APPENDIX C: OVERVIEW OF THE ADAPTIVE MANAGEMENT PLAN PROCESS FOR THE HERRING RIVER RESTORATION PROJECT

GENERAL OVERVIEW OF ADAPTIVE MANAGEMENT

As described in the draft EIS/EIR, the Herring River project will be implemented by following an adaptive approach to achieve restored tidal conditions through the management of adjustable tidal control gates and the implementation other restoration actions over a period of years. This adaptive approach is designed to minimize risk to property and the environment given current uncertainties about the response of the Herring River system to the restored tidal conditions that have not been experienced in the last 100 years. Such risks necessitate a cautious start, when uncertainty is greatest; monitoring the outcomes of initial (and subsequent) tidal influx will reduce uncertainties regarding how the Herring River system responds to new conditions and allow the restoration project to proceed at a faster rate with greater confidence and less risk of unintended outcomes.

Adaptive management (AM), in the context of natural resources, is an approach for simultaneously managing and learning about the dynamics of resources under management. It is a formal process intended to aid decision making in situations where the outcomes are uncertain and learning is achieved by monitoring the system after management actions are implemented. Learning is targeted specifically at those uncertainties that impede decision-making and, thus, serves to improve our ability to predict outcomes and make better future decisions. An AM approach is designed to address decisions that are iterated over time, permitting learning to accumulate as decisions are implemented and responses are monitored. Monitoring is used to compare observed outcomes with predictions of how the system was expected to respond to management interventions (a form of hypothesis-testing). Learning is then applied at each decision point to refine the relative amount of support (credibility) for each hypothesis of system dynamics.

USE OF ADAPTIVE MANAGEMENT FOR THE HERRING RIVER PROJECT

Each action alternative presented in the draft EIS/EIR (see Chapter 2) is based on the end-point (ecological) conditions of a step-wise process for achieving a prescribed maximum tidal range. The draft EIS/EIR is intended to address foreseeable long-term, permanent impacts of restored tidal inundation resulting from a specified tidal control gate configuration. The selection and, ultimately, the implementation of the preferred alternative in the draft EIS/EIR does not mean that the maximum specified tide regime or tide gate configuration would necessarily be achieved. Instead, the preferred alternative is intended to describe the desired end-point condition which the project aims to achieve. The sequence of decisions to increase tide range and apply other restoration actions to approach or reach conditions predicted by the preferred alternative will be guided by a process that is laid out in the Adaptive Management Plan (AMP).

Many elements of the Herring River Restoration Project make it ideally suited to a formalized adaptive management approach. Most fundamentally and despite many years of study in the Herring River (see references), much is still unknown about this very large, complex system. As such, uncertainties remain about how specific ecological processes will respond to tidal restoration. In addition, implementation of the project will involve multiple decisions, repeated over an extended timeframe (estimated as several years), with each decision carrying its own specific range of uncertainty. Various groups of stakeholders will view the project based on their own interests and may perceive some objectives differently than other stakeholders. In some instances, project objectives may be in conflict; i.e., actions required to achieve one objective may deter or delay achievement of another, making informed trade-offs a necessary factor in the decision-making process.

GENERAL STEPS FOR ADAPTIVE MANAGEMENT PLANNING

Adaptive management is founded on general principles of structured decision making (SDM), an approach that was developed in the mid-20th century for applications in engineering, operations research, and economics. Adaptive management is a component of SDM and is characterized by implementing repetitive management decisions that are inferred by learning from the results of past management actions. It has been applied to natural resource management since the 1970s (Walters & Hilborn, 1978) but even today, formal usage of AM is not common. SDM is a logical, prescriptive framework for making decisions by clearly distinguishing components of a decision that are typically subjective and values-oriented (e.g., management objectives, risk attitudes, possible actions) from more objective, science-based components (system models, measures of system state). A SDM framework can guide a transparent decision-process by explicitly linking the anticipated outcomes of all possible management alternatives to well-stated objectives. The process seeks to balance competing objectives and risk attitudes of multiple stakeholders, and incorporates quantitative measures of uncertainty to identify the policy most likely to achieve management objectives.

Implementation of adaptive management requires careful planning, which can be described as a two-step process: a deliberative or set-up phase in which key components are formalized and an iterative phase consisting of the decision making, implementation, monitoring and feedback.

