10. GLOBAL CLIMATE CRISIS

Greenhouse gas (GHG) emissions are primarily associated with the burning of fossil fuels and deforestation, as well as agricultural activity and the decomposition of solid waste. GHG pollution has led to a trend of human-induced warming of the Earth's average temperature, which is causing changes in the Earth's climate. This increasing-temperature phenomenon is known as "global warming," and the climatic effect is known as "climate change."

The following summarizes the level of uncertainty associated with potential climate changes caused by GHG emissions to the Earth's atmosphere.[1]

Temperature: Increases in very hot days and heat waves .... Very likely
Temperature: Decreases in very cold days .... Virtually certain
Temperature: Later onset of seasonal freeze and earlier onset of seasonal thaw ..... Virtually certain

Sea-Level Rise: .... Virtually certain

Precipitation: Increases in intense precipitation events .... Very likely
Precipitation: Increases in drought conditions for some regions .... Likely
Precipitation: Changes in seasonal precipitation and flooding patterns .... Likely

The U.S. Global Change Research Program, which is implemented by a collaboration of thirteen U.S. Federal entities, periodically conducts national climate assessments. The Program assesses climate change impacts on the nation's transportation systems. Key Messages from the third assessment were as follows:

1. The impacts from sea level rise and storm surge, extreme weather events, higher temperatures and heat waves, precipitation changes, Arctic warming, and other climatic conditions are affecting the reliability and capacity of the U.S. transportation system in many ways.
2. Sea level rise, coupled with storm surge, will continue to increase the risk of major coastal impacts on transportation infrastructure, including both temporary and permanent flooding of airports, ports and harbors, roads, rail lines, tunnels, and bridges.
3. Extreme weather events currently disrupt transportation networks in all areas of the country; projections indicate that such disruptions will increase.
4. Climate change impacts will increase the total costs to the nation's transportation systems and their users, but these impacts can be reduced through rerouting, mode change, and a wide range of adaptive actions. (Schwartz, Meyer, et al 2014)

[1] In "Caltrans Climate Change Adaption" slide 17 (9/27/2011); sources cited: "Adapted from IPCC (2007) and Potential Impacts to Climate Change on U.S. Transportation, National Research Council (2008)."

> "While the transportation system must continue to meet demand for reliable travel, it must do so while achieving quantifiable reductions in greenhouse gas (GHG) emissions."
> – California Transportation Plan 2040

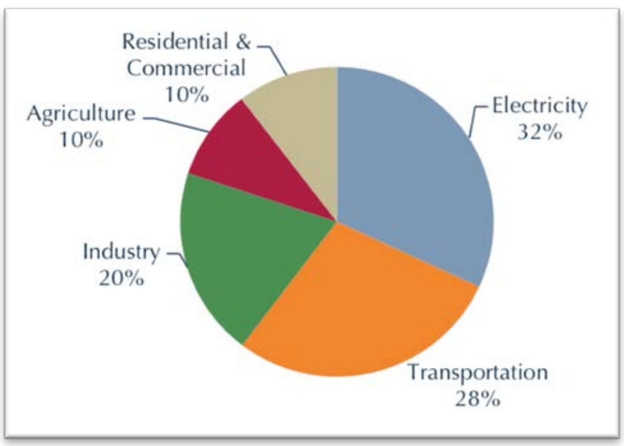
The California legislature adopted the public policy position that "Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California." Further, the state legislature has concluded that

> The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious disease, asthma, and other human health related problems…Global warming will have detrimental effects on some of California's largest industries, including agriculture, wine, tourism, skiing, recreational and commercial fishing, and forestry (and)…will also increase the strain on electricity supplies necessary to meet the demand for summer air-conditioning in the hottest parts of the state." (Health and Safety Code §38501)

The most common human-produced GHG is carbon dioxide (CO_2). California ranks as one of the world's largest emitters of CO_2; CO_2 constitutes 84% of the State's GHG emissions, and approximately 2% of the world's CO_2 emissions (California Energy Commission, 2006). The Governor's Office of Planning Research reports that transportation currently accounts for approximately half of California's overall greenhouse gas emissions.

