MEMORANDUM

To: Mark Tedesco, John Whitler, Tristan Peter-Contesse, Jeremy Martinich, and Julie Rose, U.S. EPA; Sarah Deonarine, NY DEC; Antoinette Clemetson, NY Sea Grant; Jennifer Pagach and Mark Parker, CT DEP; and Juliana Barrett, CT Sea Grant

From: Susan Asam, Marybeth Riley-Gilbert, and Liz Strange, ICF International

Date: May 21, 2010

Re: Recommendations for the LISS Draft Sentinel Monitoring Document

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1. Background and Purpose

ICF International (ICF) and EPA are working with the Climate Change Workgroup (Workgroup) of the Long Island Sound Study (LISS), a partner in EPA's Climate Ready Estuaries (CRE) Program, to: (1) review and synthesize information on climate change drivers and responses in Long Island Sound (LIS) [*completed*]; (2) develop a prioritized list of indicators for monitoring climate-driven change [*completed*]; and (3) prepare recommendations on elements of a final monitoring plan. The information produced by these activities will be included in a document by LISS describing their approach for monitoring climate change, entitled *Sentinel Monitoring for Climate Change in the Long Island Sound Region of New York and Connecticut*. This memorandum discusses ICF's review of a draft of this document and provides recommended additions and changes.

2. Review of Other Monitoring Documents

ICF reviewed information on the monitoring programs in place in several other estuaries, as well as relevant guidance materials by EPA and other agencies. The primary monitoring documents consulted included EPA's *Monitoring Guidance for the National Estuary Program*; EPA's *Developing and Implementing an Estuarine Water Quality Monitoring, Assessment, and Outreach Program*; and the *Coastal Research and Monitoring Strategy* by the Clean Water Action Plan (a partnership of EPA, NOAA, USGS, and USDA). Complete citations for these documents are provided in the References section, along with a number of other documents that provide useful information on the development of indicators and monitoring plans.

The draft LISS document is similar in many respects to the monitoring documents reviewed, but there are some additional key elements that could be added to the document to assist LISS in developing and implementing their monitoring program. Recommendations as well as some draft text for these elements are provided in Section 3, below.

3. Proposed Additions to Draft LISS Sentinel Monitoring Document

Table 1 provides a proposed outline for the monitoring document that indicates which elements are currently "included" in the document or "recommended" additions or sections that we would advise LIS to "delete." The text that follows Table 1 is numbered according to the sections in the table with recommended changes. Sections that are currently included in the monitoring document are not discussed further below.

Table 1. Proposed LISS Monitoring Strategy Outline

Element of Outline	Status in Draft Strategy
1. Background and Purpose	
1.1. Description of study area	**Recommended**
1.2. Overview of Long Island Sound Study (LISS)	
1.3. Climate Change Workgroup	Included
1.3.1. Objectives	
1.3.2. Previous accomplishments	
1.4. Purpose of document	
2. Objectives of LISS Climate Change Assessment Strategy	
2.1. Summarize the state of knowledge on observed and potential climate change impacts on LIS habitats, biota and processes.	Included
2.2. Determine necessary collaborations to establish critical research programs (if they don't already exist), needed technological advancements and long-term monitoring.	
2.3. Create and expand a data library to store information on data sources collected through these collaborations as well as other scientific efforts throughout the Sound.	
2.4. Develop climate change indicators for LIS.	**Recommended**
2.5. Develop an adaptive monitoring program to measure and evaluate indicators and associated parameters that would signal the magnitudes and rates of change in LIS habitats, biota and processes caused by climate change. The monitoring program will begin on a pilot basis, to be expanded as funding becomes available.	Included
2.6. Synthesize and review outcomes to provide regular assessments of indicators and determine if changes should be made in parameters measured.	Included
2.7. Provide data and model predictions to managers such that management decisions and adaptation strategies may be developed and implemented.	Included

