in social values that characterize the relationship of society with nature (mastery vs. harmony). Climate change and social values are the two driving forces selected by the project Science Team to represent the critical uncertainties influencing the future of the Snohomish Basin. In our research we have found that investments in natural capital, including upland intact forests, corridors of riparian habitat, and both above and below ground reservoirs represent strategies that are most robust under uncertain futures providing co-benefits and wider buffers for increased pressures and variability of key driving forces.

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EXECUTIVE SUMMARY

The Snohomish Basin

The Snohomish Basin[1] is a vast forested landscape draining from the Cascade Range to the Puget Sound. The greater Seattle Metropolitan Area relies heavily on the ecosystem services provided by these natural lands, from drinking water and biodiversity, to carbon storage and recreation. In fact, it is estimated that the Snohomish Basin provides more drinking water than any other Basin in the State [1], is one of the primary producers of salmon in the Puget Sound region [2], and supports more carbon stock per acre than any other basin in the Puget Sound[2] [3]. With over 600,000 acres of protected lands, it is one of the greatest recreation destinations within thirty minutes of a metropolitan area in the state.

Figure ES.1: Map of the Basin

Past Trends

The Snohomish Basin is also one of the fastest growing areas in the state. With major employers including Boeing, Providence Regional Medical Center and Microsoft nearby, the basin attracts employees and corresponding development growth. Over the last fifty years, the basin has shifted from supporting a largely rural population to an urban population, and along with this change it has seen dramatic transitions in landscape character, resource consumption and governance. Urban growth and ecosystem service provision don't have to be at odds with one another, but they certainly pose important challenges and tradeoffs.

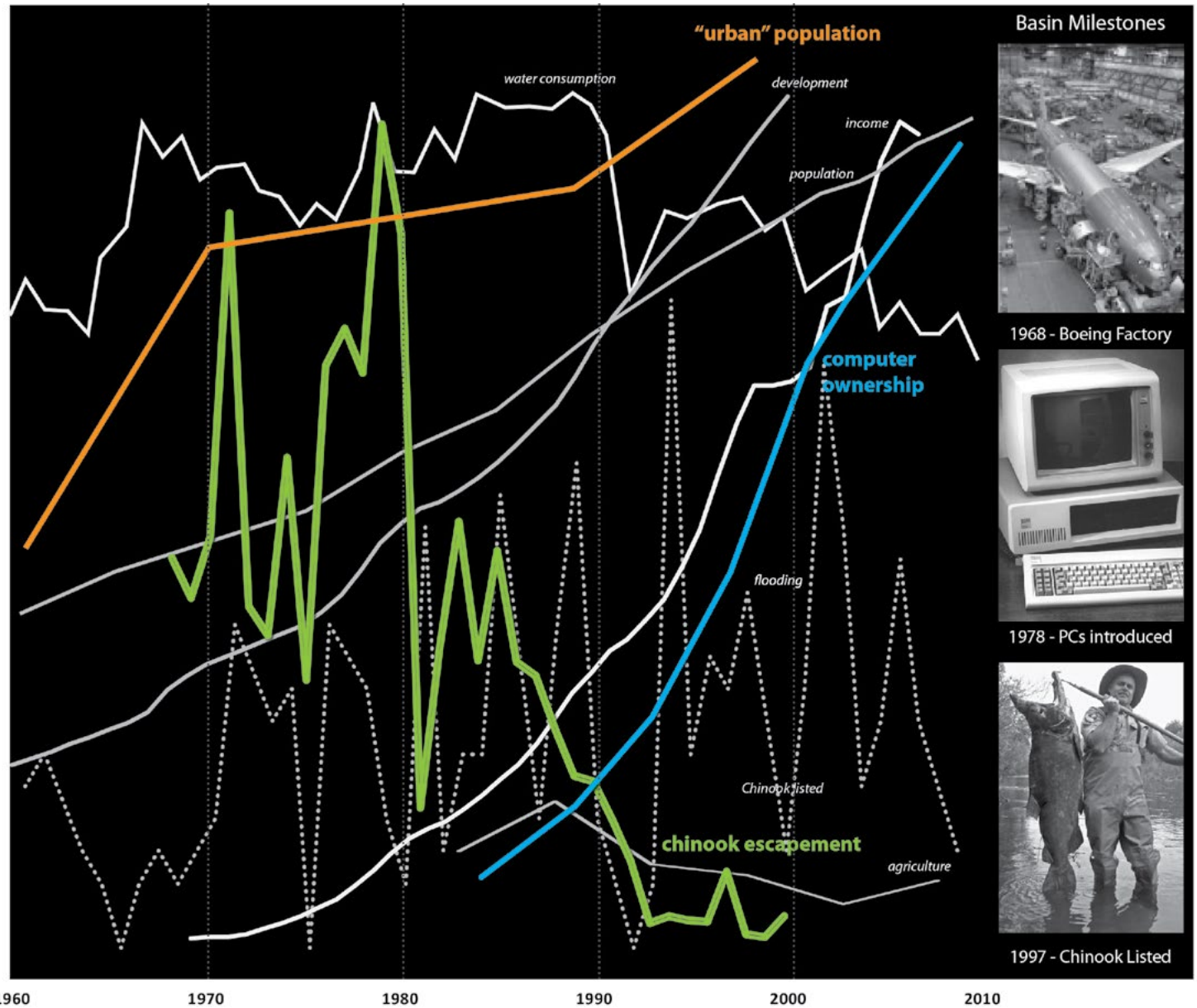


Figure ES.2: Past Trends

Future Trends

Looking out to the next fifty years, the Snohomish Basin faces many critical challenges in balancing social, economic and ecological health. Strategies that decision-makers and land managers employ today will influence the basin's ability to continue to provide the very ecosystem services that are needed to successfully support the growing population. Future conditions in the basin, controlled largely by external drivers, will change how effective regional strategies are at maintaining ecosystem service provision. The direction of technological innovation, the pace of climate change, the transformation of social values, the regulatory strength of government, global economic markets are all parts of the complex socio-ecological system governing ecosystem service provision in the basin. However, there is great uncertainty in predicting future conditions due to the complex interactions between multiple drivers at various scales.

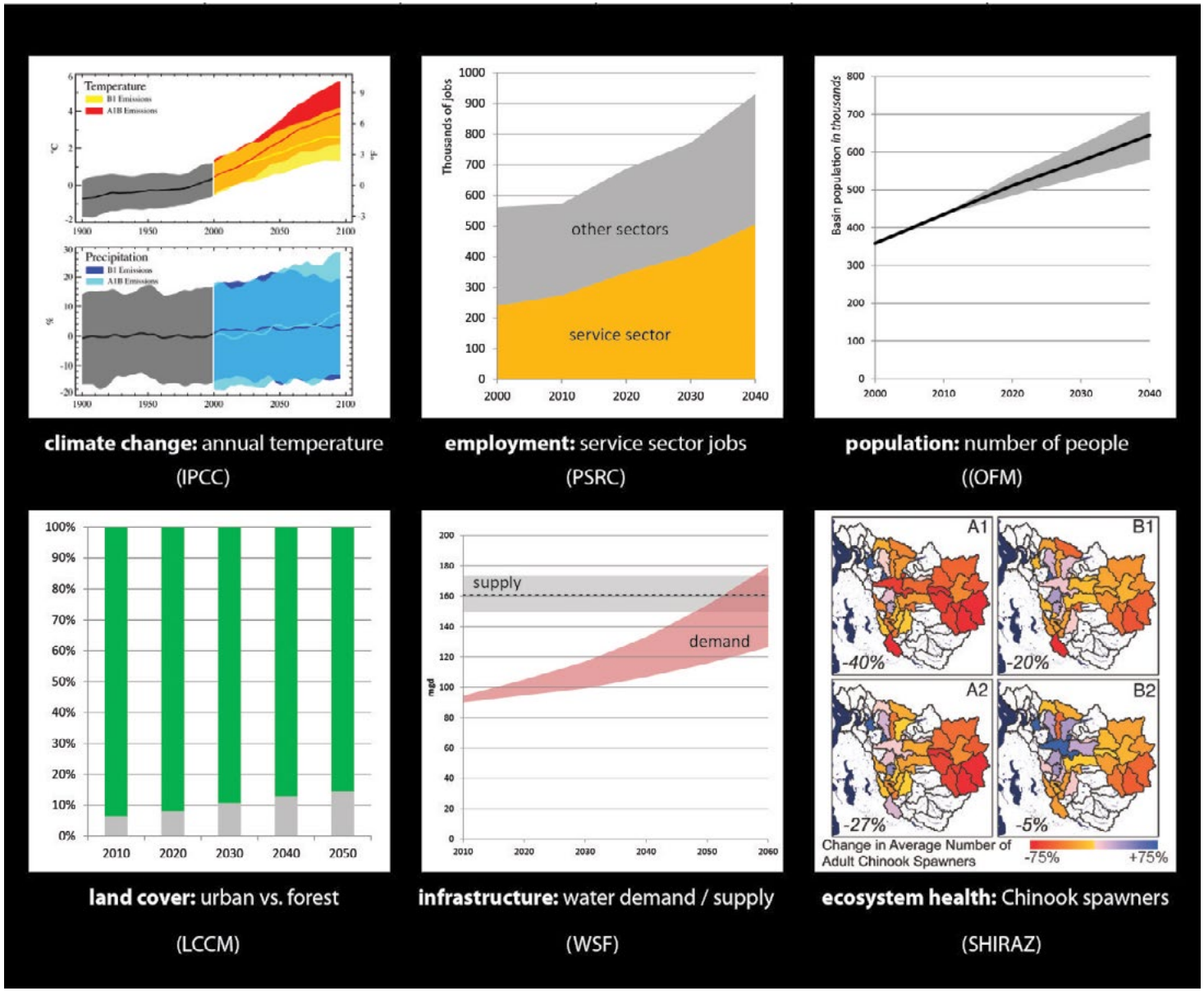


Figure ES.3 Future Trends

Project Approach

The Snohomish Basin Scenarios project characterizes the future uncertainty of the basin through four alternative future scenarios for the Snohomish Basin. The project was initiated in the summer of 2010 by the Urban Ecology Research Lab (hereafter referred to as UERL), housed at the University of Washington and under funding from the Bullitt Foundation. The primary approach of the Snohomish Basin Scenarios project was 'scenario planning'. This approach is intended to support robust decision making by characterizing alternative futures that influence the efficacy of strategic solutions. For example, what might happen if major climate change is coupled with an economic recession?

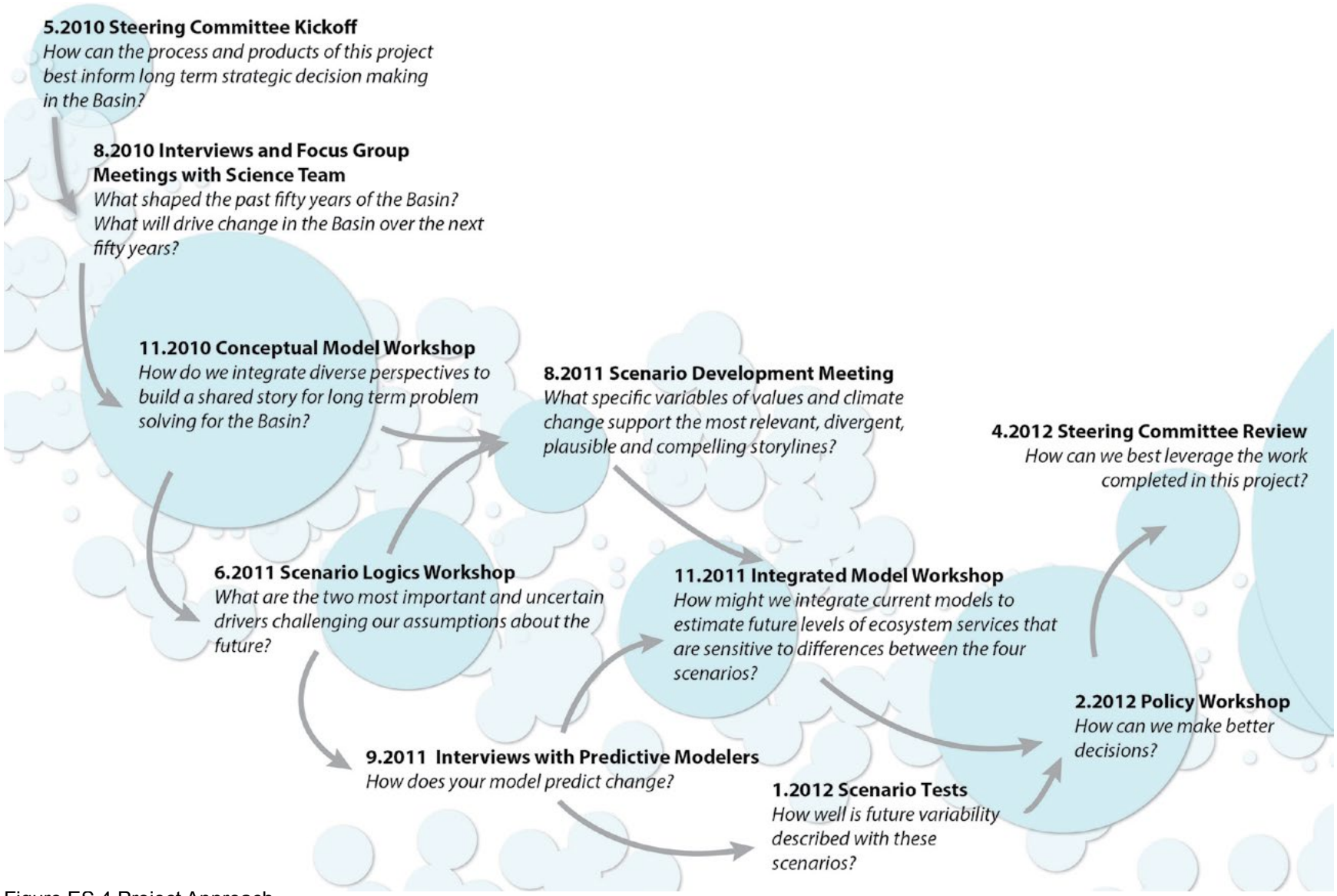


Figure ES.4 Project Approach

Project Partnerships

Scenario planning is a collaborative process grounded on the experience of diverse expertise and perspective of multiple stakeholders. The Snohomish Basin Scenarios is the result of a 2-year process involving over one hundred regional experts, representing over fifty agencies, and collectively volunteering over a thousand hours of their time. The project direction was informed by a steering committee of a dozen regional decision makers. The content of the scenarios were developed and tested with a science team of hydrologists, ecologists, economics, developers, utility analysts, naturalists, demographers, among several other disciplines. The final scenarios were interpreted in terms of their salience for regional decision makers with a team of stakeholders.

Norm Abbott
Jackie Aitchison
Marina Alberti
Sue Ambler
Dom Amor
Stanley Asah
Elaine Babby
Krista Bartz
David Batker
Kurt Beardslee
William Beyers
Bob Bilby
Christopher Bitter
Michael Blake
Heidi Bohan
Leah Bolotin
Branden Born
Alan Borning
Ann Bostrom
Mark Boyar
Nicholas Bratton
David Buerge
David Burger
Bob Burns
Ann Bylin
Dennis Canty
Ken Carter
Michelle Connor
Paul Byron Crane, B.L.A., M.A.
Sara Curran
Curtis DeGasperi
David Dilgard
Mary Embleton
Gina Estep
Nicole Faghin LEED AP
John Findlay
Jim Franzel
John Gamon
Simon Geerlofs
Bonnie Geers
Jamie Glasgow
Jonathen Guzzo
Andy Haas
Troy Hall
Alan Hamlet
Chris Harvey
Kelly Heintz
Ryan Hembree
Jan Henderson
Judy Herring
Kollin Higgins
Abby Hook
Peter Jackson
Jennifer Jerabek
Janne Kaje
Alice Kelly
Kristin Kelly
Michael Kern
Karen Kinney
Jacque Klug
Deborah Knutson
Bill Knutson
Dave Kosciuk
Sarah Krueger
Brent Lackey
Sim Larkin
Joan Lee
Tom Leschine
Dennis Lettenmaier
Roberta (Bobbi) Lindemulder
Sandra Mallory
Mike March
Stewart Matthiesen
Matt Mattson
Mark Maureen
Heike Mayer
Doug McClelland
Al McGuire
Marcia Meyers
Phyllis Meyers
Anna Miles
Jim Miller
Barbara Mock
John Monroe
Dave Montgomery
Scott Moore
John Moore
Tom Niemann
Tom O'Keefe
Deborah Oaks
Craig Partridge
Mike Pattison
Thomas Payant
Dave Peterson
Chris Picard
Patrick Pierce
Philip Popoff
John Postema
Scott Powell
Chris Raezer
Kit Rawson
Dave Redman
David Remlinger
Casey Rice
Luke Rogers
Mary Rucklehaus
Michael Rustay
Eric Salathe
Rowan Schmidt
Morgan Schneidler
Howard Schwartz
Mark Simonson
Amy Snover
David Somers
Cindy Spiry
Julie Stangell
Stephen Stanley
Andrew Stout
Don Stuart
Jeannie Sumnmer-hays
Ralph Svrjcek
Brett Swift
Debbie Terwilleger
Jim Teverbaugh
Dan Tonnes
Joe Tovar
Mike Town
Stacy Trussler
John Ufford
Anne Vernez Moudon
Elizabeth Walker
Tim Walls
Elizabeth Weldin
Richard White
Jan Whittington
Matt Wiley
Daryl Williams
Terry Williams
Clark Williams-Derry
Kathy Wolf
Hendrik Wolff
Ken Yocom
Yi Zhao
Ken Zweig

Figure ES.5 Partner list

The Four Scenarios

The Science Team identified climate change (magnitude and variability) and social values (relationship between society and nature) as the two most important and uncertain drivers influencing future conditions in the Snohomish Basin by 2060. These two drivers shaped the final four scenarios, or stories, which describe alternative trajectories, challenges, and opportunities for maintaining ecosystem service provision.

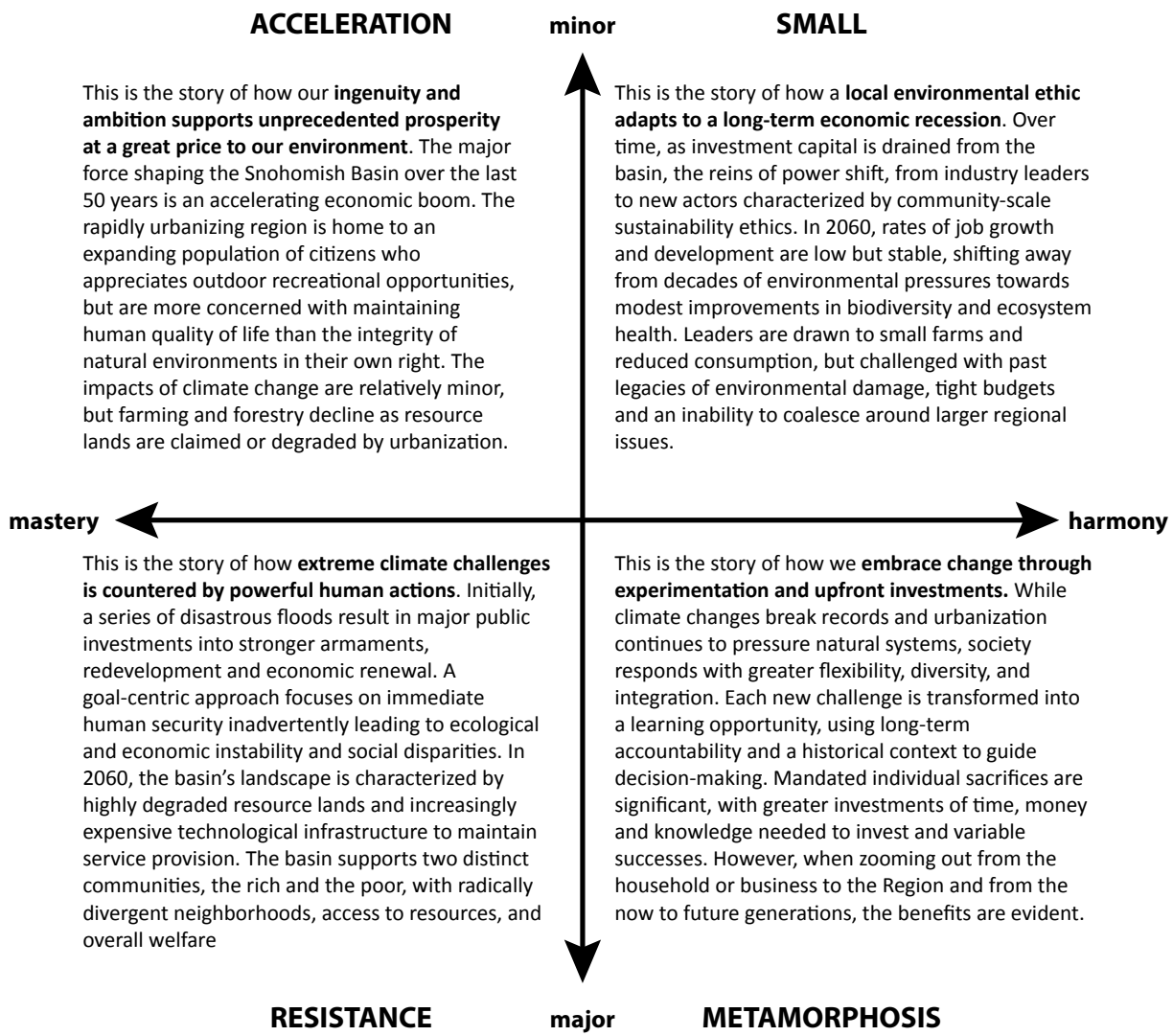
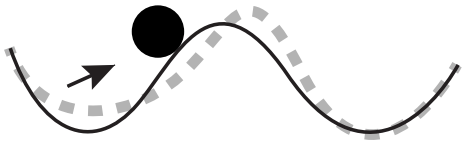


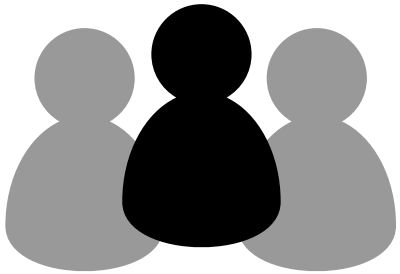
Figure ES.6 The Four Scenarios

Project Lessons

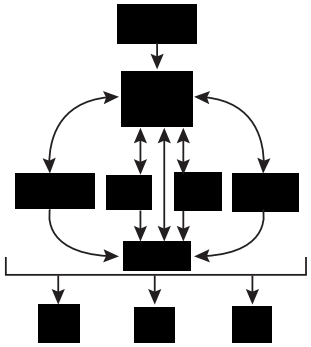
This report is oriented towards policy makers and planners. Project lessons are translated to reflect policy implications and future research arenas. Project lessons are broadly grouped into six areas of support that: 1) shift the focus to **Resilience** to consider the irreducible complexity and uncertainty of the system; 2) Redefine the **Decision Context** to expose multiple perspectives and shifting power domains; 3) support a blueprint for an **Integrated Predictive Model** to test the sensitivity of system components to expanded boundary conditions; 4) **Highlight Risks and Opportunities** that support a more creative and inclusive policy formation; 5) **Illuminate Warning Signals** to increase our anticipatory capacity and flexibility and 6) **Identify Robust Strategies** that are effective across divergent yet plausible future conditions.



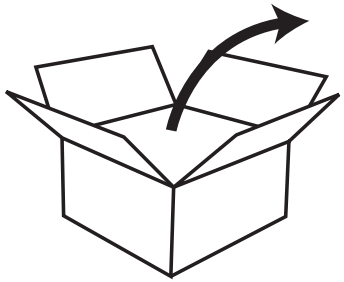
Shift Focus to Resilience



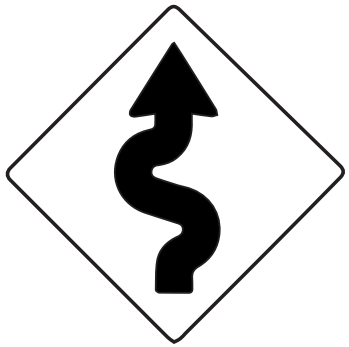
Redefine Decision Context



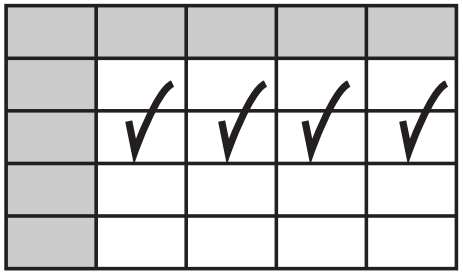
Integrate Predictive Models



Highlight Risks and Opportunities



Illuminate Warning Signals



Identify Robust Strategies

Figure ES.7: Project Lessons

CHAPTER 1 INTRODUCTION

1.1 Problem Definition

Ecosystem services reflect the multitude of benefits that are supplied by natural ecosystems. Examples include provisioning services (food, water, fiber); regulatory functions such as water and carbon cycling; cultural benefits including aesthetics, and recreational and spiritual values; and supporting services such as nutrient cycling and soil formation[4]. The Snohomish Basin provides many ecosystem services. According to a recent Earth Economics report the basin currently provides between $383.1 million and $5.2 billion in benefits every year including flood protection, water supply, climate regulation, fisheries, food production, critical habitat and waste treatment [5]. In this report we focus specifically on 6 broad groups of ecosystem services: water quality, water quantity, carbon stocks, carbon fluxes, habitat provision and species diversity. While current decisions about job growth, transportation infrastructure, new schools, agricultural production and trailhead protection do not have ecosystem service provision as their focus, the long-term health of the basin is inseparable from these investment decisions. Decision makers need to be able to assess the implications of alternative actions on these shared resources in order to protect them effectively. However, the Snohomish Basin is characteristic of a coupled human natural system in which changes by one set of agents, whether a developer (human system) or a stand of trees (natural system), influence the benefits of the other. Predicting the future condition of ecosystem services in this type of system is very difficult due to the complexity of network interactions.

Over the next decade, public decisions by basin actors will become increasingly encumbered by the number of affected parties, the information available and required to support decision-making, and both the complexity and uncertainty of interactions among important variables shaping the future. An example is today's critical decision facing the basin known as the 'Farm-Fish debate', a struggle to find ways to simultaneously support productive farms and maintain salmon viability in the basin's lowlands [6]. The challenge is to incorporate the needs and knowledge of the Tulalip Tribes, the farming community, ecologists, planners, businesses and residents. To address this challenge, decision-makers need to take into account the future implications of upland development, food security, climate change, and loss of cultural heritage associated with the interaction between multiple drivers of change [6]. This decision is emblematic of the types of complex multi-actor resource decisions that will challenge the basin's decision-makers in the future.

Decision-makers are faced with allocating limited resources while resolving conflicting interests and coordinating with jurisdictions that increasingly overlap over resource management [7]. Critical decisions are delayed in the effort to support extensive and controversial cost-benefit analyses, and due to disagreements regarding the assessment criteria. Meanwhile, critical decisions are suspended, incur paralyzing additional costs, and exhaust the time and interest of assigned committees. The Snohomish Basin Scenarios[3] provide an alternative approach for decision-makers to move forward despite irreducible uncertainty, and to make more informed decisions by integrating the uncertainty into the decision-making process.

1.2 Project goal + critical decisions

The objective of the Snohomish Basin Scenarios project is to support critical decision-making. Critical decisions are actions with pervasive long-term implications. In the context of this project, these decisions specifically focus on the investment of time, resource and money by actors with implications for the basin's ability to maintain *ecosystem service provision*. Three objectives frame the project's approach and products:

- Identify critical **factors** driving the future urban growth and associated environmental change in the basin.
- Systematically assess the impacts of future scenarios on essential **ecosystem services** focusing on *biodiversity*, *water*, and *carbon*.
- Collaborate between a diversity of **experts** and stakeholders to identify opportunities and develop a set of robust strategies to maintain human and ecosystem wellbeing under alternative futures.

CHAPTER 2: SCENARIOS FOR THE SNOHOMISH BASIN

2.1 What has driven change in the Snohomish Basin over the last fifty years?

The last fifty years in the Snohomish Basin were marked by unprecedented urban growth; 550,000 [8] additional people, living in 210,000 [9] households, developing an estimated 40,000[4] [10] acres of urban land and over 20 [11] times the total income of a half century earlier. Global socio-political, technological and ecological events have shaped the world around the basin during the last fifty years. From the end of Apartheid to the end of the Cold War, civil rights and international relationships have evolved in transformative ways. From the first man on the moon to Web 2.0, access to information has infiltrated every corner of the world. From Silent Spring to Chernobyl, to the tsunami of 2011, the environmental movement has altered how society perceives the natural environment. Through these global events, the basin has held a front seat, from the revolution of computers to the establishment of Microsoft headquarters, from the environmental movement to the listing of the spotted owl and the Chinook salmon. The first step in the scenario process involved closely examining the historical factors that have shaped the current basin conditions through interviews with the Science Team. While several variables have shaped the basin today, three recurrent stories emerged.

The Computer Age: How innovation influenced industry and everything around it.

Over the past fifty years, industry jobs have shifted from factories, farms, and construction to desk jobs. The basin lost acres of dairy farms and active timber to aerospace manufacturing and Microsoft. Today, basin residents are six times more likely to be working in the service industry than in resource extraction (e.g. farming, forestry, and manufacturing) [12]. As the service sector grew, factories, mills – and the infrastructure to support industries – were replaced with office buildings and stores [13]. The City of Smokestacks became the all American City [14], and the demographics of the basin changed alongside it. Computers altered the approach for conducting businesses, from picking lettuce to accessing health records [13,15], As computers entered every business and household, people's access to information changed. Today's opportunities and challenges, from technological security threats to networking and social media, were inconceivable for the average basin resident in 1960.

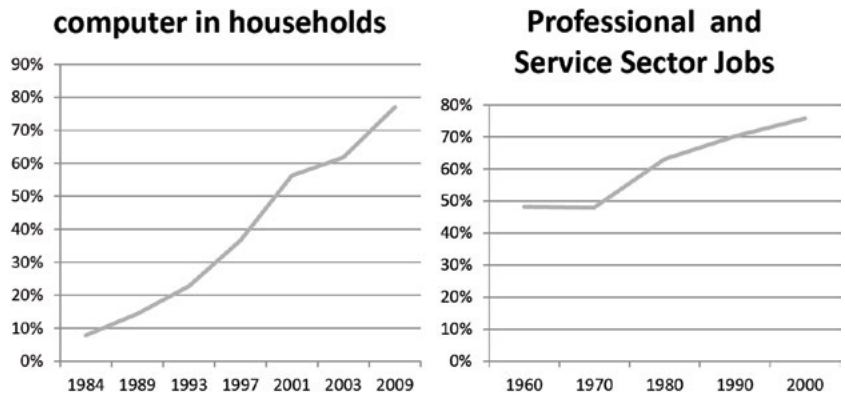


Figure 2.1 The Computer Age Trends

Social and Environmental Equity: How human impact on society and the environment changed the role of government.

Silent Spring and the establishment of the U.S. Environmental Protection Agency marked a new era of assessing human impacts on the environment, and of greater awareness about the limitations of our natural resources, once perceived as inexhaustible [16]. The basin is home to unique and sensitive species such as the spotted owl and Chinook salmon, which have significantly influenced the region's[5] economic base and development regulations over the past few decades [17]. Simultaneously, national and global social values have emerged: civil rights have expanded, more women have moved into the workforce, and Native Americans have received greater protection [18,19]. As a greater percentage of the population became endowed with rights, their participation in, and access to public decision-making grew too, significantly expanding the complexity of the decision-making process.

Timeline of Social and Environmental Equity Events

1962 Carson publishes Silent Spring
1964 Civil Rights Act passed
1964 Wilderness Act enacted
1970 EPA established / Earth day celebrated
1972 DDT is banned
1973 Endangered Species Act
1973 Abortion legalized in US
1974 Boldt decision reaffirmed
1976 No-tilage Agriculture popularized
1978 The American Indian Religious Freedom Act passed
1979 Tulalip revives First Salmon ceremony
1985 Ozone Hole discovered
1988 IPCC established
1990 Native American Graves Protection and Repartriation Act passed
1991 Apartheid Laws repealed in South Africa
1992 Official end of Cold War
1993 'Don't ask don't tell' policy implemented
2012 WA legalizes same sex marriange

Figure 2.2 Social and Environmental Equity Trends

Urban Neighbors: How changing demographics changed living standards and expectations.

The average basin resident today has an income more than ten times that of his 1969 counterpart [11]. He is 20% more likely to be African American, Hispanic or Asian and 50% more likely to have a college education [20]. Higher household income, ethnic diversity and educational attainment is characteristic of urbanization patterns. Urbanization changes happened very quickly, with urban populations nearly doubling between 1980 and 1990 [21]. According to the US Census, 86% of the basin's population was living in urban areas in 2000, compared with only 40% in 1960 [21]. These households are more likely to commute more than 10 miles to work outside the basin [22], to live in a house larger than 2,000 [23] square feet, and to spend over $5,000 a year on entertainment [24]. These new urban neighbors have grown to expect urban amenities from their small towns, dramatically shifting municipality budgets. These expectations extend across fence lines to their rural neighbors, imposing restrictions on working lands, from access to open space to the ways operations are conducted (e.g. delivery times, clearcuts, and pesticide applications) [17,25].

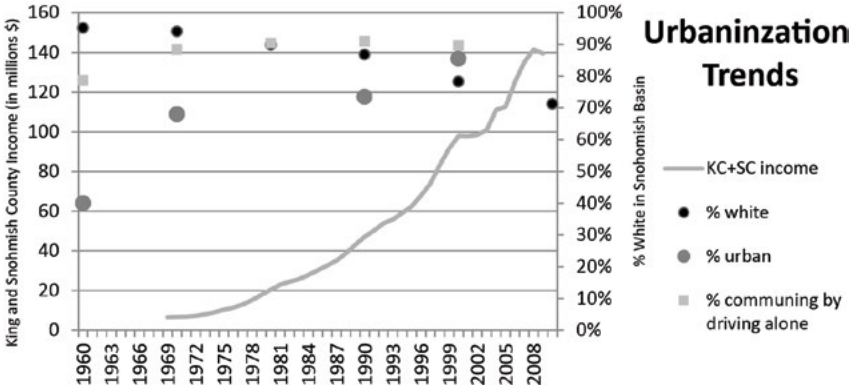


Figure 2.3 Urban Neighbor Trends

2.2 What drivers will be influential in shaping the next 50 years in the basin?

The rich legacy of the basin's past will, in many ways, influence its future. The Puget Sound will continue to attract in-migration for its myriad growth opportunities, supporting additional urbanization with more jobs, more development, and increased demand on supporting infrastructure [26]. In parallel, the population will continue to age and become more ethnically diverse, especially in its Hispanic and Asian communities [27]. Globally, technological innovation will accelerate, making technology ever more accessible and dominant in our lives [28]. Ecological challenges will also accelerate, as more people depend on increasingly stressed natural resources. Also certain will be the increasingly important role of climate change, as global temperature rise and extreme events threaten global communities.

Despite our knowledge of current trends, the trajectories of future change are largely unknown. The future will plausibly be shaped by surprise events, perhaps a volcanic eruption or massive forest fire. Perhaps an innovation will eliminate carbon emissions, or a new major employer will replace aerospace as the leading industry in the basin. However, much of the future's uncertainty will be shaped by the timing, magnitude and novel interactions of the trajectories of drivers influencing the basin today.

Global **climate change** impacts have already been observed in the region through recent fluctuations in several biophysical variables. Average temperatures have risen by 1°C per decade, snowpack has been melting earlier in the year, and indexes of extreme events have shown greater variability than historical trends [29].Over the next fifty years, the uncertainty of climate impacts, both globally and locally, includes the degree of warming, the variability of seasonal precipitation, the magnitude of sea level rise, and the pace of change overall. Further complicating model predictions are the complex relationships and feedback both between climatic variables and between those variables and the contextual landscape [30]. In the basin, critical uncertainties include the rate and extent of change in snowmelt and seasonal streamflow [30], groundwater recharge [31], and the resilience of forest [30] and salmon to additional stressors [32].

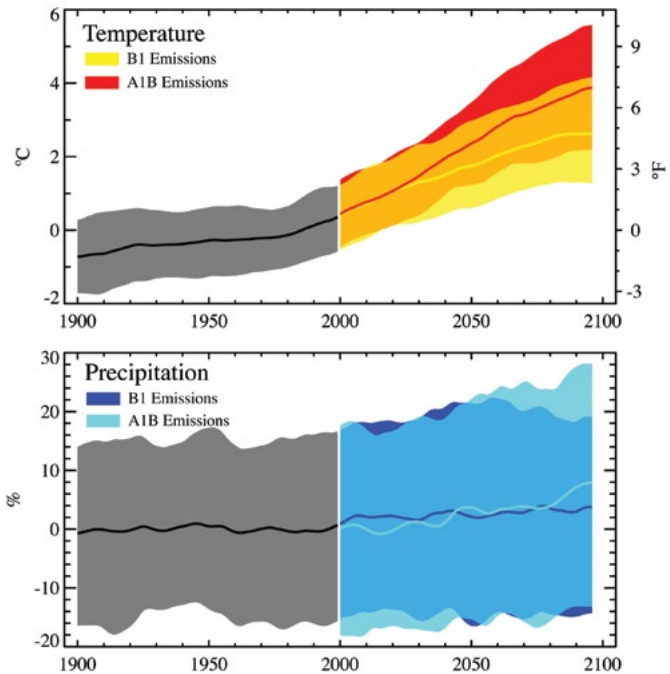


Figure 2.4 Regional Climate Forecasts

Simulated temperature change and percent precipitation change for the 20th and 21st century global climate model simulations for the Pacic Northwest. The black curve for each panel is the weighted average of all models during the 20th century. The colored curves are the weighted average of all models in that emissions scenario ("low" or B1, and "medium" or A1B) for the 21st century. The colored areas indicate the range (5th to 95th percentile) for each year in the 21st century. All changes are relative to 1970-1999 averages [30].

Economic forecasters [33,34,35] agree that service-sector jobs (from gas station attendants to software developers) will continue to dominate job growth. Meanwhile manufacturing and resource-based jobs (timber and farming) are forecasted to decline in the basin [36]. These trends are consistent with urbanization patterns seen across the globe. However, job trends are highly uncertain when we look out fifty years [37]. Future growth sectors are tied to fluxes in global markets (e.g. competition with China), governance (e.g. the strength and size of government and the cost of environmental regulations), innovations (e.g. the next 'Dreamliner' or 'Amazon'), and worldviews dictating social relationships to the natural environment (e.g. an organic Snoqualmie Valley or energy pellets as upland forestry practices). The variability of long term shifts is greater when we focus on regional and local scales. Economic sectors will shape demographic composition (age, education, diversity, values), changes in the built environment (location and type of development and resource lands), and implications for ecosystem health (e.g. forest conversion, pollution).

Future **population growth** is forecast based on rates of natural change (i.e. fertility and death) and migrations [37]. The basin's population is predicted to increase by an additional 210,000 [36] people by 2040; over 80% of them will reside in its western half [36]. How will that population choose to live, in terms of the footprint

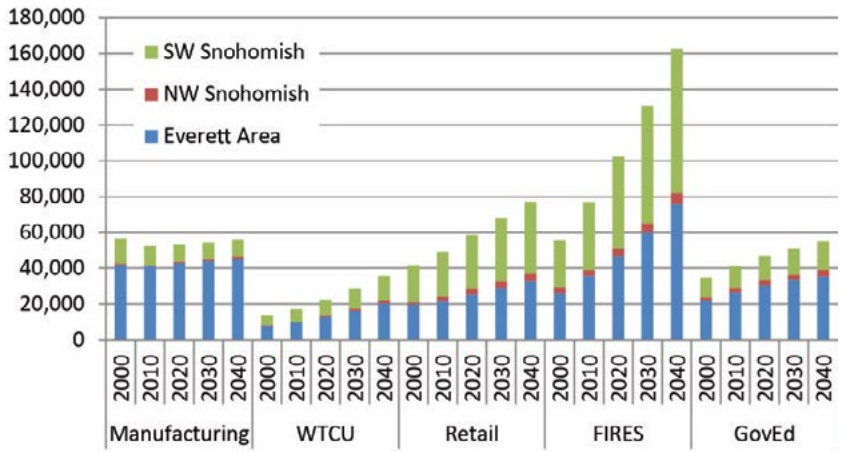


Figure 2.5 Job Forecasts by Sector

Between 2010 and 2040 the King and Snohomish Counties are forecasted to grow by an additional 520,000 jobs and 160,000 jobs, respectively. The majority of these jobs will be within the financial, professional, business and educational services sectors (FIRES). The Basin is forecasted to increase by an additional 150,000 jobs between 2010 and 2040, 57% of these additional jobs are forecasted for the FIRES sector. Manufacturing is modestly forecasted to grow by 2%. King and Snohomish Counties overall are forecasted to lose over 17,000 jobs [36].

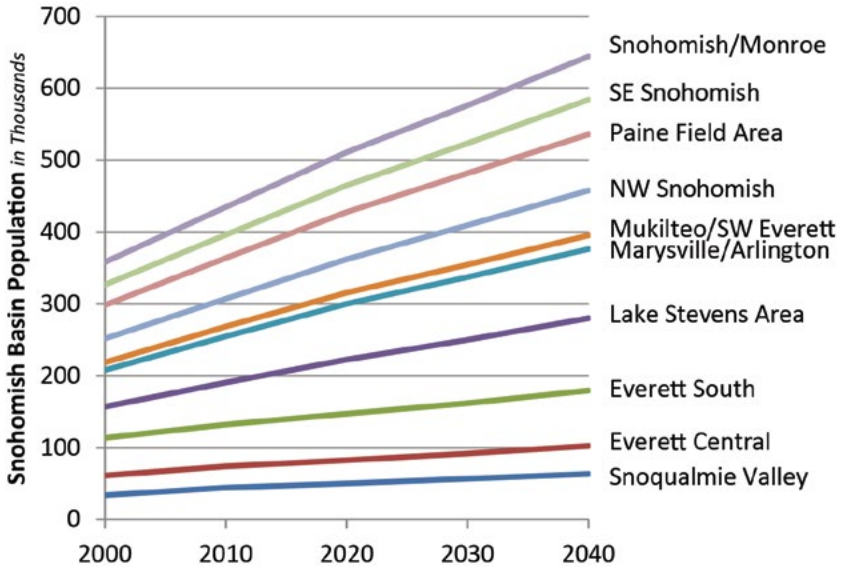


Figure 2.6 Demographic Forecasts

PSRC 2006 trends are based on declining rates of growth in both King and Snohomish Counties. While the growth rate was 9% in King and 21% in Snohomish County between 2000-2010, the rate is forecasted to decrease to 7.5% and 12%, respectively, between 2030-2040. If 2000-2040 trends were extended linearly to 2060, the Basin could be forecasted for an additional 350,000 people in the Basin (2010-2060) [36].

of their houses, the number of cars and commuting distances, the consumption of resources from water and energy to exports, and the types of policies they approve? All these changes will lead to cascading shifts in development patterns, infrastructure demands, resource management and governance structure.

Currently, over 66% of the basin is forested [38], and 25 percent of that forested land is protected from **development** as wilderness areas [39], conservation easements, parks [40], etc. The magnitude of population growth and of restrictions on development on undeveloped lands will largely determine the future land cover pattern in the basin. Based on past trajectories and land availability, urbanized areas are forecast to more than double by 2050, while agricultural lands, grasslands and lower elevation deciduous and mixed forests will be drastically reduced [38]. If growth pressures have been over-estimated and mechanisms for land protection

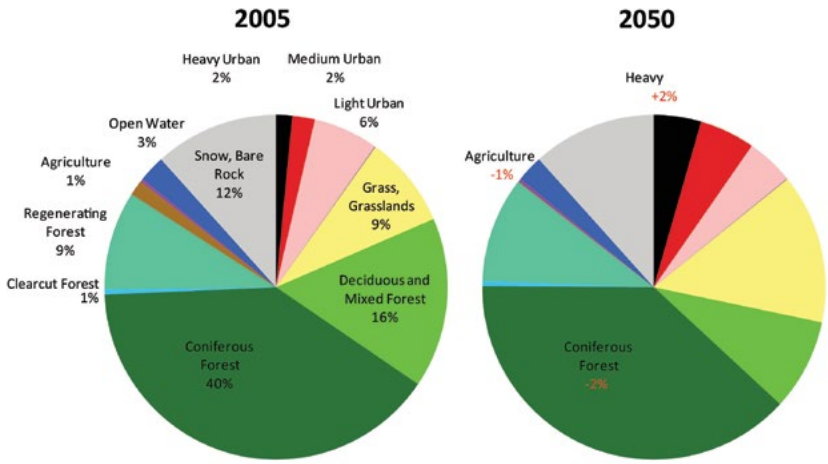


Figure 2.7 Land Cover Forecasts [38]

(zoning, conservation, household preferences for higher densities) are under-estimated, urban development and the conversion of natural lands will be minimal. Alternatively, higher development pressures and looser protections may culminate in sprawling development, eliminating nearly all the unprotected natural lands over the next fifty years[6] [41].

Future estimations for **energy and water provision** currently predict sufficient resources to support future urban growth, at least to 2050 [52]. Forecasts are based on assumptions about future demand

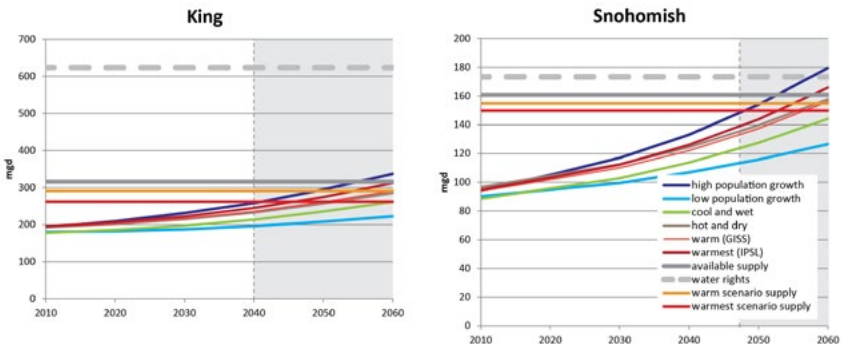


Figure 2.8 Water and Energy Provision Forecasts

Three sets of alternative demand scenarios were run by the Water Supply Forum. Population growth was forecasted using low population and high growth. The forecast also included a 2.5% below baseline and 3.5% above baseline employment growth. Weather Forecast utilized historic temperature and precipitation data to forecast alternative future weather parameters. The projected impacts of climate change utilized the A2 and B1 SRES emissions scenario. In addition to demand, supply was explored. The total amount of supply is dictated by water rights. Surface water supply is forecasted to change as a result from the expected seasonal shift in streamflow, with less runoff in late spring and early summer months, which have traditionally marked the reservoir refill period of the region's supply reservoirs. The above graphic does not represent new planned or proposed projects which will increase water supply in each County [1].

(population, industry growth), efficiencies (conservation and innovative technology, and supplies (current stocks and portfolio of new sources) [1]. Climate impacts will inevitably influence service provision in the basin; uncertain, however, are the magnitude of impact and the ability of utility providers to continue reliable service despite these challenges [1].

Over the next fifty years, the **health of ecosystem services** in the Snohomish Basin is predicted to deteriorate with increased urbanization, consumption, and climate changes. Salmon populations have been the center of attention for several decades, but their future fate is largely unknown [43]. Even if we manage to protect and restore estuaries and riparian habitat, reduce upland impervious development to slow down runoff, and improve fish passage through numerous culverts and dams, the future fate of salmon is highly uncertain [44]. Changes in the future viability of salmon have already been put into play by past legacies that we cannot reverse, from climate change to the clearing of old-growth forests and contamination of groundwater. Salmon are just one example of the many future challenges to protecting the basin's ecosystem services. Urbanization and climatic changes will influence the health of upland forests [1,17], of stream habitats and the nearshore environment, cascading implications to all of the basin's functions and species [45,18]. While highly dependent on shifts in social values and environmental regulations, great uncertainty lies in the resilience of our ecosystems, critical thresholds, and the role of system feedbacks.

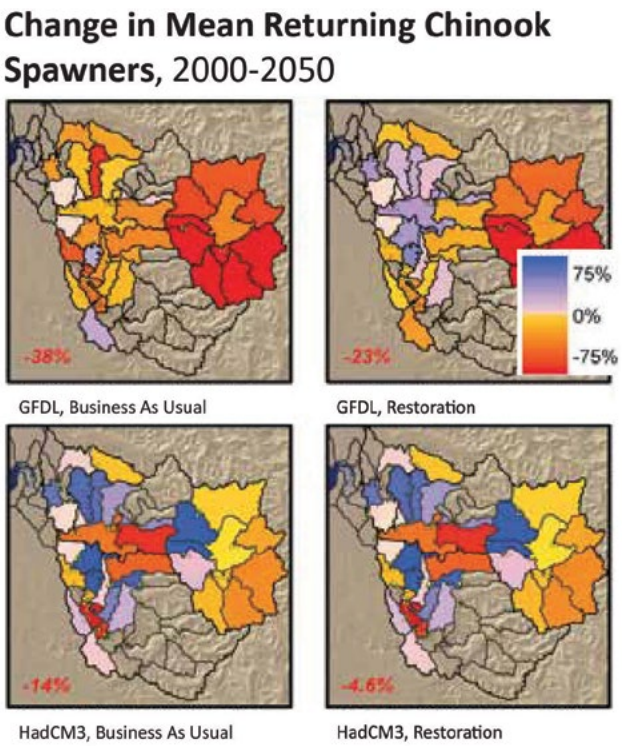


Figure 2.9 Salmon Viability Forecasts [44]

2.3 Scenario Comparison

The four scenarios look at the intersection of climate change and social values. In **acceleration**, minor climate changes and a mastery approach result in fast economic growth and urbanization, in **small**, minor climate change and a harmony approach succumb to an economic recession, a focus on conservation and a lack of regional coordination. In **resistance**, the basin experiences major hydrological shifts associated with climate change and reactions with engineered solutions and restricted viewpoints leading to social disparities and degraded ecosystem. Lastly, in **metamorphosis**, the region transforms itself responding to new challenges with flexible and accountable strategies.

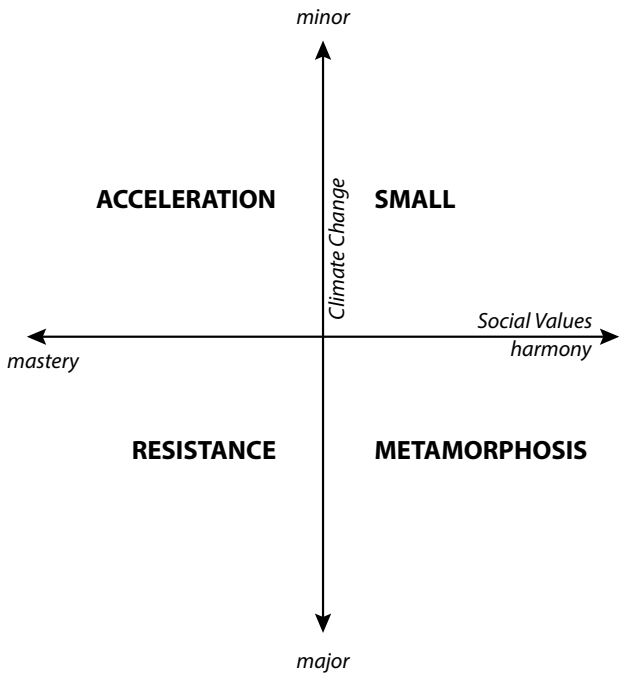


Table 2.1: Comparison of the Four Scenarios.

TREND	accelerate	small	resistance	metamorphosis
climate change	minor	minor	major	major
IPCC emissions scenarios	B1	B1	A1B	A1b
temperature magnitude	less than 1degC	less than 1degC	more than 3degC	more than 3degC
precipitation variability	historic seasonal	historic seasonal	major, extreme events	major, extreme events
snowpack and streamflow	historical variability	historical variability	early and fast	early and fast
values	mastery	harmony	mastery	harmony
Society and Nature	Nature serves society.	Society is part of nature. Nature is fragile.	Society controls nature to reduce uncertainty.	Nature and society are inseparable, mutually interdependent.
worldviews [1]	Nature Flat	Nature Anarchic	Nature Balanced	Nature Evolving
social relationships[2]	ambition, competition	equity, responsibility	security, control	accepting, informed
governance	Increased privatization	More decision makers	Government for security	Proactive, integrated, flexibility
employment (rate; sector)	Fast; High Tech	Slow; Resource Industry	Unstable; Government and Services	Stable; Diverse
population (rate; characteristic)	Fast; Diverse	Slow; Aging	Unstable; Divergent	Moderate; Diverse
wealth (income; disparity gap)	High; Wide Gap	Low; Narrow Gap	Moderate; Widest Gap	Moderate; Narrower Gap
investments	high; infrastructure	minimal; social	high; reactive	high; ecosystem
development	extensive	rural, clustered	sprawled	urban, planned
infrastructure	innovative, regional	retrofit, site-level, sharing	engineered, traditional	prioritizing natural processes, flexible
resource management	high intensity, high commodity, hobby	sustainable; family; working; volunteer	largely gone; flooded and sold	low-yields (reduced rotations), conserved
ecosystem pressures	intense use; extraction	death of a thousand cuts	cc; fragmentation	cc; novel
strategic approach	high yield, high control; innovative; market-based	site-level; risk-averse; low-tech; ecofriendly	quantitative; blunt; short-term benefits	accountability; resilience; coordination
ecosystem condition	heavily degraded. substituted	local successes, regionally degraded	past or approaching thresholds	highly variable but functioning
actors	few, wealthy, private	many, advocacy groups	federal government; opposing	linked; public
opportunities	investment capital, innovation	low pressure, ethic	crises focus	integration; flexibility
challenges	growth pressure; impervious; market-focus	no money; lack of coordination	climate pressures; social disparity; rigid approach	climate pressures; process paralysis; high cost of living

[1] Based on Gunderson and Holling. 2002. Panarchy. Myths of Nature.

[2] Based on Schwartz.Schwartz, S.H. 1999. A Theory of Cultural Values and Some Implications for Work. Applied Psychology: An International Review. 48(1). p23-47

Hypotheses of Future Ecosystem Service Conditions

The Snohomish Basin supports a multitude of resources and services that are supplied by natural ecosystems for example clean drinking water, beautiful landscapes, fuel and fiber. These 'ecosystem services' are controlled by ecosystem functions for example water filtration or carbon sequestration. In general, 6 ecosystem service groups are explored within this project including water quality and quantity, habitat and species diversity and carbon fluxes and stocks. 'Appendix 4: Ecosystem Services: Hypotheses' describes each of the systems and their relationships to key driving forces. For example, the future condition of water quantity, as measured by in-stream flows (specifically the recurrence of critical low flows) is influenced by changed in the trajectories of withdrawals (controlled by demand and technology) climate change (timing of snowmelt) and urbanization patterns (both the extent and configuration of impervious surfaces). In conjunction with the Science Team we developed hypotheses for the future trajectories of the six ecosystem services under the 4 alternative scenarios. The following hypotheses are intended to reflect potential uncertainty around future conditions and important relationships to consider when exploring the use of integrated predictive model to forecast future changes.

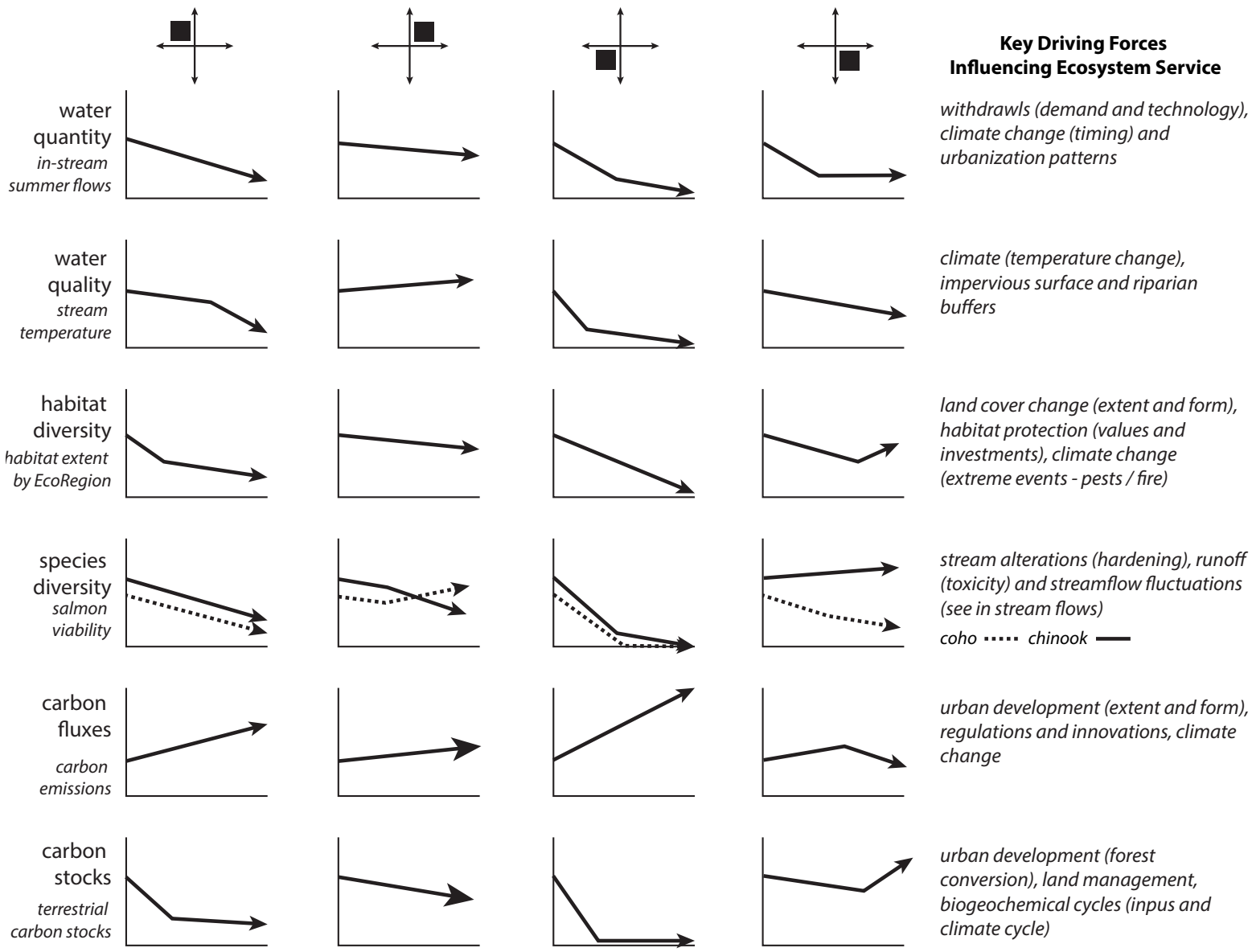


Figure 2.10 Hypotheses for Future Ecosystem Service Conditions

2.4 Acceleration

This is the story of how our ingenuity and ambition supports unprecedented prosperity at a great price to our environment.

Figure 2.11 Aerial of Accelerate, 2060

The major force shaping the Snohomish Basin over the last 50 years is an accelerating economic boom. The rapidly urbanizing region is home to an expanding population of citizens who appreciate outdoor recreational opportunities, but are more concerned with maintaining human quality of life than the integrity of natural environments in their own right. The impacts of climate change are relatively minor, but farming and forestry decline as resource lands are claimed or degraded by urbanization.

Despite nearly a decade of recession in the early 21st century, the Snohomish Basin rebounds quickly and strongly. Biotech and health services located along the I-5 corridor bring thousands of new jobs. The Providence Regional Medical Center breaks ground on a major expansion in 2035 to support the growing population of generation-Xers retiring to the basin. The Port of Everett surpasses both Seattle and Tacoma in cargo volume. Just outside North Bend, a new outdoor outfitter opened its headquarters and purchases five hundred acres as a private outdoor playground, with fee hunting, mountain biking, and ATV trails.

This economic growth makes the basin the most quickly urbanizing area in the state of Washington. Growth in housing and commercial development is accelerating both within and outside of urban centers. Cities like North Bend, Marysville, and Lake Stevens are increasing their growth boundaries to accommodate new development. Meanwhile, smaller communities like Gold Bar, Sultan, and Skykomish struggle to keep pace with the demand for increased government services. Households and businesses advocate for maintaining a high urban quality of life, characterized by reliable utilities, services for a growing aging population, better schools, and improved traffic conditions.

The region's increased wealth provides the opportunity to carry out several large-scale infrastructure projects. Tolls along I-5 and I-90 fund a wide breadth of transportation investments outlined in the Puget Sound Regional Council's 2040 plan. Increased water demands are met with additional aquifer withdrawals from the Getchell Plateau. New and restructured levees protect over 5,000 acres of lowland communities from flooding, while also providing space for a new 1000-acre recreation corridor with sports fields, bike trails, and wildlife viewing habitat.

Basin cities are bigger while the county government has been largely eliminated, as surrounding lands are annexed. Private services support new urban development as small public agencies are poorly equipped to handle additional growth. Industry leaders are the key lobbyists in the political arena, pursuing streamlined permitting processes and scaling back redundant environmental oversight. These changes are in line with national political trends, which have resulted in the restructuring and elimination of many federal agencies including the EPA, FEMA, and BLM.

Agriculture and forestry are still present in the basin as hobby farms. International resource production is better suited to meet growing demands, as land prices and degraded environmental conditions do not support profits in the basin. Upland development results in more frequent winter flooding that carries heavily polluted water and sediments onto farm fields. However, while less land is in agricultural production, some farmers have successfully transitioned to greenhouse crops and vertical production methods, or migrated to fields at higher elevations.

Moderate climate change has occurred in the basin over the last half century. Temperatures have risen modestly, and snowmelt comes earlier, altering streamflow patterns. However, the majority of environmental change in the basin stems from urbanization. Global climate change is an engine of economic growth in the region, as basin leaders reach out to support rebuilding after natural disasters in Third World nations.

Rapid urbanization disrupted the ecological integrity of the Snohomish Basin, yet many important natural features are conserved for the health and enjoyment of the region's population. Residential communities along rivers and lakes support recovery efforts to treat and reclaim waters with innovative biotechnologies. While five out of the region's 12 wild salmon stocks have declined beyond hope of recovery, new sustainable hatcheries support the continued survival of pink salmon, steelheads, and cutthroat trout in the basin.

2.5 Small

This is the story of how a local environmental ethic adapts to a long-term economic recession.

Figure 2.12 Aerial of Small, 2060

Over time, as investment capital is drained from the basin, the reins of power shift, from industry leaders to new actors characterized by community-scale sustainability ethics. Rates of job growth and development are low but stable, shifting away from decades of environmental pressures towards modest improvements in biodiversity and ecosystem health. Leaders are drawn to small farms and reduced consumption, but challenged with past legacies of environmental damage, tight budgets and an inability to coalesce around larger regional issues.

The economy of the Puget Sound region is a shadow of the booming industry before the Great Recession. Boeing has shut its Paine Field operations and global competition has resulted in out-sourcing and relocation of many high-skilled and manufacturing jobs. The rate of new business formation is high, especially in the non-profit and human service sector, but few businesses are expanding and surviving over the long term. Over 15% of the basin is retired, but the younger generations face unemployment rates around 10%.

A young, highly educated, but underemployed population is seated at the decision-making table. This diverse group, brought up on progressive social values and highly accessible technology, has transformed the basin's social and political landscape. Grassroots organizations support new informal communities oriented around neighborhoods and shared interests. Though their approaches are varied, these organizations tend to focus on protecting a fragile natural environment and on risk aversion. The values of competition and personal advancement that were prevalent around the turn of the 21st century are replaced by equity, responsibility, public and environmental health, family values, and leisure.

There is little recent development in the Snohomish Basin. Most of the new buildings are multiple-family structures within the urban center. Average household size is stable after over fifty years of continuous decline, as lower household incomes force young adults to move in with extended family and friends. A renewed "back to the land" movement and the rising cost of urban living fuel migrations into the basin's resource lands. However, despite the popularity of small rural farms, only a small percentage of the basin's population can afford this lifestyle.

The basin's population is adapted to make do with greatly reduced local government and household budgets. Approaches promote utilization of natural capital, efficiencies from greater accountability, and repairs rather than new purchases. Low-impact and low-investment development techniques that support 'off-grid' resources are popular, like cisterns for water and run-of-the-river shallow dams for community energy. Utilities and infrastructure agencies retrofit structures and abandon failing projects. For example, washed-out forest roads are removed and several aging levees are eliminated. Further, government incentive programs support small-scale local industry, alternative transportation modes and sustainable farming practices.

The effects of climate change, while minor, are highly apparent to a tenured population that lives close to the landscape. Higher average temperatures mean an expanded growing season, benefiting both agriculture and forestry. Conversely, earlier snowmelt translates into higher winter flows and lower summer flows in several watersheds, challenging resource management to handle more frequent seasonal floods and drought. However, in-stream flows are strictly regulated and managed, supporting adequate supplies for salmon and efficient irrigation technologies.

There is great enthusiasm over restoration projects, as moderate climate impacts and reduced development pressures relieve stressors on natural systems. Successful restoration efforts are benchmarked by miles of recovered streams, people volunteering, and hours of outreach. New farms are small and inspired by a humble deep ecology ethic. New foresters implement sustainable practices within their lands. Organizations such as the Washington Trails Association, Mountains to Sound Greenway, and the Mountaineers contribute thousands of volunteer hours to trail maintenance and noxious weed removal. The American Rivers and Wild Fish Conservancy support dozens of miles of restored creeks. The Tulalip tribes have expanded far beyond the reservation, collaborating on upland forest conservation easements, snowpack detention reservoirs, and estuary mitigation.

The Snohomish Basin's greatest environmental challenges are coordination and funding. Mounting criticism suggests that projects fail to scale up into a bigger picture. Restoration benefits to Chinook viability, for example, reflect the challenges of large regional investment, coordinating across thousands of adjacent parcels and diverse interest groups. The bottom-up approach characteristic of the basin's current culture is energetic, but lacks strong leadership and is overwhelmed by a sea of accessible information. Increasingly stressed agency budgets and great effort spent on 'the process' raises tensions between various interest groups, delaying critical decisions.

2.6 Resistance

This is the story of how extreme climate challenges are countered by powerful human actions.

Figure 2.13 Aerial of Resistance 2060

In 2020, a series of disastrous floods result in major public investments into stronger armaments, redevelopment and economic renewal. A goal-centric approach that is focused on immediate human security inadvertently leads to ecological and economic instability and social disparities. In 2060, the basin's landscape is characterized by highly degraded resource lands and increasingly expensive technological infrastructure to maintain service provision. The basin supports two distinct communities, the rich and the poor, with radical divergence in the quality of their neighborhoods, access to resources, and overall welfare.

In January 2018, the City of North Bend declared a Presidential Flood Disaster after an unprecedented 500-year flood covered 90% of the city and over 800 homes were inundated. Five more floods of similar severity occurred in the basin over the following decade. After each event, rebuilding of flood walls, homes, businesses, and damaged infrastructure provided economic stimulus. But with public funds diverted towards flood protection measures and emergency response programs, other priorities, from education to environmental services, suffered.

The combination of restricted waterways and rising temperatures has shifted hydrological systems beyond repair. In 2060, winter snowpack in both the Tolt and Sultan watersheds is 80% below 2010 levels. The South and North Forks of the Skykomish routinely suffer near-drought summer conditions, and higher winter flows that scour edge habitat. At low elevations, the combination of high water temperatures and pollution creates toxic conditions along urbanized stretches of rivers including the Pilchuck, Raging, and Tolt. Regional utility providers struggle to supply water and power to the Snohomish Basin's population. The Tolt and Spada Reservoirs are depleted by the summer of 2045 and 2048, respectively. Frequent power outages result from downed power lines during severe storms in the winter and hydroelectric shortages from low flows in the summer. Political turmoil over these failures leads to fast-tracking several projects with minimal environmental oversight. As the basin's ability to support energy and water through natural functions declines, the cost of service provision grows exponentially. Costs are passed on to utility customers, leading to growth outside service areas (wells, septics, wood fuel) and greater hardships for low-income households.

Given the intensity of the 'farm-fish debate' a half-century ago, it's hard to believe that now in 2060 both farm and fish are largely gone from the basin. Repeated cycles of flooding leave lowland fields contaminated, and the financial benefits of agriculture dwindle in the shadow of levee costs. As for fish, both Chinook salmon and bull trout are officially extinct in the basin. The flurry of flooding, redevelopment, and deregulation over recent decades leave little funding for restoration projects, and many streams are so degraded that little is left to save in any case. Some other wild fish stocks, while still present and monitored, are struggling to survive.

Each new tide of disasters and reconstruction ushers in a flow of jobs, followed by an inevitable out-migration. Jobs created in levee construction, housing development, road and wastewater repairs, and emergency services are often underpaid and unstable. Local governments respond to the demand for economic growth and employment stability with loosened regulations and streamlined permitting processes. Boeing remains a major employer, though it too follows a boom-and-bust cycle of job growth and massive layoffs. The Port of Everett shut its doors after over 135 years of business, unable to absorb the cost of constant repairs due to climate impacts and competition from global facilities.

Unstable economic and resource conditions drives a dividing wedge between the 'haves' and the 'have-nots.' Wealthy upland households are not afflicted by floods and shortages as their higher-elevation suburban homes are supported by private global services and elastic incomes. But members of lower-income groups, especially elderly households and migrant families concentrated in low-lying areas, are much more vulnerable. For these households, flood insurance payouts have fail to cover the cost of damages, especially as federal and regional funding is depleted after multiple disasters. Further, these groups are squeezed by unemployment and the rising cost of gas, food, health services, and utilities. The Tulalip tribes, after decades of struggling to implement proactive restoration and mitigation policies, succumb to a loss of clean reliable water and fish stocks. While they receive financial compensation, the tribes lost their tribal heritage and experienced strained relationships with their basin neighbors.

2.7 Metamorphosis

This is the story of how we embrace change through experimentation and upfront investments.

Figure 2.14 Aerial of Metamorphosis 2060

While climate changes break records and urbanization continues to pressure natural systems, society responds with greater flexibility, diversity, and integration. Each new challenge is transformed into a learning opportunity, using long-term accountability and a historical context to guide decision-making. Mandated individual sacrifices are significant, with greater investments of time, money and knowledge needed to invest and variable successes. However, when we zoom out from the household or business to the region and from the now to future generations, the benefits become evident.

Irrefutable ecological pressures support a new era of accountability. Climate change brings year after year of record-breaking events to the Snohomish Basin, from floods to heat waves to strong winds. Higher elevations lose the majority of their snowpack by early spring, leading to more frequent winter floods and declining summer flows. Stream temperatures rise, as do the levels of toxins and pollutants carried by urban streams. Salmon stocks decline and many fear the populations of these iconic fish will not rebound. Regional partnerships collaborate with academic institutions and private industries to establish a response network that can track and guide action.

Leadership and financial support empower public agencies to see new challenges as an opportunity to correct past errors. Land managers use the basin's historical geomorphology and land cover patterns as a guide to relocate and redesign patterns of development. In 2018, when a 500-year flood on the Snohomish River destroyed aging levees, new 'softer' levees were rebuilt, set back farther from the river channel with re-vegetated riparian buffers. This reduced the impacts of severe floods in subsequent decades. Meanwhile, agricultural incentive districts subsidize farms that promote sustainable practices by insuring harvests from flood damage (i.e. pay for flooded crops). Likewise, upland, private timber companies are paid to not harvest and are financially encouraged to seek alternative environmentally sustainable forest initiatives.

Expensive public investments are supported by stable economic prosperity and coupled with unprecedented political will. The Snohomish Basin is globally known as a great place to work and live, attracting additional growth. With its easy access to both healthy natural lands and thriving metropolitan centers, development pressure is intense, outpacing both Pierce and King Counties in job and population growth. As private industries prosper, their willingness to invest in regional infrastructure grows. As household wealth and quality of life increases, so too does the public's approval of costly long-term social and ecological investments.

Urbanization and technological innovation are paired to facilitate greater diversity and efficiencies. The Growth Management Act tightly funnels development into existing urban corridors, and cities like North Bend, Monroe, and Snohomish double in size. Increased density creates diverse neighborhoods with unique cultural, business, and natural amenities, and facilitates investments in public transit and efficient utility provision. In keeping with the Pacific Northwest's reputation as a high-tech hub, local governments in the basin collaborate on numerous highly successful innovations from green energy and intuitive water conservation measures, to purchasing local products. Several leading global innovation companies are headquartered right in the basin, from biotech to information technology.

Paradoxically, the basin's proactive investments and economic prosperity are one of its toughest challenges. The high cost of investments, from agricultural subsidies to the purchase of conservation lands, from cumbersome regulatory oversight to innovative regional infrastructure, from public provision of health to leading educational institutions, take a significant toll on industry and household budgets. Further, rising real estate costs and oil prices threaten to price out lower income groups and start-ups from the basin. Instead of reducing costs, municipalities respond with new development regulations, from minimum quotas for affordable housing to subsidies for incubator businesses, with the hope of supporting diversity. Over the years, social norms lead the public to embrace more equitable long-term investments, expanding the decision-making framework.

While novel conditions continue to challenge the basin, a flexible and integrated institutional framework supports a long-term resiliency. Despite inter-agency monitoring, alternative energy, and investments in social and natural capital - unprecedented changes continue. Politically, decision-makers are often paralyzed by complex factors, conflicting interests, a lack of certainty, and constricting tradeoffs. Both the size of government and the number and types of relationships with private industries, academia and advocacy group grow to support transparency and trust. Over time, economic burdens are boasted as redistributive and egalitarian. With each new hazard, the duration and intensity of emergencies is dampened by the flexibility, diversity and accountability of the basin's social and ecological institutions.

CHAPTER 3 METHODOLOGY

3.1 The Process

This scenarios report is the culmination of a 2-year research collaboration including several workshops and dozens of meetings and interviews. The timeline outlined in Table 3.1 describes the overall flow of the process. Each step is characterized by a specific meeting, a key organizing question or objective, the role of participating experts, and a specific product delivered. The process was not linear, but rather involved several iterations as we refined central questions and project deliverables. The process has been the collaborative effort of the Urban Ecology Research Lab at the University of Washington and over a hundred regional expert members. From this process four preliminary products were synthesized: driving forces, a shared conceptual model, scenario logics and an integrated model blueprint. These products were pulled together to create the final scenarios describing how the history of the basin may influence plausible alternative futures.

3.2 Project Committees

The project involved the input of many regional experts, including professionals from private industry, public agencies, the non-profit sectors and academia. Three committees were formed to support different aspects of the project. The full list of project members and their current affiliations and expertise can be found in Appendix 1.

The Snohomish Basin **Steering Committee** consists of fourteen representatives of basin municipalities and tribes, regional land holders and managers, agencies for economic growth and capital improvements, and environmental policy and advocacy groups. These partners were selected because they have direct influence over the strategic implementation of future actions in the basin. The Steering Committee met twice, once in the beginning of the project to identify project directives and once at the end of the project to provide feedback on the final report and directions for future integration of the work.

The **Science Team** included over a hundred representatives of various disciplines and backgrounds to direct research on driving forces and important relationships, as well as to ensure that the final scenarios were scientifically valid. Experts were selected based on a snow-ball technique, in order to incorporate a wide variety of perspectives. Representative fields included biological and physical science, economic forecasting, demographic and policy analysis, education and social services, real estate and development, infrastructure management, government at various scales, planning and design, innovation, restoration ecology, forestry, outdoor recreation, farming, hazard mitigation, and tribal leadership.

Science Team members supported the process at multiple levels, from participating in an online interview to attending multiple workshops and providing written feedback. Over the two-year timeline, three major workshops, two meetings, and dozens of focus groups and interviews provided opportunities for Science Team members to be involved in the process. Two subgroups of the Science Team, a Scenario Development Team and a Predictive Modeler Team, were formed to respond to two specific questions: What specific variables of values and climate change support the most relevant, divergent, plausible and compelling storylines? And How might we integrate current models to estimate future levels of ecosystem services that are sensitive to differences between the four scenarios?

The **Stakeholder Team** included representatives of twenty basin stakeholders that characterize major actors and various interests in the basin including the Tulalip tribes, aerospace industry, salmon conservation, farming, forestry, ecosystem assessment, recreation, county planning, and the non-profit stewardship and advocacy arena. At the end of the process, this group was invited to discuss the potential role of the Snohomish Basin Scenarios project in

Table 3.1: The Snohomish Basin 2-year research process

5.2010 Steering Committee Kickoff: *How can the process and products of this project best inform long-term strategic decision-making in the Basin?*

Fourteen regional decision makers representing municipalities, tribes, business interests, utilities, land managers and environmental organizations provided eight project directives.

8.2010 Interviews and Focus Group Meetings: *What shaped the past fifty years of the Basin? What will drive change in the Basin over the next fifty years?*

Seventy eight individual and focus group interviews with diverse academic and professional regional experts helped formulate the focal issue and identification of critical drivers.

11.2010 Conceptual Model Workshop: *How do we integrate diverse perspectives to build a shared story for long-term problem-solving for the Basin?*

Twenty nine science team members collaborated on a common language for a conceptual model relating drivers, actors, assessments and actions.

6.2011 Scenario Logics Workshop: *What are the two most important and uncertain drivers challenging our assumptions about the future?*

Science team members formulated alternative hypotheses for the Basin's future by exploring the trajectories of climate change and human values.

8.2011 Scenario Development Meeting: *What specific variables of values and climate change support the most relevant, divergent, plausible and compelling storylines?*

Ten science team members with disciplinary foci on climatology and social sciences refined the scenario logics to explore the magnitude and variability in future regional climate changes and the shift in social relationships to people and nature through mastery versus harmony values.

9.2011 Interviews with Predictive Modelers: *How does your model predict change?*

Eight regional predictive models were assessed in terms of their objective, approach, input and output and limitations.

11.2011 Integrated Model Workshop: *How might we integrate current models to estimate future levels of ecosystem services that are sensitive to differences between the four scenarios?*

Modelers developed a draft blueprint to explicitly link the inputs and outputs of eight predictive models forecasting future conditions in the Snohomish Basin.

1.2012 Scenario Tests: *How well is future variability described with these scenarios?*

Sixteen science team members provided detailed feedback on the draft scenarios, with specific recommendations on how to better represent the potential variability across the four scenarios with respect to their area of expertise.

2.2012 Policy Workshop: *How can we make better decisions?*

Representatives of eighteen Basin stakeholders identified ten questions to support more informed long-term critical decisions facing the Basin's uncertain future.

7.2012 Steering Committee Review: *How can we best leverage the work completed in this project?*

Feedback from Steering Committee on how to best represent project outcomes to decision makers and the public.

supporting more informed long-term critical decisions facing the basin's uncertain future. At the Policy workshop, the Stakeholder Team developed a set of questions that support a resilience framework through additional criteria for consideration by decision makers (see Section 4.1 Resilience Framework).

3.3 Preliminary Products

Four preliminary products were created to develop the final four scenarios. Each product was developed over several meetings, integrating feedback and revisions to better reflect the current state of knowledge and diverse perspectives. These four products are: the selection of driving forces shaping the basin's future, a shared conceptual model describing the relationships among driving forces, the scenario logics and storylines outlining key hypotheses about driver interactions, and a blueprint for integrating predictive models to forecast and assess the impact of the four scenarios on the basin's ecosystem services over the long term.

The final scenarios weave together these four products, bringing together the contextual stories from the initial expert narratives to the analytical frameworks of models and assessments.

Driving Forces

Driving forces are factors or phenomena that alter the future trajectory in significant ways. For example, population growth is a driving force that affects resource consumption and water quality. Driving forces are the main ingredients in scenario planning, helping planners bring together various trends to tell a coherent story of future change. Lingren and Bandhold described the important role of driving forces in 2003: "when we scan our environment we see events and can make general assumptions about what is happening. But events are just the visible tip of the iceberg. If we look below we will see what is driving those events, and only then can we understand how to change our behavior accordingly."[46]

In the summer of 2010 the project team identified an initial group of Science Team members and met with them to understand the various perspectives of regional experts on how the basin changed over the last fifty years, and thus how it might change over the next fifty years. Interviews and focus group meetings were conducted with seventy eight Science Team experts, representing over one hundred[7] agencies, departments and tribes. Over sixty hours of interviews were recorded and transcribed. Transcribed interviews notes were coded to identify major themes and potential driving forces. Fourteen drivers were synthesized, vetted and refined with the Science Team at the Conceptual Model Workshop (Figure 3.1). The driving forces were organized under four overarching categories of humans, institutions, built environments, and natural environments. Each driver takes into consideration multiple disciplines, the theoretical foundations, published literature and input on uncertainty with substantial implications for influencing future change. However, not everyone would agree with this selection of drivers, their definition or grouping. The final set of driving forces is a compromise, expanding beyond traditional criteria but not completely including all perspectives.

Shared Conceptual Model

The shared conceptual model[8] illustrates the relationships between the driving forces influencing the future of the Snohomish Basin. The objective of the shared conceptual model is to link the various conceptual models supported by different disciplines and perspectives to support a more inclusive view of the system. Further, the model highlights potential relationships between drivers and areas of agreement and disagreement.

The model is the product of both the individual and group interviews held during the summer of 2010 (see details under Driving Forces) and the Conceptual Model Workshop, held in November 2010. During interviews, Science Team members were asked to articulate a conceptual model that depicts how they see the Snohomish Basin's future (Figure 3.2). Interview notes were synthesized and shared as

HUMAN

Demography is the study of human populations including the size, structure and distribution of the population, and changes associated with birth, migration, aging and death.
Themes: Growth, characteristics, health

Behavior represents individual action including physical alterations, interactions (with people and the environment) and where we put our money (consumption and investment).
Themes: Adaptation, Consumption, Human-nature interaction, investments

Values are beliefs. They refer to the desirable goals guiding the selection or evaluation of actions, policies, people and events.
Themes: Belief, preference, perception

INSTITUTIONS

Economy refers to the production, distribution and consumption of goods and services. Economic growth is equated with profits, quantified by dollars earned.
Themes: Funding, industry, labor, market and wealth

Governance is the rules and rulers, and the various processes by which they are selected, defined and linked together.
Themes: Politics, planning and regulation and service provision

Knowledge represents the sum body of information (or facts) acquired by a population. For the purposes of this project knowledge is described in terms of the passage of knowledge through teaching or outreach, gaining new knowledge through research, science, or exploration, and innovation as the physical culmination of new ideas.
Themes: Innovation, science and outreach

Social institutions represent groups that share some mental concept of right and wrong. Institutions, by definition, are resistant to change and are there to support the current status.
Themes: Community, culture, tribes, the world, public engagement, organizations

BUILT ENVIRONMENT

Development describes the settlement pattern on the landscape and changes in land use and in land cover.
Themes: Character, form, land use, municipalities and real estate

Infrastructure refers to the technical structures that support a society, such as roads, water supply, sewers, electrical grids, and telecommunications lines.
Themes: Energy, flood mitigation, transportation, water provision and waste stream

Resource management refers to the management of materials or substances such as minerals, forests, water, and fertile land that occur in nature.
Themes: Agriculture, forestry, recreation

NATURAL ENVIRONMENT

Hydrology is the study of water, including the movement, distribution and quality of water (or water bodies).
Themes: Flooding, groundwater, streamflow, morphology, stormwater, water quality and water quantity

Climate change a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years.
Themes: Air quality, carbon, natural cycles, global change, ocean acidification, precipitation, sea level rise, snow pack, temperature

Ecosystems support life, encapsulating both organisms and their habitat.
Themes: Biodiversity, estuaries, fire, forest habitat, invasives and salmon and stream habitat

Biophysical Template focuses on the partitioning and cycling of chemical elements and compounds between the living and nonliving parts of an ecosystem.
Themes: Chemicals and nutrients, landscape movement, seismic, soils and minerals

Figure 3.1: Driving Forces

three alternative conceptual models, which were then elaborated on at the Conceptual Model Workshop (Figure 3.3). The final shared conceptual model (Figure 3.4) was then shared with the Science Team and refined through multiple follow-up conversations with the Science Team.

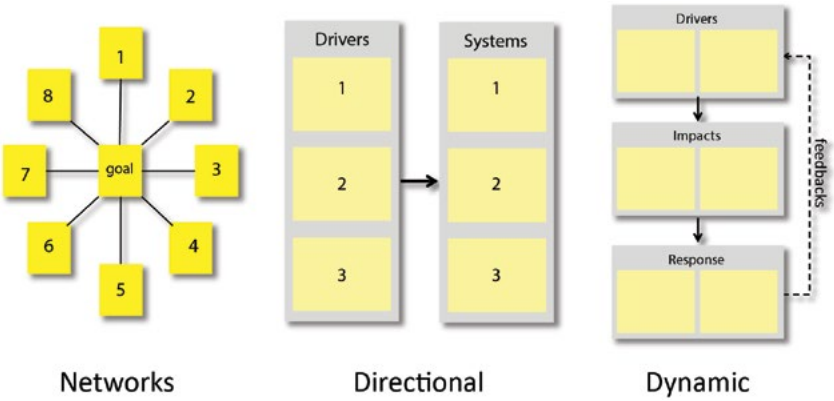


Figure 3.3 Overarching Conceptual Models

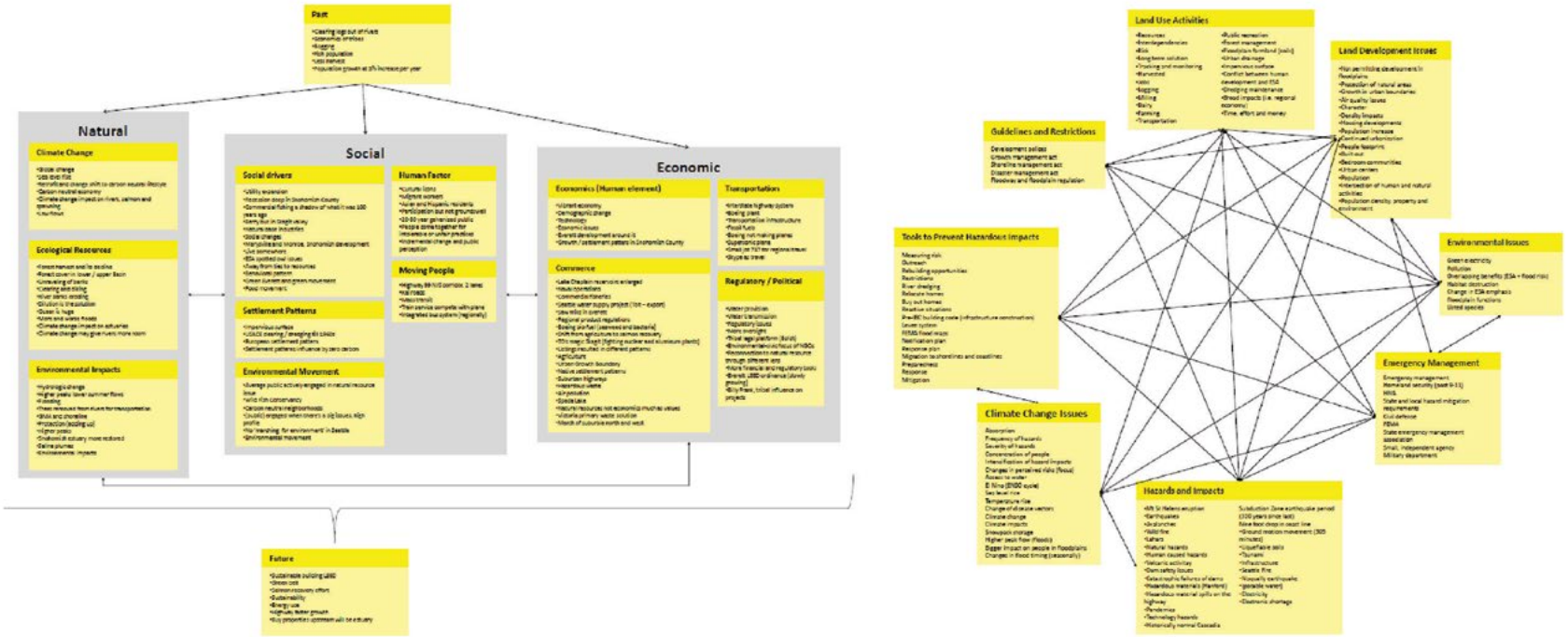


Figure 3.2 Example of Individual and Focus Team Conceptual Models

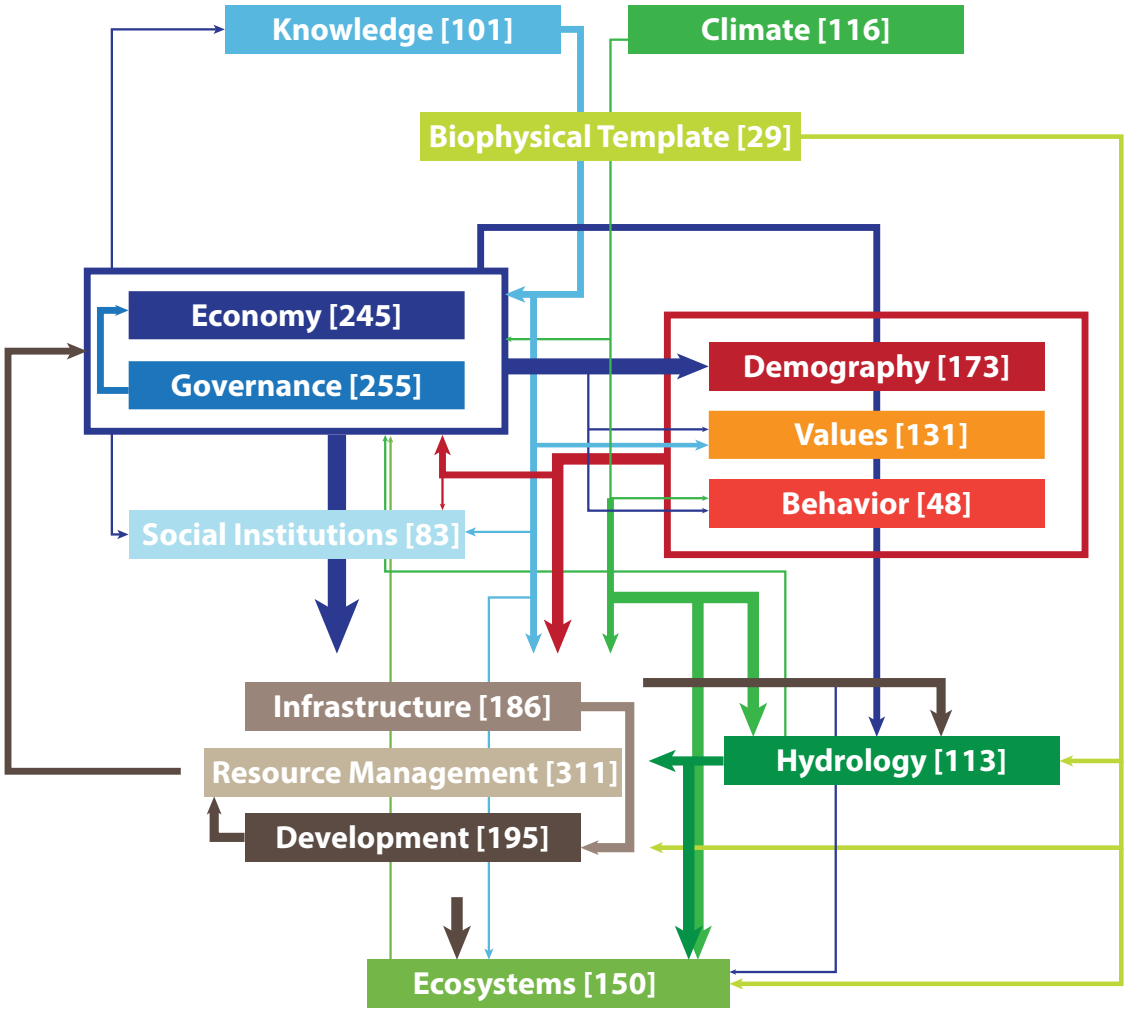


Figure 3.4 Shared Conceptual Model

The shared conceptual model illustrates a network map of described relationships between the 14 driving forces. In brackets is the number of comments made on each driver. The drivers are organized from top to bottom based on the ratio of comments about what they drive to how they are driven. For example, climate change was described as a driver of change, while ecosystems were largely described in terms of how they are influenced by other drivers. Arrow width and direction represents the relationships and feedbacks described between drivers based on the relative frequency of discussed relationships. Drivers with overlapping influences are grouped together in frames. For example, there is a tight feedback between demography, values and behavior that challenges the delineation of what is driving what.

Scenario Logics

The purpose of scenario logics is to select the two most important and uncertain drivers alongside their divergent trajectories in order to characterize the critical dimensions of the bounds of future reality. The resulting logics support a set of plausible and divergent future conditions against which decision makers can test the robustness of their strategies. There are infinite permutations of future conditions to potentially consider. Scenario logics suggest that drivers that are important and certain reflect the 'rules of the game', shaping the future in predictable ways. Meanwhile uncertain but less important drivers reflect distractions, changes that will surprise us but inevitably not shift future conditions. However, the interaction between the polar endpoints of the two most important and uncertain drivers direct decision-makers' "attention towards a handful of plausible alternative directions that contain the most relevant uncertainty dimensions."[46]

The Snohomish Basin scenario logics represent the interactions among alternative trajectories of climate change and social values, creating four alternative frames, translating into the four scenarios (Figure 3.5). The Scenario Development Team, a subgroup of the Science Team, subsequently refined the trajectories of each driver and described hypotheses for the interactions between each of the two endpoints. For climate change, the team selected the *magnitude of climate change and the variability of extreme events*. For social values, the team selected a *harmony versus mastery social disposition* regarding the relationship to society and nature. An initial hypothesis arose from each pairing. In terms of climate change, we looked at IPCC's A1B and B1 scenarios, as downscaled for the region. In terms of harmony vs. mastery we looked at Schwartz's definitions where mastery reflects an emphasis on controlling change or exploiting further interests, while harmony focuses on accepting the world as it is, trying to fit in rather than change it [47].

The Scenario Logics were developed over a series of meetings incorporating material from the Conceptual Model Workshop. At that workshop, Science Team members reviewed the working papers synthesized by the Urban Ecology Team describing definitions and past trends, and selected expert comments about the relevance and uncertainty of the set of fourteen driving forces. Workshop participants ranked the fourteen drivers in terms of their importance and uncertainty. Based on the two most highly ranked drivers, the participants, seated in teams, were asked to develop preliminary logics crossing two potential future trajectories for each axis. Participants had the opportunity to briefly 'play out' the hypothetical implications of their preliminary logics to assess if the outcomes were different enough from one another and relevant to exploring how to maintain ecosystem service provision. The great majority of workshop participants then voted on Climate Change and Social Values as the two critical uncertainties influencing the future of the basin.

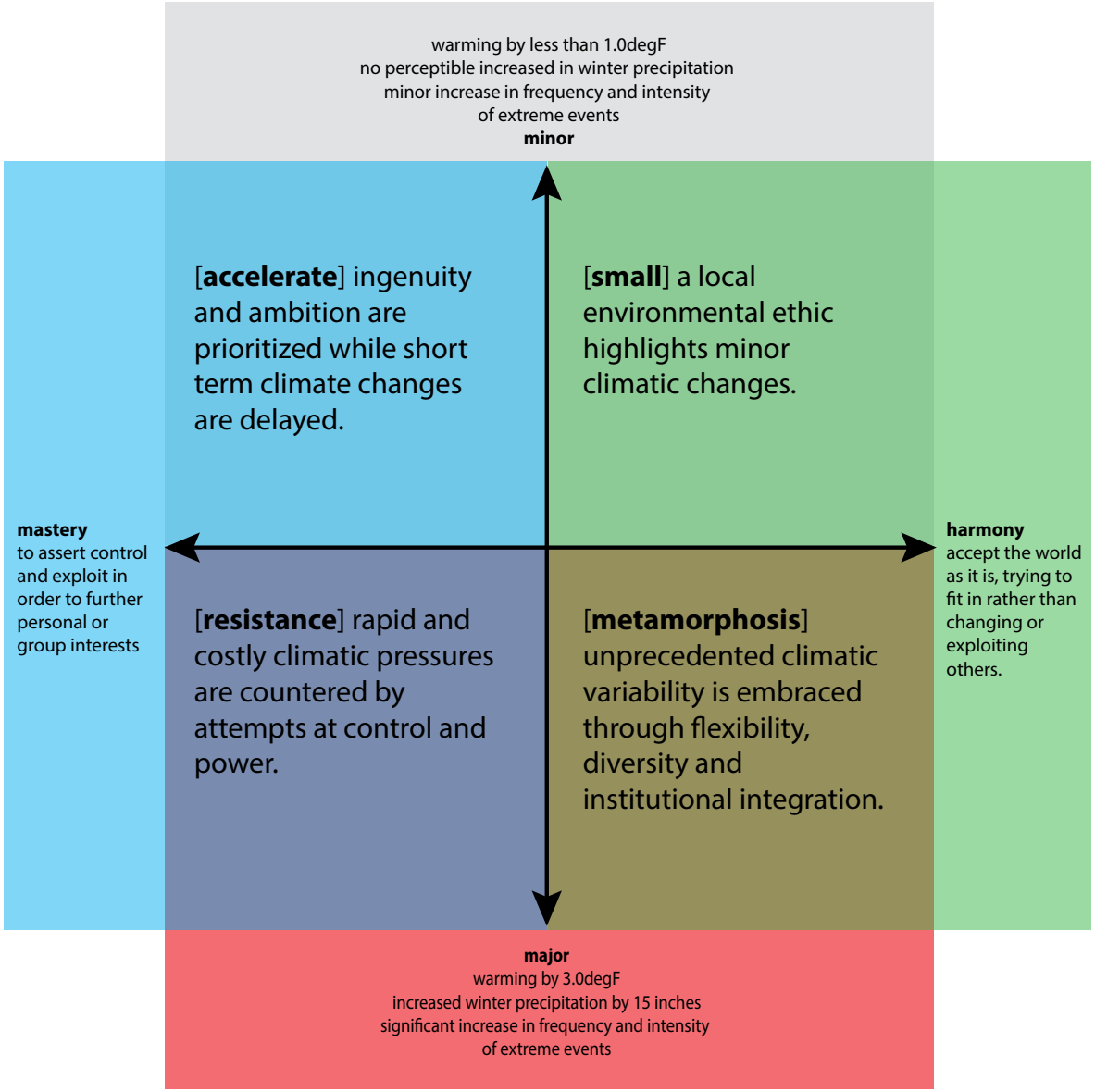


Figure 3.5 Scenario Logics

Storyline Comparison

A storyline refers to the narrative or plot described within each scenario. Once we had characterized the logics and divergent scenario hypotheses, we began to develop the scenario storylines. Each initial scenario hypothesis from the scenario logics was developed by incorporating alterative future trajectories of the remaining driving forces. The final scenarios and their respective storylines are the direct result of this integration. The process for identifying appropriate measures and logical trajectories for each driver involves several iterations of discussions with experts to identify important themes, collection of historical data to establish trends, and allocation of trajectories across the storylines to establish narratives that are internally consistent and compelling.

In order to elucidate the implications for the basin of the interactions between the two selected drivers and selected variables, we combined the divergent conceptualizations from the Science Team interviews, historical and forecast data on key trends of selected driving forces, and blueprints for integrating predictive models to assess ecosystem service conditions in the basin (see following section). The final storylines characterize the plot of each scenario by navigating the initial hypotheses through four overarching dimensions (Figure 3.6), including worldviews and governance, employment, demographics and wealth, changes to the built environment and changes toecosystem services. The four dimensions were arranged according to their correlated trajectories. Reflecting back to the Shared Conceptual Model, the dimensions were grouped together during the initial interviews.

The specific trajectories associated with each scenario can be found in Appendix 3 – Driving Forces Past and Future Trajectories. The forecasts are based on collected reports from regional agencies and conversation with Science Team members. Specific forecast products included OFM and PSRC's economic and demographic projections, land cover projections with LCCM, utility forecasts by PSE and Water Supply Forum, Climate Impact Groups State Assessment, downscaled hydrological modeling, slamm's and WashDOT sea level rise predictions and SHIRAZ's salmon model. Future baseline conditions for selected ecosystem services are hypothesized based on discussions with regional modelers exploring expanded boundary conditions of the scenarios with potential integrated predictive models. Initial ideas about future shifts are described in Appendix 4: Ecosystem Services: Hypotheses.

1. **Worldview and governance:** how values combine with climatic pressures to influence our interpretation of the world, the role of government, and the overall strategic approach.

2. **Employment, population and wealth:** the number and types of jobs, the growth and characteristic of the population, and the overall wealth and disparity in households.

3. Changes to the built environment: the shape and control over development, investment in infrastructure, and services and management of resource lands.

4. Changes to **ecosystem services**: implications for water quality and quantity, carbon stocks and fluxes, and the diversity of salmon and upland trees.

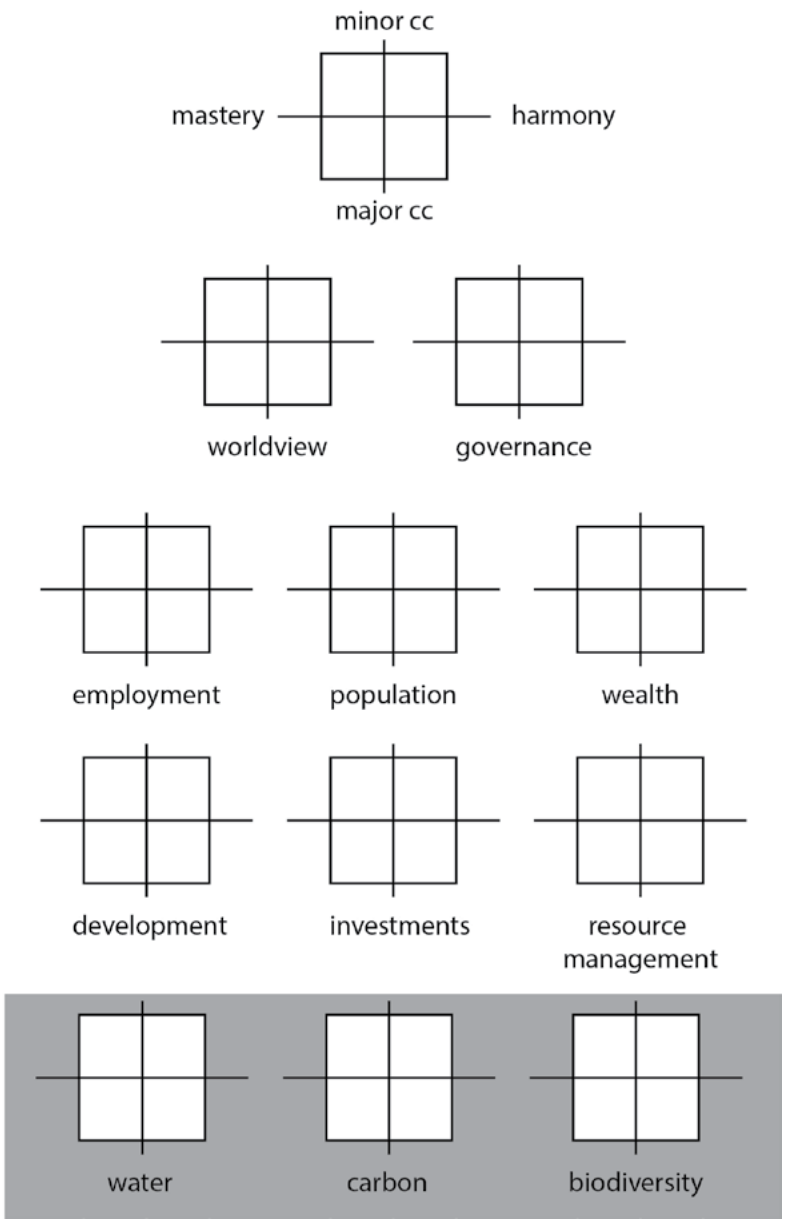


Figure 3.6 Storyline Comparison

Integrated Model Blueprint

The scenarios explore the uncertainty and relationships between critical driving forces that cannot be described by past events alone. The model integration phase of this project was pursued to complement the scenarios through two actions: 1) exploring potential relationships between systems represented by separate existent regional models, and 2) quantifying future baseline conditions associated with the alternative futures scenario hypotheses. Potential linkages between models can help us hypothesize a plausible range of future baseline conditions of ecosystem services. Based on each scenario's narrative, we can modify model assumptions and adjust model parameters. If the integrated model is sensitive to the differences between the scenarios, then the outcome (ecosystem service) will vary across the scenarios.

We conducted a series of personal interviews with regional model developers during the summer of 2011. We had three objectives for these interviews: 1) identify and summarize regional models in use (i.e. review their required input, spatial and temporal scale, assumptions and biases and results); 2) inventory the methods that have been used to address model uncertainty; and 3) explore suitability and methods for model integration.

Models were selected based on four criteria:

- They represent at least one of the 6 ecosystem service areas (species and habitat biodiversity, water quality and quantity and carbon storage and fluxes) or identified significant drivers of the outcome of interest (e.g.. land cover change).
- They have a high level of development (ideally have undergone a scientific peer review)
- They have been developed specifically for the study area (Snohomish Basin or Puget Sound lowland region).
- They have a flexible structure that can easily be (or already have been) integrated with output from others models. This was a high priority.

In November of 2011 we held an Integrated Model Workshop with 10 regional modelers to explore potential linkages between the selected models (Table 3.2). Modelers developed draft blueprints to integrate the models in order to assess future baseline ecosystem service conditions associated with the four alternative scenarios (Figure 3.7). The report of findings from the initial interviews (included as Appendix 2: Integrated Predictive Models) was intended as a reference for the modeling team to refer to as they explore model integration.

Major findings from that workshop represent both the importance of model linkages and critical gaps in current knowledge. Experts agreed that WRF (regional climate) and UrbanSim (urban development) represent overarching inputs (top level) while SHIRAZ and EcoPath represent overall outputs (bottom level). Hydrology models, LCCM (Landcover change) and Potential Vegetation Model had varied representation; however they generally incorporated the highest number of relationships, both as inputs into other models and as feedbacks. The Integrated Model would need to represent the differences across the four scenarios by varying the boundary conditions associated with dimensions of driving forces such as demography, economy, governance, and infrastructure. It was clear from the exercise outcomes that social dimensions including human values, behavior, governance and social institutions required substantially better proxies in three areas: 1) clearer definitions of what would be measured; 2) clearer representation of expected relationships to scenario logics; and 3) detailed information about what is quantitatively available.

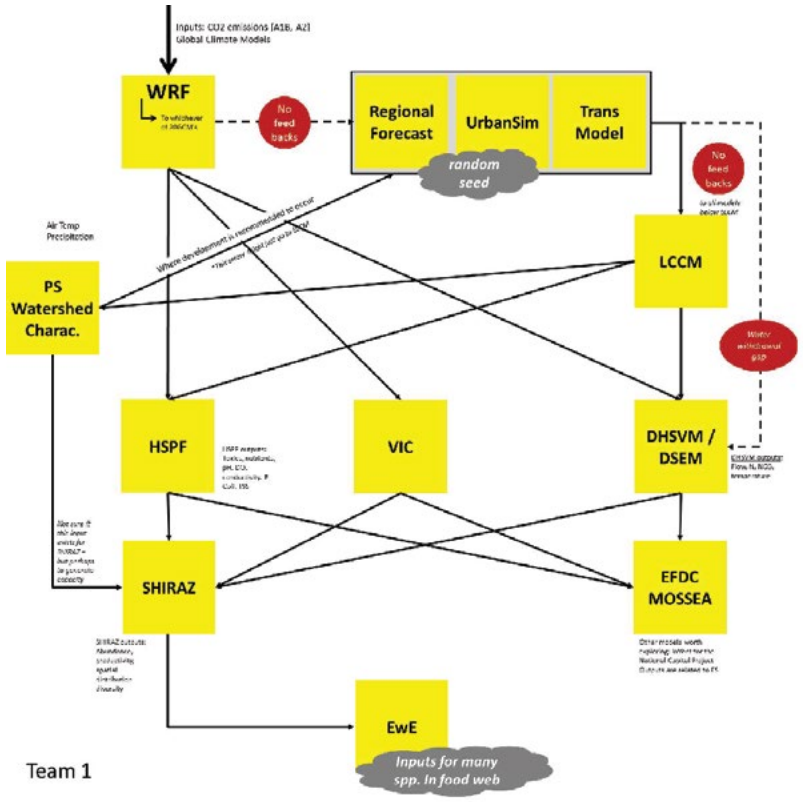
Modelers were asked to hypothesize changes in future functioning of ecosystem services as represented by the outcome of an integrated model specified by indicators for water quality and quantity, carbon fluxes and storage and species and habitat diversity.

Table 3.2 Selected Predictive Models

Model	System Modeled	Related Driving Force or Ecosystem Service
UrbanSim	Land use	Development, economy, infrastructure
Land Cover Change Model (LCCM)	Land cover change	Habitat diversity, development
Weather Research Forecast Model (WRF)	Climate change	Climate change
Shiraz	Fish population model (Chinook)	Species diversity
Potential Vegetation Model	Vegetation	Habitat diversity
Hydrological Simulation Program – Fortran (HSPF)	Hydrology	Water quality and quantity
Distributed Hydrology-Soil-Vegetation Model (DHSVM)	Hydrology	Water quantity
Variable Infiltration Capacity Model (VIC)	Hydrology	Water quantity
Puget Sound Watershed Characterization Project	Hydrology	Water quantity
Ecopath with Ecosim	marine food web biomass dynamics	Species diversity, carbon
Atlantis	marine food web biomass dynamics	Species diversity, carbon

Modelers assessed selected variables in terms of their 1) availability, if they are 2) compelling, and 3) appropriate measures that have been 4) previously linked to predictive models. The response rate and agreement level (variance) between modelers reflects that the workshop included good representation of water quality and quantity expertise, but poor representation in the other measures, especially measurement of carbon fluxes and stocks (see Appendix 6: Workshop Materials and Syntheses).

While the actual development and testing of an integrated predictive model is far beyond the scope of this project, efforts are underway to implement this research venture.



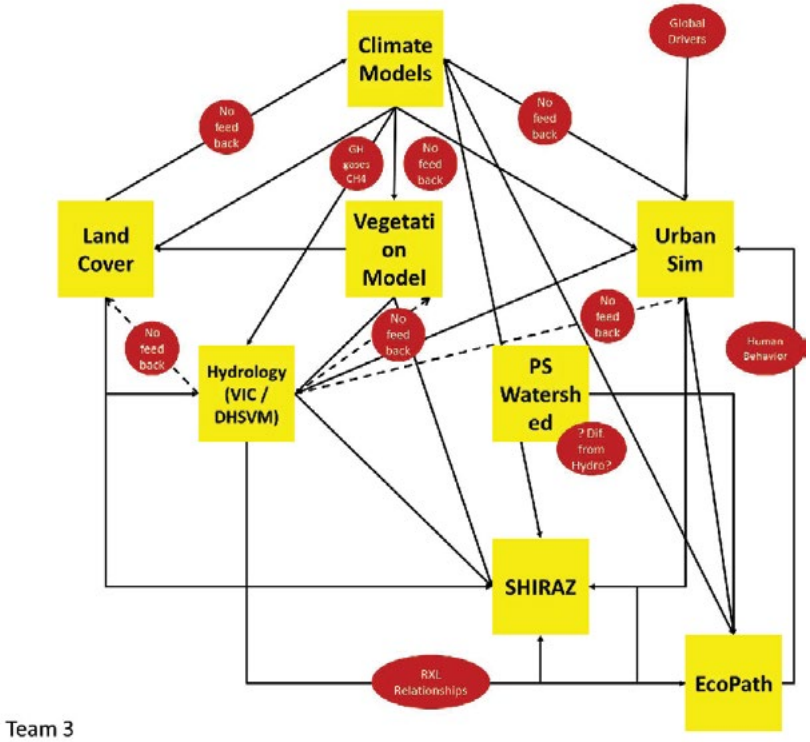


Figure 3.7 Examples of Draft Model Blueprints

CHAPTER 4: PROJECT LESSONS

In this chapter, we reflect on the lessons learned in the SBS project to articulate how scenarios can provide a systematic framework for making decisions under uncertainty. We explore six dimensions of decision support that: focus on resilience, redefine the decision framework, expand predictive models, highlight risks and opportunities, monitor early warning signals, and identify robust strategies.

4.1 A Resilience Focus

What is Resilience?

Resilience is defined as the capacity of a system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes [48]. Disturbances are pressures, either natural or man-made, that influence the ability of the system to continue its functions. Fishing, development, heavy rainfall, sedimentation and pollution are all examples of disturbances. Resilience theory assumes that there are multiple alternative states; each state is governed by different interactions and feedback mechanisms that support system functions [48] Self-organizing mechanisms in different systems allow them to absorb internal and external disturbances, but if thresholds are exceeded, systems will be attracted to an alternative state which may lead to undesirable conditions and reduced function [49]. Further, reversing a state change may be very expensive or unattainable. The concept of resilience has been applied to both ecological [50] and human [51] systems separately. The concept has also been applied to socio-ecological systems (SES) coupling interactions and feedbacks between human and natural systems at multiple scales. These coupled systems are characteristic of urbanizing environments such as the Snohomish Basin.

What is the difference between resilience and traditional resource management?

Resilience shifts the attention of decision-makers from growth and efficiency to adaptation and flexibility [52]. The aim of resilience management and governance is to keep the system within a particular system regime (or state) that will continue to deliver desired ecosystem services. Resilience theory leans on four assumptions about the nature of SES: complexity, change, diversity and uncertainty. These are unique characteristics that may be overlooked in other frameworks.

Complexity: The assumption that human and natural systems cannot be studied in isolation, and that social and ecological variables are critical to understand system functions and their interactions and feedbacks at multiple time and spatial scales [51].

Change: Social ecological systems are dynamic at various scales. Ecological systems are characterized by natural variability, from water flow fluctuations to the sinusoidal relationship between predators and prey populations over time. Resilience theory is predicated on the assumption that change is an essential element of these coupled systems, and when we try to reduce or eliminate change we actually reduce the systems' resilience (ability to withstand new or additional pressure).

Diversity: The key to resilience is diversity, or heterogeneity. How diversity is classified depends on the system of interest and interacting variables. Diversity can refer to genetic or habitat diversity, to economic sector diversity, to the diversity of urban developments or institutional partnerships. Resilience theory assumes that no one species, form, strategy or condition is 'optimal.'

Rather, due to the systems' complexity and dynamic nature, redundancy and diversity provide opportunities for adaptation to change [52].

Uncertainty: While we may be able to reduce the uncertainty around future events and conditions of complex systems by expanding empirical studies and improving predictive models, we will never have complete knowledge. We therefore need approaches to decision making that are effective across multiple future conditions (i.e. robust strategies) and that improve our adaptive capacity and opportunities for self-organization.

Maintaining the resilience of the Snohomish Basin

In answering the question of how to maintain ecosystem services in the Snohomish Basin out to 2060, the concept of resilience was a major contender. However, while publications on the theoretical concept are widely available, specific guidelines to improve the resilience of the basin are lacking and often controversial. For example: would protecting floodplains for salmon habitat improve the basin's resilience? What if we consider the implications for lowland agricultural practices and their social and ecological functions? It is important to note the critical relationships between the resilience of the basin as a whole (a coupled dynamic system) and the resilience of specific basin subsystems, for example, the resilience of Tribal culture, or upland forest systems. At times, maintaining or enhancing the resilience of one sub-system comes at the cost of the resilience of another [53]. These constitute important tradeoffs that we may not be able to eliminate, but rather introduce as components of a needed negotiation between various basin stakeholders.

Developing the four scenarios was instrumental in understanding the sensitivity of the Snohomish Basin to a diversity of future changes.

The scenario planning process deliberately sought to understand the ***complexity*** of the Snohomish Basin by exploring interdisciplinary publications and the perspective of multiple and diverse regional experts. Specific activities included 1) developing multiple conceptual models that integrate social ecological system drivers at various scales; and 2) integrating multiple predictive models to specify important mechanisms and gaps in linkages between various system components (e.g. hydrology, land cover).

Past and plausible future ***change*** in the basin was described by tracking over 67 environmental and social variables historically and through predictive and conceptual (Appendix 3: Driving Forces Past and Future Trajectories). The Scenario narrative specifically explored change as associated with extreme climatic events and increased variability and magnitude as well as how change is perceived and managed through shifting social values.

Diversity within the Snohomish Basin was explored via three different approaches. The first is the diversity of knowledge domains, specifically developing the storylines not from the consensus or common perspectives between experts, but rather at the divergent endpoints of understandings. The second is the diversity of patterns; in addition to tracking growth rates we looked at the diversity of several variables including demography, economic sectors, land cover, development typologies, infrastructure approaches and species. The third is the assumption of reduced resilience and function; when hypothesizing the implications that each scenario had for ecosystem services we assumed that scenarios in which the diversity of landscapes, actors and approaches are reduced will see declining resilience.

Finally, we explored ***uncertainties*** as they stemmed from gaps in knowledge (e.g. markets for biofuels), statistical or modeling uncertainty (e.g. temperature increase will be between 1 and 4deg C), expert disagreement (e.g. the GMA is effective at curbing sprawl) and surprises – what we don't even know that we don't know. We investigated these gaps in knowledge through expert interviews

and a review of published literature. We explored the statistical or modeling uncertainty through interviews with regional modelers and a review of model documents (Appendix 2: Predictive Models and Integration). We examined expert disagreement through interviews, development of multiple conceptual models, and collaborative workshops. Lastly, surprises were examined through the narrative development of the four scenarios and the exploration of national and global precedents for similar changes.

How can we apply a resilience framework to decision making in the Snohomish Basin?

Rather than creating a list of specific strategies that may enhance the resilience of specific subsystems, the Stakeholder Committee developed a set of questions for planners and decision makers to investigate whether an action or strategy may improve the resilience of the system as a whole (Figure 4.1). The set of questions is intended to serve as a starting point for regional agencies to develop protocols to ensure that the strategies they implement do not unintentionally reduce the system's resilience by attempting to eliminate or ignore its complexity, dynamic character, diversity or uncertainty.

Consider the National Environmental Policy Act (NEPA), an act established in 1970 requiring federal officials to consider environmental values alongside the technical and economic considerations that are inherent factors in federal decision making. Or at the state level, the SEPA (State Environmental Policy Act) which utilizes a "systematic, interdisciplinary approach to insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment;"[54] With over forty years of proposals and oversight, NEPA and SEPA standards have become the vernacular in environmental protection. However, there are no local, state or federal standards that *regulate* the potential of a decision to decrease the resilience of a system, or standards

Criteria for Resilience Framework

1. How does this strategy take into account the complexity of the system?
   a. Are both human and natural dynamics taken into consideration?
   b. Are variables and their interactions considered across multiple temporal and spatial scales?
2. Does this strategy attempt to limit change or variability in the system?
   a. What are the distributional effects of this reduction?
   b. How does this strategy improve our adaptive capacity, or ability to change?
3. How does the strategy improve on the current diversity of approaches?
   a. How does the strategy overlap existing actions and networks?
   b. How does this strategy reduce risks through redundancy and modularity?
4. How does this strategy take into account future uncertainty of key variables?
   a. How does this strategy create buffers for unanticipated changes or errors?
   b. How does this strategy incorporate diverse knowledge domains?

Figure 4.1 Criteria for Resilience Framework

that provide *incentives* to make decisions that are more robust, or enhance an institution's capacity for learning. The criteria for Resilience Framework could amend regulatory programs to expand their efficacy in supporting a more resilient system.

4.2 Redefine the Decision Framework

What is a redefined decision framework?

A decision framework represents the intersection between values and the system condition that influences the selection of appropriate decisions in a given place and time. Over time, this framework changes, as actors with different values gain or lose power, as new conditions emerge reprioritizing our attention, as new knowledge expands our understanding of system conditions and functions, and innovations expose new opportunities. When assessing tradeoffs between alternative strategies, in complex and uncertain systems, decision makers should further consider potential shifts in decision frameworks over the lifespan of the strategy. Decisions that are more effective under a shifting decision framework are generally more *1) equitable, 2) flexible, 3) proactive, and 4) anticipatory.*

The removal of the Elwha Dam in 2011 is a regional example of a shifting decision framework. In 1910, Thomas Aldwell and the Olympic Power Company built a dam in the narrow gorge of the Elwha River valley on the Olympic Peninsula. While there was opposition at the time from the Elwha Tribe, as well as regulations restricting river alterations that prevent fish migration, those voices were largely overshadowed by a growing demand to bring industrial and economic growth to the area [65]. A century later, the power domain of both the tribes (in accordance with the Boldt Decision) and environmental advocates has grown significantly. We now have greater understanding of system dynamics and the cascading implications of preventing river flow, and that understanding extends to a broader segment of the population. Further, as urbanization trends regionally and globally have depressed salmon runs, watershed health and tribal culture, society is placing a significantly higher priority on protecting natural river systems. Lastly, innovations over the last century have created several more efficient alternatives for energy provision, making it easy to find substitutes elsewhere for the hydroelectric capacity of the Elwha dams. However, one of the most important elements that has not changed over the century is the extent of development in the basin lowlands. If the lowlands had been significantly urbanized, it would not have been politically feasible to release the upland lakes. After nearly two decades of debating and analyzing the watershed, the two dams were removed and salmon have already been observed returning to the headwaters [66].

While the Elwha example shows a decision that was overturned over a century later, there is a significant risk of current strategies being ineffective, or worse, harmful, within a much shorter time span given the accelerated rates of change pervasive in the current urbanizing culture. Might shifting demographics associated with an aging population or migrant workers shift service provision? Might our understanding of regional climate impacts lead to us to invest more heavily in hydroelectric technologies? Might frequent floods destroying property and infrastructure direct political pressure towards immediate and reactive policy?

A redefined decision framework in the Snohomish Basin

In November 2011, the Science Team met to discuss how to integrate alternative perspectives for conceptualizing ways to address long-term problem-solving in the basin. While each team came up with an alternative conceptual model to tell its story, every team shared one element of the story: the need to represent the decision framework linking between the 'system' and 'actors' through both 'actions' and 'assessments' (Figure 4.2). What came across as a very important piece of the puzzle was the need to articulate the diversity of basin actors and the unique lens through which they interpret the system (including both its current state and future trajectory) as well as what they deem to be appropriate actions to improve the

system condition. These unique lenses stem from both the diversity of values and the team members' discipline backgrounds and experience.

Interviews with Science Team members helped identify the current diversity of basin actors and related actions and assessments; however the interviews further revealed how those relationships have changed over the basin's history, and how they may change in the future. For example, the ESA dramatically shifted the role and power dynamic of logging in the basin, and both the Boldt decision and the casinos have changed the role and power dynamic of the tribes in the basin. Today, Boeing is a major actor in the basin. However, if Boeing leaves who would take its seat at the table? Historically there have been tensions between farmers and salmon advocates, but innovative landscape practices might provide strategies that support both goals leading to new alliances.

In supporting decision making under irreducible future uncertainty, decision makers must incorporate tradeoffs associated with shifts in power domains (actors), problem conceptualization (information), political attention (priorities) and innovations (substitutable actions). In the Policy Workshop, held in June 2012, decision makers from around the basin described how potential shifts in the decision framework can be supported by more equitable, flexible, proactive and anticipatory strategies (Table 4.1).