LEGISLATION

Facing the global climate crisis, California's governors and legislatures have passed laws enacting policies to actively address both the causes and the risks of climate change. They have ratified California's GHG emissions targets:



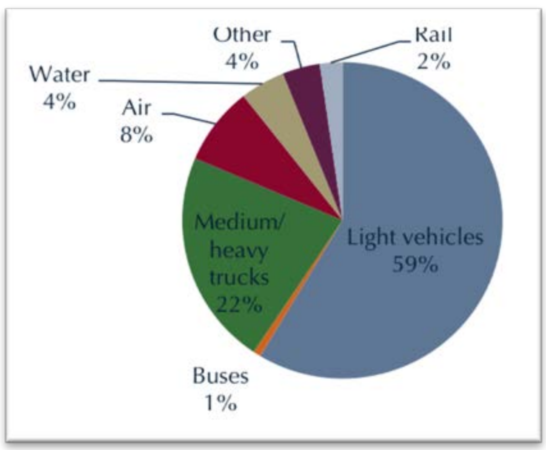


Figure *Climate-1*. U.S. Greenhouse Gas Emissions by Economic Sector (2012) Source: FAA 2015

Figure *Climate*-2. Transportation Energy Use by Mode (2012) Source: FAA 2015

- By 2010, limit GHG emissions equivalent to 2000 levels, *per Governor Schwarzenegger's EO S-3-05 (2005).*
- By 2020, limit GHG emissions equivalent to 1990 levels, *per EO S-3-05 and California Global Warming Solutions Act of 2006 (AB 32)*;
- By 2030, limit GHG emission to 40 percent below 1990 levels, *per Governor Brown's EO B-30-15 (2015) and SB 32 (Pavley 2016).*
- By 2050, limit GHG emissions to 80% below 1990 levels, *per EO S-3-05 and AB 32.*

The most recent legislation, Governor Brown's interim goal (EO B-30-15), is "the most aggressive benchmark enacted by any government in North America to reduce dangerous carbon emissions over the next decade and a half" (Caltrans 2016). As one strategy to reach the target, the bill requires the State to include life-cycle accounting—including considering climate change—when prioritizing infrastructure investments. Governor Brown separately called for up to a 50 percent reduction in petroleum use by 2030 (ibid).

> "CA is the nation's largest car market, and a dozen other states, comprising more than 40 percent of the U.S. population, have adopted California's emissions standards."
> – S.F. Chronicle, July 2017

California Air Resources Board (CARB) released in January, 2017, the second update of the statewide Scoping Plan, *2017 Climate Change Scoping Plan Update–The Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target.* CARB, in July 2017, released a new analysis, "Cap-and-Trade Economic Analysis" (July 21, 2017), as part of the Proposed Scoping Plan. CARB continues its ongoing planning process to achieve the state's 2030 greenhouse gas reduction goal.

RTP GOALS & OBJECTIVES

RTPA's have a role in meeting these goals by conducting proactive, collaborative, and "adaptive" transportation planning that always considers the real threats of global climate change, and the large role fossil-fuel-based transportation plays in it. This RTP promotes integrating transportation and land use to reduce CO_2 emissions from the regional transportation system. The RTP's goal and objectives, specifically the Environmental Stewardship objective, complement AB 32 and SB 375 goals, and support the goals and objectives of the *California Transportation Plan 2040* (CTP 2040) as well.

GOAL: Reduce greenhouse gas emissions contributed by transportation while building and maintaining a transportation system that is truly multimodal and equitable.

GOAL: Minimize the negative health, social, economic, and environmental impacts caused by global climate change and sea-level rise.

- **Balanced Mode Share/Complete Streets Objective:** promoting viable, safe, affordable, and easily accessible multimodal options.
  - **Policy**: Put forth strategies that shift travel to be more transit-focused and rideshare-oriented, to achieve more road safety benefits. *(CTP 2040 recommended policy)*

- **Efficient & Viable Transportation System OBJECTIVE:** Reduce vehicle miles traveled (VMT) and lower GHG emissions.

- **Environmental Stewardship Objectives:**
- Accelerate the use of alternative fuels, new vehicle technology, pricing strategies, public transportation expansion, more bicycling and walking to contribute to GHG reduction goals. *(CTP 2040 recommended policy)*
  - **Policy**: Promote active transportation, ridesharing, rail, and public/mass transit promoting policies for the co-benefit of reducing air pollution when they replace motor vehicle trips. *(CTP 2040 recommended policy)*

- **Equitable & Sustainable use of Resources Objectives:**
  - Recognize the connections between transportation and land use.
    - **Policy**: Support local communities in developing integrated transportation and land use strategies for responding resiliently to climate change, and codifying such strategies in General Plans, Regional Transportation Plans, and Local Coastal Programs. *(CTP 2040 recommended policy)*
  - Establish a more equitable transportation system for users of all income levels. *(CTP 2040 recommended policy)*
    - **Policy**: HCAOG will support and plan transportation and projects that provide safe and convenient travel modes for people who cannot or choose not to drive.
    - **Policy**: HCAOG will promote and support land use policies that accommodate or reinforce planning, designing, and building a truly multimodal transportation network.
    - **Policy**: HCAOG shall encourage partnerships to develop adaptation strategies that address sea-level rise in Humboldt County.

