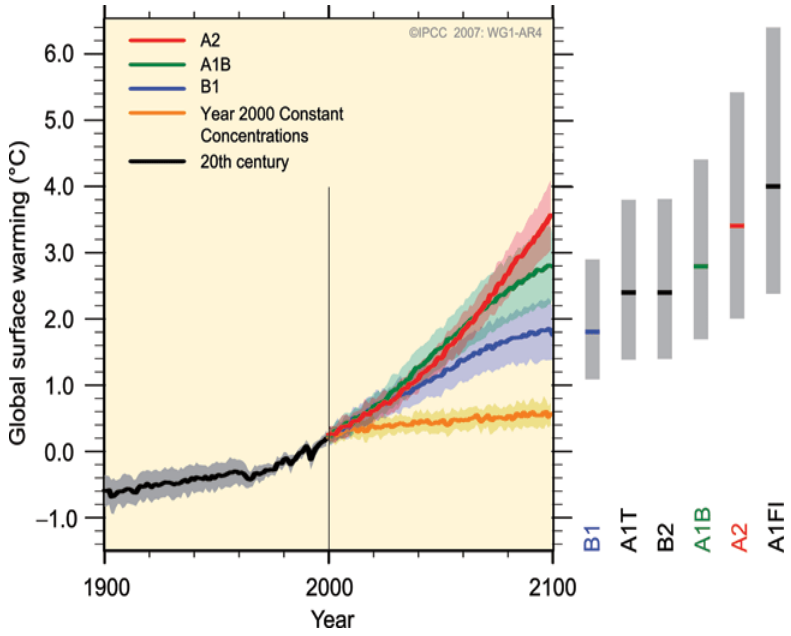
Programmatic Framework for Considering Climate Change Impacts in Coastal Habitat Restoration, Land Acquisition, and Facility Development Investments



NOAA Coastal Strategy
May 2010

ABOUT THIS DOCUMENT

The Office of Ocean and Coastal Resource Management and the Office of Habitat Conservation are pleased to present this document entitled "Programmatic Framework for Considering Climate Change Impacts in Coastal Habitat Restoration, Land Acquisition, and Facility Development Investments." The Framework is the first step in a multi-phased project to develop internal guidance for NOAA programs to consider climate change impacts in making coastal investment decisions.

This Framework describes how our offices will incorporate climate change considerations in program planning and implementation processes to safeguard a subset of coastal investments, and, where feasible, use these investments to enhance ecosystem resilience or mitigate climate change impacts. The Framework also identifies informational and programmatic needs to effectively consider climate change impacts, and advocates for new and stronger agency capabilities to address those needs.

This Framework is the first of its kind for NOAA and provides the basis for a concrete vehicle to address climate change in an integrated way across the agency. Future phases of this project include developing technical guidance and training programs for staff and project proponents; developing long-term monitoring/site management to better track impacts and results; and developing a more integrated restoration and land acquisition strategy that considers expected climate change impacts.

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NOAA Coastal Strategy
May 2010

Programmatic Framework for Considering Climate Change Impacts in Coastal Habitat Restoration, Land Acquisition, and Facility Development Investments

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EXECUTIVE SUMMARY

In August 2007 the Government Accountability Office (GAO) issued *Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources*, calling for federal agencies, including NOAA, to consider climate change impacts more systematically when implementing relevant programmatic activities. Specifically, GAO recommended clear, written communication to resource managers that explains how managers are expected to address existing and potential effects of climate change and that identifies how managers are to obtain necessary site-specific information.

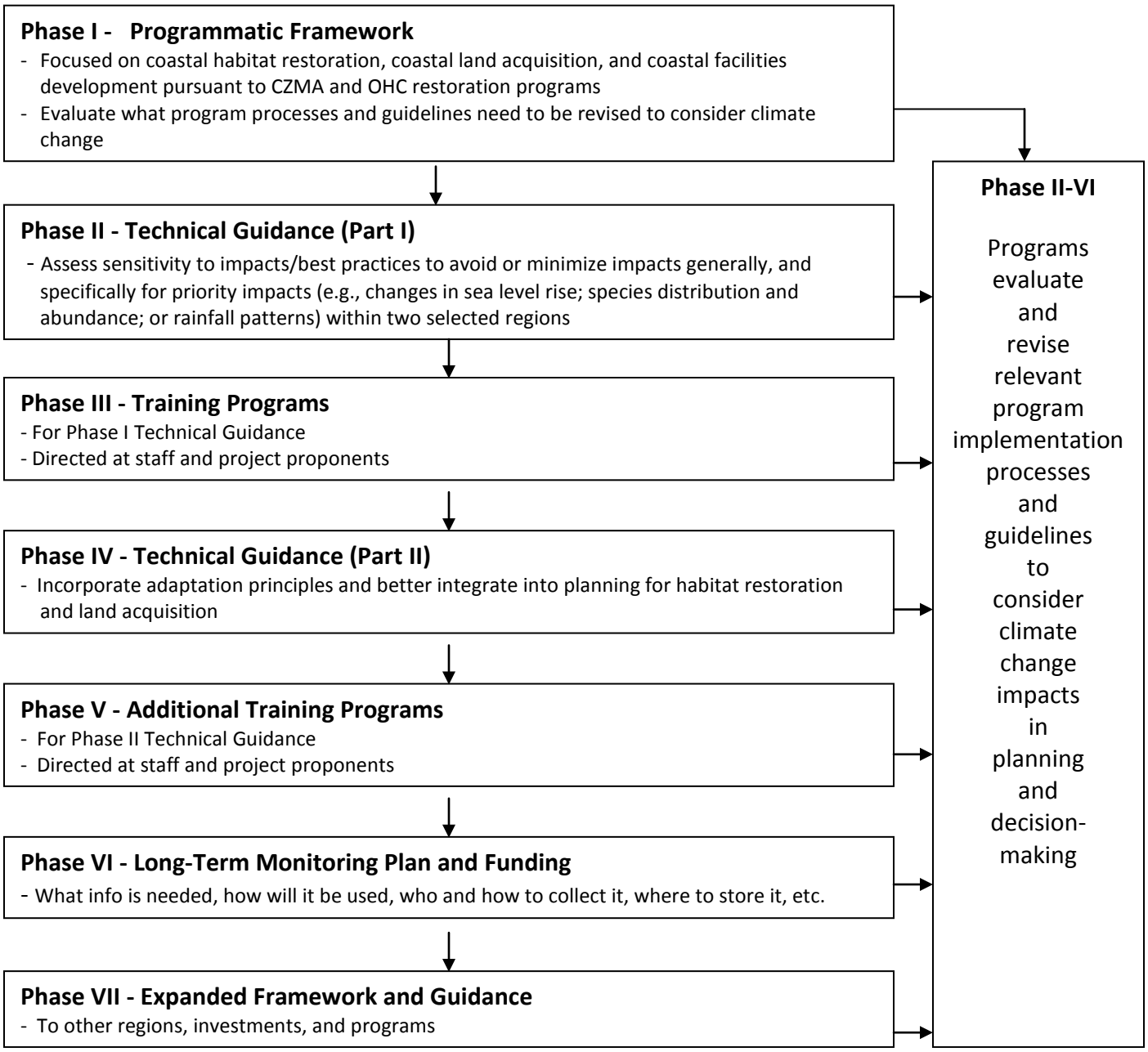
In 2009, the Coastal Strategy Team[1] embarked on a multi-year effort to develop and implement guidance to consider the impacts of climate change in program planning and decision making for its coastal investments (hereafter Climate Investment Guidance). The purpose of the Climate Investment Guidance is to safeguard these coastal investments in light of expected climate change impacts and, where feasible, to use these investments to enhance ecosystem resilience or mitigate climate change impacts in an integrated manner across coastal program offices.

Ultimately the Climate Investment Guidance effort will provide specific guidance that can be used to: (1) assess the sensitivity of coastal investments to expected climate changes and, where sensitive, identify best practices to avoid or minimize expected adverse impacts; (2) identify restoration or acquisition strategies and opportunities that could enhance ecosystem resilience; and (3) identify green designs and best practices to reduce or offset greenhouse gas emissions from facility operations. A final benefit of the Climate Investment Guidance will be more integrated planning for coastal restoration and land acquisition investments. To effectively implement the Climate Investment Guidance, other capacity building and outreach (such as staff training and changes to support for long-term monitoring) will be included in the over-all project.

This document, the "Programmatic Framework for Considering Climate Change Impacts in Coastal Habitat Restoration, Land Acquisition, and Facility Development Investments," (hereafter the Framework) is the first deliverable in this multi-phased project to develop and implement the Climate Investment Guidance. The project phases are identified in Figure 1.

[1] Coastal Strategy team includes representatives from the following NOAA Offices: National Ocean Service's (NOS) Office of Ocean and Coastal Resource Management (OCRM); NOAA Coastal Services Center (CSC); National Centers for Coastal Ocean Science (NCCOS); and Integrated Ocean Observing System Program(IOOS); National Fisheries Service's (NMFS) Office of Habitat Conservation (OHC); Oceanic and Atmospheric Research's (OAR) National Sea Grant College Program; National Environmental Satellite, Data, and Information Service's (NESDIS) National Geophysical Data Center; and Center for Satellite Applications and Research (STAR); and the National Weather Service's (NWS) Office of Climate, Water & Weather Services (CW&WS) and Office of Science and Technology (OS&T).

Figure 1: Climate Investment Guidance Project and Implementation Plan



The Programmatic Framework

The Framework provides a systematic approach to institutionalize the consideration of the impacts of climate change into program decision-making for a subset of coastal investments. The Framework addresses these coastal investments:

- Coastal land acquisition;
- Coastal facility development projects; and
- Coastal habitat restoration

The first two categories of investments, funded pursuant to the Coastal Zone Management Act (CZMA) of 1972, as amended, are managed by the Office of Ocean and Coastal Resource Management (OCRM) in the National Ocean Service (NOS). Relevant OCRM programs include: the Coastal Resource Improvement Program, being implemented by the federally-approved coastal zone management (CZM) programs; the Coastal and Estuarine Land Conservation Program (CELCP); and the National Estuarine Research Reserve System (NERRS), and as authorized under §306A, §307A, and §315 of the CZMA, respectively.

The coastal habitat restoration programs addressed by the Framework include NOAA's Community-based Restoration Program (CRP), Open Rivers Initiative, Great Lakes Habitat Restoration Program, and others managed by the Office of Habitat Conservation (OHC) in the National Marine Fisheries Service (NMFS). As applicable and to the greatest extent practicable, NOAA's DARRP and other programmatic habitat restoration activities are also included.

Framework Development Process

The Framework development was led by OCRM and OHC on behalf of the Coastal Strategy Team. A project team was formed in early 2009, with representatives from OHC, OCRM, National Centers for Coastal Ocean Science (NCCOS), NOAA Coastal Services Center (CSC), and the National Sea Grant College Program in the NOAA Office of Oceanic and Atmospheric Research (OAR).

The project team surveyed relevant NOAA programs and found no formal agency guidance to consider climate change impacts that could be used as the starting point for the Framework. The team also conducted a literature review. As a result, the Framework addresses several climate change impacts that are widely agreed upon as key and therefore worth considering in planning and implementing coastal investments.[2]

[2] Information on stressors and potential impacts from NOAA Workshop summary report: Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (eds.). 2008. Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 pp. and EPA 2008. Climate Ready Estuaries: Synthesis of Adaptation Options for Coastal Areas

Climate Change Impacts of Concern

- Changes in relative sea and Great Lake levels
- Changes in air temperature
- Changes in ocean temperature and circulation patterns
- Changes in precipitation patterns (amounts, timing, and intensity)
- Changes in air and ocean chemistry (acidification)
- Changes in tropical storm intensities and frequencies
- Changes in species abundance and distribution

Finally, the team solicited input from a wide range of NOAA programs in developing the draft Framework.

The Coastal Strategy Principals narrowed the scope of the Framework to align with the complexity of the task, the resources currently available for the project, and the scope of the Coastal Strategy effort. The Framework focused on OCRM and OHC programs because of their coastal missions and ability to implement the Framework.

The Framework contains:

- **Recommended actions** outlining how OHC and OCRM will evaluate and revise management of relevant restoration, acquisition, and facility development projects and programs to incorporate considerations of climate change to safeguard these investments.

- **General recommendations**, applicable to all three program/project types. Areas addressed include assessing sensitivity of projects to climate change impacts, considering ecosystem resilience, and project monitoring; and recommendations applicable specifically to coastal habitat restoration, land acquisition, or facility development programs, respectively. Factors to be considered include project identification, selection, design, and long-term monitoring. Operational considerations to mitigate the impacts of climate change by reducing greenhouse gas emissions are also included in facilities design and construction.

- **Strategies and guidelines** that would allow restoration and acquisition investments to be used to help natural and human communities become more resilient to the impacts of climate change, and meet original program objectives.

- **Additional guidance, information, and programmatic support** needed by programs to fully implement the Framework, including region-specific technical guidance on how to

consider climate change impacts; methodologies to assess ecosystem resilience opportunities, strategic habitat and restoration planning; training; a long-term monitoring and land management plan; and funding sources. In many cases, new and more effective agency capabilities will be required to address these needs.

A summary of recommendations and detailed explanations and rationale can be found in Sections II-VII.

Next Steps

OCRM and OHC will evaluate and revise their program implementation processes and guidance during FY 2010 and 2011 based on the Framework. Region-specific technical guidance and associated training may be needed before some programs can fully implement the Framework or that guidance can be expanded to other investments. In developing and periodically updating the technical guidance (as funding allows), OHC and OCRM will consult with NOAA offices, federal and state agencies, non-governmental organizations (NGOs), and academia to identify specific available data, information, and analytical tools and training needed to adequately consider climate change adaptation and mitigation in habitat restoration, land acquisition, and facility development in a particular region. The degree to which the Framework can be fully implemented will be highly dependent on annual appropriations received by the participating programs.

I. INTRODUCTION

Why should we consider climate change in investments?

NOAA leadership has encouraged NOAA Programs to consider climate change impacts more systematically when implementing relevant programmatic activities. The purpose of the Climate Investment Guidance is to both safeguard these coastal investments in light of expected impacts from climate change and, where feasible, to use these investments to enhance ecosystem resilience or mitigate climate change impacts in an integrated manner across coastal program offices.

Failure to adequately incorporate the best available science regarding climate change impacts in the planning, design, and implementation of coastal investments may impair the ability of these investments to deliver expected benefits. For example, a habitat restoration project may not achieve intended ecological services if it is permanently inundated due to accelerated sea level rise.

An evaluation of these programs also will help determine when these investments can be used to help natural and human communities become more resilient to the impacts of climate change, while still meeting original program objectives. In some cases the investments may even be used to mitigate the impacts of climate change–that is lessening unintended emissions or atmospheric concentrations of greenhouse gases (principally carbon dioxide). For example, the CZMA programs might include guidance to ensure facilities are constructed and operated to reduce energy consumption over the lifetime and therefore lower carbon emissions. Also, acquisition projects might be managed to enhance their capacity as carbon sinks.

It should be noted that not every impact will be avoided or mitigated. There may be cases where project benefits would be diminished by climate change, yet these projects could be funded to achieve important societal objectives or because there are limited alternatives or other compelling benefits (e.g., constructing shoreline access projects).

What is the "Programmatic Framework" and what investments are addressed?

This Programmatic Framework (Framework) is the first deliverable of a multi-phase project to develop and implement guidance to consider climate change in coastal investments. The Framework provides a systematic approach to institutionalize the consideration of the impacts of climate change into program decision-making for a subset of coastal investments. The subset of coastal investments selected to be addressed in the Framework includes:

- Coastal land acquisition;
- Coastal facility development projects; and

- Coastal habitat restoration

The first two categories of investments, funded pursuant to the CZMA of 1972, as amended, are managed by OCRM in NOS. Relevant OCRM programs include: the Coastal Resource Improvement Program, being implemented by 34 federally-approved CZM programs; CELCP; and the NERRS, and as authorized under §306A, §307A, and §315 of the CZMA, respectively.

The coastal habitat restoration programs addressed by the Framework include NOAA's Community-based Restoration Program (CRP), Open Rivers Initiative, Great Lakes Habitat Restoration Program, and others managed by the Office of Habitat Conservation (OHC) in the National Marine Fisheries Service (NMFS). As applicable and to the greatest extent, NOAA's DARRP and other programmatic habitat restoration activities are also included.

How was the framework developed?

The project team surveyed relevant NOAA programs and found no formal agency guidance being used to consider climate change impacts that could be used as the starting point for the Framework. Consequently, NOAA's coastal programs, through the Coastal Strategy effort, have taken a first step to develop integrated guidance for their programmatic activities related to coastal habitat restoration, land acquisition, and facility construction, to begin to address this gap.

The Framework document provides the Coastal Strategy Principals with recommendations and direction to selected NOAA coastal offices for incorporating consideration of climate change impacts into their program implementation processes and guidance for a subset of coastal investments. The Coastal Strategy Principals decided to narrow the scope of the Framework because of the complexity of the task, time frame, the resources currently available for the project, and scope of the overall Coastal Strategy effort. The Framework was focused on OCRM and OHC programs because of their coastal focus and ability to implement the Framework.

The project team first conducted a literature review. The team also reviewed a wide range of literature on fledgling state and federal efforts to consider climate change in resource management investments, as well as a range of climate change impact documents issued by the U.S. Global Change Research Program (GCRP), including the Climate Change Synthesis and Assessments Products (see Appendix F).

As a result, the Framework addresses several climate change impacts that are widely agreed upon as key and therefore worth considering in planning and implementing coastal investments.

Finally, the team solicited input from a wide range of NOAA programs in developing the draft Framework, including: NOAA's Coastal Services Center (CSC); Center for Operational Oceanographic Products and Services (CO-OPS) and the National Geodetic Survey (NGS) in NOS;

the National Sea Grant Program and Climate Program Office in OAR; National Environmental Satellite, Data, and Information Service (NESDIS) (including the National Oceanographic Data Center and National Geophysical Data Center), and the National Weather Service (NWS).

Programs in OCRM and OHC will begin to evaluate and revise their program implementation guidance and processes starting in FY 2010 based on the Framework. Once the Framework and related guidance have been piloted by these programs, it is expected that the guidance for considering climate change impacts will be expanded to other programs.

Next Steps in the Climate Investment Guidance Project—Developing Technical Guidance

The next step of the project would be the development of Technical Guidance–the "how to" for actually incorporating these considerations into project designs and program planning. Applicants and project reviewers will need guidance on the types of data, information, analyses, decision-support tools, and pointers to where that information exists in order to identify or address impacts of concern in project design and selection and adaptive management of a range of projects. Once the Technical Guidance is piloted for this subset of investments, the guidance can be expanded to other programs and investments in subsequent phases of this project. An outline of the long-term implementation plan is listed in Figure 1.

II. Summary Of Recommended Actions

The following summary is a presentation of the Framework's recommendations. Detailed explanations and rationale can be found in Sections III-VII.

General Recommendations For All Three Programs

Institutionalizing Climate Change Considerations

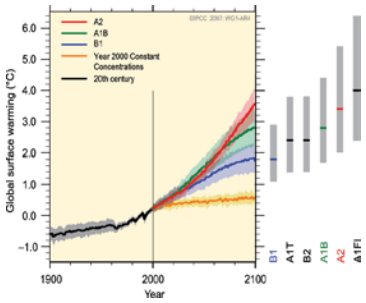
1. OHC and OCRM will[3] incorporate the best available science[4] in the implementation of the CZMA Coastal Resource Improvement Program, NERRS programs, CELCP, and coastal habitat restoration programs to safeguard NOAA investments in light of expected climate change impacts, while achieving habitat restoration, land acquisition, or facility development goals and objectives in a cost effective and sustainable manner.

2. OHC and OCRM will incorporate the best available science in the implementation of the CZMA, CELCP, and restoration programs to promote habitat restoration, land acquisition, and facility investments that enhance ecosystem resilience and sustainability and/or reduce undesired impacts of greenhouse gas emissions where feasible, while achieving current program goals and objectives.

3. Once the Technical Guidance is developed, OHC and OCRM will fully incorporate considerations of scientifically established climate change impacts into their respective planning, project solicitations, project designs and construction, and monitoring processes and guidelines at the project and program levels when appropriate. Implementation guidance will be revised based on identified schedules.

Assessing the Sensitivity of Projects to Climate Change Impacts

4. Until NOAA or a federal interagency body including NOAA establishes climate change scenarios for planning, OHC and OCRM, with input from appropriate subject matter experts, will identify a range of reference scenarios for various climate change impacts on a regional basis to be used in project design and program planning.



[3] Please note that the terms "will," " should," "could," and "are encouraged" in the guidance have the following meanings:
- Recommendations using the term "will" are obligatory within the available funding, skills, scientific understanding, and timeline. Deviations from a "will" recommendation require a compelling justification.
- Recommendations using the term "should" indicate that among several possibilities one is recommended as particularly suitable, but not mandatory due to uncertainty about costs and available resources.
- Recommendations using the terms "could" and "are encouraged" are not mandatory due to uncertainty about costs and available resources.

4 For definition of best available science and other terms used in this document please see Glossary in Appendix A

To the greatest extent practicable, these scenarios will be consistent with scenarios used by other federal agencies. OHC and OCRM will consider using a multi-scenario analysis based on recommendations outlined by the National Research Council, the U.S. GCRP, and the Intergovernmental Panel on Climate Change (IPCC).

5. The Coastal Strategy Principals will work with other relevant NOAA offices to identify or establish regional or sub-regional scenarios, reference projections, or predictions for priority climate change impacts for project planning and design purposes.

6. When assessing climate change impacts to restoration, acquisition, and facility development projects, the impacts of climate phenomena will be gauged against the expected lifespan of the project -- the length of time that ecological services or other benefits are expected to accrue from the project, or the expected life span of the footprint of any structure. Projects will address those climate change impacts that are expected to significantly affect the project within its identified lifespan.

Considering Ecosystem Resilience

7. OHC and OCRM will evaluate and where feasible incorporate the adaptation strategies and principles of ecosystem resilience and adaptive capacity into restoration and acquisition program planning and implementation. Adaptation Principles include:

- **Prioritize Connectivity of Habitat**: Focus on activities that connect habitats to allow for habitat and species migration as climate changes.

- **Reduce Existing Stressors**: In the absence of accurate, site-specific forecasts of climate change impacts or ecosystem responses, focus on reducing existing stressors (e.g., pollution, habitat fragmentation) that hinder the ability of species or ecosystems to withstand climatic events.

- **Protect Key Ecosystem Features**: Focus management protection strategies on structural characteristics, organisms, or areas that represent important keystones or trophic functions that are necessary for the overall system.

- **Maintain Diversity**: Identify and conserve a diversity of habitat and species within an ecosystem to provide resilience and a source for recovery.

Monitoring

8. OHC and OCRM will identify criteria for determining when baseline assessments and post-project monitoring will be required to be undertaken by restoration and land acquisition project proponents and/or NOAA.

9. OHC and OCRM will strive to partner with the NERRS and other NOAA and federal or state agency monitoring or observation programs. NERRS sites will be used as reference sites whenever feasible.

Level of Effort

10. OHC and OCRM will determine the appropriate level of effort to incorporate climate change considerations into project design and implementation, which includes monitoring and stewardship activities. This level of effort will be commensurate with the scale of the impacts and costs of the project.

