RESTORE SCIENCE PROGRAM

Structured Decision Making to Co-Produce an Actionable Science Plan in Support of

Louisiana, Mississippi, Alabama Coastal System Water Quality Management

Application Plan

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LIST OF ACRONYMS

Acronym	Term
ADCNR	Alabama Department of Conservation and Natural Resources
DEM	Digital Elevation Model
GOMA	Gulf of Mexico Alliance
HAB	Harmful Algal Bloom
LCPRA	Louisiana Coastal Protection and Restoration Authority
LMACS	Louisiana, Mississippi, Alabama Coastal System
MAM	Monitoring and Adaptive Management
MDMR	Mississippi Department of Marine Resources
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PrOACT	Problem, Objectives, Alternatives, Consequences, Tradeoffs
RM	Resource Manager
SDM	Structured Decision Making
SME	Subject Matter Expert
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

The Mississippi Department of Marine Resources (MDMR), Louisiana Coastal Protection and Restoration Authority, Alabama Department of Conservation and Natural Resources, and other state and federal agencies along the northern Gulf of Mexico have a shared goal to sustain and improve regional water quality and estuarine/marine habitat within the Louisiana, Mississippi, Alabama Coastal System (LMACS). These entities must identify opportunities to advance this goal, then decide which opportunities to implement based on effectiveness while avoiding negative impacts to other regional objectives such as flood risk management. Despite having shared needs in the LMACS region, there are limited mechanisms for interagency collaboration. Implementation is further complicated because the LMACS environmental system spans multiple political boundaries. In addition, there is considerable uncertainty in how the LMACS will respond to actions that could potentially improve water quality. A co-production effort of resource managers (RMs) and researchers, supported by 2021 NOAA Restore Science Program funding and executed through a series of workshops, was conducted to address these challenges by 1) identifying critical uncertainties that limits effective water quality management in the LMACS; 2) devising a research plan (*Structured decision making (SDM) to co-produce an actionable science plan in support of Louisiana, Mississippi, Alabama Coastal System (LMACS) Water Quality Management: Research and Development Plan; hereafter, "Research Plan"*) for reducing those uncertainties; and 30 formulating an application plan (this document) that establishes a framework for interagency collaboration and supports research integration into management (Figure 1).

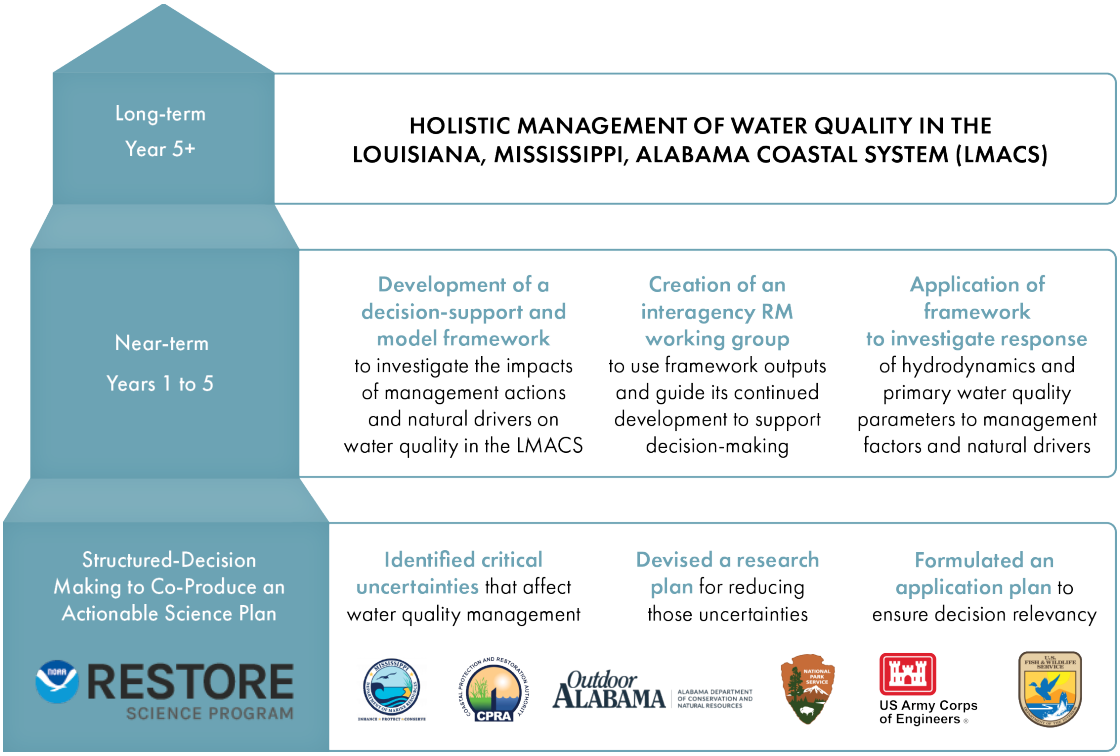

Figure 1. A collaborative, co-production approach that brought together resource managers and researchers (bottom tier) was used to develop research (this document) and application plans. The near-term objectives (middle tier) are designed to serve as the foundation for advancing a long-term goal of more holistic management of the LMACS (top tier).

The **natural resource management decision** that these plans support is selecting which restoration projects or other management actions for improving water quality and estuarine habitat are pursued for permitting in the LMACS. The associated question being asked is: *how can we advance a transboundary, project-oriented planning approach to maximize estuarine water quality and habitat suitability for associated species while also enhancing co-benefits including reducing the risk of Harmful Algal Blooms (HABs), maximizing the extent of coastal habitat, and reducing flood risk for coastal communities*?

Through the workshops, the RMs identified two needs: 1) developing a numerical model-based decision-support framework to investigate the impacts of potential management actions and natural drivers on water quality in the LMACS, and 2) creating an interagency RM working group to use framework outputs to support decision-making. There are numerous management decisions and associated uncertainties this framework could reduce. Therefore, this document and the *Research Plan* were designed to establish an RM working group (Figure 2) and decision-support framework that can address near-term research priorities, while also providing a foundation for cooperative LMACS management in the long-term (5+years). The near-term research focus is identifying the relative impact of factors that could be influenced through management action on the LMACS given natural variability and trends in environmental factors; more details are in the *Research Plan.*

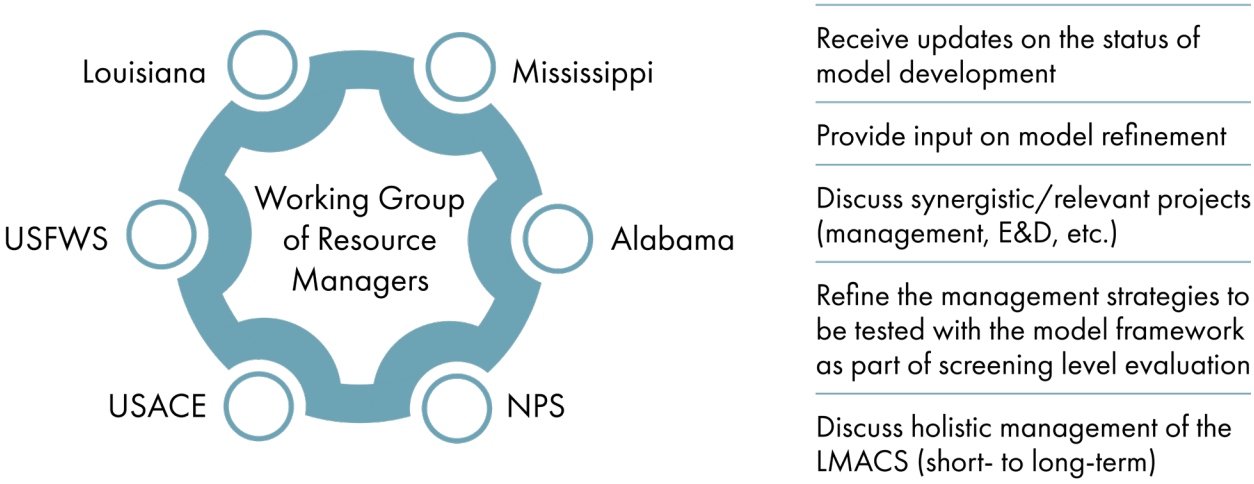

Figure 2. Louisiana, Mississippi, and Alabama Coastal System (LMACS) Interagency Resource Managers Working Group