CLIMATE CHANGE IMPACTS TO HUMBOLDT

Climate Change & SEA-LEVEL RISE Conditions

In Humboldt County, sea-level rise from global warming is compounded by local tectonic activity that causes downward vertical land movement, or tectonic subsidence. "Combining subsidence on Humboldt Bay with sea level rise over the last 100 years, tidal elevations have increased approximately 1.5 feet—the most of any area on the West Coast" (Russell and Griggs 2012 as cited by Laird 2015). Areas of former tidelands around the Bay are thus "as much as three feet lower than when they were salt marsh in the late 1800s/early 1900s" (Laird 2015).

From the dual factors of land subsidence and global warming, in the Humboldt Bay region relative sea-level is rising at a rate two- to three-times greater than anywhere else in California; "in fact, sea-level change at the Humboldt Bay North Spit tide gauge is much greater than any other tide gauge in the Pacific Northwest (Patton et al., 2017)" (Anderson 2017).

> "Coastal California is already experiencing the early impacts of a rising sea level, including more extensive coastal flooding during storms, periodic tidal flooding, and increased coastal erosion."
>
> – California Ocean Protection Council, 2017

The areas at risk of tidal inundation are multiplied by Humboldt's miles of coastline, making Humboldt one of the most vulnerable counties in California.

HCAOG and Caltrans District 1, in 2013-2014, funded a project to assess which transportation assets in the region are likely to be most vulnerable to climate change impacts. The project assessment reported that:

> Climate change is expected to increase sea levels in Humboldt Bay by a high-end estimate of up to 26 inches by 2050, and up to 70 inches by 2100. Precipitation is predicted to increase by up to 11% by 2050, and up to 14% by 2100, with estimated extreme runoff increases by up to 9% by 2050 and 12% by 2100 (Caltrans District 1 and HCAOG 2014).

Higher precipitation will cause more extreme events, such as infrequent extreme-hazard floods, which will be temporary (but nonetheless serious). Sea-level rise will, in contrast, cause tidal inundation that is a permanent condition. As Laird points out (2015), practitioners should differentiate these impacts when assessing future conditions and when planning adaptive strategies.

HUMBOLDT'S TRANSPORTATION ASSETS AT RISK

US Highway 101, running north-south, is the major transportation corridor in Humboldt County. Additional critical corridors, running east-west, are State Routes 299, 255, 96, and 36. On Humboldt Bay, the US 101 corridor includes the Northwest Pacific Railroad and the Humboldt Bay Trail (including the northern segment (Arcata to Bracut) and the proposed segment from Bracut to Eureka). Nearly 75% of Humboldt Bay (almost 77 miles) is covered by artificial shorelines; for example, US 101 and State Route 255 are constructed on former tidelands that are protected by earthen shoreline structures (such as dikes). However, only 36% of the Bay's shoreline (27.6 miles) is fortified. Nearly ten miles (9.6 miles) of low-lying shoreline, which currently protects US 101, has been rated highly vulnerable to breaching (overtopping) under current conditions during extreme tides (100-year event), or during annual king tides and/or storm surges that raise the tide by two feet or more above tidal baseline elevation (Laird 2015).

When dikes are breached or overtopped in an extreme event, it is common for jurisdictions to refortify and rehabilitate dikes because it is one of the relatively easier "quick fixes." However, it is by no means cheap. "On Arcata Bay, for example, fortification and rehabilitation of dikes cost $900,000 to $2,000,000 per mile, without any significant increase in elevations. These fortified dikes will not be able to withstand projected sea level rise above three or six feet" (ibid).

As part of the Humboldt Bay Sea Level Rise Adaptation Planning Project (Phase II), Aldaron Laird and other professionals assessed the vulnerability, among other "critical regional assets," the vulnerability of transportation infrastructure to tidal inundation under then-current conditions (2014). The final report identified these transportation resources (and associated water body(ies)) as the most at risk for flooding/inundation due to dikes or railroad beds (or other protective shoreline structures) being breached or overtopped:

- Jacobs Ave, Eureka urban area;
- Murray Field Airport (Eureka Slough);
- Portions of Caltrans Highway 101 (South Bay and Lower Arcata Bay);
- Portions of Caltrans Highway 255 (Arcata Bay); and
- City of Eureka, City of Arcata, and Humboldt County local streets and roads (Mad River Slough, Eureka Slough, and Elk River Slough) (Laird 2015).

