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Executive Summary

With climate change, rising sea levels are expected to affect low lying coastal areas world-wide. Coastal development, transportation infrastructure, agricultural lands and wildlife habitats may all be flooded over time by a general rise in water level and higher high tides, and by increasingly frequent and intense storm surge events. In California, at the Governor's behest, a Climate Action Team made up of agenc**ies** from key branches of state government is tasked with developing and implementing appropriate policies in response to climate change including sea level rise. The Climate Action Team bases its efforts on an expected 1.4 meters (55 in.) of sea level rise along the California coast by the year 2100.

We are students in the Environmental Management and Protection Spring 2011 Senior Planning Practicum here at Humboldt State University and have developed an assessment of likely implications of sea level rise for the North Humboldt Bay Area for our final project. While the rate of change, the specific magnitude and severity of sea level rise impacts are not yet predictable for this area, it is not too soon to begin to assess and plan for potential outcomes. We reviewed the literature on sea level rise and interviewed staff from local, state and federal agencies, local elected officials, landowners, business owners and real estate brokers regarding their expectations about likely impacts of sea level rise and the responses that will need to be undertaken.

Direct effects of inundation are expected to occur locally with variable severity and at unpredictable rates. Indirect effects will be to the land, water and wetlands and to infrastructure. We focused in this report on the effects to agricultural lands, wetlands and habitat for endangered species, transportation corridors, brownfields, homes and businesses. Additional factors the region will need to cope with are its geographic and political remoteness, and constraints posed by existing legislation such as the Coastal Zone Management Act and Clean Water Act which limit mitigation and retreat due to effects on current wetlands. Beginning in the near future, a variety of local responses are expected including planning for strategic mitigation, retreat and adaptation. These responses will need to incorporate changes in local, state and federal policies, provide fully transparent prioritization of mitigation efforts, and adaptation of local planning guidelines. Significant public education and outreach efforts will be required to achieve sufficient consensus on these issues to allow the area to move forward proactively rather than being forced to react in an environment of limited choices 20 -50 years from now.

Acknowledgements

Humboldt State University is located in the City of Arcata at the North end of the Humboldt Bay Estuary in Northern California. As students in the Spring 2011 Environmental Management and Protection Program's Senior Planning Practicum, we are very grateful to the many local professionals who shared their expertise and discussed the issue of sea level rise with us. Thank you, Jeff Anderson, Mark Andre, Charles Bartolotta, Dan Hauser, Gavin Hone, Kim Floyd, Ralph Faust, Dan Johnson, Gale King, Gordon Leppig, Eric Nelson, Andrea Pickart, Hank Seemann, Tim Shreeve, Ryan Wells, Mark Wheetley, Andre Whitney and Mike Wilson. We would like to offer special thanks and recognition to our community "client", Aldaron Laird, and our professor, Dr. Yvonne Everett, for their guidance, patience, and support.

Aldaron Laird, an environmental planner and Humboldt Bay Municipal Water District director is currently leading a shoreline mapping and inventory process around Humboldt Bay which will help in future sea level rise planning efforts in the area. By determining whether shoreline segments are natural or artificial and observing the condition of dikes and levees, inundation models can be made more accurate, giving local land managers better information and flexibility in exploring planning options. Laird's noteworthy project was made possible by a grant from the State Coastal Conservancy, which is taking a proactive role in sea level rise planning efforts. We hope that his effort, combined with others such as ours will stimulate efforts to proactively address sea level rise in our region.

In accordance with the requirements for exempt research by the HSU Institutional Review Board for the protection of human subjects, we attributed information received from public agency or local government staff and from expert consultants only. We used but did not directly attribute information gathered from public officials or appointees. Any errors or misrepresentations in the document are our own and should not be attributed to those whom we interviewed.

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Introduction

Climate change is affecting global weather patterns, storm intensity, variability in precipitation, and is melting glaciers and polar ice sheets (United States Environmental Protection Agency 2010a). One major resulting concern for coastal areas is sea level rise. According to the United States Environmental Protection Agency, sea level has increased on average world-wide at a rate of roughly six-tenths of an inch per decade since 1870, and the rate of increase has accelerated recently to more than an inch per decade (United States Environmental Protection Agency 2010a).

Rising sea levels are expected to affect low lying coastal areas world-wide. Coastal development, transportation infrastructure, agricultural lands and wildlife habitats may all be flooded slowly by a general rise in water level and higher high tides, and by increasingly frequent and intense storm surge events (Krolak 2001). The Pacific Institute used past models coupled with current human behaviors to hypothesize a 22-55 inches (1.4 m) rise in sea level on the California coast by 2100 (Heberger et al. 2009).

It is the purpose of this report to assess implications and explore response options for the expected impacts of accelerated sea level rise caused by climate change in North Humboldt Bay, California. This research was carried out from January – May 2011 through a review of the literature, interviews with local government and agency experts and business owners, and GIS based analysis. After a brief review of international climate and sea level rise research and its relative political salience in the United States, we introduce the three primary sea level rise response strategies of retreat, mitigation and accommodation. We then give a brief summary of California state efforts to address climate change and sea level rise, before focusing on implications of sea level rise on North Humboldt Bay. Based on a conceptual model of implications of sea level rise (Appendix A), we analyze likely direct and indirect effects of sea level rise on several key aspects of the North Humboldt Bay region's culture, economy and environment: transportation infrastructure, businesses and homes, agricultural lands, wetlands, endangered species and industrial brownfields before discussing barriers to retreat, mitigation and accommodation strategies and potential response opportunities.

Responses to Climate Change

Despite the global research effort, assessing how, when and where sea level will rise for a given coastal location is not understood with sufficient precision to galvanize widespread government response. Most decision makers have not yet had the opportunity to consider the complex implications in detail.

Furthermore, while there is significant consensus in the scientific community that climate change is real, there is considerable uncertainty and debate among the general public. A survey of 1,001 adults conducted by the Virginia Commonwealth University Center for Public Policy found that while 54% of respondents found Global Warming to be a major problem, 23% said Global Warming was a minor problem and 19% indicated it was not a problem at all (5% were unsure). In other words, nearly half of the sample felt that climate change is a minor issue or no issue at all (Virginia Commonwealth University Center for Public Policy 2010).

Any response strategy will depend on improving scientific and public understanding of the problem as a critical component. Generally, response strategies to sea level rise can be divided into three options: retreat, mitigation, and accommodation. Retreat involves putting forth no effort to protect the land from the rising sea. This would leave all flood zones unoccupied, allowing incoming sea water to flow freely (United States Environmental Protection Agency 2011a). This strategy prohibits any new infrastructure construction in flood zones, and it can also include physically moving current buildings to higher ground, if deemed necessary (San Francisco Planning and Urban Research Association 2011).

Mitigation involves taking action against rising sea level, for example, by armoring the shoreline or using a barrier to control the amount of tidal flows in a waterway. Although such forms of mitigation are costly options, they could provide the protection needed to keep coastal residents and infrastructure safe from flooding for some time. About one quarter of the Netherlands' total territory lies below sea level without flood disturbance, and this is made possible because the majority of the coastline is armored with levees. In some areas, a "smart levee" system is used which is embedded with a series of networked monitors that can predict a breach more than a day in advance. The Dutch also employ double dikes, where an interior levee and a higher exterior levee placed several hundred

meters apart create a space for floodwater to collect (San Francisco Planning and Urban Research Association 2011).

Accommodation presupposes that humans will continue to use land in the flood zones without preventing future flooding. Possibilities include elevating buildings, converting agricultural lands to fish or oyster cultivation, and growing salt tolerant crops (United States Environmental Protection Agency 2011a). An example of accommodation is the elevation of houses in New Orleans following Hurricane Katrina. New Orleans requires new or rehabilitated housing in levee-protected areas to be elevated either three feet above grade, or to the base flood elevation established by the Federal Emergency Management Agency (FEMA), whichever is higher (San Francisco Planning and Urban Research Association 2011). Putting new infrastructure on stilts or on floating platforms could allow the predicted sea level rise to occur without interruption of human activities. Efforts to apply a range of response approaches are beginning in California.

The state of California has recognized climate change as one of the most significant issues that will affect its population and resources within the next hundred years (Frost 2009). Following the Governor's Executive Order # S-03-05 on Climate Change in 2005, Assembly Bill 32, the "Global Warming Solutions Act of 2006", required state government to develop regulations that will reduce greenhouse gas emissions to 1990 levels by 2020. A Climate Action Team made up of agenc**ies** from key branches of state government was created to develop and implement appropriate policies (California Climate Change Portal 2011).

While most attention has been focused on reducing greenhouse gas emissions, several state agencies, and counties and municipalities in coastal regions have begun to conduct research related to sea level rise predictions along the California Coast, and have initiated localized efforts to respond to sea level rise. The California Coastal Commission was one of the first state agencies to address the issue beginning with a 1989 draft report on "Planning for an Accelerated Sea Level Rise along the California Coast". In 2001 the Commission issued a follow-up report: "Overview of Sea Level Rise and Some Implications for Coastal California" (California Coastal Commission 2011).

The Pacific Institute is one of the leading private non-partisan research institutes actively conducting research on sea level rise impacts and adaptation on California's coast (Pacific Institute 2011). Beginning in the early 1990s, the Pacific Institute contracted with

several state and local agencies to help address the risks of sea level rise through the creation of sea level rise maps, cost assessments of sea level rise adaptations, and vulnerability assessments for planning efforts as a means of quantifying hazards and advancing the goals of environmental protection, economic development, and social equity. The most recent report in this regard was the California Coastal Erosion Response to Sea Level Rise carried out by the Pacific Institute in collaboration with Philip Williams and Associates (2009). The report includes mapped estimates of inundation due to sea level rise for the entire California Coast.

Executive Order S-13-08, the first Executive Order to mandate a Sea Level Rise Assessment Report in California, was issued in November of 2008. Its purpose was to encourage awareness and preparedness for the effects of sea level rise on a state level and to generate planning efforts among local agencies state-wide that seek to assess, prepare for, and mitigate potential impacts. The order mandated that a Sea Level Rise Assessment Report be carried out by the National Academy of Sciences (now expected in 2012). It will include sea level rise projections for the state, a range of uncertainty for the projections, synthesis of current information on projections of state infrastructure impacts, and a discussion of future research needs. Further, key state agencies including the Ocean Protection Commission were ordered to work together under the lead of the California Resources Agency, and were called upon to assume responsibility for developing California Adaptation Strategy Reports. The first California Adaptation Strategy Report was released in 2009 (California Natural Resources Agency 2009). The report used a baseline estimate of sea level rise of 20-55 inches by 2100 drawn from Rahmsdorf (2007), which was the most current science at the time the report was released. The report began to quantify likely implications of sea level rise for California:

> *"According to recent estimates developed for the 2009 California Climate Change Impacts Assessment, a 100-year flood event after a 1.4 meter (55 inches) sea-level rise will put 480,000 people at risk and nearly $100 billion in property. In addition, California residents and out-of-state visitors make well over 500 million visits to the state's ocean beaches every year. People go to the coast to enjoy sun and sand, the vistas, and the unrivaled diversity of plants and animals that inhabit the region. All of these visits contribute greatly to California's ocean-dependent economy, which is estimated to be $46 billion per year."*(California Natural Resources Agency 2009:65)

A number of local governments at regional, county and municipal levels in California have begun to plan response strategies for sea level rise. For example, Ventura County officials have already begun to respond to a rising sea with managed retreat. They have, for example, rather than pursuing costly maintenance, removed a coastal parking lot and added sand and cobblestone, which will allow the sea to encroach on a naturalized area (Barboza, 2011). Discussions about best responses to sea level rise are also beginning in the Humboldt Bay region.

The North Humboldt Bay Region

In the Humboldt Bay Region in far northern coastal California, the initial responses to sea level rise have been mixed. Locally, the City of Arcata has been able to purchase several coastal areas threatened by future flooding as a precursor to retreat (Andre 2004), while some other local governments have not begun to discuss sea level rise at all.

Humboldt Bay is California's second largest natural estuary. Four major Klamath Region watersheds that span over 250 square miles drain into Humboldt Bay (Humboldt Baykeeper 2011). The Humboldt Bay watershed encompasses redwood forests, oak woodlands and meadows, salmon-bearing streams, and a variety of freshwater, brackish and saltwater wetlands and tidal mudflats (Humboldt Baykeeper 2011). The population of Humboldt County is 134,623 (United States Census Bureau 2010) and located predominantly around the Humboldt Bay area in the incorporated cities of Eureka (~ 46,000) and Arcata (~16,000) and in small unincorporated communities such as Manila, Samoa and King Salmon. The North Humboldt Bay, including especially the City of Arcata has a large population of about 7,000 college students attending Humboldt State University. In recent years, the economy has diversified away from its roots in timber harvesting, dairy management, cattle ranching, bulb farming, row cropping and commercial fishing to now include recreation based tourism and a significant underground economy based on marijuana cultivation (Humboldt County Community Development Services 2011; Poor, 2011))

Humboldt Bay is remote in several ways. The Bay is physically remote from any large cities or metropolitan areas, and is not what many people typically think of when they envision California. Landslide prone State Highways 36 and 299 link the region to the metropolitan area of Redding on the Interstate 5 freeway corridor, a three hour drive to the East, and Highway 101 connects the region to the south to Santa Rosa (4 hours) and the San Francisco Bay Area (5 hours away). Politically the Humboldt Bay region is also remote.

Because of its relatively small population, major political decisions made in Sacramento frequently do not take the region into consideration. While remoteness can be considered a hindrance, it may also present opportunities. Far sighted Humboldt communities that work together may be able to lead on the edge of innovation in response to sea level rise to obtain funding for pioneering experiments and pilot projects.

The purpose of this study is to assess likely implications of sea level rise and consider response options for the expected impacts of accelerated sea level rise particularly focusing on moving away from short term thinking and into long term solutions and recommendations. The study focuses on North Humboldt Bay, specifically Jacobs Avenue North of Eureka on Hwy. 101 to Samoa Blvd. in Arcata and out Hwy. 255 to Samoa. Also included is the agricultural land in the Arcata Bottoms (Figure 1).

