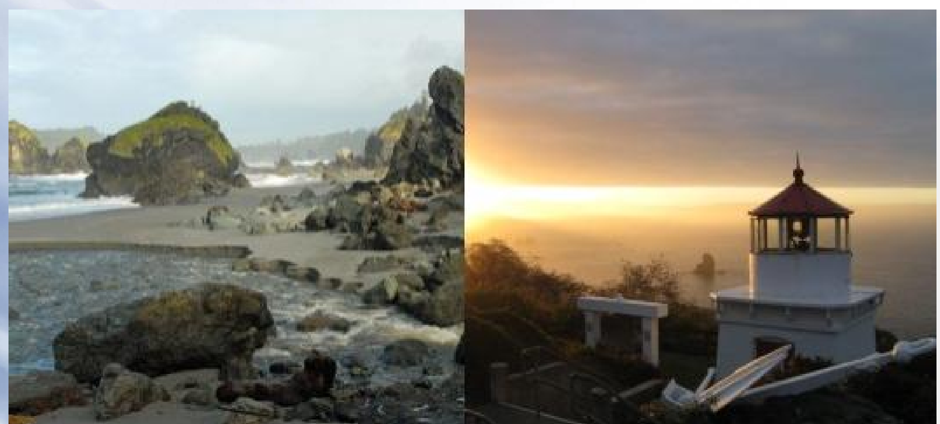

City of Trinidad

Draft Climate Change Vulnerability Report and Adaptation Response

April 2016

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1. Introduction

1.1 Purpose of this report

The intent of this document is to present to the City of Trinidad (City) some of the potential effects that could result from climate change, determine the resulting areas at risk relevant to the City, and identify some preliminary adaptation strategies that could be used to help mitigate the effects identified. With this information, the City can move forward in their planning, mitigation, and development efforts with a better understanding of where they are at risk. This document is also intended to act as a compliment to the Local Coastal Program (LCP) update, which the City is currently undertaking.

1.2 Scope and Limitations

This report is not intended to develop or present any new scientific information on climate change or its effects within the region. This report will act as a review of the available science on climate change that is relevant to the Humboldt Country coastal region. The analysis of potential impacts is based on a qualitative approach from the available literature; no modelling was performed as part of this report.

1.3 Project Background

Trinidad is a small coastal community located in Humboldt County, California approximately 20 miles north of Eureka. See Figure 1 (Streamline Planning, 2009) for a general map of the project vicinity. Trinidad has a population of approximately 370 residents. The City's principle economy is based on tourism, recreation, and fishing.

As seen in Figure 1, the City is located adjacent to the Pacific Ocean. Despite its proximity to the ocean, the City's primary infrastructure is located at an elevation of approximately 170 feet mean sea level, a result of the steep coastal bluffs surrounding the south and west portions of the city limits. The geology underlying the City is a fine sand aquifer with high permeability, which is underlain by Franciscan mélange bedrock. The City is bound at the north and east portions by Highway 101, Mill Creek, and Parker Creek. Much of the undeveloped terrain both coastally and inland is temperate rain forest.

1.3.1 Climate

Trinidad has a mild Mediterranean climate, where most of the precipitation occurs between November and April. The average annual rainfall is approximately 50 inches. Average annual temperatures range between 40- and 60 degrees Fahrenheit (°F).

1.3.2 Utilities

The City provides potable water to customers through approximately 315 connections. The source water comes from Luffenholtz Creek, with the point of diversion and treatment located approximately 1.5 miles southeast of the City (Figure 1). The diverted water from the creek undergoes treatment to reduce turbidity, adjust pH, and is then chlorinated prior to entry into storage or the distributions system.

The City has a network of stormwater infrastructure. The City's historical stormwater system collected runoff through conventional storm water drop inlets. Once collected, the water was conveyed through a network of storm sewers that outfalls to Trinidad Bay. Trinidad Bay has been designated as an Area of Special Biological Significance (ASBS), and as such the law states that non-point source discharge be controlled to the extent practical. To address this issue, the City recently completed the initial phase of a project where two areas of the traditional stormwater infrastructure were converted into onsite infiltration chambers preceded by stormwater treatment units. Subsequent phases of this project are in the planning phases, with the continued goal of converting the conventional stormwater outfall system into stormwater treatment and infiltration systems.

Due to the City's small size, all wastewater is dealt with onsite through individual septic systems; there is no centralized wastewater treatment.

1.3.3 Land Use

Land use within the City limits primarily residential. Other use types include open space, harbor, public and community, mixed use, commercial, visitor services, and special environment. See Figure 1 below for how these uses are distributed throughout the City.

1.4 Climate Change Projection vs Planning Horizons

An important consideration when comparing or analyzing data for planning purposes is the relative timeline of the information. General Plans and projects have typical lifetimes of 20- and 50-years, respectively. Some climate change projections are available on an annual scale; however, some are only published or available for discrete points in time, most commonly for the years 2050 and 2100.

When available, climate change projections in this report will include the years 2035 and 2065, the end years for the General Plan period and project lifetimes stated above, respectively. If climate change projections are unavailable for these years they will be presented for the years available, with the intention of providing some insight into the projections that have been developed for the greater Humboldt County area.

1.5 Analysis Methodology/Report Structure

To analyze the potential impacts of climate change and determine subsequent areas of risk for the City of Trinidad, a methodology was developed based on the guidance document from the California Coastal Commission (CCC) titled *Sea Level Rise Policy Guidance* (Appendix C). Although principally developed for helping coastal communities plan for sea level rise, this methodology is relevant for looking at a host of issues involving climate change, including but not limited to:

1. Gathering and review of regionally relevant climate change data;
2. Determining likely climate change effects and magnitudes within the study area;
3. Conducting a preliminary risk assessment for current and future developments and land uses based on the identified climate change effects; and
4. Identifying adaptation strategies to help mitigate climate change effects.

