USFWS

Chapter 3
Physical Environment

Chapter 3. Physical Environment

3.1 Climate and Climate Change

3.1.1 General Climate Conditions

The climate at Siletz Bay National Wildlife Refuge (NWR or Refuge) is greatly influenced by the Pacific Ocean on the west and the Coast Range to the east. The Coast Range rises between 2,000 and 3,000 feet (610-914 meters) above sea level in the north and between 3,000 and 4,000 feet (914-1,219 meters) in the southwestern portion of the state with occasional mountain peaks rising an additional 1,000 to 1,500 feet (305-457 meters). The coastal zone is characterized by wet winters, relatively dry summers, and mild temperatures throughout the year. Because of the moderating influence of the Pacific Ocean, extremely high or low temperatures are rare and the annual temperature range is lower here than in any other Oregon climate zone. Precipitation is heavier and more persistent during the winter but regular moisture occurs from rain and fog throughout the year (Western Regional Climate Center [WRCC] 2011a). The area's heavy precipitation during winter results from moist air masses moving from the Pacific Ocean onto land. The lower elevations along the coast receive annual precipitation of 65 to 90 inches (165-229 centimeters), which can cause flood events if abundant rainfall is consistent for several days. Occasional strong winds (50-70 miles per hour) occur along the coast, usually in advance of winter storms. Wind speeds have been recorded to exceed hurricane force and have caused substantial damage to structures and vegetation in exposed coastal locations (Taylor and Hannan 1999, Taylor 2008). Skies are usually cloudy in the winter during the frequent storms and clear to partly cloudy during summer, with localized fog along the coastline. As a result of persistent cloudiness, total solar radiation is lower along the coast than in any other region of the state.

Climate Change Trends

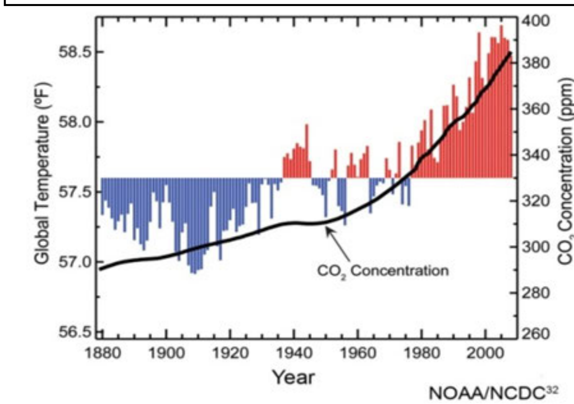
The greenhouse effect is a natural phenomenon that assists in regulating and warming the temperature of our planet. Just as a glass ceiling traps heat inside a greenhouse, certain gases in the atmosphere, called greenhouse gases (GHG), absorb and emit infrared radiation from sunlight. The primary greenhouse gases occurring in the atmosphere include carbon dioxide (CO_2), water vapor, methane, and nitrous oxide. CO_2 is produced in the largest quantities, accounting for more than half of the current impact on the Earth's climate.

A growing body of scientific evidence has emerged to support the fact that the Earth's climate has been rapidly changing during the 20th century and the magnitude of these alterations is largely due to human activities (Intergovernmental Panel on Climate Change [IPCC] 2007a, National Academy of Sciences [NAS] 2008, U.S. Global Change Research Program [USGCRP] 2009). Increasingly, the role of human activities in the concentrations of heat-trapping greenhouse gases have increased significantly over the last several hundred years due to human activities such as deforestation and the burning of fossil fuels (Ibid).

Although climate variations are well documented in the Earth's history, even in relatively recent geologic time (e.g., the Ice Age of 10,000 years ago), the current warming trend differs from shifts earlier in geologic time in two ways. First, this climate change appears to be driven primarily by human activity which results in a higher concentration of atmospheric GHG. Second, atmospheric CO_2 and other greenhouse gases, levels of which are strongly correlated with Earth temperature, are now higher than at any time during the last 800,000 years (USGCRP 2009). Prior to the start of the Industrial Revolution in 1750, the amount of CO_2 in the atmosphere was about 280 parts per million (ppm). Current levels are about 390 ppm and are increasing at a rate of about 2 ppm/year (U.S. Department of Energy [DOE] 2012). The current concentration of CO_2 and other greenhouse gases as well as the rapid rate of increase in recent decades are unprecedented in the prehistoric record (Ibid).

The terms "climate" and "climate change" are defined by the IPCC. The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007b). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (Ibid).

Figure 3-1. Global annual average temperature and CO_2 from 1880-2008 (NOAA 2012c).



Global annual average temperature (as measured over both land and oceans). Red bars indicate temperatures above and blue bars indicate temperatures below the average temperature for the period 1901-2000. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, each individual year does not show a temperature increase relative to the previous year, and some years show greater changes than others.[33] These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Niños, La Niñas, and the eruption of large volcanoes.

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s (Figure 3-1). Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions (e.g., IPCC 2007b, Solomon et al. 2007). In the Pacific Northwest, increased greenhouse gases and warmer temperatures have resulted in a number of physical and chemical impacts. These include changes in snowpack, stream flow timing and volume, flooding and landslides, sea levels, ocean temperatures and acidity, and disturbance regimes such as wildfires, insect, and disease outbreaks (USGCRP 2009). All of these changes will cause major perturbations to ecosystem conditions, possibly imperiling species that evolved in response to local conditions.

Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007b, Solomon et al. 2007). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011), who concluded that it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

In the Northern Hemisphere, recent decades appear to be the warmest since at least about A.D. 1000, and the warming since the late 19th century is unprecedented over the last 1,000 years. Globally, including 2011, all 11 years in the 21st century so far (2001 to 2011) rank among the 13 warmest years in the 130-year instrumental record (1880 to present) according to independent analyses by National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space

Administration (NASA). 2010 and 2005 are tied as the warmest years in the instrumental record and the new 2010 record is particularly noteworthy because it occurred in the presence of a La Niña and a period of low solar activity, two factors that have a cooling influence on the planet. However, in general, decadal trends are far more important than any particular year's ranking.

Trends in global precipitation are more difficult to detect than changes in temperature because precipitation is generally more variable and subject to local topography. However, while there is not an overall trend in precipitation for the globe, significant changes at regional scales can be found. Over the last century, there have been increases in annual precipitation in the higher latitudes of both hemispheres and decreases in the tropical regions of Africa and southern Asia (USGCRP 2009). Most of the increases have occurred in the first half of the 20th century and it is not clear that this trend is due to increasing greenhouse gas concentrations.

Just as important as precipitation totals are changes in the intensity, frequency, and type of precipitation. Warmer climates, owing to increased water vapor, lead to more intense precipitation events, including more snowstorms and possibly more flooding, even with no change in total precipitation (Dominguez et al. 2012). The frequency of extreme single-day precipitation events has increased, especially in the last two decades. Paradoxically more droughts and heat waves have occurred because of hotter, longer-lasting high pressure systems.

3.1.2 Air Temperatures

As a result of the ocean's proximity, winter minimum and summer maximum temperatures along the coast are moderated. It is rare for Siletz Bay NWR to experience temperatures below freezing. No days are on record with temperatures at or below 0°F. Also, it is only in the extreme occurrences that temperatures have been recorded to exceed 90°F (WRCC 2011b, WRCC 2011c).

There is no climate/weather station established on Siletz Bay NWR; however, temperature data have been consistently collected since July 1948 at the Otis station (number 356366) located approximately 8 miles north of the Refuge and since January 1893 at the Newport station (number 356032) located approximately 18 miles south of the Refuge. The proximity of these stations to the Refuge provides valuable regional data. Table 3-1 provides a summary of the periods of record.

Table 3-1. Air Temperature Summaries near Siletz Bay NWR (WRCC 2011b, WRCC 2011c)

Temperatures (°F)	Otis July 1948 – Sept. 2010	Newport Jan. 1893 – Sept. 2010
Average Monthly Temperature – High	59	57.7
Average Monthly Temperature – Low	42.6	43.9
Monthly Mean Winter Temperature – High	48.6	51
Monthly Mean Winter Temperature – Low	36.7	38.8
Monthly Mean Summer Temperature – High	68.8	63.7
Monthly Mean Summer Temperature – Low	49.3	49.6
Daily Maximum Extreme – High	99	100
Daily Maximum Extreme – Low	64	73
Daily Minimum Extreme – High	39	33
Daily Minimum Extreme – Low	4	1