Potential direct and indirect effects of sea level rise, additional challenges, and response options are considered for the key sectors of transportation, homes and businesses, agricultural land, wetlands, threatened and endangered species, and brownfields (See Appendix A: A conceptual model of implications of sea level rise on North Humboldt Bay). Overall responses that will likely be needed including public education are then considered, followed by a discussion of political decision-making processes, laws, and funding mechanisms which could be updated to respond to the threat of sea level rise. Finally, the report concludes with suggested areas requiring further study.

Transportation

Transportation infrastructure may be among the first areas to feel the impacts of rising sea level. Protecting the functionality of the transportation network is important for a variety of reasons, including through travel and local commuting to work, school, homes and businesses. Transportation infrastructure is also vital to the economy, both for the movement of goods and for allowing people to access markets (California Department of Transportation 2002). Additionally, it is essential for disaster preparedness. Redundancy in the system is a key feature to ensure continuity of services and resilience.

Sea level rise poses risks to coastal infrastructure through permanent or temporary inundation, storm surge, erosion, and flooding behind undersized culverts. The California Natural Resources Agency (2009) estimates that 2,500 miles of roads and railroads in California will be vulnerable to higher sea level, while the National Research Council (2008)

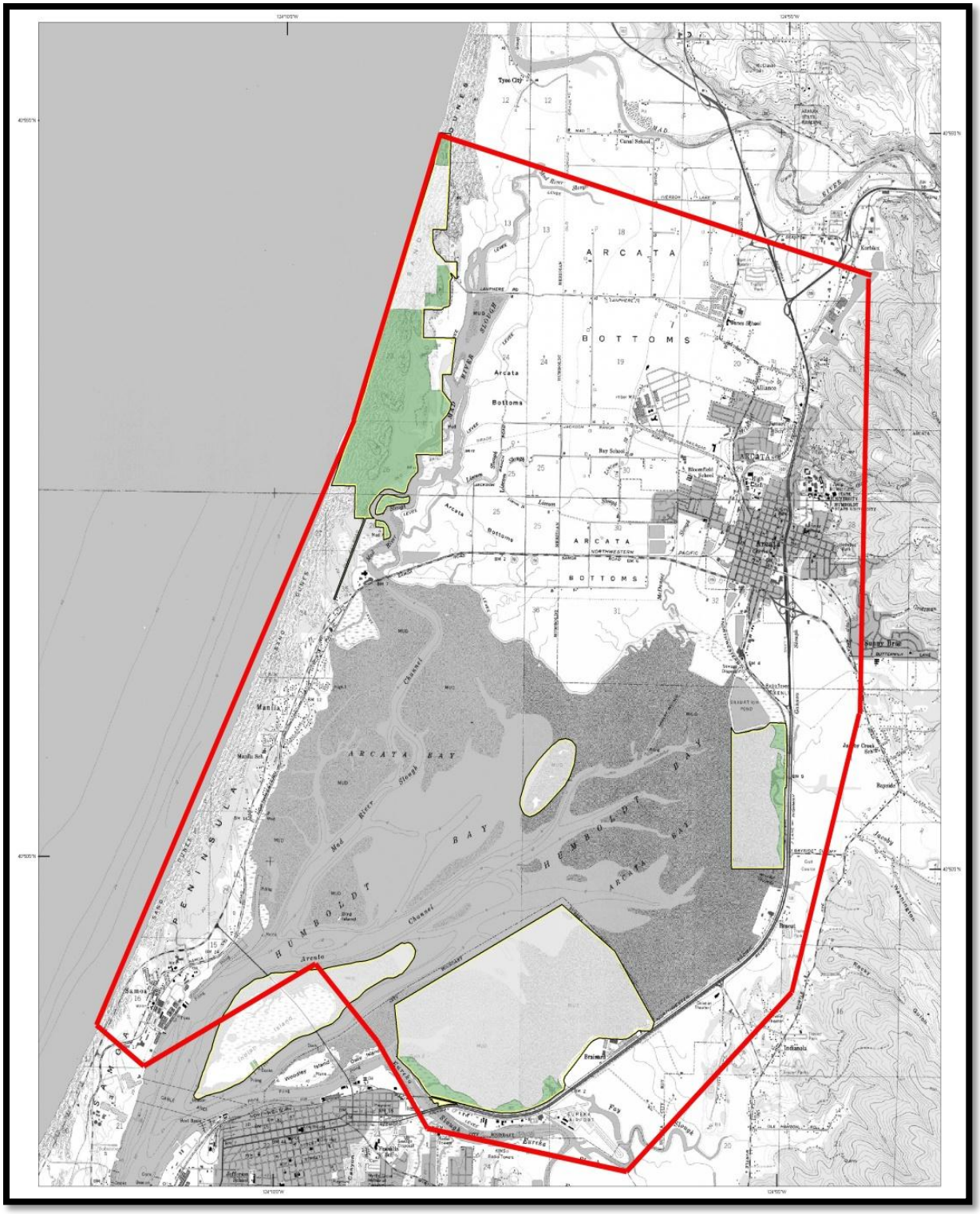

Figure 1: North Humboldt Bay Project Area

predicts that sea level rise may be the greatest challenge of climate change related impacts on transportation. Temporary inundation could occur if levees are damaged or overtopped by high tides and storm surges, disrupting travel in low-lying areas. Wave action can erode road bases and scour the bases of bridge supports (National Research Council 2008). Reduced clearance under bridges leaves them susceptible to wave damage and increased shear stress from tidal movement. Urban encroachment on streams with tidal influence constrains natural floodplains, putting nearby infrastructure at risk during flood events. When peak stream flows coincide with peak tides, culverts constrict flow and back up, causing local flooding.

Some of these issues are already a cause for concern. According to City staff, flooding along urban creeks in Arcata already occurs due in part to undersized culverts. Flooding of Highway 101 has also occurred because of storm surge combined with high tides overtopping the adjacent railroad (Federal Highway Administration and California Department of Transportation 2007). California has been on a trajectory of increasing severe winter storms with accompanying high storm surges for the last sixty years, which will exacerbate sea level rise issues. Simultaneous high sea level and high stream flow are also set to occur more frequently through the twenty-first century (California Climate Change Center 2009).

Within the study area of this project, transportation infrastructure at risk includes a portion of Highway 101; Arcata, Eureka, and county roads; and the Murray Field airport. Vulnerability will be assessed for each of these areas in greater detail followed by a consideration of additional challenges for transportation planning and sea level rise.

Highway 101 is of considerable strategic importance to the area as it is used for local, regional, and interstate travel including tourism and recreation (Federal Highway Administration and California Department of Transportation 2007). It is economically significant as a transportation route for people and for many goods, including crucial food supplies, as well as being a major route for emergency response and evacuation.

A portion of this highway between Arcata and Eureka, approximately six miles in length, may be threatened by sea level rise. While the exact elevation of this corridor may vary, it is 12.7 feet (3.87 m) on the stretch adjacent to Jacobs Avenue (H. Seemann pers. comm.). National Oceanic and Atmospheric Administration tide station elevation monitoring shows that some land in and next to this corridor is already below mean higher

high water elevation for 2000, which would be further aggravated by sea level rise (Stacey 2009).

Highway 101 lies directly east of a railroad grade which functions as a de facto shoreline protection device sitting about three feet above mean high tide (D. Hauser, pers. comm.). The railroad embankment was the first levee structure built in the area in the late 1800s, with the previous boundary of the Bay lying near the present Old Arcata Road (D. Hauser, pers. comm.). Highway 101 was later built alongside the railroad. The railroad is owned by the North Coast Railroad Authority, but it has been closed since 1998. It is not currently being maintained, nor is it reasonably foreseeable that it will be, unless funding for repairs is obtained, although the Timber Heritage Association has expressed interest in an excursion train around the Bay (G. Leppig, pers. comm.; D.Hauser, pers. comm.; North Coast Railroad Authority 2010).

The railroad embankment has experienced some damage due to overtopping and washing out of ballast during storms, reducing its height by up to one foot (0.3 m) in some locations (Stacey 2009). According to a local engineer, the railroad grade is somewhat permeable and is blown out in several places, limiting its effectiveness as a levee. Caltrans considers it an embankment "acting as a levee" rather than a levee itself, and a Caltrans employee reported that the railroad ballast's elevation is less than or equal to the elevation of the southbound lanes of Highway 101, which may create significant challenges in the future as the sea level rises (Federal Highway Administration and California Department of Transportation 2007).

Caltrans has proposed a project affecting this section of highway, and at the time of this reporting, the combined Final Environmental Impact Report/Statement was still being prepared. Although an alternative had not been definitely selected yet, the project may include construction of an interchange at the Indianola cutoff, signalization of Airport Road, replacement of the southbound bridge over Jacoby Creek, and widening the northbound bridges over Jacoby Creek and Gannon Slough in addition to other maintenance (Federal Highway Administration and California Department of Transportation 2007). The Jacoby Creek bridge sections and Indianola interchange would be planned with a 75 year design life and, according to a Caltrans employee, would be able to withstand 3.3-4.6 ft (1-1.4 m) of sea level rise as predicted by the California Climate Change Center.

Some public roads within the Cities of Arcata and Eureka as well as unincorporated areas may be affected by inundation and storm surge, depending on the height and maintenance of levees (Andre 2004). According to a local planning expert, this includes low-lying parts of southern Arcata, Jacobs Avenue, and unincorporated land adjacent to sloughs and levees. Open channels in agricultural land could potentially overflow across fields up to Samoa Boulevard/Highway 255. Inundation of any of these roads would lead to disruption of travel, negatively impacting the movement of people and goods.

Urban creeks with tidal influence within the City of Arcata present planners and city staff with additional complications due to a history of encroachment, diversion, and culverting. In interviews, city representatives noted that flooding can occur along Janes

Figure 2: Storm surge floods 11th St. in Arcata (Photo: Northcoast Journal 2011)

Creek and its tributary Sunset Creek off of Stromberg Avenue where culverts and development force the creek through 90° turns. Localized flooding is also a problem around 11th Street. Some work has already been done to address the issue in this area, including significant lengths of day-lighting, riparian restoration, and fish passage projects along Janes Creek and Jolly Giant Creek (Coastal Watershed Program 2011). Jolly Giant Creek for example, runs through a culvert of approximately 2000 ft. (610 m) under Hwy 101 between the Jolly Giant Commons on the Humboldt State University campus and a day-lighted section in Shay Park near Arcata High School, before running through several others culverts and day-lighted sections in downtown Arcata out to Butcher's Slough and into the Bay. Combined high stream flow and tidal events in the future, however, could cause flooding where it has not occurred before as culverts constrict flows.

Murray Field is a public airport owned by Humboldt County which averages 179 aircraft operations per day (AirNav 2011). Although small, the presence of this airport combined with others in the county is beneficial for disaster preparedness. The airport is located on Airport Road off Highway 101 near Jacobs Avenue. Its elevation is 7 ft (2.1 m) making inundation unlikely, and it is also protected by a levee. Sea level rise is a minor concern for the airport unless the levee fails or is overtopped, though road access from Highway 101 could be restricted if inundation occurred to the west of the site.

Additional challenges for transportation infrastructure include groundwater levels rising along with sea level, and the need to coordinate with other planning efforts. According to local experts, groundwater is expected to rise together with sea level which could lead to local inundation even if levees are of adequate height and well-maintained. The extent to which this phenomenon could affect transportation infrastructure is unknown, but according to a Caltrans employee it is not expected to cause flooding of Highway 101.

Coordination of transportation planning for sea level rise with other local and regional planning will be challenging and may require new collaborations and planning venues. As pointed out by local experts we interviewed, it is highly advisable to take these issues into account when planning for disaster preparedness including tsunamis as well as stormwater management.

Transportation planning responses will be affected by the political decision-making process. Planners should generally seek to develop a resilient, flexible system. Sea level rise assessments could be included in Route Concepts for highways, which are long term

conceptual guides in which sea level could be addressed in the Safety and Operational Improvement Strategy sections (California Department of Transportation 2002). Bridges and culverts should be assessed for adequate drainage capacity. A local expert we interviewed noted that although planning horizons typically encompass 20-30 years, this should be recognized as an artificial division of time, and long-term planning and updates should be encouraged.

Prioritization for funding transportation infrastructure improvements could be based on probabilistic risk analyses similar to the strategies used in the California Seismic Retrofit Program (National Research Council 2008). Caltrans is a member of the Climate Adaptation Working Group which will work to implement the adaptation strategies proposed in California's 2009 Climate Adaptation Strategy.

Retreat has been proposed in some areas, such as a Caltrans project to move sections of Highway 1 up to 475 feet inland near Big Sur due to increased coastal erosion (California Natural Resources Agency 2009). Mitigation could involve protective structures, new building materials, or the creation of expendable structures (California State Lands Commission 2009). Sea level rise could be accommodated through new design standards; for example, facilities could be designed to drain quickly after temporary inundation. An option for Highway 101 is to elevate at-risk portions on a causeway, similar to the Yolo Bypass near Sacramento, which could be a costly but effective longer-term solution (G. Leppig, pers. comm.) In addition to conserving wetlands to take advantage of their potential flood buffering capacity, the City of Arcata, for example, has purchased and conserved upland forested areas to protect watersheds and prevent flooding of lowlands, such as Arcata urban creeks.

It would also be valuable to integrate transportation planning more closely with other land use planning, which could encourage compact, transit- and climate-friendly development. This is important because as a local expert noted, transportation can locally account for 45% of greenhouse gas emissions. Compact, mixed use, and low impact development can encourage multiple forms of transportation including non-motorized uses and help to slow climate change. For those homes and businesses already existing, however, it would be prudent to address these concerns as soon as possible.

Businesses and Homes

Encroaching seawater and backed up creeks driven by sea level rise could cause irreversible flood damage to many homes and businesses around Humboldt Bay. Barring significant mitigation along the shoreline, for example through building up levees, incrementally rising tides or a sudden storm surge could leave some unable to recover, leading to complete displacement and a multitude of financial and humanitarian problems.

Business owners along the Bay could be financially crippled, if Highway 101 was inundated and no transportation was possible. Loss of customers and shipping routes to businesses would be extremely detrimental. Damage to property inside inundated buildings or homes represents another primary loss for private landowners. For business owners, a one-time loss of merchantable products would be a financial setback although inventory would likely be replaceable. Chronic flooding would be less surmountable.