SET-UP PHASE

Stakeholder Involvement

Identifying appropriate individuals or groups that have 1) an interest in the resources proposed for management, and 2) a willingness to come to an agreement on the scope of the problem, the objectives of other stakeholders, and potential courses of action. Representation of the full range of stakeholder values is key to successful decision making; actual stakeholder involvement at various stages of the process is context-specific.

Objectives

Desired conditions of the resource constitute the management objectives and are the foundation for any decision. Careful deliberation of clear, measurable and fundamental objectives at the beginning of the set-up phase permits a clearer understanding of the consequences and trade-offs involved with any decision, as well as a transparent means for evaluating progress towards ‘success’.

Alternatives/Management Actions

A complete set of available management actions, or combinations of actions (‘portfolios’), from which to select must be described. Alternatives should span all reasonable actions available to a decision maker and be distinct enough to predict discernible outcomes by which learning and feedback can proceed.

Predicted Consequences/Models

Predicting the outcome of an action is an essential (and natural) part of any decision making. A SDM/AM framework links management decisions to resource objectives via models that predict the outcome (both costs and benefits) of all possible alternative actions. Because of the iterative nature of AM actions and the opportunity to learn from their implementation, reducing uncertainty is a central focus during the establishment of predictive models. Important areas of uncertainty are represented by multiple hypotheses about how the system functions. Each hypothesis is given a relative credibility weight based on prior knowledge (i.e., from previous research) or stakeholder agreement and optimal decisions are based on weighted mean predictions.

Monitoring Design

A careful monitoring plan should be designed to track appropriate measures of system response after implementation of a management decision. Monitoring data should specifically track (i) progress toward achieving objectives; (ii) current resource status (state) to evaluate the next appropriate management action; and (iii) the differences between predictions of alternate hypotheses (models) and the observed system response. Comparisons between observed and predicted outcomes constitute the learning component of AM as they provide support for those hypotheses with the best predictive ability, thereby permitting updating of the weighting of competing models to improve predictive power for the next decision cycle.

ITERATIVE PHASE

Decision Making

The set-up phase provides the necessary framework for selecting the most appropriate actions for each step to achieve multiple management objectives, given the status of the current system, and predicted outcomes of each possible management alternative. Predictions consider uncertainty in the system through multiple hypotheses and, thus, are robust given the current state of knowledge. Selecting the best alternative involves balancing the anticipated costs and benefits of any action, when compared to the stated management objectives, and accounting for such trade-offs into the future.

Monitoring and Assessment

Confidence in our decision making will improve over time as our understanding of the system evolves with new information collected from the monitoring program and as hypotheses (models) are supported or refuted by empirical observations. Monitoring also provides needed information about the new state of the system in order to evaluate the appropriate action at the next point in the decision cycle.

ADAPTIVE MANAGEMENT PLANNING STEPS FOR THE HERRING RIVER PROJECT

Using the steps outlined above, this section describes the basic logic and framework being followed in the development of the Herring River AMP.

SET-UP PHASE

Stakeholder Involvement

Although not explicitly framed under the AM approach, formal engagement with Herring River stakeholders began in 2005 with the development of the first Memorandum of Understanding (MOU I) between the Town of Wellfleet and the Seashore, formation of the Herring River Technical (HRTC) and Stakeholders Committees, and the 2007 completion of the Conceptual Restoration Plan (CRP). During this process, the HRTC solicited input from the Stakeholder Committee and others (including flood plain landowners, town officials, and representatives from various interest groups) regarding their specific concerns, questions, and issues related to the restoration project. The CRP was developed to partially address these concerns and to frame unanswered questions for further analysis during the NEPA process and AMP. With the approval of the CRP by the Seashore and Wellfleet Board of Selectmen, execution of a second MOU, and formation of the current Herring River Restoration Committee (HRRC), stakeholder involvement and input has continued through regularly scheduled monthly public meetings, periodic public events sponsored by the Friends of the Herring River, and HRRC public outreach presentations at the State of Wellfleet Harbor Conference, Seashore sponsored canoe trips, and a variety of other public forums. In general, issues and questions raised by stakeholders include:

- flooding impacts to low lying roads, private properties, and the CYCC golf course,
- potential sediment and water quality impacts within Wellfleet Harbor,
- changes to freshwater habitats that have become established in the flood plain since the Chequessett Neck Road dike was constructed,
- obstructions to river herring migration,
- nuisance mosquitoes,
- project costs and timeline,
- And impacts occurring during construction.