This *Application Plan* outlines the engagement of the RM working group to guide the development and application of a decision-support and model framework for the region, as well as to identify specific management-relevant model scenarios to evaluate the impact of natural and anthropogenic factors on the LMACS. The near-term emphasis will be supporting MDMR in identifying projects to pursue in support of improving water quality and habitat suitability for species of economic importance, such as oysters. As the near-term phases of work conclude, the focus will shift to establishing the RM working group as a standing interagency collaboration for continued support of decision-making in the LMACS.

1. FINDINGS AND PRODUCTS

The Mississippi (MS) Department of Marine Resources (MDMR), Louisiana Coastal Protection and Restoration Authority (LCPRA), Alabama Department of Conservation and Natural Resources (ADCNR) and other management entities with authority in the Louisiana, Mississippi, Alabama Coastal System (LMACS; Figure 3) have a goal to sustain and improve water quality and habitat for estuarine/marine resources, which includes oysters as a keystone species. MDMR has had a strong focus on this topic in recent years. Ninety percent of Mississippi's historic oyster production has been from the western Mississippi Sound near the Louisiana border. This fishery has been in protracted decline for over a decade and has been closed for the past three years (Figure 4). Improving water quality in the LMACS to sustain a robust estuarine system, including one that can support a healthy oyster population, will require bold restoration and management action. Finite funds exist for this purpose; therefore, resource managers must decide what restoration actions to select for multilateral consideration, development, and permitting based on scientific evidence of local and/or regional benefits.

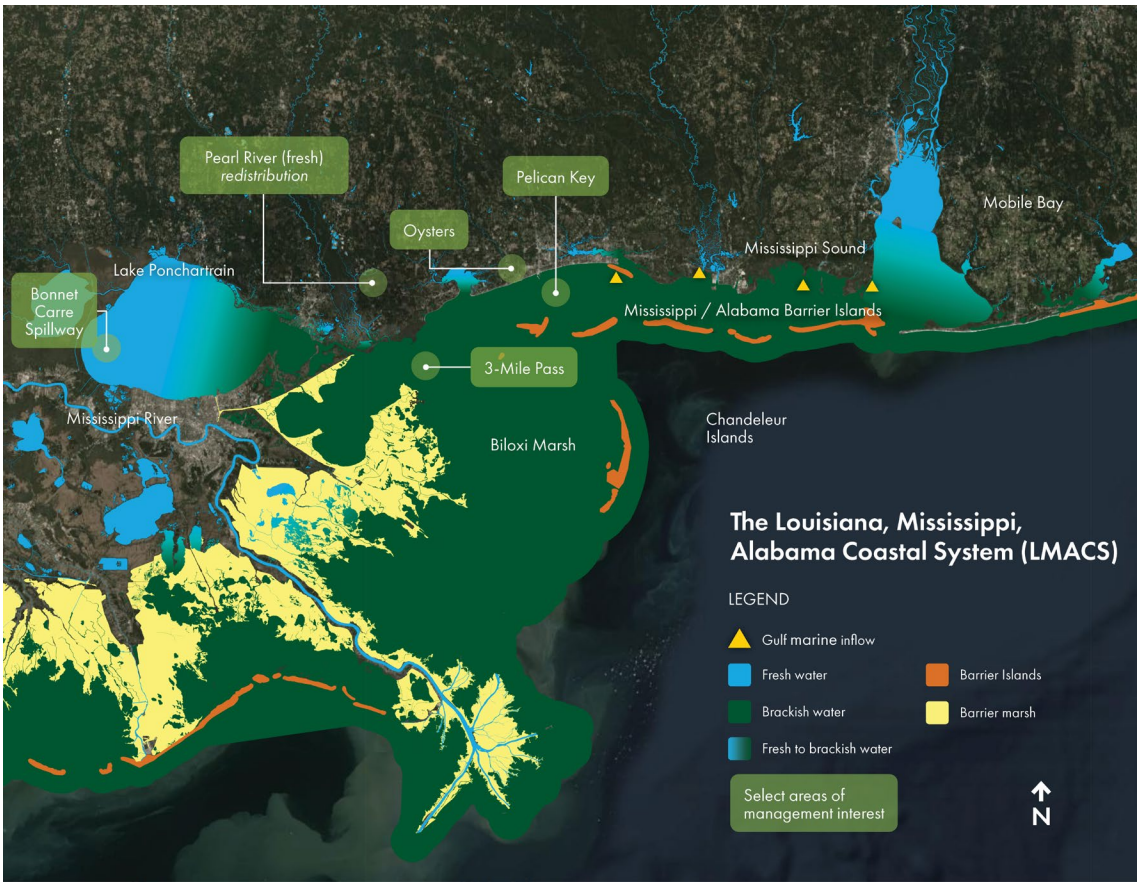

Figure 3. The Louisiana, Mississippi, Alabama Coastal System (LMACS) is a science planning domain defined by geomorphic and hydrodynamic boundaries that can be manipulated by traditional restoration practices such as rebuilding landforms.

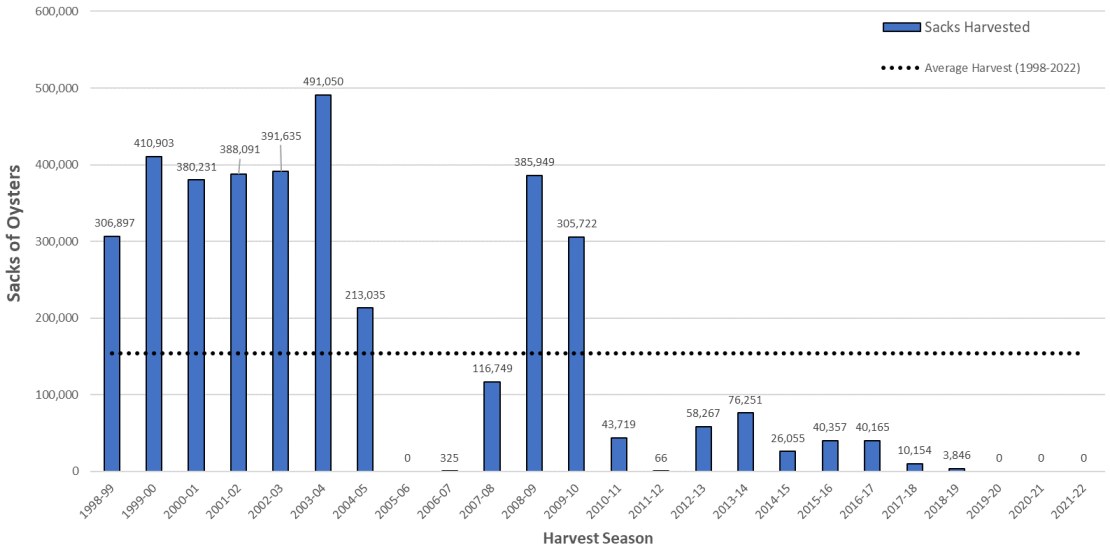

Figure 4. Time series of the Mississippi (MS) oyster harvest from public reefs between the harvest seasons (October through April) of 1998–1999 and 2021–2022. Provided by MDMR.

