A CHANGING WORLD
Key Data to Inform Port Policy Choices

"If we want our world to be different, the first act needs to be reclaiming the time to think." – Margaret J. Wheatley

The Context

The Port of Port Townsend is unique. It is the heart of the community's working waterfront and maritime heritage and is a key driver of our local economy. We are grateful to be a part of this organization – and share a deep sense of responsibility to do what we can to pass on a healthy Port to present and future generations.

Our community's past successes have depended on working together. So too will our future successes. However, looking ahead multiple data points suggest that we live on the edge of an uncertain and transformative period of history. Our community, state, nation, and world face huge challenges.

The Big Picture

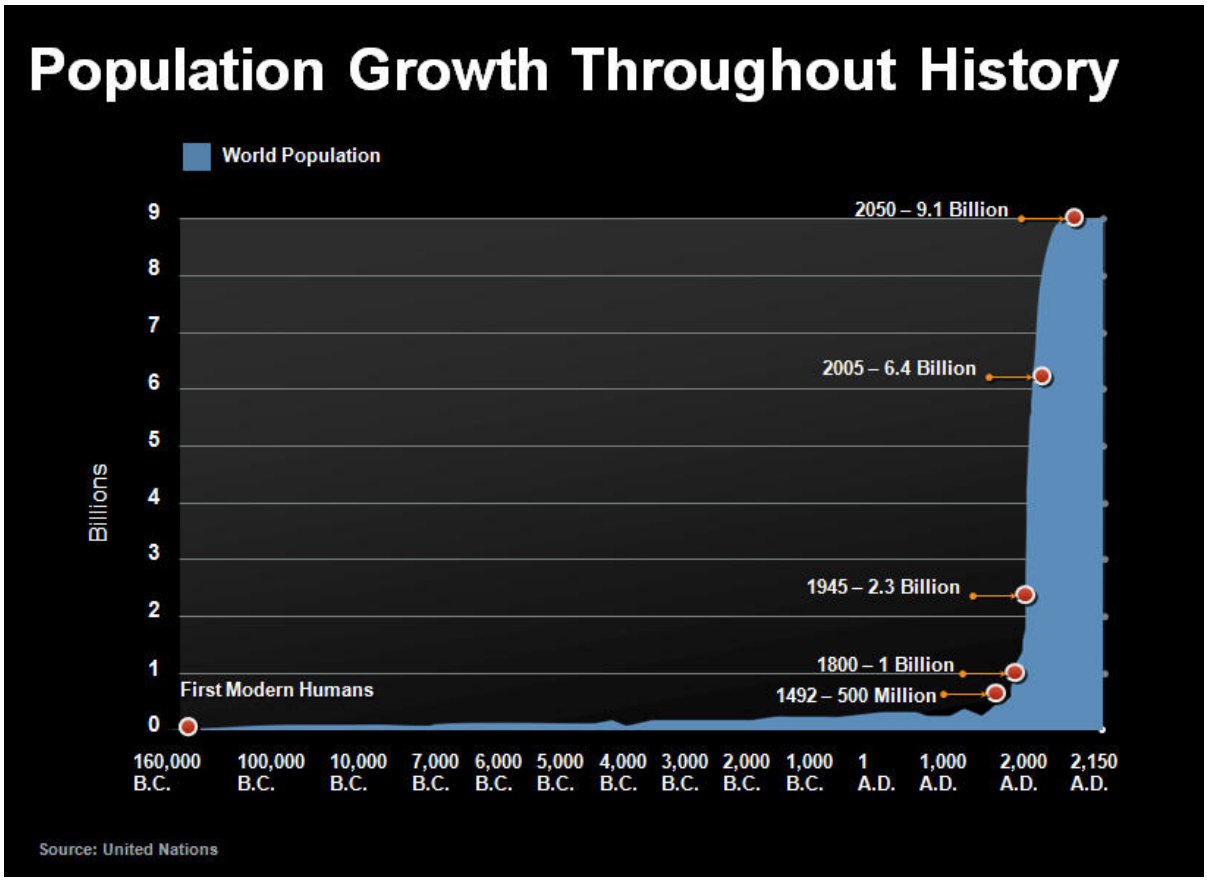
Global Trends

The next twenty years are likely to be very different from the last twenty years. From population growth to energy consumption, carbon emissions and economic growth, converging lines of evidence suggest that unsustainable trends are catching up with us and are likely to impact our community within a very narrow window of time – the next twenty years. A few of these global trends are highlighted below. Taken together, they suggest that we are entering an age of rapid change.

World Population Growth

As recently as the turn of the 19th century, there were only about 1 billion people on the planet. Today, the world's population is over 7.2 billion, and is projected by the United Nations to exceed 9.1 billion by 2050. (Source: US Census). With both more people and longer lifetimes, humanity's absolute numbers continue to rise, even though the number of children per women has been cut in half since 1950.