In addition to primary financial losses, homeowners and business owners may experience less tangible, yet significant secondary emotional losses. Personal possessions hold memories and may have irreplaceable sentimental value. A decision to retreat from the shore would bring other challenges. Currently, both business and home owners may feel a strong sense of place connecting them to the local community that cannot be exactly reproduced in another area. Relationships with one's neighbors and community are unique in that they can provide emotional connections and sense of belonging.

In the Jacobs Avenue Business Park in northern Eureka, many businesses have been passed down from generation to generation, and according to one long time business person, the surrounding businesses owners "are family". The levee along the edge of this 45 acre area protects 33 businesses and is home to 150 residents. It is likely that new FEMA mapping will classify this entire area as part of a flood inundation zone, requiring private landowners to purchase flood insurance. Business and home owners along Jacobs Avenue will eventually need to obtain FEMA certification of their levee in order to protect their investments. One business owner stated that at this point too much is invested in the Jacobs Avenue area to retreat; therefore mitigation strategies will be necessary.

One type of mitigation for these structures comes in the form of flood insurance. FEMA provides insurance for structures that have a low probability of flooding (Insurance Information Institute 2011). The financial burden on homes and businesses to protect

themselves from inundation is the most difficult challenge of sea level rise. Few options of outside government funding are available for private land owners. Retrofitting before rebuilding inundated structures can cause significant financial burdens on property owners (CSA International Inc. 2008). Grant funding is possible to decrease private owner financial burdens for hazard mitigation retrofit projects. Another alternative is to apply for pre-disaster grant funding through the FEMA Flood Mitigation Assistance and Pre-Disaster Mitigation Grant Programs (CSA International Inc. 2008). Nonetheless, receiving federal monetary assistance for sea level rise preparedness may be complicated given that FEMA is currently not including sea level rise in its risk assessments or mapping (H. Seemann pers. comm.).

The challenge lies not only in finding the funding for flood insurance but being able to provide flood insurance and protection to anyone within the flood zone. Business owners reported that regulatory constraints within FEMA guidelines currently limit the ability of small and low-income businesses and homeowners to purchase flood insurance. The FEMA mapping process is crucially important for the future of flood insurance and property protection along the North Bay. Flood plain maps designate or remove areas and structures that fall within the FEMA determined high hazard zone (Insurance Information Institute 2011). Recent reports have stated that FEMA has relaxed the deadline for the California Coastal Analysis Mapping project due to discrepancies involving FEMA methodologies for the mapping process (Edrington 2011). Despite the small reprieve from FEMA updates, one business owner indicated that the Jacobs Avenue landowners are still expecting to fall into the high risk category and are remaining proactive on developing a process for levee certification (Edrington 2011).

The Jacobs Avenue Levee Working Group presents a model of cost sharing and landowner collaboration around Humboldt Bay. The Jacobs Avenue business owners have come together in a proactive attempt to have a professional evaluation of the levee and weigh future options. The working group divides responsibility for the protective structure based on how much of the business' property is protected by the levee; each private owner pays a proportion of the initial analysis cost according to the size of their property lot. It is essential to the group that all landowners are involved in this process of cost sharing. Without the entire levee being renovated according to FEMA regulations, it would be ineffective, because if one portion of the levee were to fail, the rest of the protected land behind it would flood too (H. Seemann pers. comm.). This working group could help small

business owners along Jacobs Avenue pay for planning documents, levee condition analyses, certification of protective structures by FEMA, and payment of FEMA flood insurance. (H. Seemann pers. comm.). After the initial evaluation, a theoretical possibility for the Levee Working Group advocated by one business owner is to request formation of a "special assessment district" including all business owners. Assessment fees could help pay for future upkeep of the levee, decrease the overall price for every individual, keep all members protected, insured by FEMA flood insurance, and other funds might become available to a levee district that individual private landowners would not be eligible for.

In other areas around the Bay, homeowners might consider the idea of a working group as well. Although many homes are not directly protected by a levee, it could be beneficial to create homeowners associations that would spread the cost of flood insurance over a larger group of homes to reduce the overall costs to each individual homeowner.

Another potential response is to change the way flood insurance is operated by FEMA and private insurance agencies. In the current system, government underwrites flood insurance coverage and local private insurers administer the coverage to the public (Insurance Information Institute 2011). This system is not designed to deal with the progressively increasing threats that sea level rise presents. Another system or combination of other systems could be developed that not only protect multitudes of landowners, but also provides this protection at an affordable rate for the average homeowner. Flood coverage systems used in other countries provide models of alternative benefit and protection approaches to the current system in the United States. Countries such as Japan, the United Kingdom, and Spain have a method called "bundling". Under this structure, flood coverage is combined with that for other disasters like windstorms and fire (Insurance Information Institute 2011). This system effectively spreads the risk across a large geographical area, increasing the chances that the entire population is covered for flood damage (Insurance Information Institute 2011). A system like this could be a solution for homeowners that cannot afford flood insurance by themselves. If flood insurance is "bundled" with regular home insurance across the entire North Bay or even all around Humboldt Bay, the cost could potentially become less significant and more socially acceptable to all income levels, decreasing social injustice and increasing the possibility of insurance in all likely inundation areas.

Another system adopted in France and Spain has qualities beneficial for both homeowners and businesses. In this scenario, the government creates a compensation

program for major events, like sea level rise, that takes effect when the cost of the problem reaches a certain cost level (Insurance Information Institute 2011). A local insurance agency representative interviewed proposed a hypothetical solution much like a combination of the two systems mentioned above. In the case of sea level rise, the government would prepare by creating a fund that saves money specifically for the issue of flooding. As the issue becomes more significant, rates will increase by negotiation based on how affected or prone the area is to be inundated by sea level rise. Many of these potential responses may only be effective once sea level is a higher priority. Nonetheless, beginning to think and conceptually create alternative options now may be in the best interest of home and, businesses owners, local government and agricultural land owners.

Agricultural Land

As sea level rises, significant areas of agricultural land will be at risk. Prior to European settlement, Humboldt Bay was surrounded by approximately 9,000 acres of salt marshes. The process of draining the marshes for agriculture and constructing California's first railroad track, almost entirely converted these historic salt marshes (Pickart 2001). Today, 90% of the historic salt marshes have been converted into agricultural land. According to Arcata's General Plan, nearly 30% of the land located within the City is designated agricultural (City of Arcata 2010). Much of this agricultural land is located in North Humboldt Bay (Figure 3). With such a large amount of land designated for agricultural purposes, it is apparent how vital local farms are for the community. Agricultural lands provide the community with amenities such as food, open space, and habitat for wildlife. If sea level continues to rise at its predicted rate, an immense portion of this land will be in jeopardy.

The flooding of agricultural land poses serious threats to landowners. Some low-lying areas will be permanently inundated unless they are protected (Andre 2004). Currently, some of the agricultural lands that are most likely to be inundated are being used for cut-flower, silage and hay production, row crops, and livestock grazing (City of Arcata 2010). If this land is not protected, saltwater intrusion could result in the loss of salt-intolerant crops through diminished soil aeration, salinization, and direct damage (J. Anderson, pers. comm.). Consequently, landowners will suffer economic losses and some may even lose their livelihoods entirely. Given this hardship, landowners may find it beneficial to pursue

alternative ways of making a living on their land. For example, landowners can explore aquaculture opportunities. This process, however, would require landowners to fundamentally rethink their land management, acquire a new set of skills and take business risks in a new frontier that may prove to be too challenging, time consuming and expensive, especially for those reaching the age of retirement.

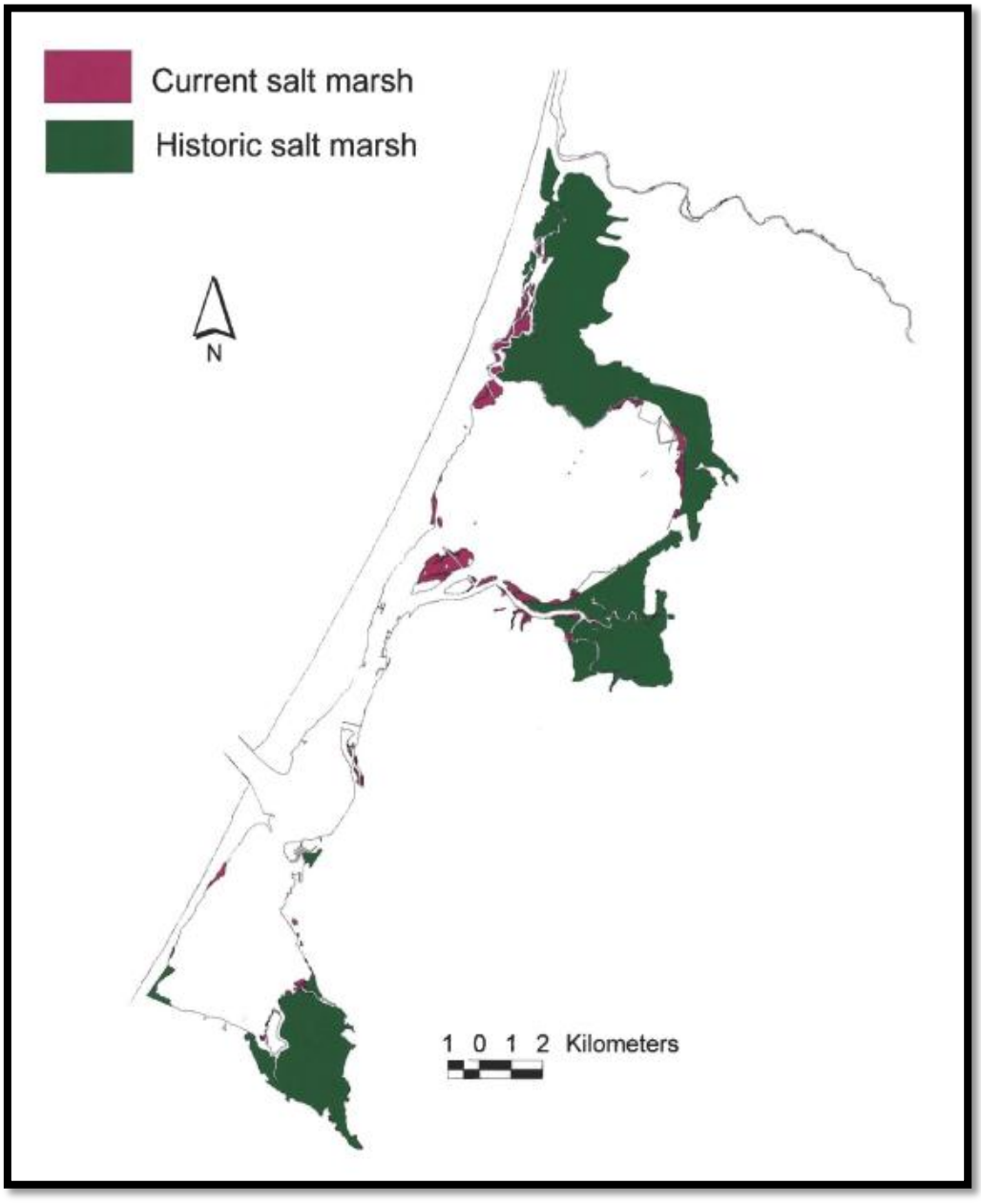

Figure 3: Extent of Historic & Current Salt Marshes (Source: USFWS, 2001)

An additional challenge mentioned by local experts is that flooded grazing land will displace livestock. When grazing land becomes inundated, affected landowners will be required to relocate their livestock to sustain their livelihoods. Those who relocate their livestock will need to find grazing land further inland that is available to lease or purchase. The process of relocating livestock will be time consuming and costly, potentially forcing many landowners to abandon their livelihood. Therefore, flooding of grazing land would burden landowners physically and financially, and could even require them to give up their means for survival. The loss of hay produced on these lands will also have regional ripple effects as inland ranchers who currently depend on this nutritious fodder have to find alternative sources.

These likely negative impacts may be somewhat minimized if landowners begin to develop response strategies. Responses for agriculture may include any or all of the three previously mentioned tactics: retreat, mitigate, and accommodate. Appropriate and sensible actions will vary with time.

According to local experts, salt water intrusion could significantly disturb the current uses of the agricultural land. Landowners who are faced with the impacts of flooded agricultural land may decide that selling their land is more feasible than maintaining it. Their land could be purchased for conservation purposes or aquaculture. There are some willing buyers. For example, the City of Arcata has slowly acquired low lying agricultural land surrounding Humboldt Bay as part of a long-term effort to buffer the City from sea level rise and return the land to its historic wetland state.

Currently, the City of Arcata owns nearly 550 acres of low lying agricultural land that is used for grazing, wildlife habitat, storm management, and open space (Andre 2004). With an increase in sea level, this property is expected to become unsuitable for agricultural purposes. The City expects to allow this property to return to salt marsh (Andre 2004). While the timing and precise magnitude of sea level rise in the local area are uncertain, the City continues to proactively purchase land in the most flood prone areas. Under their ownership, the City can currently utilize these lands, for example by leasing them for grazing while preventing others from obtaining development rights. Additionally, agencies such as US Fish and Wildlife Service have purchased agricultural land in flood prone areas close to current refuges to act as potential future refuge habitat in their retreat strategy (E. Nelson pers.comm.).

Mitigating for sea level rise would be very costly. According to a local expert, over the past century, farmers on the North Bay have protected roughly 80% of their agricultural land from flooding with earthen levees. However, because earthen levees are susceptible to erosion, they are prone to failure unless they are maintained. Further, as sea level rises, existing levees might not be high enough to withstand over-topping due to storm surges.

Figure 4: Existing Levee in North Humboldt Bay (Source: Water Structures, 2004)

Maintaining earthen levees and armoring them with rock to avoid erosion is not inexpensive. However, other alternatives such as replacing these levees with concrete structures would require extensive funding that local government currently lacks. Further, several local experts mentioned that raising the height of the levees is a key issue. In order to build existing earthen levees higher, the bases would need to be widened which would encroach on existing wetland and therefore be subject to Section 404 "no net loss of wetlands" rules under the Clean Water Act. A taller concrete levee built around Humboldt Bay might temporarily solve the problem. Realistically, however, even if the Coastal

Commission were to consider allowing this, the financial cost of building such a levee would equal or exceed the value of the agricultural land behind it. In Humboldt County, the price of agricultural land on a per acre basis ranges from $2,321-$5,342 (LandAndFarm Inc. 2011). In contrast, according to a local expert we interviewed, recent levee construction in the Arcata Bottoms cost more than $1,000,000 per mile. Further, it would not be sufficient to build only a mile or two of levee here or there. To protect the land, the levee would have to extend fully around the low-lying agricultural lands. To address these challenges, current owners of low lying agricultural land could mitigate for sea level rise by forming a reclamation district and joining together to maintain and raise the levees.

