Currituck Sound
North Carolina

Integrated Feasibility Report and Environmental Impact Statement for the Currituck Sound Restoration Project, Currituck, North Carolina

PEER REVIEW PLAN

US Army Corps of Engineers
Wilmington District

ACRONYMS & ABBREVIATIONS

AFB – Alternative Formulation Briefing

CESAW – US Army Corps of Engineers, South Atlantic, Wilmington

CWRB – Civil Works Review Board

ECO-PCX - National Ecosystem Planning Center of Expertise

EIS – Environmental Impact Statement

EPR – External Peer Review

FCSA – Feasibility Cost Sharing Agreement

FEIS – Final Environmental Impact Statement

FSM – Feasibility Scoping Meeting

GI – General Investigations

HQ – Headquarters

ITR – Independent Technical Review

LOI – Letter of Intent

NEPA – National Environmental Policy Act

OVEST -- Office of the Chief of Engineers Value Engineering Study Team

PDT – Project Delivery Team

PMP – Project Management Plan

PRP - Peer Review Plan

P&S – Plans & Specifications

SAD – South Atlantic Division

Walla Walla Dx - Walla Walla District Directorate of Expertise for Civil Works Cost Engineering

1.0 The Peer Review Plan

This Peer Review Plan (PRP) is a collaborative product of the project delivery team (PDT) and the National Ecosystem Planning Center of Expertise (ECO-PCX) and the Walla Walla District Directorate of Expertise for Civil Works Cost Engineering (Walla Walla Dx). The ECO-PCX and Walla Walla Dx shall manage the PRP, which for this study includes Independent Technical Review (ITR) only. External ITR is not deemed necessary for the initial review phase. Each of the following paragraphs (a. through j.) correspond to the guidance provided in paragraphs 6.a. through j. of Engineering Circular 1105-2-408, Planning - Peer Review of Decision Documents, 31 MAY 2005.

a. Decision Document and Team Members. The *Integrated Feasibility Report and Environmental Impact Statement for the Currituck Sound, NC* shall be the decision document. The Currituck Sound Restoration Study is being pursued under the Corps of Engineers' General Investigation (GI) Program. The integrated Feasibility Report and Environmental Impact Statement (EIS) are being conducted in response to a resolution adopted March 11, 1998:

> "Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Division Engineer dated June 25, 1991, on Eastern North Carolina above Cape Lookout, North Carolina, and other pertinent reports, to determine whether modifications to the recommendations contained therein are advisable at the present time in the interest of water quality, environmental restoration and protection, and related purposes in Currituck Sound.

The report of the House Committee on Appropriations accompanying the Energy and Water Development Appropriations Bill, 2001, recommended funds in the amount of $100,000 for the reconnaissance phase of the Currituck Sound, North Carolina, environmental restoration and protection project.

Together, the US Army Corps of Engineers (USACE) and the NC Department of Environment and Natural Resources (NCDENR) are partnering to conduct the Feasibility Study on the Currituck Sound to identify ways to improve water quality and restore the Sound. The ongoing study is being cost shared between the USACE and NCDENR, and each cost share partner pays 50% of the feasibility phase costs.

Currently data collection efforts are being conducted as part of multiple individual studies within the Currituck Sound as well as in the surrounding watersheds that impact the Sound, including Back Bay. The Currituck Sound Restoration is currently formulating recommended alternatives necessary to meet the established restoration goals and objectives. A Feasibility Report and NEPA

document recommending viable restoration projects and management measures will be the products of the study.

The Study focuses on understanding reasons for the decline in aquatic resources within the Sound and nearby vicinity, characterizing the present condition of the system, and developing plans for restoration and protection of the this valuable resource. A critical step in this multi-phase plan is the development of a regional a regional hydrodynamic numerical model coupled with local hydrodynamic and water quality models, which can be applied to the evaluation of the present state of Currituck Sound and explore possible mitigation options (**see Attachment 1 for detailed modeling information**).

Background

Currituck Sound is located on the northern portion of the North Carolina coast, Figure 1. Currituck Sound is a shallow (typically < 10 ft, 3 m), non-tidal, wind influenced estuary with limited circulation. The natural opening of the sound occurs in the south where Currituck Sound opens to Albemarle Sound at Point Harbor. Man-made connections to the Chesapeake Bay to the north and to Albemarle Sound have been constructed in the past to support navigation. Historical records indicate that Currituck Sound waters vary from fresh to saline conditions over time with salt entering from the north and south, and through over-wash of ocean water over the coastal barrier islands during major storms. During the last 20 – 30 years, the water quality of Currituck Sound has undergone significant changes, which have had impacts on the viability of aquatic species in the system. The system was at one time a fresh water system capable of sustaining large populations of fresh water game fish. Fresh water fish have declined as has the health and extent of the submerged aquatic vegetation (SAV). Among the proposed reasons for the decline are an increase in salinity, water column changes that reduce light penetration, and changes in nutrient loading. Potential sources of the changes are the channelization of connections to adjacent water bodies, freshwater diversions from tributaries to upper Currituck Sound, influx of nutrients and fines sediments and sediment re-suspension. A loss of natural (SAV) beds is theorized to have allowed additional exchange between the upper fresher portion of the Sound and the more saline waters of the southern Sound.