The estimated vulnerabilities of the US 101 transportation corridor under future conditions are described in more detail below, under the research/planning studies:

- ➢ Humboldt Bay Sea Level Rise Adaptation Planning Project (2013-2015)
- ➢ District 1 Climate Change Vulnerability Assessment (2014)

RESEARCH AND PLANNING

CLIMATE CHANGE VERNACULAR

"Adaptation planning" is a common term used to describe strategic planning for dealing with the local, regional, or global impacts of climate change. One of the first steps of the adaptation planning process is to asses which community assets must be prioritized for planning and action. Some main concepts and processes of this assessment are described in the following.

Risk — Risk is considered a function of the *likelihood* the asset will be impacted, coupled with *consequences* of the asset being impacted:

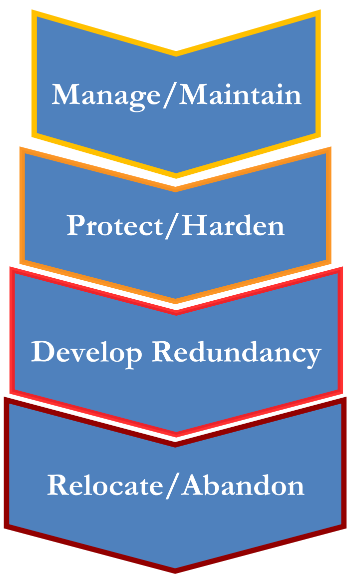
- **Likelihood —** the chance or probability of an impact occurring.
- **Consequences** — the magnitude of effects (social, economic, legal, and environmental) if an impact does occur.
- **Risk tolerance** — "The amount of risk involved in a decision depends on both the consequences and the likelihood of *realized* impacts that may result from SLR. (The realized impacts, in turn, depend on the extent to which the project design integrates an accurate projection of SLR) (CO-CAT 2013).

Vulnerability — Practitioners often assess how vulnerable an asset is by evaluating these three characteristics of an asset:

- **Exposure –** How and to what extent will the asset experience an impact?
- **Sensitivity –** How much, or to what degree, will the asset be impaired by an impact?
- **Adaptive capacity –** How well is the asset able to inherently accommodate or adjust to an impact (i.e., without or before outside intervention), thereby allowing it to maintain its primary functions? "In most situations, adaptive capacity must be front-loaded, or built into the initial project; it cannot be assumed that adaptive capacity can be developed when needed unless it has been planned for in advance" (ibid).

For instance, if an asset has *low sensitivity* and a *high adaptive capacity*, then it can tolerate impacts relatively well. Thus, overall it has a lower vulnerability. On the other hand, if an asset is *sensitive* to an impact and cannot adjust well (or at all) to the impact (*low adaptive capacity*), then the asset is more susceptible to impacts; thus, it is more vulnerable, or has high vulnerability.

Continuum of Investment Choices for Adaptation



>>Prepare for escalating cost due to increasing stress or shorter service life.

>>Enhance resiliency with natural buffers and/or modified design standards.

>>Prepare alternate routes to prepare for disrupted service/intermittent loss of service.

>>Reduce exposure to risk by moving service to lower-risk areas.

STATE-LEVEL PLANNING

The *California Transportation Plan 2040* (CTP 2014) states,

> California's goal for all sectors and economic activities is to reduce GHG emissions while we go about our daily business. For transportation, this means making significant changes in how we travel. We must provide access and mobility for people and businesses, yet reduce our single occupant miles traveled and advance cleaner vehicles and fuels. …The CTP 2040 for the first time examines various strategies to help us move towards a low-carbon transportation system (Caltrans 2016).

Caltrans also states in the CTP 2014 that "(p)reparing transportation infrastructure for climate change impacts is a new priority as future projects are designed and the current system is maintained." To this end, one of their short-range recommendations is to "Require climate change resiliency in programs and projects funded by the State Highway Operations Protection Program (SHOPP) or the State Transportation Improvement Program (STIP)" (Appendix 8, Caltrans 2016).

Regional/Local Studies & Planning

District 1 Climate Change Vulnerability Assessment (2014)

The *District 1 Climate Change Vulnerability Assessment and Pilot Studies: FHWA Climate Resilience Pilot Final Report's* (Vulnerability Assessment's) final report presents the results of Caltrans District 1 Climate Change Pilot Study (D1CCPS), which was conducted to identify and classify the state-owned transportation assets found to be potentially vulnerable to climate change impacts. The Vulnerability Assessment focused on primary climate change effects (temperature and precipitation), and projected potential impacts of secondary effects such as erosion, flooding, and landslides.