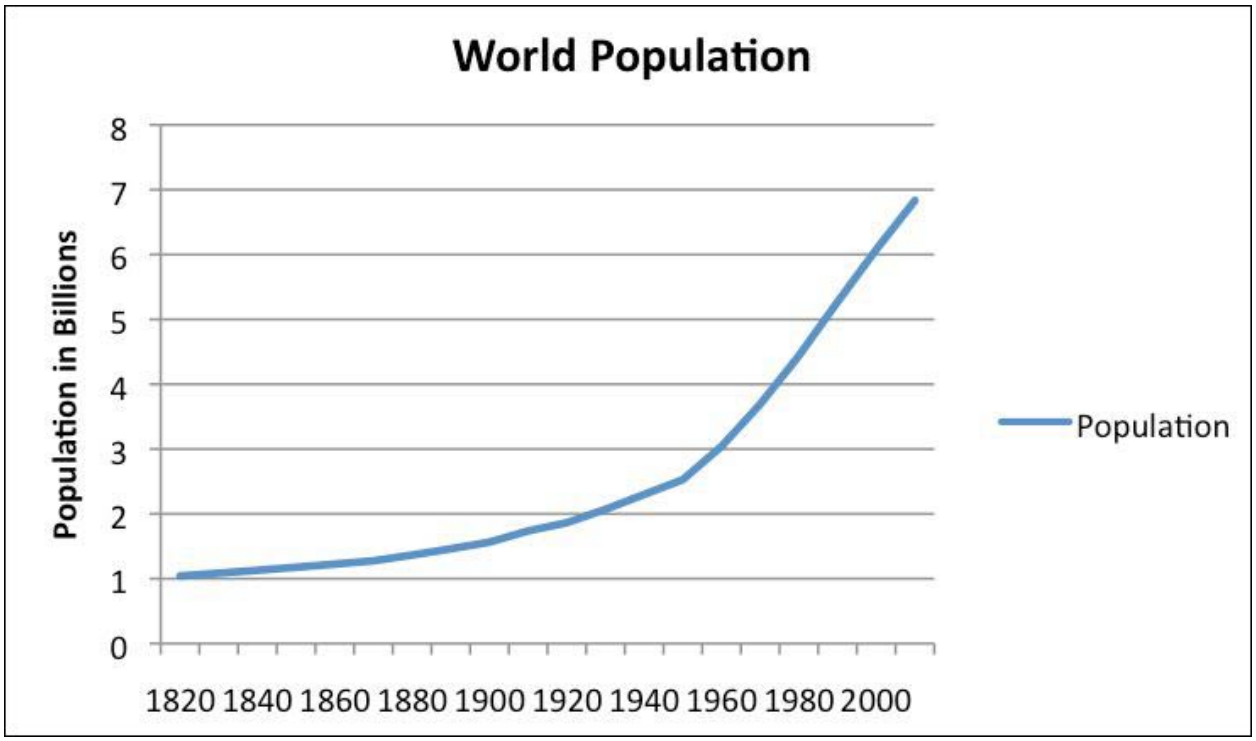
WORLD POPULATION GROWTH IN CONTEXT



Our community's growth and development are a microcosm of the world's exponential population growth. A Jefferson County population of 531 is first noted in the U.S. Census of 1860. By 1890 the population had increased to 8,368. In the decade between 1880 and 1890 alone, the County's population grew by an astounding 389%. Over the period 1860 to 2010, the County's population grew an average of 3.8% per year, a population doubling time of roughly once every 18.5 years. (Source: US Census).

The figure on the following page shows the exponential growth of the world's population from early in the industrial revolution to the turn of the 21st century.

WORLD POPULATION GROWTH – 1820-2000



Sources: World population growth based on Angus Maddison estimates, Professor Emeritus, Groningen University; and Gail Tverberg, www.ourfiniteworld.com.

Energy Consumption

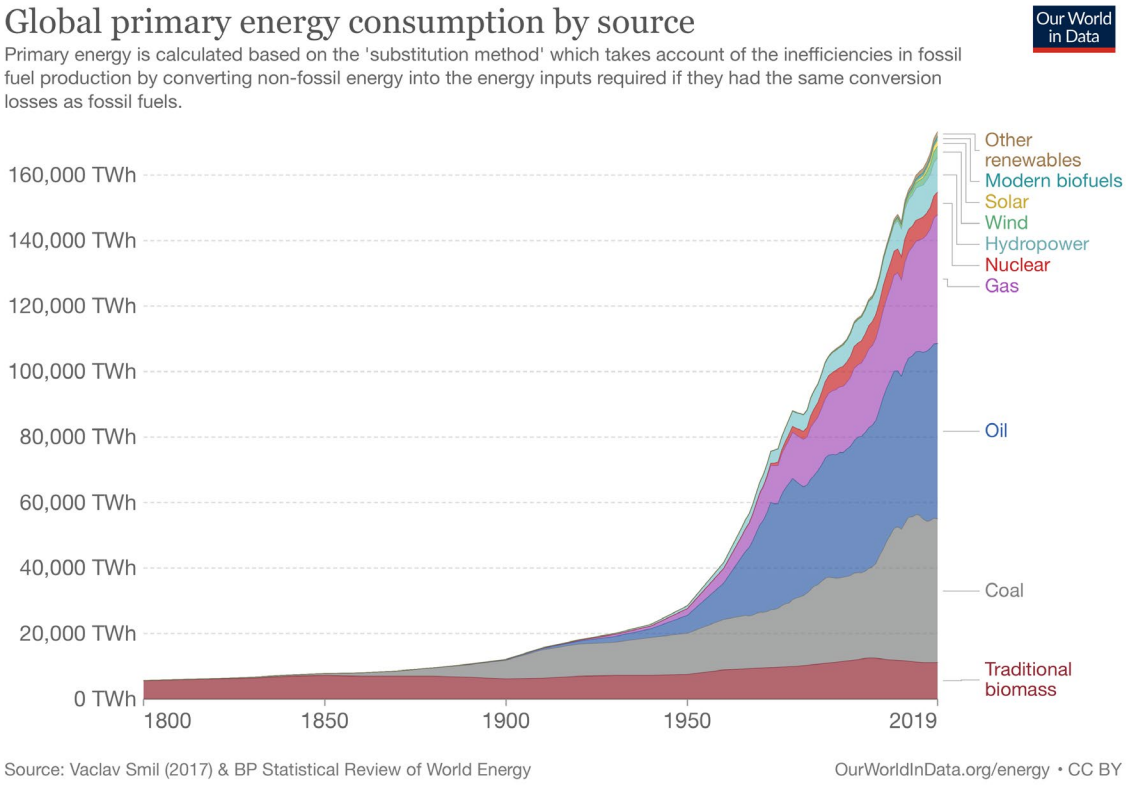
Fossil fuels (e.g., oil, coal, natural gas) have been essential for economic growth for the past two centuries and remain the key ingredient powering modern economies. The reality of dwindling supplies of affordable and easily accessible hydrocarbons is now internationally recognized, but few national, state, or local governments have developed plans to cope with a future with less energy.