These decisions are hampered by the complexity of the environmental system as well as uncertainty in how it will respond to management actions such as changing the distribution and volume of freshwater inputs and altering exchange between the estuarine system and the Gulf of Mexico through the barrier island and marsh system. In addition, the management landscape of the LMACS is as complex as the natural environment, further complicating identifying and implementing projects to improve water quality in the region. For example, the proximity of the Mississippi Sound to the Louisiana border dictates that some priority restoration projects of value to the State of Mississippi may be within Louisiana waters. Federal agencies such as the U.S. Army Corps of Engineers (USACE) and U.S. Fish and Wildlife Service (USFWS) also play key roles in LMACS management through their regulatory oversight, while multiple barrier islands that regulate conditions in the estuary are under the purview of the National Park Service (NPS) as part of Gulf Islands National Seashore or, in the case of the Chandeleur Islands, USFWS as part of the Breton National Wildlife Refuge. Research and tools to support decisions made to enhance water quality in the LMACS and improve habitat for keystone species, such as oysters, are developed and applied within the context of this interagency decision-making context.

An additional complexity is that some management actions that could improve water quality, such as altering operation of the Bonne Carré Spillway to change freshwater input to the LMACS, might produce unacceptable effects for state and regional objectives like flood risk mitigation. Tools are therefore needed that can evaluate the tradeoffs associated with potential management actions and identify strategies that produce the maximum benefit to water quality as well as other regional objectives while minimizing negative ancillary effects. In some cases, potential management strategies that could benefit water quality and species viability within the LMACS may be unimplementable due to constraints (federal or individual state policies, regulations, etc.). In these cases, tools are needed for identifying the best possible outcome for water quality and species viability within the context of practically implementable alternatives.

For these reasons, representatives from three state agencies (MDMR, LCPRA, ADCNR) and three federal agencies (USACE, USFWS, and NPS) were brought together as part of a resource manager (RM) advisory group to inform what uncertainties were most critical to resolve—and what specific form research products should take—to provide the most decision-relevant information for improving water quality in the LMACS system. In addition, subject matter experts (SMEs) with expertise in water quality, geomorphology, hydrodynamics, and oysters helped identify uncertainties and research questions that they considered relevant to supporting management decisions. This information was elicited through a facilitated structured decision-making (SDM) process (Figure 5). SDM consists of a sequence of decision-making steps including articulating the Problem and Objectives, identifying Alternatives, evaluating the Consequences of those alternatives, and considering Tradeoffs (PrOACT) (Gregory et al., 2012).

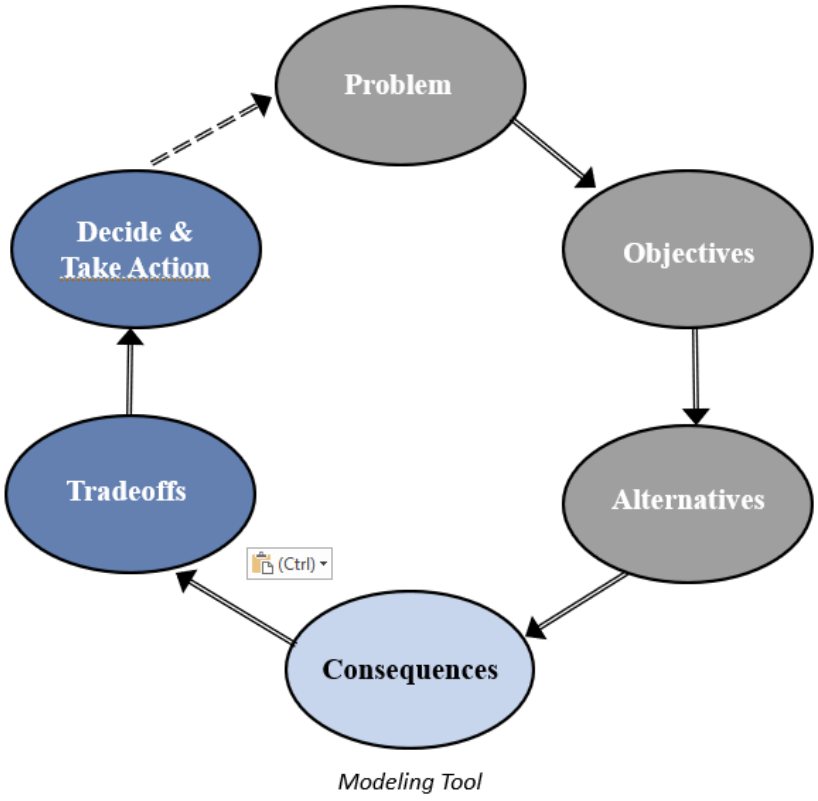

Figure 5. The PRoblem, Objectives, Alternatives, Consequences, and Tradeoffs & Optimization (PrOACT) cycle, with solid black arrows indicating initial application and dashed black arrow indicating adaptive management. Figure modified from https://www.usgs.gov/centers/eesc/science/structured-decision-making, J. Cochrane.

The natural resource management issues addressed with this plan were refined through a series of facilitated workshops with LMACS RMs and SMEs to complete the first three steps in PrOACT (gray ellipses in Figure 4): articulating the Problem (the water quality and estuarine species management issues for the LMACS), Objectives (desired outcomes for the region, including co-benefits for other interests), and Alternatives (potential management actions that could be taken to improve water quality and

estuarine habitat). The research questions and methodology, described in the *Structured Decision Making to Co-Produce an Actionable Science Plan in Support of Louisiana, Mississippi, Alabama Coastal System Water Quality Management: Research Plan* (hereafter, *Research Plan*), were developed based on uncertainties in predicting the potential Consequences of management alternatives (light blue ellipse in Figure 4). The remaining PrOACT steps are considering the tradeoffs associated with the predicted consequences and an MDMR-led, interagency supported decision on what management actions to pursue for planning and feasibility analysis (dark blue ellipses).

The **natural resource management decision** being made is selecting which restoration projects or other management actions for improving water quality and estuarine habitat to pursue for permitting in the LMACS. The associated question being asked is: *how can we advance a transboundary, project-oriented planning approach to maximize estuarine water quality and habitat suitability for associated species while also enhancing co-benefits including reducing the risk of Harmful Algal Blooms (HABs), maximizing the extent of coastal habitat, and reducing flood risk for coastal communities*?

Primary Management Question Articulated by State and Federal Resource Managers
What opportunities exist to manage freshwater, saltwater, sediment, and the coastal landscape so that water quality (salinity, biochemical stability, turbidity, dissolved oxygen, harmful algal blooms, etc.,) and habitat (estuarine, barrier island, and marsh) across the LMACS are improved while enhancing co-benefits and/or minimizing negative impacts to communities and commerce (e.g., flood risk reduction, cost of navigation channel maintenance)?

Over a dozen specific actions have been identified to date by the RM and SME groups as potential ways to improve water quality in the LMACS and increase the population of oysters within Mississippi Sound. The potential management actions were grouped in a set of five high-level alternatives that included:

1. Modification of freshwater input into the LMACS;
2. Preservation and restoration of barrier island and barrier marsh integrity;
3. Preservation and restoration of mainland marshes;
4. Direct restoration of oysters and historic reef structures;
5. Nutrient input management, and
6. Potential navigation channel realignment or modification.