At least two accommodation based approaches, use of conservation easements or exploration of aquaculture opportunities are also possible. In recognition that their land will flood eventually and thus not be suitable for development in future, landowners could sell conservation easements as a mid-term response that would allow them to remain on their land while capturing some cash value for their development rights. Along with retaining their livelihoods, landowners could receive more compensation for their land from conservation easements than they would if they were to wait and try to sell their land after sea level rise becomes more evident. The agricultural land would be preserved in the mid-term and eventually return naturally to salt marsh, becoming a wetland buffer for dry lands further inland. Therefore, conservation easements could benefit landowners as well as conservation efforts already begun by organizations including the US Fish and Wildlife Service and the California Department of Fish and Game.

Finally, landowners can accommodate sea level rise by exploring aquaculture. Flooding of low lying land may introduce alternative livelihood opportunities. Landowners may find it feasible to cultivate oysters on their inundated land. Currently, the City of Arcata leases its tidelands in the Arcata Bay to commercial oyster growers (Andre 2004). Aquaculture opportunities may also include fish cultivation. For example, submerged areas in Bangladesh are being considered for cage and pen culture (Sarwar 2005). A cage is a net-built pocket submerged in water where fish can be raised. Humboldt Bay, like coastal areas in Bangladesh, may be suitable for cage culture. While this would be a major cultural and livelihood transition, such a shift might be economically viable. Whether agricultural landowners will explore such alternatives in the near future remains to be seen. These landowners face no immediate danger requiring them to change their current ways of life or land management. Without witnessing dramatic effects from sea level rise, some

landowners may choose not to accommodate or mitigate for rising water in the short term. However, in the medium term, the potential for allowing reversion of agricultural lands to tidal wetlands may be important for both landowner economics and wetland habitat.

Figure 5: Agricultural Lands in North Humboldt Bay (Photo Y. Everett)

Wetlands

Wetlands dynamics will fundamentally change with a rise in sea level in North Humboldt Bay. The tidal influx could inundate the mudflats, and fresh and salt water marshes could experience various scenarios of loss, retreat, or expansion of land cover. North Bay wetlands that may be affected by tidal inundation are Mad River Slough, Arcata Marsh, Jacoby Creek, Fay Slough, and Eureka Slough. It is important for land managing agencies to identify how sea rise could influence these wetlands in ways that would alter their location, habitat, and resources that they provide to the surrounding area (E. Nelson pers. comm.).

The levees and tide gates that exist along the sloughs and the coast of Humboldt Bay play a significant role in how this estuarine circulatory system functions. If the containment

infrastructure that has been built on Humboldt Bay holds or continues to be maintained and strengthened, the large volume of tidal water that is forced into the marsh and mudflat area will be held back. Alternatively, the levees and tide gates could fail as tidal floods inundate wetlands as the sea level rises. Land that lies adjacent to the northern portion of Humboldt Bay's marshes and mudflats presents both opportunities and obstacles in determining how these wetlands could change with a rise in sea level.

Wetland vegetation cover and species composition are distributed along specific elevation and inundation gradients. Mudflat, salt-, brackish and freshwater marsh habitat along with species that depend on them could be lost due to tidal forces that push these habitats further inland. It is difficult, however, to gauge the extent of the impacts that a rise in sea level will have on North Humboldt Bay. It is uncertain where these different palustrine and estuarine habitats may be accommodated and what amount can be preserved.

According to a local engineer, mudflats along with other wetland cover types will likely be able to keep pace with a rise in sea level. Alterations in intensity of wave and tidal energy and sediment accretion activity are possible in the North Humboldt Bay region. Increased sediment loads from the Mad River and the surrounding slough network could provide mudflats with the amount of sediment accretion needed to keep pace with annual rises in sea level. However, research on similar sea level rise challenges in delta areas in France concluded that "if vertical accretion rates in the deltaic plain do not keep pace with present and future sea level rise rates, wetlands will undergo reduced primary production due to salt stress and water logging" and they may cease to exist (Pont *et al*. 2002).

Increased accretion activity in North Humboldt Bay could also lead to a major land cover conversion of salt marshes to mudflats. Salt marsh conversion to mudflat could result from the inability of marsh vegetation to persist when submerged in saline water introduced into the system by a change in sea level. Physical land barriers such as dunes, forests, and infrastructure inland could hinder marsh migration such that instead of a dynamic estuarine system comprising various cover types, mudflats could become a more dominant wetland cover. Another scenario could be that the proportion of marsh to mudflat that becomes submerged may be able to remain proportionately the same farther inland if marshes are allowed to retreat (J. Anderson pers. comm.; A. Pickart pers. comm.).

Another challenge is posed by a changing of the shoreline morphology due to uplift and subsidence. Geomorphological changes to coastal and estuarine ecosystems can induce

complex outcomes for the biota within them, due to the intricate network of their interactions. Shoreline subsidence has been mapped in the Pacific Northwest as a part of sea level rise research efforts (Patton 2011). While the Crescent City area seems to be rising, Humboldt Bay is experiencing subsidence (J. Anderson pers. comm.).

Among the ecosystem services that marshes provide is water quality enhancement (or water filtration), nutrient cycling, buffering between built and natural environments, accretion of carbon, and wildlife habitat. If inundated, salt marsh vegetation in the North Humboldt Bay would be vulnerable to changes in levels of salinity, nutrients, and light. When marsh vegetation experiences variation in these factors, the altered water quality can lead to changes in nutrient cycling and productivity (Hitch et al. 2009).

Sea level may increase disproportionately along the North Coast of Humboldt County, and salt marsh growth and regenerative rates would be influenced by the energy of tidal influxes in different areas (Patton 2011). Marsh wildlife species and vegetative cover are acclimated to certain elevations, and a forced migration upwards and inland could potentially cause habitat to be degraded or lost over time. Current restoration efforts conducted by the City of Arcata and the North Coast Regional Land Trust have experimented with raising salt marshes elevation in order to maintain their function and continuity with rising tides. North Bay salt marshes will likely be able to move inland because of the City of Arcata's recent land acquisitions to allow this habitat to reestablish and expand inland. The situation along North Humboldt Bay could be exacerbated by an increased tidal influx (J. Anderson pers. comm.). Similarly, landscape topography and adjacent land uses around portions of marsh lands could be a barrier to their inland migration and to tidal circulation in general. As noted in our discussion on agricultural land, historically levees and diversion infrastructure were used to drain and convert salt marsh to agricultural land.

Past landowners who re-contoured their land to make it more suitable for agricultural purposes or other forms of development, changed how the marshes' tidal flows travel inland. In particular, tide gates act as one-way valves, blocking salt water influx and water circulation that would otherwise maintain sediment and nutrient flows, wildlife migration, and brackish habitat quality. Circulation in these marshlands is a critical element influencing what proportion of these wetlands will be at risk because of the restriction of tidal flows. Restricting wetland vegetation's ability to move inland, for example by extending levees, could prevent salt marsh migration to inland areas Salt marshes would likely become

mud flats with tidal waters running up to levees, as sea level rises, simultaneously increasing the probability of coastal erosion. Additionally, according to local experts, seasonal effects create temporary wetland areas behind levee infrastructure, emphasizing the impact of artificial flow patterns. Immobile tidal flows alter the dynamics of wetland circulation that would normally occur in the absence of containment infrastructure.

Local experts indicated that a substantial change in water depth and salinity because of tidal influx could change the biophysical state of vegetation and abundance of marshes. Saltwater intrusion into groundwater would probably become a larger issue in fresh water marshes and slough networks. An increase in salinity could affect nutrient cycling, productivity, and vegetation structure that is critical to wildlife and marsh health in general. As the freshwater interface changes with the coastline reestablished farther inland, this interaction could change the productive capacity of the marshes.

The City of Arcata has acted preemptively to sustain wetlands by implementing restoration projects on salt marsh habitat. Such efforts are constrained by legal obstacles limiting landowners from fully exercising their ability to mitigate impacts to wetlands. Physical barriers that must be dealt with include the existing tide gates and, most importantly, what role the levees are to take on, if their existing role is no longer functional.

In order for wetlands to be maintained by resource managers into the future, sources of funding need to be identified. North Coast local governments may have difficulty finding funding to allocate to this issue. Current wetland restoration projects are not specific to sea level rise, although several experts interviewed hoped that salt marshes in the North Bay will be more resilient to sea level rise in the future due to these efforts. Wetland areas that are currently in need of restoration and also render valuable resources and services to the community could be a priority while a phased-in approach to accommodating wetlands' inland migration is taken as funding becomes available.

Surface water quality will be altered by the retreat of North Humboldt Bay wetlands. As a wetland migration event converts wetland types, brackish or fresh water marshes may be depleted or lost. On a state level, California and more specifically Humboldt County will have to grapple with the hard question of determining what proportions of different types of wetlands are desirable.

A policy goal of “no net loss” of wetlands that started at the federal level with the

Clean Water Act Section 404 permitting has been adopted at the state level. Resource managers in the county are aware that wetland resource quality needs to be quantified to objectively choose portions of wetlands that are indispensable and those that are not. Managing coastal wetlands in California will be monitored through CEQA and NEPA sea level rise planning guidelines addressing resilience as wetlands distribution changes.

Tidal interaction dynamics could drastically change if marshes, mudflats and sloughs become more productive as a result of removing containment structures. Current inundation models detailing the extent of portions of Arcata that may be submerged show that tide gates may become irrelevant. The extent of tidal inundation could overtop such containment infrastructure, diminishing its functionality and further validating removal of such structures. An alternative to removing levees could be requiring that they be modified to allow some tidal influence. A local expert noted that a compromise among different types of land use would be helpful for further planning and dialogue between land managers from different agencies and landowners as well as including the public at various stages of the process. The focus would probably be more on services the levees provide and less on the existing tide gates. Saltwater intrusion impacts on freshwater wetland systems present an obstacle to how adaptable these systems can be.

The way in which sea level rise is conceptualized by policy makers and resource managers draws on many perspectives and approaches. A targeted sea level rise planning process would involve extensive modeling and data collection before an objective plan for wetland preservation could be implemented in North Humboldt Bay. It is unlikely that all of Humboldt Bay's wetlands could be preserved, so land managers should focus on identifying and restoring portions that may shift to other wetland types but could be preserved from inundation. Management agencies could also explore alternative sources of funding such as establishing a carbon credit system for the wetlands. The shift in land uses around the wetlands of Humboldt Bay will influence the actions local agencies can take to respond to a change in sea level.

Figure 6: Wetlands in North Humboldt Bay (Source: Friends of the Dunes, 2009)

Inland migration of wetlands could require local government and/or other land management agencies to acquire land around the wetlands and address possible displacement of a portion of the population. A displaced population would probably require some form of support to offset the financial loss that landowners would incur. Tidal inundation of wetlands will generate a general submergence of adjacent land that necessitates deliberation of future land use of such areas by local governments. Currently, the city of Arcata has been able to purchase tracts of land for potential salt marsh habitat. Salt marshes are one of the wetland types should be able to keep pace with a 3 ft (0.9 m) sea level rise based on background data gathered by local agencies (J. Anderson pers. comm.). Additionally, adding fill as a possible management alternative to accommodate increases in both salinity and water depth has been considered by local wetland managers.

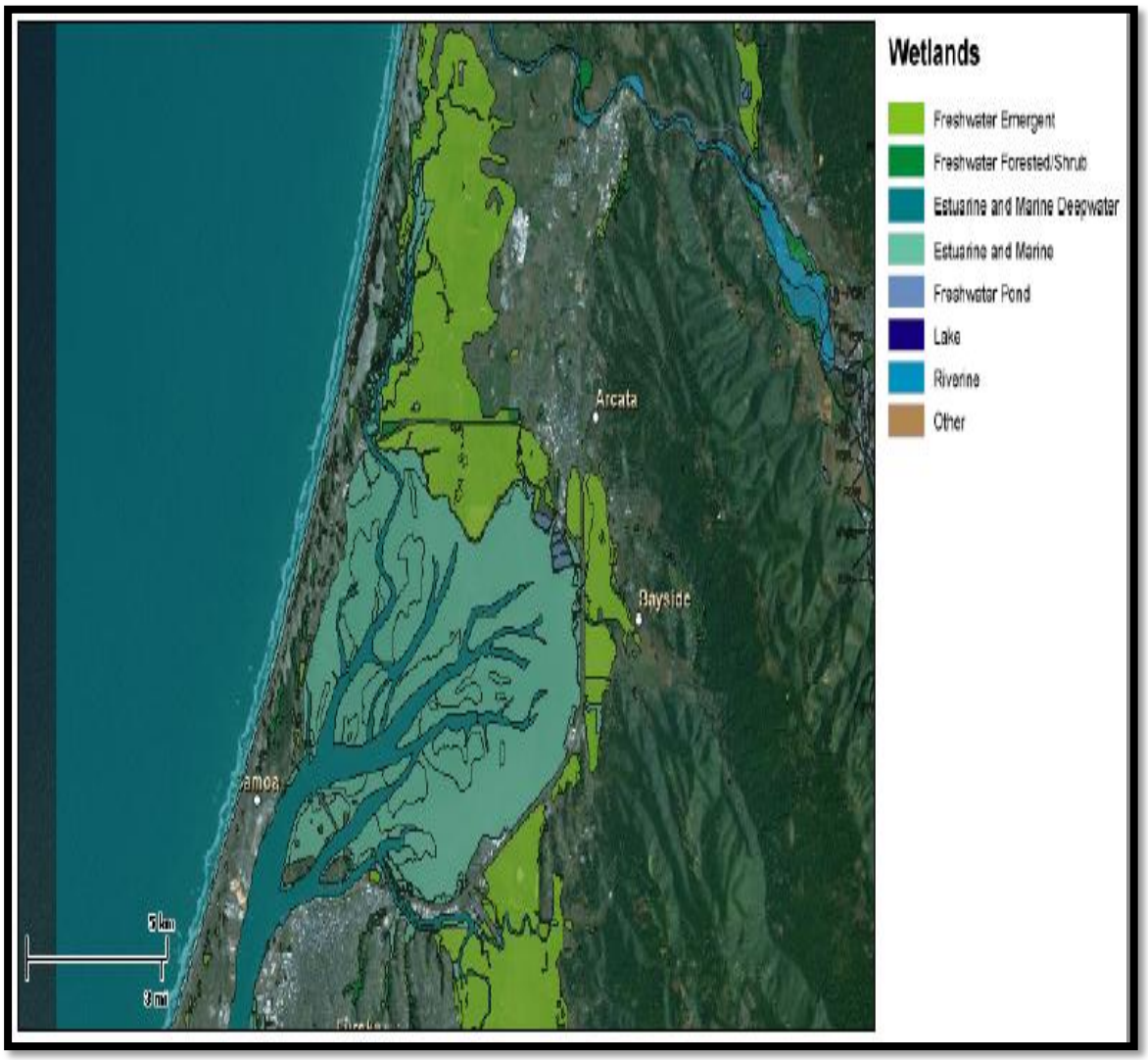

Figure 7: Wetland Inventory of North Humboldt (Source: USFWS, 2011)

Managing for ecological function of the various wetland types is an essential strategy that can align with the other conservation goals of agencies. Wetland habitats of major concern in relation to jurisdictional responsibilities should be coordinated amongst the agencies. Wetlands quality will require a regional resource management plan that addresses the desired quality of wetlands habitat because their location and proportions could conflict with agency jurisdictions. The threat of invasive species will also be a factor to consider for habitat that reestablishes inland in higher elevations. In addition, sea level rise will change the amount of viable habitat which is critical for certain threatened and endangered species.