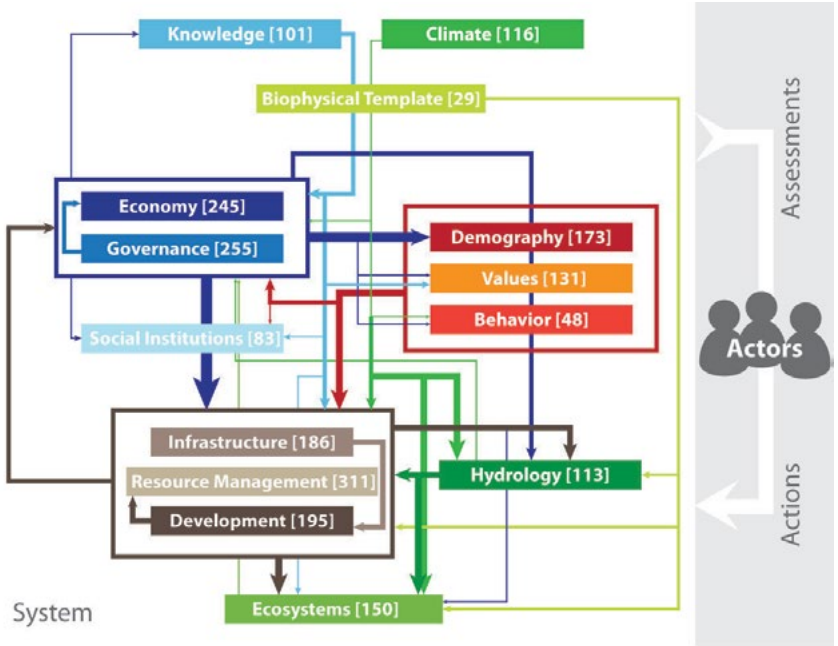


Figure 4.2 Decision Framework and Conceptual Model

Redefining the decision framework under four scenarios

The four scenarios intentionally explore divergent decision framework shifts under each of the four elements (actors, assessment, prioritization, actions; Table 4.2). For example, **Accelerate** tests a shifted power domain characterized by an unfair representation of a few industry leaders. **Metamorphosis** tests the potential implications of society adopting the concept of adaptive capacity. And **Resistance** tests the potential implications of reprioritizing restrictive flood control in response to frequent and severe flooding in the basin.

Table 4.1 Questions, Goals and Strategic Evaluations for Redefined Decision Framework

Overarching Questions	Goal	Strategy Evaluations
1. How might the diversity and power domain of Basin **actors** change in the future?	**Equity**: reduce unfair burden / benefits to one group of actors over another	What are the distributional impacts of this strategy?
		How does this strategy interact with the diverse values and priorities of current Basin actors?
		If power domains shift in the Basin - would this strategy still be supported?
		Are any actors disproportionally harmed or benefiting from this action?
2. How might additional **information** change our understanding of the current problem?	**Flexible:** prioritize projects that can be redirected if our contemporary theories are wrong	How might the logic of this strategy be challenged under currently fringe theories?
		What are the major competing conceptual models for how the system works in relation to this strategy?
		what are the unintended consequences of this strategy?
		redirecting our efforts after implementing this strategy?
3. How might surprise critical events or conditions **reprioritize** our efforts?	**Proactive:** be weary of reactive strategies with long term impacts	Is this strategy concieved in response to or in anticipation of surprise events?
		What is the opportunity cost if in delaying the implementation of this strategy?
		What are the long term consequences of this strategy?
		How effective is this strategy against the full probability distribution of future events?
4. How might innovations change the suite and relative efficacy of potential **actions**?	**Anticipatory:** research potential substitutes and their comparitive long term costs	How does this strategy compare to current and future (potential) substitutes?
		How might the future conditions interact to raise the comparitive benefits of substitutes?
		What is the direction and rate of innovation in relation to this strategy and potential substitutes.

Table 4.2 Described Shifts in Future Actors, Actions and Assessments

	Accelerate	Small	Resistance	Metamorphosis
Actors	few, wealthy, private	federal government, opposing interests	many small advocacy groups	linked, public
Assessment	innovative, capacity, efficiency	personal, emergent, indeterminate	fixed goals	variability, complexity
Prioritization	Short term, individual benefits	precaution	safety, immediacy, status quo	flexibility, diversity
Actions	high yield, high control, innovative, market based.	site level, eco-friendly	quantitative, blunt methods	accountability, resilience, coordination

4.3 Integrated Predictive Models

The benefits and limitations of predictive models

A predictive model is a simplified representation of a phenomenon or process. Models usually take the form of a series of equations which represent the relationship between the model input and outcome variables reflecting the area of interest. Progress has been made in modeling the economic and social consequences of urbanization [55] and models representing natural systems (e.g., biogeochemical, ecological, hydrological, climate, etc.) are also becoming increasingly sophisticated [56,57]. However, the integration of socioeconomic and biophysical models is still at an early stage of development [58].

Predictive models that are designed to provide accurate assessments of future conditions can only account for some of the interactions between highly uncertain drivers of change and the surprising, but plausible, futures over the long term. Complexity and uncertainty emerge from scale mismatches (e.g. downscaling to model local processes), feedbacks between dynamic models, and potentially divergent future scenarios. Predictive models generate probabilities from observed dynamics and predict with a certain level of confidence the trajectory of each variable and mechanism taken individually, but we cannot predict unexpected interactions or tipping points, since the probability distribution of any interactions is unknown.

The integration of existent regional models allows us to represent the coupled human-natural system by exploring the interaction between urban dynamics and ecological processes. By linking operational models, we can expand the representation of relationships between subsystems and increase model realism.

Linking models and scenarios

In predictive modeling, the emphasis is on what we can predict using evidence from the past. Uncertainty is treated as 'lack of knowledge' to be reduced through sophisticated statistical approaches. Alternatively, scenarios focus on the 'untreatable uncertainty', future changes that diverge from past evidence. Based on the interactions of variable trajectories of multiple drivers, scenarios explore hypothetical boundary conditions that expand beyond the scope of predictive models. Scenarios therefore allow planners to assess how robust a set of strategies will be under alternative plausible futures.

Scenarios are extremely powerful when combined with predictive modeling. An integrated model can help in three ways: 1) test hypothesized trajectories and interactions; 2) refine potential relationships and feedback among variables; and 3) assess potential impacts of hypothesized futures on ecosystem services and human wellbeing. Scenarios are not an alternative to models but rather a complement to them, expanding the boundary conditions of predictive models and providing a systematic approach to deal with intractable uncertainties to assess alternative strategic actions. Based on scenarios, we can modify model assumptions. If the integrated model is sensitive to the differences among scenarios, then the assessment will provide information about tradeoffs. Scenarios can help model building by exploring gaps in variables and knowledge of mechanisms to assess future uncertain trajectories. While the scenarios tell the story of what the future could look like depending on the trajectories of important and uncertain driving forces, predictive models can use existing knowledge about known mechanisms to predict the future under the hypothesized conditions.

Building an integrated model for the region

There is increasing interest in integrating scenarios with new integrated models for the region to support a quantitative assessment of ecosystem services. A productive step in this direction would include linking operational models of urban development, climate, hydrology, land cover change, and ecological systems. The blueprint for an integrated model, created by the regional modelers in the Science Team for this project (see Chapter 3, Integrated Model Blueprint, pg 50), can effectively support a framework in this direction. Ten regional models simulating future ecosystem service conditions and driving force trends were selected for the integrated model. These are UrbanSim, Land Cover Change Model, WRF, DHSVM, VIC, HSPF, Shiraz, Ecosim with Ecopath, Pacific Northwest Vegetation Model and the Puget Sound Characterization Model. The integrated model blueprint illustrates how models can be joined in a way that is both sensitive to differences represented in the scenarios and capable of simulating future baseline ecosystem service conditions. While the actual development and testing of an integrated predictive model is far beyond the scope of this project, efforts are underway to implement this research venture.

Figure 4.3 represents a framework for linking urban development, climate, land cover, hydrological, and ecosystem dynamics developed at the UERL for the Central Puget Sound [59]. We model land use change through *UrbanSim*, which predicts the location behaviors of households, businesses, and developers, and consequent changes in land uses and physical development. UrbanSim interfaces with the *PSRC travel sub-model,* which predicts travel demand and forecasts. These are among the inputs required to predict the changes in land cover, hydrological and ecological impacts. *LCCM* allocates specific buildings and associated infrastructure to individual cells of high resolution (30m) to predict changes in hydrology and habitat conditions. *WRF* is a regional climate model (RCM) that uses global climate model output to downscale climate changes as input to the hydrological model (daily temperature and precipitation). The regional hydrology model *DHSVM* uses representations of surface characteristics (surface topography, soil characteristics, and vegetation and land cover) and predicted changes in regional climate data to simulate water and energy fluxes at and below the land surface and their impact on watershed conditions. Outputs from the *LCCM*, *DHSVM*, and *SHIRAZ* are proposed to assess impacts on watershed conditions measured through selected metrics of flow regime and fish productivity. Changes in watershed conditions would feed back on the choices of both households and business locations, and the availability of land and resources.

4.4 Highlighted Risks and Opportunities

The blindspots of traditional practices

We all have blind spots, not only when it comes to what we expect in the future, but also where we seek solutions. In many respects these blindspots are vital: they allow us to streamline our thinking and filter the complexity of our world towards a directed focus [61]. These blindspots get larger as we isolate ourselves within disciplinary silos and as we collaborate with like-minded individuals who reconfirm our biases. Researchers have shown that when reality returns conditions that are at odds with our biases or worldviews, we consider the conditions outliers [62] and modify our 'rules' to accommodate them. A classic example is the discovery of ozone depletion. The appearance of the hole was so unexpected that scientists didn't pay attention to what their instruments were telling them: They thought their instruments were malfunctioning. Exposing our blindspots can reveal both risks and opportunities in long-term planning. The scenario planning process is aimed at the 'aha moment' where potentially overlooked conditions are exposed [63].

How does scenario planning highlight risks and opportunities?

One of the fundamental objectives of scenario planning is to explore the interactions between multiple critical uncertainties supporting otherwise overlooked future conditions that expose our blindspots. Scenarios attempt to highlight risks and opportunities of plausible future conditions by doing three things: 1) integrating multiple disciplines; 2) looking at the divergent trajectories (as opposed to averages); and 3) weaving narratives that interplay between multiple driving forces to tell a compelling story. A common pitfall in developing scenarios is creating stories that are singularly 'bad' or 'good': a worst-case and a best-case scenario. Effective scenarios are messy, each entailing challenges that may be opportunities in disguise. Effective scenarios should reveal potential myths in current culture – about what is stable, what is a 'given' and where our values truly lie.

Investments and Stability in the Snohomish Basin

The four Snohomish Basin scenarios describe futures where economic, social and ecological drivers vary greatly, testing regional worldviews about what is appropriate and certain. While the scenarios show the interplay between dozens of specific expert perspectives, they largely manipulate four myths about future risks and opportunities:

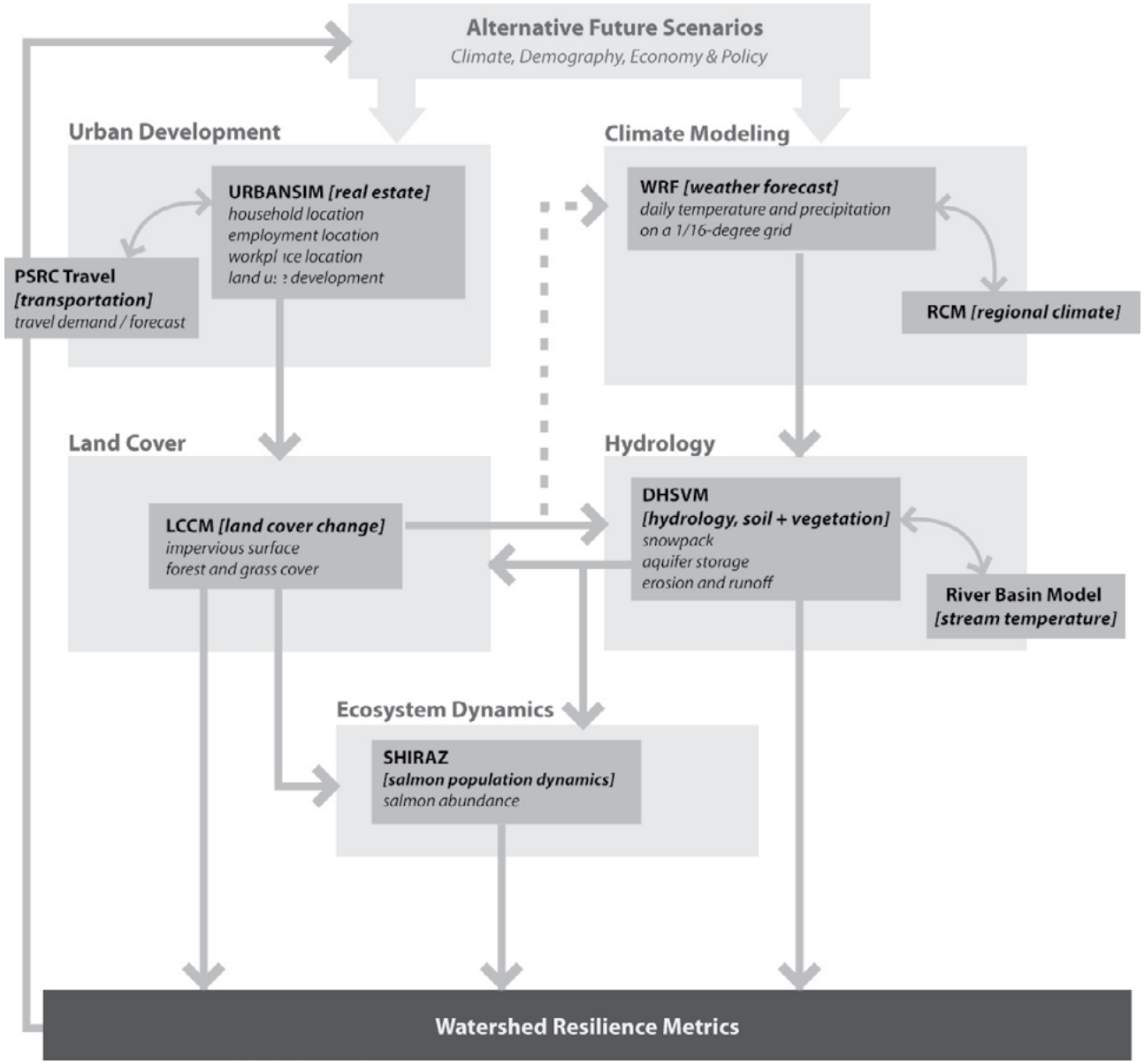


Figure 4.3 Regional Integrated Model Framework Example

- Economic growth will provide the investment dollars needed to support ecological protection.
- We can protect ourselves from future risks with stronger innovations.
- Diverse local and minimal interventions are necessary to understand and respond to environmental challenges.
- We need a dramatic event and strong leadership to fundamentally change our actions.

In some ways, these scenarios simply play the role of devil's advocate, testing the quality of alternative arguments about future conditions to identify weaknesses in their structure. Individuals hold contrasting views about the desirability of different paths towards sustainability; by considering the benefits and risks we can contribute to the dialogue among contrasting points of view [4]. Each of the myths noted above is only partially true and predicated on the linearity of other drivers – and this is of limited value in a complex coupled human natural system such as the Snohomish Basin. The four scenarios expose our assumptions about the basin's social, economic and environmental stability and the potential unintended cost of our investment strategies (Figure 4.4).

Accelerate initially shows some opportunities: significant investment in the basin from innovation and regional collaboration allow for long-term effective solutions. Meanwhile, climate impacts are minimal and the stability of the basin ecosystem appears intact. The risk in the Accelerate scenario is in our ability to counter growth pressure with larger and more effective innovations. Conversely, **Small** initially reflects how the lack of economic investment may support environmental protection. Here the surprise opportunity is in the way that economic depression may essentially 'force' us to care about the natural landscape. The risk in Small is that many environmental challenges require cross-boundary coordination and upfront investments that cannot be achieved without capital and on a site-level approach. In **Resistance** the risk is that optimizing protection at one scale (local) and towards a specific set of functions (e.g. flood protection) and actors (e.g. private and wealthy) can inadvertently reduce the overall resilience of the system. The opportunity in Resistance is perhaps the most hidden, and lies in what Holling terms 'release' or chance to start anew [64]. In **Metamorphosis** the support of experimentation and collaboration forms an obvious opportunity, but the risk that stems from abandoning the familiar looms heavily on the horizon.

Supporting a creative and inclusive policy formation

In developing the Snohomish Basin Scenarios hundreds of solutions were mentioned in early discussions with basin experts (Figure 4.5). However, we asked experts and decision-makers to suspend their judgments about how to solve the problem until the problem can be articulated fully. The scenarios redefine the problem to incorporate alternative perspectives and expose blind spots, with the assumption that diverse actors have different worldviews about what drives the system and what our priorities should be. Our untested hypothesis is that exposing designers and planners to multiple divergent scenarios supports a more creative process for imagining solutions. Further, by arguing against multiple and divergent commonly held myths about the future, we can include a more diverse constituency of participants than might otherwise feel comfortable engaging in the process. A next phase for the basin would therefore be to invite designers and planners to creatively develop strategies given the set of scenario narratives.

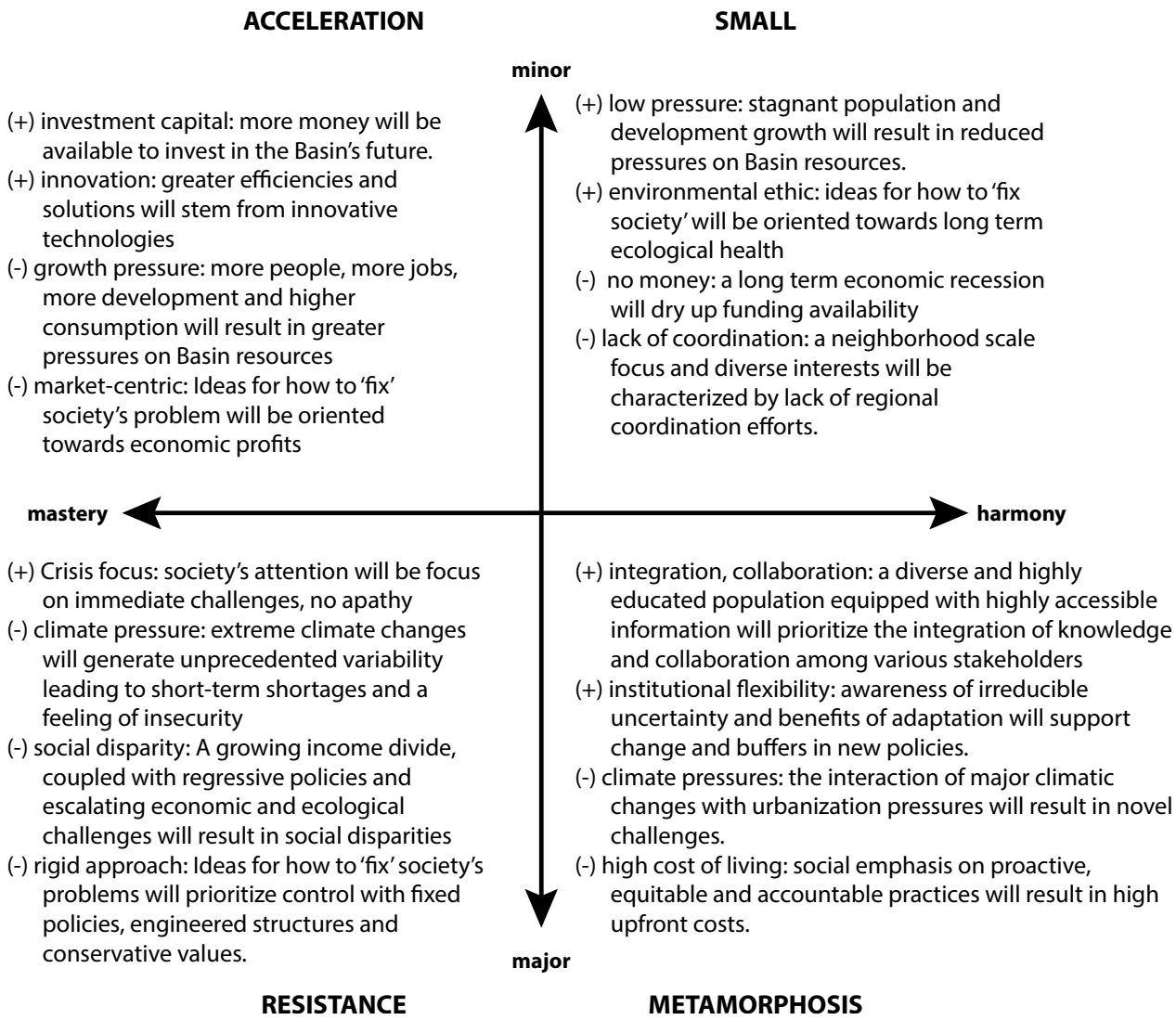


Figure 4.4 Highlighted Opportunities and Risks

to protect rural environment
hiking, camping, skiing
cultural opportunities
awareness of conservation
managing land as urban national forest
increase access
harvesting (timber)
recreation demand
encouraging population growth
institutionalize public lands
global climate impacts
technology concentration (employment center)
new freeway
renewal of tribes
resource extraction
parcelization
transfer Mountain to Greenwat model
salmon recovery and watershed health
Agricultural Drainage Assistance Program
bank armoring
forest protection rules
designate wilderness area
watershed protection measures
dredging
fish habitat protection
water rights
food production
tax incentive (built into rural lands)
conversion to ranchettes
lot size requirements (lower)
flood control
hook properties on septic onto sewer
annexation
export water to treatment plant
farmalnd protection plan (FPP)
public outreach
participante in focus groups, assess and report on distribution of salmon
improve knowledge
manage and remove dikes
3D visualization

include long term history
watershed analysis
land management
understand value of resources
protect by laws and polices
habitat assessment projects
make data publicly available to
inform better citizenship
conduct spawning survey
changes in work and family structure
women in workforce. More paid work outside of home
change caregiving for children and elders
change size of housing unit per housing structure
less households with children
more single parent households
Have children later in life
divorces
disparities between earners
social and economic support for families
flexible hours
health and unemployment insurance
support for elderly
consumption
increase in crime and terrorism
live in smaller, more efficient homes
protect Wilderness areas
growth in lowlands and along interstate and highway
build ski resort
generate power on Sultan
use up water storage over summer
more hydropower operations
small dams with small impoundments
forest conversion
fragmentation
Cascade Agenda
protect Basin's forest
afford a rural lifestyle
cluster development

financial incentives for smart development
farm
purchasing financial certainty makes it acceptable to get less revenue from the land over a large period of time
investment in large forest ownership
timber is going longer distances to be processed
transportation infrastructure (to move wood products around)
rails to trails
trees into energy
facilitating collaborative decision making
leverage assetts
increase regulations
access to informaiton
democratize expertise
air quality studies
analyze natural and human
induces climate impacts
fire suppression
focus on ecosystem health and alterantvie ecosystem services
change values, intrinsic values
influencing human behavior
visibility protection
water management
serve as open space close to city (wilderness area)
ozone regulations
wood burning fireplaces
legal statutes to regulate in light of climate impacts
integrating climate change into ESA
salinity protection (dikes)
bicycle trails
rafts and tubes
green building through incentives and policies such as permits
livei n bedroom communites and drive into the city
public transportation
drive until you qualify

direct growth (what the GMA does)
understand larger scale ties
betwene building, community and transportation network (location more important than green issues)
housing policy
housing subsidies
connect up cities along transportation corridors
fund new infrastructure
take advantage of tax credits
build smaller housing units
build to meet market demand
carbon nuetral by 2030
emission reductions
Living Building Challenge
no net water use, no net energy use, no net waste
higher density and more diversity in land use
green home market
service tourism
create economic base (tourism)
decentrlize infrastrucrue (energy, water, waste)
volunteering (hikers and climbers)
recommend open space acquisition priorities
river restoration
invasive weed removal
new trails
recreation along I-90 corridor
informal trails
annual pass for timber land access
further and quicker access to recreation areas
closing trailheads
mountain bike innovation (new shocks and brakes allow them to go deeper into pristine areas)
closer to home recreation
identfiy forest roads for repair and continued maintenance
designated dispersed areas (camping)
user fees, mandatory training programs and packing waste out (recreation)

shared staff for recreation
build trails
sustainble management funding
national heritage area
environmental planning
capital project implementation
green building codes
strawberry picking
water export from watershed to urban core
commercial fish industry
participation
public engagement
march for the environment
sustainability movement
industrial pollution (hazardous waste, air pollution_)
single occupancy vehicles
urban food communities
retrofit
make planes
integrated bus system
capital improvements
emergency management
remove levees
purchase floodplain parcels
Shoreline Act
Disaster Management Act of 2000
hazard and mitigation plans
going green
relocation out of the floodplain
track and monitor hazards
public recreation trends
boating
WA State Climate Adaptation strategies
mental health service
gated communities
layoffs
reduce VMTs by 50% in State
transportation technology changes
restrictions to travel (due to price of oil and regulations)
telecommuting
large scale transportation projects
stewardship of existing transportation networks

Figure 4.5 Suggested Basin Solutions

4.5 Illuminate Warning Signals

What do environmental indicators tell us?

Recall for a moment the canary in a coalmine. This environmental indicator was touted for not only alarming miners about air quality deterioration, but giving them enough time to change their behavior. The problem today is that, while we have amassed an unprecedented volume of environmental indicators, the links to their implications in terms of both system state and required actions are largely criticized as misleading or untimely[67]. There are several types of indicators. State of the environment indicators (as opposed to performance indicators) can be described by the specific element of the model they communicate. For example the European Environmental Agency includes Driver-Pressure-State-Impact-Response (DPSIR) indicators. Warning signals are a specific type of indicator that are intended, like the canary, to provide decision makers a clear sign of future challenges with enough time to act upon them.

The challenge with coupled and complex socio-ecological systems is identifying changes in slow and fast variables as well as potential system thresholds. Ecological systems generally correspond to a stable set of mechanisms; given a minimal level of pressure these mechanisms continue supporting an overall function. A regime shift occurs when the system reorganizes such that variables are attracted towards an alternative stable state. A clear lake, for example, maintains a stable organization of processes including plant growth limited by nutrients and high amounts of oxygen supporting high levels of aquatic vertebrates; given high levels of additional nutrients (e.g. nitrogen) the feedback loop changes. Now, additional algal growth reduces oxygen levels, reducing plant growth and aquatic vertebrates; in turn this reduces nutrient uptake, further increasing nutrient concentrations. A eutrophic lake is an alternative stable state for lakes where nutrient levels are kept high. Once eutrophic, a lake will rarely revert back to being oligotrophic (clear). Eutrophication is the most widespread water quality problem in the U.S.[68]. However, while nutrient input (e.g. fertilization) is not the only variable influencing the regime shift, it is fast and readily visible. Another factor controlling the system is the watershed's ability to retain nutrients, for example through plant uptake. Here lies the challenge. Even if input is severely limited, once upland forests are decimated they can take a very long time to regain the capacity to retain nutrients, a function often replaced by expensive wastewater treatment plants.

Scenarios and warning signals

Scenarios support effective decision making by coupling robust strategies (effective under a wide range of future conditions) with adaptive strategies (specific actions that are employed at future junctions once more information is revealed about the trajectory). To employ adaptive strategies scenarios are paired with a warning signal, i.e. "If we head in this direction, choose option C." Like a collection of colorful canaries, each warning signal is uniquely matched to the dynamics of its scenario as one cannot use the same indicator to warn of both economic growth and economic collapse. Warning signals highlight the emergence of one scenario over another, and should trigger a re-evaluation for strategic decisions.

Shifting thresholds of the Snohomish Basin

One of the challenges of managing complex ecosystems is that managers don't know where thresholds lie and how close current conditions are to those thresholds. Recent research has shown the use of variability and stochasticity as important indicator variables to assess potential thresholds early on [69]. While experimentation helps managers better identify potential thresholds, we generally don't know how close we are to a threshold until we've passed it. Despite this knowledge gap, decision makers must make assumptions about the state of the system in relationship to critical thresholds in order to prioritize actions. The scenarios, representing varied perspectives about how the future unfolds, are partially predicated on hypothetical assumptions about the resilience of the

system and proximity to potential thresholds. Figure 4.6 exposes the assumptions of the four scenarios in terms of their current state, thresholds, and change in that relationship over the next fifty years.

Examples of signals and actions in the Basin

Warning signals and respective adaptation strategies need to be developed with a specific goal in mind. The focal issue of the Snohomish Basin Scenarios is too broad to effectively define all-encompassing warning signals. Table 4.3 represents examples of warning signals that differentiate critical fast variables shifting across the four scenarios and their significance. Congruent with those changes are guidelines for potential actions that would support ecosystem provision over a longer term. These actions were selected specifically not because they are robust, but because they are fairly effective under the narrow conditions of each given scenario.

4.6 Identify Robust Strategies

Robust vs. Optimal Strategies

Optimal strategies are engineered to be the most effective approaches given a set of conditions. Robust strategies are selected to be effective under a wider range of conditions. A simple example is soccer cleats vs. sneakers: soccer cleats are optimal if you are playing soccer, but if you are not sure which sport you will be playing after school, it may be wiser to bring a pair of sneakers. Certain contexts make the selection of robust strategies more appropriate than optimal: unacceptable failures, diverse stakeholder interests and highly variable and uncertain futures.

Scenarios and Robust Strategies

One of the challenges of traditional decision-making is that it is predicated on the idea that we can identify an optimal strategy. However, this assumption is based on the ability to predict and quantify the probability of risks. The further we look into the future, the more the uncertainty increases, reducing planners' ability to quantify these risks. We may be able to assess the probability of impacts due to the trajectory of change of one variable, but when we couple the multiple uncertain trajectories of two or more variables, that may greatly diminish our ability to quantify future risks (Figure 4.7)[60] .

The key benefit of the alternative scenarios comes from anticipating impacts that lie beyond the probable estimates based on past observations alone. Instead of focusing on a single prediction extrapolated from past trends, scenarios focus on multiple uncertain drivers and expand the assumptions of predictive models to illuminate otherwise unforeseen interactions between individual trajectories. Scenarios therefore expose a wider set of 'plausible outcomes' in order to support more robust strategies [46].

Testing the sensitivity of the system to extreme divergent future conditions is generally done with a limited set of variables. For example, we have estimates for how a major vs. minor climate change affects water supply in the Puget Sound, in terms of the change in timing of precipitation coupled with temperature change (and implications on snowmelt). These estimates have further been coupled with high vs. low population growth (influencing demand) [1]. However, two very important drivers have been left out of the equation. The first is the change in land cover and its implication on water flows (especially groundwater flows); the second is the potential change in agricultural water demand over the next 50 years.

When considering alternative long-term water supply strategies, what are the benefits and costs of alternatives such as a new ground water tap, reservoir, and seasonal dam to detain snowmelt, upland forest protection and gray water infrastructure? How do these strategies compare given changes in population growth vs. the rate and location of urban development, the stability of hydrological flows or the available capital and technological advancements? Scenarios help decision makers imagine possible critical sensitivities and thresholds in the system and explore acceptable risks.

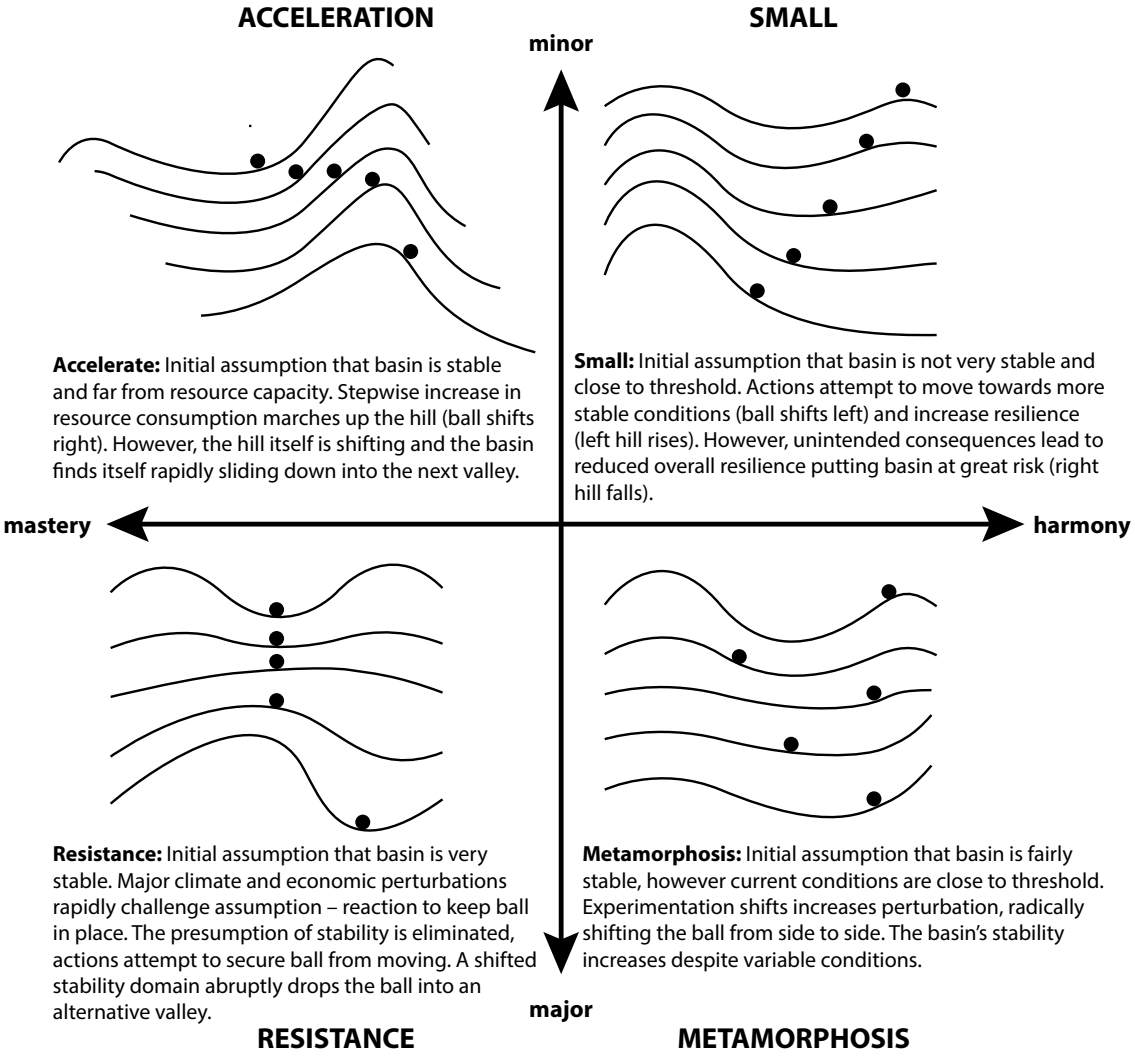


Figure 4.6 Scenario Assumptions for State, Stability and Change

Ball and Cup Diagram: The ball and cup heuristic has been used in literature to describe the movement of ecosystems between alternative stable states. The ball represents the state of the system, while the cup represents a stability domain. Pressure (perturbation) shifts the ball left and right (e.g. resource consumption) along the landscape (line). Meanwhile, the landscape shifts as the ecosystem becomes more or less stable (e.g. the cup becomes less deep and riparian buffers are removed). Resilience can be described as the ability of the ball to stay within the current cup (valley).

Table 4.3 Example Signals and Actions

	Accelerate	Small	Resistance	Metamorphosis
Indicator Description	**Rate of growth** permits, patents (buildings, income, wells, patents	**Size and numbers** many small organizations, businesses, resource parcels, approaches	Level of **borrowing:** household loans, ratio of imports, drilling deeper	**Political momentum** backed by approval and implementation
Significance	Unsustainable growth rate -> resource depletion	Many small units -> lack of coordination; lose resources despite good intentions	Increasing ratios of borrowing -> selling out our future.	Low approval and implementation levels -> paralyzed by complexity
Overall Guidance for Action	Focus on incremental changes that support net benefits through additional growth. In other words, for every 'acre' or 'tree' or 'gallon' you remove, you put > 1 back. For example, low impact development.	Top down support (not enforcement); for example outreach that reinforces regional priorities through individual actions. Example: regional invasive removal plan with articulated tasks.	Sacrifice today to invest in region long term. Raise discount rate while subsidizing local sustainable products. Example: agricultural flood insurance.	Transparent, integrated and adaptable guidelines for decision-making. For example, a criteria for density allocations based on public input

Divergent conditions represented by the Snohomish Basin Scenarios

Scenario planners do not attempt to identify every alternative future condition, but rather the most divergent, or extreme trajectories that influence the focus issue. For example, one can look at the various climate emissions models with implications for temperature change, or only at the highest and lowest. The challenge is coupling the trajectories of multiple drivers in such a way that the final emergent storyline is both realistic (plausible) and divergent. Planners can then use the final set of future conditions to test the efficacy of alternative options and identify robust strategies, or a package of strategies.

The four Snohomish Basin Scenarios were created by crossing the extreme endpoints of the magnitude and variability of climate change (a major vs. minor outcome) and social values governing the relationship between society and nature (mastery vs. harmony). These two drivers were selected by the Science Team as they represented the most important and uncertain trajectories influencing the basin's ability to maintain ecosystem services out to 2060. Within these four frames, variables associated with twelve other driving forces (e.g. demography, economics, natural resources, investments) are animated. Appendix 3 describes the specific trajectories of variables associated with each of these drivers by exploring past and future trends and their relationship to other drivers.

The specific outcomes of the multiple variables interacting within the narratives of each scenario are not model outcomes, but rather hypotheses based on the conversations with multiple basin experts. In order to test the costs and benefits of specific strategies, planners will need to develop quantitative assessments of targeted variables.

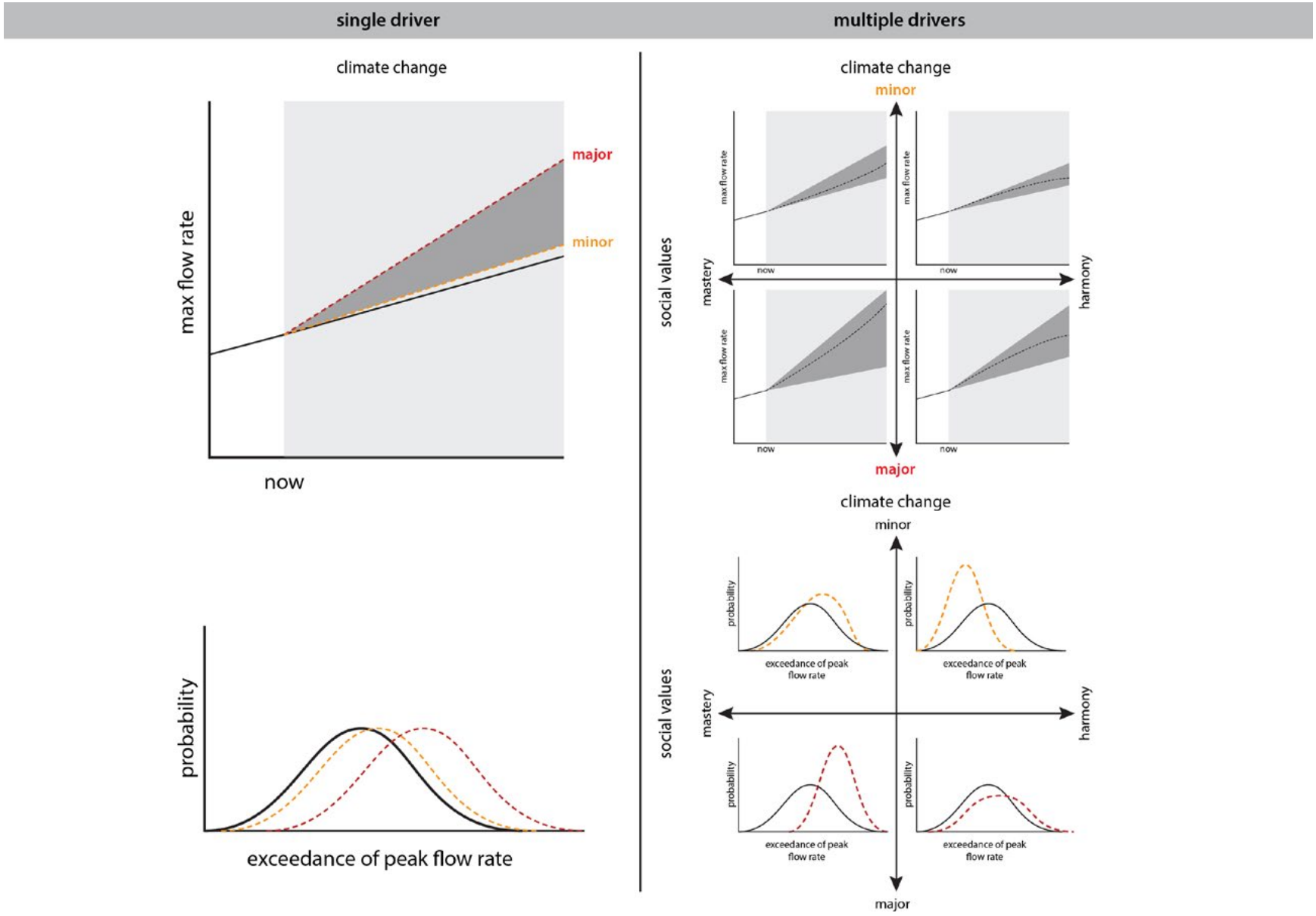


Figure 4.7 Single and Multiple Driver Risk Assessment

However, the storylines of the scenarios can challenge and expand the boundary conditions set by those models, to explore future pressures that may otherwise be overlooked. Figure 4.8 represents the 6 major trajectories depicted by the Snohomish Basin scenarios.

	Accelerate	Small	Resistance	Metamorphosis
Climate Change	Minor - B1	Minor - B1	Major -A1B	Major - A1B
Social Values	ambition, success, control, competence	peace, interdependnece, equity, environmental protection	ambition, success, control, competence	peace, interdependnece, equity, environmental protection
Worldviews and Governance	human ingenuity and knowledge surmount all obstacles, deregulation spurs innovation	persistence is possible only in a decentralized system with minimal demands	impose static goal, maximize central control	multiple stable states and shifting system stability; institutional and political flexibility
Employment, Population and Wealth	fast growth, high income - high tech and service jobs	slow growth, low wealth, aging, natural resource oriented	unstable growth, construction and government sectors, uneven wealth distribution	stable, moderate, diverse growth
Changes to the Built Environment	extensive, impervious, innovative	minimal, low-funds, local-scale	uneven, uncoordinated, reactive	urban, diverse, long term
Ecosystem Pressures	strong decline - urban pressure outweigh investments	slight decline - minor pressure but no coordinated investments	thresholds surpassed - resources are pushed beyond limits	decline and rebound - buffers and diversity relieve pressures

Figure 4.8 Snohomish Basin Major Future Trajectories

Notes

1.The study area is the Snohomish Basin, or Water Resource Inventory Area 7, hereafter referred to as 'the basin.'

2.Carbon stocks were estimated and compared per WRIA using 2007 land cover classifications for Puget Sound Basin and carbon factors per land cover supported in reference.

3.The Snohomish Basin Scenarios, or 'The Scenarios' refer to the overall Snohomish Basin project including both the specific four scenarios developed and the overall process.

4.Acres of urban land is estimated by aggregating impervious area of parcels by decade built (for 1960, 1970, 1980, 1990 and 2000) within the Snohomish Basin.

5.The Central Puget Sound Region, hereafter referred to as 'the Region' includes the four county area of King, Snohomish, Kitsap and Pierce.

6.Based on parcel level assessment of 2010 land use capacity as estimated by PSRC's UrbanSim model in conjunction with high estimates of population growth.

7.Several experts represent more than one agency, department or tribe.

8.The shared conceptual model is the product of both individual and group interviews during the summer of 2010 and the Conceptual Model Workshop, held in November 2010. During interviews, Science Team members were asked to articulate conceptual maps or models that depict how they see the Snohomish Basin's future. Interview notes were synthesized and shared as three alternative conceptual models, which were then elaborated on at the Conceptual Model workshop.

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APPENDIX 1: LIST OF PARTNERSHIPS, PROJECTS AND PEOPLE

STEERING COMMITTEE

The Snohomish Basin Steering Committee consists of fourteen representatives of Basin municipalities and tribes, regional land holders and managers, agencies for economic growth and capital improvements, and environmental policy and advocacy groups. These partners were selected due to their direct influence on the strategic implementation of future actions in the Basin.

Bob Burns: Interim Director of King County Department of Natural Resources and Parks

Nicole Faghin LEED AP. AECOM. Forterra Board Member.

Jim Franzel. Snoqualmie District Ranger. USFS.

Judy Herring. King County Farmland Preservation Program coordinator.

Abby Hook. Hook-Knauer, LLP. Formerly with Tulalip Tribes Natural Resources Department. Hydrologist.

Alice Kelly. Washington Department of Ecology. Senior Planner.

Brent Lackey. Seattle Public Utilities. Major Watersheds Strategic Advisor.

Jim Miller. City of Everett. Snohomish Salmon Recovery Forum. Engineering Superintendent.

Philip Popoff. Puget Sound Energy. Manager of Integrated Resource Planning.

Chris Raezer. City of Arlington. Councilman. Puget Sound Regional Council.

Morgan Schneidler. Tulalip Tribes Natural Resources Department. Formerly with Puget Sound Partnership. Ecosystem Recovery coordinator.

David Somers. Snohomish County councilman. Puget Sound Partnership.

Tim Walls. Snohomish County Public Works Surface Water Division. Senior Planner.

Daryl Williams. Tulalip Tribes Natural Resources Department. Environmental Liason.

SCIENCE TEAM

A group of over a hundred representatives of various disciplines and backgrounds who directed research on driving forces and important relationships, as well ensured the scientific validity of the final scenarios. Science Team members supported the process at multiple levels, from participating in an online interview to attending multiple workshops and providing written feedback. Over the two-year timeline, three major workshops, two meetings, and dozens of focus groups and interviews provided opportunities for Science Team members to be involved in the process. Two subgroups of the Science Team are indicated below: a Scenario Development Team. The list below includes the members' agency affiliation and title at that time of their involvement in this project.

Norm Abbott. Puget Sound Regional Council (PSRC). Director of Growth Management Planning. (retired).

Jackie Aitchison. Washington State Farmers Market Association. Executive Director. (former)

Sue Ambler. Snohomish County Workforce Development Council.

Dom Amor. Puget Sound Energy. Local Government and Community Relations Manager

Stanley Asah. UW College of the Environment (formerly College of Forestry). Assistant Professor.

Elaine Babby. Puget Sound Energy. Senior Land Planner.

Krista Bartz. NOAA's Northwest Fisheries Science Center, Conservation Biology Division. Fisheries Biologist

David Batker. Earth Economics. Executive Director.

Kurt Beardslee. Wild Fish Conservancy. Executive Director.

William Beyers. UW Department of Geography. Professor.

Bob Bilby. UW Water Center. Affiliate Professor. Weyerhaeuser.

Christopher Bitter. UW College of the Built Environments. Rundstad Center

for Real Estate Studies. Assistant Professor.

Michael Blake. UW Evans School of Public Affairs. Associate Professor.

Heidi Bohan. Sno Valley Tilth, Carnation Farmers Market

Leah Bolotin. Washington Department of Transportation (WaDOT)

Branden Born. UW College of the Built Environments. Assistant Professor.

Alan Borning. UW Department of Computer Science and Engineering. UW School of Information. UW Interdisciplinary Program in Urban Design and Planning. Professor.

Ann Bostrom. UW Evans School of Public Affairs. Professor and Associate Dean of Research.

Mark Boyar. Mountain to Sound Greenway. Greenway Trust Founding Board Member.

Nicholas Bratton. Forterra. TDR Project Manager

David Buerge. UW American Indians of the Pacific Northwest.

David Burger. Stewardship Partners. Executive Director.

Ann Bylin. Snohomish County Public Works Surface Water Division. Water Quality Specialist.

Paul Byron Crane, B.L.A., M.A. City of Everett. Environmental Planner and Landscape Architect.

Sara Curran. UW Evans School of Public Affairs. Associate Professor.

Curtis DeGasperi. King County Water and Land Resources Division. Engineer and Lead Hydrologist.

David Dilgard. City of Everett. Historian.

Mary Embleton. Cascade Harvest Coalition. Executive Director.

Gina Estep. City of North Bend.

John Findlay. UW History Department. Professor.

John Gamon. Washington Department of Natural Resources (DNR) Natural Heritage Program. Program Manager.

Simon Geerlofs. Battelle & Pacific Northwest National Laboratory. Marine Science and Policy Analyst.

Bonnie Geers. Quadrant Homes. Vice President of Community Development and Public Affairs.

Jamie Glasgow. Wild Fish Conservancy. Science and Research Director.

Andy Haas. Snohomish County Public Works Surface Water Division. Principal Habitat Specialist.(former)

Troy Hall. University of Idaho Department of Conservation Social Sciences. Associate Professor of Protected Area Visitor Studies.

Alan Hamlet. UW Civil Engineering. Research Associate Professor.

Chris Harvey. NOAA Fisheries. Community Ecologist.

Kelly Heintz. DNR Natural Areas Program. South Puget Sound Region Natural Areas Manager.

Ryan Hembree. Snohomish County Agriculture. (former)

Jan Henderson. Area Ecologist (retired).

Kollin Higgins. King County Water and Land Resources Division. Senior Ecologist.

Jennifer Jerabek. Master Builders Association of King & Snohomish Counties. South Snohomish County Manager

Janne Kaje. King County Land and Water Resources Division. Program Manager.

Kristin Kelly. Futurewise. Program Director. Pilchuck Audubon Society.

Michael Kern. UW/WSU William D. Rucklehaus Center. Director.

Karen Kinney. King County Department of Natural Resources and Parks. King County Hazardous Waste. Program Manager.

Jacque Klug. Department of Ecology (DOE) Northwest Regional Office. Water Resources Program. Section Manager.

(Science Team continued)

Bill Knutson. Farmer.

Dave Kosciuk. Washington Technology Industry Association

Sim Larkin. USDA Forest Service Pacific Wildland Fire Sciences Laboratory. Climate Scientist

Tom Leschine. UW School of Marine Affairs. Professor.

Dennis Lettenmaier. UW Civil Engineering. Professor.

Roberta (Bobbi) Lindemulder. Snohomish Conservation District. Lead Farm Planner / Acting District Manager.

Sandra Mallory. City of Seattle Office of Sustainability and Environment. Green Building and Resource Conservation. Program Manager.

Mike March. Hancock Forest Management. Harvesting Operations Manager.

Stewart Matthiesen. Northwest Natural Resource Group. Development Director and Policy Analyst.

Mark Maureen. DNR. Assistant Division Manager Recreation/Public Access/ WCC

Heike Mayer. Urban Affairs and Planning program at Virginia Tech's Alexandria Center, Metropolitan Institute. Economic Geographer.

Doug McClelland. DNR. Assistant Regional Manager.

Al McGuire. DNR.

Phyllis Meyers. King County River and Floodplain Management. Snoqualmie and South Fork Skykomish Basins. Senior Ecologist.

Marcia Meyers. UW School of Social Work. Professor.

Anna Miles. Snohomish County Public Utilities District.

Barbara Mock. Snohomish County Planning and Development Services. Acting Director. Division Manager.

Dave Montgomery. UW Earth and Space Sciences. Professor.

Scott Moore. Snohomish County Public Works Surface Water Division. Plant Ecologist.

Tom Niemann. Snohomish County Planning Division. Supervisor.

Tom O'Keefe. American Whitewater. Forterra. Rivers and Creeks

Mike Pattison. Master Builders Association of King & Snohomish Counties

Thomas Payant. Snohomish County Public Utilities District. Senior Utility Analyst

Dave Peterson. USDA Forest Service Pacific Wildland Fire Sciences Laboratory.

Patrick Pierce. Everett Area Chamber of Commerce; Snohomish County Young Professionals Network, Everett Chamber of Commerce. Government Affairs Manager.

John Postema. Flowerworld. Founder.

Scott Powell. Environmental Affairs Division, Seattle City Light.

Kit Rawson. Tulalip Tribes Natural Resources Program.

Dave Redman. USFS Mount Baker Snoqualmie Recreation Program Manager.

David Remlinger. Lord Hill Farms.

Casey Rice. NOAA. Research Fisheries Biologist

Luke Rogers. Rural Technology Initiative. Research Scientist and Forest Engineer

Mary Rucklehaus. Natural Capital Project. Managing Director.

Michael Rustay. Snohomish County Public Works: Surface Water Division. Senior Habitat Specialist.

Eric Salathe. Climate Impacts Group, University of Washington, Department of Atmospheric Sciences. Professor.

Rowan Schmidt. Earth Economics. Research Analyst.

Howard Schwartz. Northwest Power and Conservation Council, Washington

Department of Commerce. Senior Energy Policy Analyst.

Mark Simonson. PSRC. Principal Planner.

Amy Snover. Climate Impacts Group. Director. Assistant Dean for Applied Research, College of the Environment

Cindy Spiry. King County Rural Forest Commission, Snoqualmie Tribe's Department of Environmental and Natural Resources, Snoqualmie Watershed Forum. Director.

Julie Stangell. Hancock Forest Management. King County Rural Forest Commission. Senior forester and SFI Program Manager.

Stephen Stanley. Washington Department of Ecology (WA DOE). Wetland Specialist.

Andrew Stout. Full Circle Farm. Founder.

Don Stuart. American Farmland Trust. Pacific Northwest Director (retired).

Jeannie Summerhays. Department of Ecology Northwest Regional Office. Regional Director (former)

Ralph Svrjcek. WA DOE. Water Cleanup Specialist.

Debbie Terwilleger. Snohomsih County Public Works. Surface Water Division. Director.

Jim Teverbaugh. Snohomish County Federated Health and Safety Network. Director.

Dan Tonnes. NOAA Fisheries. Biologist.

Joe Tovar. City of Shoreline. Planning Director (former).

Mike Town. Wild Sky Wilderness. Teacher.

Stacy Trussler. WA DOT. Director.

John Ufford. Washington Emergency Management Division. Planning, Analysis and Logistics Section Manager

Anne Vernez Moudon. UW College of Built Environments, Urban Form Lab. Professor.

Elizabeth Walker. City of Duvall.

Elizabeth Weldin. King County Department of Natural Resources and Parks. Agricultural Drainage Assistance Program Manger

Richard White. Boeing. Government Affairs Manager.

Jan Whittington. UW College of the Built Environments. Assistant Professor of Urban Design and Planning.

Matt Wiley. Climate Impacts Group. 3 Tier. UW Civil Engineering. Hydrological Forecasting Engineer.

Terry Williams. The Tulalip Tribes Natural Resources Department. Fisheries and Natural Resources Commissioner.

Clark Williams-Derry. Sightline Institute. Director of Programs.

Kathy Wolf. UW College of the Environment. Research Social Scientist.

Hendrik Wolff. UW Department of Economics. Assistant Professor.

Ken Yocom. UW College of the Built Environments. Landscape Architecture. Assistant Professor.

Yi Zhao. WA Office of Financial Management. Senior Demographer.

Ken Zweig. King County River and Floodplain Management. Program Manager.

STAKEHOLDER COMMITTEE

The Stakeholder Committee includes representatives of twenty Basin stakeholders that characterize major actors and various interests in the Basin including the Tulalip Tribes, aerospace industry, salmon conservation, farming, forestry, ecosystem assessment, recreation, county planning, and the non-profit stewardship and advocacy arena. This group was invited at the end of the process to discuss the potential role of the Snohomish Basin Scenarios project in supporting more informed long term critical decisions facing the Basin's uncertain future. Note. Some of the Stakeholder Committee Members are also represented as Science Team members.

Kurt Beardslee. Wild Fish Conservancy. Executive Director

David Brock. WA Fish and Wildlife

Dennis Canty. American Farmland Trust. Northwest Regional Director.

Michelle Conner. ForTerra.

Mary Embleton. Cascade Harvest Coalition Executive Vice President - Chief Program Officer

Jim Franzel. Mount Baker-Snoqualmie National Forest.

Bonnie Geers. Quadrant Homes.

Jonathan Guzzo. Washington Trails Association

Jon Houghton. Port of Everett

Sarah Krueger. The Mountaineers

Joan Lee. King County Water and Land Resources Division

John Monroe. Snohomish County Economic Development Council

Deborah Oaks. Stewardship Partners

Craig Partridge. WA Department of Natural Resources

Scott Powell. Environmental Affairs Division, Seattle City Light

Casey Rice. NOAA Fisheries

Julie Stangell Hancock Forest Management, King County Rural Forest Commission

Jeannie Sumnmerhays. Department of Ecology Northwest Regional Office

Debbie Terwilleger. Snohomish County Public Works: Surface Water Division

Terry Williams. The Tulalip Tribes Natural Resources Department

APPENDIX 2: PREDICTIVE MODELS AND INTEGRATION

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I. Introduction

What is an integrated predictive model?

A model is a simplified representation of a phenomena or process. Predictive models usually take the form of a series of equations, which represent the relationship between the outcome of interest and expected drivers and mediating factors. The integration of existent regional models allows us to represent the coupled human-natural system by exploring the interaction between urban dynamics and ecological processes. By linking models that have already been developed and validated, we can increase the representation of relationships between subsystems. An example of an integrated model is a regional existent integrated model used by the UERL lab which integrates an urban development model (UrbanSim), a land cover change model (LCCM) and avian diversity model (Heppinstall et al 2008). The avian diversity model assesses the spatial distribution of bird communities as a consequence of urban development and resultant land cover change.

Why are we developing an integrated predictive model for this project?

The objective of the Snohomish 2060 Scenarios project is to explore how alternative future conditions will influence the efficacy of policies intended to maintain ecosystem services in the Snohomish Basin in 2060. Regional experts constructed the scenarios to explore the uncertainty and relationships between critical driving forces that cannot be described by past events alone. The model integration phase of this project is pursued to complement the scenarios by 1) exploring potential relationships between systems represented by separate existent regional models and 2) quantifying future baseline conditions associated with the alternative futures scenario hypotheses. By linking models we can estimate a plausible range of future baseline conditions of ecosystem services. Based on each scenarios' narrative, we can modify model assumptions and adjust model parameters. If the integrated model is sensitive to the differences between the scenarios, then the outcome (ecosystem service) will vary across the scenarios.

Predictive modeling and the development of scenario narratives are a nice compliment, as the strength of each of these addresses the limitation of the other. While the scenario narratives tell the story of what the future could look like depending on trajectories of important and uncertain driving forces, they are not suited to quantify the potential effects on the suite of ecosystem services of interest. On the other hand, predictive models can estimate baseline conditions and test hypothesized relationships between driving forces and baseline conditions, but are not suited to identify novel trajectories and interactions between uncertain drivers.

How are we developing an integrated predictive model for this project?

The blueprint for the integrated model will be created from discussions among regional modelers in personal interviews and a model workshop. We have identified an initial list of 10 regional models that simulate future ecosystem service conditions or driving force trends.

Models were selected based on the following criteria:

- Models that represent at least one of the 6 ecosystem service areas (species and habitat biodiversity, water quality and quantity and carbon storage and fluxes) or identified significant drivers of the outcome of interest (e.g. urban development).
- Models with a high level of development (ideally have undergone a scientific peer review).
- Models that have been developed specifically for the study area (Snohomish Basin or Puget Sound lowland region).

- Models with a flexible structure that can easily be (or that have already been) integrated with output from others models were a high priority.

We conducted a series of personal interviews with regional model developers during the summer of 2011. Our interview objectives were to 1) identify and summarize regional models in use (review their required input, spatial and temporal scale, assumptions and biases and results), 2) inventory the methods that have been utilized to estimate uncertainty and 3) explore suitability and methods for model integration. This report includes a summary of the information from these interviews and is intended as a reference for the modeling team to refer to as they explore model integration during the Integrated Model Workshop.

Overview of selected Models

This report contains information regarding eleven models (see Table 1). The first three models, UrbanSim, the Land Cover Change Model, and the Weather and Research Forecasting all represent systems which drive changes in ecosystem service levels. The models that follow provide estimates of ecosystem service indicators relating to biodiversity, water and carbon. These models include a salmon life cycle model, a potential vegetation zone model, four water movement and quality models, and two food web models.

- **UrbanSim** develops land use allocations (location of households, employment, etc) given a certain set of inputs.

- **The land cover change model (LCCM)** uses the simulated land use allocations from UrbanSim and projects land cover change as a result of the interactions between urbanization, transportation and biophysical factors.

- **Weather Research Forecast Model (WRF)** investigates what global climate changes mean at the local scale given our terrain.

- **Shiraz** a fish population model. It estimates the effects of changes in conditions (such as those resulting from land use and climate change) on fish abundance (in the selected models selected, Chinook salmon populations were assessed).

- **Potential vegetation model** stratifies the landscape into succession and growth potential vegetation zones.

- Four water movement models were investigated: **DHSVM, VIC, HSPF** and the water flow model module from the **Puget Sound Watershed Characterization Project**.

- **Ecopath with Ecosim (EwE)** is a mass balance equation model which simulates the dynamics of the marine food web under different management strategies or natural events.

The following section summarizes each model in terms of the purpose, approach, outcomes, assumptions and limitations and characterization of uncertainty. The purpose describes the systems and relationships modeled. The approach describes the model type (e.g. process based, probabilistic, etc.) and feedback between model components. The outcome summarizes model results and sensitivity to parameters and scale. Uncertainty explores how and if each model integrates and characterizes uncertainty. Uncertainty refers to situations where the current state of knowledge is such that: the order or nature of things is unknown, the consequences, extent or magnitude of circumstances is unpredictable and credible probabilities to possible outcomes cannot be assigned. Uncertainty can also refer to potential measurement or model error. Lastly, the assumptions and limitations section references how each model relies on limited knowledge to estimate future conditions, including simplifications and biases. Assumptions can come in the form of inputs (e.g. coarse resolution data), equations (e.g. square footage required per employee per industry sector) and the relationships between variables (e.g. how migrating species are handled outside the system studied, or two-way feedbacks between models). Table

2 compares and provides detailed information on the 11 models in terms of system modeled, model type, inputs and outputs and scales.

Table 1. Summary of Models

Model	**System Modeled**	**Related Driving Force or Ecosystem Service**
UrbanSim	Land use	Development, economy, infrastructure
Land Cover Change Model (LCCM)	Land cover change	Habitat diversity, development
Weather Research Forecast Model (WRF)	Climate change	Climate change
Shiraz	Fish population model (Chinook)	Species diversity
Potential Vegetation Model	Vegetation	Habitat diversity
Hydrological Simulation Program – Fortran (HSPF)	Hydrology	Water quality and quantity
Distributed Hydrology-Soil-Vegetation Model (DHSVM)	Hydrology	Water quantity
Variable Infiltration Capacity Model (VIC)	Hydrology	Water quantity
Puget Sound Watershed Characterization Project	Hydrology	Water quantity
Ecopath with Ecosim	marine food web biomass dynamics	Species diversity, carbon
Atlantis	marine food web biomass dynamics	Species diversity, carbon

Table 2. Model Synthesis

Model & System Modeled	Model Type	Scales[1]	Inputs and Outputs
LCCM: land cover change (land cover and landscape pattern)	Multinomial logit framework	**Time:** 3 year intervals	**Inputs:** Current & historic land cover, adjacent land cover, land use, transportation infrastructure, topography, critical areas (steep slopes, wetlands, etc), spatial contagion of development
		Space: 30 by 30 m pixel across the Central Puget Sound	**Outputs:** land cover change, probability of transition
UrbanSim: Urban development: household, employment + workplace locations, real estate prices, real estate development	Microsimulation, multinomial choice, multiple regression	**Time:** Annual, daily for activity-based travel	**Inputs:** households, people, parcels, buildings, natural amenities, accessibilities, employment, development restrictions, transportation, regional economic forecasts, activity-based travel (from EMME3)
		Space: buildings and parcels, travel network	**Outputs:** Location of households and employment, real estate prices, location, type and density of the built environment (dwelling units)
WRF-CCSM3: down-scaled climate predictions (atmosphere and land	Numerical simulation	**Time:** 6 hour intervals	**Inputs:** global climate simulations, topography, land cover
		Space: ~20 km grid across western US	**Outputs:** Meteorological fields (temperature, precipitation, wind, soil temperature, snow cover, soil radiation)
WRF-ECHAM5: down-scaled climate predictions (atmosphere and land	Numerical simulation	**Time:** 6 hour intervals	**Inputs:** global climate simulations, topography, land cover
		Space: ~36 km grid across continental US	**Outputs:** Meteorological fields
Shiraz: fish habitat and salmon lifecycle (Chinook)	Stochastic simulation	**Time:** annual timestep	**Inputs:** stream temperature, discharge, fine sediment, habitat types, forest cover, impervious cover, road density, precipitation, survival capacity, hatchery, harvest
		Space: user specified, often for sub-basins	**Outputs:** Salmon population attributes: abundance, productivity, spatial structure, and life-history diversity
Potential Vegetation Model: potential vegetation zone	Deterministic boundary equation model	**Time:** none	**Inputs:** total annual precipitation at sea level, mean annual temperature at sea level, fog effect, cold air drainage effect, topographic moisture, temperature lapse rate, aspect, potential shortwave radiation
		Space: 90 m pixel across WA state	**Outputs:** location of 15-20 potential vegetation zones
HSPF: local watershed hydrology and water quality	Empirically derived, deterministic discrete space/time	**Time:** subdaily	**Inputs:** rainfall and other meteorologic records (such as solar radiation) and land surface characteristics (vegetation cover, soil type)
		Space: spatially lumped into ~2 km^2 subcatchments	**Outputs:** hydrologic components (soil moisture, surface runoff, evapotranspiration), flood statistics (stream discharge, low flows), water quality

Model & System Modeled	Model Type	Scales[1]	Inputs and Outputs
DHSVM: regional hydrology	Deterministic discrete space/time mechanistic, physical (hydrologic) process[2]	**Time:** subdaily intervals (1-3 hrs depending on size of basin)	**Inputs:** meteorologic records and land surface characteristics
		Space: 30 – 200 m^2 resolution across Puget Sound basin	**Outputs:** hydrologic components and flood statistics
VIC: large scale hydrology	Deterministic discrete space/time mechanistic, physical (hydrologic) process	**Time:** daily (snow is at hourly intervals)	**Inputs:** meteorologic records and land surface characteristics
		Space: 1/16 degree (~32 km^2)	**Outputs:** meteorologic drivers (humidity, solar radiation), hydrologic components and flood statistics
Puget Sound Watershed Characterization Project: water movement	Deterministic qualitative model	**Time:** none	**Inputs:** land cover, soil types, discharge areas, habitat inventory, rain on snow areas
		Space: flexible, to a ~1 mi^2	**Outputs:** landscape indicators based of delivery and controls of water movement, surface storage, subsurface movement and recharge and discharge
Ecopath with Ecosim (EwE): a mass balance model for evaluating food web structure and community scale indicators	Trophodynamic mass balance simulation	**Time:** monthly	**Inputs:** functional groups, foodweb relationships, fishing, reproduction,
		Space: not explicitly modeled, represented with functional diet rules	**Outputs:** biomass allocation, functional group diversity, energy flow and mortality
Atlantis: biophysical ecosystem model	Spatially discrete deterministic biogeochemical whole of ecosystem	**Time:** 12 hour timesteps	**Inputs:** functional groups, foodweb relationships, abiotic features (temperature, circulation, nutrients, dissolved oxygen), spatial dynamics, species-habitat interactions, life history features, management policies
		Space: user specified	**Outputs:**

1. For some of these models, the minimum scale is finer than the recommended scale for interpreting results to inform decisions and management strategies.

2. Water and energy balance

II. Model Descriptions

URBANSIM

Purpose

The purpose of UrbanSim is to predict the locations of households and jobs across urban landscapes given current forecasts of population and economic dynamics. UrbanSim develops land use allocations (e.g. location of households, employment and population) based on the probability of transition. UrbanSim allows a user to investigate changes in future land use based on current conditions and parameterized changes in policies, transportation infrastructure or other variations. Users can run a series of UrbanSim simulations with a suite of potential future scenarios or varied boundary conditions to compare the divergence of future land use and development outcomes. Currently, the Puget Sound Regional Council (PSRC) operates UrbanSim to inform long range transportation and land use planning efforts.

Model Approach

UrbanSim is an agent based microsimulation model. It consists of a set of interacting multivariate regression and discrete choice models for estimating demographic transitions, economic transitions, household (re)location choices, employment (re)location choices, real estate development and land prices. The demographic transition model compares population and household characteristics (e.g. household size and income distribution) from a regional economic forecast model, to the UrbanSim household database to determine the number and types of households that will be added and lost in a given timestep. The economic transition model compares jobs based on economic forecasts and the UrbanSim employment database.

The household and employment relocation models predict the probability of a household or job relocating within the year. Additional and relocated households and jobs are then placed in the household and employment location choice models. The location choice models are influenced by a number of factors, including last year's land price, accessibility, household and job characteristics and neighborhood attributes. The land price model estimates real estate prices based on site characteristics (land use, critical areas, proximity to amenities, etc). Finally, the real estate development choice model predicts new or re-development occurrences, type and location.

Output

Output from UrbanSim includes the location and demographics of households, employment and population, real estate prices, and built environment characteristics across the landscape (e.g. location of dwelling units).

UrbanSim is sensitive to different variables over the short versus long term. Over the long range, exogenous demographic and economic growth is one of the most important determinants of UrbanSim model outcomes. However, dynamics over the short term range are more heavily influenced by market dynamics and location choices. Specification of policies or household and employment choice parameters (e.g. a preference for density or proximity to natural lands) influences short-range model output.

Uncertainty

PSRC has just adopted a Bayesian melding approach (Sevcikova et al 2007, Sevcikova et al 2011) to include an estimate of uncertainty in stochastic simulations. This statistically grounded method combines available observed data with simulation results for the same time period at a specific geographic level to estimate variance and bias. These measures are propagated into the last prediction time step and represented as confidence intervals. Under this approach, multiple runs could evaluate alternate model simulations using different scenarios, such as a different model structure. Bayesian melding allows you to take the uncertainty associated with model specification and merge it around all run scenarios and put it into 1 portfolio of results.

Assumptions and limitations

UrbanSim requires making several assumptions to simulate household and employee choices. Foremost are the assumptions of random utility theory, urban economic theory (rooted in bid rent theory), hedonic price theory, dynamic market equilibrium, price adjustment, and disequilibrium. In the real estate price models, households, businesses, and developers are all price-takers, and market adjustments are made by the market in response to aggregate demand and supply relationships. Each agent responds to information from a previous market period.

UrbanSim relies on external inputs and parameters that carry their own sets of assumptions and limitations. Population and household growth from OFM's model carries assumptions about future economic growth, natural increase and migration. Industry parameters including redevelopment considerations, developer costs, space (square feet) required per job by sector and development templates that identify what can be done on the land and where in the region are fixed. Environmental constraints (e.g. stream buffers) are represented as static, but could be mitigated. Transport decisions are modeled on behavior observed under relatively stable trends in the price of gas over time.

Land Cover Change Model (LCCM)

Purpose

Land cover change emerges as a result of the interactions between social (e.g. growth management policies, household preferences), economic (e. g. land development, business location), and biophysical (e.g. flooding, landslide) processes operating across multiple spatial scales. The LCCM predicts the location and quantity of land cover change in the Central Puget Sound urbanizing region (King, Kitsap, Piece, and Snohomish). In addition to characterizing the consequences of urbanization on land cover, the LCCM model output can be utilized in ecological modeling applications to investigate the implications of land cover change on ecosystem functions and services. There have been two applications where the land cover change model has been linked to an ecological model. The first includes an avian diversity model that used the land cover change predictions to assess the influence of urban development and the resultant loss of forestland and fragmentation of habitat on bird community composition across the Seattle metropolitan region (Heppinstall et al 2008). The other application was to estimate changes in aboveground plant carbon stocks due to land cover change across the Puget Sound region (Hutyra et al 2011).

Model approach

The LCCM is a high resolution spatially explicit land cover change model based on a multinomial logit framework. The LCCM estimates the land cover transition probability of a site from one land cover class to another over a four year time step using historical land cover images. The equations describing the probability of a site to transition from its current land cover to another are estimated empirically. These probabilities are determined as a function of a set of biophysical (elevation, critical areas), land use (type, development units and intensities) and change variables at three different operational scales, at the site, its location along various gradients and its spatial context (i.e. landscape patterns of neighboring pixels, such as contagion). Each land cover class has its own set of equations representing the transition probability based on the interaction of these components. Finally, the series of transition probability grids are used to simulate future transitions through a Monte Carlo process. Spatial masks were used to constrain urban land cover transitions based on empirical relationships which reflects the available space for growth based on policies (the growth management act, transfer of development rights associated with timber and agriculture), land ownership (Federal and state owned lands) and the physical limitations of the region (Cascade mountains to the east and Puget Sound to the west).

Output

Eight classes of land cover are simulated at 3 year intervals out to 2050 for the four county Central Puget Sound region. The eight classes include heavy urban (>80% impervious area), medium urban (50-80% impervious area), light urban (20-50% impervious area), grass, deciduous and mixed forest (>80% deciduous trees or 10-80% each deciduous and coniferous trees), coniferous forest (>80% coniferous trees), clearcut and regenerating conifer forest. This can then be summarized into a suite of landscape metrics which represent land cover composition (i.e. diversity, dominance), configuration (density, size, connectivity), and spatial neighborhood (contagion). A sensitivity analysis revealed landscape composition and configuration were important in predicting land cover change.

Uncertainty

The Urban Ecology Research Lab utilized the GeoPontius approach to assess uncertainty associated with both the amount of land cover change and the location agreement between observed and predicted land cover change at multiple resolutions. They are also considering the use of Bayesian melding uncertainty analysis approaches to address the temporal decay of uncertainty.

Assumptions and limitations

Land cover transitions emerge from interaction between human actions and biophysical resources and constraints of the landscape. However biophysical factors are not represented dynamically; they maintain a constant value in the model. The land cover change model does not explicitly model human behavior at the household or individual level. Urban development is simulated (UrbanSim) in tandem with land cover change; and the relationship is one directional. Being an empirically based model, land cover transition is affected by current urban patterns, so there is the implicit assumption that future trends will behave in a manner similar to the past (temporal stationarity). There are also assumptions of spatial stationarity; as such the model was also parameterized and run on sub-segments of the region that are believed to behave similarly.

Weather Research and Forecasting (WRF)

Purpose

The Weather Research Forecasting model has multiple uses and specifications; it is utilized for both operational forecasting and atmospheric research needs. In this report, we synthesize the ECHAM5–WRF and CCSM3–WRF regional models which investigate what global climate change means at the local scale. Global climate change models do not provide a fine enough resolution to account for the impact of the complex terrain, coastlines, varied ecological landscapes and land use patterns of Washington to assess the regional climate. The WRF[1] model runs create local climate scenario information which informs a cascade of models assessing the effects of projected local climate change on atmospheric (air quality), aquatic (water quality) and terrestrial systems.

Model approach

The WRF is a mesoscale atmospheric regional climate model. WRF simulates the physical processes in the climate system forced by global climate model output. It is based on fluid dynamics and principles of energy exchange. The physics package includes a microphysics scheme, a simple cloud model, a land surface model, a planetary boundary layer and an atmospheric shortwave and longwave radiation model. The microphysics scheme simulates water vapor, cloud water, rain, cloud ice, and snow. The cloud model integrates moist updrafts and downdrafts. The Land Surface Model predicts soil temperature and moisture, canopy moisture and snow cover. The planetary boundary layer represents heat and moisture fluxes from local and non-local gradients.

1 For brevity, in this report we refer to ECHAM5–WRF and CCSM3–WRF as 'WRF'. When necessarily to distinguish between the two we refer to the specific sub-model.

Global climate models provide the forcing conditions at the boundaries of the regional model (WRF). There are two applications of the WRF model in the Puget Sound region. The CCSM3-WRF was configured and run by the Pacific Northwest National Laboratory (PNNL); using forcing data from the NCAR Community Climate System Model version 3 (CCSM3). The second, ECHAM5-WRF, was run at the University of Washington in collaboration with the Climate Impacts Group at the Joint Institute for the Study of the Atmosphere and Ocean. It was forced with the ECHAM5 global model from the Max Plank Institute, Hamburg. Differences between the two simulation configurations are minor and primarily attributable to the choice of global forcing models, the grid spacing and spatial extent. CCSM3-WRF was operationalized on a 20 km grid using an extended buffer zone, while ECHAM5-WRF ran on a 36 km grid using nested grids and interior nudging with relaxation coefficients based on a linear-exponential function. The ECHAM5–WRF grid encompasses the continental US while the CCSM3–WRF grid covers just the western US. Finally, the CCSM3-WRF model is run using the Special Report on Emissions Scenarios A2, while ECHAM5 implemented the A1 B emissions scenario. Both global climate models provide data at six hour intervals.

Output

Weather data are simulated out 100 years, at 6 hour intervals by both models. The output includes temperature, precipitation, wind, soil temperature, snow cover, solar radiation and soil moisture. The largest differences in outcome between the ECHAM5–WRF and CCSM3–WRF simulations are due to the global models used to force the regional simulation. The ECHAM5 A1B simulation projects a minor temperature increase and an increase in precipitation of high magnitude, while the CCSM3 A2 projects a warmer and drier future in comparison to 19 other global climate change model projections using the same SRES emission scenarios.

Uncertainty

The output of both regional models was validated using gridded seasonal averages from a period of 30 years from weather station observations (1970-1999). An empirical model interpolated the station information, based on a simple terrain model for temperature and precipitation. Validation with the resultant gridded estimates, as opposed to raw station observations, may also introduce a small bias/uncertainty.

In general, the influence of major geographic features and the seasonal cycles are represented well with the simulated temperature profiles and overall magnitude of precipitation and its geographical distribution. However both models produce a substantial cold bias compared to the observations. The large precipitation peak over the Olympics is also poorly represented as the coarse resolution of the models effectively treat the lower elevation Cascades as more of an isolated hill than a ridge. There is also a combined bias from the global and regional model. As the regional model may introduce biases not present in the global model. Nor can it explicitly remove any systematic differences between the global forcing model and observations, except where such bias is due to unresolved processes.

Assumptions and limitations

The most important assumption of WRF is that the mathematical description of climate processes is realistic and that all significant processes are in the model. In addition, four assumptions may lead to estimation errors: lack of feedback from regional to global models, grid resolution, exogenous carbon emission estimates, and simplification of land cover classes. Mesoscale processes do not feedback onto the global climate simulation and large-scale features that depend on these feedbacks cannot be properly represented. In a comparison of the two model results, variability is likely a function of different grid resolutions. Generally, if the model resolution is too coarse, the affects from the mountains are not represented well; while a finer resolution is computationally demanding. The best global climate change models are defined by conservative criteria, so

the impact of carbon emissions is likely underestimated. There are 25 dominant land cover classes in the Anderson USGS land cover data. WRF homogenizes the pixel to the dominant vegetation (type). The potential error from this simplification/aggregation of land cover is most relevant at the urban, natural interface.

SHIRAZ

Purpose

The Shiraz model is a spatially explicit fish life cycle model that estimates population abundance across space and time. Shiraz can be used to estimate the effects of changes in conditions such as habitat loss and/or restoration, harvest or fisheries management. It is a flexible model framework that enables the researcher to investigate changes in a set of future conditions (e.g. from climate change or land-use scenarios) into consequences for salmon population status and assess likelihood of recovery. The model has been applied in the Snohomish Basin to assess the influence of habitat restoration and protection (Scheuerell et al 2006) in addition to alternative future climate (Battin et al 2007) scenarios on two Chinook salmon populations in the Snohomish River Basin. The Shiraz model provided estimates of Chinook salmon abundance which can be translated into three indicators of viable salmon populations (VSP): productivity, spatial structure, and diversity.

Model approach

The Shiraz model consists of a set of user-defined relationships among habitat attributes, fish survival, and carrying capacity. At the core of Shiraz exists a multi-stage Beverton–Holt model (Moussalli and Hilborn 1986) describing the production of salmon from one life stage to the next (e.g. spawners, eggs, fry, smolts, etc). The user specifies initial conditions for how many individuals of each life stage and stock are alive and the proportion of each life stage occupying each geographical area. Then the number of fish surviving to the next life stage is a function of the number alive at the previous life stage, their survival between those stages, and the capacity of the environment to support them.

The underlying physical environment is the primary driver of fish survival and capacity at different life stages. The physical environment (climate, land use, and landscape processes) is specified through the habitat quality and quantity parameters. For example, Bartz et al (2006) related land use variables and geomorphic characteristics to habitat quality parameters. Scheuerell et al. (2006) then linked those parameters to salmon survival between various life stages using other previously published relationships. Battin et al (2007) characterized the effects of climate change on salmon performance by linking output from DHSVM, a hydrological model. In this study air temperature, precipitation, and land use affects on stream flow and temperature were estimated and translated into the Shiraz framework as habitat quality and quantity parameters which, in turn, drove salmon survival and capacity (Battin et al 2007). The influence of fish hatcheries and harvest rates can also be investigated within the model, although these have not been explored as of yet within the Basin using Shiraz.

Output

Model output is fish abundance, which can be used to estimate productivity, spatial structure, and life-history diversity. Shiraz has been run at a yearly time step out to 2050 at the sub-basin scale. In the Snohomish River Basin, the 62 sub-basins ranged from 12.2 to 246 km^2 in area, and from 0.34 to 98 km in stream length.

Uncertainty

Scheuerell et al (2006) suggested two ways to represent uncertainty of model inputs: use Monte Carlo simulation techniques or add a stochastic element to model parameterization by randomly drawing parameter values for each time step based on hypothesized statistical distributions of these parameters. Battin and colleagues (2007) used DHSVM-generated 72-year time series of flows and

temperatures as the basis for a Monte Carlo analysis. For each climate and land-use scenario, the Shiraz model was run 500 times, each run was 100 years. At every (annual) time step, a year was randomly selected from the 72-year DHSVM flow and temperature time series and the appropriate functional relationships were applied to these values for that year. This approach maintained within-year correlations among variables while allowing the researchers to explore a wide range of future climate time series.

Assumptions and limitations

The Shiraz framework allows the model user to decide what level of spatial resolution to consider (from entire watersheds to as fine as individual stream reaches), although once defined the model treats all spatial units as identical in size with respect to fish movement. A number of assumptions were made in the parameterization of Shiraz in the Basin studies, however since the Shiraz framework is so flexible many of these parameters can be modified in future applications of the model. Below is a summary of some assumptions and choices modelers made in the previously discussed studies. Some of the peripheral driving forces were assigned temporal stationarity[2], such as hatchery operations, stray rates and harvest rates. Survival rates in the ocean were treated as a set of constants with the assumption that the ocean carrying capacity is infinite. The impacts of rising sea levels, ocean warming and ecological interactions with other species were not incorporated into local applications of the model. However with climate change, interactions with other species may affect Chinook populations differently due to changes in competitive edge under a new set of conditions. Additionally, plasticity of life-history traits may enable Chinook to adapt to climate change in ways not captured in the model.

2 Relationships and rates of change associated with model components remain constant over time.

Potential Vegetation Model

Purpose

Potential vegetation is the projected climax plant community that could occupy a site based on climate and environmental conditions. Potential vegetation is used in science and natural resource management for stratifying land relative to the environment and by informing questions regarding succession and growth potential. The potential vegetation model was created by the US Forest Service to predict and map the spatial distribution of broad categories of environmental (e.g. growth potential) and successional (climax) potential of the landscape. Predictive models which plot the location of potential vegetation zones contribute to the mapping of species and communities, a necessary tool in the management of natural resources, biodiversity, and the conservation of biotic communities.

Model approach

The potential vegetation model uses direct and indirect gradient analysis, factor analysis, and ordination methods to delineate the location of potential vegetation zones based on underlying environmental (biophysical) variables. Data on environmental and climate variables are linked to reference data of plant species presence (or sometimes absence), known plant community patterns, or field samples of plant community classes. For a full list of model input, see Table 1. Finally, boundary equations are utilized in lieu of more traditional regression-based algorithms. The boundary models are composed of a set of nonlinear quadratic equations which estimate the boundary between units of vegetation zones. The best fit line was determined by the sum of errors. Refer to the USFS General Technical Report (Henderson et al 2011) for full details.

Output

The model output is a 90 m pixel based map of the boundaries delineating potential plant association groups for the state of Washington. There are 15-20 plant association groups represented in

the model; but only 5 are found in our study area (Snohomish Basin). These include the Western hemlock zone, silver fir and western hemlock zone, mountain hemlock and silver fir zone, subalpine zone and the alpine zone.

Precipitation at sea level is the most important determinant of the boundaries between potential vegetation zones in the model. It alone can explain 50% of the variation. The fog affect is also significant; its influence is felt along the coast and at a small band along the east side of the Cascades. Fog affect includes tree drip, fog condensation, and the direct and indirect effects of evapotranspiration. Along the coast and foothills of the Cascades the effect is equivalent to approximately 40" of precipitation at sea level. Temperature at sea level, aspect and solar radiation have little effect.

Uncertainty

The boundary equations were validated by producing a map of the potential vegetation zones of the study area and by comparing it to an independent set of observations. The validation to a set of 155 independent plots showed an accuracy of 77.4 percent and the model accurately predicted the vegetation zone for 76.4 percent of the 1,497 eco-plots used to build the model. Spatial uncertainty along the edges/boundaries is hard to separate from sampling error.

Assumptions and limitations

Model assumptions stem from the simulation of simplifying complex vegetation changes and the resolution of vegetation mapping. The nature of vegetation is that it is dynamic over time, but randomness is bounded by environmental conditions on site. While every site on a landscape is different, or unique, it can be classified into an aggregate vegetation association group. In addition, while the full suite of drivers of vegetation can be discovered, the variables in the model are surrogates for much more complex relationships. Further, the model assumes that as the climate changes different species assemblages will stay the same. However, it is believed that the region will exhibit new assemblage groups from climatic changes.

Quantifying map accuracy between data from field plots collected at one scale with a map of pixels at a different scale is difficult, both conceptually and practically. The resultant pixel-based map of potential vegetation zone locations was based on fine scale field plots. The model assumes that one can translate across different scale resolutions from fine scale field plots to moderately coarse landscape classifications. Often the resolution of the types of vegetation on the ground is finer than the resolution of pixels (or polygons) used to portray them. Thus a single 90-m (0.81-ha) pixel can contain two or more fine-scale field plots of different community types or plant associations. The size of a pixel is often a function of the technology being used and the constraints of computer hardware and software used to represent them.

HYDROLOGY MODELS

Purpose

There are a suite of spatially explicit hydrology models which simulate water movement across a region's land surface. In this report we focus on three of these models in use in the Puget Sound Lowlands: the hydrological simulation program – Fortran (HSPF), a distributed hydrology-soil-vegetation model (DHSVM), and a variable infiltration capacity model (VIC). These models use continuous rainfall and other meteorologic records (e.g. solar radiation) and land surface characteristics (e.g. vegetation cover, soil type) to compute water movement. These models have been applied operationally to explore streamflow prediction, and in research endeavors to examine the effects of land use and land cover change, and climate change on hydrologic processes. While DHSVM was originally developed to predict effects of forest harvest on flooding, the model was recently modified to include parameterization to assess impacts on the hydrology of Puget Sound by urbanization (Cuo et al 2009). In addition to water quantity investigations, HSPF can be used to assess the water quality consequences of reservoir operations, point or nonpoint source treatment alternatives and flow diversions. VIC and DHSVM were developed by Land Surface Hydrology Research Group at the

University of Washington, while the modern HSPF was developed jointly by the Environmental Protection Agency and US Geological Survey.

Model approach

HSPF is an empirically derived water transport model; whereas DHSVM and VIC are mechanistic, physical (hydrologic) process models. HSPF contains hundreds of process algorithms developed from theory, laboratory experiments, and empirical relations from monitored watersheds. The VIC model is a large-scale, semi-distributed grid-based hydrology model which solves for full water and energy balances. DHSVM uses an approach similar to VIC, while DHSVM operates at a finer scale and is a fully distributed hydrology-soil-vegetation model.

One of the biggest differences between VIC and DHSVM is how water movement is transferred across a boundary between grid cells. VIC is semi-distributed, meaning all cells of the same elevation are treated as one, or as bands of land with the same elevation ranges. While DHSVM explicitly routes water over the surface and through the subsurface within and between neighboring grid cells, resulting in a more realistic representation of water movement patterns due to variation in the landscape. Effects of topography on incident and reflected solar radiation are explicitly represented. Therefore the topography and mountain ranges in the Pacific Northwest are better represented in DHSVM (at the moderate spatial resolution of 30-200 m^2). VIC is more appropriate for applications focusing on large river basins, DHSVM for smaller watersheds and HSPF for finer scale applications.

Output

Many variables are simulated by these models, including meteorological drivers (e.g. humidity, solar radiation), hydrologic components (e.g. soil moisture, surface runoff production, evapotranspiration, snowpack, etc), and flood statistics (e.g. stream discharge, low flow). In addition, HSPF can simulate water quality for both conventional and toxic organic pollutants. Soil moisture, precipitation and snow are the dominant drivers of model results.

Uncertainty

The uncertainty regarding the potential variability in hydrologic conditions due to climate change has been explored by linking and assessing different global climate models.

Assumptions and limitations

There are a number of required assumptions when translating information from observations into the mathematical hydrology model. To name a few, there are assumptions regarding the fundamental relationships between soil moisture and runoff and how information from rain gauges is interpolated across the study region. Gridded meteorological forcing data can be estimated in VIC from weather station points and translated into DHSVM. Additionally, as HSPF is predominantly an empirically derived model calibrated from data for historical conditions the model's investigative power to estimate the effects of future climate change or alternative policies on water quantity and quality are limited. Flow is dominated by elevation within DHSVM, not the gradient of the water table. There are no deep groundwater models integrated with any of the three focus hydrology models. One implication of this assumption is that the hydrology in areas with a low slope is not estimated well.

PUGET SOUND WATERSHED CHARACTERIZATION

Purpose

The Watershed Characterization Project is a coarse scale assessment tool that helps prioritize watershed actions by evaluating both the potential of and impairments to watershed processes. The project is an interagency effort funded by the EPA, and includes the Department of Ecology, Puget Sound Partnership and Washington Department of Fish and Wildlife. The goal of the project is to assist

in the identification of areas on the landscape that are important for maintaining watershed processes and to characterize and map the degree to which human activity has degraded these processes. This information is intended to assist planners in identifying both priority areas to protect or restore and areas which are less sensitive to impacts from new development and changes in land use. The characterization consists of the assessment of water flow and water quality processes (Volume 1), freshwater fish and upland terrestrial habitat (Volume 2) and nearshore habitat (Volume 3).

Model approach

The water flow models are based on a conceptual understanding of the surface and subsurface movement of water and published empirically derived indicators of importance and impairment to water flow processes. Indicators of importance involve physical controls of water movement. Two examples of these control indicators include depressions in the landscape (which retain and slow the release of surface water) and permeability of surficial deposits (which facilitate recharge and subsurface storage of water). Indicators of degradation involve known relationships between a land cover change, such as impervious surfaces, and a water flow component such as delivery (e.g. timing of delivery is altered).

There are five components to the waterflow model: delivery of water (precipitation, amount of forest cover), surface storage (wetlands and floodplains), recharge and subsurface movement (type of surficial deposits), discharge of subsurface water (streams and wetlands), and evapotranspiration. The water quality assessment module estimates export potential and degradation for the following pollutants: sediment, phosphorous, nitrogen, metals and pathogens. The export potential model evaluates both sources and sinks for a constituent. The degradation model is the NSPECT model (developed by NOAA) which uses known coefficients of pollutants associated with different types of land cover. The terrestrial wildlife and freshwater fish models are being developed in partnership with the Washington Department of Fish and Wildlife (WDFW) while the marine nearshore model is being developed in partnership with the Puget Sound Nearshore Ecosystem Restoration Project and WDFW.

Output

The output of the water flow characterization models is a series of spatially explicit maps that categorize the importance index and the degradation index into areas suited for protection, restoration and development. The outputs for the water quality assessments are very similar and include a set of spatially explicit maps that display the export potential index and degradation index from the NSPECT model. The spatial resolution of the model is flexible; however given the coarse scale of the data sets the finest recommended scale of application is one square mile. This scale is appropriate to inform planning actions (Shoreline Master Programs and Comprehensive Plan Updates) and conventional mitigation strategies. A resolution of 2-5 mi^2 is the recommended assessment unit for most of the Puget Sound lowland areas and 7-10 mi^2 is recommended in mountainous regions. Temporal scales are not represented within the model.

Uncertainty

The water flow model is in the validation stage. Model output is being compared to an HSPF flow model and other watershed characterization model(s) to assess level of agreement. They are also looking to compare model outcomes with measures of biotic integrity such as the biological index of biotic integrity (BIBI) commonly used to assess stream impairment.

Assumptions and limitations

An assumption of the water movement and water quality models is that the selected indicators reasonably depict the delivery, movement and loss of water and water quality constituents (e.g. sediment, phosphorous, metals, pathogens, nitrogen) as these indicators are supported by known geologic, physical, and chemical properties and processes.

ECOPATH WITH ECOSIM (EWE)

Purpose

The Ecopath with Ecosim (EwE) modeling software simulates the effects of user specified management strategies or events on the marine food web. The results provide insight into marine system functions, highlights potential unintended consequences of policies, and enables the assessment of tradeoffs between alternative ecosystem management strategies. Researchers at the University of British Columbia initially developed EwE for the purpose of assessing fishery management strategies, but more recently National Oceanic and Atmospheric Administration (NOAA) has applied the model in the Central Basin of Puget Sound to characterize the food web structure and function in the Puget Sound.

Model approach

EwE simulates community dynamics using principles of mass balance and energy conservation. There are two modules, Ecopath and Ecosim. The first, Ecopath, is a static mass-balance model of the perceived "initial" conditions or reference state of the food web. The second module, EcoSim, dynamically simulates biomass pools and vital rates of change through time in response to perturbations. In each different species or guilds[3] are represented as biomass pools which are regulated by gains and losses. Gains are the result of consumption, production, and immigration. Losses are due to mortality, emigration, and fisheries extraction. Habitat types are represented within the model and mediate productivity (e.g. a species is linked to eel grass). The impact of fisheries is modeled on both the targeted groups and bycatch.

Ecopath consists of a series of linear equations describing the flow of biomass into and out of discrete pools, or functional groups. The Ecopath master equations contain four core parameters that describe the basic biology of each functional group: biomass, production to biomass ratio, consumption to biomass ratio, and ecotrophic efficiency. The user needs to specify this collection of input data and parameters specific for each functional group in order to describe the reference state. NOAA staff assimilated key parameters from direct data sources and literature, and indirectly through correlations, mechanistic models, and mass balancing procedures. Typically, all but one of the four core parameters are input and the remaining parameter is estimated by the Ecopath mass balancing algorithm. In the Central Basin Puget Sound model application, the unknown parameter for a particular group was typically either ecotrophic efficiency or biomass; then Ecopath achieves mass balance by simultaneously solving for these unknowns for all functional groups.

The second module is the simulation component, Ecosim. It is governed by coupled differential equations that stem from the Ecopath linear equations. In the simulation module, parameters can be changed and perturbations simulated from the reference state in order to investigate the food web structure. For example, the strength of trophic interactions (e.g., the extent of top-down or bottom-up control), stock-recruitment relationships, or temporal patterns of fishing or climate variability can be examined in EcoSim.

Output

The Central Basin of Puget Sound EwE model application includes sixty-five functional groups (composed of either individual species or guilds of ecologically similar species). Marine mammals, communities residing in the intertidal zone, fish, sea birds and fisheries fleets are a few of the groups included. Several indices and rates are calculated as part of the mass-balancing step, for example productivity rates, changes in diet, mortality and the ratio of productivity to respiration.

A comparison of a suite of simulation runs, each with a slight modification of the model specification, reveals parameters that are highly influential in determining results. Altering the biomass

3 guilds are a classification scheme where species that occupy a common niche, or habitat, within a given community are grouped into categories, or functional groups.

of a top predator, especially raptors (e.g. bald eagles), results in a very different marine system. NOAA's EwE application is also very sensitive to migratory species with a large biomass (e.g. salmon and eagles), when these migrators re-enter the marine system, they introduce a lot of new biomass. However, since they spend a lot of time outside the system, NOAA discounts their perturbation. Finally, the introduction of stochastic variation on phytoplankton initial conditions reveals that a little variability in these primary producers can result in large fluctuations of the system.

Uncertainty

Modelers at NOAA have utilized hypothesis driven scenarios to assess model structure, behavior, performance, and overall sensitivity to perturbation parameters. They run hundreds of simulations for a single question to see how responsive the model is and to identify single parameters that operate as important drivers of community structure. Users treat simulation results as hypotheses to be verified with data or other methods. These simulations were an initial means of gauging the feasibility and stability of model estimates and predictions.

Assumptions and limitations

Model assumptions stem from two overarching challenges, the representation of dynamic relationships both within and into the model, as well as limitations of incorporated data and spatial heterogeneity. The EwE model can be characterized as unrealistically resilient. Thresholds are not represented well as the model tends to move toward the starting equilibrium state. With a perturbation, the model will move to an alternative stable state, but once a stressor is removed, the system returns to the original equilibrium domain. As such, it is hard to maintain chronic effects such as an oil spill, as the model treats it more as a one-time perturbation. Further, migratory species are poorly represented as EwE cannot dynamically model things outside of the model domain (e.g. cannot model high mortality of salmon in open Pacific). EwE is not clearly linked to physical forcings or chemical cycling.

EwE was developed for fisheries, so the primary focus was tailored to fisheries objectives. As such, the lower trophic levels are aggregated heavily; the taxonomic resolution is coarse at these lower levels. Input parameters were assimilated from data and reports from no later than 1990, limiting incorporation of recent change. Finally, the spatial heterogeneity is not explicitly represented, however the user can be clever specifying diets within the equations to represent spatial constraints.

NOAA is switching to the Atlantis model, which is spatially discrete. Atlantis is governed by space, physical forcings and chemical cycling (e.g. nutrient cycles, etc); however it is time intensive to calibrate and get the system to behave in a stable manner.

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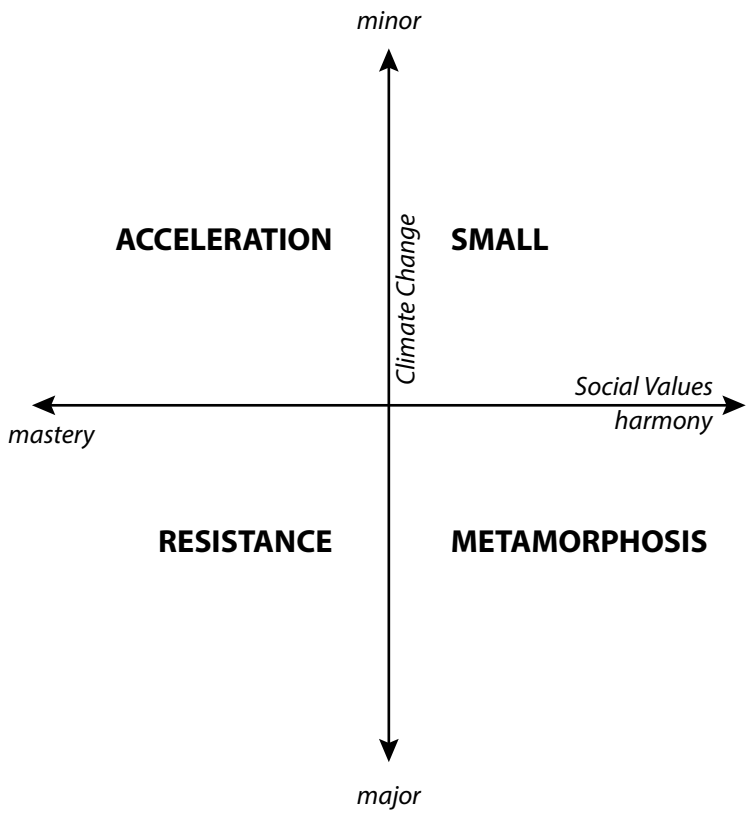


Figure A3.1 The Four Scenarios

APPENDIX 3: PAST AND FUTURE TRENDS OF KEY DRIVING FORCES

The four scenarios described in Chapter 2 weave together various assumptions about the trajectories of and relationships between key driving forces. This appendix steps backwards through the initial scenario logics and the four themes of the storylines to characterize the assumptions behind the scenario development. Each of the ten driving forces is described through: a general overview and definition, historical trends of various measures in the basin and potential future trajectories. Each driver is further described in terms of specific trajectories under each scenario alongside the basis for that decision. This appendix includes the following ten driving forces (listed with page #s):

Climate Change	A3-2
Social Values	A3-6
Worldviews	A3-8
Governance	A3-10
Employment	A3-12
Population Growth	A3-14
Wealth and Income	A3-16
Development	A3-18
Investments	A3-20
Resource Management	A3-22

Climate Change

Climate change refers to long-term shifts in the statistics of weather. Climate change incorporates both natural variability and human-induced change [1]. Historic records indicate the warming of the earth's average temperature by 1.1 °F since the early 20th century [2]. Furthermore, approximately two thirds of that warming has occurred since 1980 [3]. Global predictive models used by the IPCC[1] point to greater warming in the next century, as well as precipitation variability and sea level rise [4]. Implications of climate change, on both a global and regional scale are far reaching; from drinking water availability to stream water quality, from public health epidemics to species migrations and pests [4]. While some systems may benefit from climate changes, overall greater variability and exceedance of critical thresholds is predicted to destabilize current systems faster than we can adapt [5].

The Puget Sound region has and will continue to incur climatic changes differently than global averages given its unique topographic, vegetation and cycling features [6]. Past observations reveal regional changes; temperatures are rising faster than global average [2], estimates of snow water equivalent (SWE) in the Cascades reflect a substantial (~15–35%) decline from midcentury[7], and Puget Sound waters are warming as hydrological flows are shifting[2]. Downscaled models have applied global emission scenarios to the Puget Sound to forecast change at a finer resolution for the Region[8]. Emission scenarios refer to estimates of changes in future emission levels of greenhouse gases which depend upon uncertain economic sociological, technological and natural developments [9]. Two scenarios, the 'low' B1 and the 'medium' A1B have been used consistently by the region's leading climate research agency, the Climate Impacts Group, to describe the variability in future projections [10].

Multiple variables characterize climate trajectories in terms of both the forces and the implications of change. Climate forces can be described in terms of magnitude (e.g. warming and precipitation), pace, variability (e.g. seasonal), and the frequency and magnitude of extreme events. Climate change can also be described in terms of its implications on ecological systems (e.g. snowpack, streamflow, water and energy shortages, soil water availability, human health, forest structure, salmon, and nearshore habitat). The Snohomish Basin Scenarios focus on magnitude and extreme events, representing top level changes that are well understood and with significant cascading implications on economic, social and ecological systems, but that are equally uncertain.

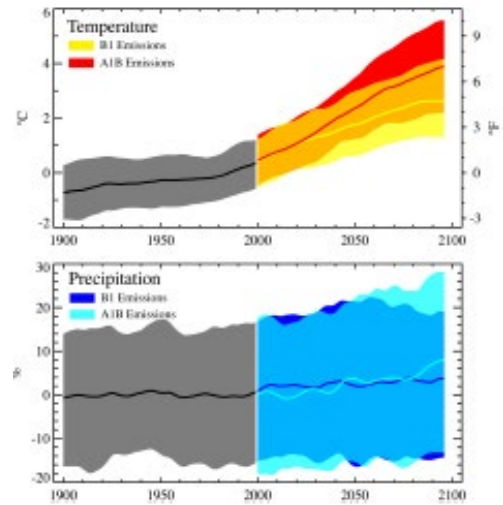


Figure A3.2 Temperature and Precipitation annual mean change [2]

Magnitude refers to the extent of change in temperature and precipitation in terms of degrees and inches and timing of rain respectively. By the 2060's the Puget Sound is projected to increase by 1-3degC annual mean (Figure A3.2). While annual precipitation is not projected to shift significantly, seasonal precipitation variability is predicted to increase, characterized by wetter winters and drier summers (Figure A3.3). Extreme events refer to weather events such as heat waves, floods, droughts, or storms that can lead to severe

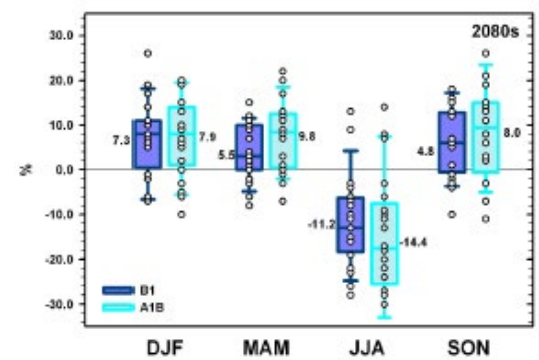


Figure A3.3 Seasonal Precipitation Variability

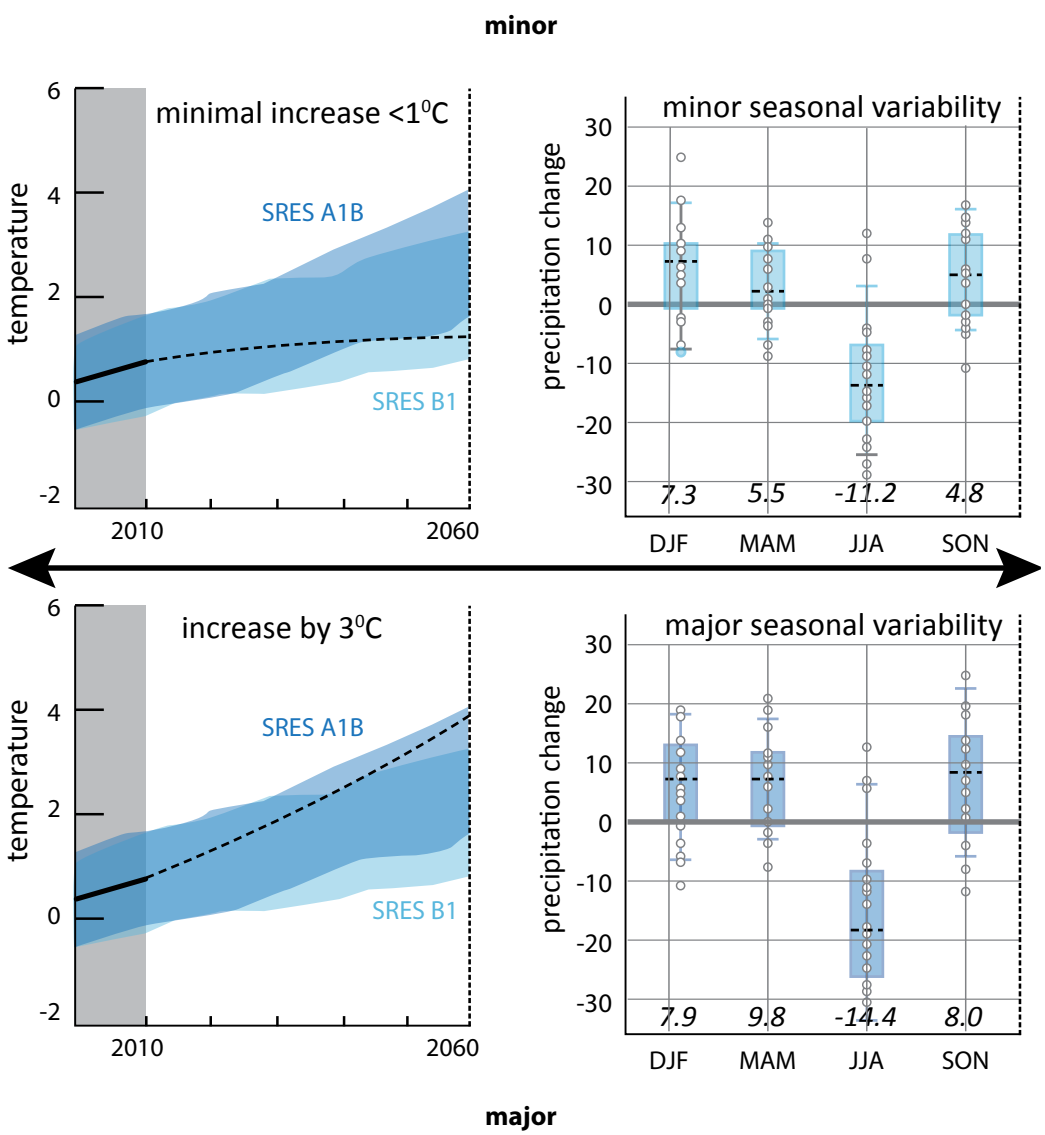


Figure A3.3 Temperature and Precipatation.

The top two diagrams represent projected trends under a 'minor' trajectory while the bottom two diagrams represent trends under a 'major' trajectory. Left side represents projected increase in mean temperature in under the downscaled A1B and B1 emissions scenarios. The right hand side represents seasonal variability in precipitation, downscaled for the Puget Sound. [17, revised]

societal and economic impacts. Events are characterized as extreme if they exceeds (+/-1.5) standard deviations from the long-term means on a particular day [11]. Extreme events are tied more closely to changes in the variability than in the mean of climate change [12]. Pacific Northwest models show an agreement for moderate increases in winter precipitation increasing the frequency of extreme events [13].

Snowpack and Streamflow

Snowpack refers to layers of snow that accumulate in high altitudes [14]. In the Snohomish Basin, snowpack is an important water reservoir that feeds streams and rivers as it melts in the early spring [15,16]. Snowpack is particularly sensitive to climate change in mid-elevation 'transition' watersheds where temperature changes impact the balance of precipitation falling as rain and snow [17]. Climate change influences both the melt timing and accumulation of snowpack. Earlier snowmelt alters seasonal stream flows leading to larger and faster winter flows and lower base flows and drought in the summer [17] (Figure A3.4 and A3.5)

Streamflow changes associated with a transition watershed will challenge the basin's salmon populations, flood risks, drinking water, hydropower, recreation and vegetation. Exaggerated streamflows will impact salmon in both winter and summer, with scouring during higher flows and temperature exceedance and migration barriers during low flows [7]. Runoff timing will also put lowland watersheds at higher risk for flooding [18]. Reservoirs, including both the Tolt and Spada, currently depend on snowmelt to refill drinking water reservoirs in the spring [17]. Earlier snowmelt will put pressure on summer water resource availability, increasing the tension between withdrawal demands and in stream flow regulations [17]. Summer low-flows will influence hydropower-generation, from 13-16% by the 2040's [17]. Reduced snowpack will influence a decline in the ski industry, transitioning to summer markets [16]. Lastly, changes in snow elevations will influence the tree line with implications on white pine and other higher elevation species[17].

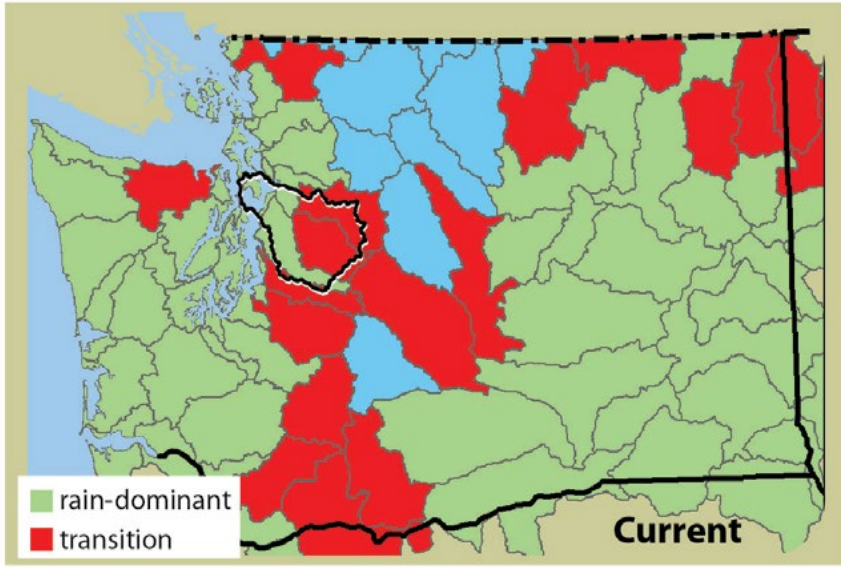
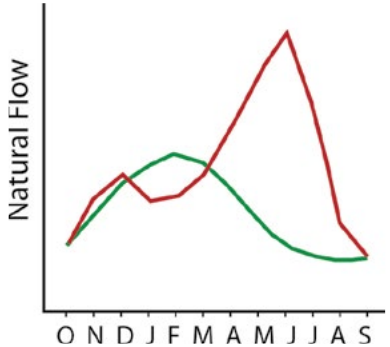


Figure A3.4 Watershed Characterization [17]

Past and Future: While both temperature and precipitation changes influence snowmelt, temperature trends are a better predictor of snowmelt than precipitation, which adds noise to the series [17]. Hydrologic models have been tested for both the A1 and B2 global scenarios for the 2040's and 2080's, utilizing the Sultan and Tolt Watersheds as case studies [17]. Under scenario A1B, the Sultan loses 88-98% of its snowpack in the 2060's with the Tolt losing slightly less, between 79-95%. Under scenario B1, Sultan loses 81-94% and the Tolt loses 70-87% [17].



Figurer A3.5 Characteristic hydrograph of transient watershed [17]

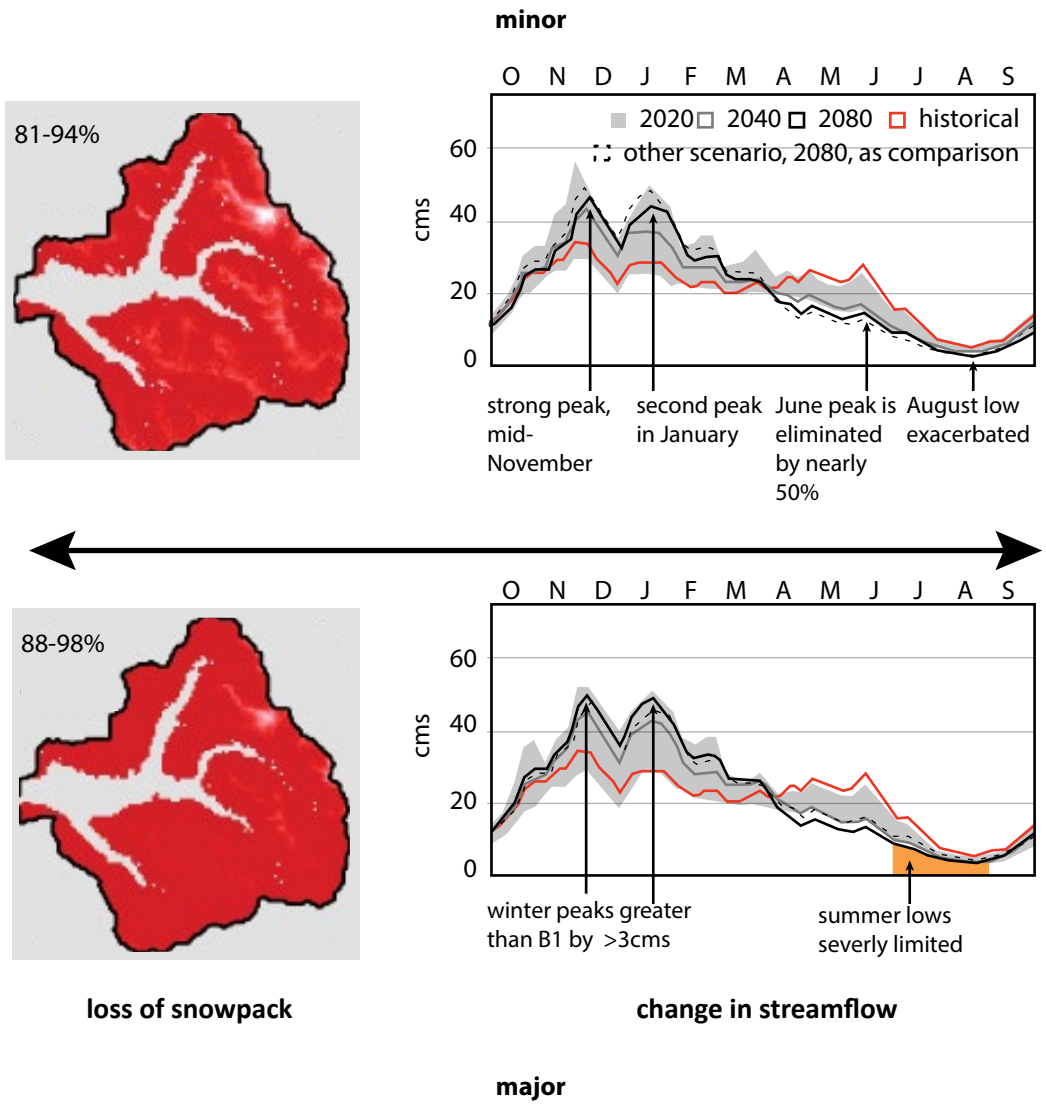


Figure A3.6 Snowmelt and Streamflow.

The top two diagrams represent projected trends under a 'minor' trajectory while the bottom two diagrams represent trends under a 'major' trajectory. Left side represents extent of snowpack loss by April 1st by 2060 in the Sultan Watershed. The Sultan watershed represents the western half of the Snohomish Basin. The right hand diagrams represent projected shifts in streamflow of the Sultan River over the next 80 years [17,revised].

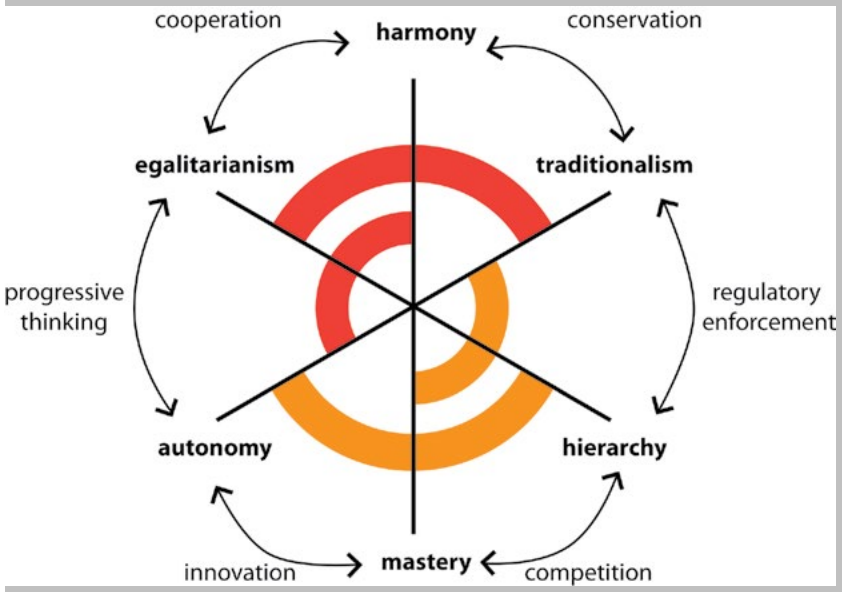
Social Values

Values are beliefs about desirable behaviors that transcend specific situations, guide evaluation of behavior, and are ordered by relative importance [20]. Cultural values reflect underlying society emphases that reflect a taken-for-granted normative system (how things should be)[21]. Cultural orientations differentiate fundamental ways of defining reality, or worldviews. Societies confront basic problems in regulating human activity. Societal responses to these issues emphasize certain values and sacrifice others [22]. These emphasized values are expressed in daily practices, ways of thinking, and the ways institutions function. For example, if a culture values ambition and success, it may support competitive legal, market and education systems [23]. Value emphases also set implicit standards, action priorities, and policies in everyday settings.

There are several theories that define the dimensions of cultural values [24-30]. Each theory is one way to see the world, each somewhat subjective and limited. Schwartz has defined and defended three bipolar cultural value dimensions from societal responses to 3 basic problems: 1) what is the relationship of the individual to the group; 2) how do we guarantee socially responsible behavior; and 3) what is the relationship of humankind to nature and society? [22] The Snohomish Basin Scenarios focus on mastery and harmony responding to the third question (above). These two value endpoints reflect important and uncertain plausible trajectories of society in the Snohomish Basin over the next fifty years[2].

Past and Future: According to various social scientists, the Western World, especially the United States, is characteristic of a 'mastery' worldview while eastern cultures are predominantly 'harmonious' [31-34]. There are published correlations between mastery and capitalistic society, higher incomes and globalization [22,35], however there is no published literature describing cultural shifts over time between mastery and harmony. Literature describing, not to mention forecasting, the drivers influencing cultural values are sparse and contextually biased. Perhaps economic stability or technological innovations will lead towards greater mastery [36]? Perhaps greater public knowledge about socio-ecological resilience theory will result in harmony? Perhaps ecological pressures will result in mastery? Perhaps not. It is precisely the uncertainty of future cultural values in relationship to other drivers that makes it an effective critical uncertainty for the scenario logics.

Figure A3.7 Direct Implications for cultural orientations:
Schwartz' three bipolar value dimensions represent opposing responses to each problem [22]. Cultures display multiple values simultaneously [22]. While mastery and harmony do not dictate the end-state of the other two values, they do share complimentary and contradictory structures with the other four dimensions. The three dimensions can be crossed to reflect four basic cultural types (red and orange arches). Pairs of value types that are compatible are located in proximity going around the circle while pairs of value types that are in opposition emanate in opposing directions from the center [22]. Paired values combine to emphasize societal tendencies (arrow text).



mastery

master and change the world, to assert control, bend it to our will, and exploit it in order to further personal or group interests
ambition, success, control, competence

harmony

accept the world as it is, trying to fit in rather than to change or exploit it
peace, interdependence, equity, environmental protection

Figure A3.8 Social Values

Left hand photos and description represents a mastery social value trajectory for the Basin. The right hand photos and description represents a harmony social value trajectory for the Basin. [22 - descriptions]

Worldviews

A worldview corresponds to how individuals and society make sense of the world around them. Worldviews provide a framework for generating, sustaining and applying knowledge [37]. Worldviews go beyond values. Holling writes that worldviews are partial representations of reality, or myths that support a temporary certitude to direct policies and actions [38]. The key here is understanding that each view is incomplete, based on certain assumptions about stability, perceptions of processes, and prioritizations of appropriate policies [38]. The complexity and uncertainty of the natural and social environment leads to debate about how to interpret facts or trends. Worldviews articulate how people bend, or conform facts to make them consistent to their cultural outlook [39].

Past and Future: Worldviews are tied to both a temporal and geographic context, as well as community and spirituality, to industrialization and globalization. Our perception of nature and society has evolved over the last fifty years. The Civil Rights movement, the position of woman in the workforce, and the end of Apartheid in South Africa are all examples of how pervasive views of human equity have changed. Yet while we can track past changes, we are so entrenched in our own current worldviews that we cannot step outside our own biases and interpretations. In fifty years, different groups in the Snohomish Basin and the Puget Sound Region could be characterized by their divergent worldviews today. However, we cannot characterize our current worldview.

Worldviews are like caricatures of aspects of reality [38]. There is no 'right worldview' for where we are today, or where we are going, each caricature is incomplete. Holling describes these caricatures in terms of five myths of nature, and we map four of these myths onto the four scenarios, responding to the intersection between values and climate change [38].