The Vulnerability Assessment identified the top three most vulnerable segments in each county in Caltrans District 1. The most vulnerable locations ("assets") did not change when different climate models predicted different impacts. The transportation assets in Humboldt County that the report found most vulnerable to climate change impacts are three segments of U.S. 101 in the greater Humboldt Bay Area:

- **Rated most vulnerable:** US 101 between Rio Dell and Eureka's southern urban boundary. Several portions of this segment are at low elevations and close to the coast/bay, creating a high potential for tidal inundation. This segment is deemed highly vulnerable in part due to its number of bridges, low redundancy (e.g., the bridge over the Eel River), and relatively high volumes of traffic (i.e., average daily trips, ADT).
- **Rated 2nd most vulnerable:** US 101 between Eureka's northern city limits and the junction with State Route 255 (south Arcata). Some of the factors that make this segment critical are its high ADT and proximity to large population centers. Its low elevation and proximity to the coast make it more vulnerable to impacts from tidal inundation.
- **Rated 3rd most vulnerable:** US 101 between Richardson Grove and Weott. The criticality and impact factors that make this segment vulnerable include having bridges over water, having many stormwater facilities, and the segment's drainage issues that have historically caused frequent slope movement (Caltrans District 1 and HCAOG 2014).

For the Vulnerability Assessment, stakeholders considered concepts for addressing sea-level rise along Highway 101 on Humboldt Bay. Among the concepts were strategies such as increasing armoring/flood walls, elevating the roadway, and relocating structures. The six adaption options that were ultimately ranked highest (in this assessment process) are summarized below in Table 1.

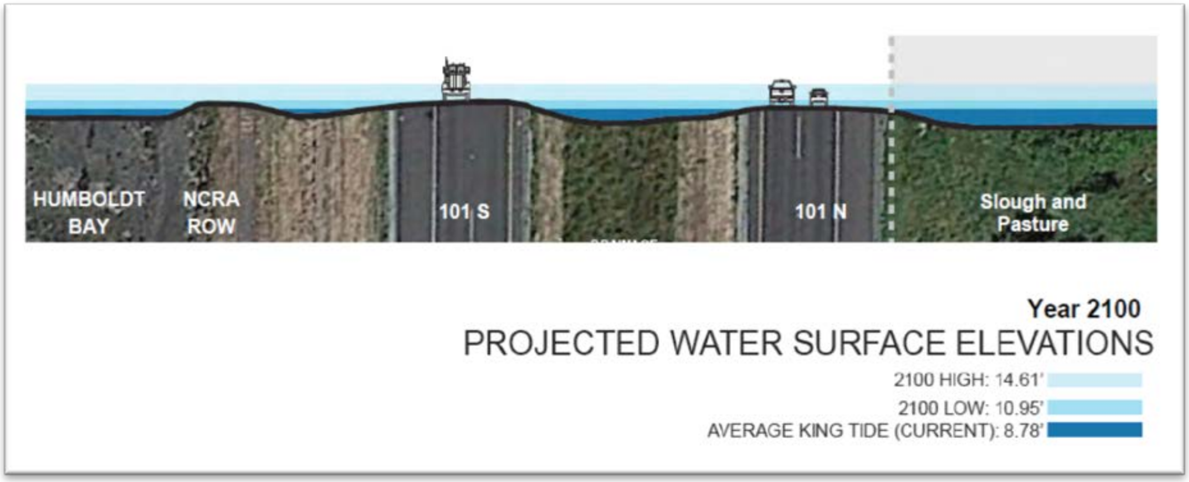


Figure *Climate-3*. Highway 101 Vulnerability to Sea-Level Rise Along Humboldt Bay
Water heights predicted for year 2100 under the high GHG emission scenario and the annual average King tide.
Source: Caltrans District 1 and HCAOG 2014

Table 1. **Summary of Humboldt County-US 101 Prototype Location Adaptation Options**

Rank	**Adaptation Approach & Option**	**Project Description**	**2050 Cost Estimate** (order of magnitude in 000s)*	**2100 Cost Estimate** (order of magnitude in 000s)*
1	*"Defend" approach*: Provide protection at existing elevations/ locations	Strengthen/add protection to existing protective structures (RR berm, dikes, fill areas) for 10 miles, including increasing height to 1 foot above 2050/2100 water level at a King tide	$121,310	$121,460
2	*"Accommodate" approach*: Elevate the infrastructure above the impact zone	Increase height of the roadway by building up the fill prism 1 foot above 2050/2100 water level at a King tide for 6 miles	$60,570	$117,630
3	*"Accommodate" approach*: Elevate the infrastructure above the impact zone	Construct a causeway, 6 miles, at a height of 5 feet above 2050 water level at a King tide	$173,680	$368,040
4	*"Retreat" approach*: Relocate infrastructure (horizontally)	Assumed 8 mile re- route to the east of the existing Hwy 101	$350,000	$350,000
5	*"Changes in policies or practices" approach*: Increase the infrastructure's maintenance & inspection interval and continue to monitor/evaluate	Equivalent to the No-Project alternative. Only temporary measures enacted and repairs made on an as-needed basis.	$950	$950
6	*"Retreat" approach*: Temporarily restrict use of infrastructure	Install ITS infrastructure to recommend use of alternate route and increase signage and warning information	$1,080	$1,080