Figure 1. Currituck Sound, NC and Surrounding Water Bodies

Nutrient levels are such that they can support elevated levels of algae in the summer months. Naturally occurring SAV have likely diminished due to poor light conditions, turbidity, and possibly changes in salinity levels. In addition, an exotic aquatic plant species (water milfoil) has, at times, established itself in the system further degrading conditions for native SAV. The seasonal death and decay of this exotic species further degrades the water column by diagenesis of detritus accumulated in the sediments.

Other potential impacts upon the waters of Currituck Sound are those associated with alterations to the watershed. Historically, the watershed surrounding Currituck Sound has been agricultural with little development. Clearing and drainage activities following WWII, and continuing, have increased the load of fine sediment into Currituck Sound while rapid development within and around

the watershed has increased water quality concerns. A water quality sampling study conducted in 1993 indicated that runoff events increased phosphorus levels immediately after storm events. Phosphorus is the limiting nutrient in the water column; increases in phosphorus during certain periods of the year can make algal blooms worse in terms of chlorophyll-a levels, duration and distribution. Such a series of events could have a long-term detrimental effect as a buildup of algal detritus occurs in the sediments.

Study Team Overview

The Currituck Sound Restoration Coordination Team is composed of multiple agencies and organizations including, but not limited to: USACE, Wilmington District, NCDENR, NC Division of Water Resources (NCDWR), Elizabeth City State University (ECSU), USACE Coastal and Hydraulics Laboratory (CHL), NC National Estuarine Research Reserve (NCERR), US Fish and Wildlife Service (USFWS), US Geological Survey (USGS), USACE Engineer Research and Development Center (ERDC), Hampton Roads Planning District Commission, NC Division of Coastal Management (NCDCM), NC Coastal Federation (NCCF), Virginia Department of Conservation and Recreation (VADCR), Currituck County, The Nature Conservancy (TNC), NC Wildlife Resources Commission (NCWRC), NC Division of Water Quality (NCDWQ), Pasquotank River Basin Regional Council, Virginia Department of Environmental Quality (VADEQ), Virginia Marine Resources Commission (VAMRC), and Albemarle Pamlico National Estuary Program (APNEP). The entities composing the restoration team participate in one or more of three Workgroups, which are: Hydrologic, Hydrodynamics, and Water Quality Modeling Workgroup; the Living Resources Workgroup; and the Planning and Public Involvement Workgroup.

The Hydrologic, Hydrodynamics, and Water Quality Modeling Workgroup is using a model to characterize existing hydrologic and water quality conditions in Currituck Sound, develop a baseline, and produce a model for use in determining the condition in which to restore the Sound, Attachment 1. This Workgroup is developing and using a modeling package based on modeling requirements of the USGS in cooperation with USACE ERDC, NCDWR, and ECSU to develop a comprehensive and cost effective data collection, and monitoring plan for Currituck Sound, including site locations, data types, frequency, and purpose of the data to be collected. The model will characterize the effects of internal and external factors such as freshwater flow, tides, wind, suspended and bottom sediments, nutrient inputs, land use, etc., on water quality and the health of the biological communities in Currituck Sound.

The Living Resources Workgroup consists of four subgroups, which have individual data collection efforts underway. The four subgroups and subject matter areas are as follows: the Vegetation Subgroup (Submerged Aquatic Vegetation (SAV), forests, wetlands, marshes, invasive species); the Survey/GIS Subgroup (land and hydrologic surveys, aerial photography, mapping, and

geographic analysis); the Fisheries Subgroup (freshwater and saltwater fisheries and crabs); and the Waterfowl Subgroup (nesting water birds and waterfowl).

The Vegetation and Survey/GIS Subgroups have completed data collection efforts for historic and existing SAV within the Currituck Sound and surrounding watershed. This is a critical component of the Currituck Sound Feasibility Study because the abundance of SAV has undergone several long-term downward trends since early 1900's and has not fully recovered to former abundant conditions of the past century. The SAV Habitat Cooperative Mapping Project at ECSU has completed and will continue with field surveys (replicating findings from a series of reports referred to as the Sincock Master Surveys (Sincock et al., 1958-1964) as well as recording data on water clarity, temperature, salinity, DO, pH Distribution, density and species composition of SAV. Also collaborative efforts to digitize the findings reported in the Sincock Master Surveys were completed by USACE, ECSU, and others. The result of this effort is an interactive site, "The Sincock Master Survey Internet Mapping Service & Website," and is available at: http://155.82.232.43/website/Currituck_Sincock_MS/ viewer.htm.