Future Trends

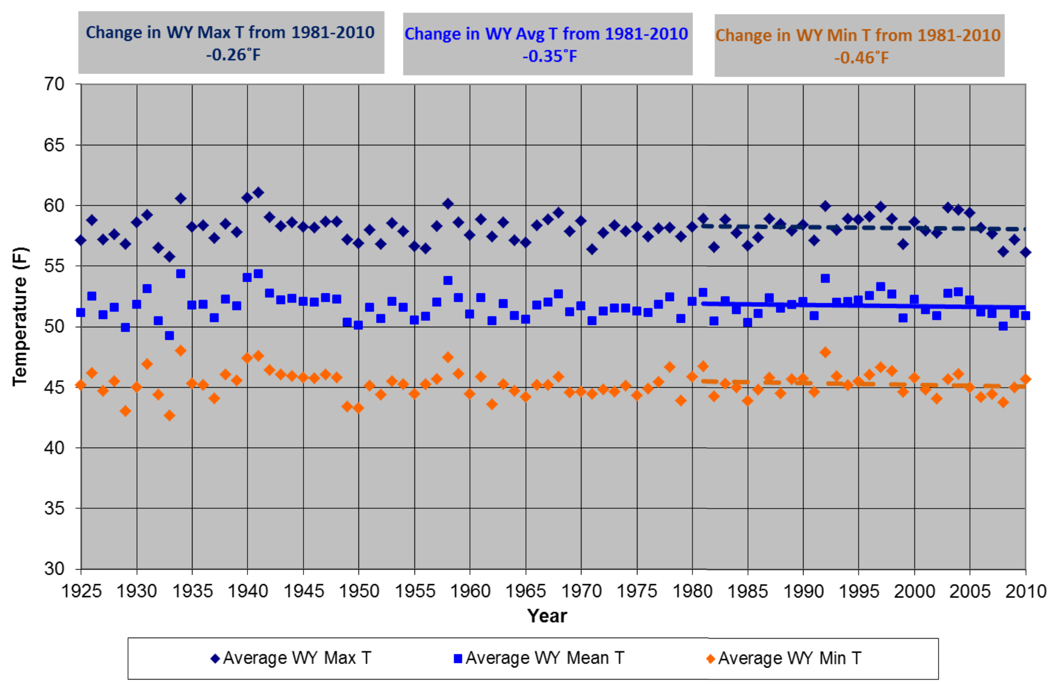
Mote (2003) observed that the Pacific Northwest region experienced warming of approximately 1.5°F during the 20th century. For trends local to the Refuge we turn to the United States Historical Climatology Network (USHCN), which provides a high-quality data set of daily and monthly records of basic meteorological variables from 1,218 observing stations throughout the continental U.S. The data have been corrected to remove biases or heterogeneities from non-climatic effects such as urbanization or other landscape changes, station moves, and instrument and time of observation changes. The closest station is Newport and trends are provided in Table 3-2 and Figure 3-2. The average yearly temperature change has decreased 0.35°F over the past 30 years (Table 3-2).

Table 3-2. Seasonal Temperature Trends, 1981-2010 (USHCN 2012)

Newport, Oregon United States Historical Climatology Network Observation Station			
Monthly Absolute Change	**Maximum Temp.**	**Average Temp.**	**Minimum Temp.**
Winter (Dec-Feb)	+0.08°F	-0.03°F	-0.13°F
Spring (March-May)	-0.83°F	-1.14°F	-1.49°F
Summer (Jun-Aug)	-0.08°F	+0.26°F	+0.59°F
Fall (Sept-Nov)	-0.33°F	-0.47°F	-0.65°F

The graphs below illustrate a sample of these temperature trends using monthly data. The most recent 30-year period is calculated using the slope of the linear trendline, and temperature change is shown as an absolute change over the 30-year period. A water year is defined as the 12-month period from October 1, for any given year, through September 30 of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months.

Figure 3-2. Water year temperature 1925-2010 at Newport, Oregon (USHCN 2012).

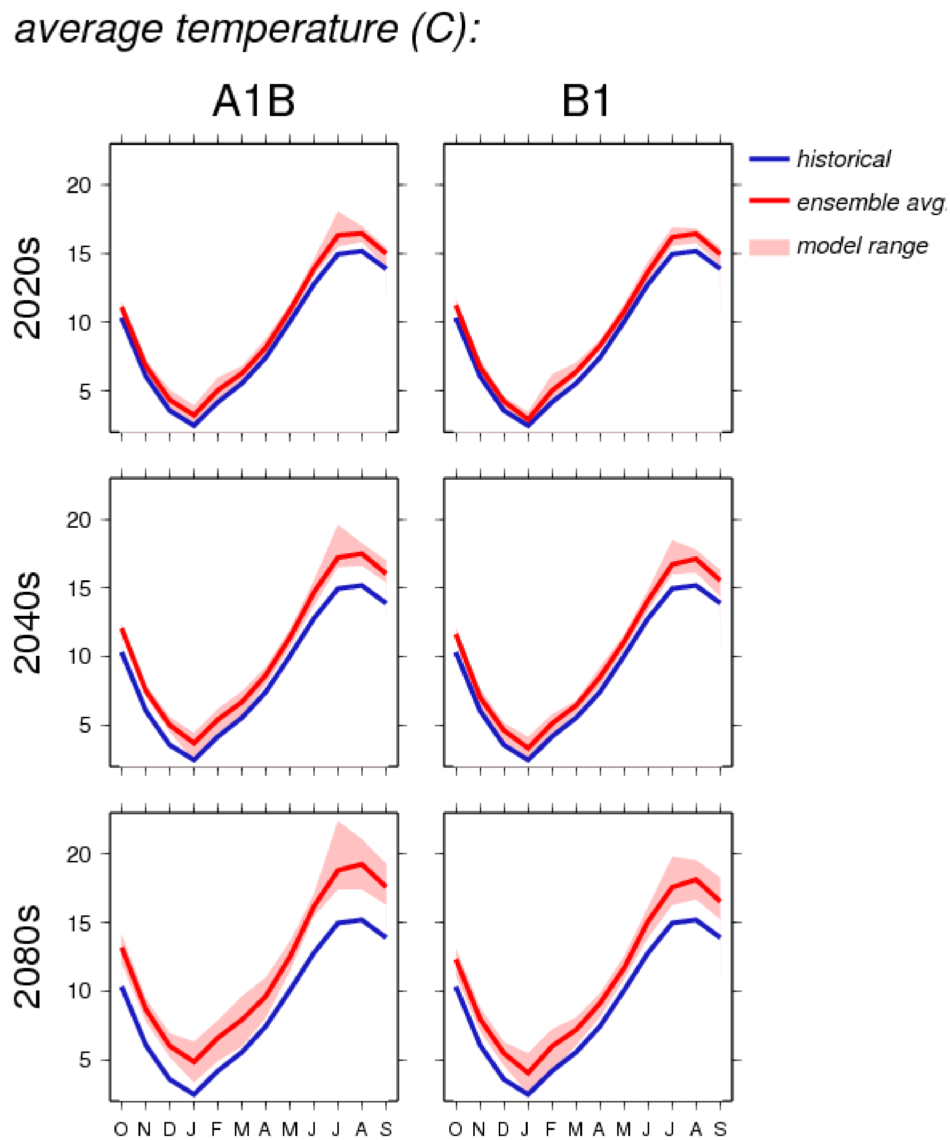


Future Trends

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl et al. 2007, Ganguly et al. 2009, Prinn et al. 2011). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (IPCC 2007c, Meehl et al. 2007, Ganguly et al. 2009, Prinn et al. 2011).

Statistical downscaling methods first derive empirically-based relationships between coarse-scale (e.g., the altitude of the 700 hPa pressure level) and observed local (e.g., precipitation or temperature) climate variables. Predicted values of the coarse-scale variables obtained from global climate models are then used to drive the statistical relationships in order to estimate the regional and/or local scale details of future climate (see Mote and Salathé 2010 for more on downscaling methods). The statistical downscaling of 20 global climate models (Mote and Salathé, 2009 and 2010) projects average annual temperature to increase 2.0°F by the decade of the 2020s for the Pacific Northwest, 3.2°F by the decade of the 2040s, and 5.3°F by the decade of the 2080s, relative to the 1970-1999 average temperature. The projected changes in average annual temperature are substantially greater than the 1.5°F increase in average annual temperature observed in the Pacific Northwest during the 20th century. Seasonally, summer temperatures are projected to increase the most. Actual global emissions of greenhouse gases in the past decade have so far exceeded the emissions scenarios used in projections of Mote and Salathé. Consequently, if these emissions trends continue, the climate projections referenced herein likely represent a conservative estimate of future climatic changes. Figure 3-3 shows these modeled, downscaled temperature projections for the Siletz-Yaquina watershed (Hydrologic Unit Code 17100204) (Hamlet et al. 2010).

Figure 3-3. Projected temperature changes for the Siletz-Yaquina Watershed under two emission scenarios. A1B is a higher emission scenario than B1. Current rates are higher than both A1B and B1 (Hamlet et al. 2010).



3.1.3 Precipitation

The discussion below includes data from the two climate stations closest to Siletz Bay NWR, located in Otis and Newport. Roughly 57 to 58 percent of the annual precipitation at these stations occurs during late fall and winter, in the months of November, December, January, and February. By comparison, the summer months of June, July, and August receive a scant 7 percent of the annual precipitation. On average, 47-69 days per year experience more than 0.50 inch of precipitation and 16-29 days greater than 1.00 inch (WRCC 2011d, 2011e). Snow events are infrequent. Fog (water vapor condensing into tiny liquid water droplets in the air) is a common phenomenon along the Oregon coast because of contrasting differences between air, land, and ocean temperatures and humidity. The average number of days per year with dense fog (visibility of 0.25 mile or less) in

Astoria is 41. June averaged the fewest days (1) with dense fog and October with the most days (7) (WRCC 2011f). Fog records for central coastal locations were unavailable. Precipitation data for Otis and Newport are summarized in Table 3-3.