In this report, Section 2 presents a brief overview to add background and context to the relevant effects of climate change and how they are predicted. Section 3 presents the results from data

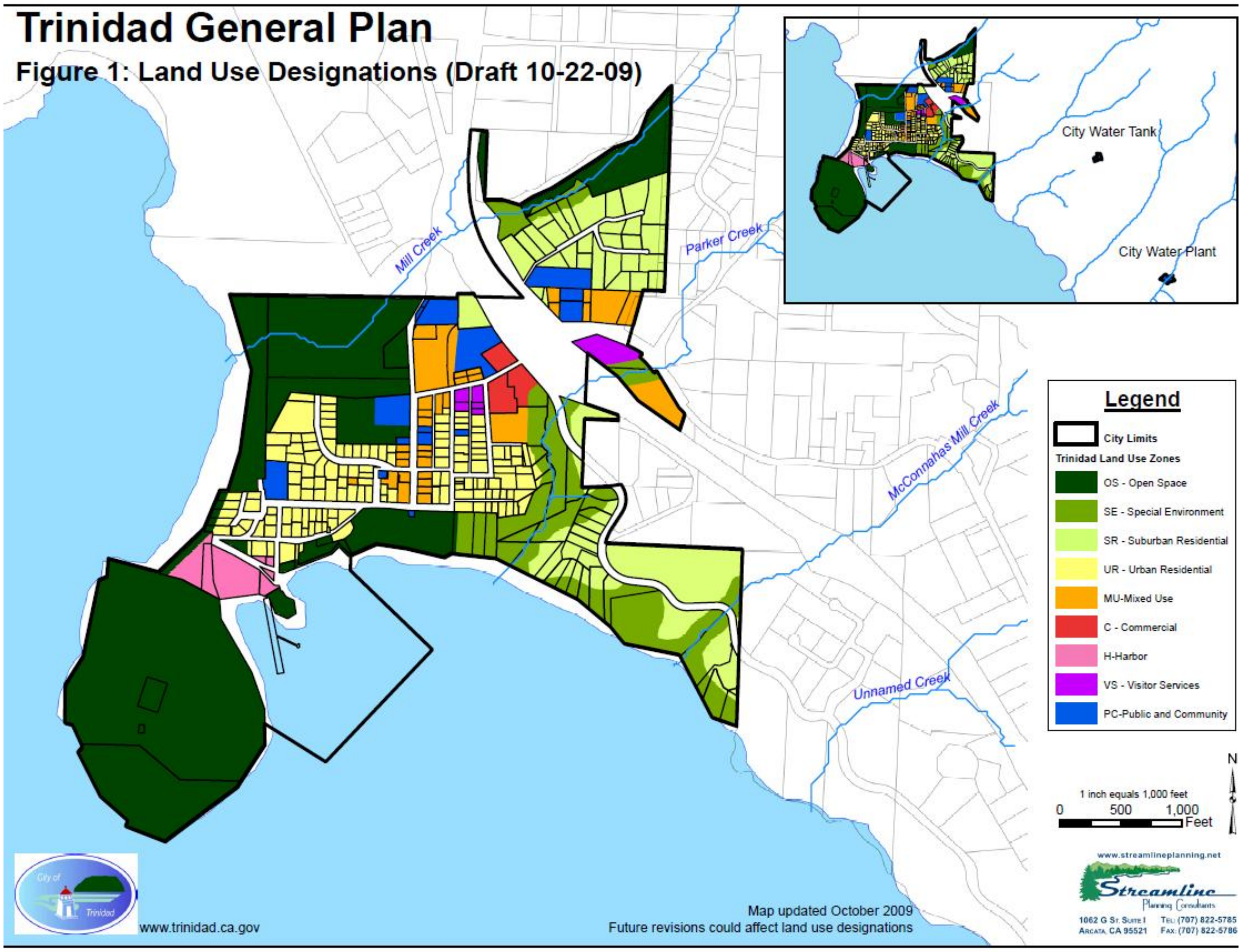

Figure 1. Trinidad land use map (Streamline Planning, 2009).

gathering efforts relevant to the City, including the potential magnitudes for each identified effect. Section 4 uses the effects identified in Section 3 to conduct a preliminary risk assessment to determine what portions of the Trinidad area are susceptible to climate change. Lastly, Section 5 presents a preliminary list of climate change adaptation measures that could be used to mitigate the effects of climate change moving forward.

2. Climate Change Overview

The term climate change refers to a shift in what is considered normal climactic behavior, persisting for several decades or longer. Commonly forecasted changes include increases in global temperature, often referred to as global warming, and changes in wind and precipitation patterns. The magnitude of these changes will primarily depend on future human-induced greenhouse gas emissions and the natural influences of climate change, which include patterns of solar intensity and volcanism (EPA, 2015). As a result of climate change there are a number of forecasted adverse physical effects, the primary of which are discussed below.

2.1 Physical Effects

2.1.1 Global Warming

The global temperature increase that has been documented over the past century is commonly referred to as global warming. Global warming is often considered the catalyst to all other potential outcomes of climate change.

Global warming in part is a result of increased greenhouse gas emissions, which is in large part a result of energy consumption. Primarily generated from the combustion of fossil fuels, gasses such as methane and carbon dioxide accumulate in the upper layers of the earth's atmosphere, effectively creating a layer that acts as a thermal insulator over the planet. This insulator traps energy from the sun, resulting in a net warming of the planet due to reduced energy dissipation.

2.1.2 Sea Level Rise

Sea level rise is the increase in global mean sea level (MSL). Sea level rise is primarily a result of global warming, and has a number of components that contribute to rising sea levels. These components include global factors such as higher melt rates from land and sea ice formations, thermal expansion of sea water due to increased ocean temperatures, and local factors such as storm surges from changing weather patterns.