The following figure depicts the growth and components of energy consumption over the past two centuries, and closely tracks the world's population growth over the same period shown in the figure above. The largest increase in energy consumption has been in the post-World War II years. As noted, increasing flows of energy are closely correlated with population growth.

Over the past two centuries of industrialization, the supply of available fuels has gradually increased to meet demand. However, oil discoveries peaked in 1964, and since that time have been outpaced by consumption by nearly 4 to 1 each year. Today, many industry analysts expect a peak in aggregate fossil fuel production to occur within this decade, proceeding thereafter to a long and permanent decline. Such a decline has profound implications for our future, as fossil fuels (oil, coal, and natural gas) presently

constitute roughly 80% of the world's primary energy supply. (Source: Vaclav Smil (2017) & BP Statistical Review of World Energy).

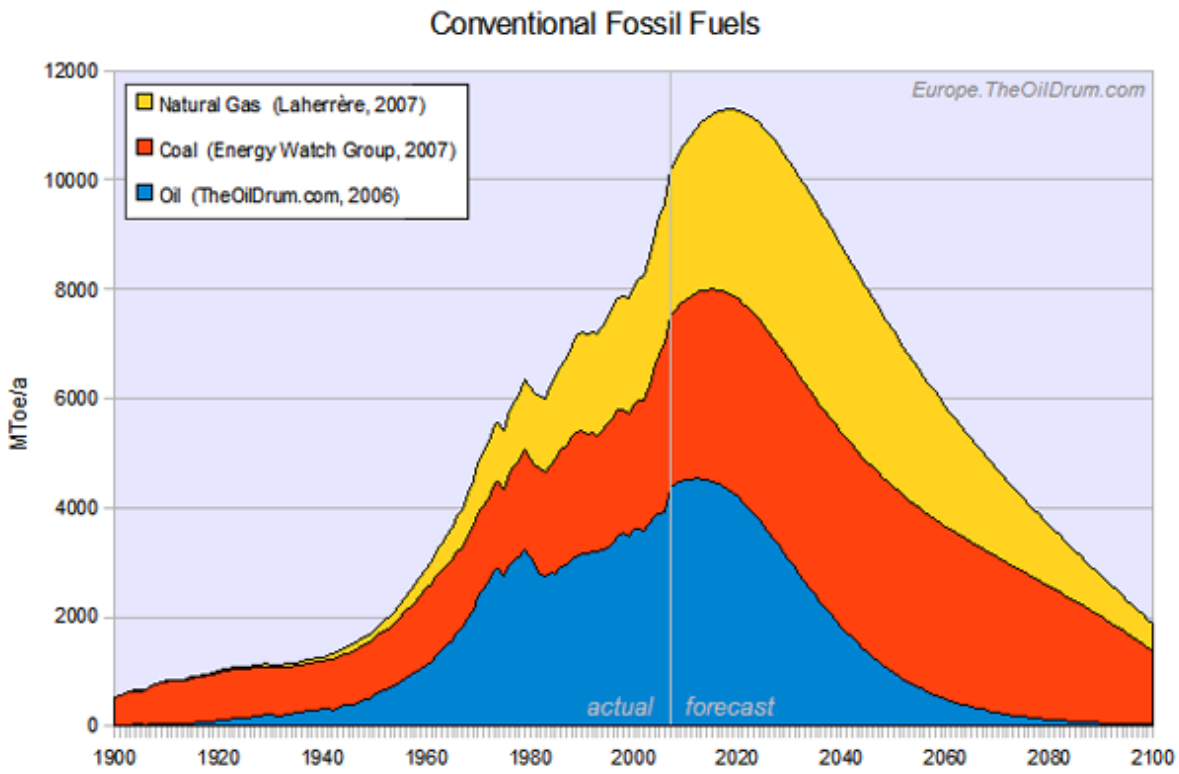
SOURCES OF WORLD ENERGY – 1800-2019



The figure on the following page shows the composite fossil fuel projections of Jean Laherrere (a petroleum engineer and consultant and advisor to the UK's Oil Depletion Analysis Centre), the Energy Watch Group (an international network of scientists and parliamentarians based in Germany), and the authors of the blog "The Oil Drum" (website published by the Colorado based Institute for the Study of Energy and Our Future).

These projections suggest that the cheap and easy to access hydrocarbons are running low, and that economically recoverable fossil fuels are depleting rapidly. The economic risks of fossil fuel depletion – to individuals, businesses, and our community - are enormous. In a future with less and less energy to fuel economic growth, our living standards and tax base will steadily erode. There is also the potential that a global financial crisis could abruptly jolt the world economy into turmoil, as occurred in 2008.