The Planning and Public Involvement Workgroup serves to gather information from the public for incorporation into the study and to disseminate information from ongoing study findings out to the public. This Workgroup is requesting historical information and records, fishing and hunting logbooks, and old photographs and maps of the Sound and Shoreline. This Workgroup will hold future Public Meetings; the public will be informed in advance. The planning function of this Workgroup serves to balance the interests of all involved entities as well as produce the Currituck Sound Restoration Feasibility Report. This report will capture and document the Currituck Sound Restoration Coordination Team's findings and make recommendations for alternatives and management measures to improve water quality and restore the Sound.

For further information or inquiries regarding the Currituck Sound Restoration Feasibility Study, you may visit http://www.saw.usace.army.mil/Currituck%20Sound/main.htm

Recommended plans will be formulated to address the ecosystem restoration needs of the Currituck Sound Basin at the basin-wide scale. Plan components will be developed by the workgroups to address needs (study objectives) identified above for the individual focus areas. All Alternative Ecosystem Restoration Plans will be subjected to a Modified Habitat Evaluation Procedure. Environmental Quality EQ benefits will be measured in Habit Units (HUs), cost will estimated for each plan and IWR Plan will be used evaluate alternatives for inclusion in the recommended plan.

Key PDT members are shown in the table below.

ROLE	NAME	ORGANIZATION
Project Manager		
Program Manager		
Lead Planner		
Biologist, Estuarine Resources		
Cultural Resources		
Coastal/H&H		
Coastal/H&H		
Cost Engineering		
Geographic Information Specialist		
Geographic Information Specialist		
Real Estate		
Contract Specialist		

For more information regarding the PRP, the project manager for the feasibility study may be contacted as follows:

US Army Corps of Engineers – Wilmington District

Independent Technical Review Team Leaders

National Ecosystem Planning Center of Expertise
US Army Corps of Engineers – Mississippi Valley Division

Walla Walla District Directorate of Expertise for Civil Works Cost Engineering

b. External Peer Review. EC 1105-2-408 provides the process for deciding whether or not to employ external peer review. The following is an excerpt of EC section 9.a: *Decision documents covered by this Circular will undergo EPR if there is a vertical team consensus (involving district, major subordinate command and Headquarters members) that the covered subject matter (including data, use of models, assumptions, and other scientific and engineering information) is novel, is controversial, is precedent setting, has significant interagency interest, or has significant economic, environmental and social effects to the nation. Decision documents covered by this Circular that do not meet the standard shall undergo ITR as described in paragraph 8, above.*

The vertical team will be included in all levels of review. The USACE, South Atlantic Division will receive the Draft Feasibility Report and will be involved in making the determination for level of review (i.e., Independent Technical Review and/or External Peer Review). This Peer Review has been submitted to SAD for approval.

For this study, it has been determined that EPR is not required. Please see the External Peer Review Decision Checklist below (1 - 6).

1. Novel subject matter? No.

2. Controversial subject matter? No

3. Precedent setting? No

4. Unusually significant interagency interest? No

5. Unusually significant economic, environmental, and social effects to the nation? No

6. Implementation costs ($50,000,000) trigger EPR? No. Reconnaissance phase costs were $100,000 and total study and project implementation costs are not to exceed the magnitude of $10,000,000 to $25,000,000.

Decision: The PDT suggests that External Peer Review is not required. Independent Technical Review by a US Army Corps of Engineers team external to the project district, CESAW, will be sufficient to comply with the spirit of EC 1105-2-408, Planning - Peer Review of Decision Documents, dated 31 May 2005. It is not anticipated that any new methodologies will be used in the analysis and preparation of the Integrated Feasibility Report/EIS, nor that any of the data collected or analyzed would be considered influential scientific data.

c. Anticipated Peer Review Schedule.

REVIEW PHASE	COMPLETION DATE	
In-House Review	Spring	2008
Independent Technical Review	**Spring**	**2008**
Feasibility Scoping Meeting (FSM)	Summer	2008
In-House Review	Winter	2008
Independent Technical Review	**January**	**2009**
Alternative Formulation Briefing (AFB)	February	2009
Final EIS / NEPA Public Review	Spring	**2009**
Civil Works Review Board	Summer	2009

d. Conducting External Peer Review. The relevant Planning Center(s) of Expertise will make the final determination as to whether or not External Peer Review is to be conducted. For this feasibility study, this decision is the responsibility of the Vertical Team, ECO-PCX, and the Walla Walla Dx.