Another phenomena contributing to the magnitude of sea level rise that is not related to climate change is the tectonics of coastal areas, more specifically the rise or fall of shoreline levels resulting from plate submergence or subsidence. When paired with the effects of rising sea levels noted above, this tandem action is collectively termed relative sea level rise, which in some areas results in increased rates of sea level rise and in other areas results in sea level decline.

Sea level rise can result in many effects to the human and natural environment including damage to structures, bluff erosion, and habitat loss.

2.1.3 Precipitation

As a result of global warming and subsequent changes in wind patterns, there is likely going to be a shift in how and where precipitation will occur. Although there is still some uncertainty as to how precipitation will change on a smaller scale, most current climate modeling suggests that precipitation will increase towards the earth's poles and decrease in areas closer to the equator. On average, the total global precipitation is increasing- largely a result of increased evaporation due to rising global temperatures. The EPA reports that in the United States, high intensity precipitation events are likely to become more frequent, even in southern areas that are projected to receive decreased amounts of rainfall moving forward.

Changes in precipitation have a wide variety of potential effects on both the human and natural environment. In areas that will receive decreased precipitation, or a decrease in the amount of precipitation falling as snow, water supply volume and reliability issues are of increased importance. Areas that will receive increased precipitation could be affected by higher flooding levels and increased erosion.

Another precipitation-related climate change effect relevant to California is the potential change of coastal fog patterns. Changing ocean, air, and earth temperatures will likely alter the timing, frequency, and duration of coastal fog. Fog is important in many areas, and among several positive outcomes provides natural cooling, decreased evapotranspiration, and more productive ecosystems.

2.1.4 Wildfire

Wildfires typically happen in forested areas that become sufficiently dry during the summer and fall months. With increasing global temperatures and in many places potentially lower precipitation, wildfire occurrences and magnitude are likely to increase moving forward.

Although wildfires are more common to warmer, drier climates, they can also occur in coastal temperate environments. From a risk perspective, areas typically not prone to fire are the areas that will be most subject to increase in relative wildfire risk, as many of these areas have not been subject to frequent burns in the past, and therefore have a large availability of combustible fuels.

According to CAL FIRE, the area surrounding Trinidad is at fire risk. Approximately 32% of the surrounding area is zoned “Moderate” for fire hazard severity, with the remaining 68% zoned “High” fire hazard severity. The Trinidad area has had wildfires in the past, including the A-Line Fire (1936) that burned 1,628 acres and the Luffenholtz Fire (1908) that burned 690 acres.

Wildfires pose significant threat to the human environment. They can burn homes, businesses, and infrastructure which can displace large numbers of people and result in tremendous economic losses for local communities. Even after large fires are put out, burn areas are prone to increased erosion, landslides, and runoff generation; all of which can lead to reductions in water quality to receiving areas downstream.

2.2 Climate Change Modeling

Climate change science is in large part forecasted using General Circulation Models (GCMs), which are meant to analyse and predict the potential impact of climate change on a global scale. GCMs are mathematical models, which subdivide the Earth into discrete sections wherein the physical relationships of energy and mass can be characterized. These models take into account the interactions between the atmosphere, oceans, land, and ice to create weather and climate predictions over various timeframes, most commonly on the decadal or century scale.

There are many different climate models that have been used in an effort to predict climate change. As might be anticipated, these models produce ranges of results that are not always in agreement with one another. It is common practice for predictions presented using climate models to take into account several different models (oftentimes through simple averaging) to ensure there is no bias towards one specific model outcome.

One of the primary unknowns of climate change modelling is quantifying how greenhouse gas emissions will continue to grow or change moving forward. To capture this uncertainty, many climate modelling studies have used the approach developed by the Intergovernmental Panel on Climate Change (IPCC), which in 2000 developed the two GHG emissions scenarios commonly considered in climate change modelling. The first is the High Emissions Scenario (A2), which is meant to represent a continuation of our current emissions trends. The second is the Low Emissions Scenario (B1), which assumes greater GHG emission reductions, and is commonly referred to as the “best-case” scenario (ESA, 2014).

Climate change models are subject to uncertainty beyond GHG emissions, and as such most predictions produced using these models are presented as ranges of possible outcomes. Much of the available regional climate change data, including that used in this report, is based on downscaling the global data either using statistical methods or Regional Circulation Models (RCMs). With these methods comes a level of uncertainty in addition to the amount present in the original GCM analyses, and as such any information presented in this report should be recognized for its potential limitations. For a more detailed discussion of GCMs, climate modelling, and data downscaling, see the ESA memo included in Appendix A.

3. Regional Climate Change Review

Physical climate change effects relevant to the Trinidad area were assessed using data and reports that have been generated for the Humboldt County area. Although climate change data review included many reputable sources, the three listed below were the primary ones chosen as containing regionally relevant information on climate change and its effects.

- ***Humboldt Bay: Sea Level Rise, Hydrodynamic Modeling, and Inundation Vulnerability Mapping****.* This report was prepared by Northern Hydrology and Engineering and finalized in April of 2015. Summarized in the report are locally relevant sea level rise magnitudes which include locally surveyed vertical land motion. The CCC document *Sea Level Rise Policy Guidance (*Appendix C) references this document as the best available science for sea level rise in the greater Humboldt Bay region.
- ***Climate Change Projections for Caltrans District 1 Climate Change Pilot Study***. This memorandum was prepared by ESA for the Caltrans District 1 Climate Change Pilot Study Report completed in 2014. Presented in the memo is a summary of the data that was gathered in an effort to characterize the potential impacts of climate change to roadways in District 1. Most of the data summarized in the memo originates from the Coupled Model Intercomparison Project (CMIP3).
- ***Cal-Adapt.org***. This website, hosted by the California Energy Commission, is designed to allow for public access to climate change research relevant to California. Hosted on the website is a collection of downloadable data and visualization tools to help understand how climate change may affect California on a local level.