Threatened and Endangered Species Habitat

Many different species rely on coastal habitat and wetlands in order to survive. Increasing sea level will drastically affect many species' habitats along the coasts of the United States, and specifically in North Humboldt Bay. Threatened and endangered species are species that are officially listed by the federal government or the state of California under the Endangered Species Act and the California Endangered Species Act (ESA). Endangered species are populations of organisms which are at risk of becoming extinct because they are either few in numbers, or threatened by changing environmental or predation parameters (Kurpis 2002). Threatened species are species which are likely to become endangered within the foreseeable future throughout all or a significant portion of their range (Kurpis 2002). Threatened and endangered species are generally species that are already unable to cope with current conditions in the world, so challenges to threatened and endangered species in the future with the changes due to sea level rise may be even more severe.

Threatened and endangered species are important species that need and deserve to be protected for a variety of different reasons. The first reason for saving threatened and endangered species is because of the need for biodiversity. Biodiversity has many definitions, but one that is often agreed upon is that biodiversity represents the variation of the different organisms in a given ecosystem (Shah 2011). Greater diversity supports the sustainability of more life forms (Shah 2011). Ecosystems with a high degree of biodiversity can better withstand disaster which leads to the second reason for preserving threatened and endangered species, namely resilience. Resilience is an ecosystem's ability to withstand perturbation or disturbance without changing its self-organized processes and structures (Gunderson 2000). A resilient ecosystem can better withstand disturbances such as fires, flooding (sea level rise), windstorms, insect population explosions, and human activities such as deforestation and the introduction of exotic plant or animal species (Gunderson 2000). All of these disturbances are prevalent throughout the world today, so resilience is exceedingly important if ecosystems are to maintain the composition and functions they fulfill today. Finally, threatened and endangered species are important due to the lack of complete understanding about them. These species have not been fully scientifically examined, so it is not known what roles they play in their communities or what they could potentially do for humans. It could be that there is a species somewhere in the world that is on the brink of extinction and holds the cure for cancer. We don't know but it is uncertain and therefore, following the precautionary principle it is necessary to protect all species.

Sea level rise will likely affect the habitat of many species in and around Humboldt Bay. Land managers need to know how this direct loss of habitat, increase in sea temperature and alkalinity may affect threatened and endangered species populations over the years. Rising sea level is expected to increase salinity of the Bay, "disrupting ecosystem balance and increasing the potential for disease," while influxes of water and sediment may detrimentally affect submerged aquatic vegetation and shellfish (The Bay Institute 2007). Rising temperatures are presumed by scientists to pose problems for many, if not most, endangered species by increasing the chance of disease and rendering old habitat areas less suitable for traditionally present species. Here in the North Humboldt Bay, potential effects of sea level rise on several threatened and endangered species, Coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tschawytscha)* salmon, tidewater goby (*Eucyclogobius newberryi)*, longfin smelt *(Spirinchus thaleichthys*), marbled murrelet (*Brachyramphus marmoratus)*, snowy plover (*Charadrius alexandrines*), northern red-legged frogs *(Rana aurora)*, Humboldt Bay owl's clover (*Castilleja ambigua* ssp. *humboldtiensis*), and Humboldt Bay wallflower (E*rysimum menziesii* ssp. *Eurekense)* should be addressed.

Figure 8 : Coho Salmon

Figure 9 : Tidewater Goby

Coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tschawytscha)* salmon are both anadromous fish, meaning they start out their life in fresh water, travel to the ocean to feed and grow, and then return to fresh water to spawn and die (Marrone 1996). These salmon eat insects and plankton in the freshwater stage of life, and when they reach the ocean they switch to a diet of smaller fish (Marrone 1996). Their habitat ranges from San Francisco Bay in California to north of the Bering Strait in Alaska, and the arctic waters of Canada and Russia (Marrone 1996). Sea level rise is expected to affect salmon throughout their various life stages and could possibly pose an additional stress to these already threatened species (United States Global Research Program 2009). Higher winter stream flows could possibly cause increased scouring along stream beds, damaging important spawning nests and

washing away incubating eggs (United States Global Research Program 2009). Warmer water created by sea level rise is predicted to create other problems for Coho and Chinook salmon. Diseases and parasites that infect salmon flourish in warmer waters, which are also unfavorable for juvenile salmon and other coldwater fish species (United States Global Research Program 2009). It is also predicted that peak stream flows will occur earlier in the year and therefore could flush out young salmon before they are physically ready to enter the ocean (United States Global Research Program 2009).

Figure 10 : Longfin Smelt

Figure 11: Marbled Murrelet

Figure 12: Snowy Plover

The endangered tidewater goby (*Eucyclogobius newberryi)* is a small fish which is nearly unique among fish of the Pacific Coast in being restricted to brackish coastal lagoons and estuaries (Wild Equity Institute 2006). Tidewater goby feed on small crustaceans and insect larvae. Their historical habitat ranges from the border between California and Oregon to forty miles north of the border between the United States and Mexico (Wild Equity Institute 2006). Tidewater goby have very specific habitat needs, which could possibly prove disastrous for this species. The tidewater goby is usually found in waters less than 3 ft (0.9 m) deep and it breeds in sandy areas (Wild Equity Institute 2006). Relying on a narrowly restricted water depth means that with the predicted sea level rise all of its existing habitat could be destroyed or shifted inland. Even as brackish water habitat may shift inland, the tidewater goby also requires sandy substrates in order to breed, and sea level rise may decrease the area where both brackish water and sandy substrate overlap. Increasing alkalinity could also threaten the population of the tidewater goby, as high alkalinity renders areas useless for goby habitat (United States Fish and Wildlife Service 2011).

Longfin smelt *(Spirinchus thaleichthys*) is another specialized species that could be negatively affected by sea level rise. Their preferred habitat is open water estuaries where

they can tolerate both seawater and freshwater areas (Swanson et al. 2007). Longfin smelt have been found as far north as Prince William Sound in Alaska, as well as in Skagit Bay, Grays Harbor, Willapa Bay, lower Columbia River, Yaquina Bay, Coos Bay, Klamath River Estuary, Humboldt Bay, the Eel River estuary, and San Francisco Bay (Swanson et al. 2007). They are found in the middle or deeper parts of the water column. This smelt's diet consists of opossum shrimp and small crustaceans (Swanson et al. 2007). The species requires specific environmental conditions for spawning, egg incubation, rearing, and larval transport from spawning to rearing habitats (The Bay Institute 2007). With changing freshwater flow, water temperature, and alkalinity, the specific conditions critical to the health of this species may drastically change. The smelt has better reproductive success in areas that are less alkaline (The Bay Institute 2007).

The marbled murrelet (*Brachyramphus marmoratus)* population will most likely not be affected more than other sea birds. The marbled murrelet is a small sea bird that nests in old-growths forests or on the ground in areas of higher elevation (Seattle Audubon Society 2011). Marbled murrelets occur in summer from Alaska's Kenai Peninsula, Barren islands, and Aleutian islands south along the coast of North America to Point Sal, Santa Barbara County, in south-central California within 1.2 miles (1.9 km) of shore (Seattle Audubon Society 2011). Marbled murrelets winter within the same general area, except they vacate the most northern sections of their range (Seattle Audubon Society 2011). The marbled murrelet's diet consists of sandeels, herring, capelin and shiner perch (Seattle Audubon Society 2011). Sea level rise will increase the surface area of the sea, thus creating more habitat for the bird. This bird is endangered because of the damage that has been done to the old growth redwood forests over the years (Seattle Audubon Society 2011). It cannot be assumed that this sea bird's population will be negatively affected; as long as the abundance of food species does not decline, sea level rise could even possibly improve the bird's current situation.

The snowy plover (*Charadrius alexandrines*) is an endangered species that could be affected by the changes brought on by sea level rise. This bird is a small, pale plover with a diet consisting of small crustaceans, mollusks, marine worms, and insects (Cornell University Laboratory of Ornithology 2011). Snowy plover can be found across North and South America, wintering primarily in coastal areas on beaches and tidal flats (Cornell University Laboratory of Ornithology 2011). This species requires open bare ground for nesting, often near a clump of grass or a piece of driftwood along the coast (Cornell

University Laboratory of Ornithology 2011). Sea level rise is predicted to put many prime nesting areas under water, along with moving the shoreline closer to vegetated areas. With much of the prime nesting areas under water, this species will likely have a hard time maintaining populations in the time frame of sea level rise.

One species of particular concern for sea level rise is *Rana aurora* or the northern red-legged frog. This species prefers the still waters of ponds, marshes or stream pools with a thickly vegetated shoreline for protection from predators (Stebbins 2003). The northern red-legged frog eats terrestrial insects, small snails, crustaceans, worms, tadpoles, small fish, and even frogs of other species (Stebbins 2003). Its traditional habitat range is western Oregon, western Washington and southwestern British Columbia including Vancouver Island (Stebbins 2003). In California, its range includes every coastal county from Mendocino County northward. Frogs breathe through their skin and therefore generally cannot handle significant alkalinity in the waters of their habitats; this is the case for the northern red-legged frog. This species can only lose habitat from the predicted sea level rise because much of its current habitat will likely have increased levels of alkalinity.

Figure 13: Red-Legged Frog

Figure 14: HB Owl's Clover

Figure 15: HB Wallflower

Humboldt Bay owl's clover (*Castilleja ambigua* ssp. *humboldtiensis*) is a a relatively rare subspecies of *Castilleja ambigua*. The plant is an annual forb generally restricted to tidal salt marshes in Humboldt Bay (Calflora 2010). Humboldt Bay owl's clover is endemic to California (Calflora 2010). This species is generally located near to sea level and therefore much if not all of its habitat will likely be inundated by sea level rise unless wetland migration can be accommodated (Calflora 2010). An additional challenge for this species is that it is found only in California with a limited number of communities of plants, so if even

one community is lost it will be a huge blow to the species and to any possible recovery efforts.

Erysimum menziesii ssp. *eurekense* or the Humboldt Bay wallflower is another endangered species that could possibly be affected by sea level rise. Humboldt Bay wallflower is a subspecies of *Erysimum menziesii* or the Menzies' wallflower (U.S. Fish and Wildlife Service 2008). Every subspecies of this plant has declining populations and is considered rare. This species is found only in the declining beach sand dune habitat in three areas on California coastline, in Humboldt, Mendocino, and Monterey Counties, with the Humboldt Bay wallflower being the subspecies found in Humboldt (U.S. Fish and Wildlife Service 2008). This species prefers coastal dune habitat ranging from 0-33 ft (0-10 m) above sea level (U.S. Fish and Wildlife Service 2008). Species lower down on the dunes, such as the Humboldt Bay wallflower, are expected to be significantly affected by sea level rise (Andrea Pickart, pers. comm.). The sea is predicted to engulf or alter much of the remaining lower coastal dune habitat area.

These are the currently listed endangered and threatened species with habitat in North Humboldt Bay. Populations of threatened and endangered species worldwide will be affected and possibly even eradicated because of the impacts caused by sea level rise. Threatened and endangered species are obviously not the only species that will be affected by sea level rise, as all species will be impacted in various ways. Many different species with currently healthy populations could become candidates for listing as threatened or endangered because of impacts to their habitats due to sea level rise.

Sea level rise may drastically alter endangered and threatened species habitat. Several local experts agreed that no matter what happens to North Humboldt Bay, some species will find a way to take advantage of the changes in habitat, but these species will probably not include most threatened and endangered species. Currently endangered species are typically specialists, meaning that they thrive under a narrow range of conditions and have difficulty dealing with changes in these conditions. The species that will be best able to cope with these changing conditions are generalists, which are typically not endangered or threatened.

Another problem with the loss of endangered species is prioritization and trying to decide which species people will attempt to protect from sea level rise and which not, which as one local planning expert noted, raises moral dilemmas and can be seen as "playing God". Ecosystems within 4.5 ft elevation (1.4 m) of the shoreline could be completely

underwater, so it is important to understand how the sea level rise might create new habitat and assess whether existing endangered and threatened species can access these new habitats. A related issue involves how the species may be able to cope with new conditions even if they transition to a new area. The only way that threatened and endangered species can be completely protected from sea level rise is with intense human intervention such as raising levees so there will be no salt water intrusion beyond Humboldt Bay, and this approach would be extremely costly and potentially infeasible for other reasons. It is likely that instead of mitigating the problem with engineering strategies, a retreat approach will be taken, leaving habitat to change naturally with sea level rise. Mitigation is likely to be necessary, however, for another environmental hazard: brownfields.