e. Public Comment on Decision Document. Once completed, the Integrated Feasibility Report and EIS will be disseminated to resource agencies, interest groups, and the public as part of the National Environmental Policy Act (NEPA) environmental compliance review. Please note where "FEIS / NEPA Public Review" is highlighted in the "Peer Review Plan" flow chart included as Attachment 2. Public entities and private individuals may also review and comment on draft documents as members of the PDT.

f. Provision of Public Comments to Reviewers. All significant and relevant public comments will be provided as part of the review package to Peer Reviewers as they are available and may include but not be limited to: scoping letters, meeting minutes, other received letters, and emails.

g. Anticipated Number of Reviewers.** The relevant Planning Center(s) of Expertise shall make the final determination for the number needed of reviewers. For this feasibility study, this decision is the responsibility of the ECO-PCX and the Walla Walla Dx.

h. Primary Review Disciplines and Expertise. The number of reviewers (Level of Review) shall vary as depicted under "Review Phase" in the "Peer Review Plan" flow chart included as Attachment 2. The ECO-PCX and the Walla Walla Dx shall make the final determination for the discipline type and number needed of reviewers depending upon the "Review Phase."

PRELIMINARY REVIEW DISCIPLINES FOR ITR**	
Plan Formulation	The reviewer should have the ability to review the planning process which should address the Nation's water resources needs in a systems context and explore a full range of alternatives in developing solutions. The reviewer should be able to recognize innovative solutions and the application of the full range of the Corps programs and authorities are integral to the planning process. The reviewer should thoroughly understand the Planning Guidance Notebook (ER-1105-100) and the Water Resources Council's Principals and Guidelines.
Environmental / NEPA Compliance	The reviewer should be able to addresses the integration of environmental evaluation and compliance requirements, pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements, into the planning of Civil Works water and related land resources comprehensive plans and implementation projects.
Hydrology & Hydraulics	The reviewer should have the ability to address river hydraulics and sediment transport, hydrologic statistics and risk analysis, reservoir system analysis, planning analysis, real-time water control management and a number of other closely associated technical subjects.
Cost Estimating	The cost estimating reviewer must be cost estimating specialist. It is imperative that estimates be prepared by, and reviewed under the supervision of, personnel who are competent in construction cost estimating. The reviewer must possess a working knowledge of construction and environmental restoration and be capable of making professional determinations based on their experience.

As the Currituck Sound Restoration Feasibility Study proceeds, additional reviewing disciplines will be added.

i. Selection of External Peer Reviewers. The relevant Planning Center(s) of Expertise and associated Vertical Team shall make the final determination for the discipline type and number needed of reviewers as well as which if any External Peer Reviewers are needed. For this feasibility study, this decision is the responsibility of the ECO-PCX and the Walla Walla Dx.

j. Nomination of Peer Reviewers by the Public. The ECO-PCX and the Walla Walla Dx shall determine if Peer Reviewers will be nominated by the Public. The public will have opportunities to review the Integrated Feasibility Report/EIS as required by the NEPA compliance process.

k. Format for Compiling Peer Review Comments. The ITR team will document its comments and recommendations, for all formal reviews, utilizing the DrChecks module in ProjNet in accordance with ER 1110-1-8159. Comments will be structured to give a clear statement of the concern, the basis of the concern and, when appropriate, the actions necessary to resolve the concern. Comments will cite appropriate references. The PDT will evaluate and respond to each comment in DrChecksm. Responses will clearly state concurrence or non-concurrence with the comment. Concurrences shall include what the corrective action is and where and when it will be done. Non-concurrences shall include an explanation or proposed alternative action. All comments are to be resolved and back checked in the DrChecksm project record prior to ITR certification.

l. Models and Certification. Multiple models are being used for evaluation of resource restoration. For model certification purposes, please see

“Attachment 1 Hydrodynamic and Water Quality Modeling of Currituck Sound and Surrounding Water Bodies” for further descriptions of the models including how they are being used, what data is input into the models, and who developed the models. All models developed or modified during for use in this study will be subjected to ITR and will be certified as required by Engineer Circular (EC) 1105-2-407, U.S. Army Corps of Engineers. *Planning Models Improvement Program: Model Certification*. All ITR documentation for all required outputs (both reports and models) will be documented using Dr. Checks in order to maintain a complete record of all comments and responses resulting from the review.