Objectives

Decisions made regarding the control of water flow into and out of the Herring River estuary will necessarily be based on considerations of the objectives for the restoration project. By ‘objectives’, we refer to the desired future state of the Herring River system, which considers both the ecological state of the watershed and the human values derived from the estuary and its environs. Some of these objectives may be in conflict, necessitating a consideration of the risks and trade-offs between them to arrive a decision that will maximize the overall benefits across objectives.

The fundamental ecological goals for the Herring River restoration project are to restore natural hydrological conditions and ecosystem functions in the watershed. Because full control over all functions within the Herring River ecosystem is unrealistic, the achievable objectives that represent the most important components of ecosystem function include, 1) benefits to native fauna and, 2) restoring the extent and quality of native vegetation communities. From these two over-arching fundamental objectives, a number of means objectives can be stated which collectively describe the inter-related physical, chemical, and biological processes which need to be established to achieve the project goals. Means objectives include targeted water surface elevations, salinity levels, sediment transport and other estuarine processes. Conceptualized relationships among fundamental and means are depicted in the objectives hierarchy show in Figure A-1.

Based on the articulation of stakeholder concerns, socioeconomic objectives have also been factored into the consideration of risks from management interventions to other resources in the Herring River system. Some of these issues, such as the risk of flooding private properties, have already been incorporated into the development of the action alternatives analyzed as part of the draft EIS/EIR, where maximum tidal water surface elevations are limited and impacts will be mitigated. In other cases, socioeconomic concerns and other constraints to fulfilling project objectives will be discussed further with stakeholders and project planners as the AMP is developed.

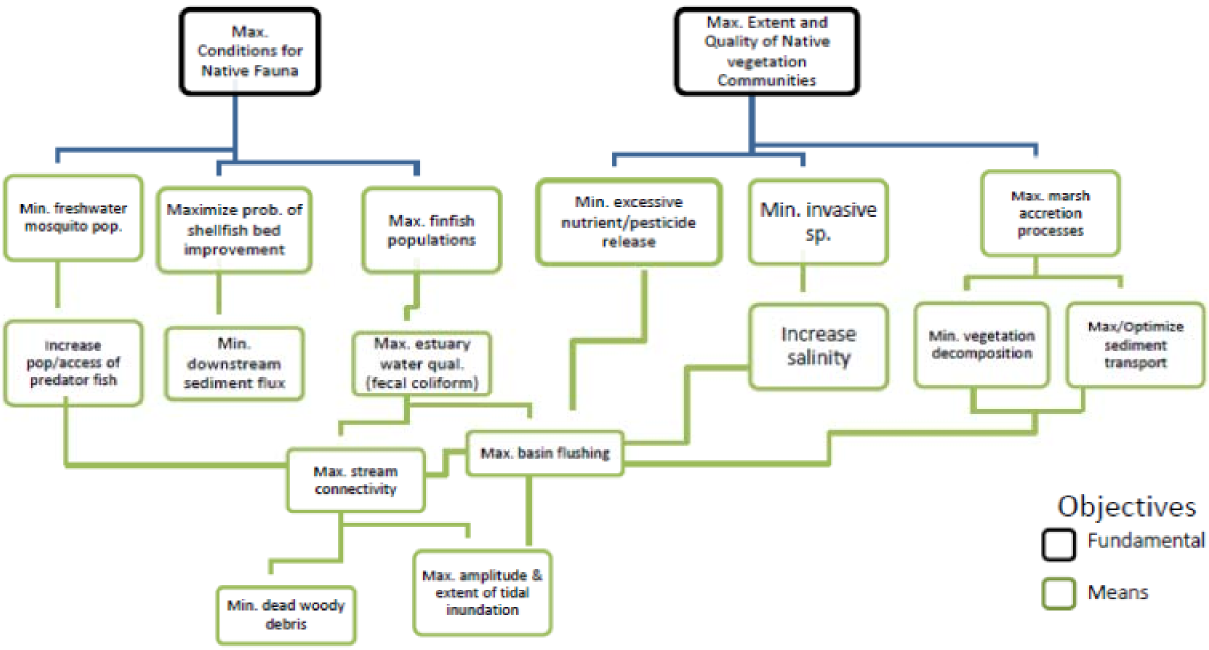

FIGURE A-1: CONCEPTUALIZED RELATIONSHIPS AMONG ECOSYSTEM OBJECTIVES FOR THE HERRING RIVER RESTORATION ADAPTIVE MANAGEMENT PLAN