Brownfields

Brownfields are legally defined as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" (United States Environmental Protection Agency 2010b). The particular effects of sea level rise on brownfields will greatly depend upon the type and level of contamination found at these sites. Several local and state agencies such as the Regional Water Quality Control Board and the Department of Toxic Substances Control operate under a legal framework that can support brownfield remediation by providing funds for cleanup and assessment projects for land owners and communities (Whitney 2010). However, to complicate matters, political boundaries such as the Coastal Zone and regulation by the California Coastal Commission may limit the extent and type of brownfield remediation allowed.

Existing databases offer significant information on brownfields which can help identify sites that will be most affected by sea level rise (California State Water Resources Control Board 2011). Humboldt County has a considerable number of brownfields throughout its boundaries however, according to Andrew Whitney's inventory of Humboldt County Brownfields (2010), the brownfield sites surrounding Humboldt Bay are some of the largest sites in the county and the most problematic from a redevelopment stand point. Existing facilities that are still operational also need to be taken into account when their proximity to the Bay and ongoing activities could potentially create future brownfields if they are inundated and no mitigation is implemented.

Sea level rise may lead to flooding of low lying brownfield sites and associated contaminated material, causing pollution to spread within the Bay and surrounding areas such as adjacent wildlife habitat, agricultural lands and residential areas. Existing low lying facilities may be inundated if they are not relocated, causing contaminants to enter the Bay and potentially creating future brownfield sites. The severity of contamination that will be released by sea level rise will depend upon the specific types of contaminants found and the rate and concentration levels at which they will be released. Some contaminants are more water soluble than others, easily dispersing into the environment and affecting humans and wildlife via direct contact with contaminated water. Other less soluble contaminants could remain in the environment for decades or even centuries, embedded and deposited into sediment substrates and dispersing into the environment via food webs (Institute of Oceanology 2007).

The accumulation and dispersal of contaminants will likely degrade water quality and impair habitats in proximity to high concentrations. Animals at higher trophic levels will be exposed to higher contaminant levels through consumption of concentrated toxins in prey sources, causing reproductive harm and lower productivity (Action Center 1995). Humans can accumulate these toxins through the consumption of contaminated animals, and some residents may experience exposure by living near contaminated sites. Depending on the levels of contamination, humans can experience neurological impairment and other health risks, especially young children. The likelihood of such impacts is unknown and may be minimal (A. Whitney, pers. comm.). Nevertheless, risks of any degree are possibilities that need to be considered.

Economic effects are also possible as tidal influences disperse brownfield contaminants. For example, the aquaculture industry including commercial oyster farms could be affected if increased levels of contaminants were found in oysters, limiting the amount available for consumption, ultimately affecting the market. Using the North Coast Regional Water Quality Control Board's Geotracker database which provides information on types of contaminants found, property owners, current regulatory status, and responsible agencies (California State Water Resources Control Board 2011), and Andrew Whitney's Inventory of Brownfields in Humboldt County (2010), several brownfield sites were identified within the likely 50 -100 year run-up zone in North Humboldt Bay (Philip Williams and Associates 2009). They include former sawmills, boatyards, underground storage tanks, and other commercial and private properties. Due to the region's extensive

logging history, the most abundant and sizable brownfields around Humboldt Bay are former mill sites.

There are several common types of contaminants found in brownfield sites which are often correlated with the previous land use. These contaminants can be broadly categorized as petroleum products, organic compounds, and dioxins. The most abundant types of brownfield contaminants found are petroleum products such as gasoline and diesel fuel. These contaminants are mainly associated with petroleum companies and gas stations that contain leaking underground storage tanks. However, lumber mills and other brownfield sites also contain petroleum based contaminants. The presence of these contaminants on most former industrial sites is a result of using heavy machinery and trucking. Thus, soils in industrial mill sites typically contain petroleum products such as motor oil, hydraulic fluids, and lubricants used for heavy machinery. Petroleum products have a very low solubility in water. However, they can be easily dispersed by water and accumulate in soil substrates. Humans and other organisms can be exposed through direct contact or consumption by drinking contaminated water. The health effects of exposure can include nausea, gastro-intestinal irritation and other effects depending on the levels of concentration and exposure (Environmental Protection Bureau 2008).

There are a few sites that contain semi-volatile organic compounds such as the pre-existing boat yard site on Indian Island (Walter 2010). The major sources of these anthropogenic organic compounds are solvents such as paints and protective coating which were used at this particular site to maintain boats. Some organic compounds are more soluble than others. The adverse effects of these compounds can range from nausea and irritation to carcinogenic effects with greater exposure.

The most volatile contaminants are found on mill sites. These contaminants are more commonly referred to as dioxins. "Dioxin" is a short name for chlorinated dibenzo-p-dioxin (PCDD) and dibenzofuran (PCDF) compounds. There are 210 different compounds in the dioxin family called congeners (Action Center 1995). Dioxins are persistent organic compounds (POPs), synthetic chemicals that can cause severe, long-term impacts on wildlife, entire ecosystems and human health. Dioxins were mostly present in older mills that burned their waste in tepee burners and created the dioxins through combustion of woody material. Due to the low water solubility of dioxins, salt water intrusion or sea level rise will likely lead to deposition of these compounds in sediments where they could accumulate up the food chain in animal fats, ultimately affecting humans through the

consumption of contaminated animal products. Health risks to humans and mega-fauna from dioxins may range from minimally noticeable effects to reproductive harm, organ damage, and cancer (Action Center 1995).

As previously mentioned, there are a number of environmental agencies with the responsibility to address and mitigate the impacts of brownfield contaminants. These agencies include the North Coast Regional Water Quality Control Board, the Department of Toxic Substances Control, Local Oversight Program, and other local governments and agencies. At the federal level, the leading environmental agency behind the regulation of brownfields and other environmental issues is the United States Environmental Protection Agency (EPA). The EPA is responsible for implementing the Small Business Liability Relief and Brownfields Revitalization Act of 2002. Under this law, the EPA provides funding for site assessment and clean up efforts. Administrative agencies must document brownfield assessments and provide funding for cleanup efforts. Eligible entities receive grant funds that provide assistance to an owner, developer, community, or other person not exceeding $200,000 dollars for any individual brownfield site (United States Environmental Protection Agency 2011b).

The California Coastal Commission is one of the most influential state agencies regarding the redevelopment of brownfields around Humboldt Bay. This is due to their role in implementing the Coastal Zone Management Act, which limits the types of development and land use practices allowed in coastal areas. Many of the brownfield sites located within the Humboldt Bay Harbor Recreation and Conservation District's jurisdiction have specific "coastal dependent industrial" zoning which also limits the possibilities of the different types of redevelopment projects and reuse opportunities for remediated brownfields.

In addition to existing brownfields, several currently operating facilities could be inundated by sea level rise. If no mitigation efforts are implemented to accommodate rising sea levels, low lying facilities such as the Sierra Pacific Lumber Company on Highway 255, the Arcata Waste Water Treatment Plant, the California Redwood Company, and the Bracut mill facilities off the Highway 101 corridor could become future brownfields.

Salt water intrusion on brownfields could distribute contaminants throughout the Bay. There was a general consensus among the land managers and agency personnel interviewed that the likely extent of dispersal and effects of salt water intrusion are not known. The implications of sea level rise are difficult to predict, because most contaminants

found in the environment undergo slow release processes. By themselves, brownfields are not expected to be the most significant threat to the environment but rather a secondary symptom of more significant environmental changes (A. Whitney, pers. comm.). Other experts agreed that the effects of contaminants released by brownfields will be minor when compared to the impacts caused by existing contaminants entering the Bay, the majority of which are non-point source contaminants. The underlying issue for agency personnel and local officials alike is not necessarily the intrusion of water on contaminated sites but rather the associated rise in ground water that may reach underground contaminants. Above ground contaminants can be cleaned up more effectively and would be less costly and time consuming to address.

Because of the physical remoteness of Humboldt County, resources such as political support and funding for mitigation projects like brownfield remediation are less readily available than they might be, if the county were in geographic proximity to California's population centers. The regulatory framework of local, state, and federal governments can also limit the types of brownfield remediation and reuse efforts that are allowed based on location. Federal and state funding for brownfield remediation for example, is typically available for projects that intend to redevelop or reuse a site after clean-up efforts. Investments made to avoid environmental impacts of encroaching sea level are just beginning to be required, for example, the California Department of Toxic Substance Control has required feasibility and remedial action planning for a brownfield site in the San Francisco Bay Area (National Brownfields Association 2010). Funding for brownfield clean-up efforts, remediation or even containment will be a daunting task, as many state and local agencies will be financially strained to fund such efforts. Yet as contaminants spread throughout the Bay, clean-up efforts will likely become more expensive and less feasible over time.

Planning for the effects on brownfields will require research, the development of physical responses, and political and financial support. To avoid the creation of future brownfields, active facilities could begin to develop a strategic managed retreat in which infrastructure is properly located away from the expected sea level rise zone. This process can be undertaken over the course of several years in response to the gradual increase in sea level while accommodating clean-up efforts. In addition to the long-term retreat response, short-term responses can take place in the form of mitigation. The impacts on brownfields can be mitigated through clean-up efforts and protective structures. For active facilities,

levees can be rebuilt to accommodate sea level rise while retreat locations are considered. Clean-up efforts must be disclosed under NEPA and CEQA. Under these legal frameworks, brownfields would undergo a site assessment which would be used to identify potential impacts and mitigation opportunities. The Environmental Protection Agency uses a response strategy called the Supplemental Interim Remedial Action Plan (Walter 2010). This approach calls for the removal of debris, targeted excavation of contaminated soil, site grading, and wetlands restoration. Geotextiles, woven polyester-based permeable fabrics, are used to strengthen soil surfaces and act as a protective barrier or filter to separate contaminants from clean soil. This material is also used for mitigating wave action and flooding. For brownfields, contaminated soil is excavated and covered with geotextiles. The soil beneath is injected with an oxidizing solution to neutralize the remaining contaminants. A layer of fill is then placed over the textile, followed by clean topsoil that would be re-vegetated with native plants.

Although the Small Business Liability Relief and Brownfield Revitalization Act provides funding for the remediation of brownfields, due to a high competition for available funding, clean-up grants are not readily available to every brownfield remediation applicant. Instead, grants are often made available to brownfields that will be developed based upon the revenues they are expected to generate. The competitive funding environment makes clean-up of sites likely to be inundated by sea level rise improbable. In order to successfully provide funding for remediation, exemptions from redevelopment and reuse would need to be incorporated in this Act. For cases in which the redevelopment or reuse of brownfields is not feasible after remediation, special legal recognition should be given to facilitate funding in cases where spread of contaminants is a threat, perhaps akin to Superfund hazardous waste clean-up efforts under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (United States Environmental Protection Agency 2011b) .

Adaptive opportunities exist when redevelopment of infrastructure and facilities are not optional. Identifying economically viable uses for inundated brownfield sites is challenging. One opportunity is generating energy. Several start-up companies in California, Australia, and Israel have created solar panels that float on water (Woody 2011). Floatable solar panels have been used in agricultural and mining ponds as solar panel "aqua farms". Aqua farms have drawn interest from municipal water agencies, farmers and mining companies intrigued by the possibility of creating a new use and revenue from their liquid assets. Such approaches may be extendable to include inundated brownfields that cannot be

developed by conventional means. Not only would this provide a reuse that would make funding for clean-up efforts more accessible, but it would also create a clean source of energy and revenue for the local economy.

It is important to expand local government officials' and the general public's knowledge of brownfield regulations and remediation issues. With available funds, this can be accomplished through demonstration projects of clean-up by local agencies that manage brownfields. Field trips and site tours can provide interactive, visual learning experiences.

The Coastal Zone Management Act is implemented by the states. The California Coastal Act mandates local governments and the California Coastal Commission to protect coastal habitats, provide permits for development projects, and to properly designate areas for growth and conservation. Several brownfield sites located around the Bay have specific "coastal dependent industrial" zoning which designate location of industrial facilities away from other coastal dependent uses. However, coastal dependent zoning may limit brownfield remediation projects. If the purpose of a remediation project does not meet the description of the intended zoning, brownfield remediation may be limited only to projects that intend to redevelop facilities that are considered appropriate for that zone. In order to address brownfield remediation within the coastal zone, local governments and the Coastal Commission should incorporate the limitations of specific zoning when brownfield redevelopment and other coastal activities are not feasible. Future development projects should be designated away from areas expected to be inundated by sea level rise and special legal recognition should be granted to remediate brownfields incapable of being redeveloped. Of course, the specific concerns about brownfield remediation will need to be integrated into the overall discussions of appropriate responses to sea level rise.

Overall Responses

There are a number of ways in which communities, local governments, and resource managers can respond to changes caused by sea level rise. The first fundamental response is the development of a region-wide consensus through planning processes that address sea level rise effects. Other responses will depend on political decision-making and funding. Agencies and local governments must also balance scientific information with policy implementation, which could call for fundamental restructuring of the decision-making process.

Changes in political decision-making may revolve around modification of existing institutions and legal frameworks that are currently inadequate to implement responses that address sea level rise. Issues such as compensation for private property and liability, interagency and transboundary coordination, and funding prioritization across federal, state, and local governments may require adjudication (United States Environmental Protection Agency 2011a). One local official stated that the need for open collaboration between private landowners and agencies members is crucial. New authorities or adaptations in existing laws and regulations may be needed to implement options, responses, and management of sea level rise (United States Environmental Protection Agency 2011a).

National coastal management plans and other state management plans will need adaptive options to account for sea level rise. To successfully encourage coastal communities to address sea level rise, policies like CEQA and NEPA will need to provide guidelines for how California and other coastal states would address sea level rise. Adaptive modification in NEPA and CEQA laws and regulations would contribute effective responses to sea level rise, for example, for cleanup efforts of brownfields that would undergo a site assessment to identify potential impacts and mitigation opportunities, and for planning guidelines addressing resilience of urban/wetland interfaces. Other laws and regulations needing modification to address sea level rise are the Safe Accountable Flexible and Efficient Transportation Equity Act - A Legacy for Users (SAFETEA-LU), Endangered Species Act (ESA), Clean Water Act (CWA), Federal Emergency Management Act (FEMA), and California Coastal Act (CCA).