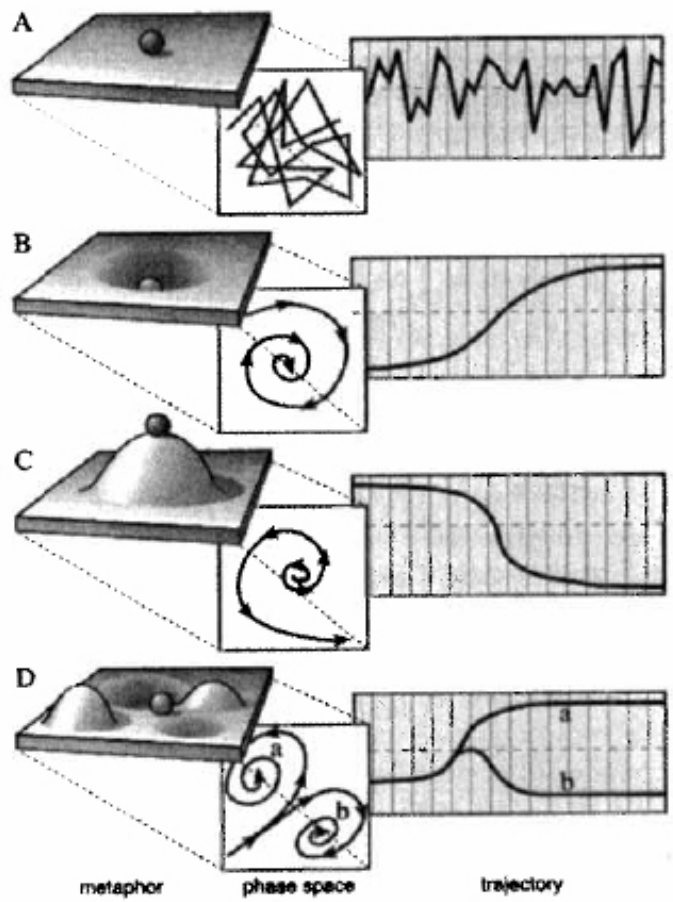


Figure A3. 9 Depictions of four myths of nature.
(A) Nature flat, (B) Nature Balanced, (c) Nature Anarchic, and (d) Nature Resilient. Each myth has three representations or metaphors: as stability landscape (left), phase diagram (center), and time course chart or trajectory of key system variables over time (right). [38]

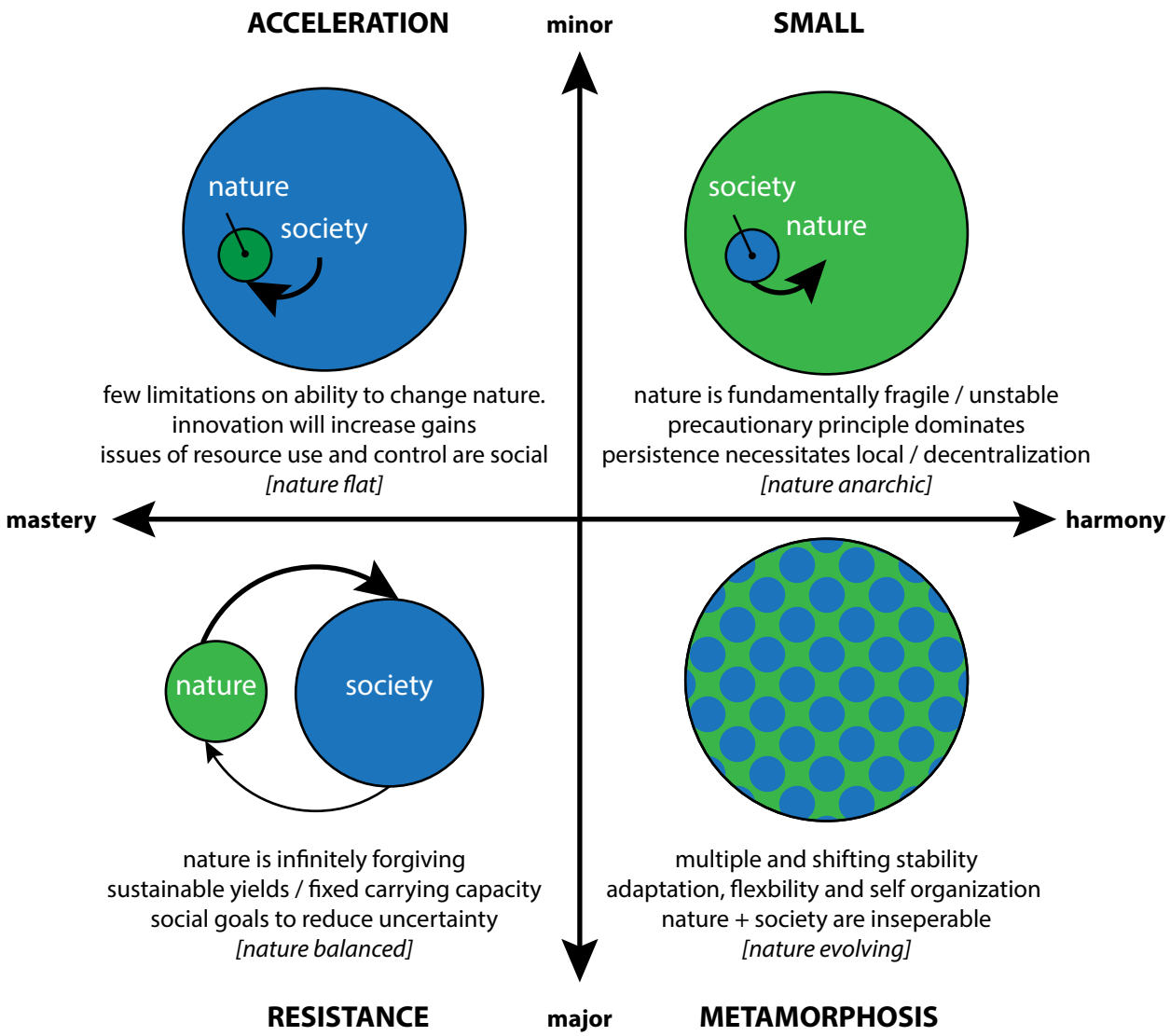


Figure A3.10 Worldviews under the four scenarios

Depictions of worldviews, or perceptions of the relationship between society and nature under the four scenarios in terms of 1) system stability 2) strategic approach and 3) driving perception / myth.

Governance

Governance, according to the World Bank, refers to the rules and rulers, and the various processes by which they are selected, defined and linked together [40]. Here, we refer to rulers as those jurisdictions, agencies, institutions, and elected officials that represent collective decision-makers. Rules are both the formally legislated regulations and the operational framework that dictate where and how funds are allocated. Governance translates dominant worldviews into legislated standards and practices that then get perpetuated through a community. While every community has diverse worldviews, it is the worldview of the voting majority or of those in power which are translated into law.

Past and Future: The Snohomish Basin is characterized by various scales of overlapping governments and approaches, including federal, state, local, and county jurisdictions shaping regulations from clean water standards to incentives and outreach. Over the last fifty years, many trends have been observed (though largely lacking quantitative data for validation) in the Region's governance. Key trends include 1) more decision-makers: from units of government to agencies and partnerships [15,41]; 2) more regulations: the number of enacted legislations on everything from overseeing funding allocations, anti-discrimination laws, and environmental permits has grown [41,42]; 3) greater size, complexity and inefficiency: while the funds and responsibilities allocated to governments have grown, as well as the operational complexity in terms of both factors and stakeholders to consider, there is increased skepticism about the efficiency of government in achieving results [41,43,44]. While some critics think government is too big, too controlling and too wasteful of public funds, others think government doesn't go far enough.

There are no predictive models forecasting how government will change in fifty years' time. While regional experts point to a continuation of trends,[41] it is likely the magnification of one trend over another that will hallmark new trajectories and critical thresholds of shifts in dominant paradigms and power holders.

Figure A3.11 Political boundaries in Snohomish Basin

The Snohomish Basin is bound by WRIA 7, a political boundary delineated by WA DOE. The Basin overlaps both Snohomish and King Counties including the City of Everett and over a dozen small towns and cities (gray). Basin lands also include the Tulalip Tribes and Snoqualmie Tribes as well as Federal and State lands (forest lands and wilderness areas, green).

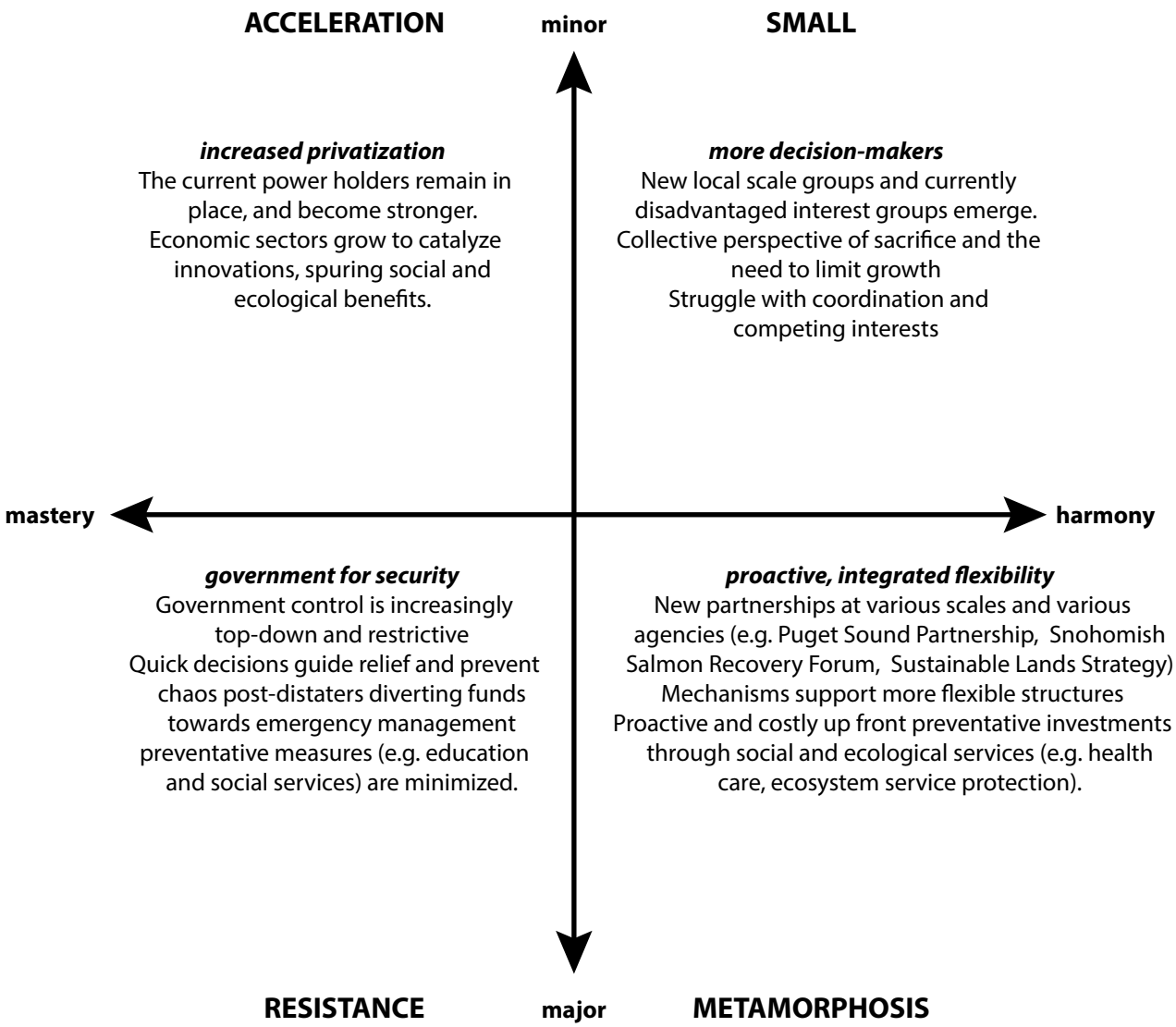


Figure A3.12 Governance trends under the four scenarios

Building on the aforementioned worldviews, as well as cultural values and climatic changes in the four scenarios, governance can be described by a focus on one or a handful of current trends [41].

Employment

Employment is here defined as both the number of jobs and their division along industry sectors representing segments of the economy. Different agencies split sectors differently; however four main groups dominate including primary raw material extraction like mining and farming, secondary refinement including construction and manufacturing, tertiary services like law and medicine and the distribution of manufactured goods, and quaternary knowledge activities including technological research, computer design, and biochemistry [45].

The total number of jobs is a major driver of in-migration as well as development pressure [46]. The growth of different industry sectors drives land use changes, resource demands, demographic changes and capital investments [47]. Job growth has direct implications for the magnitude of service needs (e.g. size of schools, size of roads), resource extraction (e.g. forestland conversions, water and energy demand) and waste streams (e.g. pollution, emissions, wastewater). Manufacturing necessitates different development patterns in terms of factories and transportation corridors compared to high-tech industry or farming [47]. Size of industry sectors correspond to labor characteristics, including educational attainment, age, and even ethnicity [48]. The rate of job growth has implications for governance, planning, and thresholds. For example, if job growth occurs very quickly we might exceed ecosystem thresholds before we have a chance to adapt. Important feedbacks influencing employment include availability of skilled workforce, supporting services (transportation infrastructure), regulatory predictability, and an attractive quality of life for employees [47].

Past and Future: Over the last 50 years, employment in King and Snohomish County has grown dramatically, more than doubling the total number of jobs between 1969 and 2009 [49]. However, while the rate of growth in King County jobs far exceeded the rate of population growth, the reverse can be said for Snohomish County [50]. King County increasingly became the employment center, while Snohomish grew as residential development. Over the past 50 years, the basin has changed from largely resource-based (timber, fishing and dairy farm) industries to manufacturing, technology and service-based industries (Boeing, health care) [51, 42,47,]. These trends are consistent in both King and Snohomish County and with the Clark Model of deindustrialization [47]. While the resource base has declined alongside declining resource lands and supportive infrastructure (e.g. mills), aerospace and Microsoft dominate the employment base and capital into the basin [47]. OFM's Input-Output model and PSRC's UrbanSim forecast jobs by sector out to 2040. The basin is forecasted to increase by an additional 150,000 jobs between 2010 and 2040. Fifty seven percent of those jobs will be in the financial, professional, business and educations sectors (including both tertiary service and quaternary knowledge activities) with construction and manufacturing jobs declining. Specifically, Redmond, Snohomish Valley and Marysville are forecasted to lose more than 15% of their manufacturing jobs, while East King County and Sisco Heights lose 30% of their construction jobs.

Long-term uncertainty in forecasts for the basin is predicated on global industry changes and competition, the cost of oil, economic markets, regional labor negotiations, research and innovation, and environmental restrictions [47]. The four scenarios explore potential growth rates in terms of total number of jobs and sectors based largely on the former drivers (climate, values, worldview and governance) [47].

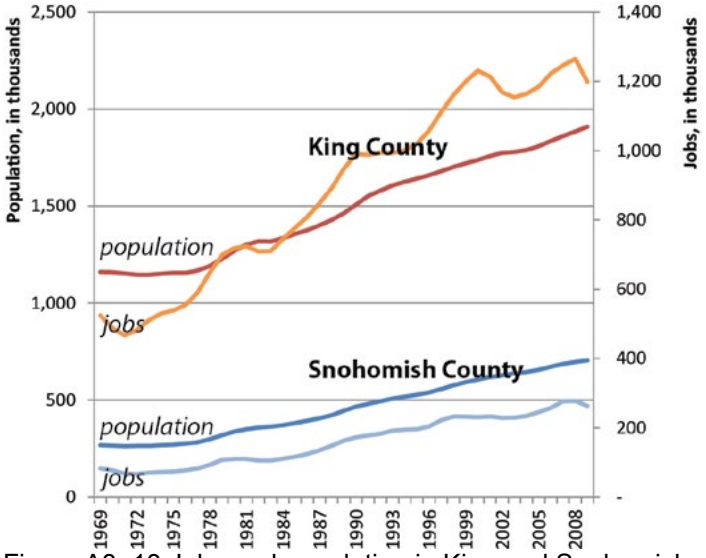


Figure A3. 13 Jobs and population in King and Snohomish Counties.

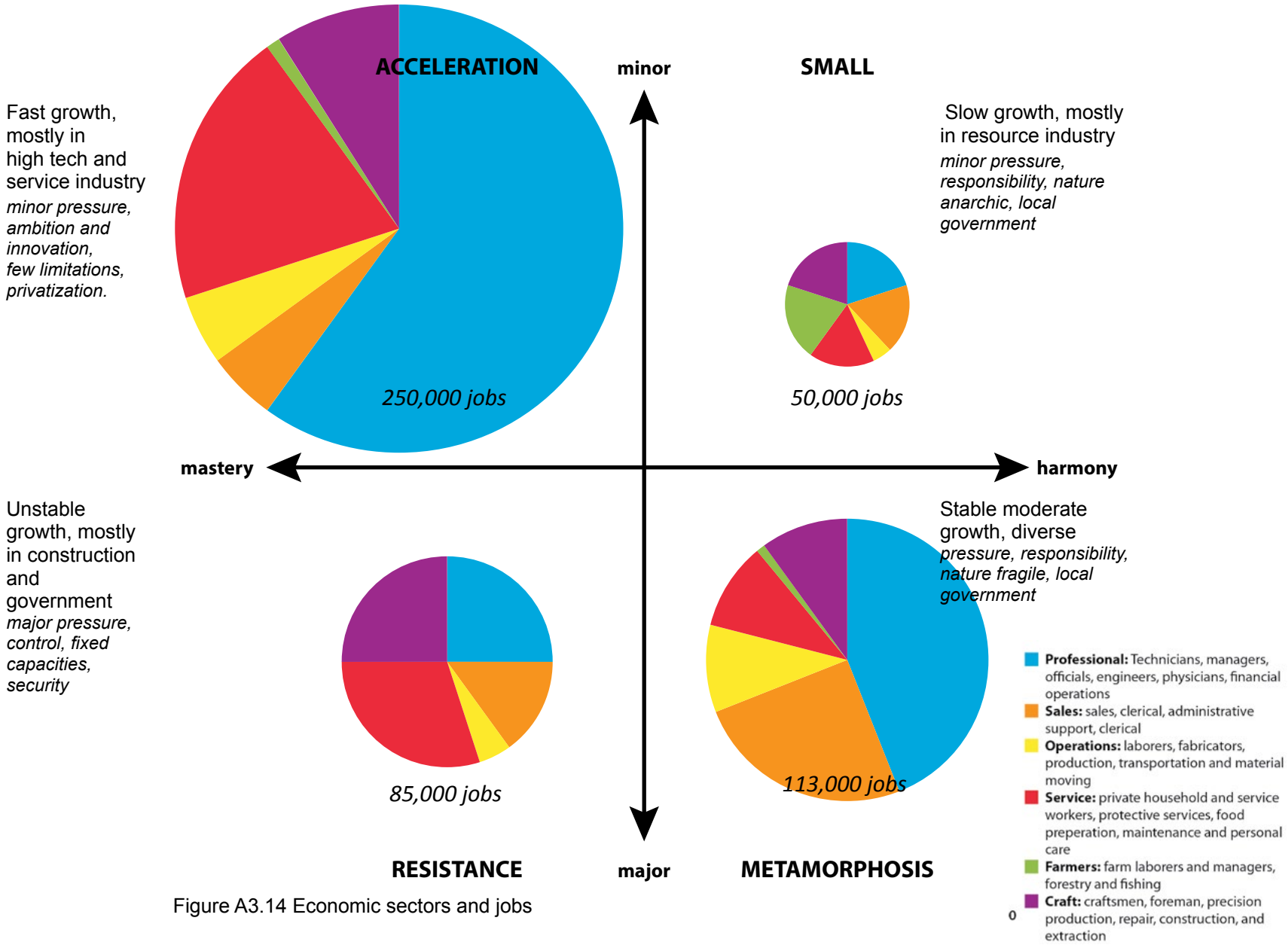


Figure A3.14 Economic sectors and jobs

Population Growth

Growth refers to the change in the number of people residing in an area. Population growth stems from both migration (in and out) and natural increase (birth rates and mortality) [51]. Demographic changes associated with changing population can be described in terms of age structure, ethnicity, household composition and size, and educational attainment [52]. Population growth is one of the most highly cited drivers of urbanization and environmental pressures [46, 47, 53]. The more people, the more development and services are required to serve that population [46,47,53]. While population growth can be distributed across the landscape in various spatial configurations and with variable demographic makeup, the larger the population growth the more water and energy consumed and the more waste produced. Demographic changes correspond to both legacy influences (e.g. current age and structure of the population) as well as in-migration and socio-economic changes [52].

Past and Future: Both Snohomish and King County have grown rapidly over the last 50 years, representing the fastest growing Counties in the State [54]. Birth rates, or fertility rates, have been pretty constant over the last couple of decades at ~13,000 additional people per year [54]. Changes in birth rates and mortality are associated with economic and cultural factors including health care, unwanted pregnancies, wealth and social norms (e.g. having children later in life or single parent households) [55]. While unwanted pregnancies and later first pregnancies have reduced fertility rates [56], medical science has conversely delayed death rates[76]. Historically, natural growth rates have stabilized, while migrations account for 96% of variability in the basin's population growth [54]. Jobs largely determine migration rates and the basin has seen growth in both high income residents working for high tech or green industry jobs, as well as Hispanic migrant workers associated with the agricultural community [46]. The basin's quality of life is considered an important factor in the decision to relocate (for both residents and employees) [47]. Significant changes such as replacement rates, or no growth scenarios, requiring government sanctions, are unlikely to occur in the basin.

Overall, there is almost unanimous agreement across experts and models that population will continue to grow over the next few decades [46, 47, 53, 15]. The Office of Financial Management and Puget Sound Regional Council have complimentary models to forecast and allocate future growth. OFM and PSRC Models describe declining population growth rates[3] with a 5% uncertainty band out to 2040, centered on an additional 210,000 people [52, 50]. Looking at past trends, it is forecasted that the basin population will continue to age (additional 9% of population over retirement age), and diversify (greater 6% non-white). Enrollment projection in 2 and 4 year colleges is projected to rise with growing population trends, dependent on age structures, budgets for higher education and economic opportunities [83].

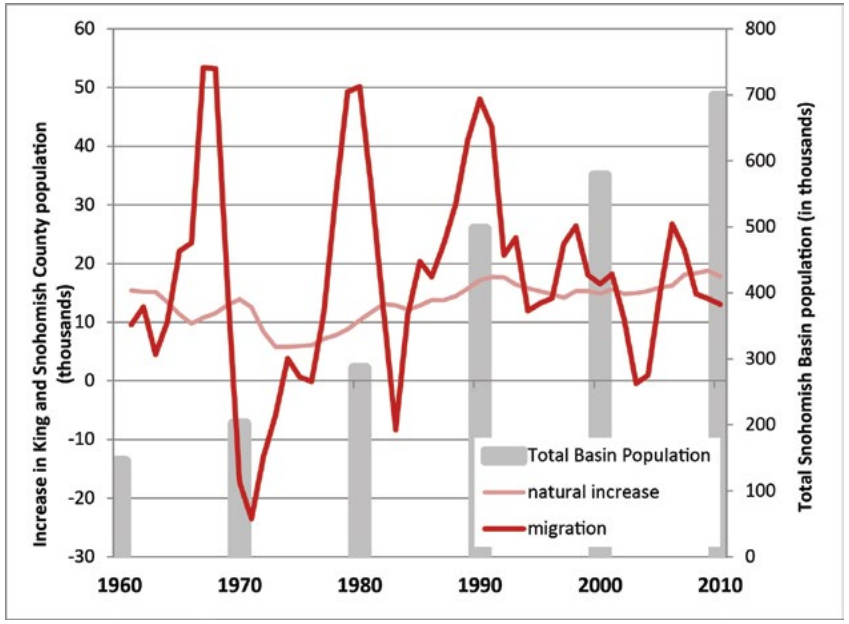


Figure A3.15 Population growth. Natural increase and migration.

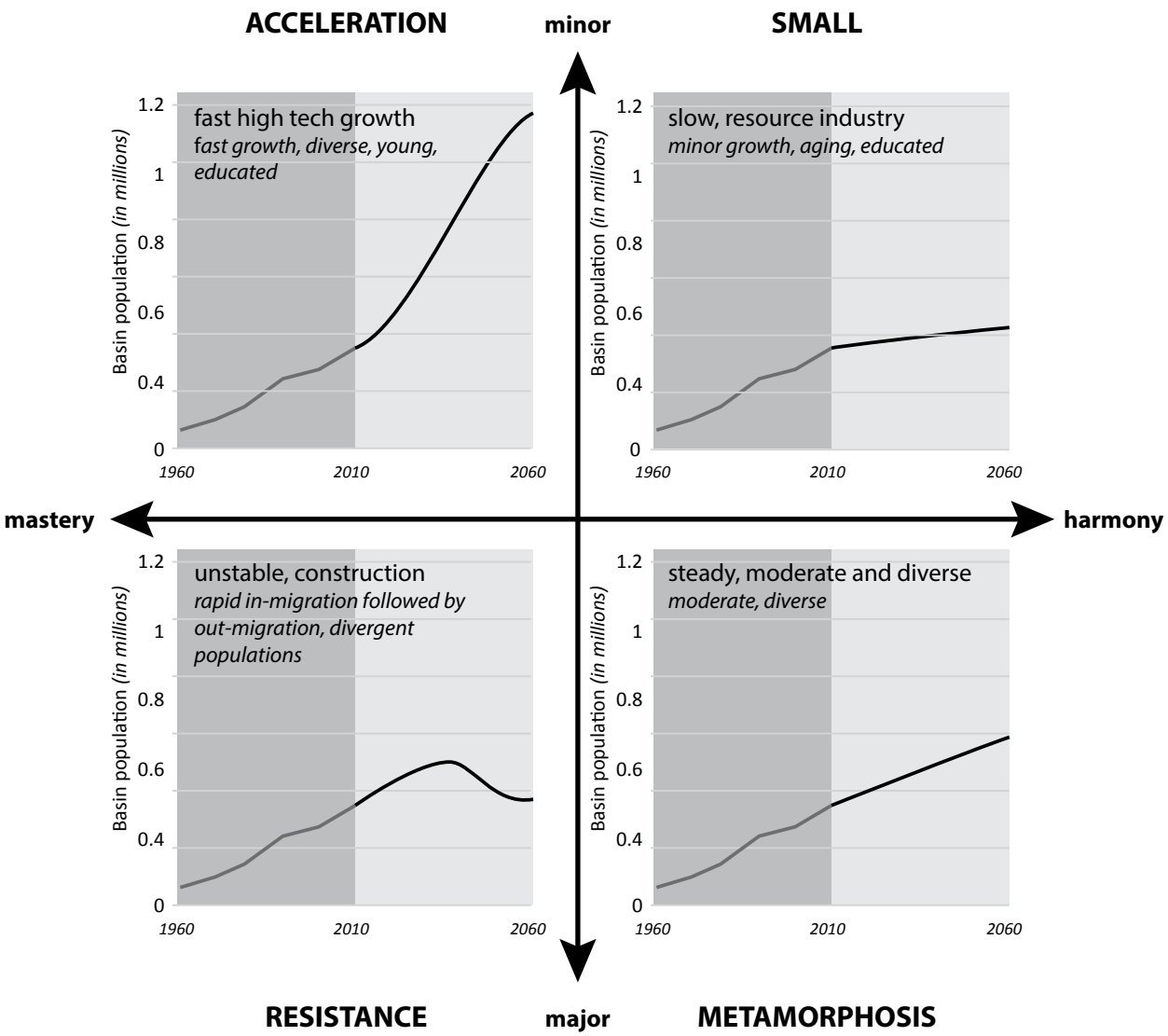


Figure A3.16 Population growth under the four scenarios

The four scenarios represent growth rates and demographic characteristics (ethnicity, age, and educational attainment) based on economic trends (growth and sectors)[94].

Wealth and Income

Wealth refers to the abundance of valuable possessions or money, while income is more specifically the amount of money earned in exchange for labor, services, or financial investments. Wealth can stem from various sources including inheritance and prudent savings; however growth in wealth is highly correlated to growth in income. Wealthier regions generally correspond to higher consumption levels [58] and educational attainment levels [58]. Of major importance is not only the level of wealth, but rather the distribution of wealth across an area [59]. Wealth and income disparities reflect the gap between the wealthiest and poorest members of a community. While gender and ethnic inequalities have declined (1960-2000), overall inequalities have grown since the 1970's, especially within the United States [60,61]. Recent publications contest that disparities are not simply borne of income growth, but rather distributional barriers, from taxation to regulations that systematically favor the top earners over the bottom earners [62]. Greater disparities have major implications on health, security, environmental equity and civil rights.

Past and Future Trends: As basin industry shifted from resources to services, the level of personal wealth in the basin rose substantially [63]. Today the basin is characterized by higher shares of disposable income affecting land use decisions, like the rise of 'ranchettes' and very large residential homes [42,53] . However, the growth in income cannot be singularly depicted as negative environmental change; for example, the Tulalip Tribes have seen a marked shift in wealth with the opening of the Resort and Casino, which has enabled a cash infusion allowing for longer term investments in natural and human resources [15]. The basin continues to house lower income households, and while suburban residential neighborhoods reflect lower income disparities [64], the overall gap between the wealthy and poor populations in the basin is widening. In general, increasing urbanization has been linked to increasing wealth disparities, barring a fundamental shift in distribution (e.g. socialism) [41]. Future challenges associated with disparities in the basin include poverty, privatization of service provision and segregation [41]. Poverty issues include homelessness, employment instability, overcrowding and lack of health care access [65]. Privatization of currently public services, from roads, schools, recreation, may exacerbate environmental and health inequities [41].

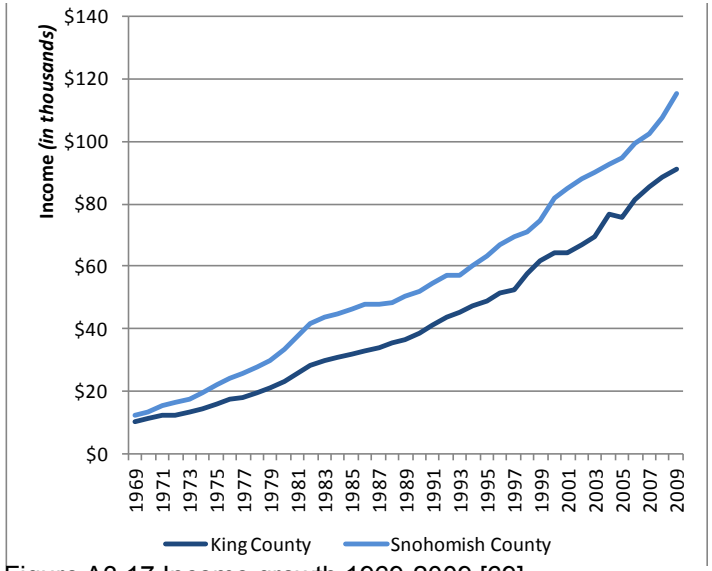


Figure A3.17 Income growth 1969-2009.[69]

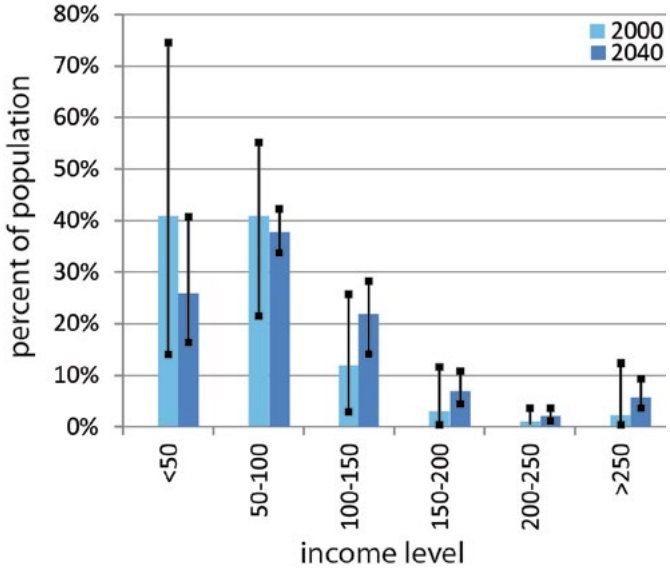


Figure A3.18 PSRC Snohomish Basin forecasted income disparity [50]

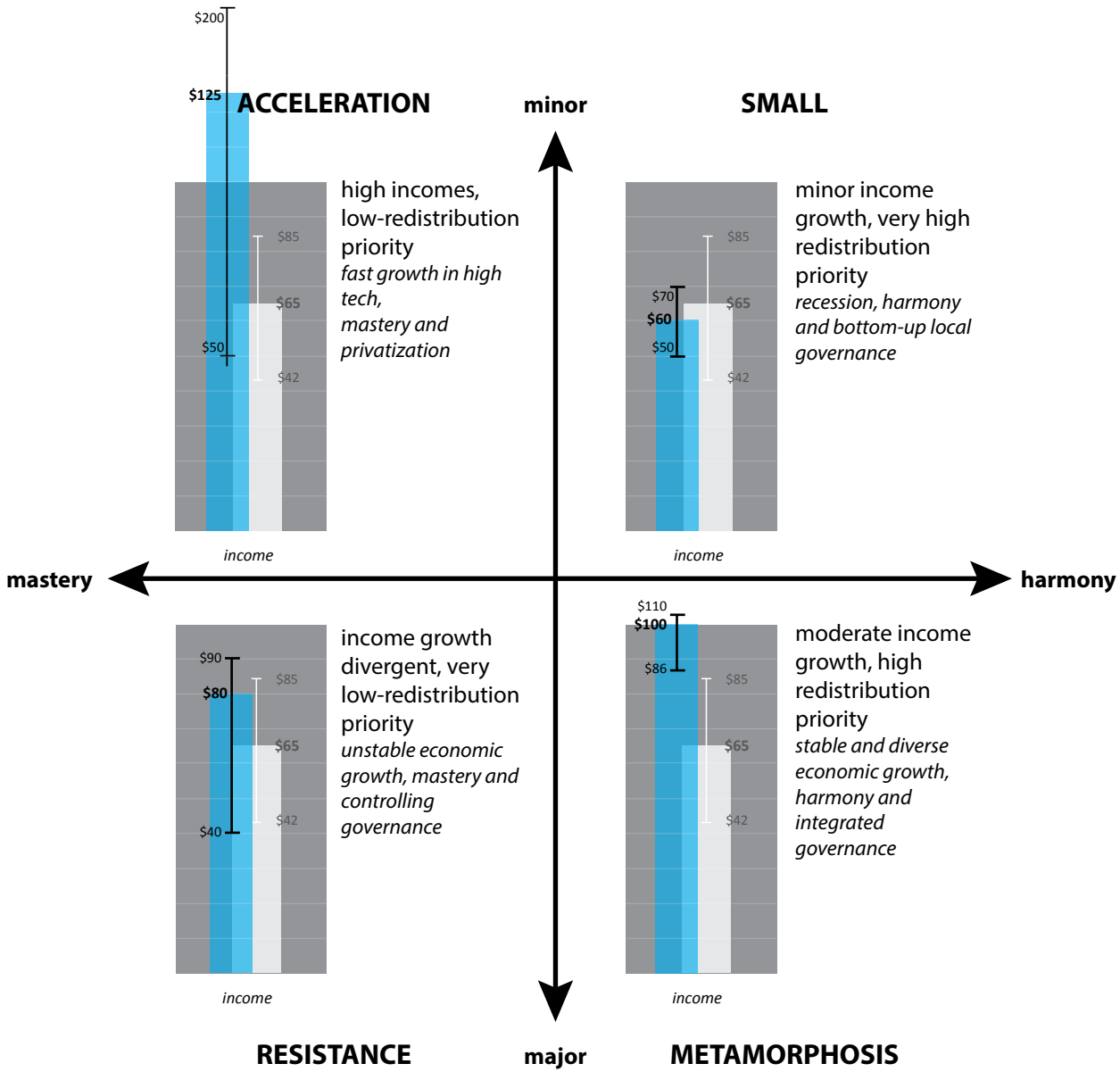


Figure A3.19 PSRC Snohomish Basin forecasted income growth and disparity

Development

Development describes the settlement pattern on the landscape and changes in both land use and cover. Economic growth largely drives development; the higher the demand for new homes, factories, stores, golf courses - the greater the conversion of current lands. However development is restricted to varying degrees by regulations, market preferences and infrastructure capacity [53]. Regulations, such as zoning or the Growth Management Act (GMA) direct the location and type of growth permitted [53]. Market preferences reflect new trends, whether for larger garages, greater densities, more flexible space, or access to services and utilities [66]. Infrastructure capacity, including water, waste, roads and industrial support, from mills to telecommunication cables, influence development [41,53].

The implications of development reflect one of the greatest and most cited sets of opportunities and challenges for economic, social and environmental systems [44,53,67,68]. Economically, development in terms of rate, magnitude and shape translate into a positive feedback to greater economic growth, resulting in construction activity, service jobs to support the new population, and greater demands on goods and services [69]. Socially, the character of development and disparities between adjacent neighborhoods leads to shifts in demographic profiles, community growth, affordability and equity challenges. In terms of environmental implications, development is linked to everything from impervious surfaces changing infiltration and drainage pathways, habitat conversion and fragmentation, the spread of invasive species, to vehicle emissions and runoff pollution [70].

Past and Future: The last fifty years has brought unprecedented development in the form of 'urbanization' into the basin. The rural landscape characterized by small resource based towns, working forests and farms and community cooperation is rapidly being converted to 2-5 acre homes, with a preference for urban amenities including parks, high tech employment and proximity to services [42, 71-74]. Over the last fifty years the basin has grown by 38-50% every decade[4]. Between 1972 and 2006 the basin grew by over 20,000 acres of urban land [75]. Today over 120,000 housing units are spread across more than 50,000 acres of urban development [76] and 2,400 miles of roads [77]. Twenty eight percent of the basin's households are outside of urban growth areas [78]. While the rate of building permits and new development has slowed down with the recent economic downturn [79], the last 20 years have exhibited some of the fastest growth rates in the State [50]. An important uncertainty is changing household size; for the past 30 years household size has declined, the rate of decline has nearly flattened over the last decade, with the potential of significantly reducing the number of forecasted housing units [53].

While future development patterns are highly uncertain, the overall drivers behind change are likely indicative of current drivers including economic pressures (how much growth we need to accommodate) market values (preferences for specific character and density of buildings), regulation (in terms of strength and effectiveness) and infrastructure limitations (traffic congestion, water withdrawals) [53].

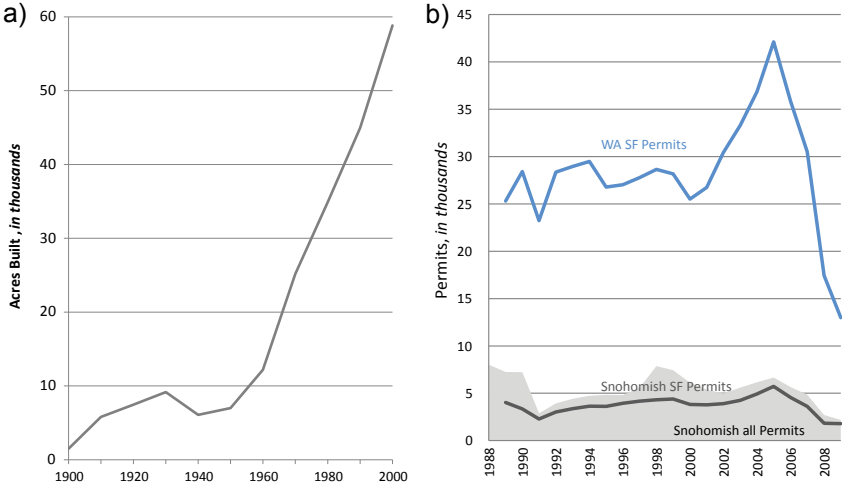


Figure A3.20 (a)Acres developed by decade. (b) Building permits 1988-2008 at the State and Snohomish County level.

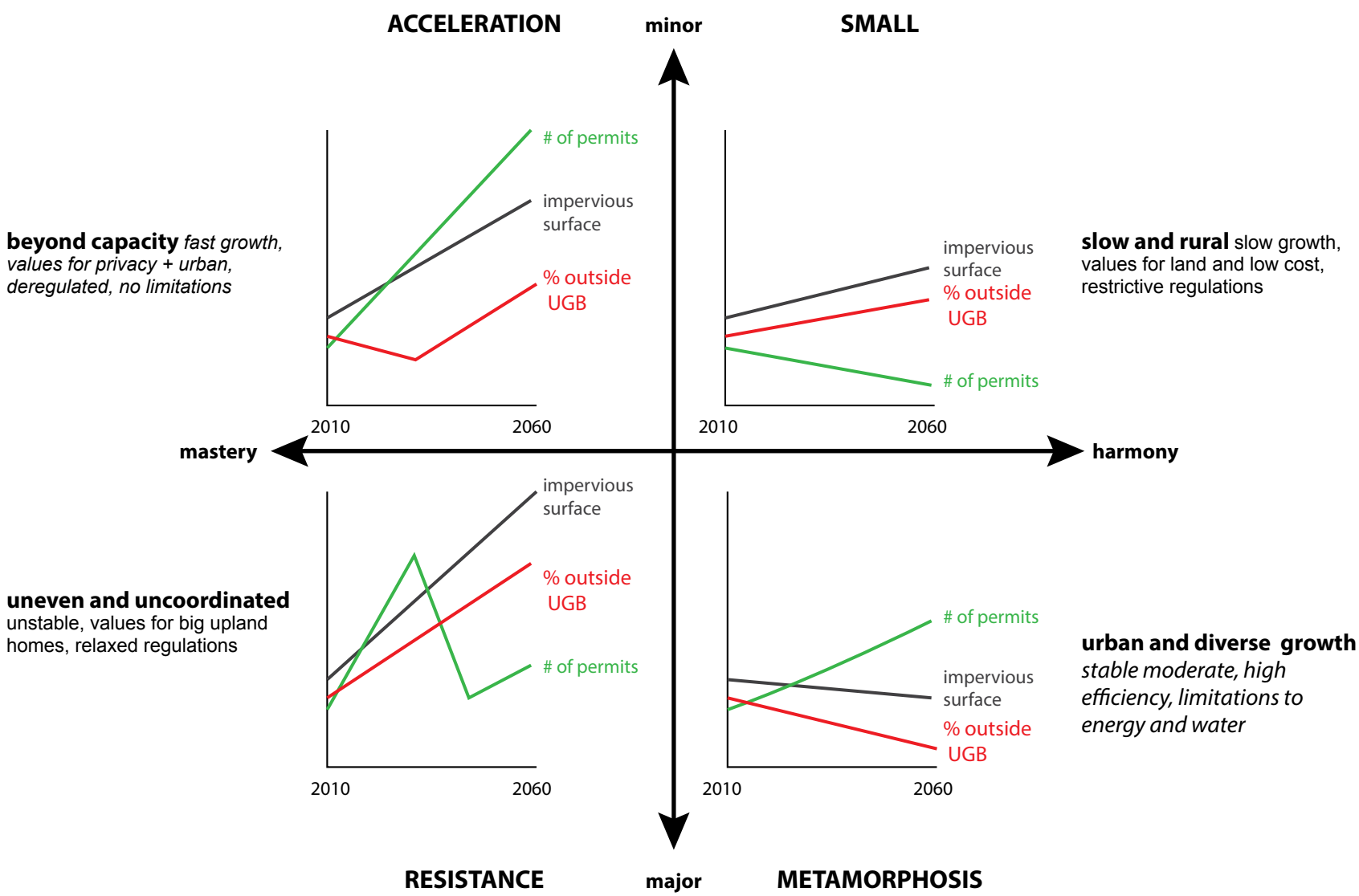


Figure A3.21 Future Development Trends:
The four scenarios can be described in terms of three development characteristics: 1) Footprint of development (i.e. total acres of impervious area), 2) Rate of development (i.e. rate of building permits for single and multiple family homes), and 3) Shape and density (i.e. % of new development outside UGA).

Investments

An investment involves the choice by an individual or an organization to commit money for the purchase of assets for the possibility of generating returns over a period of time [80], but with the awareness of a certain level of risk [81]. What we choose to invest in or 'where the money goes' has important implications to infrastructure and service provision over the long term in the Snohomish Basin. Further, higher levels of services may function as a growth magnet, attracting new development into an area, necessitating greater investments, and so forth [53,47]. Infrastructure refers to the technical structures that support a society [82], such as roads, water supply, sewers, electrical grids, and telecommunications lines. Services refers to those benefits that facilitate the health and safety of a population, including but not limited to social services, education, fire control, hospitals, police, parks and recreation.

Government, supported through taxes, has the role of ensuring adequate infrastructure and services to its population. However, social preferences, economic growth, technological innovations, and the availability of natural resources influence investments committed. Investments can be categorized by the amount (dollars) invested, approval or level of service garnered, where the investment is allocated (roads or rivers, businesses or health), the type of investments (engineered vs. natural, market-based vs. progressive) the discount rate (short vs. long term), and several other metrics.

Past and Future: There are various sources of investments supporting the Snohomish Basin, from federal agencies (federal highways), to local areas (Snoqualmie Water District), and private organizations (Puget Sound Energy). The basin's abundance of resources, from open lands to water for drinking and hydroelectricity has traditionally facilitated inexpensive and rapid infrastructure provision [68]. In recent decades, shortfalls have occurred as the area's growth rate exceeded the capacity of existing infrastructure, leading to traffic congestion, moratoriums for sewage hook-ups, and explorations for long term alternative energy provision and water withdrawals [68, 5, 83,84,53]. Public service provision has also strained small municipality budgets as revenue demanding residential development exceeded revenue building commercial growth [41].

Over the last fifty years, regulations and oversight governing infrastructure and services has risen significantly [41,42,47]. From NEPA requirements, to Citizen Review Boards, the legwork required to put in a new wastewater facilities, roads, health clinics or schools, all have extended the time and cost for implementation by public and private organizations alike [41,42,47]. On one hand, there is far greater accountability for civil rights, environmental protection, hazardous risks, and fiscal responsibility [85]. On the other hand, transformative undertakings, like the Culmback Dam, or Interstate 5, are unlikely to be supported in the near future [68,72]. Oversight costs trickle down from federal and state levels to private homeowner investments; the permits required to drain a field, add a garage to your home, or thin a forest have all grown significantly [41,42].

Technological innovations over the last fifty years are largely responsible for transforming the approach and distribution of infrastructure and service investments. Think only about the role of computers today, in everything from accessing public records to monitoring water use, to imagine the evolution. The basin infrastructure and services are now better connected to global markets and individual rural households [41,42,47]. Technology has increased the efficiency of infrastructure in terms of energy and water use [68], but also in terms of human power required[128]. Service and infrastructure provision jobs have shifted from being more human and mechanical to being technical [42]. Today's investments prioritize electronic access to government files [41] and satellite imagery to improve transportation corridors over additional agency personal and road building[72].

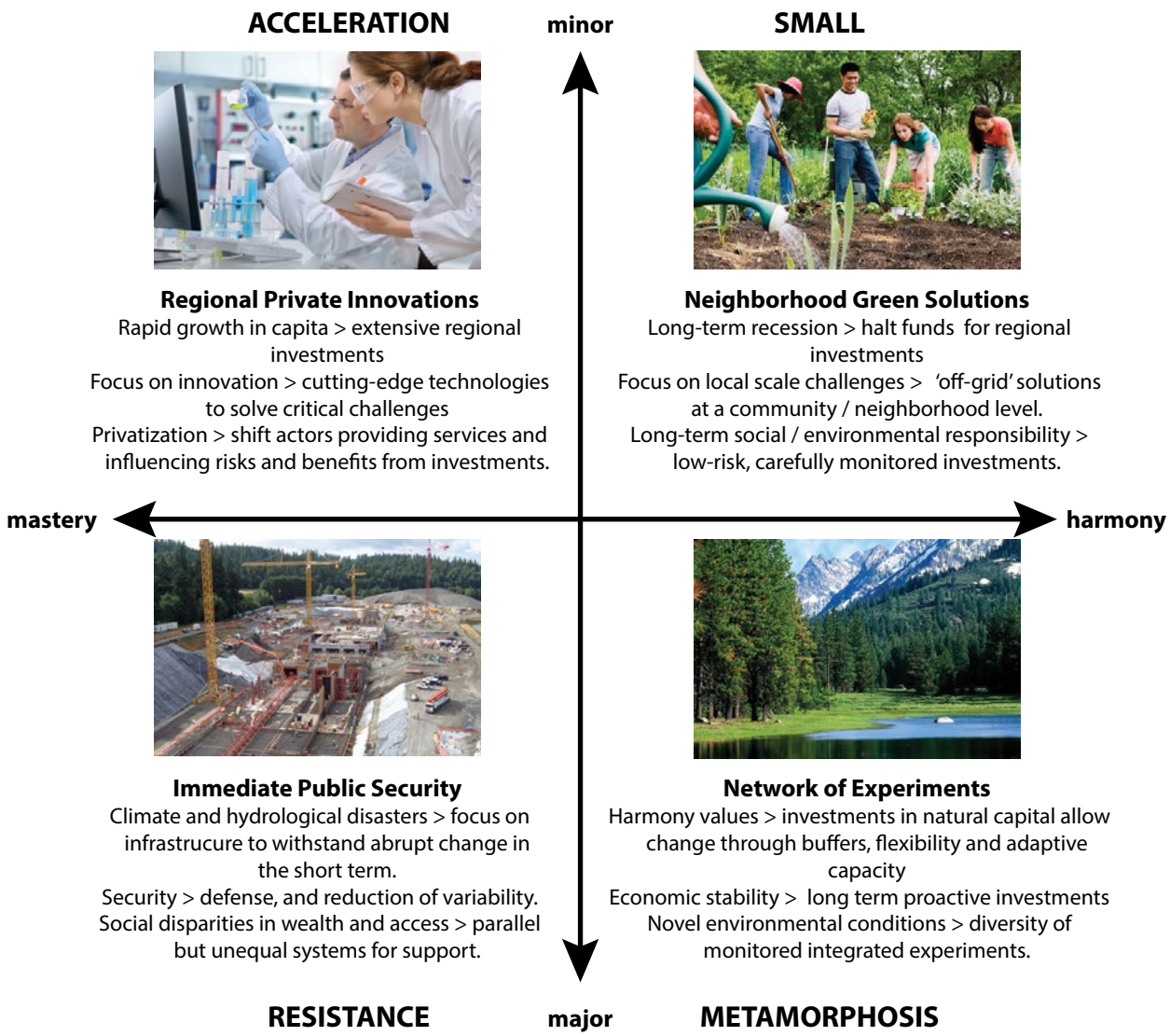


Figure A3.22 Investments under the four scenarios

Above scenarios depict how basin trends in governance, social preferences, economic growth, technological innovations, and the availability of natural resources might influence investment patterns.

Resource Management

Resource Management refers to the management of materials or substances such as minerals, forests, water, and fertile lands that occur in nature. The basin's abundant resources are characterized by a long history of management and extraction [71], which today is largely focused on urbanization pressures, environmental regulations and the legacies of past decisions. Resource management in the basin can largely be divided into agriculture in the lowlands, forestry in the mid to higher elevations, and recreation, largely focused in the higher elevation wilderness areas. While each of these resources is challenged by unique economic and ecological pressures, all three have in common their ability to support both social and ecological benefits that go beyond financial benefits.

Past and Future: Agriculture refers to the activity or business of growing crops and raising livestock. While a for-profit business, agriculture is intricately tied to food security, cultural heritage and wildlife habitat, among numerous other benefits [42,15]. The face of farming in the basin is changing. While the basin has a deep history in dairy farming (e.g. Carnation), today the basin boasts diverse crops and livestock farms, with a niche for direct-marketing and organic goods, as well as high-commodity specialty crops and hobby farms [42]. At a County level, King and Snohomish each bring in about $150 million a year from agriculture [68], supporting 1,500 [87][6] farms over 50,000 acres [88]. While the total acres of farms and total gross product have declined with associated urbanization pressures [89], the number of farms has grown [89]. The first farms in the basin removed lowland forests and dramatically altered the floodplain in terms of habitat and flow [71]. In recent years, the largest challenge for lowland farms has been flooding and restricting regulations around drainage [42]. While climate change, urbanization, public support for local food, and wildlife species protection are among the most important drivers influencing the future of agriculture in the basin, the challenges and opportunities associated with living on a floodplain will likely continue to dominate agricultural debates [42].

Forestry[5] is the science of planting and caring for forests and the management of growing timber and other valued forest products [90]. As with agriculture, the viability forestry is dependent on market values, cost of operations, regulations, and the opportunity cost of residential development [73]. Historically, the timber industry was the public face of the Snohomish Basin – with the Snoqualmie Mill and Weyerhaeuser [71]. However, several factors, including environmental regulations (e.g. Spotted Owl), urbanization pressures, globalization, closure of mills, and the purchase of Wilderness Areas, have led to the slow decline of forestry in the basin [73]. Today's working forests reflect a patchwork of public (USFS), private (both large and small) and NGOs owners with diverse management objectives and strategies [73]. Of the basin's 920,000 acres of deciduous and coniferous forests [91], approximately 300,000 acres are actively managed [92]. Between 1986 and 2007 the basin lost over 220,000 acres of forests [93]. Future forestry decisions will be constrained by current influences including available infrastructure, regulation costs, ecological damages (e.g. landslides) and market values [73]. In addition, climate change will likely influence forest management through shifts in energy and water limitations [17], disease and fire risks [17], regulations governing carbon stocks and fluxes [94], and shifts in human values around management along the urban-rural fringe [73,74].

Recreation can refer to any leisure activity, but here we specifically focus on outdoor recreation, including but not limited to skiing, hiking, climbing, fishing, camping, biking, ATV, bird and nature watching, swimming, and hunting. Currently, the basin supports 638,000 [95] acres of public recreation lands, nearly over half of which are (301,000 acres) are dedicated Federal Wilderness Areas[6]. Today, there are 1.45 acres / capita in the basin[7]; however this boundary is an ineffective parameter as basin recreation lands support a much larger regional population, including not only the City of Seattle, but in fact State-wide and even national visitors [74]. Further, contiguous Wilderness Lands expand far beyond the boundary of WRIA 7 (538,275 acres[8]). Urbanization has simultaneously increased access pressures on recreation lands (both in terms of visitors but also challenges at the wildland interface) and heightened opportunities for advocacy and volunteering (e.g. trail maintenance and invasive weed pulling)[74]. In addition to urbanization, future pressures will likely include new forms of recreation, technological innovations, higher gas prices, climate changes and funding sources [74].

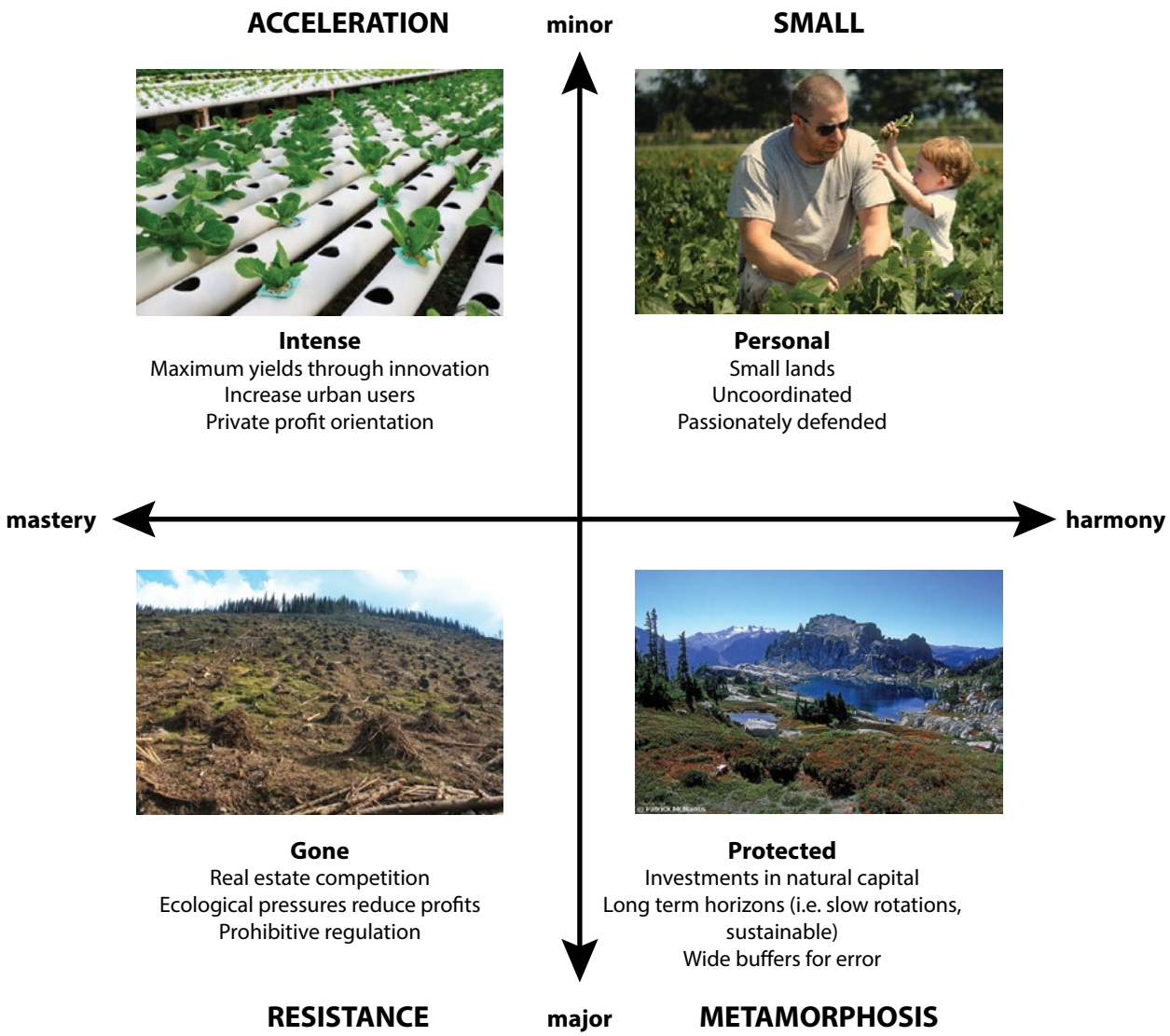


Figure A3.23 Resource use under the four scenarios

Notes

1. The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. The UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC".IPCC website: home, last accessed 04.20.12 http://www.ipcc.ch/organization/organization.shtml#.T5IuR7PZ5Yw

2. Mastery and Harmony were selected as 'the most important and uncertain social value dimensions' by a selected subset of the Science Team during the Scenario Development Meeting, August 2011.

3. Rates are dependent on the level of spatial aggregates (i.e. Census block, forecast Analysis Zone, County).

4. Comparing total impervious area based on parcel level year built data within the Snohomish Basin for 1960, 1970, 1980, 1990 and 2000.

5. Forestry, timber, active, or working forest lands all reflect a specific land use, while forests overall refer to a land cover.

6. Including acreage for Alpine Lakes, Wild Sky and Henry Jackson Areas within the boundary of WRIA 7. There are 458,000acres of Federally owned lands, and 147,000 State owned lands in the Basin in total.

7. Major Public lands acreage divided by 2010 Census tract population within WRIA 7.

8. Combination of Alpine Lakes, Wild Sky, Henry Jackson and Glacier Peak.

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APPENDIX 4: ECOSYSTEM SERVICES HYPOTHESES

The Snohomish Basin supports a multitude of resources and services that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and include products like clean drinking water and processes such as the decomposition of wastes. The Millennium Ecosystem Assessment (MEA) identifies four categories of ecosystem services: provisioning (e.g. food and water), regulating (e.g. carbon sequestration and waste decomposition), supporting (e.g. soil formation and seed dispersal) and cultural (e.g. recreation and inspiration) [1]. Some ecosystem services are already accounted for in our economic system, especially provisioning services. Others, such as regulating and supporting services, have been largely considered "externalities", assumed to be relatively inexhaustible. However, in our modern, highly populated world with its dramatically altered landscape, many of these ecosystem services have been damaged and reduced [1].

The following pages describe the relevance, current conditions and alternative hypothetical trajectories for ecosystem services including: water quality [A4-2] and quantity [A4-4], carbon stocks [A4-6]and fluxes [A4-8], and habitat [A4-10] and genetirc diversity [A4-12]. Hypothetical future trajectories are predicated on the assumptions relating changes in key drivers to changes in selected ecosystem services. These hypotheses have not been tested through quantifiable models[1]. The following hypotheses are intended to reflect potential uncertainty around future conditions and important relationships to consider when exploring the use of integrated predictive model to forecast future changes.

Water Quality

Why is water quality and stream temperature important: Generally speaking, water quality is important for both human and ecosystem health. Stream temperature is particularly important as it governs the kinds of life that can live in a stream. Fish, insects, and other aquatic species all have a preferred temperature range[2]. The rate of chemical reactions generally increases with higher temperatures, influencing biological activity (e.g. metabolisom) [2]. For example, the amount of dissolved oxygen in stream water is highly dependent on water temperature – hotter water holds less oxygen.

What are past trends and current conditions of stream temperature in the basin?

Dozens of agencies in the Snohomish basin and the Puget Sound Region track stream temperatures including the Department of Ecology, USGS, and King and Snohomish County[3]. Spatial and temporal data allows for comparisons across and within streams and over variable time scales. The Department of Ecology, in compliance with the US Clean Water Act, monitors water quality in Washington Streams and keeps track of waters for which beneficial uses such as drinking, recreation, aquatic habitat and industrial use are impaired [4]. In 2008, ten rivers and creeks [Figure A4.1] were classified as 'category 5', violating stream temperature thresholds and requiring an improvement project [5]. In 1998, only 5 of these rivers were classified as category 5 for temperature impairments [4].

What are the three major mechanisms by which stream temperature will change in the basin's future?

Climate Change: Both atmospheric temperature and seasonal precipitation variability influence stream temperature [6]. Atmospheric temperature rise can directly influence stream temperature. Climate further influences hydrological shifts through the timing and amount of precipitation, and snowmelt. High temperatures are especially critical during periods of low flows and drought [6].

Impervious surface: Major challenges to temperature in the basin include infiltration rates and surface runoff (in terms of the timing and volumes) resulting from increase in impervious surface. Development, and associated impervious surface, precludes infiltration, increases the runoff rates and reducing the timing [7] of overland flows. As waters runs over hot paved surfaces like driveways, roofs and parking lots, it heats up [8]. The distance to water bodies and alterations to vegetation and soil are also important considerations[9]. Development close to water bodies may rise stream temperatures further due to shorter time the water has to cool during transport [9]. Development over high percolating soils and mature forests with thick duff layers is significantly more detrimental than development over clay or already degraded lands.

Riparian (stream) buffers: Streamside vegetation slows down surface flow (runoff), giving it time to cool down. Streamside vegetation also shades the water, reducing summer stream temperatures [10].

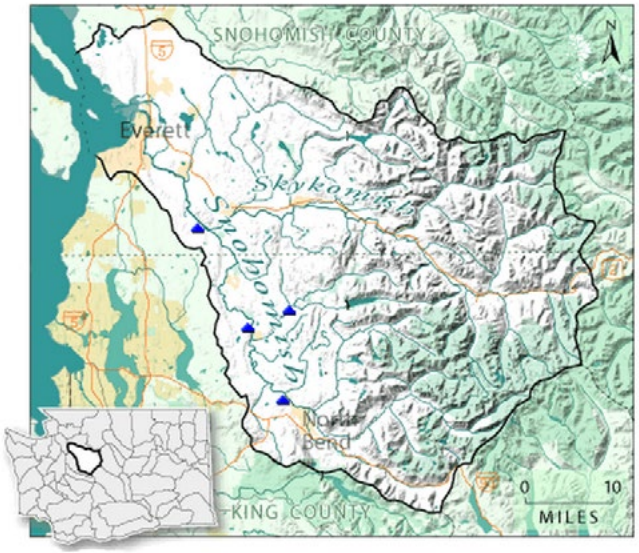
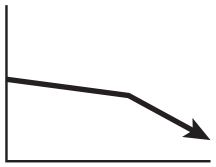
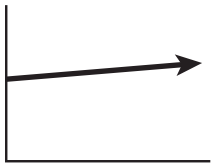
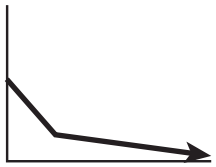
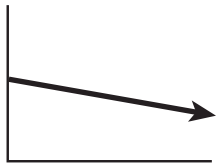


Figure A4.1 WRIA 7 303d Impaired Streams

Table A4.1 Hypotheses of future trajectory shifts of drivers influencing water quality mechanisms

	Accelerate	Small	Resistance	Metamorphosis
Water Quality over time				
Stream Temperature	*Hot*	*Cool*	*Very Hot*	*Warm*
Climate Change	Minor	Minor	Major	Major
Impervious Surface	Triple	Minor	Double	Increase
Riparian Buffers	Narrowed	Managed	Hardened	Restored

Box A4.1 WRF and Stream Temperature

The Weather Research and Forecasting Model (WRF) has multiple uses and specifications. The CCSM3 and ECHAM5 regional models investigate global climate change at a local scale. Mote and Salathe, 2009 estimated stream temperatures within Washington State utilizing the WRF model with both the A1B and B1 global scenarios report [6, p226]. Stream temperature models predict significant increases in stream temperature for both the A1B and B1 emission scenarios. Summertime temperature greater than 18degC will become the norm for Western Washington by the 2040's and stream temperatures in high elevations of the Cascades will resemble lowland stream temperatures of the 1980's. By the 2080's under the A1B scenario the majority of the Snohomish Basin is estimated to be fatal for salmon. Stream temperatures estimated by WRF do not take into account increases due to increased urbanization (e.g. runoff over asphalt) and vegetation removal along stream channels.

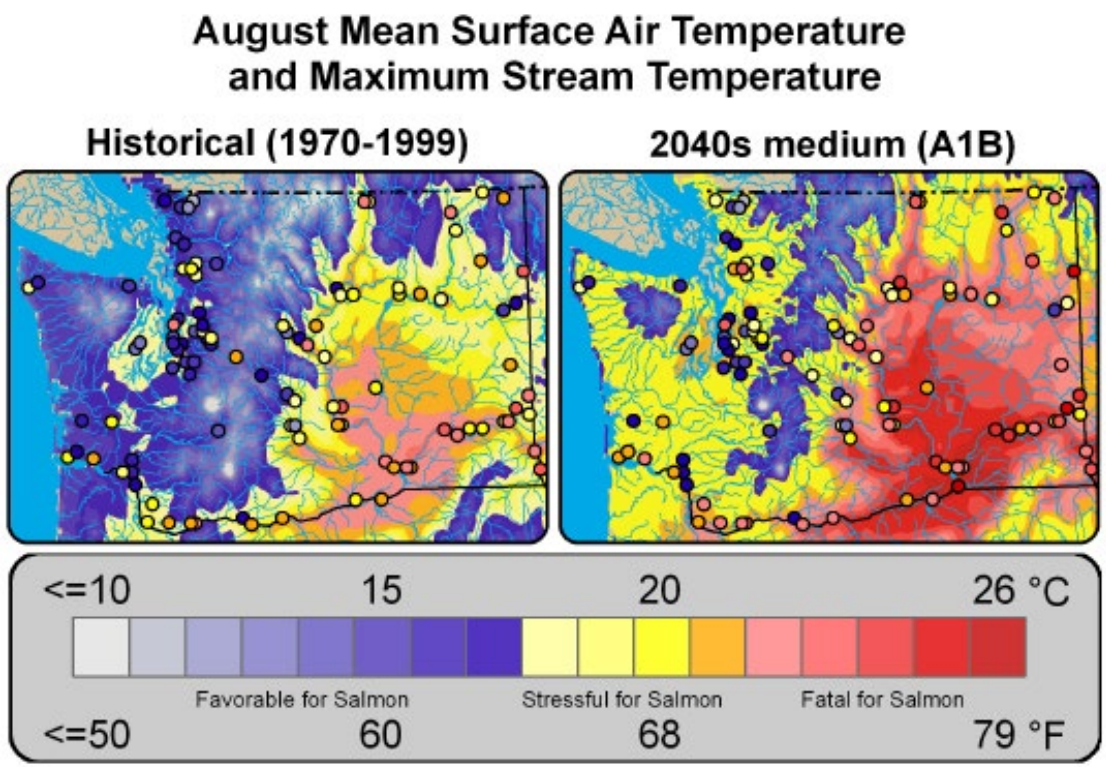


Figure A4.2 NOAA Advanced Hydrological Prediction Service, River Observations

Water Quantity

Why is water quantity and fluctuations in-stream flows important? Water quantity is important because both too little (drought) and too much (flood) can have detrimental impacts on ecosystems and humans. Seasonal variation in stream flow is natural and expected. When the magnitude and frequency of variability exceeds historical trends, it poses a significant challenge. Flood trends are unique per stream, depending on geomorphology (e.g. channel elevation), levels of urbanization, and precipitation timing. Flooding affects urban development in terms of infrastructure (roads and utilities) and properties, incurring costly damages and disruption of services. Flooding in agricultural lands leads to damaged crops, livestock, and built structures. Aquatic wildlife and vegetation can also be affected by floods, as floods carry warmer temperatures and higher levels of pollutants [11]. Floods can also increase sediment loads and disrupt streamside habitat. Alternatively, not enough water can be dangerous and costly. In-stream flow are restrictions specifying the amount of water needed meet future water management objectives for the health of ecosystems and people.

What are past trends and current conditions of streamflow fluctuations in the basin? The Snohomish Basin has abundant water resources [12]. Enough to support over 1 million residents' drinking water needs, as well as industry cooling, agricultural irrigation, and hydropower, with plenty left over for aquatic life [13]. The challenge lies in the timing of flows, and the low precipitation volumes in the summer [6]. Most of the basin's precipitation arrives in the winter, when demands are lowest while in the summer, the snowpack is gone and there is little rain, so flows are dependent on groundwater inflow[12]. Traditionally this natural variability has translated into flooding in the winter and spring, and low in-stream flows in the summer. Urbanization has increased the rate of flow in the winter, exacerbating floods, while demands in summer, exacerbate low flows. Historically, King and Snohomish County have the highest cost impacts from floods in the State [14]. Still, several basin streams have moderated levels due to dams and levees that restrict flows.

NOAA monitors stream flow over time [15], as do the Counties [16] and USGS [17]. Comparing several basin gages (Figure A4.3), all seven gages reflect increasing frequencies of peak flows and major floods [15]. The USGS has reported four stream channels with low flow values below minimums in the basin.

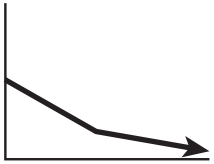
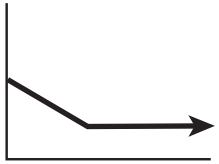
What are the three major mechanisms by which in-stream flows will change in the basin's future?

Withdrawals: The amount of water that is pulled from the stream, both directly and indirectly (i.e. from aquifers that are the water source for the streams). Water rights govern the amount of water that can be removed from a stream by municipalities, service providers and wells serving more than 6 households. In-stream flows restrict the amount of water that can be withdrawn from a water body, as specified per channel for a defined time and typically follows seasonal variations [18]. The greater the population and industry, the greater the demand and pressure to increase withdrawals [15]. In terms of demand, most of the water in the watershed has already been allocated, and obtaining new water rights will continue to be very difficult [18]. However, indirect withdrawals such as exempt wells and groundwater taps as well as Tribal water use are not restricted by water rights [19]. Further, agricultural irrigation is not forecasted by municipality service provision plans and is largely unmonitored [13]. Water conservation efforts, from high efficiency plumbing and appliances and education, can reduce per capita demand (and has over the last 50 years)[13][2]. The Central Puget Sound supports estimated utility goals of additional 12% reductions due to conservation over the next fifty years [13]. As of March 2011, there are 109 pending water right applications for WRIA 7 [18].

Climate change: Despite uncertainty in long-term precipitation trends, it is not forecasted that the annual precipitation will change dramatically over the next fifty years [6]. However, the timing of precipitation and snowmelt will have significant impacts on streamflow fluctuations [6, 13]. As described under the snowpack and streamflow section, the basin is forecasted to eventually eliminate springtime snowmelt and reduce summer in stream flows.

Impervious Surface: The urban hydrograph, dominated by impervious surfaces, is marked by higher and faster peaks [20]. Already the Snohomish, Raging and Tolt are characterized by shifted streamflows associated with urbanization [21]. Further urbanization may lead to exceeded thresholds with markedly low summer flows and flush floods in the winter [20].

Table A4.2 Hypotheses of future trajectory shifts of drivers influencing water quantity mechanisms

	Accelerate	Small	Resistance	Metamorphosis
Water Quantity over time				
In Stream flows	*Dirty and drawn (urbanization increases drinking water demand and overland flows flush through the paved system)*	*Cycled and stable (resource managers cycle use, treatment and release on-site)*	*Fast and early (Early snowmelt coupled with sprawls and levees exacerbates flow variability)*	*Variable but buffered (extreme climate events are buffered by riparian areas and efficient withdrawals)*
Withdrawals	Major demand	Local Resource	Deep Drills	Moderated
Climate change	Minor	Minor	Major	Major
Urbanization	Triple	Minor	Double	Increase, buffered

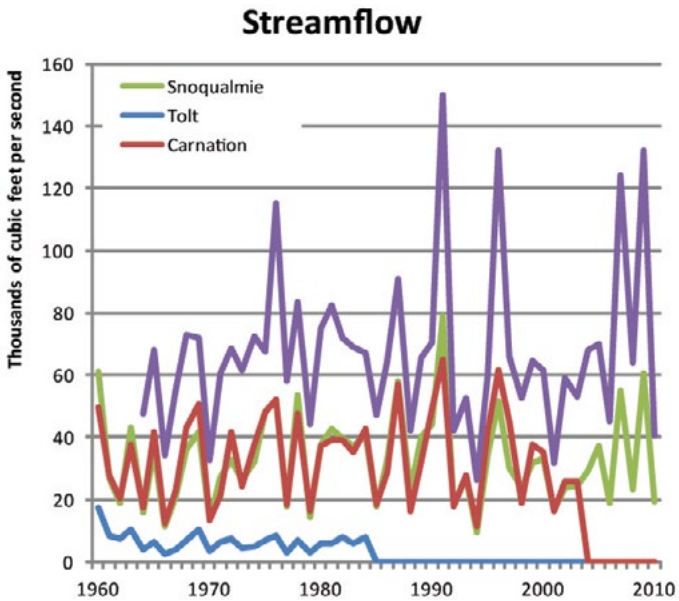


Figure A4.3 Streamflow variability 1960-2010.

Box A4.2 DHSVM and Stream flow:

The distributed hydrology-soil-vegetation model (DHSVM) is a regional-scale model forecasting hydrologic components and flood statistics based on meteorological records and land surface characteristics. The models has recently parameterized at the University of Washington to assess impacts on the hydrology of Puget Sound by urbanization and climate change. Cuo et al explored the effects of forecasted land cover change (LCCM) and climate change on streamflows in the Puget Sound by 2050[52]. While climate impacts largely control the seasonal variability of streamflow, urbanization increases runoff year-round. The eastern lowlands are expected to experience the greatest effects of urbanization, and hence the greatest hydrologic changes; this region is more sensitive to these effects than to climate change. The combined effects of climate and land cover change on the seasonal distribution of streamflow is 12-42% increase flow in the winter and 15-40% decrease flows in late spring and summer. Snohomish Basin specific estimations coupling climate and land cover change have not been estimated at the time of this writing. The DHSVM model has not been explored in conjunction with alternative withdrawal estimates not with the potential variability associated in the Snohomish Basin Scenarios.

Carbon Stocks

The Carbon Cycle: The impact of urbanizing watersheds on the global carbon cycle has started to generate new evidence of the complex mechanisms linking urbanization to carbon emissions and uptake [22]. The net carbon balance of terrestrial ecosystems is typically assessed as the difference between gross primary production (GPP) and respiration (R). Urbanization directly and indirectly affects carbon stocks (pools of carbon such as plants) and carbon fluxes (e.g, emissions of CO2). Urbanization increases impervious surface area, which alters the hydrology and reduces infiltration capacity and the microclimate. Urban activities add multiple pollution sources, including chemical inputs from industry, agriculture, and transportation. Finally, land-cover changes typically result in changes in plant species and size composition, affecting rates of C assimilation. The mechanisms influencing C stocks (pools of C) are distinct from those influencing C fluxes (rates of exchange).

Why are carbon stocks important? Why forest biomass? [23] Forests store large quantities of carbon within their live and dead organic material. Human and naturally caused disturbances to forests can shift these stocks quickly into the atmosphere; increasing CO2 concentrations. Carbon uptake by urban forests can significantly reduce local emissions and atmospheric CO2 concentrations. While carbon emissions, from vehicles, industry and residences are a critical component of the urban carbon cycle, they are not the entire budget. Characterization of carbon stocks and fluxes in urban forests is critical to understanding if an area is a net carbon sink or source. Baseline accounts of carbon stocks in urbanizing areas are very important, but can be challenging as land cover and vegetation are constantly changing. Carbon stocks vary greatly by region and condition. For example, Smithwick [24] found that old forests in the Western Cascades of Washington can store near 450 Mg C per hectare. However, recovering and or younger forests can uptake more carbon while storing lower carbon stocks.

What are the current conditions and past trends of forest biomass in the basin? Using a time series analysis of land cover, Hutyra et al.[23] explored the aboveground C stock patterns over two decades (1986-2007) in the Seattle Metropolitan Area. The Seattle MSA supports 8922Mg C per hectare of aboveground live biomass, and an additional 11.8 4 MgC per hectare of coarse woody debris (dead biomass). These values are substantially larger than comparable urban forest stocks measured nationally (~28 MgC/ha of aboveground live biomass). Between 1986 and 2007 the amount of urban land cover in

Box A4.3 LCCM and Carbon Stocks:

The land cover change model (LCCM) uses the simulated land use allocations from UrbanSim (a regional urban development model) and projects land cover transitions as a result of the interactions between urbanization, transportation and biophysical factors. The LCCM has been calibrated for the central Puget Sound region, forecasting fourteen land cover classes out to the year 2050. Using the field-based algorithems derived by Hutyra et al, the 2050 land cover grid for the Puget Sound can be used to infer potential future changes to carbon stocks. While the rate of decline is forecasted to decline from 1.64% annual loss to a 0.22% annual loss (2007-2050) the total loss of stock is still over 3.4 million metric tons. Carbon Stocks estimated based on the LCCM predictions do not reflect the plausible variability associated with the four scenarios. Further, the land cover change model does not currently integrate the mechanisms borne by climate changes and land management practices.

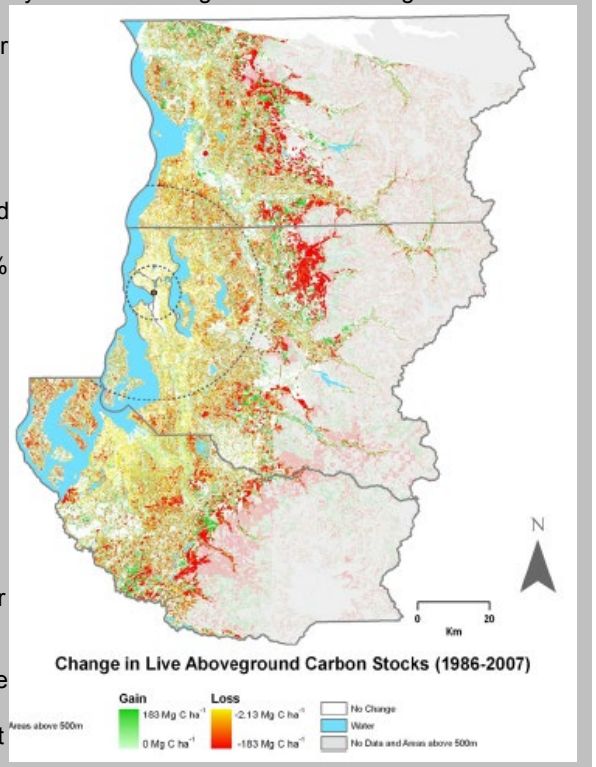
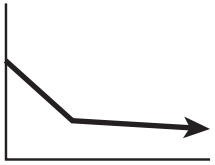
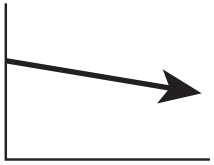
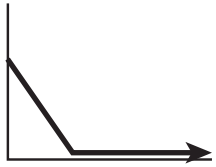
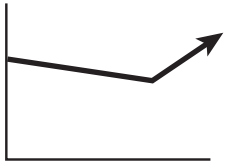


Figure A4.4 Change in Live Aboveground Carbon Stocks [23]

Table A4.3 Hypotheses of future trajectory shifts of drivers influencing carbon stocks mechanisms

	Accelerate	Small	Resistance	Metamorphosis
Carbon Stocks over time				
Forest Biomass	*Rapid loss reaches critical limits*	*Minor loss stabilized*	*Continual gradual loss*	*Initial loss rebounds*
Urban Development	20% forest cover loss mostly in lowlands	2010 levels maintained	15% forest cover loss – high at rural fringe	5% forest cover loss – mostly in lowlands
Land Management	Intense rotations and extractions	Sustainably managed	Cleared and manipulated	Diverse and native
Biogeochemical Cycles	Heavy inputs	Moderate inputs	Inputs and climate altered cycle	Minimal inputs, altered cycle

the basin doubled, virtually all at the expense of forests. Hutyra et al. estimate that during the same time frame, aboveground carbon stocks were lost at a rate of 1.2Mg C per hectare per year. The majority of the carbon losses occurred at the rural fringe, a distance greater than 7.5km (4.5 miles) from the Seattle city center as within the urban area there was little available forest land cover for development. Carbon stocks and losses within Snohomish Basin are even more dramatic. Rough estimates show average densities of 155MgC/ha in WRIA 7 in 2007 (as compared to 100Mg in the Seattle MSA). With a total aboveground terrestrial carbon stock of over 56 million MgC – The basin supports more aboveground carbon than WRIAs 8, 9 and 10 combined (the remainder of the Seattle MSA).

What are the three major mechanisms by which forest biomass will change in the basin's future?

Urban development: Higher rates of forest conversion associated with urbanization result in a reduction of terrestrial C stocks [44]. Average aboveground carbon stocks vary greatly depending on the nature of development – from high urban areas with carbon densities of 2Mg/ha to coniferous forests supporting over 183 Mg/ha. Carbon stocks at the urban fringe are likely the most susceptible due to high densities and high rates of conversion.

Land Management: Resource management, whether by timber companies, by park maintenance or by households, can influence tree removal, tree species selection and understory clearings. For example, shorter rotation cycles and understory clearing lead to lower carbon stocks in forests. Urban land-use and management practices affect soil organic matter directly by removing the mass and nutrients from leaf and woody debris [45]. These organic carbon stocks are kept artificially low in urban and suburban areas through yard maintenance practices, but the carbon fluxes (input rates) would be expected to increase linearly across the urban to rural gradient (directly proportional to biomass/leaf area index).

Biogeochemical Cycles: human modifications of nutrients including nitrogen, phosphorus and carbon, at a global scale influence plant growth rates. For example, nitrogen is historically a limiting factor in tree growth, but substantial nitrogen inputs to ecosystems by global agricultural and household fertilization practices has shifted growth curves. Different plants, from invasives to native Douglas firs, respond differently to altered cycles. Both N and CO2 fertilization have been associated with an increase in C uptake. N fertilization has been found to occur in temperate ecosystems that are currently nitrogen limited [26]. Increasing N inputs (via pollution and fertilization) will, over long time periods, result in enhanced C stocks. The responses of ecosystems to CO2 fertilization are limited by the availability of N in the system.

Carbon Fluxes

What are carbon fluxes and carbon emissions important? C fluxes are exchanges between two different stocks, such as the transfer of CO_2 from the atmosphere to the biosphere via plant photosynthesis, or emissions of CO_2 to the atmosphere from combustion processes. Emissions, from cars, industry and homes are one form of fluxes, while decomposition of organic matter also produces CO_2. Urban and urbanizing areas are a major source for emissions of CO_2 with estimates of 90% of all emissions directly or indirectly attributed to urban areas [27]. CO_2 is a powerful greenhouse gas – meaning that it traps heat within the earth's atmosphere, contributing to global warming.

What are past trends and current conditions of carbon fluxes in the basin? King and Snohomish County's per capita emissions are were estimated at 2.83 and 2.4 Mg C per year (2002, respectively). The majority of the emissions stemmed from 'on-road' sector including cars, trucks and buses (52% in Snohomish and 49% in King). Residential, industrial and aircraft emissions accounted for the majority of remaining fluxes. On average, the EPA estimates that for every vehicle miles traveled (VMT) 423g of CO2 are emitted [28]. Between 2008 and 2009, drivers in King and Snohomish Counties cumulatively drove over 21 billion miles [29], potentially emitting over 248 million Mg C. The number of vehicles miles travelled in the region has more than doubled since 1980 [29]. Meanwhile, the fuel efficiency has reduced national vehicle emissions per mile traveled by ~1.17% a year [30].

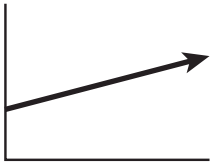
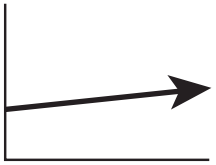
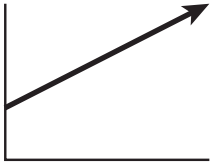
What are the three major mechanisms by which carbon emissions will change in the basin's future?

Urban development: Urban development affects the carbon cycle through both direct and indirect pathways, with increasing fossil fuel emissions among the most significant of such impacts [22]. Forty percent of total fossil fuel emissions in the United States are attributed to the transportation and residential sectors [31]. Factors that likely affect per capita CO_2 emissions include population and housing densities, the rate of population growth, affluence, and technologies [32]. Demographic trends together with increase produce an overall increase in per capita CO_2 emissions and an increase in the consumption of land associated with urban development. The pattern of urban development may be key to determining the extent to which urbanization will contribute to CO_2 emissions, since the spatial distribution of residential and commercial housing units affects commuting patterns and transportation choices. Future trajectories of urban form and infrastructure choices will be decisive in future CO_2 emissions. At the same time, as a result of land-use and management practices which affect mass and nutrients from leaf and woody debris removal, C sequestration would be expected to decrease directly proportional to loss of biomass/LAI [33]).

Regulations and Innovations: Efficiency refers to the level of emissions per mile driven or watts consumed. Regulations, such as the EPA's CAFE standards govern the level of allowable efficiencies. Innovative technologies providing cost-effective and reliable substitutes can further drive higher efficiencies.

Climate Change: As the temperature rises, biogeochemical cycles quicken, releasing more atmospheric carbon through respiration and decomposition. Soil respiration rates could be expected to increase with increasing urban temperatures. Urban heat islands also affect soil respiration rates, which are expected to be higher within the urban interior due to exponential relationship between respiration and temperature. Given the simultaneously changing N inputs and atmospheric CO_2 concentration across the urban gradient, we would also expect the CO_2-fertilization effects to affect carbon fluxes by changes in N inputs and CO2 concentrations/emissions.

Table A4.4 Hypotheses of future trajectory shifts of drivers influencing carbon emissions

	Accelerate	Small	Resistance	Metamorphosis
Carbon emissions over time				
Carbon emissions	*Increase*	*Stabilize*	*Exponential growth*	*Decline*
Urban Development	Extensive	Minor but rural	Sprawled	Urban
Regulations and Innovations	Rapid private market innovations	Regulations increase	Stagnate, deprioritized	Global, integrated
Climate Change	Minor temperature rise	Minor temperature rise	Major temperature rise	Major temperature rise

Box A4.4 UrbanSim and Carbon Emissions:

UrbanSim is a parcel based land use model. It allocates land use (location of households, employment and population) given inputs of current development patterns, restrictions, transportation, and regional economic forecasts. Currently, The Puget Sound Regional Council (PSRC) operates UrbanSim within the Central Puget Sound area out to 2040. UrbanSim works in concert with PSRC's Travel Demand Forecast which generates estimates vehicle miles traveled. Forecasted vehicle emissions can be quantified based on estimated vehicle miles traveled in the Basin. Based on rough initial estimates, the basin will see an additional 4,407,000 VMT per weekday by 2040 (a 40% increase on the current 10,980,000 VMTs, and an approximately additional 1,820 metric tons of $C0_2$ emitted per day [53]). By exploring alternative urban development and transportation scenarios decision makers can forecast alternative emission outcomes. Estimations of carbon emissions based on UrbanSim's VMT transportation output do not integrate the mechanisms borne by new regulations, innovations or climate changes.

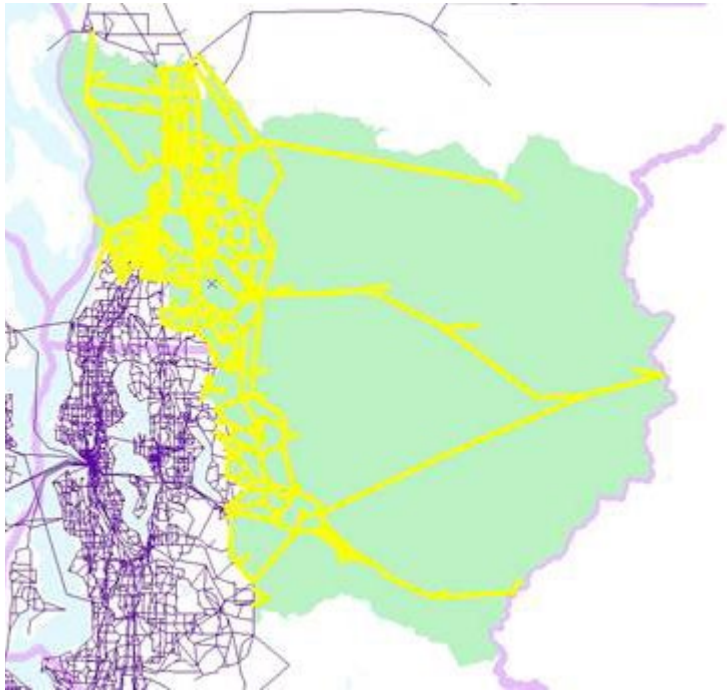


Figure A4.5 Travel Model Forecasted VMTs for Basin 2040.

Habitat Diversity

Why is habitat diversity important and habitat by Ecoregion?
Biodiversity is defined as the variety of living organisms considered at all levels, from genetic diversity through species, to higher taxonomic levels, and includes the variety of habitats, ecosystems, and landscapes in which the species are found [34]. Habitat diversity supports multiple ecosystem services by supporting healthy and resilient ecosystems [35]. Diverse habitats benefit soil fertility, moderation of floods, pest and disease control and pollination of plants [36]. Diverse habitats support species diversity and reduced vulnerability, and are better able to resist perturbations [37]. Ecoregions, compiled by Omernik in 1987, are used extensively by the US Environmental Protection Agency to support research and monitoring of ecosystems across the Nation [38]. Ecoregions are defined based on the premise that ecological patterns and phenomena, such as geology, vegetation, climate, soil and wildlife, reflect differences in ecosystem quality and integrity [39-41]. "By recognizing the spatial differences in the capacities and potentials of ecosystems, ecoregions stratify the environment by its probable response to disturbance" [42]. EcoRegions characterize broad scale habitat diversity at the basin level.

What are past trends and current conditions of habitat loss by Ecoregion in the basin?

The Snohomish Basin forest habitat can be distinguished by four ecoregions[3] [43]. Approximately 65% of the basin is covered by North Cascades Forest (including the Lowland, Highland and Alpine subRegions)[4]. The remainder of the basin is characterized as Eastern Puget Forests (divided by riverine lowlands and uplands). The once continuous forest of western hemlock, Douglas-fir, and red cedar of the Puget lowlands has given way to a variety of landscapes including lawns, parks, old fields, croplands, tree farms, and remnant forests set amid a landscape of urban, suburban, rural, and commercial uses [36]. By 1986, approximately 17,500 acres (~18%) of the lowlands were covered by impervious surface. By comparison, only about 1% of the Eastern Puget Uplands is covered by impervious surface. The North Cascades EcoRegion SubAlpine and Alpine forests are largely unaltered today; historically protected as inaccessible or economically not-viable land. Conversely, the North Cascades lowland forests were highly profitable for timber, and were drastically altered into forest monocultures by pre-WWII deforestation actions [43]. Over the last 30 years, exurban development has eliminated over 55,000 additional acres within this EcoRegion.

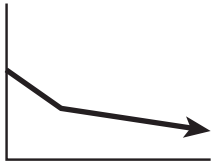
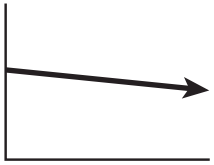
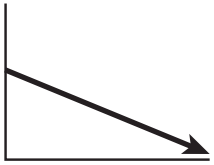
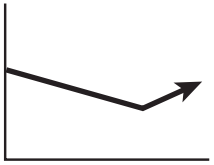
What are the three major mechanisms by which habitat loss by ecoregion will change in the basin's future?

Land cover change: Land cover change, including the amount, the pattern (e.g. dispersed) and the location of development (e.g. distance from urban core) will influence habitat loss in the basin [43,44]. Each land cover class, from heavy urban to agriculture will have variable impacts to habitat loss and relationships to the viability of surrounding lands.

Protection of Current Habitat: In conjunction with land cover change is the protection of current habitat through regulations, conservation easements and management practices. Currently over 95.2% of the Cascade Alpine forests (within WRIA 7) are protected from development, while only 38.9% of the Cascade lowland forests are protected[4]. Alongside protected conversation lands such as the Wilderness Areas, future changes in logging and forest management restrictions will influence the alteration of the Cascade EcoRegion. Meanwhile the Eastern Puget Forests are much more reliant on urbanization trends, from County zoning restrictions to household preferences for tree removal.

Climate change: Ecoregions are predicated on historical patterns of biophysical conditions, from climate and hydrology to soils and wildlife. Potential climatic changes resulting from both incremental increases and extreme events may alter the underlying patterns supporting the basin's ecoregions. Shifting climatic regimes have and will continue to influence species zones, allowing species from outside the basin to migrate in, and species from within the basin [45], such as the Subalpine Fir, to migrate higher upland into the former tree-line [46]. Earlier snowmelt will influence hydrological networks, water availability and the expose or inundations of land masses. Further, with pressures on already stressed or weakened habitats, survival rates of native species will be compromised [46]. Forests under stress are more vulnerable to disease mortality and spread of invasive species [47].

Table A4.5 Hypotheses of future trajectory shifts of drivers influencing habitat loss

	Accelerate	Small	Resistance	Metamorphosis
Habitat diversity over time				
Habitat loss	*Nearly all unprotected forests gone by 2040.*	*By 2060 about 30% of unprotected forests are gone.*	*By 2060 nearly all protected and unprotected forests are eliminated.*	*Initial decline due to development. By 2040 all remaining forests are protected. Over time total area increases.*
Land cover change	Extensive, lowland	Minor, dispersed	Sprawling upland	Dense urban
Protection of habitat	Minor increase in protections	Minor increase in protections	Decline in protected lands.	Highest protection
Climate change	Minor	Minor	Major	Major

Box A4.5 Potential Vegetation Model and Habitat Diversity:

The Potential Vegetation zone model is developed by the US Forest Service. The model stratifies the landscape into succession and growth potential vegetation zones based on climate and topographic data. The Snohomish Basin is represented by five plant association groups: Western hemlock zone, silver fir and western hemlock zone, mountain hemlock and silver fir zone, subalpine zone and the alpine zone. Precipitation at sea level is the most important determinant of the boundaries between potential vegetation models, explaining 50% of the variation alone. Habitat conversion associated with climate changes could be forecasted by recalibrating the model to future precipitation variability. Potential vegetation maps could be integrated with forecasts of additional mechanisms including land cover change and habitat protections to explore future conversions.

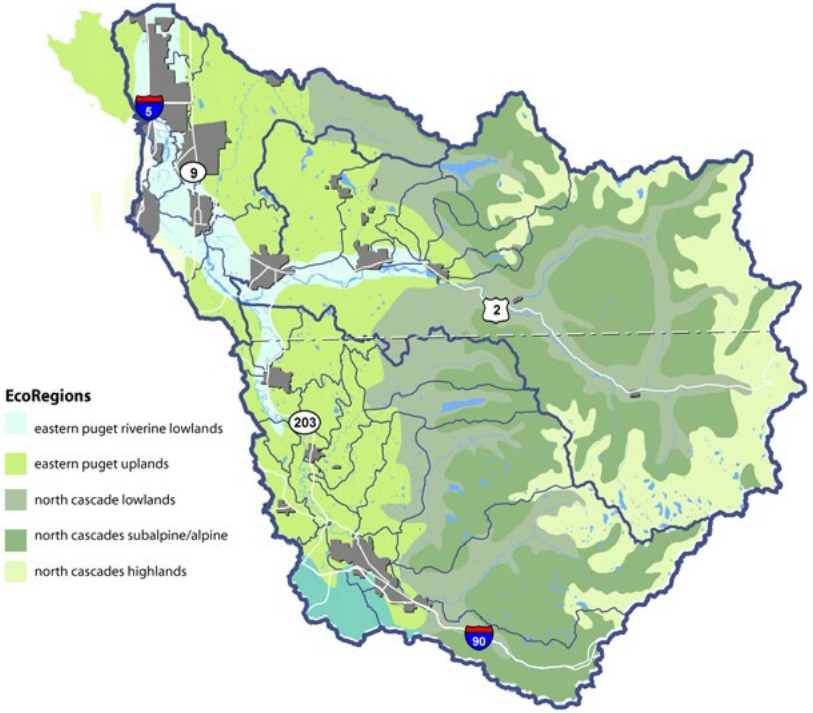


Figure A4.6 Ecoregions of the Snohomish Basin

Genetic Diversity

Why is genetic diversity important? Why C*oho and Chinook?*

Genetic diversity refers to the total number of genetic characteristics in the genetic makeup of a species. Genetic diversity is important in preserving unique genetic blueprints that may reduce vulnerability, the support human health, and cultural values, as well as intrinsic values. Within the Puget Sound, salmon have been identified as an important indicator of species diversity. Their historical cultural values, their relationship to ecosystems and food webs, and their sensitivity to alterations of natural habitat through their diverse geographic ranges make them an appropriate benchmark indicator. Within the Snohomish Basin, twelve wild stocks are currently present, in various relative conditions. The Snohomish Basin Technical Committee identified Chinook salmon (*Onchorhynchus tshawytsha*), bull trout (*Salvinus confluentus*) and coho salmon (*Onchorhynchus kistuch*) as proxy species to represent all anadromous salmonids the in basin for their assessment [48]. Coho and Chinook appropriately represent salmonids needs as they require diverse habitat and occupy the full geographic range of anadromous habitat in the basin [48].

What are past trends and current conditions of Chinook and Coho in the basin? [48]

The Snohomish Basin is one of the primary producers of anadromous salmonids in the Puget Sound. However, current production is estimated to have substantially declined from historical levels [48].

Chinook salmon naturally spawns in the basin and is divided by Skykomish and Snoqualmie populations. Historic equilibrium abundance for the Skykomish and Snoqualmie Chinook populations are 51,000 and 31,000 fish, respectively. Basin managers' data show that between 1999 and 2003, the average Chinook escapement for the basin was 3,531[6], around 5.7% of the historic equilibrium abundance[7].

Coho Salmon in the Puget Sound are designated as species of concern under the Endangered Species Act, which means that concerns exist about certain risk factors, such as population decline and loss of habitat. Coho salmon are relatively abundant in the Snohomish River basin as compared with other basins in the Region. Four Coho stocks reside in the basin. While survey data for spawning exists, it is difficult to monitor abundance, and the extent of historical Coho range is much greater than the one being monitored today.

What are the three major mechanisms by which salmon viability will change in the basin's future?

Habitat loss and degradation have been the primary causes of salmon species loss [49]. Identifying mechanistic linkages between land use change and salmon populations is critical to forecasting future population viability.

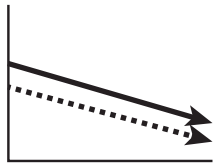
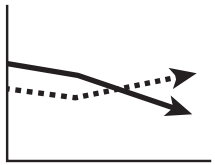
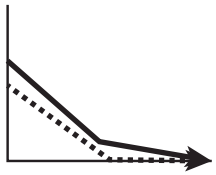
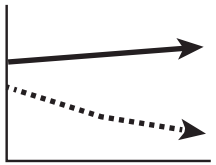
Stream alterations[8]: Direct alterations to salmon habitat and migration, including barriers such as dams and culverts and shoreline hardening from levees and docks.

Urban and agricultural runoff[9]: Indirect alterations to water quality, including pollutants and nutrients carried with surface runoff over impervious surfaces and fertilized fields. Reduced water quality impacts salmon survival through toxicity and competition from nutrient-sensitive vegetation and forage fish. The EPA and Department of Ecology monitor water quality of basin streams in terms of turbidity, dissolved oxygen, pH, nitrogen and phosphorus concentration, temperature, metals and organics. While urbanization is likely to continue to increase in the future, strict regulations for non-point source pollution and greater stream buffers may reduce pollution.

Streamflow Fluctuations: Streamflow variability is dependent on infiltration (land cover change), inputs (as influenced by climatic impacts to hydrology in terms of snowpack) and withdrawals (the amount of water we take out of streams as influenced by demands, regulations and conservation). While floods, in general, do not negatively impact salmon, they can be disastrous when coupled with high temperatures, turbidity, and lack of channel complexity through vegetation and pools [50]. On the other extreme, droughts and very low flows can harm salmon not only by restricting migration, but as also because low volumes concentrate poor water quality conditions [51].

Notes

Table A4.6 Hypotheses of future trajectory shifts of drivers influencing salmon viability

	Accelerate	Small	Resistance	Metamorphosis
Species diversity over time (chinook = solid and coho = dashed)				
Salmon viability	*Chinook and Coho severely declining.*	*Coho improved*	*Extinct.*	*Chinook Improved. Coho declining.*
Stream alterations (hardening)	Urbanized streams, narrowed buffers	Restoration and hardening – channel specific	Significant alterations	Wide natural buffers
Runoff (toxicity)	Novel toxins	Rural toxins	High toxicity	Regulated and minimized
Streamflow fluctuations (in stream flows)	Very low infiltration rates)	Channel specific withdrawal challenges	Extreme fluctuations - major climatic changes and low infiltration rates	Highly variable - early snowmelt and extreme precipitation events)

Box A4.6 SHIRAZ and Salmon Viability [50]:

The Salmon Habitat Integrated Resource Analysis Zowie! (SHIRAZ) is a fish population model. It translates the effects of changes in habitat conditions resulting from land use (development, restoration, hydropower, etc) and climate change into consequences for salmon population status and likelihood of recovery. The Shiraz model provides estimates of four important criteria for describing viable salmon populations (VSP): abundance, productivity, spatial structure, and diversity. Local applications include joint work between NOAA and the University of Washington to assess the influence of climate change (Battin et al 2007) and land use scenarios (Scheuerell et al 2006) on the Chinook salmon population in the Snohomish River Basin. Exploring the variability of downscaled climate projections and a 'bunsiness as usual' versus a 'restoration' land use scenario, SHIRAZ estimated between a 4.6 – 38% loss in mean returning Chinook spawners between 2000 and 2050. While the SHIRAZ forecast did take into account both streamflow fluctuations associated with land cover and climate changes and stream alterations, it did not manipulate variability in toxins associated with runoff. The SHIRAZ land development models do not reflect the variability of the Snohomish Basin Scenarios.

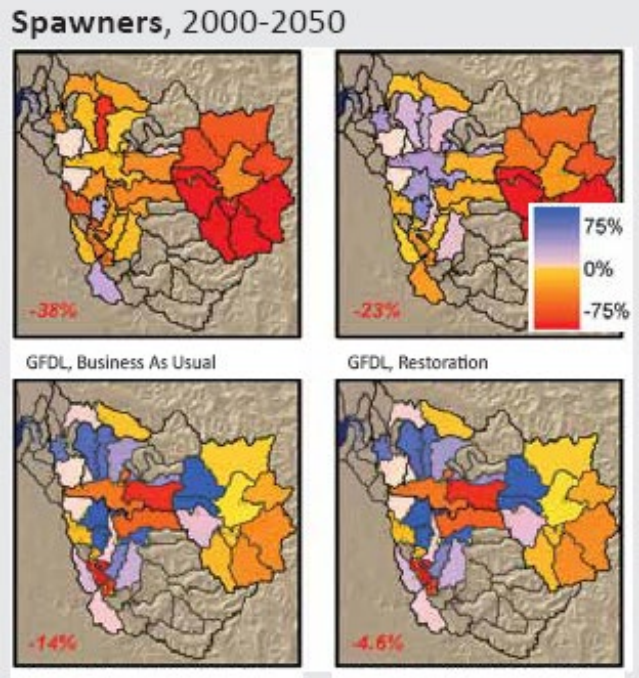


Figure A4.7 Change in Mean Returning Chinook Spawners, 2000-2050

1. The Integrated Model Workshop, held November 2011, developed a draft blueprint for how models could assess specific indicators of ecosystem services including stream variability in terms of frequency and intensity of peak and drought levels (measuring water quantity), available snowpack, fecal coliform, pesticides, water temperature (measuring water quality), salmon escapement per species (measuring species diversity), mean forest patch size, distribution and extent of land cover, contagion and aggregation index for habitat connectivity (measuring habitat diversity), vehicle miles drivers (measuring carbon fluxes) and acres of forestland along the urban-rural gradient (measuring carbon stocks).

2. Water consumption in Seattle, Tacoma and Everett is less today than it was 40 years ago.

3. Terrestrial ecosystems in the state have been grouped by similar flora, fauna, geology, hydrology, and landforms into nine ecoregions. The delineation of these ecoregions was developed by The Nature Conservancy and many partners on the basis of work done by Robert G. Bailey (U.S. Forest Service), James Omernik (U.S. Environmental Protection Agency), and other scholars.

4. GIS analysis based on 2007 impervious surface and Washington Department of Natural resource State of Washington Natural Heritage Plan's Ecoregion map.

5. GIS analysis by intersection EPA's ecoregion clipped to WRIA 7 boundary with a protected lands layers (created by the Urban Ecology Research Lab, including Wilderness lands and administratively withdrawn owl habitat, Mt Hemlock Zone, Mt Goat Habitat, riparian reserves, water, municipal watersheds, foreground (important viewsheds), late successional reserves, late successional and old growth reserves, deer and elk habitat, wildlife habitat, FS land acquired after completion of forest plan, transfer of development rights lands and purchased development land.

6. Escapement refers to number of fish returning to spawn. 3,531 includes 1,755 for the Skykomish and 1,776 for the Snoqualmie population.

7. Equilibrium abundance means that spawning salmon have maximized their use of available habitat and are simply replacing themselves in the next generation.

8. Stream alterations combine artificial barriers and changes to edge habitat.

9. Runoff includes changes in land cover (impervious cover, forest and riparian cover) as well as road density.

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5. Including all freshwater bodies within WRIA 7 classified as category 5 in 2008.

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APPENDIX 5: SCENARIO PLANNING APPROACH

A planning horizon of fifty years

How far out in the future we look determines both the uncertainty involved and the strategies we consider. The farther we look out, the greater the range of actions and potential actors we work with [1].

Take a one year plan: what can change in a year? At the Basin scale, not very much. Population growth, development patterns, and environmental resources will change, but in a largely predictable manner. A one year plan might focus on improvements in attracting skilled workforce through labor negotiations, re-vegetation of a specific parcel, or a construction plan for a new mixed-use building.

If we scale up to a to a ten year plan, what changes? There is greater uncertainty in population and economic growth, development pressure and environmental resources, but predictive models can provide a fair estimate of the magnitude of change. Ten year plans attempt to get in front of today's problems, proactively allocating resources and restrictions to shape the future, as opposed to reacting to demands as they arise. For example, Master Plans designate zoning to efficiently support new growth given the current locations of infrastructure, employment and conservation areas.

But if we scale up the time frame to a fifty year plan, the implications for decision making may be significant. Future trends become highly uncertain, even with sophisticated predictive models. People not even yet born will be leaders in the Basin. Buildings, bridges, levees, power lines will likely be torn down and rebuilt or redesigned. Technology we cannot even conceive of today might be a household staple. Climate impacts may fundamentally alter hydrological systems, such that miles of estuaries are transformed to salt marshes, and hundreds of acres of snowfields may disappear, exposing vegetation year-round for the first time in centuries. When we think fifty years out, what we know, even what we anticipate with models, becomes dwarfed by untested hypotheses [2].

Scenarios are best suited to help experts develop hypotheses about potential interactions of uncertain driving forces [3]. Thinking fifty years out simultaneously expands opportunities for decision-making and strips decision makers of certainty and control [1]. When we think fifty years out, we are thinking with a long view. Decision-makers can be freed from the need to respond to immediate pressures and can focus on developing strategies that take into account long term trajectories [3]. The question is no longer about where to allocate a thousand new homes, but rather how development pressures can be re-directed to improve the resilience of the urbanizing region [4]. The challenge for decision makers is to suspend their judgments about what we know and embrace the long view [3].

What are Scenarios?

Scenarios are alternative descriptions or stories of how the future might unfold [5]. Scenarios bring together information about different trends and possibilities into internally consistent stories of possible futures [6]. Different managers use the word scenarios in different ways. When we refer to scenarios, we mean how might different future conditions, all of which are possible, influence long-term decision-making. For example, how might a combination of regional growth in resource industries and major decline in snowpack influence our ability to restore floodplains differently than a combination of regional growth in biotech and minimal snowpack decline? The final set of conditions described attempt to represent the most dramatically different ways in which the future may challenge our decision making, not the most likely or the most appealing. Scenarios help us characterize divergent pathways when reducing future uncertainty is not appropriate [7].

Main points:

- Scenarios are hypotheses of alternative futures designed to highlight the risks and opportunities involved in strategic issues and assess strategic decisions [8].

- 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 between individual trajectories.

- Scenarios are illustrative accounts of multiple futures that direct our attention towards a handful of alternative outlooks that contain the most relevant uncertainty dimensions [9].

- Scenarios help us ask: If the future turns out differently than originally anticipated, will our strategy still work?

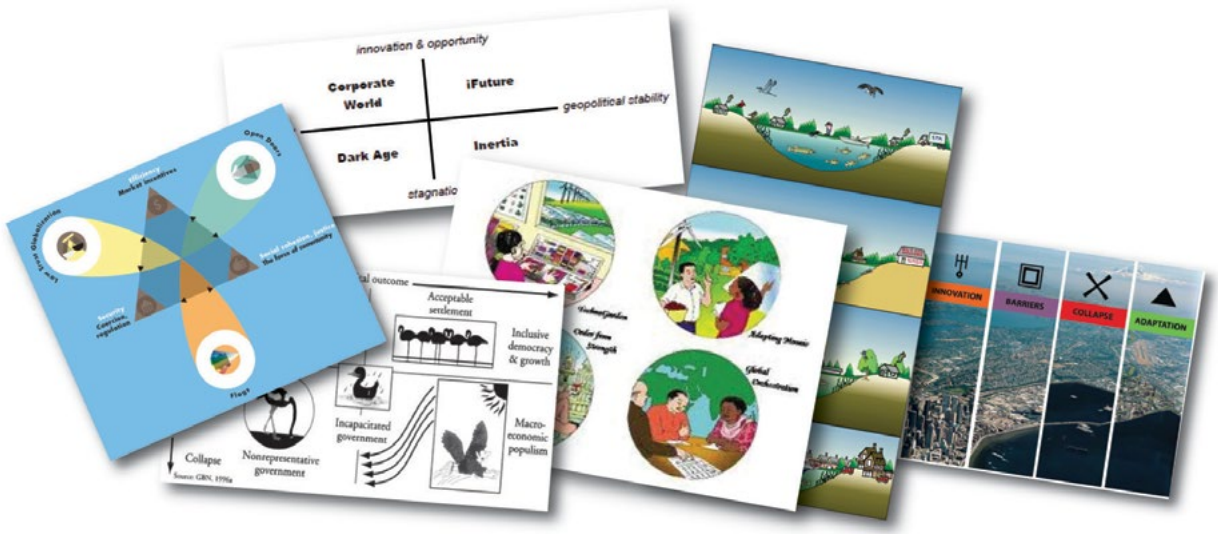
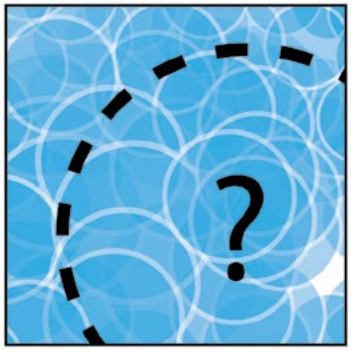


Figure A5.1 Examples of global scenarios. Pictured, left to right: Shell, Monte Fluer, WA Dept of Commerce, Millennium Ecosystem Assessment, Northern Highland Figure II.7 Lakes District, WI, and Puget Sound Scenarios.

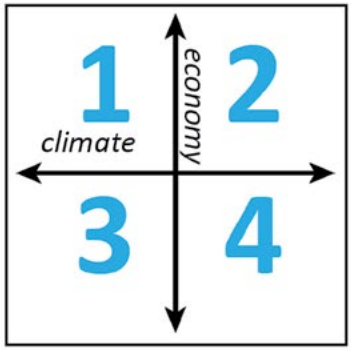


1. **Defining the focal issue**: The focal issue is the central question clarifying the focus of the scenarios, including the timeframe and central decision.

2. **Identifying the drivers**: Driving Forces (or drivers) are factors or phenomena which alter the future trajectory in significant ways. Drivers are clusters of trends or shifts. For example, population growth is a driving force with an effect on resource consumption and water quality.

driving force	I	U
climate change	***	***
economy	***	**
politics	**	***
agriculture	**	*
health	***	*

3. **Ranking the importance and uncertainty:** Scenarios focus on the most divergent and compelling future conditions affecting the focal issue (as opposed to all plausible futures). The focus is created by selecting two critical uncertainties drivers out of the identified list.

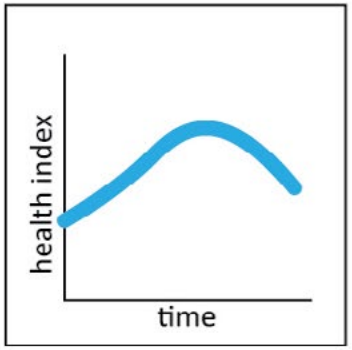


4. **Creating the Scenario logics:** Scenario logics represent the organizing structure, characterizing distinct alternative future conditions. Scenario logics are created by crossing the most extreme yet plausible end states of the selected drivers, resulting in a matrix of four frames that define the scenarios considered.

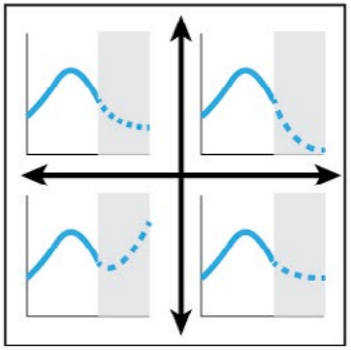
Figure A5. 2 The Scenario Planning Methodology: What goes into developing scenarios?

The Eight-Step Scenario Planning framework is described by Schwartz [3].

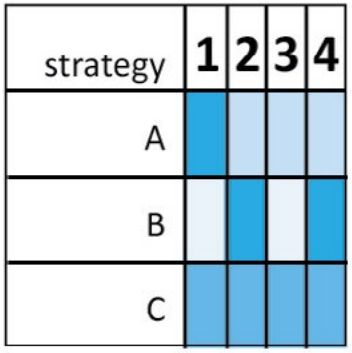
5. **Developing the Scenarios:** Scenario development entails researching and writing the narrative of each Scenario from the perspective of the selected driving forces and identified actors. The process essentially follows up the initial question of 'what if' with a plausible hypothesis based on publications and expert intuitions.



6. **Identifying the indicators:** An indicator is a measurement of an objective or an effect to be obtained. Once the Scenarios are developed, indicators describe the implication of the scenario of the focal issue. Identified indicators must be 1) relevant to the focal issue, 2) sensitive to differences between the scenarios 3) quantifiable and 4) communicable.



7. **Assessing the implications**: The implications of the scenarios are assessed by forecasting alternative future baseline conditions. This is the future value of a variable, or indicator, incorporating the implications of the scenario storylines, but not the benefits of any specific strategies.



8. **Evaluating strategies:** The final step of scenario development tests the efficacy of alternative strategies with respect to improving the future conditions of the selected indicators of concern. The scenario planning process can help identify strategies and assess their ability to achieve desired goals and objectives across the different scenarios.

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APPENDIX 6: WORKSHOP MATERIALS AND SYNTHESES

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Steering Committee Kickoff	A6-2
Key Drivers Focus Group Meetings	A6-9
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Integrated Model Workshop	A6-113
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Steering Committee Kickoff

Date(s)

5.26.10 and 7.1.2010

Location

Gould Hall. UW Seattle.

Objective

Introduction for Steering Committee members, to project and each other. Presentation on the Basin, Scenario Planning and project overview. Discussion on effective project deliverables.

Attendance

Steering Committee (see Appendix 1).

Agenda

- Presentation on the Snohomish Basin, scenario planning and the SBS project.
- Roundtable discussion of perspectives and directives.

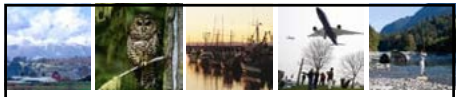
Materials

(see presentation slides pages A6-3-10)

Synthesis

Steering Committee Directives

1. Informed criteria to understand additional questions to ask in order to decide among potential strategies
2. Rigorous tests to better identify opportunities and challenges otherwise potentially unforeseen.
3. Help prioritize actions over the short term that are effective across multiple conditions.
4. Think about decisions through the lens of alternative actors
5. Integrate multiple and diverse expert perspectives on potential drivers of change.
6. Build on existing work that has been done in the basin and region.
7. Articulate the scenarios by contrasting future baselines to current conditions, onto which alternative strategies can be overlaid
8. Validate ideas expressed in project deliverable with scientific and professional work



Snohomish 2060 Scenarios
Kickoff Meeting

Steering Committee
Wednesday, May 26th 2010

introductions

project objectives

- Identify critical **factors** driving the future urban growth and associated environmental change in the Basin.
- Systematically assess the impacts of future scenarios on essential **ecosystem services** focusing on *biodiversity*, *water*, and *carbon*.
- Collaborate between a diversity of **experts** and stakeholders to identify opportunities and develop a set of robust strategies to maintain human and ecosystem wellbeing under alternative futures.

meeting objectives

- get acquainted
- introduce project and approach
- learn how to tailor the process and products to better suit your needs.

agenda

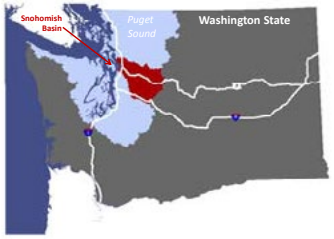
- 8:30 – 9:00 Welcome
- 9:00-10:00 Presentation
- 10:00-11:00 Roundtable Discussion
- 11:00-12:00 Student Presentations
- 12:00 - 1:00 Lunch and Next Steps

presentation outline

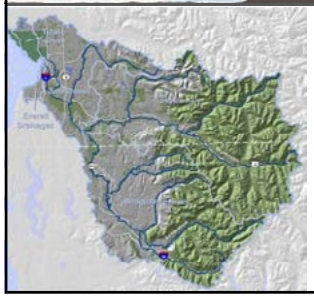
- **SB** Today and Tomorrow
- **SP** What and Why
- **SBS 2060** Intentions and Input

SB
SNOHOMISH BASIN
today and tomorrow

Snohomish Basin

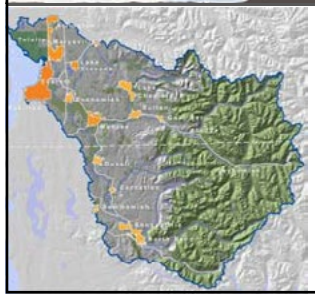


WRIA 7



- **Water Resource Inventory Area 7:** Snoqualmie, Skykomish and Snohomish Watersheds and the Tulalip and Everett Drainages

urban development

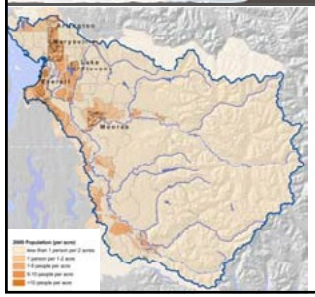


- 1,190,000 acres
- Major urban centers include Everett, Marysville, Arlington, Monroe and Lake Stevens.

urban development

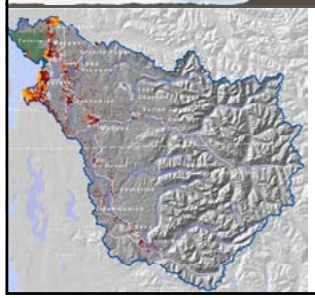
- 53,00 acres of urbanized lands
- 4.5% of Basin
- Based on 2007 land cover data including cells with more than 50% area in impervious surfaces.

urban development



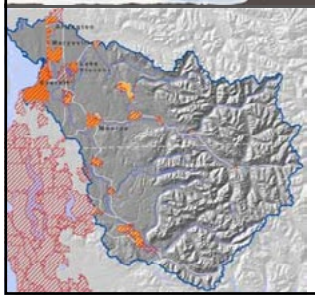
- 50% lives in urbanized areas
- 446,476 population (2009)
- 22% increase since 2000 and 1,000%+ increase since 1900(36,000)

urban development



- 170,000 employees
- Manufacturing medical and hospitality.
- ~50% of the people who live in the Basin work in the Basin.

urban development



- 20% of the Urban Growth Area extends outside current urban areas.

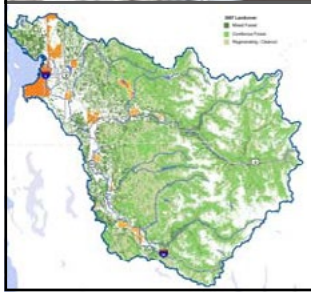
urban development

1900

urban development

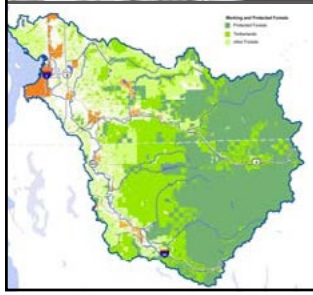
2000

forestlands



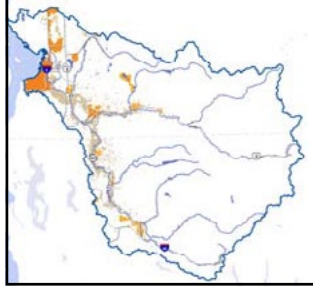
- The Basin boasts over 770,000 acres of forestlands accounting for 60% of the total land in the Basin.

forestlands



- ~50% of those forests are in active timberland
- ~40% are protected
- and 10% are under private land ownership and are not being managed for timber.

agriculture

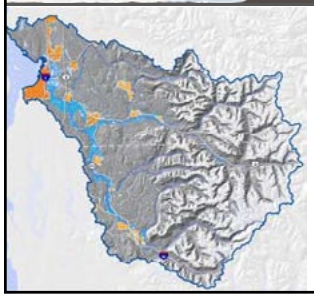


- Basin supports 46,000 acres of active farmland.

agriculture

- Topographic relief from sea level to 8,000 feet
- Flows east to west and into Puget Sound
- Along the Snohomish, Snoqualmie, and Skykomish,

agriculture

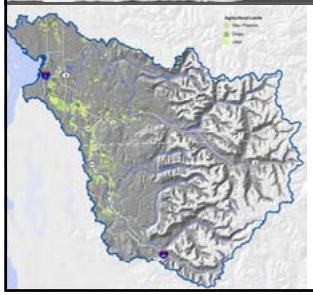


- Heavy winter precipitation and early spring snowmelt can lead to flooding in the lower valley of the Basin.

agriculture

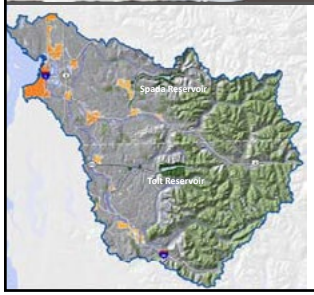
- Floodplains support good soil for farming.

agriculture



- aglands support a diversity of crops and pasture lands.
- and a diversity of farming techniques and property sizes.

drinking water

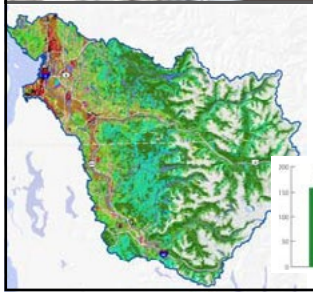


- The Tolt and Spada Reservoirs each serve ~500,000 residents in King and Snohomish County respectively.

habitat

- The Basin supports a diversity of wildlife and flora through a network of unique habitats and corridors.

Carbon Storage

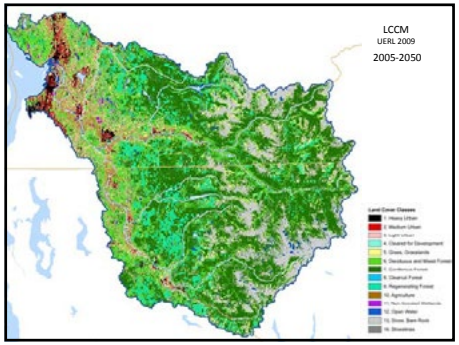


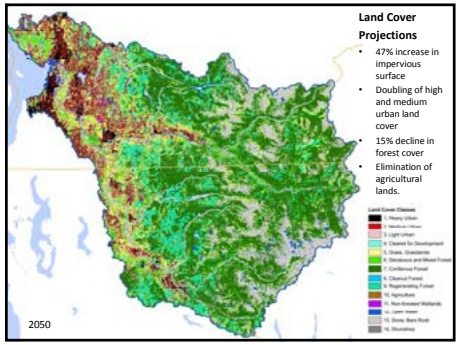
- 1.5 million tonnes of carbon are stored within the Basin's forests.