Using the sources listed above, the following sections discuss the potential magnitude of climate change effects for global warming, sea level rise, precipitation, and wildfire in the Trinidad area. Copies of all data and reports referenced below can be found in the appendix.

3.1 Global Warming

Information on temperature increases as a result of global warming was obtained from Cal-Adapt.org. Data for Trinidad was found using the Annual Averages Chart tool for the Trinidad/Westhaven area, which generates an annual average temperature graph based on four different GCMs. The resulting temperature change projections for the years 2035, 2050, 2065, and 2100 can be found in Table 1 below. Temperatures represent increases relative to the year 2000.

Table 1. Increase in average annual temperature (°F) for Trinidad area.

Year	2035		2050		2065		2100[1]	
Emissions Scenario	**A2**	**B1**	**A2**	**B1**	**A2**	**B1**	**A2**	**B1**
Cal-Adapt (Increase annual average temp, °F)	1.1	1.2	2.4	2.0	3.6	2.5	5.8	2.4

[1]Cal-Adapt data projection ends in the year 2099.

Projections for the year 2035 and 2050 are all relatively similar, with average temperature increases approximately 1- and 2-°F, respectively, for both emissions scenarios. In the year 2065, the high emission scenario begins to further separate from the low emissions scenario, with an annual average temperature increase of one-degree larger. By the year 2100, the models predict 2.4- and 5.8-°F temperature increase for the low and high emissions scenario, respectively.

A second source, the ESA climate memo prepared for the Caltrans District 1 Climate Change Pilot Study Report, also contained temperature projections for Humboldt County for a similar time period. The memo presents projected temperature changes as increases in daily maximum temperature for the years 2050 and 2100. However, the temperature projection presented in the memo was derived as a geographic average over the entire County, which includes many inland areas exhibiting less stable climates than coastal Trinidad; therefore, this data was found to not be relevant in predicting the climate of Trinidad.

3.2 Sea Level Rise

Based on the recommendation from the CCC Sea Level Rise Guidance document, the potential sea level rise magnitudes for the City were looked at using the Humboldt Bay Sea Level Rise report from Northern Hydrology and Engineering. The rationale for using this report specifically for the Humboldt Bay region is the unique case of vertical land movement that has been observed in this area. Although most of the Pacific Northwest coastline north of Cape Mendocino is actively experiencing vertical land uplift, the Humboldt Bay region is experiencing a significant rate of land subsidence. As a result, the levels of measured sea level rise in the Humboldt Bay region are the highest observed on the California Coast (CCC, 2015).

To generate estimations of sea level rise relevant to the Humboldt Bay region, the Northern Hydrology report uses the sea level rise magnitudes developed in the report *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (NRC, 2012), and adjusts them to remove the assumed vertical land motion (+1 mm/year north of Cape Mendocino). The resulting regional sea level rise range of values can be seen in Table 2 below.

Table 2. Sea level rise projections without vertical land movement (NHE, 2015).

Year	Low Range (cm)	Projection (cm)	High Range (cm)
2030	3.9	9.9	21.3
2050	10.9	21.4	46.2
2100	38.6	75.1	137.9

Using the sea level rise values in Table 2 above, regionally relevant vertical land movement can be added to the projections to produce relative sea level rise values.

The most relevant work in regards to vertical land level changes in the greater Humboldt Bay region has been performed by Cascadia Geosciences. Through their project, the Humboldt Bay Vertical Reference System Working Group, they have generated estimates of relative land level changes based on first-order leveling data. In their 2014 progress report (Appendix A) they present draft first-order leveling data collected by the National Geodetic Survey (NGS), which was collected predominantly along the US Highway 101 corridor. The resulting relative land level changes for the Highway 101 corridor near Trinidad are shown in Figure 2 on the next page.

As shown, there seems to be relatively well-defined tectonic land level activity occurring around the Humboldt Bay region. In the south along the Eel River Valley land is moving upwards, which slowly transitions to land subsidence as the river approaches Humboldt Bay. Southern Humboldt Bay then exhibits the largest measured levels of subsidence in the region, which slowly transitions to a lower subsidence level moving northward through the bay. Beginning just north of the Mad River Bridge along Highway 101, land level movement begins to consistently shift upwards again. The upward trend in land level continues to Trinidad, and subsequently further up the coast (not pictured).

There is one point shown on Figure 2 which appears to conflict with the otherwise consistent trend of land level uplift shown throughout the rest of the Trinidad area. This point appears to lie somewhere near the western boundary of the City, and exhibits a moderate level of vertical land subsidence. Given the consistently observed trend of vertical uplift in the region (including further up the coastline, again not shown in the Figure), this subsidence point is likely an outlier, which could be a result of localized conditions such as landslide. For the purpose of characterizing vertical land movement in this report, this point is considered an outlier.

Assuming the vertical land uplift shown in this Figure is an appropriate characterization of the Trinidad area, a range of uplift rates can be estimated. From the Figure, the land uplift rate in the Trinidad area appears to be approximately between one- and three-millimeters per year (mm/year). Using this range of land uplift rate and the sea level rise rates shown in Table 2, the following range of projections for sea level rise in the Trinidad area was estimated (Table 3).

Table 3. Range of potential sea level rise in Trinidad, CA.

