

PROCEEDINGS FROM THE SEA LEVEL RISE AND INUNDATION COMMUNITY WORKSHOP

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About This Report

The National Oceanic and Atmospheric Administration (NOAA) and U.S. Geological Survey (USGS), in partnership with other federal agencies and the Ocean Research and Resources Advisory Panel, are supporting a coordinated effort to develop a Community Framework for Responding to Sea Level Rise and Inundation. This effort to build a community of practice began with an assessment of the current understanding of coastal inundation impacts on coastal communities, of the requirements to assess and respond to changing coastal vulnerability, and of the status of prototype tools to identify critical risk factors and develop effective responses. Building on this shared sense of urgency, and the substantial efforts to develop effective responses, the first workshop (reported here) brought together leaders in the academic, federal, and nonfederal governmental, nongovernmental, and private sectors to initiate a framework for a more coordinated and effective response to sea-level rise and coastal inundation. This report details the framework, discussions on priority data, tools, and information, and recommendations for progress. The information gathered in preparation for this workshop, including a review of needs assessments for inundation information and three case studies of regions working on adaptation to sea level rise, also are included in this report.

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Executive Summary

Sea level rise and inundation were stated to be among the highest priorities in the community-developed Ocean Research Priorities Plan and Implementation Strategy in 2005. Although they remain stated priorities, very few resources have been allocated towards this challenge. Inundation poses a substantial risk to many coastal communities, and the risk is projected to increase due to continued development, changes in the frequency and intensity of inundation events, and acceleration in the rate of sea level rise along vulnerable shorelines.

There is an increasing urgency for federal and state governments to (1) focus on sea level rise adaptation at the local and regional levels and (2) consistently provide the information, tools, and methods necessary for adaptation. Calls for action at all levels acknowledge that a viable response must engage federal, state, and local expertise, perspectives, and resources in a coordinated and collaborative effort. In December of 2009, a workshop brought together leaders from a range of these communities to discuss and develop a framework on coastal inundation and sea level rise in order to help guide where investments should be made to enable states and local governments to assess impacts and initiate adaptation strategies over the next decade.

Framework

The framework is designed to help coastal communities structure and facilitate ongoing, community-wide adaptation processes to increase their resilience to sea level rise and inundation. The process used to apply this framework and implement the plans will be of much greater value if it is implemented collaboratively across neighboring communities. The process must be flexible, opportunistic, and embrace leadership from multiple quarters. The challenge is to have communities begin to internalize the need to plan for a “new normal” if they are to create resilient communities.

While the framework is presented as a linear process, in practice many steps will occur simultaneously and the process will be iterative in its application. The process must be dynamic in order to respond to new data and information. Outreach and communication must begin at the outset and be frequent and consistent throughout. After some experience has been gained, the most effective strategies need to be codified, institutionalized, and applied across all vulnerable communities.

Abbreviated Framework

Define the Problem and State It Richly

1. Explore the issues of sea level rise and inundation with the community to develop a shared vision of what is at risk and the qualities stakeholders want to protect in the face of a rising sea
2. Identify the geographic scope of the project area and the time scales of concern
3. Identify and recruit critical partners and stakeholders (including nontraditional partners), and then clarify roles and responsibilities

Gather the Data, Information, and Tools

4. Characterize the current and future states of sea level rise and inundation for the project area
5. Identify critical data, information, and tools that need to be refined or developed to reduce uncertainty
6. Secure or develop the necessary data, information, and tools

Identify and Explore Alternative Strategies

7. Identify and evaluate the various strategies for dealing with the projected sea level rise and inundation scenarios to protect the qualities identified in step 1

Build and Sustain Capacity and Support

8. Develop and continually support a comprehensive communication strategy
9. Build the institutional capacity and the political will to execute the strategies selected
10. Institutionalize the program and keep current

The workshop built upon substantial existing efforts and engaged committed leaders. The workshop participants considered setting priorities for the information and tool development necessary to mobilize those coastal communities that are struggling to understand the consequences of coastal inundation and sea level rise in terms of their particular community values. Consideration of the roles and responsibilities of participating agencies and organizations and the lessons learned from previous experiences were important outcomes of the workshop.

Data and Tools

For sea level rise planning and implementation (as with any science-based decision-making process), the requirements for high-quality data and information are vast. Overall, participants stressed the importance of data interoperability to (1) eliminate known incompatibilities and (2) ensure that users are able to apply data from a variety of sources.

The following six categories of data are needed to support future sea level rise planning and implementation:

1. *Data to understand land forms and where and how water will flow:* This includes data on geomorphology, topography, bathymetry, vertical datums, etc.
2. *Monitoring data and environmental drivers:* This includes data on tides, water levels, waves, precipitation, historical and predictive shoreline erosion data, local sediment budget, etc.
3. *Consistent sea level rise scenarios and projections across agencies to support local planning:* This includes data not only on the amount of sea level rise projected within a given area, but also on storm frequency information and the general time frame within which these changes are anticipated.
4. *Data to characterize vulnerabilities and impacts of sea level rise:* This includes data on population, land use, buildings and critical infrastructure, natural resources, economic information, etc.
5. *Community characteristics:* This includes data on demographics, societal vulnerabilities, economic activity, public attitudes and understanding of risks, etc.
6. *Legal frameworks and administrative structure:* This includes data on zoning, permitting regimes, legislative restrictions, etc.

Each of these categories of data is important to plan for and adapt to the impacts of inundation and sea level rise. To develop a meaningful and effective sea level rise adaptation plan, state and local planners must (1) understand the vulnerabilities specific to their communities and (2) be able to generate a clear understanding of the communities' dynamics and overall composition, perspectives on risk, economic drivers, and potential challenges in adopting new guidelines or adaptation measures.

The tools necessary for adaptation planning are difficult to prioritize, because they depend upon where each community is in the planning process. Adaptation tools need to be understood in terms of input data requirements, assumptions of the method, and the reliability and utility of the outputs. This type of information would assist the community in choosing among the available options. Tools need to be easy to access, have a transparent method, and produce output that is actionable and can be incorporated into an existing decision-making process. A suite of tools that work together to support planning and decision-making would be ideal. The following categories of tools are needed to support future sea level rise planning and implementation:

- Communication tools for stakeholder engagement, visioning, and consensus building
- Tools to monitor and model current and future states
- Visualization and scenario-building tools
- Implementation tools to build institutional capacity and implement adaptation plans

Roles and Responsibilities

Successful adaptation planning will require that all sectors—federal, state, local, academic, non-governmental, and private—to work together throughout the process to provide local communities with resources, as well as scientific and political support.

- Federal agencies will be relied upon by states and communities to develop and sustain collaboration and coordination mechanisms across agencies at the national and regional levels that will provide the funding and guidance for research, monitoring, model development, and implementation at the local level.
- State agencies—individually and through regional alliances—will play a key role in balancing the interests of the many community members involved in adaptation planning and implementation. They will link federal and regional efforts to those of local municipalities and communities to promote consistency and comparability across political jurisdictions.
- Local communities—with their land-use responsibilities—bear the most responsibility to plan, implement, and enforce adaptation strategies to achieve and maintain a sustainable community in a changing environment. They will need to request resources and guidance and will expect assistance from other community members.
- Academic communities will be critical links between the most recent and credible information from the scientific community and government organizations with specific needs for scientific information.
- Non-governmental organizations are sources for leadership and advocacy of the adaptation process.
- Private organizations—for example, design, consulting, tourism, energy, insurance, investment, and real estate development—will be important partners in understanding and meeting community needs.

Findings and Recommendations

- Communities have experience with storm and hazardous events, and the post-event response typically is to try and return the community to normal (that is, how it was prior to the event). With sea level rise, there will need to be a shift in perception and response from storm events to sea level rise. With sea level rise, the environment is actually changing; it is not a single event that happens and then gives the community time to return to the pre-event state. People must collectively arrive at a new vision for their community in light of a changing environment.
- Although there is a broad constituency that does not know the issue well, many communities are savvy about the impacts of sea level rise—but lack the funding to (1) conduct research to understand the local impacts, (2) make adaptation plans, and (3) implement adaptation plans. However, armed with the available information, resources, and an understanding of the uncertainties, many communities are ready to take action.
- There is no single agency responsible for information or guidance on sea level rise to communities. Communities that are at risk—or are being impacted—do not have a clear point of contact for assistance from federal agencies. Interagency coordination on research, policy agendas, and consequent funding are needed to provide the package of data, tools, processes, and funding for communities to adapt to inundation. Federal agencies need to coordinate on the guidance, requirements, and performance measurements for communities to apply for, receive, and carry out funding for sea level rise adaptation projects.
- Federal and state agencies have the responsibility to collaborate and communicate across agencies and multiple-levels of government on the policies and initiatives being established for sea level rise adaptation. They have the responsibility to (1) lead, (2) establish standards and guidelines for data

acquisition, monitoring, and management, and (3) establish adaptation planning guidelines. Although federal agencies have been asked to identify the impacts of sea level rise on their infrastructure, they have not been asked to identify their roles to support sea level rise adaptation in states and municipalities. A national plan is needed that details how the agencies will empower states, local communities, and non-governmental organizations to move forward in planning for sea level rise.

- Sea level rise adaptation in practice is an iterative process. Science and policy need to be tightly coupled at the beginning of the process to best understand the risk and vulnerability of a community to sea level rise. Systematic assessment of the science, existing decision-making processes, and regulatory structure can then be modified to address sea level rise.
- With the many and varied activities occurring across the nation, there is a need to share experiences and expertise across a wide spectrum of stakeholders. Regional discussions of the framework and associated stakeholder roles, tools, and information will be important next steps to broaden the community engaged in adaptation. Meetings to share the framework, tools, and recommendations with practitioners will clarify how these tools work with local decision-making processes and where agencies should focus resources in the future. These discussions will need to include the U.S. Congress and elected officials—not just scientists. In the end, sea level rise is a political, social, and scientific issue.

Introduction

The vulnerability of coastal communities to coastal inundation and sea level rise is increasing. The impacts affect nationally significant economies, critical infrastructure, and ecological, public health, and social services. Inundation from coastal storms and inland flooding—exacerbated by long-term erosion and climatic variations, such as El Niño events on the West Coast—already poses a substantial risk to coastal communities ranging from major urban centers to smaller, coastal-dependent communities. The risk is projected to increase due to continued coastal development, changes in the frequency and intensity of inundation events, and a critical acceleration in the rate of sea level rise along vulnerable shorelines.

Coastal-zone planners, managers, and policy makers at local, state, regional, and national levels face the daunting task of anticipating and adapting to future coastal inundation and sea level rise vulnerability. Inundation events are certain to occur, but their magnitude, frequency, and geographic distribution are uncertain. Projections of future conditions and vulnerability are rapidly evolving as scientific understanding of the global and regional consequences of climate change improves. As a result, coastal managers require—and have consistently requested—improved, targeted, and accessible information, tools, and methodologies to assess and respond to coastal inundation and sea level rise hazards (see Appendix I for more details). These things are required to enhance community resilience and to ensure that policy, planning, and management decisions address the long-term consequences of coastal vulnerability driven by climate change (as well as persistent natural and human processes).

Across the nation, coastal-zone managers have expressed an urgent need for the consistent provision of information, tools, and methodologies to guide investments and decisions at the local and regional levels. Calls for action at all levels acknowledge that a viable response must engage federal, state, and local expertise, perspectives, and resources in a coordinated and collaborative effort. An effective effort—reflecting the established urgency—must include continued research and immediate application of current knowledge. Implementation must (1) be driven by needs established through intensive and sustained stakeholder engagement and (2) reflect continued assessment of the efficacy of the tools provided and the actions taken (for examples, see Appendices II–IV).

To date, the response to this urgent need has been uneven and uncoordinated. However, leadership has emerged in local communities, select states, and within federal agencies where the consequences of delay and neglect have been recognized. Through these efforts, common needs have become apparent, nascent tools for response have been developed, and communities of practice have been formed and energized. As a result, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS)—in partnership with other federal agencies and with the leadership of the Ocean Research and Resources Advisory Panel—are supporting a coordinated effort to develop a “Community Framework for Responding to Sea Level Rise and Inundation.”

This effort to build a community of practice began with an assessment of the current understanding of the (1) coastal inundation impacts on coastal communities, (2) requirements to assess and respond to changing coastal vulnerability, and (3) status of prototype tools to identify critical risk factors and develop effective responses. Building on this shared sense of urgency—and the substantial efforts to develop effective responses—the first workshop (as reported here) brought together leaders in the academic, federal and non-federal governmental, non-governmental, and private sectors to initiate a framework for a more coordinated and effective response to sea level rise and coastal inundation. The workshop was held in December of 2009 in Virginia (see Appendix V for the agenda and Appendix VI for the participant list.)

The desired outcome of the workshop was to develop a shared framework for a broad partnership to reduce coastal vulnerability—and increase coastal resilience—at local and regional levels. Specific elements of the desired framework included:

1. Developing tools to support local and regional efforts to identify key risk factors, raise awareness of risk among the general public and key decision makers, and mobilize community responses.
2. Identifying critical information resources and communication tools necessary to assess risk, evaluating the consequences and efficacy of adaptation actions, and developing effective response strategies.
3. Developing a community of practice to share lessons learned and best practices in assessing and responding to coastal risk, as well as providing tools to communicate within and across communities to spur timely and effective action.

The workshop built upon substantial existing efforts and engaged already committed leaders. Participants further considered setting priorities for the (1) development of information, tools, and targeted applications and (2) identification of “pilot” programs to both demonstrate effective responses and to provide the tools necessary to mobilize those coastal communities that are struggling to understand the consequences of coastal inundation and sea level rise in terms of their particular community values. The workshop format and objectives were designed to guide the “next steps” implementation of the framework in terms of both specific local and broader national needs.

This focused effort is built on a collaborative model that spans a number of related endeavors, leveraging knowledge and resources, and seeking synergies across issues and approaches. Sea level rise and coastal inundation is a focus of both the Ocean Research Priorities Plan and the Subcommittee for Disaster Reduction. The information requirements for assessment and response to inundation hazards aligns closely with the operational and academic priorities identified within the Ocean and Coastal Mapping Integration Act, the Integrated Ocean Observing System, and the Climate Change Science Program assessment of sea level rise hazards. The principles and objectives of the developing National Ocean Policy and the Framework for Coastal and Marine Spatial Planning intersect with this effort, and they support the establishment of a science-based framework that addresses an issue of national importance through the prism of state and regional priorities. Through coordination across all these efforts, this community framework for responding to sea level rise and inundation outlines a comprehensive response to an issue of national urgency that effectively builds on existing programs and engages the required research, operational, policy, and management interests in planning, prioritization, and execution.

Workshop Declaration

Sea level rise and inundation were stated to be among the highest priorities in the community-developed Ocean Research Priorities Plan and Implementation Strategy in 2005. Although it remains a stated priority, very few resources have been allocated towards this challenge. Priority issues should command new funding; in the absence of authorizing language and available new funds, the issues must then receive attention through reallocation of existing federal budgets.

Global climate change has received attention; however, there is an increasing urgency for federal and state governments to focus at the local and regional levels. It is important to develop a common language and framework of data, models, and resources that can enable states and local governments to assess sea level rise impacts on their communities and to initiate adaptation strategies.

This workshop on coastal inundation and sea level rise has initiated a framework that can help to guide where investments should be made at the local and regional levels over the next decade. It will be the first in a series of workshops and other activities designed to bring people from different segments of the community together to refine the framework for action and test its utility in regions and communities that can serve as models for the nation.

A Community Framework for Responding to Sea Level Rise and Inundation

Introduction to the Framework

The framework below is designed to help coastal communities structure and facilitate on-going, community-wide conversations to increase their resiliency to sea level rise and inundation. It can be applied *de novo* or adapted to integrate existing planning initiatives.

The first step is to describe and define the problem as richly as possible for the specific community, and then to ensure that there is broad awareness and understanding of the inevitable implications—short-, mid-, and long-term—of sea level rise and inundation for the specific community. Until there is an explicit recognition that a problem exists—even as a looming problem—and that sea level rise and inundation threaten the qualities and characteristics valued by the community, it will be difficult—if not impossible—to identify, select, and implement strategies to deal with sea level rise and inundation. These plans will be of much greater value if they are developed collaboratively with neighboring communities and with relevant state and federal agencies.

The process of applying this framework, or any other approach, must be open and transparent. Key stakeholders—including those from the private sector—must be at the table from the outset and must return to the table on a recurrent basis. In order to build trust and take action, it is critical to have a core group of participants that (1) represent a cross-section of the community’s key stakeholders and (2) include those empowered to make commitments. The process must be flexible, opportunistic, and embrace leadership from multiple quarters.

While the framework is presented as a linear process, in practice many steps will be occur simultaneously and the process will be iterative in its application. The process must be dynamic in order to respond to new data and information, and it should be informed by flooding that occurs from storm events. The pressure following major events is to get things back to “normal” as quickly as possible. The challenge is to get communities to begin to internalize that they need to plan for a “new normal” if they are to create resilient communities. Building a plan for response to a higher sea level needs to become an integral part of the planning process from now on.

Sea level rise and inundation belong to the family of problems called “wicked problems.” Wicked problems are problems that cannot be solved—but they can be managed to keep within certain bounds. Because wicked problems cross disciplinary lines and can be viewed from multiple perspectives, it is important to take the up-front time to gain consensus on the problem to be addressed. Getting an acceptable answer to the right problem is more important than getting an elegant solution to the wrong problem!

Outreach and communication must begin at the outset, and then continue frequently and consistently throughout the process. After some experience has been gained, the most effective strategies need to be codified and institutionalized. This has been included as Step 7 in the framework process, but it may come much earlier if appropriate in a specific community.

The most important thing is for coastal communities to get started in preparing for a future with a higher stand of sea level and more frequent flooding. This framework will be helpful in providing a nudge in that direction.

Proposed Framework

- 1. Explore the issues of sea level rise and inundation with the community to develop a shared vision of what is at risk and the qualities stakeholders want to protect in the face of a rising sea:**
 - Make a preliminary and qualitative assessment of the probable sea level rise in the community/region and the potential consequences.
 - Make a preliminary and qualitative assessment of the strategies available to deal with the likely rise in sea level and associated inundation, including the advantages and disadvantage of each strategy.
 - Specify explicitly the underlying assumptions of each strategy. For example, “We believe strategy A will work because...”
 - Develop community discussions of sea level rise as an on-going process to keep the public involved and informed, as well as to secure and retain their support.

- 2. Identify the geographic scope of the project area and the time scales of concern:**
 - Use maps to identify explicitly the geographic scope of the project area.
 - Identify the range of temporal scales of concern (today, in 10, 25, or 50 years, etc.).

- 3. Identify and recruit critical partners and stakeholders, and then clarify roles and responsibilities (these should emerge from Step 1):**
 - Form a steering committee with a representative cross-section of decision makers, scientists, engineers, stakeholders, and working groups as appropriate. Include non-traditional partners.
 - Make roles and responsibilities explicit and establish authority levels by drafting “frames of reference” for each group.
 - Identify explicitly the questions that the decision makers must ask and build a science/engineering program to provide the information needed to answer those questions. Identify the triggers for action.

- 4. Characterize the current and future states of sea level rise and inundation for the project area:**
 - Assemble and synthesize the sea level rise data and information appropriate for the area. Include projected sea level rise in range number form for each selected time frame to capture the uncertainty of the forecasts as a function of time.
 - Create an inundation map for each sea level rise/time scenario that includes both sea level and changes in storm frequency, using the best available data, information, and models.
 - Identify and value the assets at risk—both man-made and natural—for each scenario and communicate that information.

- 5. Identify critical data, information, and tools that need to be refined or developed to reduce uncertainty (these deficiencies should become clear as a result of Step 3):**
 - Focus on data, information, and tools that will meet the needs of decision makers.

6. Secure or develop the necessary data, information, and tools:

- Identify and rank research and monitoring requirements to address unknowns. Estimate the costs to carry out each program.
- Initiate the necessary programs with appropriate regional, state, and federal partners drawing upon the experience and lessons learned from other communities and regions.
- Develop or adopt existing data collection standards and protocols to facilitate data sharing and ensure use for federal, regional, and local needs.
- Support data and information integration from federal, state, academic, and other sources to simplify discovery and access.
- Facilitate access to data via the web and/or a data portal.
- Work to ensure interoperability.
- Conduct necessary model development or refinement. In most cases, this should be done collaboratively with other communities, state agencies, and federal agencies to reduce costs, enhance effectiveness, and ensure interoperability.
- Initiate technical studies (such as impacts to wetlands or sustainable restoration strategies).
- Research development of decision-making tools that can consider uncertainties.
- Incorporate socioeconomic analyses into the research program.
- Evaluate socioeconomic impacts on coastal communities, as well as physical impacts to coastal structures, infrastructure, and ecosystems.
- Design and launch a sustained monitoring program to evaluate the effectiveness of mitigation/adaptation strategies and incorporate adaptive management, as needed.
- Focus the research and monitoring on the issues that decision makers must deal with.

7. Identify and evaluate the various strategies for dealing with the projected sea level rise and inundation scenarios to protect the qualities identified in step 1:

- Identify and evaluate the full range of strategies (both hard and soft solutions), including strategic retreat. Assess the capital costs, recurring costs, and environmental costs.
- Select the combination of strategies that will be robust over a range of probable future sea level and storm frequency scenarios and that will “minimize regret.”
- Bundle the strategies with temporal dimensions—such as things to do now and things that can wait. Include triggers (such as sea level elevations or damage done by storm surges) for going from one set of strategies to the next.

8. Develop and continually support a comprehensive communication strategy:¹

- Work with scientists, land and community managers, educators, and communicators to translate climate change science—with an emphasis on sea level rise and coastal inundation—into accurate, audience-appropriate information. Use stories whenever possible.
- Combine face-to-face meetings with other communication modes that make use of all media.
- Use traditional media and outreach tools, as well as social networking tools.

¹ Communication and outreach must start at the beginning of the process and continue through it, but at some point the strategies that have proven to be most successful need to be codified and institutionalized.