3. Climate Change Projections	
3.1. Climate models	**Recommended**
3.2. Projections – 2050, 2100	Included
3.2.1. Changes in air temperature	
3.2.2. Changes in precipitation and storm climatology	
3.2.3. Changes in the ocean	
3.2.3.1. sea level rise	
3.2.3.2. ocean chemistry	
3.2.3.3. sea surface temperature	**Recommended**
3.3. Changes in Sea Floor Geochemistry	**Delete**
3.4. Changes in Biological Communities/Processes	Included in Section 5
3.5. Uncertainties	Included
3.6. Uses and interpretation of climate data in context of monitoring	Recommended
4. Climate change and current stressors	
4.1.1. Land use	Included
4.1.2. Freshwater inflow	
4.1.3. Coastal flooding and erosion	
4.1.4. Nutrient runoff	
4.1.5. Harmful algal blooms (HABs)	
4.1.6. Hypoxia	
4.1.7. Pathogens	
5. Impacts of Climate Change on Habitats and Biota of LIS	
5.1. Coastal barriers, beaches and dunes	Included
5.2. Tidal wetlands	
5.3. Tidal flats	
5.4. Subtidal zone	
5.5. Open waters	
5.6. Freshwater tributaries	
5.7. Fisheries resources	Included with habitats
5.8. Shellfish resources	
6. Climate Change Indicators	
6.1. Indicator selection process	**Recommended**
6.2. LIS climate change indicators (table and explanation)	
7. Indicator monitoring plan – Data Collection	
7.1. Monitoring questions and data needed	**Recommended**
7.2. Existing monitoring	
7.3. New monitoring – sampling design	
8. Indicator monitoring plan – Data Analysis	
8.1. Definition of baseline	**Recommended**
8.2. Trend analysis	
8.3. Treatment of uncertainty	

9. Indicator monitoring plan - Data management	
9.1. Data clearinghouse	**Recommended**
9.2. Quality Assurance	
10. Indicator monitoring plan – Data Communication	**Recommended**
11. Use of Indicator Monitoring Results for Adaptive Management	**Recommended**
12. References	**Recommended**
13. Appendices	
13.1 Members of climate change workgroups	**Recommended**
13.2 Glossary	**Recommended**
13.3 Modules	Included

Background and Purpose [Section 1]

Most of the material that is typically included in an introduction is already in this section. However, we recommend adding subsections with a description of LIS and an overview of the LISS.

Objectives of LISS Climate Change Assessment Strategy [Section 2]

For completeness, we recommend adding “Develop Climate Change Indicators” to the list of objectives in Section 2, because it was part of the development of the monitoring strategy and is discussed in the document.

Climate Change Projections [Section 3]

Currently, this section provides climate change projections from the Northeast Climate Impact Assessment (NECIA, 2007), but no information on how projections are made. This information is discussed in detail in NECIA (2007), but a brief overview at the beginning of this section would provide context for understanding and interpreting the projections that are provided in the text. It is not necessary for estuary managers to understand the details of Global Circulation Models (GCMs) and GCM modeling techniques. However, it is important to understand the spatial and temporal scales of particular projections in relation to indicator monitoring data. There are important differences in the level of detail and degree of uncertainty in the large-scale output of GCMs compared to the regional and local projections that result from “downscaling” GCM output. Despite the advantages of the additional detail achieved by downscaling, smaller-scale projections involve additional modeling, which adds to the uncertainty already present in GCM output .

Because new climate change studies appear on a regular basis, we also recommend that the Workgroup check to see if any additional or updated projections have been made since the draft document was prepared. For example, a recent study by Yin et al. (2009) indicates that changes in ocean circulation could significantly increase sea level above current global estimates .

One final recommendation for this section is to delete the proposed subsection on *Sea Floor Geochemistry* because of a lack of information on any potential influences of climate change on these dynamics. However, if Workgroup members know of some relevant information, then clearly this subsection should be retained.

Climate Change Indicators [Section 6]

As discussed by ICF, EPA, and Workgroup members, and indicated in the document outline above, this section will include information on the indicator selection process; the final version of the *Table of Climate Change Impacts and Indicators* (with a description of what information it provides); and a list of the selected indicators.

ICF's indicator memo, dated 2/9/10, provides some text on indicator selection that could be retained or modified for the document, depending on the final selection process still underway by the Workgroup. For example, the following two paragraphs may remain relevant:

> Environmental indicators are used to convey scientific information on the current status of environmental conditions and changes and trends in these conditions over time. The significance of an environmental indicator is that it not only provides information about what is directly measured (e.g., water temperature) but it also provides information on the environmental condition represented by the measured parameter (e.g., water quality, aquatic habitat) (Niemeijer and de Groot, 2007).
>
> LISS selected indicators based on methods used for the development of other types of environmental indicators (NRC, 2000; Rogers and Greenway, 2005; Niemeijer and de Groot, 2008; U.S. EPA, 2008). Most of these indicator selection procedures involve some form of the pressure-state-response framework for selecting indicators, where *pressure* refers to the environmental stressor, *state* refers to the environmental condition resulting from the pressure, and *response* refers to a management response. The LISS used this type of framework to develop environmental indicators for its ongoing monitoring programs (LISS, 2008).

