

# A Framework for Climate Change Adaptation in Hawaii

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A collaborative effort of the Ocean Resources Management Plan Working Group  
with the assistance of the  
University of Hawaii, Center for Island Climate Adaptation and Policy

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**Cover Photo:** Impacts from climate change such as drought, sea-level rise, hurricanes, and severe storms will increase the vulnerability of communities to coastal hazards, and will adversely affect tourism, our water and food resources, and other natural and cultural resources in Hawaii. Photo credits: NOAA, Dolan Eversole, Marnie Meyer.

## Acknowledgements

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## Executive Summary

Impacts from global climate change are extensive and varied, from ocean and atmospheric warming to increased threats to public health and safety. Specific impacts in Hawaii may include sea level rise, ocean acidification, increased frequency and severity of storms and other coastal hazards, and drought. These effects will result in a range of adverse impacts to communities and sectors throughout Hawaii, including our economy and our natural and cultural resources. In Hawaii, we already experience periodic hazard events such as high storm surges and associated coastal erosion. It is critical for the State to act now in order to prepare for the impacts of climate change so that we can better withstand the negative impacts and take advantage of positive opportunities.

The multi-stakeholder Ocean Resources Management Plan (ORMP) Working Group, established by the Hawaii Coastal Zone Management Program to ensure implementation and further development of the ORMP, developed this framework when they collectively recognized that there were no guidelines on how the State of Hawaii could plan for adaptation to the impacts of climate change. The approach promotes an open and collaborative adaptation planning process that is based on a common vision for Hawaii's future and one that remains flexible to our ever-changing environment, economy, and society. By doing so, we will be working proactively to ensure that Hawaii's future is one in which our people and our resources are safer, healthier, productive, and resilient in the face of global climate change.

The Working Group proposes the following framework for addressing climate change adaptation in Hawaii. The proposed framework includes:

- A. Build Climate Change Adaptation Team**
- B. Develop and Adopt a Long-Term Vision**
- C. Identify Planning Areas and Opportunities Relevant to Climate Change**
- D. Scope Climate Change Impacts to Major Sectors**
- E. Conduct a Vulnerability Assessment**
- F. Conduct a Risk Assessment**

Once the steps above have been completed, the next steps are:

- A. Prioritize Areas for Adaptation Planning**
- B. Set Preparedness Goals**
- C. Develop, Select, and Prioritize Preparedness Actions**
- D. Implement Preparedness Plan**
- E. Monitor Progress and Update Plan as Appropriate**

Each step of the framework is described in greater detail and with examples in each specific section. It is the ORMP Working Group's hope that climate change adaptation planning start immediately in Hawaii, and that this framework serves as an early planning tool for identifying where to start and what the different planning stages may look like.

## List of Acronyms

BWS - Board of Water Supply, City & County of Honolulu  
CZM - Coastal Zone Management Program  
DBEDT - Department of Business, Economic Development and Tourism  
DLNR - Department of Land and Natural Resources  
DOA - Department of Agriculture  
DOD - Department of Defense  
DOH - Department of Health  
DOT- Department of Transportation  
FEMA - Federal Emergency Management Agency  
ICAP- Center for Island Climate Adaptation and Policy  
LUC - Land Use Commission  
MACZAC - Marine & Coastal Zone Advocacy Council  
NGO - Non-governmental Organization  
NMFS - National Marine Fisheries Service  
NOAA - National Oceanic and Atmospheric Administration  
NRCS - National Resource Conservation Service  
NWS - National Weather Service  
OCRM- Office of Ocean & Coastal Resource Management  
OHA - Office of Hawaiian Affairs  
OP- Office of Planning  
ORMP - Ocean Resources Management Plan  
PSC - Pacific Services Center  
SCD - State Civil Defense  
SOEST- School of Ocean & Earth Science & Technology  
UH - University of Hawaii  
USCG - United States Coast Guard  
USCOE - United States Army Corps of Engineers  
USDA -United States Department of Agriculture  
USFWS - United States Fish and Wildlife Service  
WESPAC - Western Pacific Regional Fishery Management Council

## Section 1: Introduction & Purpose

Hawaii's Ocean Resources Management Plan (ORMP) is an integrated, place-based approach to the management of Hawaii's natural and cultural resources in the islands. The ORMP purposefully recognizes the ecological connections between the land and sea, the link between human activities and their impacts on the environment, and the need for improved collaboration and stewardship in natural resources governance. The ORMP Working Group (Working Group), an interagency group tasked by the ORMP Policy Group (agency heads) with coordinating ORMP implementation efforts, meets monthly to streamline implementation and to further develop the ORMP. Although climate change is not addressed in the current ORMP (2006), the Working Group supports the development of appropriate adaptation strategies that will reduce the anticipated economic, social, and environmental costs associated with climate change impacts. This is important for the future of the ORMP as well as for the future of Hawaii's residents, property, economic vitality, and natural and cultural resources.

The purpose of this document is to encourage and facilitate state, local and federal agencies, policy makers, business, and community partners to plan ahead for the impacts of climate change. While there is a Hawaii Greenhouse Gas Emissions Reduction Task Force<sup>1</sup> to *mitigate* the impacts of global climate change, efforts toward a comprehensive plan for climate change *adaptation* in Hawaii has only recently begun. On July 16, 2009, the State Legislature met in Special Session and enacted Act 20 (Senate Bill No. 266, SD2, HD2, CD1), which establishes a Climate Change Task Force within the Office of Planning to scope the impacts of global climate change trends in the State. These efforts include addressing sea level rise; estimating the costs of the adverse impacts; and making recommendations on measures that would address the effects of climate change. This measure demonstrates the need for a coordinated effort in Hawaii to address climate change impacts and adaptation options. The message from the Legislature is clear: we need to act now to prepare the State for climate change impacts.

The Working Group proposes the following framework for timely and effective climate change adaptation planning in Hawaii. The framework (i) provides meaningful context for a number of key areas that climate change will continue to affect, such as shoreline erosion, coastal development, coastal hazards, and the preservation of our natural and cultural resources and (ii) lays out a step-by-step process by which the State of Hawaii may begin to develop plans and make informed decisions on climate change adaptation. This is an effort of the Working Group and is in clear alignment with the ORMP objective to recognize the connections between land and sea, and between human activities and the environment.