Table 3-3. Precipitation Summaries near Siletz Bay NWR (WRCC 2011d, WRCC 2011e)

Precipitation (inches)	Otis July 1948 – Sept. 2010	Newport Jan. 1893 – Sept. 2010
Average Annual Precipitation	97.35	67.77
Average Annual Snowfall	2.9	1.1
Average Monthly Snowfall Range (winter)	0.2 to 1.4	0.2 to 0.5
Highest Annual Snowfall	24.0 (1969)	11.0 (1943, 1972)
Highest Monthly Snowfall	20.0 (January 1950)	11.0 (Jan. 1943, Dec. 1972)
Wettest Year on Record	135.18 (1996)	111.03 (1968)
Driest Year on Record	71.21 (1976)	38.45 (1929)
Wettest Season on Record	67.47 (winter 1999)	49.89 (winter 1918)
Driest Season on Record	1.37 (summer 1967)	0.00 (summer 1931)

Longer-term precipitation trends in the Pacific Northwest are more variable than temperature and vary with the period of record analyzed (Mote et al. 2005). The Pacific Northwest experiences wide precipitation variability based on geography and seasonal and year-to-year variability (Salathé et al. 2010). Looking at the period 1920 to 2000, total annual precipitation has increased almost everywhere in the region, though not in a uniform fashion. Most of that increase occurred during the first part of the record with decreases more recently (Mote et al. 2005).

Precipitation trends from the Newport USHCN observation station shows the average yearly precipitation change has decreased more than 15.9% over the past 30 years, with more striking decreases in the summer and fall (Table 3-4 and Figures 3-4 to 3-6).

Table 3-4. Seasonal Precipitation Trends, 1981-2010 (USHCN 2012) Tillamook, Oregon, United States Historical Climatology Network Observation Station

Monthly Precipitation	30-yr Change % from 1981 Value
Winter (Dec-Feb)	-3.9%
Spring (March-May)	-14.9%
Summer (Jun-Aug)	-47.6%
Fall (Sept-Nov)	-25.9%

Figure 3-4. Water year total precipitation 1925-2010 at Newport, Oregon (USHCN 2012).

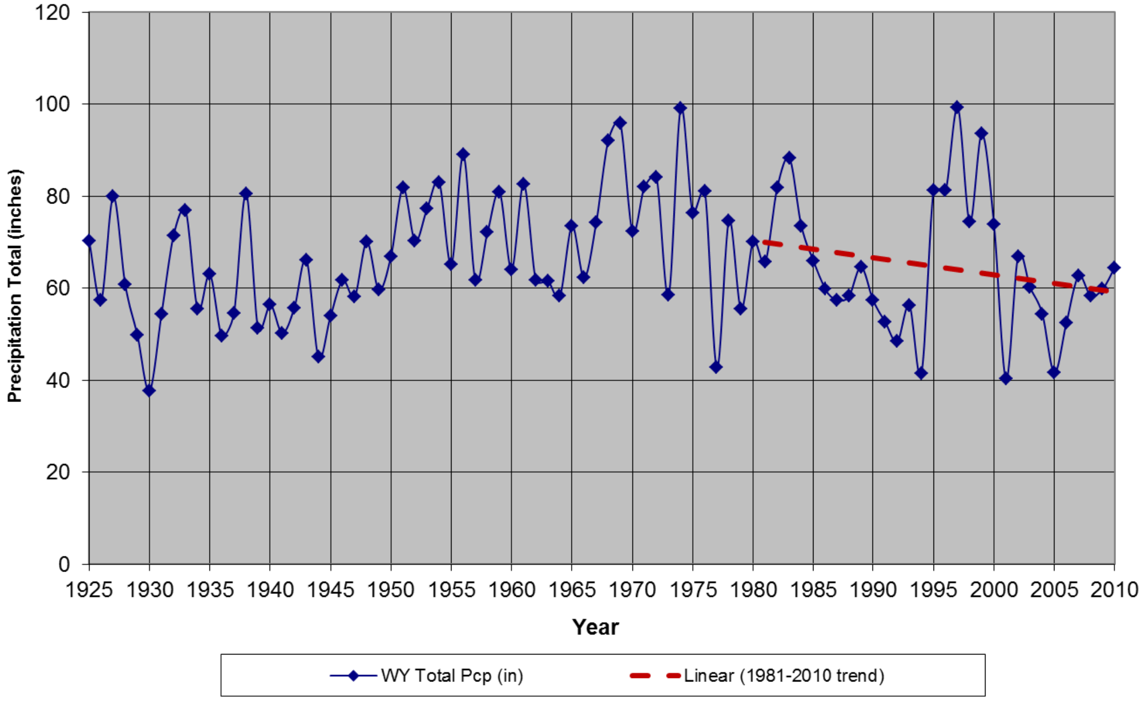


Figure 3-5. Summer (Jun-Aug) total precipitation 1925-2010 at Newport, Oregon (USHCN 2012).

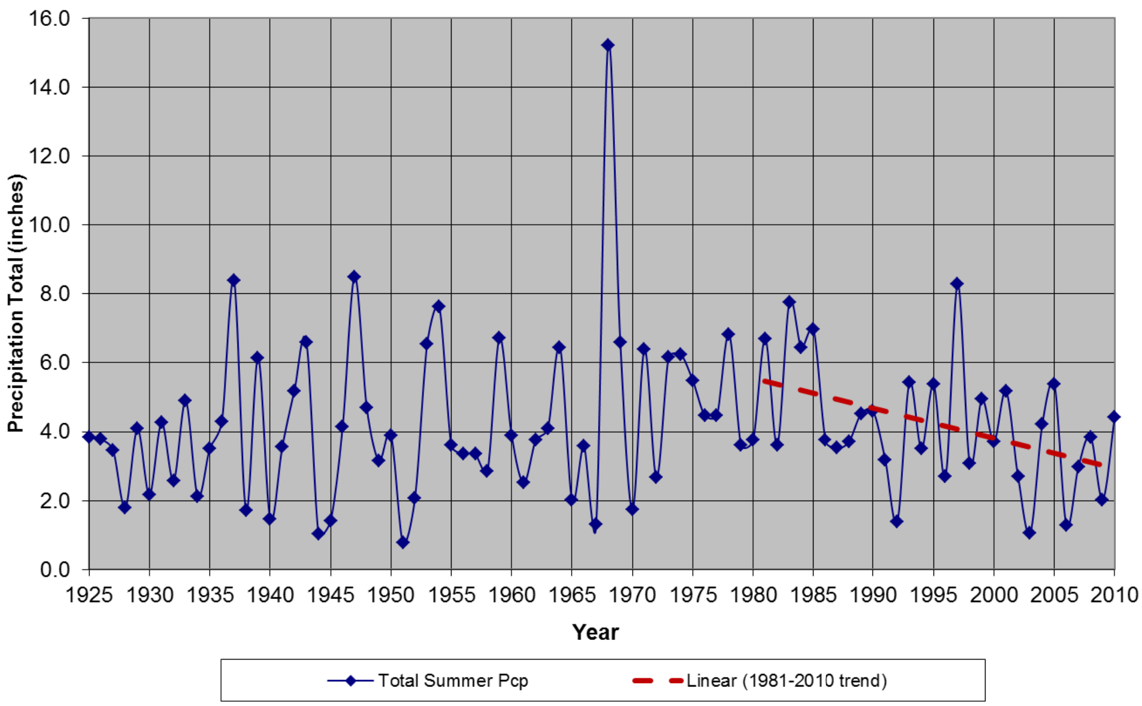
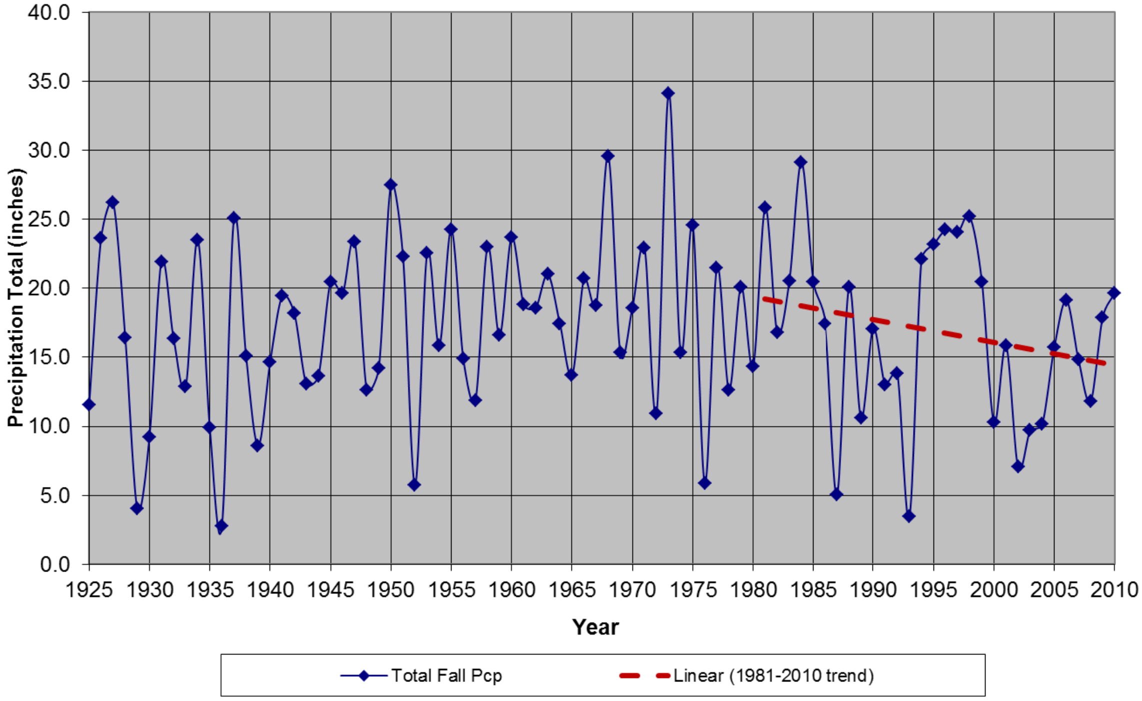