ATTACHMENT 1

Hydrodynamic and Water Quality Modeling of Currituck Sound and Surrounding Water Bodies

Hydrodynamic and Water Quality Modeling of Currituck Sound and Surrounding Water Bodies

Modeling approach involves: 1) Development and application of a Regional Domain (RDM) surface water model to better understand the influences of connected water bodies (Chesapeake Bay and Pamlico/Albemarle Sounds) on Currituck Sound, particularly for wind-driven events, and the implications of this connectivity on water and salt influxes at the boundaries of a Local Domain Model (LDM) required for investigating local higher-resolution hydrodynamics and water quality within the context of regional water circulation patterns. 2) Application of Local Domain Models (LDM) of a) hydrodynamics and b) water quality for Currituck Sound and connected water bodies, which must include calibration and validation of that models based on measurements. Measurements are needed to quantify key inputs to the LDM domain at its boundaries, and in the model domain interior to assess model skill and characterize processes within the Sound. The measurement requirements and data acquisition are being addressed in a companion work effort within the overall Currituck Sound Study. Once the models are calibrated and validated, they become very effective prediction tools for evaluating the response of the ecosystem to restoration approaches and this proposal includes hydrodynamic and water quality tasks to examine two, or perhaps three, restoration actions.

Regional Surface Water Modeling

Future adaptive management of this ecosystem will require estimates of inputs to the system that have characteristics which are beyond the range of those reflected in the one-year data record that will be used for LDM calibration and validation. Decision makers will also require information about other what-if scenarios, along with an estimate of the uncertainty of such events. Future predictions cannot be based solely on a short-term measurement record because that record may not be representative of the episodic forcing that the system might experience in the near or distant future. In light of the long residence time of the system, episodic events might have great bearing on ecosystem response. For these reasons, a regional non-structured surface water model will be developed, using ADCIRC in the SMS, and applied to help understand response of Currituck Sound within the context of a larger regional water system.

Currituck Sound is tightly coupled to Albemarle and Pamlico Sounds. Using the regional ADCIRC model will enable simulation of the atmospheric and tide-driven circulation that occurs in the much larger Albemarle and Pamlico Sounds south of and west of Currituck Sound. Water influxes created by these events are a primary process that affects hydrodynamics and salinity, residence time, and flushing within Currituck Sound. The extensive flooding and water retention in wetlands that surround the Sound and subsequent release of that water following event passage is also important. Directionality of water movement following event passage depends heavily free surface gradients created between Chesapeake Bay and Currituck Sound and Albemarle Sound and Currituck Sound. The model allows understanding of the dependency of Currituck Sound on what happens in the rest of the adjacent water bodies, beyond what might be gained through attempts to correlate wind speed and direction at a local point to water movement into and out of Currituck Sound, and local modeling alone. The regional model is an integrator of complex and interrelated water movement phenomena.

Understanding the functioning of Currituck Sound within the context of the regional Sound system is crucial.

The regional model can also simulate the following: circulation and sea water influx that might accompany a breach of the barrier islands (which occurred during Hurricane Isabel), multiple breaches, or storm induced overtopping of the barrier island, which has occurred; and the complex interactions that result from storm-induced forcing in the Chesapeake Bay which can drive flows into northern Currituck Sound. The results of the regional ADCIRC model will serve to provide accurate boundary conditions to the LDM to examine the effects of wind events and input of saline water into the Currituck Sound associated with both routine wind forcing and episodic events. The regional surface water model will allow examination of the complex interactions between different water bodies that the local domain model can only treat with input from the regional model, for types of events that are not contained in the measured data record within Currituck Sound.

The level of effort required to implement the regional surface water model is reduced because of past ADCIRC simulation work. Existing 2D ADCIRC models of Chesapeake Bay (prepared by ERDC staff) and Pamlico/Albemarle/Currituck Sounds (prepared by UNC researchers) have been created to support other studies and projects will be adapted for use in this project. Use of the unstructured grid technology, upon which ADCIRC-SMS is based, provides optimal simulation accuracy of important and complex processes in this highly irregular system (many bays and streams, highly irregular wetlands) that are not well represented by structured grid models. This valuable technology can be spun up with relative ease by building upon models that already exist.

The regional extent of this modeling effort will include a portion of the Atlantic Ocean, Chesapeake Bay and the combined area of Pamlico, Albemarle and Currituck Sounds. The idea of applying a regional grid modeling approach using ADCIRC can be more well understood by comparing the overall regional grid as shown below in Figure 2, with the more refined embedded grids representing features such at the Chesapeake and Delaware Bays, Figure 3, and that of Pamlico, Albemarle and Currituck Sounds, Figure 4.

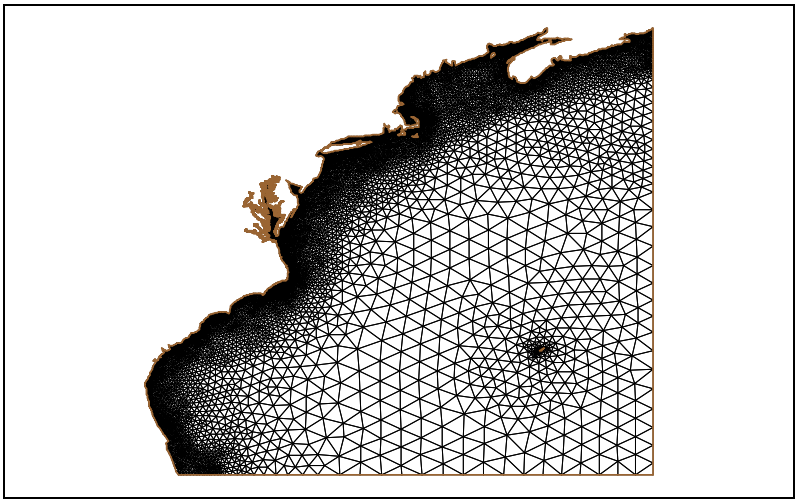

Figure 2. East Coast Regional ADCIRC Grid.