Inherent to any climate change adaptation plan is the need for flexible response. The science, policies, and social and cultural acceptance of climate change are rapidly evolving. With this

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<sup>1</sup> Act 234 of 2007 (The Global Warming Solutions Act) establishes as state policy statewide greenhouse gas emissions limits at or below the statewide greenhouse gas emissions levels in 1990 to be achieved by January 1, 2020. It further established a greenhouse gas emissions reduction task force to prepare a work plan and regulatory scheme to achieve the statewide greenhouse gas emissions limits.

pace of development, there is no way to completely understand the breadth and intensity of all future climate change impacts. As such, flexible response must be built into each portion of the framework, to allow incorporation of new and significant advancements in science and policy in the long-term planning efforts.

This document was developed in large part by reviewing recommendations made in climate change adaptation guidance documents, other state plans, and national reports and applying these concepts locally. The guidance document entitled, “Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments,” (Snover et al., 2007) written by the University of Washington Climate Impacts Group and King County, Washington, and in association with ICLEI – Local Governments for Sustainability, was of particular interest to the Working Group and was used as appropriate for this framework. The guidebook has been used and tested in other municipalities and serves to help decision-makers at any level of government prepare for climate change by laying out a simple process for preparedness and adaptation planning.

## Section 2: The Case for Adaptation Planning

Island communities are especially vulnerable to a warming and more energetic climate system. Climate vulnerabilities exist at three tiers: exposure, sensitivity, and adaptive capacity. The former, exposure, is determined by climate forecasting based on sound science while the latter two are determined by the strength of the existing policy and planning infrastructure. Climate change will profoundly affect Hawaii's natural environment and communities and place lives and property at risk. The intensity of climate change impacts on our island state is, to a significant degree, in our control. By taking immediate and concerted action to prepare for forecasted climate shifts, we can ensure that our resources and communities are safer, healthier, more productive, and as resilient as possible in the face of an uncertain future. Achieving such a resilient system is in line with the basic principles of ecosystem - or place-based management - a fundamental principle of the ORMP.

Some key vulnerabilities for U.S. Islands due to climate change include:<sup>2</sup>

- Availability of freshwater,
- Exposure to coastal hazards including sea level inundation, and
- Negative impacts of climate change to coastal and marine ecosystems.

While the *precise* timing, type, and degree of impact will remain difficult to predict for years to come it is clear that significant adaptation techniques will be necessary in the near future. Nonetheless, each island features both unique and shared traits that call for a nuanced and deliberate approach to decisions regarding energy use, transportation, public infrastructure, private property development, and overall land use patterns and policies. Local adaptation strategies will require intimate knowledge of the local economies, culture and ecosystems and attention to less obvious changes such as carrying capacities, climate-driven immigration, disease-vectors and invasive species. In order to enhance Hawaii's present adaptive capacity, Hawaii is developing a multi-sectoral scientific assessment of climate change impacts at a scale relevant to place-based planning.<sup>3</sup> Such an assessment should also identify how climate change impacts affect State and local agencies and provide strategies for agencies to enhance collaboration to mutually support each other's adaptation goals.

Thanks to Hawaii's long history of disaster management planning, many local community development and county plans include measures and data for a variety of natural hazards. Since many climate change impacts most likely will manifest as an increase in the occurrence and intensity of natural hazards, some of the very early preparedness work has been done. Hawaii's disaster management framework builds on prior hazard planning by providing a process to assess sensitivity to specific, near-term climate change impacts - such as increased storms, coastal

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<sup>2</sup> US Global Change Impacts in the United States.

<http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/islands>

<sup>3</sup> This was a key recommendation from the participants of the Hawaii Conservation Alliance Climate Change Leadership Summit held on July 31, 2009.



erosion, or flooding. This proven disaster management process gives Hawaii an important head start in the adaptation process. Further, a statewide adaptation planning process is a natural next step that builds upon Hawaii's effort to mitigate greenhouse gas emissions under the 2007 Global Warming Solutions Act.

As we embark on this process, it will be important to consider the amount of time and resources required to conduct a thoughtful assessment and planning process for increased adaptive capacity. If successful, this process and the resulting adaptation plan can serve as models for our Pacific Island neighbors.

## Section 3: Framework for Climate Change Adaptation

To encourage adaptation to climate change in Hawaii, Section 3 lays out a proposed framework for the process. The framework follows the recommendations in “Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments” (Snover et al., 2007) (hereinafter “Guidebook”). Some definitions and explanations come directly from the Guidebook.

The first steps in the framework include identifying who should be involved in adaptation planning and which planning areas will be most severely affected. After the adaptation team and planning areas are identified, a long-term vision should be articulated, along with decisions on scale. It is recommended that the team then complete a series of assessments in order to determine the range of risk and vulnerability each planning area may face from climate change. Each step of the framework is described in greater detail below.

### A. Build Climate Change Adaptation Team

Because climate change impacts affect many different services and operations across planning sectors, multi-sector coordination will be difficult but essential. A successful adaptation effort will require a long-term commitment from the various public officials, government agencies, non-governmental organizations, the business community, and other stakeholders and community partners. Support from the general public will also be crucial to the success of preparedness efforts, highlighting the need for an effective education and outreach program related to climate change adaptation.

The purpose of building a climate change adaptation team is to coordinate those local adaptation and planning activities across departments, jurisdictions, disciplines, and levels of government. The adaptation team will ideally be engaged throughout the planning process, but its primary responsibility is to provide guidance for local government climate change adaptation. Ideally, the team should consist of those that are authorized to make changes recommended by the collective team in the adaptation planning process. This is essential to ensure that plans can be funded and implemented once recommendations are made. It is also ideal to have advisory technical experts as part of the team. The adaptation team and the overall adaptation effort is typically established through a legislative or administrative mandate, such as an executive order. In Hawaii, the Climate Change Task Force being established under Act 20 may serve as the adaptation team.