Year	Land Uplift Rate (mm/year)	Low Range (cm)	Projection (cm)	High Range (cm)
2035	1	2.1	8.5	23.7
2065		10.8	28.0	62.2
2035	2	-1.4	5.0	20.2
2065		4.3	21.5	55.7
2035	3	-4.9	1.5	16.7
2065		-2.2	15.0	49.2

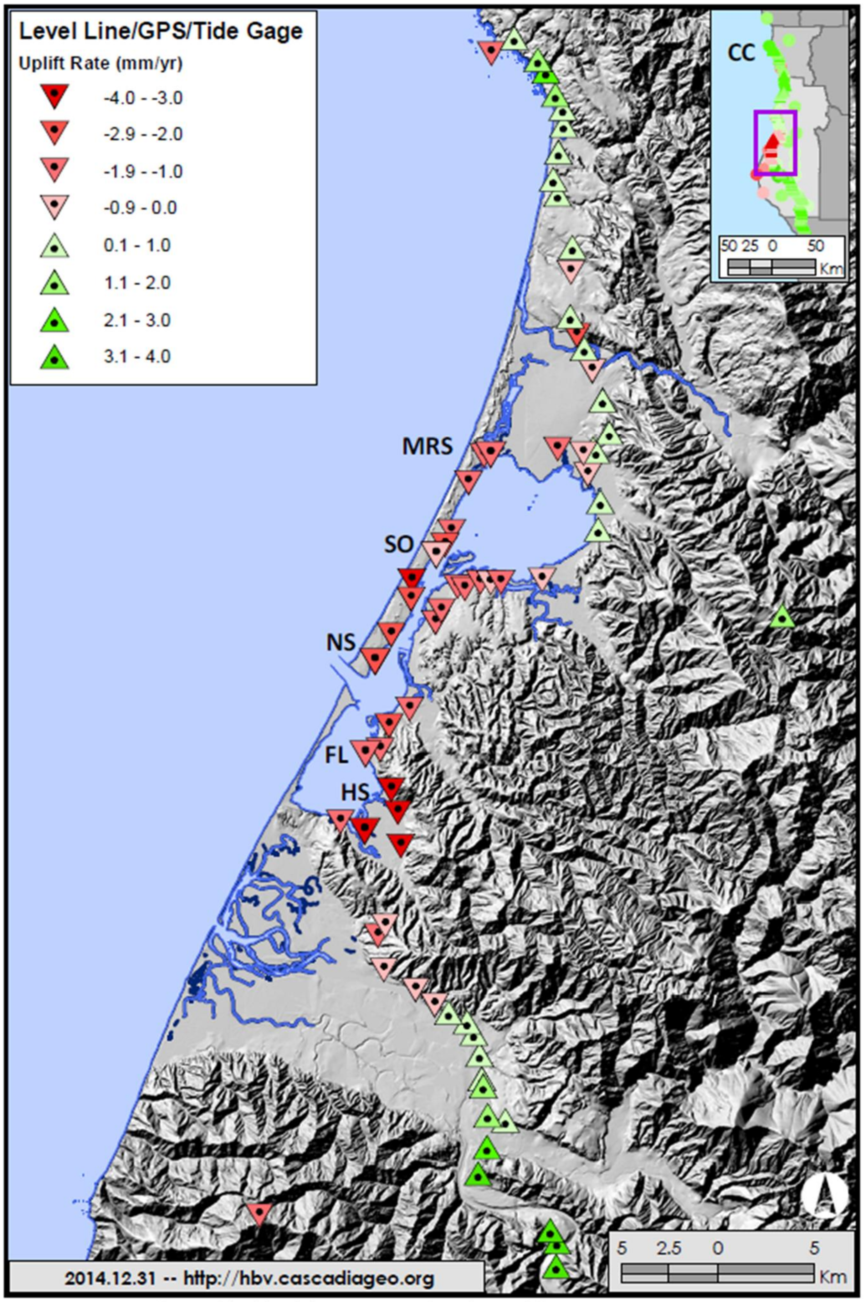

Figure 2. Vertical land movement rate based on first-order levelling data (Patton et al, 2014).

Based on the information presented above, the 'projected' magnitude of relative sea level rise in Trinidad for the land uplift rates shown is between 1.5- and 8.5-cm for the year 2035, and between 15- and 28-cm for the year 2065.

The 'high' range of sea level rise increases these projections significantly, between 16.7- and 23.7-cm for the year 2035, and between 49.2- and 62.2-cm for the year 2065.

At the 'low' range of projected sea level rise, the land uplift rate of 1 mm/year results in sea level rise between 2.1- and 10.8-cm for the years 2035 and 2065, respectively. For the higher range of vertical land uplift, the 'low' sea level rise projections result in sea level lowering, as the land uplift rate exceeds the rate of sea level rise.

Based on the data above, the sea level in Trinidad is likely to rise during the projected planning period, with an anticipated magnitude somewhere in the range reported. Although there are some scenarios based on the information above that could result in sea level lowering, they are less likely to occur based on the current information on sea level rise and vertical land movement for this region. It should be reiterated that the data presented in the Cascadia Geosciences report is in draft form. The organization has further plans to install a tide gage at the Pier in Trinidad, and after further data collection and analysis final results will be included in their final report at the end of the year (anticipated 2016). Once the report and data are finalized, sea level rise magnitudes in Trinidad could be modified if necessary.

3.3 Precipitation

Data for precipitation change as a result of climate change was obtained from Cal-Adapt.org and from the ESA climate change memo. The data in the ESA memo was obtained from CMIP3, and then subsequently processed to determine average trends. The resulting projected changes in overall precipitation compared to historic data are shown below (Table 4). Note that these values are presented as averages for all of Humboldt County, and again were only reported in the memo for the years 2050 and 2100.

Table 4. Percent changes in total annual precipitation from historic average (ESA, 2014)

Change in Precipitation				
Year	**2050**		**2100**	
Emissions Scenario	B1	A2	B1	A2
Humboldt	-3.9%	0.4%	-6.5%	-1.8%

Overall, there is a predicted decrease in the total amount of precipitation that is anticipated to fall in the Humboldt County area. The overall changes in precipitation are relatively low, and seem to be dependent on how emissions of GHGs continue into the future.

The Cal-Adapt data is available as a downloadable file of predicted precipitation for four GCMs using the A2 and B1 emissions scenario. Figure 3 below shows the resulting data, shown as the decadal average temperature averaged over all four models. Note that in this plot the decades 2030 and 2060 best correspond to the City’s planning horizon years.