FOSSIL FUEL SUPPLY PROJECTIONS



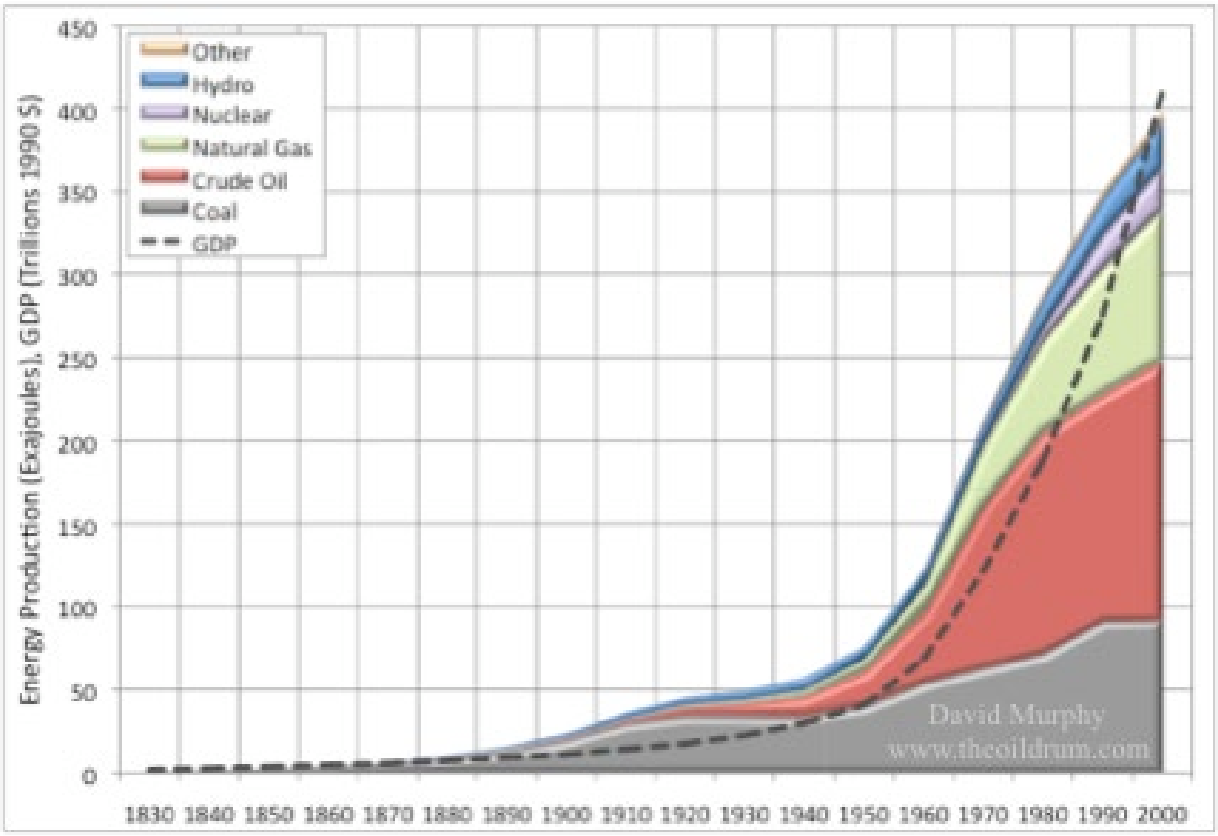
Sources: *Olduvai Revisited 2008*, Jean Laherrere, The Energy Watch Group, and the authors of the OilDrum.com.

World Economic Growth & Energy Use

Just as increasing flows of fossil fuel energy is linked to population growth, it is also tied to economic expansion. In fact, energy is the "master resource" of every modern economy, enabling work to be accomplished. The tight correlation between energy use (mainly fossil fuels) and economic growth over the past two centuries is depicted in the figure on the following page.

The world's money system, which assumes never ending economic and monetary expansion to repay principal plus interest, places impossible demands on a finite world. There is substantial risk that exponentially rising levels of debt, based on assumptions of future economic growth to fund repayment, could shudder to a halt, or even reverse in the near-term. Unfortunately, our financial system does not function in "park" or "reverse." In consequence, the risk of substantial economic contraction is significant in coming years.

ENERGY CONSUMPTION & ECONOMIC GROWTH



Source: *Energy Return on Investment, Peak Oil, and the End of Economic Growth*, David J. Murphy and Charles A. S. Hall (2011), in "Ecological Economics Reviews", Robert Costanza, Karin Limburg & Ida Kubiszewski, Eds. *Ann. N.Y. Acad. Sci.* 1219: 52–72.