Achieving the desired system states articulated by the objectives could be hindered by lack of knowledge about how the Herring River functions and how it will respond to various management actions. Based on the impact topics which comprise the draft EIS/EIR alternatives analysis, the uncertainties about Herring River tidal restoration are generally related to:

- **Salinity**: the extent to which salinity levels above 18 parts per thousand will reach mid- and upper sub-basins.
- **Water and Sediment Quality**: the rate and duration of nutrient, metals, and bacteria release and potential effects in downstream receiving waters.
- Sediment Transport:
  - the ability of subsided marsh surfaces to regain inter-tidal elevations relative to increasing tidal range,
  - the extent to which sediment will move out of the river and affect Wellfleet Harbor.

- Wetland Habitat and Vegetation Change:
  - the ability of subsided marsh surfaces to support native, estuarine vegetation,
  - the extent to which brackish marsh plant communities will shift throughout the flood plain,
  - composition of tidally influenced freshwater plant communities,
  - effect of dead and dying woody shrubs and trees on recovery of native estuarine plant communities.
- Aquatic Species:
  - the effects of the new Chequessett Neck Road dike on migrating river herring and American eels,
  - the rate and extent of colonization of shellfish,
- **State-listed Rare Species**: extent and rate of change in distribution of water-willow (*Decodon verticillatus*) and occupancy of suitable habitat by water-willow stem borer (*Papaipema sulphurata*).
- **Terrestrial Species**: suitability of restored estuarine habitat for estuarine-dependent bird species.
- **Cultural Resources**: potential effects of tidal flow and construction activities on potentially sensitive areas.
- Socioeconomics:
  - extent and rate of change from freshwater dominant to salt water dominant mosquito species,
  - sedimentation impacts to Wellfleet Harbor aquaculture areas,
  - unanticipated flood impacts to low-lying road or properties.
  - property value changes based on changes to vegetation, viewscapes, and aesthetics.

Alternatives/Management Actions

Management actions are considered those activities which need to be undertaken to achieve project objectives. For the Herring River project, the primary management actions involve the incremental opening of a series of adjustable tidal control gates over a period of several years. A central assumption for the project is that by doing so, increased tidal range and salinity (believed to be the core drivers for reestablishment of estuarine function) will stimulate a series of responses leading to the achievement of fundamental objectives of improved estuarine conditions for estuarine fauna and vegetation. Other secondary management actions may be needed to achieve the desired conditions. Because of inherent uncertainties about how the Herring River ecosystem functions and how it will respond to tidal restoration, it cannot be known whether secondary management actions will be necessary until implementation of the project begins and ecological changes can be monitored. In addition to tidal control gate management, secondary management actions for the Herring River project may include:

- Targeted herbicide application to control non-native, invasive plant species.
- Planting, seeding, or supplementing seed source of native estuarine plants.

- Removal of woody vegetation to facilitate tidal circulation and promote recovery of estuarine plants.
- Reestablishment and/or creation of sustainable tidal channels to promote tidal circulation and freshwater drainage.
- Creation of salt pannes and pools and related hydraulic connections to function as estuarine fish habitat for control of salt marsh mosquito larvae.
- Applying layers of sediment to subsided areas to supplement natural accretion processes and promote establishment of inter-tidal habitats.

Predicted Consequences/Models

A set of models for the Herring River project will link stakeholder concerns, objectives, management actions, and monitoring variables to predict the outcome of each management action in order to select the best alternative given current system characteristics. Although the existing hydrodynamic model (Woods Hole Group 2012) provides the central basis for predicting changes in tidal regime and salinity based on varying tide gate configurations, related models are needed to predict resultant changes in vegetation, water quality, sediment distribution and other processes as a function of modified hydrodynamics. In addition, development of predictive models linking actions to outcomes will facilitate identification of key ecological relationships as well as those that are most uncertain. Models will also highlight the most relevant state variables for system characterization and monitoring. The models do not necessarily need to be complex, but do need be sophisticated enough to capture the range of uncertainty for any possible outcome of management so that competing hypotheses can be represented and tested.