- Promote development and use of decision-support systems that identify and communicate vulnerability and risk—at appropriate spatial and temporal scales—to serve a variety of audiences and different skill sets.
- Solicit lessons learned from other regions, states, and international partners.
- Involve stakeholders in the process using participatory planning techniques (such as participatory mapping, joint fact finding, and shared visioning).

9. Build the institutional capacity and the political will to execute the strategies selected:

- Evaluate the effectiveness of existing organization and governance (i.e., federal, state, and local agencies) to address sea level rise and inundation on a sustained basis.
- Strengthen strategic partnerships formed earlier in the process. These should include partnerships with neighboring communities.
- Seek new partnerships and cooperative/collaborative relationships with federal and non-federal entities (including non-traditional partners).
- Leverage existing or planned projects, data, and resources (such as funding and staff).
- Develop and sustain strong political support at the local, state, and federal levels.
- Identify roles and responsibilities of academic institutions, nonprofits, and other community organizations.
- Build capacity within local communities to (1) understand and apply the data, tools, and proposed strategies and (2) secure resources.

10. Institutionalize the program and keep current:

- Select the appropriate models for sea level rise, hydrodynamics, and inundation for use in the area.
- Evaluate uncertainty in outputs.
- Maintain and upgrade computer models and other tools as new data, information, knowledge, and technology become available.
- Exercise the models on a periodic basis to provide timely information as new data are obtained.
- Synthesize the data and information in order to transform them into a variety of informational products useful to decision makers.
- Pursue development of the necessary policy documents and/or legislative or regulatory modifications to implement and sustain the approved approach.
- Ensure consistency among federal, state, and regional adaptation policies.
- Specify needs for legislation and funding.

Priority Data

As with any science-based decision-making process, the requirements for quality data and information related to sea level rise planning and implementation at regional-to-local levels are vast. Workshop participants assembled a long list of gaps related to data, modeling, and decision-support tools that would advance their efforts. However, in order to best inform agency planning processes and future funding decisions, this summary report will emphasize higher priority needs and/or those that were echoed by a number of groups.

Overall, participants stressed the importance of data interoperability to (1) eliminate known incompatibilities and (2) ensure users are able to apply data from a variety of sources. Participants also highlighted the need to distinguish between short- and long-term planning, given potential differences in data requirements or priorities. Despite this distinction, participants were able to prioritize the following six categories of data needed to support future sea level rise planning and implementation:

1. **Data to understand land forms and where and how water will flow:** This includes data on geomorphology, topography, bathymetry, vertical datums, etc.
2. **Monitoring data and environmental drivers:** This includes data on tides, water levels, waves, precipitation, historical and predictive shoreline erosion data, local sediment budget, etc.
3. **Consistent sea level rise scenarios and projections across agencies to support local planning:** This includes data not only on the amount of sea level rise projected within a given area, but also on storm frequency information and the general time frame within which these changes are anticipated.
4. **Data to characterize vulnerabilities and impacts of sea level rise:** This includes data on population, land use, buildings and critical infrastructure, natural resources, economic information, etc.
5. **Community characteristics:** This includes data on demographics, societal vulnerabilities, economic activity, public attitudes and understanding of risks, etc.
6. **Legal frameworks and administrative structure:** This includes data on zoning, permitting regimes, legislative restrictions, etc.

Each of these categories of data is very important to plan for and adapt to the impacts of inundation and sea level rise; however, some have larger data gaps than others. For example, the sixth category (legal frameworks and administrative structure) represents one of the more significant data gaps for many regions, yet it is critically important in order to understand what is possible within the current structure and what modifications may be needed to adapt to future environmental and societal changes related to sea level rise. Additionally, participants noted the lack of quality social and economic data under the fifth category (community characteristics). In order to develop a meaningful and effective sea level rise adaptation plan, state and local planners must (1) understand the vulnerabilities specific to their community and (2) be able to generate a clear understanding of the communities' dynamics and overall composition, perspectives on risk, economic drivers, and potential challenges in adopting new guidelines or adaptation measures.

Priority Tools

The tools necessary for adaptation planning are difficult to prioritize, because they will depend upon where each community is in the planning process and what the community needs. Many applicable tools are available from a variety of sources; some are specific to sea level rise issues while others have been developed for other purposes and are applicable to inundation with minor modifications. Adaptation tools need to understand in terms of input data requirements, assumptions of the method, and the reliability and utility of the outputs. This type of information would assist the community in choosing among the available options. Tools that hamper or delay the process—because of data requirements, incompatible output, or ambiguous or questionable results—are not helpful. The tools need to be easy to access, have a transparent methodology, and produce output that is actionable and can be incorporated into an existing decision-making process.

Participants stressed the need for training and the importance of technical assistance for tools that are developed. Too many tools are provided with inadequate explanations of how they should be used for a particular geography or to address a particular issue. The ability to learn from the developer and to learn from other users was seen as an important component of tool development and delivery. A suite of tools that work together to support planning and decision-making would be ideal. The way that these tools work together could be specified using a consumer guide approach that detailed how the inputs and outputs relate to each other and to the process. Participants were able to identify and prioritize the following categories of tools needed to support future sea level rise planning and implementation.

Communication Tools

These include tools for stakeholder engagement, visioning, and consensus building, such as:

- Definitions to establish a common language to discuss climate impacts and adaptation strategies
- Tools to educate the public on the science, impacts, probability, and risk
- Guidance and best practices for the planning process
- Tools for facilitation and conflict management

Monitoring and Modeling Tools

These include tools for monitoring and modeling current and future states, such as:

- Estimates of sea level rise that are negotiated and acceptable by multiple agencies and are useful at regional and local levels for comparability across jurisdictional boundaries
- Standards and data architecture to integrate existing databases of observations of water level and other relevant data
- Sophisticated, diagnostic models that include:
 - Storm surge models with wave measurements
 - Advanced circulation models
 - Geomorphic models
 - Geospatial models for sea level rise
 - Flooding/inundation models
 - Habitat models
 - Long-term erosion models
 - El Niño Southern Oscillation/climatological impact projections
- Downscaling techniques for these models for use in regional or smaller scale scenarios

Visualization and Scenario-building Tools

These include tools that would help communities identify and explore alternative adaptation solutions, such as:

- Visualizations using familiar viewers (such as Google Earth) for different sea level rise, storm frequency, and inundation scenarios that are interactive, offer planar and oblique views, and show critical infrastructure, relevant landmarks, and other information that allows communities to understand impacts
- Definitions and analysis of economic impacts and loss
- Conversions of vulnerability into risk information
- Valuations of ecosystem services
- Scenario evaluations that
 - Identify key assumptions
 - Test alternative outcomes
 - Identify signposts and thresholds based on monitoring data
 - Evaluate policy tradeoffs based on key unknowns
- Assessments of economic, social, and physical risk

Implementation Tools

These include tools that are used to build institutional capacity and implement adaptation, such as:

- Long-term policy analysis tools to help choose among options
- Database of case studies and best practices that can be queried
- Resource (such as a clearinghouse or points of contact) to understand agency activities and potential funding sources
- Evaluation tools to assess the effectiveness of adaptation strategies
- Operational tools that address current conditions and risks (that is, not only long-term planning tools)
- Engineering and solution tools

Roles and Responsibilities

The workshop reviewed the roles of all sectors—federal, state, local, academic, non-governmental, and private—and their responsibilities to support local communities in their efforts to analyze the impacts of sea level rise and put processes in place to adapt to those impacts. Successful strategies will require that all sectors work together throughout the process to provide local communities with resources, scientific, and political support.

- **Federal agencies** will be relied upon by states and communities to develop and sustain collaboration and coordination mechanisms that will provide the funding and guidance for research, monitoring, model development, and implementation at the local level. Critical to this responsibility will be interagency coordination of activities at the national and regional levels.
- **State agencies**—individually and through regional alliances—will play a key role in balancing the interests of the many community members involved in adaptation planning and implementation. They will link federal and regional efforts to those of local municipalities and communities to promote consistency and comparability across political jurisdictions.

- **Local communities**—with their land-use responsibilities—bear the majority of responsibility to plan, implement, and enforce adaptation strategies to achieve and maintain a sustainable community in a changing environment. They will need to request resources and guidance and will expect assistance from other community members. All community members will have the responsibility to demonstrate best practices in adaptation to sea level rise by protecting their own infrastructure.
- **Academic communities** will be critical links between the most recent and credible information from the scientific community and government staff with specific needs for scientific information.
- **Non-governmental organizations** are sources for leadership and advocacy of the adaptation process.
- **Private organizations**—for example, design, consulting, tourism, energy, insurance, investment, and real estate development—will be important partners in understanding and meeting community needs.

More specific detail on roles and responsibilities of the different community members to support local communities in their actions can be discerned according to the framework:

- Define the problem
- Gather the data, information, and tools
- Identify and explore alternative solutions
- Build and sustain capacity and support

Define the Problem

This phase of the framework includes the steps to develop a shared vision, understand the scope of the problem, and engage stakeholders. The roles and responsibilities of the groups for this phase are described below:

Federal Agencies

- Conduct climate science research within the appropriate agencies so that communities can assess their risk and incentivize academics to conduct use-inspired research that can be used in assessments
- Fund and support regional (multi-state) programs that allow multiple communities to work together towards adaptation

State Agencies

- Cooperate in regional efforts and collaborate with neighboring states to promote comparability across jurisdictions
- Develop and implement an adaptation plan for the state
- Coordinate risk assessments across the state (and region) to support a common understanding of risk
- Provide grants and guidance to local communities to conduct adaptation planning processes
- Establish a policy framework (such as development restrictions, hazard zones establishment, data collection, and flood forecasting infrastructure) for local communities that is conducive to implementing adaptation strategies

Local Communities

- Show leadership and recognize the need to act
- Organize stakeholders to identify key values and develop a common vision for the future of the community
- Partner with neighboring communities to leverage resources and support comparability

Academics

- Work with local community to understand the science and impacts of sea level rise and inundation
- Help to ensure knowledge is understood and used appropriately

Private Industry and Non-governmental Organizations

- Participate actively in engagements to ensure appropriate stakeholder representation, provide input, and advocate for the process

General Public

- Become educated and involved
- Assume responsibility

Gather the Data, Information, and Tools

This phase of the framework includes the steps to characterize the future state of sea level rise and inundation in the area, as well as identifying and securing the necessary data, information, and tools. The roles and responsibilities of the groups for this phase are described below:

Federal Agencies

- Provide expertise in data collection and tool development
- Provide for technology transfer, but be sensitive to local groups doing the same thing
- Conduct climate science research
- Conduct effective mapping and monitoring programs that meet the needs of states and local communities—specifically collection and dissemination of
 - Federal Emergency Management Agency (FEMA) mapping products
 - Topobathymetric mapping data (from USGS and NOAA)
 - Monitoring data (such as water levels)
 - Socioeconomic data
- Establish collection standards for relevant data to ensure compatibility across collection efforts by multiple agencies
- Establish and maintain flood forecasting infrastructure
- Provide storm surge and inundation models (from FEMA and the U.S. Army Corps of Engineers)
- Provide for effective information delivery

State Agencies

- Provide training and technical support to local communities
- Support data collection within the state
- Develop and support state and regional efforts to provide for regional-scale sea level rise rates, models, and impacts
- Develop economic models for state and local use

Local Agencies

- Contribute data to larger scale monitoring programs (for example, coordinate parcel data with USGS)

Academics

- Conduct research in support of management needs, including climate science, economics, and societal and legal implications
- Work with the local community to understand the science

Non-governmental Organizations

- Fund high-value applied research
- Develop tools appropriate for local use

Private Industry

- Tailor products to the specific needs of communities
- Provide technical assistance and technology development

Identify and Explore Alternative Solutions

This phase of the framework includes the step that is primarily the responsibility of local communities. These are the roles and responsibilities of other groups in support of this step are described below:

Federal Agencies

- Provide incentives to stimulate development of resilient coastal communities
- Remove incentives that promote irresponsible development
- Attach sea level rise adaptation to Coastal Zone Management funding as a guiding principle

State Agencies

- Provide leadership through legal changes and mandates for sea level rise consideration in Coastal Zone Management permits

Non-governmental Organizations

- Promote restoration and conservation as adaptation strategies
- Steward land and demonstrate restoration and adaptation practices

Private Industry

- Insurance, manufacturing, industrial, and financial industries in particular: provide feedback on scenarios
- Design community members: assist in planning, product design, and process design
- Environmental consultants: provide service for local planning agencies
- Tourism agencies: represent the recreation sector
- Real estate developers: consider alternatives to building in the most vulnerable places

Build and Sustain Capacity and Support

This phase of the framework includes the steps to build institutional capacity to conduct, maintain, and communicate the adaptation process. The roles and responsibilities of the groups for this phase are described below:

Federal Agencies

- Provide incentives to implement best practices that recognize the importance of coastal community resilience

State Agencies

- Incorporate sea level rise and other climate change into all planning efforts; change policies and redirect staff if necessary
- Educate the public, as well as elected and appointed officials
- Provide for operational response and disaster preparedness
- Communicate new policies, best practices, and success stories

Local Agencies

- Serve as pilots and ambassadors

Academics

- Work with Non-governmental organizations to create public education and outreach campaigns
- Train workforce to deal with sea level rise and inundation; educate the next generation on these issues and what needs to be done

Non-governmental Organizations

- Educate constituencies about sea level rise and inundation
- Engage diverse stakeholders in on-going conversations about sea level rise and inundation
- Keep the focus on the issues
- Lobby agencies and legislature in partnership with academia
- Work with partners to ensure the message to the public is consistent
- Engage in lawsuits, as needed, to advance policy

Private Industry

- Support behavioral change

K–12 Educators

- Influence the next generation to appreciate the importance of—and work to address—sea level rise and climate challenges

Findings and Recommendations

Establish a New Definition of Normal

- Communities have experience with storm and hazardous events, and the post-event response typically is to try and return the community to “normal” (that is, how it was prior to the event). With sea level rise, there will need to be a shift in perception and response from storm events to sea level rise. With sea level rise, the environment is actually changing; it is not a single event that happens and then gives the community time to return to the pre-event state.
- For stakeholders to envision a “new normal” for their community, they will need all the right people to start discussions—including lawyers and lawmakers who can provide the legal knowledge to advice on implementing strategies.
- People want to hear what is known about the issue now, but do not bury them in uncertainty.

Engage at the Community Level (where sea level rise is a significant impact)

- Although there is a broad constituency that does not know the issue well, many communities are savvy about the impacts of sea level rise—but lack the funding to (1) conduct research to understand the local impacts, (2) make adaptation plans, and (3) implement adaptation plans. However, armed with the available information and resources, many communities are ready to take action. Next steps for working with these communities are:
 - Identify successful case studies and aggregate this information into a process that is consistent and works. Part of this step would be to understand the tools that were used—and the context in which they were applied—in order to understand differences in approach and why results may differ. Develop metadata for sea level rise models and tools to help state and local partners to make informed choices (such as a consumer guide for models and tools). Local stakeholders like simple visualization tools; the tool that gets attention is not always the most complicated.
 - Talk to practitioners who have been doing this work in order to move beyond identifying the necessary steps and offer the best practices. There are current efforts being conducted at multiple levels of government—from multi-state and statewide to more local efforts.
 - Take this framework and information to select and diverse communities and exercise the framework. Engage communities using tools and scenarios to understand how the scenarios align with their values. Understand what additional information they need and where additional resources need to be focused.
 - Work in partnership with federal, regional, and local partners to move forward, which helps generate buy-in and ensure a commitment.
 - Build a communication strategy and outreach plan to open doors, engage stakeholders, and obtain funding.
- The test of this concept/framework should be done at different municipal scales, including both big cities and small communities.

Realize the Model Limitations

- Models will not obtain the level of resolution that is necessary to be truly predictive for the many communities that will request that information.
- Models should be used as scenario generators to inform and elucidate choices. Examination of a great number of scenarios will allow communities to understand their priorities and what it is about solutions that make them robust. A robust solution can be defined as a solution that meets a minimal set of criteria across a broad spectrum of characteristics.

Establish a Federal Point of Contact

- There is no federal agency focused on providing information or guidance on sea level rise. Communities who are at risk—or are being impacted—do not have a clear point of contact for assistance from federal agencies.
- At the federal level, there needs to be an interagency effort. Activities are being conducted and information made available by various agencies—including many responsible for coastal mapping—to respond to sea level rise; however, it is not organized to be easily accessible by states and communities. The Office of Management and Budget has directed NOAA and the Department of the Interior to work together on climate issues by developing a unified strategy and budget that identifies the activities and costs for each agency.
- All levels of government are responsible for sea level rise planning and there are examples of actions at each of these levels. There is a need to organize the system around this issue in order to redesign how resources are directed. This will allow resources to be added strategically and also to guide federal agencies so that they focus on things that multiple states have decided are important to do together.
- This framework will be used to communicate a consistent message to the agencies and to the Office of Management and Budget to recruit new money, as well as to shift existing resources. At some point in the near future, there will be a need for a federal agency or agencies to have legal authority to address sea level rise adaptation. However, it would be a mistake to try to fund everything through the federal budget; regional activities and resources will also be needed to support state and community activities.

Realize that Sea Level Rise Adaptation is Iterative

- This framework (as well as other guidance documents) presents steps towards adaptation; however, in practice, the process is iterative as new information becomes available and policies are put in place.
- The relationship between science and policy is critical: the science will drive policy and must be done well. Science and policy need to be tightly coupled at the beginning of the process to best understand the community's risks and vulnerability to sea level rise. The policy makers at the local level need to be engaged with scientists to make sure that the research and interpretation of the science is useful at the critical decision-making points. Systematic assessment of the existing decision making processes and regulatory structure—such as effectiveness, transferability, and flexibility of existing regulations—can then be modified to address sea level rise.
- It is important not to underestimate the barriers to this work, including issues of jurisdiction, political authority, policy making process, and trust; there are many stakeholders.

Coordinate Funding for Community Level Planning

- The process and tools largely exist for sea level rise adaptation planning, but some are difficult to use or access. (One thing that is needed is packaged funding that brings the process together for a community. Several federal agencies are issuing request for proposals to do this type of work, but they are largely uncoordinated across programs.) Federal agencies need to coordinate on the guidance, requirements, and performance measurements for communities to apply for, receive, and carry out funding for sea level rise adaptation projects.

Develop Coordinated Federal Research and Policy Agendas

- Research funding can be tied to making science useful to the community adaptation process. Communities must have guidance on appropriate use of climate science; conveying what science and models are available and understanding the needs of communities will set priorities for the future directions of science. Credible science will be very important to getting communities to act.
- However, providing funding for relevant science and specific case studies is only one approach to implementing the overall framework. Federal agencies have additional roles to enable and support state and local governments to address sea level rise. They have the responsibility to collaborate and communicate across agencies and multiple-levels of government on the policies and initiatives being established for sea level rise adaptation. They also have the responsibility to (1) lead, (2) establish standards and guidelines for data acquisition, monitoring, and management, and (3) establish adaptation planning guidelines. Although federal agencies have been asked to identify the impacts of sea level rise on their infrastructure, they have not been asked to identify their roles to support sea level rise adaptation in states and municipalities. A federal plan is needed that details how the agencies will empower states, local communities, and non-governmental organizations to move forward in planning for sea level rise.

Continue Communication

- With the many and varied activities occurring across the nation, there is a need to share experiences and expertise across a wide spectrum of stakeholders. A continued dialogue among workshop participants and other interested parties would allow a large number of people to keep up to date on new findings, initiatives, or activities.

Hold Future Workshops

- Regional discussions of the framework and associated stakeholder roles, tools, and information will be important next steps to broaden the community engaged in adaptation. Meetings to share the framework, tools, and recommendations with local practitioners will clarify how these tools work with local decision-making processes and where agencies should focus resources in the future. These discussions will need to include the U.S. Congress and elected officials—not just scientists. In the end, sea level rise is a political, social, and scientific issue.

Appendix I: Summary of Coastal Community Stakeholders Needs for Addressing Sea Level Rise and Inundation

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Objectives and Approach

The objective of this paper is to summarize relevant literature (including gray literature), which characterizes the needs of coastal community stakeholders for information and tools that address challenges posed by sea level rise and inundation. The categories addressed include (1) geospatial information, modeling, and decision-support tools, (2) adaptation planning guidance and policy, and (3) education, training, and communication at the state, regional, and federal levels.

It is important that the identified needs be considered as a more than just a list of options. They should be considered in combination and to see how they fit within a comprehensive community framework to plan for and respond to sea level rise and inundation. For example, the efficacy of geospatial information and decision-support tools in addressing community and stakeholder needs will be determined largely in relation to how they support and inform policy, planning, and management objectives.

In reviewing the literature it was sometimes difficult to parse out the community needs specific to sea level rise and inundation from the broader adaptation needs related to climate change and coastal hazards. In addition to sea level rise and lake level changes, climate-related coastal community impacts include:

- Shoreline erosion
- Storm frequency or intensity, changes in rainfall, and flooding
- Chemical change (ocean acidification) and physical characteristics (thermal stratification)
- Hydrological change and saltwater intrusion
- Harmful algal blooms
- Habitat loss (especially coastal wetlands)
- Changes in population dynamics among marine and coastal species

While these impacts are not the subject of this review, addressing the community needs for sea level rise will also—in many cases—assist in addressing these other impacts and supporting resilient and climate-ready coastal communities.

Needs have not been prioritized in this review; however, where references and recommendations were identified as a priority in a region or state that priority has been noted in this summary. Not surprisingly, there was considerable duplication of recommendations across the literature. This paper focuses on identifying specific recommendations—rather than general statements (such as those calling for improved interagency coordination, better models, and improved science). The references used in this review come from a wide range of sources, including published documents, comprehensive studies, conference reports, and meeting notes.

Background

Coastal states are particularly vulnerable to a range of potential climate change impacts, so it is not surprising that they have taken the lead in assessing potential impacts and planning for sea level rise adaptation. Coastal states are faced with the difficult task of making short-term management decisions that need to take into account not only the evolving (and sometimes confusing) predictions for sea level rise, but also the long-term threats of coastal inundation and the more immediate threats of increased vulnerability to coastal storms.