The Basin's **Future**

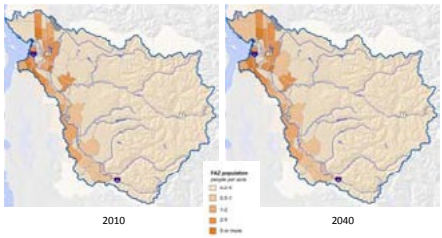
The Basin's **Future**

how will the basin change over the next 50 years.

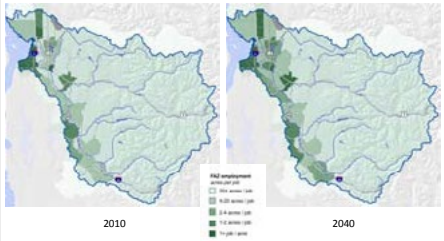




Growth Factors



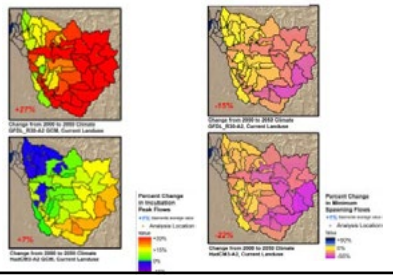
Growth Factors



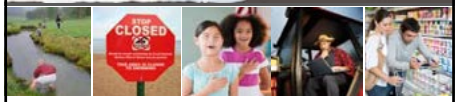
ecosystem flows

- what will grow here?
- how will forests fare?
- will we further fragment habitat?
- how will our plant communities and wildlife endure changes?
- what will be the levels of pollution?

climate change



socio-political



- will our social values change?
- how will we value our future?
- what will change about how we see the world around us?
- how will it influence our decision making?
- how will we govern ourselves?
- what types of partnerships will we create?

investments

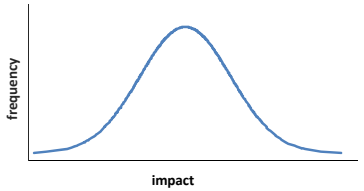
- what will be our **quality of life** in fifty years?
- how will we invest regional and local funds?
  - in social services such as education and public health?
  - in regional infrastructure and other innovations?
  - in ecosystem restoration?
- will we invest on a regional or local scale? will we integrate?
- how much money will be available?
  - who will have the money?
  - how will we try to solve problems?
  - what will be the role of citizens? public agencies? private entities?

SCENARIO PLANNING
what and why

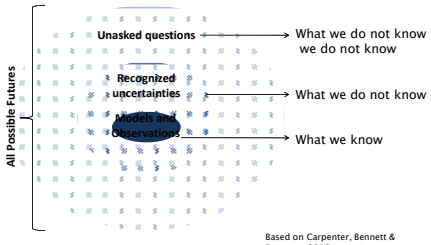
decision making

- What is the difference between scenarios, visions and predictive models?
  - **Predictive models** help us determine the probable.
    - *They are generally based on empirical data*
  - **Visions** help us determine what we want to have happen.
    - *They are generally based on community goals.*
  - **Scenarios** help us direct our strategy to the most relevant uncertainty dimensions.
    - *They characterize all plausible futures.*

future conditions

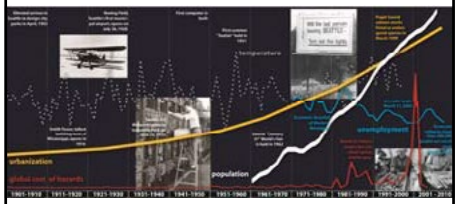


what do we know?



Based on Carpenter, Bennett & Peterson, 2006.

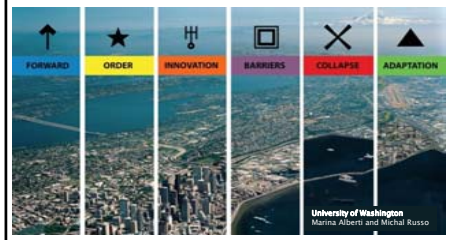
future surprises



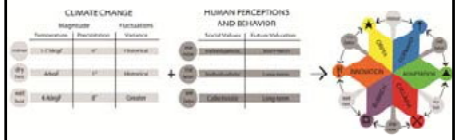
what are scenarios?

- Scenarios are **hypotheses** of alternative futures designed to ***highlight the risks and opportunities*** involved in strategic issues and assess strategic decisions.
- 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 between individual trajectories**.
- Scenarios are **illustrative** accounts of multiple futures that direct our attention towards alternative outlooks that contain the most **relevant uncertainty dimensions**.
- Scenarios help us ask: If the future turns out **differently** than originally anticipated, will our ***strategy still work***?

Puget Sound Scenarios

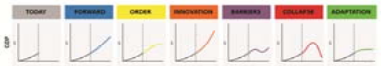


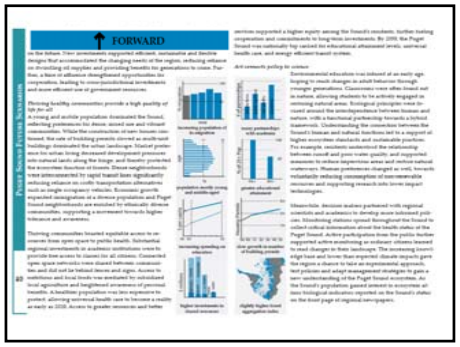
key drivers



supporting drivers

- Supporting drivers hypothesize consequent implications for the region's:
  - Demographics
  - Development Patterns
  - Economics
  - Governance
  - Knowledge and Information
  - Natural Hazards
  - Public Health
  - Technology and Infrastructure





benefits of SP

1. Provide insight into **drivers** of change
2. Reveal implications of potential future **trajectories**
3. Challenge our **assumptions** about the future
4. Take into account **uncertainty** and surprise
5. Synthesize **complex** information
6. Incorporate differences among **stakeholders**
7. Illuminate unforeseen **risks** and **opportunities**
8. Assess **tradeoffs** among alternative strategies

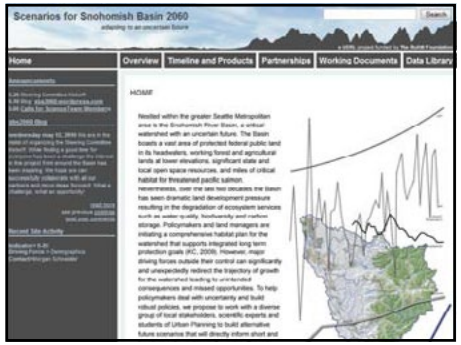
SBS2060

SNOHOMISH BASIN SCENARIOS 2060

intentions and input

focal issue

- How can we maintain Ecosystem Services (*Carbon, Water and Biodiversity*) in Snohomish Basin [WRIA 7] over the next 50 years?



Facilitating organizations working in the Basin?

HOW CAN WE HELP YOU?

- *bring together people and data*
- *integrate diverse assessments*
- *reveal questions for testing*
- *inform new strategy formation*

Facilitating organizations working in the Basin?

HOW CAN WE HELP YOU?

roundtable

discussion

- who you are?
- what is your focus and expertise in the Basin?
- how do you see the future of the basin?
- how could this project benefit your work?
- suggest one opportunity and one pitfall

Key Drivers Focus Group Meetings

Date(s)

August 2010

Location

Gould Hall. UW Seattle.

Objective

Each interview and focus group meeting included 5 overall objectives: This interview will take between 1-2 hours and has 5 overall objectives:

1. To confirm expertise to be included in the Study's Science Team Partner Bios webpage
2. To identify key elements, agents and drivers impacting the Basin's future
3. To develop a conceptual map of drivers and their relationship to ecosystem services
4. To collect data
5. To identify additional Science Team partners

Attendance

Science Team members (see Appendix 1). Focus groups included agriculture, biological scientists, economics, ecosystem restoration, governance, growth management, human perceptions and behavior, infrastrucure, physical scientists, real estate, recreation and public lands, risk management, social services, timber and forestlands, tribes, and water and energy.

Agenda

Interviews were 1 hour and focus groups were 2 hour long. They inlcuded a series of questions and a small conceptual model exercise. See Interview Instrument below).

Materials

Interview Instrument:

There are two parts to this interview. In the first part, we will do a small exercise. In the second part, we'll ask questions related to your area of expertise.

1. Can you describe your work and its relationship, if any, to the Snohomish Basin?

Part I: Future of the Basin

2. Think about the Puget Sound fifty years ago (1960), what were the fundamental differences between life today and life then?
3. Think about Puget Sound fifty years from now (2060), what do you believe will be the fundamental differences between life today and life then?
4. Think about the Snohomish River Basin fifty years from now (2060), what do you believe will be the fundamental differences between life today and life then?

What are the key elements of change (drivers) that will characterize the Basin's social-ecological system in 2060? (Moderator: write down their key elements as keywords and place in front of them)

Group the keywords into categories or subgroups. Name each group.

Draw arrows between the groups to specify networks and feedback.

Walk us through your final model. Are you satisfied with it? What, if anything do you believe is missing?

Part II: Data Collection

10. In the beginning of this interview you mentioned that your expertise and its relationship to the Basin. Choose a keyword, group or connection that you feel best reflects this area of expertise?

How do you define ___ (insert keyword, group, or connection)?

Describe its relevance to the Basin.

With reference to regional, basin or national studies, projects and data, describe its status and trend.

Which indicator(s) or metric(s) best describes its status?

11. Can you recommend 3-5 experts that we should conduct this interview with that may have a different perspective from you?

12. Is there anything else you would like to add?

Consent Form

(see pages A6-3-10)

CONSENT FORM

RESEARCHER'S STATEMENT

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. You may refuse to participate and you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF STUDY

How we think about the future has substantial consequences on how we define the problems and search for effective solutions. To help policymakers deal with uncertainty and build robust policies, we propose an innovative approach that links scenario planning and predictive modeling to identify and implement adaptive strategies to protect the long term ecosystem services of the Snohomish River Basin *(see attached map for Study boundary).* We will collaborate through partnership with managers, experts, stakeholders working in and around the Basin, and University of Washington planning students to implement the development of the scenarios. The final scenarios will represent plausible futures helping the community build a shared vision that takes into account long term uncertainties while highlighting priority actions. For more on this project, please visit our website at: www.urbaneco.washington.edu/sbs

Three **objectives** guide the development of this project:

1. Identify critical factors driving the future urban growth and associated environmental change in the Basin.
2. Systematically assess the impacts of future scenarios on essential ecosystem services focusing on biodiversity, water, and carbon.
3. Collaborate with a diversity of experts and stakeholders to identify opportunities to maintain human and ecosystem wellbeing under alternative futures.

BENEFITS OF THE STUDY

The Scenarios for the Snohomish River Basin will help shape robust policies by providing a set of plausible future conditions against which to develop strategies to achieve desired goals. Anticipating changing conditions will allow decision makers to be proactive and flexible.

1. Identify priority actions in the short term and a diverse portfolio of actions that can adapt to critical signals of change in the long term.
2. Quantified impacts to ecosystem services through predictive models providing policy makers and managers with critical data to push forward financial and political backing of specific policies.
3. Illustrative alternative futures that enable decision makers to communicate the basis of policy direction with a larger constituency and garner much needed awareness and ownership of the strategic framework within the local community.
4. Future Basin collaboration through partnerships of various committee members and experts involved in this project.

SCIENCE TEAM PARTNERSHIP

Process and Time Commitments

As a member of our Science Team we look forward to your on-going participation over this two-year project. While we have made all strides to minimize our partner's time commitment, we believe that interdisciplinary engagement and transparent feedback are essential to the credibility of our final product. Over the duration of the Study you will be invited:

- An individual or focus team interview (July, 2010)
- Half-day Conceptual Model workshop (August 2010)
- Full-day Scenario Logics workshop (November 2010)

In addition, we will request your confidential online feedback on drafts of our four project deliverables:

- Preliminary Assessment Report (Sept 2010)
- Scenario Narratives (February 2011)
- Future Ecosystem Services Assessment (July 2011)
- Final Report (December 2011)

For details of the workshops and project deliverables please visit our website at www.urbaneco.washington.edu/sbs.

Objective of Interview

This interview will take between 1-2 hours and has 5 overall objectives:

1. To confirm your expertise to be included in the Study's Science Team Partner Bios webpage
2. To identify key elements, agents and drivers impacting the Basin's future
3. To develop a conceptual map of drivers and their relationship to ecosystem services
4. To collect data and
5. To identify additional Science Team partners

Initial Interview Process

The information gathered in this interview will be used in conjunction with other expert interviews to identify a selection of driving forces and ecosystem services and develop a conceptual model of their connections. We will send you a digital transcript of this interview within 48 hours for your verification. Prior to the August Conceptual Model workshop working documents will be posted on our website summarizing material discussed within these Science Team interviews. Information gathered during the initial interview and Conceptual Model Workshop will directly inform the development of the Preliminary Assessment Report.

RESEARCHERS

Urban Ecology Research Lab (UERL)
Department of Urban Design and Planning
College of Built Environments, UW, Seattle
3949 15th Ave NE
Seattle WA 98105
(206) 616-9379
www.urbaneco.washington.edu

Marina Alberti
Director of Urban Ecology Research Lab, PI
malberti@u.washington.edu

Michal Russo
Research Scientist, UERL
mr7@u.washington.edu

Karis Puruncajas
Research Assistant, UERL
karist@u.washington.edu

Tracy Fuentes
Research Assistant, UERL
tfuentes@u.washington.edu

Printed name of study staff obtaining consent | Signature | Date

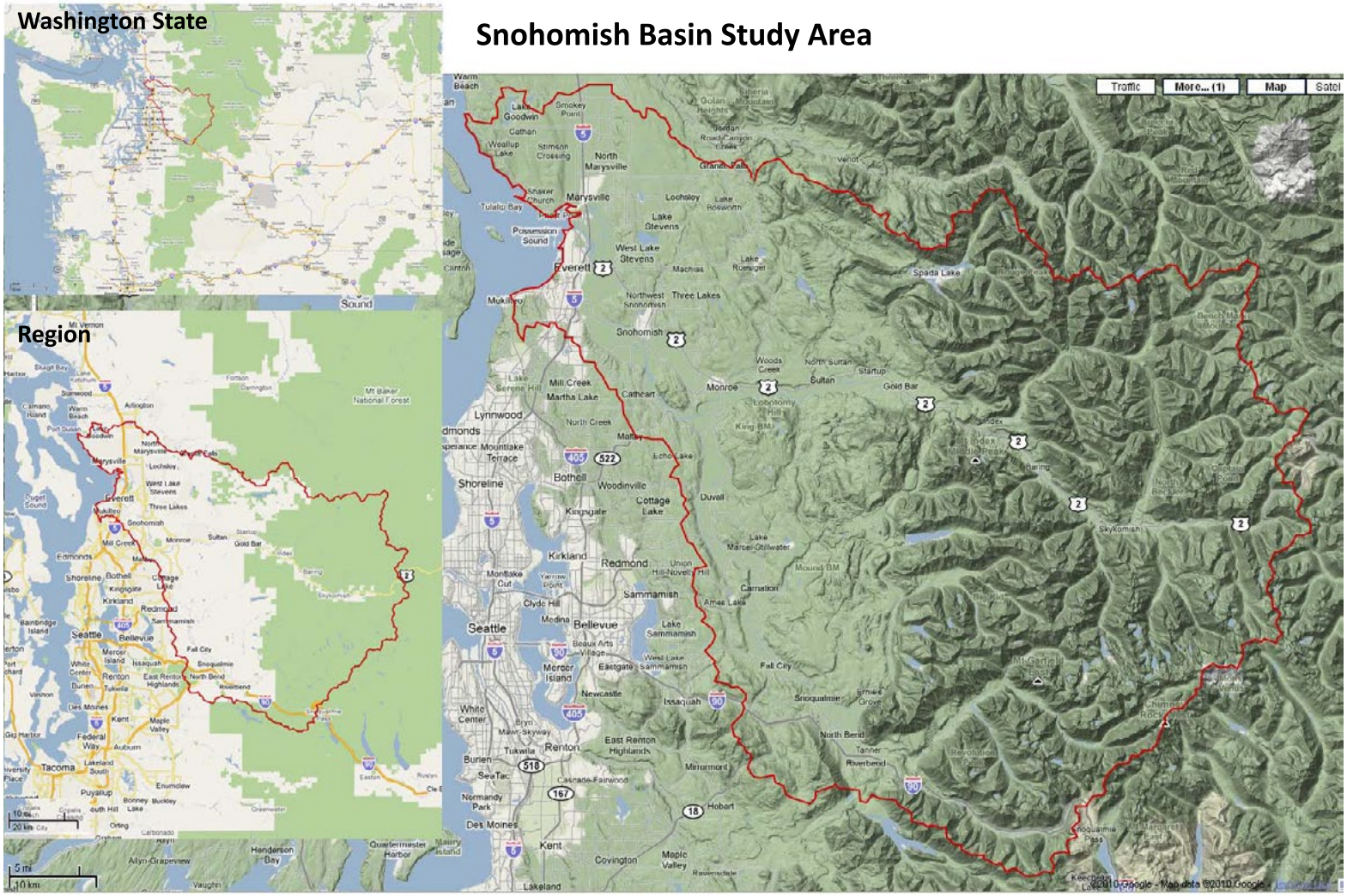
SUBJECT'S STATEMENT

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098. I give permission to include my name, title, affiliation and brief bio as a part of the study's Science Team and shared on the study's public website: www.urbaneco.washington.edu/sbs. I give permission to include my interview statement as research material within this project and its final reports. I understand that my name and affiliation will not be linked to any written comment without my prior approval.

I will receive a copy of this consent form.

Printed name of subject | Signature of subject | Date

Snohomish Basin Study Area



Synthesis

In the Summer of 2010 the UERL interviewed 78 people who identfied 3,500 keywords and drafted 49 conceptual models. The synthesis of the focus groups was directly utilized to support the conceptual model workshop (see next section) including a

> a synthesized list of keywords used by the science team to develop a shared conceptual model. (see page A6.14 for list of common keywords and group titles).

> a synthesis of problem definition and common themes (page A6.15)

> images of alternative conceptual models (pages A6.16-25)

> 3 overarching conceptual models representative of similaries and differences between focus group models. (pages A6.26)

Interviews also yielded definitions for drivers and themes (integrated in driving force working papers included under synthesis of conceptual model workshop), a list of data sets, projects and indicators (integrated into Appendix 3 Past and Future Trends of Key Driving Forces and Data Library Items available online - http://www.urbaneco.washington.edu/sbs/data-all.php), and a list of potential experts to interview and integrate into the project (included in Appendix 1: Science Team).

List of Common Focus Group Keywords (most common group titles in* bold*)

Access to information
Actors
Adaptability
Aging
Agriculture
Analysis
Annexation
Assessment
Awareness
Behavior
Benefits
Biodiversity
Capacity
Carbon neutrality
Climate Change
Communication
Community
Competition
Conflicts
Consumption
Cooperation
Costs
Culture
Dams
Density
Design
Development
Diversity
East / West Distinction
Economy
Ecosystem Health
Ecosystem Services
Education
Energy
Environmental Impacts
Engagement
Equality
Ethnicity
Fish
Flooding
Food
Forests
Forest Management
Forest Products
Funding
Geomorphology
Global Forces
Governance
Ground water
Growth
Habitat
History
Housing
Human Hazards
Human Health
Hydrology
Impacts
Income
Industry
Infrastructure
Institutions
Interdependence
Invasive species
Jurisdiction
Knowledge
Labor
Land cover
Land Use
Legacy / Time
Legal system
Management
Market (demand and supply)
Migration Patterns
Mitigation
Natural Disasters / Hazards
Natural Resources
Ocean processes
Ownership
Pace
Perceptions
Places
Planning
Plants
Politics
Pollution
Population
Preferences
Pressure
Protection / Conservation
Public / Private
Quality
Recreation
Regulation
Risks
Rural character
Scale
Settlement patterns
Snow pack
Social
Social Services
Solutions
Sprawl
Stormwater
Sustainability / Resilience
Taxes
Technology
Thresholds
Timber
Traffic
Transportation
Tribes
Uncertainty
Upland / lowland
Urban Centers
Urbanization
Waste Stream
Water Quality
Water Resources
Water Supply
Wildlife
Willingness

When asked about the past and future of the Basin, Science Team members often revolved around the same theme, but embedded in a different context, or outcome. For example, one expert may describe the GMA as effective, describing how clearly the boundary can be seen with aerial photos but proposes that the boundary doesn't do enough, while another expert may criticize the GMA as creating economic disparities. We focus on the themes as open-ended discussion points as opposed to trying to figure out which expert is right, to guide the development of the scenarios.

Our approach focused heavily on problem definition. What are the critical uncertainties affecting the future of the Basin? What should our scenarios test? What are managers grappling with for long-term strategies?

The following reflects the top ten themes and associated questions heard from our Science Team:

1. Economic competitiveness: Will the quality of life in the Basin bring in more industry or will other nations and lower-barrier regions out-compete us? Will Boeing be around? Does protecting the environment ironically support growth? Might a growing economy benefit the environment?

2. The cost of environmental regulation: Will resource industries survive additional regulations? Who wins the fish or the farmers? What are the tradeoffs and who decides? Is the burden of protection distributed evenly across the public?

3. Timing of climate change: When will the rains fall? Will major change occur soon or closer to the end of the century? Will precipitation fall as rain or snow? Will we see more flooding or drought, or both? Will severe events happen more frequently?

4. Supported demography: Will immigrants be met with equity and adequate service provision? What are the changing needs of the aging population? Will the economic divide widen further?

5. Limits to growth: Do our economic policies assume continuous growth? What is the carrying capacity of the Basin? Can we keep sprawling further? Does the GMA function in curtailing growth? Is there a threshold before natural resources provision plummets?

6. Small scale management: Is resource management sustainable at small scales? Do individual hobby farmers and harvesters have the experience, the legitimacy, the long-view to support sustainable land management? Do large scale managers share the ethical perspective as the community? Is small-scale farming economically profitable, and therefore a viable future alternative, or is it supported only by second incomes?

7. Power of innovation: Who will control the Region's innovations? Will solutions stem from public means or private investments? How will that affect the scale of operations? Will we see larger economic disparities? Will the privatization of services affect the inclusion of externalities?

8. County government: Are incorporations too costly? Are they subsidized by the GMA? Will county government still be around in 50 years? Will the county have to bail out failing municipalities?

9. Water provision: Will water be abundant in the future? Will snowpack be gone from the Basin? Will we build more reservoirs? Will we have enough water for additional users including a growing population and industries? Will we invest in water-efficient infrastructure? Will precipitation patterns change in terms of timing and magnitude of precipitation?

10. Culture shift: Will we change (in time)? Will we learn to be 'good'? Will our heritage (tribal, cultural, natural) survive? Will we listen to scientists? Will we be proactive? Will society's goals be aligned? Will we prioritize the environment? Will we sacrifice for the collective good?

Time

Predictability History

Climate

Sun
Cycles /Pulsing
Air Currents
Wind
CO2
Temperature
Global Circulation Patterns
Variation /fluctuation

Natural

Water flow
Forest growth
Nitrogen fertilization (in industrial forests or sewage application)
Timber production
Animals
Vegetation Patterns
- Potential
- Existing

Plants
Douglas Fir
Silver Fir Range
Biomass Accumulation
Herbage (for wildlife)
Meadows
Resilience

Physical – Natural

Air pollution
Geologic differences
Genetic selection
Fires
Energy (hydropower dependence)
Glaciers (snow / receding)
Management / maintenance
Water quality

Social

Education
Expectations
Schooling
Industrial
Political
Urbanization
Food
Social
Trails
Houses / Development
Wilderness
Culture
Road (access)

Drivers

- Climate change
- Warming
- Landcover
- Population
- Development
  - Location of development
  - Development practices
  - Sustainable practices

Setting

- Sensitivity
- Adapting to pattern
- Rural environment
- Large region
- Dry season
- River

Impacts

- Water availability
- Ecosystem services
- Salmon
  - Scouring
  - Spawning
- Change in timing
- Snowpack
- Rain
- Northward migration of jetstream
- Hydropower
- Water supply
- Flooding
- Ski resort gone
- North of ship canal (water allocation for Seattle)
- Swimming
- Highways
- Trends misleading
- Cultural resources
- Net energy exporter
- Foothills
- Towns
- Floodplain
- Infill
- Hillside
- Corridors
- Federally protected
- Urban/exurban
- Density
- Logging
- Regrowth
- Transient watershed
- Elevation
- Rainfall dominant

Responses

- Management practices
- Historic patterns
- Retrofit existing dams
- Impoundment
- Puget Sound Energy Snoqualmie Falls (energy)
- Dam building
- Small dams (hydropower)
- Inhibit growth
- Resolution
- Recovery
- Monitoring

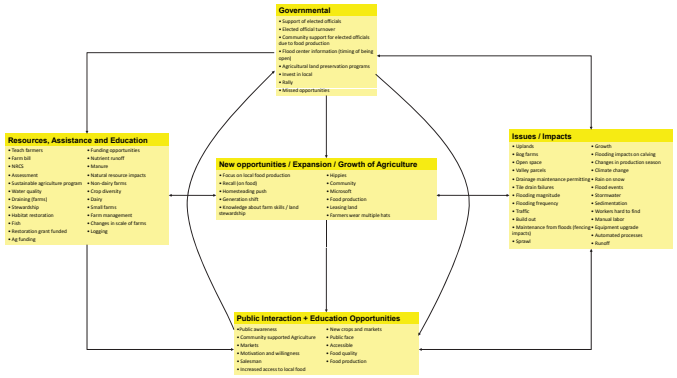
Perceptions (counter responses)

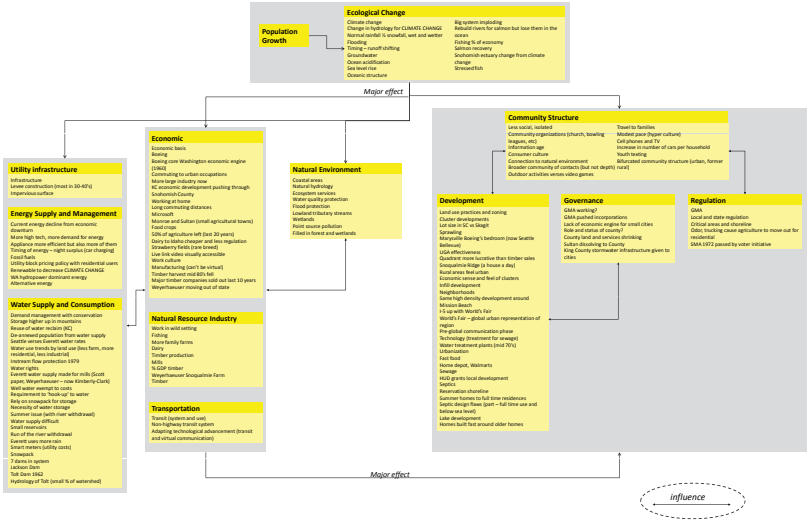
- Social acceptance
- Perception
- Expectations of water storage
- People's memory
- Instantaneous information (access)
- Inundation of information
- Precise estimate
- Annual

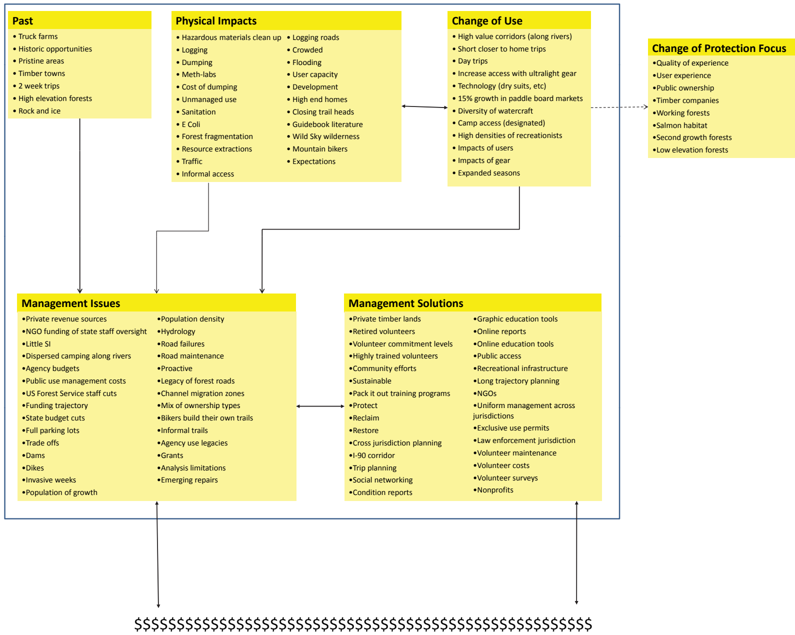
Locations

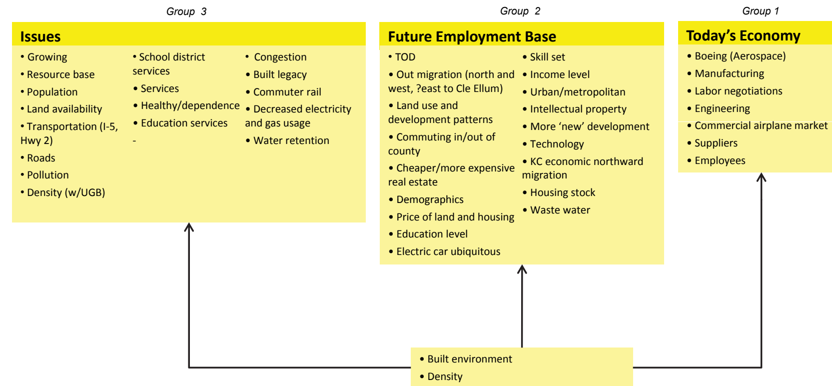
- Clouds
- Weather
- Boundary
- Snohomish
- Cascades
  - Sultan River
  - Spada Reservoir
  - Culmback Dam

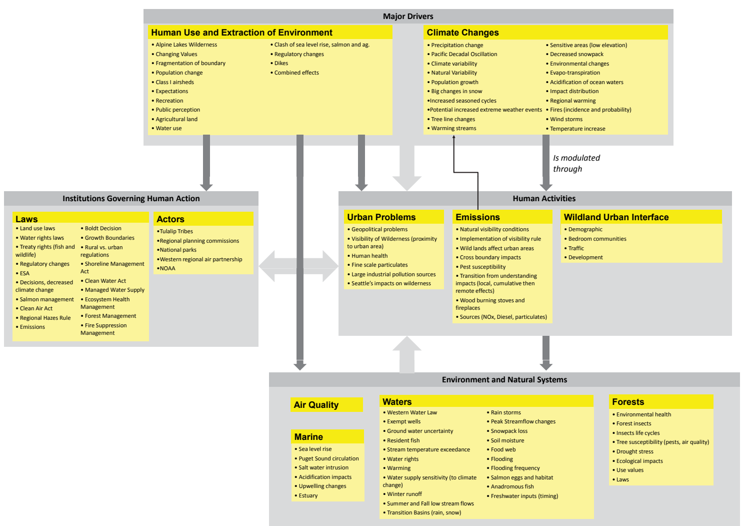
- Facilitate
- Method

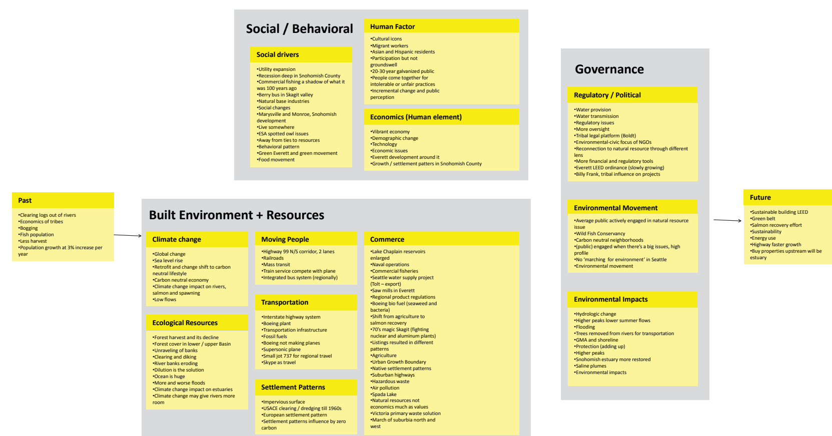


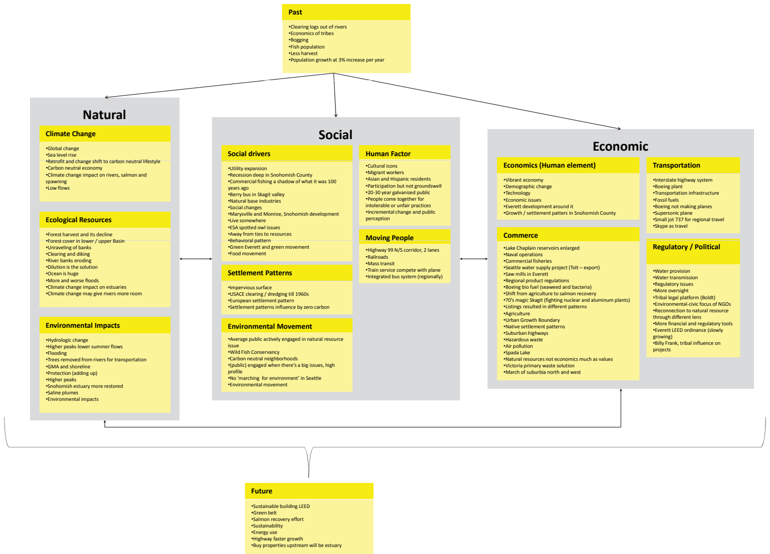



Past
• Truck farms
• Historic opportunities
• Pristine areas
• Timber towns
• 2 week trips
• High elevation forests
• Rock and ice
Physical Impacts
• Hazardous materials clean up
• Logging
• Dumping
• Meth-labs
• Cost of dumping
• Unmanaged use
• Sanitation
• E Coli
• Forest fragmentation
• Resource extractions
• Traffic
• Informal access
• Logging roads
• Crowded
• Flooding
• User capacity
• Development
• High end homes
• Closing trail heads
• Guidebook literature
• Wild Sky wilderness
• Mountain bikers
• Expectations
Change of Use
• High value corridors (along rivers)
• Short closer to home trips
• Day trips
• Increase access with ultralight gear
• Technology (dry suits, etc)
• 15% growth in paddle board markets
• Diversity of watercraft
• Camp access (designated)
• High densities of recreationists
• Impacts of users
• Impacts of gear
• Expanded seasons
Change of Protection Focus
•Quality of experience
•User experience
•Public ownership
•Timber companies
•Working forests
•Salmon habitat
•Second growth forests
•Low elevation forests
Management Issues
•Private revenue sources
•NGO funding of state staff oversight
•Little SI
•Dispersed camping along rivers
•Agency budgets
•Public use management costs
•US Forest Service staff cuts
•Funding trajectory
•State budget cuts
•Full parking lots
•Trade offs
•Dams
•Dikes
•Invasive weeks
•Population of growth
•Population density
•Hydrology
•Road failures
•Road maintenance
•Proactive
•Legacy of forest roads
•Channel migration zones
•Mix of ownership types
•Bikers build their own trails
•Informal trails
•Agency use legacies
•Grants
•Analysis limitations
•Emerging repairs
Management Solutions
•Private timber lands
•Retired volunteers
•Volunteer commitment levels
•Highly trained volunteers
•Community efforts
•Sustainable
•Pack it out training programs
•Protect
•Reclaim
•Restore
•Cross jurisdiction planning
•I-90 corridor
•Trip planning
•Social networking
•Condition reports
•Graphic education tools
•Online reports
•Online education tools
•Public access
•Recreational infrastructure
•Long trajectory planning
•NGOs
•Uniform management across jurisdictions
•Exclusive use permits
•Law enforcement jurisdiction
•Volunteer maintenance
•Volunteer costs
•Volunteer surveys
•Nonprofits
$$


Group 3
Issues
• Growing
• Resource base
• Population
• Land availability
• Transportation (I-5, Hwy 2)
• Roads
• Pollution
• Density (w/UGB)
• School district services
• Services
• Healthy/dependence
• Education services
• Congestion
• Built legacy
• Commuter rail
• Decreased electricity and gas usage
• Water retention
Group 2
Future Employment Base
• TOD
• Out migration (north and west, ?east to Cle Ellum)
• Land use and development patterns
• Commuting in/out of county
• Cheaper/more expensive real estate
• Demographics
• Price of land and housing
• Education level
• Electric car ubiquitous
• Skill set
• Income level
• Urban/metropolitan
• Intellectual property
• More 'new' development
• Technology
• KC economic northward migration
• Housing stock
• Waste water
Group 1
Today's Economy
• Boeing (Aerospace)
• Manufacturing
• Labor negotiations
• Engineering
• Commercial airplane market
• Suppliers
• Employees
• Built environment
• Density


Major Drivers
Human Use and Extraction of Environment
• Alpine Lakes Wilderness
• Changing Values
• Fragmentation of boundary
• Population change
• Class I airsheds
• Expectations
• Recreation
• Public perception
• Agricultural land
• Water use
• Clash of sea level rise, salmon and ag.
• Regulatory changes
• Dikes
• Combined effects
Climate Changes
• Precipitation change
• Pacific Decadal Oscillation
• Climate variability
• Natural Variability
• Population growth
• Big changes in snow
•Increased seasoned cycles
•Potential increased extreme weather events
• Tree line changes
• Warming streams
• Sensitive areas (low elevation)
• Decreased snowpack
• Environmental changes
• Evapo-transpiration
• Acidification of ocean waters
• Impact distribution
• Regional warming
• Fires (incidence and probability)
• Wind storms
• Temperature increase
Is modulated through
Institutions Governing Human Action
Laws
• Land use laws
• Water rights laws
• Treaty rights (fish and wildlife)
• Regulatory changes
• ESA
• Decisions, decreased climate change
• Salmon management
• Clean Air Act
• Regional Hazes Rule
• Emissions
• Boldt Decision
• Growth Boundaries
• Rural vs. urban regulations
• Shoreline Management Act
• Clean Water Act
• Managed Water Supply
• Ecosystem Health Management
• Forest Management
• Fire Suppression Management
Actors
•Tulalip Tribes
•Regional planning commissions
•National parks
•Western regional air partnership
•NOAA
Human Activities
Urban Problems
• Geopolitical problems
• Visibility of Wilderness (proximity to urban area)
• Human health
• Fine scale particulates
• Large industrial pollution sources
• Seattle's impacts on wilderness
Emissions
• Natural visibility conditions
• Implementation of visibility rule
• Wild lands affect urban areas
• Cross boundary impacts
• Pest susceptibility
• Transition from understanding impacts (local, cumulative then remote effects)
• Wood burning stoves and fireplaces
• Sources (NOx, Diesel, particulates)
Wildland Urban Interface
• Demographic
• Bedroom communities
• Traffic
• Development
Environment and Natural Systems
Air Quality
Marine
• Sea level rise
• Puget Sound circulation
• Salt water intrusion
• Acidification impacts
• Upwelling changes
• Estuary
Waters
• Western Water Law
• Exempt wells
• Ground water uncertainty
• Resident fish
• Stream temperature exceedance
• Water rights
• Warming
• Water supply sensitivity (to climate change)
• Winter runoff
• Summer and Fall low stream flows
• Transition Basins (rain, snow)
• Rain storms
• Peak Streamflow changes
• Snowpack loss
• Soil moisture
• Food web
• Flooding
• Flooding frequency
• Salmon eggs and habitat
• Anadromous fish
• Freshwater inputs (timing)
Forests
• Environmental health
• Forest insects
• Insects life cycles
• Tree susceptibility (pests, air quality)
• Drought stress
• Ecological impacts
• Use values
• Laws


Social / Behavioral
Social drivers
•Utility expansion
•Recession deep in Snohomish County
•Commercial fishing a shadow of what it was 100 years ago
•Berry bus in Skagit valley
•Natural base industries
•Social changes
•Marysville and Monroe, Snohomish development
•Live somewhere
•ESA spotted owl issues
•Away from ties to resources
•Behavioral pattern
•Green Everett and green movement
•Food movement
Human Factor
•Cultural icons
•Migrant workers
•Asian and Hispanic residents
•Participation but not groundswell
•20-30 year galvanized public
•People come together for intolerable or unfair practices
•Incremental change and public perception
Economics (Human element)
•Vibrant economy
•Demographic change
•Technology
•Economic issues
•Everett development around it
•Growth / settlement patters in Snohomish County
Governance
Regulatory / Political
•Water provision
•Water transmission
•Regulatory issues
•More oversight
•Tribal legal platform (Boldt)
•Environmental-civic focus of NGOs
•Reconnection to natural resource through different lens
•More financial and regulatory tools
•Everett LEED ordinance (slowly growing)
•Billy Frank, tribal influence on projects
Environmental Movement
•Average public actively engaged in natural resource issue
•Wild Fish Conservancy
•Carbon neutral neighborhoods
•(public) engaged when there's a big issues, high profile
•No 'marching for environment' in Seattle
•Environmental movement
Environmental Impacts
•Hydrologic change
•Higher peaks lower summer flows
•Flooding
•Trees removed from rivers for transportation
•GMA and shoreline
•Protection (adding up)
•Higher peaks
•Snohomish estuary more restored
•Saline plumes
•Environmental impacts
Past
•Clearing logs out of rivers
•Economics of tribes
•Bogging
•Fish population
•Less harvest
•Population growth at 3% increase per year
Built Environment + Resources
Climate change
•Global change
•Sea level rise
•Retrofit and change shift to carbon neutral lifestyle
•Carbon neutral economy
•Climate change impact on rivers, salmon and spawning
•Low flows
Ecological Resources
•Forest harvest and its decline
•Forest cover in lower / upper Basin
•Unraveling of banks
•Clearing and diking
•River banks eroding
•Dilution is the solution
•Ocean is huge
•More and worse floods
•Climate change impact on estuaries
•Climate change may give rivers more room
Moving People
•Highway 99 N/S corridor, 2 lanes
•Railroads
•Mass transit
•Train service compete with plane
•Integrated bus system (regionally)
Transportation
•Interstate highway system
•Boeing plant
•Transportation infrastructure
•Fossil fuels
•Boeing not making planes
•Supersonic plane
•Small jot 737 for regional travel
•Skype as travel
Settlement Patterns
•Impervious surface
•USACE clearing / dredging till 1960s
•European settlement pattern
•Settlement patterns influence by zero carbon
Commerce
•Lake Chaplain reservoirs enlarged
•Naval operations
•Commercial fisheries
•Seattle water supply project (Tolt – export)
•Saw mills in Everett
•Regional product regulations
•Boeing bio fuel (seaweed and bacteria)
•Shift from agriculture to salmon recovery
•70's magic Skagit (fighting nuclear and aluminum plants)
•Listings resulted in different patterns
•Agriculture
•Urban Growth Boundary
•Native settlement patterns
•Suburban highways
•Hazardous waste
•Air pollution
•Spada Lake
•Natural resources not economics much as values
•Victoria primary waste solution
•March of suburbia north and west
Future
•Sustainable building LEED
•Green belt
•Salmon recovery effort
•Sustainability
•Energy use
•Highway faster growth
•Buy properties upstream will be estuary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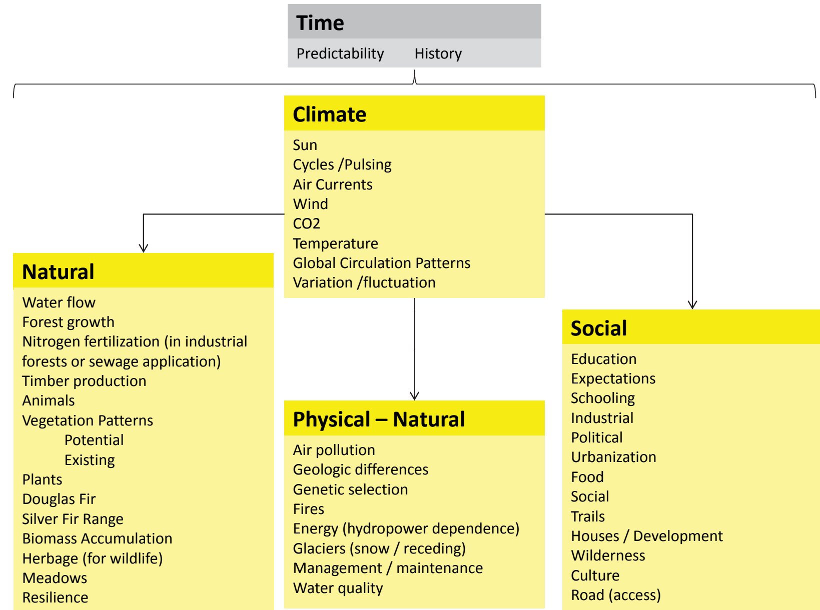
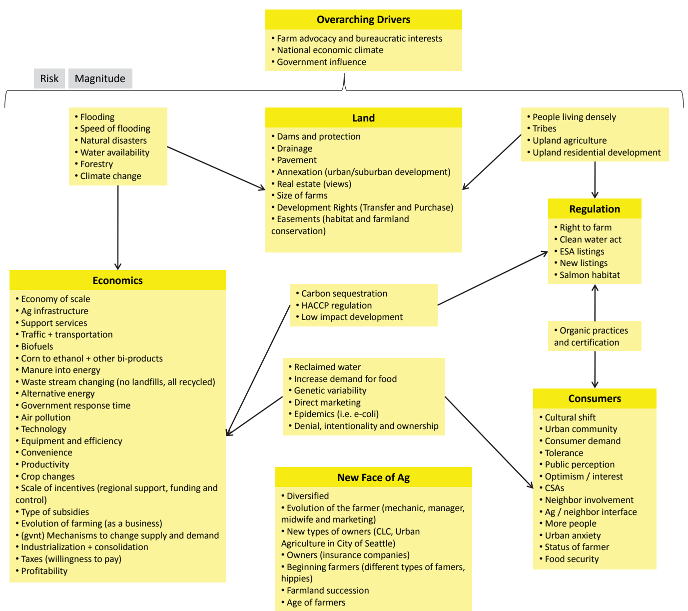
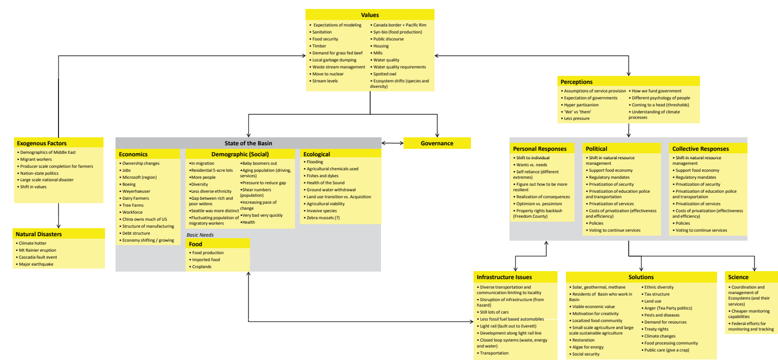
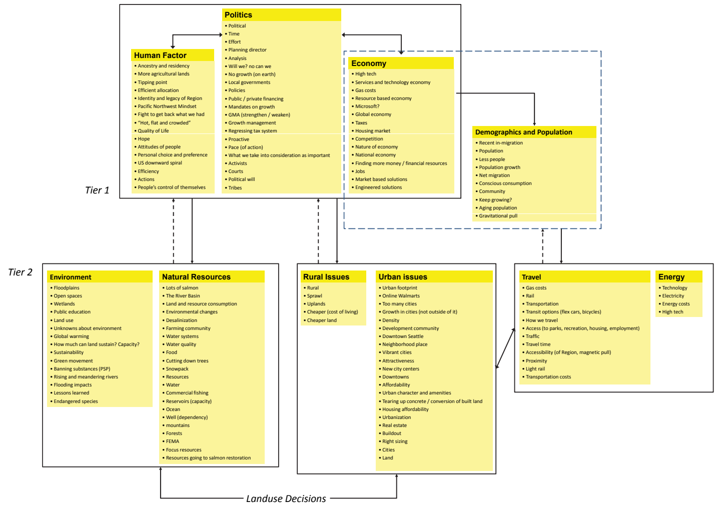
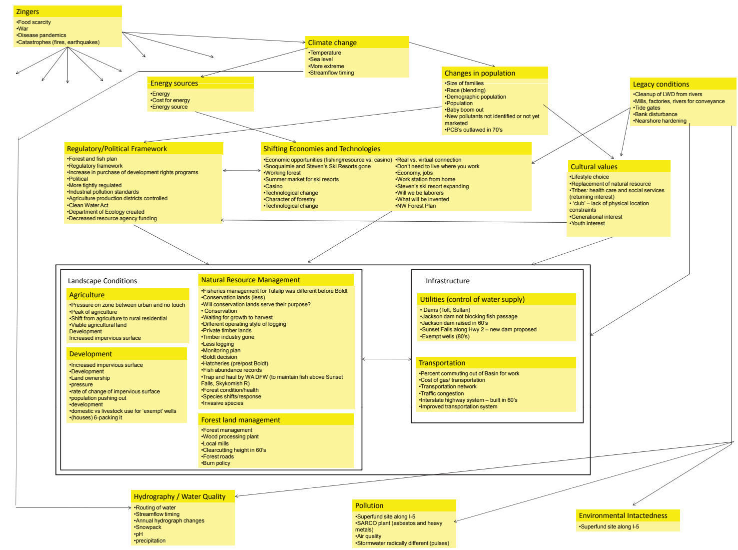
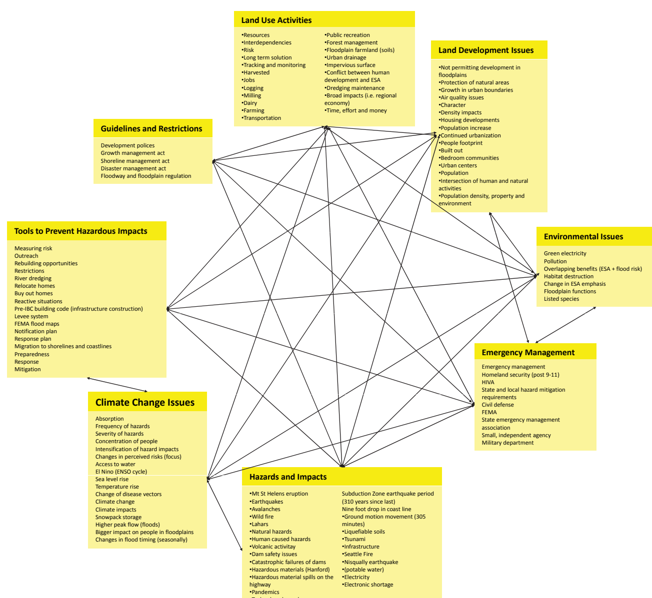

Time
Predictability History
Climate
Sun
Cycles /Pulsing
Air Currents
Wind
CO2
Temperature
Global Circulation Patterns
Variation /fluctuation
Natural
Water flow
Forest growth
Nitrogen fertilization (in industrial forests or sewage application)
Timber production
Animals
Vegetation Patterns
Potential
Existing
Plants
Douglas Fir
Silver Fir Range
Biomass Accumulation
Herbage (for wildlife)
Meadows
Resilience
Physical – Natural
Air pollution
Geologic differences
Genetic selection
Fires
Energy (hydropower dependence)
Glaciers (snow / receding)
Management / maintenance
Water quality
Social
Education
Expectations
Schooling
Industrial
Political
Urbanization
Food
Social
Trails
Houses / Development
Wilderness
Culture
Road (access)

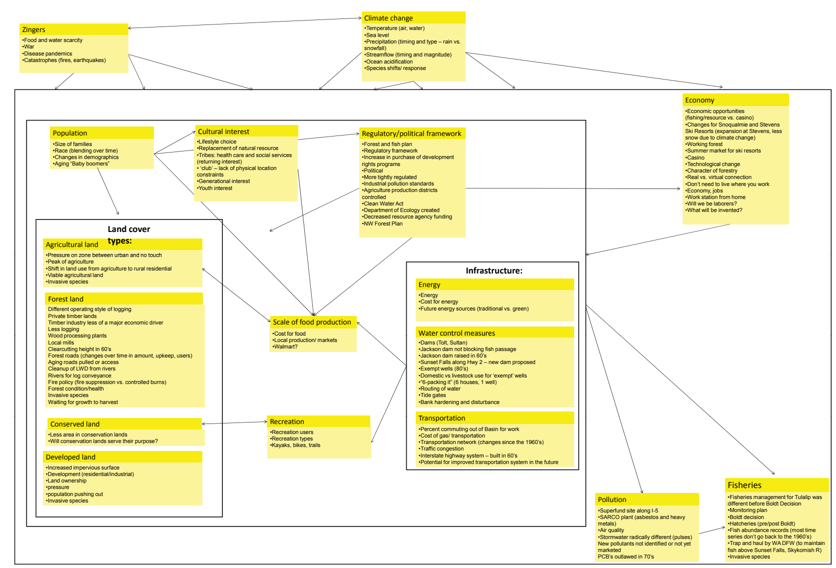

Overarching Drivers
• Farm advocacy and bureaucratic interests
• National economic climate
• Government influence
Risk
Magnitude
• Flooding
• Speed of flooding
• Natural disasters
• Water availability
• Forestry
• Climate change
Land
• Dams and protection
• Drainage
• Pavement
• Annexation (urban/suburban development)
• Real estate (views)
• Size of farms
• Development Rights (Transfer and Purchase)
• Easements (habitat and farmland conservation)
• People living densely
• Tribes
• Upland agriculture
• Upland residential development
Regulation
• Right to farm
• Clean water act
• ESA listings
• New listings
• Salmon habitat
• Organic practices and certification
Consumers
• Cultural shift
• Urban community
• Consumer demand
• Tolerance
• Public perception
• Optimism / interest
• CSAs
• Neighbor involvement
• Ag / neighbor interface
• More people
• Urban anxiety
• Status of farmer
• Food security
Economics
• Economy of scale
• Ag infrastructure
• Support services
• Traffic + transportation
• Biofuels
• Corn to ethanol + other bi-products
• Manure into energy
• Waste stream changing (no landfills, all recycled)
• Alternative energy
• Government response time
• Air pollution
• Technology
• Equipment and efficiency
• Convenience
• Productivity
• Crop changes
• Scale of incentives (regional support, funding and control)
• Type of subsidies
• Evolution of farming (as a business)
• (gvnt) Mechanisms to change supply and demand
• Industrialization + consolidation
• Taxes (willingness to pay)
• Profitability
• Carbon sequestration
• HACCP regulation
• Low impact development
• Reclaimed water
• Increase demand for food
• Genetic variability
• Direct marketing
• Epidemics (i.e. e-coli)
• Denial, intentionality and ownership
New Face of Ag
• Diversified
• Evolution of the farmer (mechanic, manager, midwife and marketing)
• New types of owners (CLC, Urban Agriculture in City of Seattle)
• Owners (insurance companies)
• Beginning farmers (different types of famers, hippies)
• Farmland succession
• Age of farmers

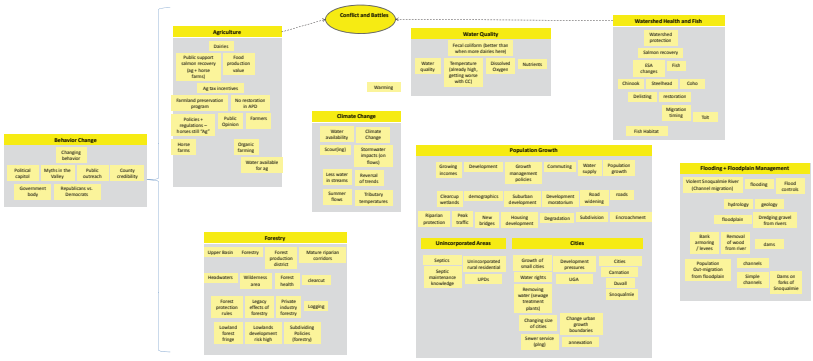

Values
• Expectations of modeling
• Sanitation
• Food security
• Timber
• Demand for grass fed beef
• Local garbage dumping
• Waste stream management
• Move to nuclear
• Stream levels
• Canada border + Pacific Rim
• Syn-bio (food production)
• Public discourse
• Housing
• Mills
• Water quality
• Water quality requirements
• Spotted owl
• Ecosystem shifts (species and diversity)
Exogenous Factors
• Demographics of Middle East
• Migrant workers
• Producer scale completion for farmers
• Nation-state politics
• Large scale national disaster
• Shift in values
Natural Disasters
• Climate hotter
• Mt Rainier eruption
• Cascadia fault event
• Major earthquake
State of the Basin
Economics
• Ownership changes
• Jobs
• Microsoft (region)
• Boeing
• Weyerhaeuser
• Dairy Farmers
• Tree Farms
• Workforce
• China owns much of US
• Structure of manufacturing
• Debt structure
• Economy shifting / growing
Demographic (Social)
•In migration
•Residential 5-acre lots
•More people
•Diversity
•Less diverse ethnicity
•Gap between rich and poor widens
•Seattle was more distinct
•Fluctuating population of migratory workers
•Baby boomers out
•Aging population (driving, services)
•Pressure to reduce gap
•Shear numbers (population)
•Increasing pace of change
•Very bad very quickly
•Health
Basic Needs
Food
• Food production
• Imported food
• Croplands
Ecological
• Flooding
• Agricultural chemicals used
• Fishes and dykes
• Health of the Sound
• Ground water withdrawal
• Land use transition vs. Acquisition
• Agricultural viability
• Invasive species
• Zebra mussels (?)
Governance
Perceptions
• Assumptions of service provision
• Expectation of governments
• Hyper partisanism
• 'We' vs 'them'
• Less pressure
• How we fund government
• Different psychology of people
• Coming to a head (thresholds)
• Understanding of climate processes
Personal Responses
• Shift to individual
• Wants vs. needs
• Self reliance (different extremes)
• Figure out how to be more resilient
• Realization of consequences
• Optimism vs. pessimism
• Property rights backlash (Freedom County)
Political
• Shift in natural resource management
• Support food economy
• Regulatory mandates
• Privatization of security
• Privatization of education police and transportation
• Privatization of services
• Costs of privatization (effectiveness and efficiency)
• Policies
• Voting to continue services
Collective Responses
• Shift in natural resource management
• Support food economy
• Regulatory mandates
• Privatization of security
• Privatization of education police and transportation
• Privatization of services
• Costs of privatization (effectiveness and efficiency)
• Policies
• Voting to continue services
Infrastructure Issues
• Diverse transportation and communication limiting to locality
• Disruption of infrastructure (from hazard)
• Still lots of cars
• Less fossil fuel based automobiles
• Light rail (built out to Everett)
• Development along light rail line
• Closed loop systems (waste, energy and water)
• Transportation
Solutions
• Solar, geothermal, methane
• Residents of Basin who work in Basin
• Viable economic value
• Motivation for creativity
• Localized food community
• Small scale agriculture and large scale sustainable agriculture
• Restoration
• Algae for energy
• Social security
• Ethnic diversity
• Tax structure
• Land use
• Anger (Tea Party politics)
• Pests and diseases
• Demand for resources
• Treaty rights
• Climate changes
• Food processing community
• Public care (give a crap)
Science
• Coordination and management of Ecosystems (and their services)
• Cheaper monitoring capabilities
• Federal efforts for monitoring and tracking

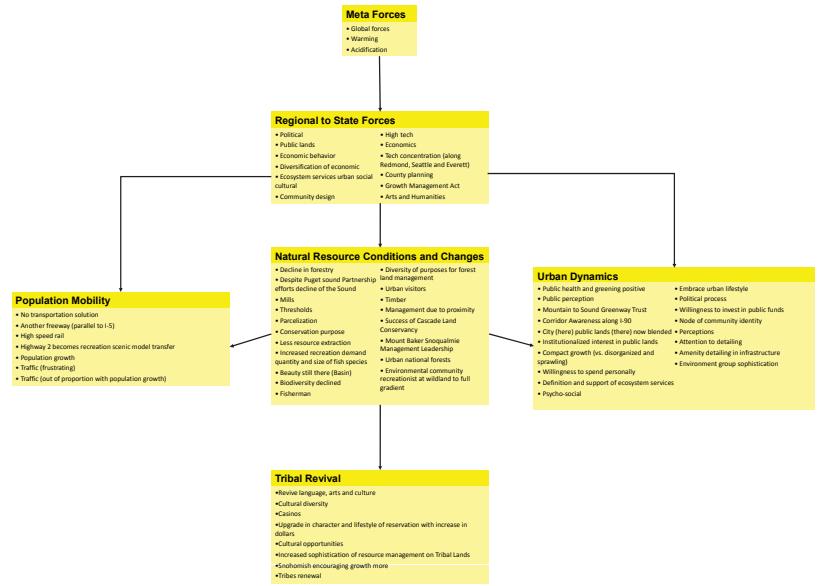

Politics
• Political
• Time
• Effort
• Planning director
• Analysis
• Will we? no can we
• No growth (on earth)
• Local governments
• Policies
• Public / private financing
• Mandates on growth
• GMA (strengthen / weaken)
• Growth management
• Regressing tax system
• Proactive
• Pace (of action)
• What we take into consideration as important
• Activists
• Courts
• Political will
• Tribes
Human Factor
• Ancestry and residency
• More agricultural lands
• Tipping point
• Efficient allocation
• Identity and legacy of Region
• Pacific Northwest Mindset
• Fight to get back what we had
• "Hot, flat and crowded"
• Quality of Life
• Hope
• Attitudes of people
• Personal choice and preference
• US downward spiral
• Efficiency
• Actions
• People's control of themselves
Economy
• High tech
• Services and technology economy
• Gas costs
• Resource based economy
• Microsoft?
• Global economy
• Taxes
• Housing market
• Competition
• Nature of economy
• National economy
• Finding more money / financial resources
• Jobs
• Market based solutions
• Engineered solutions
Demographics and Population
• Recent in-migration
• Population
• Less people
• Population growth
• Net migration
• Conscious consumption
• Community
• Keep growing?
• Aging population
• Gravitational pull
Tier 1
Tier 2
Environment
• Floodplains
• Open spaces
• Wetlands
• Public education
• Land use
• Unknowns about environment
• Global warming
• How much can land sustain? Capacity?
• Sustainability
• Green movement
• Banning substances (PSP)
• Rising and meandering rivers
• Flooding impacts
• Lessons learned
• Endangered species
Natural Resources
• Lots of salmon
• The River Basin
• Land and resource consumption
• Environmental changes
• Desalinization
• Farming community
• Water systems
• Water quality
• Food
• Cutting down trees
• Snowpack
• Resources
• Water
• Commercial fishing
• Reservoirs (capacity)
• Ocean
• Well (dependency)
• mountains
• Forests
• FEMA
• Focus resources
• Resources going to salmon restoration
Rural Issues
• Rural
• Sprawl
• Uplands
• Cheaper (cost of living)
• Cheaper land
Urban issues
• Urban footprint
• Online Walmarts
• Too many cities
• Growth in cities (not outside of it)
• Density
• Development community
• Downtown Seattle
• Neighborhood place
• Vibrant cities
• Attractiveness
• New city centers
• Downtowns
• Affordability
• Urban character and amenities
• Tearing up concrete / conversion of built land
• Housing affordability
• Urbanization
• Real estate
• Buildout
• Right sizing
• Cities
• Land
Travel
• Gas costs
• Rail
• Transportation
• Transit options (flex cars, bicycles)
• How we travel
• Access (to parks, recreation, housing, employment)
• Traffic
• Travel time
• Accessibility (of Region, magnetic pull)
• Proximity
• Light rail
• Transportation costs
Energy
• Technology
• Electricity
• Energy costs
• High tech
Landuse Decisions


Zingers
•Food scarcity
•War
•Disease pandemics
•Catastrophes (fires, earthquakes)
Climate change
•Temperature
•Sea level
•More extreme
•Streamflow timing
Energy sources
•Energy
•Cost for energy
•Energy source
Changes in population
•Size of families
•Race (blending)
•Demographic population
•Population
•Baby boom out
•New pollutants not identified or not yet marketed
•PCB's outlawed in 70's
Legacy conditions
•Cleanup of LWD from rivers
•Mills, factories, rivers for conveyance
•Tide gates
•Bank disturbance
•Nearshore hardening
Regulatory/Political Framework
•Forest and fish plan
•Regulatory framework
•Increase in purchase of development rights programs
•Political
•More tightly regulated
•Industrial pollution standards
•Agriculture production districts controlled
•Clean Water Act
•Department of Ecology created
•Decreased resource agency funding
Shifting Economies and Technologies
•Economic opportunities (fishing/resource vs. casino)
•Snoqualmie and Steven's Ski Resorts gone
•Working forest
•Summer market for ski resorts
•Casino
•Technological change
•Character of forestry
•Technological change
•Real vs. virtual connection
•Don't need to live where you work
•Economy, jobs
•Work station from home
•Steven's ski resort expanding
•Will we be laborers
•What will be invented
•NW Forest Plan
Cultural values
•Lifestyle choice
•Replacement of natural resource
•Tribes: health care and social services (returning interest)
• 'club' – lack of physical location constraints
•Generational interest
•Youth interest
Landscape Conditions
Agriculture
•Pressure on zone between urban and no touch
•Peak of agriculture
•Shift from agriculture to rural residential
•Viable agricultural land
Development
Increased impervious surface
Development
•Increased impervious surface
•Development
•Land ownership
•pressure
•rate of change of impervious surface
•population pushing out
•development
•domestic vs livestock use for 'exempt' wells
•(houses) 6-packing it
Natural Resource Management
•Fisheries management for Tulalip was different before Boldt
•Conservation lands (less)
•Will conservation lands serve their purpose?
• Conservation
•Waiting for growth to harvest
•Different operating style of logging
•Private timber lands
•Timber industry gone
•Less logging
•Monitoring plan
•Boldt decision
•Hatcheries (pre/post Boldt)
•Fish abundance records
•Trap and haul by WA DFW (to maintain fish above Sunset Falls, Skykomish R)
•Forest condition/health
•Species shifts/response
•Invasive species
Forest land management
•Forest management
•Wood processing plant
•Local mills
•Clearcutting height in 60's
•Forest roads
•Burn policy
Infrastructure
Utilities (control of water supply)
• Dams (Tolt, Sultan)
•Jackson dam not blocking fish passage
•Jackson dam raised in 60's
•Sunset Falls along Hwy 2 – new dam proposed
•Exempt wells (80's)
Transportation
•Percent commuting out of Basin for work
•Cost of gas/ transportation
•Transportation network
•Traffic congestion
•Interstate highway system – built in 60's
•Improved transportation system
Hydrography / Water Quality
•Routing of water
•Streamflow timing
•Annual hydrograph changes
•Snowpack
•pH
•precipitation
Pollution
•Superfund site along I-5
•SARCO plant (asbestos and heavy metals)
•Air quality
•Stormwater radically different (pulses)
Environmental Intactedness
•Superfund site along I-5


Land Use Activities
•Resources
•Interdependencies
•Risk
•Long term solution
•Tracking and monitoring
•Harvested
•Jobs
•Logging
•Milling
•Dairy
•Farming
•Transportation
•Public recreation
•Forest management
•Floodplain farmland (soils)
•Urban drainage
•Impervious surface
•Conflict between human development and ESA
•Dredging maintenance
•Broad impacts (i.e. regional economy)
•Time, effort and money
Land Development Issues
•Not permitting development in floodplains
•Protection of natural areas
•Growth in urban boundaries
•Air quality issues
•Character
•Density impacts
•Housing developments
•Population increase
•Continued urbanization
•People footprint
•Built out
•Bedroom communities
•Urban centers
•Population
•Intersection of human and natural activities
•Population density, property and environment
Guidelines and Restrictions
Development polices
Growth management act
Shoreline management act
Disaster management act
Floodway and floodplain regulation
Tools to Prevent Hazardous Impacts
Measuring risk
Outreach
Rebuilding opportunities
Restrictions
River dredging
Relocate homes
Buy out homes
Reactive situations
Pre-IBC building code (infrastructure construction)
Levee system
FEMA flood maps
Notification plan
Response plan
Migration to shorelines and coastlines
Preparedness
Response
Mitigation
Environmental Issues
Green electricity
Pollution
Overlapping benefits (ESA + flood risk)
Habitat destruction
Change in ESA emphasis
Floodplain functions
Listed species
Emergency Management
Emergency management
Homeland security (post 9-11)
HIVA
State and local hazard mitigation requirements
Civil defense
FEMA
State emergency management association
Small, independent agency
Military department
Climate Change Issues
Absorption
Frequency of hazards
Severity of hazards
Concentration of people
Intensification of hazard impacts
Changes in perceived risks (focus)
Access to water
El Nino (ENSO cycle)
Sea level rise
Temperature rise
Change of disease vectors
Climate change
Climate impacts
Snowpack storage
Higher peak flow (floods)
Bigger impact on people in floodplains
Changes in flood timing (seasonally)
Hazards and Impacts
•Mt St Helens eruption
•Earthquakes
•Avalanches
•Wild fire
•Lahars
•Natural hazards
•Human caused hazards
•Volcanic activitay
•Dam safety issues
•Catastrophic failures of dams
•Hazardous materials (Hanford)
•Hazardous material spills on the highway
•Pandemics
•Technology hazards
Subduction Zone earthquake period (310 years since last)
Nine foot drop in coast line
•Ground motion movement (305 minutes)
•Liquefiable soils
•Tsunami
•Infrastructure
•Seattle Fire
•Nisqually earthquake
•(potable water)
•Electricity
•Electronic shortage


Zingers
•Food and water scarcity
•War
•Disease pandemics
•Catastrophes (fires, earthquakes)
Climate change
•Temperature (air, water)
•Sea level
•Precipitation (timing and type – rain vs. snowfall)
•Streamflow (timing and magnitude)
•Ocean acidification
•Species shifts/ response
Population
•Size of families
•Race (blending over time)
•Changes in demographics
•Aging "Baby boomers"
Cultural interest
•Lifestyle choice
•Replacement of natural resource
•Tribes: health care and social services (returning interest)
• 'club' – lack of physical location constraints
•Generational interest
•Youth interest
Regulatory/political framework
•Forest and fish plan
•Regulatory framework
•Increase in purchase of development rights programs
•Political
•More tightly regulated
•Industrial pollution standards
•Agriculture production districts controlled
•Clean Water Act
•Department of Ecology created
•Decreased resource agency funding
•NW Forest Plan
Economy
•Economic opportunities (fishing/resource vs. casino)
•Changes for Snoqualmie and Stevens Ski Resorts (expansion at Stevens, less snow due to climate change)
•Working forest
•Summer market for ski resorts
•Casino
•Technological change
•Character of forestry
•Real vs. virtual connection
•Don't need to live where you work
•Economy, jobs
•Work station from home
•Will we be laborers?
•What will be invented?
Land cover types:
Agricultural land
•Pressure on zone between urban and no touch
•Peak of agriculture
•Shift in land use from agriculture to rural residential
•Viable agricultural land
•Invasive species
Forest land
Different operating style of logging
Private timber lands
Timber industry less of a major economic driver
Less logging
Wood processing plants
Local mills
Clearcutting height in 60's
Forest roads (changes over time in amount, upkeep, users)
Aging roads pulled or access
Cleanup of LWD from rivers
Rivers for log conveyance
Fire policy (fire suppression vs. controlled burns)
Forest condition/health
Invasive species
Waiting for growth to harvest
Conserved land
•Less area in conservation lands
•Will conservation lands serve their purpose?
Developed land
•Increased impervious surface
•Development (residential/industrial)
•Land ownership
•pressure
•population pushing out
•Invasive species
Scale of food production
•Cost for food
•Local production/ markets
•Walmart?
Recreation
•Recreation users
•Recreation types
•Kayaks, bikes, trails
Infrastructure:
Energy
•Energy
•Cost for energy
•Future energy sources (traditional vs. green)
Water control measures
•Dams (Tolt, Sultan)
•Jackson dam not blocking fish passage
•Jackson dam raised in 60's
•Sunset Falls along Hwy 2 – new dam proposed
•Exempt wells (80's)
•Domestic vs livestock use for 'exempt' wells
•"6-packing it" (6 houses, 1 well)
•Routing of water
•Tide gates
•Bank hardening and disturbance
Transportation
•Percent commuting out of Basin for work
•Cost of gas/ transportation
•Transportation network (changes since the 1960's)
•Traffic congestion
•Interstate highway system – built in 60's
•Potential for improved transportation system in the future
Pollution
•Superfund site along I-5
•SARCO plant (asbestos and heavy metals)
•Air quality
•Stormwater radically different (pulses)
New pollutants not identified or not yet marketed
PCB's outlawed in 70's
Fisheries
•Fisheries management for Tulalip was different before Boldt Decision
•Monitoring plan
•Boldt decision
•Hatcheries (pre/post Boldt)
•Fish abundance records (most time series don't go back to the 1960's)
•Trap and haul by WA DFW (to maintain fish above Sunset Falls, Skykomish R)
•Invasive species





Characterization / data collection / analysis

Watershed framework	Maps	Fill
Technology	Coordination	Protection
Global warming	'remarkable restoration" / successful	Wash deposits
Skill set of biologist	Carbon sequestration	Harmful algae blooms
Delineation	Long tail of data	Sediment movement
(limited) land area	Impairment	Nearshore
Data	Storm intensity	Web(site)
Estuary	Accuracy	Research (scientist)
University role	Precision	Restoration
Scientific community Ecological approach	Sustainability	Microsoft
Digital data	Critical areas	Basin (distance to urban core)
Sensors	Rural(ness)	
Number of species	Coastal streams	

Major Drivers or Stressors

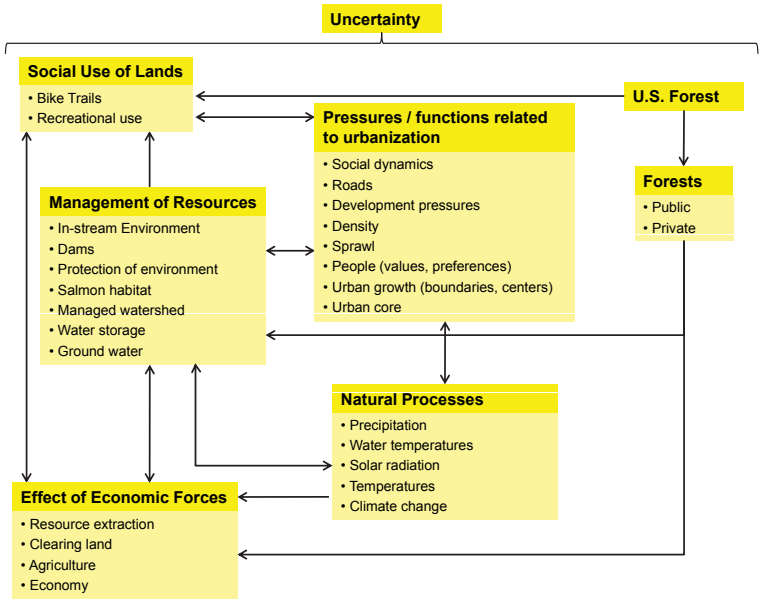
Population
Where development is going to go
Available land
Land value
Rapidly urbanizing
Conflict
Paradigm shift
Suburbanization / megalopolis
National parks land
People's behavior

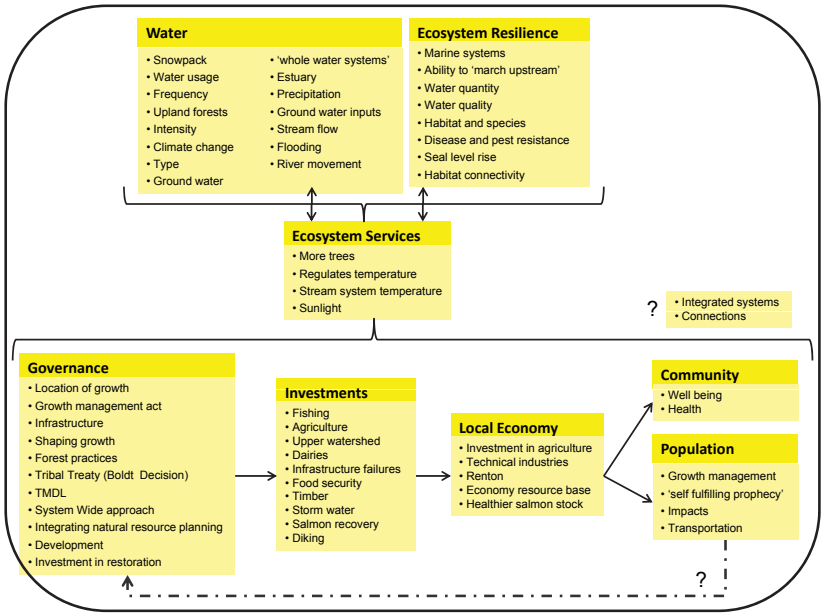
Synthesis / outreach / education

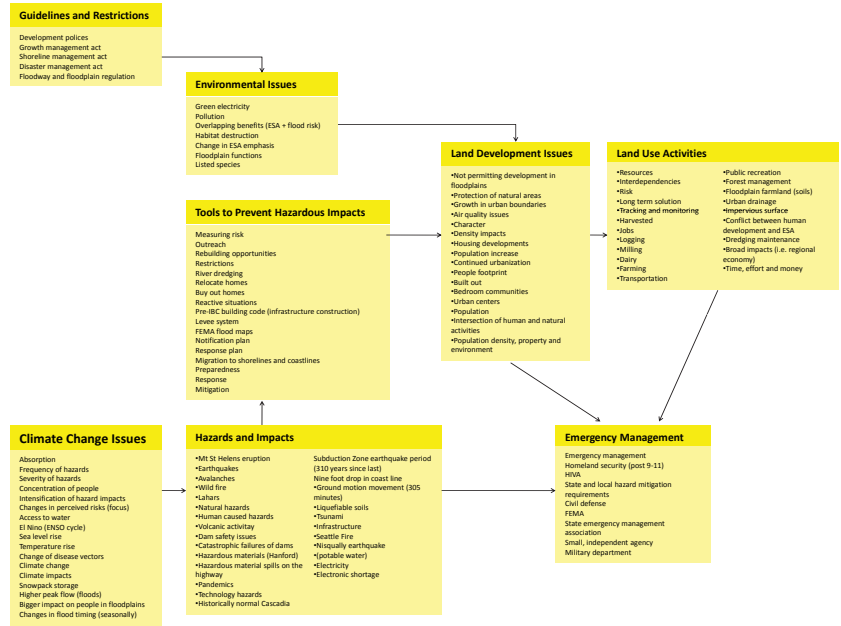
Democratize	County / city
Friendliness	government
Developers	Landowners
Jurisdictions	
Farmers	
Agencies	

Opportunities / constraints

Traffic congestion	Marshland	Lake Stevens (plateau)
Unraveling streams	Restrictions	Slow food
Permits	Zoning	Political
Steep slopes	Enforcement hammer	Building conventions
Buffers	New development	Political pressure
Water quality	Local codes	Regulations
Recognition of significance	Violations	Institutional knowledge
Land availability	Agricultural	County ownership
Farmer – relations	Drain (ing)	Mitigation
Carbon footprint	Energy	
Floodplain	Sultan (terrace)	




Water
• Snowpack
• Water usage
• Frequency
• Upland forests
• Intensity
• Climate change
• Type
• Ground water
• 'whole water systems'
• Estuary
• Precipitation
• Ground water inputs
• Stream flow
• Flooding
• River movement
Ecosystem Resilience
• Marine systems
• Ability to 'march upstream'
• Water quantity
• Water quality
• Habitat and species
• Disease and pest resistance
• Seal level rise
• Habitat connectivity
Ecosystem Services
• More trees
• Regulates temperature
• Stream system temperature
• Sunlight
?
• Integrated systems
• Connections
Governance
• Location of growth
• Growth management act
• Infrastructure
• Shaping growth
• Forest practices
• Tribal Treaty (Boldt Decision)
• TMDL
• System Wide approach
• Integrating natural resource planning
• Development
• Investment in restoration
Investments
• Fishing
• Agriculture
• Upper watershed
• Dairies
• Infrastructure failures
• Food security
• Timber
• Storm water
• Salmon recovery
• Diking
Local Economy
• Investment in agriculture
• Technical industries
• Renton
• Economy resource base
• Healthier salmon stock
Community
• Well being
• Health
Population
• Growth management
• 'self fulfilling prophecy'
• Impacts
• Transportation
?


Guidelines and Restrictions
Development polices
Growth management act
Shoreline management act
Disaster management act
Floodway and floodplain regulation
Environmental Issues
Green electricity
Pollution
Overlapping benefits (ESA + flood risk)
Habitat destruction
Change in ESA emphasis
Floodplain functions
Listed species
Land Development Issues
•Not permitting development in floodplains
•Protection of natural areas
•Growth in urban boundaries
•Air quality issues
•Character
•Density impacts
•Housing developments
•Population increase
•Continued urbanization
•People footprint
•Built out
•Bedroom communities
•Urban centers
•Population
•Intersection of human and natural activities
•Population density, property and environment
Land Use Activities
•Resources
•Interdependencies
•Risk
•Long term solution
•Tracking and monitoring
•Harvested
•Jobs
•Logging
•Milling
•Dairy
•Farming
•Transportation
•Public recreation
•Forest management
•Floodplain farmland (soils)
•Urban drainage
•Impervious surface
•Conflict between human development and ESA
•Dredging maintenance
•Broad impacts (i.e. regional economy)
•Time, effort and money
Tools to Prevent Hazardous Impacts
Measuring risk
Outreach
Rebuilding opportunities
Restrictions
River dredging
Relocate homes
Buy out homes
Reactive situations
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•Historically normal Cascadia
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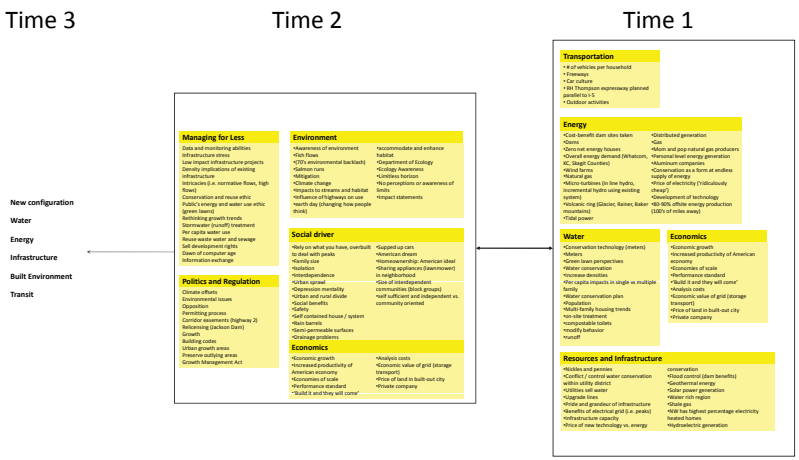
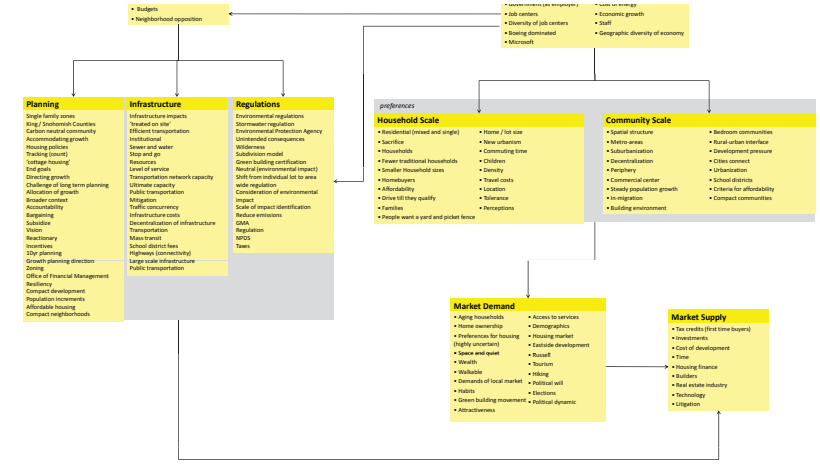
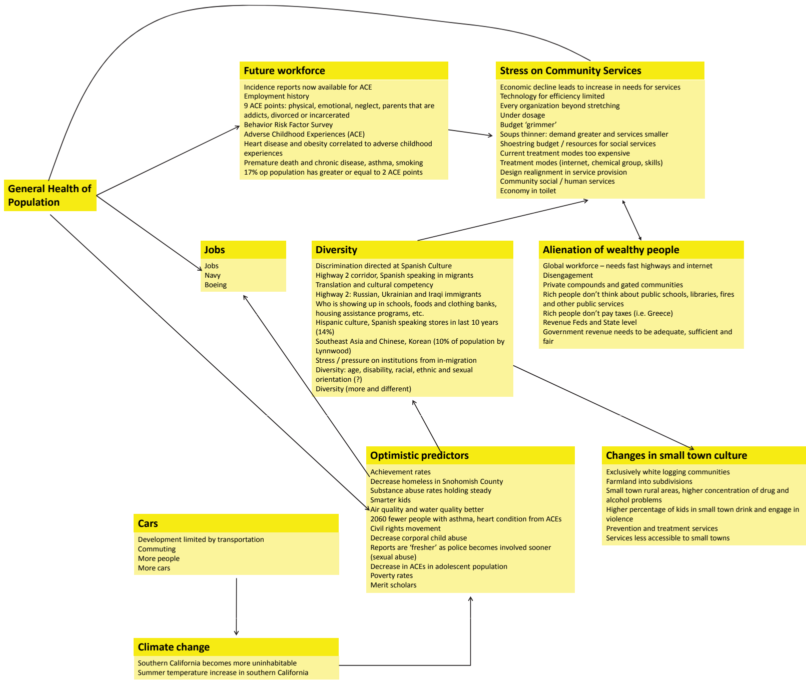
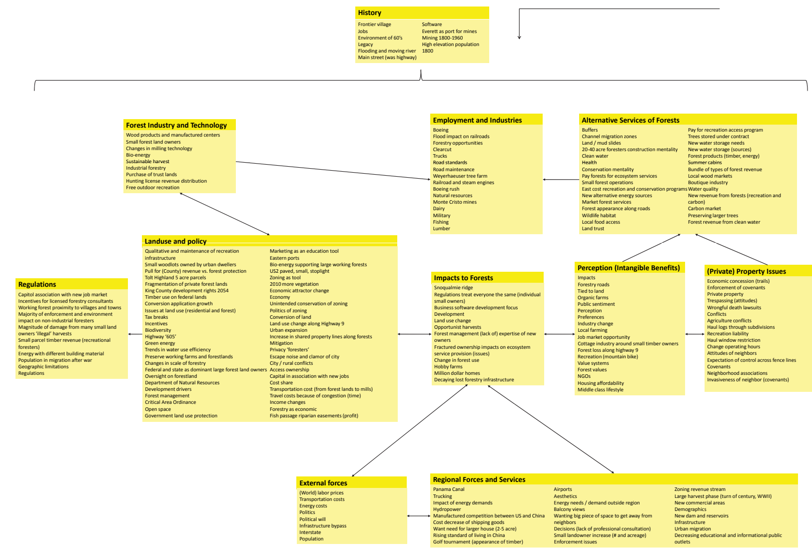
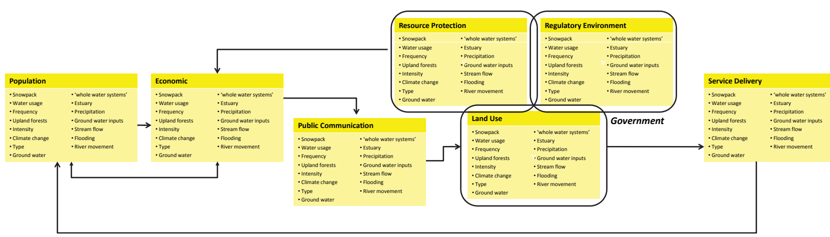
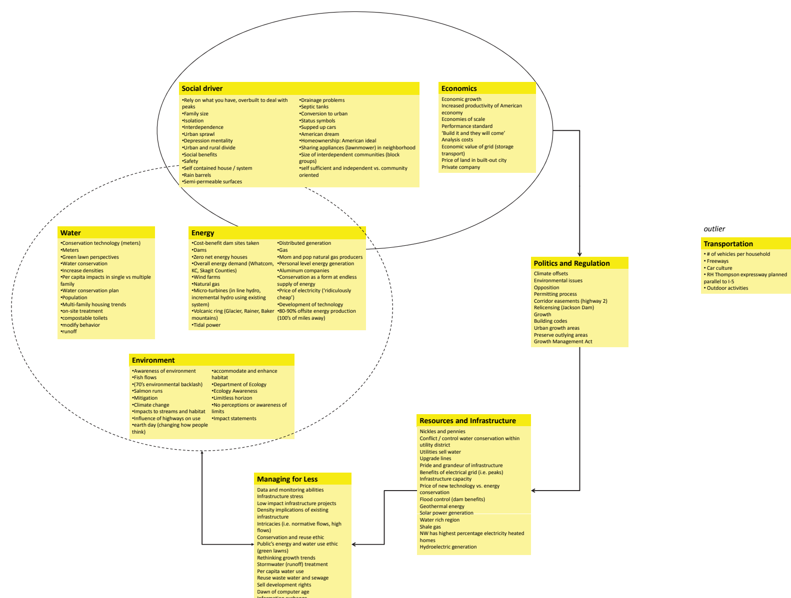

Time 3
Time 2
Time 1
New configuration
Water
Energy
Infrastructure
Built Environment
Transit
Managing for Less
Data and monitoring abilities
Infrastructure stress
Low impact infrastructure projects
Density implications of existing infrastructure
Intricacies (i.e. normative flows, high flows)
Conservation and reuse ethic
Public's energy and water use ethic (green teens)
Rethinking growth trends
Stormwater (runoff) treatment
Per capita water use
Reuse waste water and sewage
Self development rights
Down of computer age
information exchange
Environment
•Awareness of environment
•fish flows
•(70's environmental backlash)
•Salmon runs
•Mitigation
•Climate change
•Impacts to streams and habitat
•Influence of highways on use
•earth day (changing how people think)
•accommodate and enhance habitat
•Department of Ecology
•Ecology Awareness
•Limitless horizon
•No perceptions or awareness of limits
•Impact statements
Politics and Regulation
Climate offsets
Environmental issues
Opposition
Permitting process
Corridor easements (highway 2)
Relicensing (Jackson Dam)
Growth
Building codes
Urban growth areas
Preserve outlying areas
Growth Management Act
Social driver
•Rely on what you have, overbuilt to deal with peaks
•family size
•Isolation
•Interdependence
•Urban sprawl
•Depression mentality
•Urban and rural divide
•Social benefits
•Safety
•Self contained house / system
•Rain barrels
•Semi-permeable surfaces
•Drainage problems
•Supped up cars
•American dream
•Homeownership: American ideal
•Sharing appliances (lawnmower) in neighborhood
•Size of interdependent communities (block groups)
•self sufficient and independent vs. community oriented
Economics
•Economic growth
•Increased productivity of American economy
•Economies of scale
•Performance standard
"Build it and they will come'
•Analysis costs
•Economic value of grid (storage transport)
•Price of land in built-out city
•Private company
Transportation
• # of vehicles per household
• Freeways
• Car culture
• Bit Thompson expressway planned parallel to I-5
• Outdoor activities
Energy
•Cost-benefit dam sites taken
•Dams
•Zero net energy houses
•Overall energy demand (Whatcom, KC, Skagit Counties)
•Wind farms
•Natural gas
•Micro-turbines (in line hydro, incremental hydro using existing system)
•Volcanic ring (Glacier, Rainier, Baker mountains)
•Tidal power
•Distributed generation
•Gas
•Main and pop natural gas producers
•Personal level energy generation
•Aluminum companies
•Conservation as a form at endless supply of energy
•Price of electricity ("ridiculously cheap")
•Development of technology
•80-90% offsite energy production (100's of miles away)
Water
•Conservation technology (meters)
•Meters
•Green lawn perspectives
•Water conservation
•Increase densities
•Per capita impacts in single vs multiple family
•Water conservation plan
•Population
•Multi-family housing trends
•on-site treatment
•compostable toilets
•modify behavior
•runoff
Economics
•Economic growth
•Increased productivity of American economy
•Economies of scale
•Performance standard
•'Build it and they will come'
•Analysis costs
•Economic value of grid (storage transport)
•Price of land in built-out city
•Private company
Resources and Infrastructure
•Nickles and pennies
•Conflict / control water conservation within utility district
•Utilities sell water
•Upgrade lines
•Pride and grandeur of infrastructure
•Benefits of electrical grid (i.e. peaks)
•Infrastructure capacity
•Price of new technology vs. energy conservation
•Flood control (dam benefits)
•Geothermal energy
•Solar power generation
•Water rich region
•Shale gas
•WA has highest percentage electricity heated homes
•Hydroelectric generation


• Budgets
• Neighborhood opposition
• Job centers
• Diversity of job centers
• Boeing dominated
• Microsoft
• Economic growth
• Staff
• Geographic diversity of economy
Planning
Single family zones
King / Snohomish Counties
Carbon neutral community
Accommodating growth
Housing policies
Tracking (count)
'cottage housing'
End goals
Directing growth
Challenge of long term planning
Allocation of growth
Broader context
Accountability
Bargaining
Subsidize
Vision
Reactionary
Incentives
10yr planning
Growth planning direction
Zoning
Office of Financial Management
Resiliency
Compact development
Population increments
Affordable housing
Compact neighborhoods
Infrastructure
Infrastructure impacts
'treated on site'
Efficient transportation
Institutional
Sewer and water
Stop and go
Resources
Level of service
Transportation network capacity
Ultimate capacity
Public transportation
Mitigation
Traffic concurrency
Infrastructure costs
Decentralization of infrastructure
Transportation
Mass transit
School district fees
Highways (connectivity)
Large scale infrastructure
Public transportation
Regulations
Environmental regulations
Stormwater regulation
Environmental Protection Agency
Unintended consequences
Wilderness
Subdivision model
Green building certification
Neutral (environmental impact)
Shift from individual lot to area wide regulation
Consideration of environmental impact
Scale of impact identification
Reduce emissions
GMA
Regulation
NPDS
Taxes
preferences
Household Scale
• Residential (mixed and single)
• Sacrifice
• Households
• Fewer traditional households
• Smaller Household sizes
• Homebuyers
• Affordability
• Drive till they qualify
• Families
• People want a yard and picket fence
• Home / lot size
• New urbanism
• Commuting time
• Children
• Density
• Travel costs
• Location
• Tolerance
• Perceptions
Community Scale
• Spatial structure
• Metro-areas
• Suburbanization
• Decentralization
• Periphery
• Commercial center
• Steady population growth
• In-migration
• Building environment
• Bedroom communities
• Rural-urban interface
• Development pressure
• Cities connect
• Urbanization
• School districts
• Criteria for affordability
• Compact communities
Market Demand
• Aging households
• Home ownership
• Preferences for housing (highly uncertain)
• Space and quiet
• Wealth
• Walkable
• Demands of local market
• Habits
• Green building movement
• Attractiveness
• Access to services
• Demographics
• Housing market
• Eastside development
• Russell
• Tourism
• Hiking
• Political will
• Elections
• Political dynamic
Market Supply
• Tax credits (first time buyers)
• Investments
• Cost of development
• Time
• Housing finance
• Builders
• Real estate industry
• Technology
• Litigation


General Health of Population
Future workforce
Incidence reports now available for ACE
Employment history
9 ACE points: physical, emotional, neglect, parents that are addicts, divorced or incarcerated
Behavior Risk Factor Survey
Adverse Childhood Experiences (ACE)
Heart disease and obesity correlated to adverse childhood experiences
Premature death and chronic disease, asthma, smoking
17% op population has greater or equal to 2 ACE points
Stress on Community Services
Economic decline leads to increase in needs for services
Technology for efficiency limited
Every organization beyond stretching
Under dosage
Budget 'grimmer'
Soups thinner: demand greater and services smaller
Shoestring budget / resources for social services
Current treatment modes too expensive
Treatment modes (internet, chemical group, skills)
Design realignment in service provision
Community social / human services
Economy in toilet
Jobs
Jobs
Navy
Boeing
Diversity
Discrimination directed at Spanish Culture
Highway 2 corridor, Spanish speaking in migrants
Translation and cultural competency
Highway 2: Russian, Ukrainian and Iraqi immigrants
Who is showing up in schools, foods and clothing banks, housing assistance programs, etc.
Hispanic culture, Spanish speaking stores in last 10 years (14%)
Southeast Asia and Chinese, Korean (10% of population by Lynnwood)
Stress / pressure on institutions from in-migration
Diversity: age, disability, racial, ethnic and sexual orientation (?)
Diversity (more and different)
Alienation of wealthy people
Global workforce – needs fast highways and internet
Disengagement
Private compounds and gated communities
Rich people don't think about public schools, libraries, fires and other public services
Rich people don't pay taxes (i.e. Greece)
Revenue Feds and State level
Government revenue needs to be adequate, sufficient and fair
Optimistic predictors
Achievement rates
Decrease homeless in Snohomish County
Substance abuse rates holding steady
Smarter kids
Air quality and water quality better
2060 fewer people with asthma, heart condition from ACEs
Civil rights movement
Decrease corporal child abuse
Reports are 'fresher' as police becomes involved sooner (sexual abuse)
Decrease in ACEs in adolescent population
Poverty rates
Merit scholars
Changes in small town culture
Exclusively white logging communities
Farmland into subdivisions
Small town rural areas, higher concentration of drug and alcohol problems
Higher percentage of kids in small town drink and engage in violence
Prevention and treatment services
Services less accessible to small towns
Cars
Development limited by transportation
Commuting
More people
More cars
Climate change
Southern California becomes more uninhabitable
Summer temperature increase in southern California


History
Frontier village
Jobs
Environment of 60's
Legacy
Flooding and moving river
Main street (was highway)
Software
Everett as port for mines
Mining 1800-1960
High elevation population
1800
Forest Industry and Technology
Wood products and manufactured centers
Small forest land owners
Changes in milling technology
Bio-energy
Sustainable harvest
Industrial forestry
Purchase of trust lands
Hunting license revenue distribution
Free outdoor recreation
Employment and Industries
Boeing
Flood impact on railroads
Forestry opportunities
Clearcut
Trucks
Road standards
Road maintenance
Weyerhaeuser tree farm
Railroad and steam engines
Boeing rush
Natural resources
Monte Cristo mines
Dairy
Military
Fishing
Lumber
Alternative Services of Forests
Buffers
Channel migration zones
Land / mud slides
20-40 acre foresters construction mentality
Clean water
Health
Conservation mentality
Pay forests for ecosystem services
Small forest operations
East cost recreation and conservation programs
New alternative energy sources
Market forest services
Forest appearance along roads
Wildlife habitat
Local food access
Land trust
Pay for recreation access program
Trees stored under contract
New water storage needs
New water storage (sources)
Forest products (timber, energy)
Summer cabins
Bundle of types of forest revenue
Local wood markets
Boutique industry
Water quality
New revenue from forests (recreation and carbon)
Carbon market
Preserving larger trees
Forest revenue from clean water
Regulations
Capitol association with new job market
Incentives for licensed forestry consultants
Working forest proximity to villages and towns
Majority of enforcement and environment impact on non-industrial foresters
Magnitude of damage from many small land owners 'illegal' harvests
Small parcel timber revenue (recreational foresters)
Energy with different building material
Population in migration after war
Geographic limitations
Regulations
Landuse and policy
Qualitative and maintenance of recreation infrastructure
Small woodlots owned by urban dwellers
Pull for (County) revenue vs. forest protection
Tolt Highland 5 acre parcels
Fragmentation of private forest lands
King County development rights 2054
Timber use on federal lands
Conversion application growth
Issues at land use (residential and forest)
Tax breaks
Incentives
Biodiversity
Highway '605'
Green energy
Trends in water use efficiency
Preserve working farms and forestlands
Changes in scale of forestry
Federal and state as dominant large forest land owners
Oversight on forestland
Department of Natural Resources
Development drivers
Forest management
Critical Area Ordinance
Open space
Government land use protection
Marketing as an education tool
Eastern ports
Bio-energy supporting large working forests
US2 paved, small, stoplight
Zoning as tool
2010 more vegetation
Economic attractor change
Economy
Unintended conservation of zoning
Politics of zoning
Conversion of land
Land use change along Highway 9
Urban expansion
Increase in shared property lines along forests
Mitigation
Privacy 'foresters'
Escape noise and clamor of city
City / rural conflicts
Access ownership
Capital in association with new jobs
Cost share
Transportation cost (from forest lands to mills)
Travel costs because of congestion (time)
Income changes
Forestry as economic
Fish passage riparian easements (profit)
Impacts to Forests
Snoqualmie ridge
Regulations treat everyone the same (individual small owners)
Business software development focus
Development
Land use change
Opportunist harvests
Forest management (lack of) expertise of new owners
Fractured ownership impacts on ecosystem service provision (issues)
Change in forest use
Hobby farms
Million dollar homes
Decaying lost forestry infrastructure
Perception (Intangible Benefits)
Impacts
Forestry roads
Tied to land
Organic farms
Public sentiment
Perception
Preferences
Industry change
Local farming
Job market opportunity
Cottage industry around small timber owners
Forest loss along highway 9
Recreation (mountain bike)
Value systems
Forest values
NGOs
Housing affordability
Middle class lifestyle
(Private) Property Issues
Economic concession (trails)
Enforcement of covenants
Private property
Trespassing (attitudes)
Wrongful death lawsuits
Conflicts
Agriculture conflicts
Haul logs through subdivisions
Recreation liability
Haul window restriction
Change operating hours
Attitudes of neighbors
Expectation of control across fence lines
Covenants
Neighborhood associations
Invasiveness of neighbor (covenants)
External forces
(World) labor prices
Transportation costs
Energy costs
Politics
Political will
Infrastructure bypass
Interstate
Population
Regional Forces and Services
Panama Canal
Trucking
Impact of energy demands
Hydropower
Manufactured competition between US and China
Cost decrease of shipping goods
Want need for larger house (2-5 acre)
Rising standard of living in China
Golf tournament (appearance of timber)
Airports
Aesthetics
Energy needs / demand outside region
Balcony views
Wanting big piece of space to get away from neighbors
Decisions (lack of professional consultation)
Small landowner increase (# and acreage)
Enforcement issues
Zoning revenue stream
Large harvest phase (turn of century, WWII)
New commercial areas
Demographics
New dam and reservoirs
Infrastructure
Urban migration
Decreasing educational and informational public outlets


Resource Protection
Regulatory Environment
Population
Economic
Public Communication
Land Use
Government
Service Delivery
• Snowpack
• Water usage
• Frequency
• Upland forests
• Intensity
• Climate change
• Type
• Ground water
• 'whole water systems'
• Estuary
• Precipitation
• Ground water inputs
• Stream flow
• Flooding
• River movement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•Family size
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•Urban sprawl
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•Social benefits
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•Conversion to urban
•Status symbols
•Supped up cars
•American dream
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•Sharing appliances (lawnmower) in neighborhood
•Size of interdependent communities (block groups)
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Economics
Economic growth
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Performance standard
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Analysis costs
Economic value of grid (storage transport)
Price of land in built-out city
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Water
•Conservation technology (meters)
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•Increase densities
•Per capita impacts in single vs multiple family
•Water conservation plan
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•on-site treatment
•compostable toilets
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•runoff
Energy
•Cost-benefit dam sites taken
•Dams
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•Mom and pop natural gas producers
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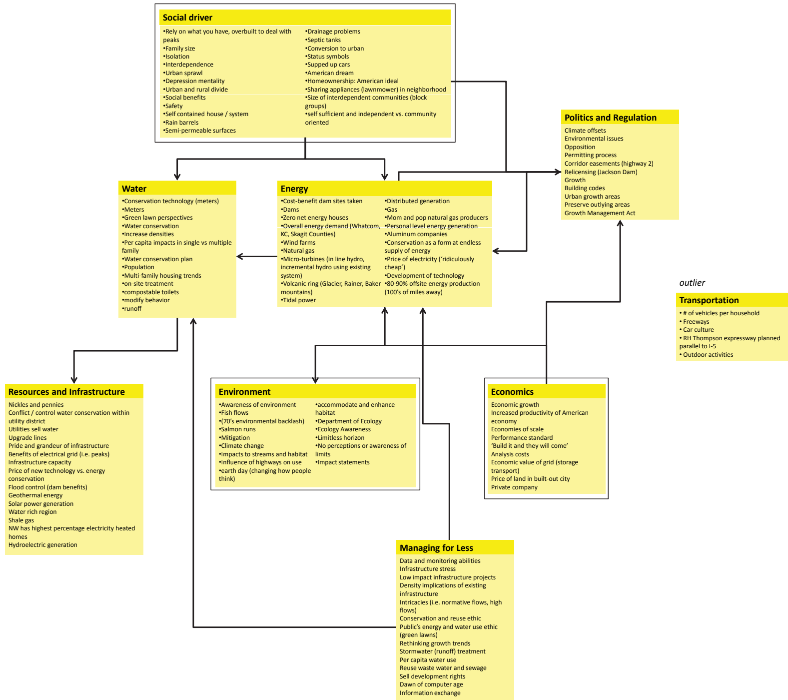
•Aluminum companies
•Conservation as a form at endless supply of energy
•Price of electricity ('ridiculously cheap')
•Development of technology
•80-90% offsite energy production (100's of miles away)
Environment
•Awareness of environment
•Fish flows
•(70's environmental backlash)
•Salmon runs
•Mitigation
•Climate change
•Impacts to streams and habitat
•Influence of highways on use
•earth day (changing how people think)
•accommodate and enhance habitat
•Department of Ecology
•Ecology Awareness
•Limitless horizon
•No perceptions or awareness of limits
•Impact statements
Politics and Regulation
Climate offsets
Environmental issues
Opposition
Permitting process
Corridor easements (highway 2)
Relicensing (Jackson Dam)
Growth
Building codes
Urban growth areas
Preserve outlying areas
Growth Management Act
outlier
Transportation
• # of vehicles per household
• Freeways
• Car culture
• RH Thompson expressway planned parallel to I-5
• Outdoor activities
Resources and Infrastructure
Nickles and pennies
Conflict / control water conservation within utility district
Utilities sell water
Upgrade lines
Pride and grandeur of infrastructure
Benefits of electrical grid (i.e. peaks)
Infrastructure capacity
Price of new technology vs. energy conservation
Flood control (dam benefits)
Geothermal energy
Solar power generation
Water rich region
Shale gas
NW has highest percentage electricity heated homes
Hydroelectric generation
Managing for Less
Data and monitoring abilities
Infrastructure stress
Low impact infrastructure projects
Density implications of existing infrastructure
Intricacies (i.e. normative flows, high flows)
Conservation and reuse ethic
Public's energy and water use ethic (green lawns)
Rethinking growth trends
Stormwater (runoff) treatment
Per capita water use
Reuse waste water and sewage
Sell development rights
Dawn of computer age
Information exchange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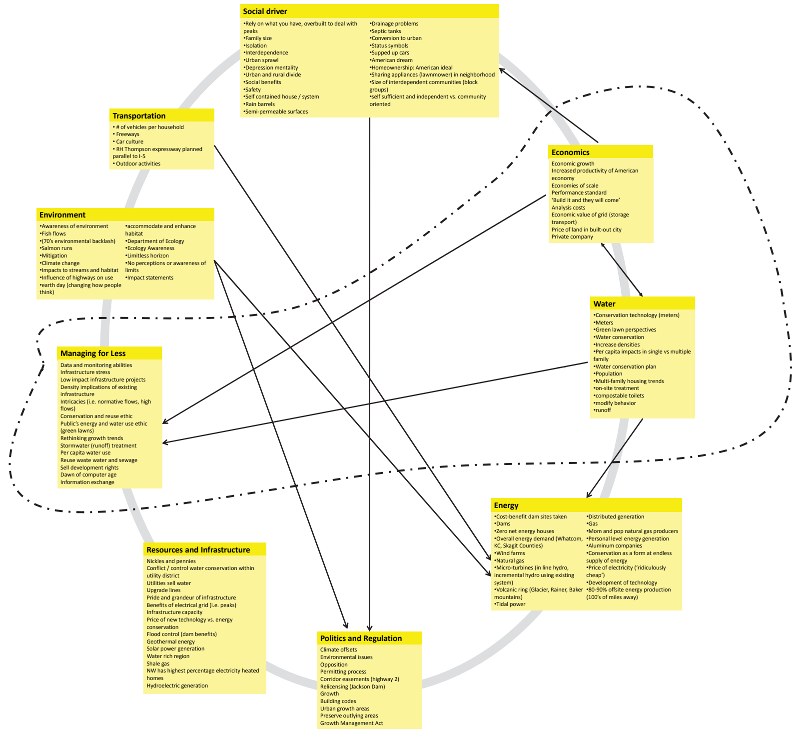
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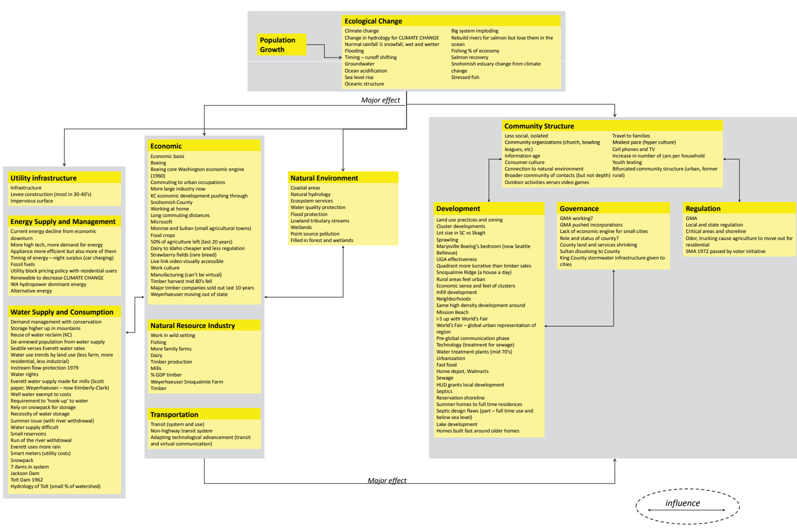
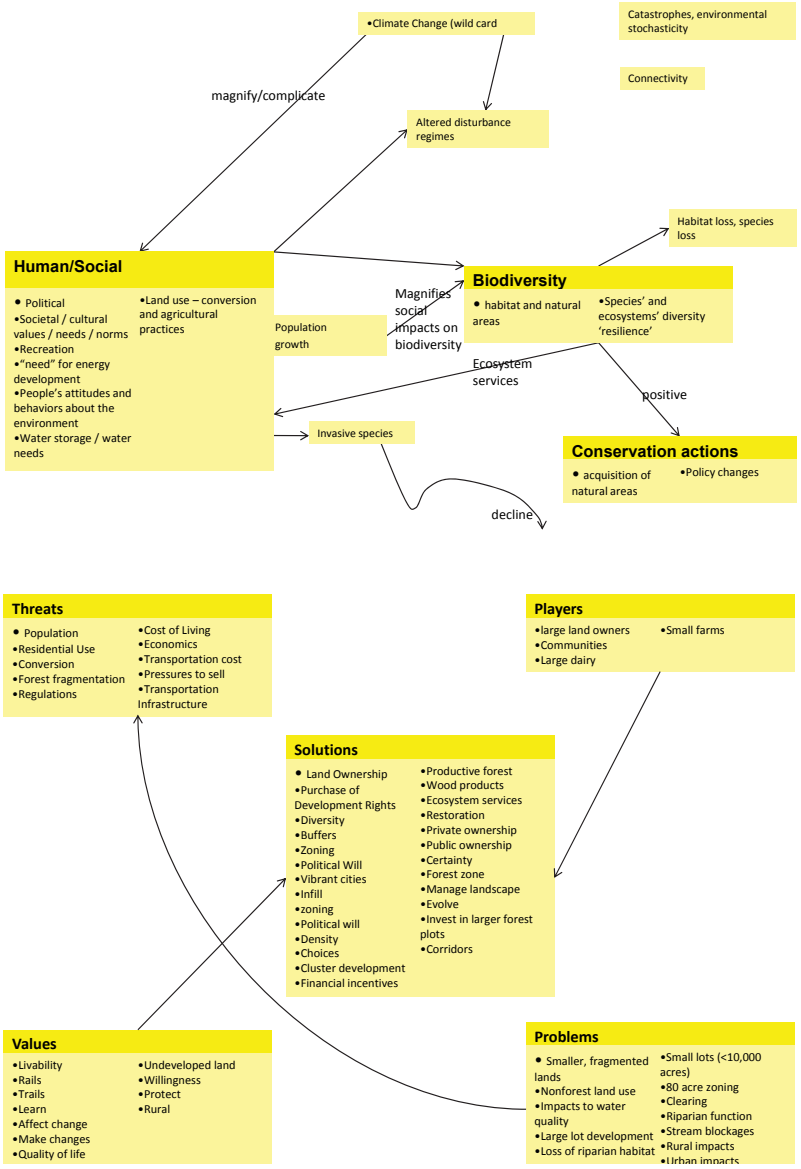

Population Growth
Ecological Change
Climate change
Change in hydrology for CLIMATE CHANGE
Normal rainfall ½ snowfall, wet and wetter
Flooding
Timing – runoff shifting
Groundwater
Ocean acidification
Sea level rise
Oceanic structure
Big system imploding
Rebuild rivers for salmon but lose them in the ocean
Fishing % of economy
Salmon recovery
Snohomish estuary change from climate change
Stressed fish
Major effect
Utility infrastructure
Infrastructure
Levee construction (most in 30-40's)
Impervious surface
Energy Supply and Management
Current energy decline from economic downturn
More high tech, more demand for energy
Appliance more efficient but also more of them
Timing of energy – night surplus (car charging)
Fossil fuels
Utility block pricing policy with residential users
Renewable to decrease CLIMATE CHANGE
WA hydropower dominant energy
Alternative energy
Water Supply and Consumption
Demand management with conservation
Storage higher up in mountains
Reuse of water reclaim (KC)
De-annexed population from water supply
Seattle verses Everett water rates
Water use trends by land use (less farm, more residential, less industrial)
Instream flow protection 1979
Water rights
Everett water supply made for mills (Scott paper, Weyerhaeuser – now Kimberly-Clark)
Well water exempt to costs
Requirement to 'hook-up' to water
Rely on snowpack for storage
Necessity of water storage
Summer issue (with river withdrawal)
Water supply difficult
Small reservoirs
Run of the river withdrawal
Everett uses more rain
Smart meters (utility costs)
Snowpack
7 dams in system
Jackson Dam
Tolt Dam 1962
Hydrology of Tolt (small % of watershed)
Economic
Economic basis
Boeing
Boeing core Washington economic engine (1960)
Commuting to urban occupations
More large industry now
KC economic development pushing through Snohomish County
Working at home
Long commuting distances
Microsoft
Monroe and Sultan (small agricultural towns)
Food crops
50% of agriculture left (last 20 years)
Dairy to Idaho cheaper and less regulation
Strawberry fields (rare breed)
Live link video visually accessible
Work culture
Manufacturing (can't be virtual)
Timber harvest mid 80's fell
Major timber companies sold out last 10 years
Weyerhaeuser moving out of state
Natural Resource Industry
Work in wild setting
Fishing
More family farms
Dairy
Timber production
Mills
% GDP timber
Weyerhaeuser Snoqualmie Farm
Timber
Transportation
Transit (system and use)
Non-highway transit system
Adapting technological advancement (transit and virtual communication)
Natural Environment
Coastal areas
Natural hydrology
Ecosystem services
Water quality protection
Flood protection
Lowland tributary streams
Wetlands
Point source pollution
Filled in forest and wetlands
Community Structure
Less social, isolated
Community organizations (church, bowling leagues, etc)
Information age
Consumer culture
Connection to natural environment
Broader community of contacts (but not depth)
Outdoor activities verses video games
Travel to families
Modest pace (hyper culture)
Cell phones and TV
Increase in number of cars per household
Youth texting
Bifurcated community structure (urban, former rural)
Development
Land use practices and zoning
Cluster developments
Lot size in SC vs Skagit
Sprawling
Marysville Boeing's bedroom (now Seattle Bellevue)
UGA effectiveness
Quadrant more lucrative than timber sales
Snoqualmie Ridge (a house a day)
Rural areas feel urban
Economic sense and feel of clusters
Infill development
Neighborhoods
Same high density development around Mission Beach
I-5 up with World's Fair
World's Fair – global urban representation of region
Pre-global communication phase
Technology (treatment for sewage)
Water treatment plants (mid 70's)
Urbanization
Fast food
Home depot, Walmarts
Sewage
HUD grants local development
Septics
Reservation shoreline
Summer homes to full time residences
Septic design flaws (part – full time use and below sea level)
Lake development
Homes built fast around older homes
Governance
GMA working?
GMA pushed incorporations
Lack of economic engine for small cities
Role and status of county?
County land and services shrinking
Sultan dissolving to County
King County stormwater infrastructure given to cities
Regulation
GMA
Local and state regulation
Critical areas and shoreline
Odor, trucking cause agriculture to move out for residential
SMA 1972 passed by voter initiative
Major effect
influence



past	both	future
Climate change		•Water supply systems pressure •Near term / long term effects of climate change •Climate change adaptation choices •Carbon emissions
Sprawl	•Shape of our cities, suburbs and exurbs •City vs outskirt roads change development patterns and transit patterns •Provision and location of roads •Shorter trip distances •Willing to pay •McMansion (want to live in big place on 3 acres by myself) •Alternatives to getting around •(per capita) vehicle miles travelled •Compact neighborhoods •Increase impervious surfaces •Land use •Sprawl •Allocation of transit policy	
Population	•Number of people •Population •Longevity •Birth rates •Health •Immigration trends •Medical technology •How soon people die •Reproductive access •Human health getting worse (?) •Access to health care •Cultural groups "intended / unintended" notion •Birth rates shift due to cultural stuff •Unwanted pregnancies (10% national rate) •Health profile •Birth + death rates •Domestic migration (economic issues) •National immigration laws •International immigration policy	
Pollution	•Pollution •Car pollution + industry pollution going down •Pollution will be less important over time •Legacy of contamination	
Economic	•Cars and gas become affordable •Wealthier •Current recession •Cost of building a house, mortgage and car •Changing economy •Computer industry	
Deforestation	•Loss of farmland and forestland •Fragmentation of habitat •Land use •Deforestation •Linkage between forest cover and population growth (not clear) •Forest cover •Ecosystem services	
Energy	•Commodity pricing •Cheaper to get copper, steel out of ground •Availability of oil •Global oil production (peak 1972) •Oil linked to natural gas •High efficiency •Forests for methanol (burn the trees) •Firewood more than construction (driver of deforestation) •Small hydro (energy resource in Basin) •Solar and wind power (not likely to be important in the Basin) •Bio-energy •No fossil fuels in the Basin •Hydropower •Energy prices and technology •Cheap vs. expensive oil •Availability of cheap energy •Energy	

Cross cutting drivers

•Cultural reasons
•Available technology
•Cultural notion
•Societal tolerance
•Regulatory policy
•Uncertainty
•Policy response to climate change

Setting Environment

- Fish habitat
- Floodplain
- Air quality
- Wildlife

Not Opportunities and threats

- Prosperity
- Oil
- Pressure for production
- Market (global, value)
- Availability of land
- Confinement
- Political change
- Competitive

Forces (drivers)

- Import / export
- Market
- In-migration
- Economy
- Population density
- Risk
- Prosperity
- Tribes
- Government
- USDA
- The Farm Bill
- Burden(some)
- GMA
- Flooding
- Sprawl
- Profitability
- Environmental regulations
- Trade regulations (WTO)
- Sprawl

Solutions

- Net gain productivity
- Partnerships

Actors

- Smaller farms
- Farmers critical and necessary
- Department of Ecology
- Tribes
- Government
- Small producer
- Local grocer
- WSDA
- Commodity farms
- Supermarket
- More farmers

Values / Priorities

- Define fairness
- Public health
- Importance
- Food security
- Importance
- Security
- Beauty
- Responsibility
- Good livable places
- Prosperity
- Democracy
- How we value agriculture
- Sustainability

Left on Board

- Machinery
- Subsidize
- Cheaper
- Pesticides
- Open space status
- Sustainable lands strategy
- Rural interests
- Everyone
- Obesity
- Big company
- Good ag practices
- Slaughterhouse
- Politics
- (Leveling out the) playing field
- Low income
- Don't have enough farmers
- Year round
- Polls showing
- Neighborhood
- Food desert
- Tighter food regulations
- Value added products
- Tracking contaminants
- Pressure
- Leasing minimum size
- Industrialized
- River
- Waste
- Environmental consequences
- Cities
- Spread out population
- '5 acre parcels'
- new vision of agriculture
- land development phasing
- danger
- prepare
- investments
- efficiency
- economic vitality
- clean water
- transfer of productivity
- economic sustainability
- powerful
- Monroe
- TMDL
- Mitigation
- Wetlands
- Cost share
- More intensive farming
- Farm value
- Land values
- Harnessing
- Restoration
- Consequences
- Incentives
- 'back of farmer'
- Performance
- Permit
- Pollution
- Allocate burdens
- Stewardship fund
- Conservation district
- Justice
- Social responsibility
- Baseline
- Buffers
- Forestlands
- Around the table
- USFW
- Mindset
- Clean Water Act
- Holding operations
- Tax program
- Chosen a course
- Ag zones
- ESA
- Fresh
- Energy
- Food miles
- The public
- Farming multiple small parcels
- Income / revenue
- Hay
- Soils
- Infrastructure
- Transportation (costs)
- Intolerable
- Social impact
- Farmers markets
- Property condemnation
- Fragmentation
- Not a Western Washington problem
- Family
- Council
- Flexibility
- Political arena
- Collectivity
- Vested interests
- Food
- Allocate rights
- Benefits
- Property rights / takings
- Stability
- Globally
- East / West divide
- Exemption
- Planning (how Agriculture is addressed)
- Kids
- Visual
- Tremendous variety of products
- Margin
- Agricultural definition
- County level
- Diversifying markets and products
- Production facilities
- Resistance
- Bottomlands
- 'make a living'
- Vegetables
- Different type of agriculture
- Lettuce
- Upland
- Grapes
- Local
- Uncertainty about the future
- Large acreage production
- Soil capacity
- Hillside
- Perceptions
- Intensive uses
- Priority
- Ag board
- RCW State law
- No returns
- Greenhouses
- Higher value of land
- Mowed lawns
- Potential

East West Division

East west divide
Rural small town oriented
County resource allocation
Small communities (i.e. Snohomish, Darlington)
Casino
Trespassing on reservation

Labor

Development of Brier
Flooded 10 times
Assuming driving to Seattle for higher education
Blue Collar / White collar transition
Nisui population
Battle of Everett
Wobbler (early labor movement)

Environment

High rise building
Draw to Snohomish for salary
level
GMA artificial constraints
Drive till you qualify
Marysville population
Design standards
Salmon not in creek
How we treat our
environment

Transportation

Full day trip to get to Basin
from Seattle
I-99 (not I-5)
Can't build subdivisions
without impact on
transportation
South of 120th Street in
Everett, oriented to Seattle
Land use and transportation
policy
After 3 no meetings in north
Everett
Traffic
2023 Lynn light rail
Shift to older generation (?)