Indicator Monitoring Plan [Sections 7, 8, 9 and 10][1]

We recommend including in the monitoring document details of the plan the Workgroup develops for monitoring the selected indicators. A monitoring plan typically includes procedures for *data collection*, *data analysis*, *data management*, and *data communication* (U.S. EPA, 2008). Each of these elements is described below, along with some examples from various guidance documents and estuary programs to assist the Workgroup in plan development (see Reference section for complete citations and additional references).

Data collection [Section 7]. The data collection plan should identify the questions to be addressed; the climate change indicators to be monitored; the data needed to measure the indicators in order to address those questions; the data sampling plan; and the methods used to develop a sampling design (U.S. EPA, 2008).

[1] A note on terminology. We use the term "program" or "strategy" when discussing the full suite of activities that make up the LISS approach to climate change monitoring, including information and activities that support monitoring, and reserve the term "plan" to refer only to the design of the monitoring itself.

Monitoring questions should be specific. For example, a fish indicator could be monitored to address questions such as, “Is the ratio of warmwater to coldwater fish species changing? Are increasing or decreasing trends of warm- or coldwater species evident in the monitoring results?”

A data collection plan could be an integrated plan for monitoring a group of indicators that are related or that are monitored at the same sites, or a separate plan may be needed for each indicator (EPA, 2008). The New Hampshire Estuaries Project (NHEP), for example, developed a different sampling and analysis design for each of several indicators (NHEP, 2008).

A data collection plan also indicates where and at what temporal and spatial scales indicators will be measured and assessed (U.S. EPA, 2008). For climate change monitoring, it is important to consider monitoring scales consistent with the available climate data, which may include a regional aggregation of data and decadal rather than annual or within year summaries.

Methods used to develop the indicator sampling design should also be described. Some methods focus on developing a sampling plan that will support statistical analyses. EPA’s Environmental Monitoring and Assessment Program (EMAP), for example, is a long-term research program that focuses on developing indicators and unbiased statistical design frameworks. EMAP’s Research Strategy (EMAP, 2002) provides details on a number of important sampling design and data analysis issues, including trend analysis considerations. For example, the detection of trends requires an evaluation of the different components of variance. The choices for minimizing variance components and effects on estimates of status and trends are discussed in an appendix to the EMAP Strategy (EMAP, 2002).

The NHEP used power analysis to develop a suitable design for each of its indicators (NHEP, 2008). The techniques of power analysis, sample size estimation, and confidence interval estimation help determine how large a sample is needed for accurate and reliable statistical judgments and how likely it is that a given statistical procedure will detect effects. A number of software programs are available for implementing such techniques. For example, EPA, the Department of Defense, and the Department of Energy collaborated on the development of a program known as the *Visual Sampling Plan*, a tool for defining an optimal, technically defensible sampling scheme for a number of applications. The program can be downloaded from http://vsp.pnl.gov/.

The LISS Climate Change Workgroup has identified a number of existing monitoring programs that may collect data relevant for LIS climate change indicators (Long Island Sound Study Science and Technical Advisory Committee, 2009). The data collection section of the Workgroup’s strategy document could include a table listing those programs and corresponding indicators. The plan should also note any established protocols and procedures for measuring indicator parameters and if and how the monitoring protocols of New York and Connecticut may differ.

Data analysis [Section 8]. A data analysis plan indicates how data will be processed and analyzed, both to address immediate information needs (e.g., identification of indicator baselines) as well as future trends. Trend analysis, analysis of seasonality, and other techniques for evaluating a time series of data will be especially important for climate change studies.

In addition to describing the analytical methods used, the analysis plan should also document the statistical limitations of indicator performance and establish thresholds or ranges of values that are considered “good” or “bad” (U.S. EPA, 2008). In the context of climate change, ranges might be defined as within (or outside of) the historical range of variability. This provides a frame of reference for interpreting current conditions and changes or trends that may occur with climate changes.