The research questions and approach, as well as the design of a decision-support framework to facilitate incorporating that research into management application, were developed by beginning the "identifying Consequences" step in PrOACT. Using the potential management actions as a lens, the RMs and SMEs were asked to

1. Consider what the outcomes (i.e., consequences) of these alternatives would be;
2. Identify existing data, tools, and studies relevant to those predictions; and
3. Articulate what uncertainties most limited robustly predicting alternative outcomes.

Dozens of uncertainties that were identified in how water quality and oyster resources in the LMACS would respond to the potential alternatives, including unknowns in how climate change will impact precipitation and freshwater inflow from rivers; the influence of barrier island and barrier marsh erosion on water quality in Mississippi Sound; and the relative impact of freshwater inflows (rivers, diversions, spillways) on salinity and temperature in the LMACS.

It was apparent based on this breadth of input from the RMs and SMEs that a science-based decision support framework is needed to support holistic management of habitats and species within the LMACS. In addition, **a numerical model-based decision support framework that can analyze the effects of portfolios of projects on a wide range of environmental factors across the LMACS would be of considerable value in supporting LMACS management**. Lastly, the workshop input reinforced that interagency coordination is necessary to ensure that research is decision-relevant and is feasible and actionable, meaning that it can be successfully transitioned through the permitting process and into application. Addressing these needs will require sustained, long-term coordination of Federal and state agencies, as well as resolving the full breadth of uncertainties in how the LMACS and associated species such as oysters will respond to potential management actions.

For that reason, this document and the associated *Research Plan* consider several time scales of implementation. The long-term (5+ years) vision is catalyzing a new paradigm in management of the LMACS under which multiple states and federal agencies collaborate to identify and implement management actions that improve water quality; increase habitat for marine, estuarine, and terrestrial species; reduce the risk of HABs; and enhance the resiliency of coastal communities in this region. This vision would be supported by the development and utilization of a numerical model-based decision support framework to address a wide range of uncertainties about the LMACS region. In addition, an interagency RM working group will be created that will use that framework to determine if management actions that provide holistic benefits to the region can be identified. In the long term, this group can use the decision support and model framework to address the full breadth of management questions and related uncertainties identified during the workshops, with the focus evolving based on agency priorities and increased understanding of the LMACS system.

The long-term vision and associated activities are referenced throughout this document and the *Research Plan.* However, the primary focus within these documents is on the near-term (1–5 year) priority of establishing a foundation for that long-term vision. This includes the creation of the interagency RM working group that builds off the RMs engaged in the planning workshops; developing a decision support and model framework that can address priority, management-relevant uncertainties about the LMACS in the next 5 years, while also having the flexibility to be readily extended to address future research questions and management needs; and the application of that framework to address priority areas of uncertainty identified for the LMACS.

The areas of uncertainty that will be addressed through planned research in the near-term are how *hydrodynamics, salinity*, and *temperature* in Mississippi Sound respond to "actionable factors" (i.e., aspects of the system that can potentially be varied through management intervention) including barrier island and barrier marsh integrity, modification of freshwater inflows, restoration of historic reef profiles and changes in the location and alignment of navigation channels. This initial focus was chosen because hydrodynamic conditions within the LMACS are a primary control on the system that influences all

factors relevant to habitat suitability (e.g., turbidity, dissolved oxygen, nutrient load, etc.). Specifically, salinity and temperature are primary water quality variables that must be within tolerable ranges for oyster populations to recover and be sustained. The planned research will result in:

- **Inventory of data collected, models developed, and ongoing and completed studies** relevant to historical, geomorphology, water quality and oyster viability in the LMACS, and/or to the development of numerical model framework for predicting the response of hydrodynamics, salinity, and temperature in the region to changes in natural drivers (relative sea level rise, quiescent and storm conditions, etc.) and management actional factors (barrier island/marsh integrity, freshwater inflows, and alignment of the navigation channel);
- **A calibrated and validated 2D Delft3D-FM hydrodynamic model** with spatial domain encompassing Mississippi Sound and associated barrier islands and extending from Breton and Chandeleur Sounds east to Mobile Bay (note: the selection of hydrodynamic model was based evaluation of factors necessary to support management needs; see Table 1 in the *Research Plan*);
- **Model simulation results** evaluating the response of LMACS hydrodynamics, salinity, and temperature to varying natural drivers and actionable factors;
- **Calculated metrics** comparing the relative influence of natural drivers and actional factors on water quality in the LMACS; and
- **Updated research and application plans** describing the next set of priority uncertainties that will be addressed with the numerical model framework, the enhancements needed to address those uncertainties, and incorporation of results into LMACS management.

Three categories of end-users have interest in these findings: (1) RMs making decisions on management actions to pursue to improve water quality in the LMACS and/or interconnected objectives such as increasing habitat for target species or enhancing the resilience of coastal communities; (2) researchers with interest in the evolution of the LMACS environmental system; and (3) stakeholders and the general public who have interest in the ecosystem health and/or services provided by the LMACS. The primary RM (decision-maker) during the initial phases of this effort MDMR. Due to the interconnected nature of the LMACS environmental system and the regulatory landscape under which projects are executed, however, successful implementation of projects will require interagency consensus and support.

Products that will be developed during the effort are targeted toward effectively engaging those groups, in the case of RMs as the primary intended end-users of this work, and communicating the results, in the case of researchers and other stakeholders as the secondary end-users. These products will include:

- A **technical report** summarizing the research. This report will summarize the effort in its entirety as an end-to-end summary of methods and conclusions, in addition to documenting restoration projects identified and management decisions made by the RMs as a result.
- A public, freely accessible **online repository** (such as a USGS Open File Report or Data Series) containing all inputs necessary to run the numerical model developed in Phase 3, including new

simulations as desired by a user, as well as the outputs for specific simulations that are developed in Phases 4–5.

- One or more **academic journal articles** summarizing the knowledge gained on the response of the LMACS to natural drivers and actionable factors, along with **annual presentations at academic conferences on progress and results**. The journal articles and academic conference presentations will be used to disseminate the knowledge gained to the research community. In addition to advancing understanding of the LMACS, the techniques used may be applicable to other regions.

- Annual presentations at **practitioner conferences and meetings** such as the Gulf of Mexico Alliance (GOMA) annual All Hands and/or future iterations of the Gulf of Mexico Conference, and a practitioner **webinar and Question & Answer session** at the completion of the initial phases of the effort (Phases 1–7; see *Description of Activities*). These venues will allow the results to be disseminated to a broad range of RMs, and engagement of this community may result in additional representatives being added to the RM working group.

- **Online story map** for public consumption of results. The RMs engaged during the development of this plan identified that a key potential impediment to execution of some management actions may be the public not understanding the expected results. The effort will therefore include the development of a visually rich, plain-language story map, developed in conjunction with input from social scientists and members of the public.

A key mechanism of dissemination will be through an RM working group that will be actively involved in the effort as described in *3. Description of Activities.* Additional detail on the process through the planned methods for reducing uncertainties may be found in the *Research Plan.*

2. GOALS AND OBJECTIVES

The overarching, long-term goal of this effort is catalyzing a new paradigm in management of the LMACS under which state and Federal agencies collaborate on the identification and implementation of portfolios of restoration projects and management actions that improve water quality; increase habitat for marine, estuarine, and terrestrial species; reduce the risk of harmful algal blooms; and enhance the resiliency of coastal communities in this region. Although ambitious, input from multiple RM agencies received during the development of these plans indicates that the concrete steps outlined within this application plan can be taken to move toward this ideal.