Social

Mount Lake Terrace Mink Farm
Abandoned BNS railroad to Redmond as a commuter
corridor
Urban railroad between Everett and Seattle
Japanese Gulch (SW Everett Forested Land
Immigration of Spanish speaking population
Training
Homeless veterans by Sultan
Professionals vs unemployed
Change of workforce
High School Diploma to 2year certification requirements
Penitentiary / the Jail
Government decisions for location of things
Social services in Everett

Quality of Life

Quality of life
opportunities (jobs and
entertainment)
Health care (Everett
national level)
Attractiveness of 1st
class city
Urbanized
Freeways
Post WWII cul de sac
subdivision
Symbiotic relationship
between Bellevue and
Seattle (2nd tier city)
Is Everett a 1st tier city?
No
Everett small town

History of Basin

Rucker Hill
Seagulls vs Bruins
(rivalry)
Scott Paper
Cascade High School in
Everett
Everett Rotary Club
Fractured county
Everett 1 mile dock into
Port Garner Bay
Dairy
Buffalo farm in South
Everett
Shingle mills
Natural resource
industry
Everett as mill town
Weyerhaeuser

Labor and Education

Labor stability
Trust with largest labor
union
Contract negotiations
based on numbers (not
emotions)
Generation worked on
the waterfront
Kimberly Clark (last
vestiges)
Export more for higher
education than import
Imbalance of jobs and
housing (60% of
commuters to King
County)
Strategic workforce
planning
Retirement
Young folks leaving
70% of people who
leave for 4 year college
stay out
Low cost high quality
care
Stormwater
Pollution

Past, Present and Future of Everett and Snohomish County

JC Penny moves to Everett Mall
Landfill line fine to mixed use development
Everett Station multi-modal hub
Light industry been redeveloped (in downtown Everett)
Exodus of downtown Everett
Density not there
Young professional live in King County
Lack of identity with younger generation connection to Everett
Arts and culture

Business Competitiveness

Policy leaders at WA picking a side
Unemployment benefits (cost structure)
Workers comp
Reformes for industry
LNI
Pensions paid out (180 vs. single digit days)
Environmental regulations
Predictable and streamlined (Environmental regulations)
Government view of industry as 'bad guy'
Meeting standards (King vs Snohomish Counties)
Taxes
Snonohomish County current administration
Goal of government to treat everyone equally
King County administration
Permits
Credits extended
Corporate income tax
Entrepreneurial region, starting business out but also at failing
Business (small startup) sticking it out long term
Education
Largest County without 4 year University
Job producer
Skilled workforce
Smart people key to innovation
Manufacturiing
Aerospace
Boeing (technology company)
Naval economic importance
Private sector jobs
Cost of doing business
Mid sized cities: Arlington, Marysville, Everett
Planned actions (upfront and done by area, SEPA, Etc)
Being in Snohomish County since 1966
Everett, largest facility employment for Boeing in the world ($6B billion)
Boeing facility bigger economic engine than some country's entire GDP
South half of Everett oriented south towards Seattle
Predictability of regulation
Initial investment vs efficiency
Mitigation and costs upfront and not an individual project level
Competing with Microsoft for innovation
Energy provision (SC PUD, Seattle City Light, PSE)
Wheeling" buy energy on an open market
Snohomish PUD from BPA

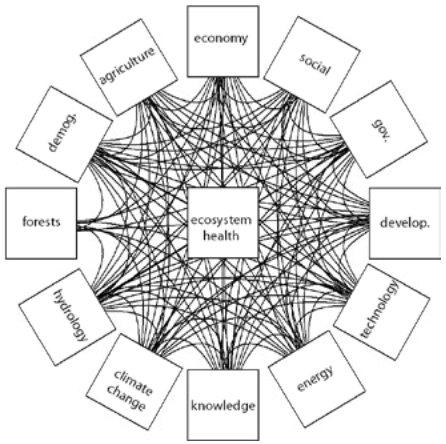
Jobs/economic

Timber town
Pulp mill
Boeing introduced manufacturing
Retaining of workforce
Emphasis on farming
Handful of fairy left from 100
Ag tourism + organic
Milk town
Naval station in Everett
Lack of private investment
Job creation
Cities taking job numbers and not housing numbers
Paine Field commercial (?)
2025 SeaTac runs out of space
Driving trade (getting on a plane)
Wealth creation economy (Boeing, Microsoft, Starbucks)
Circulating economy (restaurants, services, etc)
Airports and trade
Global port cities air travel access
Competitiveness
Fly into SeaTac for meetings
21st largest Korean population
Economy
Jobs
Transportation
Population growth
Trade and port activities
I-90 capacity
Rail and stampede
Panama Canal expansion (30% out of Everett)
Canadian alignment with rail and port
70% of goods end up in Midwest

Overarching Conceptual Models Synthesized from Focus Group Meetings and Interviews

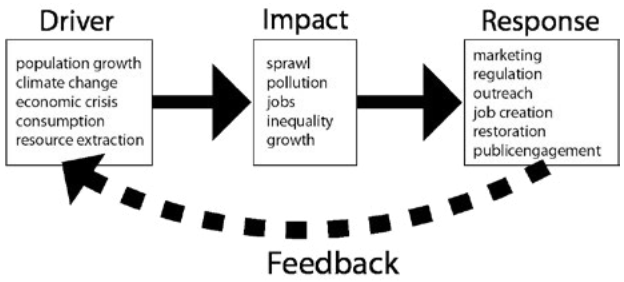
Networks (Centered on Focal Issue)

- Everything is connected to everything
- Functional groupings or sectors divide the world
- At the center is the focal issue, goal or problem



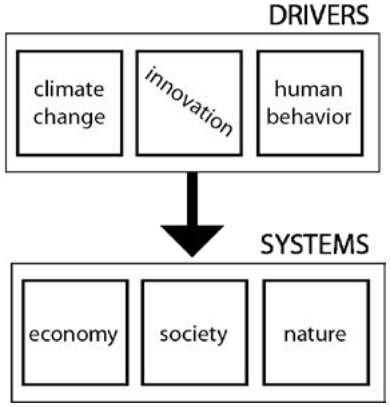
Dynamic (Driver, Impact, Response, Feedback)

- Human and natural created drivers cause change in the environment
- Impacts are characterized by changes in the patterns and processes we observe
- Feedbacks may link back from responses to influence (lessen or increase) the drivers.



Directional (Driver - Systems)

- Drivers force changes in systems
- Systems formulated around either human and natural forms or social, economic and natural systems
- Hierarchy defined by time, space or discipline.



Modifications

Time: past, current or future activities

Scale: Drivers operate at multiple levels

ie. global, national, regional, local

Uncertainty: knowledge limitations regarding the future

Risk: How uncertainty modifies human behavior and decisions

Assessment: Methods, data and conclusions characterizing current conditions and management

Indirect relationships: Influence modulated through components of the model

ie. impacts of climate change on environment are modulated through human activities

Conceptual Model Workshop

Date(s)

11.12.2010

Location

Graham Visitors Center. UW Seattle.

Objective

Develop a shared conceptual model to define the problems that the Snohomish River Basin will face over the next 50 years. Specifically the conceptual model will help the project team to identify the key driving forces that will shape the future of the Basin and explore their relationships and potential interactions.

Attendance

29 members of the Science Team representing acadmic, profession and non-profit organizations around the region including NOAA, City of Everett, King and Snohomish Counties, SPU, Wild Fish Conservancy, NW Power and Conservation Council, WA DNR and DOE, WA Emergency Mngt, American Farmland Trust, Tulalip Tribes, UW Public Affairs, Civil Engineering, College of Built Environments and College of the Environment.

Agenda

- Presentation of past syntheses and workshop activities
- Development of conceptual model teams
- Discussion and synthesis

Materials

Presentation (see pages A6.28-33)

Workshop Instructions Packet (A6.34-38)

What will be Snohomish Basin's Future?

How will the basin develop? Will agriculture disappear or prosper? Will high tech grow? Will salmon thrive? Will water be clean? Will there be enough for all users?

Conceptual Model Workshop

Snohomish 2060 Scenarios

Developing one shared story to characterize the Basin's plausible futures

Friday Nov 12, 2010

Graham's Visitors Center, Washington Arboretum, Seattle WA

Thank you for coming

Abby Hook	Clark Williams Derry	Hendrik Wolf	Kurt Burdslee	Richard White
Al McGuire	Daryl Williams	Howard Schwartz	Linda Nuenzig	Robin Lesher
Alan Berning	Dave Kasaluk	Jackie Aitchinson	Luke Rogers	Ryan Hombeze
Alan Hamlet	Dave Montgomery	Jacque Klug	Marcia Meyers	Sandra Mallory
Amy Snover	Dave Peterson	Jan Henderson	Mark Boyar	Sara Curran
Andrew Stout	Dave Rodman	Jonne Raje	Mark Maunsen	Scott Moore
Andy Haus	David Batker	Jim Miller	Mark Simonson	Scott Powell
Ann Bostrom	David Buerge	Jim Teverbaugh	Mary Embleton	Scott Powers
Ann Byles	David Burger	Joe Tuwe	Matt Mattsun	Skip Larkin
Anna Miles	David Dilgard	John Findlay	Matt Wiley	Simon Geerlofs
Anne Vernez Moudon	David Remlinger	John Gamon	Michael Blake	Stacy Trussler
Barbara Mock	David Sumner	John Moore	Michael Ferris	Stanley Amdt
Bill Beyers	Deborah Knutson	John Podema	Mike March	Stephen Stanley
Bill Knutson	Denise Pranger	John Ufford	Mike Pattison	Stewart Matthiesen
Bob Bilby	Dennis Leisenmaier	Judy Herring	Mike Tuem	Sue Ambler
Bobbi Lindemulder	Dom Amor	Karen Kinney	Morgan Schneidler	Terry Williams
Bonnie Geers	Don Stuart	Kathy Wolfe	Nick Bratton	Tim Walls
branden Born	Doug McLelland	Kelly Heintz	Norm Abbott	Thomas Payant
Brent Lackey	Elaine Babby	Ken Yocom	Patrick Pierce	Tom Leschine
Brett Swift	Elizabeth Walker	Ken Zwieg	Paul Crane	Tom O'Keefe
Chris Bitter	Elizabeth Weldon	Kolin Higgins	Peter Jackson	troy Hall
Chris Raezer	Heidi Bohan	Krista Bartz	Philip Popoff	Yi Zhao
Cindy Spiry	Heike Mayer	Kristin Kelly	Ralph Svrjcek	

Marina Alberti
Blake Trask
Karis Puruncajas
Michal Russo
Elisabeth Larson
Tracy Fuentes

UERL TEAM

Agenda

8:45-9:30	Presentation
9:30-11:00	Teams develop Conceptual Model
11:00-11:30	Teams Present
11:30-12:00	Discussion
12:00-12:30	Lunch
12:30-1:00	Synthesis Discussion

Today's objective

Develop a shared conceptual model, or framework, that defines the challenges and opportunities that the Snohomish River Basin will face over the next 50 years.

introduction | synthesis | action

Scenarios for Snohomish Basin 2060

Develop an assessment of key ecosystem services in the Snohomish Basin by characterizing the uncertainty associated with alternative future baseline conditions.

.

a 2-year research agenda

Funded by the Bullitt Foundation

introduction | synthesis | action

Snohomish 2060 Scenario project

Project Objective:

- *develop a synthesis of what we know*
- *integrate diverse perspectives*
- *challenge assumptions about the future*
- *inform development of management strategies*

introduction | synthesis | action

78 interviews **3,542 keywords** **36 conceptual models**

developing one shared story

Project TIMELINE

Meetings & *Interviews*

2010

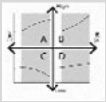
- Winter
- Spring — Kickoff
- Summer — *Driving Forces*
- Fall — **Conceptual Model Workshop**

2011

- Winter — Scenario Logics Workshop; *Scenario Development*
- Spring — *Computational Model*; Integrated Model Workshop
- Summer — *Policy options*
- Fall — Policy Workshop; *Evaluation criteria*

Snohomish 2060 Scenario project

Approach:
Instead of focusing on a single prediction, we use Scenario Planning to explore alternative plausible futures and highlight the risks and opportunities involved in strategic decisions for the basin development.



introduction | synthesis | action

Alternative Future Approaches

probable

Predictive modeling

introduction | synthesis | action

Alternative Future Approaches

desirable

probable

Visioning

Predictive modeling

introduction | synthesis | action

Alternative Future Approaches

Scenario planning

plausible

desirable

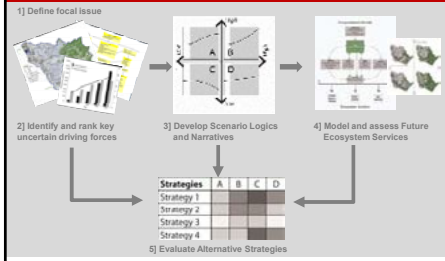
probable

Visioning

Predictive modeling

introduction | synthesis | action

Key elements of scenario planning



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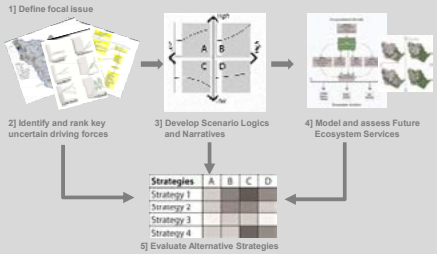
Key elements of scenario planning

1. **Define focal issue**
   - Data and observations
   - Historical documents
   - Expert knowledge
   - Conceptual models

OBJECTIVE:
Develop a shared problem definition

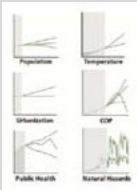
introduction | synthesis | action

Key elements of scenario planning



introduction | synthesis | action

Key elements of scenario planning

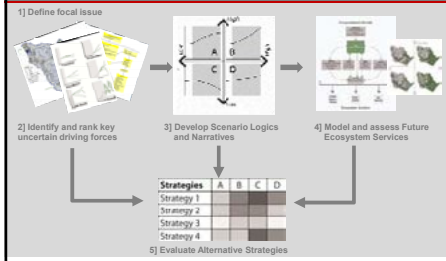


2. **Identify and rank driving forces**
   - Identify key driving force
   - Rank their importance
   - Rank their uncertainty
   - Select most important & uncertain

OBJECTIVE:
To capture the most divergent yet plausible futures

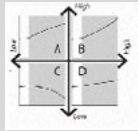
introduction | synthesis | action

Key elements of scenario planning



introduction | synthesis | action

Key elements of scenario planning

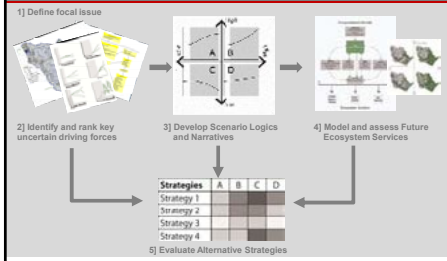


3. **Develop scenario logics and narratives**
   - Selected driving forces create the frames for scenario logics
   - Participants develop the story lines and narratives

OBJECTIVE:
The outcome are four distinct stories of how the future can unfold

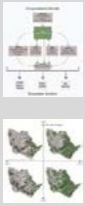
introduction | synthesis | action

Key elements of scenario planning



introduction | synthesis | action

Key elements of scenario planning



4. **Assess Impacts**
   - Identify indicators
   - Apply predictive models
   - Assess impact of future conditions

OBJECTIVE:
The is an assessment of future conditions

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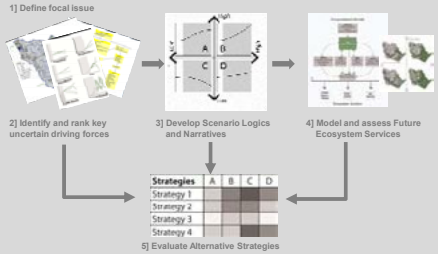
Key elements of scenario planning



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Key elements of scenario planning

5. **Evaluate alternative strategies**

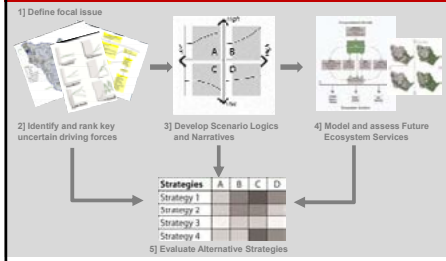
Strategies	A	B	C	D
Strategy 1				
Strategy 2				
Strategy 3				
Strategy 4				

- **Use indicators to evaluate alternative strategies (their efficacy and robustness) under alternative scenarios.**

OBJECTIVE:
The is an evaluation of alternative strategies

introduction | synthesis | action

Key elements of scenario planning



introduction | synthesis | action

The Basin

25 miles Northeast of Seattle
446,476 people
170,000 employees
1,190,000 acres
60% forested

introduction | synthesis | action

Interviews and Focus Groups
Recurrent themes
Keywords
Conceptual Models

SYNTHESIS

develop one shared story through one conceptual model

Rationale:

- Explore different perspectives
- Create a shared view of the problem
- Identify multiple driving forces before selecting the most critical and uncertain
- Explore potential relationships between drivers
- Understand areas of agreement and disagreement.

introduction | synthesis | action

Building a Conceptual Model:
What we have done so far

- Identified over 120 experts representing 100 agencies, departments and Tribes
- Conducted 78 interviews with experts and focus groups
- Recorded 60 + hours of your story

introduction | synthesis | action

Building a Conceptual model:
Survey Instrument

1. ***Stories***
   We asked
   What are some fundamental differences between the Puget Sound in 1960 and today?
   What do you believe will be the fundamental differences between the Basin today and in 2060?
2. ***Keywords and Categories***
   We asked to group and title keywords
3. ***Conceptual models***
   We asked you to link categories with arrows

introduction | synthesis | action

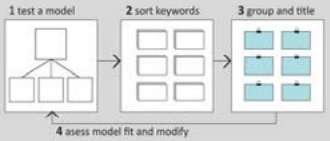
Building a Conceptual model:
What we did*: interviews and focus groups*

Your input:

- Dozens of narrated anecdotes, personal experiences and unique perspectives
- Over 3,000 isolated keywords (post it notes)
- 36 conceptual models

introduction | synthesis | action

Today's Instructions



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Stories: Three recurrent interview themes

1. **Change in industry** *with cascading changes to demography, settlement patterns and natural resources extraction.*
2. **Change in values** *with cascading changes to how we regulate, what we invest in and how we market ourselves*
3. **Environmental Assessment** *with cascading changes to information access, what we bring into decision making (scale and actors) and our risk assessment.*

introduction | synthesis | action

Mines | Timber Mills | Dairy Farms | Boeing | Microsoft | Hobby Farms

CHANGE IN INDUSTRY

City of Smokestacks
Evergreen State
All American City

CHANGE IN VALUES

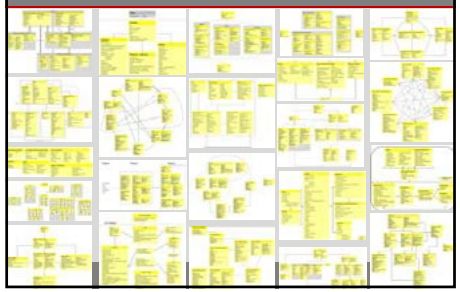
Endless bounty of Pacific Northwest
Earth Day 1970
ESA + Spotted Owl vs Timber
Sprawl and Streams (non-point pollution)
Global warming

ENVIRONMENTAL ASSESSMENT

78 interviews 3,542 keywords 36 conceptual models

developing one shared story

Comparing conceptual models



Comparison of conceptual models

No best model,

just different perspectives

Comparison of Overarching Models

Major differences

- **Groupings:** organized by functionality, sectors, (sub)systems
- **Hierarchical organization:** *i.e. national, regional and local drivers*
- **Representation of actors:** description of agents, their role and action, operating within the basin
- **Magnitude of relationships:** even weight to connections or tight and loose couplings
- **Feedbacks:** Inclusion of the feedbacks between responses, conditions and drivers

introduction | synthesis | action

Comparison of Overarching Models

Major similarities:

- Characterization of the **focal issue(s)**
- Illustration of the **complexity** of the relationships within the system
- Include the interplay between the **human** (social, economic) **and the natural system**

introduction | synthesis | action

Overarching conceptual models

You created 36 unique conceptual models.

Understanding the differences and similarities can help us bridge together one shared model.

Looking at them side by side, we saw 3 overarching conceptual models repeated with distinctive variations and hybridizations:

Networks **Directional** **Dynamic**

introduction | synthesis | action

Networks (Centered on Focal Issue)

abstract

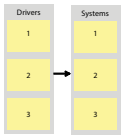
example

Highlights

- At the center is the focal issue, goal or problem
- Everything is connected to everything
- Functional groupings or sectors divide the world

Directional (Driver - Systems)

abstract



example

Highlights

- Drivers force changes in systems
- Systems formulated around either human and natural forms or social, economic and natural systems
- Hierarchy defined by time, space or discipline.

Dynamic (Driver, Impact, Response, Feedback)

abstract

example

Highlights

- Human and natural drivers cause change in the environment
- Impacts are characterized by changes in the patterns and processes we observe
- Human and natural systems respond to impacts
- Feedbacks influence the drivers.

Variations and Hybrids

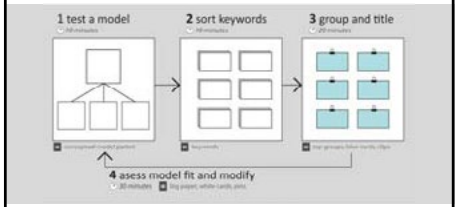
Time: past, current or future activities
Scale: Drivers operate at multiple levels
ie. global, national, regional, local
Uncertainty: knowledge limitations regarding the future
Risk: How uncertainty modifies human behavior and decisions
Assessment: Methods, data and conclusions characterizing current conditions and management
Indirect relationships: Influence modulated through components of the model
ie. impacts of climate change on environment are modulated through human activities

introduction | synthesis | action

Today's exercise: building a shared conceptual model

one shared model

Team Time



introduction | synthesis | action

Roles

Moderator
Note taker
Timekeeper
Illustrator
Presenter

introduction | synthesis | action

What's on your table

- instructions packet
- conceptual model packet
- foam board with:
  - big paper
  - keywords
  - white and blue cards
  - 'jail'

introduction | synthesis | action

Example Final Model

introduction | synthesis | action

select overarching model
sort keywords
title and arrows
develop presentation

TEAM TIME

Conceptual Model Exercise

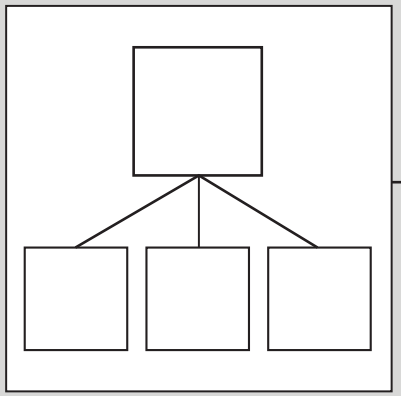
time materials

0 role selection

10 minutes M roles packet

1 test a model

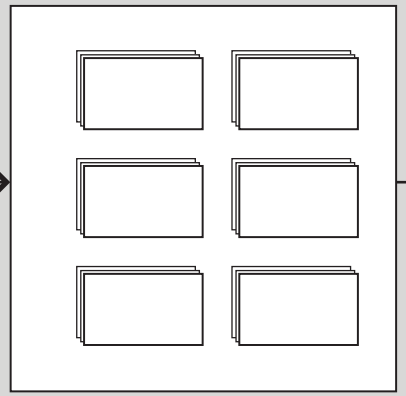
10 minutes



M conceptual model packet

2 sort keywords

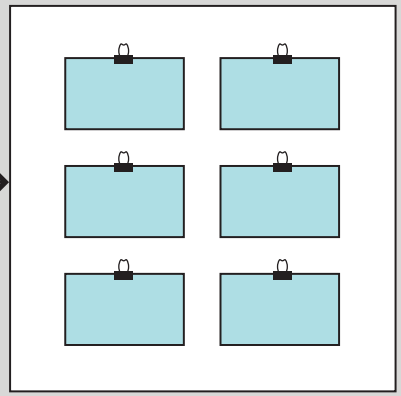
10 minutes



M keywords

3 group and title

20 minutes



M blue cards, clips

4 asess model fit and modify

30 minutes M big paper, white cards, pins

5 prepare presentation

10 minutes

Moderator

Role: Ensure everyone is being respected (heard and incorporated) and the conversation is on point and productive.

Instructions: Start by conducting a round of introductions, if not already done. Ask the table to set some ground rules. We suggest you start with the ones attached and ask team members to add any additional ones.

Tips: Try to keep everyone engaged while also ensuring the conversation focused. We understand that it can be very challenging to participate in the dialogue and to moderate simultaneously. Do make sure that your voice is being heard too and that the resulting model reflects everyone's input, including your own.

Ground Rules

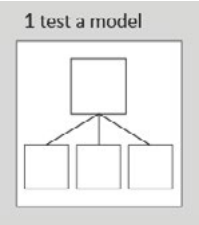
1. Be respectful of your team mates.
2. Do not talk over each other.
3. Contribute constructive criticisms (don't be negative or hurtful)
4. Stay on topic.
5. _____

Suggested moderator instructions and questions

9:30-9:40 Role selection

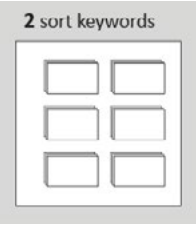
- Team members select and review individual team roles

9:40-9:50 TEST A MODEL



- Ask team:
  1. *Which, if any model they like best and why?*
  2. *Do they have any questions about any particular models?*
  3. *Are there any models that really surprise them (or don't make sense to them)?*
  4. *Do they see the solution as more of a hybrid of multiple models?*
  5. *Which model, or 'hybrid', would they like to test out today?*
- If the majority of people are going with one while 1 or 2 people want another, have the minority representatives explain what they don't like about the 'majority' model that the 'minority' model does better. Ask team:
  1. *Is there is a way to combine the critical components of the two (or three) models together?*
  2. *Is everyone comfortable with testing out their 'hybrid' and checking back in 45 minutes to see how to amend it?*

9:50-10:00 SORT KEYWORDS

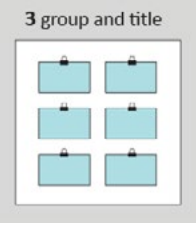


- Give each member a fifth of the pile and ask them to create groups. If they are stuck on a keyword or think it is unimportant they can put it in the 'Jail' pile. If anyone is done early, feel free to look through and sort the Jail pile.

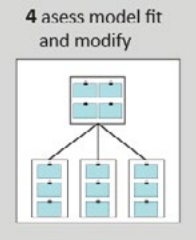
10:00-10:20 GROUP AND TITLE

- As a table, go through team member's groups and have them describe what is in each stack and give each stack a temporary title.
- Have other team members add their groups if similar. Revise titles as appropriate.
- After going around the whole table, have team decide on selection of groups and their titles. Let them know there will be another chance to revise these.

10:20-10:10:50 Assess Fit and Modify



- Have team try to place each group within a box of your overarching conceptual model (that your illustrator drew).
- Discuss:
  1. How well do the groups fit within the boxes?
  2. Does this model make sense? Is this model still the best fit (out of the three)?
  3. How should it be revised? Is there a potential hybrid model? Should we add additional boxes? Variables? Arrows?
  4. Is there anything really missing or misrepresented in the model
- Remind note taker to record successful solutions and unresolved challenges
- Have illustrator revise the conceptual model to incorporate changes.
- Place clipped groups within revised team model. Discuss:
  1. *Are there any obvious subgroups that need to be formed? Sort, clip and provide titles.*
  2. *Are there any important keywords missing from any groups? Fill in new white cards*
  3. *Are there any cards that may belong under multiple headings?* How should they be handled (create duplicates? draw arrows? Create new subgroup?)
- Ask Team:
  1. *Look at final model. Ask everyone what are they most happy with? What would they still like to see resolved?*
- Finalize conceptual model. Have illustrator 'finalize' model by drawing in final lines and boxes, titling everything and then clipping and pinning the keywords in their groups.



10:50-11: 00 Prepare presentation

- Presenter tests out his/her presentation

NOTE TAKER

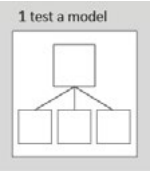
Role: Keep track of discussion, especially ideas that don't fit well into the preconceived products.

Instructions: Shorthand conversation topics and points of disagreement or discussion. You do not need to script verbatim, nor include who said what. Check in with team mates regularly to ensure you captured their ideas correctly. You do not need to duplicate the model or keywords aggregation as the illustrator will take care of this.

Materials: suggested discussion notes, pad of paper, pen and pencil.

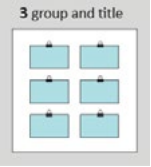
Suggested discussion notes

1. **TEST A MODEL**
   - Benefits and limitations of specific overarching models
   - Questions about particular models
   - Models that surprise, why?
   - Potential hybrid solutions

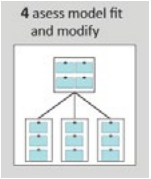


2. **Sort keywords**

3. **GROUP AND TITLE**
   - List merged groupings (*Example: Demography -> Population -> (final) Society)*



4. **ASSESS FIT AND MODIFY**
   - Do the groups fit in the overarching model? Why?
   - Does the model make sense?
   - Model revisions?
   - Anything missing from model? Anything misrepresented?
   - What are people most happy with?
   - What would they still like resolved?



5. **Prepare presentation**

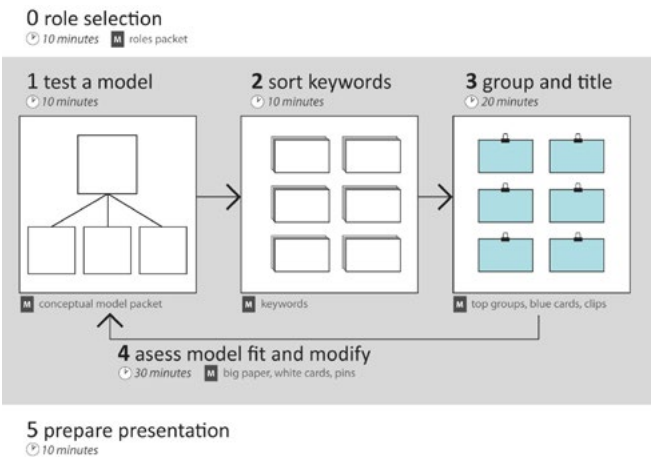
TIME KEEPER

Role: Ensure team accomplishes all 4 steps in the time allocated by keeping track of time and informing team of time how much time is left.

Instructions: Not all workshop teams will follow the exact same time table. Some teams will take longer to accomplish step 1 and then breeze through the rest, others will follow exactly the schedule suggestion we have provided. It is up to you to decide whether you want to adhere strictly to the schedule or to let your team deviate as need be. When you feel it is time to move on, please be respectful of whoever is talking, wait until they are done (or paused) and let them know it is time to move on to the next task. If the discussion lingers, reiterate how much time is left and what tasks still need to be accomplished.

Materials:

> ***Available time piece:*** if you do not have a reliable time piece available to you, raise your hand and we will supply you with one. In addition, there is a countdown projected on the northern wall of the room (it will reach zero at 11:00am)
>
> ***Schedule suggestion:***

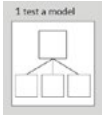


ILLUSTRATOR

Role: Assist team in creating a legible and coherent model by drawing, writing, stacking, clipping, etc (you can let others draw too).

Materials: Foam board, marker, pen, scratch paper, 120 keywords, 20 blank white flashcards, 20 blank blue flashcards, binder clips, pins.

Suggested Instructions: *Draw conceptual model (f*or a view of what the finished model looks like see attached photo, or look at the prototype at the front of the room (by speaker)). Remember to check with teammates often to ensure you are representing their ideas accurately.



1. TEST A MODEL

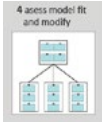
Sketch the overarching model / hybrid model your team selects; draw in boxes, arrows and titles as necessary. Do not just duplicate what's on the template, but rather incorporate specific team ideas.

2. Sort keywords

3. GROUP AND TITLE

Write group titles on blue cards. As new group titles emerge, just cross out the old ones and write the new on the same card.

Clip together each group.



4. ASSESS FIT AND MODIFY

Revise model to incorporate additional boxes, names, arrows and variables.

Ask team members if you are representing their ideas correctly.

5. PREPARE PRESENTATION

Redraw model (if necessary) to incorporate all final changes

Pin to foam board

Rewrite (if necessary) blue group cards

Pin clips inside appropriate boxes

Stand on easel

PRESENTER

Role: Succinctly represent your team's model to the rest of the workshop.

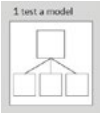
Instructions: Review the 'template' and example narrative (included below). Please keep in mind your will have 5 minutes to present a focused account of your team's model. While participating in the development of the model, keep notes on critical ideas you will want to present. Specifically, highlight unique features and unresolved challenges. During the last ten minutes of the exercise fill in the template and check in with your team mates to ensure you are representing the model accurately. When presenting, focus on the overall narrative of your model and critical features, see example below. Please note, to ensure all teams have time to present; we will stop you after 5 minutes.

Template: *[things to be mindful of when preparing your presentation]*

0. ROLE SELECTION

Your team: "Name" and team members

1. TEST A MODEL



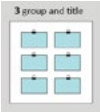
Selected overarching model

Major modifications / hybridization of overarching model

2. Sort keywords
3. GROUP AND TITLE

Titles of groupings / sub-groupings

If important to explain overall story, name a few keywords in each group or special groups



If important, location of groupings / proximity to other groups

4. Assess Fit and Modify

Description of arrows (directionality, importance, feedbacks, positive / negative influence)

Special features / variations / additional dimensions etc. *For example, adding uncertainty as an overarching driver, or ecosystem services as an output.*

Highlights

one or two important strengths of the model that you want to underscore

one unresolved challenge, that you hope the final shared conceptual model could address better.

Example: We are Team A and include Anna, John, Frank and Elizabeth. Our model is based largely off the 'directional' model but add in a third dimension of time. Our global drivers are climate change, technology and the economy and they influence regional drivers including human perceptions, demographics, regulations, and natural resources. These regional drivers influence more localized systems including development [market and form], timber, agriculture, hydrology, ecosystem functions [biodiversity and habitat] preferences and values, funding availability, and social services. As you can see, as you move down the scale becomes smaller (global to local). Not well represented here is the third dimension, of time, so the 'deeper' you look into the page the further back in time you go. And these stories and legacies influence the picture of the system today. The arrows pushing down are the most influential but arrows going up reflect cumulative feedbacks. The interactions between individual systems and drivers are also important, especially at specific time and spatial scales. We all like that the model clearly represents time and space and the hierarchy of drivers. What we wish we had more time to explore is the finer interactions between drivers and systems, those elements that don't neatly fit into one box or another. For example, the issue of salmon and agriculture coexisting in floodplains brings together several boxes in a unique way that isn't immediately obvious from just looking at the model, but is really important to us. It's almost like if we want to represent special issues or decision points along both the time and space continuum in an elevated manner.

Syntheses

At the Conceptual Model Workshop, Science Team members provided aggregate models and guiding directives on what the shared conceptual model should include and how it should be represented. Moving forward, we took the 6 team models and combined them into one shared model.

The most significant challenge highlighted during the workshop was balancing a dynamic model including various relationships and feedbacks with a parsimonious and clear model that can be communicated effectively.

Further challenges included how to traverse scales, how to validate the model and how to reflect uncertainty and risk. In addition, participants wanted the model to express the role of various stakeholders while highlighting the decision making process including assessments, strategies and current gaps. A process related challenge was how will the UERL will interpret team models and incorporate various levels of feedback from participants.

Workshop Directives (for building a model)

1. Have **clarity**: Easily understood and communicated. Well organized. Clear purpose. Captured at a glance. Transparent.

2. Be **parsimonious**: Balance complexity and simplicity (of relationships)

3. Traverse **scale**: Be relevant at local scale. Include exogenous factors. Keep Basin in mind.

4. Reflect **actors**: Stakeholders and decision makers should see themselves in the model

5. Be **dynamic**: Relationships occur on many levels. Not linear or mechanistic. Show feedbacks and impacts. Reflect interdependence and linkages. Ordered processes and indirect relationships should be traceable.

6. Cite **validation**: Include references. Claims should be validated consistently. Multiple audiences and inputs. Defend relationships and feasibility.

7. Quantify **impacts**: Depict strong relationships. Express multiple relationships. Incorporate feedbacks. Show relative importance of drivers. Evaluation criteria should be explicit.

8. Highlight **uncertainty**: Focus on uncertainty. Incorporate risks and resilience.

9. Link to **measurements**: Characterization, indicators, metrics or system assessment should be expressed.

10. Express **decision making**: Highlight gaps in knowledge and strategies. Reflect who is decision makers. Linkages to goals and absence of policy.

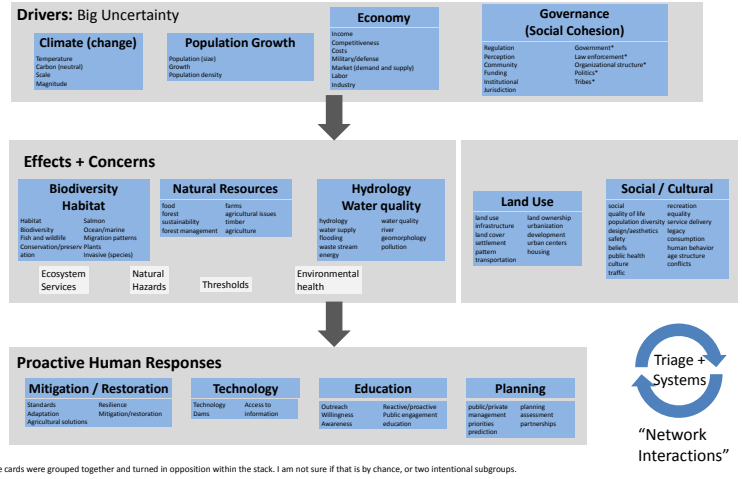
11. Incorporate **time**: Legacies and baselines inform future condition. Functional considerations, like time, influence model. Legacies inform econometric model.

12. Be **organized**: Add systems between drivers and impacts. Divide by environmental, social and economic groups or human / natural. Include governance as driver. Include both important and 'stray' drivers. Include social and human dimensions, economic (growth, development, commercial, industry) and legal constraints

13. Synthesize **intersections**: The combination of multiple drivers, systems and / or impacts is what makes this study compelling

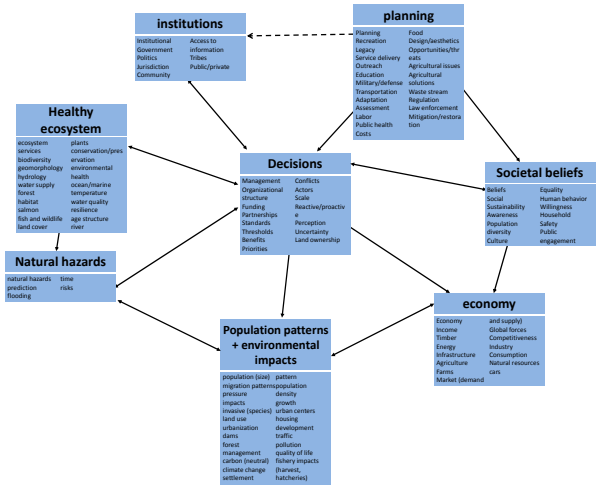
6 Team Conceptual Models

Team 1

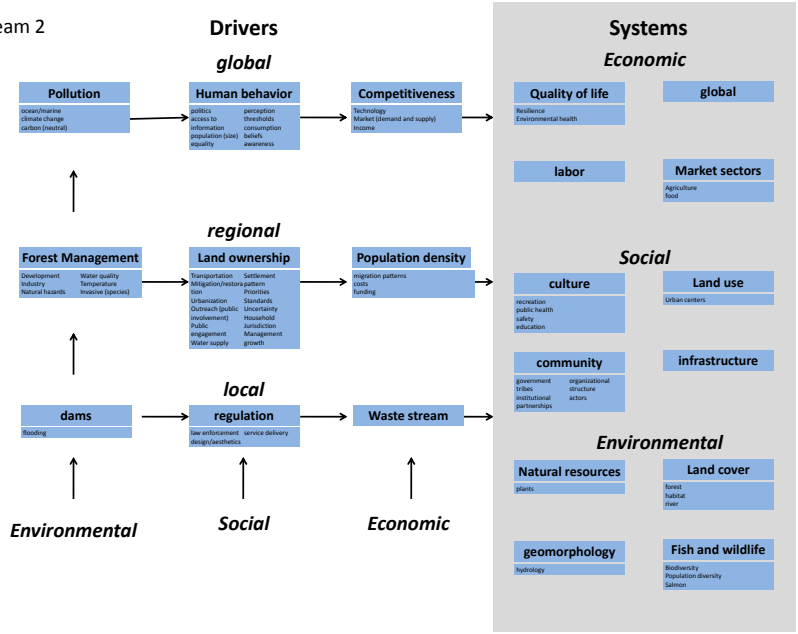


* These cards were grouped together and turned in opposition within the stack. I am not sure if that is by chance, or two intentional subgroups.

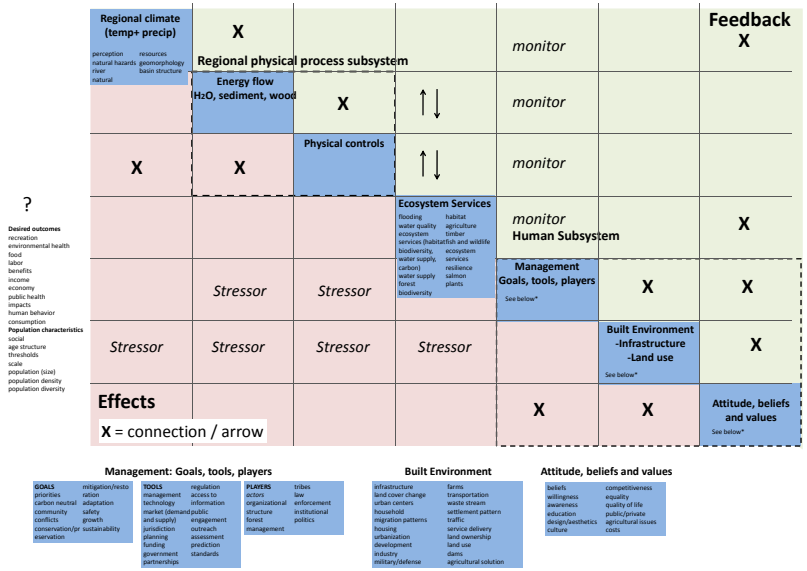
Team 3



Team 2

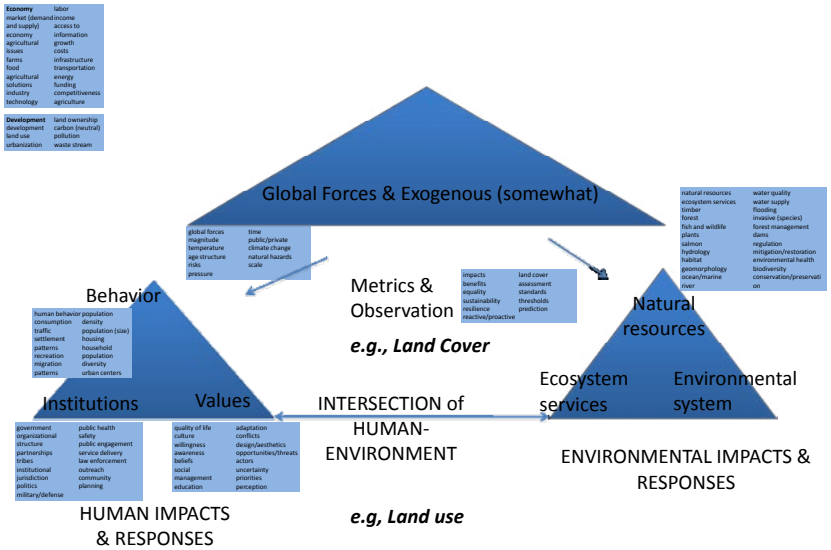


Team 4

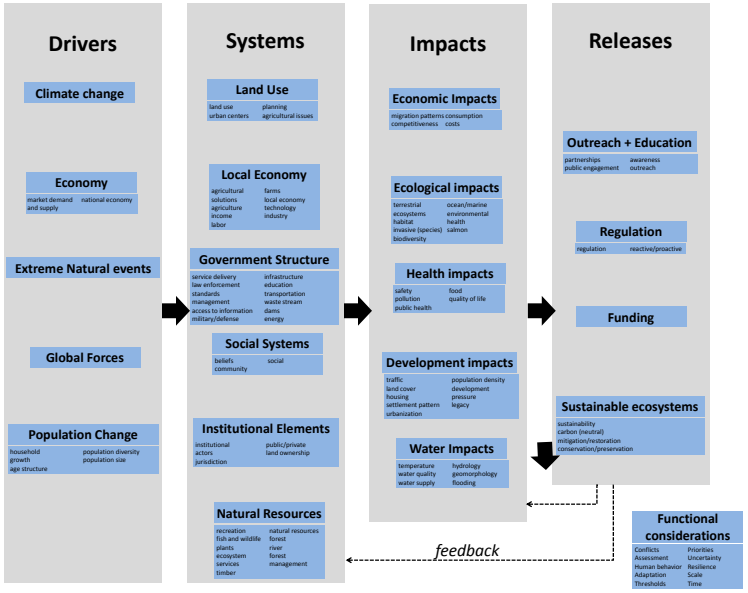


Team 5

?



Team 6



List of 14 Drivers, their overarching categories and sub-drivers

HUMAN
Behavior
- Adaptation
- Consumption
- Interaction with nature
- Investments

Demography
- Characteristics
- Growth
- Health

Values
- Belief
- Preference
- Perception

INSTITUTIONS
- Economy
- Funding
- Industry
- Labor
- Market
- Wealth

Governance
- Politics
- Planning and Regulation
- Services

Knowledge
- Innovation
- Science
- Outreach

Social Institutions
- Community
- Culture
- Tribes
- The World
- Public engagement
- Organizations

BUILT ENVIRONMENT
Development
- Character
- Form
- Land Use
- Municipalities
- Real Estate

Infrastructure
- Energy
- Flood Mitigation
- Transportation
- Waste stream
- Water provision

Resource Management
- Agriculture
- Forestry
- Recreation and Fishing

NATURAL ENVIRONMENT
Biogeochemistry
- Chemicals and Nutrients
- Landscape Movement
- Seismic
- Soils and Minerals

Climate
- Air Quality
- Carbon
- Natural Cycles
- Global Change
- Ocean Acidification
- Precipitation
- Sea Level Rise
- Snow Pack
- Temperature

Hydrology
- Flooding
- Groundwater
- Hydrograph
- Morphology
- Stormwater
- The Watershed
- Water Quality
- Water Quantity

Terrestrial Biosphere
- Biodiversity
- Estuaries
- Fire
- Forest Habitat
- Pests and Invasive Species
- Salmon and Stream Habitat

Driving Forces Working Papers

Working documents are internal reports created through the scenario development process. Working documents are the emergent and collaborative product of interviews with the Science Team. Working documents are living documents, meaning they are constantly being updated and revised through input.

Driving forces, or drivers, are the main ingredients of scenario planning, describing factors or phenomena which alter the future trajectory in significant ways. Examples of driving forces include demographics, climate change and governance. Identifying and researching driving forces allows us to be explicit about the assumptions we make under each scenario.

On pages A6.42-63 we include emergent definitions and themes for the 14 driving forces as well as a sampling of published data describing current conditions, and past and future trends. In the following sections we further describe Science Team input describing the ***relationships*** between drivers, as well as the ***relevance, importance*** and ***uncertainty*** of each driver in the basin.

Behavior

Behavior represent individual action including physical alterations, interactions (with people and the environment) and where we put our money (consumption and investment). Social or group action is described under the overarching organization (ie economy, government, Tribes, community).

Adaptation is the ability to adjust to new information and experiences.

Consumption refers to the using up of goods and services by consumers. Consumption is also viewed as a basically subjective phenomenon, with individual utility, or satisfaction, assuming primary importance.

Human environmental interaction refers to how we affect and are affected by the environment, and also how we disturb the natural environment.

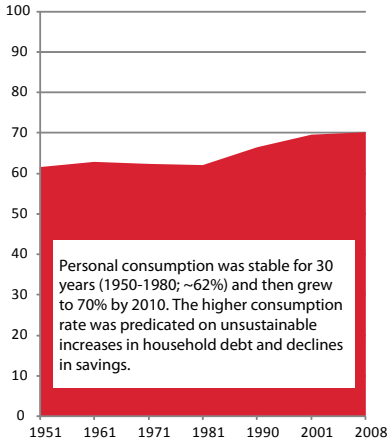
An **investment** involves the choice by an individual or an organization, to commit money to the purchase of assets for the possibility of generating returns over a period of time, but with the awareness of a certain level of risk. It is related to saving or deferring consumption.

One common measure of consumption is personal consumption expenditures (PCE) which includes new goods and services purchased by individuals (measured by US Dept of Commerce) the second is Consumer expenditure survey (measured by the Bureau of Labor Statistics) which are diaries of frequently purchased items and regularly billed items collected from sample households .

While the last decade was termed an 'orgy of consumption' the Brookings Institute predicts the US will settle into a new era of lower consumption as a share of GDP after the economic crisis of '07-'09. Businesses will shift towards more exports and abroad countries will shift towards domestic consumption. The uncertainty lies not in the direction of change (towards lower $ in consumption) but rather in the magnitude.

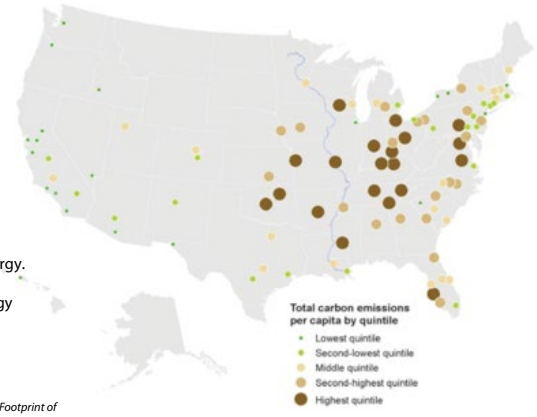
Galston, W.A. 09.01.08. The "New Normal" For the U.S. Economy: What Will It Be? The Brookings Institute.

US Personal consumption as a % of GDP



Smallest Carbon Footprints (out of 100 metro areas)

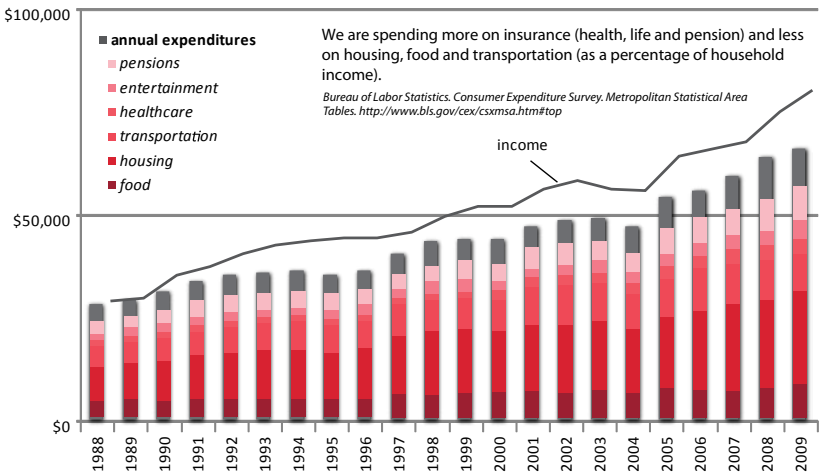
1	Honolulu, HI
2	Los Angeles, CA
3	Portland, OR
4	New YorK, NY
5	Boise City, ID
6	Seattle, WA
7	San Jose, CA
8	San Francisco, CA
9	El Paso, TX
10	San Diego, CA



Seattle has a low carbon footprint due its reliance on hydropower energy. Per capita carbon emissions from transportation and residential energy use for 2005 were 1.5 metric tons (a decrease of 4.4% from 2000, a time when the nation's footprint rose by 2.2%).

Sarzynski, A. et al. 05.29.08. Shrinking the Carbon Footprint of Metropolitan America. The Brookings Institute. http://www.brookings.edu/~/media/Files/rc/reports/2008/05_carbon_footprint_sarzynski/carbonfootprint_report.pdf

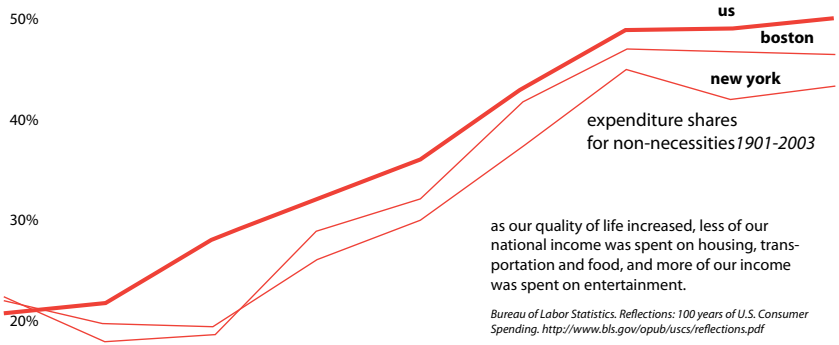
Consumer Expenditure Survey - Seattle Metropolitan Area 1988-2009



We are spending more on insurance (health, life and pension) and less on housing, food and transportation (as a percentage of household income).

Bureau of Labor Statistics. Consumer Expenditure Survey. Metropolitan Statistical Area Tables. http://www.bls.gov/cex/csxmsa.htm#top

Behavior *published data*



as our quality of life increased, less of our national income was spent on housing, transportation and food, and more of our income was spent on entertainment.

Bureau of Labor Statistics. Reflections: 100 years of U.S. Consumer Spending. http://www.bls.gov/opub/uscs/reflections.pdf

Behavior *published data*

Demography

Demography is the study of human populations including the size, structure and distribution of the population, and changes associated with birth, migration, aging and death.

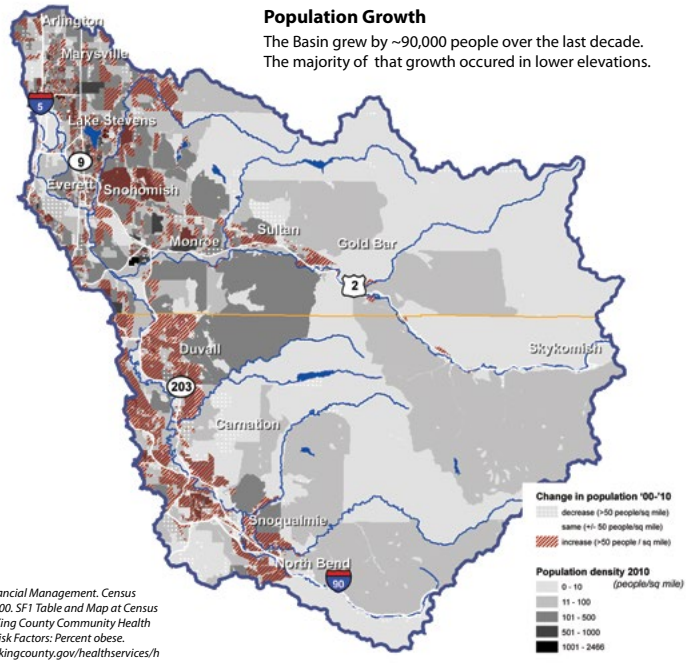
Characteristics refer to attributes that describe the population including age structure, diversity, educational attainment, households and income.

Health is the state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Public health is the study of prevention through surveillance of cases and promotion of healthy behaviors .

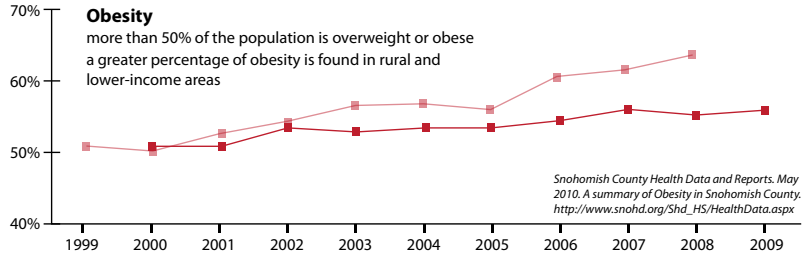
Growth refers to the change in the number of people residing in the Basin. Population growth stems from both migration (in and out) and natural increase (birth rates and mortality).

Population Growth

The Basin grew by ~90,000 people over the last decade. The majority of that growth occured in lower elevations.



Office of Financial Management. Census 2010 and 2000. SF1 Table and Map at Census Block level. King County Community Health Indicators. Risk Factors: Percent obese. http://www.kingcounty.gov/healthservices/health/data/chi2009.aspx



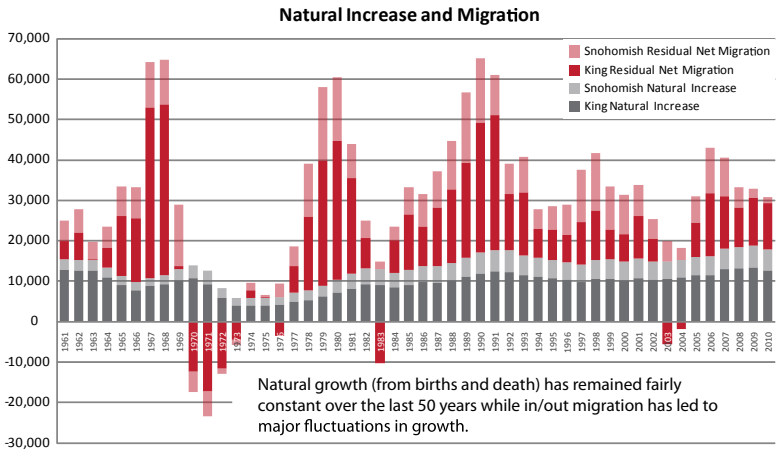
Obesity

more than 50% of the population is overweight or obese

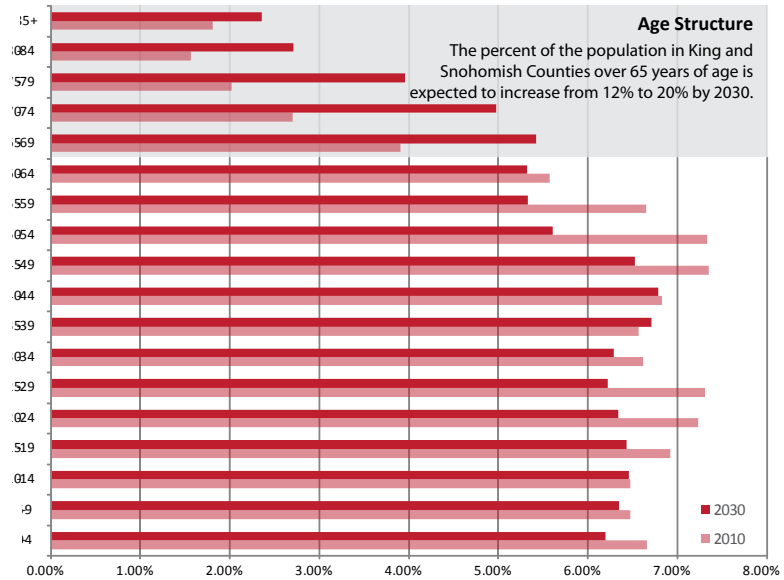
a greater percentage of obesity is found in rural and lower-income areas

Snohomish County Health Data and Reports. May 2010. A summary of Obesity in Snohomish County. http://www.snohd.org/Shd_HS/HealthData.aspx

Demography *published data*



Office of Financial Management. July 2010. Migration: Population, population change, births, deaths and residual migration 1960 to 2010 by county by year.



Office of Financial Management. Projections by age, sex and race for the State of Washington: 2000-2030.

Demography *published data*

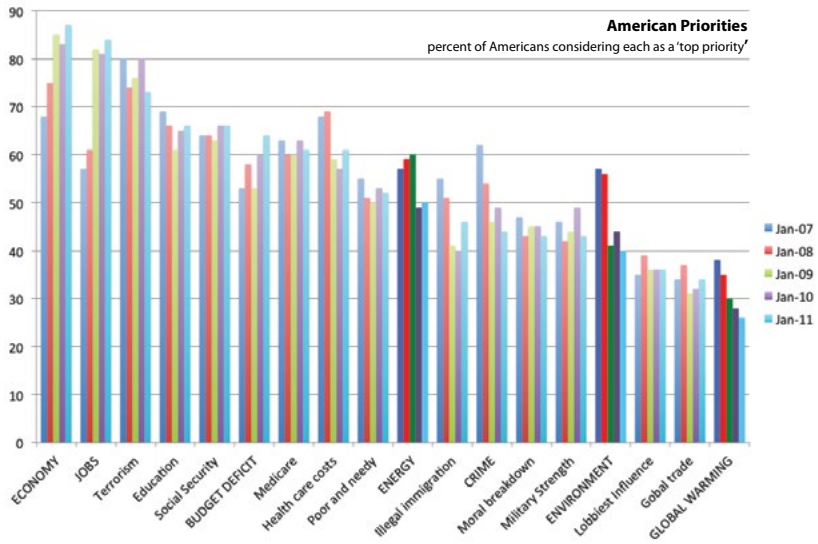
Values

Values are broad preferences concerning appropriate courses of action or outcomes. A value system is a set of subjective personal, varying across individuals and cultures. Values are generally aligned with beliefs and tend to influence attitudes and behavior.

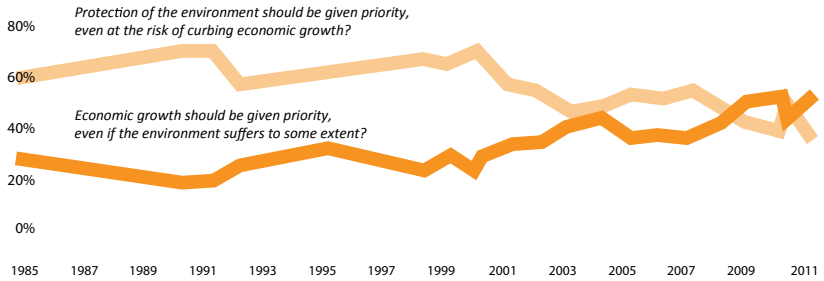
Belief is the psychological state in which an individual holds a proposition or premise to be true. Beliefs are described as ethics, consciousness, respect and faith.

Preferences reflect the priorities a population places on certain values. Closely associated with preferences are comments on quality of life and a willingness to act on certain values.

Perception is the process by which an organism attains awareness or understanding of its environment. Perceptions lead to what an individual or population perceives as acceptable or ideas about how things should be.



ecoAmerica. 2011. Trends in America's Climate and Environmental Attitudes: 2011: Summary results from recent major polls: Pew Research Center, Gallup, Rasmussen, Yale Project on Climate Change Communication.



ecoAmerica. 2011

Environmental Concerns
What are the environmental issues of our time (2011)

	Great deal/ Fair amount	Not much/ Not at all
Contamination of soil and water by toxic waste	79%	20%
Pollution of rivers, lakes, and reservoirs	79%	22%
Pollution of drinking water	77%	23%
Maintenance of the nation's supply of fresh water for household needs	75%	24%
Air pollution	72%	28%
Extinction of plant and animal species	64%	36%
The loss of tropical rain forests	63%	35%
Urban sprawl and loss of open spaces	57%	42%
Global warming	51%	48%

ecoAmerica. 2011

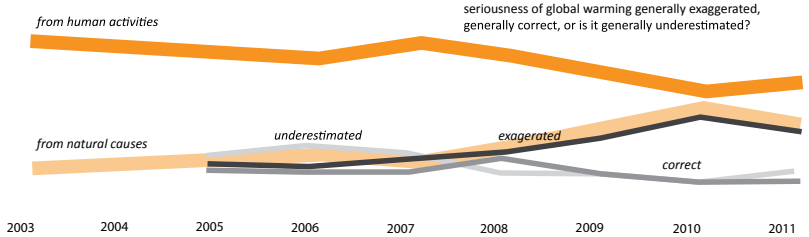
Perceptions

Is Climate Change man made? or natural?

Historically about 60% of Americans have believed that temperature changes on the planet are man-made. Over the past two years this has declined to just about half of the population.

Is Climate Change exagerated or underestimated?

Thinking about what is said in the news, in your view is the seriousness of global warming generally exaggerated, generally correct, or is it generally underestimated?



ecoAmerica. 2011

Values *published data*

Values *published data*

Economy

Economy refers to the production, distribution and consumption of goods and services. Economic growth is equated with profits, quantified by dollars earned.

Funding refers to money made available by an organization or government to support a particular purpose.

Industry sectors represent the four segments of the economy, including the the primary sector (raw material extraction like mining and farming), secondary sector (refining, construction and manufacturing), tertiary sector (services like law and medicine and the distribution of manufactured goods) and quaternary sector (knowledge industry focusing on technological research, design and development such as computer programming and biochemistry).

Labor, or the labor force, refers to the number of people employed or seeking employment.

Market, or market value, refers to the decision and pricing of goods and services guided solely by the aggregate interaction of a population and businesses. The lack of a market refers to the lack of consumer demand, or low valuation, for a product or service.

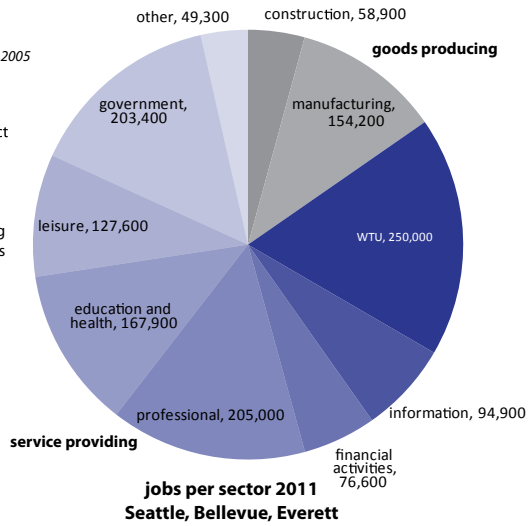
Wealth is the abundance of valuable possessions or money, or the state of being rich.

Employment

1,747,611 jobs *in Central Puget Sound, 2005*
77,255 *in Everett (4.4%)*

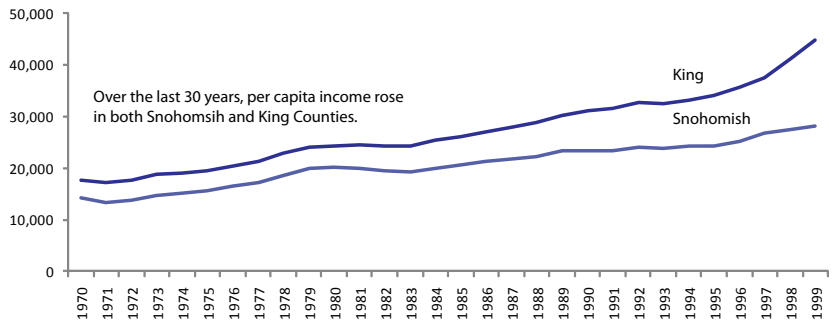
Regional employment during the 2000-2008 period reflects the impact of the 2001 recession. Aerospace manufacturing was among the sectors with dramatic employment declines, and subsequent job recovery. Paine Field (Manufacturing Industrial Center) lost 19% of its jobs between 2000 and 2004, and rebounded by 45.6% by 2008.

PSRC trends



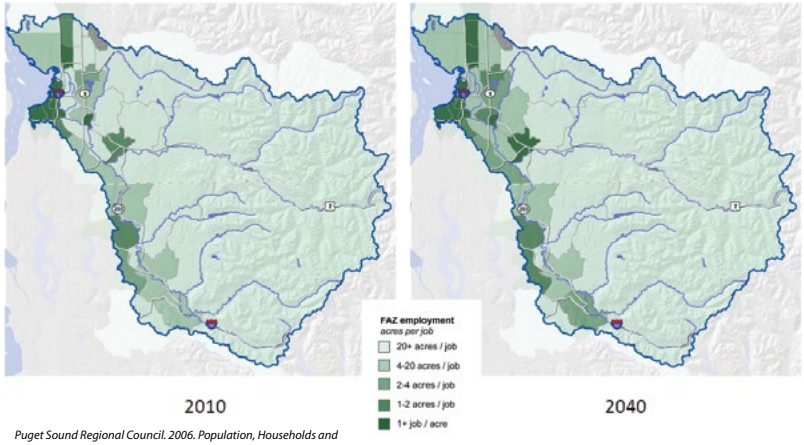
WA State Employment Security Department. March 2011. Seattle-Bellevue-Everett MD Labor Area Summary. Vol 2011. #3.

Annual per Capita Income *in '99dollars*



Puget Sound Regional Council. October 2001. Puget Sound Trends: Per Capita and Total Personal Income, 1970-1999.

Economy *published data*



Puget Sound Regional Council. 2006. Population, Households and Employment Forecasts.

PUGET SOUND AND U.S. GROWTH RATES

Average Annual Percent Change

	1970-01	2001-40
PUGET SOUND		
Employment* (thous.)	2.8	1.4
Goods producing	1.2	1.0
Construction	3.6	2.3
Manufacturing	0.4	-0.2
Service producing	3.2	1.5
Personal income (mils. $00)	4.1	3.3
Per capita income ($00)	2.4	2.2
Consumer price index (82-84=1.000)	5.0	2.7
Population, July 1	1.7	1.1
UNITED STATES		
Gross Domestic Product (bils. $00)	3.1	2.9
Employment* (mils.)	1.8	1.0
Goods producing	0.0	0.8
Construction	1.9	2.5
Manufacturing	-0.6	-0.6
Service producing	2.4	1.0
Personal income (bils. $00)	3.1	3.1
Per capita income ($00)	2.0	2.3
Consumer price index (82-84=1.000)	4.8	2.6
Population, July 1	1.1	0.8

*Wage and salary employment excluding agricultural workers and the military.

Puget Sound Regional Council. Puget Sound Economic and Demographic Forecast. February 2006.

Economy *published data*

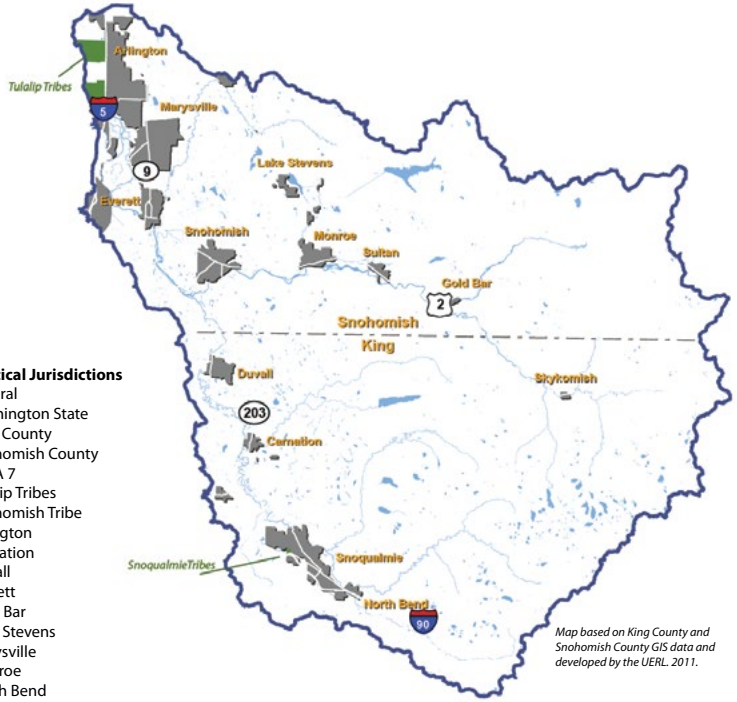
Governance

The World Bank describes governance as the rules and rulers, and the various processes by which they are selected, defined and linked together.

Politics is the process by which groups of people make collective decisions. For this project, politics refers mainly to the agencies, organization, elected officials, partnerships and jurisdictions involved in decision making.

Planning and regulation refers to actions and decision carried out by government agencies towards meeting stated objectives. While regulations can compel or prohibit behaviors, planning sets out guidelines for how to achieve success by describing what the future should look like.

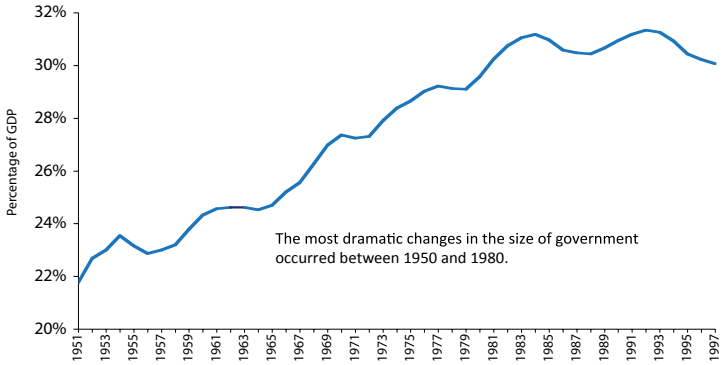
Services refers to those benefits that facilitate the health and safety of a population, including but not limited to social services, education, fire control, hospitals, police, parks and recreation. Provision of utilities, including waste removal, water distribution, energy and transportation is included under the heading of 'infrastructure'.



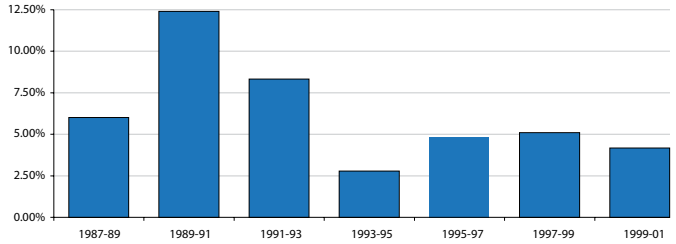
Political Jurisdictions
Federal
Washington State
King County
Snohomish County
WRIA 7
Tulalip Tribes
Snohomish Tribe
Arlington
Carnation
Duvall
Everett
Gold Bar
Lake Stevens
Marysville
Monroe
North Bend
Skykomish
Snohomsih
Snoqualmie
Sultan

Governance *published data*

Total Federal, State, and Local Government spending as a percentage of GDP, FY 1951-1997



Real Growth in State General Fund Expenditures



Strong Economy, Increased Spending on Health Care and Education

Smaller growth in government spending due to economic slow-down

Economy recovers, Initiative 601 takes effect, slowdown in spending, tax reductions

Office of Financial Management. August 1999. Changing the rules of the game: WA Fiscal Developments before and after initiatives 601.

Governance *published data*

Knowledge

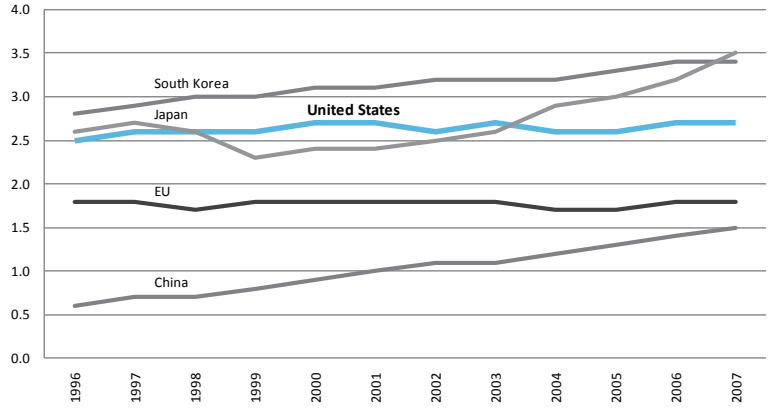
Knowledge represents the sum body of information (or facts) acquired by a population. For the purposes of this project knwledge is described in terms of the passage of knowledge through teaching or outreach, gaining new knowledge through research, science, or exploration, and innovation as the physical culmination of new ideas.

Innovation refers to the creation of new thoughts, products, processes and organization resulting from study and experimentation.

Science refers to the intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through observation and experiment.

Outreach is an effort by individuals in an organization or group to connect its ideas or practices to the efforts of other organizations, groups, specific audiences or the general public. Outreach often takes on an educational component (i.e., the dissemination of ideas or teaching).

R&D expenditures as share of economic output of selected countries: 1996-2007



National Science Board. January 2010. Science and Engineering Indicators: 2010. R&D expenditures as share of economic output of selected countries: 1996–2007.

Research and Development Funds

Washington Innovation Statistics
4.85% of Washington's GDP is in Research and Development ($15,061mil) ranking the State in fourth place nationally.

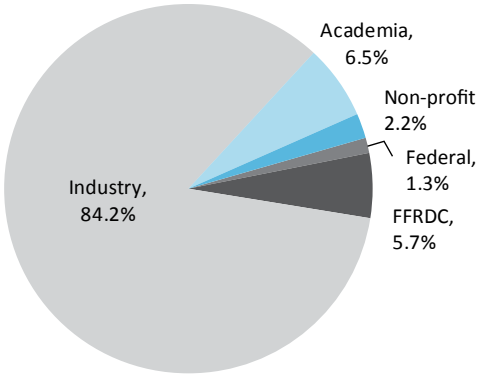
The far majority of that money stems from industry.

53 Patents per 100,000 people (210% of US)

$195 NSF funding to Universities (per capita, 2005; 300.6% of US)

$300 Venture capital funding (per capita, 2006; 341.4% of US)

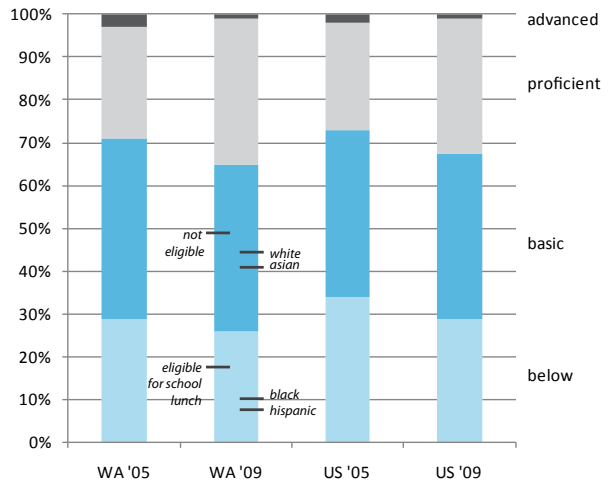
6.7 Research and Development workers per 1,000 workers (163.6% of US)



Brookings Institute. 2005. MetroNation Profile: Puget Sound Region.

Knowledge *published data*

4th Grade Science Proficiency



Science Statistics - Washington State

In 2009, the average score of fourth-grade students in Washington was 151. This was not significantly different from the average score of 149 for public school students in the nation.
In 2009, Black students had an average score that was 34 points lower than White students. Hispanic students had an average score that was 35 points lower than White students. Students who were eligible for free/reduced-price school lunch, an indicator of low family income, had an average score that was 29 points lower than students who were not eligible for free/reduced-price school lunch. While these performance gaps are not significantly different from the nation, they do indicate prioritized social reform challenges.

Higher Education Attainment

35.8% of adults with bachelors degree (131.8% of US)

12.3 with graduate degree (123% of US)

52.2% recent in-movers with bachelor's degrees (138% of US)

Brookings Institute. 2005. MetroNation Profile: Puget Sound Region.

Knowledge *published data*

Social Institutions

In addition to economy, governance and knowledge, social institutions represent groups that share some mental concept of right and wrong, order and relationships, and patterns of good (positive values). Institutions, by definition, are resistant to change and are there to support the current status.

Community, in this context, refers to a social group with shared resources or beliefs.

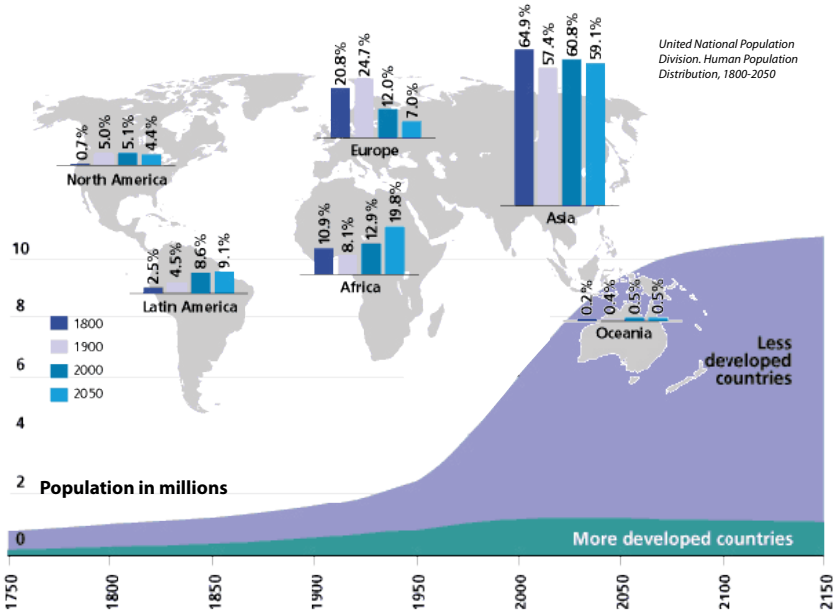
The term **culture**, in this context, refers to the anthropologically distinct ways that different people living in different physical or socio-economic areas represent and share their experiences. Further, culture refers to those arts and humanities associated with 'good taste'.

Organizations are a social arrangement to distribute tasks for a collective goal. In this context, organizations refers to non-governmental organizations, international organizations, charities, not-for-profit corporations, partnerships, cooperatives, and universities. In general, organization can also refer to governmental and for-profit organizations; these can be found under 'politics' and 'industry' respectively.

Native American tribes refer to any extant or historical tribe, band, nation, or other group or community of Indigenous peoples in the United States. **Tribes** are often associated with territory in the form of a reservation. The Snohomish Basin is home to both the Tulalip Tribes and Snoqualmie Tribes.

The **world** refers to international affairs, other countries, and global changes.

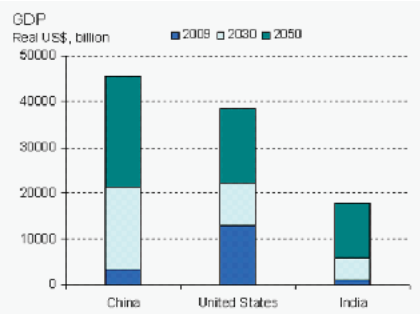
Public engagement, or political will, entails the combination of three factors: opinion, intensity and saliency. Opinions are shaped by awareness of topics and sway of issue formation. Intensity is shaped by how much we care about something. Lastly, saliency, the connection to public affairs, the relevance to mass population is necessary.



United National Population Division. Human Population Distribution, 1800-2050

United Nations Population Reference Bureau. World Population Growth, 1750-2150.

China, India, and the United States will emerge as the world's three largest economies in 2050. Their total GDP, in real U.S. dollar terms, will be over 70 percent more than that of the other G20 countries combined. In China and India alone, GDP is predicted to increase by nearly $60 trillion—the current world GDP—but the wide disparity in per capita GDP among these three will persist.



Dadush, U. and B. Stancil. 11.19.2009. The G20 in 2050. International Economic Bulletin: Weekly economic commentary and analysis from the Global Think Tank.

Social Institutions *published data*

Chronology of Tulalip History

1792 Snohomish tribes meet explorer Captain George Vancouver.
1820 Fur trade routes established though Puget Sound region.
1833 Possible date of Camano Head falling and burying a Snohomish village below it, causing a large number of deaths.
1841 Captain Charles Wilkes is the first American to chart the waters of Puget Sound.
1842 Settlers start to move into the Puget Sound region.
1848 The Oregon Territory is created with the provision that Indian lands and property cannot be taken without Indian consent.
1853 The Washington Territory is created with the provision that the US has the right to regulate Indian land, property and other rights.
1853 Several Americans build a sawmill and homesteads on Tulalip Bay.
1855 On January 22nd, Governor Isaac Stevens concludes the Treaty of Point Elliott at Mukilteo, which establishes the Tulalip Reservation.
1859 Treaty ratified by U.S. Congress, and soon, the Tribes that agreed to the treaty begin to settle in the vicinity of Tulalip Bay.
1861 Snohomish County is created.
1863 Father Chirouse opens a new school on the Tulalip Reservation.
1868 Sisters of Charity of Montreal begin the education of Indian girls on the Tulalip Reservation.
1869 Father Chirouse receives a contract with U.S. Government to support the Tulalip Mission School of St. Anne.
1875 Congress extends the homestead laws to Indians willing to abandon their tribal affiliation.
1875 Canning process improves and a large commercial fishery begins to develop.
1883 John Slocum founds the Indian Shaker Church near Olympia, a form of religion that some Tulalip people will join.
1884 Allotment of Tulalip Reservation begins.
1887 Congress passes the General Allotment Act, which allots land on reservations to individual Indians.
1889 Washington becomes a state.
1891 Seattle and Montana Railway is completed, this rail service is the first in the vicinity of the Tulalip Reservation.
1902 A new school is built on Tulalip Reservation, called the Tulalip Indian Boarding School.
1915 A Tulalip Indian is jailed for hunting on contested reservation land.
1912 First Tulalip Treaty Days celebration is held through the efforts of William Shelton to preserve the songs and dances.
1916 Destruction of fish habitat begins through logging, dredging, agriculture, industry and the creation of dams and developments.
1924 Indian Citizenship Act passed by Congress. Indians become citizens and can now vote.
1924 Steelhead becomes a game fish.
1928 The Problem of Indian Administration is presented and is highly critical of U.S. Indian policy
1930 Beginning of fish ladders being installed on dams.
1933 Steelhead becomes a sport fish.
1934 Indian Reorganization Act is passed by Congress, enabling tribes to organize in local self government and elect leaders.
1935 Indians of the Tulalip Reservation write a constitution and vote to approve it.
1936 The secretary of the Interior approves the Tulalip Constitution, and Tulalips elect their first Board of Directors.
1939 Tulalips begin to lease land for homes on Tulalip Bay.
1946 Congress creates Indian Claims Commission to settle disputes between Indians and the Federal Government.
1950 Tulalip Agency of the BIA is moved from Tulalip Reservation and the new Western Agency is located in Everett, Washington.
1973 Washington Department of Game gives Indians the right to fish steelhead.
1974 The Boldt decision gives Washington Indian Tribes the right to co-manage fishing resources and take 50% of the harvestable fish.
1975 The Indian Self-Determination and Education Assistance Act is passed
1978 The American Indian Religious Freedom Act passed, which protects the traditional religious practices of Native Americans.
1979 U.S. Supreme Court upholds the 1974 decision of U.S. v. Washington (the Boldt decision).
1979 Tulalip revives the First Salmon Ceremony, which continues to be held annually.
1985 Pacific Salmon Treaty signed between the United States and Canada.
1985 Puget Sound Salmon Management Plan adopted by the Washington Department of Fisheries and the Indian Tribes.
1985 Puget Sound Water Quality Authority is created by Gov. Booth Gardner, with Tribal representatives being appointed to it.
1990 Native American Graves Protection and Repatriation Act passed by U.S. Congress.

Tulalip Tribes Website

Social Institutions *published data*

Development

Development describes the settlement pattern on the landscape and changes in land use and in land cover.

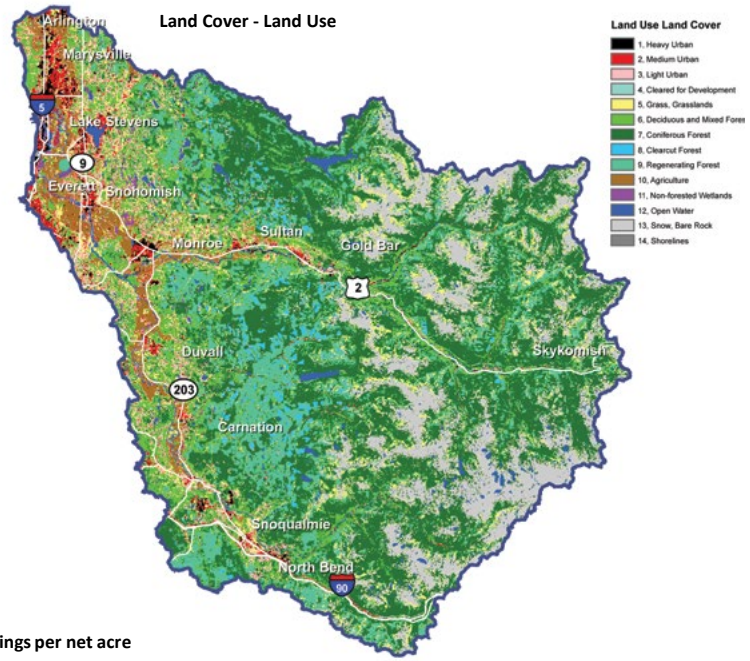
Character describes the actual look and feel of the development or landscape, whether rural or urban, resource-based or hobby ranchette, green build-low impact construction or dominated by impervious surfaces.

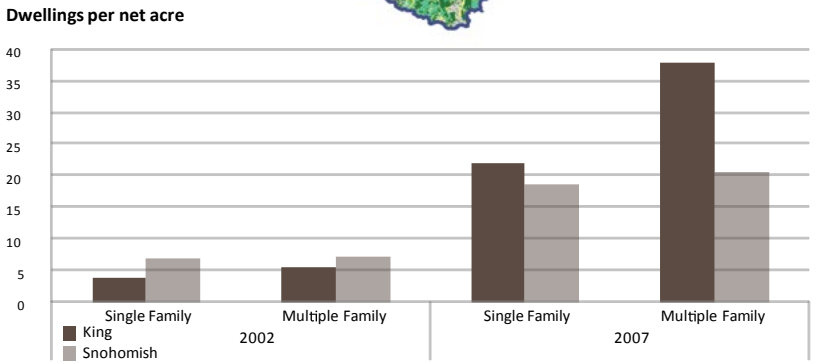
Form indicates the shape and pattern of development.

Land use refers to the management and modification of natural environment into the built environment for human use. Land use is generally categorized as residential, industrial, commercial, open space and agriculture.

A municipality refers to a town or city with a defined local government authority, territory and associated population.

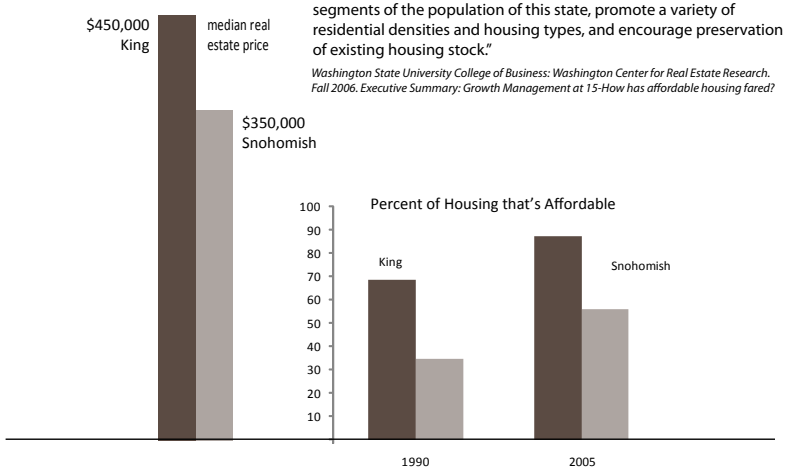
Real estate refers to the value (cost) associated with a property of land along with improvements such as buildings.





Buildable Lands Report 2002, 2007

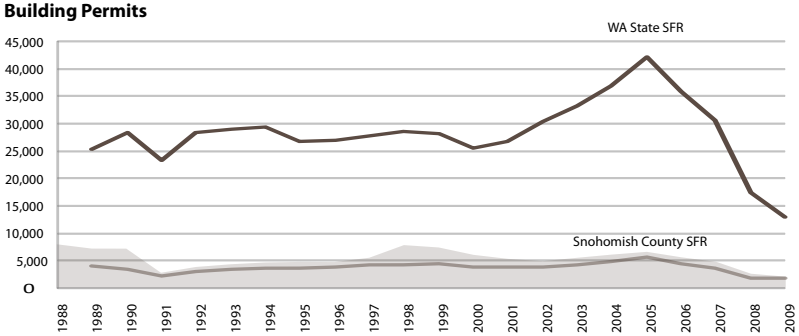
Development *published data*



"Encourage the availability of affordable housing to all economic segments of the population of this state, promote a variety of residential densities and housing types, and encourage preservation of existing housing stock."

Washington State University College of Business: Washington Center for Real Estate Research. Fall 2006. Executive Summary: Growth Management at 15-How has affordable housing fared?

Building Permits



Washington State University College of Business: Washington Center for Real Estate Research. Washington State Single Family Building Permits (Annually) 1988-2009

Development *published data*

Infrastructure

The term typically refers to the technical structures that support a society, such as roads, water supply, sewers, electrical grids, telecommunications lines, and so forth.

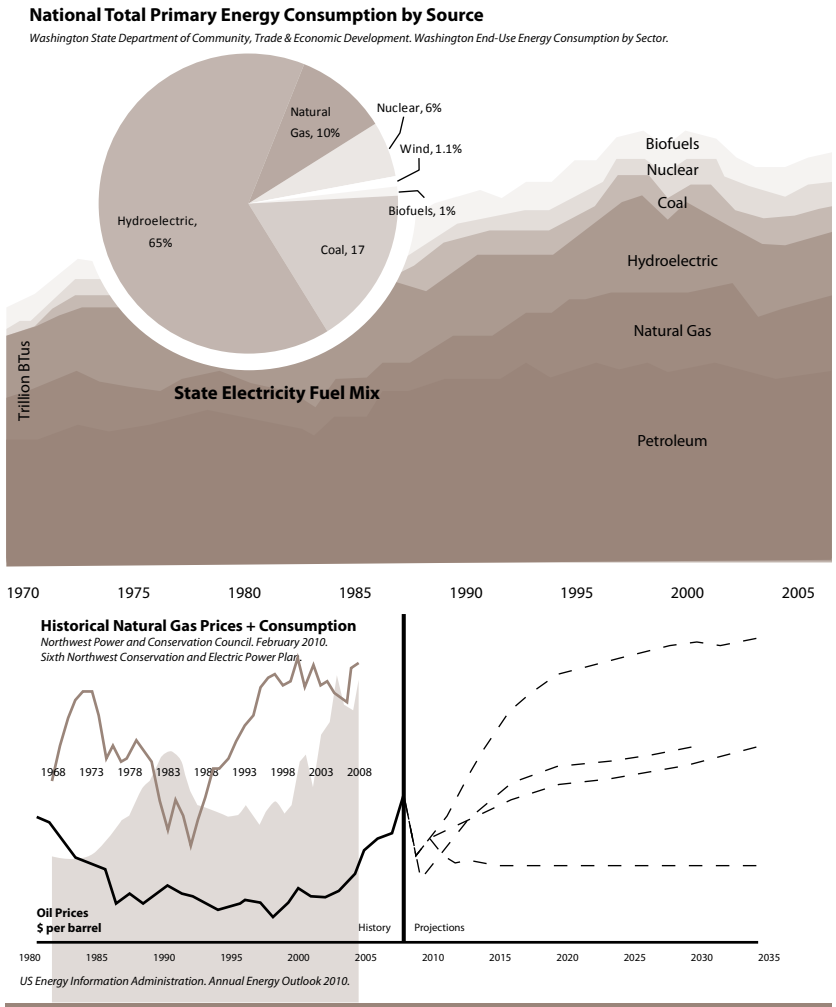
Energy provision refers to the effort to provide sufficient energy sources for a population to operate transportation, heating and cooling, appliances and machinery. Energy consumption refers to the usage of energy by a population associated with needs and behavior. Energy production refers to the transformation, storage and transmission of energy from fossil fuels, nuclear material, biomass, wind, solar, tidal, and water (dams) to usable forms.

Flood mitigation refers to dams, dikes, levees and armaments. These systems influence the timing and flow of the waterway in order to decrease upland flooding by hardening of the shoreline and / or the raising of the stream bank to reduce flood events.

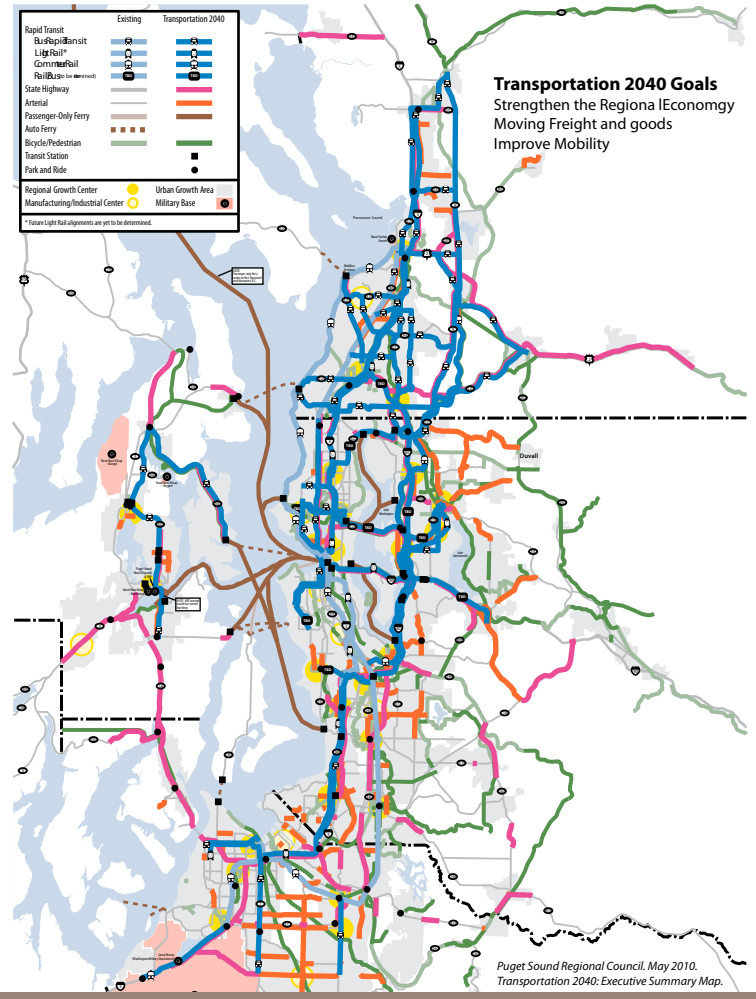
Transportation is the movement of people and goods across a landscape. Transportation entails the infrastructure network, modes of travel, and associated environmental, social and economic costs.

The waste stream describes the overall disposal cycle for a population including air and water pollution, solid waste and recycling, as well as sewer and septic infrastructure.

Water provision refers to the supply of clean drinking water to a population by a public utility or individual wells. Water provision includes the management, storage and distribution of water resources.



Infrastructure *published data*



Infrastructure *published data*

Resource Management

Materials or substances such as minerals, forests, water, and fertile land that occur in nature and can be used for economic gain.

Agriculture refers to the activity or business of growing crops and raising livestock.

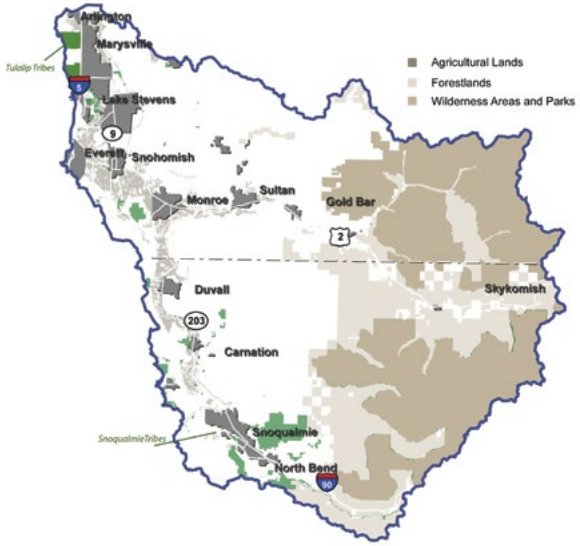
Forestry is the science of planting and caring for forests and the management of growing timber. and other valued forest products.

Recreation refers to the expenditure of time in a manner designed for therapeutic refreshment of one's body or mind.

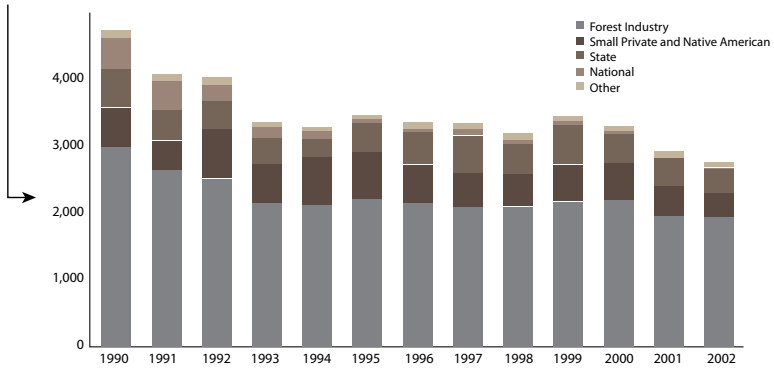
Forestland at Risk

There are 361,187 acres of private forestland in WRIA 7. Of those, 185,959 are DFL protect while 151,709 (87%) are at high risk of development.

Department of Revenue Washington State. 2011. Harvest Statistics.



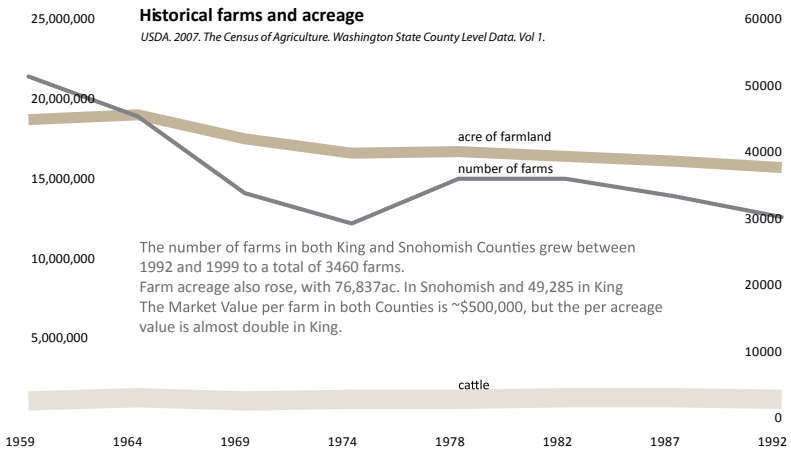
There are 410,344 acres of forestland in King County and 319,300 acres in Snohomsish. In King the majority is in industrial (41%) while in Snohomish the majority is in small private ownership (68%)

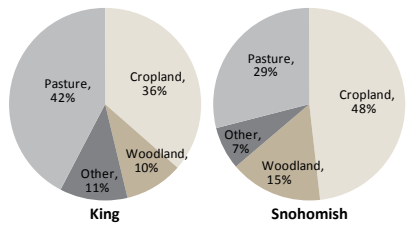


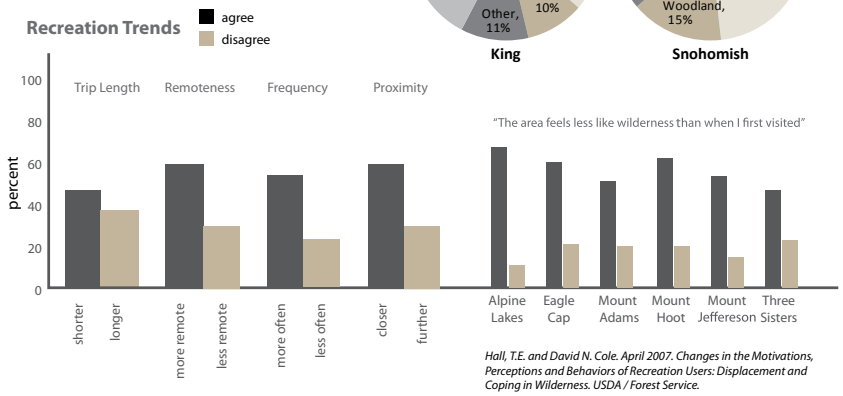
Acres of Forestlands in Washington

College of Forest Resources: University of Washington. March 25, 2001. Retention of High Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State.

Resource Management *published data*







Resource Management *published data*

Biophysical Template

Biophysical template focuses on the partitioning and cycling of chemical elements and compounds between the living and nonliving parts of an ecosystem.

Nutrients, such as nitrogen and phosphorus, stem from emisisons, sewers and fertilizers to enhance plant growth. **Toxic chemicals**, such as lead, mercury, sulfur are associated with industrial pollution, pesticides and vehicle leaks. When concentrations are too high, nutrients and toxic chemicals can damage and even kill organisms.

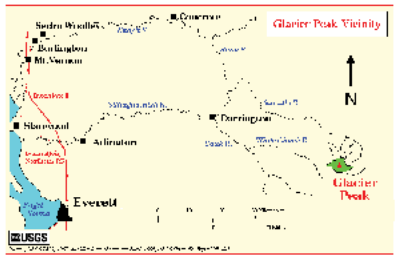
Landscape movement refers to the migration of soil (earth, dirt) both through water (bedload transport and sedimentation), over land (erosion) and through wind (lahars) and through snow (avalanches).

Seismology is the study of earthquakes propagated through waves in the earth's crust. The field also includes studies of tsunamis and volcanic eruptions

Soil is the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants. Soil productivity is the output of productive capability to support organic materials over a specified area. Soil minerals, such as gravel, gold, copper and silver may be extracted (mined) for economic profit.

Glacier Peak - Volcanic Activity

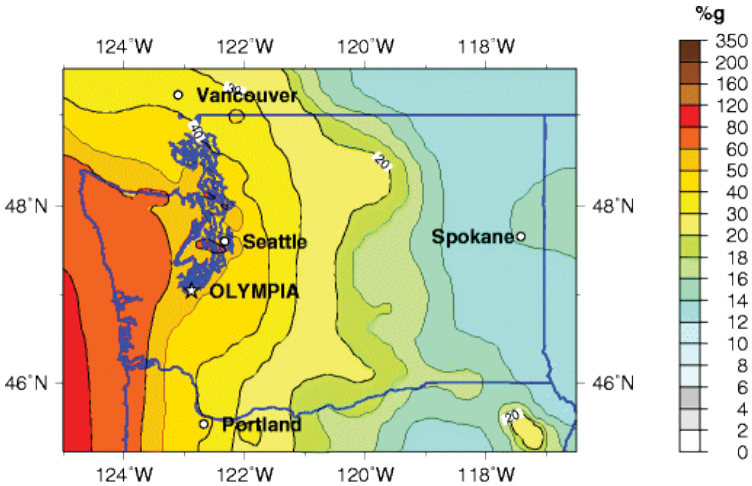
USGS. Glacier Peak: History and Hazards of a Cascade Volcano



Glacier Peak lies only 70 miles northeast of Seattle -- closer to that city than any volcano except Mount Rainier. But unlike Mount Rainier, it rises only a few thousand feet above neighboring peaks, and from coastal communities it appears merely as a high point along a snowy saw-toothed skyline. Yet Glacier Peak has been one of the most active and explosive of Washington's volcanoes. -- *Excerpt from: Mastin and Waitt, 2000*

USGS Seismic Hazard Map

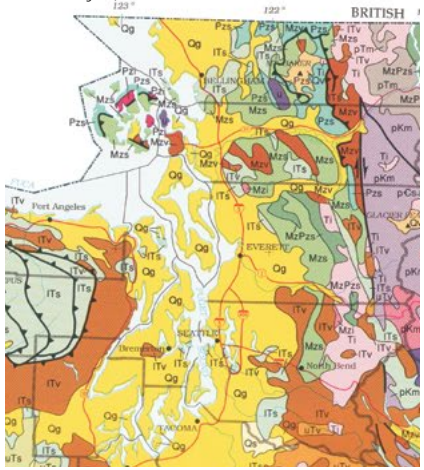
USGS. Seismic Hazard Map. http://earthquake.usgs.gov/earthquakes/states/washington/hazards.php



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)

Biophysical template *published data*

USGS. Geologic Map of the North Cascade Range, Washington.
10.15.10. Haugerud, R.A. and R.W. Tabor



Geologic Map of Northern Cascades

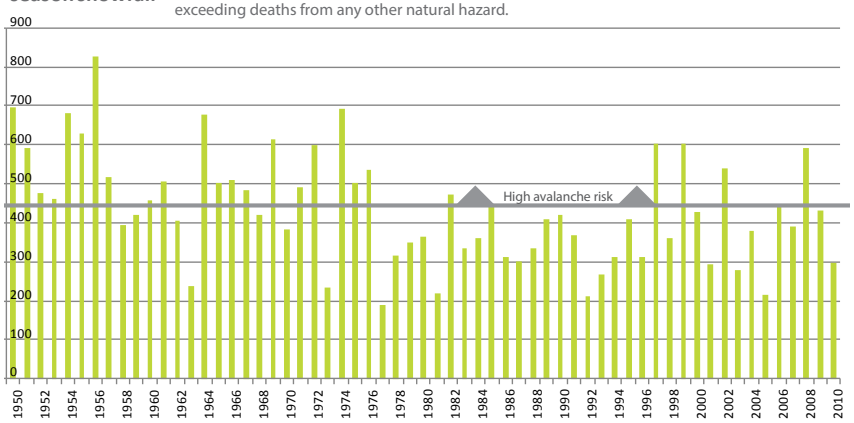
The Cascade Range is part of a vast mountain chain that extends from British Columbia to northern California. It separates the coastal Pacific lands from the interior of North America. The Cascades consist of an active volcanic arc superimposed upon bedrock of Paleozoic to Tertiary age. Pliocene to recent uplift has created high topographic relief. As a result, the Cascades form an effective barrier to moisture carried eastward by the prevailing Pacific winds. This has a great effect on the productivity of the land.

- Qg — Quaternary sediments, dominantly glacier drift; includes alluvium

Sedimentary Rocks

- uTs — Upper Tertiary (Pliocene–Miocene)
- lTs — Lower Tertiary (Oligocene–Paleocene
- Mzs — Mesozoic
- MzPzs — Mesozoic–Paleozoic
- Pzs — Paleozoic
- pCs — Precambrian

An avalanche occurs when a layer of snow loses its grip on a slope and slides downhill. When the snow piles up and conditions are right, avalanches result. Avalanches have killed more than 190 people in the past century in Washington State, exceeding deaths from any other natural hazard.



WA Military Department. Emergency Management Division. Natural Hazards: Avalanches.

Biophysical template *published data*

Climate

Climate is how the atmosphere "behaves" over relatively long periods of time. Climate change refers to long-term shifts in the statistics of weather. Climate change incorporates both natural variability and human-induced change.

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species and / or to any human need or purpose.

Carbon dioxide, a side product of fossil fuel combustion, is a greenhouse gas associated with environmental pollution and climate impacts.

Confounding anthropogenic changes to climate patterns are **natural variations** associated with La Nino, El Nino and Pacific Decadal Oscillation, jet stream shifts as well as solar radiance. These variations may create large variations in wind, temperature and precipitation patterns.

Climate change will influence different areas of the world in various magnitudes and pathways. **Global change** refers to climate impacts that are relevant on a global scale, as opposed to changes significant within the Basin or Region.

Ocean acidification is the name given to the ongoing decrease in the pH of the Earth's oceans, caused by their uptake of excess carbon dioxide from the atmosphere.

Precipitation is the product of the condensation of atmospheric water vapor that falls under gravity in the form of rain or snow.

Sea level measures of the average height of the ocean's surface, halfway between the mean high tide and the mean low tide. Sea level has been increasing over the last century due to human-induced climate change through three main processes: thermal expansion, the melting of glaciers and ice caps, and the loss of ice from the Greenland and West Antarctic ice sheets.

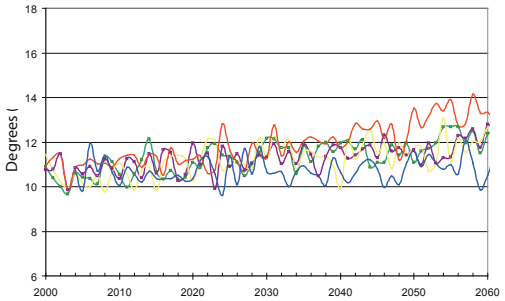
Snowpack forms from layers of snow that accumulate in geographic regions and high altitudes where the climate includes cold weather for extended periods during the year. Snowpack is an important water resource that feedsstreams and rivers as they melt. Snowpack is the drinking water source for many communities.

Temperature shift, or warming, refers specifically to changes in ground-level atmospheric temperature.

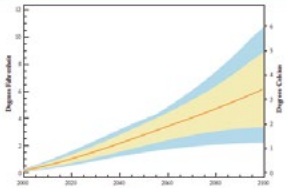
21st Century Climate Impacts for the Pacific Northwest Region

University of Washington and NOAA. Dec 6, 2005. Modeling the Impacts of Climate Change and Restoration on Chinook Salmon in the Snohomish Basin.

Annual Average Temperature *at Snoqualmie Falls*

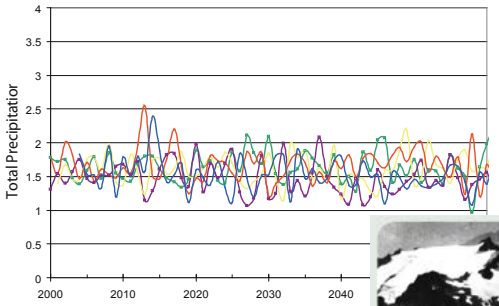


Warming since 1900 in the Pacific Northwest ranges from 0F to 4F. By 2100, models project warming near 5F west of the Cascades, with much larger warming further east in the Canadian model.



Northwest Warming Trends

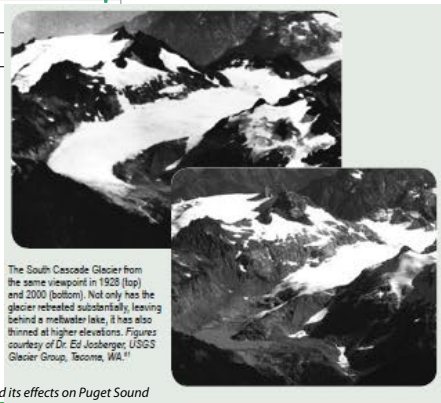
Annual Precipitation *at Snoqualmie Falls*



Precipitation has increased over of the Pacific Northwest since 1900. Climate models project continued precipitation increases, with the largest increases in the southern part of the region.

Snowpack

Nearly every glacier in the Cascades and Olympics has retreated during the past 50-150 years in response to warming.21 Small glaciers are disappearing rapidly, and glacial mass is being reduced on the larger ones. While the total water input into Puget Sound from melting glaciers is minimal, glacial retreat can have important local effects. In higher reaches of certain river basins (such as the Nooksack) and some tributaries to the Skagit, melting glaciers provide a substantial portion of stream flow in late summer. This is also true for the Nisqually River, which is fed by receeding glaciers on Mt. Rainer. Glaciers also have significant local effects on stream temperature and water supply for aquatic plants and animals. Significant reductions in glacial input to streams would dramatically alter vulnerable aquatic habitat.

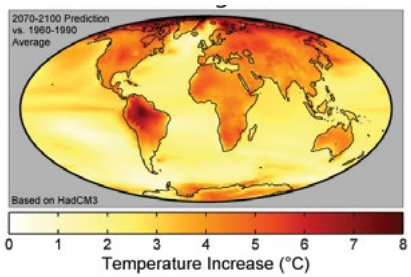


The South Cascade Glacier from the same viewpoint in 1928 (top) and 2000 (bottom). Not only has the glacier retreated substantially, leaving behind a meltwater lake, it has also thinned at higher elevations. Figures courtesy of Dr. Ed Josberger, USGS Glacier Group, Tacoma, WA.[1]

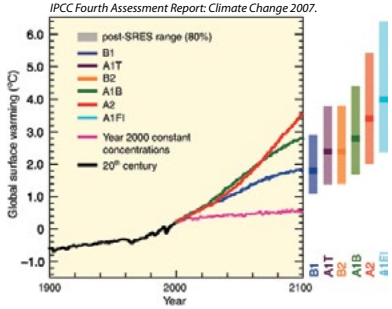
Climate Impacts Group. Oct 18.2005.Uncertain Future: Change and its effects on Puget Sound

Climate *published data*

Global Climate Impacts

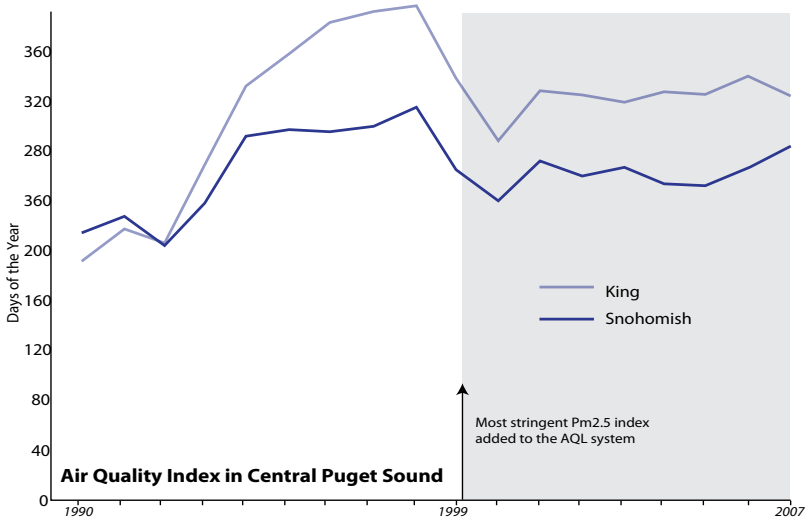


IPCC Fourth Assessment Report: Climate Change 2007.



Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]°C[1] is larger than the corresponding trend of 0.6 [0.4 to 0.8]°C (1901-2000).

NASA. Annual average global warming by the year 2060 simulated and plotted using EdGCM.



Puget Sound Clean Air Agency; PSRC

Climate *published data*

Hydrology

Hydrology is the study of water, including the movement, distribution and quality of water (or water bodies).

A **flood** is an overflow of an expanse of water that submerges land.

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water.

Morphology refers to the shape of the river, how straight it is, its width and the presence of eddies.

Stormwater refers to overland flow due to precipitation and snowmelt that is not intercepted or infiltrated.

The **'watershed'** refers to the Snohomish Basin, its three major watersheds, (Snohomish, Skykomish and Snoqualmie), and its four major rivers, (Snohomish, Skykomish, Snoqualmie and Tolt).

Water quality is a measurement of physical, chemical and biological characteristics of water. Water quality matters for clean drinking water and public health, salmon protection (fish and habitat) and recreation.

Water quantity refers to water available for human consumption, industrial use and in-stream habitat.

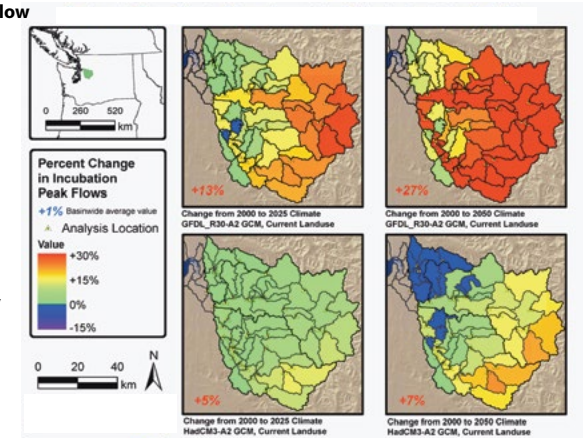
WRIA 7

Water Resource Inventory Area 7 includes the 4 major river basins of the Snohomish, Snoqualmie, Skykomish and Tolt. This Basin is known for both its once abundance salmon tributaries and frequently flooding rivers.

Hydrologic Impacts- Peak Flow

The GFDL model forecasts more significant increases in the peak flows with higher winter temperature increases and increased winter precipitation.

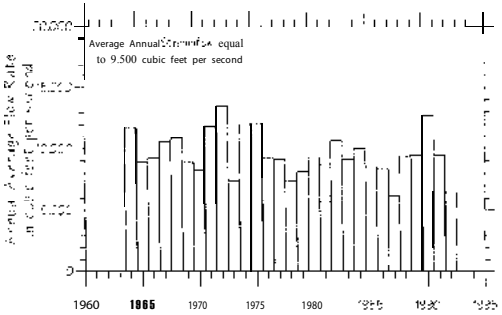
The upland basins are in a transitional state where precipitation may fall as rain or snow. Temperature shifts will change the state of the precipitation and can noticeably shift the hydrologic response of the basin. The lower basins mainly just receive rain and so the temperature warming will not create the same impacts.



Hydrology *published data*

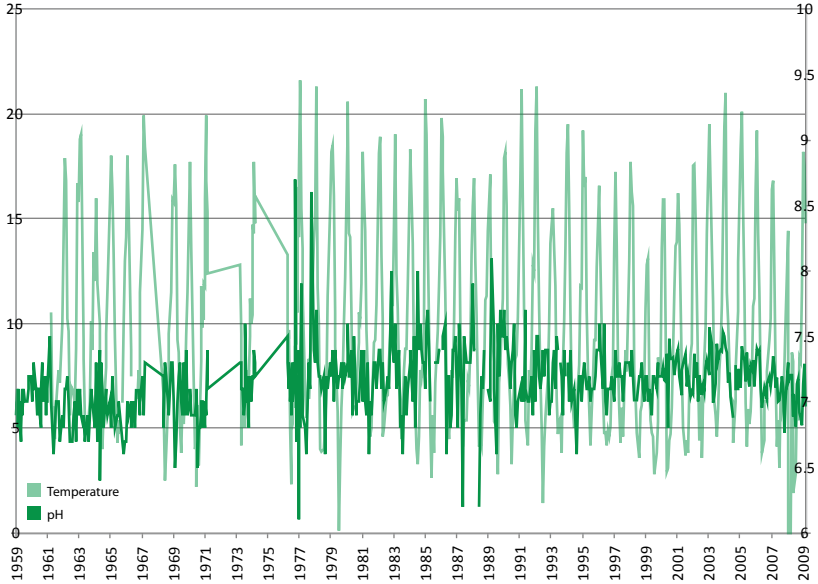
Streamflow

Annual streamflow in the watershed varies widely from one year to the next in a pattern which reflects annual precipitation. This high variability is demonstrated by the annual flow record on the Snohomish River at Monroe. Long-term trends in annual streamflow will be affected by trends in precipitation, water consumption and land use practices. Recent analysis of annual streamflow trends, adjusted for precipitation, is inconclusive but suggests a possible reduction in streamflow over time.



Annual streamflow in the Snohomish River

Water Quality at Snohomish River Station *Ave D in Snohomish*



Hydrology *published data*

Terrestrial Biosphere

The terrestrial biosphere is a thin layer around the earth's crust that supports life. The terrestrial biopsphere works in concert with the lithosphere, hydrosphere and atmosphere. The terrestrial biosphere encapsulates organisms and their habitat.

Biodiversity reflects the full complement of species and ecosystems within an area requiring intact ecological functions and processes.

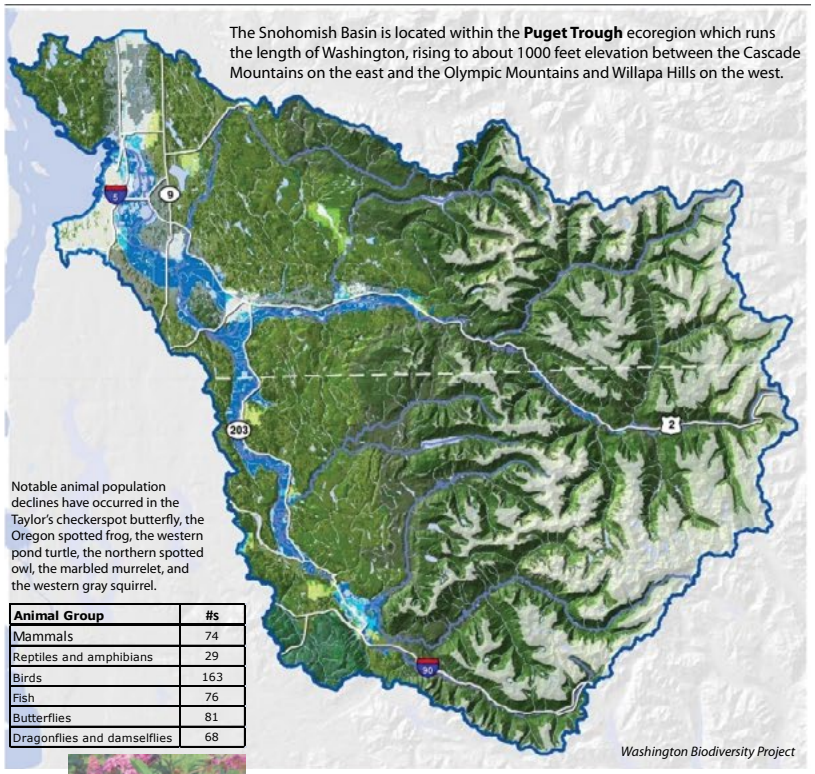
Estuaries are the transition zone between the ocean and rivers. Estuaries are subject to both marine influences, such as tides, waves, and the influx of saline water and riverine influences, such as flows of fresh water and sediments.

Wildland fires are fires caused by nature or humans that result in the uncontrolled destruction of forests, brush, field crops, grasslands, and real and personal property. Urban or industrial fires, caused by technological hazards were not discussed by participants.

Forest habitat consists of lowland riparian forests and upland conifer forests dominating the land cover in the Basin.