A data analysis plan also includes procedures for addressing uncertainty. A report by EPA’s National Center for Environmental Assessment identified the following three sources of environmental indicator uncertainty (U.S. EPA, 2009):

- Uncertainty caused by the failure of the monitoring design to capture the true value of the indicator in time and space (e.g., sampling error in probability designs, failure of the design to detect rare events, sensitivity of the indicator to a few large sources or events).
- Uncertainty caused by the measurement itself (e.g., instrument error, inadequate quality control).
- Uncertainty caused by data reporting, management (e.g., entry errors, database corruption, computation errors), and analysis (e.g., methods used to aggregate data).

Though the studies described in the report were designed to address the assessment of uncertainty and scaling for indicators used in EPA’s Report on the Environment, much of the information is applicable to other environmental indicators. The document summarizes investigations related to uncertainty to help interpret and better understand the accuracy of current environmental conditions and trends in environmental quality. The principal focus of the project was the question, “How accurate are the presented indicator values, and are changes or trends over time statistically significant?”

Data management [Section 9]. The primary objectives of a data management plan are to establish procedures to ensure high quality data (i.e., data quality standards); coordinate data management among monitoring programs; transfer and exchange information among all participants; and provide ease of access to the data (U.S. EPA, 2008).

A particular focus of the Climate Change Workgroup is to facilitate information exchange among the many stakeholders, including academic researchers, that monitor the resources of LIS. To meet this objective, the Workgroup has begun development of a “data clearinghouse” and directory of data sources. At present, information exists in multiple formats in a variety of places, and different procedures and protocols are used for data collection, analysis and storage. A clearinghouse provides for quality control and some degree of standardization across datasets.

An online clearinghouse involves an “exchange platform” for data sources and other information. Chapter 5 of U.S. EPA (2002a) provides step-by-step details on how they developed a website for data access. The New Hampshire Department of Environmental Services (DES) has developed a data clearinghouse known as the Environmental Management Database (EMD) (http://des.nh.gov/organization/divisions/water/wmb/emd/index.htm). The EMD website provides some excellent information on the various considerations and techniques that are important in clearinghouse development. For example, the DES decided that sampling data would be submitted using Microsoft Excel templates (spreadsheets are the most common way to exchange data). The templates include information on the required format and domain lists and an example data record. When templates are uploaded via the web interface, the data are automatically checked for validity.

The LISS has identified a number of existing online databases that may be candidates for inclusion in the Workgroup's data clearinghouse. For example, the Connecticut Department of Environmental Protection and the University of Connecticut have created an online database for researchers to enter information about long-term sampling efforts in LIS. There are dozens of datasets that include monitoring data on water quality indicators (e.g., dissolved oxygen, water temperature, salinity); physical characteristics of the estuary (e.g. wave height, surface elevation changes and sediment accumulation using marker horizons; habitat indicators (e.g., "benchmarks" in each of three marsh habitats, including bayfront salt marsh, interior salt marsh, and restoration marsh); and biological indicators (e.g., the abundance of lobster larvae). Another online database is the Long and Fishers Island Sound Sentinel Monitoring database.

Other important considerations in developing a clearinghouse include plans for updating content (e.g., continuous updating or updates at defined times) and for defining and implementing data quality standards. EPA has developed guidelines for developing a quality assurance project plan, which includes recommendations on data quality, data verification and validation, and the use of existing data, among other relevant topics (U.S. EPA, 2002b). U.S. EPA (2006a) provides detailed guidance on data management and interpretation.

Data communication [Section 10]. The Workgroup can draw upon a number of existing communication programs (e.g., the Connecticut and New York Sea Grant programs) to disseminate results of climate change indicators, with communication products tailored for particular stakeholder groups (the public, managers, scientists). For the general public, the Workgroup could prepare periodic "fact sheets" summarizing key results for a specific period, such as average conditions over the period of record (baseline) or periodic summaries of future conditions, such as decadal results (U.S. EPA, 2008). For technical specialists, communications will provide greater detail on monitoring and assessment methods, results of formal analyses, and the characterization of uncertainties. Managers will be most interested in how indicator results relate to management goals (U.S. EPA, 2008).

The Northeast Coastal Indicators Workshop noted that the following types of communication tools are particularly useful (NCIW, 2004):

- Period assessments and maps;
- Data integration and interpretation tools;
- Integrated assessment products, including those that relate changes to stressors;
- Workshops, seminars, and other knowledge-sharing meetings; and
- Reports on the socioeconomics of impacts and actions.