Community strategies to adapt to sea level rise and other climate change impacts on coastal and ocean ecosystems are beginning to be developed at the same time as a much more extensive effort to develop federal, state, and local greenhouse gases mitigation strategies. For example, at the federal level there is a Climate Czar and a coordinated multi-agency team, and many states have adopted greenhouse gas reduction strategies. There is no comparable commitment to the consideration of potential climate change impacts on ocean ecosystem health and community sustainability. The coastal and ocean community faces a substantial challenge in attracting leadership, interagency governmental coordination, and investment in research, tool development, and other support for implementation of sea level rise adaptation strategies and policies.

From the perspective of a coastal community, consideration of sea level rise adds an additional factor and level of complexity to an already complicated suite of coastal management issues. At the same time, considering the impacts of sea level rise in isolation can be misleading, making the impacts appear incremental, uncertain, variable, and not of immediate concern to coastal communities and stakeholders (in relation to other issues). In order to spur on local community action, it will be necessary to bridge the gap between the current lack of urgency associated with sea level rise and its potentially significant impacts. A Coastal States Organization survey in 2008 reflected the following variation among states that were using estimates of sea level rise for their current planning efforts.

Sea Level Rise in Millimeters (mm) Per Year	States	Percent
1–3 mm/year (approximately 0.3–1.0 feet/century)	2	9.09%
3–6 mm/year (approximately 1.0–2.0 feet/century)	7	31.82%
6–9 mm/year (approximately 2.0–3.0 feet/century)	7	31.82%
9–12 mm/year (approximately 3.0–4.0 feet/century)	4	18.18%
12–15 mm/year (approximately 4.0–5.0 feet/century)	2	9.09%
Greater than 12 mm/year (greater than 5.0 feet/century)	3	13.64%

Summary of Issues

The coastal states have identified 13 potential threats from sea level rise:

- Loss of beaches
- Vulnerability to storms
- Coastal hazards
- Marsh drowning
- Estuarine exposure to the ocean
- Saltwater intrusion
- Disruption of sewer infrastructure
- Loss of tourism
- Threat to road infrastructure
- Invasive species
- Species loss
- Interruption of port operations
- Public access to the coast

This list provides a good starting point for assessing the relevance and utility of data, information, and tools in relation to how effectively they assist states and communities in addressing the listed threats. Adoption of a community framework to support sea level rise planning and adaptation will likely require (1) a reconsideration of existing priorities, and (2) a new way of thinking and doing business along the coast, including the following:

- A renewed—and substantial—commitment to natural systems and ecological services, as well as land conservation and restoration along the coast and coastal watersheds.
- Infrastructure reinvestment, elevation or removal of at-risk structures, re-engineering of the coast, and “hard” solutions at a scale never seen in this country.
- Support for new policies and incentives—or disincentives—for communities, insurance sectors, and financial sectors to invest (or not) in coastal development (including changes in land use and enabling retreat in some areas).

Adaptation is dependent on numerous stakeholders from government (at the federal, state, and local levels), science and academia, the private sector, and community residents working together to develop solutions to complex problems for which prior approaches may not be adequate. Adaptation to sea level rise will require creativity, compromise, and collaboration across agencies, sectors, and traditional geographic and political boundaries.

Getting behind adaptation strategies will pose particularly difficult challenges for coastal communities and stakeholders invested in the *status quo*. The current environmental and coastal hazard laws focus on single-issue management, and the laws provide inadequate tools for multi-sector and multi-purpose management (such as establishing trade-offs with the socioeconomic issues that states and localities need to consider in making sea level rise adaptation decisions). The laws also focus on a fairly stable climate range: they are based on recent climate history rather than projections of climate change.

There are examples of local communities taking action to address specific sea level rise issues, such as desalinating ground water, protecting infrastructure and communities from flooding and more severe hurricanes, and preparing for water shortages. However, these actions are not part of a coordinated framework, and they are usually operating outside the scope of a comprehensive climate change and greenhouse gas mitigation initiative. Here are some examples of local initiatives:

- In 2006, King County in Washington State formed an inter-departmental climate change adaptation team. The King County Climate Plan lays out detailed goals and actions for six strategic focus areas for adaptation efforts going forward.
- In late 2005, the International Council for Local Environmental Initiatives launched a Climate Resilient Communities program to help local governments prepare for global warming impacts.
- In April 2007, Mayor Bloomberg released his *PLANYC: A Greener, Greater New York*, which calls for the city to conduct adaptation planning to address critical infrastructure, specific communities at high-risk from climate change, and an overall adaptation planning process.

To be successful, these local model initiatives will require much more comprehensive support (including the state and federal programs) to address the needs identified below.

Coastal Community Stakeholder Needs and Priorities

Geospatial Information, Modeling, and Decision-Support Tools

The following informational products and decision-support tools have been identified by coastal states and other stakeholders as important for the formation of adaptation strategies for sea level rise and inundation:

- Historic shoreline position maps, historic shoreline erosion rates, and inventories of shoreline features and conditions.
- High-resolution topography and bathymetry.
- Sea level rise inundation models
- Inundation models that link storm surge and sea level rise.
- Shoreline change models based on sea level rise projections.
- Integrated national program to develop comprehensive, highly-resolved, and well-vetted coastal topography and shallow bathymetric coverage.
- Research to address the assessment of sea level rise impacts on the open ocean coast, as well as other critical coastal habitats.
- More detailed, spatially-specific planning, assessments, governance models, and decision-process tools.
- Studies of vulnerability, as well as socioeconomic, environmental, and habitat changes associated with sea level rise (e.g., coastal wetlands, salt wedge migration).
- Concise depictions of wetland status for resource managers and locally relevant sea level rise impact scenarios.
- Models that predict (1) migration and accretion of coastal wetlands and beaches in response to accelerated sea level rise and (2) consequences of taking action.
- Models of (1) ecological migration of habitats and species and (2) impediments to migration, in order to prioritize opportunities for conservation.
- Studies and decision-support tools that will (1) provide additional clarity and (2) reduce variability and the level of uncertainty regarding critical decision-relevant factors (including what will erode, what will be inundated, and what will/should be protected over time).

- Reduce the level of uncertainty evident in currently available research that precludes the ability to accurately model and precisely predict outcomes of the processes of sea level rise.
- The Gulf of Mexico places a high priority on needs related to sea level rise impacts on coastal processes, sediment management, and coastal restoration, including:
 - More integrated models linking sea level rise and coastal processes
 - Research on the natural protective features and ecological services provided by beaches, dunes, etc.
 - Greater understanding of coastal erosion processes and response strategies
 - Seamless bathymetric-topographic datasets for use on storm surge and inundation prediction
 - Gulf-wide coastal sediment database and fate/movement of sediment sources for restoration and regional sediment management
 - Cost-effective restoration technologies

The following additional needs for modeling and mapping tools were identified in numerous reports:

- Climate models should be improved so that they are more robust, diverse, and higher resolution. Spatial resolution is particularly important for planning, advocacy, and education purposes, while temporal resolution is necessary to capture the role of storms, climate change, and sea level rise.
- Models are needed that address a variety of temporal scales, because it is recognized that user and stakeholder groups operate on very different short-, medium-, and long-term planning horizons (such as port or transportation capital infrastructure vs. coastal management decision making).
- Climate change and sea level rise data related to coastal hazards at the state level need to be mapped and modeled. LIDAR (Light Detection and Ranging) and other subaerial and submarine data, as well as dynamic geomorphic modeling, should be utilized.
- HAZUS (Hazards United States) and other models should be used to produce estimates of physical damage, economic loss, and social impacts due to wind and flooding during storm events.
- The Federal Emergency Management Agency (FEMA) should develop a sea level rise module for HAZUS that considers not only static changes in sea level rise, but also resultant impacts on other hazards (such as erosion, storm surge, wetlands loss, and increased storm frequency).
- Sea level rise should be modeled for states based on Intergovernmental Panel on Climate Change scenarios, and cost estimates should be developed for resulting effects in terms of natural resource impacts and adaptation of existing coastal development.
- Additional collaborative and peer-reviewed information (such as coastal upland topography) is needed to improve model accuracy.
- Federal and regional partners need to work with the states to develop a realistic range of sea level rise planning scenarios based on clear, explicable assumptions at a variety of scales—including specific local scenarios that address impacts on infrastructure, economic enterprise, and society.
- Specific examples should be developed to demonstrate the relevance of sea level rise information, models, and scenarios. Additionally, concrete frameworks should be provided illustrating how to incorporate information and tools into decision making.
- Risk and vulnerability assessments and maps should be developed at all scales, including states working with each coastal community.

- At a minimum, the risk and vulnerability assessment should include the following:
 - Critical facilities and infrastructure
 - Erosion and flood hazard areas
 - Evacuation routes
 - Transportation infrastructure
 - Socioeconomic data (including zoning, property boundaries, and valuation)
- Information and tools need to reflect community expertise and include training and technical assistance in order to build and sustain capacity.
- A standardized GIS (geographic information system) methodology should be developed and utilized for assessment and mapping.
- Greater collaboration and information sharing is needed between the private and public sector in applying risk prediction and risk prevention models to sea level rise, inundation, and coastal hazards.
- A way should be identified to transfer the risk and loss-prevention business models used by the insurance industry, which can be complex and expensive, to the public sector.
- The sea floor, coast, and nearshore (including the distribution and abundance patterns of coastal marine organisms and habitats) need to be mapped and characterized.
- Improved understanding of ocean and coastal hydrology is needed, including linkages between freshwater inputs and coastal waters, water budgets, saltwater intrusion, hydrological modeling, and factors controlling freshwater inputs.
- Planning and decision-making tools should be improved to inform interstate water management and in-state water management about potential impacts of sea level rise.

Adaptation Planning, Guidance, and Policy

- In order to devise adaptations strategies for a variety of sea level rise scenarios and adjust these in the future as forecasting improves, state coastal managers identified a need for new policies to address the following:
 - Siting of public infrastructure
 - Site-level project planning
 - Wetland conservation and restoration
 - Shoreline building setbacks and building elevations
 - Alternatives to shoreline “armoring”
- Recognize that urbanized, suburbanized and more natural coastal areas need different policy approaches and tools to assess the legal, economic, and social issues related to consideration of alternative responses to sea level rise (including shoreline retreat, armoring and engineering solutions, shore protection, and a no action alternative).
- Perform a national study focused on the impacts of climate change and sea level rise on ports and maritime commerce. Include adaptation options in the study.
- Develop tools to adapt current wetlands protection and restoration efforts in order to incorporate sea level rise will help address management options to raise elevations of threatened wetlands and/or provide for managed natural retreat and space for creation of new replacement wetlands.
- Place more emphasis on tools, including land-use policies to assist coastal communities prevent development of properties that may allow for retreat and “rolling easements” in the face of sea level rise, including legal research and regulatory models to address private property concerns, public trust, health, and welfare.
- Develop comprehensive regional and state coastal restoration and conservation priority plans, including consistent and defensible methodology designed to buffer sea level rise and prevent storm damage.

- Design a strategy to identify needs and secure the substantial funding that will be needed for acquisition, restoration, and conservation easements.
- Perform further evaluation of uncertainties, information, and decision-support tools to justify setback requirements, buffer areas, and “living shoreline” approaches that take into account sea level rise, inundation, and stormwater runoff. Include legal and economic analysis.

The following federal policy needs were identified to assist states and localities to implement sea level rise adaptation strategies:

- Create a clear federal strategy for intergovernmental coordination to address sea level rise adaptation including interagency cooperation between the National Oceanic and Atmospheric Administration (NOAA), FEMA, the U.S. Army Corps of Engineers, coastal management programs, and floodplain management programs. (Note: This recommendation is also relevant at the state and local level where the strategic plans for climate change, coastal zone management, hazard mitigation, land use, and ocean management are usually disjointed).
- Develop regional “clearinghouses” for ongoing information exchange among federal, state, and local programs and research activities. (For example, International Council for Local Environmental Initiatives, NOAA).
- Support the governors’ regional ocean collaborations and regional coastal and ocean observing associations as a forum for information, tool development, and research.
- Reauthorize the Coastal Zone Management Act to foster integrated planning and implementation of adaptation strategies.
- Include funding dedicated to state and local adaptation efforts in federal legislation addressing climate change.

Policies adopted by states include recognition of the following stakeholder needs to support sea level rise adaptation:

- Develop model governance policies and programs that integrate adaptation and response planning strategies for coastal erosion, coastal storm, and sea level rise into existing state and local policies and programs.
- Create state and local adaptation policies (i.e., protect, retreat, abandon) for vulnerable public and private sector infrastructure.
- Adopt key principles that should help guide communities as they build local adaptation strategies for sea level rise including:
 - Plan early
 - Build on existing policy tools
 - Integrate across sectors, disciplines, and jurisdictions
 - Build capacity
- Strengthen building codes and construction techniques for new infrastructure and buildings in vulnerable coastal areas.
- Study the risk that climate change poses to the availability and affordability of insurance.
- Require a statement to inform prospective coastal property purchasers of the potential impacts of climate change and sea level rise.
- Identify high priority protection areas, and then strategically and cost-effectively direct protection and restoration actions.
- Develop and implement a package of appropriate regulations, financial incentives, and educational, outreach, and enforcement approaches to adapt to sea level rise.

- Update and maintain statewide, sea level rise mapping, modeling, and monitoring products.
- Utilize new and existing educational, outreach, training, and capacity building programs.
- Identify ways to encourage innovative engineering and design solutions, so that the structures are resilient to potential flood or erosion events (or can be easily relocated or removed to allow for progressive adaptation to sea level rise, flooding, and erosion).
- Develop statewide frameworks that can be used by state and local agencies as guidance in preparation of adaptation plans, including regulatory and legal frameworks and changes as necessary.

Education, Training, and Communication

- Identify what organizations—including agencies at all levels of government and groups in the academic, non-government organization, and private sectors—are doing to (1) develop and sustain sea level rise adaptation strategies, (2) evaluate potential alternatives, (3) facilitate best practices, and (4) build necessary capacity.
- Develop an inventory of (1) efforts, plans, and strategies to address and/or adapt to accelerated rates of sea level rise, (2) lessons learned, and (3) best management practices.
- Establish a clear vocabulary for mapping and other needs related to sea level rise and climate adaptation plans. Currently, state and federal managers use different terminology to describe needs, technical requirements, and desired outcomes.
- Make a concerted effort to develop reliable, consistent sea level rise information from scientists, educators, and managers that is understandable to user and stakeholder communities (to help minimize public skepticism and scientific uncertainties).
- Develop specific strategies, information, and “messages” for target groups, including decision makers, coastal homeowners, real estate interests, recreation and tourism groups, journalists, and opinion leaders.
- Define what key concepts a climate-literate citizen should know to make informed decisions.
- Capitalize on point-of-sale of real estate to deliver information (associated risk, etc.) to property owners. Landowners should be familiar with flood maps, as well as inundation/hazard mapping.
- Improve public understanding and provide a clear explanation of the different causes and variation of sea level rise. (It is not simply a function of climate change.)
- Develop transparent and participatory approaches that involve stakeholder groups, particularly in developing community vision and reviewing scenario and policy options.
- Create model approaches, case studies, and training to ensure effective outreach and engagement.
- Develop and provide ongoing support for information clearinghouses and web portals that address effective ways to manage sea level rise information and to make decision support tools readily available to the stakeholder communities. Two good, local examples are the *Storm Smart Coasts* web portal initiated in Massachusetts and the *Shoreline Online* website developed in Maryland. This need was called for in numerous reports.
- Address the gap between long-term sea level rise and climate change scenarios with specific education, training, and outreach efforts. These efforts should also address the need to make management decisions and take adaptation actions now.
- Perform additional sea level rise socioeconomic impact, risk studies, and cost-benefit analyses. These will be very important to create the sense of urgency that will justify the extensive planning—and potentially costly intervention—in the short term to abate future impacts.
- Prepare an inventory and description of federal inundation and other models relevant to sea level rise and coastal hazards as a users’ guide for states and other stakeholder groups.

- Sustain mechanisms for regional collaboration on climate change and sea level rise adaptation. The Regional Governors' Ocean Councils and Regional Ocean Observing Associations present an opportunity to support this collaboration.
- Recognize that regional groups may (1) have limited capacity to incorporate information, tools, or policies important to sea level rise adaptation, and (2) be focused on other priorities. Address these limitations and build capacity.
- Address issues of scale. For example, how useful will vulnerability assessments and adaptation plans be at regional scales vs. state vs. local? Identify the regional-scale questions related to sea level rise that regional councils can or should address.
- Develop specific agreements, shared plans, and objectives between the regional observing and governance groups. Integrate plans for observing platforms, buoys, monitoring stations that will inform sea level rise, inundation, and other related community needs.
- Facilitate cooperation between states and federal agencies and regional associations, so that they can inventory data, identify data gaps, develop strategies to fill gaps, and disseminate information and products through common portals.

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Appendix II: Planning for Sea Level Rise in Delaware, a Case Study

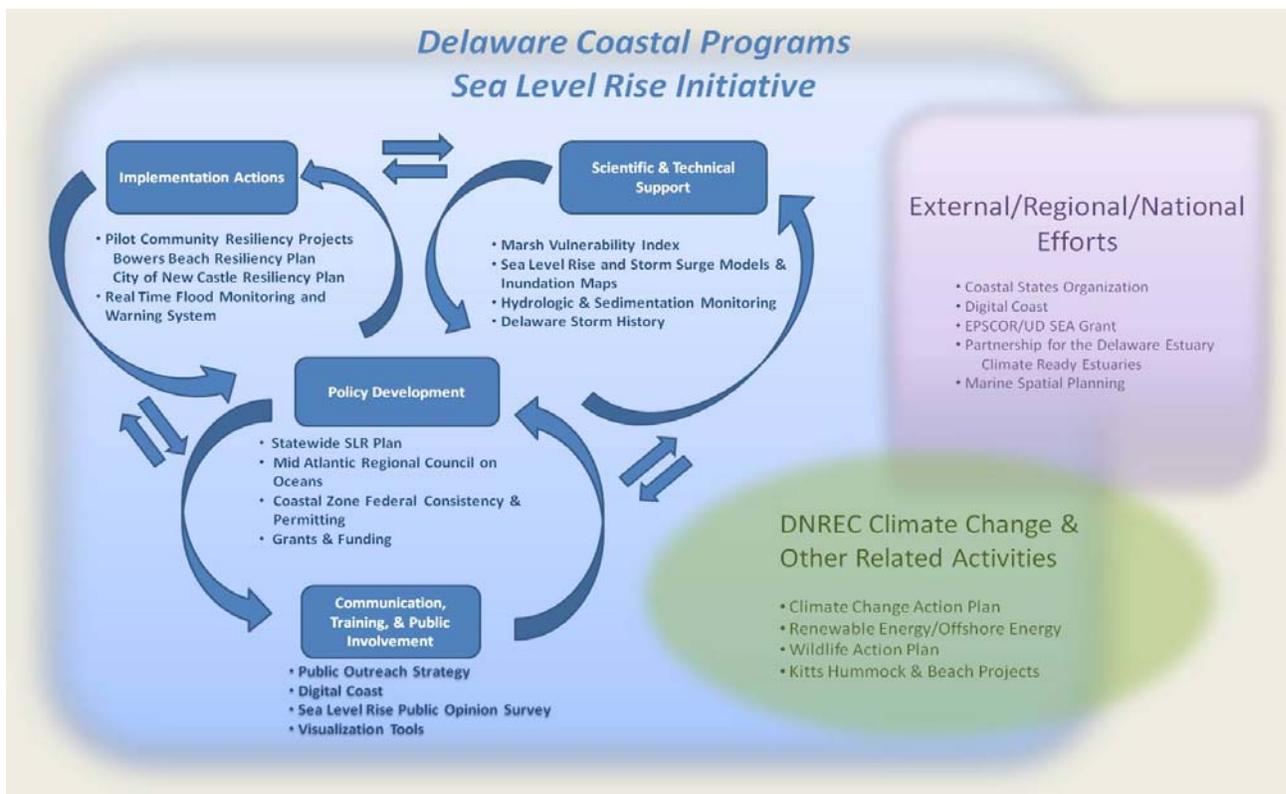
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Coastal managers in Delaware have been mindful of the need to plan for sea level rise for over twenty years, yet Delaware’s concerted effort towards sea level rise planning has only recently begun in the form of the Delaware Sea Level Rise Initiative. Although the concern existed for quite some time, the tools, technology, and public support for such a planning effort did not exist until recently.

The ultimate outcome of the Delaware’s Sea Level Rise Initiative will be the institutionalization of sea level rise considerations into decision-making practices at the state and local level. In order to achieve this outcome, stakeholder groups must gain an increased awareness of sea level rise issues; decision-making tools must be developed; technical assistance must be provided to partner agencies and local governments that will enable them to plan for sea level rise impacts at a smaller scale; and everyone must learn to plan for and make decisions with a long-range perspective. Meeting these goals will require a considerable amount of funding and resources, partnerships, and technology transfer between all levels of government and the private and nonprofit sectors.

This case study will describe Delaware’s Sea Level Rise Initiative, a five- to seven-year effort that contains four basic components: Scientific and Technical Support; Communication, Training, and Public Involvement; Policy Development; and Implementation Actions. Each component feeds another component in an iterative and flexible way.



Process

The components of the Sea Level Rise Initiative must be adaptive and iterative. Tools, information, data, and policies developed within each component are utilized by staff and partners working on other projects. As needs are identified, additional resources are sought to fill the data and information gaps. However, it is important to note that the evolution of this model happened over the course of several years; realigning staff roles and program resources was a critical first step in the process.