CO2 Concentrations & A Warming World

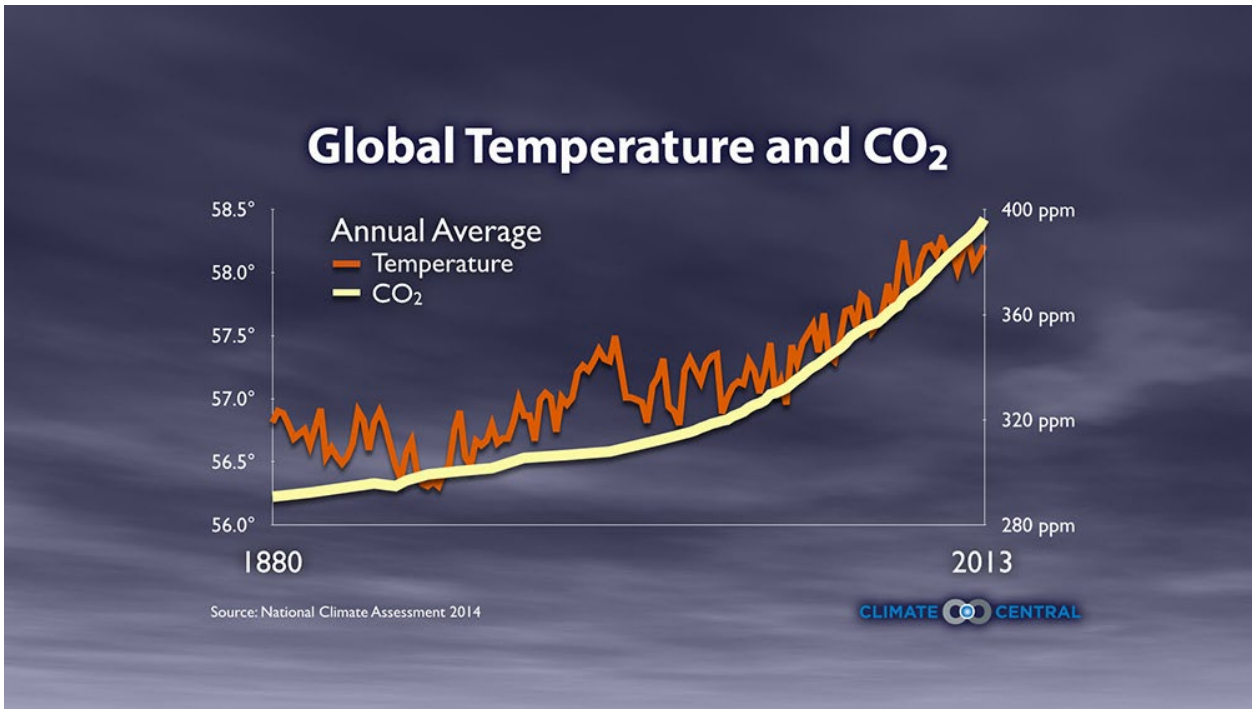
There is no doubt that carbon dioxide and other greenhouse gas emissions from human activities have risen dramatically over the past two centuries of exponentially expanding fossil fuel use. And, although average global temperature fluctuates every year, a snapshot of the global temperature trend is undeniable, particularly since 1970.

Several factors influence temperatures in different regions across the globe: El Niño, the Pacific Decadal Oscillation, aerosols from natural and human sources, and solar cycles, to name just a few. These factors taken individually and together account for the year-to-year variability seen in global average temperatures but fail to explain the 1.6°F warming since 1880.

However, overlaying the amount of carbon dioxide in the atmosphere shows a clear correlation with that rise in temperatures. Decades of peer-reviewed research, basic laws of physics, the ability to track the specific chemical fingerprint of fossil fuel-driven carbon, and the fact that no models can replicate this century's warming without pumping up carbon dioxide and other greenhouse gases in the atmosphere, have given

scientists confidence that human carbon emissions are driving the globe's temperature higher.

RELATIONSHIP BETWEEN CO2 & GLOBAL TEMPERATURE



Other indicators such as ocean acidification, increasing deep ocean heat, melting ice and permafrost, shrinking snowpack, and sea level rise further make the case that the additional carbon dioxide is affecting the global climate system. If greenhouse gas emissions continue to rise, the globe's average temperature is projected to follow suit. The worst-case emissions scenario, the track that we are currently on, estimates a rise in temperature of 4.7° to 8.6°F by 2100.

Anthropogenic climate change portends accelerating climate effects over the coming decades (e.g., Arctic Sea ice loss, droughts, heat waves, crop failures, rising sea levels, floods), food and water shortages, geopolitical instability, and widespread threats to the viability of public infrastructure and governance. Anticipated local and regional (i.e., North Olympic Peninsula) climate impacts are discussed under "The Local Picture", below.

The Local Picture

Climate Change Impacts

Farmers, fishermen, natural resource managers, public health practitioners, utility managers, emergency responders, coastal residents, businesses, and others, have

already noticed changes in the climate and extreme weather conditions on the North Olympic Peninsula, including Jefferson County. These changes are part of the larger trends observed globally.