A number of estuary programs present indicator results as "report cards" or "state of the bay" reports indicating how results relate to certain management objectives or thresholds (e.g., the Casco Bay Estuary

Partnership, http://www.cascobay.usm.maine.edu/SOTB.html). The Gulf of Maine Ecosystem Indicator Partnership (ESIP) has developed an Indicator Reporting Tool that can be accessed on its website www.gulfofmaine.org/esip. U.S. EPA (2006a) provides some excellent examples of presentation options.

Use of Indicator Monitoring Results for Adaptive Management [Section 11]

It is also helpful to establish a process for using indicator results to assess and adjust monitoring as needed to meet changing priorities or monitoring needs. EPA suggests that indicator programs should be updated every five years to ensure that they are meeting objectives (U.S. EPA, 2008).

Results of climate change indicator monitoring can be used along with other monitoring data to help guide management activities, including changes in existing actions. This process supports "adaptive management," whereby management actions are adjusted according to new information (Holling, 1978; Walters, 1986). The process recognizes the dynamic nature of environmental structures and functions, while at the same time acknowledging ranges of variability that are consistent with a healthy ecosystem. Adaptive management is now commonly applied in environmental management programs (e.g., Williams et al., 2009).

References [Section 12]

In the document's reference section we recommend including both the literature cited in the document as well as other references helpful for working out details of the strategy. Below is a list of references we have cited in this memo, along with some other relevant references.

Coastal Research and Monitoring Strategy Workgroup. 2000. Clean Water Action Plan: Coastal Research and Monitoring Strategy. Published September 2000. Available at: http://www.epa.gov/owow/oceans/nccr/H2Ofin.pdf.

EMAP (Environmental Monitoring and Assessment Program). 2002. EMAP Research Strategy. EPA 620/R-02/002. U.S. EPA, Office of Research and Development, National Health and Environmental Effects Research Laboratory Research Triangle Park, NC. Available at: http://www.epa.gov/emap/html/pubs/docs/resdocs/resstrat02.html.

Holling, C.S. 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, New York, NY.

IPCC (International Panel on Climate Change). 2007. Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

LISS (Long Island Sound Study). 2008. Indicators of Sound Health. Available at: http://www.longislandsoundstudy.net/monitoring/indicators/index.htm.

Long Island Sound Study Science and Technical Advisory Committee. 2009. Review of Current Monitoring Efforts in Coastal Ecosystems. Internal document prepared by Mark Hoover and Santiago Salinas, February 9, 2009.

NCIW (Northeast Coastal Indicators Workshop). 2004. NCIW Workshop Summary. Available at: http://www.gulfofmaine.org.

NHEP (New Hampshire Estuary Program). 2008. Monitoring Plan. Available at: www.prep.unh.edu/resources/pdf/nhep_monitoring_plan-nhep-08.pdf.

Niemeijer, D., and R.S. de Groot. 2008. A conceptual framework for selecting environmental indicators. Ecological Indicators 8:1 4-25.

NECIA (Northeast Climate Impacts Assessment). 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Available at: http://www.climatechoices.org/ne/resources_ne/nereport.html.

NOAA (National Oceanic and Atmospheric Administration). 2008. Literature Review of the U.S. Northeast Coastal Community: Management of Coastal Ecosystems and Natural Hazards. Coastal Resources Center at the University of Rhode Island for NOAA. NOAA Coastal Services Center, NOAA/CSC/RPT 08-02, Charleston, SC.

NRC (National Research Council). 2000. Ecological Indicators for the Nation. National Academy Press, Washington, DC.

O'Neill, S.M., C.F. Bravo and T.K. Collier. 2008. Environmental Indicators for the Puget Sound Partnership: A Regional Effort to Select Provisional Indicators (Phase 1). Summary Report-December 2008. NOAA Fisheries, Northwest Fisheries Science Center.

Partnership for the Delaware Estuary. 2008. State of the Delaware Estuary 2008. Summer, 2008. Available at: http://www.delawareestuary.org/pdf/EstuaryNews/2008/SummerNews08.pdf.