SPECIFIC RECOMMENDATIONS FOR COASTAL HABITAT RESTORATION PROGRAMS

Project Design and Selection

11. OHC will evaluate and revise the habitat restoration program guidelines and Federal Funding Opportunity (FFO) notices, and OCRM will evaluate and revise CZMA §306A guidance to incorporate best available climate science and related criteria into restoration project selection, design, and construction. The revisions to guidance should result in restoration projects that are selected, designed, and implemented to avoid or minimize expected climate change impacts that would jeopardize achievement of anticipated project objectives over the expected life of the project, unless there are compelling reasons to the contrary. Project proponents will be encouraged to: identify the lifespan and expected climate change impacts of concern to the project; assess the sensitivity of the project to those impacts; describe how the project design and implementation will address impacts of concern; and describe the process or methodology by which they made these determinations. In selecting projects, the climate-related criteria alone would not be determinative, but would be one of several criteria considered.

Monitoring Projects

12. OHC and OCRM, in consultation with other relevant NOAA offices, will explore the feasibility of establishing a sufficient, cost-effective baseline assessment, long-term monitoring approach, and funding mechanism to determine long-term climate change impacts and inform potential adaptive management, where potential impacts may be expected to significantly hinder restoration goals or objectives. This approach should identify: criteria to establish when monitoring is required; information that assessments and post-project monitoring should

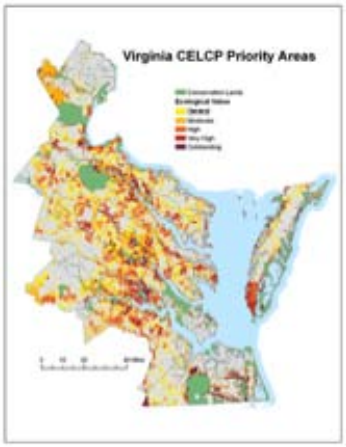
provide; how and when the information will be used; who is responsible for the cost and potential data stewardship of the monitoring, enforcement, and any adaptive management; and how the monitoring will be funded over the longer term.

Restoration Planning Processes

13. OHC and OCRM will reference or use existing restoration plans that have considered climate change impacts in setting habitat restoration priorities to communicate to prospective project proponent's priority sites for enhancing ecosystem resilience. In the absence of existing plans or if available plans are inadequate, OHC and OCRM will evaluate the feasibility of refining existing programmatic processes that would allow NMFS, NOS, or state partners to develop regional or state restoration plans, or tier from and modify existing ones as needed.

SPECIFIC RECOMMENDATIONS FOR COASTAL LAND ACQUISITION PROGRAMS

Coastal Land Acquisition Planning Processes



14. OCRM will revise CELCP programmatic guidelines and NERRS management plan guidance to require the consideration of climate change impacts in future updates to state CELCP plans and portions of NERRS management plans specifically related to CELCP acquisition funding. Once the Technical Guidance is completed, OCRM will revise CELCP guidelines to add climate-related criteria to the list of existing national conservation criteria that are used to identify acquisition priorities in future FFOs (e.g., potential project criteria could include: "[l]ands that facilitate adaptation to or mitigation of climate change impacts)."

Identifying/Selecting Projects

15. OCRM will evaluate and revise land acquisition project selection processes in the CELCP FFOs and CZMA §315 guidelines and §306A guidance and project checklist to consider relevant climate change impacts. Future CELCP FFO notices will solicit project proposals that are consistent with the climate-related objectives described in relevant, updated CELCP and/or NERRS management plans, or encourage project proponents to assess the sensitivity of the parcel to expected climate change impacts and systematically address them with respect to project design and management in the proposed CELCP and §315 acquisitions. Future guidance and FFOs will specifically mention any monitoring requirements.

16. OCRM will include specific, climate-related, national criteria in future CELCP and §315 annual FFOs that will promote land acquisition projects which address any climate-related goals that OCRM may develop in consultation with relevant NOAA Offices, as well as existing program goals.

17. OCRM will work with NERRS to integrate climate considerations into their management and acquisition plans.

18. OCRM will revise §306A guidance to encourage §306A acquisition projects to be consistent with state CELCP, other coastal land acquisition plans, or any other relevant planning documents such as conservation and restoration plans that consider climate change in setting plan priorities.

Monitoring Projects and Ensuring Long-Term Site Management

19. OCRM, in consultation with other relevant NOAA offices, will explore the feasibility of developing a cost-effective baseline assessment and long-term monitoring approach that would address activities beyond the grant award period. In addition, OCRM will explore the feasibility of requiring CELCP recipients to develop and submit management plans and periodic updates that address climate change adaptation. OCRM will work with relevant NOAA offices and others to determine the feasibility of providing assistance, both financial and technical, to CELCP recipients to develop long-term management and monitoring plans and identify needed adaptive management.

SPECIFIC RECOMMENDATIONS FOR COASTAL FACILITY DEVELOPMENT PROGRAMS

Designing, Constructing, and Operating Projects

20. OCRM will evaluate and revise its §315 and §306A guidelines for NOAA-funded facilities to consider the impacts of climate change and related climate criteria in project selection planning, design, and

construction. The revisions should result in facility development projects that are designed and implemented to avoid, minimize, or mitigate expected climate change impacts that would jeopardize achievement of facility development objectives over the expected life of the footprint of the structure, unless there are compelling reasons to the contrary. The revised Guidelines will encourage project proponents to: identify the expected lifespan of the facility and expected climate change impacts of concern to the facility; assess the sensitivity of the project to those impacts; and describe the process or methodology by which these determinations were made. For projects sensitive to expected climate change impacts, project proponents should explain how the project design and implementation would address impacts of concern. The §315 and, where relevant, §306A guidance will encourage project proponents to identify possible carbon dioxide reduction opportunities and which "green design" elements can be incorporated. OCRM will provide notice of these requirements and their priority for funding in future FFOs or funding guidance.

21. New facilities will be developed to have minimal environmental disruption and minimize the modification of the physical environment as much as possible. This will minimize additional stress and improve ecosystem resilience and adaptability.

22. OCRM will investigate the feasibility of developing a "net gain in carbon reduction" policy for facility development, and if such a policy is deemed feasible, to develop, provide guidelines, definitions, and recommendations for its development.

Selecting Projects

23. OCRM will revise NERRS §315 guidance and FFOs to incorporate selection criteria for competitive facility development projects that reduce the carbon footprint of the facility and avoid or minimize impacts from climate change.

24. OCRM will evaluate §306A guidance and/or §306A checklist to include proposed eligibility criteria for development projects that support avoiding or minimizing the impacts from climate change.

Modifying Program Objectives

25. OCRM will revise the §315 guidance to promote green facility development project designs that decrease a development's "carbon footprint" to reduce undesired impacts of greenhouse gas emissions. OCRM also will investigate the possibility of developing a "net-gain" carbon reduction objective.

PROGRAM NEEDS FOR FULL IMPLEMENTATION

Developing Technical Guidance

26. Prior to fully implementing this Framework, OHC and OCRM, in consultation with relevant NOAA offices, federal agencies, states, NGOs, and academia will develop regionally-specific Technical Guidance for considering climate change in these coastal investments based on best available science. The Technical Guidance will assist project proponents understand how to assess the sensitivity of their projects to expected climate change impacts and avoid, minimize, adapt to, or mitigate adverse climate change impacts. The guidance will facilitate consideration of climate impacts in restoration project design and planning, acquisition planning, project identification, and adaptive management, and facility development project design and construction. The guidance will also provide the technical basis for project reviewers to evaluate how projects address expected impacts. The Technical Guidance should identify and describe the use of regionally specific protocols, scenarios, information, and tools to assess project sensitivity to expected climate impacts, and provide best management practices to avoid, minimize, adapt to, or mitigate these impacts. In developing and periodically updating the guidance as funding allows, OHC, OCRM in consultation with other NOAA offices and others will convene regional workshops to bring together relevant science experts (e.g., climatology, biology, oceanography, hydrology, etc.) and program execution staff, to identify specific available data, information, and analysis tools and training needed to adequately consider climate change adaptation and mitigation in habitat restoration, land acquisition, and facility development in a particular region. Scientific experts will be identified from NOAA, other federal and state agencies, as well as universities and NGOs.

Engaging NOAA and Non-NOAA Partners

27. The Coastal Strategy Principals will engage relevant NOAA Advisory Groups (e.g., the Science Advisory Board, its subgroups) NOAA Climate Services, NOAA regional management staff, NOAA Regional Collaboration Teams, relevant federal agencies, and NGOs in understanding, developing, and implementing Technical Guidance.

Developing Training Programs for NOAA Staff and Project Proponents

28. The Coastal Strategy Principals will work with relevant NOAA offices to develop training programs for NOAA staff and project proponents to develop an understanding of and assist with the implementation of the Framework and any Technical Guidance as funding allows.

Assessing Ecosystem Resilience/Reduction of Unintended Impacts

29. The Coastal Strategy Principals will work with relevant NOAA offices to identify or undertake efforts to develop a regional habitat restoration/acquisition strategy that incorporates climate criteria and or adaptation strategies into the process for prioritizing habitat restoration/coastal acquisition sites. The resulting strategy could be incorporated into program planning or used by project proponents to identify up front, projects that can enhance ecosystem resilience and adaptive capacity. The strategy should identify or investigate the feasibility of developing standard protocols for assessing or measuring ecosystem resilience and adaptive capacity and, when feasible, consider carbon sequestration and/or carbon emission reductions to assist in program planning, project design, and development of standardized project selection criteria.

Long-term Monitoring and Management

30. The Coastal Strategy Principals will work with relevant NOAA offices to develop guidance and a sustainable funding source to allow for implementation of long-term monitoring, management plans, stewardship, and adaptive management for NOAA habitat restoration and land acquisition investments called for in the programmatic Framework. The guidance would: set out the objectives of such a monitoring program; detail how, what, when, and by whom the monitoring information would be collected, managed and used; assign costs to NOAA and/or funding recipients; and identify specific sources of funding for the monitoring program.

Using This Guidance to Inform NOAA Coastal Investment Strategies

31. The Coastal Strategy Principals, in consultation with relevant NOAA Offices, will evaluate whether gaps in climate data, tools, and analytical or other technical information identified in the development of Technical Guidance are being addressed by existing NOAA programs. If not, the team should communicate these needs to appropriate NOAA offices. The Coastal Strategy Team should also consider including such projects that address these needs as priority coastal strategy deliverables.

III. Recommendations For All Programs

Assessing the sensitivity of projects to expected climate change impacts

An investment's sensitivity to climate change means the degree to which the goals or objectives of an acquisition, restoration, or construction project may be significantly affected positively or negatively by the climate phenomena during the expected life of the project. The steps necessary to assess an investment's vulnerability/sensitivity to expected climate impacts include: identifying the expected climate change impacts that affect the investment; determining the extent of climate impacts over time, based on one or more climate change scenarios; identifying the life span of the project; and gauging the extent of those impacts over the life span of the project.

Assessing the Sensitivity/ Vulnerability of Investments to Expected Climate Change Impacts

- Identify the expected climate change impacts that affect the investment;
- Make determinations about what we think the extent of the climate impacts will be over time based on one or more climate change scenarios;
- Identify the life span of the project;
- Gauge the extent to which those projected impacts will affect project objectives/ benefits over the life span of the project.

Project proponents and program staff should address and monitor those climate change impacts that are expected to substantively and adversely affect the investments within its identified life span.

What impacts should be addressed?

Because climate change research is still evolving, the range of future climate change impacts is not yet fully understood. Nonetheless, there are several anticipated stressors that are widely agreed on and therefore worth considering in planning and implementing coastal investments:[5]

- Changes in precipitation patterns (amounts, timing, and intensity) can result in increased or decreased drought, flooding, plant growth, runoff rates, sediment and pollutant loadings, freshwater inputs to estuarine systems, changes in salinity regimes, water quality/clarity and erosion due to high-stream flows, and changes to Great Lake levels.

- Changes in air temperature can result in changes to water availability, species distribution, increased risk of parasitism and disease, expansion of invasive species, evaporation rates,

[5] Information on stressors and potential impacts from NOAA Workshop summary report: Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (eds.). 2008. Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 pp and EPA 2008. Climate Ready Estuaries: Synthesis of Adaptation Options for Coastal Areas

and soil moisture content, and changes to Great Lake water levels as a result of evaporation rates.

- Changes in relative sea level/lake level can result in changes to areas subject to erosion rates, storm surge, wave action and flooding, changes in salinity regimes (surface and groundwater), inundation, disappearance, or migration of marsh and mangroves, and structural and functional habitat changes.

- Changes in tropical storm intensities and their associated storm surge and wave action and winds will result in additional coastal erosion and habitat damage.

- Changes in air chemistry, specifically increases in atmospheric carbon dioxide levels, can result in changes in lowered pH levels in the oceanic waters (ocean acidification) and in precipitation (acidic rain), which may, in turn, affect soil and water pH, as well as the composition and health of plant and animal communities.

- Changes to ocean temperature and circulation patterns can result in changes to marine/estuarine species distribution, functional habitat changes, and severity and frequency of storms and is a factor in coral bleaching.

For a more regional perspective on impacts see *Appendix* E– *Summary of Regional Impacts*.

Many existing environmental stressors, such as invasive species and nutrient loadings, will be exacerbated under climate change scenarios. Furthermore, stressors and their impacts also may interact to either negate or amplify anticipated effects. A systems-level perspective may be needed to fully evaluate impacts.[6,7]

We should note that not all impacts from climate change will be deleterious. Increased levels of carbon dioxide and longer growing seasons may mean increased primary production for some habitats and perhaps increased ability to keep up with sea level changes. Also, changes in ocean circulation could modify ocean upwelling in certain areas in a beneficial manner.

While each impact may be extremely significant for a specific activity (e.g., ocean acidification is projected to be a key impact for coral restoration), we may need to indicate priority impacts if NOAA is not able to address all issues at once. NOAA should identify priority climate change impacts regionally.

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[6] Heller, N.E., and E.S. Zaveleta, 2009. Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological Conservation 142:14-32.

7 NOAA Workshop summary report: Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (eds.). 2008. Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 pp.

Assessing climate impacts of concern over time--climate impact scenarios

To assess the likely extent of climate change impacts of concern over time, project proponents and program planning staff will need guidance on which climate change scenarios or projections to use in project design or program planning. At this time, neither NOAA nor any federal entity has identified or established a single most likely scenario or projections of impacts to use for planning and design. Moreover, there is a significant degree of uncertainty in the key variables used to develop the scenarios (e.g., GHG emissions, resulting atmospheric concentrations) and the variability in scenarios argues against using a single "most likely" scenario[8].

Therefore, until such time that NOAA and others identify a most likely scenario to use, it would make sense for OHC and OCRM, with input from appropriate NOAA or other subject matter experts, to identify a range of reference scenarios (e.g., low, medium, and high) for various climate change impacts on a regional basis, to be used in project design and program planning. To the greatest extent possible, these scenarios should be consistent with scenarios used by other federal agencies. Plans should be developed and project designs should be evaluated by choosing strategies or designs that are the most robust (i.e., maximize ecosystem benefits or project objectives) over the range of possible future climate change scenarios. It may be possible to evaluate and rank competing projects based on those that produced the greatest services or benefits across the range of climate change impact scenarios.

In a multi-scenario analysis, project performance under different climate change scenarios (e.g., low, medium and high rates of change) and projects can be adjusted to minimize risk and maximize potential benefit under all of the scenarios for that project. Program strategies may be able to be analyzed in much the same manner. Multi-scenario analyses force decision-makers to consider alternate views of what may unfold. The identification and use of these scenarios should be spelled out in the Technical Guidance to be developed.

To assist programs and increase efficiency, the Coastal Strategy Team should provide direction to NOAA climate experts to identify/adopt reference climate change impact scenarios or projections for identified priority impacts by regions or sub-regions. Any Technical Guidance developed should identify regional impact scenarios or projections to use in sensitivity and other analyses.

Identify the life span of the investment/project

Project proponents will be expected to identify expected project life spans and the methods by which they were determined. The life span of the investment is the length of time that ecological, recreational or other services or benefits are expected to accrue from an investment

[8] Emissions Scenarios, Summary for Policymakers. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change , 2000.

(e.g., restoration or construction project), or the reasonably expected life of the footprint of any facility or structure constructed. Construction and restoration projects may have variable life spans, depending on the size and nature of the project. Land acquisition projects, on the other hand, are intended to protect lands indefinitely.

Project proponents will need to identify project life spans early in the process. NOAA programs might evaluate how they and other agencies determine the expected life span and, where possible, develop consistent life span durations for similar project types. This might be a part of the evolving Technical Guidance.

Determining if project is sensitive to Impacts and the degree of sensitivity

Once the life span of the project is determined, project proponents should gauge the investment's sensitivity to the climate impact(s) of concern. The sidebar contains some terminology for assessing sensitivity.

If a project proponent's analysis determines that climate changes will affect project objectives and benefits (investment is moderately to critically sensitive to impacts), then they need to: a) assess whether the project can be designed to avoid or minimize those impacts, b) address the impacts through adaptive management (project modifications, retrofits added as needed); or c) determine that the consequences of design failure are such that the project must be significantly redesigned or abandoned.

Degrees of Sensitivity *

Low sensitivity: Minimal or negligible impacts on the project.

Moderate sensitivity: A particular change in the climate parameter would require minimization or mitigating measures.

Sensitive: Project design depends on climate phenomena.

Critical: Project successes depend on the climate phenomena remaining within a certain range or may fail as a result of its response to changes in climate phenomena.

* Adapted from: Canadian Environmental Assessment Agency, *Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners*, (November 2003)

In the following sections specific to restoration, acquisition, and facility development a few general "best practices" for avoiding or minimizing potential impacts to coastal habitat restoration, land acquisition and facility development projects are identified. However, additional best practices tailored to specific activities and regions will be identified in the Technical Guidance.

Using investments to enhance ecosystem resilience

It may be possible to use restoration and acquisition programs as tools to enhance habitat resilience or adaptive capacity to climate change, in addition to meeting current program goals.

The U.S. GCRP and other groups have identified a number of adaptation principles

and strategies that may be useful in this evaluation. The habitat adaptation principles outlined in the sidebar were highlighted in the Climate Change Science Program Synthesis and Assessment Product 4.4, as well as other climate publications[9]. For example, NOAA programs could focus on restoring sites that would aid in connecting fragmented habitats and thus creating migratory corridors that could allow species to move as changing climate results in habitat shifts.

OHC and OCRM, in consultation with relevant NOAA and non-NOAA programs, will evaluate how the relevant adaptation strategies might be integrated into strategic planning and priority setting for these programs to enhance resilience and adaptive capacity to climate change impacts. Efforts to use these principles to develop project selection criteria will likely require research into developing standard protocols for assessing or measuring ecosystem resilience, adaptive capacity, and carbon sequestration potential.

Adaptation Principles

- **Prioritize Connectivity of Habitat:** Focus on activities that connect habitats to allow for habitat and species migration as climate changes.
- **Reduce Existing Stressors:** In the absence of accurate site-specific forecasts of climate change impacts or ecosystem responses, focus on reducing existing stressors (e.g., pollution, habitat fragmentation) that hinder the ability of species or ecosystems to withstand climatic events.
- **Protect Key Ecosystem Features:** Focus management protection strategies on structural characteristics, organisms, or areas that represent important "keystones" of the overall system.
- **Maintain Diversity:** Identify and conserve a diversity of habitat and species within an ecosystem to provide resilience and a source for recovery.

Baseline assessments and long-term monitoring

According to the literature reviewed, baseline assessment and long-term monitoring will be critical for understanding site-specific sensitivities to and/or impacts from climate change and to provide the basis for any needed adaptive management of projects. Baseline assessment of site conditions, including vegetation, geomorphology, and species distribution and abundance, is essential to accurately assess ecosystem change over time and to document how climate changes are affecting biodiversity and ecological services at the site. However, monitoring is resource intensive and may not be necessary for every project. OHC and OCRM will develop criteria for determining when baseline and long-term monitoring will be required for habitat restoration and acquisition programs, and how monitoring can be implemented with available resources.

We should note that any long-term monitoring or adaptive management for current programs will be problematic. Most of the programs provide funding to recipients via grants or

[9] Pyke, C. R., R. G. Najjar, M. B. Adams, D. Breitburg, M. Kemp, C. Hershner, R. Howarth, M. Mulholland, M. Paolisso, D. Secor, K. Sellner, D. Wardrop, and R. Wood. 2008. Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations. A Report from the Chesapeake Bay Program Science and Technical Advisory Committee (STAC), Annapolis, MD. 59 pp.

cooperative agreements which usually last from two to four years. Therefore, there is no way to fund or assure that recipients can undertake long-term monitoring or management–over 30+ years–that may be desired. Consequently, before any long-term monitoring or management requirements are implemented, a long-term monitoring and management plan and dedicated funding source will have to be established within NOAA to address this issue. Long-term monitoring is addressed in more detail in other sections of the Framework.

Using "best available science"

Given the widespread use of "climate change" as a tool to advance positions surrounding connected political issues, there exists a wide variety of information and misinformation regarding potential climate change. Some of this information may be cloaked in the mantle of science, but has not been subjected to rigorous scientifically-based review and appropriate vetting by the relevant scientific community. Use of such misinformation as legitimate could lead to incorrect assessments of climate change impacts and irreparably derail the otherwise positive intentions of these guidelines and their subject projects.

As such, project proponents and NOAA staff will need to use the "best available science" to assess the impacts of climate change on projects, develop best practices to avoid or minimize those impacts and, where feasible, plan or design those projects to enhance ecosystem resilience or reduce unintended/anthropogenic greenhouse gas emissions.

Best available science is broadly defined to mean the best available biological, ecological, physical, chemical, and social science and information that facilitate identification and assessment of potential climate impacts as well as the social and ecological response to those impacts and the sensitivity of various projects to those impacts in the future. In most instances it should include findings that have been published in the peer-reviewed literature, but should not be strictly limited to these data sets. Best available science should include both NOAA and non-NOAA sources, including data from relevant government resource management agencies, research or educational institutes, and private NGOs with specific scientific functions or mandates. This will be especially true in attempting to identify/assess regional and sub-regional impact scenarios.

What is the expected level of effort for analysis and monitoring?

The intent of these recommendations is to ensure that climate related analysis and monitoring will make a meaningful difference to the ultimate project benefits, given that these additional requirements could be resource intensive. Consequently, the expected level of effort to incorporate climate change into the project implementation, which includes monitoring and stewardship activities, will be commensurate with the scale of the impacts and costs of the project. These considerations will be determined by OHC and OCRM.

How will these considerations be institutionalized?

It is envisioned that the approaches and actions identified in this Framework will be formalized in revisions to OHC and OCRM habitat restoration, land acquisition, and facility construction program implementation guidance. However, before the recommendations can be formalized and implemented, NOAA will need to address identified program needs for implementation (see p. 36).