Realignment of Staff and Resources

The Delaware Coastal Program (DCP) is comprised of both the Delaware Coastal Management Program and the Delaware National Estuarine Research Reserve (DNERR). The makeup and diversity of technical expertise within DCP—and the close working relationship between the two programs—makes DCP uniquely suited to take the reins of a statewide planning effort that includes development of technical tools, technical assistance, and outreach. However, in order to take advantage of these skills for sea level rise planning, the roles and responsibilities of staff had to be shifted and the direction of the program had to be realigned to have a strong focus on issues of coastal resiliency and sea level rise.

To provide a critical mass of staff and fiscal resources for this type of change, DCP re-aligned a significant portion of its existing staff and funding resources into a Sea Level Rise Initiative to serve as a catalyst for the needed changes. This organizational restructuring has enabled DCP to redirect approximately six full-time equivalents and approximately \$500 thousand per year for a three- to four-year period from both the Delaware Coastal Management Program and DNERR to develop strategies, begin implementation of strategies, and refine the approaches as part of the Sea Level Rise Initiative. While largely a programmatic effort, the initiative is intended to provide a focal point for involvement and engagement of many other programs and stakeholders in the process—leading to an “organic” growth of coordination of efforts.

This shift took approximately two years. Every DCP staff member—whether an educator, scientist, manager, or planner—now has a role in the Sea Level Rise Initiative.

Building the Scientific Foundation

Before sea level rise planning processes can begin, a foundation of data sufficient to support the effort must be available. To be able to scientifically predict future changes in sea level for planning and policy development purposes, researchers must know (1) the historic trends, (2) current conditions, and (3) information regarding how the environment is adapting to these changes. To be able to provide adequate data for the needs of policy development and early implementation, DCP has spent several years gathering existing data, collecting new data, identifying and filling data gaps, and using the data to model sea level rise scenarios.

Any research involving sea level rise requires a base framework of accurate topographic information. Among other things, this allows the development of geographically accurate vulnerability assessments (that is, the identification of areas at risk). Prior to 2005, the state had only 30-meter digital elevation models with two- to three-meter vertical accuracy. These data could not provide the needed accuracy for defensible results from any research activity. Through the cooperative effort of several state and federal agencies over a five-year period, LIDAR (Light Detection and Ranging) topography data were collected throughout the entire state. While this process had many pitfalls and complications, it was a necessary first step. For more information on this, please see the LIDAR case study online: http://www.csc.noaa.gov/digitalcoast/inundation/pdf/de_lessons.pdf.

Enhancing physical parameter monitoring and accessibility of the data was deemed crucial for researchers, coastal managers, governmental personnel, and the general public. Having extensive, publically available data sets not only aids ongoing research, but it also provides the opportunity for others to see the baseline data (including identification of areas at risk) from which many decisions and policies are derived. Making these data available in real time allows emergency personnel to quickly react to situations that might be exacerbated by the effects of sea level rise and climate change. To bolster the amount and accessibility of data, DCP installed new monitoring platforms which included two wave buoys in the Delaware Bay, water-current profilers in two tidal rivers, and additional water-level recorders in critical habitats along the coast of Delaware Bay. Additionally, DCP supported the efforts of the University of Delaware to determine where data gaps exist, which led DCP to also support a consequent increase in the capacity of the Delaware Environmental Observing System to help fill the gaps.

The collection of historic data is key to understanding how the environment and people adapt to changes in sea level. Through DNERR funding, graduate students have documented vegetation changes over time using over 70 years of historic photos and other historic data. This information, coupled with a DCP series of deep marsh cores around the state, provides researchers a short-term and long-term picture of how the estuarine environment has changed over time. In addition to these decadal and centurial time frames, several sediment elevation tables are monitored quarterly to determine how the marsh reacts to seasonal and annual variations. Through the University of Delaware, a comprehensive history of coastal storms is being updated. This coastal storm history will not only include factors pertaining to flooding extent and damage, but also the meteorological and tidal conditions preceding the events. Understanding all of the factors involved will help emergency planners and responders more accurately predict the effects of oncoming storms. It will also allow the development of scientifically-based and socially-supported responses to sea level rise.

Evaluations of existing conditions can be done using historic data and currently monitored parameters. These evaluation research projects have a wide range; examples include determining the health and vulnerability of marshes based on their surface elevation in the tidal prism, examining the flooding and drainage scenarios of small coastal communities, and estimating the outflow potential of municipal storm sewers with outfalls below the high tide level. Of critical importance—not only for research but for outreach and planning—is the development of inundation maps based on storm frequency coupled with sea level rise for the entire coast of Delaware.

By combining historic information and current evaluations with monitored physical and biological data, predictions can be derived on the effects of sea level rise along the Delaware coast. Using the Sea Level Affecting Marshes Model DCP can provide a coarse-scale picture of (1) how sea level rise might cause the migration of coastal marshes and (2) any impediments to this migration over long time scales. To understand the acute consequences of sea level rise coupled with coastal storms, the comprehensive 2-D model MIKE FLOOD is being implemented at the local scale.

The culmination of all this scientific and technical support provides the needed base for all policy, implementation, and outreach activities. In turn, the policy, implementation, and outreach activities give insight on where additional research is needed.

Initiating Early Implementation Actions

Working closely with constituents and end users from the beginning of a multiyear process ensures that policy decisions are not made in a vacuum; in this manner, they take into consideration the very real problems that are faced by coastal managers, mayors, town councils, engineers, and landowners as they make land-use decisions. Conducting early implementation actions provides examples, scenarios, and solutions that can be applied later to a broader audience. It can also address existing coastal vulnerability issues, while at the same time preparing for increased rates of sea level rise. Early implementation also shows progress towards end goals, which is a very real indication that policy development for sea level rise is intended to be implementation-based. Building early implementation into the adaptation planning process also provides an opportunity for partners to address critical needs as they arise, rather than after a planning process is completed.

DCP is currently working with the town of Bowers Beach (a small coastal enclave that experiences coastal inundation during storms and unusual high tides) and with the city of New Castle (a colonial town settled by the Dutch in 1651 and protected from coastal flooding by a series of dikes and impoundments). In Bowers Beach, a vulnerability assessment is being conducted by DCP staff through hands-on workshops with community members and technical experts. In New Castle, before a vulnerability assessment can be conducted, the structural integrity of the dike system must be assessed. DCP has assisted New Castle with contracting and funding that study.

During the course of these and other projects, it was also discovered that the current network of tide and stream gauges did not provide adequate warning to coastal residents regarding potential flooding events. To provide coastal emergency managers with better tools, DCP partnered with the Delaware Environmental Observing System, the Delaware Experimental Program to Stimulate Competitive Research, and Kent County to fund the development of an early warning system for coastal flooding based on real-time monitoring coupled with National Oceanic and Atmospheric Administration (NOAA) predictive climate models. If the county pilot project proves successful, this early warning system will be implemented statewide.

Communication, Training, and Public Involvement

No public policy changes can occur at the state or local level without support of the public, legislators, and managers of coastal resources. For these audiences to support changes, they must understand what sea level rise is, why it is happening, how it could affect them, how to interpret and work with scientific uncertainty of sea level rise predictions, and the social and economic cost of potential adaptation strategies.

Recent national surveys have shown that public opinion on climate change is mixed. In October 2009, Pew Foundation survey found that during the past year (1) there has been a decline in the percentage of Americans who think there is solid evidence that temperatures are rising, and (2) there has been a significant decline in the percentage of people who think that global warming is a serious problem. There are no national surveys that address sea level rise as an individual issue, but the climate change surveys show that there is a lot of work to do before wide public support for climate change and sea level rise adaptation strategies can be achieved.

DCP understands that communication and training will be central to successfully planning for sea level rise and implementing adaptation actions at the state and local level. As such, DNERR's Coastal Training Program will focus on issues of sea level rise and adaptation. DNERR recently hired a part-time Coastal Training Program Coordinator who will (1) plan and lead end-user training programs and (2) plan and design programs for general outreach.

In December 2009, a statewide survey of opinions and attitudes towards sea level rise was conducted. The survey was designed to test respondents' knowledge of sea level rise, their concern about sea level rise and its potential effects, and their level of support for potential adaptation strategies. The results of this survey will inform development of a long-term public outreach strategy that will be implemented by DCP, with strong support from the Coastal Training Program.

Although the Coastal Training Program Coordinator has just recently begun work, several trainings and outreach events have already begun. Over the past year, two trainings co-sponsored by DNERR and the NOAA Coastal Services Center (CSC) were held; one addressed vulnerability assessments and one addressed inundation mapping techniques. Both trainings were attended by a range of local, state, and federal employees, and the trainings resulted in partnerships and increased networking opportunities. The two pilot projects outlined above were a direct result of the vulnerability assessment training, where local government officials in attendance were encouraged to partner with DCP, take advantage of available funding, and put into practice what they had learned. DCP also began increasing public knowledge of the threats of sea level rise by designing an interactive educational display for the University of Delaware's annual Coast Day. The display will be used at other upcoming events to reach general audiences.

These activities give Delaware a good start towards building the knowledge and support necessary for state and local policy changes. As additional training and educational needs are identified, DCP will work with its partners to meet those needs.

Developing the Policy Framework

Developing policies to address sea level rise at the state and local level is at the center of the Sea Level Rise Initiative model: the ultimate outcome for this project is to institutionalize sea level rise planning at all levels of government and in the public consciousness. Policy development will be informed through partnerships with local governments and early implementation, information learned through outreach and training, and products and data developed through scientific and technical support.

In 2007, staff from DCP began to formally plan for a multi-year, statewide sea level rise adaptation planning process. The proposed approach follows a phased collaborative planning process that DCP has successfully used in previous multi-stakeholder initiatives. Based on this framework, DCP submitted an application to CSC to compete for a two-year coastal management fellow; DCP was successful in their bid.

Although the CSC fellow came on board in September of 2008, the adaptation plan has yet to make substantial progress. Central to the delay was a change in administration at the state level, and a subsequent delay in the appointment of a new cabinet secretary for the Department of Natural Resources and Environmental Control (under which DCP is housed). The change in administration and uncertainty about department-wide direction and goals—coupled with baseline data sets that were not yet completed and ready for use—caused DCP to veer slightly from its planned, multi-phase process.

The phased collaborative process envisioned the creation of a steering committee that would be comprised of high-level state administrators, local government officials, and leaders of business and citizen groups. The steering committee would oversee and direct numerous workgroups, who would be comprised of technical experts and stakeholders. Information would flow upward to the steering committee, be debated and approved, and incorporated eventually into a comprehensive statewide plan that contained recommendations for action. This top-down approach was proven to be unworkable during a political transition period.

In order to start the planning process without first designating a steering committee, DCP hosted a day-long stakeholder workshop in March of 2009. The workshop was co-hosted by the Delaware Experimental Program to Stimulate Competitive Research. The workshop was the first step in characterizing the issues facing Delaware. Workshop proceedings are available online at: <http://www.swc.dnrec.delaware.gov/coastal/Documents/Sea%20Level%20Rise%20Adaptation%20March%202009%20Workshop%20Summary%20Document%20FINAL%20-%20Full%20Document.pdf>.

It was hoped that committees could be formed soon after the workshop took place; however, this has not yet occurred. The new administration is greatly concerned with issues of climate change and green energy, and consequently it plans to implement carbon reduction goals and update the state's Climate Change Action Plan. DCP has been working to determine how the Sea Level Rise Initiative would fit into these plans, and whether the timing, funding, and staff resources would allow them to proceed on a parallel track. It remains unclear how this will play out, but it appears that we are getting closer to being able to formally move forward with the sea level rise adaptation process as originally planned.

The delay in the formal, committee-based planning process may prove to be a benefit to the overall sea level rise planning effort. The delay has provided DCP staff with opportunities to focus on baseline data collection and modeling. It has also provided opportunities for participation in regional and federal efforts, such as the Mid-Atlantic Regional Council on Oceans and CSC's Digital Coast Initiative. Staff has also been able to spend timeworking with several towns to assess vulnerability to sea level rise and coastal inundation; DCP will be announcing shortly the availability of additional grant funds for sea level rise and coastal resiliency planning. These efforts have strengthened DCP's partnerships with agencies at all levels of government, increased DCP's interaction with communities, and increased DCP's level of technical knowledge—all of which will be assets once the formal, statewide planning process is initiated.

Lessons Learned

For several years, DCP has been working towards reducing the future risks of sea level rise to the people, infrastructure, and natural resources of Delaware; while much has been accomplished, the progress has been much slower than originally anticipated. Three key lessons have emerged thus far: know your political arena, ensure adequate baseline data, and build capacity both internally and externally.

The Political and Management Arena

Delaware's Sea Level Rise Initiative has been organic: originating from technical experts within the field with knowledge of the state's vulnerabilities, the changing federal climate, and significant technological advances. This type of process requires different management techniques than those used for states, such as Maryland and California, that have been mandated (though state legislation or executive orders issued by the governors) to develop a climate change or sea level rise plan.

Given the lack of an executive mandate, coupled with political uncertainty and incomplete data sets, Delaware may have tried to jump too soon into a formal adaptation plan process. Development of informal networks of experts was just beginning. High resolution elevation data were not yet available for use (due to problems with final products delivered by the contractor). Staff members who were new to the issues of climate change and sea level rise were still struggling to get current with the vast amount and breadth of research. However, the delay in the formal planning process may prove to be helpful overall. During the past year, DCP staff and other partners have finished several pilot projects using the Sea Level Affecting Marshes Model, initiated projects to fill evident data gaps, completed training from CSC in inundation modeling and vulnerability assessments, developed a statewide survey to investigate attitudes and perceptions regarding sea level rise, and started to work with local government entities.

Development of Informal Networks and Capacity Building

To date, one of the primary successes of this effort is the development of informal networks and capacity building of both staff and partner organizations. Early implementation activities (such as the coastal hazards projects for the two Delaware towns and the inundation modeling at Prime Hook National Wildlife Area) have given staff a chance to obtain experience with the issues and available technology—while at the same time establishing partnerships and working relationships. In addition, these early implementation projects have helped establish DCP as a leader in sea level rise issues in Delaware.

Staff and partners have also attended two trainings hosted by CSC to address sea level rise and vulnerability. These trainings also added to the informal network and built capacity both within and outside of DCP.

DCP is building capacity at the local level through the Sustainable Coastal Community Program. Using NOAA Coastal Zone Management funds, this is a pass-through grant program specifically designed to provide seed money and technical assistance to local governments, non-governmental organizations, and others to begin developing plans to help communities become resilient to existing and future coastal hazards. In Delaware, this program provides the opportunity to provide capacity to local governments to implement and test strategies that may be useful statewide. Both the Bowers Beach and New Castle coastal resiliency planning efforts are an outgrowth of this program.

DCP is also building networks outside of the state through the Mid-Atlantic Regional Council on Oceans, a regional initiative by the governors of the five mid-Atlantic states that will include regional planning and action on sea level rise as one of their priority issues. This effort will provide the opportunity to consider regional impacts of sea level rise, placing Delaware's within the context of the mid-Atlantic region.

DCP has benefited greatly from involvement in numerous national efforts, including the Digital Coast, the Coastal States Organizations Climate Change Workgroup, and other efforts. These efforts have provided critical information and contacts at the federal level to assist Delaware. For example, as part of these efforts, DCP was able to secure significant assistance from technical CSC staff to reprocess and drastically improve Delaware's statewide LIDAR data. In addition, the development work for the Digital Coast project has enabled DCP to be better informed about emerging approaches to coastal inundation planning and sea level rise, which are now being tested through on-the-ground projects in Delaware. This has been extremely valuable as part of our local capacity building efforts. This experience provides critical evidence of the importance of state and local officials making the time to participate in efforts beyond their jurisdictional geography and to be engaged on all geographic levels. There is extensive national expertise and assistance available, once you learn where it is and who to ask for help.

Robust Baseline Data Sets

An extraordinary amount of data and information is necessary to begin planning for sea level rise adaptation. Delaware has a wealth of statewide GIS (geographic information system) data layers that are hosted centrally and can be used as baseline geographic data; however, there are no statewide data sets on frequently flooded areas outside of a mapped floodplain and no statewide sea level rise inundation products. The state also has limited access to social data at a scale that will allow for community-based planning.

The following is a list of data sets that DCP recommends for sea level rise planning efforts. This list does not include commonly available baseline GIS data sets (such as roads, land use, political boundaries, floodplains, and wetlands).

To assess level of vulnerability to sea level rise, the following are minimum requirements:

- Accurate LIDAR topography data
- Continuous water level data
- Wave height and frequency data
- Inundation maps
- Inventory and locations of tide/flood gates and management plans
- Condition analyses and locations of coastal dikes, berms, and management plans
- Inventory and locations of public, community, and social infrastructure at risk
- Shoreline recession rates and locations
- Storm surge data
- Historic and current marsh surface elevation change data
- Cost/benefit studies for adaptation scenarios
- Storm histories and historic flood levels
- Public perceptions of the science of sea level rise
- Assessment of level of public support for adaptation options

Recommendations for Future Actions

Over the past several years, DCP staff has worked with land managers (at the federal, state, and local levels), town councils, emergency managers, university researchers, and citizens on issues of sea level rise and inundation. DCP has participated in national committees, sponsored workshops, and testified on Capitol Hill. DCP been frustrated by a lack of reliable national and local data sets and by overlapping federal responsibilities, and DCP has been confused about the best available science and how to communicate it to real people. Based upon this, DCP recommends the following actions:

1. **The U.S. Climate Change Science Program (CCSP) should provide local-scale sea level rise scenarios for both short-term and long-term planning processes.** State and local entities do not have reliable local-scale sea level rise scenarios. Planning products like CCSP's Synthesis and Assessment Products and the Intergovernmental Panel on Climate Change report provide guidance on a global scale until 2100; they point out that local levels of rise could be greater or lesser than the global scale, and they do not provide any regional estimates at all. States and local governments need defensible projections, based upon local conditions and subsidence rates. State and local governments who are currently planning projects with 25- to 50-year life spans also need defensible incremental projections for shorter term planning.
2. **NOAA and the U.S. Geological Survey (USGS) should standardize all monitoring devices.** Delaware relies upon federally owned and operated coastal monitoring data, both for immediate emergency management and for long-term planning. However, USGS and NOAA currently do not use the same datum; NOAA uses mean lower low water while USGS primarily uses National Geodetic Vertical Datum 29 in Delaware (but in surrounding states has recorders using sea level and Penn Central Railroad datum). In order to use these data, state managers must be aware of this issue and correct the data to a common datum, which can cause delays in getting products out and has increased potential for erroneous data to be used in products released to the public.

3. **NOAA and USGS should develop and publish standard operating procedures and complete metadata for monitoring sites.** Recently, Delaware discovered issues in at least one important coastal monitoring station operated and maintained by the federal government that have resulted in differences of more than one-foot in tidal elevation. These erroneous data are available to the public and have been used by the state for planning and emergency planning purposes. To avoid inappropriate use of data and to ensure end users of data reliability, complete metadata for all monitoring sites should be made available. Additionally, publishing standard operating procedures would allow end users to discern how often sites are calibrated and maintained.
4. **USGS should provide data and information on groundwater aquifers and how they are likely to be affected by sea level rise.** Thus far, the primary focus of sea level rise planning has been inundation, but Delaware is concerned about how groundwater aquifers are likely to respond to rising sea levels. There is little information in the literature addressing this topic; there should be increased emphasis on this topic at the federal level, coupled with technical products for state and local practitioners.
5. **CCSP should develop and publish guidance on sea level rise models.** State and local managers need specific guidance regarding proper use of the various inundation models that are available. Guidance should be developed that will detail what data are needed for each type of model, the resolution of the data, the type of landscape where the model can be used, and at what scale the model can be used to make predictions.
6. **The Environmental Protection Agency (EPA) should conduct sea level rise vulnerability assessments of coastal wastewater treatment facilities (including septic systems) and their associated disposal areas.** Little information is available regarding regional impacts of sea level rise to wastewater treatment facilities, such as issues with combined sewer overflows and the operation of spray irrigation fields.
7. **EPA should provide guidance to wastewater treatment facility operators regarding rates of sea level rise for planning, and EPA should require any facility receiving federal funding to be designed to those planning levels.** As a result of the Economic Recovery Act and funding dedicated to wastewater treatment plants, major upgrades to wastewater treatments systems are being made—many without taking into consideration the effects of future sea level rise. EPA should take a risk-adverse position and require consideration of future sea level rise for all infrastructure projects funded in whole (or in part) by the EPA grants or loans.
8. **EPA should conduct sea level rise vulnerability assessments of drinking water systems, including private wells.**
9. **EPA should provide guidance to drinking water facility operators regarding rates of sea level rise for planning, and EPA should require any facility receiving federal funding or permits to be designed to those levels.**
10. **EPA should comprehensively review all of its programs for opportunities to encourage planning for sea level rise.** In addition to the wastewater and drinking water programs, EPA provides funding to state and local governments for a wide array of tasks, including brownfield and superfund sites cleanup, waste stream management, and wetlands preservation and protection.
11. **The U.S. Army Corps of Engineers (USACE) should work closely with states to reassess historic methods of utilizing dredged materials.**

12. **NOAA should assist states to develop and host interactive websites that deliver sea level rise information and planning tools.** Some states lack the capacity to design and operate interactive websites or are constrained by “common look and feel” guidelines. This makes it difficult to serve data and tools to end users and community members. CSC should assist states to creatively work around these technological issues.
13. **The Federal Emergency Management Agency (FEMA) should produce a series of flood maps that include buffer zones indicating areas that may be vulnerable to future sea level rise.**
14. **NOAA should conduct a national survey on sea level rise attitudes and perceptions.** Public support is critical for the success of any sea level rise planning effort, yet there is not a clear understanding of the public’s level of knowledge about sea level rise or about their level of support for adaptation actions. Delaware has initiated a statewide survey that will be valuable to DCP efforts, but specific national data would be extremely useful as well.
15. **NOAA, USGS, USACE, FEMA, and EPA should place a high priority on staff working one-on-one with state and local governments on issues of sea level rise.** Federal staff members need to interact in person with state and local staff in order to see firsthand the very real issues that local entities are dealing with—issues that are often greater than just data availability. The federal agencies should encourage staff participation and travel in local projects, task forces, and collaborative planning efforts.
16. **State and local governments should look to regional ocean governance entities for assistance in assessing and solving shared water body issues.** For example, they could promote greater regional involvement in on-going federal mapping activities, including a potential role under the Ocean and Coastal Mapping Integration Act that is part of Public Law 111-11 Omnibus Public Land Management Act of 2009.
17. **NOAA should ensure that financial support to Sea Grant programs is linked to providing support for sea level rise adaptation at the state and local level.** In addition, NOAA should ensure alignment and knowledge transfer between Sea Grant Programs, State Coastal Management Programs, and National Estuarine Research Reserves on issues of climate change and sea level rise.
18. **The U.S. Department of Transportation should require sea level rise vulnerability assessments and improved design criteria for any project receiving federal funding.** The Department of Transportation has drafted several reports outlining the risks associated with climate change and sea level rise in the United States, but has not yet implemented sea level rise and inundation design standards for projects receiving federal funding. Federal funding should no longer be utilized to construct projects that may be subject to future inundation.