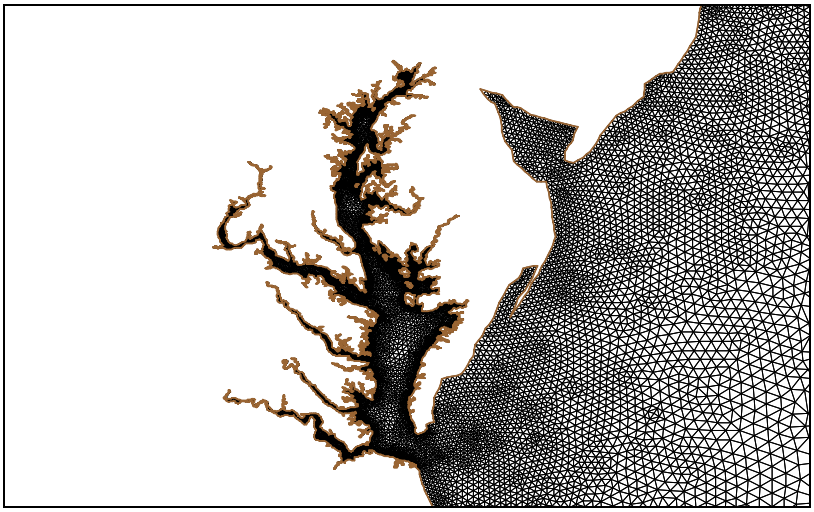

Figure 3. Chesapeake Bay ADCIRC Grid.

Figure 4. Local Scale Pamlico, Albemarle and Currituck Sound Grid.

Forcing of the northern model boundaries in Chesapeake Bay using long-term measured water level will also be examined if it is determined that the influence of the Bay can be properly represented without detail modeling. Model validation will be accomplished using existing water level and velocity data along with water surface and velocity elevation data collected during the 1-year measurement program proposed in the current study. A 1-yr. simulation period corresponding to the 1-yr. data collection campaign will be provided with additional actual and hypothetical episodic events, and additional short-term scenario periods as required by the study team. This linked modeling approach, regional water surface model linked to local 3D hydrodynamic and water quality models has been successfully applied previously and is currently being applied to dredge operations and water quality issues within the complete Mississippi Sound/Mobile Bay water system (Table 3).

Local Domain Hydrodynamic and Water Quality Modeling

A local domain hydrodynamic model (LDHM) is required to compute transport input for the water quality model (WQM). The hydrodynamic model predicts surface level, currents, and mixing as well as salinity and temperature. Computed salinity and temperature fields allow the representation of density effects on circulation. In addition, they provide common variables between the LDHM and WQM, which allow for comparative validation of the computed transport processes. The HM must be able to represent the geometry of the Currituck Sound system, couple with the WQM, represent transport processes over the time scales of interest. Spatial resolution of the HM must be adequate to capture relevant features of the system. These required characteristics have been repeatedly demonstrated via the coupling of CH3D hydrodynamic model and the CEQUAL-ICM water quality model (Table 3). More importantly, software has been developed and tested that seamlessly links the regional ADCIRC model with CH3D, as well as CH3D with CE-QUAL-ICM. In addition, CH3D has been the preferred HM-WQM linkage model because of it long-term simulations capability (order of years), and its proven reliable linkage with CE-QUAL-ICM as demonstrated by numerous successful application such as the Chesapeake Bay Program. An example of a local scale grid is presented in Figure 5, the CH3D-ICM grid for the Chesapeake Bay and its tributaries.

Figure 5. Local Scale CH3D-ICM Grid for the Chesapeake Bay

The data requirements for application of an HM are extensive. Some of the required information is readily available while other information may require special surveys if it is not available. Freshwater runoff, wind stress, atmospheric pressure and tides, for the duration of the simulation period, are required to force the model. Salinity observations outside the mouth, for the duration of the simulation period, are required to force salinity transport. Records of surface level, currents, salinity, and temperature at multiple locations within the Currituck Sound are required for validating the computed transport processes. Much of the data will be acquired during the field data collection campaign described previously. Local wind data and weather data, including data measured at the ERDC Field Research Facility, will also be utilized.