Anticipated Changes in Sea Level

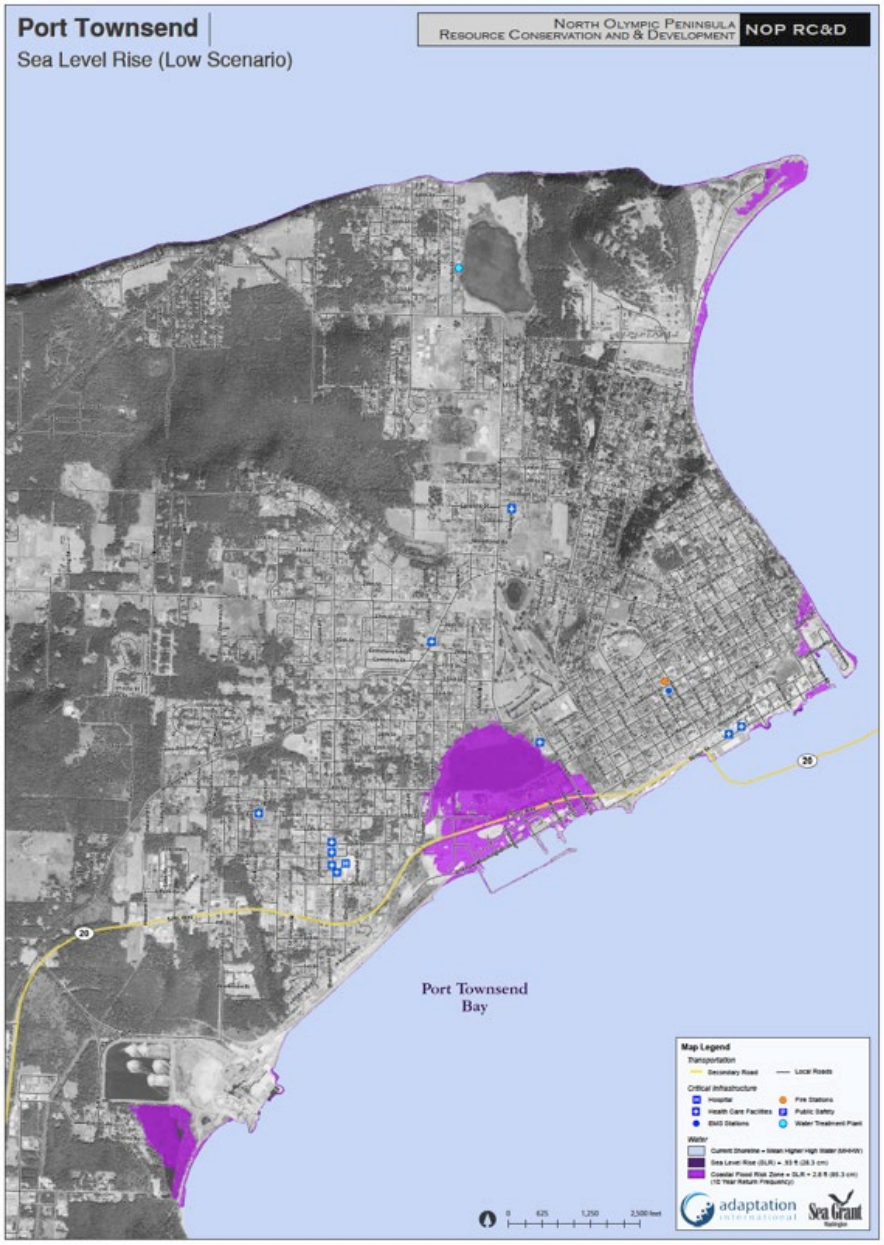
A recent 2015 report prepared as part of the North Olympic Peninsula Resource Conservation and Development Council's project, "*Planning for Climate Change on the North Olympic Peninsula*" graphically presents "low" and "high" severity scenarios for sea level rise and coastal flooding risk over the coming century (see Figures on the following pages). The mapped scenarios are based principally on the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report. The data indicate that our community is likely to face escalating challenges as we seek to defend, retreat, and reimagine our relationship with the shoreline over the coming decades. Whether these changes become obvious in the next few years or later in the 21st century, the mounting costs and consequences of adapting to climate disruption will be substantial and unrelenting. The long-term implications for key Port infrastructure (e.g., breakwaters, stormwater systems) and economy (e.g., maritime manufacturing areas at Boat Haven and Point Hudson) are profound.

Temperature Trends & Extremes

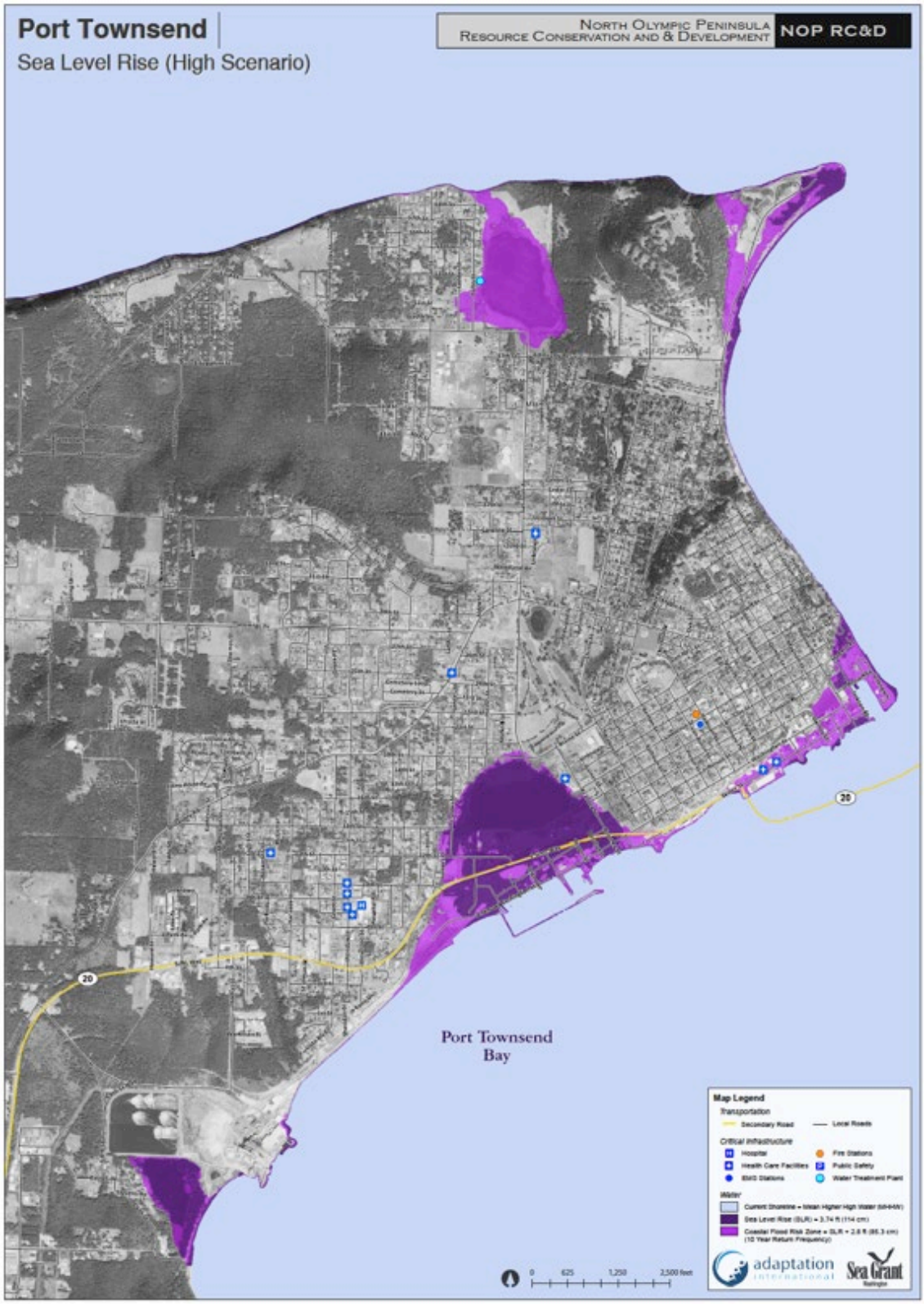
Over the last century, average annual air temperature in the Pacific Northwest has increased by 1.3°Farenheit (F) (i.e., slightly less than the global average of 1.6F). Average annual temperature for the 2050s is projected to increase 4.5°F to 5.8°F (relative to 1950-1999) depending on future greenhouse gas emissions scenarios (University of Washington Climate Impacts Group). Although this increase may not at first blush seem significant, it is comparable to the difference in average annual temperatures that separates our time from the last ice age. Overall, our community is expected to see markedly warmer and wetter winters, and hotter, dryer summers. (Source: *Projected Climate Change & Impacts for the North Olympic Peninsula*, Adaptation International, January 2015).