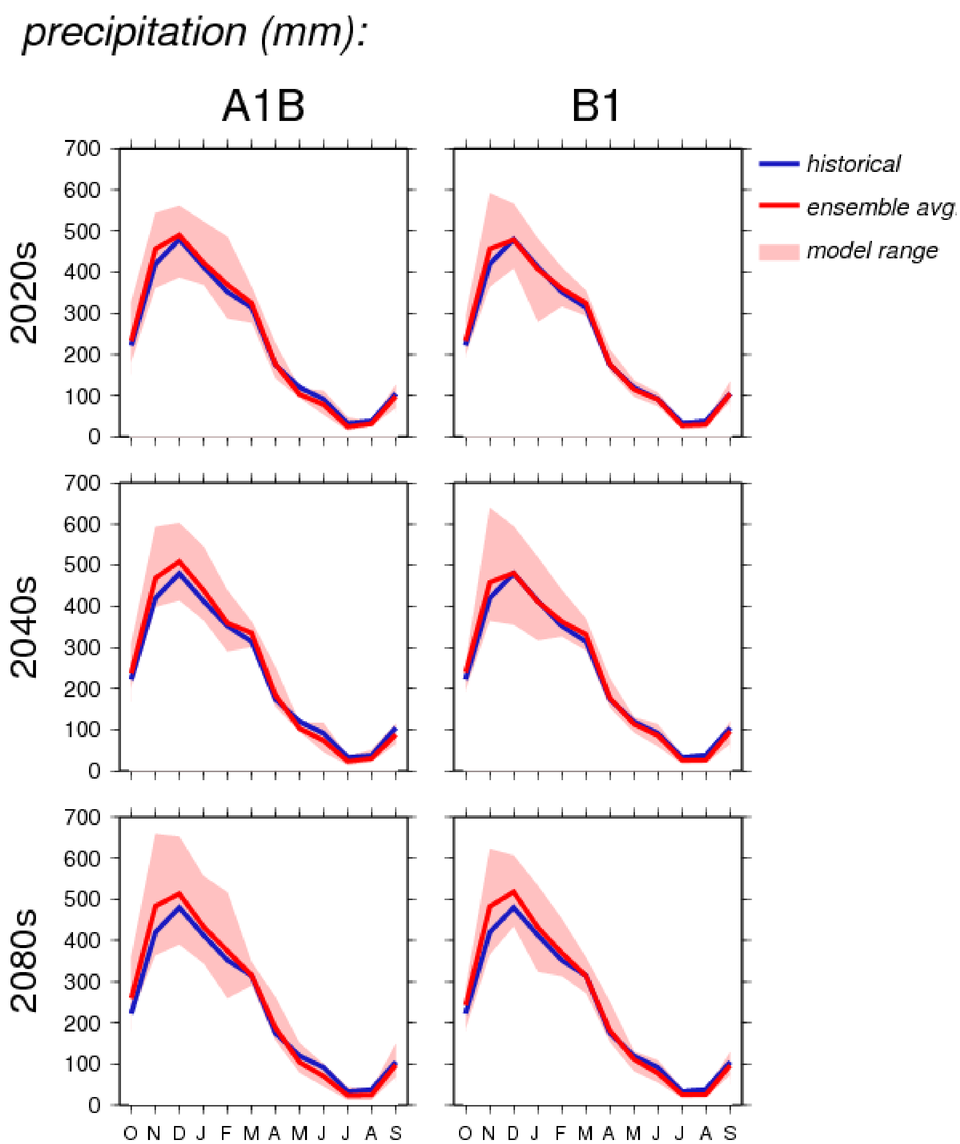
Figure 3-6. Fall (Sept-Nov) total precipitation 1925-2010 at Newport, Oregon (USHCN 2012).



Future Trends

On a global scale, warmer temperatures are predicted to lead to a more vigorous hydrologic cycle, translating to more severe droughts and/or floods (IPCC 1996). Using data derived from the statistical downscaling of 20 global climate models, projected changes in annual precipitation within the Pacific Northwest throughout the twenty-first century, averaged over all models, are small (+1% to +2%) though individual models produce changes of as much as -10% or +20% by the 2080s. Some models project an enhanced seasonal cycle with changes toward wetter autumns and winters and drier summers (Mote and Salathé 2010). However, even small changes in seasonal precipitation could have impacts on streamflow flooding, summer water demand, drought stress, and forest fire frequency. Additionally, researchers have consistently found that regional climate model simulations yield an increase in the measures of extreme precipitation. This finding suggests that extreme precipitation changes are more related to increased moisture availability in a warmer climate than to increases in climate-mean precipitation (Leung et al. 2004, Salathé et al. 2010). It is important to note that the one conclusion shared by researchers is that there is greater uncertainty in precipitation projections than that of temperature predictions and models (Leung and Qian 2003, CIG 2004, Salathé et al. 2010). Figure 3-7 shows these modeled, downscaled precipitation projections for the Siletz-Yaquina watershed (Hydrologic Unit Code 17100204) (Hamlet et al. 2010).

Figure 3-7. Projected precipitation changes for the Siletz-Yaquina Watershed under two emission scenarios. A1B is a higher emission scenario than B1. Current rates are higher than both A1B and B1 (Hamlet et al. 2010).



3.1.4 Wind

During the spring and summer, the semi-permanent low-pressure cell over the North Pacific Ocean becomes weak and moves north beyond the Aleutian Islands. Meanwhile, a high-pressure area spreads over the North Pacific Ocean. Air circulates in a clockwise direction around the high-pressure cell bringing prevailing westerly and northwesterly winds. This seasonal flow is comparatively dry, cool, and stable (WRCC 2011g).

In the fall and winter, the high-pressure cell weakens and moves southward while the Aleutian low-pressure cell intensifies and migrates southward as well (WRCC 2011g). It reaches its maximum intensity in midwinter. Wind direction switches to primarily southeasterly or easterly prevailing winds. The air mass over the ocean is moist and near the temperature of the water. As it moves inland, it cools and condenses, bringing the beginning of the wet season by the end of October (Taylor and Hannan 1999).

Wind data collected hourly from automated stations at reporting airports on the Oregon coast have been used to draw generalizations about wind activity in/on Siletz Bay Refuge (Table 3-5). Average wind speeds have been calculated on hourly data collected from 1996 to 2006. The highest average wind speeds at Astoria and Newport occurred during the winter months of December, January, and February. At North Bend, the highest average wind speeds occurred during the summer months of June, July, and August. The calmest months at Astoria and Newport were during the late-summer/early-fall months of August, September, and October. At North Bend, the calmest months were October, November, and February.

Prevailing wind direction, defined as the direction with the highest percent of frequency, was calculated from hourly data during 1992 to 2002. In Astoria, easterly winds occur from October through March, switching to southerly winds in April, and then to west and northwest winds from May through September. In Newport, winds from the east occur in December through February, from the south during fall and spring, and north-northwest during the summer months. In North Bend, winds blow from the south-southeast from November to April before becoming northerly for the remainder of the year.

Table 3-5. Wind Data Summaries for Three Locations along the Oregon Coast (WRCC 2011h, WRCC 2011i)

	Astoria	Newport	North Bend
Prevailing Wind Direction	E	S	N
Average Annual Wind Speed	7.7 mph	8.8 mph	8.9 mph
Average Monthly Wind Speed Range	6.7 (Sept.) – 8.7 (Dec.) mph	6.5 (Sept.) – 11.2 (Dec.) mph	7.3 (Oct.) – 11.2 (Jul.) mph

Several times each year, very strong winds hit the Oregon coast (Taylor and Hannan 1999). Wantz and Sinclair (1981) published estimates of extreme winds in the Northwest. They estimate that speeds along the coast sustained for an average of one minute and recurring on average every two years are as high as 56 miles per hour, while fifty-year events would produce winds of approximately 74 miles per hour. Peak gusts would be about 40% higher.