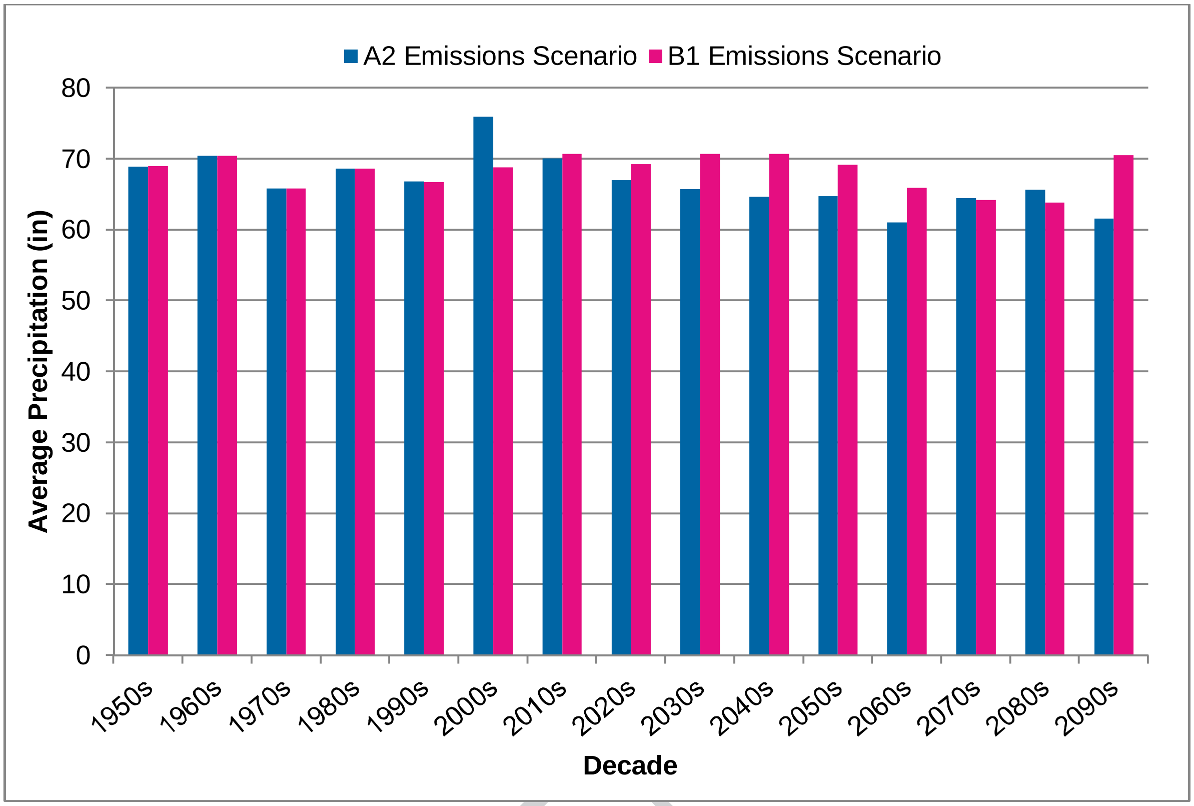

Figure 3. Decadal average precipitation (in) for A2 and B1 emissions scenarios (Cal-Adapt, 2015).

Figure 3 shows that under these modeling scenarios, the decadal average precipitation in the Trinidad area could decrease slightly. For the decade 2030, there is no appreciable change in projections, and in the decade 2060 there may be a small decrease; however, the decrease subsequently rebounds in the modeled decades that follow. It should be noted that one of the four models used in this average predicted an increase in precipitation, so there is still some variation among the direction of results among climate models.

Another important consideration for changes in precipitation is how it will fall. As mentioned in Section 2.1.3, the EPA predicts that the total amount of rain falling in high-intensity precipitation events is likely to increase in most regions. Although this has not been specifically shown in the data obtained for this report, several sources suggest that in the United States this is a likely outcome.

As noted above, another possible outcome in relation to precipitation is the potential change in coastal fog patterns. In 2010 (Johnstone and Dawson), a study was completed that found that during the 20th century there was an approximately 33% decrease in fog frequency along the Pacific Coast. Since this report, a large effort has emerged to better understand coastal fog, so that its potential impacts can be assessed moving forward. Although literature agrees that fog modeling contains a large amount of uncertainty, and that the cyclic nature of fog patterns over time is difficult to characterize, most science seems to agree that a decrease in fog on California's coast is likely.

3.4 Wildfire

Wildfire data was obtained from Cal-Adapt.org. The data is available as GIS heat maps and charts that present the increase in burned area projected for the years 2020, 2050, and 2085 using three climate models and both the A2 and B1 emissions scenarios. These models take into account climate change projections such as temperature and precipitation- they do not currently account for landscape or fuel sources. Table 5 below summarizes the available data.

Table 5. Projected increase in burned area for various climate change modelling scenarios (Cal-Adapt, 2015).

Climate Model	Year	A2	B1
Cnrm	2020	1.3	1.2
	2050	1.4	1.5
	2085	1.9	3.6
Gfdl	2020	1.5	1.5
	2050	1.7	1.5
	2085	4.1	1.7
Pcm1	2020	1	1.1
	2050	1.6	1.3
	2085	2.5	1.4

The values presented in Table 5 above are approximate; they were interpreted from the charts available from Cal-Adapt.org. Although the data was not available for the planning years of 2035 and 2065, it should be noted that wildfire risk in the Trinidad area is anticipated to increase moving forward.

3.5 Continued Impact Evaluation

Predicting how, when, and where the climate will change is a difficult task for any agency or individual. The magnitudes of possible climate change effects presented above are based on what is considered the best possible information at present. However, as time progresses new advancements in climate science can reveal new or improved information, and as such, reevaluating climate change magnitudes and interpreting their potential impacts should be a continual process.