Appendix III: A Strategic Regional Framework for Responding to Sea Level Rise in Southeast Florida

Jim Murley, Barry Heimlich, Leonard Berry, and Patricia Springer

Center for Environmental Studies, Florida Atlantic University

Florida has the longest coastline in the continental United States. From the Florida – Georgia border the Atlantic coastline is dominated by barrier islands with sandy beaches, coastal marshes and predominately low lying mainland. South of Biscayne Bay, the Florida Keys bracket Florida Bay and the 10,000 Islands, together forming an interconnected web of national parks, marine sanctuaries, refuges, state parks, and aquatic preserves. In Southwest Florida, the Gulf Coast curves north and west, sandy beaches punctuated by gulf-fringing marshes and finally ending with coastal bluffs that are some of the highest points along the Gulf of Mexico shoreline. The Florida peninsula was one of the last landforms to be exposed after the last ice age, and it will be one of the first areas significantly impacted by sea level rise and inundation associated with climate change. Florida’s population includes more than 18 million people—three-quarters of which live within 25 miles of the ocean shoreline. Given that, Florida must develop the data that will allow decision makers to choose a range of sea level rise projections and planning standards for future adaptation actions. Over the last 100 years, Florida has experienced an estimated 12 inches of sea level rise, and projections for the future range from 3–5 feet.

The premise of this case study is based on the assumption that the most efficient approach to sea level rise planning is to use existing regional management and research structures augmented by existing and expanded partnerships between federal and regional agencies active in Florida. Local governments and nonprofit organizations will be integrated into a process of collecting data, modeling, planning policy, and providing public information. The initial region on which this case study will focus is southeast Florida, an area encompassing one-third of the state’s population. It is also the area identified by the U. S. Congress as part of the South Florida Ecosystem, within which the U.S. Corps of Engineers (USACE) and the South Florida Water Management District are currently conducting programs and projects authorized under the Comprehensive Everglades Restoration Plan (CERP). The temporal period of the study will be for 50- and 100-year projections of sea level rise, with the possibility of additional shorter temporal benchmarks based on availability of future regional-scale climate data and models. The outcome of the study will be a cooperative program involving local, regional, state, tribal, and federal agencies focused on projecting sea level rise impacts on efforts to restore the Everglades and on assisting community-level responses to impacts on bordering urban areas.

In Southeast Florida, the government roles for addressing sea level rise are organized around two major initiatives. Federal, regional, and state agencies are primarily involved in the Everglades restoration process described below. Local governments have recently organized themselves under a Regional Climate Change Compact to (1) leverage their influence over ongoing federal and state studies and (2) maximize the potential funding that might be obtained in future federal climate change legislation.

Examples of these efforts include the following:

- Federal agencies are working individually and together with the South Florida Water Management District on sea level rise assessment and adaptation. Overall guidance is being provided by the South Florida Ecosystem Restoration Task Force.
- Two counties, Miami-Dade and Broward, have well-developed climate change adaptation task forces. They recently invited Palm Beach and Monroe (Florida Keys) Counties to join them in a regional summit.

- The State Energy and Climate Commission is addressing coordination among its other activities.
- Florida Atlantic University, under its Integrated Collaborative Climate and Energy Initiative, is working with other public and private universities—as well as state and federal agencies—to develop integrated approaches to climate change adaptation.

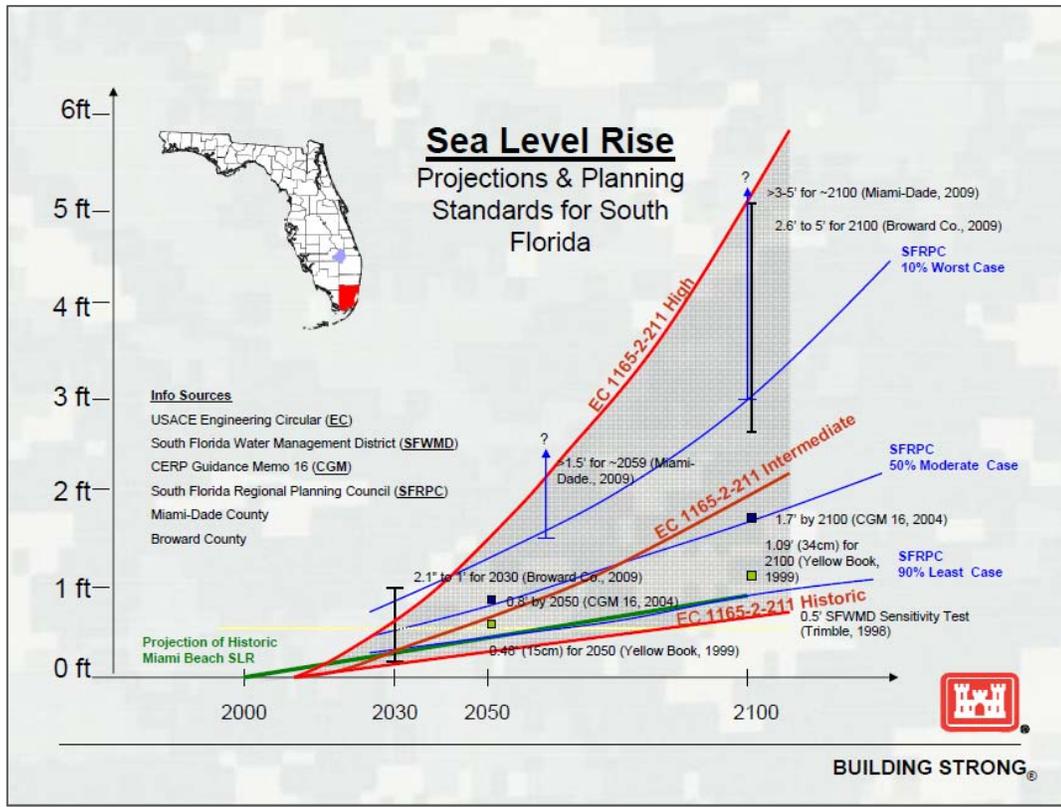
A Regional Perspective

CERP Sea Level Change Guidance

Participating agencies in the CERP process have been following prior guidance developed by USACE (2000), the National Research Council of the National Academies of Science (1987), special CERP Guidance Memorandum for Sea Level Rise Considerations for Formulation and Evaluation of CERP projects, and observations on sea level rise contained within a National Academies of Science Committee on Independent Scientific Review of Everglades Restoration Progress (2008). These reports projected 0.5–3.0 feet of sea level rise. More recent, independent studies have projected from 3.0–5.0 feet of sea level rise. In July of 2009, USACE issued a new Engineering Circular that builds on past planning guidance, but also acknowledges uncertainties and risks in rate and depth of sea level rise. New guidance requires consideration of scenarios to include low, intermediate, and high rates of sea level rise (low corresponds to a continuation of historic trends and high corresponds to increases in the range of 5 feet).

The CERP process will begin with a technical report describing climate change challenges, identifying efforts underway, describing an initial impact assessment using existing models and geographic information systems, and outlining future work plans. It will be followed by a second technical report that will summarize climate change sensitivity data collection and model development efforts through 2011. Subsequent CERP Climate Change Regional Adaptation Planning studies are anticipated to develop and recommend appropriate adaptation strategies, policies, and plans. The draft vision statement for the CERP Climate Change Team is:

“A wide range of potential global climate change impacts are forecast in coming years for the Everglades and South Florida. To minimize future negative impacts and adaptation costs, the CERP partner agencies will collaborate to quickly identify climate change sensitivities in natural areas and developed areas, and then work proactively with stakeholders and decision makers to develop and implement climate change adaptation policies and plans by 2015 that will be models for the rest of Florida and our Nation.”



Players Involved in CERP

The CERP process provides an existing framework for responsible agencies and other players to provide essential tools and information.

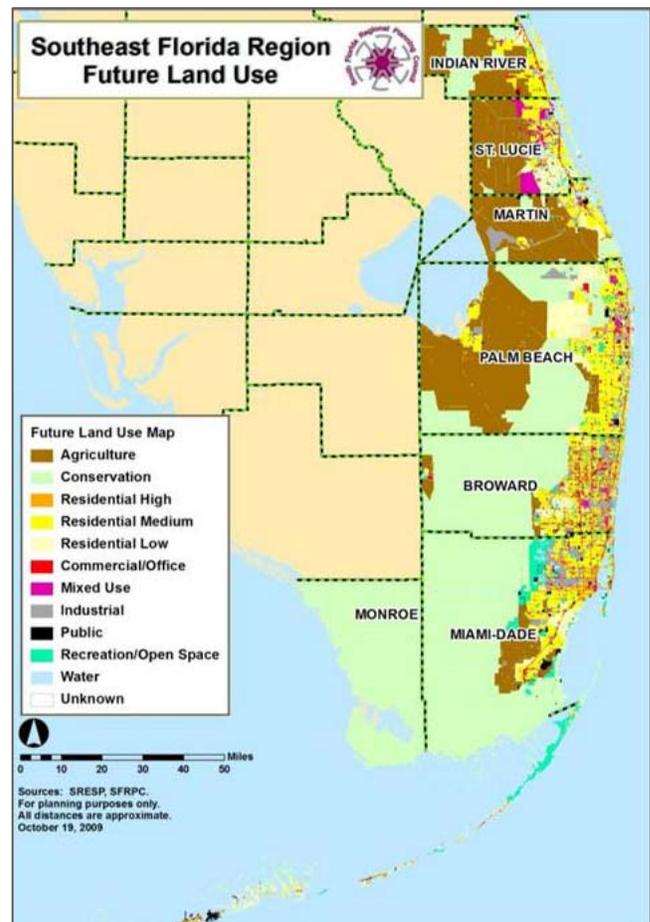
1. U.S. Geological Survey will be providing research and models to explain the impact of climate change effects on the South Florida ecosystem, habitats, species, and groundwater hydrology. Specific models are linked to the South Florida Water Management Model.
2. U.S. Fish and Wildlife Service is focusing on climate change impacts to its 27 Florida National Wildlife Refuges, in order to analyze how much land will be lost due to sea level rise. They have a joint project with the Massachusetts Institute of Technology and the U.S. Geological Survey to complete a two-year pilot study that (1) analyzes stakeholder interests related to climate change, growth, development and other issues, and (2) develops scenarios of sea level rise alternatives to address those interests with respect to U.S. Fish and Wildlife Service trust resources.
3. National Park Service's Everglades National Park has issued a Resource Evaluation Report: *Potential Ecological Consequences of Climate Change in South Florida and the Everglades*. Everglades National Park is developing a vegetative succession model for the Everglades and surrounding coastal areas to model landscape-scale vegetation community transitions.
4. Environmental Protection Agency will be focusing on national climate change program applications in South Florida, with a special focus on Charlotte Harbor National Estuary Program's participation in the Climate Ready Estuary pilot projects.
5. National Oceanic and Atmospheric Administration's Florida Keys National Marine Sanctuary conducts ongoing data collection and studies the effects of climate change on coral reefs.

6. Federal Emergency Management Agency is updating their flood insurance maps through their climate change risk studies.
7. U.S. Navy is conducting studies and reviewing adaptation measures to ensure the future capability of the Boca Chica Naval Air Station in the Florida Keys.
8. USACE is now supporting the use of risk-informed decision making and implementing new guidance on Sea Level Change Considerations for Civil Works programs (July 2009).
9. Florida Fish and Wildlife Commission conducted a summit on impacts to fish and wildlife species leading to the development of an agency action plan.
10. South Florida Water Management District is the local partner for CERP and is involved in all of the federal, state, and local studies dealing with sea level rise. For the 16 county areas within their jurisdiction, they are responsible for floor protection, water supply, and environmental restoration. The district has extensive modeling capabilities that are constantly being updated based on new data. District staff prepared a white paper on the impacts of climate change and sea level rise for the South Florida Water Management District Governing Board in the fall 2009.
11. South Florida and Treasure Coast Regional Planning Councils are conducting regional hurricane evacuation studies utilizing LIDAR (Light Detection and Ranging) data. They are also conducting a study on model practices for building climate resilient communities.

Southeast Florida Climate Summit

The Southeast Florida Climate Summit was held on September 23, 2009, in Fort Lauderdale; it was hosted by the Broward County Commission in partnership with Palm Beach, Broward, and Monroe Counties. Participants included local officials, federal and state legislators, regional transportation planning authorities and water management authorities, and members of the climate change task forces representing the four co-hosting counties.

All four of the Southeast Florida counties share challenges related to their urban areas being wedged between the Everglades and the Atlantic Ocean. In particular, the counties noted that rising sea levels could limit the effectiveness of critical drainage infrastructure, endanger beaches and coastal natural resources, and increase incidents of saltwater intrusion on the Biscayne Aquifer—putting at risk the drinking water supply of the entire population of Southeast Florida. The counties pledged to adopt a Regional Climate Change Compact that includes a joint policy position to the U. S. Congress and the Florida Legislature urging them to pass legislation recognizing the unique vulnerabilities of Southeast Florida. The four counties also pledged to work together to develop a Southeast Florida Regional Climate Change Action Plan (see Appendix III-A).



An Integrative and Collaborative Climate and Energy Research Program

Florida Atlantic University has formed a coalition of research institutes and assembled an interdisciplinary team to assist in developing adaptation and mitigation strategies for climate change. Initial core research for this effort includes sea level rise impact studies funded by the National Commission on Energy Policy. The Florida Atlantic University initiative has a forthcoming report, *Southeast Florida's Resilient Water Resources: Adaptation to Sea Level Rise and Other Impacts from Climate Change*, which includes an adaptive planning framework that matches impacts with potential adaptation tools considered best for responding to the impact (see Appendix III-B).

Florida Energy and Climate Commission

In 2008, the Florida Legislature created the Florida Energy and Climate Commission to coordinate the state's renewable energy programs and implement the State Climate Action Plan (including a section on adaptation to the impacts of sea level rise). The Commission is assisted by the Florida Energy Systems Consortium within the State University System.

Lessons Learned

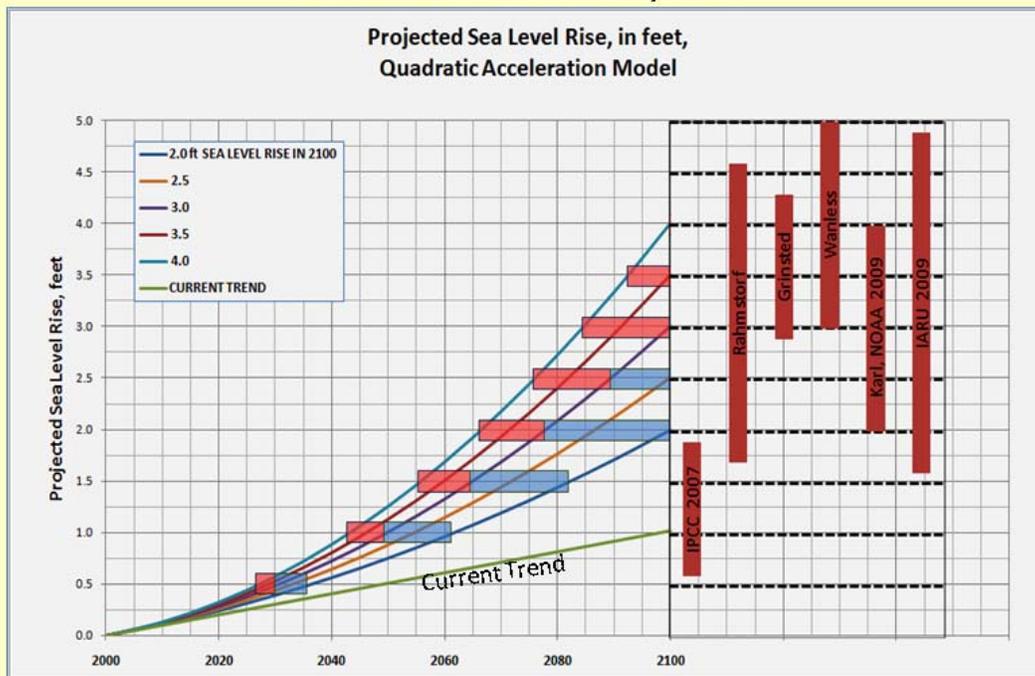
A common problem with existing data sets includes aggregating the various sea level rise projection maps. The scenario sea level maps and the models are also dependent on establishing a common use of mean sea level datum, comparing 1929 to 1988, and updating for survey future datum.

Another common problem identified is the lack of planning data on sea level rise for intermediate benchmarks between the commonly used time frames of 2050 and 2100. Researchers at Florida Atlantic University derived more detailed projected time frames.

Sea level rise in 21st Century

2 to 4 feet forecasted by 2100

Sea Level Rise, feet



Method of Heimlich, 2009

The table below provides a projected range of sea level rise values for 10-year intervals beginning in 2000 and a projected date range for a three- to four-foot sea level rise before 2100.

Year	Sea level rise (in feet) since 2000			Sea level rise (in feet) since 2000	Projected date ranges for sea level rise in 2100:		
		-			4 feet	3 feet	2 feet
2000	0.00	-	0.00	0.00	2000	2000	2000
2010	0.11	-	0.12	0.25	2017	2018	2021
2020	0.24	-	0.32	0.50	2027	2031	2036
2030	0.39	-	0.57	0.75	2036	2041	2050
2040	0.56	-	0.88	1.00	2043	2050	2062
2050	0.75	-	1.25	1.50	2056	2065	2082
2060	0.96	-	1.68	2.00	2067	2078	2100
2070	1.19	-	2.17	2.50	2076	2090	2116
2080	1.44	-	2.72	3.00	2085	2100	2130
2090	1.71	-	3.33	3.50	2093	2110	2144
2100	2.00	-	4.00	4.00	2100	2119	2157

Framework

In order to enable community-level responses to sea level rise and inundation in Florida, the strategic framework that is emerging for developing and integrating science-based data and information is one based on a series of regional-scale approaches customized to the unique attributes of Florida’s extensive coastline. (Florida has the longest coastline in the continental United States.) Local communities are currently pursuing initiatives under different labels: sustainable and resilient communities, green communities, and climate-ready communities. Their efforts often start with relatively non-technical actions that will lead to a cumulative reduction in green houses gases and mitigate climate change impacts.

However, with the onslaught of extensive international—and now national—data and science on climate change impacts, local communities are asking for reliable estimates of sea level rise over short-, intermediate-, and long-range time scenarios. They also need assistance mastering new data sets (such as LIDAR maps) in order to make defensible determinations of areas vulnerable to sea level rise in their jurisdictions. With 67 counties and over 400 cities in Florida, the only way to effectively and efficiently provide that data is through regional partnerships that have expertise in data, modeling, and other information dissemination tools.

Because of the significant existing and future funding commitments made by the federal and state governments to the comprehensive restoration of the Everglades, the CERP process is ideally suited to field test the framework in the South Florida region. Transferability of lessons learned can be achieved through the other four water management districts, working with federal and state partners and other stakeholders. There may be data gaps and limitations, because the other four districts do not have federal partnerships of the same magnitude as the CERP program. However, because USACE will implement their new sea level rise guidance throughout the state, there will be common points of reference. The eventual statewide process and products can be assembled and analyzed by the Florida Energy and Climate Commission (working with key state agencies), and by adapting amendments to the statewide Climate Action Plan.

Summary Comments

Recent reports have listed Florida as one of the most vulnerable areas exposed to future sea level rise change. Recent high tide flooding events led to the back-up of storm sewers in several coastal cities, which is starting to produce anecdotal examples showing communities that sea level rise is a slow change in conditions occurring at the interface of the shoreline and low lying areas that will cause a rise in water table levels as salt water intrudes into the fresh water table. Floridians are used to dealing with climate events, hurricanes, and their collateral impacts from wind and surge. They receive federal and state assistance in recovering from these climate events and getting back to “normal.” They are not used to the change in conditions that will be characterized by sea level rise. They need better science, data, modeling, best practices, and community-wide dissemination tools to help future residents of Florida adapt to the reality that they will not be able to return to “normal.”

Recommendations

1. In regions and states where the federal government has designated regional ecosystem restoration or regional ocean governance initiatives (such as the Everglades, Gulf of Mexico, and Chesapeake Bay), every effort should be made to use these existing coordination mechanisms to facilitate the dissemination of data, models, and outreach information.
2. At the individual state level, federal funding for responding to sea level rise impacts should be coordinated with the state agency responsible for the state climate action plan or with the state agency designated by the governor for similar responsibilities.
3. Coordinated federal agency action is needed to assist regions and states with the models and data to develop time increments of projected sea level rise for planning purposes—especially for the planning of adaptation improvement to the most vulnerable infrastructure.
4. Federal government agencies should assist with funding and participation in regional technical and scientific workshops for scientists, engineers, policy makers, planners, and other stakeholders to exchange information and develop a comprehensive list of policy and planning recommendations for regions and states vulnerable to sea level rise.
5. Federal government agencies should examine how risk diversion tools (such as federal flood insurance) can be modified to be more sensitive to the climate change trends—rather than climate events—in order to assist regions and states adapt measures to reduce the risk of property damage due to sea level rise.