IV. Recommendations For Coastal Habitat Restoration Programs And Projects

Applicability

The Framework is applicable to NOAA's habitat restoration investments funded pursuant to the CZMA, Community-based Restoration Program (CRP), Open Rivers Initiative, and Great Lakes Habitat Restoration Program. To the greatest extent applicable, NOAA's Damage Assessment, Remediation, and Restoration Program (DARRP) and other programmatic habitat restoration activities are also included. Habitat restoration projects can be funded through the CZMA §306A Coastal Resource Improvement Program (§306A) and, to a very limited extent, under §315 of the CZMA, the NERRS. The CRP awards significant funds annually to national and regional partners and local grassroots organizations to implement habitat restoration projects to benefit NOAA trust resources. In a competitive process, projects are selected for funding based on technical merit, level of community involvement, cost-effectiveness, and ecological benefit. Individual projects funded range from $30,000 to more than $500,000. Additionally, national or regional partnerships are awarded every three years, establishing multi-year cooperative agreements with NOAA to support multiple habitat restoration projects across a broad geographic range. Proposals for partnership grants range from $100,000 to nearly $2 million, with funds provided annually. Sub-awards made through partnerships are typically $75,000 or less; these small-scale projects may have limited lifespan s or may not be cost effective to fully analyze the impacts from stressors such as climate change.

TYPES OF RESTORATION PROJECTS UNDERTAKEN

Community-Based Restoration Program

- In-stream restoration (fish bypass, dam removal, stream restoration)
- Salt marsh restoration
- Riparian zone (non-wetlands)
- Oyster, reef shell bottom
- Submerged aquatic vegetation
- Mangrove restoration

Source: CRP website: http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/index.html

CZMA §306A Coastal Enhancement Grants Program

- Marsh restoration (restoring tidal flow, removing fill, removal of invasive species)
- Living shorelines
- Stream restoration
- Limited oyster reef construction/ restoration

The CRP-funded activities result in establishment or restoration of stable, productive marine, estuarine, or coastal riverine biological systems. Restoration may include, but is not limited to: improvement of coastal wetland tidal exchange or reestablishment of historic hydrology; dam or berm removal; fish passageway improvements; natural or artificial reef/substrate/habitat creation; establishment of riparian buffer zones and improvement of freshwater habitat features that support anadromous fishes;

planting native coastal wetland and submerged aquatic vegetation (SAV); and improvements to feeding, spawning, and nursery areas essential to fisheries.

NOAA's DARRP collaborates with other federal and state agencies, industry, and citizens to protect and restore coastal and marine resources that are threatened or have been injured by oil spills, releases of hazardous substances, and vessel groundings. The DARRP conducts habitat restoration projects that are similar to NOAA's CRP, but the funding comes from litigated court settlements rather than grants or cooperative agreements, and use of the funds is case-specific. The Framework should be used to guide DARRP restoration planning, but its applicability may vary from case to case depending on the type of resources injured, and the nexus of the compensation for the injury. Examples of marine and coastal habitats that have been restored through NOAA's CRP and DARRP are listed in Table 1. The amount of DARRP work conducted varies in any given year and depends on the number of accidents or natural disasters.

§306A of the CZMA allows a state to use a portion of its allotted program implementation funding to undertake projects that restore: specific areas that the state CZM program has designated as "Areas of Preservation or Restoration" for their "conservation, recreational, ecological, or esthetic values," or areas that contain one or more coastal resources of national significance, or shellfish bottoms or reefs.

These projects are intended to be "low cost," which is defined in the §306A program guidance of 1996 as less than $100,000 (including up to $50,000 in federal funds). §306A projects are not competitively selected by NOAA, although they may be selected through a competitive process at the state level. They are submitted to NOAA as part of a state's annual CZMA cooperative agreement application. It should be noted that the majority of states do not use their annual CZMA funding for these types of projects, and for those that do, many of these small-scale projects may have limited life spans or may not require as high a degree of analysis as other projects. NOAA funds about 30 of these projects annually.

Periodically, NOAA will fund small restoration projects in NERRS under §315 of the CZMA. These projects are awarded non-competitively as part of a reserves annual award. When these projects occur, they will conform to the CZMA §306A guidance for restoration projects.

Why it's important to factor in climate change - aspects of restoration projects most sensitive to climate conditions

Based on our review of the literature[10], the most prevalent habitat restoration project types funded by these programs could be sensitive to a wide variety of anticipated climate changes:

[10] Among others: NOAA Workshop summary report: Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (eds.). 2008. *Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress*. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 pp.; *Climate Change and the Chesapeake Bay-State of the Science Review and Recommendations*, Chesapeake Bay Program Science and Technical Advisory Committee (2008).

- In-stream restoration: Changes in water temperatures, flow regimes and salinity concentrations may result in reduced target species utilization of restored habitats (e.g., diadromous fish). Increased flooding and flash flooding from more intense rainfall events may cause degradation of the habitat through increased channel erosion, siltation, and destruction of pools and riffles.

- Marsh restoration and mangrove restoration: Post-project relative water levels (inundation frequency and duration), are critical aspects of tidal, freshwater marsh, and mangrove restoration, and will be affected by changes in relative sea level and rates of vertical sediment accretion from plant productivity and sediment availability and trapping. Changes in sedimentation rates and air chemistry (carbon dioxide levels) and resulting changes to plant production may positively affect vertical accretion rates of restored marsh. Restored marsh and mangroves will attempt to migrate inland as local sea level rises and may succeed only if there is an absence of hard structures or steep slopes in the way. Long-term marsh success will also be adversely affected by increased erosion rates, flooding and scouring, and general stress from relative sea level rise and increased severity of tropical and extra-tropical storms. Over the long term, species composition of restored marsh and mangrove habitats can be affected by changes in local relative sea level and salinity zones as certain species of vegetation may only survive in a narrow tidal inundation and salinity range. Climate change also may bring changes in species composition through the spread of invasive species, or the migration of some species towards higher latitudes. Target species utilization of marshes and mangroves will be affected by changes in water temperatures, salinity concentrations, and vegetation composition. Finally, sea level changes and increased rainfall can diminish opportunities for some types of marsh restoration (e.g., removal of tidal restrictions) due to potential flooding to adjacent development.

- Riparian zone (non-wetlands): Increased air temperature and decreased soil moisture content can result in reduced growth or mortality of restored riparian vegetation. Increased rainfall and high intensity rainfall may increase erosion rates and decrease the effectiveness of a given riparian restoration project's ability to reduce pollutant loadings to coastal waters.

- Oyster reef shell bottom: Changes in salinity concentrations and water temperatures above certain thresholds can result in the increased rates of oyster-related diseases such as MSX and Dermo. When water temperature and salinity values both rise, harmful bacteria are more likely to grow and infect target animals. Also, increased nutrient over-enrichment and water temperatures may affect disease growth and survival due to hypoxia events and harmful algae blooms.

- Submerged aquatic vegetation (SAV) restoration: Increased water temperatures and turbidity (resulting from more intense rainfall patterns) have been linked to reduced growth and survival rates of SAV due to attenuation of light to the vegetation or smothering of SAV. Increased severity of tropical and extra-tropical storms may result in loss of SAV because of increased bottom scour.

Table 1 provides a quick guide to the relative sensitivity to climate change phenomena and impacts for the various types of restoration projects.

Table 1

KEY RELATIONSHIPS TO INFORM RESTORATION CONSIDERATIONS [1]

		CHANGES DUE TO CLIMATE				
HABITAT RESTORATION		**Changes in Precipitation Patterns**	**Changes in Air Temperature**	**Changes in Ocean Temperature and Circulation**	**Changes in Relative Sea and Great Lakes Water Levels**	**Changes in Air/Water Chemistry**
	RELATIVE SENSITIVITY*					
PROJECT TYPE by prevalence		Sensitivity	Sensitivity	Sensitivity	Sensitivity	Sensitivity
Tidal Wetlands		**high**	**low/medium**	**medium/high**	**high**	**low**
Adjacent Coastal Buffer (beaches, dunes , riparian upland)		**high**	**low/medium**	**low/medium**	**high**	**low**
Shellfish Beds		**medium/high**	**low**	**med/high**	**medium**	**low**
Submerged Aquatic Vegetation		**high**	**low**	**high**	**low/medium**	**low**
Mangroves		**high**	**low**	**low**	**high**	**low**
Other Coastal Wetlands		**high**	**low/medium**	**low/medium**	**high**	**low**
Benthic Substrate		**medium/high**	**low**	**low/medium**	**low**	**low**
Coral Reefs		**medium/high**	**low**	**high**	**low/medium**	**high**
Kelp and Other Macroalgae		**low**	**low**	**medium/high**	**low**	**low**
Water Column		**high**	**medium/high**	**low**	**low**	**medium**
Coastal Shoreline		**high**	**medium/high**	**high**	**high**	**high**
Average Sensitivity		***med/high***	***low/medium***	***medium***	***medium***	***low/medium***

Table 1 is intended to be used by program offices/project proponents as a quick reference to identify climate change impacts of concern and their anticipated influence on habitat restoration projects with various conservation objectives; however these impacts are considered in isolation. While this table may serve as a general guide, the specific characteristics of the restoration site (e.g., location, size) and objectives will determine how it may be affected by climate change.

* The relative sensitivity to impacts depicted in Table 1 (i.e., high, medium, low, none) represents a consensus of informed, qualitative opinions, but is nonetheless, a subjective effort.

What are priority climate change impacts for restoration projects?

It should be noted that in a survey of NOAA restoration programs, sea level changes were by far the most frequent climate change impacts considered, with species composition/distribution and water temperature addressed slightly more often than storm frequency, change in precipitation, erosion, and ocean circulation.

How do programs address expected project life span?

Both the CRP guidelines and §306A guidance include the phrase "useful life of the project," but neither defines "useful life." Based on discussions with NMFS staff, the "useful life" of restoration projects varies widely and can range normally from 15 to 30 years, with major projects potentially having a significantly longer life span, depending on the presence and extent of external conflicts. The CZMA places a lower limit of 20 years on projects that require easements, but is silent on an upper range.

Incorporating climate considerations into CRP and CZMA programs and projects

To better sustain and guide NOAA's restoration investments, OCRM and OHC will incorporate consideration of climate change impacts into various facets of program planning and implementation.

<u>Considering climate change in project identification and design</u>

To ensure that NOAA restoration investments provide the intended ecosystem services in light of expected climate change, OHC and OCRM will encourage project proponents and reviewers to consider priority impacts (e.g., changes in sea level, precipitation patterns, and air and water temperature) in project design and implementation.

Restoration project design information is provided in CRP applications and in §306A applications and Project Checklists. There are currently no specific protocols for evaluating CRP or §306A cooperative agreement proposals as they relate to climate change. Technical reviewers of CRP projects currently use best professional judgment to determine whether the objectives, benefits, or ecological or other services provided by the project could be compromised through inadequate consideration of climate change impacts. OCRM staff relies on state CZM program input, information from other resource agencies, and best professional judgment for technical reviews of restoration projects.

While project proponents and reviewers can use the key relationships tables in this publication to begin to identify priority climate change issues, the tables should be refined for specific regions to be more accurate and useful. When assessing project sensitivity, project proponents should describe the process or methodology by which they identified impacts of concern, the

lifespan of the project and the sensitivity of that project to those impacts. They should use any predetermined project life spans that NOAA has identified. OCRM and OHC will evaluate the use of a climate change impact analysis or checklist for restoration project proponents submitted to OHC and OCRM. A climate change checklist or other impact analysis tool could provide applicants with a standardized format for identifying and considering expected climate change impacts of concern, a uniform and systematic means to assess the sensitivity of the project to those impacts and, if necessary, a step-by-step process to explain how the project design and implementation will address impacts of concern through best practices, adaptive management, or an alternate approach.

Examples of best practices for restoration adaptation to expected climate impacts[11]

Until the Technical Guidance is completed, program staff should work with project proponents to recommend approaches for considering climate adaptation in the project design. Some examples follow:

- Increasing average annual temperatures should result in longer growing seasons. Thus, projects should consider vegetation that can live in a wider variety of conditions, include a diversity of vegetation types, and plan to address invasive species.

- With regard to sea level rise and salt marsh restoration, project proponents should consider how to design and maintain biologically adaptive living shorelines. Projects could be designed to grade marsh elevations to transitional levels that will not be inundated as quickly, that can still support marsh vegetation, and allow for a horizontal movement of the living shoreline over time. As for an example of adaptive management, sediment replenishment can help marshes keep up with sea level change, either through restoring the natural sediment input and/or thin-layer deposition of dredged material.

- Projects should focus on planting higher in the marsh, if lower areas will be drowned due to sea level rise. In addition, planting should occur early on, as vegetation can keep sediment in place and build organic matter. Proponents may create native seed banks to preserve diversity. To allow for inland/landward migration of marsh from relative sea level change, projects can maintain or protect transition/buffer zones, incorporate gradual slopes, and remove barriers where possible. The use of "living shorelines," which use natural habitat elements like marsh grasses and oyster reefs instead of hardened structures to stabilize and protect shorelines, may allow restored areas to keep up with sea level changes and thus may be a promising approach to coastal

[11] Adapted in part from "*Impacts of Climate Change on Salt Marsh Restoration in the Northeast United States*" by Catherine M. Bozek and Craig A. Woolcott, NOAA Restoration Center; presentation for Restore Americas Estuaries 2008 Conference; and input from other NMFS/OHC Staff.

restoration. Projects can incorporate a mix or mosaic of habitat types including upland, and high and low marsh to allow the site to be more adaptable to changing conditions.

- With regard to tidal reconnection projects, proponents may need to use modeling to anticipate how hydrology will change with relative sea level changes and increased precipitation. Consider the appropriate size for culverts and at what elevation culverts should be set, to address concerns about restricting tidal hydrology and drainage. Project proponents should consider the potential for more frequent and severe storm surge flooding and potential flooding from greater number or more intense rain events, especially when private property and infrastructure are adjacent to the project site. Private parties may increasingly resist tidal or riparian restoration if concerns about property protection are not incorporated into the project design.

- Sea level change will have secondary effects on the tidal ebb and flood cycles. Project proponents should consider incorporating higher elevations in project design that would accommodate the more extreme tidal and flooding ranges anticipated. In the Great Lakes region, lake levels may continue to drop as a result of less precipitation and/or greater evaporation, resulting in adverse hydrologic conditions for restoration sites.

- Regarding changes in precipitation patterns and extreme events (e.g., intense rainfall and stronger tropical storms), project proponents should obtain information on anticipated water flows from watershed and how flooding from storms is projected to flood the project area (will likely require modeling hydrologic system). Projects should ensure that there is enough material in sediment placement projects and that the sediment is stabilized quickly. Finally, with tidal reconnection projects, consider potential impacts of increased high tide events and storm surges on nearby development.

Considering climate change in project selection

Incorporating climate-related criteria into the existing suite of CRP project selection criteria will allow project reviewers to select well-designed projects that will better meet long-term program objectives in a changing climate.

Currently, CRP projects are selected for funding based on five criteria: technical merit; level of community involvement; cost-effectiveness; ecological benefit and applicant qualifications. Climate-related criteria could be included separately or integrated into existing criteria. For example, projects that include discussions and options to address likely climate change impacts could receive more points in scoring than proposals that have no plans to address impacts. For major projects, more complex criteria could be developed to incorporate the project's expected delivery of ecological or other services into a cost benefit analysis based on a multi-scenario analysis. Once NOAA develops Technical Guidance or chooses to develop a climate change impacts analysis checklist, projects could receive part of their score based on how well they meet the Technical Guidance or impact analysis.

Similarly, projects that seek to increase natural resource or community resilience or adaptive capacity to climate change impacts could accrue additional points during the technical evaluation and scoring. This scoring, however, would be contingent on OHC, OCRM, or NOAA developing an accounting system for measuring ecosystem resilience or carbon sequestration. Therefore, the Coastal Strategy Principals will work with relevant NOAA offices to assess the feasibility of developing a protocol or accounting system for documenting or measuring a project's ability to enhance ecosystem resilience or greenhouse gas reduction. This might be the subject of a future Climate Program Office FFO pursuant to the Regional Integrated Sciences and Assessments (RISA) or Sectoral Applications Research (SARP) Programs.

There is no federal competitive process that employs selection criteria for §306A restoration projects–§306A guidance does have eligibility criteria for projects that is based on the CZMA statute. If states choose to use some of their annual funds for restoration projects, they may or may not select projects through a competitive state process. Once states have identified or selected projects, they submit those projects in their annual cooperative agreement application. Proposed projects must meet minimum requirements in the §306A guidance, and applicants must complete a §306A checklist to comply with other federal requirements. Neither of these contains climate change criteria. OCRM will evaluate its existing §306A guidance and checklist to encourage States that run competitive processes to select §306A restoration projects using climate impact-related criteria or otherwise incorporate climate change considerations into those processes. Alternatively, OCRM may include a requirement in the §306A guidance or checklist that the program must describe how it has considered climate change impacts in project design or adaptive management.

Considering climate change in project monitoring

Restoration project monitoring can be critical to understanding actual site specific climate change impacts and to guide any necessary adaptive management. It is also resource intensive.

Baseline and periodic monitoring of plant and animal species distribution and geomorphology and other attributes is critical for: understanding site-specific sensitivities to climate change; assessing ecosystem change over time; and providing the basis for adaptive management of projects. This monitoring information can give project proponents or others information to support adaptive management activities or NOAA information to support project or program performance evaluations.

Baseline and long-term biological (vegetation and animal species) monitoring is quite expensive, which could reduce project submissions from cash-strapped states and local communities. Alternatively, if NOAA funds restoration monitoring, current levels of restoration cannot be sustained. However, it is likely more cost effective over time to require and use information gained from monitoring sites to ensure successful projects.

In accordance with the Estuary Restoration Act of 2000 (ERA), Title I of the Estuaries and Clean Waters Act of 2000, the NOAA Restoration Center is committed to monitoring elements of habitat restoration projects in order to evaluate project and program success. The NOAA Restoration Center has restoration specialists to help funding recipients develop a monitoring plan which minimizes financial and labor resource needs, yet allows for a quantitative evaluation of restoration results. NOS National Centers for Coastal Ocean Science has science-based restoration monitoring guidance that provides technical assistance, outlines necessary steps, and provides useful tools for the development and implementation of sound scientific monitoring of coastal restoration efforts[12]. While there are some monitoring requirements for NMFS restoration projects, there are no monitoring requirements for restoration projects funded by §306A or §315 programs.

OHC and OCRM must balance considerations for required baseline or periodic monitoring with meeting restoration objectives. The programs will need to evaluate and identify criteria or thresholds (e.g., cost, project size, potential impacts, whether adaptive management is part of original project, etc.) that trigger required monitoring. Otherwise, programs should address monitoring on a case-by-case basis. Baseline monitoring would appear to be a higher priority, given that additional funding may be obtained at a later date for follow-up monitoring. If monitoring is warranted, OHC and OCRM can advise project proponents and include monitoring as part of the CRP or §306A application narrative or impose special award conditions that can be used to require project specific monitoring. As noted previously, given the relative short duration of the award (2-4 years in most cases), NOAA cannot expect or ensure long-term monitoring (30+ years) by the applicant. In addition, before embarking on a long-term monitoring effort, OHC and OCRM will need to have a clearly identified plan for collecting, storing, and using the monitoring information before requiring project proponents to provide it.

To provide for critical long-term monitoring the Coastal Strategy Principals will work with relevant NOAA offices to develop agency-wide guidance and a long-term planning program and funding mechanism for restoration monitoring and adaptive management. There needs to be an explicit long-term plan and guidance in place clearly indicating who should bear the costs of the monitoring, how the baseline and periodic monitoring should be undertaken, what should be monitored, and what specifically will be done with the information for the various types of projects.

In the meantime, programs should look for opportunities to partner with existing monitoring programs and evaluate new observation technologies that may cut monitoring costs. When possible, programs should use monitoring information from NERRS and/or use NERRS as reference sites. The Reserves will become increasingly useful for monitoring, as instrumentation is installed to measure accurate relative sea level rise, and marsh, and submerged aquatic vegetation habitat response is monitored as part of the NERRS sentinel site initiative.

[12] An electronic copy is available at: http://coastalscience.noaa.gov/ecosystems/estuaries/restoration_monitoring.html.

Considering climate change in restoration planning processes

OHC and OCRM will evaluate the CRP and CZMA planning processes to promote, where feasible, enhancing ecosystem and community resilience. OHC and OCRM will work with other programs and partners to identify existing regional or state restoration plans that have incorporated climate change considerations/criteria in setting restoration priorities. These plans could be referenced by project proponents and reviewers to promote or guide project selection toward enhancing long-term habitat resilience and/or adaptability to climate change. Project proponents would know up front which sites were priorities for NOAA and would receive priority consideration in the selection process. This would be far more practical than trying to do this on a project-by-project basis. If such plans do not exist, OHC and OCRM will consider working with regional collaboration teams and/or other NOAA offices and partners to develop such plans. In addition, OCRM may evaluate the feasibility of allowing state CZM programs to use CZMA §309 enhancement grant funding to develop restoration plans that consider such impacts.

OCRM will evaluate whether it makes sense to have CZM programs that use §306A funds indicate how the proposed projects conform with existing state or regional restoration plans that considered climate change impacts in setting priorities. Another, possibly less cost-effective option would be to have states that routinely undertake §306A projects reevaluate their currently designated Areas of Protection and Restoration (APR) considering climate change impacts. States could identify existing APRs or designate new APRs based on other plans that have considered climate change in prioritizing restoration sites.

These restoration plans should incorporate criteria for encouraging adaptation/resilience strategies in their priority setting process. For example, potential restoration sites might receive higher priority in these plans if a site were to advance, in addition to restoring trust resources, one or more of the ecosystem adaptation principles–promoting habitat connectivity, reducing existing stressors, restoring "keystone" ecosystem features–or mitigate climate change impacts by enhancing carbon sequestration.

However, to be able to develop these criteria, programs may need to have some consistent protocol to assess or measure ecosystem resilience or adaptation for comparison purposes.

Finally, OHC and OCRM will consider developing a strategic plan for considering climate change in habitat restoration. Each program should evaluate current capabilities to determine how existing processes can be tiered from or modified as needed, and develop a strategic five-year action plan. The plan should establish short- and long-term internal planning and action horizons, and provide the Framework for the other activities.

1) Short-term - The programs will develop a strategic five-year action plan. The plan will identify and address climate change-related impacts or issues that could have immediate effects on the program's priority (at-risk) habitats, as well as a vision for addressing the long-term strategic plan. The action plan will include: considerations for project design

elements; criteria to evaluate restoration funding proposals, habitat protection and restoration project implementation and monitoring; adaptive management options; and internal (within NOAA) and external coordination strategies.

2) Long-term - Each program will develop a strategic vision that considers a 20-plus year horizon. The vision will address impacts and issues identified in the action plan, for known chronic or predictable long-term impacts or issues that are likely to affect the program's priority habitats. These plans should consider how to plan for and fund contingencies and include descriptions of the types of data needed, tools and technologies available or needed, partners and collaborators, etc.

V. Recommendations For Coastal Land Acquisition Programs And Projects

Applicability

The following recommendations address NOAA programs that provide grant funding for land acquisition projects: the Coastal Resource Improvement Program; CELCP; and the NERRS, as authorized under §306A, §307A, and §315 of the CZMA, respectively.