Invasive species applies to non-indigenous species, or "non-native", plants or animals that adversely affect the habitats and bioregions they invade economically and environmentally.

Salmon, more specifically the Pacific Salmon of the family Salmonidae, generally refer to anadromous fish that migrate from upland stream tributaries to the ocean, and then back upstream to spawn. Pacific salmon are the Northwest's biological and cultural icon. Salmon, and their associated habitat, is protected by the Endangered Species Act.



The Snohomish Basin is located within the **Puget Trough** ecoregion which runs the length of Washington, rising to about 1000 feet elevation between the Cascade Mountains on the east and the Olympic Mountains and Willapa Hills on the west.

Notable animal population declines have occurred in the Taylor's checkerspot butterfly, the Oregon spotted frog, the western pond turtle, the northern spotted owl, the marbled murrelet, and the western gray squirrel.

Animal Group	#s
Mammals	74
Reptiles and amphibians	29
Birds	163
Fish	76
Butterflies	81
Dragonflies and damselflies	68

Washington Biodiversity Project

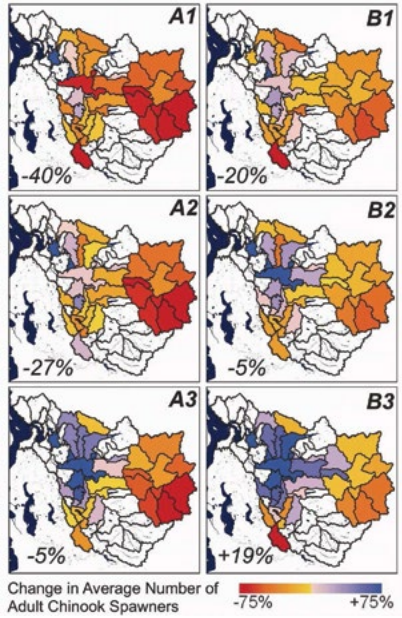
The butterfly bush is one of 153 non-native plants and 30 noxious weeds found in the Basin.

Historically, coniferous forest dominated the vegetation in the Puget Trough ecoregion. Many of the planet's most impressive stands of trees grew here. Also present were a mix of riparian habitats, oak woodlands, and prairies. The vegetation in most of the ecoregion's landscapes has now been altered. Cities, suburbs, and industrial lands are common. Managed forests and agricultural lands changed the vegetation, and themselves face pressure from sprawling development. The native forest here is primarily of Douglas fir, western red cedar, and western hemlock. Red alder and big leaf maple grow in riparian areas. Red alder also colonizes areas disturbed by fire or logging. Understory plants include sword fern and shrubs such as snowberry, Oregon grape, salmonberry, and many others.

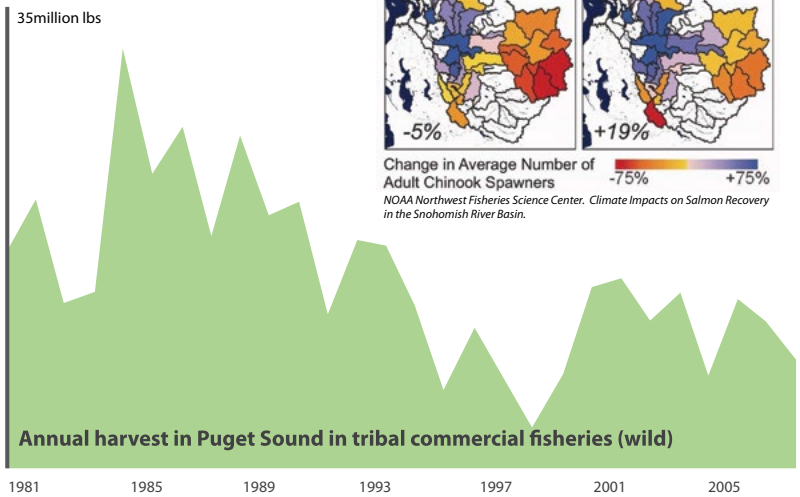
Terrestrial Biosphere

Salmon

Despite uncertainty in climate change, predictions and modeled impacts on freshwater salmon are consistently negative.



NOAA Northwest Fisheries Science Center. Climate Impacts on Salmon Recovery in the Snohomish River Basin.



Puget Sound Partnership. 2009. State of the Sound.

Terrestrial Biosphere *published data*

Assessment of Relationships between Drivers

The conceptual model workshop highlighted the differences and similarities in how experts organize the relationship between drivers, in terms of both their impacts and feedbacks. What came across as an essential piece is the need to synthesize the various relationships in a systematic manner (as opposed to simplifying only the most commonly shared concepts).

We coded interview transcripts based on the initial list of drivers to assess member comments about the relationships between drivers. For example, if a member said 'population growth is dependent on more jobs' we tallied 1 comment for economy>labor impacting demographics>growth. Based on the tallies of all 44 interviews and focus groups we created a cross-interaction matrices and series of network graphs to illustrate the cumulative set of comments describing the relevance of various relationships.

The series of network graphs (pages A6.64-70) isolate the represented relationships per driver. Drivers are organized from top to bottom based on whether they drive (top) or are driven by (bottom) the specified driver. The number of comments tallied are provided by each arrow head.

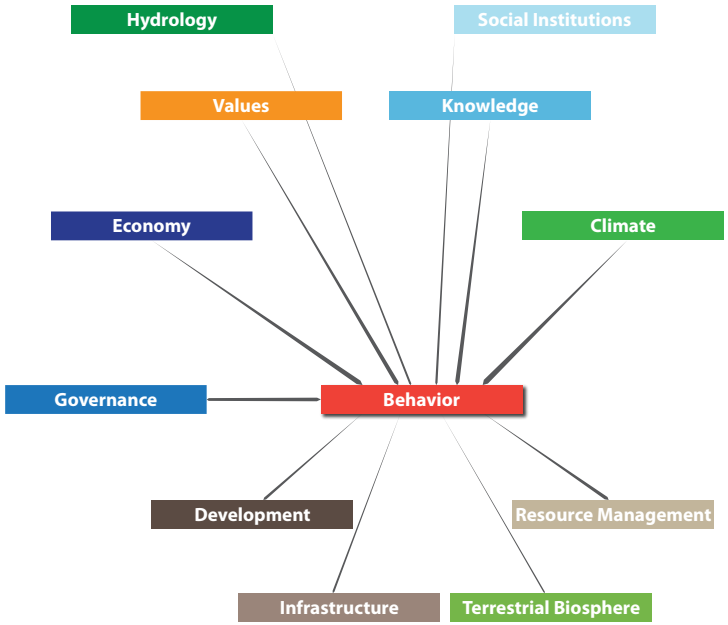
The cross interaction matrices summarizes the relationships in a tabular format where the list of drivers is repeated along the top row and left hand side. Cell values represent the number of times a comment was made on on the interaction between two drivers (page A6.71-73).

Science Team member descriptions of each driving forces' relevance, importance and uncertainty during focus group meetings are included in pages A6.74-87.

according to our Science Team

Behavior

is most directly influenced by economy , climate, values and knowledge
is responsible for driving the built environment and alterations to the terrestrial biosphere



relationship not described*

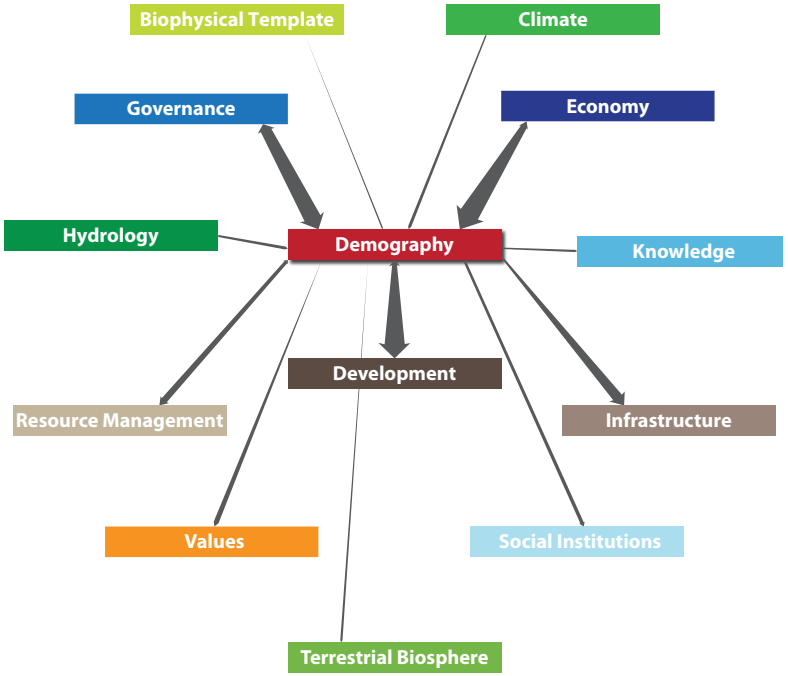
Demography | Biophysical Template

*minimum comment count of 2

according to our Science Team

Demography

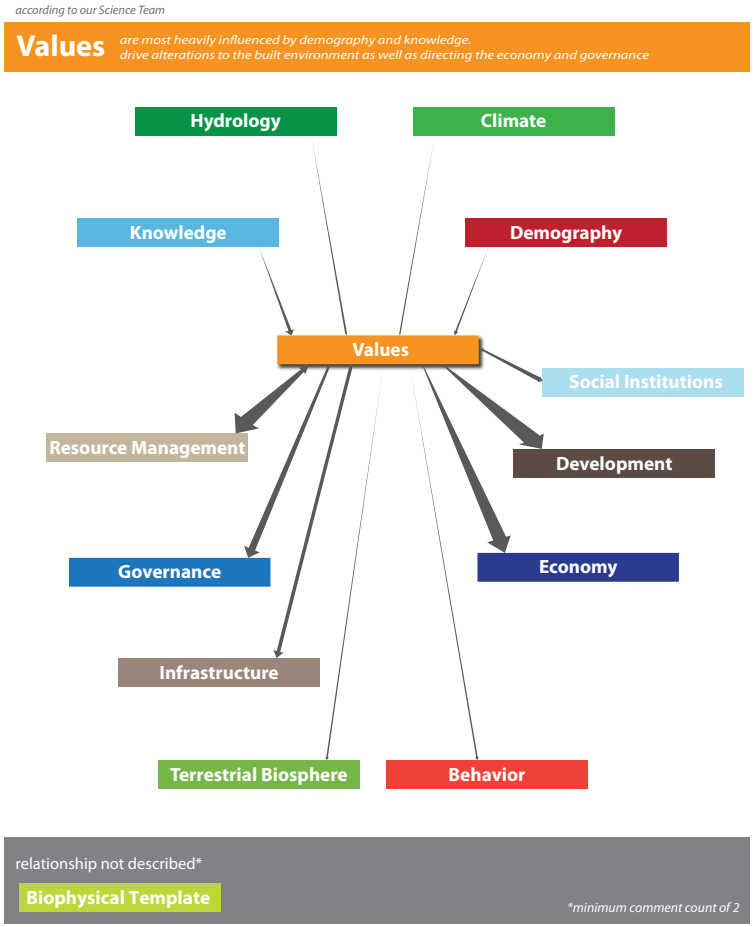
is regulated by governance and economy
drives the built environent with weaker associations onto our values, institutions and knowledge

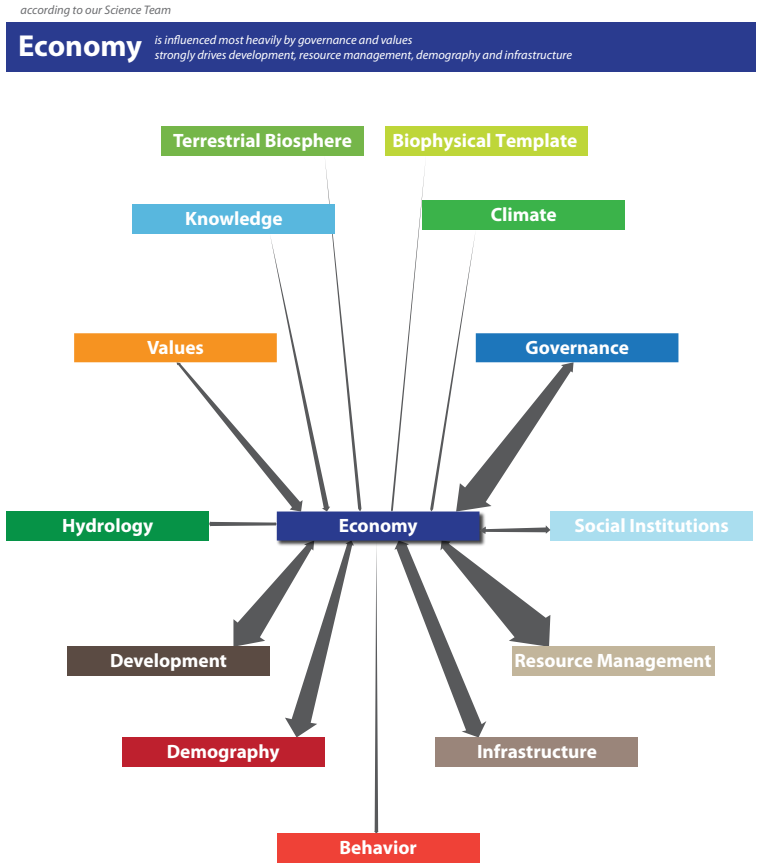


relationship not described*

Behavior

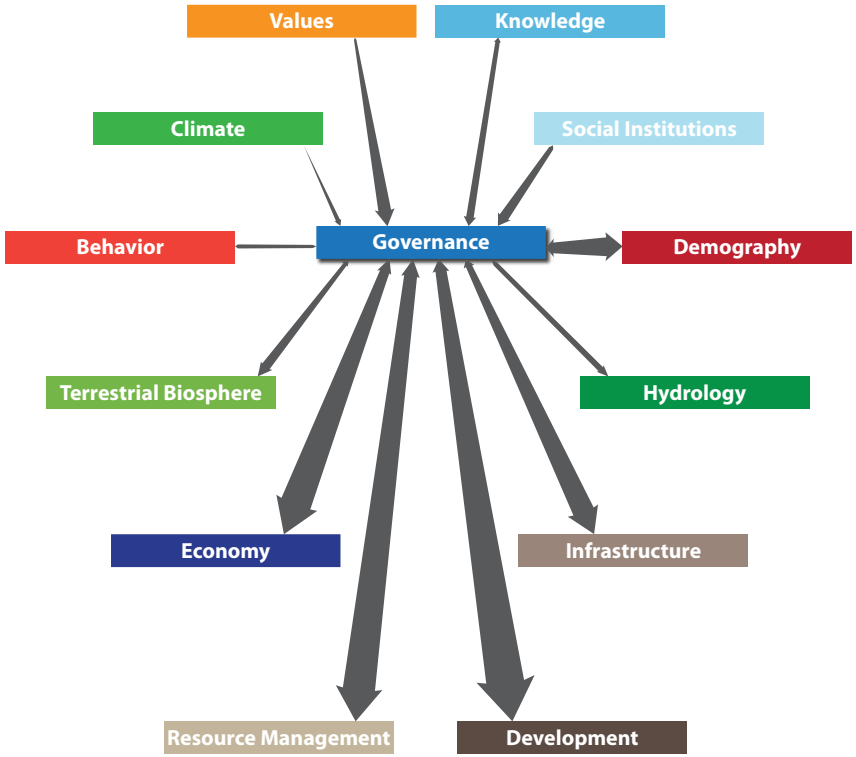
*minimum comment count of 2


according to our Science Team
Values
are most heavily influenced by demography and knowledge.
drive alterations to the built environment as well as directing the economy and governance
Hydrology
Climate
Knowledge
Demography
Values
Social Institutions
Resource Management
Development
Governance
Economy
Infrastructure
Terrestrial Biosphere
Behavior
relationship not described*
Biophysical Template
*minimum comment count of 2


according to our Science Team
Economy
is influenced most heavily by governance and values
strongly drives development, resource management, demography and infrastructure
Terrestrial Biosphere
Biophysical Template
Knowledge
Climate
Values
Governance
Hydrology
Economy
Social Institutions
Development
Resource Management
Demography
Infrastructure
Behavior

Governance

has a bi-directional relationship with most other drivers but is overall considered to have a stronger role as a driver than a feedback, especially its effect on the built environment and economy.



relationship not described*

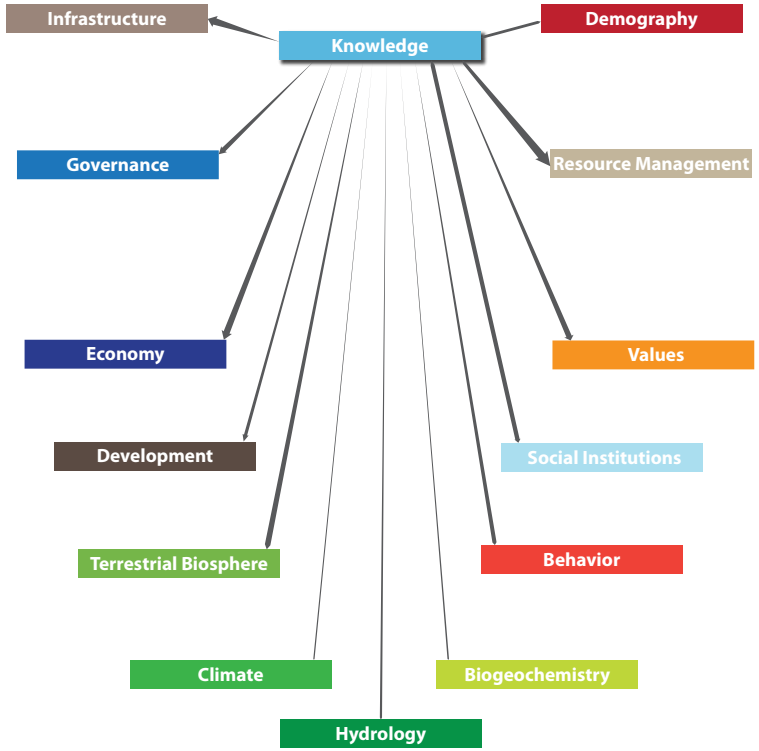
Biogeochemistry

*minimum comment count of 2

according to our Science Team

Knowledge

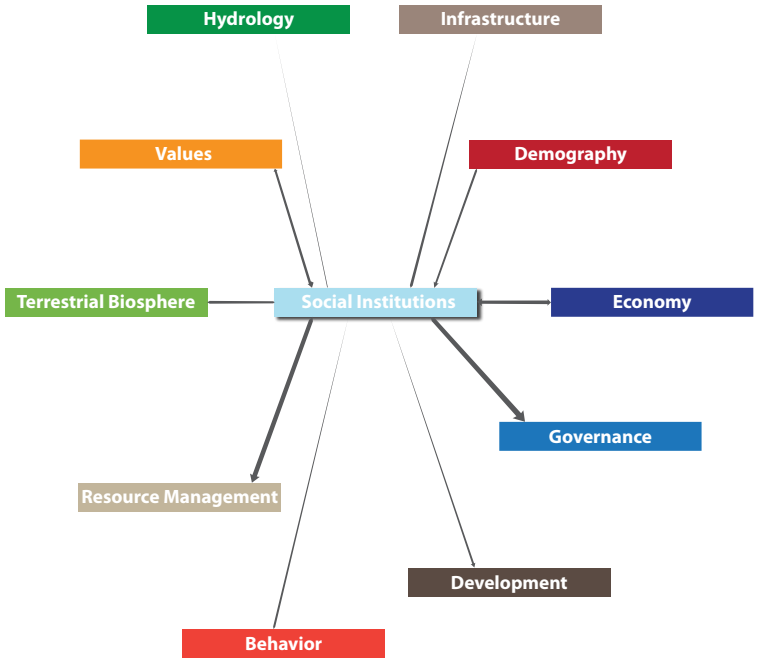
is minimally influenced by demography, social institutions and resource management. drives all drivers with a higher relevace to the built environment and institutions.



according to our Science Team

Social Institutions

function comparitively as both drivers and impacts, with emphasis on impacts from values, demograpghy and infrastruture and driving governance, resource management and development.



relationship not described*

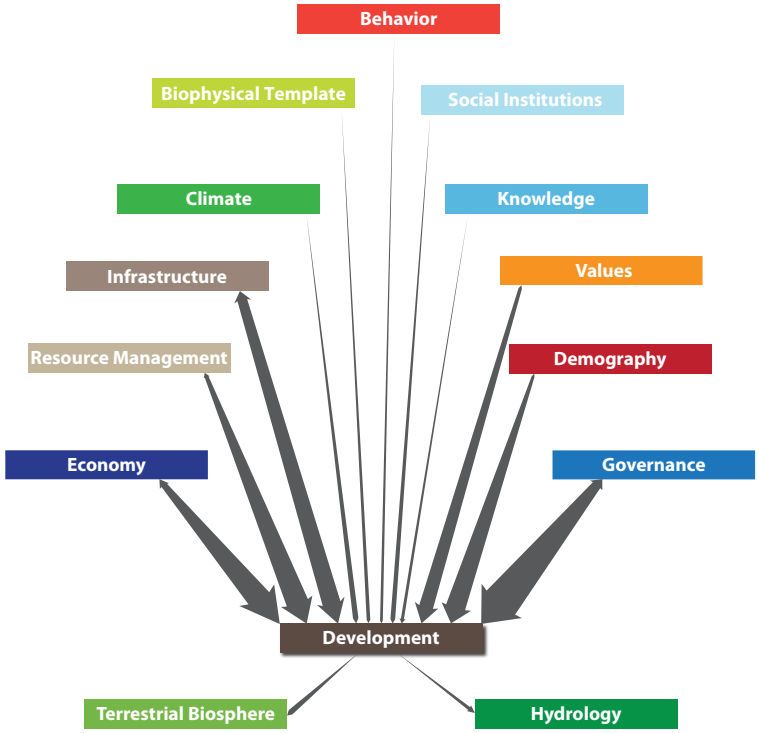
Climate | Biophysical Template | Knowledge

**minimum comment count of 2*

according to our Science Team

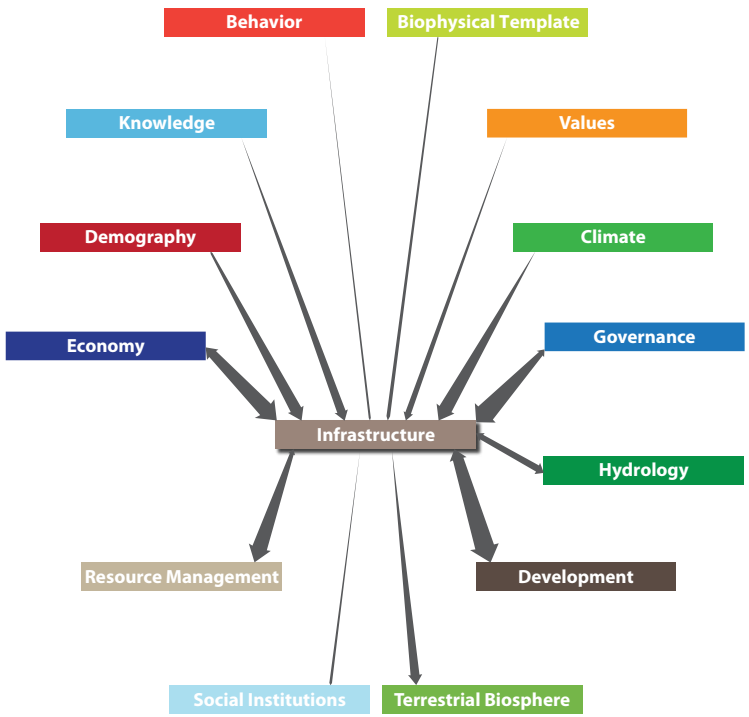
Development

is shaped by most drivers, with governance and economy having the strongest influence alters hydrology and the terrestrial biosphere



Infrastructure

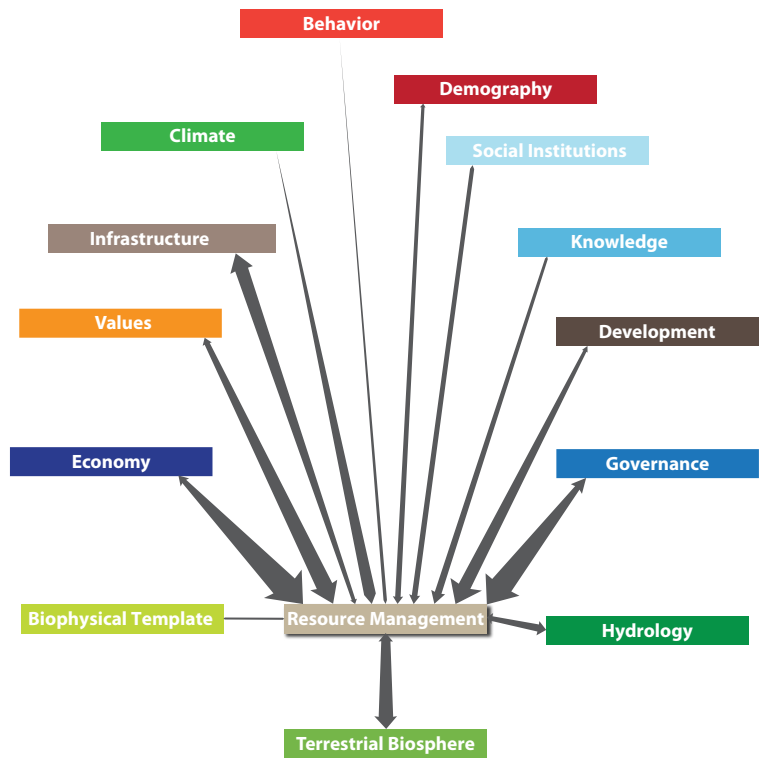
most closely influences other built environment drivers as well as the terrestrial biosphere. is controlled by economy and governance with additional human and environmental pressures.



according to our Science Team

Resource Management

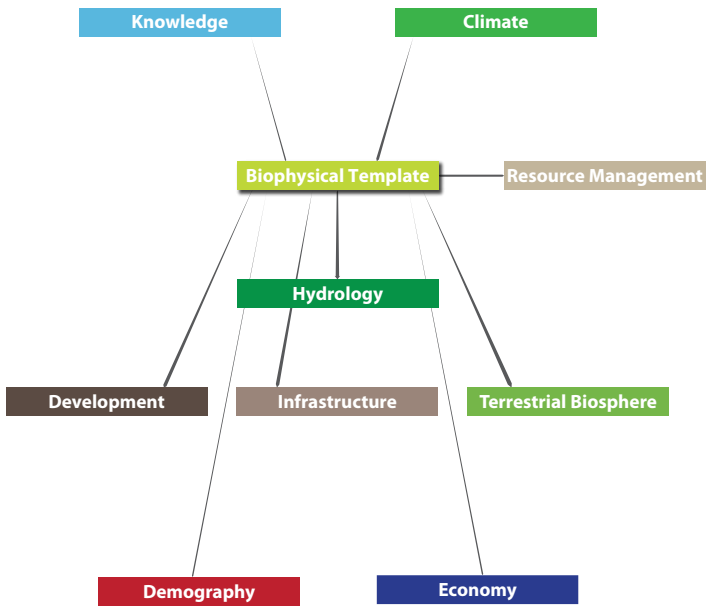
is shaped by most drivers, with governance and economy having the strongest influence. alters the terrestrial biosphere.



according to our Science Team

Biophysical Template

is influenced by climate, knowledge and resource management. drives changes in the hydrological and terrestiral systesm, and shapes development and indfrasturucre patterns.



relationship not described*

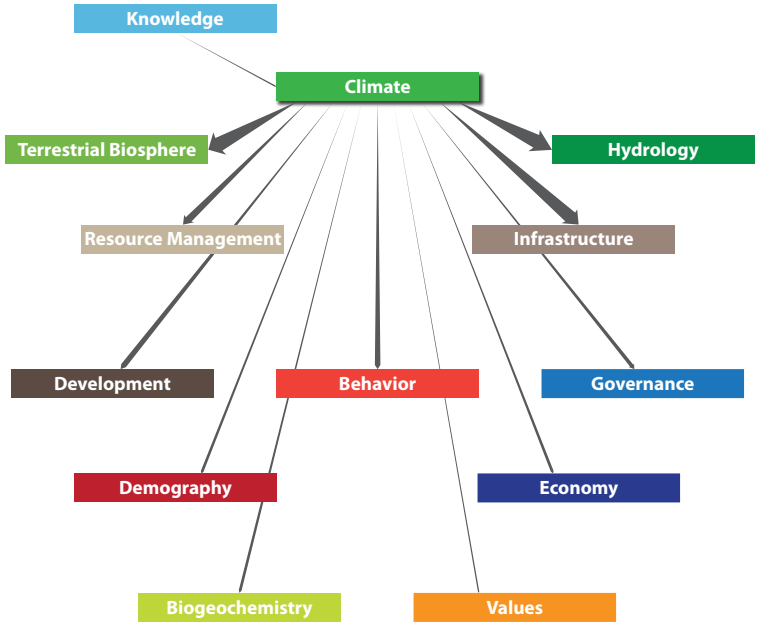
Social Institutions | Governance | Behavior | Values

**minimum comment count of 2*

according to our Science Team

Climate

primarily drives the natural and built environments, with secondary impacts on human and institutional sectors is more remotely influenced by institutions and the built environment



relationship not described*

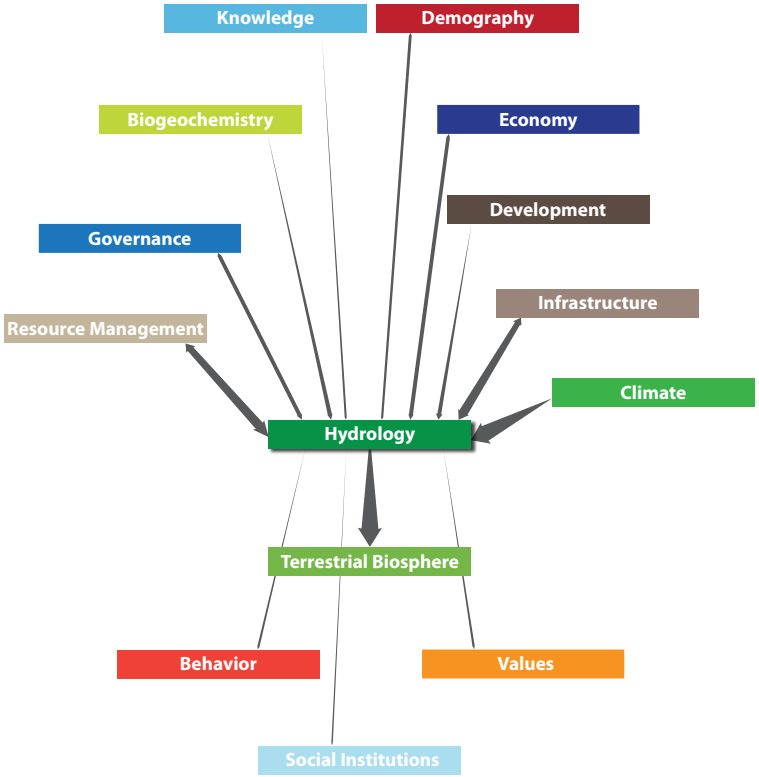
Social Institutions

**minimum comment count of 2*

according to our Science Team

Hydrology

is driven by climate and resource management, as well as infrastructure, development, and governance, impacts the terrestrial biosphere



according to our Science Team

Terrestrial Biosphere

is driven by nearly every driver but most significantly by changes in the natural and built environments. influences economy.

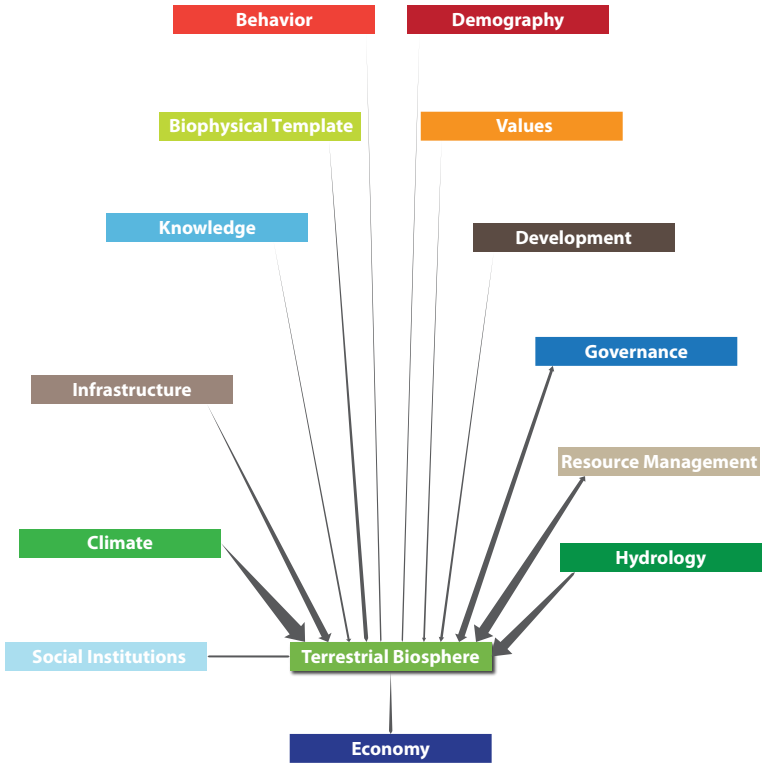


Table A6.1a Relevance Cross Interaction Matrix .The following 3 matrices represent the synthesis of 44 interview transcripts and the Conceptual Model Workshop.The synthesis was conducted by coding transcripts in NVivo and exporting the summary relationship table. The table is intended to represent how various Science Team members view the relationships between drivers. ***Relevance*** refers to how frequently the specific impact was mentioned during interviews and focus groups. The assumption is that the more an impact was mentioned the more relevant it is to consider in the study.The list of drivers is repeated along the top row and left hand side. Cell values represent the number of times a comment was made on on the interaction between two drivers.The top 5% of cell values are highlighted in dark gray. Comments are synthesized and available on the website at: http://www.urbaneco.washington.edu/sbs/images/summary_relationships1.xlsx

Drivers → ↓	Behavior	Demography	Values	Economy	Governance	Knowledge	Social Institutions	Development	Infrastructure	Resource Management	Biogeochemistry	Climate	Hydrology	Terrestrial Biosphere
Behavior	48	1		1	4			4	3	5			1	2
Demography	1	173	7	13	24	4	8	44	25	15		2	3	2
Values	6		131	23	25		9	35	15	42				6
Economy	7	44	6	245	19	1	12	61	39	65		2	8	1
Governance	5	36	3	56	255	7	6	75	41	60	1	2	12	18
Knowledge	6	3	14	12	16	101	9	9	20	21	2	2	3	8
Social Institutions	3	3	6	11	19	6	83	7	1	15				4
Development	1	15	5	16	22		1	195	25	48	2	2	10	8
Infrastructure		3	4	22	14		4	42	186	34	2	2	18	21
Resource Management		8	14	18	24	4	6	9	10	311	3		21	33
Biogeochemistry		2		2				5	5	3	29	1	8	6
Climate	8	4	2	4	9	1	1	8	30	18	4	116	34	37
Hydrology	3	4	3	6	6		2	2	14	16	2		113	35
Terrestrial Biosphere			1	5	9	1	3	2	1	11			4	150

Table A6.1b Uncertainty Cross Interaction Matrix. ***Importance*** refers to how important participants believed the specific impact is. Importance is defined as the magnitude of impact, how wide spread it is, or having a cascading effect.The list of drivers is repeated along the top row and left hand side. Cell values represent the number of times a comment was made on on the interaction between two drivers.The top 5% of cell values are highlighted in dark gray.

Drivers → ↓	Behavior	Demography	Values	Economy	Governance	Knowledge	Social Institutions	Development	Infrastructure	Resource Management	Biogeochemistry	Climate	Hydrology	Terrestrial Biosphere
Behavior	13													
Demography		22												
Values			22										2	1
Economy				43	6			12	4	8				1
Governance				5	33	1		8	2	11				3
Knowledge				3	2	20	1		2	5			1	1
Social Institutions	1			3	1	2	12			2				1
Development				2				30	2	3		1	4	
Infrastructure				7	1			6	34	4				5
Resource Management						1	1	4	1	45			1	1
Biogeochemistry									1	1	5		3	
Climate	2		1	1	1			1	7	1	1	20	4	4
Hydrology	1		2		2				2				15	
Terrestrial Biosphere	1						1	1		2		4	2	16

Table A6.1c Importance Cross Interaction Matrix. ***Uncertainty*** refers to how uncertain participants believed the specific impact is. Uncertainty is defined as questions about the future, expressed by participants by posing multiple future trajectories or stating 'we (or I) don't know how…'The list of drivers is repeated along the top row and left hand side. Cell values represent the number of times a comment was made on on the interaction between two drivers. The top 5% of cell values are highlighted in dark gray.

Drivers → ↓	Behavior	Demography	Values	Economy	Governance	Knowledge	Social Institutions	Development	Infrastructure	Resource Management	Biogeochemistry	Climate	Hydrology	Terrestrial Biosphere
Behavior	11													
Demography		25										1		1
Values			21											2
Economy				54	13	3	3	7	13	17		1		
Governance					49	6	3	8	11	14		1	1	5
Knowledge						29	2	4	8	5		1	1	1
Social Institutions							14	3		6				1
Development				1				40	1	7			1	2
Infrastructure								6	70	18		1	2	9
Resource Management								1	1	66	2	8	1	11
Biogeochemistry									2	2	7		2	1
Climate	2	2		1	4	4	1		12	8	2	45	7	21
Hydrology			1	1	3			1	2	3	2		15	6
Terrestrial Biosphere			1	2	3					4	1			44

Behavior's *Relevance to the Basin*

Can we adapt: Experts discussed human ability to adapt. For example, 'can we get out of our cars?' and 'can we adapt to technological advances?' We discussed the impetus for adaptation, whether reactive or proactive; for example, will climate change force us to change our behavior?' or perhaps a major hazard. Also, the direction of adaptation; whether towards needs or desires, going green or towards self reliance, defense, or evading regulations.

Changing consumerism: Human consumption was discussed as both a driver of resource needs and as an impact of values and the economy (the market). Discussions generally mentioned changes in 'what people buy', 'human use' and 'increased demands'. Specific consumption patterns included conscious consumption (the active decision to consume less) and energy consumption.

The Human-Nature Dimension: How we interact with the nature is continually changing. Participants discussed legacy of dumping, or 'dilution as the solution' and more generally human footprint and the change we leave behind. There was also discussion of our connection to nature, and how technology or values can influence that connection.

Investment choices: What we choose to invest in or 'where the money goes' was discussed as a component of human behavior. For example, whether we purchase new items or repair existing materials, whether we create subsidies for responsibility and invest conservation versus HazMat cleanup.

"importance"

13 ***comments***

The difference between Western and Tribal culture has had a major impact on behaviors in the Basin.

There has been a huge shift in our the types of chemicals we use, in residential, commercial and agriculture.

History is of critical importance to apply better decisions in the future.

Human use is an important category.

The shift from industrial to service economy has altered people's habits dramatically.

Before you could dump a load of rock in the river, now there is a lot of oversight.

Global climate impacts will become a more dominant impact in how we live.

A major hurdle is people don't adapt very well.

Impacts associated with recreation are minor compared to other impacts of human behavior

It's about getting the information out so people can modify their behavior

"uncertainty"

10 ***comments***

Perhaps in the future we will have more respect for what we have because we will have less?

There is a lot of uncertainty about near and long term affects of climate change on our choices to adapt.

People can get really creative in the face of disasters.

Self reliance could take many forms, maybe living off the grid or heading out to bunkers with AK47s.

I have seen models of zero growth, but can humans control themselves that much?

The green movement and conscious commitment to consume less may later trajectories.

What is our ability to adapt?

Going green will depend on government incentives

Are regulations so heavy the public rebels?

How will people adopt and interact with new technology?

Demography's *Relevance to the Basin*

Characteristics

Aging Population: Over the next fifty years the Basin will experience a significant change in age structure. The average baby boomer is 65 today, and the average farmer is 58. This population has shaped policy in the Basin and they will be gone by 2060. The Basin will likely see significant changes in service demands, average working age and development patterns associated with retirement and changes in preferences.

More Diversity: Experts agree that the Basin is becoming and will continue to be more diverse. Diversity has doubled since 1990s and we are expecting to see a 50% increase between 2000 and 2010 (when the census data comes in). Changes in diversity are not limited to ethnicity, we have seen changes in age structure, income, disability and other characteristics. Forecasting to 2060, many experts believe we will see more inequality and social segregation alongside the growth in diversity.

Exporting Education: Educational attainment in the Basin has increased over the last half decade, largely coincident with the Boeing rush and influx of skilled labor. While children have higher achievement scores, the Basin exports students for enrollment in four year colleges.

Greater Income Disparities: Over the last fifty years the Basin has been influened by higher income jobs. In the future, many experts discussed growing disparities in income and challenges associated with poverty, service provision and segregation. Poverty issues include homelessness, employment instability, overcrowding and lack of health care access. Community disengagement associated with wealthier households can lead to gated communities, privatization of services, private security and lack of funding for schools, libraries and social services.

Growth

Unchecked growth: Population growth was one of the most frequently mentioned human factor when discussing change in the Basin. Population growth was a determining factor not only in how the Basin is what it is today, but also how it will change in the future. In the last decade, Snohomish County was the fastest growing county in country. Overall, there was almost unanimous agreement that the Basin population will continue to grow, though many questioned the benefits of unchecked growth.

Fluctuations in Migration: Fertility and mortality have been stable for the last few decades, therefore while they can affect population growth, migration (both in and out) is a more significant factor determining changes in growth rate in the Basin. Jobs largely determine migration rates and the Basin has seen growth in both high income residents working for high tech or green industry jobs, as well as Spanish speaking migrant workers associated with the agricultural community. Lesser migration trends are associated with international immigration policies and academic outmigration (for higher education). The Basin's quality of life associated with proximity to Seattle, growth management policies and natural resources is considered an important factor in the decision to relocate (for both residents and employees).

Health

For Better or for Worse: While some experts discussed improvements in human health, associated with better access to health care and longer lifespans, others mentioned deteriorating health conditions dueto obesity and water quality issues. Current topics reflected local food movement, air and water quality standards, and psychosocial benefits associated with relationships to nature. Future concerns focused on climate change (both temperature and virology), increase in population (overcrowded) and change in economic conditions (income disparities and lack of funding for social services).

"importance"

17 ***comments***

The demographic shift caused by software development has been a big part of change in the Basin.

Population is the biggest difference in a whole bunch of different things, it's not just the number of people that matters.

Population growth will continue, we won't be able to constrain it.

Population growth is huge, it drives everything.

Public perception of food safety is important.

Sheer population numbers are important.

I think growth is the number one driver, it impacts on everything.

There has been incredible population growth.

The primary difference (out to 2060) would be population growth.

Impacts are measured as a systematic assessment of incidence on people, the economy, property and the environment; all four factors are correlated to population growth.

Human population growth is the largest issue we need to deal with.

The influx of people altered the motivation for development in a profound way.

Migration drives change.

"uncertainty"

19 ***comments***

We may see more people as well as older people.

There are a lot of challenges in front of us due to population growth.

A question still remains on how to transition farmland to the next generation.

The University of Washington could be private and only the wealthy can afford to attend.

I question that we will always increase our population numbers. There has to be a tipping point.

What happens with the aging population?

What are the legacies of past population growth?

How will air quality influence health?

The Puget Sound Region is a magnet for bringing in people, the question is will they end up in the Basin?

If the economy remains depressed and Boeing doesn't stay, and farmland is turned into subdivisions, will poverty rates be much higher in 50 years?

Recreation trends are changing, perhaps due to Americans becoming more overweight.

The major question is: will we see change back to growth once the economy recovers? The situation is currently difficult to read.

Values' *Relevance to the Basin*

Respect: Most experts discussed beliefs in association with implications on management and consumption. For example, "perhaps in the future we will have more respect for what we have, because we will have less". Topics included past values movements such as the 'depression mentality', the 'environmental movement', 'conservation ethics' and 'a connection to the environment'. A more recent value shift corresponded to 'a commitment to the Basin' (and the importance of appearing committed as a market value). Religious or ethical topics related to Tribal and Western thought. The majority of discussion related to changes in 'how people look at things' influencing conscious consumption and environmental impacts. Future value changes include faith in government, interest in higher education, apathy about privacy issues and acceptable norm (i.e. recycling grey water).

Doing things right: Participants generally saw preferences as arising from new knowledge and with potential influences on setting the public agenda. Several participants discussed a willingness to 'do things right' defined variably as accepting more growth, embracing the urban lifestyle, advocating the protection of the River, personally donating, funding change, and discussing the environment.

Protecting a high Quality of Life: While a higher quality of life (QOL) may be an obvious shared objective, defining what is a higher QOL is highly subjective. Participants shared ideas that the Region's natural resources support a high QOL, which simultaneously should be protected and draws more people here. These valued amenities relate to an urban-rural tension; namely the desire of the urban community to protect ecosystem services and recreate in natural areas while maintaining an affordable cost of living. The agricultural community has seen market changes related to this preferece, including an increase in demand for local, grass fed beef and organic produce, as well as personal interest and participation farms and the farmers.

Shifting norms: Norms have shifted dramatically and the clearest example is that of a smokestack once depicted as a positive sign of industrial production (i.e. jobs) to now a negative health factor. Other examples include seeing the river as 'owned by industry' to that of a public recreation amenity or seeing farmers shift from being seen as "dummies" to "heroes". Changes in these perceptions influence market values and acceptable production modes, with examples including the Spotted Owl controversy, GMOs, recycled water at Brightwater. There is uncertainty in regards to future norms, for example, will passive management be the preferred forestry management in Wilderness Areas if we have a major fire? Will aging households downsize? Will we regain confidence in lenders? Will our ideas of what is "built out" or capacity change? There is the hope that we will shift towards longer term thinking and be more proactive. And there is the fear that we will become meaner, associated with a larger income gap and increased anxiety over security, power and limited funds.

Raising awareness: Awareness was discussed in relation to 'making the right decision' (generally through outreach). The sentiment was the public officials and the public need to become more aware of a number of issues in order to influence behavior. Issues included importance of local food (agriculture), ecosystem services, and floodplains, as well as the implications of uncontrolled growth, climate change (and the need to reduce emissions), fractured ownership (of forestlands) and privatization (of services). The general public was credited with a better understanding of the inter-relationships of our actions and the need to strategize on a larger scale (i.e. the green building community looking beyond solar panels and towards neighborhood-scale strategies). Perhaps less so is the credit to the public understands of lag times (between action and impact).

"importance"

23 *comments*

The difference in perspective between Tribal and Western thought has led to a lot of differences in management.

This land is beautiful and people expect to drive out and see it. Its important to them.

Values drive everything.

How we value agriculture? Collectively we will agree agriculture is important.

Quality of life is very important

Flooding and rivers will play a huge role in what people think is important for their quality of life.

Changing people's perception is a major factor.

We are perceived nationwide as having an abundance of pristine habitat.

Expectations are an important category.

Change revolves around people and the economy.

Attitudes have changed. Social expectations have changed. People think they have control, they would have been told to mind their business back then.

Privacy is a huge thing. It's a huge motivator.

How do we get society to pay for these values? To keep the forest forested?

It ends up being about our thoughts.

Another driver influencing change is personal choice and how people's attitudes change.

"uncertainty"

20 *comments*

Perhaps we will have respect for what we have in the future, because we will have less.

Public perceptions can change agricultural practices from reactions, such as the reaction to growth hormones in milking cows.

The use of reclaimed water, for example, is controlled by human perceptions.

How do we value agriculture?

How do choices like those of the aging population influence the market?

How do lag times, between impact and ecological effect influence land manager perceptions?

We will want to make the changes but will we have the funds?

People will need to make choices for urban development and to protect forests.

I couldn't bear to live in the City, but maybe a shift toward urban living and driving out to rural areas to see the wildflowers is coming?

Issues of the day, like the avian flu are ephemeral in our focus and hard to predict.

What would a changing demographic be willing to pay for? Not just demand.

Is it possible to learn about the importance of forests and where materials come from?

We may see the concept of reusing wastewater take hold. We will see a continued consciousness.

Economy's *Relevance to the Basin*

Dwindling Funds: Across the board there is less funding and more demands, and we are challenged to find new ways to pay for all the thing we love. In terms of municipal funds, or public budgets, we are seeing more layoffs, closure of programs and efforts to increase efficiency as means of combating insufficient sales tax revenue. The three main opportunities for funds are business revenue, privatization of services and infrastructure repairs. The era of new grandiose municipal infrastructure is over, and we are seeing more of the European model of repair and mechanisms for increased efficiency supported by federal funds such as stimulus or congestion funding.

Shift from resource to service: Over the last fifty years the Basin has changed dramatically from largely resource based (timber, fishing and dairy) industries to manufacturing, technology and service based industries (Boeing, health care). While somewhat diversified, aerospace and Microsoft dominant the cash infusion into the. Economic forecasts rely on global industry changes to predict industry growth, including the cost of oil, recessions, industry organization, telecommuting, research + innovation, global competition, multinational trade, and recovery efforts.

Staying competitive: Associated with changes from resource, military and manufacturing to technogloy and service based jobs those jobs are demographic changes in family structure, gender, diversity, age and educational attainment. The Basin has, until recently, surpassed national averages for job growth. This growth has not always been well planned or coordinated and has challenged the provision of governmental services and economic saliency of incorporations. Potential future challenges will include the ability of the Basin to compete globally and within the Region to maintain and attract jobs through 1) amenities and high quality of life for employees, 2) predictable and fair permitting standards and 3) skilled and affordable (via effective negotiations) labor.

A Green Market: Conscious consumption and market demand, or lack thereof, for 'green' or environmentally safe products in the Basin may be reflected in higher density housing, carbon neutral developments, smart metering, rain barrels, on-site waste treatment, local agriculture and diversified crops. The market is often realized at a global scale by influential determinants such as gas prices and the energy market, privatization of services, the national economic climate and global trade. Global shifts then influence the Basin including effects on the role of aerospace, salmon fishing and local ag products.

Wealth Divide: As the industry shifted from resources to services, the level of personal wealth in the Basin rose dramatically. Today we see higher shares of disposable income affecting land use decisions, like the popularity of ranchettes, small scale tree farms, double income 5-acre farms and very large residential homes. On the other hand, for farmers, frequent floods and heavy regulation challenge profit making. The Basin continues to house lower income households, and in many ways the gap between the wealthy and poor is widening, with future implications on the privatization of services, affordable housing vs. gated communities, direction of recreation, and inequalities in health.

"importance"

27 *comments*

the National economic climate changes everything; it influences the amount of conservation efforts that can be accomplished, what people can buy, where the money goes.

Peak oil production will influence the price of oil which, will wreak economic havoc and uncertainty.

Up here in Snohomish we are very reliant on Aerospace. It's not healthy, but it supports us.

Trade and port activity is important!

Regulatory oversight has increased significantly, leading to substantial economic burden on industries (including farmers).

Quality of life is important, but trends correlate most strongly to jobs.

Biggest challenge will be staying competitive against growing countries like China.

Changes revolves around economy and people.

The biggest on-the-ground change is that there is a far broader diversity in job centers, with many new job centers sprouting all over the Region.

The shift from an industrial to service based economy has changed people's habits dramatically.

Funding, money, is a major issue. It's what it all comes down to.

Recreation is a huge industry here that is still largely unpaid for.

Employment is a big driver in the Puget Sound; if we lose Boeing or Microsoft we could see less people leading to less pressure on resources.

"uncertainty"

24 *comments*

Perhaps in the future we will have more respect for what we have because we will have less?

Will the economy be restructured so we get more local productivity? Will we be forced into that?

There may come a time when you don't have to live where you work. What might that do to Basin culture?

Will we become wealthier?

Business and economy is an uncertainty.

I would be surprised if Boeing was around 50 years from now.

Perhaps in the future subsidies will be different, like the Farm Bill which shaped agriculture.

We assume the economy will continue to grow, but how much growth can the region sustain?

What comes out of the labs and how industry is organized are uncertainties governing future industry growth in the Basin.

There will be good information. We will want to make changes. Will we have the funds?

The hope is that we will continue to generate employment but reduce impacts at the same time.

Going green will depend on how effective we are with government incentives.

Perhaps we will become a manufacturing center again.

What will be China's role in our economy?

With economic distress we may see incorporated areas dissolving back into counties.

Governance's *Relevance to the Basin*

It's political! Politics was loosely described as an uncontrolled shifting variable as in, politicians don't want to pick a side, or leave it to policymakers, the challenge with turnover of politicians, or depending on the shift in partisanship, or the political situation, etc. Alongside this uncertain shift were a few discussions of credibility, especially associated with the 'farm fish debate', coming from both the side of scientists disillusioned with assessment of habitat and farmers frustrated with costly and cumbersome regulations. Specific institutions were discussed at various scales, including 1) federal regulators such as EPA and FEMA, 2) Washington State agencies including the PSP, DOE and DOT 3) the Counties, 4) the Tribes and 5) municipalities. Overall, challenges discussed included the need for coordination among jurisdictions, the importance of government in pushing the public agenda (or any visionary agenda), and the impact of changing funding sources.

Level of services within municipalities and at the County level can determine where people choose to live, and where industries choose to locate. Over the last 50 years we have seen significant increases in wastewater and sewer treatment, access to health care, police, libraries and fire service within rural areas of the Basin. While expectation of services rose, many incorporated areas can't balance increasing demand (residential population) with lack of new funding leading to declining LOS. Economic hard times exacerbate difficulties, increasing the gap in access between wealthy and poor populations. Further, it is during these hard times that social services for the poor are at the highest demand. Changes in family structure, non-English speaking populations and dominant industry sectors may change the needs of the population.

Growth Managment: Over the last 50 years, we have seen a major policy overhaul increasing the complexity of regulations governing new development with the goal of protecting natural resources. Perhaps the most significant in the Basin have been the implementation of the Growth Management Act and Forest Plan. The allocation of funds, including Federal, State and local taxes has been, and continues to be a major driver of GM. Incorporations were cited as a way to get State funds, but also as a challenge in maintaining sufficient funds for service provision associated with different land use patterns (housing vs. commercial). Experts frequently mentioned how some counties have more stringent or effective rules governing management than other Counties.

Stringent Regulations: regulations have been seen as becoming a larger obstacle to profitable industry: banning the dumping of certain pollutants, referring to the Spotted Owl and decline in timber industry, and the predictability of the permitting process deterring new industries from forming here. The public agenda has also changed, especially with new development alongside agricultural lands and forests. This was most commonly described in terms of changed expectations for harvesting, viewsheds, access and safety, as well as changes in participation and trust of government agencies. But the most frequent discussion revolved around policies impact on agriculture associated with the protection of riparian areas for salmon. Farmers, described a need to subsidize agriculture and clarify definitions. In the future, new policies will need to be revamped to incorporate new knowledge and values around climate and sustainability. Experts also mentioned future changes associated with changing housing policies, new pollutants, and potential new listings.

"importance"

34 *comments*

Growth management encourages incorporation, then the County needs to bail out municipalities.

Turnover of elected officials is a major challenge.

The health of the Puget Sound water will drive regulations.

There will be little progress in constraining development.

Regulatory oversight and bureaucracy have significantly increased.

Regulations in general have a high cost. A new listing, for example, could lead to the elimination of farmland.

The EPA wasn't here 50 years ago. Federal government has caused a big shift in who you talk to about your problems.

Salmon decline is huge! Our tax money is going into analyzing and solving the problem, educating the public and court battles.

The expectation of services is an important category.

Accommodating growth is the focus now.

We are on the cusp of major changes in housing policy with huge implications on directing growth.

The public will lose interest and faith in government if we don't make enough progress. This is a big issue.

Zoning is a huge issue. Drawn on county lines and difficult to predict. As population goes up, zoning can drive up the revenue stream.

Wilderness act led to a profound change.

"uncertainty"

48 *comments*

Biggest uncertainty is on emission and energy consumption, which is influenced by national and state level policy.

Are rules such as the Critical Area Ordinance being enforced? Are they even effective?

What is missing from public policy to keep Boeing here?

How do local versus federal subsidies affect control and support?

Can emerging environmental markets protect agricultural land better than draconian land use laws?

Democracy in this county could have a serious shift towards defense.

There could be a shift to the federalization of environmental management.

We could have great cities, we could do these things, but will we? The major question is political.

We have yet to see our track record with the GMA. Does it prevent sprawl? What will it shape growth? Can we stick to it?

Going green will depend on government incentives.

We have to remember the goal behind all this is to protect resources. The question is, are the regulations too heavy so the public rebels?

What is the future role of county government?

How do we craft regulations to meet the changing needs of smaller scale farms with a higher diversity of products?

Knowledge's *Relevance to the Basin*

Predicting innovation into the next fifty years is a major challenge. After all, fifty years ago the personal computer was not around. We expect there will be more of the innovations we have seen in the past: advances in medicine, increased land productivity, automation and efficiency and reductions in costs. As far as new innovation direction, one certainty is increased energy efficiency and lower reliance on fossil fuels. We are expected to close the waste stream loop (eliminate pollution) and identify new technologies to help us go faster and further (shale gas, sonic boom travel, distributed solar power, cellulose, electric cars). Lastly, if the past has taught us anything, it's that technology always comes with unintended consequences. Recent challenges include: a hyper culture where twitter replaced deeper 'friendships', short term memory loss due to instantaneous access to information, virtual entertainment replacing contact with the natural world, and recreation gear (bikes, lightweight backpacks, all season garments) increasing access to pristine areas.

The role of science: Scientists are gaining new knowledge about the complexity of issues influencing the human-natural environment. We have seen a paradigm shift from understanding local impacts (industrial pollution) to cumulative impacts (impervious surfaces) and remote impacts (global warming). There is also increased awareness of thresholds, pollutants, biodiversity and resilience; though most experts agree our knowledge is still limited and always unfolding. With remote data we are able to conduct larger scale observations at lower costs, increase the density of our observations and monitoring, and improve the visualization of data. However, whether this has improved resource management or the accuracy of understanding is still up for debate. Lastly, distributed technology has revolutionized where the expertise lies. Experts now work directly with the public to identify and understand restoration actions.

Public outreach: A corollary to what we know is the communication or sharing of that knowledge through teaching. Experts, especially in the government and non-profit sector, believed that public outreach is critical to raise awareness and change behavior. The Tribes are an interesting factor in the Basin, with a unique long term perspective and mechanism for passage of knowledge. Technology, visualizations, assessments, farmer education programs and marketing were all mentioned as tools for communication.

"importance"

21 *comments*

New energy technology could be a big deal.

The assessment of the Snohomish Basin is of critical importance as the four rivers here determine policies for the rest of the State.

The sharing of cultural knowledge is important; an awful lot to learn.

There is a global value to biodiversity that science hasn't fully determined yet. It's like throwing out books without looking inside them first.

Technology is major predictor in terms of the future role of industry. What's coming out of those labs.

School and education are important in the recognition of historic conditions.

Convincing people to make the right decisions. It's a major factor.

Getting people to understand history and apply lessons to better management decision in the future is of critical importance.

Its important to save what's precious, but we need to understand the drivers. We need to improve our knowledge and pay attention to history.

The rise of digital data will be very important in the future.

Teaching the next generation to unravel some of the problems we have already created.

Its about getting the information out so people can modify their behavior.

We may see more technology on a personal level. This will be a big game changer.

Knowledge and development drive economic growth.

"uncertainty"

28 *comments*

Uncertain about information technology's future.

We may become aware of pollutants that haven't been identified yet.

Technology change, what will be invented?

In the future, will we recycle everything?

What is the value of biodiversity?

What changes will technology bring to our lifestyles? Will we commute?

Hard to predict what's coming out of the labs.

Climate model predictions are uncertain, especially in their evaluation of the effect of water

Our current understanding of steelhead population is skewed. How many orders of magnitude off is our understanding of the richness of how our environment was?

Will we recognize, as a society the maximum number of people the Basin ecosystem can hold? Will we understand thresholds?

New reports may alter regulations and policies, especially around carbon.

A potential future tool will be technology to visualize impacts.

Could we shift through technology to a different zero discharge community?

Will outreach teach the importance of forests? We all learned to recycle.

How will people interact with technology advances? Will the communication network promulgate virtual commuting?

Social Institutions' *Relevance to the Basin*

The rural, the urban and the recreation: Participants loosely described 3 communities in the Basin: the rural resource based community, the urban (largely residential) community, and the recreation community. The rural community has been shrinking, meanwhile intensifying its importance and cooperation with neighbors. Many participants described a growing contentious divide between urban and rural communities as urbanization pressures increase. The residential community is shifting away from inter-dependency and towards self-sufficiency. Meanwhile, the recreation community is growing significantly.

The New Tribes: Over the last 50 years, the roles of both the Tulalip and Snoqualmie Tribes have changed dramatically in terms of both culture and rights. The Tribes are increasingly seen as influential actors in the Basin, especially in the realm of natural resource protection. Native Americans share cultural norms that are uniquely different from Western thought and have influenced their management perspective for centuries. Despite massive social casualties from direct attacks, disease, and loss of land and resources (i.e. salmon) the Tribes have witnessed a renewal and livelihood. This renewal can be attributed to a heroic reconstruction of culture, a cash infusion brought on by the casinos, and recognition of tribal rights (Boldt Decision). Despite significant progress and investments towards cultural sustainability, infrastructure and resource management, the Tribes struggle with future uncertainty in regards to salmon and ecosystem service provision as well as the generational passage of cultural lessons and skills.

A lost culture: Overall, participants discussed a fear over the loss of ties to the Basin's natural and cultural history. Most discussion revolved around the Tribes and farming heritage. Further, many experts brought up the influence of technology, shifting the pace and accessibility to influence changes in work/life balance and social interactions. Other cultural elements included the increase in Basin cultural diversity, the competitive advantage of Seattle in terms of opportunities for arts and humanities and the influence of costs as overriding cultural preferences.

Globalization: An overarching driver of change in the Basin was global change, or more specifically the influence of other countries on the perception, economy and policy in the Basin. The competitive advantage, due to lower costs and increasing skillsets, of the developing world was discussed in terms of retaining global industries (Boeing, Microsoft) and attracting new innovation jobs. Global policy, including regional barriers multinational trade, anxiety of loss of US power and displacement of global refugees (due to political unrest and climate impacts) was sparingly discussed.

Public engagement: The two topics discussed as polarizing public engagement include density (the public being for it, or against it) and natural resource protection (relating to how connected to nature the population and presence, or lack of groundswell movement to protect it).

NGOs chip in: The increasingly important role of Non-Governmental Organizations is working to bridge the gap between landowners and County government. Environmental groups are supporting the protection of natural resources through large networks of volunteers. Otherwise, activism and engagement in civic organizations while not carrying the groundswell importance it once did, still shoulders the interest and attention of Basin stakeholders.

"importance"

12 *comments*

The difference in perspective between Western and Tribal culture has led to a lot of differences in management and behavior in the Basin.

Heroic reconstruction of culture and language of the Tribes.

Tribes play an important role.

The Tribes are a bigger factor now, both in managing resources and treaty rights.

Tribes are influential.

Biggest challenge will be staying competitive against growing countries like China.

Political will determines a lot.

Political will and developers are very important drivers.

A major hurdle is societal resistance to change.

Fish and culture are important things that lead to joint decision making

"uncertainty"

15 *comments*

There may be a time when you don't have to live where you work. What might that do to Basin culture?

Will we, as a society recognize and make the choices in regards to carrying capacity and thresholds?

The Tribes are trying to improve and sustain fish population. Perhaps by 2060 all of Snoqualmie will be protected.

Perhaps in the future the Tribes can educate the community about their culture and show their good will. The hope is their will be more influence.

We could have a large terrorist attack. We lie at the border of Canada and the Pacific Rim.

We could see the rise of an increasingly radical population in the Middle East that are extremely technologically savvy and very angry.

There needs to be a willingness to see cities change.

People will need to make choices for urban development and to protect forests.

There is an ebb and flow of public engagement that can be very influential but is unpredictable.

Perhaps we will become an international manufacturing center again?

What will China's role in our economy be?

Development's *Relevance to the Basin*

The Urban-Rural Divide: The Basin is described as 'fractured along the rural and urban divide; old residents don't like the urban change while new comers connect more with Seattle, than their new farming neighbors'. New applications for development are mostly for converting forests to 2-5 acre homes. And while movement is into rural area, residents are also looking for urban amenities such as parks, employment, services. Further dividing the population, new upland development is seen as detrimental to lowland agricultural practices and sustainability of Basin forests. Zoning has the potential to control character but is largely criticized as counter-productive. Construction techniques are shifting towards mixed use, higher density, transportation networks and low impact development.

Housing: In the past, residences were associated with the resource industries, but as Boeing and Microsoft came to the Basin, residences changed accordingly. The automobile is major determinant of residential growth today. Conversion of larger parcels of undeveloped land is controlled by land values and regulations. The rate of conversion is shaped by the high value of housing, in contrast to timber and agricultural lands, and the increasingly burdensome role of County permitting. In the future, we may see, increasing residential intolerance of resource based industry, increasing income inequalities, aging households migrating back towards services, and a shift towards green-high density houses.

Locations of growth: Growth is slated to be focused West of the Cascades, along I-5, with rural infill in the northern portion of the Basin and urban development south of I-90. We are likely to see density at the intersection of I-9 and Route 2, continued protection of uphill lands (wilderness and national forest) and rural fragmentation of 5 acre lots on well and septic at the urban-rural interface. Environmental considerations have generally focused on a shift upland from floodways due to increased flooding, regulations and costs.

Good density: Density was seen as an environmentally and socially positive pattern, but lacking market demand. Density is seen as conducive to supporting arts and culture, service provision, reducing land conversion and fragmentation, reducing VMTs and paved surfaces, and increasing quality of life attributes. The Growth Management Act was seen as a driver of density, though often criticized as ineffective and poorly implemented.

The Incorporated Basin: Historically, the Basin was organized around the City of Everett, with rural resource-based communities within unincorporated King and Snohomish Counties. However, over the last decade Snohomish County was the fastest growing county in the country, and the majority of the growth occurred within small incorporated cities within the Basin. Municipalities generally favor annexing commercial lands, as they bring in a larger tax revenue, while residential lands are increasingly recognized as being cost prohibitive to service. Some cities, like Duvall, Carnation and North Bend, were growing so fast they actually had to put in place moratorium to stop additional growth. The Basin's landscape today is characterized by several small to mid-sized cities (with Seattle being the closest-first tier city), often outcompeting each other for resources.

Drive till you quality: As higher income jobs moved in, so have residents, and rises in rents, making farming and timber production less affordable and increasing the conversion rate of residential land. Subsequently, land ownership has been increasingly fragmented into smaller parcels which affect management and long-term protection. Participating farmland advocates mentioned that floodplains may actually protect agricultural production by keeping real estate values low while upland parcels with good views can maintain high values even when development rights are purchased. Lastly, the recent downfall in economic downturn has shifted the Basin's significant growth trends, albeit perhaps only in the short term.

"importance"

34 *comments*

Incorporations are an important factor.

Built out, growth and sprawl. Not a bad thing, but the #1 driver.

Credit ratings are important, what a home appraises at.

More development, influencing the shape of the floodplain.

Land use changes may encompass loss of farmland, forest loss, increased fragmentation and impervious surfaces.

There will be little progress in constraining development.

The shift in housing and job numbers has important land use and transportation implications.

The urban footprint is significantly different today compared to 50 years ago.

The accessibility of an area to the rest of the region is a vital component.

Biggest on-the-ground game changes are the broader diversity in job centers.

Geographic diversity is key.

Accommodating growth is the focus now.

We're on the cusp of major changes in housing policy.

Cost of mortgage and commute time are important.

There has been a dramatic march of suburbia north and south.

The challenge will be where to locate development so that it will not impact critical watershed processes and functions.

Privacy is huge.

"uncertainty"

40 *comments*

We could see a move toward more compact residential development.

If the current recession is masking peak oil production, we may see increased efficiency and compact neighborhoods in the future.

We may need to slow down development and convert some back to agriculture.

There is only so much land, how much upland is available for build out?

Will the aging population stay in their houses or downsize?

How do choices of the green movement alter the housing market?

If the region is growing, Basin could be a value to where the growth could go.

Either people will live in more efficient homes or inequalities will heighten.

We have yet to see how our track record hold up with the GMA. Can we stick to it?

It is risky to base trends on today. Excluding the past two years, the trend in housing was to go larger.

Everyone recognizes that the majority of growth will happen at the periphery, the question is will it be more compact and connected with mass transit?

Increased flooding may lead to relocation out of the floodplain, easing the purchase of easements .

Perhaps in 50 years there will be more telecommuting. This may cause people to live further in the woods.

Will the GMA actually shape growth?

How will zoning and land use change?

Will we see more multi-family and condominiums?

Infrastructure's *Relevance to the Basin*

Transportation Costs: Transportation choices have environmental, economic and social costs. Environmental costs stem from the initial clearing of forests, impervious surfaces, non-point pollution, fragmentation of habitat, spread of invasive species and emissions. Economic costs are associated with funding new infrastructure, maintaining failing roads, externalizing the costs of transportation, as well as opportunity costs associated with limited infrastructure. The number one social cost discussed was traffic. 130,000 people leave Snohomish County for King County every day creating drastic congestion along the I-5 corridor.
Vehicle miles traveled (VMT), has risen faster than population rates in the Basin, indicating increasingly inefficient growth patterns.

New energy sources: Since the 1970's energy consumption has remained flat because consumption grew alongside gains in efficiencies. The 6th Power Plan assumes a continued modest growth of 0.3% energy consumption per year, even considering economic growth. However, uncertainty around peak oil production is challenging long term estimates. Sources of energy in the Basin are currently 90% fossil fuels (from hundreds of miles away) and 10% hydropower (Culback Dam). There is currently a massive push to change the sources of energy provision due to resulting emissions (climate change), biodiversity loss, and the cost of infrastructure. Participants focused their discussion on sources of energy generation (fossil fuels, hydropower, biofuels and green energy), format of distribution (centralized versus distributed) and the cost of energy.

Flood mitigation: Flood mitigation lies at the intersection of the agriculture and salmon controversy. The majority of armaments along Basin waterways were placed around the 30's and 40's by King and Snohomish Counties to protect properties from flooding. Shoreline armaments have since been linked to reduction in riparian habitat, loss of hydrological function and loss of rearing salmon habitat. In the 1990's the Shoreline Management Act ushered a flood consciousness with a resulting shift in County actions towards floodplain protection. Increasing flood frequency has exacerbated tensions between lowland properties, owners and County agencies. Furthermore, tensions arise as climate impacts are anticipated to increase the frequency and magnitude of floods.

Waste stream: Today's three main waste stream issues are carbon emissions, stormwater runoff and wastewater (sewer and septic). With increasing concerns over climate impacts, air pollution associated with energy (home electricity), car emissions, and industry pollution are likely to be under closer scrutiny of regulations. Increasing stormwater runoff is rivaling river flooding as one of the most damaging hazards to lowland properties, carrying non-point source pollution, as well as temperature and timing impacts affecting the protection of water quality. Bacterial contamination of water bodies associated with sewer and septic provision (waste water) continues to be challenge to water quality (eColi and HABs).

Will we have enoguh water? The Snohomish Basin was traditionally seen as a wet watershed with abundant water resources. The current system is largely divided by individual wells (rural) and reservoirs (supported by dams) servicing urban users. Within the Basin, the Tolt (King County) and Spada (Snohomish County) reservoirs service 80% of the population. While there is currently plenty of water in the reservoirs to service even a growing population, seasonal shortages associated with climatic changes are foreseen as a future obstacle. The decline of snowpack as temporary reservoirs coupled with lower summer precipitation may have a significant impact on summer volumes. Further, extension of services to new residential customers is very costly. When major expansion to facilities do occur (such as those in North Bend and Duvall) they usher in tremendous new growth.

"importance"

33 *comments*

When we reach peak oil production it will usher in increased efficiency.

Historically the loss of forests was due to firewood and steel production. This could return and be a big deal.

Water will be an issue in Snoqualmie. We may need to seriously look at constructing dams for flood protection and irrigation.

A shift in housing and job numbers has important land use and transportation implications.

Trade and port activity is important, especially accommodating vehicles to support the port's activities.

Water will definitely influence future growth, especially those on individual wells.

Climate impacts coupled with levees will make rivers such as the Tolt dramatically less hospitable to salmon.

There is a lot to think about with biofuels, growing trees to turn into energy.

Transportation costs and infrastructure are important in determining where people live.

By 2060 we will have hit peak oil production and associated environmental impacts will be severe.

We could see a catastrophic failure, a structural collapse of the Tolt and Culmback dams wreaking massive damages on the lower valley.

Financing any new infrastructure is extremely difficult.

Population and transportation will be key drivers.

Transportation will shape the impact and delivery of economic services.

A big game changer will be solar powered generation on roof tops.

The era of no limits is over. It is more economical to conserve than to build more.

"uncertainty"

59 *comments*

Currently exempt wells may see more regulations, no more free water.

Will we invest in new stuff or repair existing infrastructure?

What will be the future influence of oil prices?

What could allow vehicle miles to continue to decrease?

What new transportation options will arise?

Will cellulose be a viable alternative source of energy?

Biggest uncertainty is on emission and energy consumption.

What will happen to port activity with the Panama Canal expansion?

We have talked about too much water with flooding/ Could we not have enough?

Maybe in 50 years there will be no more landfills. We will recycle everything.

Maybe we will use reclaimed water from Brightwater to irrigate fields and recharge wetlands.

Rainier could erupt and destroy a lot of infrastructure.

We could see closed loop systems for water, energy and waste.

Dams might come back.

Timber may be more valued if energy costs go up.

We may see more distributed technology.

We may see more alternative energy growth, not much within the Basin other than hydro.

The extraction of shale gas may be a new important driver.

Resource Management's *Relevance to the Basin*

The farm fish debate: Farming today is not what is was 50 years ago, and for agriculture to remain in the Basin another 50 some drastic changes will need to occur. In Snohomish Basin, the largest obstacle is the 'farm fish debate', the culmination of half a dozen challenges, bringing a lot of attention to agriculture. The farm fish debate is predicated on the idea that agriculture and salmon protection are mutually exclusive, and is exacerbated by dwindling profits, urbanization, climate impacts, regulation, shifts in public perception and peak oil. While many farmers and farmland advocates argue that farming and salmon can (and even must) coexist, current solutions remain controversial.

Today's farmer: The perception and expectations from farmers and the farming community have changed. The farmer's role is much broader today, characterized as hired hand, mechanic, manager, website developer, public persona, midwife, marketer, even experts in regulatory reform and funding opportunities. Many farmers are new to the field and don't yet know what they are doing, yet they are committed to reducing their impact to the land. And in today's market consumers expect farmers to tend their market stand, apply wholistic or organic practices, be 'salmon safe' and safeguard long term food security for the urban community.

Wilderness: One mechanism to protect forests and sensitive ecosystems is to purchase them and limit their operations and management. In addition to National Parks and preserved easements (such as the Snoqualmie Tree Farm) the Basin boasts three large wilderness areas (Alpine Lakes ('76), Henry Jackson ('84) and Wild Sky ('07). These federally owned lands allow only minimal grazing, harvesting or motorized travel. While their annual usage is higher than any State parks, there is little visible human impacts. It seems their largest influences come from outside their boundaries including conflicts at the urban-interface, species migrations from climate change, and long-term regulations and managements dictated by politics.

Forest Industry: Looking back, at its peak logging accrued over 50% of the State's domestic product. Most employment was intricately linked to natural resources, and most residences could walk to a working forest. By the late 90's the timber industry collapsed, the mills were closed and large parcels subdivided and sold.Today's forests are owned by insurance companies, conservation minded recreational forests, US Forest Service and few remaining middle sized family farms (i.e. Pilchuck Tree Farm). Many of the small forest parcels are managed by owners who have a lower economic dependence on timber sales, have limited experience, or operational knowledge as foresters and have purchased the land for privacy, conservation ethic, and aesthetics. While large scale owners have in the past been blamed for habitat destruction, their larger scale, years of experience, longer-term vision and need for public credibility may lead to better practices.

The future of recreation: Participants are predicting further changes as we see more urban users, higher gas prices, technological innovations, climate change and budget cuts. For example, horse ranches, petting farms and bicycle trails are gaining popularity along the rural landscape. New watercrafts and mountain bikes are letting users into natural areas further and faster. The proximity to urban centers and increasing gas prices may shift hiking towards day or weekend uses. Websites are changing the communication of trail conditions and networks. Higher gas prices and private passes may lead towards exclusion of lower income households. Climate change may shift ski resorts towards a summer market. Lastly, cuts in agency budgets may lead to trail closures, reduced regulatory oversight, lack of maintenance, and innovative strategies to manage 'more use and less impact'.

"importance"

45 *comments*

The balance between fish habitat protection and agricultural use is a major challenge and will continue to be so.

The lack of agricultural infrastructure is one of the biggest problems.

Forests in the Basin were used as firewood for steel production. This could return and be a big deal.

There is a huge emphasis on farming now, it's coming back.

ESA listings have significantly increased resulting in substantial conservation donations from farmers.

Collectively we agree that agriculture is important. We all need to eat, we need to demand it as a priority.

There has been a striking upgrade in resource management on behalf of the Tribes.

There is a lot to think about with biofuels, growing trees into energy.

In this region, recreation is an immense natural resource opportunity.

Chuckanut Mountain is now used for recreation. It's a major shift.

Privacy is a huge thing for small forest landowners. It's a huge motivator.

The first question to ask is will it be a forest. The second is whether it will be working.

The damage to public resources resulting from the smaller manager parcels can be huge.

Local organic farmers are the fastest growing sector in agriculture. The big mover.

60,000 acres of protected agricultural lands are not high above sea level.

"uncertainty"

64 *comments*

Will the economy be restructured so we get more local productivity? Will we be forced to do that?

Maybe increased fire risk due to lack of forest management, especially with declining funding.

Soon it may be too wet to farm.

Perhaps all of Snoqualmie will be protected by 2060?

Will drain permit costs lead to the demise of farms?

Investment firms now own the majority of timber. For good or bad, it's a major shift in the pool of investors.

In the future, all local farms may be organic? Or none?

Perhaps in the future subsidies will be different.

Future of agriculture goes to intensifying production?

May need to slow down development and convert some land back to agriculture.

Will there be more support from outside our region for us to grow food for the country?

We could see synbio (synthetic biology) changing how we produce large amounts of food.

Basin becomes even more recreation focused?

Perhaps forests will be used for carbon storage, no rotation at all.

Do we need farmland for people, or do we need fish? They can coexist, but may entail litigation.

If we lose Boeing or Microsoft, we could see less people and less pressure on resources

There may be changes towards active management in wilderness areas where before it was more 'hands offs'

How do we craft regulations to meet the changing needs of farmers?

Biophysical templates'

Relevance to the basin

Rich Basin earth: The Basin's soils and minerals were described in terms of rich agricultural soil and a legacy of mines. The Basin has traditionally supported agricultural activities in its lowlands (floodplain) although recent introductions of new crops (such as grapes and ornamentals) are utilizing upland soils. In the past, the Cascades were mined for copper, gold, and silver bringing the first large economic migration into the Basin. The Basin's geology is also responsible for the support of fish and wildlife, from fish spawning to bird feeding. The thick organic horizon (duff) that once comprised the forest floor has largely been removed and replaced with impervious surfaces, exposed earth and frequently harvested monocultures. These changes have led to greater sedimentation and lower infiltration rates in lowland areas.

Seismic opportunities: The Basin lies atop the Cascadia Subduction Zone including the volcanic mountains of Ranier and Glacier Peak. The last earthquake occured 310 years ago, with a 500 year interval. Tsunamis have historically occurred along the coast. A seismic hazard event would incur major economic and human health costs. Globally, major disasters such as volcanic eruptions, can affect the region's economy via increases in industries associated with relief efforts. In the 1920's a major earthquake in Japan created a major economic boom in the shingle industry.

Nutrients and chemicals: Described Basin sources of nutrients and chemicals included nitrogen fertilization, manure waste from leaky septics and cattle manure, toxins associated with transportation corridors, and bacteria (eColi and Harmful Algal Blooms associated with fecal matter).

Landscape movement: Participants discussed salmon habitat deterioration associated with sedimentation and the loss of bedload transport as a result of agriculture and development. Lahars and avalanches were mentioned in relation to increasing recreation trends in wilderness areas and potential future climate impacts.

"importance"

5 comments

Snowpack is an important to support decompositional activity.

Earthquakes and avalanches are some of the major hazards in the Basin.

There is a significant increase in water quality problems, such as increased nutrient loading and responses in the environment such as harmful algae blooms.

"uncertainty"

7 comments

What about natural disasters? Earthquakes?

Natural disasters could get worse

A big one could occur, like a volcanic eruption.

Rainier could erupt or an event along the Cascadia Fault. Either would destroy lots of infrastructure.

We may be due for an earthquake in 20-30 years. This could be good or bad; an opportunity to renew aging infrastructure.

We may see a slight decline in soil and air temperature due to the reduction of insulating snow.

Soil carbon could have an inhibitory effect on decomposition if levels get too high.

Public recreation trends and avalanches may be a new big death contributor. This currently unregulated factor could shift the safety focus.

Climate's *Relevance to the Basin*

Controlling air quality: Air quality in the Basin has significantly changed over the last fifty years; in one regard there was smaller population and less traffic, on the other hand industrial pollution regulations were more permissive. The legacy of contamination includes asbestos, sulfides, diesel, and fires while more current pollution is associated NO_X and ozone. Future regulations might tighten further alongside escalating human and environmental health problems. The organic movement, the Regional Haze Rule governing air quality standards, and technological innovations may affect air quality, all with significant economic implications for the Basin.

Carbon counts: Development patterns and energy consumption are the leading contributors to fluxes in the carbon cycle. Carbon storage is largely associated with forest stands and marine vegetation. Future fluxes and storage are largely uncertain including factors such as validation of climate models, potential efficacy of regulations, and incentives (trade and cap), and energy technologies (wood burning stove or green energy). Carbon enrichment may have significant implications to ecosystem health influencing forest stocks (growth stocks currently 40% beyond expected model curves), and decomposition rates (influenced by soil carbon).

When will the fall rains start? Changes stem from a shift in the annual precipitation, seasonality (timing) and severity of storms. By 2080, the Region is projected to increase by 1-2% with increaes in precipitation fluctuations and extreme events. Precipitation changes has implications on vegetation patterns, water storage, stream vegetation and fire. There is a lot of uncertainty associated with future predictions of precipitation patterns, influence of transient watershed zone and changes in snowpack, and implications on ecosystem and infrastructure services (i.e. resilience, flooding, pests, water availability).

Melting snow pack: Temperature increases are influencing mid-elevation basins due to changes in melt timing and accumulation of snowpack. This has a significant implication on seasonal stream flows, water storage, recreation and vegetation. Transient (snow-rain, mid-elevation) watersheds, such as the Snoqualmie, are more sensitive to temperature changes as warmer temperatures will shift them from being snow- to rainfall-dominant. This will result in larger, faster winter flows and lower base flows and drought in the summer. The cumulative impact (water quality impairments due to temperature and flow changes) will have significant impacts on stream habitat and salmon. Runoff timing will also put us at higher risk for flooding (especially streamside residents and infrastructure). As our glaciers recede we will experience lower summer water availability as we currently rely on snowmelt for water supply. This will increase our reliance on reservoirs and groundwater.

Rising temperature: Current models project 3degF increase by 2040 and 5.3degF increase by the 2080's. We are likely to see warmer winters, a shift in seasonal timing and warmer stream temperatures. Warmer temperatures will likely lead to increase infrastructure pressure, including higher energy consumption and lower water storage. Water temperatures will also influence water quality, with implications for anadromous fish and other aquatic organisms. Exceedance of thermal envelopes is especially relevant as human landscape alterations already increase temperatures via development, extraction, pollution. Furthermore, shift from snowpack- to rain-dominant watersheds will reduce summer flows exacerbating temperature increases. Hazards are likely to coincide with extreme temperature events (rather than average annual increase) including floods, fire, pests, human disease.

Global climate change: Global climatic changes may impact the Basin indirectly. The most significant implications may be climate change refugees, global unrest and agricultural value associated with changes in global food scarcity.

"importance"

19 *comments*

Climate change may be more influential in the future, it hasn't really driven much yet.

Rising rivers, meandering channels and more flooding – these will all play a huge role in where people live and what they think is important for their quality of life.

Water is the most important greenhouse gas, accounting for 90% of the effect. It effectively swamps out anthropogenic carbon impacts.

Given levees and climate impacts, rivers like the Tolt will be even more inhospitable to fish.

Some systems will see a transition from a snowmelt to a rainfall dominated watershed.

Air quality standards affect all sectors of the economy

Global climate change issues will become more of dominant impact in how we live.

Climate change in the next 60 years could be pretty dramatic.

Looking at climate change and the concentration of people, there will be an intensification of impacts associated with hazards.

"uncertainty"

44 *comments*

Climate change is the wildcard that magnifies our impacts on biodiversity and what we can get out of biodiversity via ecosystem services.

Was it cleaner with lower populations of commuters and roads?

What will be the responses of plant communities to extreme temperature changes?

We have been emitting high levels of carbon, but the impacts are still yet to be understood.

Climate change may be more influential than it has been

There is a lot of uncertainty about near- and long-term affects and our choices to adapt.

Maybe we get wetter. Not enough water may be an issue.

Recovery efforts for Puget Sound may not be effective. Especially when adding climate change into the mix.

Silver Firs have been expanding their range downward, which may be due to climate changes.

The big question every year is: when will the fall rains start?

We may see a shift in stream peak flow in fall-summer months.

We may see more forest insects as climate impacts may change life cycles.

How will climate impacts affect fish and wildlife?

How do we integrate climate into national policy?

Dams might come back due to climate impacts. So far the DOE has said no, but what if we did allow it?

Previously estuaries could march upstream with sea level rise, now there are dams and dikes that may limit upstream migration.

Will we have a robust trade and cap system in place?

Hydrology's *Relevance to the Basin*

More flooding: Flooding is considered to be one of the largest challenges to the built environment (in terms of development, natural resources and infrastructure) in the Basin. Participants seemed pretty sure the future will bring more flooding due to climate change, upland stormwater runoff, alterations to the rivers' morphology and loss of infiltration. Floods impact industry, houses, agriculture and fish. In terms of agriculture while flooding created the rich fertile soil that has allowed farming, it now leads to costly infrastructure repairs, changes in practices, selection of crops, and timing.

Don't contaminate our groundwater: Groundwater aquifers serve as longer term storage for drinking water. As our demands increase (more population) and storage capacity decreases (melting snowpack, quicker flows, lower infiltration) the pressure on our groundwater will increase. In order to protect groundwater, we must change our behavior to reduce contamination, especially as groundwater is more difficult to clean up, and can determine subsurface flows and water quality.

Rapid streamflows: Changes are largely associated with 1) hydrologic maturity of the Basin, 2) loss of forest duff layer, 3) increase in impervious surface and 4) climate change (change in timing of precipitation and snow melt associated with temperature increase). A shift in the hydrograph will influence water supply (all water in winter, larger need for reservoirs, flooding, scouring, salmon habitat, high temperatures, more pollutants and altering passage through dry streams).

Altered morphology: Channel migration zones are the areas adjacent to the river into which the river can move into, or flood. These zones serve as important habitat and water filtration areas. In the Basin, the rivers' morphology has been dramatically altered via industry (dredging and removal of trees), flood mitigation (levees and dams) and increase in bedload transport (development). Our understanding of the importance of these zones is still limited.

A functional watershed: The Basin we see today is a shadow of the functional watershed found a century ago. The Basin has seen drastic change from industries, agricultural and timber production, diking of the delta, filling the wetlands, development of the lowlands, and most recently climate impacts leading to warmer, faster, more acidic and earlier flows. Accordingly, our connection to and perception of the Basin has changed, from industrial backyard to personal recreation and sanctuary.

Water quality: Water quality varies due to natural processes (rain, soil ,biology) however extreme variation is not natural. Water quality has been characterized in the Basin in terms of pH, dissolved oxygen, turbidity and scour, temperature, bacteria (fecal coliform, manure), nutrients (phosphorous and nitrogen), and toxins (arsenic, HABs). Temperature increases, a consequence of urbanization (extracting, stripping, developing, consuming), was the most frequently referred to water quality impairment. Climate change is predicted to further challenge water quality levels. Regulation around water quality initiated with the Clean Water Act (1972) has continued to strengthen towards a systems-approach integrating the management or protection of riparian areas, streamflows, infiltration, groundwater, and storage.

Water conservation: The Pacific Northwest is seen as a water 'rich' Basin. Prior to 1960's conservation (of water supply) wasn't thought about. This abundance has shaped the Basin in terms of industry and population migration as well as our behavior. In the future, we may see shortages due to changes in 1) population (more people, higher consumption), 2) climate change (lower summer flows, loss of snowpack 'reservoirs') and 3) land cover change (loss of storage) with the potential for 4) loss due to contamination (of groundwater).

"importance"

15 *comments*

The health of the water in Puget Sound will drive future regulations

Development will influence the shape of the floodplain

Water quality has become more of a problem on the Snoqualmie and its tributaries

The Snohomish Basin is of critical importance as the 4 rivers here determine policies for the rest of the State.

Rising rivers, meandering channels and flooding impacts will play a huge role in where people live and what they think is important for their quality of life.

Change in forest land cover has had impacts on water quality and quantity and all the other ecosystem services provided by intact forests

Flooding is a major hazard in the Basin.

In 50 years, flooding will certainly be an issue, it has been since settlement times.

There is a significant increase in water quality problems.

The challenge will be where to locate development so that it will not impact critical watershed processes and functions.

The first goal, the limiting factor is getting the delta back. And to do that, we need to slow down our rivers.

"uncertainty"

15 *comments*

Soon it may be too wet to farm

Climate change, dams, food security and flooding – what if we don't have enough water?

Natural disasters could get worse.

We may see a shift in stream peak flow in the fall-winter months. We may see warming rivers and repeated exceedance of temperature thresholds impacts anadromous fish.

We could see increased summer drought stress

Flooding and relocation out of the floodplain may ease purchase of development easements, increase protection of natural areas for reduced risk and greater public access to open space

Even if our restoration efforts succeed in getting the land back to the streams and rivers, the water may be too acidic and early.

There is uncertainty with salmon recovery.

Terrestrial Biosphere's *Relevance to the Basin*

Understanding biodiversity: Biodiversity provides ecosystem services such as provision of food, fuel and fiber, control of pests and diseases, cultural and aesthetic benefits, and genetic resources. Regulations such as the Endangered Species Act are specifically targeted to mitigate human impacts. In the Snohomish Basin, both the Spotted Owl controversy and salmon listing, associated with the ESA, have had direct implications on agriculture, timber and cultural perceptions. Future impacts of climate change, increasing population growth and lag times associated with past change are believed to magnify future threats to biodiversity.

Sea Level Rise and Estuaries: The Snohomish Estuary is still relatively intact and features 40 miles of slough channels, nine upstream miles of tidal influence and a protected upper watershed, all within proximity to a major urban core; a truly unique amenity. However the potential to protect and restore the delta relies heavily in our ability to slow down our rivers and the sediment associated with first and second order streams. A major future uncertainty lies in the implications of sea level rise and the associated salinity plumes on salmon, especially when confounded by dikes limiting upland migrations.

Fire risks: While outside the fire zone, the Basin has experienced several major fires in the past including a massive wet coniferous 'crown fire' (last one in 1701) and lightening fires on a 100-200 year return interval. Potential increases in risks are associated with changes in precipitation, temperature and deforestation. A Basin fire would have significant sociopolitical implications, especially to smaller rural communities. However, the West side is in good shape in terms of resilience from fire' due to higher elevations (drought tolerant) species, active management (private lands), wind migrations (east to west is rare) and moisture.

Forest habitat: While much of the Basin was logged a century ago, current aerial photos show more vegetation now than in 1950 as the forest is re-growing. Challenges today include continued fragmentation due to residential development and management practices (harvest rotations and monoculture stands). Many experts are also seeing shifts associated with climate change variables leading to species migrations and increase in biomass accumulation. There is disagreement among experts on the implications of ownership (private vs. public), recreation, and resilience. The future outlook among experts is largely positive, due to protection measures in place and supportive public awareness and engagement.

The spread of invasives: Over the last two decades the Basin has experienced a massive increase in weeds associated with fragmentation and loss of native habitat, transportation corridors (traffic, wheel dump) and time. Insects and diseases are correlated to plant susceptibility (sometimes attacking weaker plants while at times attacking more vigorous specimens).

Salmon and streams: The Snohomish Basin is home to 2 Chinook populations and steelhead. Salmon have important cultural and economic values; they also function as indicators of watershed health. The Basin's streams are home to migrating salmon and are critical to their survival, alongside other ecosystem services such as drinking water, recreation, habitat for a bio-diverse community of plants and animals, and Tribal livelihood. Basin streams are described as 'unraveling' both physically and biologically; no longer as productive or with the same species richness. The salmon decline has been huge and according to some groups, our current assessment of decline may still be orders of magnitude off. The major restoration objectives are to reestablish riparian habitat and large woody debris, reduce winter scour, slow down the river, raise summer base flow, and to cool water temperature.

"importance"

16 *comments*

The salmon decline is huge, the efforts mandated by the ESA. That is a big difference between then and now, because our resources weren't as stressed.

This denial of historical resources is a major driver for losing our wetlands and tributaries.

The balance between fish habitat protection and agricultural use is a major challenge and will continue to be so.

Given levees and climate change, rivers like the Tolt will be even more inhospitable to fish – perhaps dramatically so.

In 50 years habitat could be completely devastated from invasive weeds.

Huge explosion of invasive species, especially in the last 15-20 years.

CO_2 enrichment, an unexpected dramatic change from 40 years ago is the growth rate of young National Forest stands. Forest growth is off the chart!

Digital data will be even more important in the future, depicting boundaries of critical areas.

The limiting factor is getting the delta back.

Fish and culture are important things that lead to joint decision making for salmon.

The underpinning for a new look: how do we get society to keep the forest forested?

"uncertainty"

44 *comments*

What are the thresholds for biodiversity?

What will be the responses of plant communities to extreme temperature changes?

Due to burn policies or lack of forest management maybe increased fire risk?

If management practices actually succeed in benefitting salmon will it only lead to bigger buffers?

How resilient is the ecosystem?

Climate change is the wildcard that magnifies our impacts on biodiversity.

Insects and diseases are related to plant susceptibility, sometimes they attack vigorous plants, sometimes weaker specimens, it is unique to the disease.

Given levees and the likely impacts of climate change, rivers like the Tolt will be even more inhospitable to fish – perhaps dramatically so.

Will the ESA standards be lowered? Will there be additional listings?

How skewed is our understanding of historical Steelhead populations?

How often will we exceed temperature thresholds?

Snohomish estuary could be much more restored along some of the major rivers.

There is the fish vs. agriculture conflict: do we need farmland for people or do we need fish?

The Whitebark Pine may be designated as an endangered species.

There is uncertainty with salmon recovery.

The question is how do we accommodated growth while maintaining habitat.

Scenario Logics Workshop

Date

6.9.2010

Location

Graham Visitor's Center. Seattle, WA

Objective

One day workshop to develop Scenario Logics for the Snohomish Basin. Specifically select most important and uncertain driving forces and identify hypotheses for alternative futures including potential threats and opportunities.

Attendance

26 members of the Science Team.

Agenda

- Presentation on scenario planning approach and synthesis of project progress.
- Team exercise: teams test out hypotheses by intersecting the two most critical and uncertain driving forces.
- Discussion: Participants discuss prioritization of driving forces with the goal of developing divergen scenarios. Participants vote on key drivers.
- Team exercise 2. Teams develop final logics based on selected key drivers. Teams establish alternative hypotheses and discuss tradeoffs across scenarios.
- Discussion: participants evalute alternative scenarios.

Materials

(see presentation slides pages A6.89-97)

Scenario Logics Workshop

June 9th 2011

Thank you for coming!

- Abbott, Norm
- Babby, Elaine
- Bartz, Krista
- Beyers, Bill
- Bilby, Bob
- Bolotin, Leah
- Bostrom, Ann
- Bylin, Ann
- Crane, Paul Byron
- Gamon, John
- Geerlofs, Simon
- Hamlet, Alan
- Heintz, Kelly
- Hook, Abby
- Jerabek, Jennifer
- Kaje, Janne
- Kelly, Alice
- Klug, Jacque
- Lackey, Brent
- Leschine, Tom
- March, Mike
- McGuire, Al
- Meyers, Phyllis
- Moore, Scott
- Powell, Scott
- Rawson, Kit
- Rustay, Michael
- Schmidt , Rowan
- Snover, Amy
- Teverbaugh, Jim
- Tonnes, Dan
- Vernez Moudon, Anne
- Walls, Tim
- Whittington, Jan

UERL Team

Marina Alberti
Blake Trask
Michal Russo
Karis Puruncajas
Elisabeth Larson

Scenarios for Snohomish Basin 2060

Develop an assessment of key ecosystem services in the Snohomish Basin by characterizing the uncertainty associated with alternative future baseline conditions.

a 2-year research agenda
Funded by the Bullitt Foundation

.

Project TIMELINE

2010	Winter	*Urban Planning Class*
	Spring	Kickoff
	Summer	*Interviews*
	Fall	Conceptual Model Workshop
2011	Winter	*Basin Assessment*
	Spring	Scenario Logics Workshop
	Summer	Integrated Model Workshop
	Fall	Policy Workshop

Workshop objective

Identify alternative hypotheses (storylines) for future conditions in the Basin by exploring possible interactions among key drivers of change and their implications on future conditions.

Agenda

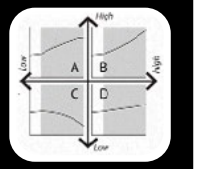
- Presentation by Marina Alberti
- Step 1 Driver Exploration
- Team Presentations
- Step 2 Discussion + Driver Selection
- **Lunch Break**
- Step 3 Scenario Logics
- Discussion + Next Steps

Project approach

Why scenario planning

Project approach

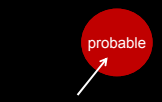
Instead of focusing on a single trajectory or prediction, we use Scenario Planning to explore alternative plausible futures and highlight the risks and opportunities involved in strategic decisions for the basin development.



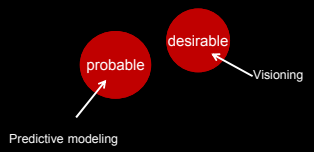
What are Scenarios

- Scenarios are **hypotheses** of alternative futures that highlight the ***risks*** and ***opportunities***.
- Scenarios focus on interactions among uncertain drivers and **expand the assumptions** of predictive models.
- Scenarios direct our attention towards the most **relevant uncertainty dimensions**.
- Scenarios ask: How robust are alternative strategies under plausible future conditions

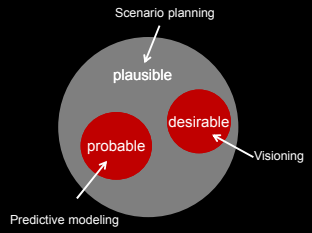
Alternative Future Approaches



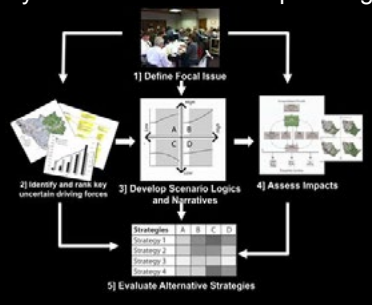
Alternative Future Approaches



Alternative Future Approaches



Key elements of scenario planning

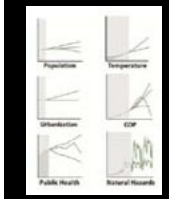


Key elements of scenario planning

1. **Define focal issue**
   - Data and observations
   - Historical documents
   - Expert knowledge
   - Conceptual models

OBJECTIVE:
Develop a shared problem definition

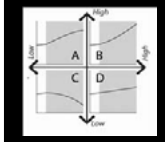
Key elements of scenario planning



2. **Identify and rank driving forces**
   - Identify key driving force
   - Rank their importance
   - Rank their uncertainty
   - Select most important & uncertain

OBJECTIVE:
To capture the most divergent yet plausible futures

Key elements of scenario planning



3. **Develop scenario logics and narratives**
   - Selected driving forces create the frames for scenario logics
   - Participants develop the story lines and narratives

OBJECTIVE:
Four distinct stories of how the future can unfold

Key elements of scenario planning

4. Assess Impacts

- Identify indicators
- Apply predictive models
- Assess impact of future conditions

OBJECTIVE:

An assessment of future conditions

Key elements of scenario planning

5. Evaluate alternative strategies

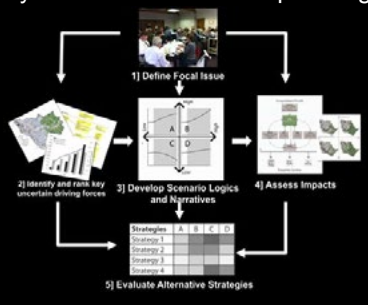
Strategies	A	B	C	D
Strategy 1				
Strategy 2				
Strategy 3				
Strategy 4				

- Use indicators to evaluate alternative strategies (their efficacy and robustness) under alternative scenarios.

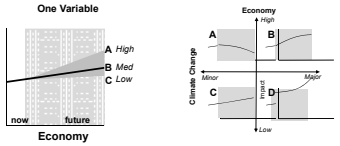
OBJECTIVE:

An evaluation of alternative strategies

Key elements of scenario planning



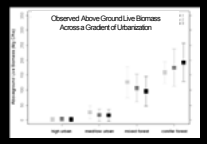
Predictions vs. Scenarios



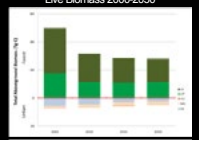
Predictive Models

Predicting Carbon Stocks in Central Puget Sound

Land Cover Change 2000-2050

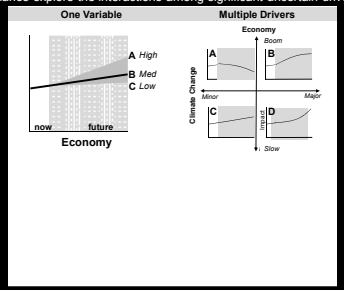


Live Biomass 2000-2050



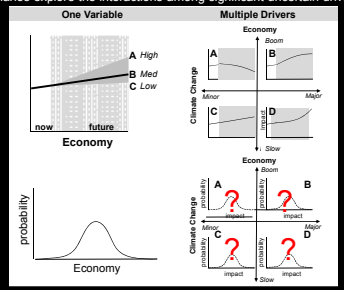
Uncertainty of Multiple Drivers

Scenarios explore the interactions among significant uncertain drivers



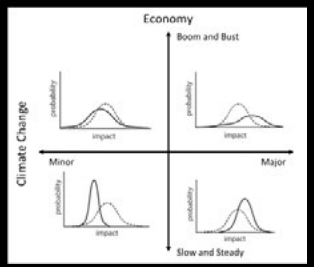
Uncertainty of Multiple Drivers

Scenarios explore the interactions among significant uncertain drivers

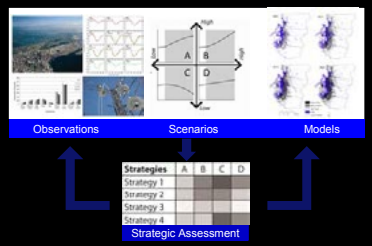


Uncertainty of Multiple Drivers

Scenarios explore the interactions among significant uncertain drivers



Linking Observations, Scenarios, and Models



Synthesis

What we heard from you

Rationale behind scenario logics

In order to develop scenarios that take into the most divergent plausible futures, we must explore interactions among critical and uncertain driving forces which may challenge our assumptions about future trajectories.

Your input

- Formulate questions and frame the problem from different perspectives
- Identify driving forces and develop shared definitions
- Explore past, current and future trajectories of the selected driving forces
- Explore similarities and differences in how experts view relationships, uncertainty, and importance of different driving forces

Teams and Activities

Steering Committee

Science Team

Expert Interviews

Conceptual Model workshop

Synthesis

Keywords

60+ stories about the Basin's past and future

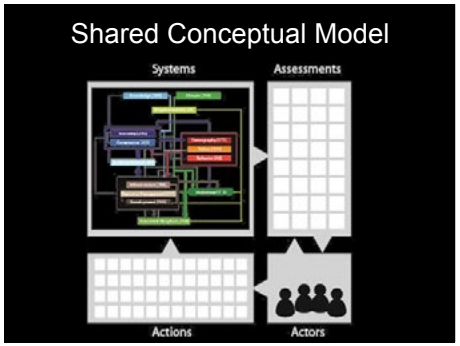
Mines
Hobby Farms
Timber Mills
Dairy Farms
Boeing
Microsoft

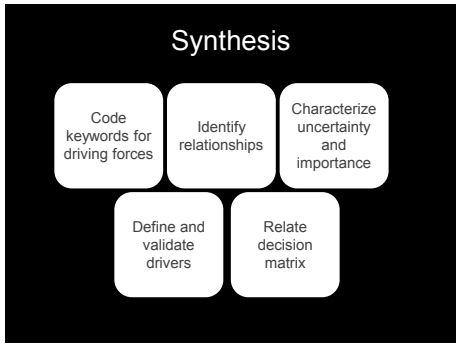
Example: Change in industry

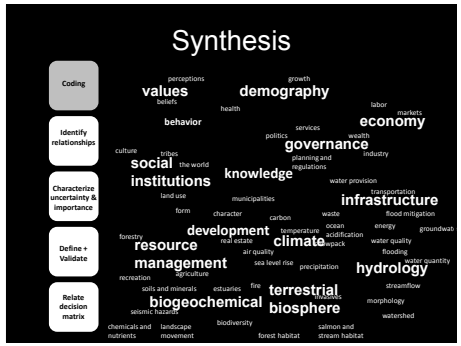
Team Conceptual Models

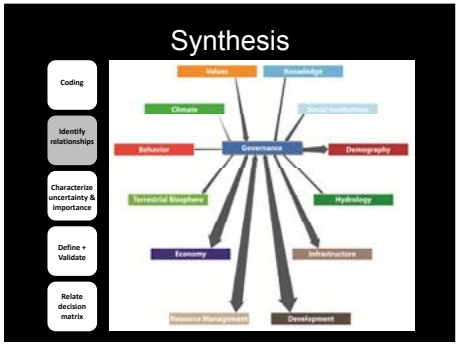
Workshop Directives

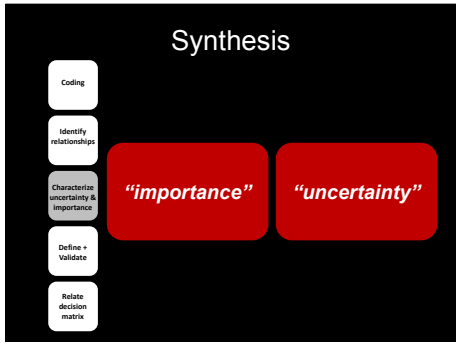
- **Clarity:** Clear purpose, well communicated, transparent
- **Parsimony:** Balance complexity and simplicity
- **Multiple scales:** Be relevant at local and regional scale.
- **Actors:** Representing stakeholders and decision makers
- **Dynamic:** Show feedbacks and interdependences.
- **Validation:** Claims should be validated
- **Impacts:** Depict strong, multiple relationships.
- **Highlight uncertainty:** Incorporate risks and resilience.
- **Link to measurements:** Indicators and metrics.
- **Decision making:** Reflect who are the decision makers.
- **Time:** Legacies and baselines inform future condition.
- **Organization:** Organize by environmental, social and economic groups

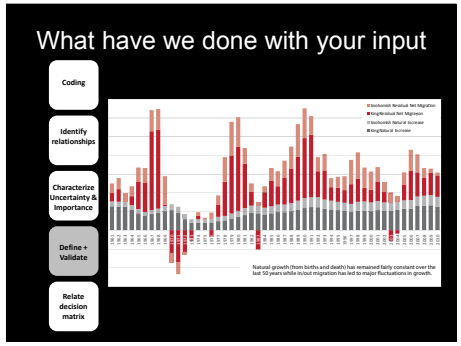

Shared Conceptual Model
Systems
Assessments
Actions
Actors

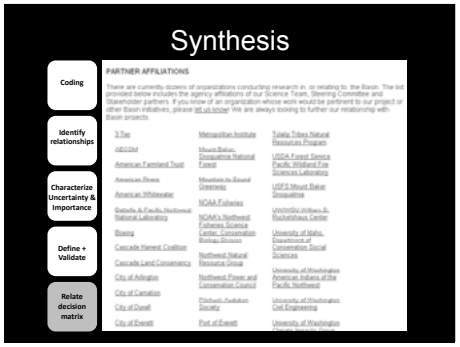

Synthesis
Code keywords for driving forces
Identify relationships
Characterize uncertainty and importance
Define and validate drivers
Relate decision matrix

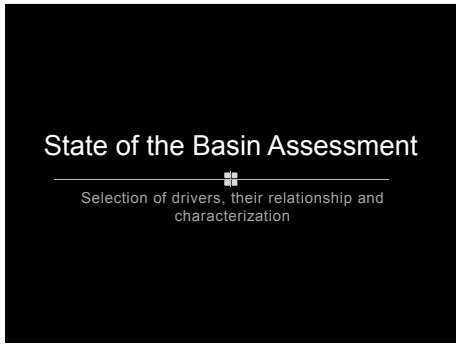

Synthesis
Coding
Identify relationships
Characterize uncertainty & importance
Define + Validate
Relate decision matrix
values
demography
economy
behavior
governance
social
knowledge
institutions
infrastructure
development
climate
resource
management
hydrology
biogeochemical
terrestrial
biosphere

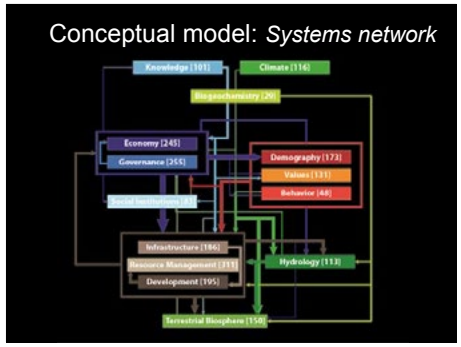

Synthesis
Coding
Identify relationships
Characterize uncertainty & importance
Define + Validate
Relate decision matrix
Values
Knowledge
Climate
Social Institutions
Behavior
Governance
Demography
Terrestrial Biosphere
Hydrology
Economy
Infrastructure
Resource Management
Development


Synthesis
Coding
Identify relationships
Characterize uncertainty & importance
Define + Validate
Relate decision matrix
"importance"
"uncertainty"


What have we done with your input
Coding
Identify relationships
Characterize Uncertainty & Importance
Define + Validate
Relate decision matrix


Synthesis
Coding
Identify relationships
Characterize Uncertainty & Importance
Define + Validate
Relate decision matrix
PARTNER AFFILIATIONS


State of the Basin Assessment
Selection of drivers, their relationship and characterization


Conceptual model: Systems network
Knowledge [101]
Climate [116]
Biogeochemistry [29]
Economy [245]
Governance [265]
Demography [173]
Values [131]
Behavior [68]
Social Institutions [4]
Infrastructure [186]
Resource Management [211]
Development [195]
Hydrology [113]
Terrestrial Biosphere [150]

Human Drivers

Demography | Behavior | Values

90,000 people
diversity
aging

consumption

environment

Institutional Drivers

Economy

resource to service

Governance

heavy regulation

Knowledge

computer age

Social Institutions

global

Built Environment Drivers

Development

sprawl

Infrastructure

abundance to conservation

Resource Management

smaller scale

Natural Environment Drivers

Hydrology

changed timing and volume

Climate

got on the agenda

Terrestrial Biosphere

salmon protection

Biophysical Template

contamination + sedimentation

Scenario Logic Exercise

introduction

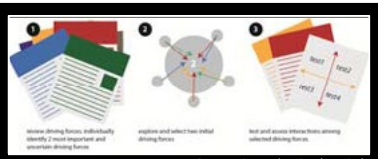
Scenario logics objectives

- **Objective for Today:** Identify alternative hypotheses (storylines) for future conditions in the Basin by exploring possible interactions among key drivers of change and their implications on future conditions.

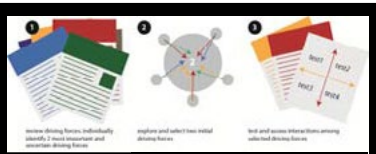
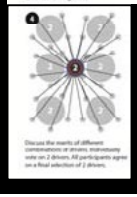
  Step 1 Driver Exploration *(Morning)*: Explore and assess importance and uncertainty of various driving forces by testing initial selection and postulating alternative hypotheses from their interactions (Individually and by teams).

  Step 2 Driver Selection *(Lunch)*: Select final key driving forces which will guide the development of the story lines (All).

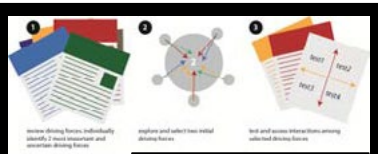
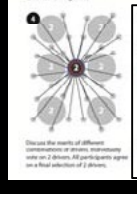
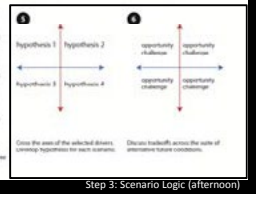
  Step 3 Scenario Logics (*Afternoon*): Develop scenario hypotheses and highlight tradeoffs by identifying opportunities and challenges.



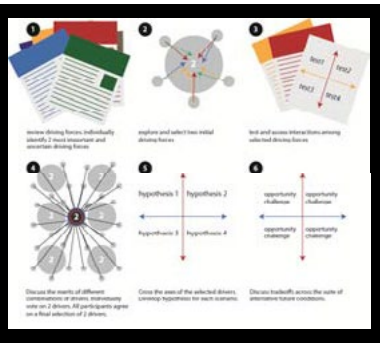
Step 1: Driver Exploration (morning)

Step 2: Driver Selection (before lunch)

Step 3: Scenario Logic (afternoon)



Importance and Uncertainty

- **Importance:** The magnitude of impact on the focal issue.
  - *For example, precipitation and impervious surfaces are important drivers in streamflow.*
- **Uncertainty:** The magnitude and direction of a trend is unknown or accurately predictable
  - *For example: The Region could become the next biotech center, or Boeing could leave the Basin.*

Step 1 Driver Exploration

instructions

Instructions

- Look over the driving forces working documents and choose the 2 most **critical and uncertain drivers**.
- Discuss selection and **finalize 2** per table.
- Test selected drivers and their interactions in relation to the focal issue.
- Select a **variable** and 2 **end-state** conditions per driver.
- Discuss selected drivers against other alternative choices.

Roles

- Moderator
- Note taker
- Timekeeper
- Illustrator
- Presenter

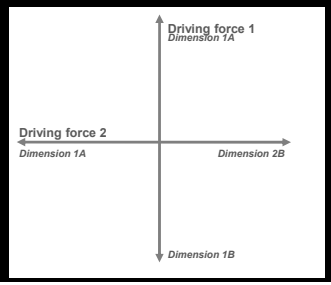
What's on your table

- Instructions packet
- Driving forces working documents
- Scenario logics board
- Voting ballots (index cards)

Driving Force Working Document

- **Objective:** To help make an informed decision in selecting the most important and uncertain driving forces.
- **Contents:**
  - Definitions
  - Published Data (graphs and maps)
  - Science Team Synthesis
    - Relevance to the Basin
    - Importance and Uncertainty
    - Relationship to other driving forces

Your logics should look like this



Step 1 Driver Exploration

Review drivers
Select 2 drivers
Cross axes
Identify variables and end states
Discuss hypotheses and driver interactions
Discuss assumptions challenged

Presentations

What assumptions did your team challenge?
State your two drivers and variables

Discussion

Selecting the most important and uncertain driving forces

Discussion Questions

- What are critical uncertainties of the selected driving forces?
- How do they affect the focal issue?
- What are some hypotheses about future interactions?
- How do these hypotheses challenge the assumptions we make about the future?
- What are some alternative hypotheses about what drives the future?

Step 2 Driver Selection

Discuss implications of alterative driving forces
Vote on final set of drivers

Importance and Uncertainty

- In order to identify the most divergent scenarios, scenario planning requires that we identify the most important and uncertain driving forces.
- Important because they have an effect on the focal issue (whether direct or indirect)
- Uncertain because we cannot accurately predict the occurrence of future conditions.
- Uncertainty also relates to controllability. We generally look for drivers that we (as stakeholders and decision makers) cannot directly control.

Plausible not Probable

- The role of the Scenario Logics is to identify alternative plausible scenarios that takes into account irreducible uncertainties. It is not to accurately predict future conditions.
- Our aim is to characterize the most **divergent** (different) hypotheses.

Divergence and Robustness

- The objective of scenario planning is to inform decision making towards robust strategies that are effective across various plausible future conditions.
- By identifying the most divergent scenarios we aim to ensure that strategies are rigorously tested against potential future challenges.
- Scenario planning aims to identify most robust strategies (that will be effective across a range of plausible futures) as opposite to optimal solution (that will work under a probable one).

Additional objectives of Scenario Logics

- **Relevant:** in relation to the focal issue
- **Compelling:** suite of storylines, not comprehensive
- **Valid:** based on empirically based information and arguments, not opinions.

Discussion

Which two drivers are the most important and uncertain?

Step 3: Scenario Logics

Cross selected drivers
Select variables and end states
Develop hypotheses
Characterize trajectories
Discuss opportunities and challenges
Articulate tradeoffs

Instructions

- Draw logics on board including selected drivers
- Decide on variable and end state conditions for each driver
- Develop hypothesis for each frame based on the interaction of the two end state conditions.
- Characterize each scenario with three keywords
- Identify a potential opportunity and challenge for each scenario
- Articulate tradeoffs across the 4 scenarios

Step 3: Scenario Logics

Cross selected drivers
Select variables and end states
Develop hypotheses
Characterize trajectories
Discuss opportunities and challenges
Articulate tradeoffs

Discussion

Scenario Evaluation

How do we evaluate the Scenarios?

- Relevance
- Divergence
- Tradeoffs
- Compelling

Discussion

How might the scenarios challenge the assumptions of the GMA? Of restoration investments?

Dicussion

Did any of the challenges or opportunities surprise you?

Next steps

- Identify core Science Team with expertise in selected drivers.
- Refine logics and hypotheses.
- Work with predictive model team to identify forecasts and indicators of ecosystem services.

Moving forward

What would you like to see?

Synthesis

Workshop synthesis is organized around the 3 major steps of the meeting:

- Step 1: Driver Exploration,
- Step 2: Driver Selection
- and Step 3: Scenario Logics.

Step 1: Driver Exploration

Participants were asked to review a set of 14 working documents (see synthesis of Conceptual Model Workshop - pages A6.42-63)

Participants selected the two most important and uncertain driving forces, first individually and then as a table. Participants then selected a variable and set of end-states for each driver and crossed their axes to create four frames. Lastly, each table discussed potential storylines associated with each frame.

Discussion: Which drivers are more uncertain or critical?

Participants discussed the need for drivers to be both critical and uncertain. Some drivers were important and less uncertain, while others were uncertain while less important. Infrastructure, social institutions and governance were seen as relatively predictable over a 50-year time horizon. Knowledge and hydrology were seen as highly uncertain.

Participants discussed how drivers are also driven, which creates a circular argument of what drives what. This is un-resolvable in the hierarchical structure. However, some drivers have a stronger role associated with their impact as opposed to their feedback in terms of the Basin and 50 year time frame. For example, demography and ecosystems (terrestrial biosphere) were discussed as following other drivers and being more predictable. Economy, on the hand, was said to drive both values and governance, and incorporate uncertain structural change.

The other major topic of discussion was control; drivers that are outside local control, such as climate, were at first discussed as being less relevant to explore. However, scenario planning specifically focuses on drivers outside of decision maker's control, as those drivers that are controlled serve more as strategic decisions than characterizing future uncertainty.

Variable Selection: Each table selected two drivers, and then defined a variable and endpoints for each driver (see table A6.2)

Table A6.2 Step 1 Driver and Variable Team Selections

Driver	Variable	End-states
Behavior	Human-Environment interaction	no / yes
Demographics	Population well-being	low / high
Values	Perception	Common good / individualism
Values	Individual resource consumption	low / high
Economy	Adaptable market place	more / less
Economy	Wealth	high / low
Social Institutions	Culture	Sustainability / consumption
Development	Form	Sprawling / Compact
Climate	Rain / Snow	more / less
Climate	Change	global / no
Climate	Change	major / minor
Terrestrial Biosphere	Ecosystem health	full complement of species / impaired

Discussion: Implications of driver selection

Participants discussed the implications of selected drivers and associated end-states.

Correlation: some pairings of drivers are more heavily correlated than other. For example, development was said to be correlated with resource management, and climate correlated with hydrology. Looking across the four groupings of human, institutions, built environment and natural environment we looked at the pairings identified by the 6 teams (table 2). It is important to consider how the selection today may be the result of our limited knowledge base and the representation at the workshop.

Scales of influence: Spatial scale is important to consider as having different impacts. For example, what is more relevant to assess, global economic growth or regional shift in industries? Or global climate change versus local precipitation change?

Defining values: Where does the subjective bias lie in defining 'what is good'?

Outcomes vs. drivers: outcomes are the effects that occur given a set of drivers. Participants discussed how certain outcomes may lead to subsequent change, i.e. drive future conditions. For example, ecosystems are an important driver and also an outcome, prompting us to respond. Perhaps development is an outcome and not a driver? Whether something is a driver or an outcome can only be answered in relationship to the focal issue, including the scale of analysis.

STEP 2 DRIVER SELECTION go to step 3

Each team presented their initial driver selection and draft storylines. Participants discussed criteria to consider when selecting the two drivers. Individuals voted before going to lunch. After lunch, workshop participants discussed the final selection and agreed to move forward with the selection.

Participants overwhelmingly selected climate and values as the two most important and uncertain drivers (see table A6.3). The selection of values (beliefs, or intentions of actions) as opposed to behavior (actions) was challenged. On one hand, behavior is more directly related to on-the-ground changes. On the other hand, values have larger influence over multiple variables in the long term. Further, small changes in the collective cultural values can really shift the direction of investments and governance.

Table A6.3 Step 2 Driver Selection

Driver	Votes
Demographics	4
Behavior	5
Values	11
Economy	6
Governance	
Social Institutions	2
Knowledge	
Development	4
Infrastructure	
Resource Management	
Hydrology	1
Climate	12
Terrestrial Biosphere	5
Biophysical Template	

STEP 3 DRIVER SELECTION

Each team started with the two selected drivers, climate and values, and then defined a variable and two end-states for each driver. Based on these drivers and variables, each team developed storylines for four scenarios including an initial hypothesis, characterized trajectories and tradeoffs associated with opportunities and challenges. Lastly, participants joined to share their storylines and discuss how they have challenged current assumptions about future conditions.

Variable and end-state selection

Human Values: Each team characterized values in slightly different ways. The 3 common threads were:

- Individualism vs. collectivism (i.e. public good, common good, communal). A sub topic of this was willingness and responsibility; to sacrifice as an individual, to take personal responsibility and action vs. to sacrifice as a group with the potential to rely on others and exhibit individual complacency.

- Consumption vs. conservation (i.e. sustainability). A sub topic of this was environmental indifference vs. ecosystem protection. Values in relation to the environment could remain static or improve. Our acceptance of different environmental conditions could change (low vs. high quality).

- Short term and selfish vs. long term and egalitarian. A sub topic of this was how (where) we choose to invest as well as whether we adapt or postpone changing.

Climate Change: Teams seemed to be challenged by selecting only on variable of climate change and spent considerable time debating how to incorporate myriad changes in one keyword or phrase. The 4 common threads were:

- Snowpack (decreasing relative to historic records vs. stable.. Snowpack was selected for integrating both variables of precipitation and temperature as well as taking into account the challenge of water storage. Other related variables include: water supply (plentiful vs. none), precipitation (high vs. low), timing of precipitation (rain vs. snow) and temperature.

- Variability (high, major, extreme or severe vs. low, minor, mild and moderate.). A sub topic was the stability of the system.