### B. Develop and Adopt a Long-Term Vision

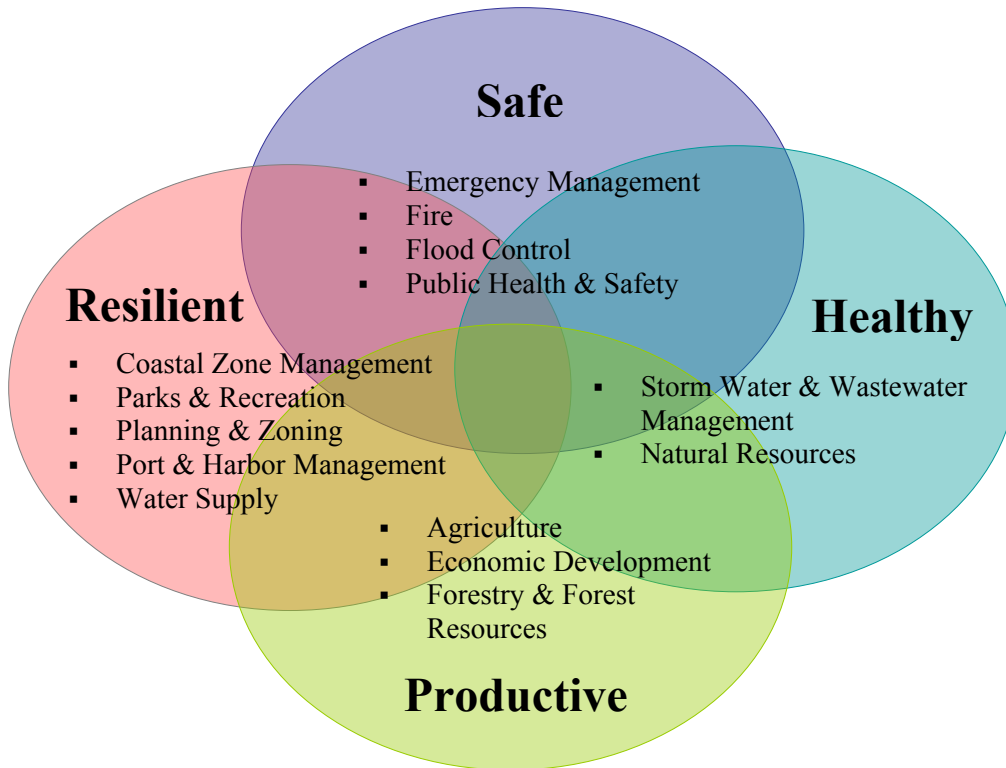
Because the impacts of climate change are widespread, affecting a multitude of planning sectors, it is easy to become overwhelmed by the task at hand. Complicating the issue is the realization that the need for adaptation is rarely an issue *only* due to climate change, as there are multiple stressors on various planning sectors (e.g. hazard mitigation). Furthermore, because we can no longer plan based on our historical data, climate change is a moving target, requiring continuous reassessment. The complex circumstances under which adaptation planning must occur makes the development of a coherent, long-term vision imperative.

The need for a long-term vision is easy to overlook, and it is common to assume that a common vision is already in place. However, without a clearly articulated vision, conflict may quickly arise across the multiple planning sectors when it comes time to prioritize and implement adaptation strategies with limited resources. In essence, adapting to climate change is a debate about values: how the stressors are going to affect what we value and how we view the options before us.

Climate change is forcing states to engage in a new way of thinking- to start with the *values and needs* of that place, then to determine how those values and needs will be affected by climate change. This shift should be viewed as an opportunity for states to plan and implement actions in a *proactive* manner, rather than a *reactive* manner. In other words, rather than haphazardly trying to address every single impact of climate change on a case-by-case basis, Hawaii can determine what is essential for its long-range future, based on island values and needs, and prioritize accordingly.

**Figure 1** below provides an example of elements that might be included in a long-term vision of Hawaii. The circles represent possible core values for the state to pursue, resulting in a vision of a safe, healthy, productive and resilient Hawaii. It is important to recognize that these values must be further defined and articulated. The overlapping nature of the circles represents the interconnected and interdependent nature of these values (e.g., a healthy Hawaii is not possible without a safe environment). The bullets listed under each core value represent various planning areas that are responsible for ensuring that these values are addressed. As the values are interconnected and interdependent, so too are the planning sectors; the actions of one sector affects the impacts or actions of another. In addition to challenges, this overlapping nature among the planning sectors also lends well to cross-sectoral planning efforts.

**Figure 1.** The overlapping nature of the values and where the planning areas lie illustrate the opportunities and need for collaboration.



The adaptation team will need to develop a clear vision that represents the values of state and county government agencies, conservation groups, non-profit organizations, and the broader community at large.<sup>4</sup> The adaptation team will need to determine how to effectively and efficiently gather and integrate the input necessary for this process from stakeholders.

At this early stage in the planning framework, the adaptation team must also consider the **scale(s)** at which adaptation actions and plans will be developed and implemented. A few obvious for scale include the following:

- a) State of Hawaii;
- b) the main Hawaiian Islands and Northwestern Hawaiian Islands;
- c) county;
- d) island;
- e) agency; or
- f) planning sector.

<sup>4</sup> This was a key recommendation from the participants of the Hawaii Conservation Alliance Climate Change Leadership Summit held on July 31, 2009.

The adaptation team may also choose include a combination of the above, depending on the values, needs, and objectives to be addressed. Some items that the adaptation team might consider to determine the scale(s) to be used include the following:

- a) scale of currently available data;
- b) scale of data soon to be available;
- c) funding sources and purposes;
- d) agents of implementation; and
- e) other logistical concerns.

Whatever the decision, it is important to make these delineations early in the process.

### **C. Identify Planning Areas Relevant to Climate Change**

After determining vision and scale, the adaptation team must identify planning areas that are likely to be affected by climate change. Planning areas are defined as the areas in which a government or community manages, plans, or makes policy affecting the services and activities associated with built, natural and human systems. Systems refer to the networks that provide important services and activities within a community or region.

Once the adaptation team identifies the relevant planning areas, it is important to identify the projected stresses or impacts to those areas. Preparing an inventory of planning areas likely to be affected by climate change can help focus prioritization of preparedness and adaptation efforts later in the process. Categorizing these planning areas by sector reminds us of the larger vision for a safe, healthy, productive, and resilient Hawaii.

To initiate the adaptation process, the Working Group has identified a list of adaptation team players and planning considerations in each of the planning areas likely to be affected by climate change (Table 1). This list contains mostly state and county agencies and is not exhaustive, nor do we assume the team members identified will want to participate. Other potential team members could be the business community, non-profit organizations, the science community, and other local, federal and international agencies.