Management application objectives identified based on the input received from RMs include:

- Establishment of an interagency RM working group that can support holistic management of the LMACS;
- Development and application of a science-based decision support framework that can directly incorporate management-relevant research into a decision-making process;
- Development and dissemination of metrics that capture the response of the LMACS to natural drivers (relative sea level rise, quiescent and storm conditions, etc.) and actionable factors (barrier island and barrier marsh integrity, freshwater inflows, navigation channel alignment, etc.), and that are synergistic with goals and objectives associated with current restoration activities in the northern Gulf of Mexico; and
- Identification of an initial portfolio of management actions to pursue for project-level planning based on the research conducted under this effort.

These objectives are also designed to support a science-driven process for holistic management of the LMACS that is durable and sustainable. The RM working group is intended as a mechanism for continued interagency coordination to prioritize portfolios of management actions that benefit multiple objectives for the region. In addition, the decision support and modeling framework developed and implemented in the initial phases of this effort can continue to provide support to that RM working group as described in *7. Mechanism for Updating the Plan*.

3. DESCRIPTION OF ACTIVITIES

An RM working group comprised of federal and state agency representatives as described below will be established and meet regularly with a core team of researchers and RMs conducting the technical tool development and analyses throughout this process (see *5. Resource Managers, Researchers, and Other Stakeholders* for the members of the core team and the RM working group). During these working sessions, progress and results of the research will be provided by the core team; the research and application plans will be reviewed and revised as needed; targeted input will be elicited through facilitated discussion (described below); and the composition of the RM working group will be updated to determine if new members should be added based on the results of each phase. In addition, RMs and the core team will have the opportunity to identify additional subject matter experts (SMEs) to engage based on their relevant expertise.

The research associated with this effort, described in more detail in the *Research Plan,* will be conducted in seven phases (Figure 5). Each phase has associated application activities, given below, to facilitate the incorporation of outcomes into management practice.

Phase 1. Review of available background literature. An inventory will be developed of data, journal articles, gray literature, and completed and ongoing studies that include historical information on natural drivers, water quality, abundance of oysters, and response of the LMACS and/or oysters to perturbations in natural drivers or anthropogenic influences. The desired outcomes from engagement of the RM working group include disseminating the inventory of data, models, and studies, so that the RMs can use that information where relevant to their decision-making; and eliciting their input on additional sources of information to add to the inventory, given that many of the engaged RMs have supported or been engaged on research projects throughout the northern Gulf of Mexico.

RM engagement during this Phase will include two working sessions:

- **An in-person working session at the beginning of Phase 1**, during which the RM and core team will review the overarching research and application plans for awareness and revision. In addition, additional RMs and SMEs they identify will be elicited for their input on data sources, numerical models, and completed or ongoing studies relevant to the project. A preliminary inventory developed by the core team in Phase 1 will serve as the initial basis for discussion and will be expanded during the meeting.
- **A virtual working session at the end of Phase 1,** during which the completed background literature review will be presented so that the RM working group is made aware of any information the team has discovered that is relevant to their agencies and broader LMACS programmatic goals.

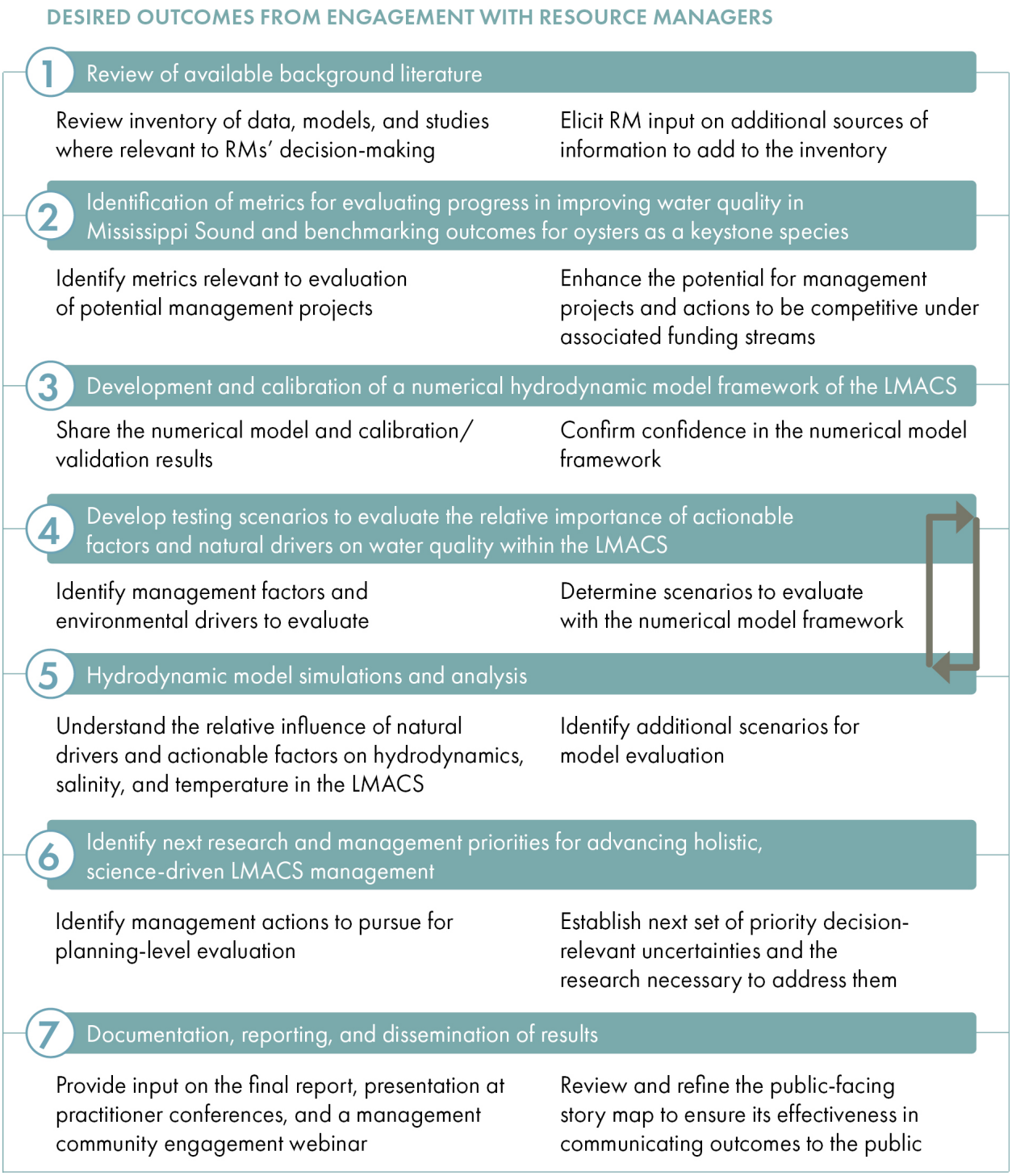

Figure 6. Engagement of the RM working group through the seven phases of research associated with a near-term (5 year) effort to support science-based management of water quality in the LMACS.