The water quality modeling required for Currituck Sound has been inferred from documentation provided by the Wilmington District, literature obtained from various sources, and conversations with other ERDC employees familiar with the region. Based on this information a modeling approach is envisioned that incorporates eutrophication processes (nutrients, algae, DO), sediment diagenesis (computed sediment fluxes), and benthic processes (benthic algae, filter feeders, benthic invertebrates).

The models that will be developed for the local domain are flexible, in that they allow processes to be simulated in two horizontal dimensions (2D), or three dimensions (3D). 2D simulations are appropriate where variations of water parameters within the water column (current speed, temperature, salinity, etc.) are small. If there is vertical structure in these parameters, in areas that are of present or future interest, 3D simulations may be required. Existing information suggests that a 2D approach may be sufficient for these shallow water bodies, but the 3D capability will be there if needed as indicated by the measurement program.

Initially, measurements will be used to drive the boundary conditions of the LDM, and used to assess model skill in predicting water conditions throughout the Currituck/Back Bay system. A number of low-relief watersheds and streams contribute water to Currituck Sound and Back Bay. These are very complex systems in and of themselves. Linkages between ground water and surface water within these systems are unclear at present. The wetlands that fringe Currituck Sound and Back Bay are extremely complex networks, in terms of their capacities to hold water then release it. Currituck Sound has a small tidal signature, and the system appears to be dominated by wind-driven flows and extreme storm events (flows from adjacent water bodies and precipitation). Connections between the LDM and other important features of the water exchange system are extremely important, but quantifying their influence on the local domain model is equally challenging. So the approach adopted here will be to calibrate/validate the LDM (water circulation and water quality) by measuring water inputs to the system, for a period of one year, and using the measured data to both force the model at its boundaries and evaluate its accuracy in the interior of the system away from the boundaries. This will establish confidence that the local domain models are valid, provided accurate inputs into the water bodies are well-known, water, suspended sediments, salinity, and nutrients. Specifics of the data collection activity were discussed previously. Analysis of the measurements will also provide valuable information for fine-tuning the modeling approach and identifying other aspects of data analysis or modeling that might be needed.

Brief descriptions of the model components of the ADCIRC - CH3D - CEQUAL-ICM model suite are provided below.

ADCIRC

ADCIRC is a highly developed computer program for solving the equations of motion for a moving fluid on a rotating earth. (Luettich, Westerink, and Scheffner 1992). These equations have been formulated using the traditional hydrostatic pressure and Boussinesq approximations and have been discretized in space using the finite element (FE) method and in time using the finite difference (FD) method. ADCIRC can be run either as a two-dimensional depth integrated (2DDI) model or as a three-dimensional (3D) model. In either case, elevation is obtained from the solution of the depth-integrated continuity equation in Generalized Wave-Continuity Equation (GWCE) form. Velocity is obtained from the solution of either the 2DDI or 3D momentum equations. ADCIRC can be run using either a Cartesian or a spherical coordinate system, and all nonlinear terms have been retained in these equations.

ADCIRC boundary conditions include: specified elevation (harmonic tidal constituents or time series), specified normal flow (harmonic tidal constituents or time series), zero normal flow, slip or no slip conditions for velocity, external barrier overflow out of the domain, internal barrier overflow between sections of the domain, surface wind stress, atmospheric pressure, and outward radiation of waves.

ADCIRC can be forced with: elevation boundary conditions, normal flow boundary conditions, surface stress boundary conditions, tidal potential, and earth load/self attraction tide.

ADCIRC has been successfully applied by ERDC staff in a large number of studies, including storm-surge, tidal circulation, and ship simulation studies, as well as in support of water-quality studies in concert with CH3D and ICM. Furthermore, grids presently exist for the Atlantic coast, Chesapeake Bay, Delaware Bay, Albemarle, Currituck and Pamlico Sounds.

CH3D

CH3D-WES (Curvilinear Hydrodynamics in 3 Dimensions) is a 3D, boundary fitted, finite difference hydrodynamic model. CH3D-WES is capable of generating hydrodynamic, temperature and salinity fields in the Currituck Sound system and adjacent waters. CH3D-WES has been used in support of water quality modeling in numerous studies, (i.e. Chesapeake Bay (Cerco and Cole 1994), Delaware Inland Bays (Cerco et al. 1994), Newark Bay (Cerco and Bunch 1997), the San Juan Estuary (Bunch et al. 2000). CH3D-WES can be applied using the sigma-stretched vertical coordinates or the z-plane version if greater vertical representation is needed. The z-plane version of CH3D-WES gives better representation of vertical mixing when bathymetric variations are not highly resolved. Since Currituck Sound is a shallow well-mixed estuary, the 2D depth averaged sigma version may be all that is required.