**Table 1.** Adaptation team players and planning considerations for each of the planning areas that are likely to be affected by climate change. The planning areas are organized by the values depicted in **Figure 1**.

Proposed Adaptation Team Member	Potential Impacts and Adaptation Planning Considerations
<b>SAFE</b>	
<b>Emergency Management</b>	
Counties (depts. of water, planning), DOT, DLNR, FEMA, LUC, SCD, UH, USACE, shipping and cargo industries, public utility companies	<ul style="list-style-type: none"> <li>Increased potential and frequency for floods and storm damage</li> </ul>
	<ul style="list-style-type: none"> <li>Damage to critical infrastructure due to sea level rise and storm flooding</li> </ul>
	<ul style="list-style-type: none"> <li>Threats to transportation infrastructure (evacuation routes) due to sea level rise and storm flooding</li> </ul>
	<ul style="list-style-type: none"> <li>Disaster relief funds may be diluted nationally and state-wide due to increased number and scale of disasters</li> </ul>
	<ul style="list-style-type: none"> <li>Aging public infrastructure including roads, sewer and communications.</li> <li>Increased and more vulnerable population to protect (general population growth immigrants from Pacific Island nations, etc)</li> </ul>
<b>Fire</b>	
Counties (fire depts.), DLNR (Drought Council, Water Commission), NWS	<ul style="list-style-type: none"> <li>Changes in weather patterns and development increase risk of wildfires</li> </ul>
	<ul style="list-style-type: none"> <li>Increased variability in weather and rainfall increases difficulty in fighting fires and allocating resources in advance</li> </ul>
<b>Flood Control</b>	
Counties, DOT, DLNR (National Flood Insurance Program, Engineering Division), FEMA, NWS, USACE	<ul style="list-style-type: none"> <li>Increased frequency and intensity of storms that could lead to flooding</li> </ul>
	<ul style="list-style-type: none"> <li>Weakening of infrastructure due to repetitive and prolonged stress (dams, roads, bridges, tunnels, storm drains)</li> </ul>
<b>Public Health and Safety</b>	
Counties (depts. of water, planning), DOA, DOH, DOT, DLNR (Water Commission, Drought Council), LUC, SCD, OHA (traditional practices)	<ul style="list-style-type: none"> <li>Growth and spread of existing infectious tropical diseases</li> </ul>
	<ul style="list-style-type: none"> <li>Stagnant water in low lands due to inland flooding (water table rising) leads to growth of airborne vectors</li> </ul>
	<ul style="list-style-type: none"> <li>Decreased fresh water supplies and coastal ocean nutrient loading</li> </ul>
	<ul style="list-style-type: none"> <li>Isolation of islands increases potential of nutrition related disease development</li> <li>Increased frequency and severity of heat waves, floods, and other weather-related disasters</li> </ul>

<b>HEALTHY</b>	
<b>Natural Resources / Environmental Protection</b>	
Communities, Counties, DOA, DOH, DLNR, DOT, OHA, OP/CZM, SCD, UH, industry, NGOs, USFWS, NOAA/NMFS, USACE, WESPAC	• Invasive species growth with changing environmental variables
	• Reef degradation and bleaching due to warming and ocean acidification
	• Negative impacts on fisheries from ocean acidification and other impacts
	• Loss and migration of native species due to changes in terrestrial and aquatic climates
	• Salt water intrusion and loss of wetlands, coastal ponds, and estuaries due to sea level rise
	• Hydrologic cycle shifts with precipitation and evaporation changes
	• Possible impacts on ocean current patterns, may circulate more marine debris and invasives to our shorelines, among other impacts
<b>Storm Water and Wastewater Management</b>	
Counties (depts. of water, planning, wastewater, civil defense), DOH, DLNR, DOA, OP/CZM, SCD, USACE, USCG	• Increased storm frequency and intensity leads to increased discharge
	• Submersion of pipes by sea level rise and flooding impacts water management
	• Better land use measures will need to be implemented (such as porous pavements, riparian buffers, etc) to reduce non-point source pollution and runoff
<b>Productive</b>	
<b>Agriculture</b>	
DOA, DLNR, DOH, LUC, UH College of Tropical Ag & Botany Dept, Counties, farmers, land owners, NRCS	• Land use changes threaten agricultural land as urban areas retreat from the coast
	• Ocean variability changes viability of offshore and onshore aquaculture
	• Climate variability influences growing and propagation of native and invasive species
	• Demand for alternate energy sources (bioenergy, wind, solar) may lead to loss of agricultural land for food production
	• Climate variability may impact food crop seasonality, yields, nutrient content, leading to reduced food sustainability
<b>Economic Development</b>	
Counties, DBEDT, LUC, visitor industry bureaus, business bureaus, shipping and cargo industries, public utility companies, other private companies/industries	• Loss of shorelines and beaches may negatively impact tourism
	• Increased worldwide demand for fuel along with declining sources of oil may lead to increased costs in travel (tourism, transportation), island imports/exports
	• Sea-level rise threatens expensive infrastructure (power, waste, transportation, communications)
	• Industries can grow out of climate change and benefit Hawaii: <ul style="list-style-type: none"> <li>○ Solar, wind, geothermal, and wave power</li> </ul>