- Streamflow or flooding (high flow vs. low flow)

- Global vs. local impacts

Initial hypotheses

Each team developed four hypotheses based on the drivers and their selected variables. While each hypothesis was unique, some overarching themes did emerge (see table A6.4). The interaction of each variable produced different storylines, however due to the limited team time end-states superficially interacted as major and minor climate impacts and same (consumptive, short term) values vs. more conservation minded (long term and collective) values. Areas of agreement between teams are included below. Areas of potential disagreement include: migrations (in which scenario are they high / low), investment decisions (i.e. mitigation vs. engineered solutions), and willingness to act (individually or collectively).

Table A6.4 Step 3 Scenario Logics Common Hypotheses

"same values" and "major climate impacts" Worst case scenario. High pressure and impacts. Consumption is high and resilience is low. Ecosystem services: degraded Details: more jobs, resource dwindled, development sprawling, less personal sacrifice, more competition and conflict	"conservation values" and "major climate impacts" Adaptation or challenge scenario. Pressure is met with opportunity for improvement. Ecosystem services: ? Details: increased environmental regulation, sustainable development and innovation, higher assessments and monitoring, clear mandate, reallocation of resources, collaboration.
"same values" and "minor climate impacts" Business as usual scenario. Normal, boring, medium levels. Consumption is high. Ecosystem services: fair Details: non-climate problems rise in priority, complacency.	"conservation values" and "minor climate impacts" Best case scenario. Pressure is low and social action is highest. Social and environmental problems are low. Ecosystem services: improved Details: shared responsibility, opportunity to fix non-climate issues, greater success, healthy, no water shortage, more time.

Trajectories

Teams discussed implications of storylines on the trajectories of other driving forces. These discussions pose important correlations to consider when developing the final scenarios in terms of both assumptions to test and specific variables to consider as indicators of change.

- Behavior: Adaptation vs. reactive, postponing change or mitigation.
- Demographics: Migration (including a mobile population) and health (including well being and early childhood experiences).
- Economy: Spatial scale (local vs. global), cost of solutions, wealth (lower vs. higher), physical size relative to biosphere, and rigid vs. adaptable.
- Governance: Alternative government and policies, tight vs. loose environmental regulations and healthcare costs.
- Social institutions: Polarized society and disparity.
- Knowledge: innovation
- Development: Pressure, form (sprawling vs compact or sustainable) and housing.
- Infrastructure: Engineered solutions, more or less extensive network, energy solutions (sustainable), levees break vs. a stepped back, more money in transportation and more driving
- Resource management: Levels of resource protection, resource exploitation, loss of agriculture (due to salmon) vs. locally grown, funded, and sustainably produced agriculture.
- Terrestrial biosphere (ecosystems): Biodiversity, carbon levels and salmon condition (none vs. healthy).
- Hydrology: Frequency and magnitude of flows (and floods) and water supply vs. shortages.

Potential opportunities and challenges

Teams finished their discussions with a look at potential opportunities and challenges associated with the different scenarios. Even a seemingly negative scenario may have potential opportunities in relationship to the focal issue, and conversely, what may at first seem like major opportunities may lead to unintended consequences.

Investment choices
Innovative funding mechanisms vs. less capital
Economic growth vs. lower environment pressure
Pressure to conserve vs. complacency
Incentives to adapt behavior
Move agriculture and people out of floodplain
Engineer solutions vs. adaptive solutions.
Innovation
Small scale vs. big
Changes in thinking and management

See flooding as natural vs. problem
Timing: too late / in time
Reactive vs. proactive
At what point are people motivated to act?
How do we achieve resilience or sustainability?
Exploit different resources based on changing conditions
In-migration and growth vs. out migration and lower consumption
Social conflicts vs. environmental justice

Final Discussion

Workshop participants wrapped up the day's activities with a discussion of the scenarios.

1) How do the scenarios challenge the assumptions of current policies, such as the GMA?

- We have a conservative expectation of supporting and maintaining salmon populations. At what point do you start to let go of current expectations of a healthy environment? Or should our actions focus on supporting important values to control future conditions?

- Planning utilizes 20 year plans time frames, but perhaps we should also create 50 year plans, that are not actually plans, but rather scenarios to address uncertainty and evaluate the 20 years plans in the context of the longer time frames.

- What scenario are we in? How does that affect our thinking about the future?

2) Have any of the opportunities or challenges surprised you?

- Innovation may look very different based on national and international trends and values. How does the outside influence big scale technology? The Basin in context to global changes in important to consider.

- If we plan for 20 years, but resilience and vulnerability require that we look ahead 100 years, we may end up developing in a direction that may lead us to catastrophe.

- Futures may vary (be non-stationary) from decade to decade. We may jump from quadrant to quadrant in terms of the directions of the future. Today's drivers may shift.

A final note on the process

One thing that has surprised us in a positive sense is the similarity of outcome between the driver selection from this exercise and a similar exercise we conducted in the larger Puget Sound region with 50 scientists in a previous project. This might suggest that there is some level of robustness to this process, a hypothesis that would be valuable to test.

Scenario Development Meeting

Date

8.4.2011

Location

Gould Hall. UW Seattle.

Objective

Refine scenario logics and hypotheses developed at Scenario Logics Workshop.

Attendance

Ten science team members with disciplinary foci on climatology and social sciences r

Agenda

- Introductions
- Selection of variable and end states
- hypotheses development: each team developed a one line statement that summarizes the storyline or overarching assumption of each scenario. Teams also described changes in related trajectories in 3-5 phrases (i.e. in-migration of young, diverse and talented workforce).
- Discussion. Questions for UERL to test after meeting in order to finalize the scenarios.

Materials

Presentation (pages A6.104-106)

Pre-meeting handout - potential human value and climate change variables and trajectories (pages A6.107-108)

Synthesis

(pages A6.130-136)

Scenarios for Snohomish Basin 2060

Develop an assessment of key ecosystem services in the Snohomish Basin by characterizing the uncertainty associated with alternative future baseline conditions.

a 2-year research agenda
Funded by the Bullitt Foundation

Meeting objectives

Refine the scenario logics developed at the Scenario Logics Workshop by selecting final variables, end-states and hypotheses.

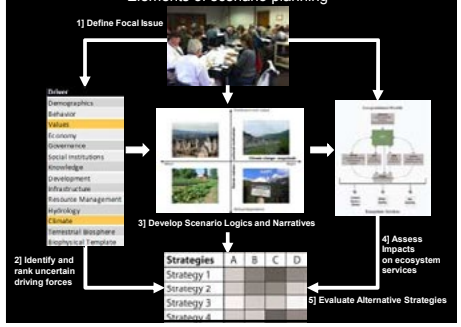
Agenda

- Brief introduction
- Selection of variables *[45min]*
- Development of hypotheses *[45min]*
- Discussion of next steps *[15min]*

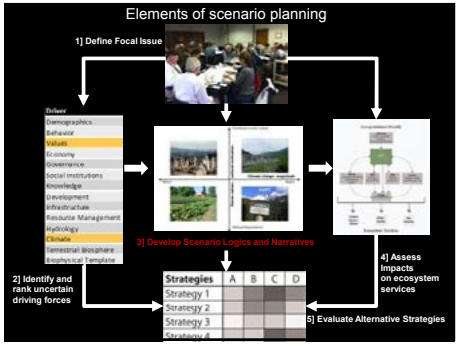
Project TIMELINE

2010	Winter	*Urban Planning Class*
	Spring	*Kickoff*
	Summer	*Interviews*
	Fall	Conceptual Model Workshop
2011	Winter	*Basin Assessment*
	Spring	Scenario Logics Workshop
	Summer	*Scenario Building Team*
		Integrated Model Workshop
	Fall	Policy Workshop

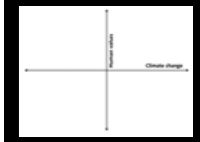
Elements of scenario planning



Elements of scenario planning



In Detail: Developing scenario logics and narratives

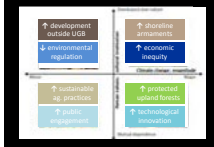


1. Selected driving forces create frames for scenario logics

In Detail: Developing scenario logics and narratives

1. Selected driving forces create frames for scenario logics
2. Participants select variables and end points for key driving forces

In Detail: Developing scenario logics and narratives



1. Selected driving forces create frames for scenario logics
2. Participants select variables and end points for key driving forces
3. Participants develop hypotheses about driver interactions

In Detail: Developing scenario logics and narratives

1. Selected driving forces create frames for scenario logics
2. Participants select variables and end points for key driving forces
3. Participants develop hypotheses about driver interactions
4. Participants develop scenarios with rich storylines

Synthesis: Scenario Logics Workshop

- **Driver Exploration:** Teams explored *14 driving forces* previously identified by the Science Team and selected the two most *important and uncertain* driving forces.
- **Driver Selection:** Participants discussed *criteria* for driver selection and *agreed* on the two most important and uncertain driving forces.
- **Scenario Logics:** Each team developed four *scenarios storylines* including variable *end-states*, *hypotheses*, characterized *trajectories* and *tradeoffs* associated with opportunities and challenges.

Initial Driving Forces

Human
- Behavior
- Demography
- Values

Built Environment:
- Development
- Infrastructure
- Resource Management

Institutions
- Economy
- Governance
- Knowledge
- Social Institutions

Natural Environment
- Biophysical Template
- Hydrology
- Climate Change
- Ecosystems

Most important and uncertain driving forces (votes)

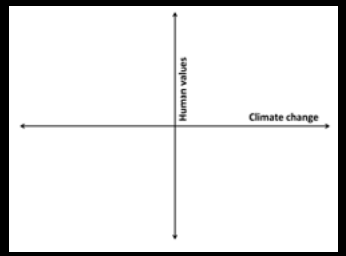
Human
- Behavior [5]
- Demography [4]
- Values [12]

Built Environment
- Development [4]
- Infrastructure
- Resource Management

Institutions
- Economy [6]
- Governance
- Knowledge
- Social Institutions [2]

Natural Environment
- Biophysical Template
- Hydrology [1]
- Climate Change [11]
- Ecosystems [5]

Refining the Scenario Logics

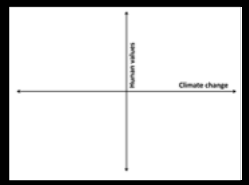


Potential variables and endpoints

Climate change:
- Magnitude (*major vs. minor change in annual mean precipitation & temperature)*
- Seasonality *(earlier vs. later precipitation peak)*
- Extreme Events (historic rates vs. frequent exceedance of temperature and precipitation)
- Snowpack *(historic levels vs. near extinction of snow water equivalent on April 1st)*
- *Scale of impact (local vs. global change)*

Human values:
- Cultural Motivation *(dominance over nature vs. mutual dependence)*
- Individual values (collectivism vs. individualism)
- Future valuation *(short vs. long term investments)*
- Consumer behavior *(high vs. low consumer spending)*
- Attitudes *(prioritization of environment vs. economy)*
- Awareness: *(high vs. low congruency between scientific knowledge & public opinion)*

Selecting variables and endpoints



Objective: Develop scenarios that are:
- Relevant
- Divergent
- Plausible
- Compelling

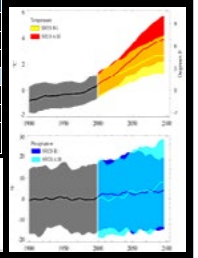
Relevant

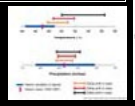
Focal Issue: *To maintain ecosystem services in the Snohomish Basin out to 2060*

Ecosystem Services
- **Water:** quality and quantity
- **Carbon:** storage and fluxes
- **Biodiversity:** species and landscape

End states example: *climate change*

Major Change	
IPCC Scenario	A1
Temperature	3.0degC increase by 2060
Precipitation	Increase in winter precipitation
Minor Change	
IPCC Scenario	B1
Temperature	0.5degC increase by 2060
Precipitation	No significant change in annual precipitation





End states example: *human values*

Variable	Mastery	Harmony
Relationship to natural and social world	master and change the world, to assert control, bend it to our will, and exploit it in order to further personal or group interests.	accept the world as it is, trying to fit in rather than to change or exploit it.
Cultural emphasis	*Getting* ahead through active self-assertion .	*Fitting harmoniously into the* environment .
Keywords	ambition, success, daring, competence	unity with nature, protecting the environment, world of beauty

Example hypotheses of driver interactions

Dominance over nature

cultural motivation

Climate change: *magnitude*

Minor — Major

Human values:

Mutual dependence

Example hypotheses of driver interactions

High

Awareness

Climate Change: *scale of change*

Local — Global

Human Values:

Low

Example hypotheses of driver interactions

Long term

Future valuation

Climate change: snowpack

Near extinction — Historic

Human Values:

Short term

Plausible

- Are the scenarios:
  - Logical?
  - Testable?
  - Grounded in theory?
  - Evidence based?
  - Internally consistent?

Compelling

- Are the scenarios:
  - Communicable?
  - Memorable?
  - Transformative?
  - Powerful?

Are the hypotheses divergent?

Dominance over nature

cultural motivation

Climate change: *magnitude*

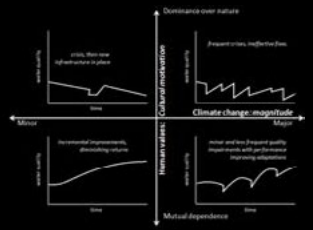
Minor — Major

Human values:

Mutual dependence

Are hypothesized implications on ecosystem services divergent?

Example hypotheses of baseline trajectories for water quality



CLIMATE CHANGE VARIABLES:

MAGNITUDE (potential indicator: change in annual mean precipitation and temperature): Magnitude refers to the extent of change in temperature and precipitation in terms of degrees and depth of rain respectively. The Intergovernmental Panel on Climate Change (IPCC) has brought forth several global models that reflect changes in both temperature and precipitation associated with variable levels of CO2 scenarios. Downscaled models have been applied to the Puget Sound and specifically the Snohomish Basin (Zhang, et al, 2009) to predict the magnitude of temperature and precipitation impacts at a finer resolution.

SEASONALITY (potential indicator: centroid of timing): The timing of precipitation can influence shifts in seasons with implications on runoff, streamflow and water availability. Precipitation trends roughly fall under heavier winter precipitation and lighter summer precipitation. Downscaled models show considerable variation in regional precipitation simulations for 2030 to 2059 (Salathe, 2010).

EXTREME EVENTS (potential indicator: exceedance of long term daily temperature and precipitation means): Extreme weather events such as heat waves, floods, droughts, or storms can lead to severe societal and economical impacts. Events are characterized as extreme if they exceeds (+/-1.5) standard deviations from the long-term means on a particular day (CIG website, 2011). Downscaled models have been developed for the Pacific Northwest that better represent local terrain and meso-scale weather systems, necessary to understanding processes causing localized extreme weather events (Duliere, 2009). Extreme events are tied more closely to changes in the variability than in the mean of climate change (Katz and Brown, 1992). Pacific Northwest models show an agreement for moderate increases in winter precipitation increasing the frequency of extreme events (Mote, 2003).

SNOWPACK (potential indicator: snow water equivalent, April 1st): Snowpack refers to layers of accumulated snow that may serve as temporary upland reservoirs of water. "The hydrology of the Pacific Northwest (PNW) is particularly sensitive to changes in climate because seasonal runoff is dominated by snowmelt from cool season mountain snowpack" (Elsner, 2009). Temperature changes influence whether precipitation will occur as rain-on-snow or snow-on-snow events. Warming trends are hypothesized to lead to a decline in snowpack. Relative declines grow from minimal at ridgetop to substantial at snowline. Transient Watersheds are likely the most sensitive to warming trends (Hamlet and Lettenmaier, 2007).

GLOBAL CLIMATE CHANGE (potential indicator: local versus global change): Climate changes may be greater outside the Basin (global or region) than within it leading to surprising and significant implications on the Basin. Global climate change models show variable future change with respect to temperature, sea levels, soil moisture and precipitation across the world (BBC, 2011). Further, a country's vulnerability and economic development compounds the effect of climate change. Currently, unstable developing countries and regions with critically threatened ecosystems have been the most affected by climate change (Thakker, 2009). However, richer countries incur higher damages in absolute dollars. Future global climate change may catalyze resource demands and economic opportunities in the Basin (i.e. in-migrations, agricultural productivity, and timber production).

HUMAN VALUES VARIABLES:

CULTURAL VALUES (potential indicator: dimensions of cultural adaptation)

Values are considered one of the most fundamental factors governing human behavior. Values are described as: beliefs, which when activated become infused with feeling; referring to desirable goals and modes of conduct; transcending actions and situations; guiding the evaluation of behavior, people and events; and as ordered by relative importance. Values prioritize behavior,

accounting for the initiation and direction of actions. Schwartz' research has supported the near-universality of ten types of individual values (1992). However, when moving to the level of cultural values, different issues and dimensions of values become relevant. One common dimension is individualism vs. collectivism. Schwartz alternatively identified three bipolar cultural adaptations: conservation versus autonomy, hierarchy vs. egalitarianism and mastery versus harmony (Schwartz, 1999).

FUTURE VALUATION (potential indicator: public investments in fixed public assets)

Future valuation, or simply put how much a society values the future, is important in understanding how much the public is willing to forgo certain current values in order to maintain benefits and reduce future risk. Understanding society's valuation of future conditions is fundamental to properly estimating the costs and benefits of major environmental policies (). Future valuation is directly related to intergenerational equity, or how much we value future generations. There are several means to measure future valuations. Economists, for example, measure future value by quantifying the discount rate. Investments in benefits that pay out over a long term are indicative of a high(er) future valuation.

CONSUMER BEHAVIOR (potential indicator: spending patterns in non-necessities)

Consumer behavior reflects how people behave when obtaining, using, and disposing of products (and services). Higher consumption rates have been associated with developed countries, with the United States having one of the highest ratings (Mooij, 2011). Consumption of resources has been linked to impacts on the natural environment, and more recently our carbon footprint (Hertwich, 2009). Consumer behavior can be measured not only through how much we spend, but also the types of (goods and services) (BLS, 2006).

ATTITUDE PRIORITIES: (potential indicator: prioritization of issues)

Priorities refer to the ordering of importance of topics or actions based on an individual's attitudes. Attitudes reflect favorable or unfavorable evaluations of an object. Values are less directly implicated in behavior, however are considered more durable than attitudes (Hitlin and Piliavin, 2004). Environmental attitudes are linked to socio-economic conditions and heavily influence political decisions.

AWARENESS: (potential indicator: congruency between scientific knowledge and public opinion)

Awareness refers to having knowledge and being cognizant of information. There is generally a delay between scientific knowledge and the transfer of that knowledge into the public domain (Boreaux, 2009). It is presumed that once the public is sufficiently aware of new knowledge, they will change their actions (i.e. consumption pattern, voting preference, activities) accordingly (Rochon, 1998).

Synthesis

I. Discussion of variable selection:

Human Values	Climate Change
Cultural motivation + individual values (mastery/individualism vs. harmony/collectivism)	*Great changes in extreme events vs. no changes*
Future Valuation (high value on immediate present vs. high value on long-term)	*Extreme events (historical norms vs. extreme variability)*
Cultural motivation + individual values (microeconomic valuation of ES vs. collectivist valuation)	*Extreme Events (higher frequency vs. lower frequency of extreme events)*
Consumer behavior (amount and type)	*Magnitude (minor change vs. major change)*
Cultural motivation (harmony vs. mastery)	**Magnitude and Variability (extreme events + major change vs. historical variability + minor change)**

Figure 1: Team selected variables and end-states (*italicized*) and agreed upon final selections (**bold**).

Climate Change

Extreme Events:

1. Can reflect both a change in frequency and magnitude of events. Should be defined, as exceedance of specific parameters.
2. Should not be limited to precipitation and temperature, but also changes in flooding, drought, soil moisture and frost dates.
3. A general increase in extreme events may still include a decrease of specific variables, for example flood.
4. One end-state can be historic variability; another could be decreased variability, or fewer extreme events. That might have implications on our behavior as it would reduce pressure (we are not currently well equipped to deal with even the current frequency of events). However, reduced capacity to handle extreme events (as documented in policy response due to low variability in the 40-70's) may reduce ecosystem resilience and lead to higher vulnerability to future perturbation.
5. The other variables (snowpack and seasonality) are highly correlated. The only one that isn't is global vs. local.

Magnitude:

1. Magnitude seems like a fundamental piece that we need to include.
2. Perhaps people notice extreme events more than long term increases, in let's say temperature. But we do also track magnitude changes, reflecting back to how things have changed.
3. Extreme events change the system, causing a shift by surpassing threshold. Magnitude can also shift the system, but it is less important.
4. The impact of a 'major' change versus extreme events is different. It is important to capture both dimensions in the scenarios. Could we include both of them along one axis, major and extreme events vs. minor and historic variability? Or are the two poorly correlated, could we have an extreme events and minor magnitude change? The most logical and divergent end states can be combined.

Human Values

Control: Selected variables should not reflect what decision makers in the Basin can control.

1. Consumer behavior and future valuation may be influenced by internal drivers (in addition to external drivers).
2. While climate change may be outside the realm of Basin decision makers' control, human values is affected by our actions. How does that affect human values variable selection?
3. Is consumption controlled more than a mastery/harmony or modes of production? Dimensions of consumption can relate to type, not just amount. For example, disposable consumptive spending vs. 'greener' spending.

Correlation: *Is individualism correlated with mastery?*

1. Individualism and mastery, and collectivism + harmony are more common cultural combinations, but the other combinations (individualism + harmony, and collectivism and mastery) can occur and are present in other nations or sub-cultures.
2. Collectivism and harmony may well represent collectivist modes of production, while individualism and mastery may reflect market based production systems. However, individual and harmony isn't broad enough to capture various institutions. While less probable, it should not be eliminated.
3. Does the axis of individualism + mastery and collectivism + harmony reflect more divergent endpoints? Yes. But not necessarily the most divergent scenarios. Outliers are an important element of scenarios,
5. Can we capture some of the ideas of individualism vs. collectivism and short vs. long term valuation while keeping mastery and dominance as the major dimension? Yes. By simplifying multiple dimensions along one axis we may be eliminating alternatives that are plausible and compelling.

II. Discussion of hypotheses and potential trajectories of the other drivers

Scenario 1: *Minor change and less extreme events + cultural motivation led by harmony*

- Overarching Idea: Low pressure, collectivist solutions. 'recovery'
- Implications to Ecosystem Services: Best possible scenario. Potential for improvements.

Other drivers:
1. Development: compact growth
2. Technology: biomimcry
3. Demography: more equity
4. Economy: away from market based solutions.

Scenario 2: *Major change and extreme events + cultural motivation led by harmony*

- Overarching idea: higher pressure met with collectivist patterns
- Implications to ecosystem services: diversification. Potential for maintenance (mitigation)

Other drivers:
1. Resource management: scarcer resources and diversified management practices
2. Development: compact efficient pattern, move uphill from flooding
3. Infrastructure: retreat from natural disasters.
4. Economy: pattern of production towards collectivism + more efficient use of resources.
5. Social Institutions: smaller, more community-based

Scenario 3: *Minor change and fewer extreme events + cultural motivation led by mastery*

- Overarching idea: 'status quo', similar pressure and values to today. Lower diversity.
- Implications to ecosystem services: slow decline. Expansion of utilization.

Other drivers:
1. Technology: will innovation keep pace? Biomimcry?
2. Resource management: more homogeneity. increased extraction. Depletion.
3. Infrastructure: higher demands for energy.

Scenario 4: *Major change and extreme events + cultural motivation led by mastery*

- Overarching idea: technocratic society working to innovate and compete our way out of climate challenges. 'worse'.
- Implications to ecosystem services: uncertainty, shortages and crises. high stress.

Other drivers:
1. Technology: high reliance on innovation. 'techno-fixes'
2. Demography: inequality, disproportionate distribution of impacts
3. Infrastructure: more built, protection
4. Resource management: shortages and conflicts. higher focus on resource management.

Discussion Questions:

1. What are the limits? This is both a temporal and spatial question. We may see a shift towards another 'quadrant / scenario' if our actions do/don't work.
2. Where are we right now? (which scenario)
3. What might the implications of climate change be on environmental regulation? What is the relationship between regulation and cultural motivation?

Interviews with Predictive Modelers

Date

9.2011

Location

UW Seattle

Objective

To understand more about each model (structure, assumptions, and theory) and to evaluate the potential for integration.

Attendance

Interviews were conducted with individual or small groups of predictive modelers representing a regional model.

Materials

Survey Instrument - see page A6.112

Synthesis.

See Appendix 2 Predictive models and integration

SURVEY INSTRUMENT FOR INTEGRATED MODEL

Introduction

This interview is part of the modeling component of the Snohomish Basin Scenarios Project. The objective of the Snohomish Basin Scenarios project is to inform strategies for long term protection of ecosystem services in the Basin. The modeling component aims to explore how existent models can be integrated to evaluate future ecosystem service conditions in the Basin, under alternative scenarios.

The Snohomish Basin Scenarios project engages experts in the development of scenarios that propose divergent hypotheses for how the future can unfold in the Basin. These scenarios are combined with predictive models to quantify key ecosystem services in the Basin under alternative futures. The suite of scenarios and assessments allows decision makers to select robust strategies that are effective under divergent trajectories. The scenarios help highlight opportunities and challenges that may otherwise be overlooked through assessments culminating in a single prediction or vision for the future.

The project includes four components 1) conceptual model and Basin assessment 2) scenario logics 3) integrating predictive models and 4) supporting decision making through an evaluation framework.

During the first phase (conceptual model and Basin assessment) we interviewed Basin and regional experts to look at what factors drive urban growth and environmental change in the Basin. Interviews were followed up with a Conceptual Model Workshop in which experts built a framework for asking the question 'what is the future of the Snohomish Basin look like?' This information will be compiled in an assessment of the current state of key ecosystem services as a State of the Basin Report.

The second and third phases which involve developing scenario logics and identify predictive models, occur concurrently. The scenario logics are hypotheses describing alternative future baseline conditions in the Basin in 2060. Regional experts and stakeholders are asked to develop these logics by selecting the most important and uncertain drivers influencing the Basin's future at the Scenario Logics Workshop.

The model integration piece, which this interview is a component of, is the third phase of the project. In order to quantify baseline conditions of ecosystem services under alternative scenario logics, we will be exploring how to integrate existent regional models. We will also investigate which parameters, starting conditions or model assumptions could be modified to represent the status or trend of the driving forces from each scenario. The ecosystem services we are interested in modeling include those related to biodiversity, water (quality and quantity) and carbon (storage and fluxes).

Finally, the project team will develop evaluation criteria to inform the selection of robust strategies that effectively maintain ecosystem services across alternative futures. By understanding the full range of opportunities and challenges we may face, even those less probable or outside our realm of influence, we can identify a more robust and adaptable suite of strategies to protect the future of the Basin.

Do you have any questions about the project in general?
As I mentioned earlier, today's interview is aimed at informing the integrated model phase of the project. Our objectives are to understand more about the model (structure, assumptions, and theory) and to evaluate the potential for integration. Based on these interviews we will develop a white paper that summarizes a selection of appropriate regional models. An Integrated Model Workshop will be held to explore ways to integrate identified models to evaluate future baselines that are sensitive to differences represented in the scenarios.

Model Characteristics

1. Please describe the *name of* model for us.
2. What is the purpose of the model?
3. What is the output?
4. What are the assumptions?
5. What is the modeling approach?
    a. Equations/models/theory (Monte Carlo, linear regression, etc)
6. What systems (or predictor variables) are represented explicitly within the model? Which are endogenous, exogenous (parameters)?
7. Which is the model most sensitive to (or drives the outcome)?
8. What is the model input?
9. What is the spatial and temporal scale (resolution and extent)?
10. What are the current model limitations? Assumptions?
11. How is uncertainty treated/represented in your model?

Model Output

1. Describe the range of the model outputs? Are there multiple output modes?
2. Describe the most divergent endpoints (realized or expected)? What is the model output most sensitive?
3. What are future developments (currently planned, or in early stages) for the model?

Integrating Models

1. What, if any, models has *model name* been integrated with?
2. How has it influenced the scope and extent of model predictions?
3. Which additional model (specific or type) might *model name* be paired with?
4. During the CarbonFinity Workshop (which you attended), MIMEs was proposed as a systems based platform that links existent regional models to assess ecosystem services. What are your thoughts on its use? Did you find it was helpful or limiting?

Expanding our Research

Handout: Provide a list of the identified models and contacts.

1. Are there any publications we could look at to understand more about *model name*?
2. What other models would you recommend we look at?
3. What other agencies or experts should we be contacting to complete our assessment? (show list)
4. Do you have any recommendation for our modeling workshop?

Interview Wrap Up

1. Do you have any final suggestions, considerations or questions for us?

Integrated Model Workshop

Date

11.3.2011

Location

Peterson Room. UW Seattle

Objective

Discuss how regional models can complement the Scenario Planning approach in characterizing long term implications of multiple uncertain drivers. During the workshop we will focus on drafting a blueprint for integrated modeling to assess future conditions of ecosystem services in the Snohomish Basin [WRIA 7] under alternative scenarios. The models we are currently investigating include Shiraz, DHSVM, HSPF, WRF, LCCM, UrbanSim and EcoPath. We are also exploring the possible links between the model outputs and InVEST and the DOE's Watershed Characterization Model.

Attendance

Ten science team members with disciplinary foci on regional predictive models.

Agenda

- Presentation: how can models help scenarios expand our ability to characterize uncertainty?
- Team exercise 1: explore the relationships between scenario and models
- Team exercise 2:draft model integration
- Discussion: Potential benefits and limitations of model integration

Materials

> Presentation (pages A6.114-121)

> Pre-Meeting handout - Draft scenarios and indicator trajectories across draft scenarios (A6.122-128)

> Summary of selected predictive models (A6.129)

> Driver Forces Future Trajectories Database

Workshop participants were sent a web-based spreadsheet relating the draft four scenarios with the 14 driving forces identified by the Science Team. Each driving forces is described through a selection of 2-5 indicators. The main page includes a brief summary the historic trajectory of each indicator, the spatial and temporal extent of the available data and potential future trajectory in association with each scenario. Details on each indicator can be reviewed by clicking on the hyperlink to reveal a summary worksheet including a description, graph, raw numbers, and references. The selection of indicators was based on recommended good measures of the driving force, available data and relevance to the draft scenario narratives. After the workshop, the UERL team discussed the selection and trajectories of each indicator with science team members to assess if: 1.They are appropriate? If there are indicators that may be more applicable? easier to communicate? available data? more direct? 2.To see if experts agree with the trends depicted? Do they agree with the direction of the trends?

The database of indicators and trajectories can be found here:

http://www.urbaneco.washington.edu/sbs/docs/data/7631_SBS2060.xlsx

Integrated Model Workshop

November 3rd 2011

Project Objective

Develop an assessment of key ecosystem services in the Snohomish Basin by characterizing the uncertainty associated with alternative future baseline conditions.

a 2-year research agenda
Funded by the Bullitt Foundation

Project TIMELINE

2010	Spring	*Kickoff*
	Summer	*Interviews*
	Fall	Conceptual Model Workshop
	Winter	*Basin Assessment*
2011	Spring	Scenario Logics Workshop
	Summer	*Scenario Development* *Model Assessment*
	Fall	Integrated Model Workshop
	Winter	Policy Workshop

Thank you to our Science Team
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Bob Bilby
Christopher Bitter
Michael Blake
Heidi Bohan
Leah Bolotin
Branden Born
Alan Borning
Ann Bostrom
Mark Boyar
Nicholas Bratton
David Buerge
David Burger
Bob Burns
Ann Bylin
Ken Carter
Paul Byron Crane, B.L.A., M.A.
Sara Curran
Curtis DeGasperi
David Dilgard
Mary Embleton
Gina Estep
Nicole Faghin LEED AP
John Findlay
Jim Franzel
John Gamon
Simon Geerlofs
Bonnie Geers
Jamie Glasgow
Andy Haas
Troy Hall
Alan Hamlet
Chris Harvey
Kelly Heintz
Ryan Hembree
Jan Henderson
Judy Herring
Kollin Higgins
Abby Hook
Peter Jackson
Jennifer Jerabek
Janne Kaje
Kristin Kelly
Alice Kelly
Michael Kern
Karen Kinney
Jacque Klug
Bill Knutson
Deborah Knutson
Dave Kosciuk
Brent Lackey
Sim Larkin
Tom Leschine
Dennis Lettenmaier
Roberta (Bobbi) Lindemulder
Sandra Mallory
Mike March
Stewart Matthiesen
Matt Mattson
Mark Maureen
Heike Mayer
Doug McClelland
Al McGuire
Phyllis Meyers
Marcia Meyers
Anna Miles
Jim Miller
Barbara Mock
Dave Montgomery
Scott Moore
John Moore
Tom Niemann
Tom O'Keefe
Mike Pattison
Thomas Payant
Dave Peterson
Chris Picard
Patrick Pierce
Philip Popoff
John Postema
Scott Powell
Chris Raasor
Kit Rawson
Dave Redman
David Remlinger
Luke Rogers
Mary Ruckelhaus
Michael Rustay
Eric Salathe
Rowan Schmidt
Morgan Schnaidler
Howard Schwartz
Mark Simonson
Amy Snover
David Somers
Cindy Spiry
Stephen Stanley
Andrew Stout
Don Stuart
Ralph Svrjcek
Brett Swift
Jim Teverbaugh
Dan Tonnes
Joe Tovar
Mike Town
Stacy Trussler
John Ufford
Anne Vernez Moudon
Elizabeth Walker
Tim Walls
Elizabeth Weldin
Richard White
Jan Whittington
Matt Wiley
Terry Williams
Daryl Williams
Clark Williams-Derry
Kathy Wolf
Hendrik Wolff
Ken Yocom
Yi Zhao
Ken Zweig

Workshop Objectives

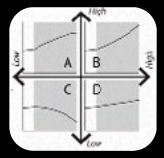
Workshop objectives are to draft a blueprint for an integrated model and select indicators of Ecosystem Services sensitive to different trajectories of alternative scenarios?

Workshop Agenda

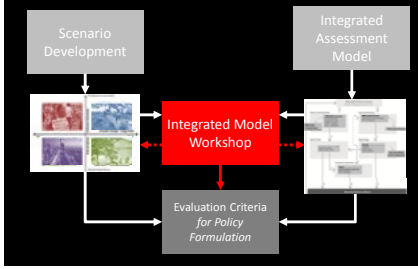
- **12:00-12:30** Lunch and Presentation by Alberti, Purucajas and Russo
- **12:30-1:00** Exercise 1: *Explore the relationships between scenarios and models*
- **1:00-1:30** Exercise 2: *Ecosystem Services Indicator Selection*
- **1:30-2:30** Exercise 3: *Model Integration*
- **2:30-3:15** Blueprint Presentations
- **3:15-4:00** Model Integration Discussion

Project approach

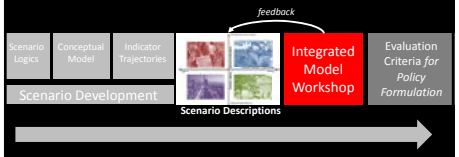
Instead of focusing on a single trajectory or prediction, we use Scenario Planning to explore alternative plausible futures and highlight the risks and opportunities involved in strategic decisions for the basin development.



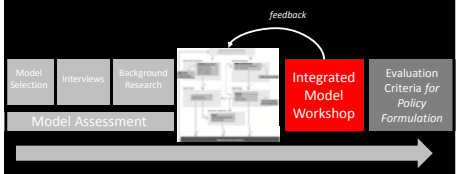
How did the process inform the workshop, and how will the workshop inform the overall process?



Scenario Development



Integrated Model



HOW CAN MODELS SUPPORT SCENARIO PLANNING?

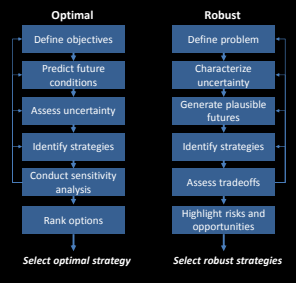
Why multiple scenarios

- Strategies aimed to maintain ecosystem services require looking beyond **current** baseline conditions.
- Scenarios help highlight potential threats and opportunities that can emerge from interactions among **uncertain** driving forces
- Alternative scenarios challenge our assumptions about how the future can play out to help identify **plausible futures**
- *'the objective of good scenarios is better decisions not better prediction' (Dearlove 2002)*

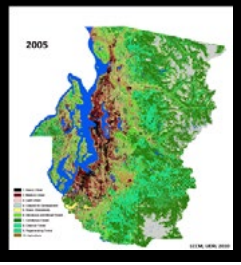
How do scenarios help make better decisions

- Characterize uncertainties of future conditions
- Identify sensitivity of strategies to uncertainties
- Seek robust rather than optimal policies: Select robust strategies (performance is insensitive to uncertainties)
- Facilitate developing adaptive plans and strategies by highlighting warning conditions of failure scenarios
- Provide algorithms for inference that can complement models with incomplete data

Decisions under uncertainty

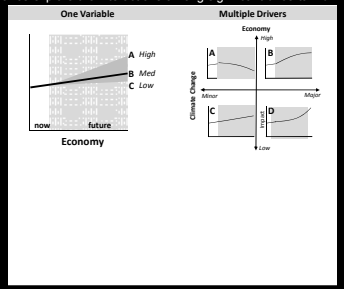


Predictive Models



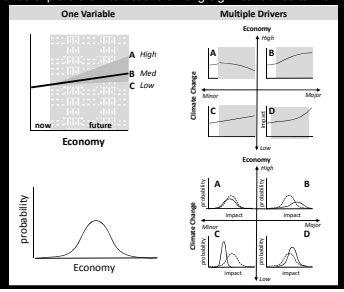
Uncertainty of Multiple Drivers

Scenarios explore the interactions among significant uncertain drivers



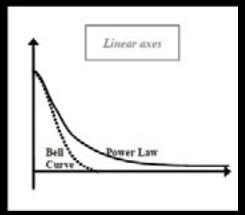
Uncertainty of Multiple Drivers

Scenarios explore the interactions among significant uncertain drivers



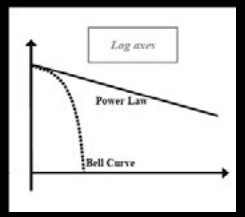
Low Probability High Impact

Scenarios explore the interactions among significant uncertain drivers



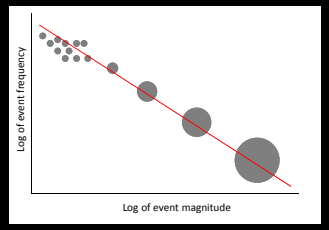
Low Probability High Impact

Scenarios explore the interactions among significant uncertain drivers



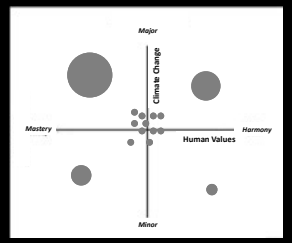
Low Probability High Impact

Scenarios explore the interactions among significant uncertain drivers



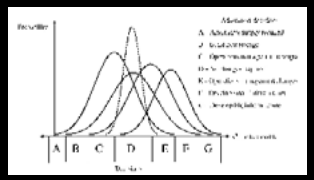
Low Probability High Impact

Scenarios explore the interactions among significant uncertain drivers



Low Probability High Impact

Scenarios explore the interactions among significant uncertain drivers



Scenarios and Models

- Scenarios
  - Define alternative, plausible, and most divergent futures and uncertain trajectories that affect ecosystem services over the long term
- Models
  - Predict impacts of alternative futures on

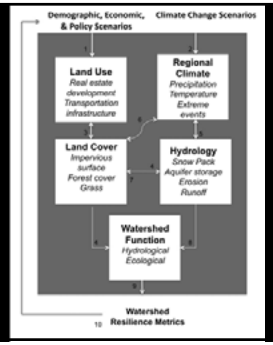
Potential Relationships

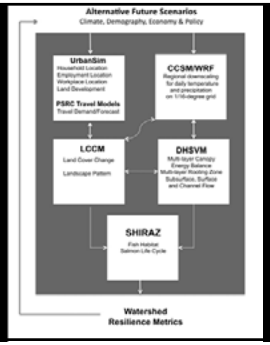
Models to Scenarios

- Refinement of relationships
- Hypothesis (testing)
- Impact assessment

Scenarios to Models

- Expand boundary conditions
- Explore inclusion of additional parameters and variables
- Identify gaps in knowledge
- Characterize uncertainty





Integrated Models

- Problem definition
- Multiple actors
- Time scale
- Spatial scale
- Feedback
- Uncertainty

10 models reviewed

SELECTED MODELS

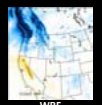
Model Selection Criteria

- Models that represent at least one of the 6 ecosystem service areas (species and habitat biodiversity, water quality and quantity and carbon storage and fluxes) or identified significant drivers of the outcome of interest (e.g.. land cover change).
- Models with a high level of development (ideally have undergone a scientific peer review)
- Models that have been developed specifically for the study area (Snohomish Basin or Puget Sound lowland region).
- Models with a flexible structure that can easily be (or that have already been) integrated with output from others models were a high priority.

Selected Models

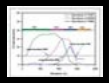
LCCM

UrbanSim


WRF

DHSVM /HSPF/VIC

SHIRAZ


Potential Vegetation

EcoPath with EcoSim

PS Watershed Characterization

Interviews with Modelers

1. Purpose
2. Model type
3. Spatial and temporal scale
4. Input, output
5. Assumptions and limitations
6. Uncertainty
7. Integration with other models

Summary Table (handout)

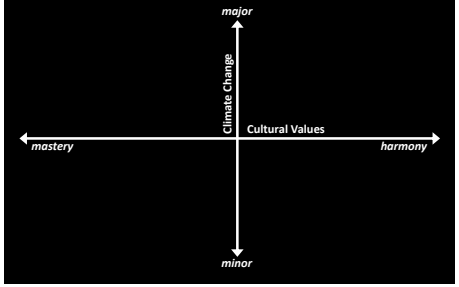
Model Elements

- Variables: input / output
- Boundary conditions
- Spatial and temporal scale (resolution, extent)
- Uncertainty
- Feedbacks, model integration
- Gaps in knowledge

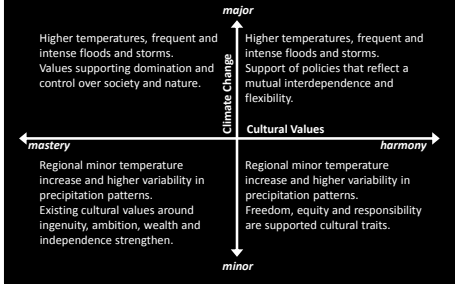
Snohomish Basin 2060

SCENARIO DEVELOPMENT

Scenario Logics



Scenario Hypotheses



Scenarios

Scenario Development

Climate Change:

Major + Extreme

- ↑ 1°C / decade
- ↑ 0.1"/ decade Precipitation
- ↑ frequency + intensity of HW + DTR
- ↑ flooding and storms
- ↓ snowpack
- Fast streamflow
- Poor water quality
- Damages to infrastructure / property
- Ecosystem regime shift
- ↓ habitat quality
- *Confounding Uncertainty: Pace??*

Minor + not extreme

- ↘ rate of climate change
- ↑ 0.2°C / decade
- No clear precipitation change
- ↘ snowpack
- ↗ floods
- Shift in temperature sensitive plants and animals
- *Confounding Uncertainty: Apathy / proactive response??*
- *Confounding Uncertainty: Scale of change ??*

Cultural Values

Mastery

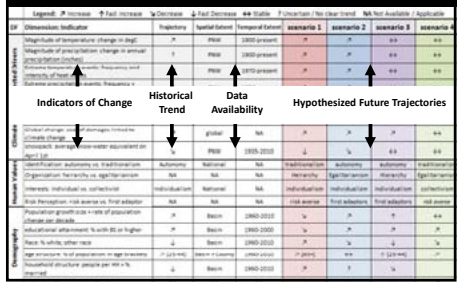
- getting ahead through active self-assertion over the natural world and society.
- ↑ traits: ambition, success, and competence.
- ↑ infrastructure and reliance on technological solutions that restrict change and direct benefits towards human resource needs.
- + w/Hierarchy: legitimize unequal distribution of power, rules and resources.
- *Confounding uncertainty: top-down regulations or free market exchange??*

Harmony

- accepting the world as is and trying to fit in rather than changing the natural world and society.
- ↑ attitudes: environmental protection, peace and unity
- ↑ strategies that minimize environmental degradation and support redistribution of personal wealth.
- + w/egalitarianism: prioritizes a voluntary commitment to promoting the welfare of others through freedom, justice and honesty.

(Revised) Conceptual Model

Scenario Trajectories



Scenario Development

Dimensions of Driving Forces to represent the scenarios

EXERCISE 1: EXPLORE THE RELATIONSHIPS BETWEEN SCENARIOS AND MODELS

Prioritize Driving Force Dimensions

Objective

- Identify which dimensions can best represent our scenarios?
- Identify which dimensions can be modeled?
- Identify what information could complement selected dimensions to support predictions of future change?

Step 1: telling a good story

- Team up (2 people per team). Look over scenarios. Review list of dimensions.
  - Which dimensions seem most critical to telling the story?
  - Which dimensions can be left out?
  - Are there additional dimensions / measures that should be included.

Step 2: selecting appropriate measures

- Of the indicators that you prioritized, highlight which ones:
  - are available?
  - are relevant?
  - represent model input variables?

Step 3: bringing ideas together

- After highlighting dimensions, share your selection with your table-mates.
  - Assign one person to be the secretary.
  - Review which dimenions you prioritized.
  - Bring your lists together.

A few more details

- 4+1 tables of dimensions
- Notepad + highlighters
- Scenario descriptions, summary table of models are available in packet.
- You have 30minutes. May we suggest:
  - 20min in 2-people team
  - 10 minutes to synthesize together

Indicators to determine outcomes

EXERCISE 2: ECOSYSTEM SERVICE INDICATOR SELECTION

Prioritize Ecosystem Service Indicators

Objectives

- How can we quantify scenario outcomes as alternative future baseline conditions of ecosystem services (ES)?
- What are potential indicators of ES for water quality + quantity, biodiversity and carbon stocks + fluxes?

Step 1: review list of indicators

- Team up (2 people per team). Review list of indicators.
- Which indicators are the best measures of:
  - Water Quality?
  - Water Quantity?
  - Species Diversity?
  - Habitat Diversity?
  - Carbon Stocks?
  - Carbon Fluxes?
- Which ones can be eliminated?
- Which additional indicators should be included?

Step 2: Rate Indicators

- Of the indicators you highlighted as good measures. Which ones are the most:
  - Relevant and Informative?
  - Available?
  - Modeled?

Step 3: bringing ideas together

- After highlighting indicators, share your selection with your table-mates.
  - Review which indicators you prioritized.
  - Bring your lists together.

A few more details

- Brief descriptions and references are available in packet.
- You have 30minutes. May we suggest:
  - 20min in 2-people team
  - 10 minutes to synthesize together

Bringing models together to explore scenarios

EXERCISE 3: MODEL INTEGRATION BLUEPRINT

Step 1: Review Working Pieces

- List of models
- List of prioritized indicators of driving forces
- List of prioritized indicators of ecosystem services
- Large format paper, markers, post-its
- Legend

Step 2: Draft a Blueprint

- Pair up.
- Draft connections between the various models.
- Illustrate:
  - Flows (solid arrows) into and out of models.
  - Feedbacks (dashed arrows)
  - Variables (name indicators) as going into, out of, or within model
  - Gaps in knowledge (?)

Step 3: Bringing Ideas Together

- Shares blueprint with table-mates.
- Bring models together.

Step 4: Test drive Scenarios

- "Run" (hypothetically) the scenarios through the model blueprint.
- Iteratively run each scenarios by following the flow of the model.
  - Start with the scenario logics (climate and values endpoints.
  - Denote changes to driving force indicators
  - Denote changes to ecosystem services indicators

Discuss

- Is the model sensitive to differences between the scenarios?
- Which driving force indicators may influence the boundary conditions of current models? (highlight)
- Which indicators of ecosystem services best represent differences between the scenarios given the model structure? (highlight)

A few more details

- You have one hour. May we suggest:
  - 20min draft initial blueprint (2-people team)
  - 20min synthesize models together
  - 20min run scenarios
- Secretary: write down important discussion points.
- Presenter: Write down major linkages and challenges of model. List critical indicators (of both DF + ES). 5 min per table.

Share draft model with everyone

BLUEPRINT PRESENTATIONS

Discussion of Draft Models

- Are the models sensitive to differences between the scenarios?
- What are the models good at predicting? What are they poor predictors of?
- What are critical questions raised by model integration?

Benefits and challenges

MODEL INTEGRATION DISCUSSION

Benefits of Model Integration

- What are potential benefits of model integration?
- In what ways can models best support the scenario planning process?
- Can uncertainty be more formally characterized through an integrated model?
- Can scenarios expand the consideration of uncertainty in model predictions?

Challenges to Model Integration

- What are potential challenges and limitations to model integration?
- What are the current gaps in our knowledge?
- What are current gaps in model components and empirical data necessary for modeling the impact of the future scenarios on the selected ecosystem services?
- What are impeding inconsistencies between models (scale, variables, approach)?

SNOHOMISH BASIN SCENARIOS

Rationale: This document presents four scenarios that explore plausible future conditions in the Snohomish Basin with divergent implications on maintaining ecosystem services[1]. The scenarios describe shifts in baseline conditions that influence the efficacy of our decisions but whose trajectory is uncertain. Scenarios help organize expert perspectives to characterize future uncertainty when past conditions are not sufficient and our ability to assign probabilities to predictions is limited. Our goal in describing the following scenarios is to challenge our collective assumptions of how the future can unfold in order to test the efficacy of alternative strategies[2] in a more inclusive manner. Our objectives are therefore to describe relevant, plausible, compelling and divergent scenarios that can teach us something new about long-term planning the Snohomish Basin. The probability of any one of the four scenarios depicted below being the real future is very small. Despite our tendency to select one scenario as either a desired or most probable future and dismiss the others, exploring the implications of the entire suite should provide additional insight to support more informed, flexible strategies that hopefully lead to a more resilient Basin ecosystem.

Methods: The current scenarios are the outcome of multiple iterative collaborations of the Science Team. The first step involved interviews with 78 regional experts to identify current and future driving forces influencing the state of the Basin and a conceptual model linking the drivers together. At the Scenario Logics workshop, participants reviewed the 14 potential drivers and identified climate change and human values as the two most important and uncertain drivers. On August 4th, a subset of members with expertise in the selected drivers refined four endpoints for the scenario logics by specifying variables for each driver. For climate change, participants selected a major versus minor magnitude of temperature and precipitation and frequency and intensity of extreme events. For human values, participants selected a 'mastery' versus 'harmony' cultural value. Descriptions of the implications of each endpoint are included on the following page. Draft scenario hypotheses were refined through dialogue with individual Science Team members. Over the last three months, a team at the Urban Ecology Research Lab reformatted the Conceptual Model to reflect the hypotheses structured by the scenario logics (see table 1). The research team explored past trends of indicators describing each of the 14 driving forces. The team then composed the scenarios by describing potential changes in future trajectories of each indicator, under each scenario (see table 2). Changes largely fell under three categories: 1) changes that are a direct result of logics (i.e. endpoint interactions), 2) changes that are related to potential variations associated with uncertain trajectories of pathways of driving forces. We selected the variations that created the most divergent or compelling storylines and 3) changes that cascade from the former two changes (see table 3). Over the next two months, these scenario narratives will be vetted and finalized through phone meetings with selected Science Team members focusing on the plausibility of future trajectories and interactions between drivers. In addition to the indicators of driving forces, hypothesized future trajectories of ecosystem service indicators will be associated with each scenario. These future baseline conditions will serve as starting point for evaluating the efficacy of alternative policies for maintaining current levels of ecosystem services in the Basin.

[1] This project specific ally explores six dimensions of ecosystem services including water quality and quantity, carbon fluxes and stocks and biodiversity at the landscape and species level.
[2] The focal question for this project and the intent behind the development of strategies is how to maintain ecosystem services in the Snohomish Basin by 2060.

DESCRIPTION OF SCENARIO LOGICS ENDPOINTS:

Major Climate Change: A "major" climate change in the Region can be characterized by rise in temperature by 1degCelsius and 0.1" of annual precipitation per decade. This would be coupled with an increase in the frequency and intensity of extreme events leading to strong precipitation and wind storms, flooding, and heat waves. Consequently, the majority of snowpack would be gone, the Basin's waterways would incur rapid streamflow, poor water quality due to higher temperatures, and increased runoff, buildings would incur costly damages and infrastructure would be disrupted by unreliable availability of resources and repair closures. Natural systems would be affected by shifting regime and degrading quality (water and habitat). A confounding dimension of uncertainty is the pace of change. If change occurs very quickly Basin decision makers will have very little time to prepare, consequently response may need to be immediate and reactive.

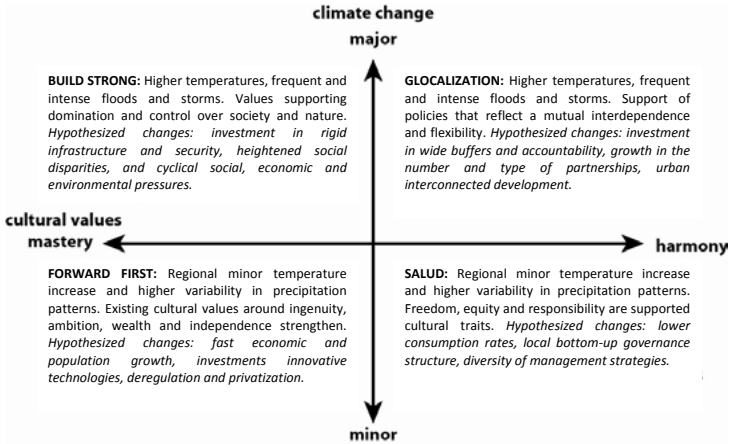
While the Basin already experiences severe floods, a major climate change would result in both a higher frequency and more intense flooding of the Basin's lowland.

Minor Climate Change: Based on past observations of climate change, the notion of no climate change occurring is not possible. However, over the next fifty years we may see a declining rate of climate change resulting in an increase of 0.2deg Celsius and no clear trend in annual precipitation. Even small degrees of climate increase would result in decline of snowpack, increase in lowland flooding and shifts in temperature-sensitive plants and animals. Consequent low short-term pressures on environmental, social and economic resources may be either temporarily overlooked, leading to societal apathy or proactively managed leading to increased ecosystem resilience. A confounding dimension of uncertainty is whether we experience the same level of minor change globally, or if the region is disproportionately spared.

Mastery Human Values: A "mastery" human value is characterized by a cultural emphasis on getting ahead through active self-assertion over the natural world and society. Mastery values include traits such as ambition, success, and competence. Mastery values would correspond with personal behavior and support of decision that attempt to master and exploit the world in order to further personal or group interests. Consequently, the Basin would invest in infrastructure and reliance on technological solutions that restrict change and direct benefits towards human resource needs. Mastery values correlate positively to hierarchy values which legitimize unequal distribution of power, rules and resources. A confounding dimension of uncertainty is whether control is achieved through top-down regulations or free market exchange.

Bioengineering solutions, while appreciating ecological health, seek innovative strategies to manipulate environmental services towards greater societal benefits.

Harmony Human Values: Harmony values are characterized by cultural emphasis on accepting the world as is and trying to fit in rather than changing or exploiting the natural world and society. Protection of the environment, peace and unity are valued attitudes. Harmony values correspond with personal behavior and support of decisions that protect equity and conserve environmental resources. Consequently the Basin would invest in strategies that minimize environmental degradation and support redistribution of personal wealth. Harmony correlates positively with egalitarianism which prioritizes a voluntary commitment to promoting the welfare of others through freedom, justice and honesty.



Scenario Logics and key themes

SUMMARY OF THE FOUR SCENARIOS

BUILD STRONG [major / mastery]: By 2060, the Basin can based be described by a divided population and cycles of intense success and failures.

Frequent hazards from flooding and storms damage lowland properties leading to investments in infrastructure projects that minimize natural change and secure assets. Short term (10-20 years) benefits include job growth in government and construction and stable conditions in select protected areas. Immediate and prevalent environmental problems that affect well-being are prioritized while challenges that emerge slowly are harder to control and leave the Basin vulnerable to surprises. Meanwhile, the cost of living has dramatically increased due to costly damages to unprotected resource and built lands and a rise in the cost of oil. Social disparities in wealth and well-being rise as the low-income groups fall further into debt while wealthier households secure private services and global goods. Society divides; the 'have-nots' increasingly resort to disruptive behavior (rioting, theft, illegal waste disposal, development without permits, etc.) while the 'well-to-do' barricade from social and environmental challenges (upland gated communities, personal vehicles, household purification systems, etc.). The number and scope of enforcing regulations escalate rapidly attempting to minimize further environmental and social damages (more permits, more restrictions and more oversight). Government funds are diverted towards emergency services and away from education, health and other social services. The amount of impervious surfaces, waterway hardening and commuting time in the Basin has tripled. By 2060 the rich live safely upland while for the poor degraded water and food quality, insufficient services, and declining health have become epidemics.

GLOCALIZATION [major / harmony]:

Early in the century, multiple factors came together to enable the support and implementation of proactive, integrated and adaptive investments that consequently alleviated the impacts of major climate change on economic, social and environmental systems in the Basin. While climate changes did occur, a slow rate of increase pushed most of the change towards mid-century. The Basin's affluent and educated populace and abundant natural resources came together to redistribute wealth and invest in a collective future. Households demanded full-cost accounting and transparency from both private industry and government. The Basin became globally renowned for its best-practice approaches and high quality of life resulting in strong pressure for industry growth and in-migration. Innovative programs resulting from public-private partnerships funneled much of the growth into newly emerging urban centers, served by innovative green utilities, a connected multi-modal transportation system and buffered with protected resource lands. By the time the Region experienced higher temperatures and shift in extreme events the Basin had built up an adaptive capacity and inter-agency monitoring system. There were still many challenges along the way, from newly emerging diseases to public disagreement over initiatives and priorities; however the duration and intensity of crises were dampened by a flexible, buffered and diverse hybrid social-ecological system.

FORWARD FIRST [minor / mastery]: The Puget Sound region experiences minor climate impacts, while

evidence of global climate change is characterized by unprecedented rate of natural disasters, economic and political destabilization and human suffering. Existing cultural values around ingenuity, ambition, wealth and independence strengthen. The Basin enjoys a competitive economic advantage due in part to its low environmental pressure, available educated workforce and a high global demand for regional products. Society does value environmental health, but sees laissez faire markets spurring innovation and competition as the best strategies for alleviating environmental problems. Rapid economic growth around port activities and resource and bioengineering industries lead to an infusion of private wealth and capital into the Basin. Private industry invests in the Region's economic future with world-class innovative resources, from alternative energy to connected light rail and academic institutions. Corporations also invest in the quality of life of their workers, purchasing natural lands for passive and active recreation , supporting cleanup efforts and funding regional research opportunities. By mid-century the Basin is largely deregulated and owned by private corporations. However, an almost exclusive reliance on technological innovation and private entities leaves a major blind spot when unanticipated challenges emerge. As the rate of growth increases so does the rate of new environmental problems and consequent innovations. By the end of the century the Basin struggles with a cacophony of tangled

innovations trying to gain ground on an ever-growing list of social-environmental challenges.

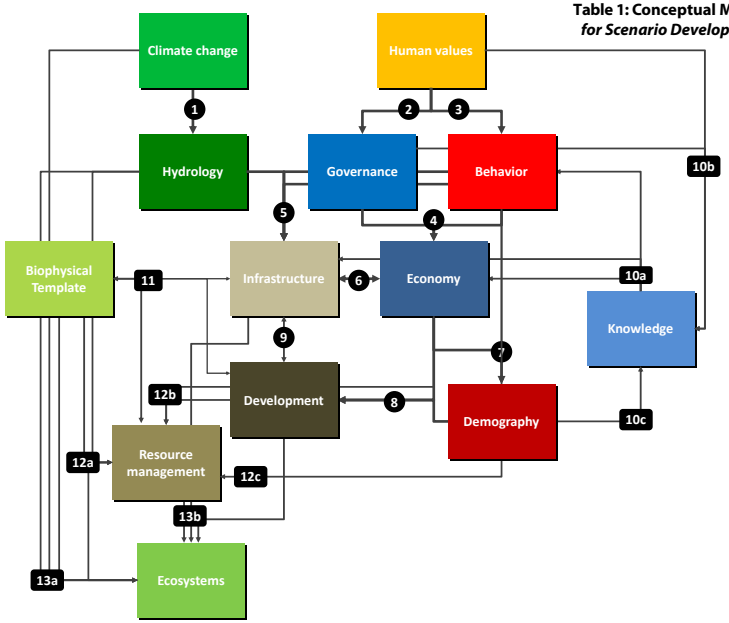
SALUD [minor /harmony]: After more than a decade of unsuccessful attempts to stabilize economic growth, society has adapted to alternative tactics for achieving a high quality of life. Households grow as traditional families and friends move back together for mutual support. Consumption levels decline as wealth declines, and resources are more efficiently managed through sharing, reuse and repair. Low property values and growing interest to 'live in harmony with nature' fuel migrations back into the Basin's resource lands. However the 'new farm' bears little resemblance to its predecessor characterized by small parcels, optimistic and highly educated young managers, and a humble deep ecology ethic. Numerous grass-roots organizations spring to support informal new communities from neighborhoods to shared interests. Family, public and environmental health, and leisure are promoted over work centrality and the notions of freedom, equity and responsibility surface as sought after traits. Climate impacts, while minor, are apparent to a demographic that is intimately close to the landscape. Past restoration actions are revealing benefits and enthusiasm over past successes has catalyzed exponential growth in the number of volunteers and provision of public funds towards restoration actions. There is a great variation in management strategies, at all scales. Despite highly accessible information there is little coordination between the growing number of institutions. Economic growth has been slow but steady. While initially lower expenditure rates threatened economic stability, strong local support for regional industry eased the transition to a new economy with a high diversity of sectors providing flexibility and adaptive capacity. While ratings of quality of life are higher, the Basin is constantly challenged with failed experiments, lack of coordination and global isolation.

COMPARISON OF DRIVING FORCES INDICATOR TRAJECTORIES ACROSS THE 4 SCENARIOS

This linked spreadsheet relates the above four scenarios with the 14 driving forces identified by the Science Team. Each driving forces is described through a selection of 2-5 indicators. The main page includes a brief summary the historic trajectory of each indicator, the spatial and temporal extent of the available data and potential future trajectory in association with each scenario. Details on each indicator can be reviewed by clicking on the hyperlink to reveal a summary worksheet including a description, graph, raw numbers, and references. The selection of indicators was based on recommended good measures of the driving force, available data and relevance to the draft scenario narratives. Over the next month we will discuss the selection and trajectories of each indicator to assess if:

1. These the appropriate indicators? Are there indicators that may be more applicable? Easier to communicate? Available data? More direct?
2. Experts agree with the trends depicted? Do they we can make these inferences? Do they agree with the direction of the trends?

Table 1: Conceptual Model *for Scenario Development*



The diagram highlights the relationships between driving forces used in the formation of scenario narratives. While this diagram stems directly from the Conceptual Model developed by the Science Team, it not inclusive of all relationships and feedbacks.

1] Changes in temperature and precipitation, as well as snowpack, influence hydrology by changing the streamflow, morphology, flooding, water quality and water quantity
2] Human values influence behavior including how we relate and perceive nature, what we invest in, and level of consumption.
3] Human values also influence the type and strength of governance we support (e.g. singular and strict versus multiple partnerships)
4] Governance (regulation and incentives) and behavior (consumption rate and investments) influence regional industry and economic growth.
5] Values (level of control), behavior (consumption rate), governance (public funding) and hydrology (water quantity and flooding) influence the type and amount of infrastructure in the region (e.g. Alternative energy, flood walls).
6] The economy and infrastructure influence one another. Economic growth can spur demand for and investment in regional infrastructure. Infrastructure projects can spur economic growth, both directly (construction and management jobs overseeing projects) and indirectly (competitive advantage for relocation).
7] Economy, through growth in job availability influences migration rates. Industry sectors also influence educational attainment, wealth and ethnicity. Demography is also influenced by human behavior (E.G. natural increase)
8] The number of households and number of jobs influences the amount and type of development.
9] Development and infrastructure influence each other. The more development, the more infrastructure needed to support the development; meanwhile, infrastructure growth is a catalyst for new development. The relationship between development and infrastructure is secondary to influence of economy and governance (directing available funding and control) on development and infrastructure.
10] Knowledge, in terms of innovation stems from global changes and drives 10a) economic, infrastructure and behavioral changes, 10b) governance and values influence outreach while 10c) demography (educational attainment) influences the use of science.
11] Biophysical template, 11a) including soil characteristics and seismic events influence infrastructure and development patterns. Modifications to the biophysical template in terms of 11b) chemical inputs and landscape movement are driven by the built environment (resource management, development and infrastructure).
12] Resource management is largely influenced by the 12a) capacity of the land (biophysical template, ecosystem and hydrology), 12b) ability to make a profit (economy and development values) and 12c) human behavior in terms of relationship to nature.
13] Ecosystems have largely been described outcomes of other drivers, but they do feedback to influence the drivers as well. 13a) ecosystems are most directly influenced by the natural environment (hydrology, climate and biophysical template) while 13b) human influence of the natural environment through alterations to the built environment (infrastructure, resource management and development) have caused notable changes to ecosystem health.

Table 2: Comparison of Indicator Trajectories across scenarios

Legend: ↗ Increase ↑ Fast Increase ↘ Decrease ↓ Fast Decrease ↔ Stable **?** Uncertain / No clear trend **NA** Not Available / Applicable

DF	Dimension: Indicator	Trajectory	Spatial Extent	Temporal Extent	scenario 1	scenario 2	scenario 3	scenario 4
Selected Drivers	Magnitude of temperature: change in degC	↗	PNW	1900-present	↗	↗	↔	↔
	Magnitude of precipitation: change in annual precipitation (inches)	?	PNW	1900-present	↗	↗	↔	↔
	Extreme temperature events: frequency and intensity of heat waves	↗	PNW	1970-present	↗	↗	↔	↔
	Extreme precipitation events: frequency + intensity of consequtive dry and wet days	?	PNW	1970-present	↗	↗	↔	↔
	Relationship to Society + Nature: mastery vs. harmony	Mastery	National	NA	Mastery	Harmony	Mastery	Harmony
Climate	Pace: rate of climate chage	↔	PNW	1900-present	↑	↗	↔	↔
	Global change: cost of damages linked to climate change	↗	global	NA	↗	↗	↗	↔
	snowpack: average snow-water equivalent on April 1st	↘	PNW	1935-2010	↓	↘	↔	↔
Human Values	Identification: autonomy vs. traditionalism	Autonomy	National	NA	traditionalism	autonomy	autonomy	traditionalism
	Organization: heirarchy vs. egalitarianism	NA	NA	NA	Heirarchy	Egalitarianism	Hierarchy	Egalitarianism
	Interests: individual vs. collectivist	Individualism	National	NA	individualism	individualism	individualism	collectivism
	Risk Perception: risk averse vs. first adaptor	NA	NA	NA	risk averse	first adaptors	first adaptors	risk averse
Demography	Population growth: rate of population change per decade	↗	Basin	1960-2010	↘	↗	↑	↔
	educational attainment: % with BS or higher	↗	Basin	1960-2000	↘	↗	↗	↗
	ethnicity: % white; other race	↓	Basin	1960-2010	↗	↘	↓	↘
	age structure: % of population in age brackets	↗ [25-44]	Basin + County	1960-2010	↗ [65+]	↔	↑ [25-44]	↗
	household structure: people per HH + % married	↓	Basin	1960-2010	↗	?	↘	
	public health: percent healthy days	NA	NA	NA	↓	↔	↔	↗
Behavior	consumer expenditures: % expenditures on food, housing & transportation	↘	Seattle-Everett Metro Area	1988-2009	↗	↗	↘	?
	relationship to nature: 'myths of nature'	?	NA	NA	nature capricious	nature resilient	nature benign	nature ephemeral
	investments: NA	NA	NA	NA	security	adaptation	economic growth	social + env.
Economy	Dominance of industry sectors: fastest growing sector(s) by % of employee	professional	Basin	1960-2000	service + operations	professional	professional	diverse
	Market: consumer price index	↗	Seattle-Everett	1960-2010	↑	↗	↗	↔
	labor: % unemployed	?	Basin + County	1960-2000	↗	↘	↓	↔
	wealth: average wages; gini index	↗	County	1969-2009	↗ / ↘	↗	↑	↔
	economic growth: total personal income as proxy for GDP	↗/ ↑	County	1969-2009	↘	↗	↑	↔

DF	Dimension: Indicator	Trajectory	Spatial Extent	Temporal Extent	scenario 1	scenario 2	scenario 3	scenario 4
Selected Drivers	Magnitude of temperature: change in degC	↗	PNW	1900-present	↗	↗	↔	↔
	Magnitude of precipitation: change in annual precipitation (inches)	?	PNW	1900-present	↗	↗	↔	↔
	Extreme temperature events: frequency and intensity of heat waves	↗	PNW	1970-present	↗	↗	↔	↔
	Extreme precipitation events: frequency + intensity of consequtive dry and wet days	?	PNW	1970-present	↗	↗	↔	↔
	Relationship to Society + Nature: mastery vs. harmony	Mastery	National	NA	Mastery	Harmony	Mastery	Harmony
Governance	scale of political strength: budget per regulatory agency	↗	NA	NA	state / federal	county / region	municipality	local
	planning and regulation: # of regulations + initiatives passed	NA	NA	NA	↗	↗	↓	↘
	service provision: NA	NA	NA	NA	poor	public, good	private, good	equitable
Social Institutions	community: % in urban vs. rural development	↑	Basin	1960-2000	↔	↗	↑	↘
	work centrality: importance of work relative to family and leisure	↗	NA	NA	↔	↔	↗	↓
	strength and influence of tribes: NA	↗	NA	NA	?	?	?	?
	global cooperation (with region): NA	?	global	NA	↘	↗	↑	↘ then ↗
	global stability: NA	?	global	NA	↘ then ↓	↘ than ↗	↘ and ↗	↔
	political will: voter turnout by county	?	County	NA	↘	↗	↔	↑
	organization: # of ngo / npo	NA	NA	NA	↘	↗	↔	↑
Knowledge	investment in innovation: $s spent in R+D	↗	US	1953-2008	↗	↗	↑	↘
	access to information: NA	NA	NA	NA	↔	↗	↗	↔
	specialization in science and technology: % of degrees in science & engineering	NA	NA	NA	↔	↗	↗	↔
Development Pattern	character: people per built area	?	Basin	1960-2000	↘	↗	↓	↔
	shape / centrality of development: aggregation index by year built	↘	NA	NA	↘	↗	↘	↘
	land use dominance: % change in LU	NA	NA	NA	residential	urban clusters	industrial	resource
	residential development: residential building permits	↗	Basin / WA	1988-2009	↘	↗	↑	↔
	real estate: housing values	↗	Basin	1960-2000	↘ / ↗	↗	↑	↘
	municipalities: percent incorporated	↗	Basin	1960-2010	↘	↗	↑	↘

DF	Dimension: Indicator	Trajectory	Spatial Extent	Temporal Extent	scenario 1	scenario 2	scenario 3	scenario 4
Selected Drivers	Magnitude of temperature: change in degC	↗	PNW	1900-present	↗	↗	↔	↔
	Magnitude of precipitation: change in annual precipitation (inches)	?	PNW	1900-present	↗	↗	↔	↔
	Extreme temperature events: frequency and intensity of heat waves	↗	PNW	1970-present	↗	↗	↔	↔
	Extreme precipitation events: frequency + intensity of consequtive dry and wet days	?	PNW	1970-present	↗	↗	↔	↔
	Relationship to Society + Nature: mastery vs. harmony	Mastery	National	NA	Mastery	Harmony	Mastery	Harmony
Infrastructure	energy source: % total consumption by source	↑ gas | ↔	WA	1970-2005	↑ gas | ↘	↘ gas | ↘	↑ gas | ↗	↓ gas | ↘
	energy conservation: Btus per capita	↘	WA	1970-2005	↔	↘	↗	↘
	waste generated: tons disposed per capita	↘	King County	1977-2010	↔	↘	↗	↓
	water consumed: total water consumed by user	↗	NA	NA	↘	↘	↗	↓
	water povision: % of residences on well vs. city water	↘	NA	NA	↗	↘	↘	↔
	transportation: time and distance traveled	↗	Central PS	1960-2006	↗	↔	?	↘
	waterway alteration: dams and stream permits for bank + flow control	NA	County	1989-2010	↑	↔	↔	↘
Resource Management	agriculture: acres by type	↘	County	1974-2009	↘	↔	↗	↗
	forestry: timber tax revenue as % of County personal income	↓	County	1978-2009	↘	↔	↗	↗
	recreation: acres of recreation lands (parks, wilderness)	↗	NA	NA	↘	↗	↗	↗
Biophysical Template	soils and minerals: % of soil built over by year	↘	Basin	1960-2000	↘	↔	↘	↗
	landscape movement: elevation of development by year built	↗	Basin	1960-2000	↑	↔	↗	↗
	toxins and chemicals: application of fertilizers, # of livestock, impervious surfaces, traffic counts, industry	↘	County / WA	1974-2009	↗	↔	↗	↓
Hydrology	flooding: frequency and stage	↗	Basin	1960-2010	↑	↗	↗	↔
	streamflow: selected river (cfs)	↗	Basin	1960-2010	↑	↗	↗	↔
	water quality: NA	NA	NA	NA	↓	↘	↘	↗
	water quantity: NA	NA	NA	NA	↘	↘	↘	↔
Ecosystems	biodiversity: # of Endangered and Threatened species per year	↗	County	1967-2006	↑	↔	↑	↘
	forest habitat: acres of forested land	↘	NA	NA	↘	↔	↓	↗
	invasives: NA	↑	NA	NA	↑	↗	↑	↔
	salmon and stream habitat: salmon escapement for WRIA7 species	?	Basin	1965-2005	↓	↘	↘	↗

Table 3: Indicator Trajectory Decision Process

Selected Drivers	Magnitude of temperature: change in degC
	Magnitude of precipitation: change in annual precipitation (inches)
	Extreme temperature events: frequency and intensity of heat waves
	Extreme precipitation events: frequency + intensity of consequtive dry and wet days
	Relationship to Society + Nature: mastery vs. harmony
Climate	Pace: rate of climate chage
	Global change: cost of damages linked to climate change
	snowpack: average snow-water equivalent on April 1st
Human Values	Identification: autonomy vs. traditionalism
	Organization: heirarchy vs. egalitarianism
	Interests: individual vs. collectivist
	Risk Perception: risk averse vs. first adaptor
Demography	Population growth: rate of population change per decade
	educational attainment: % with BS or higher
	ethnicity: % white; other race
	age structure: % of population in age brackets
	household structure: people per HH + % married
	public health: percent healthy days
Behavior	consumer expenditures: % expenditures on food, housing & transportation
	relationship to nature: 'myths of nature'
	investments: NA
Economy	Dominance of industry sectors: fastest growing sector(s) by % of employee
	Market: consumer price index
	labor: % unemployed
	wealth: average wages; gini index
	economic growth: total personal income as proxy for GDP
Governance	scale of political strength: budget per regulatory agency
	planning and regulation: # of regulations + initiatives passed
	service provision: NA
Social Institutions	community: % in urban vs. rural development
	work centrality: importance of work relative to family and leisure
	strength and influence of tribes: NA
	global cooperation (with region): NA
	global stability: NA
	political will: voter turnout by county
	organization: # of ngo / npo
Knowledge	investment in innovation: $s spent in R+D
	access to information: NA
	specialization in science and technology: % of degrees in science & engineering
Development Pattern	character: people per built area
	shape / centrality of development: aggregation index by year built
	land use dominance: % change in LU
	residential development: residential building permits
	real estate: housing values
	municipalities: percent incorporated
Infrastructure	energy source: % total consumption by source
	energy conservation: Btus per capita
	waste generated: tons disposed per capita
	water consumed: total water consumed by user
	water povision: % of residences on well vs. city water
	transportation: time and distance traveled
	waterway alteration: dams and stream permits for bank + flow control
Resource Management	agriculture: acres by type
	forestry: timber tax revenue as % of County personal income
	recreation: acres of recreation lands (parks, wilderness)
Biophysical Template	soils and minerals: % of soil built over by year
	landscape movement: elevation of development by year built
	toxins and chemicals: application of fertilizers, # of livestock, impervious surfaces, traffic counts, industry
Hydrology	flooding: frequency and stage
	streamflow: selected river (cfs)
	water quality: NA
	water quantity: NA
Ecosystems	biodiversity: # of Endangered and Threatened species per year
	forest habitat: acres of forested land
	invasives: NA
	salmon and stream habitat: salmon escapement for WRIA7 species

Legend:

- **Expert selected driving force variables**
- **Primary relationships**
- Secondary relationships
- external selections (not impact)

Summary of Selected Predictive Models

Model & System Modeled	Model Type	Inputs and Outputs	Scales
LCCM: land cover change (land cover and landscape pattern)	Multinomial logit framework	**Inputs:** Current & historic land cover, adjacent land cover, land use, transportation infrastructure, topography, critical areas (steep slopes, wetlands, etc), spatial contagion of development **Outputs:** land cover change, probability of transition	**Time:** 3 year intervals **Space:** 30 by 30 m pixel across the Central Puget Sound
UrbanSim: Urban development (household, employment + workplace locations, real estate prices, real estate development, activity-based travel	Multinomial choice, multiple regression	**Inputs:** parcels, buildings, natural amenities, accessibilities, employment, development restrictions, transportation, regional economic forecasts **Outputs:** Location of households and employment, real estate prices, location, type and density of the built environment (dwelling units)	**Time:** Annual, daily for activity-based travel **Space:** buildings and parcels, travel network
WRF-CCSM3: down-scaled climate predictions (atmosphere and land surface)	Numerical simulation	**Inputs:** global climate simulations, topography, land cover **Outputs:** Meteorological fields (temperature, precipitation, wind, soil temperature, snow cover, soil radiation)	**Time:** 6 hour intervals **Space:** ~20 km grid across western US
WRF-ECHAM5: down-scaled climate predictions (atmosphere and land surface)	Numerical simulation	**Inputs:** global climate simulations, topography, land cover **Outputs:** Meteorological fields	**Time:** 6 hour intervals **Space:** ~36 km grid across continental US
Shiraz: fish habitat and salmon lifecycle (Chinook)	Stochastic simulation	**Inputs:** stream temperature, discharge, fine sediment, habitat types, forest cover, impervious cover, road density, precipitation, survival capacity, hatchery, harvest **Outputs:** Salmon population attributes: abundance, productivity, spatial structure, and life-history diversity	**Time:** annual timestep **Space:** user specified, often for sub-basins
Potential Vegetation Model: potential vegetation zone	Deterministic boundary equation model	**Inputs:** total annual precipitation at sea level, mean annual temperature at sea level, fog effect, cold air drainage effect, topographic moisture, temperature lapse rate, aspect, potential shortwave radiation **Outputs:** location of 15-20 potential vegetation zones	**Time:** none **Space:** 90 m pixel across WA state
HSPF: local watershed hydrology and water quality	Empirically derived, deterministic discrete space/time	**Inputs:** rainfall and other meteorologic records (such as solar radiation) and land surface characteristics (vegetation cover, soil type) **Outputs:** hydrologic components (soil moisture, surface runoff, evapotranspiration), flood statistics (stream discharge, low flows), water quality	**Time:** subdaily **Space:** spatially lumped into ~2 km^2 subcatchments
DHSVM: regional hydrology	Deterministic discrete space/time mechanistic, physical (hydrologic) process[1]	**Inputs:** meteorologic records and land surface characteristics **Outputs:** hydrologic components and flood statistics	**Time:** subdaily intervals (1-3 hrs depending on size of basin) **Space:** 300 – 200 m resolution across Puget Sound basin
VIC: large scale hydrology	Deterministic discrete space/time mechanistic, physical (hydrologic) process[1]	**Inputs:** meteorologic records and land surface characteristics **Outputs:** meteorologic drivers (humidity, solar radiation), hydrologic components and flood statistics	**Time:** daily (snow is at hourly intervals) **Space:** 1/16 degree (~32 km^2)
Puget Sound Watershed Characterization Project: water movement	Deterministic qualitative model	**Inputs:** land cover, soil types, discharge areas, habitat inventory, rain on snow areas **Outputs:** landscape indicators based of delivery and controls of water movement, surface storage, subsurface movement and recharge and discharge	**Time:** none **Space:** flexible, to a ~1 mi^2
Ecopath with Ecosim (EwE): a mass balance model for evaluating food web structure and community scale indicators	Trophodynamic mass balance simulation	**Inputs:** functional groups, foodweb relationships, fishing, reproduction, mortality and habitat types **Outputs:** biomass allocation, functional group diversity, energy flow and mortality	**Time:** monthly timesteps **Space:** not explicitly modeled, represented with functional diet rules
Atlantis: biophysical ecosystem model	Spatially discrete deterministic biogeochemical whole of ecosystem	**Inputs:** functional groups, foodweb relationships, abiotic features (temperature, circulation, nutrients, dissolved oxygen), spatial dynamics, species-habitat interactions, life history features, management policies **Outputs:**	**Time:** 12 hour timesteps **Space:** user specified

[1] Water and energy balance

Synthesis

Integrated Model Workshop Nov. 3, 2011
Synthesis of Findings. UERL.

Who was there and what did we do?

10 model experts and scenario developers attended the workshop on November, 3rd (Table 1). We divided up into three teams of 3-4 people. For exercises 1 and 2, teams were asked to rank pre-selected dimensions of driving forces and indicators of ecosystem services (respectively) based on how compelling they are (important to telling a good story), if they are a good measure (relevant to the focal issue[1], an accurate measure and informative of the condition), if data is available (for the Snohomish Basin and for at least the past 10 years) and they can be modeled (as either an input or output in one or more of the selected models).

Major Findings (Table 2 summary of linkages; Figures 1-3 Team Blueprints)

Major inputs external to the integrated model include global climate, socio-political and economic drivers. Within the integrated model frameworks experts agreed that WRF (regional climate) and UrbanSim (urban development) represent overarching inputs (top-level) while SHISRAZ and EcoPath represent overall outputs (bottom-level). Hydrology models, LCCM (Landcover change) and Potential Vegetation Model had varied representation, however they were generally incorporated the highest number of relationships (both as inputs into other models and as feedbacks). The PS Watershed Characterization Model appeared to be poorly represented or understood as its representations was highly inconsistent across the three teams.

The Integrated Model would need to represent the differences across the four scenarios by varying the boundary conditions associated dimensions of driving forces such as demography, economy, governance, and infrastructure. The list of over 60 dimensions was reduced to ~26 (Table 3). It was clear from the exercise outcomes that social dimensions including human values, behavior, governance and social institutions required substantially better proxies in terms of 1) clearer definition of what would be measured 2) clearer representation of expected relationship to scenario logics and 3) detailed information about what is quantitatively available.

Change in future functioning of Ecosystem Services would be represented by the outcome of the Integrated Model specified by indicators for water quality and quantity, carbon fluxes and storage and species and habitat diversity. Table 4 includes the list of the highest ranking indicators, in terms of availability, compelling, appropriate measures that have been previously linked to predictive models. It was clear from looking over the response rate and agreement level (variance) in the team's ranking that the workshop included good representation of water quality and quantity expertise, but poor representation in the other measures, especially measurement of carbon fluxes and stocks.

[1] The focal issue is: To maintain ecosystem services (around water quality + quantity, carbon stocks and fluxes and species and habitat diversity) in the Snohomish Basin out to 2060

Table 1: Workshop Attendees

name	agency
Bartz, Krista	NOAA's Northwest Fisheries Science Center, Conservation Biology Division
Beyers, William	University of Washington Department of Geography
DeGasperi, Curtis	King County Water and Land Resources Division
Hamlet, Alan	University of Washington Civil Engineering
Harvey, Chris	NOAA Fisheries
Lettenmaier, Dennis	University of Washington Civil Engineering
Salathe, Eric	Climate Impacts Group, University of Washington, Department of Atmospheric Sciences
Schmidt , Rowan	Earth Economics
Simonson, Mark	Puget Sound Regional Council
Stanley, Stephen	Washington Department of Ecology

Table 2: Represented Linkages between Selected Models

Arrow from \ Arrow to	Climate Change	Hydrology	LCCM	UrbanSim	Vegetation	PS Characterization	EcoPath	Shiraz
Climate Change		H	L	M	M	L	H	H
Hydrology	N		L	M	M	L	L	L
LCCM	L	L		N	N	M	H	M
UrbanSim	H	M	H		N	N	H	H
Vegetation	N	M	M	N		N	H	H
PS Characterization	N	N	N	M	N		M	L
EcoPath	N	N	N	M	N	N		M
Shiraz	N	N	N	N	N	L	M	

H=all teams represented linkages. M=2 out of 3 teams. L=1 team. N=no team.

diagnol lines= feedback needed. Dots = indirect linkages

**Only 2 teams represented UrbanSim and 2 (different) team represented Vegetation.*

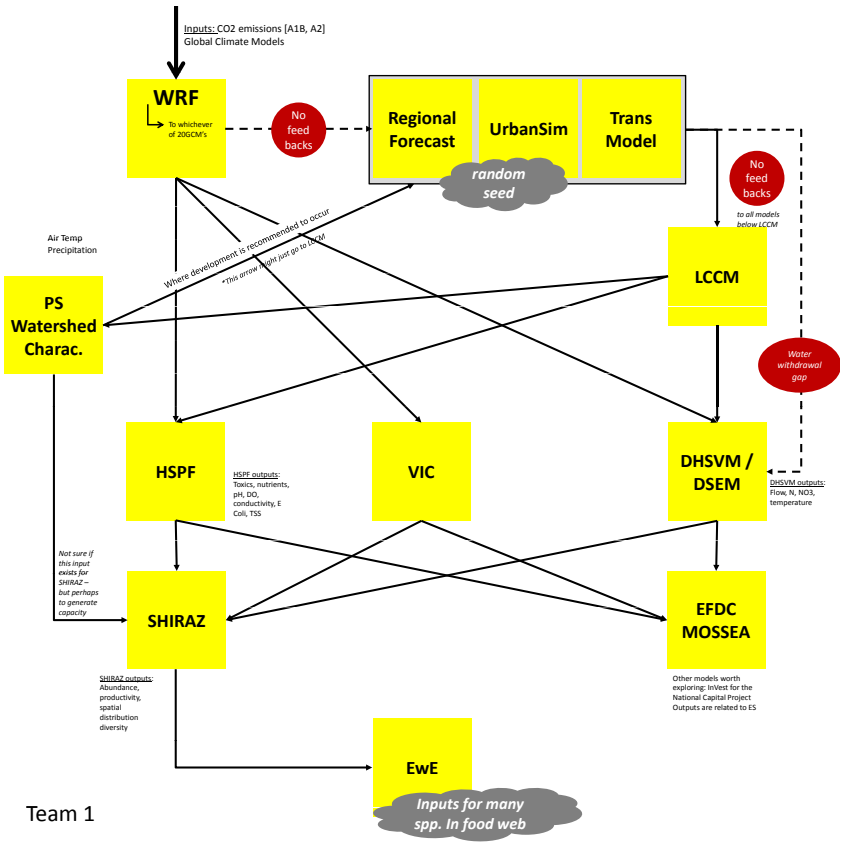
Table 4. Compelling, Appropriate, Available Indicators of Ecosystem Services

Ecosystem Service	Indicator
Water Quantity	Stream Variability: Frequency and intensity of peak and drought levels
	Available Snowpack: SWE April 1st
Water Quality	Fecal Coliform
	*pesticides and water temperature were rated high and selected by many, but reflected higher levels of disagreement across participants
Species Diversity	Salmon escapement per species
Habitat Diversity	Mean patch Size (total forest cover)
	Land use/cover change: Distribution/extent of land cover transition
	Habitat connectivity: Contagion Index / Aggregation Index
Carbon Fluxes	CO2 Emissions: # of Vehicles / Miles driven
Carbon Stocks	Forest stocks: Acres of forestland by urban-rural gradient

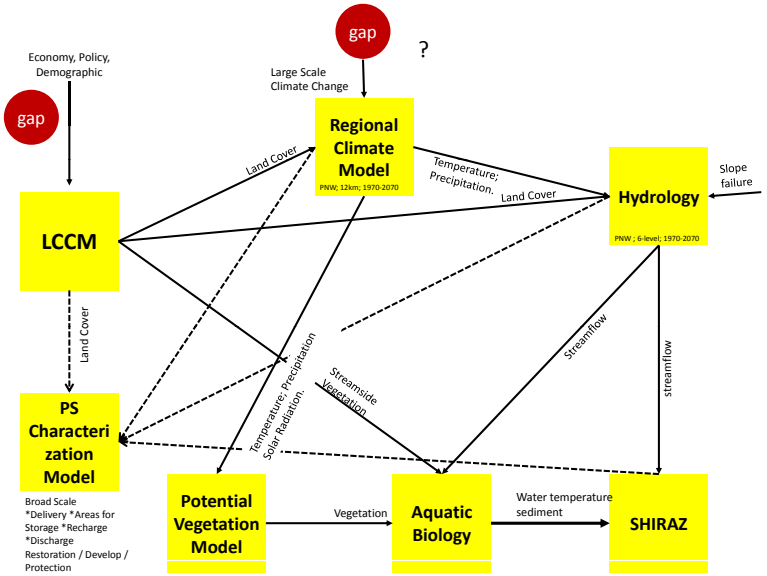
Table 3: Compelling, Appropriate and Available Driving Force Dimensions

Driving Force	Dimension
Climate Change	**Almost all dimensions fit the above criteria except the magnitude of precipitation, represented as the least compelling.*
	Magnitude Of Temperature: Average annual surface air temperature for Puget Sound in Deg C
	Extreme Temperature Events: Frequency / Intensity Of Heat Waves
	Extreme Precipitation Events: Frequency + Intensity Of Consecutive Dry And Wet Days
	Rate Of Climate Change: Increase in Annual Temperature / Decade
Human Values	**none of the dimensions fit the above criteria. This may be due to a lack of definitions / available measures.*
Demography	Population Growth: Rate + Size of Population Growth Per Decade
	Age Structure: Population Pyramid (Basin and Counties)
Behavior	Consumer Expenditures: % Expenditures On Food, Housing & Transportation
	** CE was the second most popular dimension, but some mentioned it should go under Economy*
Economy	Total Income
	Labor: % Unemployed
	Average Wages; Gini Index
Governance	**none fit criteria. This may be due to a lack of definitions / available measures.*
Social Institutions	Community: % In Urban Vs. Rural Development
Knowledge	Investment In Innovation: $s Spent In R+D
Development	People Per Built Area
	Residential Building Permits
Infrastructure	**Almost all dimensions fit the above criteria except water provision and waterway alteration. [Energy Source*
	Energy Source: % Total Consumption By Source
	Energy Conservation: Btus Per Capita
	Water Consumed: Total Water Consumed By User
	Transportation: Time And Distance Traveled
Resource Management	Acres Of Recreation Lands (Parks, Wildemess)
Biophysical Template	Toxins And Chemicals: Application Of Fertilizers, # Of Livestock, Impervious Surfaces, Traffic Counts, Industry
	Elevation Of Development By Year Built
Hydrology	Flooding: Frequency And Stage
	Water Quantity: Snowpack SWE April 1st
Ecosystems	Acres Of Forested Land
	Salmon Escapement For WRIA7 Species

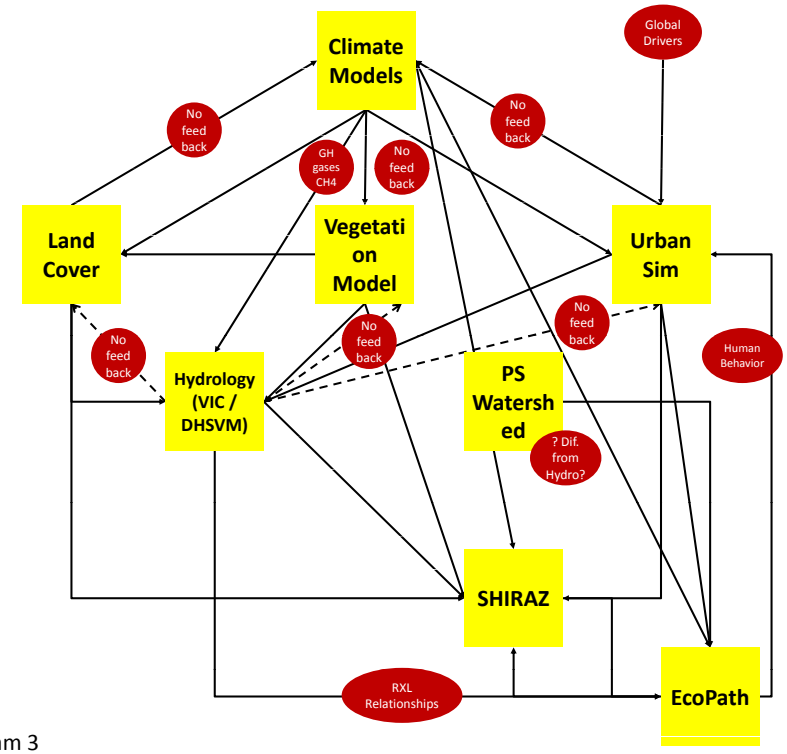
** dimensions that can be represented by current models are in gray*


Inputs: CO2 emissions [A1B, A2]
Global Climate Models
WRF
To whichever of 20GCM's
No feed backs
Regional Forecast
UrbanSim
Trans Model
random seed
No feed backs
to all models below LCCM
Air Temp
Precipitation
Where development is recommended to occur
*This arrow might just go to LCCM
PS Watershed Charac.
LCCM
Water withdrawal gap
HSPF
HSPF outputs: Toxics, nutrients, pH, DO, conductivity, E Coli, TSS
VIC
DHSVM / DSEM
DHSVM outputs: Flow, N, NO3, temperature
Not sure if this input exists for SHIRAZ – but perhaps to generate capacity
SHIRAZ
EFDC MOSSEA
SHIRAZ outputs: Abundance, productivity, spatial distribution diversity
Other models worth exploring: InVest for the National Capital Project Outputs are related to ES
EwE
Inputs for many spp. In food web

Team 1


gap
?
Economy, Policy, Demographic
Large Scale Climate Change
gap
Regional Climate Model
PNW; 12km; 1970-2070
Land Cover
Temperature; Precipitation.
Land Cover
Hydrology
Slope failure
PNW ; 6-level; 1970-2070
LCCM
Land Cover
Streamflow
streamflow
Temperature; Precipitation Solar Radiation.
Streamside Vegetation
PS Characterization Model
Broad Scale
*Delivery *Areas for Storage *Recharge
*Discharge
Restoration / Develop / Protection
Potential Vegetation Model
Vegetation
Aquatic Biology
Water temperature sediment
SHIRAZ

Team 2



Team 3

Integrated Model Workshop Nov. 3, 2011
Synthesis of Findings. UERL.

Detailed Methodology of Synthesis:

For exercises 1 and 2, teams were asked to rank pre-selected dimensions of driving forces and indicators of ecosystem services (respectively) based on how compelling they are (important to telling a good story), if they are a good measure (relevant to the focal issue[2], an accurate measure and informative of the condition), if data is available (for the Snohomish Basin and for at least the past 10 years) and they can be modeled (as either an input or output in one or more of the selected models). Not all teams integrated their input into 1 document, so available individual responses were used in this synthesis.

Overall, we synthesized 7 worksheets for exercise 1 and 5 worksheets for exercise 2. Scores were normalized to a 5pt score[3]. Generally a score greater than or equal to 4 were identified as a high score. Response rate reflected the number of worksheets (count) that had any response (whether high or low). The assumption was that a high response rate reflected a presence of knowledge or expertise, while a low response rate reflected a gap in represented knowledge. Generally, a response rate of 2 or lower represented a gap. Divergence was calculated as the variance in scoring between the submitted worksheets. The assumption was that a high variance reflected disagreement across represented experts. Variance was only considered when response rate was 3 or higher.

In exercise 3, teams were asked to develop an integrated model blueprint and then run a hypothetical test case for each scenario, exploring changes in the trajectories of selected dimensions and indicators from exercise 1 and 2. All three teams developed a paper blueprint. Trajectories for the selected dimensions and indicators were too varied to integrate, but a few highlights are synthesized in the details below.

DETAILS: EXERCISE 1: DIMENSIONS OF DRIVING FORCES

1. **The 25 most compelling, appropriate measures that we have data for were:**
   - Climate change *(note: all selected except magnitude of precipitation which was not considered 'compelling)*
     - Magnitude Of Temperature: Average annual surface air temperature for Puget Sound in Deg C
     - Extreme Temperature Events: Frequency / Intensity Of Heat Waves
     - Extreme Precipitation Events: Frequency + Intensity Of Consecutive Dry And Wet Days
     - Rate Of Climate Change: Increase in Annual Temperature / Decade
     - Global Change: Cost Of Damages Linked To Climate Change
     - Snowpack: Average Snow-Water Equivalent On April 1St
   - Human Values (note: none selected. Worst ratings for data availability)
   - Demography: (note: population growth scored highest of all dimensions from all driving forces; while available race and educational attainment were considered poor measures).
     - Population Growth: Rate + Size of Population Growth Per Decade

[2] The focal issue is: To maintain ecosystem services (around water quality + quantity, carbon stocks and fluxes and species and habitat diversity) in the Snohomish Basin out to 2060
[3] X=4, 0=1 and 1-3 scale was converted to 1=1, 2=3 and 3=5. Scoring was calculated by averaging out the worksheets

- Age Structure: Population Pyramid (Basin and Counties).
- Household Structure: People Per Hh + % Married

- Behavior: (note: CE was the second most popular dimension, but some mentioned it should go under Economy).
- Economy:
  - Labor: % Unemployed
  - Wealth: Average Wages; GINI Index
  - Economic Growth: Total Personal Income As Proxy For GDP
- Governance (note: none selected, high disagreement among participants on what is compelling and good)
- Social Institutions: % in urban/rural development
- Knowledge: Investment in Research (vs. Development)
- Development Patterns: (note: while generally considered available, these dimensions were generally not highlighted as the most compelling or good measures).
  - People per Impervious Area
  - Residential Building Permits
- Infrastructure (note: these were generally seen as compelling)
  - Energy Source: % Total Consumption By Source
  - Energy Conservation: Btus Per Capita
  - Water Consumed: Total Water Consumed By User
  - Transportation: Time And Distance Traveled
- Resource Management: Acres of recreation (seen as most compelling and good measure)
- Biophysical Template: (Note: not seen as compelling nor available)
- Hydrology:
  - Flooding
  - Water Quantity
- Ecosystems:
  - Acres of Forested Lands
  - Salmon Escapement

2. The worst (least compelling, appropriate and available) dimensions are:

- In general, the dimensions that ranked lowest were ones that were not specified. Either characterized as NA (e.g. service provision or investments) or with a title that is not self-explanatory (e.g. 'myths of nature' or work centrality'). These indicators ranked low because of lack of data availability (except investments and number of NGOs that were considered poor measures).

3. The most divergent perspective on dimensions[4] were:

[4] Divergence was calculated as the variance in response rate between the submitted worksheets.

- Climate change and social institutions (including governance) reflected the most divergent perspectives overall.
- Human Values had the most divergent perspective on available data

4. Dimensions that represented knowledge and gaps[5] were:

- Highest response rate (whether high or low scoring) was for climate, infrastructure, and hydrology.
- Poorest response rate was social institutions
- Fair-to-poor ratings for economy, human values, knowledge, ecosystems and development patterns

5. What additional dimensions were suggested:

- Climate Change: 1) Seasonal changes in temperature / precipitation
- snow line extent 2) explicit linkages to ecosystem services
- Human Values: 1) Business as usual vs. Integrated / Consensus 2) explicit linkages to economy, development and social
- Behavior: 1) transportation choices
- Economy: 1) Consumer Expenditures (moved from behavior) 2) investments (moved from behavior) 3) exports
- Governance: 1) ability to fund new improvements + maintenance 2) geographic scale (local vs. federal) 3) FEMA[6] 4) nested attributes of governance[7]
- Knowledge: 1) Investment in research vs. development[8] 2) Degree of separation between science and policy
- Development Pattern: 1) Growth Management act 2) Shoreline development and Armoring
- Infrastructure: 1) Transportation mode 2) Links to Growth Management Act 3) Wastewater Management
- Resource Management: 1) Open space and Conservation lands
- Biophysical Template: 1) Recharge (Wetlands and Floodplains)

4) Ecosystems: 1) Salmon life stage survival rates 2) fragmentation 3) Land and Water Interfaces 4) Terrestrial and Marine Interfaces

6. Which dimensions are uncertain / had question marks associated with them:

- Land Use Dominance: % Change In Lu
- Municipalities: Percent Incorporated
- Soils And Minerals: % Of Soil Built Over By Year

[5] Level of awareness and gaps were calculated based on the number (count) of responses. The assumption is, that if many experts responded (whether high or low) to a dimension/ indicator they are aware / knowledgeable of it. While if no responses occur, it reflects gap in represented knowledge.
[6] Unclear what was meant by this suggestions.
[7] It was noted that level of urbanization is not 'with their flow chart'. It was unclear what was meant by this.
[8] It was suggested to look at research versus development as opposed to the funds allocated to both together.

- Landscape Movement: Elevation Of Development By Year Built
- Toxins And Chemicals: Application Of Fertilizers, # Of Livestock, Impervious Surfaces, Traffic Counts, Industry

7. **Additional comments:**
   - A few dimensions were notes as 'outputs' (not inputs of the scenarios).
     - Global Change: Cost Of Damages Linked To Climate Change
     - Snowpack: Average Snow-Water Equivalent On April 1st
     - Age Structure: Population Pyramid (Basin and Counties).
     - Labor: % Unemployed

DETAILS: EXERCISE 2: ECOSYSTEM SERVICE INDICATORS

1. **Overall, the most compelling[9] indicators selected were:**
   - Forest stocks: Acres of forestland by urban-rural gradient [5]
   - CO2 Emissions: # of Vehicles / Miles driven [4.5]
   - Habitat connectivity: Contagion Index / Aggregation Index [4.5]
   - Pollution levels: Levels of exposure to PCB's, PBDE, Dioxins, Pesticide [4.5]
   - Stream Variability: Frequency and intensity of peak and drought levels
   - Available Snowpack: SWE April 1st
   - Pesticides + Toxins: Likelihood of Dieldrin in Fish
   - Pesticides + Toxins: Mercury levels
   - Acres of protected natural area: Distribution & extent of public & private lands amenable to biodiversity & NGO/trust lands for biodiversity
   - Dominance of habitat: Landscape diversity (Shannon landscape evenness index)
   - Disturbance Regimes: Occurrence/abundance of disturbance sensitive vs. tolerant vs. dependent bird species; Spatial extent of fire, insect outbreaks, floods & windthrows occurrence rates of floods; Occurrence rates of droughts
   - Land use/cover change: Distribution/extent of land cover transition
2. **The most agreed upon good high ranked indicators:**
   - High agreement generally reflected low response rates. But the three most responded to indicators that ranked high by all were:
     - Precipitation: Total depth (inches) per month
     - Bacteria: Fecal Coliform / E Coli
     - Nutrients: Conc. Of Nitrates and Phosphates
     - Available habitat: Mean patch Size (total forest cover)
3. **Which indicators reflected the most divergent views[10]:**

[9] Scores of 4.2 or higher and number of responses >4.
[10] Divergence was calculated as the variance in response rate between the submitted worksheets.

   - Groundwater recharge (is it compelling? Appropriate?)
   - Water quality index (is it appropriate?)
   - Pollution levels (while considered compelling by majority, whether it's an appropriate and available measure was disagreed upon.
4. **Represented knowledge and gaps:**
   - There was a clear knowledge gap in terms of carbon fluxes and stocks. Out of 5 worksheets collected rarely did more than 1 worksheet reflect any response to these indicators[11].
5. **What additional ecosystem service indicators did you suggest?**
   - Frequency of fish kills
   - Nutrient Loadings
     - Pesticides linked to pollution levels of species diversity
6. **Which ecosystem service indicators are uncertain / had question marks associated with them:**
     - For species diversity it was uncertain whether indicators were specific to marine species.
     - Un-described questions marks appeared next to: Invasive species, Ecosystem Integrity: Soil organic matter (SOM), Plant productivity: Net primary productivity (NPP) and Chemistry: dissolved oxygen

DETAILS EXERCISE 3: MODEL INTEGRATION

Hierarchy *(assumption: highest placement: driver / lowest placement: outcomes)*

- Climate: driver
- LCCM: secondary driver
- EcoPath and Shiraz: outcomes
- Hydrology: generally a secondary driver alongside LCCM.
- PS Characterization: Uncertain placement
- Vegetation: Uncertain placement

Important linkages: *direct and indirect relationships and feedback*

- EcoPath and Shiraz were linked to by all models. They were linked to each other. The following models, in addition to being linked to Shiraz and Ecopath were linked to:
- Climate was linked to hydrology directly (by all).

[11] However, it should be noted that these were the last set, so perhaps participants simply ran out of time.

- Hydrology models were linked to other models by one team. Hydrological models were only differentiated by Team 1. Experts reflected varied linkages between the hydrology models and EcoPath. All showed a direct link to SHIRAZ.
- LCCM was linked to PS Characterization. It was linked to hydrology and climate change indirectly (by one team).
- UrbanSim was linked to Climate and land cover
- Vegetation was linked to hydrology and LCCM (by one team)
- PS Char. Was linked to UrbanSim (by one team)

Gaps and Uncertainty

- Feedbacks between UrbanSim, Regional Forecast and transportation model to 1) to WRF 2) to DHSVM as water withdrawls and 3) from all other models.
- Uncertainty around 'random seed' of urbanSim, Regional Forecast and transportation model
- Uncertainty of inputs for many species associated with EcoPath
- Large scale inputs into regional climate and economic, policy and demographic inputs for LCCM
- Feedback to climate from LCCM, Vegetation Model and UrbanSim
- Vegetation from Shiraz,
- Hydrology from UrbanSim and LandCover
- How human behavior influences UrbanSim (from EcoPath?)
- How global drivers influence climate (WRF)
- How greenhouse gases influence hydrology

Selected inputs

Looking at the **blueprints** *inputs* may include global climate inputs (emissions, temperature, and or precipitation) as well as economy, policy and demographic inputs (into LCCM).

Looking at exercise 1, the flowing dimensions were identified as **potential model inputs** (scoring 4 or above on average) that were also considered compelling, appropriate and available.

- Magnitude Of Temperature: Average annual surface air temperature for Puget Sound in Deg C
- Extreme Temperature Events: Frequency / Intensity Of Heat Waves
- Extreme Precipitation Events: Frequency + Intensity Of Consecutive Dry And Wet Days
- Rate Of Climate Change: Increase in Annual Temperature / Decade
- Population Growth: Rate + Size of Population Growth Per Decade
- Age Structure: Population Pyramid (Basin and Counties).
- Household Structure: People Per Hh + % Married
- Consumer Expenditures: % Expenditures On Food, Housing & Transportation
- Labor: % Unemployed

- Wealth: Average Wages; Gini Index
- Economic Growth: Total Personal Income As Proxy For Gdp
- Energy Source: % Total Consumption By Source
- Energy Conservation: Btus Per Capita
- Water Consumed: Total Water Consumed By User
- Transportation: Time And Distance Traveled
- Recreation: Acres Of Recreation Lands (Parks, Wilderness)
- Flooding: Frequency And Stage
- Water Quantity: Snowpack SWE April 1st
- Forest Habitat: Acres Of Forested Land
- Salmon And Stream Habitat: Salmon Escapement For WRIA7 Species

Inputs across scenarios: The majority of dimensions whose potential trajectory was described in Exercise 3 were shown to be hypothetically 'sensitive' to the scenarios. However, many were described by question marks including: export, population growth, educational attainment, consumption, land use, and infrastructure.

Selected outputs

Looking at the **blueprints** outputs may for water quantity may include flow from hydrology model outputs. Water quality may be comprised from various indicators from both hydrology models[12] and EcoPath. Species diversity in regards to salmon may come from Shiraz[13] while food web relationships may come from EcoPath. Broad estimations of Habitat diversity may stem from the Potential Vegetation Model and the Puget Sound Characterization Model. Forest biomass may come from LCCM (land cover),

Looking at exercise 2, the flowing ecosystem indicators were identified as **potentia**l **model outputs** (scoring 4 or above on average) that were also considered compelling, appropriate and available.

- Stream Variability: Frequency and intensity of peak and drought levels
- Available Snowpack: SWE April 1st
- Precipitation: Total depth (inches) per month
- Cost of Water Provision: $ / gallon (to consumer)
- Water Temperature: # of Exceedance of Water Temperature / year
- Bacteria: Fecal Coliform / E Coli
- Pesticides + Toxins: Likelihood of Dieldrin in Fish
- Pesticides + Toxins: Mercury levels
- Salmon: Salmon escapement per species
- Available habitat: Mean patch Size (total forest cover)
- Available habitat: Total area by vegetation type
- Acres of protected natural area: Distribution & extent of public & private lands amenable to biodiversity & NGO/trust lands for biodiversity
- Habitat connectivity: Contagion Index / Aggregation Index
- Phenological trend: Leaf-on/-off dates, Flowering dates, Timing of migration

[12] HSPF outputs: Toxics, nutrients, pH, DO, conductivity, E Coli, TSS and DHSVM outputs: Flow, N, NO3
[13] Abundance, productivity, spatial distribution, diversity

- Land use/cover change: Distribution/extent of land cover transition
- CO2 Emissions: # of Vehicles / Miles driven
- Forest stocks: Acres of forestland by urban-rural gradient

Outputs across scenarios: The majority of outputs whose potential trajectory was described in Exercise 3 were shown to be hypothetically 'sensitive' to the scenarios. During the discussion many questions came up on how predictable these changes are.

- Water Quality Index
- Stream flow (seasonal variability)
- Biodiversity: # threatened and endangered
- Salmon Escapement
- Richness
- Balance Eveness
- Invasives
- Pollution
- # Priority habitats listed
- Habitat Connectivity
- Acres Protected
- Snowpack
- Stream flow (seasonal variability)
- # impaired water bodies
- water temperature
- sediments / turbidity
- nutrients
- HABs
- streamflow / SWE / 7Q10
- Peak summer water temperature
- area/hydroperiod of existing wetlands

Scenario Tests

Date

1.2012

Location

Phone and online interview.

Objective

Targeted meetings with selected members of Science Team to test the validity of specific trajectories of each driving force

Attendance

20 phone and online interviews with Science Team members.

Materials

Participants were shared the draft scenarios packet (see under Materials of Integrated Model Workshop, pages A6.122-128)

Survey Instrument (pages A6.138-139 Note. Each interview was slightly different, included here was the interview for Drinking Water Trajectories)

Synthesis

Science team members provided detailed feedback on the draft scenarios, with specific recommendations on how to better represent the potential variability across the four scenarios with respect to their area of expertise. The synthesis of the interviews was directly incorporated into the revisions of the final scenarios and specific driving force and ecosystem service trajectories described in Appendices 3 and 4.

A **Scenario overview**

1 Did you have a chance to review the scenarios? Do you have any initial questions about them?

2 Before we discuss specific drinking water trajectories, I'd like to hear your perspective on the scenarios overall. How did you read the narratives and what, if anything, needs our further attention (e.g. not logical, not clear what we mean, etc).

a Pretend for a moment you were describing these scenarios to a colleague. Can you distinguish between the four scenarios in a sentence or two?

- Are there any inconsistencies in the narratives?
- Is there anything missing from the storylines that would help make the story more compelling? Logical?

b Focusing only on drinking water, how would you describe the differences across the scenarios?

- Are these the most divergent plausible outcomes for the region in 50 years? What, if anything, would you change (either to an individual storyline or to the suite of scenarios)?

B **In-field Trajectories:** The next series of questions will attempt to largely unpack your drinking water distinctions from the question above.

1 Defining Drinking Water

a Define drinking water? Why is it important?

b What are good measures to describe drinking water? Water quantity? (cost, variability...)

c How might drinking water change over the next 50 years? What are potential extremes? (try to discuss in terms of the aforementioned measures).

d Are there any publications that discuss future predictions for drinking water in the basin?

e What are the most important drivers governing drinking water?

f Which of the important drivers' trajectory is the most uncertain, looking over the next 50 years? (e.g. precipitation pattern, urban development?)

g When thinking about the Basin's future drinking water, we largely saw four drivers to consider: *demand, regulations, climate change and technology* (efficiencies). We'd like to walk through each one of these to explore their potential relationship to drinking water.

2 Before we do, are there any additional drivers or variables we need to consider?

3 **Demand:** we thought of demand as the amount of households and industry that are using the regions resources.

a What is the relationship between demand and drinking water currently?

b What are critical challenges looking over the next 50 years?

c Are you familiar with any projections in regards to demand?

d For households we are thinking about total population growth, household size and percent on exempt wells vs. centralized water.

- What do we need to consider when thinking about these future trajectories?
- What is the uncertainty around exempt wells in this region?
- What is the trajectory around centralized service?

e How much can we grow before demand exceeds supply?

f For industry we looked at both industry sectors (manufacturing vs. Service) and acres of Copland (agriculture).

- What is the relative importance of industry consumption in the basin? What do we need to consider?
- Based on your reading of the four scenarios, what is the relative change in withdrawls under each scenario?

4 **Regulation:** includes new regulations, e.g. salmon protection, exempt wells, stricter regulations, even loss of the watershed protection.

a What are potential changes to regulation influencing drinking water in the Basin?

b What are critical challenges looking over the next 50 years? Where does the uncertainty lie?

c Are there any forecasted trajectories for regulatory reform?

d Based on your reading of the four scenarios, what is the relative change in regulation that might be associated with each scenario?

5 **Climate change:** here we are largely thinking of snowmelt and precipitation variability.

a Are you familiar with any publications that provide quantitative predictions for SWE for the Basin in 2060 (or 2040, or 2080 for that matter)? Are you comfortable putting any numbers in the 'major' vs. 'minor' categories?

b Are you familiar with any publications that provide…precipitation variability? Are you comfortable putting any numbers down?

c Is there any other climate variable that will influence the long term availability of drinking water in the Basin?

d Are there any significant thresholds associated with precipitation variability and snowmelt in the Basin?

e The scenarios articulate major and minor climate change. What is the potential relationships between those overarching changes and specific changes to water availability?

6 **Technology:** we saw technology as largely increasing efficiencies of water consumption, from household appliances to industry (cooling) and agricultural (irrigation) use.

a Are there technologies that are currently being developed that you might influence the Basin' water usage over the next 50 years? Which ones?

b What is the current elasticity of water consumption? How much further might be able to extend conservation measures? How does this region rank nationally in terms of current efficiencies?

c In addition to efficiencies, it there any other technological advances that we should consider? Perhaps in terms of water quality? Gray water?

d Can you describe potential changes in drinking water under the four scenarios, based on how you read the scenarios?

C **Relationship to other variables**

1 **Drinking water** has important feedbacks to the system. Can you describe potential feedback across the scenarios? (i.e. spiritual benefits? Economic – quality of life? Public Health

2 What is the relationship between drinking water and provision of services?

D **Anything else?**

1 In addition to drinking water, what do you think is important for us to describe when distinguishing between the scenarios?

2 Is there anything else that you would like to add (e.g. reflecting on the scenarios?)

3 Do you have any questions for us?

Policy Workshop

Date

2.24.2012

Location

Graham Visitors Center. Seattle, WA.

Objective

The Policy Workshop focused on key challenges and opportunities for maintaining ecosystem function in the long term and identifying questions to facilitate robust decision making under uncertainty.

Attendance

24 basin stakeholders representing key actors influential in shaping the basin's future. See Appendix 1: Stakeholder Committee

Agenda

Exercise 1: Decisions under uncertainty

Plenary discussion 1: How to make better decisions

Team discussion 1: identfying critical decisions, actors and strategies

Team disucssion 2: risks, trade-offs and policy evaluation

Plenary discussion 2: Redefining the problem: what questions should we ask?

Materials

> *Snohomish Basin Forecast package*

A collection of forecasts characterizing potential changes within the Snohomish Basin and surrounding Puget Sound Region. The forecasts were synthesized by the UERL team into 8 overarching categories including: demography, economy, land cover change, climate, hydrology, sea level rise, water and energy supply and demand, and salmon.

see pages A6.142-145

> *State of the Basin 2010 Package*

A collection of current statistics and historical trends characterizing influential variables within the Snohomish Basin and surround Puget Sound Region. The graphs, maps and descriptions have been synthesized by the UERL team into seven overarching categories including: demography, economy, development, resource management, infrastructure, hydrology and ecosystems.

see pages A6.146-150

> *Decision making under uncertainty exercise instructions and background data*

Instructions for the exercise played during the Policy Workshop. Includes overview, list of eight pre-selected strategies and four indicators for assessing improvements. Background data includes narratives of the four scenarios and graphic illustration of potential future trajectories of key driving forces under the four scenarios.

see pages A6.151-158

> *Presentation*

see pages A6.159-168

Snohomish Basin Forecast Package

This package includes a collection of forecasts characterizing potential changes within the Snohomish Basin and surrounding Puget Sound Region. The forecasts have been synthesized by the UERL team into 8 overarching categories including: demography, economy, land cover change, climate, hydrology, sea level rise, water and energy supply and demand, and salmon. Included below are the references and links for each forecast . This package was developed to support the discussion at the Snohomish Basin Policy Workshop hosted by the UERL on February 24, 2012.

REFERENCES:

Demography:

- **Population Growth per Decade:** Puget Sound Regional Council. Puget Sound Economic and Demographic Forecast. 2006. http://psrc.org/data/forecasts/econdem/
- **Household Growth:** Ibid.
- **Ethnicity and Race in WA:** State Forecast 2000-2030. Office of Financial Management.
- **Age Structure in Washington State:** Ibid.

Economy:

- **Employment density:** Puget Sound Regional Council. Puget Sound Economic and Demographic Forecast. 2006. http://psrc.org/data/forecasts/econdem/
- **Total Number of Jobs in the Snohomish Basin:** Ibid
- **Employment Trends:** Ibid
- **Jobs per Sector in the Snohomish Basin:** Ibid

Land Cover Change:

- **Land Cover Change:** Land Cover Change Model for Central Puget Sound: Land Change Predictions to 2050. April 2010. Report prepared for Weyerhaeuser as part of the Puget Sound Development and Climate Change Project. Matt Marsik and Marina Alberti. Urban Ecology Research Laboratory. Department of Urban Design and Planning. University of Washington. http://www.urbaneco.washington.edu/R_LandcoverChange.html

Climate:

- **Temperature and Precipitation:** Implications of 21st Century Climate Change for the Hydrology of Washington State. The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. 2009. Climate Impacts Group. http://cses.washington.edu/cig/res/ia/waccia.shtml
- **Seasonal Variability.** Ibid. p34-35
- **Extreme Events.** Ibid. p61-63

Hydrology:

- **Snowpack Loss:** Implications of 21st Century Climate Change for the Hydrology of Washington State. The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. 2009. Climate Impacts Group. P95. http://cses.washington.edu/cig/res/ia/waccia.shtml.
- **Watershed Transitions.** Ibid. P9 and P234
- **Groundwater**: Water Supply Forum. Appendix X. Technical Memorandum #8: Impacts of Climate Change on Groundwater Resources: A Literature Review Prepared for: Climate Change Technical Committee. 12/13/2007.
- **Flow Statistics:** Implications of 21st Century Climate Change for the Hydrology of Washington State. The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. 2009. Climate Impacts Group. p236-7. http://cses.washington.edu/cig/res/ia/waccia.shtml.

Sea Level Rise:

- **Habitat Vulnerability Assessment:** Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. July 2007. National Wildlife Federations. p47 and p49.
- **Transportation Vulnerability Assessment:** Transportation Vulnerability Assessment: Washington State Department of Transportation for submittal to the Federal Highway Administration. November 2011. Climate Impacts Vulnerability Assessment Report. p58-59

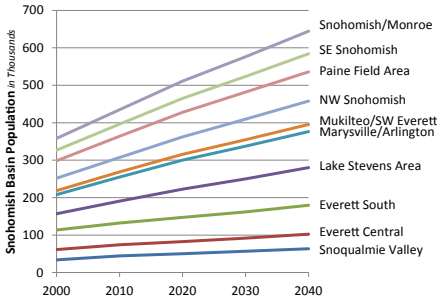
Water and Energy Supply and Demand

- **Water Supply and Demand:** Regional Water Supply Outlook. 2009. Water Supply Forum. http://www.watersupplyforum.org/home/outlook/
- **Energy Supply and Demand:** 2012 Washington State Energy Strategy. December 8, 2011. 2.3 Forecasting Energy Indicators Through 2035. p17-22. http://www.commerce.wa.gov/DesktopModules/CTEDPublications/CTEDPublicationsView.aspx?tabID=0&itemID=10206&MId=863&wversion=Staging
- **Climate impacts on Hydropower Supply and Climate impacts on energy demand due to changes in heating and cooling days**: Implications of 21st Century Climate Change for the Hydrology of Washington State. The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate. 2009. Climate Impacts Group. http://cses.washington.edu/cig/res/ia/waccia.shtml

Salmon:

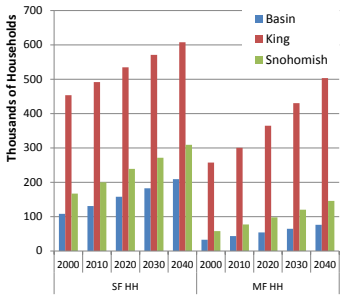
- **Air Mean Surface and Maximum:** Climate Impacts Group, University of Washington. June 2009. The Washington Climate Change Impacts Assessment Stream Temperature: Evaluating Washington's Future in a Changing Climate. p222 and p228.
- **Change in Mean Returning Chinook Spawners, 2000-2050:** J. Battin, K. Bartz, M. Ruckelshaus, H. Imaki, M. Wiley, E. Korb, and R. Palmer. NOAA Northwest Fisheries Science Center and University of Washington Civil and Environmental Engineering. Climate Impacts on Salmon Recovery in the Snohomish River Basin. http://cses.washington.edu/cig/res/ae/snohomish.shtml
- **Results of Hydrologic Model on Key Salmon Survival Limiting Factors:** Ibid.

Population Growth / Decade



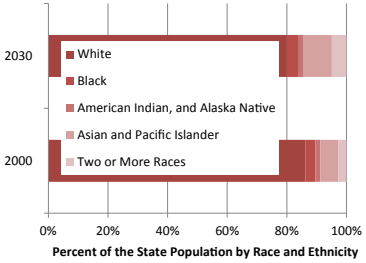
PSRC 2006 trends are based on declining rates of growth in both King and Snohomish Counties. While the growth rate was 9% in King and 21% in Snohomish County between 2000-2010, the rate is forecasted to decrease to 7.5% and 12%, respectively, between 2030-2040. If 2000-2040 trends were extended linearly to 2060, the Basin could be forecasted for an additional 350,000 people in the Basin (2010-2060)

Household Growth



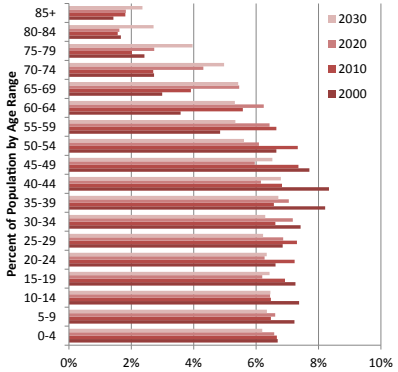
In 2010, 25% of the Basin households lived in multiple-family units. By 2040, the percentage is forecasted to rise modestly to 26.7%. In King County, during the same time frame, the percentage of MF units is expected to rise from 38% to over 45%.

Ethnicity and Race in WA



In 2000, 7.5% percent of the State was of Hispanic Origin. By 2030, the percentage is forecasted to rise to 12.9%.