Phase 2. Identification of metrics methods for evaluating progress in improving water quality in Mississippi Sound and benchmarking outcomes for oysters as a keystone species. The metrics will include values that can be directly calculated by the numerical model output, such as daily, seasonal, or annual means, maxima, and ranges of salinity and temperature. The desired outcome from engagement of the RM working group is ensuring these metrics are relevant to their evaluation of potential management projects. The core team will begin by reviewing guidance from Monitoring and Adaptive Management (MAM) plans that have been developed for the northern Gulf, including those associated with the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies Council; National Fish and Wildlife Foundation Gulf Environmental Benefit Fund; and Natural Resource Damage Assessment. In many cases, these plans have identified specific metrics, goals, and/or objectives. Alignment with these plans and their associated objectives enhances the potential for management projects and actions that are prioritized based on the results of this analysis to be competitive under associated funding streams. In addition, the work conducted under the LMACs project can be leveraged to advance the goals and objectives of the MAM plans.

After a preliminary set of metrics has been developed, the RMs will be engaged through **a virtual working session at the end of Phase 2**, during which the identified metrics and calculated methods will be reviewed and refined based on input from RMs and SME participants they identify.

Phase 3. Development and calibration of a hydrodynamic model framework of the LMACS. During this phase, a Delft3D-Flexible Mesh model will be developed and calibrated for the region, including Quality Assessment and Quality Control against observational measurements. The desired outcome from engagement of the RM working group is confirmed confidence in the numerical model framework. The team will develop, calibrate, and validate the model prior to meeting with the RMs and will develop a presentation reviewing the model, with a particular emphasis on the validation results.

These results will then be presented to the RMs through **a virtual working session at the end of Phase 3** wherein the core team will present the model. A facilitated discussion will take place during which the RM group, and any SMEs they identify to participate, provide input in their level of confidence in the model and/or provide suggestions on additional calibration/validation or refinement that would increase their confidence.

Phase 4. Identify testing scenarios to evaluate the relative importance of actionable factors and natural drivers on influencing water quality within the LMACS. These scenarios will include future without action simulations that capture the mean, range, and variation in annual and seasonal hydrodynamics, salinity, and temperature under a range of realistic quiescent and storm conditions, as well as freshwater and groundwater inflows and potential future changes in sea level, storminess, and precipitation. The core team will develop a preliminary list of potential scenarios (i.e., the range and variability in natural drivers and actional factors) based on input received during development of this plan as well as through the Phase 1 background literature review. This list will then be presented to the RMs to make the final decision on the scenarios that will be evaluated with the numerical model framework.

Once a preliminary inventory is complete, the RMs will be engaged through **an in-person working session mid-way through Phase 4** to review, refine, and expand the preliminary list of scenarios through a facilitated discussion.

During the development phase of this application plan, RMs indicated there was considerable value in this Phase being conducted iteratively with an initial round of scenarios identified and simulated (in which each of the actionable factors was independently varied across the range of natural variability and trends) and the results used to identify additional scenarios for testing. After an initial round of Phases 4 and 5 are completed, there will be one or more additional iterations consisting of **virtual working sessions in Phase 4** to review the results from the prior round(s) of simulations and identify new testing scenarios that utilize the results to further evaluate the individual and combined influence of natural drivers and actionable factors.

Phase 5. Hydrodynamic model simulations and analysis. The hydrodynamic model developed in Phase 3 will be used to simulate the set of scenarios identified in Phase 4 to produce outputs including maps of mean, range, and variability in salinity, temperature, water levels, and currents in the LMACS. In addition, the metrics developed in Phase 2 will be used to benchmark the relative influence of natural drivers and actionable factors on the response of the LMACS, supporting the MDMR-led, interagency-supported identification of management actions to pursue for permitting. The core team will produce outputs for RM review including maps of mean, range, and variability in salinity, temperature, water levels, and currents in the LMACS. In addition, the metrics developed in Phase 2 will be used to benchmark the relative influence of natural drivers and actionable factors on the response of the LMACS.

These results will be presented during **a virtual working session(s) mid-way through Phase 5.** During the first Phase 5 session, the core team will present the results of the initial set of scenarios in which natural drivers and actionable factors are individually varied to benchmark their relative influence on hydrodynamics, salinity, and temperature in Mississippi Sound. Through discussion facilitated by the core team, the RMs will evaluate what actionable factors and natural drivers should be co-varied in subsequent rounds of simulations, and which information appears sufficiently definitive to further pursue into feasibility, engineering & design, and/or permitting activities outside of the core team–RM interactions. **Additional virtual and/or in-person working sessions in Phase 5** will continue to refine and adapt the modeled scenarios based on needs identified by the RMs.

Phase 6. Identify next research and management priorities for advancing holistic, science-driven LMACS management. During the workshops used to develop this Application Plan, RMs indicated there was considerable value in interagency collaboration and coordination on management of the LMACS. In the 5 years of initial implementation, the focus is an MDMR-led effort to identify projects to pursue for further planning and permitting that can restore the hydrodynamic, salinity, and temperature regime within the LMACS to support keystone species such as oysters. In the long term (5+ years), the interagency RM working group—supported by an adaptable decision-support and model framework—can then consider a wider range of issues and holistic solutions for the region.

This Phase advances that vision by working with RM group to define the next set of priorities for application of the decision support and model framework developed and applied in Phases 1–5. This includes identifying what RM alternatives to pursue for evaluation (additional scenarios, specific project designs, etc.); establishing the uncertainties associated with those uncertainties; and identifying if and what model or research advancements needed to address those uncertainties. Phase 6 therefore transitions the effort from the near-term focus on decision-support and model framework development and application to analyze primary water quality variables of hydrodynamics, salinity, and temperature to a

sustainable, long-term effort in which researchers and RMs iterate through Phases 4–7 to support holistic, science-based management of the LMACS.

The desired outcomes from engagement of the RM working group are to: (1) identify which management actions to pursue in the near-term for planning-level evaluation based on the results of Phases 1–5; (2) establish the next set of priority uncertainties and the associated advances to the model framework and/or research necessary to address them; and (3) to refine the interagency RM working group structure as needed for long-term sustainability and success. These outcomes will be achieved through:

- Identification of potential management actions to pursue for planning and permitting;
- Selection of the next set of management alternatives and associated uncertainties to evaluate and address with the decision-support framework and model; and
- Refinements to the structure of the RM working group for continued sustainability and effectiveness in interagency coordination.

Phase 6 working sessions will be conducted to facilitate interagency collaboration and discussions of management implications and actions that can be taken based on the results of Phases 1–5. Recurring workshops will be conducted to focus on each of the target topics.

Phase 7. Documentation, reporting, and dissemination of results. The outputs described in *1. Findings and Products* will be developed during this phase, which will occur concurrently with Phases 1–6. The desired outcome from engagement of the RM working group is ensuring the outputs targeted toward managers – including the final report, presentation at practitioner conferences, and a management community engagement webinar – are effective in communicating the results to the target audience. Reports, presentations, and journal articles will be drafted by members of the core team, then provided to the RM working group for review and input before finalizing (see *6. Resource Managers, Researchers, and Other Stakeholders*).

An additional product that will be developed under this phase is a visually rich, public-facing story map that includes plain language summaries of results for stakeholders and the public. This element to the effort is particularly important given that RMs have indicated public acceptance was a significant factor that could greatly enhance—or impede—the implementation likelihood of potential management actions with regionwide impact in the LMACS, particularly actions to benefit one state that require implementation in another. A social scientist will be engaged during the story map development process, and input on the design and presentation of results will be elicited from the RM working group and other LMACS stakeholders. In addition, a draft story map will be beta tested through:

- **A virtual working session mid-way through Phase 7 with the RM working group** to review the draft story map and provide suggestions on content and presentation; and
- **Targeted virtual sessions with a select group of stakeholders** to elicit their input on draft story map design and its effectiveness in communicating information relevant to their interests.