	<ul style="list-style-type: none"> <li>○ Recycling</li> <li>○ Shoreline engineering and geo-engineering</li> <li>○ Vertical farming</li> <li>○ High tech (fuel cell, efficient solar, geothermal)</li> </ul>
	<ul style="list-style-type: none"> <li>● Climate Migration: Increased need for aid to residents from other Pacific Islands who are moving to Hawaii as their lands are submerged</li> </ul>
<b>Forestry and Forest Resources</b>	
Counties, DLNR, USDA Forest Service	<ul style="list-style-type: none"> <li>● Clearing of land for development/agriculture</li> <li>● Spread of invasive/dangerous species to upland forest zones</li> <li>● Growth and decline of forest species due to changing climate</li> </ul>
<b>RESILIENT</b>	
<b>Coastal Zone Management</b>	
Communities, Counties, DOA, DOH, DLNR, DOT, industry, NGOs, OHA, OP/CZM, SCD, UH, NOAA/NMFS, USACE, WESPAC	<ul style="list-style-type: none"> <li>● Loss of shorelines and beaches for public use and recreation</li> <li>● Changes in the rate of coastal erosion may require new setbacks, elevation standards, building codes, and other coastal hazard mitigation measures for development in coastal areas and to enhance protection of existing ocean front property</li> <li>● Loss of natural and cultural resources such as fisheries, coral reefs, wetlands, and anchialine ponds due to changing ocean and atmospheric conditions and ocean acidification</li> <li>● Communities will be at an increased risk associated with more frequent and more intense coastal hazards, declining food and water resources, and deteriorating public infrastructure</li> <li>● Threats to historical resources due to changing oceanic and atmospheric conditions</li> <li>● Threats to scenic and open spaces due to migration away from the shoreline</li> </ul>
<b>Parks and Recreation</b>	
Counties , DLNR, LUC	<ul style="list-style-type: none"> <li>● Increased pressure to develop and instrument park lands</li> <li>● Loss of land due to sea level rise</li> </ul>
<b>Planning and Zoning</b>	
Counties, Communities, DLNR, DOT, LUC, OP, UH, land owners, NGOs	<ul style="list-style-type: none"> <li>● Loss of zoned lands to sea level rise and inundation</li> <li>● Changes in land uses</li> <li>● Revision and development of new long-range plans to include forecasted climate changes</li> <li>● Zone conflicts as space becomes limited or development increases in high-demand areas</li> <li>● Unpredictability of climate requires fluid approach to planning</li> <li>● New planning theories/methods to more accurately account for environmental impacts are required</li> </ul>



<b>Port and Harbor Management</b>	
DLNR, DOT, USACE, USCG, shipping and cargo industries, public utility companies	<ul style="list-style-type: none"> <li>• Submersion of harbor infrastructure due to sea level rise and flooding</li> </ul>
	<ul style="list-style-type: none"> <li>• Increased public safety risk at passenger terminals due to hazardous flooding conditions</li> </ul>
	<ul style="list-style-type: none"> <li>• Weakened drainage systems that remove storm water runoff from harbor facilities</li> </ul>
	<ul style="list-style-type: none"> <li>• Increased potential for the spread of diseases and other public safety issues due to flooding conditions</li> </ul>
	<ul style="list-style-type: none"> <li>• Delayed shipments, higher shipping costs, and loss of operational time due to flooding conditions at cargo terminals</li> </ul>
<b>Transportation</b>	
Counties, DOT, OP, LUC, shipping and cargo industries, public utility companies	<ul style="list-style-type: none"> <li>• Submersion of vital transportation infrastructure due to sea level rise and flooding</li> </ul>
	<ul style="list-style-type: none"> <li>• Migration of beaches over coastal lands due to wave climatology</li> </ul>
	<ul style="list-style-type: none"> <li>• Increased dependence on ocean transportation networks given higher cost of fuel and submersion of roads and rails</li> </ul>
	<ul style="list-style-type: none"> <li>• Higher cost of fuel and drive for clean energy increases need for public transit options</li> </ul>
<b>Water Supply</b>	
Counties (depts. of water, planning), DLNR (Water Commission, Drought Council), LUC, Communities	<ul style="list-style-type: none"> <li>• Sea level rise impacts water quality and quantity <ul style="list-style-type: none"> <li>○ Water quality degradation from the intrusion of salt water into fresh and brackish water aquifers and stream estuaries as sea level rises.</li> <li>○ As coastal communities retreat from the coast, development pressures will increase in agricultural and conservation zoned lands. Increased urbanization may reduce prime recharge areas (&gt; 50" annual rainfall) affecting water supply.</li> </ul> </li> </ul>
	<ul style="list-style-type: none"> <li>• Sea level rise immerses more metallic pipeline infrastructure in seawater increasing corrosion, main breaks and replacement costs.</li> </ul>
	<ul style="list-style-type: none"> <li>• Climate change reduces aquifer recharge and available water supply: <ul style="list-style-type: none"> <li>○ More frequent and severe drought</li> <li>○ Changes in rainfall patterns, such as thermal inversion effects</li> <li>○ Higher evaporation due to higher global temperatures reduces recharge</li> <li>○ Increased runoff if forest health declines</li> </ul> </li> </ul>
	<ul style="list-style-type: none"> <li>• Climate change increases water demand <ul style="list-style-type: none"> <li>○ Higher evapo-transpiration rates in landscaping from warmer temperatures</li> <li>○ Demand increases with severe and frequent drought</li> <li>○ Population growth and migration from inundated Pacific islands</li> </ul> </li> </ul>
	<ul style="list-style-type: none"> <li>• Increased capital costs and water rates to develop alternative water supply. <ul style="list-style-type: none"> <li>○ Expansion of recycled water treatment and systems for irrigation to replace depleted fresh and brackish water supplies.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"><li>○ Expansion of brackish and seawater desalination to supplement natural potable water supplies. Brine concentrate discharge in ocean outfalls threatens coastal zone and shallow waterway ecosystems unless mitigated, which increases cost.</li></ul>
	<ul style="list-style-type: none"><li>• Increased capital costs to harden water delivery, communication and emergency response facilities from more severe and frequent hurricanes caused by climate change.</li></ul>

## **D. Scope Climate Change Impacts to Major Sectors**

The adaptation team must now scope out the projected impacts of climate change for each planning area. The results of this effort will serve as the foundation for the rest of the adaptation effort. Scoping the impacts involves pulling together and analyzing all of the current information available on climate change and how it will affect Hawaii. The amount of published research available for Hawaii will determine how long this step may take and who should conduct the study. It can be done by an interagency team, consultants, local scientists/researchers, graduate students, or staff.

A major part of this step should be dedicated to the specific climate changes expected to happen throughout Hawaii. This includes an assessment of the climate variables that will be affected, such as temperature and precipitation, and how these climate changes will vary seasonally. It is important to collect information about the range of climate change that Hawaii could experience and to understand and log the uncertainty associated with climate projections.

Scoping the impacts of climate change in Hawaii should be comprehensive and should not only include impacts to the shorelines and our marine resources, but also to our fresh water resources, the agricultural sector, the economic sector (such as tourism and fisheries), and key social and cultural arenas. Rising population growth and increasing numbers of people living along the shoreline, loss of property and open space, and increased flooding and severity of storms should all be included in the scoping.