Monitoring Design

With objectives, risks, and management actions fully articulated, and predictive models developed to capture the uncertainty in our understanding of system behavior, appropriate state variables will be identified to track and measure progress toward achieving objectives and test the hypotheses represented in the models to increase their predictive power. The monitoring variables identified by the AM planning process and specified in the AMP are intended to provide needed information for comparing predictions to observations in order to discern among alternative hypotheses of system functioning. The prime intent is to reduce uncertainty (i.e., learning) to optimize decisions over time through the AM process.

Although the AM planning process has not been completed for the Herring River project, based on anticipated uncertainties and the general project objectives, there are several areas for which it is clear that monitoring will be necessary to inform the decision making process prescribed in the AMP. Among these are:

- Water surface elevations
- Water column salinity
- Vegetation and wetland habitat states
- Sediment spatial distribution
- Marsh accretion

- Abundance and distribution of state-listed rare species and obligate habitat
- Water quality

The AMP will describe in detail the specific state variables for each category and the monitoring activities associated with each, as well as the relationship between state variables and project objectives and models. The Seashore has already collected data for all of these in the Herring River and several studies are on-going. Formal protocols developed by the NPS Inventory and Monitoring Program are either completed or in development and are used to guide study design, data collection, analysis, and other technical procedures. However, for the AMP, these protocols will need to be reviewed, and possibly modified, to ensure that the monitoring plan is designed efficiently for providing appropriate information within the spatial and temporal scales required by the AM decision making process. It is likely that additional parameters and metrics will be incorporated into the plan as the AM planning process proceeds.

Monitoring in the context of AM is distinct from standard, omnibus monitoring programs commonly used in research programs. In those situations data collection and analyses are performed solely for scientific curiosity and for detecting change along a trajectory from one condition to another. In contrast to a general monitoring program conducted without specific management models to evaluate, the monitoring plan for the Herring River AMP is intended to apply ‘learning’ specifically to reduce uncertainty about the system in order to inform management decisions and maximize project benefits. Because of this, variables commonly monitored in tidal restoration projects may not be included as part of the Herring River AMP. Examples may include changes to fish, macroinvertebrate, and bird populations and certain water quality indicators. This isn’t meant to imply that these elements are not important or that knowledge about them has no value, but that information obtained from such measures are unlikely to affect decisions to alter management policies for the system. This could be because there is relatively little uncertainty or risk about the variable, changes in the variable are not detectable in the spatial and/or temporal scale at which it can be monitored, or because no practicable alternate management actions are known which could stimulate a response. Some of these variables may be monitored outside of the AMP depending on the interests of particular investigators, agencies, funding programs, or other stakeholders, but for the Herring River restoration project as a whole they would be approached at a lower level of priority compared to the monitoring needs defined by the AMP.

ITERATIVE PHASE

Decision Making

The preceding steps described as part of the AM Set-up Phase will be conducted as the AMP is developed, beginning with the preparation and review of the DEIS, FEIS, and Record of Decision (ROD) and through final design, permitting, and outreach, leading up to actual implementation of the project. A central component of the AMP will be a strategy for how management decisions for the project are made and who will make them. As described previously, broad primary decisions will involve modifications to the tidal control structure(s) installed as part of the project and more narrow decisions about any number of secondary management actions in order to achieve the project objectives articulated in the AMP.

Although the details are currently not known, it is envisioned that several integrated groups will be established to oversee and manage the implementation of the Herring River project and the AMP (see Figure A-2, below). At the core of these groups would be an executive committee representing the superintendent of the Seashore and the Wellfleet and Truro Boards of Selectmen, the entities ultimately responsible for stewardship of the Herring River flood plain. A management committee, with a composition and purpose similar to the current HRRC, would be established by the executive committee to meet regularly to review and discuss day-to-day project details and make management recommendations to the towns and the Seashore. The management committee would also develop a science team to work closely with Seashore natural resource staff and other collaborators to be responsible for monitoring and data reporting. The management committee would review data provided by science team and incorporate it into the adaptive decision making framework. In addition, a stakeholder and outreach team would be formed to provide information to the public at regular intervals and proactively seek public input and involvement in the management process. A technical oversight committee, analogous to the current Technical Working Group established by MEPA (see draft EIS/EIR Chapter 5, Section 5.2.1), would also be established to meet on a regular basis (perhaps once or twice per year) to review monitoring reports and results of predictive models, management committee recommendations, and authorize proposed management actions requiring regulatory review according to guidelines set forth by individual permitting agencies (see draft EIS/EIR Chapter 5, Section 5.3).