Compared to many areas, however, the climate models suggest that the North Olympic Peninsula and Port Townsend may somewhat protected from the extremes experienced elsewhere, due to our location close to the North Pacific Ocean. Nevertheless, summer high temperatures could increase substantially, over 10 degrees Fahrenheit or more, although no significant trend has yet been observed in daytime heat events (over the period 1895-2011). Changes in minimum temperatures are already being observed. The frost-free season has lengthened by 35 days relative to the historical period 1895-2011, and nighttime heat events have become more frequent in Western Washington State. (Source: University of Washington Climate Impacts Group).

“LOW SEVERITY” SEA LEVEL RISE & COASTAL FLOOD RISK

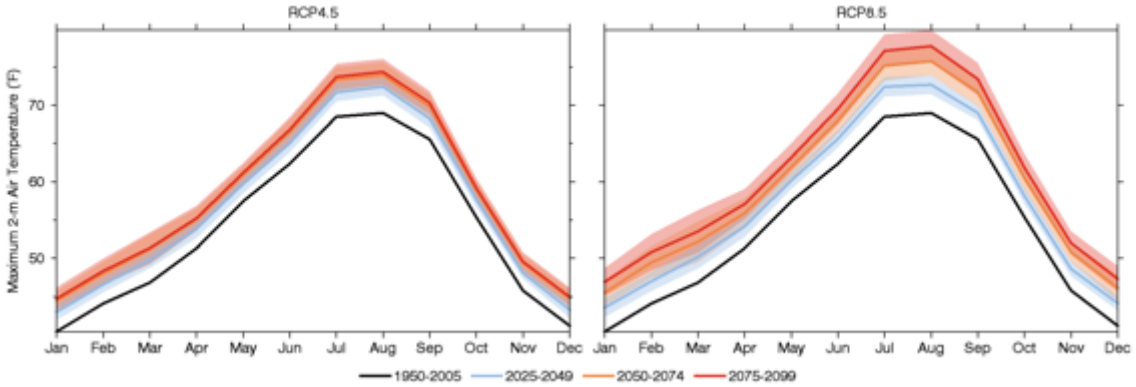


“HIGH SEVERITY” SEA LEVEL RISE & COASTAL FLOOD RISK



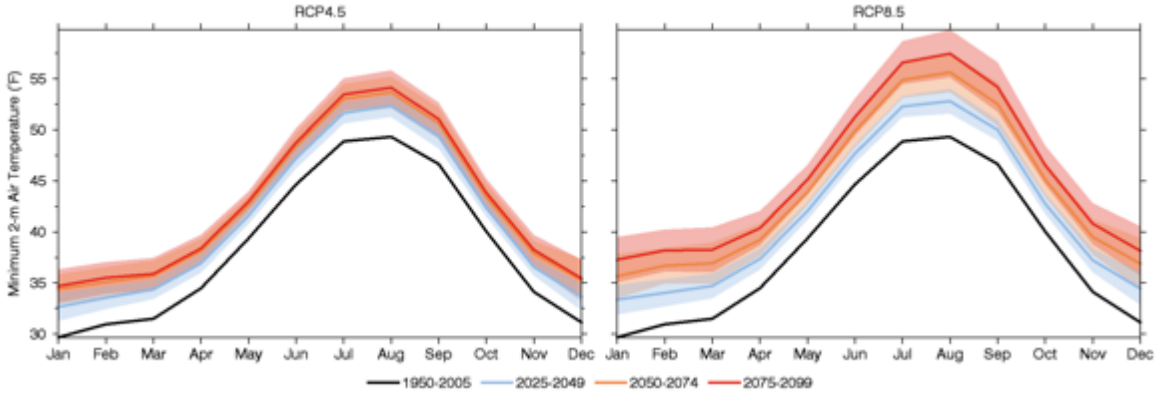
The figures below show expected monthly average maximum and minimum air temperatures for Jefferson County during four different time periods under two distinct greenhouse gas (GHG) emission scenarios from the IPCC's 4th Assessment Report. The "RCP 4.5" scenario assumes significantly reduced greenhouse gasses (GHGs), while the "RCP 8.5" scenario assumes a continuation of current levels of GHG emissions. Each solid line indicates an average of 30 climate models, with their standard deviations shown by their respective shaded envelopes. (Source: *Projected Climate Change & Impacts for the North Olympic Peninsula*, Adaptation International, January 2015).