Upon completion of this step, the State should have a summary of how climate change is likely to affect Hawaii, and how each of the planning areas will be affected by these projections.

## **E. Conduct a Vulnerability Assessment**

A climate change vulnerability assessment may be one of the more research-intensive phases of the adaptation process. Detailed suggestions for how to conduct this assessment are offered in the Guidebook. In summary, a vulnerability assessment includes three parts:

1. A sensitivity analysis for the systems associated with the planning areas identified;
2. An evaluation of the adaptive capacity of the systems associated with each of these planning areas; and
3. An assessment of how vulnerable the systems in the planning areas are to the effects of climate change.

*Sensitivity* is the degree to which a built, natural or human system is directly or indirectly affected by changes in climate conditions or specific climate change impacts. If a system is likely to be significantly affected as a result of projected climate change, it should be considered sensitive to climate change.

*Adaptive capacity* describes the ability of built, natural and human systems associated with a given planning area to accommodate changes in climate with minimum disruption or minimum additional cost. In general, systems that have high adaptive capacity are better equipped to deal with climate change impacts.

*Vulnerability* refers to the susceptibility of a system to harm from climate change impacts. Vulnerability is a function of a system's sensitivity to climate and the capacity of that system to adapt to climate changes. In other words, systems that are sensitive to climate and less able to adapt to changes are generally considered to be vulnerable to climate change impacts.

## **F. Conduct a Risk Assessment**

Once the vulnerability assessment is complete, the next step is to conduct a risk assessment. This step is necessary to prioritize planning areas in the next steps of the adaptation framework, as prioritization will be based on the State's long-term vision and the estimation of risk to systems in the planning areas. While several approaches are available, the following is one example of how to assess risk:<sup>5</sup>

$$\text{Risk} = \text{Consequence} \times \text{Probability}$$

The information collected for the vulnerability assessment will help estimate consequence, probability, and resulting risk of specific climate change impacts to systems in the planning areas. For an example of a risk assessment taken from the Guidebook, see Appendix B.

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<sup>5</sup> Guidebook, p. 87.

## Section 4: Next Steps

Climate change adaptation planning can succeed after completion of the impacts analysis and risk and vulnerability assessments for each planning sector. While there are many different approaches used to develop action and implementation plans, Section 4 describes an example of the next steps the state may choose to take. These steps include prioritizing areas for adaptation planning, setting preparedness goals, developing an action plan, and implementing and monitoring that plan. It is important to note that there are many different options on how to move forward after the first steps of the framework are complete. The decisions on vision and scale made earlier in this process will help to determine how to proceed.

### A. Prioritize Areas for Adaptation Planning

*Priority planning areas* are the planning areas that our community and government determine to be most important given Hawaii’s vulnerabilities to climate change and the associated risks. To prioritize planning areas, the results of the vulnerability and risk assessments may be grouped into categories ranging from high risk/high vulnerability to low risk/low vulnerability. The following matrix illustrates prioritization:<sup>6</sup>

	<b>High vulnerability</b>	<b>Low vulnerability</b>
<b>High risk</b>	<b>Should be</b> priority planning area	<b>May be</b> priority planning area
<b>Low risk</b>	<b>May be</b> priority planning area	<b>Unlikely</b> to be priority planning area

Other considerations that may prove difficult but must be considered include the costs and benefits of adaptation, irreversible consequences, political will, community support, and data uncertainties. From this point forward, climate change preparedness efforts should focus on the articulated vision and the priority planning areas identified in this step.

### B. Set Preparedness Goals

*Preparedness goals* are desired accomplishments in each of the priority planning areas to address through preparedness actions. The goals will vary from one community to another, based upon the magnitude of projected impacts and the scale of the planning effort. The goals may also vary by agency jurisdiction, by geographic area, by specific resource, such as fisheries or freshwater, or by the larger planning sector.

It is important to consider a set of guiding principles agreed upon by the adaptation team to assure communities will be resilient to climate change impacts when setting preparedness goals. It is also important to keep in mind the timeframe for implementation, to encourage input from the public, and to remain flexible since climate change adaptation is necessarily an ongoing process.

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<sup>6</sup> Guidebook, p. 91.

### **C. Develop, Select, and Prioritize Preparedness Actions**

*Preparedness actions* are the activities that the government will undertake to achieve its preparedness goals. Preparedness actions will vary in different communities, based on vulnerabilities, risks, and community variables, such as available resources. Preparedness actions often include activities such as the following: modifying policies, practices, and procedures; diversifying options; building new or upgrading existing infrastructure; improving community awareness and preparedness; and building partnerships with other communities and agencies.

Once preparedness actions are developed, the next step is to prioritize them. The Guidebook suggests categorizing the actions into groups such as those that can and will be implemented in this planning process, those that could be implemented now or in the future but require additional information, resources, or authorities before implementing, and those that are not suitable at this time. Once again, there are additional criteria that will need to be considered when prioritizing preparedness actions, such as the costs, timeframe, flexibility, and equitability of the actions. Furthermore, it is important to continuously return to the vision that has been adopted in order to always keep the goals and values articulated in mind.

### **D. Implement Preparedness Plan**

The composition of the climate change adaptation team is important for implementing the preparedness plan because this determines which *implementation tools* are available to the process. Implementation tools are authorities and/or avenues over which our government has control or influence in policy, planning and infrastructure. Examples include legislative, regulatory, and/or fiscal authorities, infrastructure development, permitting and enforcement, and emergency management powers. The adaptation team should explore opportunities to align preparedness actions with existing policies, planning efforts, or goals - such as the ORMP, and those identified by the Greenhouse Gas and Climate Change Task Forces - and county shoreline setback regulations. It is also important to consider the different levels of uncertainty and risk associated with climate change and to maintain long-term support of the preparedness efforts from the community through education and outreach activities.