CELCP provides funding to state and local governments to acquire coastal land, or interests in land, with exceptional ecological, conservation, historical, aesthetic, and/or recreational value. Recent changes to the CELCP program now direct a portion of the CELCP funding to support funds for NERRS to acquire land, or interests in land, that will contribute to the long-term protection and management of reserves. The Coastal Resource Improvement Program (§306A) allows states to use a portion of their annual coastal program implementation funding to acquire lands within designated areas that contain protected resources or that otherwise are areas of concern. Funds also may be used to acquire lands for public access to beaches and other coastal areas.

PRIMARY GOALS FOR §306A, §307A, or §315 ACQUISITION PROJECTS

- Protect important coastal habitats such as wetlands and streams, marshes, islands and peninsulas, maritime forests, coastal prairies and savannahs, beaches, and other water-fronting habitats
- Protect habitat for threatened or endangered coastal species
- Conserve buffers, hubs, in-holdings, and corridors
- Provide public access and recreation
- Protect drinking water supplies
- Protect lands with geological significance
- Preserve aesthetic/scenic vistas
- Reduce or mitigate risk to life or property from coastal hazards
- Preserve historic/cultural resources
- Enhance research and education opportunities, including acquiring sites to construct research/education facilities

Although the goals and objectives of these programs vary, each implements acquisition projects that will likely be affected by climate change. Currently, NOAA's involvement in land acquisition projects ends with the acquisition of conservation easements or land, unless the acquisition project includes the need for future restoration. With adequate research and planning, NOAA may anticipate potentially harmful consequences to better guide acquisition funding decisions and protect these investments over the long-term. NOAA may also consider guiding project planning and implementation to acquire properties that help communities mitigate and/or adapt to the effects of climate change.

Why it's important to factor in climate change: aspects of acquisition projects sensitive to current and future climate conditions

NOAA programs acquire land, or interests in land, to achieve multiple, important benefits, including protecting habitat, providing public access, constructing research or education facilities, preserving historic or cultural resources, mitigating hazards, and protecting watershed health and water supplies. Key stressors associated with changes in climate are likely to affect the resources and ecosystem services that acquisition projects seek to protect[13].

For example, changes in air temperature and rainfall patterns and resulting changes to water availability may alter species distribution, increase the risk of parasitism and disease, and facilitate the expansion of invasive species. Thus, for a property being acquired for species, habitat, or biodiversity protection, climate change may ultimately prevent achieving the project's goals.

Similarly, changes in precipitation patterns may cause drought conditions, or alternatively, increased flooding, and increased erosion due to high-stream flows, increased sedimentation and runoff, or reduced water quality, all of which may impair water resources or services targeted for protection through acquisition.

Other climate stressors with the potential to affect acquisition project goals include: changes in relative sea and Great Lakes water levels, which may lead to increased erosion, landward migration of coastal features, decreased water quality, migration and inundation of marsh species, and structural and functional habitat changes; and changes in greenhouse gases, which may affect soil and water pH, as well as the composition and health of plant communities.

Table 2 provides a summary of how anticipated climate change stressors may affect land acquisition program and project goals.

It is important to note that projects funded under NOAA's land acquisition programs often have multiple important benefits. In addition to the primary purpose of an acquisition, several secondary or ancillary benefits are usually identified for a single project, each of which may be affected by climate stressors. However for simplicity, the following discussion will focus on a project's primary purpose for protecting land through acquisition.

[13] Information on stressors and potential impacts from: EPA 2008. Climate Ready Estuaries: Synthesis of Adaptation Options for Coastal Areas; and NOAA Workshop summary report: Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (eds.). 2008. *Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress*. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 pp.

Table 2

KEY RELATIONSHIPS TO INFORM LAND ACQUISITION CONSIDERATIONS[1]

PROJECT OBJECTIVES		CHANGES DUE TO CLIMATE				
		Changes in Precipitation Patterns	Changes in Air Temperature	Changes in Ocean Temperature and Circulation	Changes in Relative Sea and Great Lakes Water Levels	Changes in Air Chemistry
LAND ACQUISITION	RELATIVE SENSITIVITY[1]	Priority	Priority	Priority	Priority	Priority
Protect important coastal habitats such as wetlands and streams, marshes, islands and peninsulas, maritime forests, coastal prairies and savannahs, beaches and other water-fronting habitats		**high**	**high**	**medium/high**	**high**	**medium**
Protect habitat for important coastal species		**high**	**high**	**high**	**high**	**medium**
Protect drinking water supplies		**high**	**medium/high**	**none/low**	**medium/high**	**high**
Conserve lands with geological significance		**low**	**low**	**low**	**medium**	**low/none**
Conserve buffers, hubs, in holdings, corridors		**high**	**high**	**low**	**medium/high**	**low**
Provide public access and recreation		**low**	**low**	**high**	**medium/high**	**low**
Provide aesthetic/scenic vistas		**low**	**none/low**	**none/low**	**medium**	**low**
Prevent hazards		**high**	**medium**	**low**	**high**	**none/low**
Preserve historic/cultural resources		**low**	**low**	**low**	**medium**	**none/low**
Enhance research and education opportunities, such as acquiring sites to construct research/education facilities		**low**	**low**	**low**	**low**	**low**
Average Priority		***medium/high***	***medium***	***low/medium***	***medium/high***	***low/medium***

Table 2 is intended to be used by program offices/project proponents as a quick reference to identify climate change impacts of concern and their anticipated influence on acquisition projects with various conservation objectives. While this table may serve as a general guide, the specific characteristics of the land to be acquired (e.g., location, existing stressors, adjacent land features, etc.) will determine how it may be affected by climate change.

1. The relative sensitivity to impacts employed in Table 2 (i.e., high, medium, low, none) represent a consensus of informed, qualitative opinions but is nonetheless, a subjective effort. It is also important to note that the Table considers impacts mostly in isolation.

Incorporating considerations into CELCP and CZMA §306A and §315 acquisition programs

To better sustain and guide NOAA's acquisition investments, OCRM will incorporate consideration of climate change impacts into various facets of land acquisition program implementation including land acquisition planning and project selection processes.

CELCP and §315 projects are selected through national competitions and solicited when NOAA publishes an FFO that outlines the application requirements and evaluation criteria for proposed projects. For CELCP, projects must be consistent with the priorities and project areas identified in the state or territorial CELCP plan, as well as with national objectives. NERRS acquisition projects receive more points if they are identified in the relevant reserve management plan or a separate acquisition plan. For both programs, a peer review process is used to evaluate and prioritize nominated projects. Resulting ranked lists of proposed projects guide the final project selection, within the funding amounts available.

Considering climate change in land acquisition planning process

OCRM will evaluate and revise CELCP guidelines and work with and provide support to program participants (i.e., states, territories, reserves) to take into account climate change impacts in their acquisition planning processes.

NOAA's CZMA §306A, §315 and CELCP acquisition programs include a planning component designed to help identify projects that achieve program goals and address priorities. State/territorial "CELCP plans", required for participation in that program, provide an assessment of priority conservation needs (e.g., lands and values to be protected) and identify discrete geographic areas that reflect the state or territory's conservation priorities (project areas). Projects that are nominated to the national CELCP funding competition by a state must be derived from the priority conservation needs and project areas described in that state's CELCP plan. State/territorial CELCP plans are required to be updated every five years, with the next round of updates expected to begin in approximately 2011.

Each NERR is required to develop and update a reserve management plan every five years that includes an acquisition component. Acquisition projects nominated to the NERRS Acquisition and Construction Program competition are given more points for the degree to which they further the goals and objectives of the relevant reserve management plan. Some of these plans are already taking climate change into consideration by identifying habitats for protection.

CZMA §306A acquisition projects must be located in designated "Areas of Protection and Restoration" (APRs), or areas that contain nationally significant resources.

To allow for the adequate consideration of climate change impacts, the next round of CELCP and NERRS management plans should consider climate change impacts in setting conservation priorities. One avenue to accomplish this would be to revise the CELCP guidelines (June 2003)

and §315 guidelines to consider climate change impacts on planning activities. These efforts would: identify specific climate change impacts of concern; identify likely effects of those impacts on a state, territory, or reserve's conservation priorities; and add climate change criteria to the existing list of conservation criteria that are used to prioritize acquisition sites for these Plans. OCRM would then work with states and reserves as they update their plans.

Example Conservation Criteria for Prioritizing Acquisition Sites

- Sites that are less sensitive to climate change impacts of concern, or that can clearly lessen these impacts through adaptive management
- Sites that enhance ecosystem resilience
- Sites that reduce atmospheric concentrations of greenhouse gases

Recent reports published by a climate change science working group[14] and by EPA for Climate Ready Estuaries[15] proposed several management approaches for maximizing ecosystem resilience to climate change that are relevant to NOAA's land acquisition programs. They include the following.

- Connect landscapes with corridors to allow for species migration as the timing of seasons and sea levels change.
- Protect key ecosystem features that represent important keystones for ecosystems, such as structural components, and organisms that play a significant role in maintaining function and normal processes.
- Reduce anthropogenic stressors to minimize stressors that may be exacerbated by climate change.
- Maintain diversity by identifying and conserving a diversity of habitat types and species within an ecosystem to provide resilience and a source of recovery.

These kinds of strategies might inform plan developers on how to consider enhancing ecosystem resilience in conservation priorities. Plan developers also should be directed to identify and consult climate change plans of other relevant organizations in their regions so that climate change conservation efforts in coastal areas are better aligned.

[14] Climate Change Science Program, Synthesis and Assessment Product 4.4 Preliminary review of adaptation options for climate-sensitive ecosystems and resources.
[15] U.S. EPA (2009). Synthesis of Adaptation Options for Coastal Areas. Washington, DC, U.S. Environmental Protection Agency, Climate Ready Estuaries Program. EPA 430-F-08-024, January 2009.

For CZMA §306A planning, OCRM will evaluate possible changes to §306A guidance to promote enhancing ecosystem resilience. One approach could be limit acquisition projects funded with section §306A funds to those identified in the states "updated" CELCP plan, unless there are compelling reasons for doing otherwise. Another more costly approach could be having states update their APR designations to incorporate climate change considerations. Alternatively, OCRM could work with the subset of states that use §306A funds for acquisition to evaluate their lists of designated APRs, as well as their public access plans (if they have them). Those APRs could be updated by designating sites listed in the next generation of CELCP and NERRS plans, or other state plans which have incorporated climate change considerations as new APRs.

Considering climate change in project identification, selection and design

OCRM will craft future CELCP and §315 FFOs to promote project proposals that demonstrate how the project will help meet CELCP or NERRS goals and priorities in light of the anticipated effects of climate change. This may simply require project applicants to demonstrate that a proposed project is consistent with the project areas described in an updated state/territorial CELCP plan or the acquisition goals described in the updated reserve management plan noted above. If CELCP plans have not been updated to consider climate change, revised Guidance or future FFOs could require applicants to discuss likely climate change impacts and how these impacts will affect the feasibility of achieving the objectives of the acquisition and what, if any, adaptive management practices would be employed and on what information they based these determinations. Currently, CELCP applicants must describe the context of a proposed acquisition, as well as threats to the subject property (e.g., contextual land use patterns and pressures). These criteria could be extended to include a discussion of the assessment of long-term threats from climate change and how they have systematically addressed those impacts. An alternative approach would be to revise the CECLP and §315 FFOs to ensure that project applicants complete a climate change impact analysis/checklist, or similar mechanism that would provide a uniform approach for considering climate change impacts. Once OCRM has identified a long-term management plan and monitoring scheme, project applications also would be asked to describe how the how long-term management and/or monitoring of acquired properties will be addressed. (See the "Long-term Management and Monitoring" section for additional discussion.)

OCRM will develop and incorporate specific climate-related national criteria in the CELCP and §315 annual funding notices. Project applicants would then be encouraged to submit projects that contribute to climate-related objectives that have been developed by NOAA, while achieving the broader goals of the CELCP and §315 programs (as defined in the CZMA). Projects that address climate impacts could either be awarded "bonus points" through the project evaluation and scoring process, or the climate-related objectives could be used as selection factors that would allow the selecting official to choose projects that especially meet NOAA's goals. Climate-related criteria would be supplemental not determinative criteria. For example, OCRM could identify specific management approaches for maximizing ecosystem resilience to climate change (see section on project planning and identification) as a priority. In future

CELCP and §315 competitions, NOAA could promote projects that, in addition to meeting program goals, maximize resilience to climate change. The funding notices should include clear criteria, outline the types of information that project applicants would need to provide to demonstrate how their proposed project would meet the criteria, and list examples of projects that address the priority. Projects meeting the criteria could either earn additional points in the scoring process or be eligible to be chosen out of ranked order by the selecting official. This would require development of an accounting system for documenting or measuring a project's ability to enhance ecosystem resilience or greenhouse gas reduction.

As noted before, states may use a portion of their annual funding to conduct §306A low-cost acquisition projects to protect designated areas or areas with nationally important resources in a national, non-competitive process. OCRM will work with state and territorial partners to evaluate and develop revisions to future §306A guidance and project checklists that build in an approach for considering climate change impacts for potential acquisition projects. For example OCRM may: include a §306A checklist criteria that the project is consistent with the state or territory's acquisition priorities—as expressed in the state's APRs, or its CELCP plan; include a new §306A checklist item that asks the applicant to describe how the project addresses climate change impacts; require applicants to complete a "Climate Change Impact Analysis/Checklist" or similar mechanism; or work with states to include climate-related criteria in their competitive selection process for §306A projects. OCRM should include options or requirements for considering climate change impacts in the §306A checklist in future updates to the §306A guidance.

Considering climate change in long-term management and monitoring

This Framework should enable NOAA to better protect acquisition investments over the long-term, avoid or minimize adverse climate change impacts, and help maintain the primary purpose for which properties were originally acquired, by requiring that climate change impacts be considered in design and implementation of long-term management activities.

Long-term management of NOAA acquisitions has often been at the discretion of recipient states, territories, and reserves for CELCP and §306A acquisition projects. There are no current requirements for long-term monitoring or management plans for CELCP or §306A acquisitions even though acquisition projects are considered to be in perpetuity. CELCP management plans include baseline reports of the significant physical and biological features of a property, as well as existing stressors; discussions of expected climate change impacts to these features and project objectives (including possibly modeling potential climate changes and ecosystem responses[16]); and outline proven strategies and staffing for monitoring and maintenance adaptive management to ensure that the primary purposes of the project will continue to be achieved. NERRS management plans serve as the long-term management plans for the acquisitions under CZMA §315.

[16] Climate Change Science Program, Synthesis and Assessment Product 4.4 Preliminary review of adaptation options for climate-sensitive ecosystems and resources

OCRM will evaluate this opportunity to strengthen long-term management requirements in general and by including climate-related considerations where warranted. However, as with restoration projects, OCRM must balance considerations for long-term management plans and post-acquisition monitoring with funding constraints and identify criteria or thresholds establishing when long-term management plans and monitoring should be required to protect NOAA investments. OCRM will evaluate and identify these criteria or thresholds in CELCP Programmatic Guidelines and §306A guidance and make sure any requirements are referenced in the revisions to the Guidance or FFOs. Otherwise programs should address long-term management and monitoring on a case-by-case basis. If monitoring is warranted, OCRM can advise project proponents and include monitoring as part of the CRP or §306A application narrative or impose special award conditions that can be used to require appropriate project specific monitoring that is consistent with the available capacity. However, as noted before, special award conditions without a long-term source of sustainable funding to monitor and implement management plans are not realistic or effective.

Long-term management of NERRS acquisitions is generally directed by the reserve management plans. OCRM will address incorporating climate considerations into long-term management in the development of the reserve management plans. Reserve management plans are updated approximately every five years, and some of these plans already take climate into consideration in designing long-term management goals and objectives.

For §306A acquisition projects, the §306A guidance may provide the appropriate mechanism for states and territories to build in climate considerations for potential acquisition projects. OCRM should work with states and territories when updating the §306A guidance to determine how it could include components that address anticipated long-term management and monitoring.

Just as with restoration projects, full implementation of monitoring requirements should wait until NOAA has developed a long-term monitoring and land management plan and a dedicated source of funding to ensure a sustainable and useful monitoring and land management program.

Finally, OCRM will evaluate the feasibility of addressing climate change considerations for existing, previously funded coastal land acquisition projects. A significant amount of land that has already been acquired with NOAA funding to date—over 45,000 acres of coastal habitat with CELCP funding alone—that were not designed with climate change in mind. To be fully effective, future climate impacts may need to be considered. Furthermore, these properties may be important to include in local or regional climate change adaptation planning. OCRM will consider advising grantees on how they might best protect existing CELCP, §306A, and §315 properties from climate change impacts. OCRM may work with programs with similar situations (e.g., National Marine Sanctuaries) to develop approaches. Since climate change considerations were not included in the award requirements for these properties, any long-term monitoring would be voluntary.

VI. Recommendations For Facility Development Programs And Projects

Applicability

The guidance is applicable to siting, site planning, design, and construction of facilities pursuant to §315 and §306A of the CZMA.

Under CZMA §315, OCRM administers a competitive construction and acquisition program with NERRS "Procurement, Acquisition, and Construction" funds. Typical construction projects for NERRS facilities include construction, renovation, and/or upgrading of facilities to support core reserve programs of management, research and monitoring, education, training, and stewardship, design and installation of exhibits and ancillary trails.

CZMA §306A allows state and territorial CZM programs to use a portion of their annual funding to construct low-cost projects to redevelop deteriorating and underused urban waterfronts and ports and provide or enhance public access to public beaches and other public coastal areas and coastal waters. State-submitted §306A projects do not compete against one another at the national level, but may have been selected through a state or local competitive process.

Types of Facility Development Projects

Upland

- Administrative offices (§315)
- Visitor centers (§315)
- Indoor and outdoor classrooms and training centers (§315)
- Laboratories (§315)
- Storage and maintenance facilities (§315)
- Trails, boardwalks, dune walkovers (§306A and §315)
- Internal and external exhibits (§306A and §315)
- Structural enhancements to improve energy efficiency, such as installment of geothermal heating facilities and solar panels, and upgrading facilities (§315)
- Parks and parking lots to facilitate public access (§306A)
- Repair reconstruction/relocation of historic buildings and structures (§306A)

In Water

- Boat launches, docks, and piers for access and recreational use (§306A and §315)
- Docks, piers, pilings, and stabilization measures to revitalize urban ports (§306A and §315)

Why it's important to factor in climate change: aspects of facility development projects sensitive to current and future climate conditions

In coastal areas, the location of infrastructure, buildings, and other structures on property is very sensitive to areas currently or expected to be vulnerable to storm surge, wave velocity zones, flood zones, and areas inundated by sea level rise. The elevation of buildings, docks, and piers is sensitive to current and anticipated base flood elevations, storm surge, wave heights, and sea and lake level changes. Increased base flood elevations due to increased rainfall patterns and intensities, coupled with watershed development or increased storm surge from relative sea level rise, can cause frequent flooding of structures designed for previously lower flood elevations.

The location, types, and sizing of wastewater/septic systems are sensitive to current and expected ground water levels. Raised water tables from rising sea levels, increased annual rainfall, and more frequent flooding can cause septic systems relying on underground drain fields to become less efficient or fail. The location, type, and size of stormwater management systems are sensitive to current and expected rainfall patterns and intensities, groundwater levels, and areas inundated by sea level changes. Increases in rainfall patterns and intensities can result in under-designed stormwater retention or treatment facilities that will not address regular storm events resulting in additional pollutant loading to coastal waters. Higher groundwater tables resulting from increased annual rainfall or sea level rise can cause infiltration systems to become less efficient or fail. Water supply systems are sensitive to current and expected groundwater levels and quality. Salt water intrusion into coastal aquifers as a result of sea level rise can degrade well water systems. Lowered water tables resulting from decreased annual rainfall or prolonged drought can also affect well water supplies.

The types of building materials (siding, roof tiles) and fastening techniques employed in construction, hence the durability/survivability of structures, are sensitive to the current and expected intensity of tropical and extra-tropical storms and resulting wind speeds.

The efficiency of heating and cooling systems, as determined by the orientation of the building (north, south), the maintenance of shading or wind protection , as well as the types of heating and cooling systems used, is sensitive to current and future air temperatures.

Table 3 provides a quick guide to the relative sensitivity to impacts from various climate change phenomena for the various types of facility development projects.

Table 3

KEY RELATIONSHIPS TO INFORM FACILITY DEVELOPMENT CONSIDERATIONS [1]						
		CHANGES DUE TO CLIMATE				
Facility Development		**Changes in Precipitation Patterns**	**Changes in Air Temperature**	**Changes in Ocean Temperature and Circulation**	**Changes in Relative Sea and Great Lakes Water Levels**	**Changes in Air Chemistry**
	RELATIVE SENSITIVITY [1]					
Siting of buildings or other structures on the property		**medium**	**low**	**none**	**high**	**none**
Infrastructure planning (roads, stormwater management facilities, etc.)		**high**	**low**	**none**	**high**	**low**
Construction–building design, orientation, construction materials		**high**	**high**	**none**	**medium**	**none**
Coastal public access improvements: dune walkovers, boardwalks, fishing piers, beach rest areas, parking lots, etc.		**high**	**low**	**none**	**high**	**none**
Waterfront redevelopment revitalization		**high**	**none**	**none**	**high**	**none**
average sensitivity		***medium/high***	***low/medium***	***medium***	***medium/high***	***low/medium***

Table 3 is intended to be used by program offices/project proponents as a quick reference to identify climate change impacts of concern and their anticipated influence on facility development projects. While this table may serve as a general guide, the specific characteristics of the facilities to be developed will determine how they may be affected by climate change.

1. The relative sensitivity to impacts employed in Table 3 (i.e., high, medium, low, none) represent a consensus of informed, qualitative opinions but still are considered a subjective effort to develop a quantitative comparison. It is also important to note that the Table considers impacts mostly in isolation.

Considering climate change in facility design, construction, and operation

To protect NOAA funded facilities and, where feasible, help reduce greenhouse gas emissions and enhance ecosystem resilience, OCRM will consider impacts of climate change in the planning and design of NOAA-funded facilities.

Facility development project design information is provided in NERRS §315 applications and in CZMA grant application task descriptions and §306A checklists. There are currently no specific protocols for evaluating NERRS or §306A facility development proposals as they relate to climate change. Technical reviewers of NERRS projects use best professional judgment to determine whether the objectives, benefits, or other services provided by the project could be compromised through inadequate consideration of climate change risks. OCRM staff relies generally on state CZM program reviews and best professional judgment for technical reviews of §306A facility development projects, but does not typically consider climate impacts.

OCRM will evaluate its current §315 guidelines and revise them as needed to promote new NERRS facilities that avoid or minimize the impacts of climate change by designing, siting, orienting, and constructing structures and infrastructure to reduce project vulnerability to impacts such as sea level rise, storm surge, erosion, estuarine flooding, or salt water intrusion. Moreover, OCRM will revise guidelines to promote facilities that minimize their carbon footprint. For example, revised §315 guidance could encourage Reserves to conduct a climate change impact analysis for anticipated projects within the reserve management plan or provide analysis of climate change impacts in annual funding proposals submitted to OCRM.

Project proponents should assess the sensitivity of facilities to expected climate change impacts. Where projects are sensitive to impacts, project proponents should identify how the facility will avoid or minimize those impacts, what green designs might be employed to reduce their carbon footprint (where feasible), and describe the methodology they have used to make these determinations.