As a rule, Oregon does not experience hurricanes, and tornadoes are infrequent and generally small in the northwestern part of the United States. However, the National Weather Service issued a hurricane warning for the first time for the Oregon coast during an extremely powerful storm that slammed into the Pacific Northwest during December 2-4, 2007, during which winds topped out at 130 miles per hour (209 kilometers per hour) along coastal Oregon (Read 2008). The National Climatic Data Center maintains a database that provides information on the incidence of tornadoes reported in each county in the United States. This database reports that 100 tornadoes were reported in Oregon from 1950 to 2010. In Lincoln County, only three tornadoes have been recorded. All three tornadoes had maximum wind speeds estimated in the range of 40 to 72 miles per hour (64-116 kilometers per hour, or F0) (NCDC 2011).

3.1.5 Climate Cycles in the Pacific Northwest

Two climate cycles have major influences on the climate and hydrologic cycles in the Pacific Northwest: the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). In El Niño years, average sea surface temperatures in the central and eastern equatorial Pacific Ocean are warmer than average and easterly trade winds in the tropical Pacific are weakened. A La Niña is characterized by the opposite – cooler than average sea surface temperatures and stronger than normal easterly trade winds. These changes in the wind and ocean circulation can have global impacts to weather events. The ENSO influence on Pacific Northwest climate is strongest from October to March. During an El Niño event, the winters tend to be warmer and drier than average. La Niña winters tend to be cooler and wetter than average. Each ENSO phase typically lasts 6 to 18 months and the shift between the two conditions takes about four years (CIG 2011, Conlan and Service 2000).

Like ENSO, the PDO is characterized by changes in sea surface temperature, sea level pressure, and wind patterns. The PDO is described as being in one of two phases: warm and cool. During a warm phase, sea surface temperatures near the equator and along the coast of North America are warmer while in the central north Pacific they are cooler. During a cool phase, the patterns are opposite. Within the Pacific Northwest, warm phase PDO winters tend to be warmer and drier than average while cool phase PDO winters tend to be cooler and wetter than average. A single warm or cool PDO phase lasts 20-30 years. The triggering cause of the PDO phase shift is not understood.

The potential for temperature and precipitation extremes increases when ENSO and PDO are in the same phases and thereby reinforce each other. When ENSO and PDO are in opposite phases, their opposite effects on temperature and precipitation can cancel each other out, but not in all cases and not always in the same direction (CIG 2011).

Future Trends

Based on the evidence of the history of ENSO and PDO events, it is likely that these cycles will continue to occur far into the future. However, the potential influence of anthropogenic climate change on ENSO and PDO is unknown because more information is needed by the experts.

3.2 Hydrology

3.2.1 Refuge Hydrology

Siletz Bay NWR is located within the Siletz Bay estuary, which covers approximately 1,862 acres, including diked and filled lands, and has a watershed of about 373 square miles (Good 2000, Adamus et al. 2005). Estuarine influence extends inland about 23 miles but fluctuates considerably due to the geomorphology of this watershed (Oregon DSL 1989). Currently, the estuary contains a total of 623 acres of tidal and formerly tidal marshes and swamps (Brophy 2001). A comparison of 1850s historic vegetation with recent vegetation mapping by Brophy (2011) using Scranton (2004) and Hawes et al. (2008) indicates a 47% loss of tidal marsh and 84% loss of tidal swamp within the estuary.

The majority of the Refuge is composed of either intertidal, muted tidal, or diked tidal marshes draining into the Siletz River, Millport Slough, Drift Creek, or directly into Siletz Bay. Several diked freshwater wetland tracts within this Refuge have already gone through a restoration process to restore tidal flow to the lands. Other tracts experience varying degrees of muted tidal action mostly due to deterioration or abandonment of tidegates and other control/drainage structures. Excluding the Schooner Creek Tract, and parts of the Watson Tract above Drift Creek, the upland portions of Millport Slough South, and the Erickson/Schaffer Easement, most of the Refuge is within the boundary of the 100-year floodplain (FEMA 2009a, 2009b, 2009c).

Wetlands west of U.S. Highway 101 are largely intact, with natural tidal hydrology. However, old dikes located on the Siletz Keys parcel affect tidal exchange. A small tidal marsh restoration project on the Schnuelle Tract, located north of the mouth of Drift Creek and west of the highway, was completed in November 2000, returning tidal action to the site.

East of Highway 101 and on the south bank of the Siletz River, the 10-acre Schoen Tract contains a perimeter dike that prevents tidal flows except during extreme high tides. The Millport Slough marshes contain both natural and restored tidal marsh areas. The marsh to the north of Millport Slough is a relatively undisturbed tidal prairie with intact tidal hydrology (i.e., with highly sinuous, dendritic, deep, and steep-sided tidal channels). Millport Slough South is a tidal wetland that was diked and managed as pasture for many decades until dike failures occurred in the 1980s and 1990s. A restoration project was completed in late 2003 through a partnership with Ducks Unlimited and the Confederated Tribes of Siletz Indians. The restoration involved breaching 220 feet of dike, removing two dikes totaling 9,300 feet and filling 1,200 feet of artificial ditches. The western half had been subjected to muted tidal influence since water control structure failure in 1981.

Refuge lands in the Drift Creek area located on the east side of the highway are primarily muted tidal wetlands. Historically, this area was comprised of tidal marsh, and floodplain overflow areas. This and other adjoining parcels were diked and drained and converted to pastureland for grazing of livestock. A severe flood event in the late 1990s resulted in the complete loss of the water control structure on private land located adjacent to the southeast corner of the Shaffer Tract. Loss of the water control structure and subsequent breaches in the dikes adjacent to Drift Slough and along Drift Creek now allow significant but muted tidal flows on the property. The portion of the Watson Tract located south of the Drift Slough tidal channel and east of the refuge residence is also a diked tidal marsh with muted tidal flow. A tidegated culvert formerly existed at the northwest corner of the site. Upon failure, limited tidal flow restricted by to beaver dams now enters the site.

The Kangas Tract is located east of Highway 101, south of SE 64th Street, and west of South Drift Creek Road. Historically, this entire lowland area was tidally-influenced wetland; however, the area is now diked, ditched, and drained and until the mid-1990s was heavily grazed and hayed for cattle forage. The ditches on the property receive extremely muted tidal flows through a culvert under the highway and a failed tidegate located on private property. Beaver dams in the ditches and plugging of the Highway 101 culvert have caused water inundation on some parts of the property and flooding of private lands on the east side. In 2012, the Oregon Department of Transportation is planning to replace the culvert under Highway 101 with a much larger 12-foot-diameter box culvert. This size culvert will allow for future tidal restoration of the Kangas Tract.

The wetland within the Erickson/Schaffer Easement is a former tidal marsh that has been altered by construction of the Siletz River Highway (Highway 229) and placement of a tidegate in the culvert under the highway. In fall 2000, the tidegate was only partly functional (i.e., it did not close completely) and as a result, a brackish-water-tolerant Lyngby sedge community has become established in the west end of the wetland near the culvert. A strong pattern of remnant tidal channels exists on this wetland, particularly in the southeast third of the site (Brophy 2002). The major tidegate affecting this area is located on the adjoining private property on the north boundary.

Future Trends

While the refuge lands themselves currently receive the vast majority of their annual precipitation as rainfall, the watershed feeding the Siletz River currently receives substantial quantities of its annual precipitation as snow. One of the most important responses to warmer winter temperatures in the Pacific Northwest has been the loss of spring snowpack (Mote et al. 2005). Climate impacts on snow hydrology in the Pacific Northwest are particularly sensitive because total annual precipitation is highly concentrated in the winter months and the region includes a large amount of snow cover that accumulates at temperatures near 0°C; areas at greater risk to climate warming than cold climate snowpacks because temperature affects both precipitation phase (snow versus rain) and the rate of snowpack ablation (Nolin and Daly 2006). As temperatures rise, the likelihood of winter precipitation falling as rain rather than snow increases. Small increases in average winter temperatures can lead to increased rains, reduced snowpack, and earlier snowmelt.

Also, the changes in precipitation described in Section 3.1.3, above, foretell lower freshwater flows to the Refuge especially in the summer and fall months.

3.2.2 Tides and Salinity

The nearest National Ocean Survey tidal benchmark to Siletz Bay NWR is located in Depoe Bay, approximately 7 miles south. However, subordinate tidal stations with available predictions closer to the Refuge are available in Kernville and Taft. Additionally, tide gages placed at Millport Slough and Siletz Keys during 2007 to 2008 also provide local tidal datums. Tidal benchmark information for Depoe Bay for the 1983-2001 period and tidal datums calculated at Millport Slough and Siletz Keys are summarized in Table 3-6. Historic records of tides and water levels from the Depoe Bay, Kernville, and Taft tide stations are summarized in Table 3-7. Data for each station includes mean ranges, diurnal ranges, and the minimum and maximum water levels on record where available. The mean range is the difference in height between the mean high water and the mean low water. The diurnal range is the difference between the mean higher high water (MHHW) and the mean lower low water (MLLW) of each tidal day.

Tide water is brackish: more salty during the growing season, and more fresh during high winter river flows. Mean salinities recorded for the Siletz Bay estuary at the location nearest to the Refuge for January-March, April-June, July-September, and October-December are 1, 8, 22, and 22 parts per thousand (ppt) (Hamilton 1984). These measurements indicate that during winter and spring, the freshwater flow into the bay strongly limits the intrusion of marine water. Freshwater flow, measured at Siletz, is usually lowest in August and September and highest during December and January (USGS 2011).