### **E. Monitor Progress and Update Plan as Appropriate**

Because the science, policies, social and cultural acceptance, and economic factors guiding the preparedness efforts will evolve through time, progress should be monitored regularly. The adaptation team, the community, and others should review existing policies and plans, measure implementation progress, and reorient long-term goals to ensure our communities are safe and resilient to the impacts of climate change. This effort should be built around a real-time repository for pertinent information, where participants can log topical papers, reports, policies, etc. and provide rationale for inclusion in the next scheduled review. Examples of submissions for the repository to be used during a regularly-scheduled review process include the following:

- Peer-reviewed scientific findings that improve or change the community's vulnerability;
- Submissions impacting priority planning areas;
- Submissions impacting the vision and guiding principles, and their relevancy to the adaptation team's goals;

- New information about the success or failure of the preparedness actions in building climate change resiliency;
- Successful local, state, federal, and international programs that deal with similar issues;
- Assessments of levels of social and cultural acceptance of climate change impacts and willingness to adapt to and mitigate those impacts; and
- Updated economic forecasts for impacts.

Measuring progress and remaining flexible are important elements of the climate change adaptation process that will enable the adaptation team to update the plan with new information generated on climate change. The ultimate goal is to ensure that the preparedness goals, actions, and plan continue to be appropriate for the environmental, economic, political, and social conditions in Hawaii.

## Section 5: Conclusion

Impacts from global climate change are far reaching and will affect the health and well being of Hawaii's people, natural resources, economy, and future. Many scientists and climate policy experts contend that that we are just beginning to experience the climate change impacts. In Hawaii, we already experience periodic hazard events such as high storm surges and hurricanes and associated coastal erosion. The urgency to act now to prepare and plan ahead for the impacts of climate change cannot be overstated. By assessing the regional impacts and engaging in an open and collaborative adaptation planning process, we stand to learn the best ways to ensure our communities and our people are able to withstand the negative impacts, and embrace new opportunities for positive change. By doing so, we will be working proactively to ensure that Hawaii's future is one in which our people as well as our natural and cultural resources are safer, healthier, productive, and resilient. Such an effort will not be easy, and will require political will, time, resources, and community support to achieve success.

The ORMP has the potential to serve as a good starting point for climate change adaptation preparedness. Not only does the ORMP address a broad range of natural and cultural resource management issues specific to Hawaii, but it is already structured as a multi-sector management plan. Several of the proposed climate change adaptation team members already participate on the Policy and Working Groups of the ORMP and advocate for the need for climate change adaptation planning in Hawaii. While the current ORMP does not include management goals and strategic actions specifically addressing climate change adaptation, it does include several related adaptation measures such as coastal hazard preparedness and mitigation of shoreline erosion. Furthermore, the ORMP will be updated on a regular basis and will be further developed to include climate change adaptation measures.

The ORMP Working Group stresses the importance of taking on this challenge immediately and in an inclusive manner. The group remains open to all possible opportunities to participate in such an important and crucial step for ensuring a healthy and vibrant future for Hawaii.



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## Appendix A

### Regional Highlights from *Global Climate Change Impacts in the United States – Islands*

# Regional Highlights from Global Climate Change Impacts in the United States

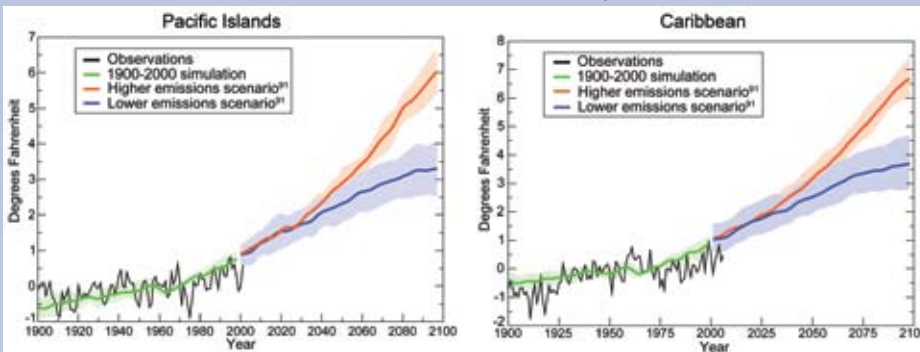
[www.globalchange.gov/usimpacts](http://www.globalchange.gov/usimpacts)

## Islands

Climate change presents U.S.-affiliated islands with unique challenges. Small islands are vulnerable to sea-level rise, coastal erosion, extreme weather events, coral reef bleaching, ocean acidification, and contamination of freshwater resources with saltwater. The

islands have experienced rising temperatures and sea level in recent decades. Projections for the rest of this century suggest continued increases in air and ocean surface temperatures in both the Pacific and Caribbean, an overall decrease in rainfall in the Caribbean, an increased frequency of heavy downpours nearly everywhere, and increased rainfall during the summer months (rather than the normal rainy season in the winter months) for the Pacific islands. Hurricane wind speeds and rainfall rates are likely to

Air Temperature Change, Observed and Projected, 1900 to 2100 relative to 1960-1979 average



Air temperatures have increased and larger increases are projected in the future, with higher emissions scenarios producing considerably greater increases. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models.

increase with continued warming. Island coasts will be at increased risk of inundation due to sea-level rise and storm surge with major implications for coastal communities, infrastructure, natural habitats, and resources.

**A note on the emissions scenarios:** None of the emissions scenarios used in this report include any policies specifically designed to address climate change. All, including the lower emissions scenario, lead to increases in heat-trapping gas emissions for at least the next few decades, though at different rates.

## Key Issues

**Island communities, infrastructure, and ecosystems are vulnerable to coastal inundation due to sea-level rise and coastal storms.**