PROJECTED CHANGES TO MAXIMUM TEMPERATURES IN JEFFERSON COUNTY



Source: *Projected Climate Change & Impacts for the North Olympic Peninsula*, Adaptation International, January 2015.

PROJECTED CHANGES TO MINIMUM TEMPERATURES IN JEFFERSON COUNTY



Source: *Projected Climate Change & Impacts for the North Olympic Peninsula*, Adaptation International, January 2015.

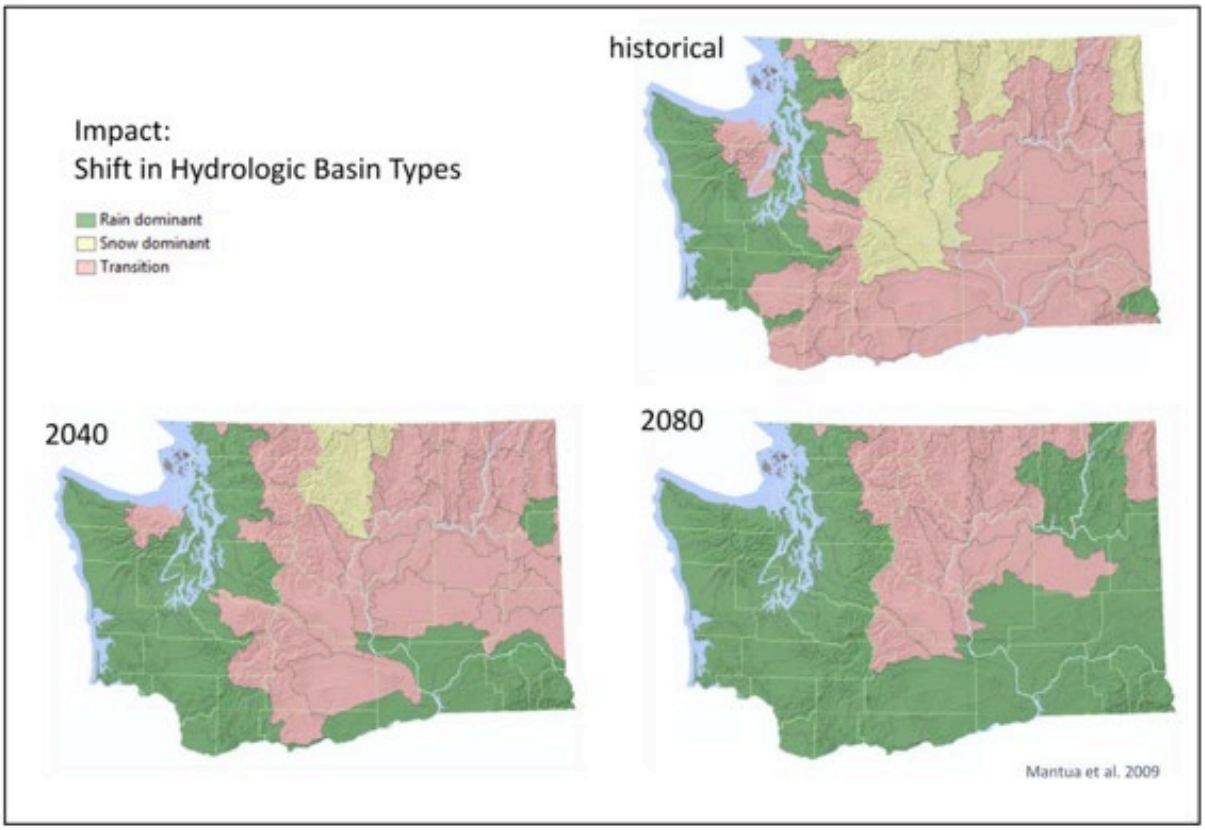
Changes in Water Supply (the Hydrologic Regime)

In addition to changes in temperature and precipitation trends, and ocean conditions, the "*Planning for Climate Change on the North Olympic Peninsula Report*" also anticipates impacts specifically relevant to the community's water resources, including shifting hydrologic basin types and timing of seasonal stream flows. These anticipated changes are depicted in the figure below. Warmer overall temperatures will drive historical snow events towards the thaw threshold, leading to more precipitation

throughout the fall-winter-and spring falling as rain instead of snow. This shifting freezing threshold will be particularly pronounced in those high elevation zones in the Olympic Mountains where snowfall has historically maintained glaciers and influenced entire ecosystems as a "partial-snow" hydrologic basin. The figure below, shows projected shifts in our State's hydrologic basin types.

Shifts in hydrologic basin types necessarily influence the way that the precipitation is stored and the timing of its release and flow from high elevation sources to downstream lowlands. The general projection of increased fall and winter precipitation and decreased summer precipitation in the region, paired with the shift towards a more rain dominant watershed, suggests long-term changes to watershed flow on the North Olympic Peninsula. Adapting to this changing hydrologic regime will be a persistent challenge for water resource managers. (Source: *Projected Climate Change & Impacts for the North Olympic Peninsula*, Adaptation International, January 2015).

SHIFTING HYDROLOGIC BASIN TYPES



Source: *Projected Climate Change & Impacts for the North Olympic Peninsula*, Adaptation International, January 2015.