Appendix III-A: Southeast Florida Regional Climate Change Compact



Southeast Florida Regional Climate Change Compact

WHEREAS, there is consensus among the world’s leading scientists that global climate change is among the most significant problems facing the world today; and

WHEREAS, Florida is considered one of the most vulnerable areas in the country to the consequences of climate change with Southeast Florida on the front line to experience the impacts of climate change, especially sea level rise; and

WHEREAS, Broward, Miami-Dade, Palm Beach and Monroe Counties, herein the four counties that constitute the Southeast Florida Region, share in common a strong quality of life rooted in the region’s rich cultural heritage, vigorous economy, and environmental resources of global significance; and

WHEREAS, the aforementioned four counties of Southeast Florida, which represent approximately 30% of the population of the State of Florida, are physically linked one to the other by the Atlantic Ocean coastline and share some of the world’s most renowned natural resources such as the Everglades, our unique coral reefs, beautiful beaches, and fragile Keys ecosystem; and

WHEREAS, the four counties of Southeast Florida and their respective populations, totaling more than five million residents, are expected to share in disproportionately high risks associated with climate change due to low land elevations, rising sea level projections, and anticipated increases in tropical storm events; and

WHEREAS, rising sea levels could limit the effectiveness of critical drainage infrastructure, endanger beaches, and coastal natural resources and increase incidents of saltwater intrusion on the Biscayne Aquifer – putting at risk the drinking water supply for the entire population of Southeast Florida; and

WHEREAS, local governments, and the region as a whole, must give significant consideration to adaptation strategies designed to protect public infrastructure, property, water resources, natural areas and native species, and basic quality of life; and

WHEREAS, the aforementioned four counties of Southeast Florida account for a combined Gross Domestic Product of more than \$2.5 billion annually and more than 37% of statewide economic output; and

WHEREAS, while the four counties of Southeast Florida have independently taken steps to address global climate change, all parties recognize that coordinated and collective action on this, the defining issue for Southeast Florida in the 21st Century, will best serve the citizens of the region;

NOW THEREFORE, BE IT RESOLVED BY THE BOARDS OF COUNTY COMMISSIONERS OF THE FOUR COUNTIES OF SOUTHEAST FLORIDA:

SECTION 1: That each county shall work in close collaboration with the aforementioned counties of Southeast Florida party to this compact to develop a joint policy position urging the United States Congress to pass legislation that recognizes the unique vulnerabilities of Southeast Florida to the impacts of climate change and to further a joint policy position that includes specific recommendations regarding the allocation of federal climate change funding based on vulnerability to climate change impacts. Such recommendations might include designation of areas of Southeast Florida as uniquely vulnerable and of federal interest for the purpose of securing enhanced levels of federal participation in regional adaptation projects.

SECTION 2: That each county shall work in close collaboration with the other counties party to this compact to develop additional legislative policy statements relating to global climate change and future legislation to be considered by the Congress of the United States for transmittal to the Congressional Delegation representing, in part or in whole, districts within the area covered by this compact.

SECTION 3: That each county shall work in close collaboration with other counties party to this compact in developing joint position statements on proposed State legislation and energy/climate policies including but not limited to issues such as the region's energy and climate security and a renewable energy portfolio standard that defines renewable energy sources as wind, solar, geothermal, biomass, landfill gas, qualified hydropower, and marine and hydrokinetic energy and to collaborate on other emerging energy/climate issues that may be considered by the 2010 Florida Legislature for transmittal to the Legislative Delegation representing, in part or in whole, districts within the area covered by this compact.

SECTION 4: That each county shall work with other counties party to this compact in developing joint position statements for future State legislation that may be considered by the Florida Legislature for transmittal to the Legislative Delegation representing, in part or in whole, districts within the area covered by this compact.

SECTION 5: That each county shall commit appropriate staff resources and expertise, within budget constraints, to participate in a Regional Climate Team with other counties party to this compact toward the development of a Southeast Florida Regional Climate Change Action Plan.

SECTION 6: That each county shall work with other counties party to this compact in developing a Southeast Florida Regional Climate Change Action Plan. The Action Plan could, at a minimum, include the following components:

- (a) A baseline of greenhouse gas emissions for Southeast Florida;
- (b) Strategies for coordinated emission reductions throughout the built environment to include the use of energy efficiency, energy conservation, and the use of demand-side renewable energy resources;
- (c) Strategies for coordinated emission reductions from the transportation sector to include increased reliance on public transit, emerging vehicle technologies, and advanced biofuels;
- (d) Strategies for coordinated emission reductions resulting from changes in local and regional land use;
- (e) Strategies for the coordinated regional preparation for and adaptation to a rapidly changing global environment based upon regional mapping of projected sea level rise and any resulting amplification of localized impacts of tropical cyclone events. Such strategies shall incorporate climate preparation concerns for the regional economy, regional infrastructure and the built environment, social and cultural needs, and natural systems within the four counties party to this compact.

SECTION 7: That each county shall commit to participating with other counties party to this compact in hosting the Second Southeast Florida Regional Climate Change Summit in October, 2010.

Appendix III-B: Framework from *Southeast Florida's Resilient Water Resources: Adaptation to Sea Level Rise and Other Impacts from Climate Change*

ADAPTATION TOOL		SEA LEVEL RISE		MORE INTENSE HURRICANES	SEVERE DROUGHT	TORRENTIAL RAINS	SEVERE HEAT WAVES
Conservation		Counteract low water tables and saltwater intrusion, dry season			Conserve water supply		Counter water losses due to evapotranspiration
Protect Existing Water Supplies	Relocation of Wellfields	Locate wells away from saltwater intrusion zone		Locate wellfields away from surge zones	Locate wells away from saltwater intrusion zone		
	Hydrodynamic barriers w/treated wastewater or stormwater	Protect wells from saltwater intrusion		Risk of flooding during periods of heavy rainfall	Protect wells from saltwater intrusion	Risk of flooding during periods of heavy rainfall	
		Risk of flooding in injection zone during rainy season					
	Redesign/Relocate Salinity Structures/Locks and Pumps	Reengineer or relocate to counteract saltwater intrusion, sea level rise, and enhance stormwater drainage		To prevent storm surge penetration up primary canals and rivers enhance stormwater drainage		Reengineer or relocate to enhance stormwater drainage	
Land Use Planning Protect High Recharge Areas	Counter low water tables and saltwater intrusion		Locate recharge areas away from surge zones	Counter low water tables and saltwater intrusion		Recharge to offset evapotranspiration	
Alternative Water Supplies	Floridan Desalination	Replace supply threatened by saltwater intrusion		Not vulnerable to storm surge contamination	Supplement water shortages		
	Storage Reservoirs & Impoundments	Supplement supply of fresh water		Locate storage away from surge zones. Levee adequately for surge in reservoir.	Supplement water shortages	Storage of excess stormwater	Increases supply during hot, dry periods of high evapotranspiration
	Aquifer Storage & Recovery (ASR)	Store excess storm and waste water in rainy season for use during water shortages			Supplement water shortages	Storage of excess stormwater	Avoids evapotranspiration
Wastewater Recovery and Reuse	Irrigation	Conserve water supply	Risks Flooding Heavy Rain		Conserve water supply	Risk of flooding during heavy rainfall	Conserve water supply
	Agriculture	Conserve water supply			Conserve water supply		Conserve water supply
	Industry/cooling water	Conserve water supply			Conserve water supply		Conserve water supply
	Recharge aquifer for indirect potable use	Biscayne and/or Floridan recharge			Applicable to Floridan recharge. Also to Biscayne only during drought	Biscayne and/or Floridan recharge	Counter losses due to evapotranspiration
Biscayne recharge could contribute to flooding							
Reengineer Stormwater Systems	Forward Pumping to Ocean	Begin improving flood control systems immediately before sea level rises by 3-6 inches		Improve stormwater drainage as sea level rise exceeds 1-1.5 feet		Flood control, last resort	
	High Treatment and Discharge to Everglades WCAs.	Control flooding in low lying westerly flood plains due to sea level rise effects on drainage			Hydration of Everglades	Control flooding in low lying westerly flood plains due to sea level rise effects on drainage	

Appendix IV: Response to Sea Level Rise in the San Francisco Bay Area

Steve Goldbeck

Deputy Director for Climate Change, Water, and Legislation
San Francisco Bay Conservation and Development Commission

The scope of this white paper encompasses the San Francisco Bay region, including the jurisdiction of the San Francisco Bay Conservation and Development Commission (BCDC) and additional shoreline areas vulnerable to potential inundation due to sea level rise. BCDC is a state agency that has regional jurisdiction to regulate all dredging, filling, and changes in use in the Bay and along the shoreline.

For over 20 years, BCDC has been studying and planning for sea level rise. In 1982, it adopted policies that required proposed projects to (1) prepare more comprehensive analyses of shoreline protection and (2) continue to track sea level rise (given the uncertainty at that time regarding the potential acceleration of sea level rise in the future). Recently, as the scientific data and analysis of climate change and sea level rise has become more compelling, BCDC determined that it was imperative to update its analysis.

In 2006, BCDC developed an outreach campaign based on maps of sea level rise to raise awareness of the issue in the Bay Area. These maps, based on topographic data, identified low-lying shoreline areas vulnerable to a one-meter sea level rise. The campaign was instrumental in raising public awareness and elevating this critical issue throughout the region and state.

Vulnerability Assessment

In 2008, BCDC prepared a vulnerability assessment, *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on the Shoreline*, that identifies:

- Key Bay systems, both in the natural and the built environment
- Stressors the systems presently face
- Potential impacts due to inundation and coastal flooding
- Sensitivity of the systems to these impacts
- Adaptability of the systems

The analysis is based on sea level rise projections of 16 inches within a 50-year time frame and 55 inches within a 100-year time frame. These projections are currently near the upper end of the sea level rise range cited by climate researchers as having a reasonable chance of occurring based on the United Nation's Intergovernmental Panel on Climate Change (IPCC) scenarios (IPCC 2007). As such, the sea level rise projections provide BCDC with an analysis of an emissions scenario for which greenhouse gases are produced at an accelerated rate (owing to rapid development and the absence of strong mitigation policies for greenhouse gas emissions). The results show that approximately 180,000 acres of shoreline are vulnerable to flooding following a 16-inch rise in sea level, and more than 213,000 acres following a 55-inch rise in sea level. The replacement value of the resources at risk is about \$62 billion (Pacific Institute 2008). For more information, see http://www.bcdc.ca.gov/proposed_bay_plan/bp_1-08_cc_draft.pdf.

Integral to preparation of the assessment was research on sea level rise inundation in the Bay Area by the U. S. Geological Survey (USGS) and an analysis of the socioeconomic impacts of that potential inundation by the Pacific Institute. Both studies were funded in part by the California Energy Commission's Public Interest Energy Research program (see Partner Efforts).

Inundation Mapping

In their research, USGS used sea level rise projections downscaled from global climate model data—using IPCC A2 and B1 scenarios—as a primary input for a numerical model of flooding in the San Francisco Bay (Knowles 2009). The other primary input data to the flood model were water level observations from Fort Point (near the mouth of the Golden Gate); these are the oldest known records of tides and water levels in the United States. Over the past 100 years, water levels at this gauge have been influenced by conditions ranging from daily tides to storm surges driven by climatic events associated with the El Niño Southern Oscillation and the Pacific Decadal Oscillation patterns. Thus, this approach provided an estimate that integrates tides and climatic variability. Shoreline topography was obtained by merging the best available elevation data sets (which varied significantly in vertical and horizontal accuracy).

The flood model provided water level observations for the Bay projected over the next 100 years, which could then be statistically analyzed to develop elevations for a range of probable flood conditions (for example, the yearly, 10-year, and 100-year flood). Inundation maps were produced by comparing the flood elevations resulting from projected rates of sea level rise and the current topography of the Bay shoreline. The impact of shoreline levees and protective devices was not evaluated, because accurate information on these structures was not available. Wind, waves, and fluvial inputs from tributaries were not included either.

Socioeconomic Impact Analysis

The Pacific Institute used the inundation maps provided by USGS to evaluate socioeconomic impacts (Heberger and others 2008). They mapped the locations of vulnerable populations (using Census 2000 information), as well as developments and infrastructure at risk. They also identified “environmental justice” communities. Further, they estimated the cost of replacing inundated buildings and contents using the Federal Emergency Management Agency's (FEMA) Hazards United States (HAZUS) model. The estimated impact to wetlands was also evaluated. BCDC also used the Census 2000 data to examine the risk faced by low-income communities along the shoreline. The socioeconomic analysis report was funded by the California Energy Commission, California Environmental Protection Agency, Metropolitan Transportation Commission, California Department of Transportation, and the California Ocean Protection Council. For more information, see http://www.pacinst.org/reports/sea_level_rise/index.htm.

Climate Change Policies in the San Francisco Bay Plan

To address the findings of the BCDC vulnerability assessment, BCDC initiated an amendment of the San Francisco Bay Plan to address climate change. This revision is part of BCDC's ongoing effort to keep the plan current and based on the best scientific information available. The draft policies would require permit applicants to evaluate their projects for a range of sea level rise over the life of the projects, specify detailed criteria for new construction in undeveloped, at-risk areas, and require projects to be resilient to sea level rise. The amendment also proposes policies for safety of fills, public access, wetlands, and shoreline protection. Staff members are now revising the proposed policies in light of public comments. For more information, see http://www.bcdc.ca.gov/proposed_bay_plan/bp_amend_1-08.shtml.

This amendment of the San Francisco Bay Plan is an important step towards integrating adaptive measures into the design of Bay and shoreline projects in the near-term. However, BCDC recognizes that a fundamentally new plan is needed to respond to the threat posed by sea level rise, and that available information and resources are inadequate to prepare such a plan. To provide the needed information and resources, BCDC is implementing the studies and programs that follow.

Legislation

In 2008, BCDC sponsored state legislation that gave BCDC the explicit authority to (1) address climate change and sea level rise in its planning work and (2) collaborate with other regional agencies and interested parties to prepare a regional plan for climate change and sea level rise. The enactment of this legislation (AB 2094) also made BCDC a voting member of the Joint Policy Committee.

Joint Policy Committee

Recognizing that it does not have the resources to respond to sea level rise by itself, BCDC is partnering with a variety of agencies and groups. A key partner is the Joint Policy Committee, which coordinates the policy development of the four regional agencies responsible for land-use planning, transportation, air quality, and coastal management—the Association of Bay Area Governments, Metropolitan Transportation Commission, Bay Area Air Quality Management District, and BCDC. The committee provides a key regional focus in developing a climate change strategy for the Bay Area, including addressing sea level rise.

The Joint Policy Committee partners recognize that tackling complex climate-related problems and overcoming adaptation planning barriers should not fall immediately to individual local governments. In response, the committee agencies have established a Regional Agency Climate Change Adaptation Program. BCDC and the Association of Bay Area Governments jointly lead the program and have articulated a set of tasks for the program over the next three years that will set the stage for developing and implementing a regional adaptation strategy:

- Identify and summarize Bay Area climate change impacts in 2050
- Produce a foundation document and website on impacts and the need for action
- Create a campaign to generate action on adaptation
- Create a regional adaptation strategy
- Create and implement a local adaptation assistance program (see below)

For more information, see http://www.abag.ca.gov/jointpolicy/jpc_climate_change.htm.

Adaptation Assistance for Local Governments

Local governments and resource-based managers need to ramp up adaptation planning efforts to help the Bay Area address climate change impacts, but they face big hurdles to taking action. They lack funding, staff resources, accessible and relevant scientific and policy information, and often political will for these planning efforts. Local decision makers and agency staff have called for a regionally organized and coordinated effort to assist them in overcoming these hurdles.

BCDC has taken a lead in developing an adaptation assistance program to provide information and resources to Bay Area local and regional governments in order to assist them in planning for and adapting to the impacts of a changing climate. These outreach efforts have included land-use planning committees, public works departments, parks and open space departments, and public health departments, flood control districts and wastewater authorities, as well as resource managers. The adaptation assistance

program is supported by the Bay Area Joint Policy Committee through their Regional Agency Climate Protection Program.

The long-term goal of the adaptation assistance program is to help Bay Area communities achieve coordinated and region-wide adaptation to climate change impacts. The program contributes to this goal by building capacity within local governments to assess climate change issues and then plan for and implement adaptation strategies. BCDC identified the following objectives for achieving this program goal:

- Provide and facilitate access to information, tools, guidance, and training for adaptation planning that are (1) relevant to the needs of local governments and resource managers, (2) easily accessible to—and in formats easily utilized by—planners and managers, and (3) derived from current and reliable sources.
- Help local and regional governments and resource managers integrate and coordinate climate change adaptation planning with (1) ongoing planning and management for the region and (2) their greenhouse gas mitigation efforts.
- Aid local governments and resource managers in finding and securing resources (such as funding, staff time, expert consultation time, and data) needed to conduct adaptation planning and implement strategies and ongoing monitoring.
- Facilitate coordination among planners and managers of neighboring and overlapping jurisdictions to help achieve consistent adaptation planning.
- Provide guidance for local and regional agencies and organizations on how to (1) achieve consistency with federal, state, and regional adaptation policy and (2) take advantage of available federal, state, and regional resources for adaptation planning and implementation.

BCDC has identified five broad program components for accomplishing these adaptation assistance program objectives:

1. Build partnerships that cut across jurisdictional boundaries, both geographic and sectoral
2. Create a “one-stop shop” website and information clearinghouse
3. Provide public outreach to build community and institutional support for adaptation planning
4. Offer educational opportunities to help planners and managers develop knowledge and skills for adaptation planning
5. Develop and disseminate strategies to improve the region’s resilience and adaptive capacity

Work on some of these components, such as partnership building and educational workshops for local governments, has already begun. For example, BCDC staff has already held three workshops for local governments on adaptation. The first was held in association with the Association of Bay Area Governments, San Francisco Bay National Estuarine Research Reserve (SF Bay NERR), and Bay Area Air Quality Management District. The other workshops were held in association with the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC) and SF Bay NERR. Partners in the adaptation assistance program will be prioritizing the next steps in program development based on feedback about initial outreach and education efforts, as well as available resources.

Research and Planning Program

To help specify the information needed for analyzing sea level rise impacts, BCDC convened a forum of scientists and agency staff to discuss Bay-related climate change research needs and reach consensus on research priorities. The resulting document guides BCDC’s planning and research program. BCDC is

implementing the studies using grant funds and collaborative partnerships. For more information, see http://www.bcdc.ca.gov/planning/climate_change/climate_research.pdf.

Innovative Wetland Adaptation Strategies

Bay tidal wetlands can help reduce future coastal flooding impacts from sea level rise. Significant shoreline areas not previously at risk from flooding will be vulnerable to more frequent flooding as a result of sea level rise (Gleick 1990; Cayan and others 2009; BCDC 2009). With each flood event, valuable real estate, critical public infrastructure, and natural resources along the Bay shoreline are at risk of flood damage from waves overtopping levees and other flood protection devices. Coastal flooding also increases erosion of levees and wetlands, further increasing the vulnerability of shoreline communities.

Bay wetlands may be permanently inundated or eroded as a result of sea level rise unless (1) adequate amounts of sediments and/or production of organic matter allow marsh elevations to rise at the pace of sea level rise and/or (2) the wetlands are able to migrate inland as the sea level rises (Phillip Williams and Associates and Faber 2004; Orr and others 2003). Insufficient sediment supply and existing structural barriers to migration are increasing the vulnerability of tidal marshes in the Bay (Parris and Lacko 2009; BCDC 2009).

While tidal wetlands in the Bay are vulnerable to sea level rise and coastal flooding, they may also be part of adaptation. Currently, structural protection (such as seawalls, riprap revetments, and levees) is the most common form of protection against flooding and erosion along the Bay shoreline (BCDC 1988). Despite their expense, these structures are used because the engineering standards for their design and implementation are fully developed and widely disseminated (BCDC 1988; Smits and others 2006). However, these same structures can diminish public health and safety by increasing erosion and by preventing dynamic coastal processes (Griggs and others 2005). Wetlands can attenuate waves and reduce the required levee height for flood protection—lowering the total cost of the levee by up to one-third (Turner and Dagley 2003). Thus, wetland restoration and conservation are critical components of mitigating existing water quality impacts and adapting to future sea level rise, because sustainable wetlands form a healthy, diverse buffer between shoreline infrastructure and floodwaters from the Bay.

Before shoreline adaptation strategies can be developed, tools for mapping coastal flooding hazards must be improved. A 2009 National Research Council report, *Mapping the Zone: Improving Flood Map Accuracy*, evaluated the accuracy of conventional methods for establishing FEMA's flood hazard zones. This report concluded that inaccurate, imprecise, and incomplete topographic and bathymetric data are primary causes for inaccurate flood models. In particular, these data result in inaccurate Base Flood Elevations, which are used to establish insurance premiums. The National Research Council made several recommendations for improving the accuracy of flood mapping:

- Use better and more precise topographic and bathymetric data, including pre- and post-storm data
- Use two-dimensional storm surge and wave models
- Determine the effect of tidal marsh plants, tidal flats, and eelgrass on increasing bottom friction and reducing wave height through the use of FEMA's one-dimensional wave model, WHAFIS (Wave Height Analysis for Flood Insurance Studies).