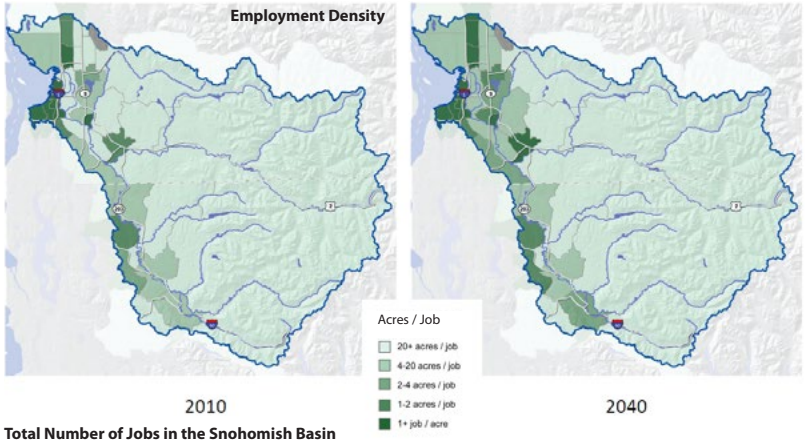
Age Structure in Washington State



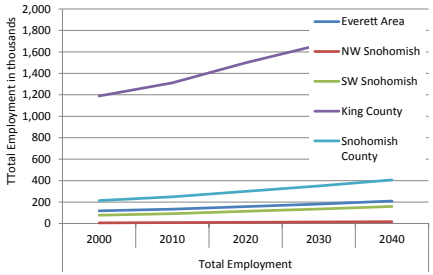
In 2000, the median age in the State was 35. By 2030, the median age is forecasted to rise to 39.
In 2000, 19% of the population was school aged (5-17). By 2030, only 16.7% of the population will be school aged. However, there will be over 300,000 more students in the system.
In 2000, 11% of the State population was of retirement age. By 2030, an additional 1 million people will be of retirement age (65+), one fifth of the total population.

In 2010, the Basin's population represented ~6.5% of the State's population. If growth trends in the Basin remained fairly consistent with the State's growth trends, the Basin can be forecasted to grow by an additional 20,000 students and 65,000 retirees by 2030.

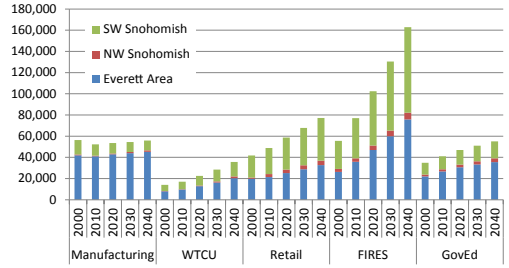
Demography *published data*



Total Number of Jobs in the Snohomish Basin



Jobs per Sector in the Snohomish Basin



Employment Trends

Between 2010 and 2040 the King and Snohomish Counties are forecasted to grow by an additional 520,000 jobs and 160,000 jobs, respectively.

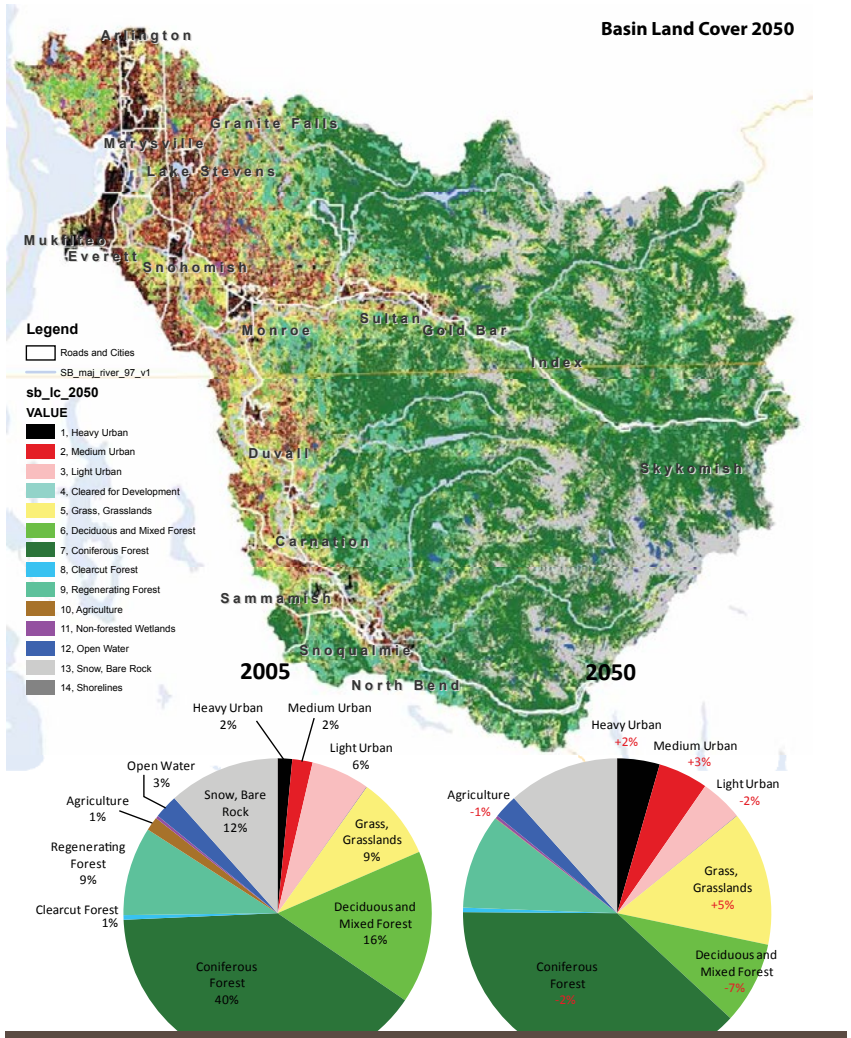
The majority of these jobs will be within the financial, professional, business and educational services sectors (FIRES).

The Basin is forecasted to increase by an additional 150,000 jobs between 2010 and 2040, 57% of these additional jobs are forecasted for the FIRES sector.

Manufacturing is modestly forecasted to grow by 2%. King and Snohomish Counties overall are forecasted to lose over 17,000 jobs.

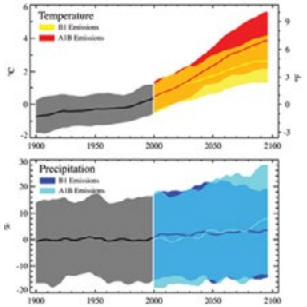
Note: PSRC's forecast was updated in 2006. Since the release of the forecasts, important changes to underlying planning assumptions and trends have occurred, an updated release is slated for Spring 2012.

Economy *forecast data*



Land Cover Change *published data*

Simulation of Annual Changes in Temperature and Precipitation

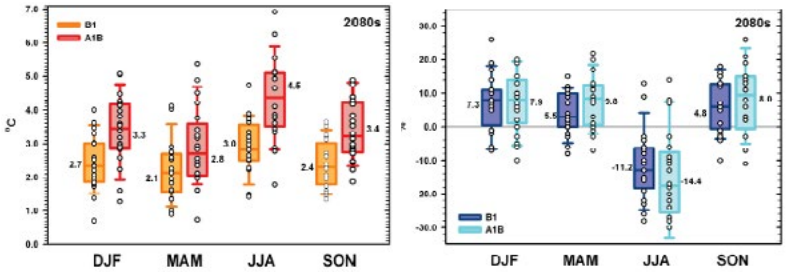


Simulated temperature change and percent precipitation change for the 20th and 21st century global climate model simulations for the Pacific Northwest. The black curve for each panel is the weighted average of all models during the 20th century. The colored curves are the weighted average of all models in that emissions scenario ("low" or B1, and "medium" or A1B) for the 21st century. The colored areas indicate the range (5th to 95th percentile) for each year in the 21st century. All changes are relative to 1970-1999 averages.

	Temperature Change degF	Precipitation Change (%)
2020's	+2.0 (+1.1 to +3.3)	+1.3 (-9 to +12)
2040's	+3.2 (+1.5 to +5.2)	+2.3 (-11 to +12)
2080's	+5.3 (+2.8 to +9.7)	+3.8 (-10 to +20)

(39 combinations averaged for each cell in the table). The ranges for the lowest to highest projected change are in parentheses.

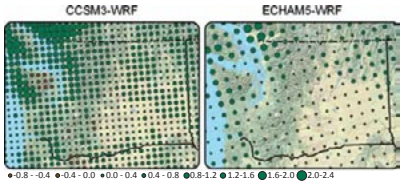
Seasonal Variability



Range (lowest to highest) of projected changes in temperature (red) and precipitation (blue) for each season (DJF=winter, etc.), relative to the 1970-99 mean. In each pair of box- and-whiskers, the left one is for SRES scenario B1 and the right is A1B; circles are individual model values. Box-and-whiskers plots indicate 10th and 90th percentiles (whiskers), 25th and 75th percentiles (box ends), and median (solid middle bar) for each season and scenario. While some precipitation models project increases and some project decreases, the vast majority project decreases for summer and increases for winter by the 2080s.

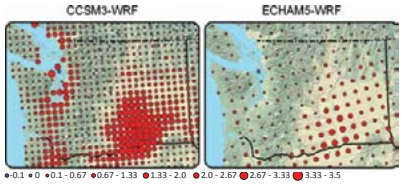
Extreme Events,

Change in the number of heat wave events



A heat wave is an episode of three or more days where the daily heat index (HUMIDEX) exceeds 32°C. The CCSM3-WRF shows considerable increase in heat waves in the lowlands of western Washington.

Change in the fraction of daily precipitation exceeding the 20th century 95th percentile (R95)



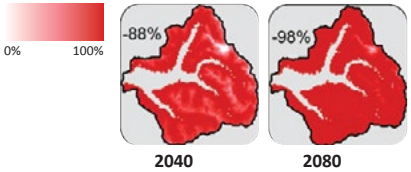
An increase reflects that a greater percentage of precipitation occurs during extreme precipitation events. Both models show increases, with CCSM3-WRF showing considerablly more change.

Climate *forecast data*

Snowpack Loss (SWE)

The hydrology of the Pacific Northwest (PNW) is particularly sensitive to changes in climate because seasonal runoff is dominated by snowmelt from cool season mountain snowpack, and temperature changes impact the balance of precipitation falling as rain and snow.

Projected changes in snow water equivalent (SWE) in the Sultan Watershed for 2040 and 2080 according to the A1B SRES scenario compared with simulated mean historical April 1 SWE (1916-2006) as simulated by DHSVM (below). By 2040, the Sultan is forecasted to lose 88% of April 1 SWE, by 2080 nearly all of the snow (98%) will be gone by the first of April. In the Tolt watershed (not pictured) 79% is forecasted to be lost by 2040, and 95% lost by 2080.

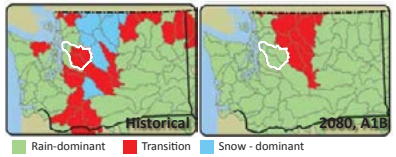


Groundwater

The literature review indicates that a wide range of groundwater impacts could result from climate change. Some studies indicate negative impacts to groundwater recharge related to climate change, while other studies predict increased groundwater recharge. In general, results suggest that changes in precipitation, caused by different emissions of greenhouse gases in the future, influence the amount of recharge. However, in some situations, local conditions, such as evapotranspiration, surface water exchanges, and changes to groundwater pumping, are more significant to groundwater systems than changes in climate. many studies indicate the relative importance of hydraulic conductivity to rivers and changes in river flows to groundwater levels.

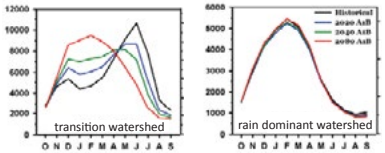
Watershed Transitions

Historically, both the Skykomish and the Snoqualmie were transition watersheds. By 2020, under both the A1B and B2 scenarios,the Snoqualmie would become a rain dominant watershed. By 2040 under the A1B scenario, and by 2080 under the B2 scenarios, the entire Basin would become rain dominant.



Streamflow Changes

Transient basins will likely experience significant streamflow shifts, becoming rain dominant as winter precipitation falls more as rain and less as snow. The characteristic double-peak hydrograph of the transition watersheds will shift towards a single-peak characteristic of rain-dominant watersheds (left below). Watersheds that are rain dominated will likely experience higher winter streamflow because of increases in average winter precipitation, but overall will experience relatively little change with respect to streamflow timing. These changes are important because they determine when water is available and how it must be stored.

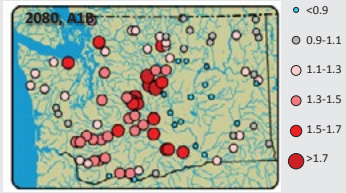


Flow Statistics

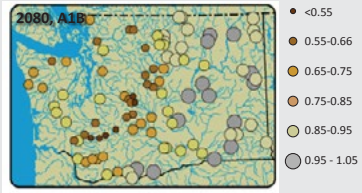
The magnitude and frequency of flooding are predicted to increase most dramatically in the months of December and January for what are now Washington's transient runoff watersheds. Rain-dominant watersheds are predicted to experience small changes in flood frequency.

Reductions in the magnitude of summer low flows are predicted to be widespread for Washington State's rain dominant and transient runoff river basins. Future estimates of the annual average low flow magnitude (7Q2, which is the 7 day average low flow magnitude with a 2 year return interval) are projected to decline by 0-50% by the 2080s under both the A1B and B1 emissions scenarios (see 2080, A1B above). The reduction in streamflow for more extreme (7Q10) low flow periods in rain dominant and transient runoff basins is also predicted to change by a similar amount, ranging from 5-40% (not shown). Further, the duration of the summer low flow period is projected to expand significantly

Ratio of 20-year Flood Statistics



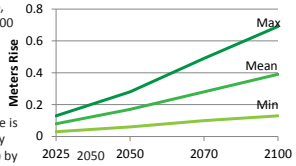
Ratio of Low Flow (7Q2) Statistics



Hydrology *forecast data*

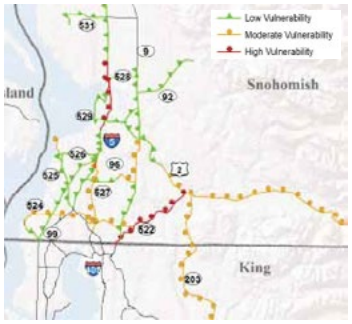
Pacific NW Seal Level Rise

Medium projections of sea level rise for 2100 are 2 inches to 13 inches (depending on location) in Washington State. Substantial variability within the region exists due to coastal winds and vertical land movement. The small possibility of substantial sea level rise from the melting of the Greenland ice cap lead to projections as high as 35 inches to 50 inches for 2100 (depending on location).The IPCC Sea Level Rise projections for moderate A1B scenario, range across the next 100 years and under a minimum, mean or maximum trajectory (see below). In WRIA 7 (Coast from Everett – Marysville) sea level rise is projected to increase by 0.36 meters (14 inches) by under the A1B Maximum.



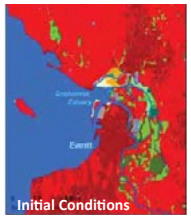
Transportation Vulnerability Assessment

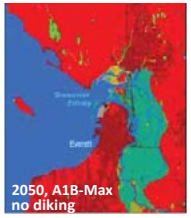
- Northwest Region Area 3 consists predominantly of urban and suburban roads in Snohomish County and US 2 to the region boundary and SR 203 in northern King County. In general, most climate impacts would result in either reduced capacity or temporary road closures due to heavy rain events.
- US 2 has impacts now from flooding and debris moving down the Skykomish River. If sea level rises 2 feet, US 2 could see more log jams collecting on bridge piers, but they would be easier to reach. With 4- and 6-foot sea level rises, the river could overtop the dikes and the water would spread, easing pressure on the bridge.
- US 2 is the sole mountain pass in this Maintenance Area. Climate impacts are anticipated to result in temporary closures rather than closures lasting over 60 days.
- SR 104 at the intersection to the Edmonds ferry terminal already has flooding during high tides and during average tides in heavy rain events. This is expected to increase with higher sea levels. Low-lying roads will be impacted by higher sea levels.
- SR 203 is impacted now by high winds coming off the Cascades. Winds may increase with more extreme weather events.
- In general, with increased heavy rain events, existing drainage ditches and culverts may be undersized for larger events. Roads at the base of steep slopes may see more landslides, but these are not anticipated to close the road for more than 60 days.

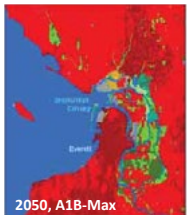


Habitat Vulnerability Assessment

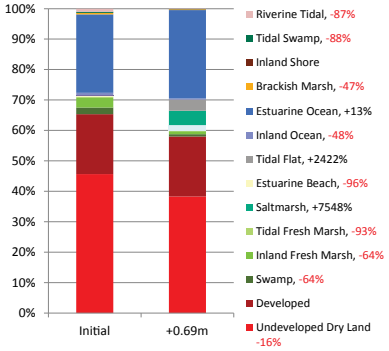
Extensive dikes protect the low-lying dry land and marshes within Everett. This reduces the predicted effects of sea-level rise for this site. Assuming that dikes in this area are able to withstand the predicted increases in sea level rise, the most significant prediction at this site is the inundation of brackish marsh and inland fresh marsh north of Smith Island and west of Marysville. However, it is not unreasonable to suggest that, because many of the dikes in this area were constructed with wood waste from lumber mills and other degradable materials, they may be vulnerable to damages associated with sea-level rise. The Tulalip Tribe and other stakeholders in the region are currently working to remove some of the region's dikes to restore habitat.







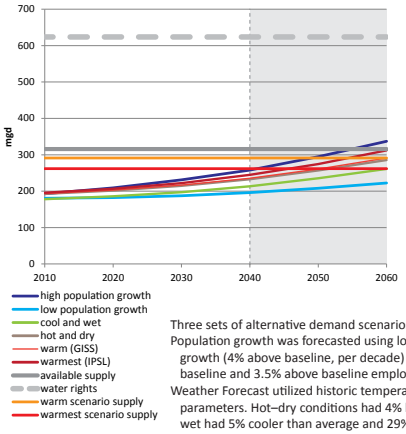
Projections for Habitat Changes for Everett Area, Site 4 Projections for Habitat Changes Assuming no Dikes



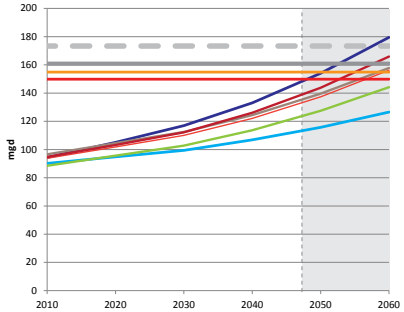
Sea Level Rise *forecast data*

Water Supply and Demand

King



Snohomish



Three sets of alternative demand scenarios were run by the Water Supply Forum:

Population growth was forecasted using low population (3.5% below current PSRC baseline, per decade) and high growth (4% above baseline, per decade) for households and population. The forecast also included a 2.5% below baseline and 3.5% above baseline employment growth.

Weather Forecast utilized historic temperature and precipitation data to forecast alternative future weather parameters. Hot–dry conditions had 4% hotter temperatures and 38% less precipitation than average. Cool and wet had 5% cooler than average and 29% wetter than average weather.

The projected impacts of climate change utilized the A2 and B1 SRES emissions scenario. With A2 representing the warmest (IPSL) scenario and B1 representing the warm (GISS) scenario.

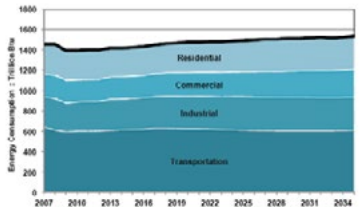
Changes to existing supply was explored. Included in the above diagrams are current water rights

In addition to demand, supply was explored. The total amont of supply is dictated by water rights.

Surface water supply is forecasted to change as a result from the expected seasonal shift in streamflow, with less runoff in late spring and early summer months, which have traditionally marked the reservoir refill period of the region's supply reservoirs. As with demand, the warm scenario represent SRES emissions scenario B1 while the warmest scenario represents A2. The above graphic does not represent new planned or proposed projects which will increase water supply in each County.

Energy Supply and Demand

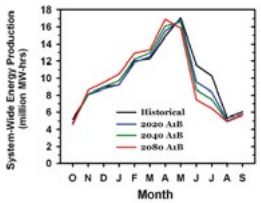
Forecast primary energy consumption in Washington, by end use sector



Washington residential energy expenditures projection through 2035. Expenditures are expected to decline primarily driven by improving efficiency in transportation standards, but also partly due to more purchases of efficient appliances, electronics and heating systems.

Climate impacts on Hydropower Supply

Hydropower accounts for roughly 70% of the electrical energy production in the Pacific Northwest and is strongly affected by climate-related changes in annual streamflow amounts and seasonal streamflow timing.



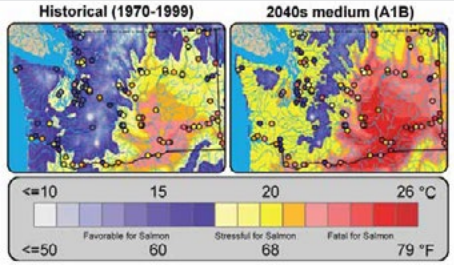
Climate impacts on energy demand due to changes in heating and cooling days

Combining the effects of warming with population growth

	HEDI (heating)	CEDI (cooling)
2020's	22% to 23%	165% to 201%
2040's	35% to 42%	363-555%
2080's	56% to 74%	981-1845%

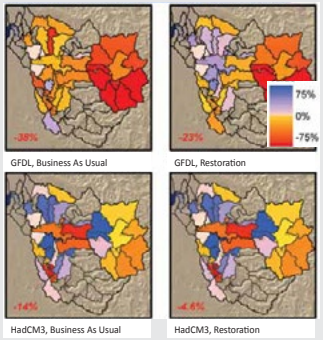
Infrastructure *published data*

Aug. Mean Surface Air + Maximum Stream Temperature



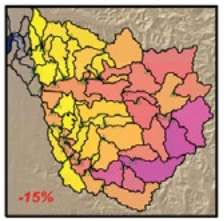
Had-CM3 has slightly more optimistic spawners. The major difference between the two models lies in the seasonal variability of precipitation. GFDL has a big decrease in summer and fall and big increases in Winter, while Hadley is more even across the year. Despite model uncertainty impacts on freshwater salmon are consistently negative. Restoration efforts can offset some of these impacts, more so under the GFDL model.

Change in Mean Returning Chinook Spawners, 2000-2050

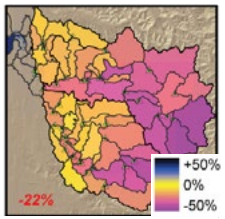


Results of Hydrologic Model on Key Salmon Survival Limiting Factors

2000-2050 Percent Change in Minimum Spawning Flows.

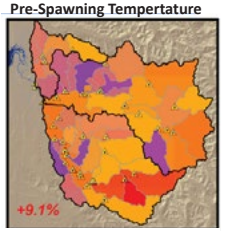


Current Landuse, GFDL_R30_A2

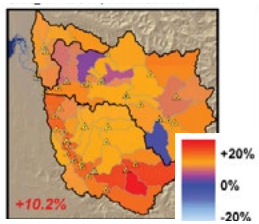


Current Landuse, HaDGM3-A2

2000-2050 Percent Change in Average Daily Maximum Pre-Spawning Tempertature

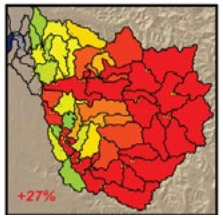


Current Landuse, GFDL_R30_A2

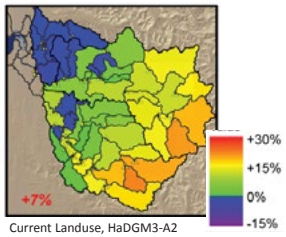


Current Landuse, HaDGM3-A2

2000-2050 Percent Change in Incubation Flows



Current Landuse, GFDL_R30_A2



Current Landuse, HaDGM3-A2

Salmon *forecast data*

State of the Basin 2010 Package

This package includes a collection of current statistics and historical trends characterizing influential variables within the Snohomish Basin and surround Puget Sound Region. The graphs, maps and descriptions have been synthesized by the UERL team into seven overarching categories including: demography, economy, development, resource management, infrastructure, hydrology and ecosystems. Included below are the references and links for each set of statistics. This package was developed to support the discussion at the Snohomish Basin Policy Workshop hosted by the UERL on February 24, 2012.

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- **Households:** Census 1960 and 2010. People per household by census Tract. Social Explorer. http://www.socialexplorer.com/pub/reportdata/home.aspx
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- **Number of Jobs in the Puget Sound Region:** Bureau of Labor Statistics. http://www.bls.gov/home.htm
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- **Personal per Capita Income.** Total wages, unadjusted for King and Snohomish Counties. Bureau of Economic Analysis. 1969-2009. April 21, 2011. http://www.bea.gov/

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  - Percent permitted New Housing Units inside the UG. Development Patterns Shift Under Growth Management. April 2008. Puget Sound Regional Council. http://psrc.org/assets/783/d5apr08.pdf
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- **Building Permits:** Washington Center for Real Estate Research. Washington State's Housing Market. http://www.wcrer.wsu.edu/WSHM/WSHM.html
- **Single vs. Multiple Family Housing Households:** Summarized Percent of units as single and multiple family in King and Snohomish Counties. Puget Sound Economic and Demographic Forecast. Puget Sound Regional Council. **http://psrc.org/data/forecasts/econdem/**
- **Rent as percentage of income:** Percent Monthly Income Spent on Gross Rent. Housing Prices and Affordability . August 2009. Puget Sound Regional Council. http://psrc.org/assets/2429/e16aug09.pdf

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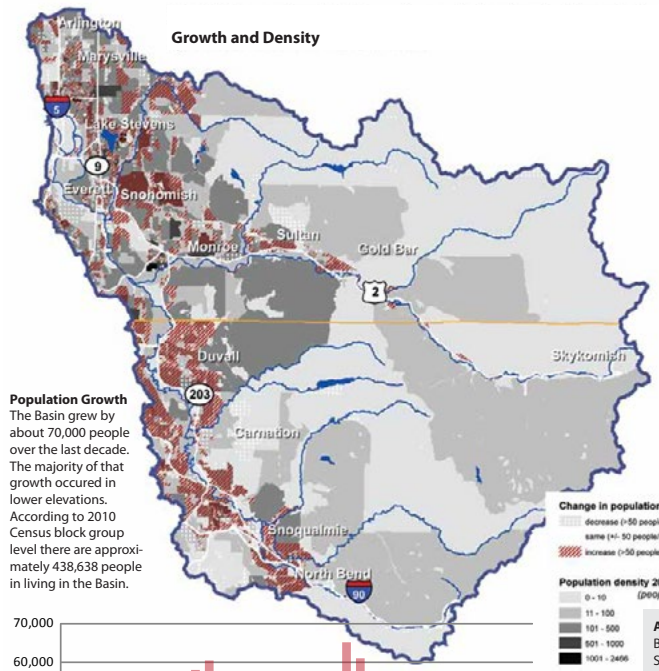
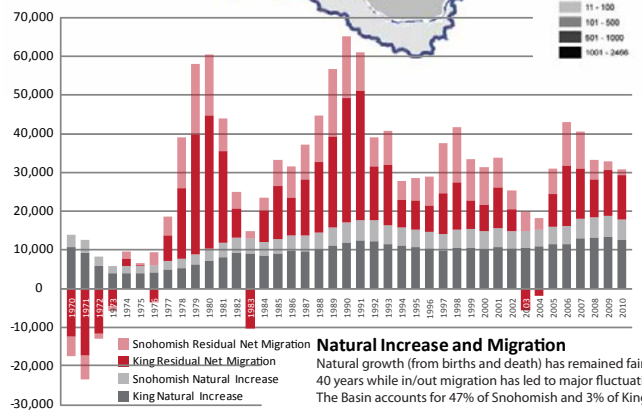


Population Growth
The Basin grew by about 70,000 people over the last decade. The majority of that growth occured in lower elevations. According to 2010 Census block group level there are approximately 438,638 people in living in the Basin.

Marriage
Percent of people married dropped from 48% in 1960 to 26% in 2010.

Households
People per household dropped from 3.07 in 1960 to 2.72 in 2010.

Ethnicity
In 1980, only 5.3% of Snohomish County population was considered minority, by 2010 25.7% is minority. The largest increase has been in the Hispanic population, which now comprises 9.4% of the County (4%, 2000). Asian population was also estimated at 9.3% in 2010.



Natural Increase and Migration
Natural growth (from births and death) has remained fairly constant over the last 40 years while in/out migration has led to major fluctuations in growth.
The Basin accounts for 47% of Snohomish and 3% of King County's population.

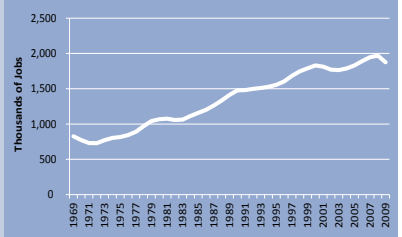
Age Structure
Between 1960 and 2010 Snohomish and King County experienced a growth in older age groups (45+) relative to younger age groups (under 44). However, if we isolate only the age structure in the Snohomish Basin, we don't see a significant trend in aging or loss of younger age groups. Since 1960 there has been an increase in the percentage of the population age 25-44, and a decrease in school age population (5-24).

Demography *published data*

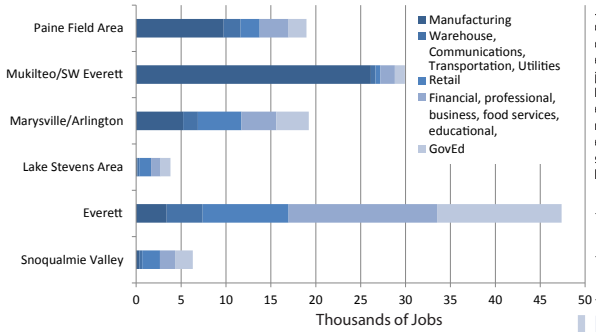
Top Employees of Snohomish County, 2009

COMPANY	TYPE	FTE 2009
Boeing	Aircraft manufacturing	32,000
Naval Station Everett	U.S. Navy Base	6,000
Providence Regional Medical Cen	Medical services	3,200
Premera Blue Cross	Health Insurer	3,200
Tulalip Tribes Enterprises	Real estate, Retail, Gaming	3,020
Snohomish County Government	County Government	2,965
Washington State	State Government	2,800
Everett School District	School District	1,700
Philips Medical Systems	Ultrasound technology	1,600
Verizon Northwest	Communications	1,500
Stevens Healthcare	Health care	1,400
Zumiez	Sporting Goods	1,400
Aviation Technical Services	Aircraft repair/maintenance/parts	1,400
Everett Clinic	Health care	1,400
Edmonds School District	School District	1,350

Number of Jobs in the Puget Sound Region

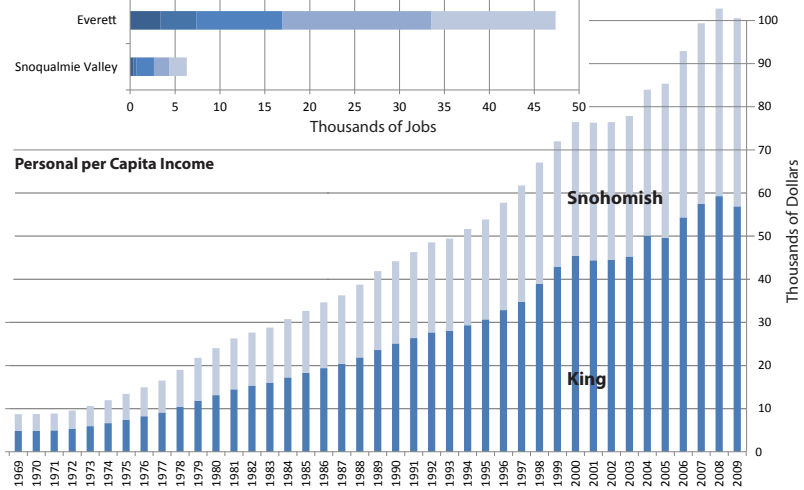


Jobs per Sectors *2006*



Jobs in service industries now dominate an increasingly diverse central Puget Sound economy. In the early 1970s, military and manufacturing jobs each outnumbered services jobs. In 1980, services were growing, but the economy still relied primarily on manufacturing and government employment. By 1998, services surpassed all other sectors as the largest sector of the regional economy.

Personal per Capita Income



Economy *published data*

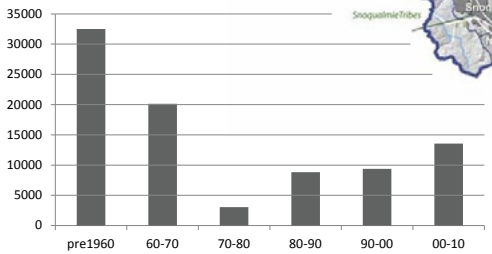
Urbanization Stats

According to the US Census, in 1960 40% of the Basin Population resided in Urbanized areas while in 2000 that figure rose to 85%.

According to the PSRC, in 2007, 94.9% of new housing was inside King County's Urban Growth Areas, and 83.5% inside Snohomish's UGA.

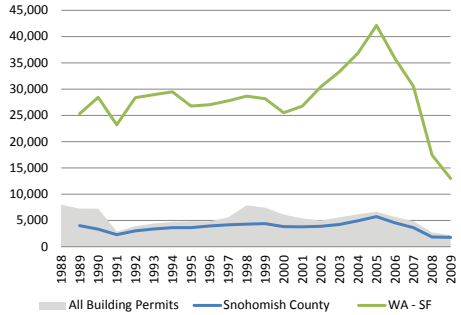
Between 2000 and 2007 24% of new housing units were within Metropolitan Cities in the Central Puget Sound. 2&% occurred in inner suburban areas while 48.5% occurred in outer suburban areas. PSRC 2008.

Acres of Annexed Land

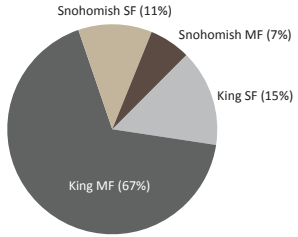


About 32,000acres of land had been annexed into cities by 1960s. The majority of cities had been incorporated around the turn of the century. Over the last 50 years another 55,000 acres had been added. Currently about 5.5% of the Basin is incorporated.

Building Permits



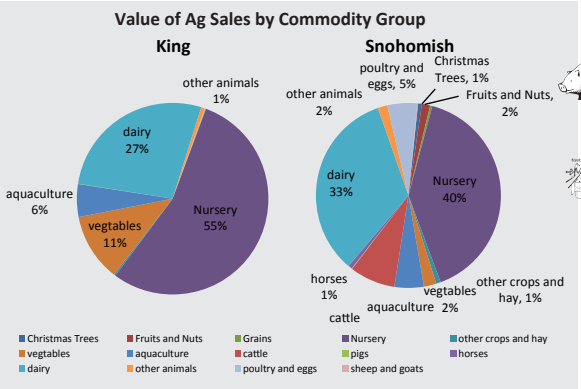
SF vs. MF Housing Households

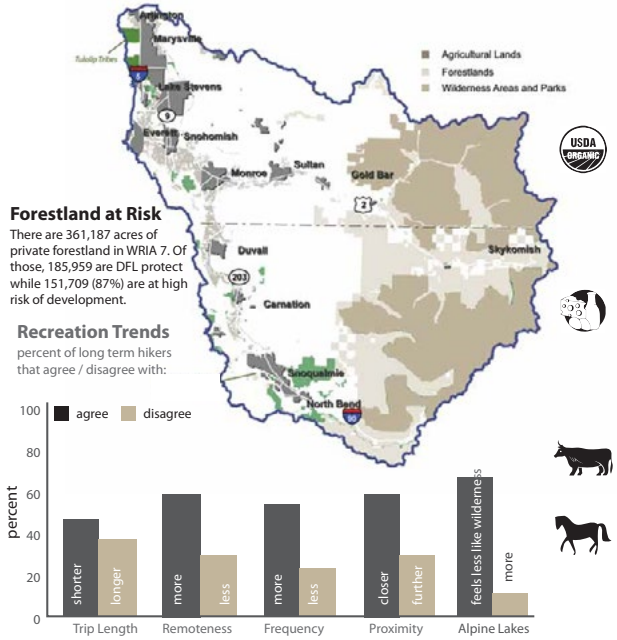


Rent as percentage of income

According to the US Census Bureau, in 2007 36% (the majority) of households spent more than 35% of their monthly income on gross rent. In 1989, the majority (>30%) of households spent less than 20% of their monthly income on rent.

Development *published data*





Forestland at Risk

There are 361,187 acres of private forestland in WRIA 7. Of those, 185,959 are DFL protect while 151,709 (87%) are at high risk of development.

Recreation Trends

percent of long term hikers that agree / disagree with:

Agricultural Statistics

Revenue
Snohomish County farmers sold more than $154 million in agricultural products in 2002. 89% of farms in King, and 87% of farms in Snohomish County bring in less than $50,000 in annual revenue.

Direct Marketing
Many of the strategies for increasing the viability of agriculture in Snohomish County are based on increasing markets and developing value-added or niche products. In western Washington, Snohomish County has the greatest number of farms that sell direct to individuals. In 2002, 284 or 18% of all farms reported selling direct to individuals either through roadside stands, farmers' markets, pick-your-own sites, or other means, an 8% increase since 1997. In King County 237 farms sold directly representing a 15% increase since 1997. The number of farms selling directly is believed to have increased especially in more recent years.

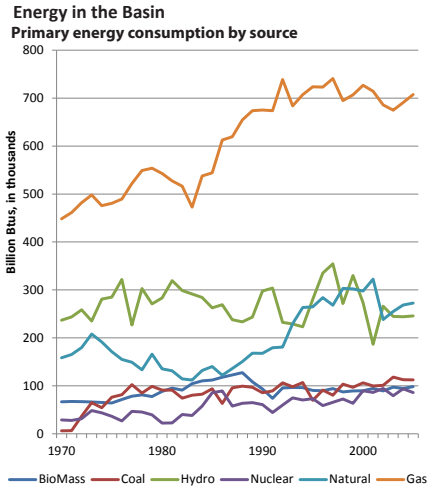
Certified Organic
2002 was the first year for which data on the number of farms that are certified organic was tabulated by the US Agriculture Census. In 2002, 25 farms, or 2% of Snohomish County farms, reported being certified organic. 41 farms, or 3% of King County farms were certified organic.

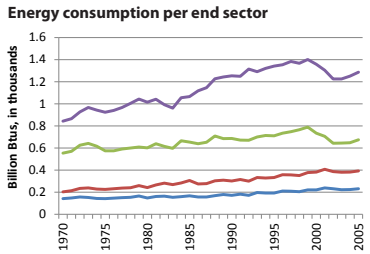
Dairy
In 2002 there were 84 dairy farms, down from 108 in 1997. In addition, the number of farms selling dairy products also declined over the same period. However, dairy still represents a significant portion of the agricultural sales in Snohomish County at more than $42 million dollars in 2002.

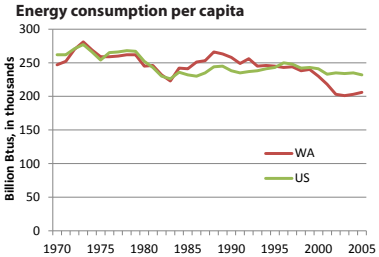
Cattle
Cattle and calves represent the third greatest sales producing commodity in Snohomish County at more than $10 million in 2002.

Horses
In 2002 there were a total of 4,907 horses and ponies in Snohomish County, which ranked fifth among Washington State Counties.

Resource Management *published data*







Water Supply in the Basin

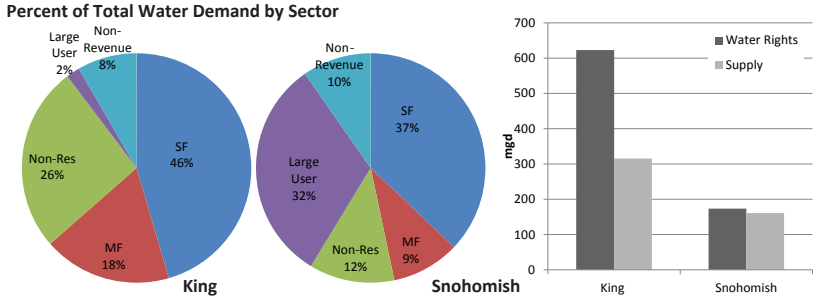
The major sources of the Basin's water supply are surface diversions on the Sultan and Tolt that collect natural runoff originating from the Cascade Mountains. Groundwater is also a significant source for some of the water providers in the region. In 2005, it is estimated that surface water comprised 66% of the region's total supply; while groundwater comprised 34%.

The municipal groundwater sources are tapped by wells with depths ranging from less than 100 feet to more than 1,000 feet.

Municipal water demand does not include agricultural water use or water used by industries that have their own water supply, such as private wells.

The total current demand for water in 2010 for Snohomish County 92 mgd and In King County, 168. The current supply within Snohomish and King counties is 160.9 and 315.6, respectively.

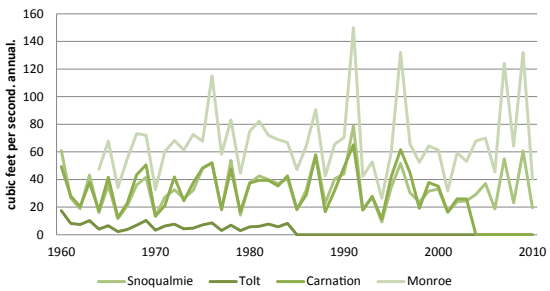
Single Family households utilize ~130-370gallons/day. Multiple Family households use less, at ~40-255 gallons/day. Non-residential customers are calculated by gallons per employee per day, at an average 57gped for the Region. Large Water users utilize ~30mgd.



Infrastructure *published data*

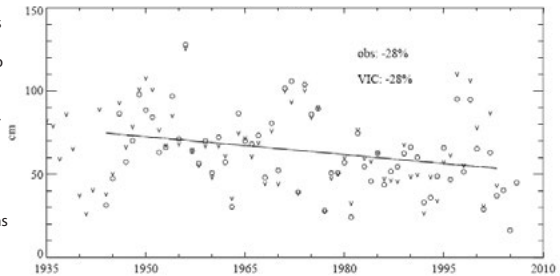
Streamflow

Annual streamflow in the watershed varies widely from one year to the next in a pattern which reflects annual precipitation. Long-term trends in annual streamflow will be affected by trends in precipitation, water consumption and land use practices. Recent analysis of annual streamflow trends, adjusted for precipitation, is inconclusive but suggests a possible reduction in streamflow over time.

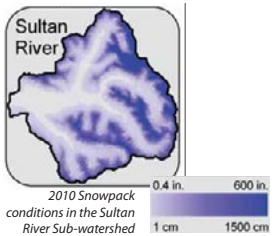


Snowpack

Nearly every glacier in the Cascades and Olympics has retreated during the past 50-150 years in response to warming. Small glaciers are disappearing rapidly, and glacial mass is being reduced on the larger ones. While the total water input into Puget Sound from melting glaciers is minimal, glacial retreat can have important local effects. In higher reaches of certain river basins (such as the Nooksack) and some tributaries to the Skagit, melting glaciers provide a substantial portion of stream flow in late summer. Glaciers also have significant local effects on stream temperature and water supply for aquatic plants and animals. Significant reductions in glacial input to streams would dramatically alter vulnerable aquatic habitat.

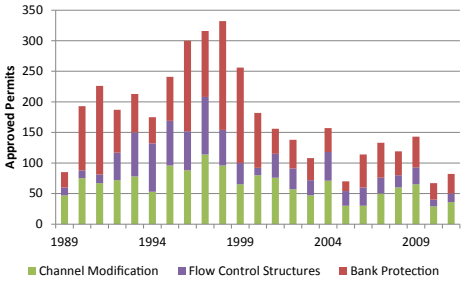


Regionally averaged 1 April SWE for observations (o) computed for the 1944–2006 snow courses using area-weighting and infilling of missing values with best-correlated time series, and VIC (v). The VIC values have been scaled to the mean observed SWE. Linear fits for observed (solid) and VIC (dashed) overlap.



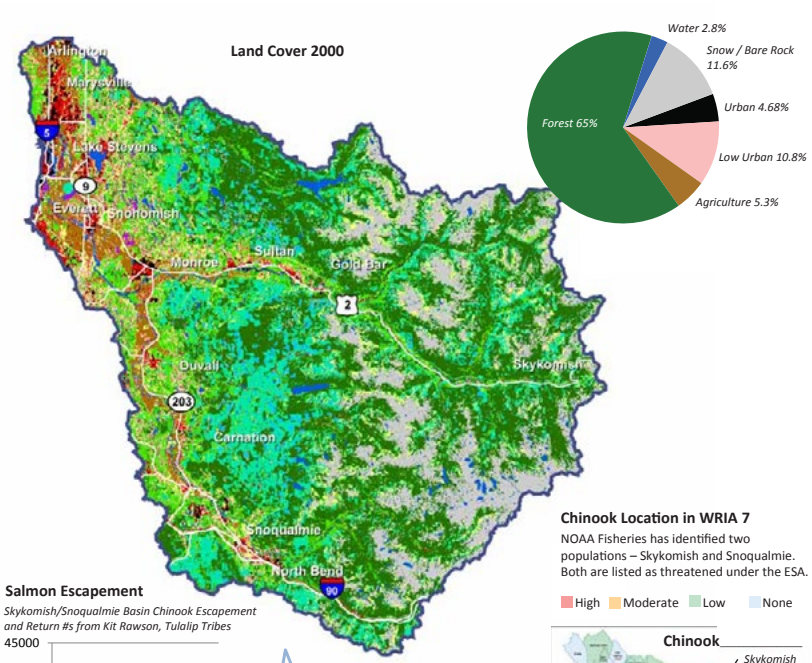
2010 Snowpack conditions in the Sultan River Sub-watershed

Freshwater Stream Alterations



Number of HPAs, per year, and per channel modification, flow control structures and bank protection permits in WRIA 7. WA Dept Fish and Wildlife

Hydrology *published data*



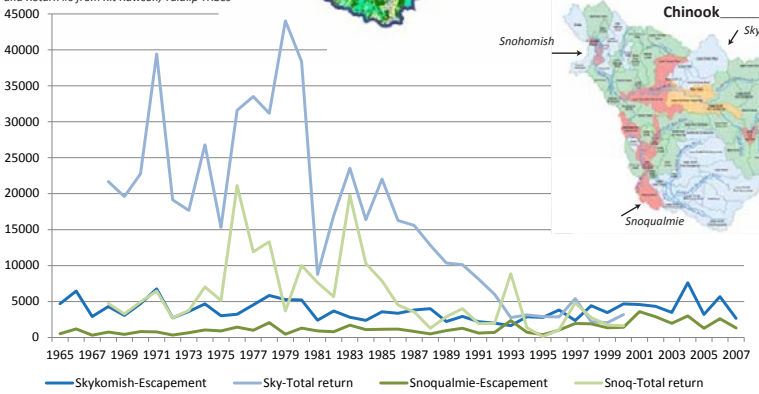
Chinook Location in WRIA 7

NOAA Fisheries has identified two populations – Skykomish and Snoqualmie. Both are listed as threatened under the ESA.

High Moderate Low None

Salmon Escapement

Skykomish/Snoqualmie Basin Chinook Escapement and Return #s from Kit Rawson, Tulalip Tribes



Ecosystems *published data*

Exercise 1: Decisions under Uncertainty

You are a member of an ad hoc task force appointed by Snohomish County in partnership with all local governments involved in the Snohomish Basin to develop a strategic plan aimed at protecting the long term watershed function in the Snohomish Basin. You represent your agency or other organization at the table. The EPA has committed to fund three projects within the next twelve months to help meet your goals. Please find attached a selection of eight projects identified as alternative approaches to maintain watershed function in the Basin over the next fifty years. The task force must agree on which three of the eight strategies to fund. A designated Science Team has identified 4 indicators of water quality and quantity to monitor in order to evaluate the performance of the selected projects; stream temperature, nutrient concentrations, and base flows and flood frequency. Please find attached a brief description of the four indicators. The Science Team has also supported today's decision making process with a quantitative model to forecast changes in indicator values associated with selection of alternative strategies.

Small Reservoirs: Reservoirs detain upstream flows, and can be used for multiple purposes including provision of water (drinking, irrigation), hydro-electric energy, and flood protection. Reservoirs can be managed to release cool water during low flow times (e.g. summer, drought). Reservoirs require a very costly initial investment for their construction and planning (e.g. Environmental Impact Statement). While small reservoirs don't carry the significant environmental impacts of major dams and reservoirs (i.e. hydrological and biotic disconnection), they still interrupt fish migration and sediment flows. Small reservoirs will likely be most effective if the region experiences major snowpack decline, which would exacerbate winter flooding and summer drought extremes.

Purchase of Development Rights (PDR) in Upland Forests: PDR refers to a planning program whereby the landowner voluntarily sells the 'right' to develop their land in the future to a government agency, thereby restricting the type and amount of development that may take place on their property. This strategy focuses on upland forests which have deep soil horizons capable of infiltrating runoff and recharging groundwater aquifers. Reduced overland flows and increased groundwater flows are expected to increase base stream flows, reduce summer stream temperatures, and reduce frequency of low-intensity flood events. By reducing the rate of runoff, input of nitrogen and phosphorus pollution may be reduced. This program does not restrict harvesting of timber and other resource management activities. This strategy is most effective if the margin between timber value and real estate value is close. In other words, if real estate value is much greater than timberland value, the incentive to sell rights is not present for the landowner, and if timberland value is much greater than real estate value, than the threat of conversion is suppressed.

Floodplain Conservation Easement: Conservation Easements restore and protect the functions of the floodplain. Landowners voluntarily sell the easement to their land within a floodplain to a government agency that then actively restores natural features and characteristics of the floodplain by re-creating the topographic diversity, increasing the duration of inundation and saturation, and providing for re-establishment of native vegetation. This program restricts farming and other resource management activities. Landowners retain the right to control public access and passive recreation. The restored floodplain acts like a sponge, soaking up water during peak flows to reduce flooding. Streamside (riparian) vegetation can reduce stream water temperature through shading, and reduce nitrogen and phosphorus concentration through plant uptake of these nutrients. While an effective tool to support salmon restoration, lowland farm communities generally oppose this program. An unintended consequence of restored floodplains is the increased flooding on adjacent parcels; as stream flows are effectively slowed, a bottleneck is created and upland parcels may experience more frequent periodic floods. This program works best if large contiguous parcels are restored and if flooding is frequent and intense enough to warrant the removal (or relocation) of farmlands.

New Building Impervious Surface: New regulation requiring all new developments (industrial, commercial and residential) to include a minimum 1:2 ratio of natural vegetation to impervious surfaces. In other words, for every square foot of roof, driveway and hard surface the developer must include at least half a square foot of tree cover, natural grasses or native drought-tolerant plants. If a minimum area cannot be met, developer can employ alternative Low Impact Development strategies (e.g. greenroofs or cisterns). The primary objective is to decrease urban runoff. This strategy is most

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effective at reducing nitrogen and phosphorus concentrations and minimizing extreme stream temperatures during frequent high-flow events (e.g. 48 hour storm). This strategy is most appropriate during periods of fast urban growth, especially of greenfield developments.

Water Tax: An increase in the cost of water during summer months when supply is low is imposed on households and industry (e.g. cooling and irrigation uses). The objective is to reduce withdrawals through market disincentives that indirectly increase efficiency, thereby bolstering in-stream flows during a characteristically low base-flow period. A water tax is not expected to benefit flood mitigation. By increasing the volume of water in streams, the effect of rising temperature and nutrient concentrations may be minimized. This strategy is most effective when consumption is in-efficient or wasteful. The unintended consequence of this strategy is an increased (regressive) burden on low-income households and struggling businesses such as small farms. In addition, if consumers are already operating at very efficient (minimal) rates, this strategy would not reduce consumption by much.

Phytoremediation Wetlands: Phytoremediation (from Greek: phyto=plant and Latin: remedium=remediation) describes the use of plants to mitigate environmental problems without the need to actively remove pollutants and dispose of them elsewhere. Phytoremediation wetlands are engineered to filter out inorganic fertilizers, minerals and toxins that contaminate waterways. These wetlands detain overland flows to increase water residence time needed for plants to remove the contamination. This process can indirectly benefit flood mitigation and reduce stream temperatures. Wetlands are generally engineered to be separate from groundwater flows in order to reduce threat of contamination, and therefore do not aid base flows. Phytoremediation wetlands are most effective if constructed downhill from clustered pollution source (e.g. urban development). In other words, this strategy works best when development is compact, not dispersed.

Agricultural Incentive District: An agricultural incentive district is a designated boundary within which participating farmers comply with a set of restrictions in exchange for a monetary benefit (e.g. reduced property tax). This proposed strategy specifically addresses the use of pesticides and fertilizers within floodways. This strategy can be highly effective at reducing stream nutrient concentrations from agricultural runoff. Temperature, base flow and flooding would not be affected by this planning tool. For this strategy to work well, there would need to be a lot of farmland in the Basin, and a desire for farmers to comply (i.e. the benefit of reduced taxes is greater than the lost revenue from not using fertilizers).

High Efficiency Household Water: A program to increase the efficiency of household fixtures and appliances to reduce water consumption. Municipalities (cities and counties) would provide in-home installation of low-flow fixtures (e.g. aerated showerheads) and provide discounts towards the purchase of new high efficiency (HE) appliances such as dishwashers, washing machines and low-flow toilets. This program would especially support low-income households who might not be aware of, or able to afford these conservation measures. If effective, the program could in-directly improve summer base-flows by reducing withdrawals. This program is not targeted at flood mitigation or water quality measures, however by increasing the volume of water in streams, the effect of rising temperature and nutrient concentrations may be minimized. This program would be most needed if snowpack decline reduces summer water availability.

WATER QUALITY AND WATER QUANTITY MEASURES

The Snohomish Basin supports a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as **ecosystem services** and include products like clean drinking water and processes such as the decomposition of wastes. Each strategy is associated with potential progress towards maintaining and improving future ecosystem service provisioning with regards to water quality and quantity. In an effort to evaluate tradeoffs across the strategies, the Snohomish Basin Resource Team selected two measures of water quality and two measures of water quantity: stream temperature and nutrient (nitrogen and phosphorus) concentrations for water quality, and flooding (magnitude and frequency) as well as low flows for quantity. The selected measures were chosen because they were determined to be the most 1) relevant to identified critical challenges in the Basin today 2) easily understood by a large audience 3) readily available 4) accurate and 5) sensitive to differences between the strategies. Below, we describe each of the four measures in terms of their current importance and potential challenges.

Stream Temperature: Stream temperature governs the kind of aquatic life that can live in a stream. Fish, insects, zooplankton, etc. have a preferred temperature range. Temperature also influences water chemistry. The rate of chemical reactions generally increases at higher temperatures, which in turn affects biological activity. Already many Basin streams are classified as 'impaired' due to poor temperature conditions. Major challenges to temperature in the Basin include runoff over impervious surfaces (e.g. asphalt), in terms of the timing and volume, infiltration rates in upland areas (associated with alternative land covers from urban to forest), climate change (as affected both by warming atmospheric temperatures and shifts in precipitation and snowmelt), and reductions in shoreline vegetation (which provide shade).

Phosphorus and Nitrogen Concentrations: Nitrogen and phosphorus in fertilizers, livestock and pet wastes dissolve in rain or irrigation water and wash into the soil. Sewage and septic systems sometimes leak, also contributing to high soil nutrient levels. While some is used up by plants, the rest migrates into water bodies where is can cause algal blooms, reducing dissolved oxygen concentrations. This is especially critical for NW streams because cold water fish, such as salmon, require high oxygen levels. Algal blooms also lead to beach and shellfish bed closures as they may be toxic, posing a public health concern. Rivers from fast-flowing urban and agricultural areas typically have the highest inputs of nutrients. Phosphorus is currently a major problem in many Basin lakes.

Flood Magnitude and Frequency: Seasonal variation in stream flow is natural and expected. When the magnitude and frequency of variability exceeds historical trends, it poses a significant challenge to built lands in lower elevations (i.e. floodplains). Urban development is affected as infrastructure (roads and utilities) and properties incur costly damages and disruption of services. Flooding in agricultural lands leads to damaged crops, livestock and built structures. Aquatic wildlife and vegetation can also be affected by floods. Floods associated with urban runoff carry warmer temperatures and higher levels of pollutants. Floods can also increase sediment loads and disrupt streamside habitat. King and Snohomish County have the highest cost impacts from floods in the States. The Basin has experienced significant increased flooding as land cover and drainage rates changed from development. In the future, snowmelt timing and precipitation variability is predicted to exacerbate these effects with an increase in both flood frequency and magnitude.

Low Flows: Just as too much water poses a challenge, not enough water can be dangerous and costly. The Snohomish Basin has abundant water resources: enough to support over 1 million residents' drinking water, as well as industry cooling, agricultural irrigation, hydropower, with plenty left over for aquatic life. The challenge lies in the timing of flows, and the low precipitation volumes in the summer. Many of the Basin's streamflows are controlled by upstream dams. As the Basin's population and economy grows, higher withdrawal demands are stressing summer low base-flow supplies. Climate forecasts further warn that the spring snowmelt we rely on to dampen low summer precipitation rates may occur earlier in the year and be gone by summer. Low summer flows drive higher water costs (domestic and industrial) and great stress on salmon and other aquatic species.

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Acceleration

The Basin's economy rebounded quickly and strongly after nearly a decade of recession early in the century. Biotech and health services located along the I-5 corridor, ushering in thousands of new jobs. The Providence Regional Medical Center expanded its campus to support the growing sector of retiring generation Xers in the Basin. The Port of Everett also experienced significant growth, improving West Coast and Pan-Pacific connections, surpassing both the Port of Seattle and the Port of Tacoma in cargo. Just outside the City of North Bend, a new outdoor outfitter opened their new headquarters and purchased five-hundred acres as a private outdoor playground, supporting per fee hunting, mountain biking and ATV trails.

The Basin was the fastest urbanizing area in the State of Washington. Housing and commercial development was catalyzed both within and outside of urban centers. Cities like North Bend, Marysville and Lake Stevens increased their growth boundaries to accommodate the surplus of growth. Smaller cities, like Gold Bar, Sultan and Skykomish, struggled to expand their government services in pace with additional growth. Citizen prioritized more reliable utilities, services for a growing aging population, better schools and improved traffic conditions.

Many successful regional capital projects were implemented as a result of increased wealth and investment opportunities. Tolls along I-5 and I-90 funded PSRC's Full Transportation 2040 Plan.

Increased water demands spurred additional groundwater withdrawals, serving an additional 80mgd from the Getchell Plateau aquifer source. Flood mitigation measures included new and restructured levees protecting over 100 acres of lowland communities. This networked system of flood prevention boasted the development of 50 acres of recreation corridor with active sportfields, bike trails and wildlife viewing habitat.

The role of local government changed dramatically. As many Basin cities grew, so did their power to annex surrounding lands. Despite many challenges, by 2060 County government is essentially eliminated west of Snoqualmie and Sultan. Large industry leaders increased their influence in the political arena. Permitting processes were significantly streamlined and cumbersome environmental oversight was minimized. As the pace of urbanization exceeded institutional capacity, many public services became privatized. Contractors were hired by municipalities to perform traditionally government jobs. Nationally, political decisions led to down-sizing government control; restructuring and eliminating many federal agencies including the EPA, FEMA and BLM.

Working lands were squeezed by increasing costs and degrading environmental conditions. Winter floods became more frequent due to upland development. These floods carried heavily polluted water and sediments onto farm fields, destroying hundreds of acres of crops and eliminating the opportunity to raise cattle year-round in the Basin. Despite subsidies, mitigation projects and regulations, the ability of the floodplains to sustainably produce food in the Basin was lost. However, several farmers transitioned successfully to greenhouses, vertical production, and higher

elevation fields, supporting a higher intensity food production. Upland industrial forests were met with conflicts from nearby residents, increased opportunity costs for development and competition from Latin American timber industries. By the 2060, most of the timber production occurred on small-parcels by homeowners pursing a disposable income hobby.

As for climate variability, perhaps the natural variability of the Basin was enough to mask significant changes, perhaps the models over-estimated the degree of impact, or perhaps the Basin was more resilient than initially anticipated. Regardless of the reason, while temperatures rose modestly, and while streamflows transitioned to earlier snowmelts, the majority of the Basin's environmental changes stemmed more heavily from urbanization than any systematic shift driven by global climate change. Globally, natural disasters did occur with increasing frequency and magnitude. Third-world nations were hardest hit, leading to immigration pressures and the need for global aid. Basin leaders reached out with their support, often leading to extended economic growth for labor, resources and research in the Region.

The ecological integrity of the Basin was strongly impacted by the rapid urbanization in the Basin. However, many important characteristics of the system were conserved for the health and enjoyment of the Basin population. Earlier snowmelt flowing over expanded roadways and housing developments heightened winter scour and reduced summer flows, raising stream temperatures and pollution concentrations along lowland riparian habitats. Several pest and bacterial outbreaks led to the public closure of several streams and small lakes. Residential communities along rivers and lakes supported recovery efforts to treat and reclaim waters utilizing innovative biotechnologies. While five out of the 12 wild salmon stocks declined beyond hope of recovery, new sustainable hatcheries supported the continuation of salmon survival in the Basin including the Pink, Steelhead and Cutthroat Trout.

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Small

The economy of the Puget Sound never quite rebounded as initially anticipated. Global competition led to out-sourcing and relocation of many high skilled and manufacturing jobs. By 2060, Boeing's Paine Field operations closed their doors. The Basin was home to many start-up companies, many of which were very successful, but the overall unemployment rate stayed at around 10%. While a growing sector of the Basin's population was retired, those entering the workforce, generation Y, were hardest hit by the long term recession.

On the flip-side of economic challenges, urbanization pressures declined. Population growth rates stabilized at around 10% per decade. The rate of new building permits declined, as did the overall rate of land conversion. The average household size stabilized after over fifty years of continuous growth, as a larger percentage of young adults moved in with extended family and friends. The percentage of multiple-family housing developments rose with declining wealth and rising costs of living relative to household income. As land values declined, the conversion of farmlands and working forests into new subdivisions lessened dramatically.

The long-term economic recession crippled large stakeholders, bringing to the table new actors. As big industry lost their purchasing power, a young, highly educated, but out of work, population drove a new form of activism reflecting their demographic characteristics: highly diversified, egalitarian, technologically savvy and cooperative. Numerous grassroots organizations sprung to support new informal communities, from neighborhoods to shared interests. While highly varied in approaches and causes, these organizations shared a focus on investing in the environment as if their life depended on it. The notion of nature as being fragile, and the need to avert risks refocused priorities. Values around equity, responsibility, public and environmental health, family values and leisure prevailed over the recent era's mantra of competition and personal advancement.

The Basin's population adapted institutional frameworks and investments to make do with highly reduced budgets. New policies pushed improvements in natural capital, greater levels of oversight and accountability, and repairs. Utilities and infrastructure agencies were forced retrofit existing structures and abandon failing projects. For example, washed-out forest roads were removed and several aging levees were eliminated. The conservation of existing resources was prioritized, increasing efficiencies and reducing consumption to make do with less. A diverse set of new small-scale technologies came on-line, characterized by low initial investment and flexible structures, including low-impact development techniques such as greenroofs and bioswales, run-of-the-river shallow dams, and alternative low-fuel transportation modes. Incentive programs were developed to support local industry, including subsidized flood insurance for farmers, paying for damaged crops and livestock and improved farmland preservation. Despite good intentions, most innovative practices failed due to lack of funding, poor coordination and competing interests.

Shifted dominant social values and the rising cost of urban living fueled migrations back into the Basin's resource lands. New farms were characterized by small parcels, a humble deep ecology ethic, but a lack of traditional agricultural knowledge. Innovative farming practices, from direct marketing to organic produce dominated farming practices in the valley. New communities leveraged technologies to share resources, knowledge and labor. The role of the Tulalip Tribes expanded far beyond the reservation, purchasing upland forests and collaborating on several restoration and water storage projects. While funding for park maintenance and acquisition was lost, organizations such as the Washington Trails Association, Mountain to Sound Greenway and the Mountaineers invested thousands of volunteer hours towards trail maintenance and noxious weed removal.

Climate impacts, while minor, were highly apparent to a population that is intimately close to the landscape. Earlier snowmelt transitioned in several watersheds to higher winter flows and lower summer flows. Higher annual temperatures increased the growing season, benefiting agricultural and forestry practices. In-stream flows were heavily regulated, ensuring adequate supplies for salmon. While the number of farms and rising temperatures led to increase demand for irrigation, efficient technologies reduced groundwater withdrawals, while adaptive rotation cycles increase infiltration and recharge. Drinking water supply challenges were minimized due to low growth rates and reduced consumption levels.

Culminating from minor climate impacts and limited land conversion, monitoring of past restoration projects revealed benefits. Enthusiasm over past successes catalyzed numerous different volunteer groups to conduct site-level stream habitat improvements across the Basin, improving fish passage and restoring riparian vegetation. Unfortunately, small-scale projects largely failed to scale-up into a bigger picture. The efficacy of individual actions became increasingly dependent on adjacent uses, leading to greater complexity of dispute resolutions. As resource and recreational use in the Basin rose, so did conflicts between different interest groups.

By 2060, the Basin saw modest improvements in biodiversity and overall ecosystem health. The greatest challenges were coordination and funding. A sea of highly accessible information overwhelmed the rapidly growing number of small-scale institutions. Without strong leadership, the energized bottom-up approach lacked coordination and a big-picture perspective. With increasingly stressed agency budgets and great effort spent on 'the process,' contentions rose between highly active yet divergent interest groups. While many small battles were won, efforts that required larger regional investments dragged on for decades.

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Resistance

In January 2018, the City of North Bend declared a Presidential Flood Disaster after an unprecedented 500 year flood covered 90% of the City and over 800 homes were inundated. Major investments poured in to rebuild flood walls and redevelop homes, businesses and damaged infrastructure. In the following decade five additional presidential floods occurred within the Basin, each resulting in significant investments towards strengthened flood protection measures and redevelopment of community resources. Public funds were diverted towards emergency response programs and several social programs, from education to environmental services, suffered significantly diminished budgets.

Climate changes were pervasive throughout the Snohomish Basin and Region. By 2060, over 80% of snowpack was eliminated from both the Tolt and Sultan watersheds. The South and North Fork of the Skykomish suffered near-drought summer conditions, and exacerbated winter flows that scoured edge habitat. Low lying urbanized streams, including the Pilchuck, Raging and Tolt, incurred near-toxic summer flows from high temperatures and polluted waters when the legacy effects of urbanization combined with hydrological shifts. Along the coast, sea level rise lead to over 1,500 acres of additional salt marshes and 200 acres of tidal flats, at the expense of estuary beaches and freshwater and brackish marshes.

The economy in the Basin ebbed and flowed with the each tide of new disasters and reconstruction. Thousands of new jobs supported levee construction, new housing developments, road and wastewater facility repairs, as well as government emergency services. The majority of new jobs included seasonal or temporary positions and many workers lived in poor conditions or continued to live outside the Basin. Securing economic growth and employment stability was prioritized over long-term environmental concerns. Government programs attempted to incentivize business retention and relocation into the Basin by reducing regulatory overhead and costly permitting processes. Boeing stayed within the Basin but followed a boom and bust cycle of job loss and growth. By the 2060, the Port of Everett shut its doors, after over 135 years of business. The cost of repairs associated with sea level rise and the competition with the new Pan-Maxes proved too challenging a hurdle to overcome.

The costs and challenges of water and energy provision grew at a regional level as demands were coupled with increased natural variability and inflexible infrastructure. The Tolt and Spada Reservoirs were depleted by the summer of 2045 and 2048, respectively, as low summer flows and increased demand associated with higher summer temperatures led to supply shortages. Energy provision by PSE was frequently interrupted by downed power lines from severe storms in the winter and hydroelectric shortages from low flows in the summer. Political turmoil over intermittent services and consequent health impacts led to fast-tracking several projects with minimal environmental oversight. Groundwater withdrawals were expanded, steel powerlines replaced wooden poles, and several small dams were permitted along higher elevation streams within the Central Puget Sound. The cost of implementation of these new infrastructure projects were offset by increasing utility costs to customers. New residential homes on exempt wells and with alternative energy sources did not incur these costs, inadvertently leading to higher development pressure outside of service areas and spurring innovation of off-grid technologies.

The population of the Basin can best be described by the growing social disparities between the 'haves' and the 'have-nots'. Despite floods and costly repairs in lower elevations, many of the wealthier households were largely unaffected by the aforementioned changes. Suburban houses, largely in higher elevations, relied more heavily on private services to supplement failing utility and governmental services. Higher income households invested in 4-wheel vehicles able to forge through high water, sent their kids to private schools and private doctors, purchased back-up generators and filtration devices, and enjoyed private access to natural areas. The same cannot be said for lower income groups, especially aging households and a growing community of migrant families. Aging households along low-lying areas were most vulnerable. Damaged houses incurred thousands of dollars of damages. Flood insurance pay-offs were eventually eliminated as Federal funding ran out and regional funding was equally diluted. For those households that received compensation, the cost of redevelopment was often greater than their house value. Aging homes and lower mobility populations were heavily hit by inconsistent service provision, especially during heat waves and cold spells. Many of these populations were also uninsured as regional services were severely cut. As global and regional costs associated with gas, food and services increased, the percentage of income spent on necessities increased substantially for lower brackets.

Despite a decade characterized by the 'farm-fish debate,' by the 2060's both farm and fish are largely gone from the Basin. Except for a handful of upland specialty farms, agricultural production has ceased in the Snohomish Basin. As flood frequency increased, it simply did not make financial sense to repair failing levees and then utilize the land for food production, especially as the soil was so heavily contaminated during flood events. The longer growing season did facilitate the rise of new hobby farms, typically run by retired professionals with a disposable income, but few were economically viable. By the 2060's Chinook and Bulltrout are officially extinct from the Basin. The laundry list of restoration projects fell to the side as more pressing social concerns dominated agency budgets and political interest. In the flurry of flooding, redevelopment and deregulation, streams were so degraded there was little left to save. The other wild stocks, while still present and monitored, are struggling to survive.

Over the years conflict arose with a several minority populations within the Basin. Nowhere was it as powerful as the conflict with the Tulalip Tribes. After decades of struggling to implement proactive restoration and mitigation policies, the Tulalip Tribes filed a multi-billion dollar Boldt 2 lawsuit over the loss of loss streamflow protection for sustainable water supply and fish stocks. While receiving financial compensation, the Tribe never regained their traditional livelihood leading to the loss of tribal heritage and strained relationships with their Basin neighbors.

Metamorphosis

Early in the century, the Puget Sound won a long fought battle: equal bargaining power for the environment. The major power brokers of the Region woke to a mandated epiphany centered on full accounting of ecosystem services, fast-tracking projects that support resiliency and financial incentives for projects that emphasize transparency and collaboration. While the next fifty years were fraught with intense climatic shifts, numerous errors, and hot political debates, the majority of economic, social and environmental progress indicators reflected positive change.

Climatic changes were evident throughout the Basin. Year after year the Region was faced with record breaking events, from intense precipitation periods to heat waves and strong winds. Higher elevations lost the majority of their snowpack by early spring, leading to more frequent winter floods and declining baseline flows. Stream temperatures rose, as did levels of toxins and pollutants carried by urban streams. Salmon stocks declined and many feared population numbers would not rebound. However, each new challenge was transformed into a learning opportunity, and chance to correct past errors. Empowered public agencies prioritized innovative and integrated strategies that focused on supporting flexibility through buffers, diversity and inter-agency monitoring.

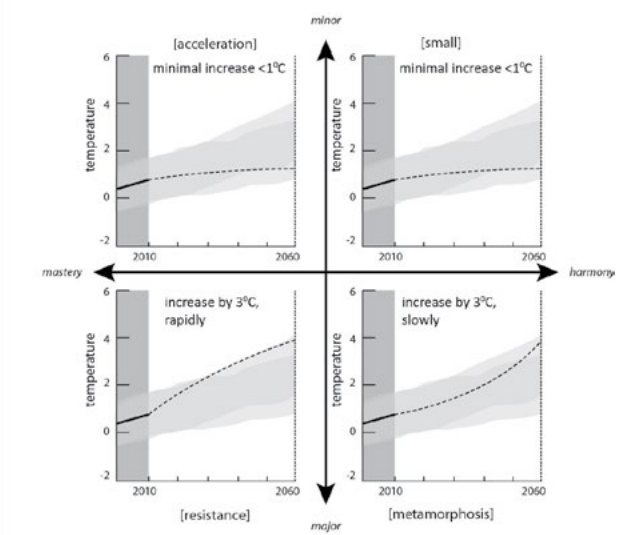
Over the years, the Basin's historical geomorphology and land cover served as a guide to relocate and redesign patterns of development. When major floods destroyed aging levees, restructured new 'softer' levees were set back and riparian buffers were re-vegetated. With each new flood the Basin regained its hydrological connectivity, reducing flood impacts in consequent decades. Meanwhile, agricultural incentive districts subsidized farms that promoted sustainable practices by insuring harvests from flood damage (i.e. pay for flooded crops). Upland, private timber companies were paid to not harvest and financially encouraged to seek alternative environmentally sustainable forest initiatives. Several non-profit organizations collaborated with government agencies to support smaller land owners, representing the fastest growing sector of resource managers. These organizations provided small forest and natural lands owners with a network of free scientific expertise and volunteer laborers that promoted diverse and healthy forestlands while performing County audits.

The pressure to grow continued to be one of the toughest challenges for the Basin. The word was out; the Region was a global magnet, a great place to live, work and play. The Basin continued to boast abundant accessible natural lands just a short distance from several metropolitan centers, outpacing Pierce and King Counties for new jobs and migrations. Growth was tightly funneled into urban corridors as directed by the GMA. Denser clusters of diverse jobs and housing facilitated investments in more efficient and adaptive infrastructure. However, the cost of permitting rose substantially and many companies were priced out of developing in the Basin. While real estate values skyrocketed, affordable housing quotas forced developers to allocate 25% of all new housing to lower income households. Cities like North Bend, Monroe and Snohomish doubled in size, boasting diverse neighborhoods with unique cultural, business and natural amenities. Smaller cities, further east, also grew, serving as Regional outdoor recreation hubs with industries built around seasonal tourism.

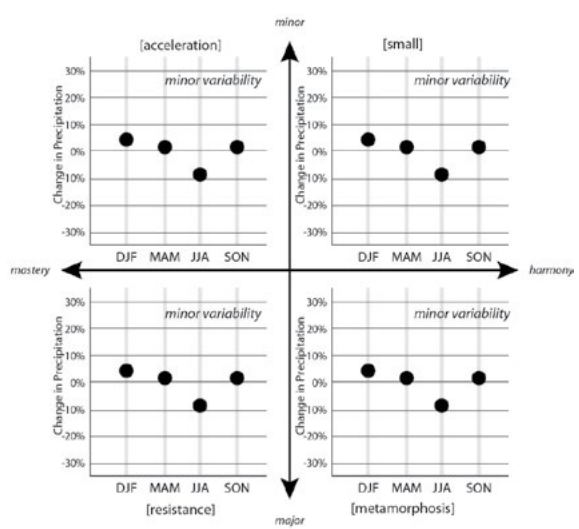
Technological advancements fundamentally altered people's mobility, lifestyle choices and socio-economic networks. Vanpools ferried people across the Basin utilizing live geotracking to serve emergent clusters of commuters. Many region-based 'green-energy' technologies came online, from wind turbines to in-stream microturbines, affordable solar panels to methane digestion and biofuels. While the business side of innovation spurred economic growth, ecologically the majority of projects failed to meet intended goals. The most significant improvements stemmed from a highly accessible localized indicators platform, which supported household decision making, from what produce to buy, to needed water conservation measures and public health alerts. While some improvements facilitated better knowledge sharing and proactive management, the abundance of available information and an over-reliance on synthesized data were criticized by many as leading to a loss of natural response mechanisms and significant blind spots.

Over the years, social norms embraced more equitable and long term investments, which radically altered the Region's response to novel challenges. While the size and power of the public sector grew, institutional frameworks changed to be more adaptive and flexible, yet demanding. The cost of living in the Basin grew significantly within rising taxes and regulatory overhead as many new social programs and large scale infrastructure investments were made. Public provision of public health, education, unemployment assistance, child care, assisted-living, public transportation and open space took a significant toll on industry and household budgets. Over time, economic burdens were boasted as redistributive and egalitarian. As natural hazards, emerging diseases, economic crises, and protests occurred, the duration and intensity of emergencies were dampened by the strong partnerships, flexible institutions, wide buffers and diverse hybrid social-ecological system in place.

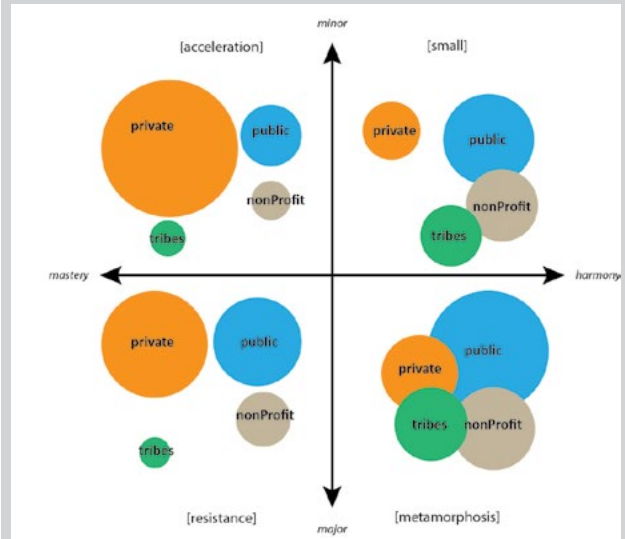
DRAFT



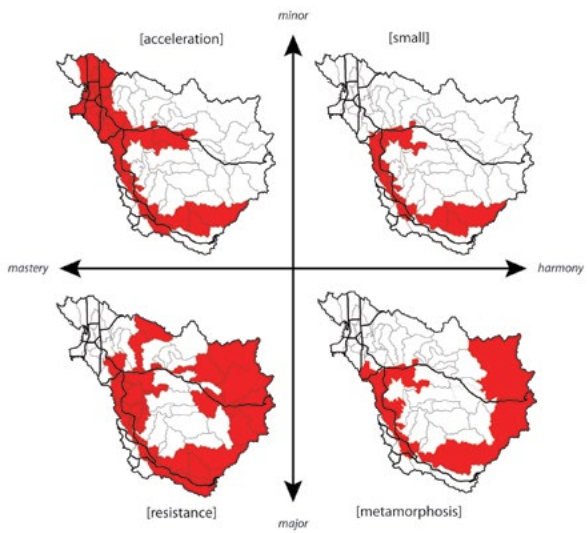
Annual Temperature Change



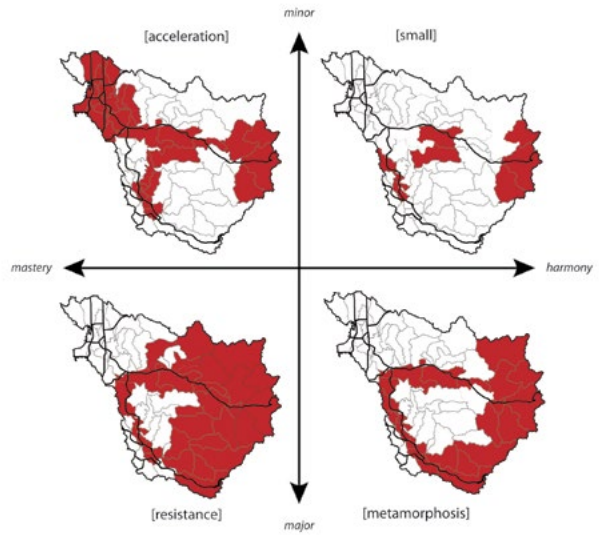
Seasonal Precipitation Variability



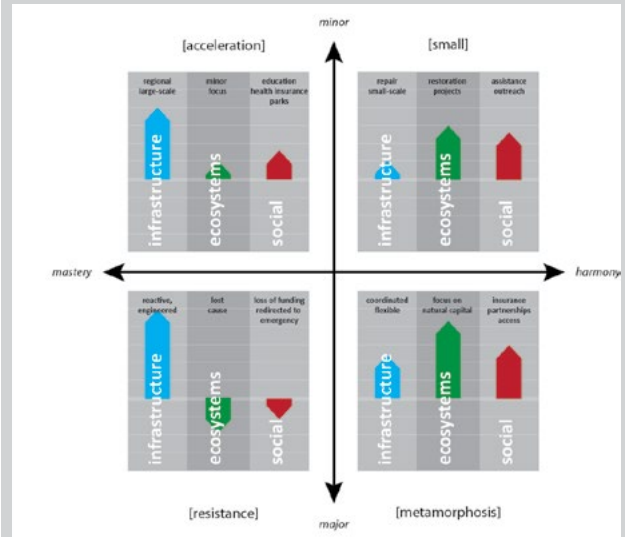
Actors



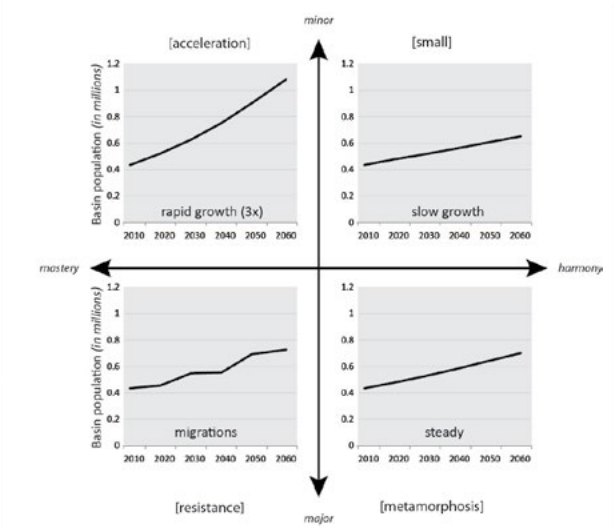
Maximum Stream Temperatures



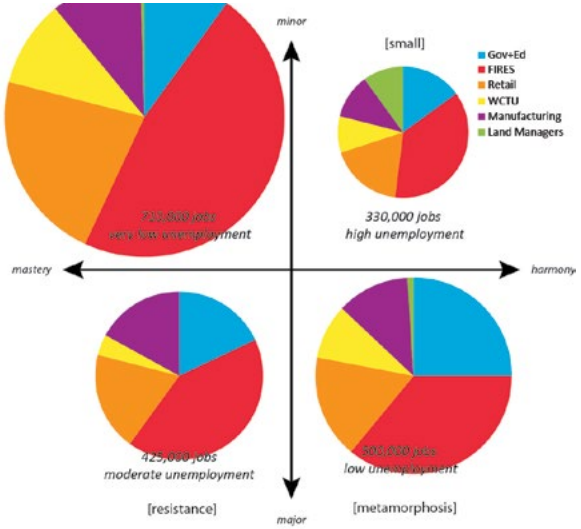
Change in Minimum / Maximum Flows



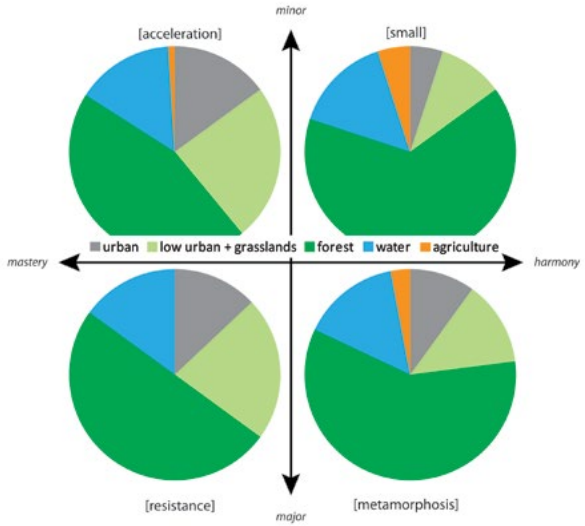
Investments and Approval Ratings



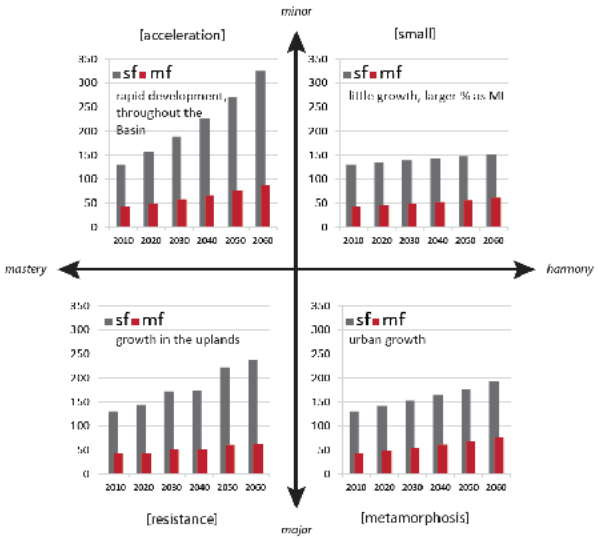
Population Growth



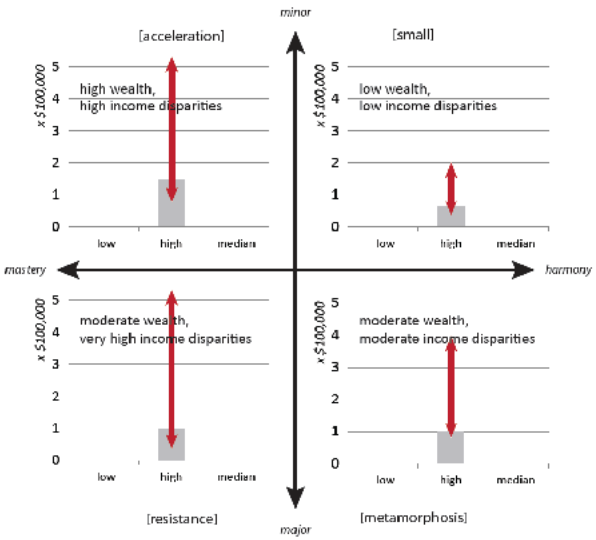
Jobs by Sector



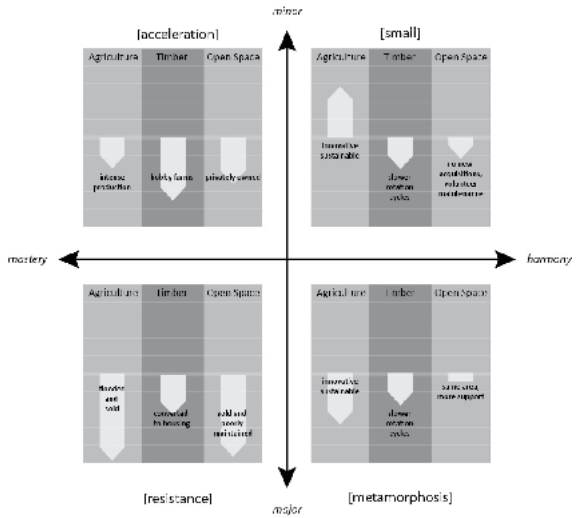
Land Cover



Building Perrmits



Wealth Disparities



Resource Management

Agenda

9:00-9:30	Introductions
9:30-11:15	Exercise: Decisions under Uncertainty
11:15-11:25	Coffee Break
11:25-12:00	Plenary Discussion. How to Make Better Decisions
12:00-1:00	Lunch and Presentation by UERL team
1:00-2:00	Team Discussions. Identifying Critical Decisions, Actors and Strategies
2:00-2:30	Team Presentations
2:30-2:40	Coffee Break
2:40-4:00	Team Discussions. Risks, Trade-offs, and Policy Evaluation
4:00-5:00	Plenary Discussion. Redefining the Problem: What questions should we ask?

INTRODUCTIONS

Scenarios for Snohomish Basin 2060

- Develop an assessment of key ecosystem services in the Snohomish Basin by characterizing the uncertainty associated with alternative future baseline conditions.

a 2-year research agenda

Funded by the Bullitt Foundation

Snohomish 2060 Scenario project

Project Objective:

- *develop a synthesis of what we know*
- *integrate diverse perspectives*
- *challenge assumptions about the future*
- *inform development of management strategies*

Making Better Decisions: Myths

- Eliminate uncertainty
- Remove differences
- Have complete knowledge
- Have plenty of resources
- Achieve perfect coordination

….. Probably there was no decision to be made

Making Better Decisions: A Hypothesis

- Embrace uncertainty to build robust decision
- Build on differences to explore opportunities
- Use information to test what we know
- Exploit resources to maximize benefits
- Transform redundancy into partnership

Workshop Objective

Explore how Scenario Planning can expand our decision framework by:

- *Challenging our assumptions*
- *Accounting for uncertainty*
- *Identifying risks and opportunities*
- *Prompting new questions*

Simulation

- *Four Scenarios*
- *Decision Context*
- *Exercise*
- *Discussion*

9:30-11:15

DECISIONS UNDER UNCERTAINTY

instructions

- You are a member of a task force aimed at protecting the long term watershed function in the Snohomish Basin.
- Represent yourself
- The EPA has committed to fund three projects within the next twelve months to help meet your goals.
- Select and agree on 3 strategies
- Material: strategies, indicators, current state and forecasts, dashboard implications of selection

9:35-9:45

STEP 1: REVIEW MATERIAL

9:45-10:15

STEP 2: SELECT AND AGREE ON 3 STRATEGIES

10:15-10:35 Review Scenarios
10:35-11:05 Select and Agree on 3 Strategies
11:05-11:15 Reflect

STEP 3: THE SCENARIOS

11:15-11:25

COFFEE BREAK

11:25-12:00

PLENARY DISCUSSION: HOW TO MAKE BETTER DECISIONS

How to make better decisions

- How did you choose the 3 strategies? What criteria did you use for selecting them?

How to make better decisions

- How did you choose the 3 strategies? What criteria did you use for selecting them?
- How did you take uncertainty into account in the decision making process?

How to make better decisions

- How did you choose the 3 strategies? What criteria did you use for selecting them?
- How did you take uncertainty into account in the decision making process?
- How did the information provided differ from your everyday decision making process?

How to make better decisions

- How did you choose the 3 strategies? What criteria did you use for selecting them?
- How did you take uncertainty into account in the decision making process?
- How did the information provided differ from your everyday decision making process?
- What additional insight do scenarios provide?

12:00-1:00

LUNCH AND PRESENTATION

Bob Burns, *King County*
Nicole Faghin, *AECOM*
Jim Franzel, *USFS MB-S*
Judy Herring, *KC Farmland*
Abby Hook, *Tulalip Tribes*
Alice Kelly, *Dept. of Ecology*
Brent Lackey, *Tolt Watershed*
Jim Miller, *City of Everett*
Philip Popoff, *PSE*
Chris Raezer, *City of Arlington*
Morgan Schneidler, *PSP*
Dave Somers, *Snohomish County*
Brett Swift, *American Rivers*
Tim Walls, *the Forum*
Daryl Williams, *Tulalip Tribes*

Steering Committee

July 2010

▪ the Project

Steering Committee Directives, July 2010

- Additional Questions
- Opportunities and Challenges
- Priority Actions
- Decisions through Actors
- Integrate Multiple Perspectives
- Build on Existing Works
- Articulate Current and Future Baselines
- Validate Ideas

▪ the Project

Steering Committee Directives, July 2010

- Additional Questions
- Opportunities and Challenges
- Priority Actions
- Decisions through Actors
- Integrate Multiple Perspectives
- Build on Existing Works
- Articulate Current and Future Baselines
- Validate Ideas

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A 2.5-year Research Agenda

Year 1: Defining the Problem
- Build a Science Team
- Identify drivers of change
- Develop a conceptual model
- Compile data on current status and past trends

Year 2.5: Evaluate Implications
- Indicators of Ecosystem Services
- Opportunities and Challenges
- Basin Actors and Approaches
- Interactions with Potential Strategies

Year 2: Alternative Plausible Futures
- Important and uncertain drivers
- Scenario logics
- Forecasts and predictions
- Model integration
- Assessment of alternative trajectories
- Narratives

▪ the Project

State of the Basin 2010

DEFINING THE PROBLEM

our Science Team

Norm Abbott
Jackie Aitchison
Marina Alberti
Sue Ambler
Dom Amor
Stanley Asah
Elaine Babby
Krista Bartz
David Batker
Kurt Beardslee
William Beyers
Bob Bilby
Christopher Bitter
Michael Blake
Heidi Bohan
Leah Bolotin
Brandon Born
Alan Boming
Ann Bostrom
Mark Boyer
Nicholas Bratton
David Buerge
David Burger
Bob Burns
Ann Bylin
Ken Carter
Paul Byron Crane, B.L.A., M.A.
Sara Curran
Curtis DeGasperi
David Dilgard
Mary Embleton
Gina Estep
Nicole Faghin LEED AP
John Findlay
Jim Franzel
John Gamon
Simon Geerlofs
Bonnie Geers
Jamie Glasgow
Andy Ha
Troy Hall
Alan Hamlet
Chris Harvey
Kelly Heintz
Ryan Hembree
Jan Henderson
Judy Herring
Kollin Higgins
Abby Hook
Peter Jackson
Jennifer Jerabek
Janne Kaje
Kristin Kelly
Alice Kelly
Michael Kern
Karen Kinney
Jacque Klug
Bill Knutson
Deborah Knutson
Dave Kosciuk
Brent Lackey
Donnie Le Bonnemaier
Roberta (Bobbi) Lindemulder
Sandra Mallory
Mike March
Stewart Mathieson
Matt Mattson
Mark Maureen
Heike Mayer
Doug McClelland
Al McGuire
Phyllis Meyers
Marcia Meyers
Anna Miles
Jim Miller
Barbara Mock
Dave Montgomery
Scott Moore
John Moore
Tom Niemann
Tom O'Keefe
Mike Patterson
Dave Peterson
Chris Picard
Patrick Pierce
Philip Popoff
John Postema
Scott Powell
Chris Raezer
Kit Rawson
Dave Redman
David Remlinger
Luke Rogers
Mary Rucklehaus
Michael Rustay
Eric Salathe
Rowan Schmidt
Morgan Schneidler
Howard Schwartz
Mark Simonson
Amy Snover
David Somers
Cindy Spiry
Stephen Stanley
Don Stuart
Ralph Svrjcek
Brett Swift
Jim Teverbaugh
Dan Tonnes
Joe Tovar
Mike Town
Stacy Trussler
John Ufford
Anne Vernez Moudon
Elizabeth Walker
Tim Walls
Elizabeth Weldin
Richard White
Jan Whittington
Matt Wiley
Terry Williams
Daryl Williams
Clark Williams-Derry
Kathy Wolf
Hendrik Wolff
Ken Yocom
Yi Zhao
Ken Zweig

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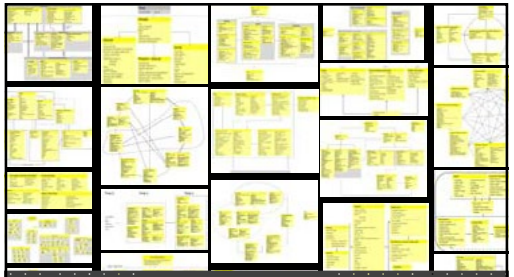

Interviewed 64 science team members and asked them:
How will the Basin change over the next fifty years?

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Drivers	Behavior	Demography	Values	Economy	Governance	Knowledge	Social Institutions	Development	Infrastructure	Resource Management	Biogeochemistry	Climate	Hydrology	Terrestrial Biosphere
Behavior	48	1		1	4			4	3	5			1	2
Demography	1	172	7	13	24	4	8	44	25	15		2	3	2
Values	6		131	23	25		9	35	15	42				6
Economy	7	44	6	245	19	1	12	61	39	65		2	8	1
Governance	5	36	2	56	255	7	6	75	41	60	1	2	12	18
Knowledge	6	3	14	12	16	101	0	0	20	21	2	2	3	8
Social Institutions	3	3	6	11	19	6	83	7	1	15				4
Development	1	15	5	16	22		1	195	25	48	2	2	10	8
Infrastructure		3	4	22	14		4	42	186	34	2	2	18	21
Resource Management		8	14	18	24	4	6	9	10	311	3		21	33
Biogeochemistry		2		2				5	5	3	29	1	8	6
Climate	8	4	2	4	9	1	1	8	30	18	4	116	34	37

Synthesized interview transcripts and models by grouping drivers and relationships between them

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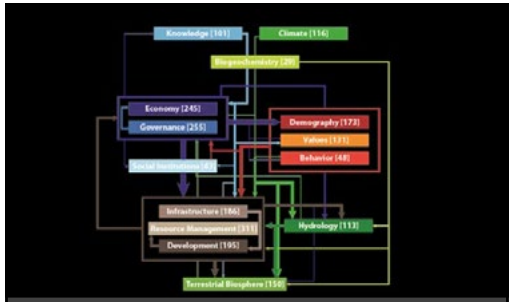

Developed a shared conceptual model based on input

▪ the Project

Compiled data on status and past trends of key drivers

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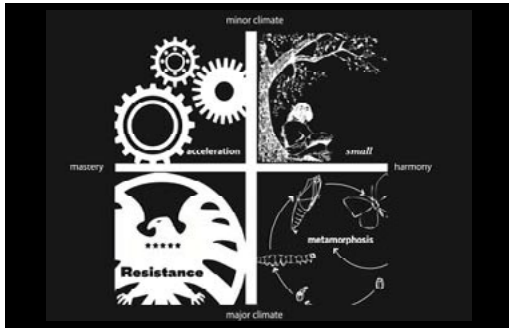
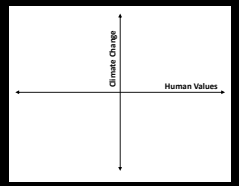
State of the Basin 2060

THE SCENARIOS



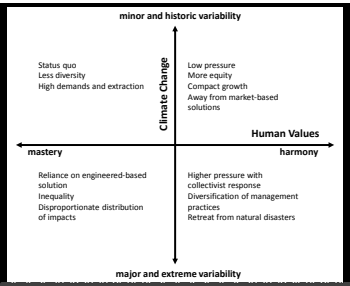
▪ the Scenarios

Driver	Votes
Demographics	4
Behavior	5
Values	11
Economy	6
Governance	
Social Institutions	2
Knowledge	
Development	4
Infrastructure	
Resource Management	
Hydrology	1
Climate	12
Terrestrial Biosphere	5



Identify the most important and uncertain drivers

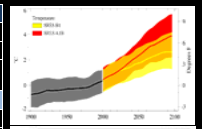
▪ the Scenarios

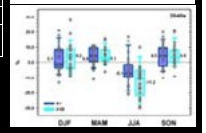


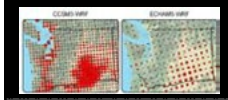
Scenario Development Team selected variables and initial hypotheses

▪ the Scenarios

Major Change	
IPCC Scenario	A1B
Temperature	3.5degC increase by 2060
Variability	Extreme events, exaggerated seasonal variability
Minor Change	
IPCC Scenario	B1
Temperature	1.5degC increase by 2060
Variability	Historical variability. Hard to detect change from high noise.







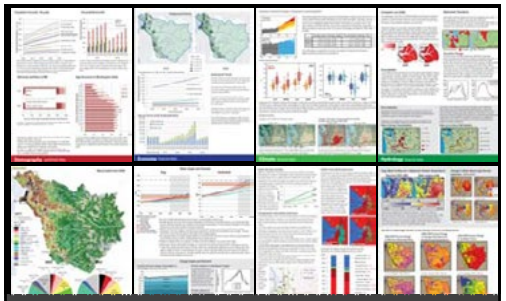
Selected Climate Change variables: magnitude and variability

▪ the Scenarios

Variable	Mastery
Relationship to natural and social world	master and change the world, to assert control, bend it to our will, and exploit it in order to further personal or group interests.
Cultural emphasis	*Getting* ahead through active self-assertion .
Keywords	ambition, success, daring, competence
Variable	**Harmony**
Relationship to natural and social world	accept the world as it is, trying to fit in rather than to change or exploit it.
Cultural emphasis	*Fitting harmoniously into the* environment .
Keywords	protecting the environment, equity

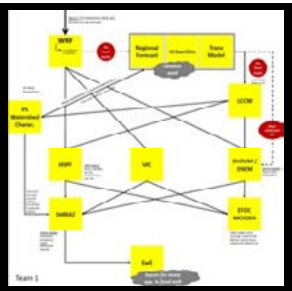
Selected human values variables: mastery vs. harmony

▪ the Scenarios



Collected forecasts and predictions for the region

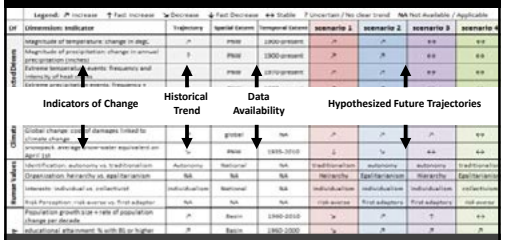
▪ the Scenarios



Brought modelers together to draft an integrated model

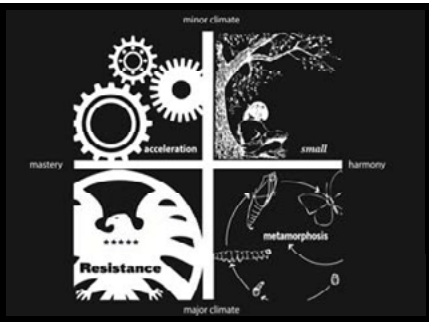
▪ the Scenarios

Scenario Trajectories

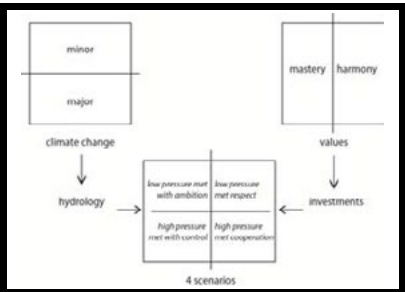


Tested potential future trajectories with Science Team

▪ the Scenarios

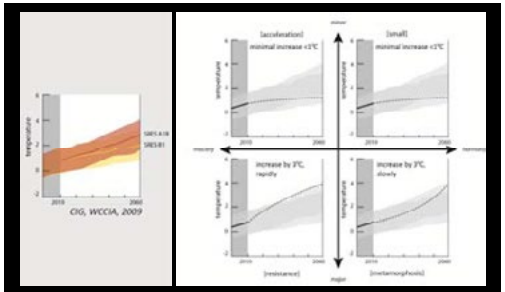


▪ the Scenarios



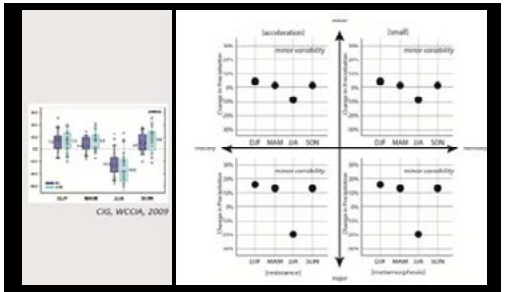
crossing the drivers

▪ the Scenarios



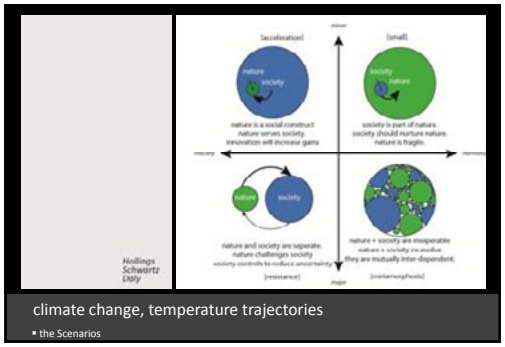
climate change, temperature trajectories

▪ the Scenarios



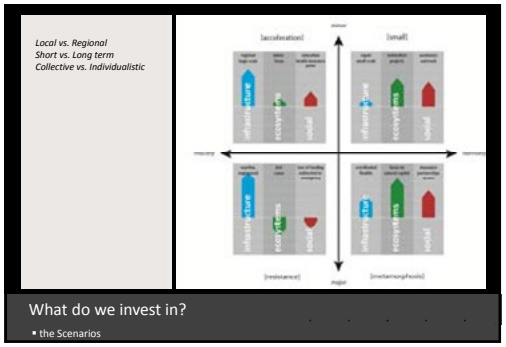
climate change, precipitation seasonal variability

▪ the Scenarios



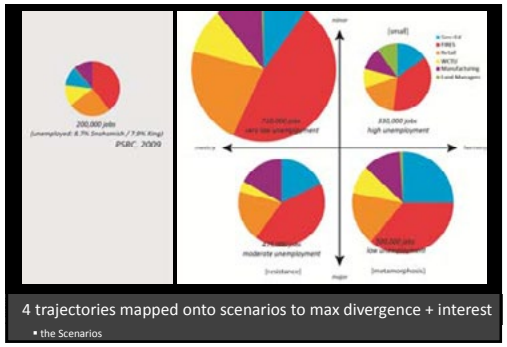
climate change, temperature trajectories

- the Scenarios



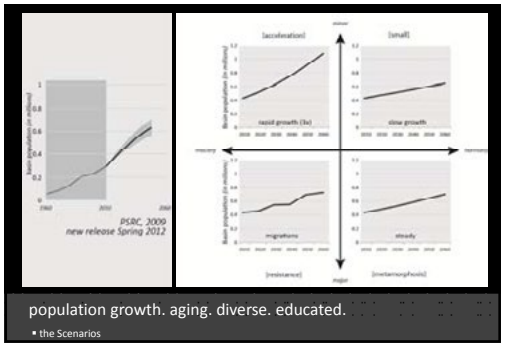
What do we invest in?

- the Scenarios



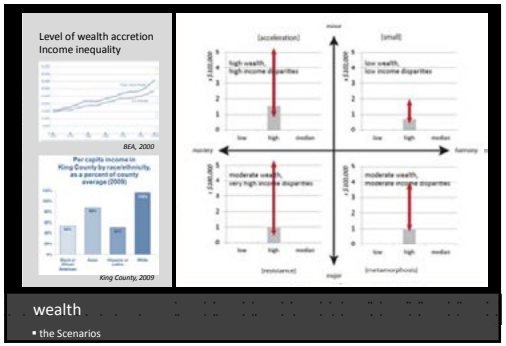
4 trajectories mapped onto scenarios to max divergence + interest

- the Scenarios



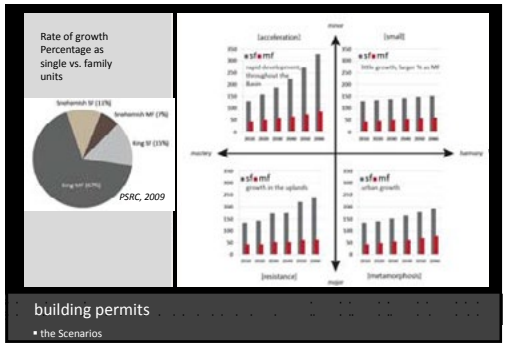
population growth. aging. diverse. educated.

- the Scenarios



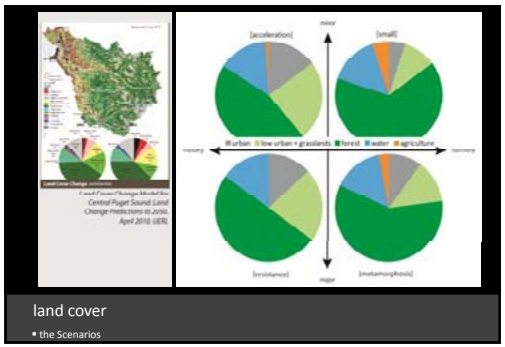
wealth

- the Scenarios



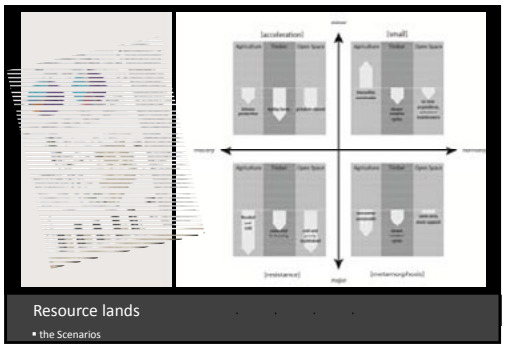
building permits

- the Scenarios



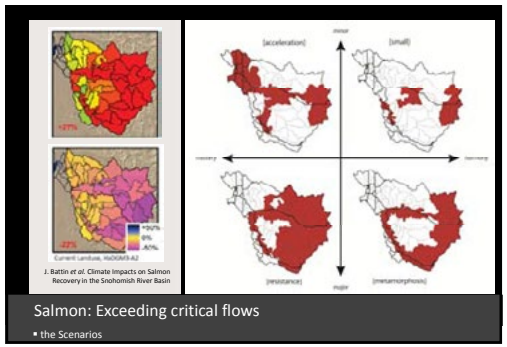
land cover

- the Scenarios



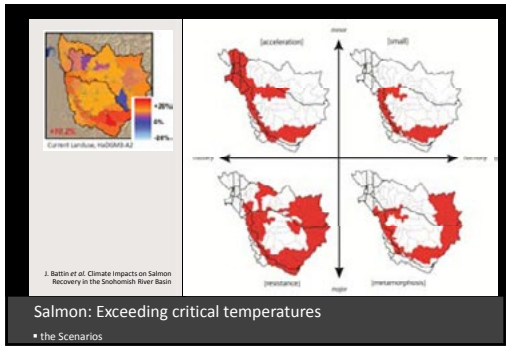
Resource lands

- the Scenarios



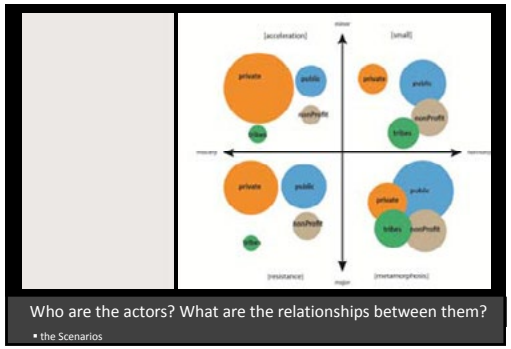
Salmon: Exceeding critical flows

- the Scenarios



Salmon: Exceeding critical temperatures

- the Scenarios



Who are the actors? What are the relationships between them?

- the Scenarios

Indicators of Ecosystem Services
Opportunities and Challenges
Basin Actors and Approaches
Interactions with Potential Strategies

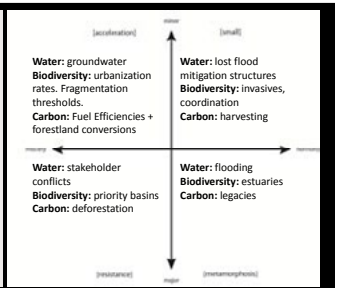
EVALUATING IMPLICATIONS

Indicators of Ecosystem Services

- Evaluating Implications

Across the Scenarios..

- Water quality
- Water quantity
- Species biodiversity
- Landscape biodiversity
- Carbon stocks
- Carbon fluxes



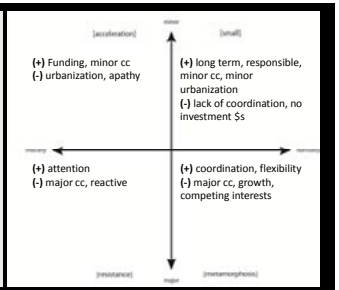
Are the implications of indicator trajectories linked to strategies?
What are measures of resilience?
How do we prioritize across indicators?
Which indicator gives us enough warning to change strategies?

INDICATORS

WHAT ARE THE KEY OPPORTUNITIES AND CHALLENGES?

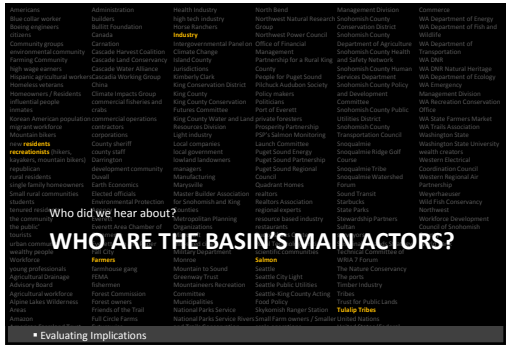
Unique to the Snohomish Basin and Region?

Challenges we heard about…
global and local climate change
growth and funding
age structure and development patterns
flood protection and farms
working and protected forests



Opportunities and challenges

- the Scenarios



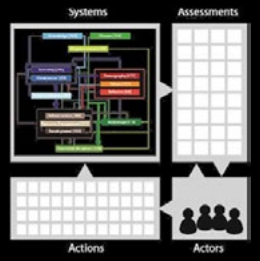
- Evaluating Implications

Actions we heard about…

WHAT ARE TODAY'S ACTIONS

▪ Evaluating Implications

Decision Framework



▪ Evaluating Implications

WHO WILL BE THE ACTORS IN 50 YEARS?

How will their perspectives shift? Who will win? Who will lose?

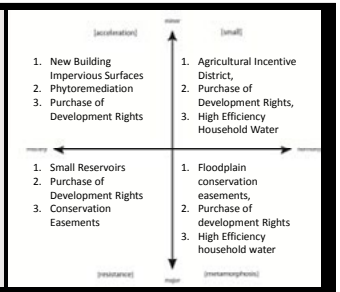
▪ Evaluating Implications

Evaluating robustness

SCENARIO INTERACTIONS WITH POTENTIAL STRATEGIES

▪ Evaluating Implications

- Small Reservoirs
- Purchase of development rights in Upland Forests
- Floodplain Conservation Easements
- New Building Impervious Surfaces
- Water tax
- Phytoremediation wetlands
- Agricultural incentive District
- High Efficiency Household Water



Alternative future conditions support alternative decision options

▪ the Scenarios

1-2 Team discussion - Identifying Critical Decisions, Actors and Strategies

AFTER LUNCH

1:00-2:00

TEAM DISCUSSION - IDENTIFYING CRITICAL DECISIONS, ACTORS AND STRATEGIES

Instructions

- Re-divided by number on nametags
- Small group discussions on key topics
- Handout of discussion questions at each table
- ~10 minutes per question
- Meet back at 2:30pm for short team presentation of findings.
- Please select a note-taker in the group and a presenter
- Presentations should synthesize key ideas. 5 minutes per team.

Discussion Questions

- What are critical decisions facing the Snohomish basin over the next 50 years?
- What are key uncertainties?
- What are the alternative strategies (options)?
- Which indicators should we monitor to evaluate success?

2:00-2:30 five-minute per team

TEAM PRESENTATIONS

2:30-2:40

COFFEE BREAK

2:40-4:00

TEAM DISCUSSION – RISKS, TRADEOFFS AND POLICY EVALUATION

Instructions

- Re-divided by color, same as initial teams
- Small group discussions on key topics
- Handout of discussion questions at each table
- ~30 minutes per question
- Please select a note-taker in the group

Discussion Questions

- What are potential trade-offs of alternative strategies across the 4 scenarios?
- Which strategies might be most robust (effective across all four scenarios)?
- How do we evaluate success?

4:00-5:00

PLENARY DISCUSSION: REDEFINING THE PROBLEM. WHAT QUESTIONS SHOULD WE ASK?

Defining ecosystem service provision in the face of uncertainty

WHICH DECISIONS ARE MOST SENSITIVE TO CHARACTERIZED UNCERTAINTY?

What questions should we be asking?

HOW DO WE EVALUATE STRATEGIES?

Gap analysis

WHAT DO WE NEED TO KNOW?

IS ADAPTATION SUFFICIENT TO ACHIEVE DESIRABLE CONDITIONS?

How do we generate transformation?

HOW DO WE DEFINE WHAT IS DESIRABLE?

Synthesis

10 directives for making decisions under uncertainty

1. Does this strategy improve the resiliency, or ability of the system to withstand change?
2. What are the opportunity costs if we do not implement this strategy? If we implement it later? What are the tradeoffs in comparison to other options?
3. Does this strategy improve on the current diversity of approaches, spatial allocations, and goals?
4. What are the ecological, economic and social distributions of impacts, across time and space and actors associated with this strategy?
5. At what indicator levels do we change the strategy because of critically close thresholds or because we have achieved acceptable standards?
6. Does this strategy facilitate our capacity to learn, or institutional long-sightedness?
7. How does this strategy overlap existing actions and networks to support a thick and redundant response?
8. Does this strategy build on natural processes?
9. Is this strategy robust, aimed at improved benefits across plausible futures or optimal, effective under a predefined set of conditions?
10. How does this strategy leverage linkages between stakeholders and tradeoffs to meet multiple needs through fewer resources?

EXERCISE 1: decisions under uncertainty

A. In an exercise focused on decision making under uncertainty, workshop participants were asked to select 3 of 8 pre-defined strategies to improve long-term watershed health in the Snohomish Basin. The options included: small reservoirs, Purchase of Development Rights (PDR), floodplain conservation easements, low impact development restrictions (LID), water tax, Phytoremediation wetlands, agricultural incentive district, high-efficiency water fixture incentives. Click her for the full instructions including description of strategies. Teams 1-4 ***selected these strategies,*** respectively:

- PDR, Phytoremediation, agricultural incentive
- PDR, floodplain conservation easement, LID
- PDR, LID, Agricultural incentives
- PDR, floodplain conservation easements, LID

B. Participants made the following ***observations*** about the given strategies:

- PDR: restricts harvesting. Already in place, not really utilized. Ideally also TDR and also include Ag.
- Small reservoirs: release warm water (because of season in which it is needed). Too expensive, hard to permit.
- Floodplain conservation easement: agricultural challenges, off the table (?).
- LID / New building impervious surfaces: where will this impact water? Benefit to Sound pollution, not upland runoff. Supports mix of land uses. Efficacy dependent on soil and infiltration capacity.
- Water tax: requires stepped pricing based on household use. Unpopular, don't do much.
- Agricultural incentive: Is Ag incentive better than floodplain conservation? You need to focus on the trust of farmers, and involve everyone. Good because it encourages mix of land uses. Should include riparian restoration.
- Phytoremediation wetlands: skeptical. Do they function? How long? Better to improve hydrologic function via restoration.

- High efficiency water: the market is already handling this for industrial and commercial. Not a lot of new development, and retrofitting isn't choosing high efficiencies.

C. What were your ***criteria*** for selecting the strategies? What do you watch (factor / trend) in decision making?

- Most effective, based on knowledge
- Practical
- Implementable
- Greatest spatial reach
- Prioritize / take advantage of natural processes over technical solutions
- What is the scale at which these strategies are implemented?
- Need to integrate forest and agricultural lands together (look at whole Basin)
- Group interests and dynamics
- What are the expertise around the table
- Balance environmental and economic viability

D. How did you take **uncertainty** into account in the decision making process?

- Looked at strategies that work across agricultural, open space and urban lands.
- Lower risks by diversifying. Spread the involvement / risk
- Making the system more resilient
- Monitoring is key. What is the strength of adaptive management? What are the warning signals?
- What is the role of self-awareness? How susceptible is the system to learning?
- Asking what is robust vs. optimized.
- What is the consequence of acting / not acting?
- What are the indicators representing variability?
- What is irreversible? What are critical thresholds?

E. What additional ***insight*** do scenarios provide?

- Scarcity: Resource allocation
- Flexibility / adaptability (e.g. reservoirs require a lot of $$ but uncertain effectiveness, less adaptable)
- What are we trying to protect? – be clear
- Limitation of presented scenarios:
- Feedback – can we change the scenarios?
- What is desirable? Visioning needed. All scenarios seemed like terrible worlds.
- No buy-in or trust in these scenarios.
- Risks – precautionary principle
- Acceptable vs. unacceptable uncertainty
- Drivers are not static, but rather shifting.

AFTER LUNCH DISCUSSION

Workshop participants divided into two teams and discussed 5 themed questions reflecting on long term decision making in the Snohomish Basin. Below are the captured notes from the discussion.

A. What are ***critical decisions*** facing the Snohomish basin over the next 50 years?

- (T1) where to put everybody, how to put everybody
- (T1) feeding people
- (T1) maintaining socio-ecological integrity
- (T1) not enough water
- (T2) Managing resource lands in the face of development, demographics, and economics
- (T2) Investment in restoration
- (T2) Regulatory stringency
- (T2) Investment in knowledge and predictive power

B. What are key ***uncertainties***?

- (T1) technological age / values, unanticipated consequences
- (T1) Streamlining permitting, eliminating inconsequential requirements
- (T1) Renewable energy
- (T2) Degree of climate change
- (T2) Ecological thresholds
- (T2) Economic trends
- (T2) Institutional stability and policy direction (vs. short sightedness)

C. What are potential ***opportunities and risks***?

- Team 1
- (+) knowledge to participate in ecological recovery. Institutional capital and foundation.
- (+) Undeveloped land – choices to make, ability to learn from others.
- (-) risk of mis-investment
- (+) Incentivizing ecosystem services
- (-) sense of entitlement by resource owners, self perpetuating.
- (+/-) Maintaining or losing cultural moral sense.
- (+/-) Values of younger generation

D. What are the ***alternative strategies*** (options)?

Team 1:

- Increase blending (e.g. Sustainable lands strategy)
- Reservoir – opportunities and challenges associated with sovereignty
- Buy in- across scales
- Redundancies – a good thing
- coordination

Team 2:

- All the usual suspects (regulatory, market, voluntary)
- Integrated
- Co-created / actor
- Not single goal
- Spatial

E. Which ***indicators*** should we monitor to evaluate success?

- (T1) Sensitivity of indicators to changes in the system
- (T1)Indicators representing values (low flows, water quantity for fish, drinking water, etc.)
- (T1) Full spectrum of indicators (social indicator, e.g. income disparities)
- (T1) Long term indicators to keep track of where we are headed.
- (T2) something, make sure it's linked to decision making.
- (T2) responsible, set of broad directly measureable indicators of whole system health.
- (T2) specific measureable outcomes we care about (responses) (e.g. certain valuable species).
- (T2) distinguish between what's influential and what's not (need both)
- (T2) triple bottom line. +4th, health. Integrated.

WRAPUP

A. Redefining the problem. What questions should we ask?

- Limits of adaptive management, irreducible uncertainty
- Learning and capacity to change
- Powerful outcome if represents perspectives of current community
- Scenarios too cartoony
- Triple bottom line
- Interface of opportunities (health)
- How flexible is it?
- Outcomes, how can we measure its efficacy?
- What are the thresholds?
- What are we satisfied with?
- Linkages (e.g. how will the legal world of 'neighbors' change?)
- Biophysical, legal, moral, human dimensions
- Distributional consequences
- Take out to broader scale
- Redefine our community
- How complexity can influence decision making – fast context
- Seed planting (how ideas take root)
- Benevolent dictator (leadership)
- 80% choice 20% out of control

B. How do we know what is desirable?

- Trust, capacity of society to transform
- Participatory approach 'on crack'
- Scenarios can help describe the outcome of paradigms over time, then read in terms of implications on personal (and collective) desires
- Historical conditions with moderate variation
- Broad socio-economic health
- Multi-dimensional, messy scenarios (good)
- How are my desires challenges by alternative paradigms?
- Does the desirable shift?
- False equivalency of indicators

Steering Committee Review

Date

8.7.2012

Location

Gould Hall. UW, Seattle.

Objective

To recieve feedback on the Final Report and define next steps for how to effectively share project lessons.

Attendance

Steering Committee members

Agenda

Presentation on final report.

Questions and answer session on findings and overall process

Steering Committee feedback on the report

Discussion of next steps

Materials

(draft final report)

Discussion questions:

Plausible Scenarios

- Are these four scenarios plausible?
- How do they differ from your previous/current view of the future?
- What do they add? Are there surprises?
- What are some missing elements?

Decision Making

- How do the scenarios expand the current decision framework of your organization?
- How can they help your agency make robust decisions to protect ecosystem services?
- How can they help the Snohomish community generate creative solutions to current challenges?
- How can they help the region adaptation to environmental change?

Communication

- Does the report provide a compelling story about the scenarios?
- Is the report well documented and clear?
- Can you provide a specific example in the report of effective communication?
- Is there any specific element and/or information missing?
- What would help to make the report more effective?

Scenarios: Next Steps

- How might the Snohomish Basin Scenarios be used in practice?
- How can we best share/present this information to these actors?
- Did you learn any insight from the Scenario process?
- What can we learn from this experience to lead the next scenario process?

Synthesis

We had some great input into how to streamline the final report by 1) highlighting findings for decision support and 2) providing practical examples.

Plausible scenarios **>** the scenarios and their logics should be vetted with the Science team.

Decision Making **>** use specific example to ground the theoretical ideas in regional applicaitons. An integrated model would be a complement to this exercise to test some of these ideas.

Communication **>** The report is too long for most decision makers to utilize. Put the analysis and backgorund into appendices. Highlight the scenarios and the lessons learned.

Next Steps **>** It would be great to have a meeting in Everett with diverse stakeholders and agencies to discuss how to some of these ideas can be applicable to current challenges.