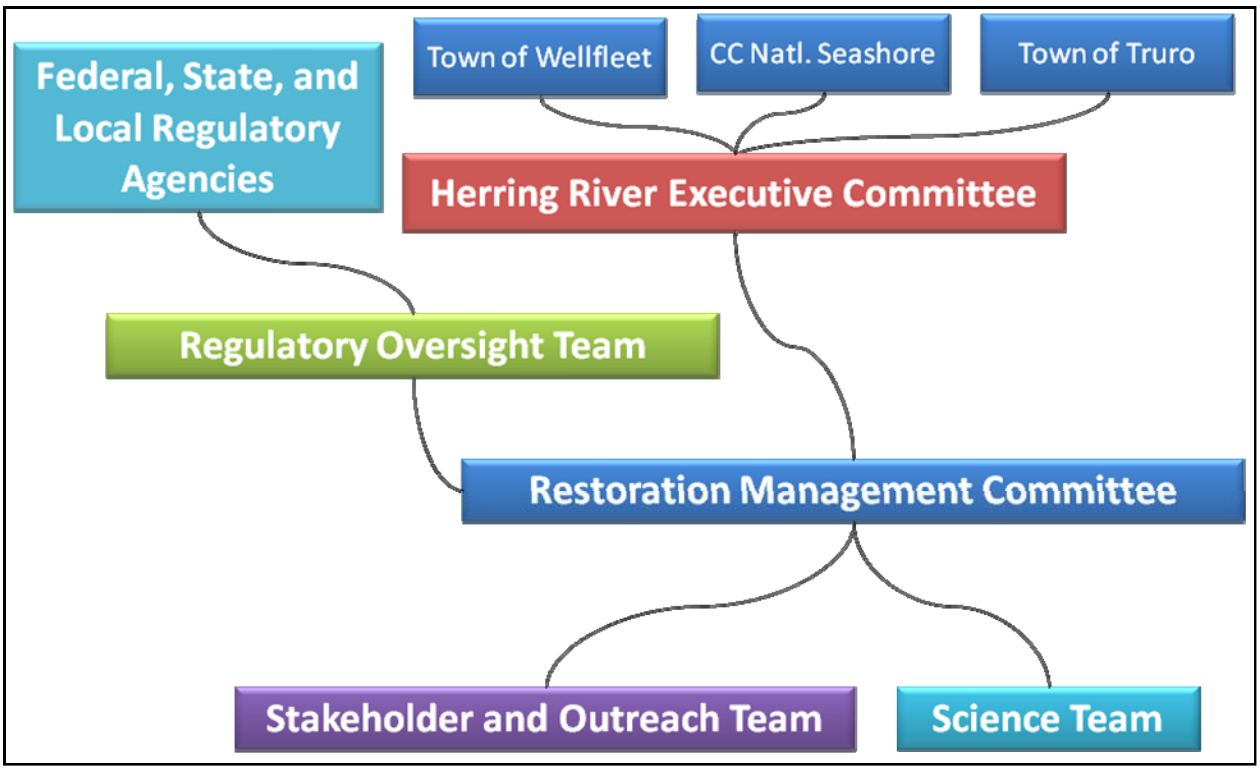

FIGURE A-2: POTENTIAL MANAGEMENT STRUCTURE FOR HERRING RIVER RESTORATION PROJECT AND ADAPTIVE MANAGEMENT PLAN IMPLEMENTATION

Monitoring and Assessment

Monitoring of the parameters needed to establish baseline conditions and to evaluate and optimize predictive models will begin as the AMP is completed and monitoring plan details are developed. The science team will oversee monitoring as the project is implemented and the AMP is carried out. At each decision point to alter tidal control gate openings or to implement any of the secondary management actions, the management committee will review monitoring data and reports and revisit the predictive models to assess system responses to previous decisions. New data will be integrated into the models to update the credibility in each proposed hypothesis, ensuring that subsequent decisions draw on empirical observations from the Herring River, and thereby increase our knowledge of the system and the confidence in our management at each decision point. Throughout this process, the management team will continue to receive feedback from stakeholders as the system changes, revisit the AMP objectives, and refine management actions, models, and the monitoring plan as new information becomes available.