Conceptual models for the wave attenuation benefits of tidal wetlands in the Bay have been developed for large-scale wetland restoration projects (Phillip Williams and Associates 2005), but few studies—if any—have directly measured the attenuation of waves and corresponding reduction in coastal flooding in the Bay. As a result, WHAFIS does not include accurate information for determining the wave attenuation benefit of tidal marshes and tidal flats in the Bay. To address this, BCDC is managing a study with the following goals:

- Measure wave attenuation across a tidal marsh and tidal flat on the Bay margin
- Assess the resilience of tidal marshes to sea level rise and coastal flooding
- Improve analytical tools for assessing risk of coastal flooding
- Improve guidance for local decision makers regarding the ability of existing and restored tidal wetlands to provide flood protection as an adaptation strategy

In Phase 1 of this project, BCDC will coordinate an assessment of the wave attenuation benefits of tidal marshes and ecosystem vulnerability at a 200-acre tidal marsh on the Marin County shoreline near Corte Madera, California. Fieldwork will involve measurement of wave attenuation across wetlands, which will be used (along with associated water level and elevation data) to construct and validate 2-D and 3-D models of wave attenuation. In Phase 2, the modeling efforts will be enhanced by additional research on sediment patterns and characteristics on site, including measuring sediment fluxes through the site and analysis of sediment cores. During Phase 3, design strategies will be developed to help the tidal wetlands on site adapt to sea level rise (such as through the use of offshore berms) in order to preserve the wave attenuation benefits and to reduce ecosystem vulnerability to climate change. This work will be closely coordinated with the flood control district's work in the upstream watershed. BCDC anticipates obtaining funds for implementation of the experimental design in future phases of this study.

Regional Sediment Management

An understanding of sediment dynamics is particularly important to predicting the impact of sea level rise and global climate change on the Bay. Sediments can feed tidal flats and wetlands to maintain their elevation in the tidal frame while minimizing erosion and inundation. Decreases in local or regional sediment supply can exacerbate erosion and inundation.

Bay sediment dynamics control many estuarine processes, such as locations of tidal flats and marshes, habitat variability, and the productivity of Bay waters. The net flux of sediments into and out of discrete portions of the Bay (1) determines whether erosion or accretion occurs and (2) creates features (such as shoals and channels) and specific habitat environments (such as fine-grained or sandy bottoms). An adequate supply of sediment is needed to maintain the dynamic equilibrium of wetlands and tidal flats within the Bay system, while excessive volumes of sediments can silt in channels and reduce open-water habitats.

Regional sediment management (RSM) is an approach to manage sediments within the context of the entire system, including sediment sources, movement and sinks within the system, and exchange with the ocean. Application of RSM to the Bay will allow BCDC and other coastal managers to better understand the impacts of (1) individual permit decisions on the entire system (such as dredging and disposal) and (2) systemic processes (such as climate change and sea level rise) on permitted projects (such as success of wetland restoration projects). In order to apply RSM, adequate data must be available on Bay sediment processes in order to understand how the system functions; additionally, geomorphic or numerical models must be sufficiently accurate to predict how the system will react to changes in forcing processes, such as sea level rise or reduced inflow from the delta.

To develop a RSM strategy for the Bay, better information is needed on Bay sediment dynamics. Below are some of the data issues:

- Suspended sediment levels are being measured by USGS at several Bay stations, but the stations do not measure current flow—and thus cannot be used to determine sediment flux.
- There are insufficient data on nearshore sediment processes to understand sediment exchange between tidal flats and wetlands.
- The impacts of wind wave energy in tidal restoration projects are poorly understood and controversial.
- Adequate measurements are not available for the sediment supply from Bay tributaries.
- A current and accurate map of the stratigraphy of the Bay floor is not available.
- The exchange of sediment with the ocean has not been directly measured.
- Numerical models of water circulation and currents have become increasingly sophisticated and accurate, yet the application of these models to make reliable and validated estimates of sediment transport within the Bay has not been accomplished.

BCDC will work collaboratively with other Bay management and research agencies, organizations, and interested parties to prepare a RSM strategy for the Bay. This strategy will have a strong focus on identifying sediment management needs and research needed to support RSM for the Bay. Partners include the Coastal Conservancy, San Francisco Bay Regional Water Quality Control Board, San Francisco Estuary Institute, USGS, and U.S. Army Corps of Engineers (USACE). The project is partly funded by—and will be closely coordinated with—the California Coastal Sediment Management Workgroup, which is overseeing RSM plans for the rest of the California coast. Much of the early focus of the strategy will be identifying research needs that are most directly related to Bay sediment management.

The first year of the project will consist of (1) identifying, gathering, and cataloging existing data on sediment distribution and processes, and (2) working with researchers and Bay managers to identify data gaps and key management questions. Past and ongoing research has provided important information on Bay sediment processes. However, this information has not been gathered and analyzed in any comprehensive fashion, and many of the data sets are not generally available. The predicate for a RSM strategy is to understand the research done to date, provide a synthesis of the known information, and compare the information to the needs identified by resource managers. Input from resource managers is key to focusing on those aspects that are most critical to management of Bay resources, particularly for adaptation to sea level rise.

The second year will involve (1) preparing a research agenda that is coordinated with other Bay management and research entities and (2) completing a framework document that outlines a RSM strategy for BCDC. Staff will also attempt to coordinate and help identify funds for potential demonstration projects (with USGS, San Francisco Estuary Institute, and/or other research groups) in order to gather key sediment dynamics data and work to refine and flesh out the framework.

The third and fourth year will involve first evaluating where serious erosion can be expected (particularly in light of climate change), and then evaluating potential sources and mitigating strategies to address it. Focus will be given to assessing potential sources of material from Bay tributaries and to beneficial reuse of dredged material. The second part of this phase of the project consists of (1) analysis and synthesis of the data and (2) development of lessons learned into a RSM strategy. This work will be closely coordinated with (and complementary to) other work on Bay sediment dynamics, particularly the Coastal Conservancy's and Corps' South Bay Salt Pond Restoration Project and the Stanford Unstructured Nonhydrostatic Terrain-following Adaptive Navier-Stokes Simulator modeling initiative for the Bay.

Head of Tide

Head of tide is the interface where freshwater moving down tributaries meets tidal currents pushing up from the Bay. Many Bay cities were located where freshwater met navigable Bay waters, and this is also a zone of high ecological importance. Sea level rise will shift head of tide upstream and increase flood risks. However, head of tide for Bay tributaries is not mapped, and these risks have not been evaluated. The study will establish a protocol for determining head of tide and will involve work with local governments and special districts to gather existing information regarding head of tide. It will also develop a protocol to evaluate changes due to sea level rise.

Permit Digitization

Although BCDC has mapped vulnerability to sea level rise around the Bay using GIS (geographic information systems), the location of projects that BCDC has permitted have not all been digitized from the paper permit files. This effort will create a database of BCDC permit records for use in the web-based decision support tool for sea level rise and other planning.

Climate Ready Estuary Pilot

The U.S. Environmental Protection Agency's (EPA) Climate Ready Estuaries program is working with the San Francisco Estuary Partnership, BCDC, and the EPA's Office of Research and Development's Global Change Research Program on a pilot project to assess key vulnerabilities of the San Francisco estuary system to climate change. The assessment will take advantage of significant work that is already underway in the region (particularly on sea level rise) to support further analysis of climate drivers and ecosystem effects.

A major objective under the Climate Ready Estuaries pilot program is the development of a San Francisco Estuary Partnership climate change adaptation plan. This plan will be informed by the planning process for the California State Climate Adaptation Strategy (coastal sector), as well as the rich array of other climate adaptation activities going on in California.

The initial work focused on a workshop with regional technical experts to identify and describe known stressors and potential climate change impacts. Next, the work focused on preparing conceptual models for several key potential climate impacts. When the team realized that there were insufficient data to implement the proposed methodology, they decided to use expert elicitation (the synthesis of expert opinions on a subject where there is uncertainty due to insufficient data) instead to evaluate several key climate impacts of sea level rise and climate change.

Rising Tides Competition

Realizing the need to encourage new ideas about how to design and build around a rising Bay, BCDC sponsored an international design competition—in partnership with the San Francisco Chapter of the American Institute of Architects and with financial support from NOAA. The competition was primarily targeted to design professionals, but engineers, planners, and others were also encouraged to enter and collaborate. The challenges to be addressed by the entries included (1) rethinking how to build new communities in areas susceptible to future inundation, (2) retrofitting valuable public shoreline infrastructure, (3) protecting existing communities from flooding, (4) protecting wetlands, and (5) anticipating changing shoreline configurations. More than 130 entries were received from around the world; many singular and innovative ideas were represented by the diverse range of entries. From those, six winning entries were chosen by an independent judging panel.

The posters presenting the entries themselves became an important benefit from the competition; thousands of people viewed the posters at the Ferry Building in San Francisco. Climate change and sea level rise are often dispiriting topics that are difficult to present to the public without engendering depression and denial. People tend to shut down when a problem is presented without a way forward to address it. The posters offer an upbeat view because the focus is on how to respond to sea level rise. BCDC is now curating the posters as a traveling exhibit in various public spaces to raise awareness about sea level rise and the need to adapt. For more information, see <http://www.risingtidescompetition.com/risingtides/Home.html>.

Partnership with the Netherlands

BCDC entered into a unique partnership with the Netherlands to learn from their experience in protecting low-lying areas from flooding for centuries. With funding provided by the Dutch government, experts from the Netherlands came to work with BCDC staff on adaptation planning. The respective situations in the Netherlands and the Bay Area were compared and contrasted.

With a principal focus on planning for adaptation, the analysis described a range of shoreline typologies, identified potential adaptation measures, developed a decision-making matrix for their use, and identified differences in governance with respect to adaptation between the Netherlands and the Bay Area. A well-attended and well-received symposium was held in San Francisco on September 21, 2009, to publicly present and discuss the results of the collaboration and present a final report entitled: *San Francisco Bay: Preparing for the Next Level*.

As part of the analysis, technical research regarding the impact of sea level rise on the Bay was performed using a numerical model. Several important points were revealed: (1) tidal elevations due to sea level rise will largely be linear across the Bay, (2) tidal velocities within the Bay will likely increase, and (3) wave heights within the Bay will also likely increase. The resultant impacts remain to be evaluated.

The success of the collaboration spurred BCDC and the Dutch to resolve to pursue the joint refinement of adaptation strategies, focusing on both technical approaches and governance issues. For more information, see http://www.bcdc.ca.gov/planning/climate_change/SFBay_preparing_for_the_next_Level.pdf.

Business Council on Climate Change and the Bay Area Climate Compact

BCDC recognizes the need to partner with businesses (as well as other public agencies) to effectively address climate change issues in the San Francisco Bay Region. BCDC accepted an invitation to become a partner in the San Francisco Business Council on Climate Change, which is advancing the goal of reducing greenhouse gas emissions in the Bay Area and has made several presentations on the need for adaptation to sea level rise. BCDC staff also participated with the Silicon Valley Leadership Group (a Bay Area business group) in preparation of a Climate Compact for both businesses and governments in the region; the compact includes preparing an adaptation plan to sea level rise and other climate impacts by 2013.

State Climate Strategy

The *2009 California Climate Adaptation Strategy Discussion Draft* summarizes the best available science on climate change impacts across California in seven specific sectors and provides recommendations on how to manage against those threats. The public comment period on this document closed on September 17, 2009. The Ocean Protection Council (see the Coastal Conservancy section later in this paper) worked with BCDC, Coastal Commission, Department of Fish and Game, State Lands Commission, and State Parks to prepare the ocean and coastal resources climate impacts summary, adaptation guiding principles, and short- and long-term adaptation strategies.

The draft strategy includes the following major policies regarding sea level rise:

- State agencies should incorporate a policy regarding development in areas that will be affected by climate change into their decisions; other levels of government are also encouraged to do so. The most risk-averse approach for minimizing the adverse effects of sea level rise and storm activities is to carefully consider new development within areas vulnerable to inundation. State agencies should generally not plan, develop, or build any new significant structure in a place where that structure will require significant protection from sea level rise, storm surges, or coastal erosion during the expected life of the structure. However, vulnerable shoreline areas containing existing and proposed development that have regionally significant economic, cultural, or social value may have to be protected, and in-fill development in these areas should be accommodated.
- All state agencies responsible for the management and regulation of public health, infrastructure, or habitat subject to significant climate change should prepare as appropriate agency-specific adaptation plans, guidance, or criteria by September of 2010,
- Using existing research, the state should identify key California land and aquatic habitats that could change significantly this century due to climate change. Based on this identification, the state should develop a plan to minimize adverse effects from climate change induced phenomena by (1) expanding existing protected areas or (2) altering land and water management practices.
- Communities with general plans and local coastal plans should begin—when possible—to amend their plans to assess climate change impacts, identify areas most vulnerable to these impacts, and develop reasonable and rational risk-reduction strategies using the California Adaptation Strategy draft document as guidance. Every effort will be made to provide tools to assist in these efforts.
- A Climate Adaptation Advisory Panel will be appointed to assess the greatest risks to California from climate change and recommend strategies to reduce those risks, which will build on California's Climate Adaptation Strategy draft document. This panel will be convened by the California Natural Resources Agency, in coordination with the Governor's Climate Action Team, to complete a report by December of 2010.

For more information, see <http://www.climatechange.ca.gov/adaptation/>.

Lessons Learned

- **LIDAR (Light Detection and Ranging):** The inundation mapping prepared to date is adequate for regional planning. However, more detailed topographic data of the shoreline are needed for local planning. Moreover, data are needed on the location, condition, and height of existing levees and shoreline protection structures—so that inundation mapping can include them.

- **Regional sea level rise estimates:** There has been little or no sea level rise recorded at the NOAA tide station at the Golden Gate for the last 30 years. While this could be due to regional oceanographic and climatic events, such as the Pacific Decadal Oscillation, no research has been conducted to determine the mechanism(s). There is a critical need to prepare a scientific estimate of future regional sea level rise, in terms of regional deviation from world sea level rise over time. These estimates should take into account oceanographic, climatic, tectonic, and other forcings.
- **Adaptation will require an iterative approach:** Given the lack of data and tools and the uncertainty in sea level rise estimates and potential impacts, BCDC cannot conduct comprehensive vulnerability assessments and adaptation plans at this time. However, given the decisions being made about land use and management, BCDC needs to undertake analysis and planning now, knowing that many aspects will be out of date soon and need to be redone.
- **Need planning and policies that recognize and deal with uncertainty:** There are multiple levels of uncertainty surrounding sea level rise, particularly when planning for a specific area: how global sea level will rise over time, what local sea level rise will be, what the variability in sea level rise will be due to El Niño and other impacts, what the effects of local storm climate will be, whether local wetlands and other soft-shoreline protection will persist or erode, whether shoreline protection structures will fail during storm events, and how extensive and prolonged the resulting inundation will be. BCDC does not have good analytical tools to assess these factors in determining the potential risks to shoreline development and habitat. Without such tools, it is difficult to determine the tradeoffs between different management and development scenarios.
- **Need coordinated federal response:** Multiple federal agencies are offering to help with sea level rise, sometimes seemingly at cross-purposes. USACE has recently directed assessment of sea level rise in all projects and permits. However, FEMA—the agency most local governments look to for assessing flooding risks—is not including sea level rise in its revised flood mapping. A particular example is LIDAR: FEMA, USACE, and USGS have all acquired LIDAR in the Bay Area, but with different resolutions and characteristics—and without checking with state coastal managers to coordinate the acquisition. Recently, NOAA did consult with the state and coordinate with USGS and USACE on a LIDAR acquisition, but the effort proved complex and difficult due to the various logistical challenges. High-level direction should be provided to the federal agencies to harmonize and coordinate their climate change research, planning, and policy. In particular, a single federal West Coast Climate Center—staffed by NOAA, USGS, FEMA, and USACE—would allow the agencies to coordinate their efforts, decrease duplication, and make it easier for state managers to gain access to federal expertise and data.
- **Local governments lack capacity:** BCDC has jurisdiction over the Bay, managed wetlands and salt ponds, and in a 100-foot shoreline band can only require public access. No other regional agency has authority to enforce adaptation actions. This leaves adaptation planning for the hundreds of thousands of acres of shoreline vulnerable to sea level rise flooding in the hands of local governments and special districts. There are more than 100 of them in the Bay Area, 54 of which front on the Bay.

Local governments in California have been beggared by limits on property taxation and the recent economic collapse. Bay Area local governments are fairly progressive in their planning approach: they are embracing sustainability practices and long-term planning for earthquakes, pandemics, wildfire, etc. However, they do not have the technical capacity or knowledge to plan for sea level rise. At the present time local governments are laying off planners, not adding capacity. (For example, the City of Petaluma recently laid off its entire planning staff.) They are oversubscribed dealing with day-to-day issues facing all local governments. Not only do they lack the capacity to address climate change and sea level rise, for the most part it is not even on their radar screens.

- **Need to build local public awareness:** Part of the reason that sea level rise is not a priority concern at the local level, is that local planners’ resources are constrained—and thus necessarily prioritized, usually by the priorities of locally elected officials. Most locally elected officials are responding to the priorities of their constituents, and climate change is now starting to be recognized as a priority in the Bay Area. However, the focus is on mitigation of greenhouse gases. Adaptation is either not in the mix, or is downplayed, because (1) no one is aware that sea level rise is a problem, (2) sea level rise is perceived to be an impact too far out on the horizon (that is, something their kids will have to figure out), or (3) turning attention towards adaptation to climate change impacts is seen as “giving in.” In order to make progress on adaptation, BCDC needs to build public awareness at the local level on the need for planning—and why it should be a priority for them right now.
- **Motivate, not just scare:** BCDC found that when the public and local decision makers are informed about sea level rise impacts, they often become depressed rather than proactive. The work of social scientists (such as Dr. Susanne Moser) show that it is important to provide a positive message in order to build public acceptance of and support for adaptation planning. The results of the Rising Tides competition are an excellent example of how to pose sea level rise adaptation in a more optimistic and constructive light.
- **In shallow estuaries, adaptation often equals flood control:** In contrast to high-energy, open ocean coasts with rocky shorelines, sea level rise adaptation has a different face in the Bay. Much of the Bay shoreline is relatively flat, already subject to storm flooding, and protected by levees. Therefore, adaptation planning for sea level rise is—to a great extent—inextricably tied to flood protection.
- **The regional level is the “sweet spot” for adaptation planning:** Adaptation planning should occur at every level of government, but the regional level may be the best approach for now. Efforts at the state or federal level are often too coarse to address local conditions, and local planners do not have the necessary resources and expertise. Moreover, planning for the Bay or other bio-geographical regions needs to be integrated. For example, if one locality protects their shoreline and the neighboring one does not, then all will likely flood.

BCDC is finding that planning at the bio-geographical scale of BCDC’s jurisdiction (that is, the San Francisco Bay region) allows integrated planning to be performed. As a regional entity, BCDC can access state and federal resources, while at the same time be familiar with local conditions and have the ability to work with local planners and decision makers.

Steps Moving Forward

- **New Bay plan:** As stated before, an entirely new approach is needed to manage an expanding—rather than shrinking—Bay. BCDC needs to identify areas where protection will be required to guard existing high-value development, areas where the Bay can be allowed to migrate upland, and areas where more complex responses are needed. The plan must:
 - Be prepared in light of RSM, shifts in wetlands and habitats, and management of stressors other than climate change (such as invasive species).
 - Integrate both soft- and hard-shoreline protection and include both short- and long-term responses.
 - Include a broad suite of adaptation patterns (whose application is appropriate to the location).
 - Provide for critical technical and planning studies, and also specify needed legislation and funding.

- **Climate analysis:** To help build public understanding of the need for adaptation, BCDC will join with regional partners to sponsor an analysis of climate impacts and potential adaptation responses that are specific to the Bay Area. The analysis will be prepared by academic experts—not by the agencies. The results of the analysis will be used to provide short, cogent presentations for the public that explain how impacts will affect the Bay Area and the benefits of adaptation planning. It will also be the basis for a regional adaptation effort.
- **Partnering with the Dutch:** BCDC will continue its partnership with the Dutch to evaluate adaptation planning.
- **Decision-making approaches:** BCDC will collaborate with RAND Corporation analysts to adjust tools for decision-making under uncertainty for application to sea level rise adaptation planning.
- **Shoreline study:** BCDC will collaborate with USACE on a pilot project for a shoreline study on existing and potential shoreline protection in response to sea level rise.
- **Bay Area Ecosystem Climate Change Consortium:** BCDC will work as a member of the consortium on science relating to sea level rise and climate change impacts on Bay ecosystems (see the Coastal Conservancy section below).

Transferability

The majority of BCDC’s methodology and results are transferable. However, as discussed previously, the Bay estuarine system is lower energy, shallow, and with extensive shoreline inundation potential—in contrast to rocky, high-energy, open coast systems.

Summary

BCDC is planning for sea level rise now to respond in advance of the crisis. The planning is hampered by inadequate data, analytical tools, funding, and recognition of the need for adaptation by those outside of the coastal community. Provision of needed information and tools by federal agencies could provide invaluable aid to state and local agencies attempting to plan for adaptation to sea level rise, but this aid should be carefully developed in light of what is needed for on-the-ground planning—rather than what fits neatly into the federal agency’s present operations.

Partner Efforts

Coastal Conservancy

The California Coastal Conservancy is a state agency whose geographic jurisdiction includes the entire nine-county San Francisco Bay Area, and whose programmatic goals include the protection of coastal and marine habitats, urban waterfronts, and coastal watersheds; development of educational projects and programs; administration of the Ocean Protection Council; and implementation of the San Francisco Bay Trail, California Coastal Trail, and the San Francisco Bay Area Water Trail Plan. The Coastal Conservancy has supported planning and restoration of approximately 40,000 acres of tidal wetlands in San Francisco Bay.

In its 2007 strategic plan, the Coastal Conservancy identifies many effects that climate change will have on ocean, coastal, and near-coastal resources, and the plan also stresses the need to (1) consider these climate change impacts when determining the priority of expenditures in the design and siting of conservancy-funded projects, (2) improve understanding of the effects of climate change, and (3) identify and support climate adaptation tools.

The Coastal Conservancy adopted a Climate Change Policy on June 4, 2009, which required staff and grant applicants to consider and address vulnerabilities to sea level rise and other climate change impacts. The policy states the conservancy's intention to collaborate with other agencies and entities to develop, support, and implement climate change adaptation plans, strategies, and projects that minimize or offset impacts to natural resources, public access, and other matters specified in the conservancy's enabling legislation. For planning and project evaluation purposes, the policy requires the use of 16 inches of sea level rise by 2050 (and 55 inches by 2100), which is consistent with the scenarios adopted by BCDC. The Climate Change Policy encourages applications for certain types of projects that will support adaptation to climate change, such as acquisition of land adjacent to shoreline habitats, RSM, setbacks, rolling easements and planned retreat projects, invasive species management, living shoreline projects, and monitoring to support adaptive management.