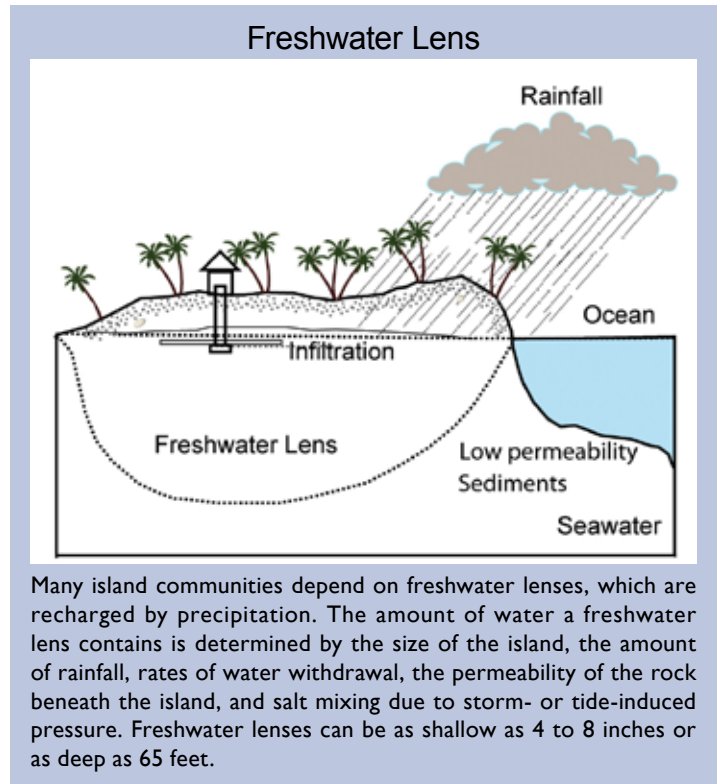
Flooding will become more frequent and coastal land will be permanently lost as the sea inundates low-lying areas and the shorelines erode. Loss of land will affect living things in coastal ecosystems. For example, the Northwestern Hawaiian Islands, which are low-lying and therefore at great risk from rising sea level, have a high concentration of threatened and endangered species, some of which exist nowhere else. Hurricanes and other storm events cause major impacts to island communities including loss of life, damage to infrastructure and other property, and contamination of freshwater supplies. With further warming, hurricane and typhoon peak wind intensities and rainfall are likely to increase, which, combined with sea-level rise, would cause higher storm surge levels.



Coastal houses and an airport in the U.S.-affiliated Federated States of Micronesia rely on mangroves' protection from erosion and damage due to rising sea level, waves, storm surges, and wind.

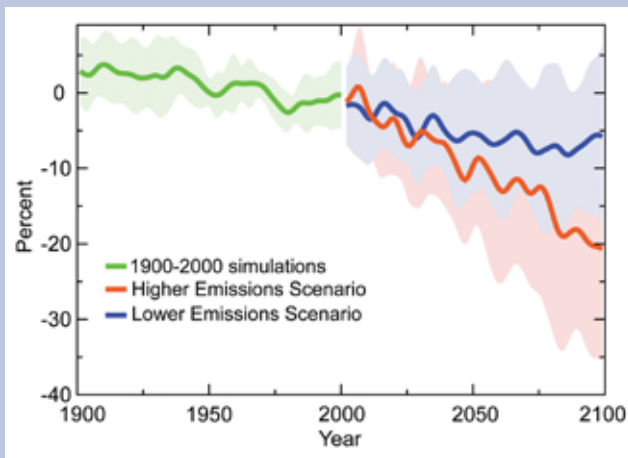
**The availability of freshwater is likely to be reduced, with significant implications for island communities, economies, and resources.**

Most island communities in the Pacific and Caribbean have limited sources of freshwater. Many islands depend on freshwater lenses below the surface, which are recharged by precipitation. Changes in precipitation, such as the significant decreases projected for the Caribbean, are thus a cause of great concern. Sea-level rise also affects island water supplies by causing salt water to contaminate the freshwater lens and by causing an increased frequency of flooding due to storm high tides. Water pollution (such as from agriculture or sewage), exacerbated by storms and floods, can contaminate freshwater supplies, affecting public health.



Many island communities depend on freshwater lenses, which are recharged by precipitation. The amount of water a freshwater lens contains is determined by the size of the island, the amount of rainfall, rates of water withdrawal, the permeability of the rock beneath the island, and salt mixing due to storm- or tide-induced pressure. Freshwater lenses can be as shallow as 4 to 8 inches or as deep as 65 feet.

**Caribbean Precipitation Change  
1900 to 2100**



Total annual precipitation has declined in the Caribbean and climate models project stronger declines in the future, particularly under higher emission scenarios. Such decreases threaten island communities that rely on rainfall for replenishing their freshwater supplies.

**Climate changes affecting coastal and marine ecosystems will have major implications for tourism and fisheries.**

Coral reefs are particularly sensitive to the impacts of climate change as even small increases in water temperature can cause coral bleaching. Ocean acidification due to rising carbon dioxide levels poses an additional threat to coral reefs and rich ecosystems they support. Fisheries feed island people and island economies. Nearly 70 percent of the world's annual tuna harvest comes from the Pacific Ocean. Climate change is projected to cause a decline in tuna stocks and an eastward shift in their location.



The full report, including references for the material above, can be found online at:  
[www.globalchange.gov/usimpacts](http://www.globalchange.gov/usimpacts)

It is published by Cambridge University Press, with hard copies available at: [www.cambridge.org](http://www.cambridge.org)  
ISBN 978-0-521-14407-0

## Appendix B

### Example of a Risk Analysis

Example taken directly from page 89 of the Guidebook (Snover et. al., 2007): This table shows an example of a qualitative risk assessment for systems associated with the sample planning areas of water supply, stormwater management, and road operations and maintenance.

Planning Areas	Current and Expected Stresses to Systems in This Planning Area	Projected Climate Change Impacts to Systems in This Planning Area	RISK ANALYSIS		
			Consequences of Impact (high, medium, low)	Probability of Impact (high, medium, low, unknown)	Estimated Risk to Systems in This Planning Area (high, medium, low)
Water supply	More summer drought	More drought, summer water stress likely due to lower winter snowpack and warmer, drier summers. Population growth will compound this problem.	High - threat to public safety, loss in consumer confidence, lost revenue. Affects entire customer base.	High - already a concern and warmer, drier conditions expected.	High
Stormwater management	Combined sewer over-flows (CSOs)	More localized flooding, water quality problems possible if precipitation becomes more intense, frequent.	Medium - contributes to water quality degradation, potential health, and ecosystem impacts. Affects combined sanitary/storm sewer piping in about 30% of the city.	Unknown at the regional level, but issue is already a major management concern and more intense precipitation observed since 1973.	Medium
Road operations and maintenance	Pavement buckling on asphalt roads during extreme heat events	More required asphalt maintenance likely.	Medium - potential implications for public safety, higher road maintenance costs, travel restrictions for heavy loads. Affects about 55% of the city's medium and high volume roadways.	High - warmer summer temperatures expected.	Medium - high