4. Vulnerabilities and Impacts

As a result of climate change, there are several vulnerable areas within the City. The following sections build upon the effects and magnitudes of climate change for the four categories discussed in Section 3 by identifying these vulnerable areas and the potential impacts that may occur as a result of climate change.

4.1 Global Warming Impacts

As noted above, annual average temperature increase in the Trinidad area is projected to be approximately 1- and 3.6-degrees in the years 2035 and 2065, respectively, for the high emissions scenario. As noted in the climate change planning document Safeguarding California: Reducing Climate Risk, warmer temperatures can lead to drier soil conditions, which increases the need to irrigate outdoor landscaping (e.g., both residential and commercial). An increase in water demand of any kind can place added stress on a City's water treatment and distribution system.

4.2 Sea Level Rise Impacts

Based on the sea level rise and draft vertical land movement projections produced by Northern Hydrology and Engineering and Cascadia Geosciences, the projected sea level rise magnitudes range between 1.5- and 8.5-cm for the year 2035, and between 15- and 28-cm for the year 2065. High sea level rise scenarios increase these projections, and low sea level rise projections in conjunction with high land level uplift rates result in sea level lowering.

During the majority of the sea level rise and land uplift scenarios considered, including the 'projected' sea level rise magnitudes, sea level is projected to rise moving forward. Examining Figure 1 with this result, this increase in mean sea level could have an effect on public beaches, coastal bluff erosion, Trinidad harbor, and the land uses adjacent to coastal bluffs.

The impacts to public access beaches and bluffs are directly related to one another. As sea levels rises, and with them the elevations of large waves and storm surges, the total beach area as it exists currently will decrease. As part of natural processes, the higher water levels will begin to further erode the coastal bluffs, subsequently moving the beach area further inland. However, as a result of this additional bluff erosion, land uses adjacent to the coastal bluffs, which are primarily urban and suburban residential, open space, and special environment, become vulnerable to damage.

The rate and magnitude of bluff erosion will depend on where within the predicted range sea level rise will occur. Specifically quantifying bluff erosion potential based on the sea level rise magnitudes presented above is outside the scope of this report. However, other agencies have looked at this issue in general across the State, and these results are helpful in understanding how vulnerable the coastal bluff of Trinidad could be. Included in Appendix D is a figure that was developed from a study by the Pacific Institute (2009), *The Impacts of Sea-Level Rise on the California Coast.* As can be seen in the Figure, the high coastal erosion hazard zone in the year 2100 (denoted by the yellow line) extends inland in the Trinidad area approximately 800 feet. A hazard zone of this magnitude would have potential effects on any land uses within, or in the immediate proximity of this hazard line. It should be noted that the coastal erosion hazard zone map developed by the Pacific Institute is based on sea level rise predictions separate than those presented in this report.

Another area vulnerable to sea level rise is Trinidad harbor. This area is primarily composed of buildings, a dock, and parking areas. Depending on the specific elevations or construction of these features, they could be at risk for damage due to higher sea levels.

4.3 Precipitation Impacts

Current climate modeling data suggests that precipitation in the Trinidad area is likely to undergo a small decrease in annual volume while experiencing an increase in the amount of precipitation that falls in heavy rainfall events. The areas identified as most vulnerable to these impacts are the City's stormwater infrastructure, and the City's water diversion and treatment facilities.

As mentioned previously, the City receives its drinking water supply as surface water from Luffenholtz Creek. Therefore, any decrease in annual average precipitation will have some effect on the water available for diversion in the Creek, and ultimately the water supply available to the City.

If more precipitation begins to fall in large storm events this could put more stress on the City's drinking water treatment and stormwater treatment and conveyance infrastructure. High intensity storm events typically lead to increased turbidity in streams, which ultimately would have to be handled by the City's potable water treatment facility. In urban impervious areas of the City in particular, higher intensity storm events lead to increased runoff peak flows, which could put stress on existing older stormwater infrastructure. In addition to the problems associated with higher flows, larger storm events have the potential to entrain more sediment and pollutants in the runoff, which could lead to increased pollution to the areas receiving the runoff, including Trinidad Bay which has been designated an Area of Special Biological Significance (ASBS). It should be noted that some of the City's stormwater infrastructure has undergone recent upgrades as part of the Trinidad ASBS Project, and there are future plans to expand upon those improvements. These upgrades should assist in minimizing the vulnerability of the City to increased stormwater volumes.

Current studies on coastal fog indicate that fog frequency has reduced over the past century, as could further reduce as global warming continues to progress. Decreased fog could result in further temperature increases, as fog acts to cool areas within its influence. Decreased fog in the Trinidad area could also lead to drier soil, increased wildfire risk, and risk to the coastal ecosystems that depend on summer fog for moisture.

4.4 Wildfire Impacts

Wildfire risk in the greater Northern California area, including Trinidad, is anticipated to increase as discussed in Section 3.4. The City is surrounded by open space, forest, and rural suburban residential development, which typically are the areas at highest risk in wildfire scenarios. As such, the City and its surrounding land use should be considered vulnerable to the increase in wildfire danger moving forward. In addition to the at-risk land use types mentioned above, rurally located utility installations, such as power lines and the City's water supply (Luffenholtz Creek) and treatment facilities, are likely to experience increased vulnerability as well.

5. Adaptation Strategies

Based on the vulnerabilities and impacts identified above, a list of adaptation strategies was compiled that could help alleviate the effects of climate change experienced by the City. Many of these adaptation strategies were obtained from the planning documents Safeguarding California: Reducing Climate Risk and the CCC's Sea Level Rise Policy Guidance Document. It should be noted that this is not a comprehensive list of adaptations and not all of them may be deemed necessary for Trinidad. This list should be viewed as a starting point to begin to identify projects and policies that could assist in climate change impact mitigation moving forward.