* 2014 dollars. Source: District 1 and Caltrans 2014 *(adapted from Table 5)*

Humboldt Bay Sea Level Rise Adaptation Planning Project (2013-2015)

The Humboldt Bay Sea Level Rise Adaptation Planning Project, funded by the California Coastal Conservancy, provided

- a shoreline inventory, mapping, and vulnerability assessment (Laird, Powell, & Anderson 2013; Laird 2015); and
- inundation/flood vulnerability modeling and mapping (NHE 2015).

Figure *Climate-4,* below, depicts area around Humboldt Bay near Eureka (the second-most vulnerable transportation segment in Humboldt, according to the Caltrans District 1 Assessment), as it would be inundated based on projections (circa 2015) of SLR in 2050. This segment of US 101 is currently protected from inundation by the natural shoreline, dikes or berms, and railroad or road grades, but it is vulnerable to existing and future sea levels (NHE 2015).

Phase II of the SLR Adaption Planning Project mapped areas most at risk of water inundation/flooding if existing shoreline structures, such as dikes and railroad beds, are breached or overtopped. The transportation systems (and associated water body) thus identified are:

<u>Years 2015 to 2050, near- term conditions:</u>

- Highway 101 (South Bay and Lower Arcata Bay)
- Highway 255 (North Arcata Bay)
- City of Eureka, City of Arcata, and County local streets and roads (Mad River Slough, Arcata Bay, Eureka Slough, Eureka Bay, Elk River Slough and South Bay)

<u>Years 2050 to 2100, long- term conditions:</u>

- Highway 101 (Upper Arcata Bay and Elk River Slough)
- Highway 255 (West Arcata Bay)
- City of Eureka, City of Arcata, and County local streets and roads (Mad River Slough, Arcata Bay, Eureka Slough, Eureka Bay, Elk River Slough and South Bay) (Laird 2015)

Figure *Climate-4*. US 101 Eureka to State Route 255 Possible Inundation

Inundation map of northeastern Eureka and Highway 101 with a half-meter of sea-level rise, which is predicted for the year 2050. Source: NHE 2015

Figure *Climate-5*. North segment, lower Arcata Bay Reach existing conditions:
Assuming tidal elevation is 9.99 feet (MMMW+100 - year stillwater level) and that protective shoreline structures are compromised north of Airport Road, extensive flooding of south and north bound lanes.
Source: Laird 2015 (Figure 22)

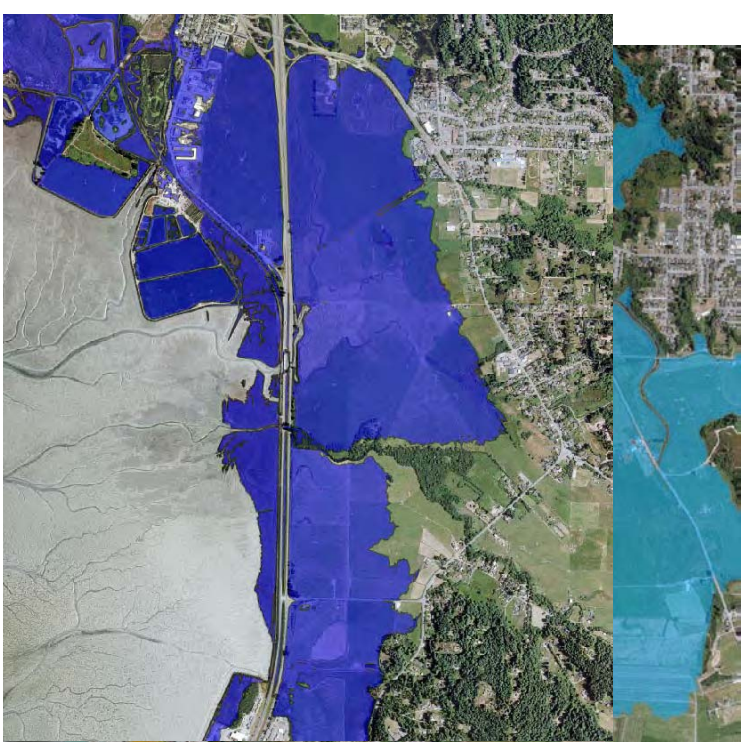


Figure *Climate-6*. Middle segment, South of Eureka existing conditions:
Assuming tidal elevation is 9.99 feet (MMMW+100 - year stillwater level) and that protective shoreline structures are compromised, the land adjacent to the road prism is flooded to the west and east of Highway 101, with limited flooding of south and north bound lanes.
Source: Laird 2015 (Figure 23)