HERRING RIVER ADAPTIVE MANAGEMENT CASE STUDY EXAMPLE

Although the full suite of objectives, models, and other elements of AM planning have not been fully developed to date for the Herring River project, it is possible to illustrate how the process is envisioned to unfold through a hypothetical case study. Discussions among various stakeholders to date have raised a specific concern about plant community dynamics in response to tidal restoration and changes in water column and porewater salinity. As discussed in detail in Section 4.5, salinity values in the lower sub-basins are expected to be high enough to stress the non-native invasive species *Phragmites australis* and to support the recovery of salt marsh vegetation. However, mid-level salinity values may persist over the long-term in some upper sub-basins, creating conditions where *Phragmites* could gain a competitive advantage over less salt-tolerant plants. Increased coverage of *Phragmites*, especially within sub-basins where it presently does not exist, would be considered an adverse impact and in conflict with the goals of the project to restore native tidal wetland habitats. Uncertainty in the current hydrodynamic models regarding predicted salinity levels following a tide-gate opening leads to lower confidence in any prediction as to which vegetation community type will eventually become established. Model uncertainty represents different hypotheses of how the system responds to actions; confidence in each hypothesis can be modified by comparing its predictions to actual outcomes via a monitoring program. Thus, for the AMP an objective statement needs to be developed which articulates project objectives to restore native tidal wetland vegetation. Uncertainty in the belief of how salinity and vegetation will respond to management can be represented by competing hypotheses which can be used to select the most probable outcome and then be tested by comparing observations to predictions. An example of an appropriate objective statement could be: “Restore native tidal wetland vegetation through natural recolonization in response to reintroduction of tidal exchange while minimizing establishment of non-native invasive plant species throughout the project area”. During development of the actual AMP, meetings and discussions will held with various groups to appropriately frame all stakeholders’ concerns in order to construct specific, measurable and achievable objective statements.

With the objectives adequately articulated, we can then develop applicable models for describing key drivers and dynamics of tidal marsh habitat transition as related to a policy of tide gate openings and other restoration actions. Models are intended to identify key relationships between the driving forces, the physical and chemical conditions likely to be affected by the project, and the biological communities of concern. For the Herring River project, the hydrodynamic model is a key tool for simulating and predicting tidal regimes, salinity levels, and other hydrologic-driven factors resulting from various culvert and tide gate configurations. Much of the information derived from the hydrodynamic model, combined with professional judgment and knowledge from experts in salt marsh ecology and tidal wetland vegetation communities can be applied to formulate a set of hypotheses and predictions about the conditions which could result in increased probability of *Phragmites* expansion. This synthesis of factors could be expressed in a number of formats, ranging from a relatively simple, narrative form conceptual model or influence diagram to a complex, dynamic computer simulation. Regardless of the format, the central point of the model, or models, is to represent two or more alternate hypotheses about the predicted consequences of implementing any particular action. For the Herring River vegetation colonization case study, example hypotheses could be:

- Hypothesis #1: Restoring mean high spring tides will result in salinity levels high enough to stress and kill *Phragmites* in the Middle Herring River sub-basin.
- Hypothesis #2: Restoring mean high spring tides will result in salinity levels which will cause *Phragmites* to expand its range in the Middle Herring River sub-basin.

These two competing hypotheses, and possibly others, would be translated into vegetation dynamics models that can be used as the basis for a management decision. Based on expert opinion, published literature, or prior experience, one model could be weighted in favor of the other to express a greater level of confidence. If there's no basis for a priori confidence in one or the other, they would both be weighted equally. The optimal decision at any point in time will be based on the outcome predicted under each hypothesis, weighted by their respective confidence levels. As management proceeds, the observed response of *Phragmites* in the sub-basin would be monitored, along with water surface and salinity levels. Given the observed data, the relative likelihood of each hypothesis will be used to update its confidence value. As more data are collected over time, the better performing model will be weighted more favorably and thus will contribute more to the selection of an optimal decision. Learning will increase our understanding and confidence about how *Phragmites* will respond to future management. These analyses and discussions will be part of the routine activities of the management committee, with input from the science and outreach teams. When proposed management actions involve issues pertaining to the regulatory agencies, similar reviews and discussions will be held with the oversight team before receiving permitting approval.

Just as the AMP will describe a strategy for a flexible and iterative approach to implementing the Herring River project, the plan and decision making process itself, will be similarly adaptive, flexible, and iterative. Although the overview describes an AM team framework in general, which will be addressed in more detail in the actual AMP, it is expected that, like the AM process, the management team structure will be modified and adapt to the needs of the project as the implementation and evaluation processes unfold.