Table 6. Example adaptation strategies.

Adaptation Measure	Climate Risk Addressed	Descriptions/Example Actions
Establish mapped hazard zones or overlays	All	• Update land uses and zoning requirements to minimize risks from climate change effects
Continued Climate Change Evaluation	All	• Continue to re-address climate change effects including sea level rise, global warming, precipitation patterns, and wildfire risks on a regular interval
Promote Fire Safe Communities	Wildfire	• Identify specific areas of fire concern or vulnerability • Develop local fire plans and define landowner responsibilities • Promote wildfire risk awareness and encourage actions such as vegetation clearing and other fire hazards away from buildings
Evaluate current and future water demands to assess adequacy of available water storage	Decreased precipitation, global warming	• Monitor annual water usage in conjunction with available water supply
Increase water conservation	Decreased precipitation	• Promote water conservation
Evaluate water treatment system performance	Increased storm intensity	• Monitor raw water sediment concentrations and treated water turbidities
Control stormwater runoff and pollution	Storm intensity increases	• Update or expand water quality Best Management Practices (BMPs) • Increase the capacity of stormwater infrastructure

Adaptation Measure	Climate Risk Addressed	Descriptions/Example Actions
		• Employ on-site stormwater drainage strategies when feasible • Retrofit existing development with inadequate stormwater infrastructure • Promote residential Low Impact Development (LID)
Establish shoreline management plans to address long term sea level rise	Sea level rise	• Create policies that require a management plan for priority areas that are subject to sea level rise hazards
Limit new development in hazard areas	Sea level rise	• Restrict or limit construction of new development in zones or overlay areas identified as hazardous
Develop a plan to remove or relocate structures that become threatened	Sea level rise	• Require new development authorized through a CDP that is subject to wave action, erosion, or other hazards to be removed or relocated if it becomes threatened in the future
Plan ahead to replace loss of access and recreation areas	Sea level rise	• Protect existing open space adjacent to the coast • Plan for removal of structures that limit inland migration of beaches
Foster efforts to better understand impacts of sea level rise	Sea level rise	• Support research on impacts to recreation and public beach access

6. Summary

Below is a brief summary of the potential impacts of climate change that the City of Trinidad may experience. These impacts are based on reviewing regionally relevant science and reports that have been produced for the Trinidad and greater Humboldt County area.

- **Global Warming:** Temperature increase as a result of global warming is likely to continue. Temperature increases for the year 2035 are approximately 1 °F for both the A2 and B1 scenarios. Temperature increases for the year 2065 are 2.5- and 3.6-°F for the B1 and A2 scenarios, respectively.
- **Sea Level Rise:** Based on draft data from Cascadia Geosciences, land uplift rates in the Trinidad area are estimated between 1- and 3-mm/year. For this range of land uplift, the projected sea level rise in Trinidad is between 1.5- and 8.5-cm for the year 2035, and between 15- and 28-cm for the year 2065. Depending on the magnitude of both sea level rise and vertical land movement, sea level rise rates could be as high as 23.7- and 62.2-cm for the years 2035 and 2065. Conversely, if sea level rises at a lower rate and land level is uplifted at a higher rate, the net effect could result in sea level lowering.
- **Precipitation:** Precipitation is anticipated to decrease slightly by the end of the century, perhaps as much as 6% if GHG emissions are not drastically reduced. However, even though this data suggests a decrease, many sources and models suggest that predicting areas that will experience precipitation increase versus decrease is difficult. However, in areas of both increase or decrease, the amount of precipitation falling in heavy rainfall events is likely to grow. In addition to precipitation, fog frequency is also projected to decrease. Although future coastal fog modeling is in the early stages of development, a study performed in 2010 found that over the 20th century there was an approximately 33% decrease in fog along the California coast.
- **Wildfire:** Burned areas from wildfires are likely to increase. Currently modeled levels of increased burned area average approximately a one-fold increase for both emissions scenarios by 2020, a 1.5-fold increase for both scenarios by 2050, and a range between 1.5- and 4-fold increases for both scenarios by 2085.

Based on these potential changes in climate the following vulnerabilities have been identified:

- The City's potable water infrastructure, including the treatment facility and water storage are vulnerable to changes in rainfall intensity and amount. In addition to changes in rainfall, an increase in average temperature could lead to dryer conditions, which could increase the demand for potable water use for outdoor irrigation.
- The City's currently unimproved stormwater infrastructure, both treatment and conveyance, are vulnerable to changes in precipitation intensity and amount. In addition to the infrastructure, areas receiving stormwater, including Trinidad Bay, may be vulnerable.
- Trinidad harbor, the public access beaches, and the coastal bluffs are vulnerable to the changes in mean sea level.
- Buildings, residences, or properties located in areas that could experience increased risk of wildfire.

To address some of these vulnerabilities, or to continue to adapt to the climate change that has been forecasted in the Trinidad area, the following adaptation measures have been identified. Many of these adaptation measures are from the Coastal Commission planning document Sea Level Rise Policy Guidance Document.

- Identify and establish mapped hazard zones to be used for planning purposes.
- Control stormwater runoff by expanding the use of BMPs, onsite stormwater infrastructure, and stormwater treatment units.
- Plan ahead to replace loss of public access recreation areas.
- Establish policies for shoreline management.
- Plan for the protection, relocation, or removal of structures threatened by sea level rise.
- Limit or prohibit new development in areas identified as hazardous.
- Foster efforts to better understand the potential impacts of climate change, including the continued evaluation on climate science as it is made available.
- Foster community awareness of the possible effects of climate change, and encourage involvement in planning for the future.

The vulnerabilities and adaptation measures presented above are intended to be a preliminary assessment on the issue of climate change. Further work should be performed to identify specific climate change hazard areas, and to identify and select adaptation measures to be included in policies are planning efforts going forward.

7. References

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