The conservancy is working with the U.S. Fish and Wildlife Service, USGS, NOAA Sanctuaries, NOAA CSC, NERR, and other entities in launching the Bay Area Ecosystem Climate Change Consortium. The consortium identifies and addresses climate change impacts on ecosystems by using science to inform adaptive management for long-term ecological and economic benefits—with a focus on the pelagic, nearshore, and coastal areas of the Greater Gulf of the Farallones to the subtidal, tidal wetland, and adjacent uplands of San Francisco Bay. Working with numerous agencies, non-governmental organizations, academia, and other collaborators, the consortium ensures timely, accessible, web-based information sharing—as well as ongoing outreach to policymakers and the public to advance its vision. The consortium members jointly:

- Assess climate change impacts at a regional scale
- Conduct scientific research and monitoring
- Develop predictive models to understand possible future changes and prioritize conservation actions
- Guide natural resource managers in employing, testing, and improving adaptive management strategies
- Conduct outreach to local and regional stakeholders, policymakers, and the public

The executive director of the Coastal Conservancy is the secretary of the California Ocean Protection Council. Some of the roles of the Ocean Protection Council include identifying changes to laws and policies necessary to improve ocean management, improving science to inform policy decisions, performing interagency coordination, and providing funding for ocean management. The council is the lead entity for the Ocean and Coastal Resources Sector for the State Climate Adaptation Strategy. The council will be working with other agencies to host coastal adaptation workshops, provide support for coastal/ocean vulnerability assessments and adaptation research, and produce a more detailed decision framework to be used by state agencies and to guide local governments in making decisions regarding development in sea level rise hazard zones.

The Ocean Protection Council staff has been working with the California Air Resources Board and the Climate Action Reserve to launch an initiative to develop a carbon offset protocol for tidal wetland restoration. Research shows that tidal wetlands can sequester as much carbon as certain forests—and that saltwater marshes release only small amounts of methane.

Through the West Coast Governors' Agreement on Ocean Health, the Ocean Protection Council is working with Oregon, Washington, and NOAA CSC in supporting a National Academy of Sciences report on sea level rise on the West Coast, which will address uplift, subsidence, El Niño, coastal erosion, and uncertainties.

California Energy Commission's Public Interest Energy Research Program

One of the California state agencies at the forefront of climate change research is the California Energy Commission (CEC), which plans and regulates power production in the state. Not only is power production a key greenhouse gas contributor, but the CEC also has a strong research arm and a funding source. In 2003, the CEC's Public Interest Energy Research program established the California Climate Change Center to fund and document research on climate change and mitigation of greenhouse gas reduction. This center is a virtual organization with research activities at Scripps Institution of Oceanography, University of California at Berkeley, and other research institutions. Fortunately, the center has also recognized the need for research on adaptation to climate change and sponsored several of the key sea level rise studies used by the commission.

San Francisco Bay National Estuarine Research Reserve

Two of the most pristine wetlands left in the San Francisco estuary are protected as part of SF Bay NERR: Rush Ranch (Solano County) and China Camp State Park (Marin County). SF Bay NERR is part of the National Estuarine Research Reserve System, a network of 27 reserves around the country established for long-term research, education, and stewardship of the nation's estuaries. SF Bay NERR is a partnership among NOAA, San Francisco State University, California State Parks, Solano Land Trust, and BCDC. Addressing climate change is reflected in all areas of the SF Bay NERR's activities, including:

- Protecting more than one million acres of estuarine land and water
- Providing essential habitat for wildlife
- Offering educational opportunities for students, teachers, and the public
- Serving as a living laboratory for scientists

Education and Coastal Training Program

SF Bay NERR education staff incorporates information about climate change into every program they offer for the public or K–12 teachers. For example, discussion of sea level rise is interwoven into several of their new interpretive exhibits—and their upcoming professional development workshop for teachers is about ocean acidification.

SF Bay NERR's Coastal Training Program provides training about potential climate change impacts to the Bay Area. In April of 2008, they offered *Preparing for Rising Sea Levels in the Bay Area: A Local Government Forum*, offered in partnership with BCDC and the Association of Bay Area Governments. This day-long forum focused on the potential consequences of sea level rise in the Bay Area. Local climate change experts shared the latest scientific data and predictions of regional impacts, followed by an interactive session on assessing municipal vulnerabilities and working with other agencies and organizations to address those risks. They trained over 100 agency staff and officials about local sea level rise impacts and vulnerability assessments. Another set of trainings took place in September of 2009. These workshops were likewise geared towards municipal planners and public works staff, and were delivered in partnership with BCDC, the Association of Bay Area Governments, and NOAA CSC. Future workshops will be developed for different audiences (such as elected officials and natural resource managers). As a result of these workshops and other technical assistance efforts, the Coastal Training Program will develop the tools and resources that coastal decision makers need in order to address climate change issues in their work.

Monitoring the Extent and Ecological Effects of Sea Level Rise

SF Bay NERR is engaged in a variety of monitoring programs to evaluate the extent and ecological effects of sea level rise on two tidal marshes in San Francisco Bay: China Camp State Park and Rush Ranch. Currently, these monitoring programs are focused on documenting changes in:

- Water level
- Marsh elevation
- Vegetation communities across transition zones that are expected to migrate with rising sea level
- Water column salinity and groundwater salinity

All of these programs build upon the existing System-wide Monitoring Program that provides basic data on water quality, dissolved nutrients, and atmospheric conditions. (For basic data, visit <http://cdmo.baruch.sc.edu/QueryPages/googlemap.cfm>.)

Changes in Water Level

The water quality monitoring component of the System-wide Monitoring Program includes long-term records of water level measured every 15 minutes with YSI™ 6600 data loggers deployed at a fixed subtidal depth. SF Bay NERR has been collecting these data since 2005, and they are now working to increase the utility by surveying the data loggers with static Global Positioning Systems (GPS) and high-precision digital leveling. Rigorous placement and calibration of the data loggers provides repeatable measurements from the same physical location in space—thereby allowing detection of slight changes in water level over time.

Changes in Marsh Elevation

In collaboration with researchers from the University of San Francisco and San Francisco State University, SF Bay NERR is using a combination of static GPS, real-time kinetic GPS, and high-precision digital leveling to survey existing surface elevation tables. These tables maintain a fixed vertical position—thereby allowing measurement of the surrounding sediment surface subject to the deposition and accretion that is expected to accompany sea level rise. Over the next few years, additional surface elevation tables will be installed in both SF Bay NERR sites; all of the tables will be surveyed and monitored to track slight changes in the elevation of the marsh surface over time.

Changes in Vegetation Communities

Permanent vegetation monitoring transects spanning key habitat transitions (such as high marsh to uplands) allow detection of changes in the distribution of plant species that differ in their requirements for water inundation, salinity, and soil characteristics. Because sea level rise will alter spatial and temporal patterns of these environmental parameters, monitoring plant communities will be an important aspect of marsh conservation and restoration as uplands become increasingly subject to tidal inundation. Aerial imagery of vegetation patterns will add to these data.

Changes in Salinity

Along with the measurements of water level described above, the System-wide Monitoring Program data loggers have been monitoring water column salinity (and other parameters) every 15 minutes since 2005. Sea level rise will contribute to increased estuarine salinity and, possibly, the intrusion of salt into groundwater. To better understand these processes, SF Bay NERR has recently begun measuring groundwater salinity to complement the ongoing water column measurements. Monitoring of salinity in intertidal porewater (the water contained within saturated sediments) is also planned.

Examples of Adaptation Planning in Bay Area Communities

Marin County Plan

The Marin County Community Development Agency has laid the groundwork for its adaptation program in its General Plan update of 2007. The policies under *GOAL AIR-5: Adaptation to Climate Change* outline a process of:

- Coordinating with local and regional agencies to leverage funding and expertise
- Studying and identifying climate change impacts and issues specific to Marin County within various sectors
- Preparing response strategies for these issues
- Monitoring climate change impacts within the county
- Seeking resources to implement response strategies
- Protecting and enhancing native habitats and biodiversity
- Conducting public outreach and education to Marin residents and businesses
- Committing to implementing floodplain ordinances
- Amending the Marin County Code to include construction standards for areas threatened by future sea level rise.

Marin County has begun work on identifying (1) how bayshore wetland habitat will change as a result of sea level rise for the Marin shoreline (Richardson Bay, San Pablo Bay, and the Petaluma River) and (2) potential adaptive strategies for these habitat areas. For more information, see <http://www.co.marin.ca.us/depts/CD/main/comdev/ADVANCE/CWP/INDEX.CFM>.

Hayward Shoreline: Preliminary Study on the Effect of Sea Level Rise on Resources

The Hayward Area Shoreline Protection Agency is studying (1) the impact of sea level rise on the resources of the Hayward shoreline and (2) the actions that could be taken to protect both the wetlands and shoreline development in this area. The goal of this project is to provide the agency with a preliminary assessment of the possible impacts, mitigations, costs, funding sources, and strategies to manage the effects of sea level rise on both the natural and developed resources in the study area, which is the agency's area from north of Highway 92 to San Leandro (Citation Marsh).

The study used sea level rise estimates and maps prepared by the State Resources Agency and BCDC. Staff members from interested agencies were invited to visit the site to discuss both existing and planned development in the impacted area. Information from these discussions is being used to (1) annotate the sea level rise maps with the infrastructure that would be affected and (2) create a narrative describing the map, potential impacts of sea level rise, opportunities, constraints, and potential adaptation measures.

The measures that the study will investigate are:

- Modifications to the existing wetlands to enhance their ability to buffer the impacts from the rise in sea level (e.g., managing the shape of the mudflat [mudflat recharge])
- Realignment of levees to modify tidal flow (e.g., realigning outboard levees to gain more marsh)
- Installation of offshore barriers to reduce wave energy (e.g., breakwaters)
- Increased levee height

For more information, see http://www.pwa-ltd.com/projects/pr_cc_haywardShrlnSLR.html.

City of Pacifica Managed Retreat Project

The City of Pacifica prepared a managed retreat project that reduced flooding hazards by realigning oceanfront property and infrastructure away from coastal erosion hotspots and restored estuarine functioning on San Pedro Creek. For more information, see http://www.pwa-ltd.com/projects/pr_cstl_Pacifica.html.

City of San Rafael Climate Action Plan

The City of San Rafael's Climate Action Plan chapter, *Our Environment*, includes recommendations for adapting to sea level rise, participating in a Marin regional vulnerability assessment, and creating a local vulnerability assessment. For more information, see http://www.cityofsanrafael.org/Government/Community_Development/Green_Initiatives.htm.

Resilient San Francisco

The City of San Francisco has multiple measures to address sea level rise and climate change. For example, through the San Francisco Public Utilities Commission, the city has been identifying (1) vulnerabilities in its water supply, stormwater systems, and wastewater treatment facilities due to projected climate change impacts and (2) ways to address these issues in management of systems (as well as in design of capital improvement projects).

In summer of 2009, the city began expanding its Adaptation Planning Program by embarking upon a city-wide, multi-sector assessment of vulnerabilities to climate change impacts and development of a comprehensive adaptation plan. This is a coordinated effort of staff from the Public Utilities Commission, the Mayor's Office, and the Department of the Environment. The city plans to engage stakeholders in the planning process through different groups:

- Climate Adaptation Taskforce with key city and non-governmental stakeholders who will develop the plan's recommendations.
- Taskforce Working Groups, which will include participants that may not be part of the larger taskforce, will consider climate change impacts on areas of the built environment.
- Project Consultant who will identify anticipated climate impacts on San Francisco (including the range and probability of these impacts) and help the taskforce understand how these impacts inform long-term planning.
- Scientific Advisory Panel, which will direct the consultant to existing data and analysis on regional climate impacts, review projections of anticipated impacts, and provide ongoing technical expertise to the taskforce.

The city is in the process of issuing a request for proposals for the vulnerability assessment work.

Santa Clara Valley Water District

On January 29, 2008 the Santa Clara Valley Water District's Board of Directors hosted a special meeting and work study session to explore climate change—and its potential local impacts and policy implications. Based on the findings, the board adopted a Resolution on Climate Change and Water Resource Management in Santa Clara County in which the board made a strong commitment to take a leadership role in addressing climate change. The resolution specified that:

“The District will apply understanding of climate change and climate change impacts as appropriate in water supply plans, flood management project plans, asset management and infrastructure plans, California Environmental Quality Act assessments and environmental impact reports, energy management plans, business plans, and strategic plans.”

The board also modified the district’s policies to reflect and implement the adopted resolution. The district incorporates consideration of climate change impacts into long-term water supply planning processes, watershed and flood control planning processes, and as part of its preparation of environmental documentation for projects.

The district has also recently launched a climate change portal with an extensive, well-organized library of climate change information—as well as tools for assessing sea level rise impacts to infrastructure and community resources in Santa Clara County. In tandem with the launch of the portal, the district has done extensive outreach to city and county planners and public works staff to (1) understand what information and tools they need to incorporate consideration of climate change impacts into their planning decisions and (2) introduce them to the portal. For more information, see http://www.valleywater.org/Water/Where_Your_Water_Comes_From/Water%20Supply%20and%20Infrastructure%20Planning/Climate%20Change/.

Multi-Jurisdictional Local Hazard Mitigation Plan Update 2010

The federal Disaster Mitigation Act of 2000 requires that cities, counties, and special districts have a Local Hazard Mitigation Plan to be eligible to receive FEMA hazard mitigation funds. To assist local governments in meeting this requirement, the Association of Bay Area Governments is the lead agency on the Multi-Jurisdictional Local Hazard Mitigation Plan for the San Francisco Bay Area. Cities and counties can adopt and use all, or part, of this plan in lieu of preparing all, or part, of a Local Hazard Mitigation Plan themselves—as long as they participated in the development of the multi-jurisdictional plan.

The multi-jurisdictional plan has chapters that address infrastructure, health care, housing, economy, government, schools and education, environment, and land use. For each of these sectors, the chapter includes various mitigation strategies to address earthquake, flooding, wildfire, landslide, tsunami, hazardous material release, and dam failure. The chapters additionally outline regional priorities for these strategies.

The 2005 version of the plan concluded that climate change should be studied and monitored, but included no specific actions related to climate change and hazard mitigation. The 2010 draft carries through this recommendation that jurisdictions remain informed and includes strategies (that are identical to the U.S. Conference of Mayors’ Climate Protection Agreement) for mitigating greenhouse gas emissions. Additionally, two of the chapters—*Housing* and *Economy*—each contain a hazard mitigation strategy to “inform private shoreline-property owners of the possible long-term economic threat posed by rising sea levels.”

Addressing climate change issues through disaster preparation and hazard mitigation will be one critical component of the Bay Area’s successful adaptation to a changing climate. The next multi-jurisdictional plan update will occur in 2015—potentially providing an opportunity to comprehensively integrate considerations of climate change impacts into Bay Area hazard mitigation. The Association of Bay Area Government’s hazards planning staff encountered some resistance to the concept of climate change impacts as “disasters.” This suggests that in the interim time period, an extensive outreach and education effort is needed to help institutions, businesses, and the public understand why—and how—to consider climate change in hazards planning.

For more information, see: <http://quake.abag.ca.gov/mitigation/>.

Appendix V: Agenda

Sea Level Rise and Inundation Community Workshop

December 3–5, 2009
Lansdowne Resort

“If there’s no action before 2012, that’s too late. What we do in the next two to three years will determine our future. This is the defining moment” said IPCC Chairman Rajendra Pachauri in preparing for Copenhagen, November 2009.

Workshop Goal

To produce a strategic framework that (1) supports the development and integration of science-based data, information, and products, and (2) makes those readily available (in appropriate formats) to enable a community-level response to sea level rise, tidal flooding, and inundation.

The framework will inform agencies at the federal, state, regional, and local levels, academic institutions, nonprofits, and other organizations that can influence (1) the development and dissemination of data, information, and informational products, and (2) the adoption of policies and budgets that support implementation of the proposed framework and recommended actions.

Desired Outcomes

- A nation well prepared to deal with sea level rise and inundation on a variety of spatial and temporal scales.
- A sustainable network—or community—of people dedicated to working together to (1) develop information and tools and (2) execute strategies to enable local communities to deal effectively with sea level rise and inundation in order to create resilient coastal communities.

Desired Outputs

- A framework with ranked and sequenced strategies to address sea level rise and inundation on different spatial and temporal scales. Elements of the framework include:
 - Roles and responsibilities of agencies at the federal, state, and local levels, academic institutions, nonprofits, and other community organizations to formulate and implement strategies to respond to sea level rise and inundation in a timely way.
 - Prioritized tasks with preliminary estimates of funding requirements by region.
 - Descriptions of geospatial frameworks, modeling, decision-support tools, adaptation planning, and policy and communication approaches that have been proven to be effective at meeting the needs of local communities.
 - Validated list of required information, tools, and products needed by coastal managers, other decision-makers, and community leaders to address sea level rise and inundation at a variety of spatial and temporal scales, including: (1) a list of gaps and a preliminary assignment of what agency, or agencies, should be responsible for filling those gaps and on what time scales, and (2) a preliminary needs assessment based on existing regional and sector-specific inventories that were refined during the workshop.
- A Workshop Declaration that inspires commitment from agencies at the federal, state, and local level, academic institutions, nonprofits, and other community organizations to implement the framework and associated strategies.

Thursday, December 3 – Lansdowne Resort – Faulkner Room

- 1:30 p.m. Arrival and Registration
- 2:00 p.m. Welcome, Context, and Workshop Objectives **in which we describe what we intend to accomplish** – **Margaret Davidson** (NOAA), **John Haines** (USGS), and **Jerry Schubel** (Aquarium of the Pacific)
- Introduction to the Draft Framework – **Jerry Schubel**
- 2:45 p.m. Panel: Three Case Studies of Sea Level Rise and Inundation Planning Activities and Processes **in which we explore approaches in three regions to create resilient coastal communities in the face of sea level rise and inundation** – **Jerry Schubel**
- Delaware – **Sarah Cooksey** (Delaware Dept. of Natural Resources)
 - San Francisco, CA – **Steve Goldbeck** (San Francisco Bay Conservation and Development Commission)
 - Southeast Florida – **Jim Murley** (Florida Atlantic University)
 - Commentary – **Mike Orbach** (Duke University)
- 4:00 p.m. Break
- 4:15 p.m. Discussion Session with Panel (above) **in which we clarify the problem we are attempting to resolve and search for critical elements of a framework to guide communities in their efforts to respond to sea level rise and inundation** – **Jerry Schubel**
- 5:00 p.m. Panel: Lessons Learned from Sea Level Rise Pilot Projects – **Jerry Schubel**
- Mississippi/Alabama – **Cindy Thatcher** (USGS)
 - Delaware – **Rob Thieler** (USGS)
 - Pacific Northwest – **John Marra** (East-West Center, NOAA)
- 5:30 p.m. Wrap-up and Plan for Day 2 **in which we recap what we have heard and how it will affect plans for Day 2** – **Jerry Schubel**
- 5:45 p.m. Adjourn
- 6:30 p.m. Dinner
- Societal Implications of Rising Sea Level: Run for Your Lives!*
Rob Young (Western Carolina University)
- Lansdowne Ballroom D

Friday, December 4 –Lansdowne Resort – Faulkner Room

- 8:00 a.m. Welcome, Summary of Day 1 – **Jerry Schubel**
- Review of Needs Assessments – **Tony MacDonald** (Monmouth University)
- 8:30 a.m. Developing the Strategic Framework: Breakout Sessions **in which three groups work independently to review and refine the draft Strategic Framework – Facilitators: Mary Culver, Roger Griffis, Laurie McGilvray, and Kimberly Texeira**
- Dogwood Rooms A, B, and C
- 10:15 a.m. Break
- 10:30 a.m. Report from Breakouts and Panel-led Discussion **in which we search for robust strategies from the three groups and get panel reaction to further refine the Strategic Framework – Jerry Schubel**
- **Jim Lopez** (Housing and Urban Development)
 - **John Dorman** (North Carolina Emergency Management)
 - **Susanne Torriente** (Miami-Dade County Office of Sustainability)
- 12:00 p.m. Lunch
- Tyranny of Millimeters and Priorities Shmiorities*
- Paul Gaffney** (President, Monmouth University)
- 1:30 p.m. Developing the Strategic Framework: Breakout Sessions **in which we identify priority data, information, and tools and their availability; and describe the roles and responsibilities of the players. – Jerry Schubel**
- Dogwood Rooms A, B, and C; **Facilitators: Mary Culver, Roger Griffis, Laurie McGilvray, and Kimberly Texeira**
- 3:30 p.m. Break
- 3:45 p.m. Report from Breakouts and Panel-led Discussion **in which we seek consensus on priority data, information and tool needs; and roles and responsibilities of the players.**
- **David Carter** (Coastal States Organization and Delaware Dept. of Natural Resources)
 - **Stephen Jordan** (U.S. Chamber of Commerce)
 - **Bill Walker** (MS Dept. of Marine Resources & GOM Alliance)
- 5:00 p.m. Adjourn
- Dinner on your own

Saturday, December 5- Lansdowne Resort – Faulkner Room

- 8:00 a.m. Welcome, Summary of Progress – **Jerry Schubel**
- 8:30 a.m. Finalize Strategic Framework and other workshop outputs – **Jerry Schubel, Margaret Davidson, and John Haines**
- Breakout groups if needed
- 10:00 a.m. Workshop Declaration **in which a draft declaration is presented and reviewed and refined, or rejected and a new one drafted.** (Breakout sessions if needed) – **Margaret Davidson, John Haines, and Jerry Schubel**
- 11:00 a.m. Next Steps **in which we celebrate or commiserate...but have a plan to move forward.** – **Margaret Davidson, John Haines, and Jerry Schubel**
- 12:00 p.m. Adjourn

Appendix VI: Participant List

Sea Level Rise and Inundation Community Workshop

December 3–5, 2009
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