Table 3-6. Tidal Benchmark Summary for Depoe Bay, Oregon, and Tidal Datum Summary for Millport Slough and Siletz Keys (NOAA 2011a, Brophy et al. 2011)

Station Information	Depoe Bay Sta. ID 9435827	Millport Slough (10/25/07-7/27/08)	Siletz Keys (07/2007-10/2007)	Siletz Keys (10/2007-06/2008)
Mean Higher High Water (MHHW) (ft)	8.24	7.68	7.23	7.90
Mean High Water (MHW) (ft)	7.53	7.00	N/A	7.23
Mean Tide Level (MTL) (ft)	4.45	N/A	N/A	N/A
Mean Sea Level (MSL) (ft)	4.42	N/A	N/A	N/A
Mean Low Water (MLW) (ft)	1.37	N/A	N/A	N/A
North American Vertical Datum 1988 (NAVD88)	0.63	0.00	0.00	0.00
Mean Lower Low Water (MLLW)	0.00	N/A	N/A	N/A

Table 3-7. Historic Tidal Data Summary for Depoe Bay, Kernville, and Taft, Oregon (NOAA 2011b, NOAA 2011c)

Station Information	Depoe Bay Sta. ID 9435827	Kernville Sta. ID 9436031	Taft Sta. ID 9436101
Mean Range (ft)	6.16	4.6	5.0
Diurnal Range (ft)	8.24	6.1	6.6
Mean Tide Level (MTL) (ft)	4.45	3.1	3.4
Minimum Water Level (ft below MLLW)	-3.33 (05/24/1982)	N/A	N/A
Maximum Water Level (ft above MLLW)	12.22 (01/26/1983)	N/A	N/A

Future Trends

It is anticipated that the warming of Oregon's temperate climate will contribute to fundamental changes along the coast, including but not limited to shifts in the timing and intensity of coastal storms, changes in precipitation and the delivery of freshwater inputs, sea level rise, and increased inundation of the shallow tidal basins. Regional coastal climate change may also result in changes in the intensity and timing of coastal upwelling, shifts in temperatures and dissolved oxygen concentrations, and alteration of the carbonate chemistry of nearshore waters. The combination of these changes will alter chemical concentrations in estuaries (Ruggiero et al. 2010). As a moderately river-dominated drowned river mouth estuary (Lee and Brown 2009), the Siletz Bay estuary may experience changes in the salinity regime in response to changes in precipitation and snow melt in the watershed (resulting in changes in freshwater inflows) and increased intrusion of seawater associated with rising sea levels. However, the effect of climate change on estuarine salinity will vary with location inside the estuary and the magnitude of the relative sea level rise rate in the vicinity of the estuary.

3.2.3 Sea Level Rise

Sea level rise on the Oregon coast is the result of three major forces: global mean sea level rise driven by the melting of land-based ice, local dynamical sea level rise driven by changes in wind which pushes coastal waters toward or away from shore, and localized vertical land movements driven primarily by tectonic forces (Mote et al. 2008, McKay et al. 2011). Mean sea level is defined as the average sea level over a 19-year period, above which other fluctuations (e.g., tides, storm surges, etc.) occur (Smerling et al. 2005). Global mean sea level rise has been in the range of 1.3 to 2.3 millimeters (0.05 to 0.09 inch) per year between 1961 and 2003 (IPCC 2007a). But since 1993 the rate has increased about 50% above the 20th century rise rate to 3 millimeters (0.12 inch) per year (Bromirski et al. 2011) and the latest global satellite sea level observations measure a rate of 3.19 millimeters (0.13 inch) per year (NASA 2012). This acceleration is primarily the result of ice field and glacier melt-off (McKay et al. 2011). For example, the total global ice mass lost from Greenland, Antarctica, and Earth's glaciers and ice caps between 2003 and 2010 was about 4.3 trillion tons (1,000 cubic miles), adding about 0.5 inch (12 millimeters) to global sea level in a seven-year period (Jacob et al. 2012).

Based on monthly mean sea level data from 1967 to 2006, the mean sea level trend at South Beach, Oregon, located approximately 19 miles south of the Refuge, is 2.72 millimeters/year with a 95% confidence interval of ±1.03 millimeters/year. This is equivalent to a change of approximately +0.89 feet per century (NOAA 2011d).

Future Trends

The IPCC Special Report on Emissions Scenarios (SRES) forecasts that global sea level will increase by approximately 12 inches (30 centimeters) to 39 inches (100 centimeters) by 2100 (IPCC 2001). However, more recent analyses (Chen et al. 2006, Monaghan et al. 2006) indicate that the eustatic rise in sea levels is progressing more rapidly than was previously assumed, perhaps due to the dynamic changes in ice flow omitted within the IPCC report's calculations. Vermeer and Rahmstorf (2009) suggest that, taking into account possible model error, a feasible range by 2100 might be 30 inches (75 centimeters) to 75 inches (190 centimeters) (Vermeer and Rahmstorf 2009).

Tebaldi et al. (2012) show that even seemingly low increases in sea level will have significant impacts in the short term when storm surges are taken into account. An analysis of historic data combined with future projections of sea level rise is used to estimate future return periods for what today are considered 50-year and 100-year events. This magnifies sea level rise by a factor of five, on average, and dramatically increases the occurrence, or return periods, of storm surge events. The closest area to the Refuge that was analyzed is the South Beach tide gauge in Newport. The return period for storm surges currently qualifying as 100-year events is projected to change to every 5 years at this site by 2050. The analysis shows that 50-year storm surges events are projected to increase by approximately 52 inches at the tide gauge, and 100-year storm surges events are projected to increase approximately 54 inches.

Rising sea levels may result in tidal marsh submergence (Moorhead and Brinson 1995) and habitat migration as salt marshes transgress landward and replace tidal freshwater and brackish marsh (Park et al. 1991). Changes in tidal marsh area and habitat type in response to sea level rise were modeled using the Sea Level Affecting Marshes Model (SLAMM 6), which accounts for the dominant processes involved in wetland conversion and shoreline modifications during long-term sea level rise (Park et al. 1989, Clough et al. 2010, Clough and Larson 2010). Within SLAMM, there are five primary processes that affect wetland fate under different scenarios of sea level rise: inundation, erosion, overwash, saturation, and accretion. There are currently several active projects involving the use of SLAMM 6 to estimate the impacts of sea level rise on the coasts of the Pacific Northwest (e.g., Glick et al. 2007).

For Siletz Bay NWR, SLAMM 6 was run using mean and maximum estimates from scenario A1B from the SRES. Under the A1B scenario, the IPCC AR4 (IPCC 2007a) suggests a likely range of 0.21 to 0.48 meters of sea level rise by 2090-2099 "excluding future rapid dynamical changes in ice flow." The A1B-mean scenario that was run as a part of this project falls near the middle of this estimated range, predicting 0.40 meters of global sea level rise by 2100. The A1B-maximum scenario predicts 0.69 meters of sea level rise by 2100. To allow for flexibility when interpreting the results, SLAMM was also run assuming 1 meter (3.28 feet), 1.5 meters (4.92 feet), and 2 meters (6.56 feet) of eustatic sea level rise by the year 2100. Pfeffer et al. (2008) suggests that 2 meters (6.56 feet) by 2100 is at the upper end of plausible scenarios due to physical limitations on glaciological conditions. Model results through 2025 for Siletz Bay NWR under several sea level rise scenarios where the dikes would not continue to be maintained or raised and thus subjected to inundation, are presented in Table 3-8 (Clough and Larson 2010, So et al. 2011). All model results are subject to uncertainty due to limitations in input data, incomplete knowledge about factors that control the behavior of the system being modeled, and simplifications of the system.

Table 3-8. Predicted Change in Acreage of Land Categories at Siletz Bay NWR by 2025 Given SLAMM Modeled Scenarios of Sea Level Rise (Clough and Larson 2010, So et al. 2011)

		Sea Level Rise Scenarios				
	Initial Condition	A1B Mean (.39 meter [1.28 feet] by 2100)	A1B Maximum (.69 meter [2.3 feet] by 2100)	1 meter (3.28 feet) by 2100	1.5 meters (4.92 feet) by 2100	2 meters (6.56 feet) by 2100
Tidal Flat	715.8	716.1	716.2	716.3	716.5	716.8
Undeveloped Dry Land	395.6	355.6	352.1	348.1	342.0	335.4
Regularly Flooded Marsh	280.6	296.1	298.2	301.7	309.9	322.8
Estuarine Open Water	261.3	260.4	260.4	260.5	260.5	260.5
Irregularly Flooded Marsh	234.6	235.3	236.1	237.0	237.9	238.2
Inland Fresh Marsh	62.4	41.6	38.0	33.0	25.6	21.5
Tidal Swamp	18.1	15.9	14.8	13.6	12.1	11.1
Developed Dry Land	15.3	14.3	14.2	14.2	14.1	14.0
Ocean Beach	10.3	10.3	10.4	10.4	6.6	2.4
Transitional Salt Marsh	5.1	50.1	55.3	61.0	66.5	64.9
Estuarine Beach	1.1	3.7	3.7	3.8	3.8	3.9
Inland Open Water	1.1	0.6	0.6	0.6	0.6	0.6
Swamp	0.7	0.7	0.7	0.7	0.7	0.7
Inland Shore	0.2	0.2	0.2	0.2	0.2	0.2
Open Ocean	0.0	1.4	1.4	1.5	5.4	9.6

For example, mineral sedimentation rates and organic matter (vegetative) accretion rates need to be taken into account for inland marine influenced ecosystems such as the Refuge's marshes. Nyman et al. (2006) find that the vegetative component is the more significant of the two factors (i.e., accretion varied with organic accumulation rather than mineral sedimentation). Salt-marsh accretion rate was investigated by Thom (1992) at six sites that spanned a gradient in relative rate of sea level rise in Washington and Oregon. Mean accretion rate over all sites was found to be 3.6 millimeters (0.14 inch) per year (95% confidence interval = 2.4 to 4.8 millimeters [0.09 to 0.19 inch] per year). However, marsh accretion rates specific to Siletz Bay taking in both mineral and organic sources have not yet been measured.