The initial story map and other products will be disseminated to RMs, stakeholders, and the public through:

- **A webinar and Q&A at the end of Phase 7** to roll-out the story map and other products of Phases 1–6; and
- **Informal presentations** to stakeholders to demonstrate present results and strengthen interagency and regional support for holistic management of the LMACS.

In the long term, the story map, presentations, and publications associated with this effort will continue to be expanded and disseminated as new management priorities and associated uncertainties are identified and addressed through application of the decision-support and model framework and collaboration of the interagency RM working group.

4. SCHEDULE

The primary decision-maker utilizing the results of this effort in the near-term is MDMR, who will use the outcomes as they become available to identify projects and management actions to pursue for planning-scale evaluation and permitting. MDMR is responsible for prioritizing conservation and restoration activities that support improved water quality, oyster habitat and fisheries resources in Mississippi (MS) waters. MS is currently identifying and implementing projects to protect its primary estuary and advance the goals set in a 2015 Governor's Oyster Council Report. Projects may include: realignment or reapportionment of the Pearl River and/or informing policy for the Bonnet Carré Spillway (BCS) operations; local ecosystem restoration such as Three Mile Pass in Biloxi Marsh, LA; and regional ecosystem management, such as barrier island chain restoration. Projects that maximize improvement of WQ or other key parameters will move forward to permitting. The approximate management timeline and next steps of project selection and permitting for this portfolio include:

1. Assessment of the local and regional benefits and impacts of restoration/conservation alternatives (2022+).
2. Resolution of critical uncertainties limiting restoration/conservation project prioritization (2022–2024+).
3. Project prioritization and permitting (2022–2027+). The final phase will be identifying a prioritized portfolio of restoration, management or conservation alternatives that MDMR (in coordination with Alabama and Louisiana) moves into the regulatory approval and permitting process working closely with state regulatory entities and regional federal partners.

The near-term phases (Figure 7) of the effort described here and in the *Research Plan* are designed to support MDMR through this process by resolving critical uncertainties that are inhibiting prioritization of projects that can effectively improve water quality in Mississippi Sound. In addition, the decision-support and model framework is deliberately designed to be readily transitioned to support additional needs; for example, the spatial resolution of the flexible mesh hydrodynamic model (see the *Research Plan*) can be increased to allow modeling of the impacts of specific restoration/conservation projects as they are identified.

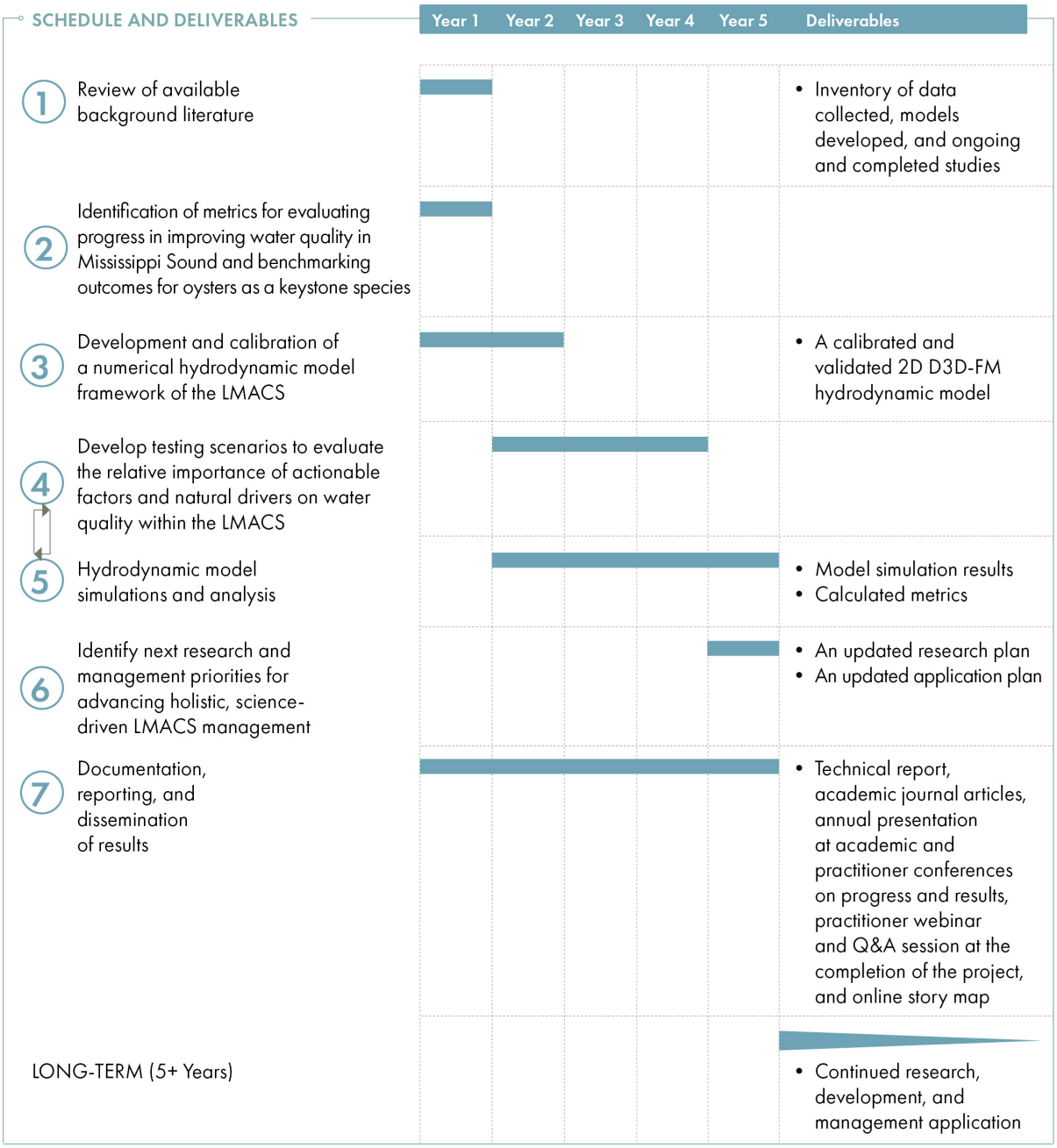

Figure 7. Schedule for developing and implementing a decision support and model framework for reducing uncertainties relevant to improving water quality and habitat in the LMACS ; year 1 in the schedule is planned for 2023. Phases 1–7 were primarily designed to support MDMR in identifying priority restoration/conservation projects for improving water quality, while also setting the foundation for increased interagency coordination and collaboration.

The near-term Phase 1–7 activities are intended to provide a foundation for collaborative, interagency, science-based management and for the products and outcomes of this work to lead to continued research, development, and management application across multiple state and federal entities. The PrOACT planning cycle (Figure 5), in conjunction with the establishment of an RM working group that will utilize

the results, provides the mechanism for continuing to update and extend this document and the associated *Research Plan* to address management needs in the long-term (5+years).

5. RESOURCE MANAGERS, RESEARCHERS, AND OTHER STAKEHOLDERS

Individuals for an RM working group were identified based on input received during development of this research plan regarding which agencies and entities needed direct representation, with the understanding that all representatives on the list would also reach out within their agencies as needed. The role of the RM working group will be to provide input at select points in each of the project Phases as outlined in *3. Description of Activities*. Input will be solicited from the RMs throughout Phases 1–6 on any additional representatives that should be added to the RM group as the project progresses. The working group will build off the RMs engaged during plan development, including:

- Jared Harris and Rhonda Price, MDMR
- Jim Pahl, LCPRA
- Will Underwood, ADCNR
- Justin McDonald, USACE Mobile District
- Jon Hemming, USFWS
- Jonathan Kleinman, USFWS
- Bruce Leutscher, NPS

Other management agencies with interests in the LMACS will be provided the opportunity to add representatives to the RM working group, including (but not limited to):

- Alabama Geological Survey,
- Alabama Marine Resources Division,
- Louisiana Department of Wildlife and Fisheries,
- Mississippi Department of Environmental Quality,
- USACE New Orleans District, and
- USACE Mississippi Valley Division.