The political decision-making process will affect transportation planning responses. At the federal level transportation planning is based on the 2005 SAFETEA-LU, which calls for 20-30 year forecasts and planning supplemented by four-year Capital Improvement Plans (CIPs) (National Research Council 2008). Sea level rise planning can be incorporated into CIPs, which may include retreat, mitigation, or adaptation.

For the protection of private land, homes and businesses, regulatory constraints within FEMA need to be adapted to evaluate the degree of hazard from sea level rise and equitable insurance coverage options. Protection of diked agricultural lands will require additional mitigation through raising, widening and thus strengthening existing levees. Army Corps of Engineers and Federal Emergency Management Agency Guidelines for levee maintenance will need to be modified to address conditions of sea level rise and increased likelihood of storm surges.

Sea level rise may potentially create new non-point sources of pollution from existing land uses surrounding the Bay. Federal protections for wetlands under Section 404 of the Clean Water Act will need to be modified to address these new sources of non-point sources of pollution. Another law that needs to be addressed is the Endangered Species Act (ESA). The ESA does not take sea level rise into account. In order to protect endangered species from sea level rise, the habitat that will become endangered species habitat needs to be protected, in addition to land that is currently endangered species habitat. If potential future habitat for endangered species is protected, then species will have areas to retreat to as sea level rises.

Similarly, the California Coastal Act (CCA) is a piece of the legislative puzzle that challenges the ability of the population of Humboldt County to maintain certain ways of life. A shift in how coastal resources are protected from natural episodic events may require the coastal commission to reexamine how the CCA addresses sea level rise. Articles addressing coastal, marine, and land resources and development could undergo a fundamental reworking to address the effects of sea level rise, as well as how Humboldt County will be able to approach redevelopment without developing on the coast. A cooperative focus group of federal and state resource agencies such as the Humboldt Bay Initiative could possibly initiate a dialog to propose amendments to the Act. A current example of policy change revolves around the footprints of protective structures such as levees. To protect the coastal zone from new development, coastal zone processes in California are now starting to account for sea level rise by not allowing protective structures to be built. Protective structures are only allowed to increase girth and strength when being "grandfathered in" by protecting an already existing development structure (i.e. a house on the shoreline) (H. Seemann pers. comm.).

In addition to laws and regulations, another way to mitigate sea level rise is the formation of local reclamation districts. Reclamation districts are a form of special-purpose district which are responsible for reclaiming and maintaining land that is threatened by flooding for agricultural, residential, commercial, ecological or industrial use. The land would be protected by raising, building, and filling levees in order to completely protect North Humboldt Bay from rising water levels. Currently, Reclamation District 768, in Arcata, is responsible for maintaining levees around Humboldt Bay with local government input (H. Seemann pers. comm.). However, forming a local reclamation district might be more responsive to the needs of nearby landowners. The district, if successful, might then

transition into a regional reclamation district to accommodate other portions of Humboldt County. This strategy could comprehensively assess, prioritize and mitigate impacts of sea level rise. However appealing in theory, this approach would be extremely costly, so much so that it seems implausible at this time.

Several local experts indicated that a plausible strategy for retreat is the buying of land further inland. If land is bought further inland, the current land at the edge of the sea will serve as a buffer zone for sea level rise. As the water level rises, land inland will become the new agricultural, wetland, and habitat areas. Where this option exists, this approach would be one of the least costly and most effective ways to handle sea level rise.

A local planning expert noted that dialog within governments currently suffering from financial fatigue will need to address governmental prioritization of funding. Funding will be an immense challenge in upcoming years**.** Competing urgent priorities will continue to outweigh the need for funds to be allocated for response strategies addressing sea level rise. Coming up with the necessary funds will be strenuous but addressing sea level rise will be more costly the longer it takes individuals, communities and governments to respond to its presence. Recommendations to address prioritization of funding can come from interagency cooperation.

Federal, state, local, business interests and private parties need to have open lines of communication in order to address each issue addressed above and more. Without interagency cooperation, the lack of communication can create ineffective management and weaken preparation and reduce response options for sea level rise. Successful discussion and collaboration between agencies will help facilitate prioritization and modifications to laws and regulations.

Conclusions

It is clear that sea level rise will be a critical issue to address around North Humboldt Bay in the coming years. Local government and agencies are aware of the issue, and planning responses have already begun. Public education will be important to ensure common understanding of the potential risks, response options, and opportunities available. Those communities which begin preparing responses early will be in the best position to face the many changes to come. Seeking funding for projects at an early stage can help ensure that Humboldt communities obtain access to grants and other funding mechanisms before other

less isolated and more politically significant areas become a higher state priority. The sooner Humboldt communities assess their situations, the more flexible their response options are likely to be.

There is a strong need for continued data gathering in the area to better understand how sea level rise may affect communities, habitat, and infrastructure. For example, LIDAR data would be useful in creating more detailed and accurate models of inundation. While this report has assumed a gradual, linear rise in sea level, it is important for planning to consider the possibility of a sudden increase in the rate of sea level rise. More information is also needed regarding the interaction of sea level rise and subsidence or uplift along the coast. Institutions such as the Humboldt Bay Initiative have an important role to play in collating information, encouraging discussion and maintaining strong communication among agencies, local governments and members of the public.

Landowners and land managers along North Humboldt Bay will likely need to respond to sea level rise through a combination of retreat, mitigation, and accommodation measures. Because it will not be possible to protect everything, it will be necessary to evaluate and prioritize projects around the Bay. For those areas that cannot be adequately protected, seeking sources of compensation will be an important component of the retreat strategy. Resistance to change is widespread and will need to be addressed as well. It is difficult to comprehend the scale of the problem and the timeframe over which it operates, and public education will be a key issue.

Some planning has already begun to address the issue, such as the City of Arcata's purchase and easements on nearby lands that can serve as buffer zones. Future planning throughout the region should begin to address the problems of climate change. Coastal Commission decisions, which so far have been on a case-by-case basis, could involve more overall planning. With a lack of higher state or federal planning, local decisions may become the planning frontier. For example, local General Plan updates could include sea level rise analyses.

Due to time constraints for this project, not all sea level rise implications could be discussed in this report. Further research would be beneficial on a number of related topics. The interactions of sea level rise with dune formations and ecosystems require more study. Non-point source pollution will also need to be addressed in terms of water quality and contamination risks. Cultural sites, including Native American and more recent historical

sites, also require responses to be developed for their protection. The potential effects on tourism and recreation have not been explored. Impacts on the port, shipping, and other boat-related travel have not been examined. Additionally, an analysis should be completed for utilities such as water and electricity supplies.

There are many different responses that are possible to address sea level rise and it is hard to predict the best ones. One thing that is for certain is that there is no "silver bullet" for this problem, no one solution will immediately solve all of the problems that are going to occur due to sea level rise. Sea level rise is a huge issue that will need to be addressed throughout the world and there will likely be a blend of different responses that will ultimately protect various areas from the flooding that is on the horizon. It should be remembered, however, that there may also be opportunities to find value in the changing landscape, such as the potential for increased wetland habitat or aquaculture. Through collaboration with all stakeholders in the area, we are confident that Humboldt communities will create innovative solutions and adapt to our changing environment.

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Photo Credits

Coho Salmon http://www.peachygreen.com/wp-content/uploads/2010/07/coho-salmon1.jpg

Tidewater Goby Photo Credit: Greg Goldsmith, USFWS
http://www.fws.gov/arcata/es/fish/Goby/goby.html

Marbled Murrelet: USFWS

Longfin Smelt http://www.bay.org/rivers-and-delta/saving-endangered-species/longfin-smelt

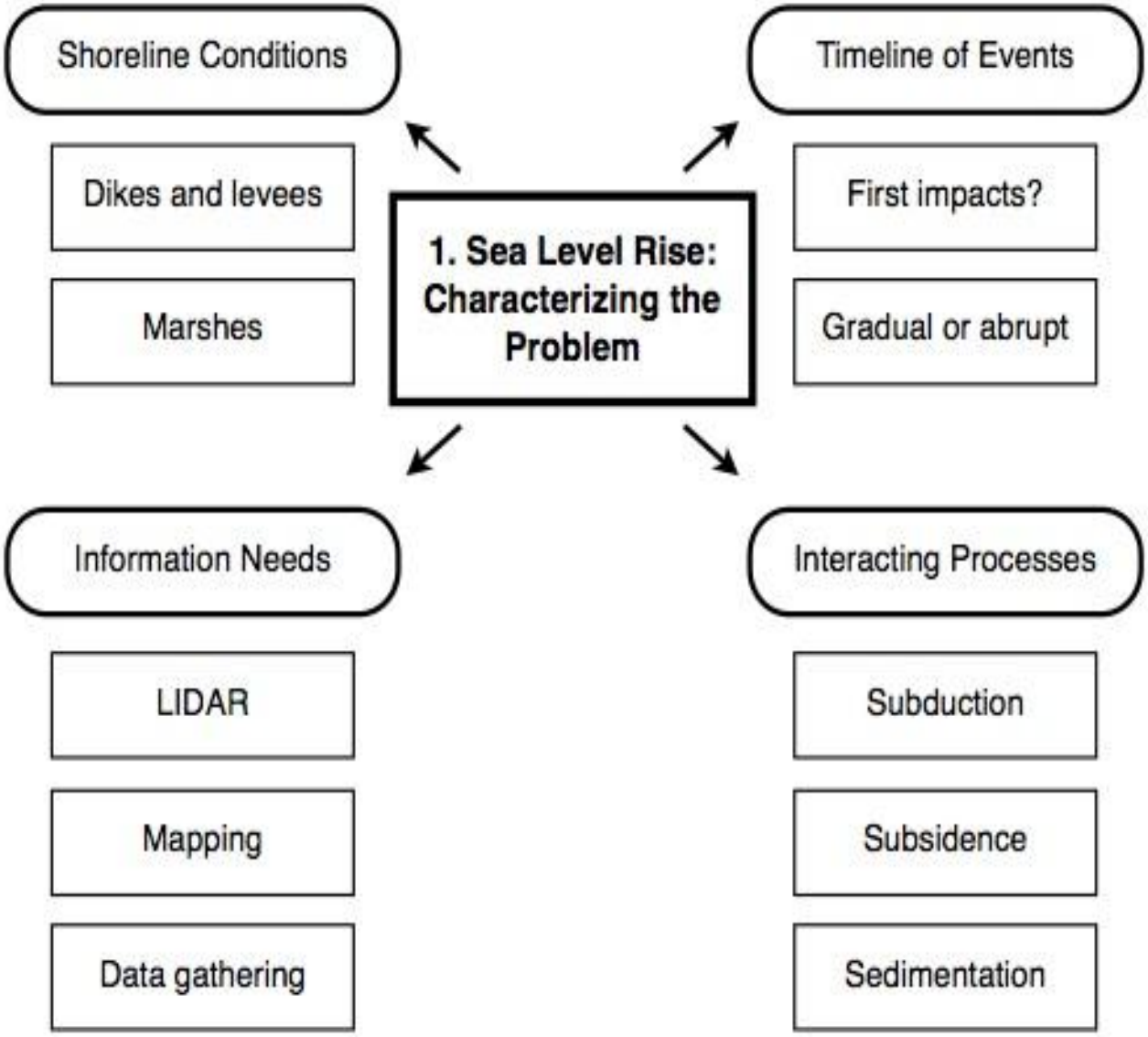
Snowy Plover: Callie Bowdich

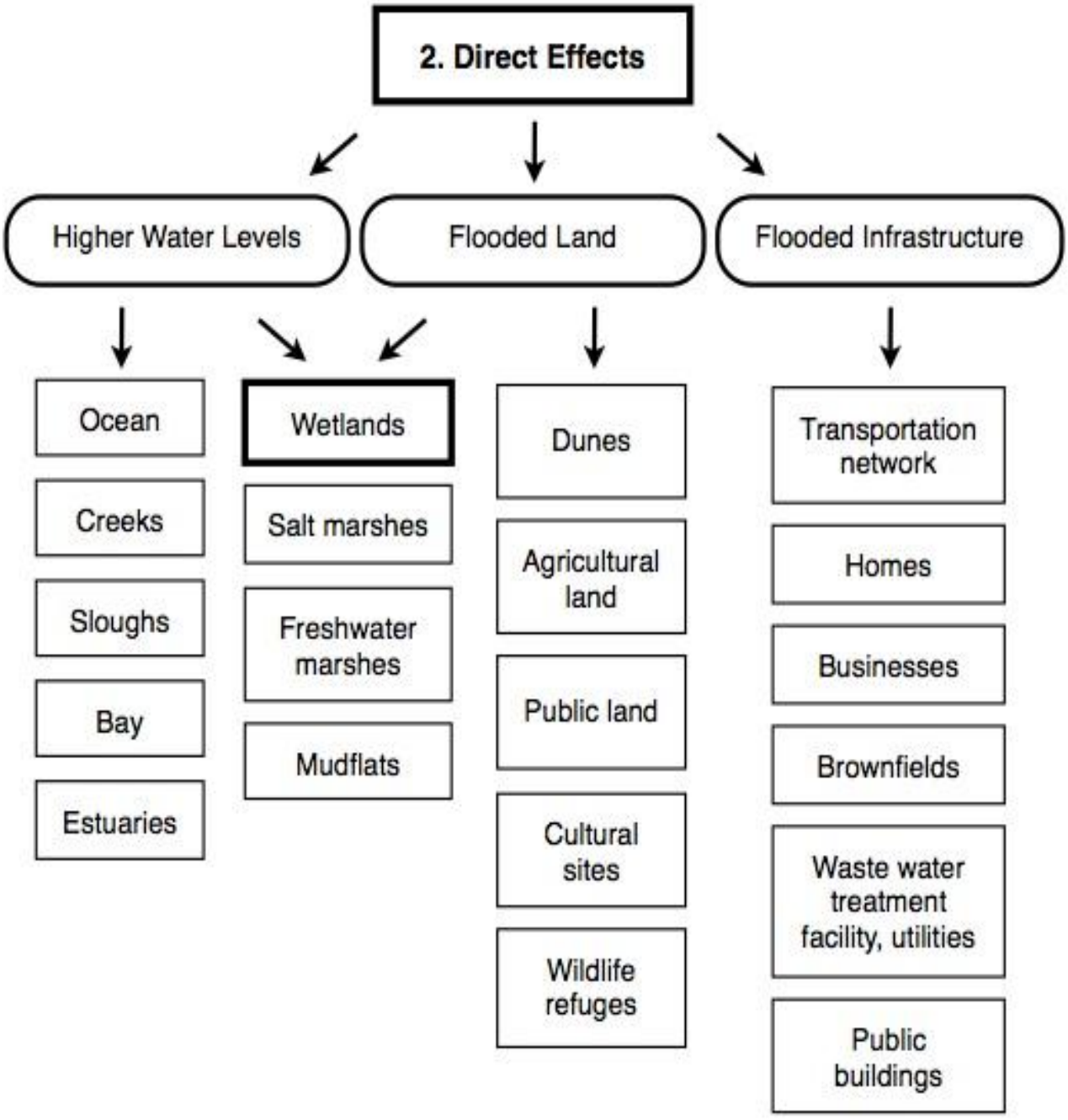
Red Legged Frog: Andrew Harmer
http://www.californiaherps.com/frogs/pages/r.aurora.html