Puget Sound Partnership(PSP). 2009. Ecosystem Status & Trends: A 2009 Supplement to State of the Sound Reporting. November 2009. Available at: http://www.psp.wa.gov/downloads/2009_tech_memos/Ecosystem_status_and_trends_tech_memo_2009_06_11_FINAL.pdf.

Rogers, S.I., and B. Greenway. 2005. A UK perspective on the development of marine ecosystem indicators. Marine Pollution Bulletin 50: 9–19.

Shared Strategy for Puget Sound. 2007. Puget Sound Salmon Recovery Plan: Adaptive Management and Monitoring for the Puget Sound Salmon Recovery Plan. Available at: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/PS-Recovery-Plan.cfm.

USACE (U.S. Army Corps of Engineers). 1999. Engineering Pamphlet EP 1165-2-502: Supporting Policy Information for Ecosystem Restoration. Published September 1999. Available at: http://140.194.76.129/publications/eng-pamphlets/ep1165-2-502/entire.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2002a. Developing and Implementing an Estuarine Water Quality Monitoring, Assessment, and Outreach Program (The MYSound Project). EPA/625/R-02/010. November 2002. Available at: www.epa.gov/nrmrl/pubs/625r02010/625R02010.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2002b. Guidance for Quality Assurance Project Plans. Publication EPA/240/R-02/009. U.S.EPA, Office of Environmental Information, Washington, DC. Available at: www.epa.gov/quality/qs-docs/g5-final.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2002c. Guidance on Environmental Data Verification and Data Validation (QA/G-8). EPA/240/R-02/004. U.S. EPA, Washington, DC . Available at: www.epa.gov/quality/qs-docs/g8-final.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2006a. Chapter 8: Data Management, Interpretation, and Presentation. Volunteer Estuary Monitoring Manual, A Methods Manual, Second Edition. EPA-842-B-06-003. Available at: http://www.epa.gov/owo/estuaries/monitor/.

U.S. EPA (U.S. Environmental Protection Agency). 2006b. Chapter 14: Salinity. Volunteer Estuary Monitoring Manual, A Methods Manual, Second Edition. EPA-842-B-06-003. Available at: http://www.epa.gov/owow/estuaries/monitor/.

U.S. EPA (U.S. Environmental Protection Program). 2008. Indicator Development for Estuaries. Publication No. EPA842-B-07-004, U.S. EPA, Office of Water, Washington, DC. Available at: www.epa.gov/nep/pdf/indicators_manual.pdf.

U.S. EPA (Environmental Protection Agency). 2009. Report on the Environmental Indicators: An Uncertainty and Scaling Pilot Study. EPA/600/R-08/149F. National Center for Environmental Assessment, Washington, DC. Available at: http://www.epa.gov/ncea.

U.S. EPA (U.S. Environmental Protection Agency). 2010a. Climate Change Indicators in the United States. EPA 430-R-10-007. Washington, DC. Available at: http://www.epa.gov/climatechange/indicators.html.

U.S. EPA (U.S. Environmental Protection Agency). 2010b. Definition and Criteria: What is an Environmental Indicator? Available at: http://cfpub.epa.gov/eroe/index.cfm?fuseaction=main.criteria.

Walters, C.J. 1986. Adaptive Management of Renewable Resources. Blackburn Press, Caldwell, NJ.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. Available at: http://www.doi.gov/initiatives/AdaptiveManagement/documents.html.

Yin, J., M. E. Schlesinger and R. J. Stouffer. 2009. Model projections of rapid sea-level rise on the northeast coast of the United States. Nature Geosciences 2:262-266.

Appendices [Section 13]

The draft document includes supplementary material such as the Tidal Wetlands Module. Other recommended appendices include the following:

Members of climate change workgroup [Section 13.1]. As suggested in the draft document, it will be helpful to include an appendix with the names and contact information for both the Connecticut and New York members of the Workgroup.

Glossary [Section 13.2]. In response to the request of LISS, we have prepared a glossary of terminology that we identified in the current draft that may not be clear to non-specialists. The definitions we have used are standard definitions taken from EPA documents, particularly the document *Developing and Implementing an Estuarine Water Quality Monitoring, Assessment, and Outreach Program* (U.S. EPA, 2002a).

Acidification: A decrease in the pH of a solution, such as seawater, due to the incorporation of carbon dioxide (CO_2) into the water. The pH of seawater is typically 7.5-8.4 (reference: a pH of 7.0 indicates a neutral solution and a pH of greater than 7.0 indicates a basic solution). The level of ocean acidification resulting from the absorption of excess atmospheric carbon dioxide that is considered harmful to marine life is a pH below 5.0 (U.S. EPA, 2010a).