Figure *Climate*-7.. North segment, upper Arcata Bay Reach 2015–2050:
Assuming tidal elevation is 9.38 feet (MMMW+0.5 meter sea level rise) and that protective shoreline structures are compromised, the land adjacent to the road prism is inundated to the west and east of Highway 101.
Source: Laird 2015 (Figure 25)

The Impacts of Sea-Level Rise on the California Coast (2016)

"The Impacts of Sea-Level Rise on the California Coast" is a paper from the California Climate Change Center (CCCC 2016). The paper presents estimated length in miles and dollars in costs of infrastructure impacted by climate change. Impacts are calculated for the Californian counties and cities expected to be most at risk for impacts caused by climate change and corresponding sea-level rise. The paper states,

> Under current conditions, we estimate that 1,900 miles of roadway are at risk of a 100- year flood event. With a 1.4 m sea- level rise, 3,500 miles of roads will be at risk of flooding, nearly a doubling of current risk. Of the total, about 430 miles are highways (12% of the total mileage), while the remainder are neighborhood and local streets. About half of the roads at risk are around San Francisco Bay, and another half on the Pacific Coast.

Three of the paper's tables are reproduced below.

Table *Climate*-2. Miles of roads and railways vulnerable to erosion and flood from a 1.4-meter sea-level rise along the Pacific Coast, by county and type

County	Highways (miles)		Roads (miles)		Railways (miles)	
	Erosion -	Flood-risk	Erosion -	Flood-risk	Erosion -	Flood-risk
Del Norte	4.3	8.2	14	80	-	-
Humboldt	6.0	58	20	190	-	28.0
Marin	2.1	4.1	19	27	-	-
Mendocino	13.0	7.9	25	41	-	4.0
Monterey	11.0	31	15	110	2.1	23.0
San Francisco	0	8.0	17	25	-	-
San Luis Obispo	2.5	0.4	18	22	-	0.3
San Mateo	9.8	11	18	67	-	-
Santa Barbara	0.7	7.4	12	21	6.4	7.0
Santa Cruz	2.4	5.0	20	30	1.6	5.5
Sonoma	6.2	8.0	8.4	57	-	-
Total	**58**		**180**		**10**	

Note: Numbers may not add up due to rounding. Source: CCCC 2016 (Table 27)

The CCCC's paper shows that under current conditions, Humboldt County has the most miles of highway vulnerable to 100-year floods, with Orange County coming in second highest and Monterey coming in third. These three counties comprise 96 of the total 150 miles (2/3) currently at-risk, and over half of the highway miles at risk, statewide, with 1.4 meters of sea-level rise.

Table *Climate*-3. Miles of roads and railways vulnerable to a 100-year flood in 2000 and with a 1.4-meter sea-level rise along the Pacific Coast, by county and type

County	Highways (miles)		Roads (miles)		Railways (miles)	
	Current Risk	Risk with 1.4-m SLR	Current Risk	Risk with 1.4-m SLR	Current Risk	Risk with 1.4-m SLR
Del Norte	6.6	8.2	59	80	-	-
Humboldt	37	58	120	190	21.0	28.0
Los Angeles	14	31	42	140	5.6	14.0
Marin	1.2	4.1	22	27	-	-
Mendocino	5.6	7.9	28	41	2.7	4.0
Monterey	27.0	31.0	85	110	19	23.0
Orange	32.0	48.0	340	490	5.3	6.6
San Diego	0.6	8.0	12	57	3.0	9.8
San Francisco	0.2	0.4	17	22	-	-
San Luis Obispo	5.3	7.4	10	21	0.02	0.3
San Mateo	3.4	5.0	23	30	-	-
Santa Barbara	1.5	8.0	9.1	25	3.4	7.0
Santa Cruz	9.4	11	52	67	4.2	5.5
Sonoma	4.5	5.9	14	20	-	-
Ventura	2.4	11.0	69	150	3.7	10.0
Total	**150**	**250**	**910**	**1,500**	**68**	**110**

Note: Counties with borders on the Pacific coast and San Francisco Bay (e.g., San Mateo) were separated based on the shoreline affected. Numbers may not add up due to rounding. Source: CCCC 2016 (Table 15)

Table *Climate-4*. Replacement value of buildings and contents at risk of a 100-year flood event along the Pacific coast, by county