The majority of §306A coastal public access projects and waterfront redevelopment revitalization projects are by statute “low cost” and are typically expected to have relatively short life spans because of the harsh conditions they are subject to in their required locations in or adjacent to coastal waters. OCRM has previously identified useful life spans for most of these low cost construction projects of less than or equal to 20 years. And while the life spans of many in-water and water-dependent projects such as walkovers, boat ramps, piers, etc. can be significantly reduced by erosion, storm surge, or inundation, the need to provide access to

these sites and lack of alternatives may provide a compelling reason to fund these projects in spite of potential impacts of climate change. OCRM will evaluate and identify which §306A projects would trigger such an analysis in its revised §306A guidance.

While project proponents and reviewers can use the key relationships tables in this publication to begin to identify priority climate change issues, the tables should be refined for specific regions to be more accurate and useful.

Examples of best practices for facility development adaptation to expected climate impacts

Until Technical Guidance is developed, program staff can work with project proponents to recommend approaches for considering climate adaptation in project design. For example, for upland development (as opposed to water-dependent or in-water facilities), projects should address possible climate change impacts on siting of attendant infrastructure such as roads, parking, stormwater management, and on-site disposal facilities. Priority impacts to consider appear to be sea/lake level changes, changes in precipitation patterns and intensities, and potential increase in tropical and extra-tropical storm intensity.

Buildings, roads, and other structures should be set back from current and anticipated hazard areas susceptible to inundation, flooding, storm surge, wave energy, and erosion. Sites without adequate areas to build outside anticipated special flood hazard, storm surge, or inundation areas should be avoided. If structures must be constructed in A-zones, they will need to be elevated to provide adequate freeboard above higher scenario base flood levels. Changes in relative sea level and storm surge and erosion should be considered for water-dependent and in-water projects at or near the shoreline. Conversely, in the Great Lakes, projects built to access lake waters could fail to meet those objectives if lake levels continue falling due to less precipitation and greater evaporation.

Stormwater facilities should be designed with capacity to account for current and anticipated rainfall patterns and attendant on-and off-site runoff. Alternatively, the design should allow for expansion of stormwater facilities if needed, or the entire project could be designed to reduce generation of on-site runoff by limiting impervious surfaces or capturing rainfall (e.g., in gutter barrels). Stormwater management should be an integral part of project design and should consider including features such as green roofs, pervious surfaces, and landscaping in order to minimize stormwater impacts.

On-site wastewater disposal facilities should be sited to avoid areas susceptible to current or anticipated inundation or flooding and designed to avoid, or be able to operate in, areas that may be subject to anticipated elevated water tables resulting from sea level change.

A well understood approach to adapt to climate change is to minimize existing stressors on the ecosystem. A significant component of local and micro-scale climate change is forced by changes in the underlying physical geography (i.e., urbanization, land use/land cover/topographic changes). These local-scale changes feed into larger scale climate change processes and can have unintended consequences. Consequently, the development of new facilities should have minimal disruption of the environment and minimize the modification of the physical environment as much as possible. For example, facility planning and design should address impacts on habitat. Vegetated riparian buffers should be maintained or enhanced to provide additional protection from coastal flooding and storm surge. Designers should keep in mind that habitat migration, connectivity, and natural biodiversity determine an ecosystem's resilience to climate change impacts. Water-dependent and in-water structures, especially hardened shoreline structures, can hinder habitat's ability to migrate during rising sea levels. Roads and parking lots can alter hydrology, sediment transport, and habitat connectivity, increasing the risk of introducing invasive species and altering biodiversity.

OCRM, on behalf of NOAA, will take a leadership role and promote facility project designs that help reduce greenhouse gas emissions, where feasible. OCRM currently recommends informally that NERRS facilities constructed with NOAA funds promote green design. NERRS supports incorporating green design technology, and reliance on LEED (Leadership in Energy and Environmental Design) guidance. In FY09, for example, the NERRS are implementing a formal policy for the first time, through revised criteria in the §315 FFOs to clarify that support for structural enhancements that incorporate green design will be awarded more points than projects that don't incorporate green design technology. OCRM anticipates that this will be effective in influencing the design and impact of facilities constructed with NERRS funds.

The LEED® green building certification program is a voluntary, consensus-based national rating system for buildings designed, constructed and operated for improved environmental and human health performance. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality.

OCRM will evaluate additional considerations for the NERRS program guidance such as:

- To the extent possible, require all NERRS management plans to consider climate change impacts in facility plans; and

- To the extent relevant, support acquisition of high resolution topographic and

bathymetric data for the reserve and adjacent areas, to provide adequate information to evaluate climate impacts on structural and siting considerations of reserve facilities.

In addition, to lead by example, OCRM may consider going beyond "offsetting" to actually "reducing" greenhouse gas production. OCRM will investigate the feasibility of establishing a "net-gain in carbon reduction" policy for the NERRS, as opposed to a carbon neutral policy. If OCRM were to establish a net gain in carbon reduction policy, project proponents would need to quantify and address greenhouse gas emissions. Applicants would be encouraged to not only mitigate impacts of emissions through the use best management practices and incorporate measures that mitigate the impacts of unavoidable greenhouse gas emissions, but to reduce atmospheric concentrations of carbon by promoting carbon sequestration activities. For example, if a project uses the best management practices, but still results in some carbon dioxide emissions, offsets such as tree planting could be included in the project. A number of carbon footprint calculators are available to estimate some but not all of these measures.

To achieve a net gain in carbon sequestration, an implementation strategy may include phased-in benchmarks (from no-net gain in carbon footprint to a net gain in carbon sequestration over time) and consider innovative strategies for reversing carbon impacts. Strategies might include combining investments in landscaping and habitat protection or restoration to offset carbon emissions. Policies should consider calculations of carbon emissions over the life span of the project.

This policy would be challenging to implement. Additional guidance to address the location of carbon sequestration strategies relative to the construction projects will need to be considered, as well as whether the project is responsible for directly implementing carbon sequestration strategies. It may be necessary to partner with other organizations to address this goal.

With regard to §306A projects, the nature of these projects (boat ramps, dune walkovers, boardwalks, etc.) may limit the opportunities for reducing greenhouse gas emissions. As such, OCRM will evaluate the §306A projects and determine whether there are any projects for which greenhouse gas reduction is feasible and that warrant revision of the §306A guidance.

Considering climate change in project selection

To assure that investments are protected and mitigation of climate change impacts is promoted where feasible, OCRM will evaluate and modify project selection criteria to incorporate climate change considerations.

Current selection criteria identified in the §315 FFO for consideration by project evaluators address climate impacts related to green building design. Project applicants are asked to describe the green design elements in their projects. However, no specific weight is assigned to these criteria. Project reviewers consider inclusion of green design elements within a broader criterion related to the technical merit of the project.

OCRM will consider developing new criteria that could grant additional points to those projects that have adequately addressed identified climate change impacts. As technical assistance guidance or climate change impact analysis/checklists are developed, the criteria could be linked to how consistent the project is with the guidance or checklist. The criteria could provide additional points to projects that propose to reduce greenhouse gas emissions or are greenhouse gas neutral. This will require identification or development of a consistent means for measuring greenhouse gas emission reductions from various design treatments. Finally, if one of these two conditions is met, the project might obtain additional credit for investing in carbon sequestration to more than compensate for the carbon footprint over the life of a given project.

OCRM will evaluate whether development of §306A eligibility criteria related to avoiding minimizing climate impacts and reducing carbon footprints for these low cost construction projects is warranted.

Considering climate change in program objectives

NOAA and OCRM can promote the development of facilities with reduced carbon footprints and thus lead by example to reduce greenhouse gases. They also can incorporate this goal into these facility development program goals and objectives. Given the statutory nature of CZMA §306A goals and objectives, OCRM will investigate the feasibility of including these objectives, where relevant, in the §306A guidance.

It should be noted that recommendations for program planning and monitoring are not relevant for these facility development programs.

VII. Program Needs For Implementation

While this Framework calls for changing planning and decision-making to safeguard against and mitigate climate change for these projects, the Framework cannot be fully implemented until certain activities are completed.

Development of Technical Guidance

Coastal habitat restoration, land acquisition, and facility development project proponents and reviewers will need guidance, training, and a supporting infrastructure to effectively implement the recommendations in the Framework and adequately evaluate, consider, and address climate change impacts. Therefore, prior to full implementation of this Framework, OHC and OCRM, in consultation with relevant NOAA offices, federal agencies, states, NGOs, and academics, will develop regionally specific Technical Guidance. The Technical Guidance will help project proponents assess, avoid, minimize, adapt to, or mitigate expected climate change impacts for restoration project planning and design, acquisition planning and project identification, adaptive management, and facility development project design and construction.

Technical Guidance

- Regionally specific
- Developed with NOAA and non-NOAA subject matter experts
- Identifies impact assessment protocols and best practices including best available data, information and tools, sources of information and experts that can provide advice
- Guidance on how to take action in an environment of uncertainty
- Regularly updated

The Technical Guidance should be regionally specific, yet attempt to be nationally consistent across all relevant NOAA programs and, ideally, across all federal programs (or at least not in conflict with the Technical Guidance of other agencies managing coastal resources). The guidance should identify/provide regionally specific protocols, impact projections or scenarios, and information and tools to assess project sensitivity to expected climate impacts. It should also identify/provide best management practices to avoid, minimize, adapt to, or mitigate climate change phenomena that would significantly impact project objectives. Later iterations of the Technical Guidance also should begin to identify methods of accounting for or assessing ecosystem resilience, adaptive capacity, and potential to reduce greenhouse gases levels to establish project selection criteria.

Examples of technical information and decision–support tools would include: precise and accurate geospatial foundational information, including land elevations and local tidal datum (e.g. local mean sea level); current localized predictions of inundation and storm surge at the best available resolution; current/down-scaled precipitation pattern and intensity projections, other local hydrographic projections, such as water levels, tidal ranges, and currents; current

and projected hydrologic data, such as stream velocity, rates of stormwater runoff; assessments of current environmental engineering models, weather patterns, and climate forecasts; detailed habitat maps including vegetation communities, existing studies on the likely responses of ecosystem components to these phenomena and regional or national contacts who may assist in an analysis. Where feasible, the guidance should include information on the availability of appropriate data sets, methodologies, and models and sources of expertise needed to facilitate their use.

Based on discussions with NOAA program staff, it would appear that many are unsure of how to take action in what they consider is an environment of significant uncertainty. Therefore, to be useful, the guidance must assist project proponents and reviewers to overcome the inertia of uncertainty and be able to take action (considering climate impacts in planning and design) with the best available (but often incomplete) information.

OHC and OCRM, in consultation with relevant NOAA Offices will convene regional workshops to bring relevant subject matter experts (e.g., climate, ecosystem, oceanography, hydrology) together with restoration, acquisition and facility development "practitioners" to identify specific available data, information, and analyses tools and training needed to adequately consider climate change in habitat restoration, land acquisition, and facility development in a particular region. The subject matter experts should include both NOAA and non-NOAA experts and program execution staff from other Federal agencies, states, universities and NGOs. These workshops should encourage a dialogue between the science and practitioner communities to help identify the best available and most relevant science needed to consider climate change impacts in these investments. The Technical Guidance will likely need the participation of other non-NOAA scientists to obtain information on regional or local level impacts.

In order to learn from past implementation and capitalize on the numerous efforts underway to better assess climate impacts and develop strategies for adaptation, OHC and OCRM will strive to update the guidance on a periodic basis, as funding allows.

In scoping out development of the Technical Guidance, if all relevant impacts or activities cannot be addressed at once, the Technical Guidance should be developed first for priority impacts of concern (e.g., priority impacts such as sea level change, changes in precipitation patterns and intensity, and changes in water temperature) and by priority restoration, acquisition or facility development projects for selected regions.

It is expected that other regions and programs will be able to use this guidance to begin to consider climate change in their program implementation decision-making, even before the guidance can be refined for that program or region.

To enhance efficiency and consistency among project proponents and reviewers considering climate change, OCRM and OHC could consider developing a climate change impact assessment checklist or similar mechanism as part of the Technical Guidance. A checklist could identify the acceptable processes and methodologies for assessing impacts as well as referencing data

standards (e.g., standards and methods for storm surge and inundation being developed by the NOAA CSC). The checklist would need to be evaluated and endorsed by the NOAA and non-NOAA experts.

Assessing ecosystem resilience and reduction of unintended greenhouse gases

Project proponents and NOAA staff will need guidance to plan for, identify/design and select land acquisition or habitat restoration investments that can enhance ecosystem resilience or reducing anthropogenic or unintended carbon emissions or concentrations of greenhouse gases.

Specifically, project proponents and staff would benefit from access to state or regional restoration strategies (or maps) that include consideration of climate change impacts as a factor in prioritizing acquisition or restoration sites. These strategies would need to factor in the various adaptation strategies identified earlier as priority site selection criteria. In addition, for restoration and acquisition project selection criteria to be used in a meaningful way to promote enhancing ecosystem resilience and adaptive capacity or to mitigate climate impacts through carbon sequestration, standard protocols for measuring these phenomena will need to be identified or developed. Similarly, for facility development project criteria seeking to be carbon neutral or result in a net carbon reduction, protocols for measuring carbon reduction from facility development should be identified or developed.

Therefore, the Coastal Strategy Principals will work with relevant NOAA offices and others to:

1) Identify or undertake efforts to develop a regional habitat restoration strategy that would prioritize habitat restoration or acquisition sites in light of climate change impacts;

2) Identify or investigate the feasibility of developing standard protocols to assess or measure ecosystem resilience, adaptive capacity, carbon sequestration, and carbon emission reductions, and to assist in program planning, project design and development of standardized project selection criteria. For example, development of these protocols might be included as priority funding activities in future NOAA SARP FFOs.

Engagement of NOAA and non-NOAA partners

As noted above, OHC and OCRM will engage a range of NOAA and non-NOAA entities to develop Technical Guidance, monitoring plans, etc. to implement this Framework. OHC and OCRM will engage relevant NOAA Advisory Groups (e.g., the Science Advisory Board, its subgroups) and NOAA Climate Services to implement this Framework. Given that many of the impacts and specific technical requirements likely will be regionally or sub-regionally specific, OHC and OCRM will engage NOAA regional Program staff (e.g., NMFS regional habitat restoration and science staff), NOAA Regional Collaboration Teams, as well as relevant federal agencies and NGOs in understanding, developing and implementing any Technical Guidance.

Regional staff will play a key role in identifying appropriate regional data, information sources, tools, and analyses. All of these groups will be engaged to identify the appropriate contacts and resources within each line office to assist with identifying existing data, information, tools and analyses needed to develop the guidance. While the investment guidance team has tried to ensure coordination with broader efforts, the extraordinary number and pace of climate change activities taking place in NOAA has left room for additional coordination and collaboration. Hopefully the new Climate Services Office, the Coasts, Climate and Ecosystem Group, or other similar group could play a key advisory role in enhancing this coordination and collaboration.

Long-term monitoring and management

Even if OHC and OCRM programs develop criteria for requiring baseline assessments and long-term monitoring, and adaptive management, there is no assurance that the monitoring or management activities can take place or that monitoring information could be effectively used to consider/address climate change impacts.

Currently there is no way to assure that long-term monitoring will be maintained. Subject programs all provide funding through grants that expire within 3 years of obligating the funding. Consequently, even if programs include special award conditions to require long-term monitoring, there is no way to assure that proponents will have adequate funding to conduct monitoring or adaptive management 10 to 20 to 50 years down the road. Nor do these (or other) NOAA programs have consistent protocols for determining what needs to be monitored, when, and how the information will be collected, stored, and ultimately used.

Therefore, the Coastal Strategy Principals will work with relevant NOAA offices to educate them on the need for guidance and to obtain assistance to develop guidance and sustainable funding source(s) to allow for implementation of any long-term monitoring, management plan, stewardship, and adaptive management for NOAA habitat restoration/land acquisition investments called for in the Framework. The guidance would: set out the objectives of such a monitoring program; detail how, what, when, and by whom the monitoring information would be collected, managed and used; assign costs to NOAA and or funding recipients; and identify specific sources of funding for the monitoring.

Development of training programs for NOAA staff and project proponents

Even when Technical Guidance is developed, some, if not all of OCHC and OCRM staff will likely need training on how apply the guidance. OHC and OCRM will work with relevant NOAA offices, and partners such as the NERRS, the NOAA CSC, the National Sea Grant Program, and others to develop training programs to help program staff and project proponents understand climate impacts, this Framework document and Technical Guidance or other projects developed to assist in the implementation of the Framework.

Using this guidance to inform NOAA Coastal Strategy priority projects

The Coastal Strategy team should use the development of the Technical Guidance as a strategic planning tool. Gaps in specific data, information, analyses, and tools will likely be identified in the development of the Technical Guidance and elsewhere. The Coastal Strategy Team, in consultation with relevant NOAA offices, and perhaps through the Climate Services Office, will evaluate whether these gaps are being addressed by existing NOAA programs. If not, the team should communicate these needs to appropriate NOAA offices. The core team should also consider including such projects that address these needs as priority coastal strategy deliverables.

APPENDIX A: GLOSSARY

For the purpose of this document, the following words have the following meanings:

• ***Adaptive capacity***: The capacity of natural and human systems to adapt to impacts from climate changes.

• ***Adaptation***: Changes in natural or human systems in response to actual or expected climatic stimuli or their effects, which reduce risk or exploits beneficial opportunities.

• ***Best available science***: Best available science is broadly defined to mean the best available biological, ecological, physical, chemical, and social science and information that allow one to identify and assess potential climate impacts as well as the social and ecological response to those impacts and the sensitivity of various projects to those impacts in the future. It should primarily include findings that have been published and/or peer reviewed, but should not be limited to these data sets. And best available science should include both NOAA and non-NOAA sources, including data from relevant government resource management agencies, research or educational institutes, and private NGOs with specific scientific functions or mandates." This will be especially true in attempting to identify/assess regional and sub-regional impact scenarios.

• ***Climate change checklist or impact analysis*:** A standardized format for identifying expected climate change impacts of concern; a uniform and systematic means to assess the sensitivity of projects to those impacts; and a systematic step-by-step process to explain how the project design and implementation will address impacts of concern.

• ***Coastal investments***: NOAA funding or staff time expended to restore habitat, acquire coastal lands or develop facilities pursuant to NOAA's Coastal and Estuarine Land Conservation Program (CELCP) program, National Coastal Zone Management Program (CZMA) and NOAA's Community-based Restoration Program (CRP); includes funding for facility construction pursuant to the Coastal Zone Management and National Estuarine Research Reserve (NERR) Programs.

• ***Coastal Strategy*:** An initiative within NOAA to integrate planning and execution efforts across a range of NOAA offices to advance identified outcomes under three priority "Coastal" issue areas including: climate change and coastal hazards; competing coastal uses and habitat loss; and coastal pollution and human health.

• ***Coastal Strategy Principals***: The group of directors for a core set of program offices which have committed staff time to coordinate on Coastal Strategy activities. Directors from the following program offices are participating: National Ocean Service's Office of Ocean and Coastal Resource Management, Coastal Services Center, National Centers for Coastal Ocean Science, and Integrated Ocean Observing System Program; National Fisheries Service's Office of

Habitat Conservation; Oceanic and Atmospheric Research's National Sea Grant College Program; National Environmental Satellite, Data, and Information Service's National Geophysical Data Center, and Center for Satellite Applications and Research; and the National Weather Service's Office of Climate Water & Weather Services, and Office of Science and Technology.

• ***Ecosystem resilience***: The ability of natural and human systems or communities to withstand or recover from the impacts of climate change.

• ***Expected life span of the investment/project***: The length of time that ecological services or other benefits are expected to accrue from a project or the expected life of the footprint of any facility or structure constructed. Construction and restoration projects may have variable life spans dependent on the size, nature, and cost of the project. Land acquisition projects are usually thought of as providing benefits "in perpetuity" or for an indeterminate time–although climate change impacts could diminish or curtail these benefits.

• ***Habitat connectivity***: An adaptive management strategy that expands connections between habitats that will allow species/habitats to migrate in response to climate change impacts. For example cold-water species are under threat from shifts in water and air temperature. Cold-water species (e.g., trout) need cold water throughout the year to survive. Removing dams and protecting habitat corridors are adaptation strategies that expand habitat connectivity and allow species to seek refuge from temperature change.

• ***Mitigation***: Actions taken to reduce the drivers of climate change, including strategies to reduce greenhouse gas sources and emissions (reducing energy demand/use) and enhancing greenhouse gas sinks (e.g., increasing forest cover).

• ***Multi-scenario analysis****:* Method to evaluate the risk in an investment. In a highly uncertain environment, investments (projects) are selected by choosing a design that will be robust under a range of possible futures, not by optimizing them to a single "most probable" outcome.

• ***Protect key ecosystem features*****:** A habitat management adaptation strategy, which focuses protection on structural characteristics, organisms, or areas that represent important "keystones" of the overall system.

• ***Reducing existing stressors*****:** In the absence of accurate site-specific forecasts of climate change impacts or ecosystem responses, at a minimum, efforts should focus on reducing existing stressors (e.g., pollution, habitat degradation, loss or fragmentation) that hinder the ability of species or ecosystems to withstand climatic events.

• ***Risk*****:** The likelihood and severity of adverse outcomes.

• ***Sea level/lake level change***: An increase or decrease in the mean level of the ocean or Great Lake levels. Global sea level change is the result of changes in the shape of the ocean basins,

changes in the total mass of water, and changes in water density. Of more interest to this guidance is relative (i.e., local) sea level change, which is the net change in sea level when global sea level change is factored with local land change (subsidence or uplifting) due to geological processes. Changes in Great Lake levels are not affected by global sea level changes, but are driven by precipitation, runoff, and evaporation rates.

• ***Sensitivity to climate change***: The degree to which the goals, objectives or benefits of an acquisition, restoration, or construction project may be significantly jeopardized during the expected life of the project.

• ***Technical Guidance***: Those data, information, analysis, decision-support tools, and sources of expertise needed by a project proponent or project reviewer or programmatic staff to effectively and efficiently assess project sensitivity to climate change impacts and if sensitive, to avoid, minimize, adapt to or mitigate climate change impacts at the project level.

• ***Uncertainty****:* The result of imperfect knowledge concerning the present or future state of a system, event, situation, or (sub) population under consideration.

• ***Vertical accretion rates***: The rates of vertical movement of a marsh surface as a result of the accretion of organic matter and sediment over time. Marshes with high vertical rates may ultimately keep pace with sea level rise and avoid inundation.

APPENDIX B: SUMMARY OF NOAA CLIMATE SURVEY

In February 2009, we surveyed selected NOAA offices to identify practices, criteria, or guidance to consider climate change impacts in habitat restoration, land acquisition, or facility construction investments. We received responses from 11 individuals. The following is a summary of the major points of those responses.

Existing Guidance: Most offices surveyed had informal guidance considering climate change impacts related to habitat restoration (7 of 11), while only one had them for acquisition and two for construction.

Types of Activities Guidance Addressed: Most habitat restoration projects appeared to be marsh, vegetated wetland restoration, although there was some mention of stream restoration and some examples of dam removal/aquatic habitat restoration.

Impacts Considered: Sea level rise was by far the most frequent climate change impact considered (7 of 11), with species composition/distribution and water temperature slightly more prevalent than storm frequency, change in precipitation, erosion, and ocean circulation.