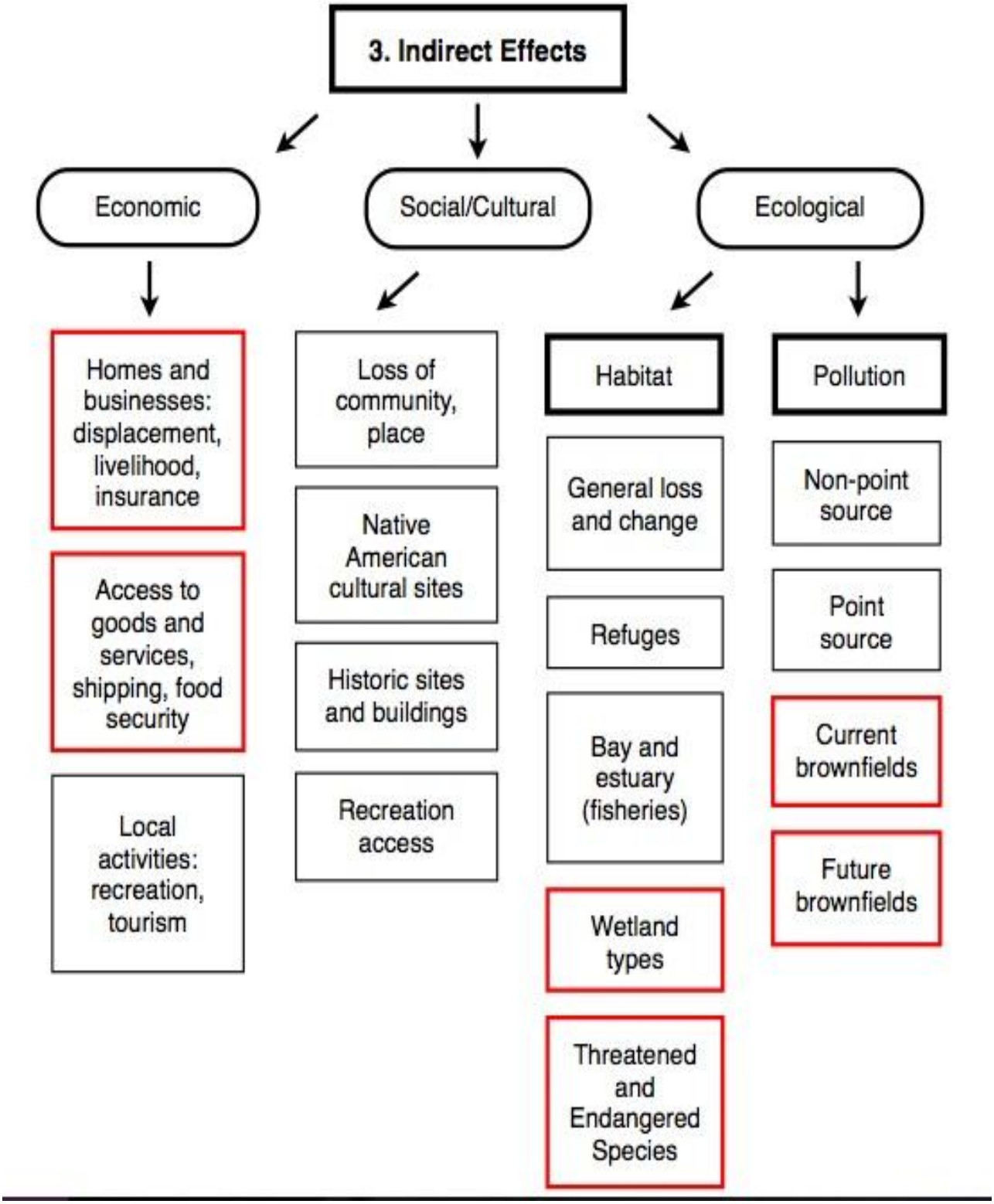
Owls Clover: usfws http://www.fws.gov/humboldtbay/spartina.html

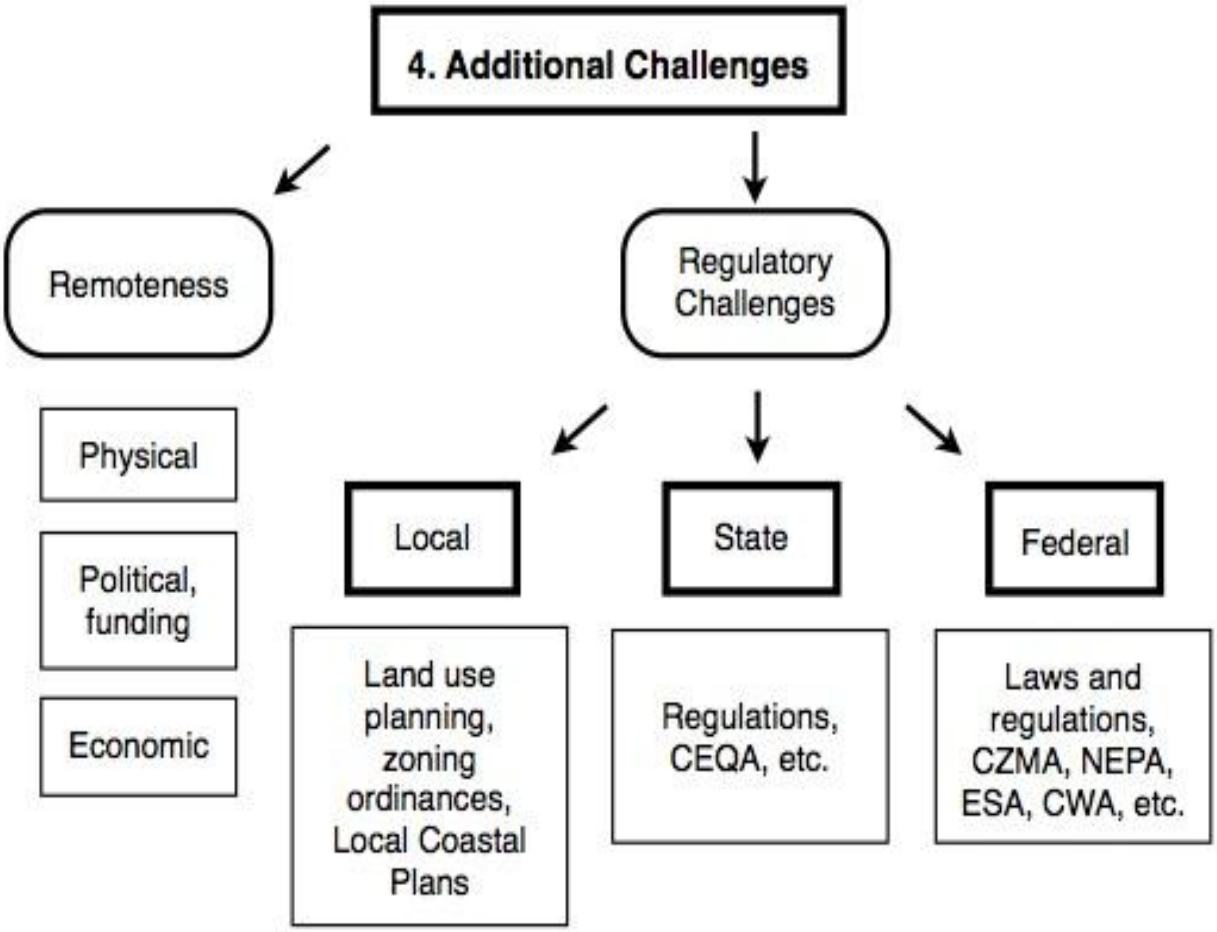
Menzies Wallflower: Dave Imper USFWS
http://www.fws.gov/arcata/es/plants/menziesWallflower/gallery/menziesWallflower_gallery.html

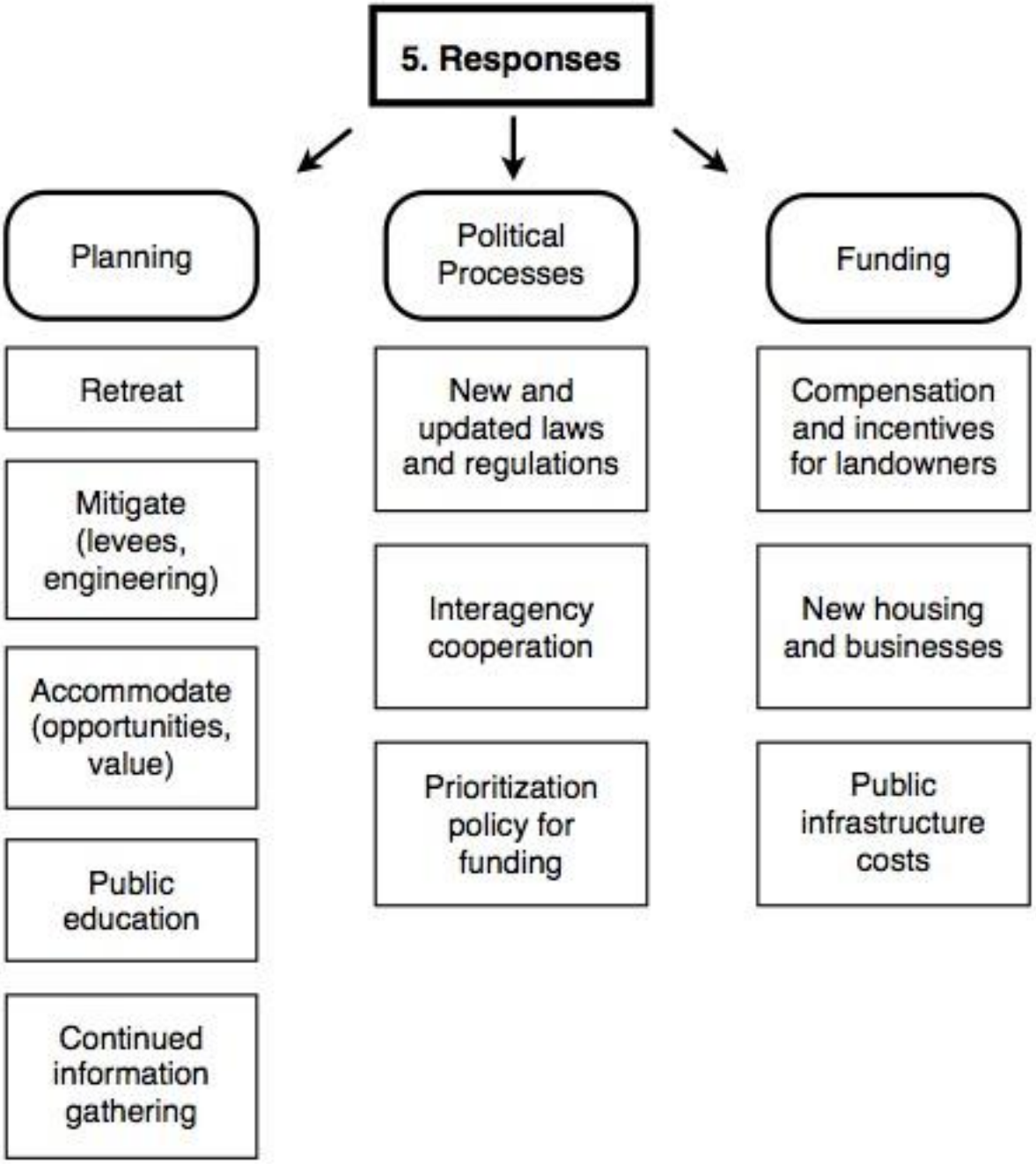
Appendix A: a conceptual model of implications of sea level rise on North Humboldt Bay




2. Direct Effects
Higher Water Levels
Flooded Land
Flooded Infrastructure
Ocean
Creeks
Sloughs
Bay
Estuaries
Wetlands
Salt marshes
Freshwater marshes
Mudflats
Dunes
Agricultural land
Public land
Cultural sites
Wildlife refuges
Transportation network
Homes
Businesses
Brownfields
Waste water treatment facility, utilities
Public buildings


3. Indirect Effects
Economic
Social/Cultural
Ecological
Homes and businesses: displacement, livelihood, insurance
Access to goods and services, shipping, food security
Local activities: recreation, tourism
Loss of community, place
Native American cultural sites
Historic sites and buildings
Recreation access
Habitat
General loss and change
Refuges
Bay and estuary (fisheries)
Wetland types
Threatened and Endangered Species
Pollution
Non-point source
Point source
Current brownfields
Future brownfields


4. Additional Challenges
Remoteness
Regulatory Challenges
Physical
Political, funding
Economic
Local
State
Federal
Land use planning, zoning ordinances, Local Coastal Plans
Regulations, CEQA, etc.
Laws and regulations, CZMA, NEPA, ESA, CWA, etc.


5. Responses
Planning
Political Processes
Funding
Retreat
Mitigate (levees, engineering)
Accommodate (opportunities, value)
Public education
Continued information gathering
New and updated laws and regulations
Interagency cooperation
Prioritization policy for funding
Compensation and incentives for landowners
New housing and businesses
Public infrastructure costs