The core team of researchers and a subset of the RM working group that will be fully integrated within the continued co-development process described in Phases 1–7:

- Mr. Jared Harris and Ms. Rhonda Price (MDMR) will provide guidance to ensure the research and outcomes are relevant to MDMR management of water quality and species in the LMACS, including decisions on projects or management actions to pursue based on the project outcomes. In addition, Mr. Harris will serve as the overall project lead.

- Dr. James Pahl (LCPRA) will represent the interests of Louisiana in management of the LMACS, including providing input on the tradeoffs of potential management actions to improve water quality with other priorities for the state.
- Dr. Soupy Dalyander (The Water Institute of the Gulf) will lead implementation of the SDM framework (e.g., facilitation of working sessions with the RM working group to identify scenarios) and development of metrics for characterizing LMACS system response.
- Dr. Mike Miner (The Water Institute of the Gulf) will provide expertise on the response of the LMACS to natural drivers and actionable factors and support development of metrics for characterizing LMACS system response.
- Dr. Ioannis Georgiou (The Water Institute of the Gulf) will provide input on the development of the hydrodynamic model in the western portion of the LMACS.
- Dr. Scott Hemmerling (The Water Institute of the Gulf) will provide guidance and input on the development of a story map for disseminating results to stakeholders and the public.
- Dr. Davina Passeri (U.S. Geological Survey) will develop, calibrate, validate, and implement the Delft 3D-Flexible Mesh numerical hydrodynamic model and support the identification and calculation of outcome metrics. In addition, USGS will host and support development of the story map.
- Dr. Anna Linhoss (Auburn University) will lead the background literature review on the LMACS, provide input in the development of the hydrodynamic model, and support characterizing water quality and oyster response.
- Dr. Paul Mickle (Northern Gulf Institute) will serve as a liaison to the Mississippi research community, particularly those researchers engaged in water quality and oyster research through Mississippi Based RESTORE Act Center of Excellence.
    - Mr. George Ramseur (Moffatt & Nichol) will provide continuity in concept origination, development and management context between the planning and implementation phases of this project.

Note, all core team members will be involved throughout the project.

Researchers with expertise relevant to water quality and species management will be identified during Phases 1–6 by the RM working group or the core team researchers and engaged as SMEs to provide input and expertise. This SME group will provide input through targeted participation in working sessions with the RM working group. The RMs will be given an opportunity to identify SMEs with whom they have trusted relationships and/or whose input they would like to have; for example, Alabama DNR suggested that a representative from the AGS participate. An initial set of SMEs will be identified after the completion of the background literature review, which will be used to identify expertise relevant to the effort that is not represented on the core team.

Other stakeholders with interest in water quality and oyster viability in the LMACS include local, state, and Federal governance entities (e.g., state governors); recreational and commercial fishermen; boaters

and other non-consumptive recreational users; coastal communities; tourists; and the public. These entities will primarily be engaged through the development and dissemination of the plain-language summaries and story map described in *1. Findings and Products*. However, the core team will review the potential value of direct engagement throughout the project and incorporate feedback from additional stakeholders if and where valuable.

6. BUDGET AND POTENTIAL FUNDING

Due to the nature of the proposed effort, which continues to strongly integrate RM input into the implementation of research to resolve critical uncertainties and research into the decision-making process being established for the LMACS, the Budget is the same as in the associated section of the Research Plan.

The estimated costs associated with the near-term phases of this project are:

- Phase 1. Review of available background literature: **$100,000**
- Phase 2. Identification of metrics and calculation methods for evaluating progress in improving water quality in Mississippi Sound and benchmarking outcomes for oysters as a keystone species: **$200,000**
- Phase 3. Development and calibration of a numerical hydrodynamic model framework of the LMACS: **$400,000**
- Phase 4. Develop testing scenarios to evaluate relative importance of actionable factors and natural drivers on water quality (identified in Phase 2) within the LMACS: **$200,000**
- Phase 5. Hydrodynamic model simulations and analysis: **$200,000**
- Phase 6. Identify next research and management priorities for advancing holistic, science-driven LMACS management: **$75,000**
- Phase 7. Documentation, reporting, and dissemination of results: **$75,000**

Potential sources of funding for this work generally need to be viable for simultaneous application across multiple states and could include:

- **NOAA Restore Science Program.** A Federal Funding Opportunity (FFO) for collaborative, actionable science research projects representing implementation of at least part of the actions outlined in this Research Plan and its attendant Application Plan is currently open, with an estimated $15 million available to support approximately 10 projects. The core team outlined in Section 6 is preparing proposal information pursuant to that FFO.
- **Gulf of Mexico Alliance (GOMA).** Pursing the development of an LMACS decision-support capacity is currently included in the Tier 2 Work Plan of the GOMA Integrated Planning Cross-team Initiative. GOMA activities are funded through a combination of private sector donations through the Gulf Star Public-Private Partnership, and competitive federal awards. Recently, GOMA was eligible for Infrastructure, Investment and Jobs Act funds in support of the nation's Regional Ocean Partnerships. GOMA is currently preparing its application for those funds, and will then develop guidance to the individual priority issue teams for pursuit of those funds. Mr. Harris, Ms. Price, and Dr. Pahl will lead consideration of an LMACS project submission through GOMA once that guidance is released.

- **NOAA – Bonnet Carré 2019 Fisheries Disaster Recovery Program**. The U.S. Department of Commerce is providing disaster-relief funding to mitigate the negative impacts of 2019 openings of the Bonnet Carré Spillway. Although not yet confirmed, this funding may include support for restoration of oysters in Mississippi.

In addition to the priority activities identified for the near-term project, several other areas of research were identified through the collaborative workshops used in developing the *Research Plan* associated with this effort. The schedule for these activities is in the 5+ year time frame based on the budget and timeline that has been developed for project. However, additional funding from the sources identified above could be leveraged to advance these activities on a faster timeline.

7. MECHANISM FOR UPDATING THE PLAN

The decision-support framework that forms the basis of development of this application plan provides an effective structure for continued updating this document. The input to be elicited from the RM working group, working session format, and timing of working sessions will be reviewed by the core team throughout Phases 1–5 based on the effectiveness of engagement strategies. For example, the RM working sessions are currently envisioned as a mix of in-person (to facilitate collaboration and cooperation) and virtual (to facilitate broader participation) meetings.

The first steps of the PrOACT cycle (Figure 5) will be revisited in Phase 6 of the effort, using the results of Phases 1–5 to prioritize the next set of management alternatives and associated uncertainties to evaluate. This process will be done through an in-person meeting with the RM working group as described *3. Description of Activities* and will be used by the core team to update this application plan and the associated *Research Plan*.

In the longer term, the interagency RM working group provides a durable mechanism through which the decision-support and model framework, and research and application plans will be updated and enhanced as needed by the RMs to address priority needs for holistic management of the LMACS. Because SDM is an established methodology widely used throughout the USFWS and USGS, there is flexibility on the agency or individuals that can facilitate the process. The interagency RM working group, and the tools developed in this initial project to support them, can therefore provide the basis for continually improving holistic management of the LMACS for years to come.

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