Mandatory or Advisory Guidance: None of the practices, criteria, or guidance that offices use are mandatory. Several offices strongly encouraged applicants to use their guidance, while other offices made guidance available to applicants or dealt with applicants on a case-by-case basis.

Information Required from the Applicant: With the exception of sea grass restoration supported by NCCOS, none of the offices required specific information for restoration projects, although some of the usual habitat restoration project information requirements may address it indirectly. There was some information required for construction projects, such as anticipated maximum flooding or storm surge for siting lowest floor of structures.

How Guidance was Applied: Most tried to work through considerations in the project design discussions/negotiations. Several simply ask project proponent to describe the potential climate change impacts to the project and how they are addressing them. Others encourage construction of projects to allow upslope migration of restored habitat over time. Some have modified their project objectives to allow/encourage applicants to restore habitat from the perspective of adapting to climate change impacts (the ability to create buffers or green infrastructure to protect coastal communities from flooding and storm surge, or to allow migration of habitat).

Challenges or Needs: Practitioners would consider impacts if more/better tools (e.g., sea level rise inundation models, sea level rise forecasts) were available. There is a need to include pre-and post-restoration monitoring to allow for adaptive management. Guidance should emphasize designing projects with microhabitat variations in climate in mind. Regional guidance (with regional conditions, forecasts, modeling) would be preferred.

APPENDIX C: STEPS IN CONSIDERING CLIMATE CHANGE IN PROJECT DESIGN[17]

A. Determine project sensitivity to expected climate change impacts

1. Identify critical project components/aspects and the expected life span of project.
   - *Project practitioners should develop an inventory of critical project components and/or expand on the list in guidance – which components are key to project success.*

   - *NOAA should consider developing, to the extent possible, consistent "life spans" for similar habitat restoration or facility development projects and make them available to programs and applicants*.

2. Identify which climate parameters will directly or indirectly affect critical project components.

   - *Climate scientists and practitioners should confirm sensitivity of components to current climate phenomena - expand on tables 1 and 3 in guidance.*

3. Determine how sensitive a project is to changes in key climate parameters.

   a. Perform sensitivity analysis for each key climate phenomena/impact assign sensitivity score to phenomena:

Low sensitivity:	Minimal impacts on the project
Moderate sensitivity:	A particular change in the parameter would require minimization or mitigating measures
Sensitive:	Project design depends on climate phenomena
Critical:	Project successes depend on the climate phenomena remaining within a certain range or may fail as a result of its response to changes in climate phenomena.

[17] Taken and adapted from: Canadian Environmental Assessment Agency, *Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners*, (November 2003)

b. Estimate the extent to which key climate parameters/phenomena are projected to be affected by climate change for the area of concern.

- Determine useful life span of project.

- Locate available or develop information on regional or local predictions, projections of expected climate change impacts (e.g. *land elevations, local mean sea level, and predicted local sea level change information - NOAA CO-OPS, NGS; storm surge, wave heights and inundation - CO-OPS, CSC, NWS, and DOI/USFWS; ocean temperatures and currents – NESDIS; etc.)*

B. Determine if the projected climate changes and uncertainties merit more detailed analysis/investigation.

1. *Will significant climate changes occur during life span of project?*

2. *Are key climate phenomena projected to change to the extent that historical data is not considered representative of the period of the project?*

3. *Would the projected climate changes likely result in changes in project design?*

4. *Are the off-the-shelf data or projections considered insufficient or too general for the specific site location? Is the level of uncertainty considered to be too great to use the projections for project planning and design?*

5. *Are the consequences of design failure such that uncertainties must be minimized?*

6. *How flexible is the project design – can the project address climate changes through adaptive management (project modifications, retrofits added as needed)?*

7. *Will a more detailed analysis investigation likely provide more credible projections or yield additional useful information?*

C. Conduct multiple scenario analysis if more detailed analysis is warranted.

APPENDIX D- USEFUL INFORMATION BY CLIMATE IMPACT TYPE

NEEDS	TABLE 4 -INFORMATION USEFUL TO PROJECT PROPONENTS TO CONSIDER CLIMATE CHANGE				
	CHANGES DUE TO CLIMATE				
	Changes in Precipitation Patterns	**Changes in Air Temperature**	**Changes in Ocean Temperature and Circulation**	**Changes in Relative Sea and Great Lakes Levels**	**Changes in Greenhouse Gases (ocean acidification, acid rain)**
Project proponents and reviewers would like to have information on the following to better consider these impacts:	*• Local or regional predictions of in stream flows and resultant changes to salinity ranges and duration;* *•Local regional predictions of changes to instream flows runoff and resulting riverine and coastal flooding* *•Predictions of changes to groundwater levels•* *Predictions of temporal and spatial changes to vegetation and species utilization*	*• Local or regional predictions of water temperature changes and their effect on vegetation, habitat, construction location, etc.* *• Predictions of temporal and spatial changes to vegetation and species utilization*	*• Local or regional predictions of ocean temperature and circulation changes* *• An understanding of the impacts of ocean temperature and circulation on coastal and marine vegetation, and fauna in that locality or region* *• Predictions of temporal and spatial changes to vegetation and species utilization*	*• Local or regional predictions of extent of inundation or changes in lake levels* *• Local or regional l predictions of salt water intrusion* *• Local or regional predictions of extent of flooding/storm surge* *•Local or regional predictions of ecological response to sea/lake level changes (e.g. marsh migration).* *• Predictions of temporal and spatial changes to vegetation and species utilization*	*• Forecasts of ocean acidification* *• Predictions of soil and freshwater pH change.* *• Implement mitigation strategies or reduce coincident stressors.* *• Link ecological models to economic models to forecast how loss of resources will affect human communities.*
Types of existing analysis and where you might find them	*•Runoff models coupled with projected precipitation rates* *•Runoff models coupled with projected precipitation rates and land use/land cover* *• Groundwater models*	*• Regional humidity and temperature model.*	*• Ocean circulation modeling; impacts of various circulation patterns on habitat, objectives, etc.*	*•*Appropriate local sea level inundation modeling based on precise and accurate combination of tidal and geodetic datum; models coupled with projected relative sea level rise* *•Groundwater modeling* *•Storm inundation models coupled with wave modeling and projected shore erosion and relative sea level rise*	*• Regional flora and fauna change modeling in relation to atmospheric acid precipitation* *• Models of effects of acidification precipitation on freshwater and soil fauna and flora* *• Socio-economic vulnerability assessment of resources*

1. Many of the options are taken from the NOAA Workshop summary report: Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (eds.). 2008. Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 pp. http://spo.nwr.noaa.gov/tm/spo95.pdf

Note: The preceding table is intended to help identify key information needs regarding future impacts of climate change. Project types are linked to guidance regarding data, information, and assistance to help plan for climate change in habitat restoration, land acquisition, and facility development programs.

APPENDIX E - SUMMARY OF REGIONAL IMPACTS [18]

Region: Southeast[19]

Changes in Temperatures

- Rise in average temps between 4.5 ^{o} and 9 ^{o} F by 2080 with average increases up to 10.5 ^{o} in summer

Changes in Precipitation Type, Amount, Frequency and Intensity

- Projections for avg. precipitation are divergent except for indications that the amount of rainfall from individual hurricanes will increase. Models project Gulf Coast states will tend to have less rainfall in winter and spring, compared with more northern states in the region.
- The increase in heavy downpours seen over the last decade may persist.
- Project an overall decrease in availability of water due to higher temps, evaporation, and increased number of dry days between rainfall events.
- Spring and summer rainfall is projected to decline in South Florida during this century.

Changes in Ocean Temperature and Circulation

- Decline in dissolved oxygen (DO) levels in shallow estuarine waters.

Changes in Sea and Great Lakes Levels

- Increase in average sea levels between 1- 2' by 2100. Local or relative rise will vary considerably. Projections range between 2-4' in relative sea level rise (SLR) for LA and East TX due to subsidence.
- A 2' rise in global sea level would likely result in a relative SLR of 2.9' in Hampton Road VA and 3.5' in Galveston TX.

Changes in Storm Intensity and Frequency

- Increased storm surge is predicted: under high scenario the current 100 year flood event would be projected to be 50 year flood by 2050 and 10 year flood event by 2100.
- Populations areas on the coast adjacent to rivers could also experience significant flooding from coincidence of increase storm surge, relative sea level rise and riverine flooding from runoff.

Changes in Stream /Lake Temps

- Project decline in DO levels in streams and lakes.

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[18] Source: Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

[19] VA, NC, SC, GA, FL, AL, MS, LA and TX

Region: Northeast[20]

Changes in Temperatures:

- Rise 2.5-4° F in winter and 1.5-3.5 o F in summer by 2040

Changes in Precipitation Type, Amount, Frequency and Intensity

- Average precipitation amounts are expected to increase in the region as a whole with variability in sub-regions.
- Precipitation intensity increases throughout region, with the greatest increases in areas where average precipitation increases the most with likely increased runoff and flooding.
- Number of dry days between events expected to increase. Under high scenarios short term droughts (1mo - 3mo) are expected to occur once each summer across Catskills and New England States.
- Transition to more rain and less snow in winter.
- Runoff in snow-melt dominated areas has been and is expected to occur earlier by almost 14 days by 2100. Earlier runoff projected to result in lower late summer stream flows.

Changes in Ocean Temperature and Circulation

- Average ocean temperatures may exceed key temperature thresholds for Cod of 54° F for surface waters and 47°F for bottom waters by the 2100 under a higher emission scenario.
- Cod fishery in North Atlantic will be negatively impacted due to shifts in suitable habitat and stress resulting in decline in growth and survival.
- The center of lobster fisheries is projected to shift northward into Gulf of Maine with declines in southern parts of the region.

Changes in Sea and Great Lakes Levels

- Local /relative sea level change in the region is projected to vary considerably but is projected to rise more than the global average Local or relative rise will vary considerably dependent on land movement. Under low scenario NYC project to see relative SLR of 2.3' by 2100; while Maryland Eastern shore could see between relative SLR of 2-3' by 2100.
- Expected increases in coastal flooding, storm surge levels and coastal inundation.
- Great lake levels are projected to drop between 1-2' by 2100 and vary a good deal by lake--due to increased evaporation as a result of increased temps and reductions in winter ice cover.

Changes in Storm Intensity and Frequency

- Increased storm surge is predicted: under high scenario the current 100 year flood event would be projected to be 50 year flood by 2050 and 10 year flood event by 2100.
- Populations areas on the coast adjacent to rivers could also experience significant flooding from coincidence of increase storm surge, relative sea level rise and riverine flooding from runoff.

Changes in Stream /Lake Temps

- Projections call for loss of most trout streams in states up to New England

[20] ME, NH, MA, RI, CT, NY, PA, NJ, DE, MD and DC

Region: Great Lakes[21]

Changes in Temperatures

- N/A

Changes in Precipitation Type, Amount, Frequency and Intensity

- Precipitation is projected to increase in winter and spring, and to become more intense throughout the year, also expected to lead to more frequent flooding.
- Number of dry days between rainfall events expected to increase increasing the likelihood of short term drought and reduced river and stream flows.
- Projections of greater evaporation in summer would lead to more periods of both floods and water deficits.

Changes in Ocean Temperature and Circulation

- N/A

Changes in Sea and Great Lakes Levels

- Great lake levels are projected to drop between 1-2' by 2100 due to increased evaporation as a result of increased temps and reductions in winter ice cover.

Changes in Storm Intensity and Frequency

- N/A

Changes in Stream /Lake Temps

- Changes in water temperatures resulting in earlier and longer periods of stratification.
- Reductions in coldwater fish populations (e.g., lake and brook trout) and replacement with cool-water and warm-water species.

[21] Midwest includes: MN, WI, MI, IL, IN, OH, PA and NY

Region: Southwest[22]

Changes in Temperatures

- The average annual temperature is projected to rise about 4°F to 10°F above the historic baseline.

Changes in Precipitation Type, Amount, Frequency and Intensity

- Precipitation (both rainfall and snow fall) is projected to be substantially reduced (20-40%) in the spring months, when precipitation is most needed to fill reservoirs to meet summer demand.
- Winter precipitation may become more variable, but is likely to transition to more rainfall and less snowfall – which could lead to additional flooding and issues with keeping dams filled to capacity.
- A greater percentage of rainfall events may be occurring as heavy downpours.

Changes in Ocean Temperature and Circulation

- Climate change is projected to affect the California Current from British Columbia to Baja California, and possibly the larger scale natural oscillations (El Niño Southern Oscillation and the Pacific Decadal Oscillation) as well, though these effects are not well understood.

Changes in Sea and Great Lakes Levels

- Sea level change is projected to be at or below global average and will be generally less than other US regions.

Changes in Storm Intensity and Frequency

- Increased storm surge is predicted: under high scenario the current 100 year flood event would be projected to be 50 year flood by 2050 and 10 year flood event by 2100.

Changes in Stream /Lake Temps

- Rising temperatures will limit river flows.

[22] Southwest includes: CA

Region: Northwest[23]

Changes in Temperatures

- Rise in average temps from 3.0°F to 10°F by 2100
- Declining springtime snow pack by 25-40% by 2100
- Changes in precipitation type, amount, frequency and Intensity

Changes in Ocean Temperature and Circulation

- Precipitation is generally projected to increase in winter and spring, and decrease in summer- resulting in more winter flooding, salmon habitat scouring, and increased landslide risk.
- Transition to more rain and less snow in winter, leading to earlier snowmelt and increased winter flooding in warmer watersheds
- Runoff in snow-melt dominated areas has been and is expected to occur earlier. Earlier runoff projected to result in lower late summer stream flows.

Changes in Sea and Great Lakes Levels

- Mid range projections call for a rise of about 13" in Puget Sound by 2100. High scenarios (with glacier melt) could be as much as 50" by 2100.
- Combined with expected increases in Southwesterly winds projected sea levels would result in significant coastal erosion

Changes in Stream /Lake Temps

- Stream flows will continue to decrease in late spring, summer and fall with associated warmer waters and adverse impacts on salmon.

[23] Northwest includes: WA and OR

Region: Alaska[6]

Changes in Temperatures

- AK's annual average temperature projected to rise between 5 and 13°F; in the last 50 years it has risen by average of 3.4°F in summer and by 6.3°F in winter.
- Higher temps are expected to continue to reduce Arctic sea ice coverage, and increase thawing of permafrost.

Changes in Precipitation Type, Amount, Frequency and Intensity

- Climate models project increases in precipitation over Alaska.
- Simultaneous increases in evaporation due to higher air temperatures, however, are expected to lead to drier conditions overall, with reduced soil moisture.

Changes in Ocean Temperature and Circulation

- Sea surface temperatures are projected to increase and combined with a reduction of ice cover are likely to lead to northward shifts in the Pacific storm track.

Changes in Sea and Great Lakes Levels

- Low lying coastal areas will be increasingly vulnerable to relative sea level rise due to land subsidence from thawing of permafrost.

Changes in Storm Intensity and Frequency

- Storm intensity and frequency are projected to increase due to (1) projected northward shifts in the Pacific storm track; (2) significant decreases in atmospheric pressure over the Bering Sea; and (3) greater availability of heat and moisture in the Arctic Ocean from longer ice-free season.
- Increased storm intensity combined with the loss of their protective sea ice buffer, and thawing coastal permafrost have been and are projected to continue to result in significant coastal erosion (currently in some places from 30-110 feet/year).

Region: Pacific Islands[24]

[24] Pacific Islands includes: HI, American Samoa, CNMI and Guam

Changes in Temperatures

- Rise in average temps from 3.4°F to 6°F by 2100

Changes in Precipitation Type, Amount, Frequency and Intensity

- Average annual precipitation projections in the Pacific are highly variable.
- An increased frequency of heavy downpours and increased rainfall during summer months (rather than the normal rainy season in winter months) is projected for the Pacific (again the variability of projections in the Pacific is still quite large).
- The number of heavy rain events is very likely to Increase.
- Water availability may decrease – increased rainfall in summer may lead to flooding not infiltration; sea level rise may lead to saltwater contamination of freshwater lenses.

Changes in Sea and Great Lakes Levels

- Relative sea levels are expected to rise
- Islands and other low-lying coastal areas will be at increased risk from coastal inundation due to sea level rise and storm surge, with major implications for coastal communities, infrastructure, natural habitats, and resources.

Changes in Storm Intensity and Frequency

- Hurricane (typhoon) wind speeds and rainfall rates are likely to increase
- Islands and other low-lying coastal areas will be at increased risk from coastal inundation due to sea level rise and storm surge, with major implications for coastal communities, infrastructure, natural habitats and resources.

Region: Caribbean Islands[25]

[25] Caribbean Islands includes: Puerto Rico and U.S. Virgin Islands

Changes in Temperatures

- Projected rise in average temperatures between 3.6°F to 6.6°F by 2100

Changes in Precipitation Type, Amount, Frequency and Intensity

- Overall average annual precipitation is expected to continue to decline between 5-20%.
- The number of heavy rain events is very likely to increase.
- Water availability is expected to decrease.

Changes in Ocean Temperature and Circulation

- Coastal waters are very likely to continue to warm by as much 4°F to 8°F in this century, both in summer and winter. This will result in a northward shift in the geographic distribution of marine life along the coasts; this is already being observed

Changes in Sea and Great Lakes Levels

- The Caribbean region experienced on average a sea-level rise compared to land-levels of nearly 0.33 feet during the 20th century. Estimates for the rise of global sea level rise range from 0.6 to 1.9 feet by 2100 (IPCC). Many think this figures are low because they do not factor in the potential response of glaciers and polar ice sheets. Most at risk are low-lying areas. Examples of sites that are already close to sea level include much of the metropolitan area of San Juan in Puerto Rico.

Changes in Storm Intensity and Frequency

- Hurricane wind speeds and rainfall rates are likely to increase.

Changes in Stream /Lake Temps

- N/A

Region: Coasts Generally

Changes in Ocean Temperature and Circulation

- Coastal waters are very likely to continue to warm by as much 4 to 8°F in this century, both in summer and winter. This will result in a northward shift in the geographic distribution of marine life along the coasts; this is already being observed.

- Climate change will affect winds and currents that move along the nation's coasts and possibly the larger scale natural oscillations (e.g., El Nino) as well, though these effects are not yet well understood.

Changes in Sea and Great Lakes Levels

- Estimates for the rise of global sea level rise range from .6 to 1.9 feet by 2100 (IPCC). Many think these figures are low because they do not factor in the potential response of glaciers and polar ice sheets.

- Even a 2-foot rise in relative sea level over a century would result in the loss of a large portion of the nation's remaining coastal wetlands, as they are not able to build new soil at a fast enough rate. Accelerated sea-level rise would affect sea grasses, coral reefs, and other important habitats. It would also fragment barrier islands, and place into jeopardy existing homes, businesses, and infrastructure, including roads, ports, and water and sewage systems. Portions of major cities, including Boston and New York, would be subject to inundation by ocean water during storm surges or even during regular high tides

Changes in Storm Intensity and Frequency

- Hurricane wind speeds and rainfall rates are likely to increase.

Changes Water Chemistry:

- Projections call for continued decreases in ocean pH resulting in increased ocean acidification. Combined with warmer temps will be problem for corals, mollusks, and shellfish.

- Coastal dead zones in places such as the northern Gulf of Mexico and the Chesapeake Bay are likely to increase in size and intensity as warming increases, unless efforts to control runoff of agricultural fertilizers are redoubled. Greater spring runoff into East Coast estuaries and the Gulf of Mexico would flush more nitrogen into coastal waters, stimulating harmful blooms of algae and the excess production of microscopic plants that settle near the seafloor and deplete oxygen supplies as they decompose.

APPENDIX F: SOURCES OF INFORMATION FOR PROGRAMS AND PRACTITIONERS

PRIMARY REFERENCES

U.S. Global Change Research Program: The U.S. GCRP, formerly the U.S. Climate Change Science Program (CCSP), supports research on the interactions of natural and human-induced changes in the global environment and their implications for society. The U.S. GCRP began as a presidential initiative in 1989 and was codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606), which mandates development of a coordinated interagency research program. One important function of the group has been to produce Climate Change Synthesis and Assessments Products, which now include:

1-1 Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences
1-2 Past Climate Variability and Change in the Arctic and at High Latitudes
1-3 Re-analyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change.
2-1 Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Application
2-2 North American carbon budget and implications for the global carbon cycle
2-3 Aerosol properties and their impacts on climate
2-4 Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure
3-1 Climate Change Models: An Assessment of Strengths and Limitations
3-2 Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols
3-3 Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific islands.
3-4 Abrupt Climate Change
4-1 Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region
4-2 Thresholds of Change in Ecosystems
4-3 The effects of climate change on agriculture, biodiversity, land, and water resources
4-4 Preliminary review of adaptation options for climate-sensitive ecosystems and resources
4-5 Effects of Climate Change on Energy Production and Use in the United States
4-6 Analyses of the effects of global change on human health and welfare and human systems
4-7 Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study
5-1 Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions.
5-2 Best practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decision making.
5-3 Decision support experiments and evaluations using seasonal to interannual forecasts and observational data. http://www.climatescience.gov/Library/sap/sap-summary.php.