3.3 Ocean Chemistry

The ocean will eventually absorb most carbon dioxide released into the atmosphere as a result of the burning of fossil fuels and other sources. Current rates of carbon dioxide emissions are causing and an increase in the acidity of ocean surface waters and a decrease the saturation of calcium carbonate ($CaCO_3$), a compound necessary for most marine organisms' development of shells and skeletons (Hönisch et al. 2012). Oceanic absorption of CO_2 from fossil fuels may result in larger acidification changes over the next several centuries than any inferred from the geological record of the past 300 million years (with the possible exception of those resulting from rare, extreme events such as meteor impacts). In the past 300 million years, three analogous ocean acidification events have been identified and these events coincided with mass extinctions of marine organisms, however it should be noted that warming and corresponding oxygen depletion co-occurred during these events and contributed to the extinctions (Hönisch et al. 2012).

Virtually every major biological function of marine organisms has been shown to respond to acidification changes in seawater, including photosynthesis, respiration rate, growth rates, calcification rates, reproduction, and recruitment. Much of the attention has focused on carbonate-based animals and plants which form the foundation of our marine ecosystems. An increase in ocean acidity has been shown to impact shell-forming marine organisms from plankton to benthic mollusks, echinoderms, and corals (Doney et al. 2009). Many calcifying species exhibit reduced calcification and growth rates in laboratory experiments under high-CO_2 conditions. Ocean acidification also causes an increase in carbon fixation rates in some photosynthetic organisms (both calcifying and noncalcifying) (Doney et al. 2009, Smith and Baker 2008, and Ocean Carbon and Biogeochemistry Program 2008). These potential impacts to the marine food web may obviously negatively affect refuge resources such as seabirds, shorebirds and salmonids. Localized acidification rates within Siletz Bay have not been evaluated.

3.4 Topography and Bathymetry

With the exceptions of the Schooner Creek Tract, and parts of the Watson Tract above Drift Creek and Erickson/Schaffer Easement, the topography of the Siletz Bay NWR does not vary significantly and is largely flat, with most areas below 12.0 feet North American Vertical Datum 1988 (NAVD88) in elevation (OLC 2010). The majority of the Refuge is composed of either intertidal, muted tidal, or diked tidal marshes draining into Siletz Bay, the Siletz River, Millport Slough, or Drift Creek. Elevations of the marsh surfaces typically range between 8.0 to 9.0 feet NAVD88; however the diked or formerly diked areas of the Millport Slough, Drift Creek, and Kangas Tract areas, as well as the Erickson/Schaffer Easement likely experienced variable amounts of subsidence. The highest elevations within the Refuge occur within the Schooner Creek Tract at around 250.66 feet NAVD88. The forested areas within the Watson Tract and the Erickson/Schaffer Easement also reach over 200 feet NAVD88.

3.5 Geology and Geomorphology

3.5.1 Tectonic Context

The Oregon coast is located on the western margin of the North American continental plate near its junction with the Juan de Fuca plate, a section of denser oceanic crust. Where the latter plate moves eastward and collides with the North American plate, it slides underneath and descends into the earth's mantle in an area known as the Cascadia Subduction Zone (Orr et al. 1992, Nelson et al. 1995). Although the subduction process is very gradual, proceeding at a relative velocity of 4 centimeters (1.12 inches) per year, the massive forces that drive the converging plates cause strain to accumulate at the edge of the North American plate (Douglas 1991). Over time, the accumulation of strain causes the edge of the continental plate to bend and rise in elevation in a process known as uplift. Periodically, this strain is released during an earthquake and the edge of the North American plate rapidly drops downwards, suddenly lowering the coastline, and correspondingly raising the relative sea level. The elevation drop which occurs during an earthquake is termed subsidence. These processes of regional plate tectonics have had substantial influence in shaping the physical features and geographic characteristics of the Oregon coast.

3.5.2 Geologic and Geomorphologic Overview

Siletz Bay NWR is within the Coastal Range physiographic province described by Orr et al. (1992). The Coast Range, a long narrow belt of moderately high mountains and coastal headlands, extends southward from the Columbia River to approximately the middle fork of the Coquille River, and inland from the continental shelf and slope to the western edge of the Willamette Valley. Over 200 miles long, and 30 to 60 miles wide, the province averages 1,500 feet in altitude with a maximum elevation of 4,097 feet at Mary's Peak.

The Coast Range has its origins in accreted oceanic sediments born from volcanic activity approximately 64 million years ago. These Roseburg volcanics in the southern portions of the range were followed by the Siletz River and Tillamook volcanics in the northern portions of the range, formed mostly during the Paleocene to middle Eocene (about 60 to 45 million years ago). Deposited with these volcanics but also overlying them and intruded by them is a regionally extensive marine sandstone and siltstone commonly referred to as the Tyee Formation. Successively younger deposits of sediments and volcanics are found to the east of the Coast Range and along the coast. During the Oligocene (-25 million years ago), uplift of sedimentary basins in Oregon resulted in the westward migration of the coastline from as far east as Idaho towards the present position. As the western edge of the North American plate was uplifted by pressure from the subducting Juan de Fuca plate, a series of basalt flows from fissures in eastern Oregon began to reach the coast. During the Miocene, Columbia River lavas invaded the northern coastal area. By the Pliocene, the current coastline was approximately in place and rivers continued to cut deep valleys through igneous and sedimentary rocks.

Subduction of the Juan de Fuca plate under North America is continuing to push the Coast Range upwards, albeit at varying rates along the coast. For example, Cape Blanco is being uplifted at a rate of 1 inch every 3 years while Astoria is only being uplifted at a rate of 1 inch every 36 years (Orr et al. 1992). The last great (moment magnitude >8) Cascadia Subduction Zone earthquake occurred on January 26, 1700 (Atwater et al. 2005). Hazard estimates, based on the magnitude-9 earthquakes, had set the recurrence interval at about 500 years, with a 10-15% chance of another in the next 50 years.

However, Goldfinger et al. (2010) determined an average recurrence interval of about 240 years, leading to a 37% probability of a great earthquake occurring somewhere along the Cascadia fault in the next 50 years.

The Alsea Formation, a marine siltstone and very fine-grained sandstone stratum uplifted during the Oligocene, underlies the Schooner Creek Tract and the upland areas of the Watson Tract and Erickson/Schaffer Easement. Excluding the upland areas of the Refuge overlaying Oligocene sedimentary rock, the remainder was formed during the Holocene (12,000 years ago to present) following series of sea level rise, subsidence, and uplift events.

Considered a "drowned river" estuary, the Siletz Bay estuary formed when melting glaciers at the end of the most recent ice age caused global and regional sea level rise. The remnant river mouth was then submerged and over time infilled with sediment. Infilling of the estuary and marsh development occurs as runoff from precipitation washes sediments from slopes into streams or their flood plains. These sediments are then transported downstream to the estuary where they settle and become influenced by tides (Simenstad 1983). Most of the present-day Refuge is located on this alluvium, which is predominantly composed of mixtures of sand, silt, clay, and organic matter (Schlicker et al. 1973, Snavely et al. 1976). Much of the coarser sediment settles out near the banks of the river, forming natural levees. The finer materials such as fine sands and clayey silts remain suspended longer and settle throughout the intertidal zone and flooded lowlands. Additionally, sediments are moved into the lower estuary from the ocean shore by tsunamis, storm surges, and dune building.

3.6 Soils

With the exception of some soils formed from the weathering of Oligocene age sedimentary rock in the forested upland areas near Schooner Creek, Drift Creek, and the Erickson/Schaffer Easement, the majority of the Refuge is primarily overlain with alluvium deposited after the last glacial period (Snavely et al. 1976, USDA 1997).

The principal soil type in both the diked and undiked tidal marsh areas of the Refuge is Coquille silt loam (0 to 1 percent slopes). Coquille silt loam is a deep, poorly drained soil formed in silty recent alluvium derived from mixed sources with slow permeability and water capacity of about 11 to 13 inches. The effective rooting depth is more than 60 inches but is limited by a seasonal high water table 2 feet above to 2 feet below the surface throughout the year. This soil is frequently flooded for brief periods throughout the year.