Anthropogenic: A process or impact that is due to human activity.

Adaptation: In the context of climate change, adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

Bathymetry: The measurement of the depth of an ocean or other large body of water (U.S. EPA, 2002a).

Carbon Dioxide (CO_2): A gas that is generated through both natural and anthropogenic activities. When dissolved in water, CO_2 and water combine to form carbonic acid, resulting in acidification of seawater.

Chlorophyll *a*: A green pigment in phytoplankton that transforms ultraviolet (UV) light energy into chemical energy during the process of *photosynthesis* (U.S. EPA, 2002a).

Decomposition: The breakdown of organic matter by bacteria and fungi (U.S. EPA, 2002a).

Dissolved Oxygen (DO): The concentration of free molecular oxygen that is dissolved in water, usually expressed in milligrams per liter (mg/L), parts per million (ppm), or percent of saturation. DO allows fish and other life to live in water. Levels of 5 mg O_2/L are optimal for sustaining life; most fish cannot survive prolonged periods at levels of less than 3 mg O_2/L. *Hypoxia* refers to conditions with DO of less than 1 mg O_2/L (U.S. EPA, 2002a).

Drivers: In the context of climate change, drivers of climate change are "forcings" such as increased atmospheric concentrations of greenhouse gases (either through anthropogenic or natural activities), changes in the Earth's orbit, or changes in the ocean's currents. Climate change itself can be a driver on ecosystems and hydrologic systems, such as increases in air temperatures leading to warming water temperatures or leading to changes in animal or plant phenology.

Ecosystem: An ecosystem is a biotic community together with its physical environment, considered as an integrated unit (USACE, 1999).

Estuary: A semi-enclosed coastal body of water that has free connection with the open sea and within which sea water is diluted by fresh water from land drainage (U.S. EPA, 2002a).

Eutrophication: Enrichment of a water body by nutrients, such as phosphorus and nitrogen. This can lead to excessive growth of algal blooms.

Harmful Algal Blooms (HAB): Excessive growths of harmful algae caused by nutrient (phosphorus, nitrogen) loading (U.S. EPA, 2002a).

Hypoxia: Dissolved oxygen (DO) levels of less than 1 mg O_2/L (U.S. EPA, 2002a).

Impervious Surfaces: Surfaces such as paved roads and parking lots that prevent precipitation from being absorbed into the underlying soil, leading to additional runoff. Such runoff can cause erosion and may pick up contaminants from roadways that are harmful to estuary systems (U.S. EPA, 2002a).

Indicator: In the context of the natural environment, an indicator is a numerical value derived from actual measurements of a pressure, state or ambient condition, exposure or human health or ecological condition over a specified geographic domain, whose trends over time represent or draw attention to underlying trends in the condition of the environment (U.S. EPA, 2010).

Land Use: The uses of land, such as for forests, crops, pastures, or urban settlements.

Nonpoint source: A source of pollution that is diffuse, such as that associated with agricultural land use or contaminated groundwater flow (U.S. EPA, 2002a).

Pathogens: Disease-causing organisms (U.S. EPA, 2002a).

pH Scale: Scale used to determine the alkaline or acidic nature of a substance. A pH of 1.0 indicates a pure acid and 14 is a purely alkaline (basic) substance. Pure water is neutral (pH of 7.0) (U.S. EPA, 2002a).

Phytoplankton: Microscopic floating plants, mainly algae, that live suspended in bodies of water. These plants drift with currents (U.S. EPA, 2002a).

Salinity: Amount of salts dissolved in water, usually expressed in parts per thousand (ppt). Within an estuary, salinity levels are referred to as oligohaline (0.5-5.0 ppt), mesohaline (5.0-18.0 ppt), or polyhaline (18.0-30.0 ppt) (U.S. EPA, 2006b).

Turbidity: Measure of water clarity (degree to which light is blocked due particulate matter suspended in the water column). Turbidity inhibits the growth of submerged aquatic vegetation (SAV), which provides important habitat and a food source for many estuarine organisms (U.S. EPA, 2002a).

Watershed: All land and water areas that drain toward a given water body (also called a drainage basin) (U.S. EPA, 2002a).