Since its inception, U.S. GCRP-supported research and observational activities, in collaboration with several other national and international science programs, have documented and characterized

important aspects of the sources, abundances, and lifetimes of greenhouse gases; mounted extensive space-based systems for global monitoring of climate and ecosystem parameters; begun to address the complex issues of various aerosol species that may significantly influence climate parameters; advanced understanding of the global water and carbon cycles; and taken major strides in computer modeling of the global climate. http://www.usgcrp.gov/usgcrp/default.php

IPCC – Fourth Assessment Report (AR4): This latest assessment by the IPCC forms the standard scientific reference for all those concerned with the consequences of climate change. The Assessment is composed of 4 reports:

* Working Group I Report "The Physical Science Basis." Working Group I contribution to the IPCC's Fourth Assessment Report (AR4) provides a comprehensive assessment of the physical science of climate change and continues to broaden the view of that science, following on from previous Working Group I assessments. The results presented are based on the extensive scientific literature that has become available since completion of the IPCC's Third Assessment Report, together with expanded data sets, new analyses, and more sophisticated climate modeling capabilities.
http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm

* Working Group II Report: "Impacts, Adaptation and Vulnerability." This report provides a comprehensive and up-to-date scientific assessment of the impacts of climate change, the vulnerability of natural and human environments, and the potential for response through adaptation. The report makes a detailed assessment of the impacts of future climate change and sea-level rise on ecosystems, water resources, agriculture and food security, human health, coastal and low-lying regions and industry and settlements; provides a complete new assessment of the impacts of climate change on major regions of the world (of note: North America, polar regions and small islands); considers responses through adaptation; explores the synergies and trade-offs between adaptation and mitigation; evaluates the key vulnerabilities to climate change, and assesses aggregate damage levels and the role of multiple stresses.
http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm

* Working Group III: Mitigation. The third volume of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) provides an in-depth analysis of the costs and benefits of different approaches to mitigating and avoiding climate change.
http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=0

* Climate Change 2007 Synthesis Report: *Contribution of Working Groups I, II and III.* This Synthesis Report with its Summary for Policymakers is the fourth and final part of AR4 – "Climate Change 2007". It summarizes the findings of the three Working Group reports and provides a synthesis that specifically addresses the issues of concern to policymakers in the domain of climate change: it illustrates the impacts of global warming already under way and to be expected in future, and describes the potential for adaptation of society to reduce its vulnerability; finally it presents an analysis of costs, policies and technologies intended to limit the extent of future changes in the climate system. By drawing together and integrating up to date policy-relevant scientific, technical and socio-economic information on climate change the report is intended to assist governments and other decision-makers in the public and private sector in formulating and implementing appropriate responses to the threat of human-induced climate change. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

GENERAL MULTI-PURPOSE SITES:

NOAA Webpage on Climate Activities: Contains links to various NOAA climate programs related to (1) Climate Observations and Monitoring; (2) Climate Research and Modeling; (3) Climate Information Services; and Operational Climate Program. http://www.noaa.gov/climate.html

NOAA Climate Program Office Homepage: NOAA's Climate Program Office (CPO) provides strategic guidance and oversight for the agency's climate science and services programs. Designed to build knowledge of climate variability and change—and how they affect our health, our economy, and our future—the CPO's programs have three main objectives: describe and understand the state of the climate system through integrated observations, monitoring, and data management; understand and predict climate variability and change from weeks to decades to a century into the future; and improve society's ability to plan and respond to climate variability and change. The CPO funds high-priority climate research to advance understanding of atmospheric and oceanic processes as well as climate impacts resulting from drought and other stresses. This research is conducted in most regions of the United States and at national and international scales, including in the Arctic. Recognizing that climate science literacy is a prerequisite for putting this new knowledge into action at all levels of society, the CPO also helps to lead NOAA's climate communication, education, and professional development and training activities.
http://www.cpo.noaa.gov/index.jsp

NOAA CSC Coastal Climate Adaptation: An inventory of state and local adaptation initiatives and tools that also includes basic climate change information.
http://community.csc.noaa.gov/climateadaptation/

National Climatic Data Center (NCDC), Climate Monitoring: The NCDC monitoring section includes U.S. and global reports, research, maps, datasets, and indices related to climate monitoring. Information includes: Climate At A Glance; U.S. Temperature and Precipitation 2000-2009; Weekly Maps; Daily ASOS Maps; National Climate Impact Indicators; Drought Monitoring; Extreme Climates in the U.S.; Hurricanes and Tropical Storms; Snow and Ice Data; Download Climate Information Record (CIRs) Data; Special Reports; Global Climate Change; Global Surface Temperature Trends; NSIDC Arctic and Antarctic Sea Ice; Recent Extremes and Climate Trends; Climatic Extremes; U.S. Gridded Population; Stratospheric Ozone; U.S. Heat Stress Index Data; Hazards Support; Map of U.S. Climate Regions; Map of U.S. Climate Divisions (large); Map of U.S. Climate Divisions (small); and Climate and Network Monitoring
http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html

EPA Climate Change Website: The EPA climate change Web site has a wide variety of information including: basic information; FAQs; past, recent, and future climate change, greenhouse gas emissions inventories and projects; health and environmental effects of climate change; energy production and use; US climate policy; climate economics (economic analyses, long-term scenarios, non-co2 mitigation) and other resources. http://epa.gov/climatechange/index.html

EPA Climate Ready Estuaries Coastal Toolkit: provides resources for programs that are interested in learning more about climate change impacts and adaptation. The Toolkit pages below provide information and links to websites, reports, and other resources related to the following areas: Monitoring Climate Change Where to Find Data, Coastal Vulnerability and Adaptation Tools; Adaptation Planning; Smart Growth in the Context of Climate Change; Sustainable Financing Options; Communications and Outreach Materials. http://www.epa.gov/cre/toolkit.html

DOE Climate Change Sciences Program: This Department of Energy (DOE) program includes process research and modeling efforts to (1) improve understanding of factors affecting the Earth's radiant-energy balance; (2) predict accurately any global and regional climate change induced by increasing atmospheric concentrations of aerosols and greenhouse gases; (3) quantify sources and sinks of energy-related greenhouse gases, especially carbon dioxide; and (4) improve the scientific basis for assessing both the potential consequences of climatic changes, including the potential ecological, social, and economic implications of human-induced climatic changes caused by increases in greenhouse gases in the atmosphere and the benefits and costs of alternative response options The Environmental Processes subprogram is DOE's contribution to the U.S. Climate Change Science Program, a program that integrates federal research on global and climate change. http://www.er.doe.gov/OBER/CCRD_top.html

Pew Center on Global Climate Change: Information on global warming, climate change science and impacts, technology solutions, adaptation, policy and legislation and economics. http://www.pewclimate.org/

The Climate Impacts Group Website: The Climate Impacts Group (CIG), part of the Center for Science in the Earth System at the University of Washington's Joint Institute for the Study of the Atmosphere and Ocean (JISAO), is an interdisciplinary research group studying the impacts of natural climate variability and global climate change on the U.S. Pacific Northwest. The CIG's research focuses on four key sectors of the Pacific Northwest environment: water resources, aquatic ecosystems, forests, and coasts. The CIG website has information on the Northwest climate variability, change and impacts; Research on regional climate, hydrology and water resources, forest ecosystems aquatic ecosystems, coastal environments, societal dimensions, and integrated assessments; Forecasts and planning tools; publications and links to data. http://cses.washington.edu/cig/

Union of Concern Scientists –Global Warming Site: The Union of Concerned Scientists website contains information on global warming science, impacts and solutions. It also includes a number of regional climate change impact assessments they have prepared for Western, Midwestern, Northeastern, Southeastern, Southwestern and most recently Gulf States. http://www.ucsusa.org/global_warming/

Intergovernmental Panel on Climate Change: The Intergovernmental Panel on Climate Change (IPCC) is a leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences. http://www.ipcc.ch/

United Nations Environment Programme - Climate Change: Has a wealth of information on climate change with focus areas on climate change science, adaptation, mitigation, sustainable buildings and construction. http://www.unep.org/climatechange/Home/tabid/389/language/en-US/Default.aspx

CLIMATE CHANGE IMPACTS IN UNITED STATES

Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.), Cambridge University Press, 2009. This report summarizes the science of climate change and the impacts of climate change on the United States, now and in the future. It is largely based on results of the U.S. GCRP, and integrates those results with related research from around the world. This report discusses climate-related impacts for various societal and environmental sectors and regions across the nation. www.globalchange.gov/usimpacts. Specific projected **regional impacts** can be found at http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts

Potential Impacts of Climate Change in the US, Congressional Budget Office (2009): This Congressional Budget Office (CBO) paper—prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources—presents an overview of the current understanding of the impacts of climate change in the United States, emphasizing the wide range of uncertainty about the magnitude and timing of those impacts and the implications of that uncertainty for the formulation of effective policy responses. The analysis draws from numerous published sources to summarize the current state of climate science and provide a conceptual Framework for addressing climate change as an economic concern. In keeping with CBO's mandate to provide objective, impartial analysis, the paper makes no recommendations. www.cbo.gov/ftpdocs/101xx/.../05-04-ClimateChange_forWeb.pdf

U.S. EPA, Synthesis of Adaptation Options for Coastal Areas (2009): This guide, produced by the EAA Climate Ready Estuaries Program, provides a brief introduction to key physical impacts of climate change on estuaries and a review of on the-ground adaptation options available to coastal managers to reduce their systems' vulnerability to climate change impacts. The guide focuses on climate change adaptation for estuaries and coastal areas. The guide is organized as follows: Overview of key climate change impacts on coastal areas; existing adaptation options as they relate to estuarine management goals (e.g. wetlands protection); and selected resources for further information. www.epa.gov/CRE/downloads/CRE_Synthesis_1.09.pdf

North American Regional Climate Change Assessment Program (NARCCAP): is an international program that serves the climate scenario needs of the United States, Canada, and northern Mexico, using regional climate model, coupled global climate model, and time-slice experiments. NARCCAP produces high resolution climate change simulations in order to investigate uncertainties in regional scale projections of future climate and generate climate change scenarios for use in impacts research. NARCCAP modelers are running a set of regional climate models (RCMs) driven by a set of atmosphere-ocean general circulation models (AOGCMs) over a domain covering the conterminous United States and most of Canada. http://www.narccap.ucar.edu/

The Fourth United States Climate Action Report (2006): The fourth CAR provides an update on key activities conducted by the U.S. since 2002, an inventory of U.S. greenhouse gas emissions and sinks, an estimate of the effects of mitigation measures and policies on future emissions levels, and a description of U.S. leadership and involvement in international programs, including associated contributions and funding efforts. In addition, the text discusses U.S. national circumstances that affect U.S. vulnerability and responses to climate change. Finally, the CAR presents information on the U.S. Climate Change Science Program, the U.S. Climate Change Technology Program, our efforts in systematic observations, including the U.S. Integrated Earth Observation System, and our education, training and outreach efforts. The report takes into account activities up to and including 2006. http://www.state.gov/g/oes/rls/rpts/car/index.htm

Northeast Climate Impacts Assessment: The Northeast Climate Impacts Assessment (NECIA) is collaboration between the Union of Concerned Scientists (UCS) and a team of more than fifty independent experts to develop and communicate a new assessment of climate change, impacts on climate-sensitive sectors, and solutions in the northeastern United States. Launched in May, 2005, the goal of the assessment is to combine state-of-the-art analyses with effective outreach to provide policymakers, opinion leaders, and the public with the best available science upon which to base informed choices about climate change mitigation and adaptation. In Phase I of the Northeast Climate Impacts Assessment (completed in October 2006), collaborating scientists developed a core set of climate projections for the Northeast region. These projections were used as the basis for Phase II of the assessment (completed in spring 2007), which explored impacts of projected climate change on key climate-sensitive sectors. http://www.northeastclimateimpacts.org/

***Regional Climate Change Projections for the Northeast U.S. (2007)*:** This paper demonstrates how both statistical and dynamical downscaling methods applied to relatively coarse-scale atmosphere-ocean general circulation model output are able to improve simulation of spatial and temporal variability in temperature and precipitation across the region. The researchers then developed high-resolution projections of future climate change across the northeast U.S., using IPCC emission scenarios combined with these downscaling methods. The projections show increases in temperature that are larger at higher latitudes and inland, as well as the potential for changing precipitation patterns, particularly along the coast. While the absolute magnitude of change expected over the coming century depends on the sensitivity of the climate system to human forcing, significantly higher increases in temperature and in winter precipitation are expected under a higher as compared to lower scenario of future emissions from human activities. www.northeastclimateimpacts.org/pdf/miti/hayhoe_et_al.pdf

Climate Change and the Chesapeake Bay: State of the Science Review and Recommendations A Report from the Chesapeake Bay Program Science and Technical Advisory Committee. This report addresses the U.S. EPA's Chesapeake Bay Program charge to the Bay Program's Scientific and Technical Advisory Committee (STAC) to review the current understanding of climate change impacts on the tidal Chesapeake Bay and identify critical knowledge gaps and research priorities. The report also provides the basis for incorporating climate change considerations into resource management decisions. http://www.chesapeake.org/stac/Pubs/climchangereport.pdf

Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage (2001). This report, released by the Union of Concerned Scientists and the Ecological Society of America and written by university and government scientists in the Gulf States, examines the potential impacts of climate change upon the various ecosystems of this diverse and rich region: http://www.ucsusa.org/gulf/gcchallengereport.html

Confronting Climate Change in the Great Lakes Region: Impacts on Our Communities and Ecosystems (2003): This report, released by the Union of Concerned Scientists and the Ecological Society of America, and written by university and government scientists in the Great Lakes region, examines the potential impacts of climate change upon the various ecosystems of this diverse and rich region. http://www.ucsusa.org/greatlakes/glchallengetoc.html

Regional Impacts of Climate Change, for Pew Center on Global Climate Change (December 2007). Four case studies in the United States examines impacts of particular interest to different regions of the country including: the Midwest, the West, the Gulf Coast and the Chesapeake Bay. http://www.pewclimate.org/regional_impacts

The US Environmental Protection Agency Climate Variability: EPA maintains a Web site on climate variability and change. The "Where You Live" section of this Web site contains links to clickable maps of the World, United States, and Natural Places, as well as material on how these regions and ecosystems may be affected by climate change. The link is: http://yosemite.epa.gov/OAR/globalwarming.nsf/content/index.html

The Nature Conservancy "Climate Wizard." The ClimateWizard is a web-based analysis conducted to understand the effects of climate change. This tool uses sophisticated climate models and advanced statistical analysis to examine both the current and future climate conditions of any place on the Earth. It can produce an array of historic data going back to 1895, or projected data through 2099, bringing together for the first time the full spectrum of climatic concerns for a landscape. The web-based program—which will soon be made available to anyone with internet access—allows its user to specify any region on a map, pose a series of questions about past, present, and/or future climate variables, and then generate a spatially explicit climate change assessment of that region. ClimateWizard is designed to enhance the effectiveness of global conservation efforts by supporting the free and open sharing of climate change information and knowledge. http://climatewizard.org/

OBSERVATION SYSTEMS

Continuously Operating System (CORS) Network: A growing network of continuously operating GPS reference stations that that provide Global Navigation Satellite System (GNSS) data to support three-dimensional positioning, meteorology, space weather, and geophysical applications throughout the United States, its territories, and a few foreign countries. The CORS network is a multi-purpose cooperative endeavor involving over 200 government, academic, and private organizations. NGS partners contribute more than 1,200 independently owned and operated stations to the CORS network. The primary objective of the CORS Program is to define and maintain the National Spatial Reference System (NSRS). The CORS network provides free access to GNSS data, establishes coordinates and velocities of CORS stations with respect to the NSRS, enables

users to determine centimeter-level positions with respect to the NSRS, computes satellite orbits to support post-processes of GPS/GNSS data, and supports a host of other high precision GPS/GNSS applications.

National Water Level Observation Network (NWLON): The NWLON consists of networks of long-term and short-term water-level stations and is an "end-to-end" system of data collection, quality control, data management and product delivery. The NWLON serves as a water level datum reference system for the Nation. The tide and water-level datums derived from the NWLON have traditionally been important primarily for navigation and shoreline boundary purposes, but they will be critical in assessing accurate localize sea level change. For example, the tidal datum of Mean Lower Low Water (MLLW) is used as the reference datum, or Chart Datum, for U.S. nautical chart products in tidal waters. Similarly, Mean High Water (MHW) is used as the reference datum for the National Shoreline. http://tidesandcurrents.noaa.gov/nwlon.html

National and Regional Ocean Observing Systems: IOOS represents a national partnership in which 17 Federal agencies and 11 Regional Associations (RAs) share responsibility for the design, operation, and improvement of the national, coastal network of observations. The IOOS coastal component includes a national network of observations, data management, and modeling capacities for U.S. Ocean, coastal, and Great Lakes environments, including an extensive Federal observing capacity and 11 RAs that augment the Federal systems. Together, this nation-wide network addresses a combination of national, regional, and local priorities. IOOS works across the Federal agencies and with the regional partners to integrate data to provide a more comprehensive, detailed view of coastal, Great Lakes, and ocean environments. http://ioos.noaa.gov/partners/

National Estuarine Research Reserve System System-Wide Monitoring Program: The NERR System-wide Monitoring Program tracks short-term variability and long-term changes in estuarine waters to understand how human activities and natural events can change ecosystems. It provides valuable long-term data on water quality and weather at frequent time intervals. Coastal managers use this monitoring data to make informed decisions on local and regional issues, such as “no-discharge” zones for boats and measuring the success of restoration projects. The reserve system currently measures physical and chemical water quality indicators, nutrients and the impacts of weather on estuaries. As the program expands, plans include adding a biological monitoring component and tracking changes in land use through remote sensing. http://nerrs.noaa.gov/Monitoring/welcome.html

National Ecological Observatory Network (NEON): NEON is a large facility project funded by the National Science Foundation to manage large-scale ecological observing systems and experiments on behalf of the scientific community. The goal of NEON is to contribute to global understanding and decisions in a changing environment using scientific information about continental-scale ecology obtained through integrated observations and experiments. This new national observatory network will be the first of its kind designed to detect and enable forecasting of ecological change at continental scales over multiple decades. After partitioning the U. S. into 20 ecoclimatic domains, data will be collected from sites within each domain and synthesized into information products that can be used to describe changes in the nation’s ecosystem through space and time. http://www.neoninc.org/

Surface Elevation Tables (SETs): As described in the **U.S. Climate Change Science Program SAP4.4**, a program of geodedically linked SETs, land elevations, and tide gauges are required to evaluate the vulnerability of vegetated coastlines to the impacts of sea level rise. SETs are portable measuring instruments that have been developed to measure sub-centimeter changes in wetland surface elevations repeatedly over time. The instruments are deployed atop *in situ* wetland bench marks and provide a method of following the long-term trajectory of a wetland surface over time with respect to the bench mark. By connecting the elevation of such wetland bench marks to land elevations and to the nearest tide gauge, the relationship between sea level, land elevation, and wetland elevation can be determined. Since wetland elevation trajectories are different from those of adjacent uplands, this combined approach allows researchers and managers to evaluate coastal habitat vulnerability in the face of local sea level rise.

The Millennium Ecosystem Assessment: The Millennium Ecosystem Assessment (MA) was called for by the United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, the objective of the MA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MA involved the work of more than 1,360 experts worldwide. Their findings, contained in five technical volumes and six synthesis reports, provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems. See: http://www.millenniumassessment.org/en/Index.aspx

SEA LEVEL CHANGE INFORMATION AND TOOLS

Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region: U.S. Climate Change Science Program Synthesis Assessment Product 4.1. The focus of this report is to identify and review the potential impacts of future sea level rise based on present scientific understanding. This report describes potential changes to barrier islands, wetlands, other coastal habitat, and vulnerable species; societal impacts and implications of sea-level rise; decisions that may be sensitive to sea-level rise; opportunities for adaptation; and institutional barriers to adaptation. It also outlines current coastal policy in the mid-Atlantic region and describes the implications for the other regions of the United States. The report also discusses opportunities for natural and social science research to enhance understanding of potential impacts of sea-level rise and society's ability to respond. http://www.climatescience.gov/Library/sap/sap4-1/default.php

NOAA's National Geodetic Survey (NGS) manages the National Spatial Reference System (NSRS) which is the national coordinate system that defines latitude, longitude, height, scale, gravity and orientation throughout the United States. NSRS comprises a consistent, accurate, and up-to-date national shoreline; a network of continuously operating reference stations (CORS) which supports 3-dimensional positioning activities, including crustal velocities; a network of permanently marked reference points (or bench marks); and a set of accurate models describing dynamic, geophysical processes that affect spatial measurements. In particular, NGS is developing a new national gravity

model for increased accuracy of GPS-derived heights. NGS also provides a national array of State Geodetic Advisors, who can provide expert technical assistance and guidance to local geodetic projects; the Height Modernization program provides support for states to update the elevations on state-wide bench marks. NGS provides technical support for SET-based coastal/wetland monitoring efforts, to characterize coastal vulnerability to local sea level rise. More information on NGS can be obtained at http://www.ngs.noaa.gov/ and for NGS products and services at http://www.ngs.noaa.gov/products_services.shtml

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS): CO-OPS operates and maintains the National Water Level Program and the National Water Level Observation Network. This network provides up to two hundred years of water level and tidal datums in at these stations--information that is critical in helping understand trends in sea level rise, the impact of coastal storms and El Nino-type events, and the impact of long-term falling water levels in the Great Lakes. CO-OPS recently created the Coastal Oceanographic Applications and Services of Tides and Lakes (COASTAL) Program to focus on these non-navigational uses of water-level and datum information. They include beneficial uses of dredged material, coastal planning projects, marsh restoration projects, long-term sea-level assessments, storm-surge monitoring, emergency preparedness, and HAZMAT response. http://www.co-ops.nos.noaa.gov/index.shtml and COASTAL at http://www.co-ops.nos.noaa.gov/coastal.html

NOAA CO-OPS Sea Levels Online: Provides a map with illustrating regional trends in sea level, with arrows representing the direction and magnitude of change a t various water level stations. Users can click on a trend arrow to access additional information about that station. http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

NOAA's NCDDC Coastal Risk Atlas: The Coastal Risk Atlas (CRA) project goals aim at aiding hurricane preparedness efforts by providing the data and methodology necessary to conduct vulnerability assessments for the coastal United States. Provided data include: acquired hazard model outputs such as storm surge, maximum winds, and inland flooding to help locate vulnerable areas; U.S. Census demographic data to help locate vulnerable populations; critical facilities such as police and fire stations, emergency centers, and hospitals; base layers such as evacuation routes and other roadways, streams, water bodies, and land use data showing economic sectors within the community; boundary areas such as evacuation zones and populated places. Resources available through the CRA include: vulnerability assessment mapping, national observations and vulnerability mapping, downloadable ARCGIS extensions; downloadable data; and links to GIS and emergency management resources. http://www.ncddc.noaa.gov/cra/

NOAA Coastal Service Center's Digital Coast: The Digital Coast is an information delivery system that serves not only data, but also the training, tools, and examples needed to turn data into useful information. Launched in 2008, phase one of the site focused on content provided by the NOAA Coastal Services Center, subsequent phases are adding content from other sources including: Association of State Floodplain Managers; Coastal States Organization; National Association of Counties; National States Geographic Information Council, and the Nature Conservancy. Digital data includes digital orthoimagery, elevation, benthic, land cover, hydrography and marine boundaries. Digital Tools include: Habitat Priority Planner-which can help to identify priority locations for conservation and restoration planning; Sea Level Affecting Marshes Model- which

simulates potential impacts of long-term sea level rise on wetlands and shorelines; Digital Shoreline Analysis System- which computes rate-of-change statistics from multiple historic shoreline positions; and eCoastal Tools- which provides data management and analysis solutions for coastal engineering projects. Relevant digital training includes: a coastal inundation mapping course. Case studies are also provided. http://www.csc.noaa.gov/digitalcoast/index.html

The LIDAR Data Retrieval Tool (LDART): LDART is a web-based application that NOAA's Coastal Service Center developed to allow customers to obtain topographic LIDAR data from its archive. LDART allows users to customize their output data set, interactively choosing geographic boundaries, projections, horizontal and vertical datums, and output file formats. LDART can be used to generate custom elevation data sets for use in decision making, research, and for general information. http://www.csc.noaa.gov/crs/tcm/about_ldart.html

USGS Center for LIDAR Information Coordination and Knowledge: This site is a U.S. Geological Survey (USGS) resource center for LIDAR, containing a community bulletin board, data viewer, and links to other LIDAR resources. http://lidar.cr.usgs.gov/

NOAA NESDIS National Geophysical Data Center (NGDC) Bathymetry and Topography: This NOAA NESDIS site provides a variety of products and resources, including coastal relief digital elevation models, bathymetric maps, and satellite-derived data.
http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html

NOAA NESDIS National Geophysical Data Center (NGDC) Integrated Models of U.S. Coastal Relief: NGDC builds and hosts/provides access to digital elevation models (DEMs) of the U.S. coast that integrate ocean bathymetry and land topography.
http://www.ngdc.noaa.gov/mgg/coastal/coastal.html