The soil types underlying the forested uplands of the Schooner Creek, Drift Creek, and Millport Slough South areas, and the Erickson/Schaffer Easement are primarily Fendall-Templeton silt loams (45 percent Fendall soil, 35 percent Templeton soil, 35 to 60 percent slopes) and Templeton-Fendall silt loams (55 percent Templeton soil, 30 percent Fendall soil, 5 to 35 percent slopes). The Fendall-Templeton silt loam is found on the side slopes while the Templeton-Fendall silt loam is found on the broad top. Both Fendall and Templeton soils are formed in colluviums weathered from sedimentary rock. The Fendall soil is moderately deep and well drained. Permeability is moderately slow and available water capacity is 4 to 10 inches. The Templeton soil is deep and well drained. Permeability is moderate and available water capacity is 8 to 16 inches. The native vegetation on both of these soil types is mainly western hemlock, Sitka spruce, Douglas-fir, red alder, salal, salmonberry, thimbleberry, red huckleberry, evergreen huckleberry, and western swordfern.

The northeastern-most section of the Schooner Creek Tract adjacent to SE 54th Drive is underlain with Gleneden silty clay loam (2 to 12 percent slopes). This soil type is deep, somewhat poorly drained, and formed on marine terraces in clayey alluvium derived from mixed sources. Permeability is slow and available water capacity is 8 to 10 inches.

3.7 Fire

3.7.1 Pre-settlement Fire History

There is little published information available describing the specific historic role of fire on lands that are now within Siletz Bay NWR. Wildland fires on the Oregon coast have always been infrequent and do not exhibit any predictable cycle. The forested Refuge areas are dominated by Sitka spruce and located in the "near coastal zone" where climatic conditions limit the frequency and intensity of naturally occurring fires. The limited data available indicate that fires in this zone were very infrequent and tended to burn wide areas but only under very rare, extremely dry and windy conditions in late summer and fall. In the tidal and freshwater marsh ecosystems that comprise much of the Refuge, fire was likely very infrequent. However, Native Americans in the Siletz Bay area are thought to have set fires to create habitat for game animals and to promote the growth of weaving materials and food.

3.7.2 Post-settlement Fire History

The only recorded large fires in post-settlement times were the Siletz Fire (800,000 acres) and the Yaquina Fire (estimated 500,000 acres), both in the mid to late 1800s. Both of these catastrophic fires were thought to have been set by settlers to clear land for other purposes.

The normal fire season recognized by the U.S. Forest Service and the Oregon Department of Forestry (ODF) Toledo District is June 1 to September 30. There have been no recorded fires on or near Siletz Bay refuge lands in the past 10 years.

Under the current refuge fire management plan, guidelines for appropriate wildland fire suppression, hazard fuel reduction, and pile burning are detailed. Mechanical treatment may be used as a fire management strategy for hazard fuels reduction. Pile burning as a limited prescribed fire technique may be used to reduce hazard fuels; however, no prescribed burning has been conducted on the Refuge. Typical "prescribed fire season" is fall and spring and is weather-dependent. Pile burning can occur year-round depending on weather conditions and restrictions placed by the Oregon Smoke Management Plan. There is no formally established "prescribed burning season" as any domestic pile or barrel burning is allowed all year contingent on weather conditions. Larger scale burning such as forestry slash burning requires a permit and a pre-burn inspection by ODF. Lincoln City has permanently banned all outdoor burning within the Lincoln City Fire District.

3.8 Environmental Contaminants

3.8.1 Air Quality

The Oregon Department of Environmental Quality (ODEQ) does not have any ambient air quality monitoring stations located on the Oregon Coast. The majority of ODEQ's air quality monitoring stations are located within the interior valleys between the Coast and Cascade Mountain Ranges where the majority of Oregon's population resides. The lack of ambient air quality monitoring on the Oregon Coast makes it difficult to assess baseline air quality conditions.

Siletz Bay NWR is located within the Oregon Coast Airshed, which is generally well mixed year-round due to the influence of the Pacific Ocean. Low pressure systems move through the airshed throughout the year and usually bring wind, clouds, and rain. The intensity and frequency of these low pressure systems increases during the fall through winter resulting in sometimes very rainy and windy conditions. In between these low pressure systems high pressure systems move in resulting in drying trends. High pressure systems generally dominant the airshed during late spring, summer, and early fall. Coastal fog due to inland heating is common during the summer months. In general, the Oregon Coast Airshed remains relatively unstable resulting in a well-mixed airshed with suspected good air quality.

Locally, air quality may be affected by various activities on and adjacent to the Refuge including: marine vessels, automobiles, and other human caused activities such as outdoor burning, wood stoves, and operation of various vehicles and machines (e.g., gasoline/diesel powered equipment, motorboats). The refuge staff uses various types of equipment and transportation methods to achieve the refuge habitat conservation projects, monitoring and research. Habitat improvement projects and daily monitoring activities may include the use of tractors, heavy equipment and/or the operation of trucks, boats, or other vehicles.

3.8.2 Water Quality and Contaminants

No areas within the Refuge are currently considered contaminated and there are few existing contaminant threats. However, the Refuge is in an estuary, which could be exposed to upriver, as well as ocean contaminant sources. The watershed contains large areas of private commercial forest land where chemical herbicides are heavily used and could be transported to the Refuge via surface water. If a large coastal oil spill occurred in the vicinity of the Refuge, the estuary could be contaminated with material carried in with the tide. In addition, U.S. Highway 101 runs through the Refuge and could be a source for a spill or pollution resulting from an auto accident. Lincoln City, north of the Refuge, could be a source for pollutant entering into the Bay.

A state is required to identify waters that do not meet that state's water quality standards under Section 303(d) of the Clean Water Act (CWA). These waters are considered "water quality limited" and placed on the state's 303(d) impaired waters list. Section 303(d) requires the state to develop Total Maximum Daily Loads (TMDLs) for impaired waterbodies. TMDLs are the amount of each pollutant a waterbody can receive and not exceed water quality standards. Water quality standards for Oregon include beneficial uses, narrative and numeric criteria, and antidegradation policies. The Oregon Department of Environmental Quality (ODEQ) lists impaired water segments by designated fish uses; therefore, entire tributaries can be listed after one assessment event. Parameters included in the assessment are aquatic weeds or algae, bacteria (E. coli), bacteria (fecal coliform), biological criteria, chlorophyll a, dissolved oxygen, pH, sedimentation, temperature, total dissolved gas, toxic substances, and turbidity.

No waters within the Siletz Bay NWR boundary were listed as impaired because these waters have not been assessed under the CWA. However, temperature was reported as significantly impaired on Siletz River and Drift Creek adjacent to the Refuge in the 2002 and 2004/2006 303(d) reporting cycles. This impairment affects the beneficial uses of anadromous fish passage, and salmonid fish rearing (ODEQ 2011). Turbidity was added as a significant impairment to Siletz River in Oregon's

2010 Section 303(d) List of Category 5 Water Quality Limited Waters Needing a TMDL submitted by ODEQ to EPA for review and approval in January 2011. Turbidity affects the beneficial uses of drinking water and water supply (ODEQ 2011). Additionally, municipal sources discharge into streams eventually draining into the Siletz Bay NWR. These discharges operate under NPDES permits containing effluent limitations which reflect State water quality standards and monitoring requirements. ODEQ has initiated (initial scoping and data collection phase) a TMDL in the Siletz-Yaquina subbasin.

Climate change has the potential to cause water quality impairments including possible effects on estuarine water temperature, salinity, dissolved oxygen, nutrients, chlorophyll a, bacterial contamination, and carbonate chemistry (Ruggiero et al. 2010).

3.9 Surrounding Land Use

The Refuge is bordered by Lincoln City to the north and is located within Lincoln County, Oregon. Most of the Refuge, with the exception of the Schooner Creek Tract, falls outside of City limits. Urban zoning around the Refuge is limited to the Taft, Cutler City, and south Lincoln City area. Rural residential areas are scattered along the Siletz River near the town of Siletz, and along lower Drift and Schooner Creeks. Residences also line Salishan Spit and are adjacent to the Refuge at the Siletz Keys. The Schooner Creek Tract is located immediately north of a small group of residences, and the road comprising its north and west boundary leads to the city sewage treatment plant. Immonen Road, which leads into the Millport Slough area, has several structures located at the beginning of the road, as well as a pottery shop and glass blowing studio on the bayside of the road. The Schaffer easement is located along the Kernville Highway, and has several privately-owned structures located just outside of the southern tip of the easement. There is also an inholding with a cluster of residences and outbuildings located downhill from the east boundary of the easement, surrounded by mixed Douglas-fir woodland. The Salishan Spa and Golf Resort is located south of the Refuge.

The vast majority of the County is zoned for Forestry use. About 60 percent of the commercial forest is privately owned. The rest is publicly owned and is administered mainly by the U.S. Forest Service, Bureau of Land Management, and Bureau of Indian Affairs and by the State of Oregon. Agriculture use areas are primarily located along the mainstem Siletz River from Moonshine Park downstream to the estuary, and along lower Drift Creek and Schooner Creek. Farming primarily consists of livestock grazing and forage production.

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