County	Current risk, in millions $	Risk with 1.4-m sea- level rise, in millions $	Percent increase
Del Norte	240	350	+ 43%
Humboldt	680	1,400	+ 110%
Los Angeles	1,400	3,800	+ 180%
Marin	220	260	+ 16%
Mendocino	120	150	+ 22%
Monterey	1,700	2,200	+ 36%
Orange	11,000	17,000	+ 63%
San Diego	690	2,000	+ 190%
San Francisco	670	890	+ 33%
San Luis Obispo	220	360	+ 67%
San Mateo	730	910	+ 26%
Santa Barbara	460	1,100	+ 140%
Santa Cruz	2,400	3,300	+ 34%
Sonoma	170	200	+ 20%
Ventura	980	2,200	+ 120%
Total	**21,000**	**37,000**	**+ 71%**

Note: All values are shown in millions of year 2000 dollars. Counties with borders on the Pacific coast and San Francisco Bay (e.g., San Mateo) were separated based on the shoreline affected. Source: CCCC 2016 (Table 21)

Other estimates presented in this paper include:

- Estimated length (in miles) and capital cost of required defenses needed to guard against flooding from a 1.4 m sea-level rise, by county; and
- Population vulnerable to flood and erosion from a 1.4 m sea-level rise along the Pacific coast, by county.

REFERENCES

CITATIONS

Anderson 2017. Anderson, J., L. Aldaron, and J. Patton. Letter to Ocean Protection Council, State of California, dated 6 June 2017.
CCCC 2016 (California Climate Change Center). "The Impacts of Sea-Level Rise on the California Coast." Prepared for the CCCC by Heberger, M., H. Cooley, P. Herrera et al. (http://research-Climate Chg/sea-level-rise. Pacific Institute_2016.12.12download.pdf)

CO-CAT 2013 (Coastal and Ocean Working Group of the California Climate Action Team) "State of California Sea-Level Rise Guidance Document, March 2013 update." (March 2013)

Caltrans 2016 *California Transportation Plan 2040*. (Adopted June 2016.) (www.dot.ca.gov/hq/tpp/californiatransportationplan2040/2040.html)

Caltrans District 1 and HCAOG 2014 "District 1 Climate Change Vulnerability Assessment and Pilot Studies: FHWA Climate Resilience Pilot Final Report (Prepared by GHD, ESA, PWA, Trinity Associates) (December 2014) (www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/ccps.pdf)

Cascadia Geosciences 2013 *as cited in Laird 2015*. "Tectonic land level changes and their contributions to sea-level rise, Humboldt Bay region, Northern California: 2013 Status Update."

FAA 2015 (Federal Aviation Administration) *Aviation Emissions, Impacts & Mitigation: A Primer*. FAA Office of Environment and Energy. (January 2015)

Griggs and Russell 2012 *as cited in Laird 2015*. "Adapting to sea level rise: A guide for California's coastal communities." Russell, Nicole and Gary Griggs. University of California, Santa Cruz.

NHE 2015 (Northern Hydrology Engineering). **"**Final HBSLR Modeling Inundation Mapping Report." Prepared for the Humboldt Bay Sea Level Rise Vulnerability Assessment Project. (April 2015.) (www.humboldtbaykeeper.org/climate-change-impacts-sea-level-rise/69-in-the-news/986-humboldt-bay-sea-level-rise-inundation-mapping.html, accessed August 8, 2017)

Schwartz, Meyer, et al 2014 (Schwartz, H. G., M. Meyer, C. J. Burbank, M. Kuby, C. Oster, J. Posey, E. J. Russo, and A. Rypinski) "Ch. 5: Transportation. *Climate Change Impacts in the United States: The Third National Climate Assessment*," J. M. Melillo, Terese Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 130-149. (http://nca2014.globalchange.gov/report/sectors/transportation)

S.F. Chronicle 2017 "EPA chief lets up on California" (A10). Carolyn Lochhead. (July 10, 2017)

RESOURCES

Adapting to Rising Tides: A project of the San Francisco Bay Conservation and Development Commission. www.adaptingtorisingtides.org.

Assembly Bill 32 (AB 32) (2006) Global Warming Solutions Act of 2006 California Statute, Chapter 488, California Health & Safety Code §38500- 38599.

"Humboldt Bay Sea Level Rise Adaptation Planning Project, Phase I: Humboldt Bay Shoreline Inventory, Mapping, and Sea-Level Rise Vulnerability Assessment." January 2013. Prepared for the California State Coastal Conservancy by Laird, A., Powell, B. and Anderson, J.

"Humboldt Bay Sea Level Rise Adaptation Planning Project, Phase II: Final Report" 2015. Prepared for the California State Coastal Conservancy by Laird, A.

(www.coastalecosystemsinstitute.org/humboldt-bay-slr-vulnerability-and-adaptation-planning/)

Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments. (http://cses.washington.edu/db/pdf/snoveretalgb574.pdf)