Sea, Lake, and Overland Surge from Hurricanes SLOSH Model: The SLOSH model is a computerized model developed by the Federal Emergency Management Agency (FEMA), United States Army Corps of Engineers (USACE), and the National Weather Service to estimate storm surge depths resulting from historical, hypothetical, or predicted hurricanes by taking into account a storm's pressure, size, forward speed, forecast track, wind speeds, and topographical data. SLOSH is used to. SLOSH output is used to: evaluate the threat from storm surge; determine evacuation areas real-time and conduct Hurricane Evacuation Studies assist with the creation of state and local hurricane evacuation plans or zones. SLOSH model results are combined with roadway network and traffic flow information, rainfall amounts, river flow, or wind-driven waves to determine a final analysis of at-risk areas. http://slosh.nws.noaa.gov/sloshPub/ or
http://www.fema.gov/plan/prevent/nhp/slosh_link.shtm

USGS Sea Level Rise Efforts: The USGS role in sea-level research is national in scope and ranges from remote sensing and geologic mapping of wetlands to studies of coastal erosion and evidence of older shorelines in the geologic record. http://geochange.er.usgs.gov/poster/sealevel.html

DRAFT Addressing Elevation and Inundation Issues in Habitat Restoration Planning and Implementation A Guidance Document, National Ocean Service, Office of Response and Restoration (2004). This document was developed for coastal restoration professionals in

government, industry, academia, and non-governmental organizations who need to know whether and how to use geodetic positioning tools, water level information, and other technologies to support restoration project planning and implementation. Restoration projects must consider the requirements necessary for vegetation to grow successfully, the environment that will allow target species to flourish, the long-term stability of the habitat, and the preservation of surrounding properties. This document is designed to illustrate how NOS' tools and methods can be applied to restoration projects. These include the measurement of geodetic and water level data, the determination of reference elevations from these data, and the application of the information to a project area. http://response.restoration.noaa.gov/book_shelf/91_DRAFTelev-inundationissues90804.pdf

• **Sea Level Rise & Global Climate Change: A Review of Impacts to U.S. Coasts, Pew Center on Global Climate Change (2000)**. This Report examines the potential impacts of climate change on the U.S. environment and society. This report finds that the vulnerability of a coastal area to sea-level rise varies according to the physical characteristics of the coastline, the population size and amount of development, and the responsiveness of land-use and infrastructure planning at the local level. www.pewclimate.org/docUploads/env_sealevel.pdf

ECOSYSTEM CHANGE/RESPONSE INFORMATION AND TOOLS

Climate Change Science Program SAP4.4-- Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research (2008). Synthesis and Assessment Product 4.4 provides preliminary information on the state of knowledge regarding adaptation options for key, representative ecosystems and resources that may be sensitive to climate variability and change. The report explores potential adaptation options that could be used by natural resource managers within the context of the legislative and administrative mandates of the six systems examined: National Forests, National Parks, National Wildlife Refuges, Wild and Scenic Rivers, National Estuaries, and Marine Protected Areas. Case studies throughout this report examine in greater detail some of the issues and challenges associated with implementation of adaptation options, but are not geographically or ecologically comprehensive and do not address all adaptation options. http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-all.pdf

Regional Ecosystem Data Portal: NOAA's National Coastal Data Development Center (NCDDC) provides a coordinated data management system and data discovery mechanism for atmospheric, oceanographic, and terrestrial physical sciences to facilitate sustained economic growth, scientifically sound environmental management, and public safety to the Nation and the international community. The Regional Data Portal is an interactive, map-based catalogue of government and non-government environmental datasets provides data on physical resources, water quality, sediment quality, and marine resources. User can define searches. https://ecowatch.ncddc.noaa.gov/catalog/gmap

***Ecological Impacts of Climate Change**:* Committee on Ecological Impacts of Climate Change, National Research Council (2008). In this book, the National Research Council provides a broad overview of the ecological impacts of climate change, and a series of examples of impacts of different kinds. The book was written as a basis for a forthcoming illustrated booklet, designed to

provide the public with accurate scientific information on this important subject. http://www.nap.edu/catalog.php?record_id=12491#toc and illustrated booklet at http://dels.nas.edu/dels/rpt_briefs/ecological_impacts.pdf

NOAA National Centers for Coastal Ocean Science, Center for Sponsored Coastal Ocean Research: Coastal Ecosystem Effects of Climate Change (CEECC) Program: The outcome of this research program will be the development of tools useful for coastal managers to mitigate regional ecological impacts of sea level rise.
http://www.cop.noaa.gov/stressors/climatechange/current/slr/slr_new_intro.html

NOAA National Centers for Coastal Ocean Science, Center for Sponsored Coastal Ocean Research: 'Ecological Effects of Sea Level Rise' Project: NCCOS in consultation with NOS Office of Coast Survey, CSC and research partners (East Carolina University, University of North Carolina, University of South Carolina, and Vanderbilt) is developing a spatially explicit model of coastal marsh responses to sea-level rise for Pamlico and Core Sounds in North Carolina. NCCOS is adapting existing models that integrate vegetation responses to changes in mean sea level with sediment accretion and supply to the marsh communities and conditions of Pamlico Sound to characterize the ecological impact of SLR. The goal is to develop a 2-D landscape model for Pamlico coastal wetlands capable of forecasting changes in plant community composition, sediment accretion, and geomorphology in response to tidal forcing and sea-level rise. The ecological models will be coupled to two dimensional hydrodynamic models being developed by the Coast Survey Development to simulate tidal response, regional synoptic wind events, and hurricane storm surge propagation to study changes due to SLR. Accurate simulation of inundation patterns is accomplished by high localized resolution in the coastal zone, continuous bathy/topo data, provided by a coastal flooding model, and an accurate wetting/drying algorithm. The model will be validated against observational data before modification of initial and boundary water levels to represent eustatic SLR. Shoreline migration can be dynamically computed from the model simulation output as a function of SLR. Finally, the hydrodynamic model will be coupled to sub-models that. http://www.cop.noaa.gov/stressors/climatechange/current/sea_level_rise.html

The Sea Level Affecting Marshes Model (SLAMM): The Sea Level Affecting Marshes Model (SLAMM) uses digital elevation data, habitat data, and other information to simulate the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. SLAMM considers sediment and organic matter accumulation on the marshes, erosion from tides and storms that can overtake coastal barrier beaches, and other factors. The outputs include mapped distributions of wetlands (predicted under conditions of accelerated sea level rise), as well as summary tables and graphs. SLAMM can be downloaded and applied any area where data are available. SLAMM-View is a web-based browsing application that displays pairs of SLAMM output maps for the same area, each at different sea levels. The strength of this tool is its ability to visually show the modeling outputs of sea level rise predictions, allowing people to see the impacts in a more intuitive way. SLAMM outputs for several locations are available in SLAMM-View. Users can select different scenarios for each location by combining time, in 25-year intervals, at different severities, e.g., 0.5 meters to 1 meter increase in sea level. For more information see: http://www.slammview.org. or http://www.warrenpinnacle.com/prof/SLAMM/index.html

NOAA Climate Program Office's Regional Integrated Sciences and Assessments (RISA) program: RISA supports research that addresses complex climate sensitive issues of concern to decision-makers and policy planners at a regional level. The RISA research team members are primarily based at universities though some of the team members are based at government research facilities, non-profit organizations or private sector entities. Traditionally the research has focused on the fisheries, water, wildfire, and agriculture sectors. The program also supports research into climate sensitive public health issues. Recently, *coastal restoration* has also become an important research focus for some of the teams. For more information see: http://www.cpo.noaa.gov/cpo_pa/risa/

NOAA Climate Program Office's Sectoral Application Research Program (SARP) SAR catalyzes interdisciplinary research on the affects of and potential responses to climate variability and change in specific sectors of society. Current projects serve the Coastal and Water sectors. SARP projects include development of innovative outreach activities to enhance sector abilities to use climate information and decision support resources. http://www.cpo.noaa.gov/cpo_pa/sarp/

NOAA OAR's Atlantic Oceanographic and Meteorological Laboratory: AOML, one of OAR's research facilities, is located in Miami, Florida. AOML's mission is to conduct basic and applied research in oceanography, tropical meteorology, atmospheric and oceanic chemistry, and acoustics. The research seeks to understand the physical characteristics and processes of the ocean and the atmosphere, both separately and as a coupled system. AOML predicts and assesses decadal to centennial change http://www.aoml.noaa.gov/

DOI USGS Relevant Climate Projects: The following are some USGS projects relevant to identifying impacts to ecosystems:

- Extrinsic and Intrinsic Factors Affecting the Resilience of Corals to Climate Change, and Their Use in Designing Marine Reserves - (Principal Investigator: Charles Baekeland, Hawaii Cooperative Fishery Research Unit; Virginia Garrison, FISC)

- Forest Dieback and Carbon Relations of Coastal Forests of the Southeast under Changing Climate: Interactive Effects of Drought Severity, Hurricanes, Sea-level Rise and Coastal Management - (Principal Investigator: Thomas W. Doyle, Ph. D., NWRC)

- Predicting the Persistence of Coastal Wetlands Under Global Change - (Principal Investigators: Glenn R. Guntenspergen, PWRC and McKee, NWRC)

- Spatial And Temporal Effects Of Climate Change On Great Lake Wetlands - (Principal Investigator: Dr. Douglas A. Wilcox, GLSC)

Relevant EPA Estuary Projects: The EPA National Estuary Program is currently conducting a number of projects relevant to this guidance:

- Partnership for the Delaware Estuary (Delaware, Pennsylvania, and New Jersey): Partnership for the Delaware Estuary (PDE) will work with EPA in further quantifying and valuing the effects of climate change on the provisioning of ecosystem services in the Delaware Estuary.

This work will aid PDE in developing an adaptation plan by providing information related to the vulnerability of various habitat types and ecosystem services, options for improving resilience, and additional considerations for estuarine restoration. http://www.delawareestuary.org/

- Tampa Bay Estuary Program and Coastal Bend Bays and Estuaries Program (Florida and Texas) EPA will work with these two NEPs in organizing a workshop to initiate the *development of a manual for Gulf Coast communities to assist in incorporating climate change effects into habitat restoration and protection*. This project will identify actions for improving resiliency in estuarine restoration and protection plans in all coastal communities along the Gulf Coast. http://www.tbep.org/

USGS Climate Change Science Program: USGS Global Change Research activities strive to achieve a whole-system understanding of the interrelationships among earth surface processes, ecological systems, and human activities. Activities of the program focus on documenting, analyzing, and modeling the character of past and present environments and the geological, biological, hydrological, and geochemical processes involved in environmental change so that future environmental changes and impacts can be anticipated. http://geochange.er.usgs.gov/ . Two relevant research programs are the Exploring Future Flora, Environments, and Climates through Simulations (EFFECTS) and Climate, Land Use, and Environmental Sensitivity (CLUES) programs:

USGS Exploring Future Flora, Environments, and Climates Through Simulations (EFFECTS) Program: The goal of the program (a research activity of the U.S. Geological Survey (USGS) Earth Surface Processes Team - Central Region and funded by the USGS Earth Surface Dynamics Program) is to develop a better understanding of the potential magnitude, rate, and spatial expression of both future climate changes and their effects. This research uses a variety of numerical modeling approaches to explore the potential impacts of climate changes on species and ecosystems and the implications of these impacts for conservation and natural resource management efforts. To create higher resolution input climate datasets for models to simulate ecosystem responses to future climate change, USGS used coupled ocean-atmosphere general circulation model (OAGCM) data from the World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php). USGS Then simulated vegetation responses to future climate change USGS using mechanistic vegetation models, such as BIOME4 (Kaplan et al. 2003) and LPJ (Lund-Potsdam-Jena, Sitch et al. 2003). These models simulate the distribution of plant functional types (e.g., grass, evergreen needle-leaved trees), which can be combined to represent biomes and habitat types. Future vegetation simulations reveal the effects of changes in temperature, precipitation, and atmospheric CO2 concentrations on the distribution of simplified habitat types. http://esp.cr.usgs.gov/info/effects/

USGS Climate, Land Use, and Environmental Sensitivity (CLUES): Climatic changes cause changes in vegetation cover which in turn has a strong influence on regional climates. Therefore the relationship between climate change and vegetation cover needs to be better understood to develop more accurate regional climate change models. This project investigates vegetation response to climatic change, and vegetation-land surface impacts on climate change. The project

involves calibration of the modern relations between the range limits of plant species and climatic variables, relations that are then used: 1) to estimate past climatic fluctuations from paleo-botanical data for a number of time periods within the late Quaternary; 2) to 'validate' climate model simulations of past climates; 3) to explore the potential influences of land cover changes on climate change; and 4) to estimate the potential future ranges of plant species under a number of future climate scenarios. Methodologies and data developed by this project are being used as part of the national global change assessment of potential impacts of future climate changes. http://esp.cr.usgs.gov/info/clues/

USGS Permafrost Monitoring Program: The Department of Interior's (DOI) permafrost network in Alaska is part of a global network of permafrost monitoring stations (GTN-P) designed to monitor for changes in the solid-earth component of the earth's cryosphere. Changes in permafrost temperature and active-layer thickness reflect changes in surface climate over time, and therefore serve as useful indicators of climate change. GTN-P is one of several global networks designed to monitor for changes in the terrestrial component of the earth's climate system. The GTN-P network is able to monitor the active layer (the surface layer that freezes and thaws annually) and the thermal state of the underlying permafrost. Active layer measurements are made using automated semi-permanent surface instrument stations, whereas the deeper permafrost is monitored through periodic downhole temperature measurements in boreholes. DOI's contribution to GTN-P results from collaboration among USGS, U.S. Bureau of Land Management, and U.S. Fish and Wildlife Service. http://geochange.er.usgs.gov/poster/permafrost.html

US Army Corps of Engineers (ACE) Restoration Decision Criteria: The ACE is developing a methodology/decision criterion to compare performance of plans across multiple future scenarios. Typically, the Corps' planning process calls for the comparison of plan performance to a single, most-likely future condition. Through this comparison, Corps planners identify the plan that maximizes expected net benefits, or in the case of ecosystem restoration, the plan that is most cost-effective in achieving its objectives. However, the Corps cannot identify a single most-likely future condition when considering climate change or other broadly uncertain drivers, so methods are needed to compare performance across multiple future scenarios.

NOAA's Coral Reef Watch: NOAA's Coral Reef Watch Program's satellite data provide current reef environmental conditions to quickly identify areas at risk for coral bleaching, where corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and partial mortality become likely, and the entire colony may die. Continuous monitoring of sea surface temperature at global scales provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. When bleaching conditions occur, these tools can be used to trigger bleaching response plans and support appropriate management decisions. http://coralreefwatch.noaa.gov/

The Nature Conservancy: Helping Natural Areas Adapt to Climate Change Website: Website contains information on Climate change impacts, impacts on biodiversity, and carbon footprint calculators. http://www.nature.org/initiatives/climatechange/strategies/art19628.html

HYDROLOGY CHANGE INFORMATION AND TOOLS

Climate Change Science Program Synthesis and Assessment Product 3.3 - Weather and climate Extremes in a changing Climate (June 2008): SAP 3.3 provides an in depth assessment of the state of our knowledge about changes in weather and climate extremes in North America (and U.S. territories). The report focuses on extreme events including: temperature extremes (heat waves, frost days) heavy precipitation events, droughts, and tropical storms and hurricanes. http://www.climatescience.gov/Library/sap/sap3-3/final-report/sap3-3-final-all.pdf

USGS Hydroclimatology Program: Begun in 1990, the program seeks to develop data, understanding, and predictive capabilities related to water and associated aspects of carbon and greenhouse gases as they interact with global systems. Global Change Hydrology has two broad components: 1) investigations of hydroclimatic variability, and 2) studies of the biogeochemistry of greenhouse gases. This includes identification of seasonal variations in regional stream flow in relation to atmospheric circulation (for regional stream flow prediction and flood/drought hazard assessment); the linkage between atmospheric circulation and snowpack accumulation (for forecasting spring and summer water supply in the western United States and for flood forecasting) as well as glacier mass balance; and the physical and chemical variability in riverine and estuarine environments in relation to large-scale atmospheric and oceanic conditions (to discriminate natural from human-induced effects on such systems). It also includes documenting the long-term behavior of hydrologic systems in response to past climatic variations and changes (from decades to hundreds of thousands of years) as well as more recent (decadal) hydrologic trends. http://water.usgs.gov/osw/programs/globalchange.html

National Wetlands Inventory: Digital National Wetlands Inventory (NWI) maps developed by USFWS http://www.fws.gov/wetlands/

OCEAN TEMPERATURE

NOAA CoastWatch: NOAA CoastWatch, established in 1987, provides a variety of environmental data (i.e., sea surface temperature (SST), ocean color, winds, etc.) from several different satellite platforms covering all U.S. coastal waters, including Hawaii and Alaska. Today, SST maps support meteorological weather predictions and also support commercial and recreational activities (e.g., fishing). Biologists utilize ocean color radiometry data and derived chlorophyll-a and total suspended matter/turbidity products to identify runoff plumes and blooms and also predict HABs; and sailors and commercial shipping pilots use ocean surface vector winds for safe navigation. http://coastwatch.noaa.gov/

LAND COVER INFORMATION

NOAA Coastal Change Analysis Program: The Coastal Change Analysis Program (C-CAP) is a nationally standardized database of land cover and land change information, developed using remotely sensed imagery, for the coastal regions of the U.S. C-CAP products inventory coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years. The development of standardized, regional land

cover information enables managers to coordinate the planning of shared resources, facilitating an ecosystem approach to environmental issues that transcends local and state regulatory boundaries. C-CAP has recently released two time periods of mapping for all of the Conterminous United States (CONUS), and is now working to update these products. The goal is to have this 2005/06 update complete by 2010, so that we can then start on the next update cycle. http://www.csc.noaa.gov/crs/lca/ccap.html

USGS Land Cover Characterization Program: (USGS) National Mapping Division has initiated a Land Cover Characterization Program to provide land cover and vegetation data for inventory, monitoring, modeling, and management in the public and private sectors. The Program's general goal is a multi-scale, multi-purpose land characteristics data base using: various types of satellite imagery, digital ortho-quads combined with ancillary data to produce a multilevel, geographically referenced land cover data base for global change research. The ortho-quads are as a source for land cover and land use interpretations in selected urban areas for the National Water Quality Assessment (NAWQA) Program. A selection of current land cover applications ongoing within USGS includes biodiversity conservation, water quality and assessment, phenology of ecosystems, and assessing the rates, causes and consequences of contemporary United States land cover change. Land cover research and applications is now a significant growth area in the world of science and we can expect to see further opportunities in the coming years.
http://landcover.usgs.gov/index.php

Measuring and Reducing Greenhouse Gas Emissions

The U.S. Carbon Cycle Science Program (CCSP) is an interagency partnership that draws on the expertise and ongoing research in numerous agencies (e.g., Agriculture, Commerce, Energy, Interior, NASA and National Science Foundation), with the objective of developing a whole-system predictive capability for the global carbon system. The ultimate goal is to provide integrated estimates of carbon sources and sinks, with a focus in FY 2000 on implementing activities to determine the magnitude, location, and cause of the North American terrestrial sink. The program will develop the understanding of how sinks might be enhanced and how they might change in the future, information that is of critical importance to potential decisions to manage the carbon system. http://www.carboncyclescience.gov/

DOE Carbon Sequestration Program Website: This website details the DOE's program to provide a science-based assessment of the prospects and costs of carbon sequestration. The program will focus on a number of approaches including improving full life-cycle carbon uptake of terrestrial ecosystems that may be the most relevant to these Guidelines.
http://www.fossil.energy.gov/programs/sequestration/ and
http://www.fossil.energy.gov/programs/sequestration/terrestrial/index.html

USGS Carbon Cycle Research: USGS research is conducted in cooperation and partnership with other agencies and academic collaborators. In direct support of the Carbon Cycle Science Program, the USGS activities include the following:

Carbon sequestration in sediments - Redeposition of eroded soils and sediments and their associated organic carbon is sequestering large quantities of carbon, buried at the base of slopes and in wetlands, riparian areas, reservoirs, etc. Field-based measurements and modeling are developing a quantitative understanding of the role of land-use change and associated erosion and sedimentation processes on carbon storage and nutrient cycles within the Mississippi Basin. Rates of organic carbon accumulation, erosion, and burial are being used to develop whole-basin models of these dynamic relationships.

USGS Fate of Carbon in Northern Landscapes - Cold region forests (boreal ecosystems) contain large carbon reserves that are today highly susceptible to changes in climate. Soils and wetlands comprise more than 2/3 of the boreal carbon reserves, and changes in fire and seasonal temperatures may cause changes in ecosystem structure, permafrost recovery, nutrient cycling, and carbon exchange. Central to the fate of these carbon reserves is the interaction between fire occurrence and permafrost changes in the surface layers. Process studies and modeling are being expanded to better understand the historic and modern interactions among climate, surface temperature and moisture, fire, and terrestrial carbon sequestration.
http://geochange.er.usgs.gov/carbon/

STATE LEVEL RESOURCES

California

California Climate Portal: http://www.climatechange.ca.gov/index.php

Coastal Conservancy Climate Change Policy and Project Selection Criteria– Guidelines to consider climate change in projects: http://www.scc.ca.gov/index.php?title=draft_climate_change_policy_and_project__2009&more=1&c=1&tb=1&pb=1

Maryland

MD Commission on Climate Change: http://www.mdclimatechange.us/

Florida

Climate Commission: http://www.myfloridaclimate.com/
Green Building Standard: http://www.flsenate.gov/data/session/2008/House/bills/billtext/pdf/h713503er.pdf

Maine

Climate Change Institute: http://www.climatechange.umaine.edu/
Climate Action Plan: http://www.maine.gov/dep/air/greenhouse/

New York

New York DEC Climate Change Information Resources: http://www.dec.ny.gov/energy/50399.html
Metropolitan Climate Change Information Resources: http://ccir.ciesin.columbia.edu/nyc/

North Carolina

Climate Action Plan Advisory Group (CAPAG) http://www.ncclimatechange.us/

South Carolina

South Carolina Climate, Energy & Commerce Advisory Committee http://www.scclimatechange.us/

The Impact of Climate Change on South Carolina:
http://www.dnr.sc.gov/climate/sco/Publications/climate_change_impacts.php

Oregon:
Oregon Climate Change Portal http://www.warmoregon.org/ENERGY/GBLWRM/Portal.shtml

Washington: Department of Ecology Climate Site: http://www.ecy.wa.gov/climatechange/

OTHER PUBLICATIONS:

- *Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress*. NOAA Workshop summary report: http://spo.nwr.noaa.gov/tm/spo95.pdf

- *Incorporating Climate Change into Environmental Assessments:*
http://www.ceaa.gc.ca/default.asp?lang=En&n=9699932C-1&toc=show&offset=10#s4_1

- *Comprehensive Everglades Restoration Plan Adaptive Management Strategy Management*
http://www.evergladesplan.org./pm/program_docs/adaptive_mgmt.aspx

- *Economic Valuation of Natural Resources -- A Handbook for Coastal Resource Policymakers*
http://www.mdsg.umd.edu/programs/extension/valuation/handbook.htm

- *Guidance Manual for Tidal Hydrology Restoration in the Southeastern United States*
http://www.csc.noaa.gov/restoration_workshop/index.html

- *Reef Manager's Guide to Coral Bleaching* http://www.coris.noaa.gov/activities/reef_managers_guide/pdfs/reef_managers_guide.pdf

- *Science-Based Restoration Monitoring of Coastal Habitats* http://coastalscience.noaa.gov/ecosystems/estuaries/restoration_monitoring.html