These models will be applied in a sequential manner of increasing resolution and closer focus to the Currituck Sound area. The ADCIRC mesh will bring the tidal boundary conditions into the southern portion of the study domain, Pamlico Sound and Albemarle Sound. The precise location of HM/WQM boundaries will be determined subsequent to a close examination of available field data and those collected during the proposed hydrodynamic and water quality data sampling program.

CE-QUAL-ICM

CE-QUAL-ICM will be used for the water quality model. CE-QUAL-ICM was designed to be a flexible, widely applicable eutrophication model. The model was developed for application to Chesapeake Bay (Cerco and Cole 1994) and has been applied extensively in water bodies close to Currituck Sound, Table 1. Subsequent additional applications include the, Newark Bay (Cerco and Bunch 1997), and the San Juan Bay Estuary (Bunch et al. 2000). The Chesapeake Bay application is of particular relevance since cultural eutrophication, including bottom-water anoxia and loss of living resources, is the primary environmental issue there. The experience gained in Chesapeake Bay and the associated model developments provide an excellent starting point for efforts in Currituck Sound. CE-QUAL-ICM contains multiple components or sub-models.

In the following sections the major components of CE-QUAL-ICM are described. As can be seen CE-QUAL-ICM has the capability to address complex water quality/ecological modeling issues. CE-QUAL-ICM also has the flexibility to “step back” and use a limited set of processes and variables for a more cursory study of the issue. The major components of CE-QUAL-ICM described in this document are the water column, sediment diagenesis model, living resources modules. The modeling approach for Currituck Sound can be modified to include any of the model capabilities described in this document.

The Water Column

The foundation of CE-QUAL-ICM is the solution to the three-dimensional mass-conservation equation for a control volume. Control volumes correspond to cells on the hydrodynamic model grid. CE-QUAL-ICM computes nearly thirty interacting state variables. These can be individually selected depending on application and data availability. For eutrophication applications, a suite is selected that represents various physical properties as well as the cycles of carbon, nitrogen, phosphorus, dissolved oxygen, and silica (Table 1). An additional component, light attenuation, is derived from computed chlorophyll and suspended solids.

Table 1
Water Column State Variables

Temperature	Salinity
Fixed Solids	Algal Biomass, as Carbon (up to three groups)
Dissolved Organic Carbon (labile and refractory)	Particulate Organic Carbon (labile and refractory)
Dissolved Organic Nitrogen (labile and refractory)	Particulate Organic Nitrogen (labile and refractory)
Ammonium	Nitrate+Nitrite
Dissolved Phosphate	Dissolved Organic Phosphorus
Particulate Phosphorus	Dissolved Oxygen
Chemical Oxygen Demand (methane or sulfide)	Dissolved Silica
Particulate Biogenic Silica	

The data requirements for application and validation of the water column component of the model are extensive. Ideally, observations of each of the quantities listed in Table 1 should be available at multiple locations and depths throughout the simulation period. This ideal is seldom realized but representative data should be available for each component with more intensive observations, in space and time, for algae, nutrients, and dissolved oxygen. The most common form of algal observations is chlorophyll concentration. This can be related to carbonaceous biomass through a carbon-to-chlorophyll ratio. In addition, observations of light attenuation are required. The validation of the model is greatly enhanced by observations of processes as well as state variables. The most important process observations are primary production and respiration.

Sediment Diagenesis Model

Bottom sediments continuously exchange organic matter, nutrients, and dissolved oxygen with the water column. Diagenesis (decay) of particulate organic matter deposited in the sediments creates sediment oxygen demand, which contributes to depletion of oxygen in the overlying water. The diagenesis process simultaneously recycles to the water column, in dissolved form, a fraction of the nutrients in the particulate organic matter. Denitrification (the reduction of nitrate to nitrogen gas) can be a significant sink of estuarine nitrogen. Oxygen consumption, nutrient cycling, and nutrient losses must be considered as components of the eutrophication process.

CE-QUAL-ICM incorporates a predictive diagenetic submodel. The model was initially developed for Chesapeake Bay (DiToro and Fitzpatrick 1993, DiToro 2001) and has subsequently found extensive use elsewhere. A particular advantage of the model is that it can be used in predictive fashion to compute changes in diagenetic processes (e.g. sediment oxygen demand) that result from management activities.

The sediment sub-model (Table 2) is driven by net settling of organic matter from the water column to the sediments. In the sediments, the sub-model simulates the diagenesis of the organic matter. Diagenesis produces oxygen demand and inorganic nutrients. Oxygen demand, as sulfide (in saltwater) or methane (in freshwater), takes three paths out of the sediments: export to the water column as chemical oxygen demand, oxidation at the sediment-water interface as sediment oxygen demand, or burial to deep, inactive sediments. Inorganic nutrients produced by diagenesis take three paths out of the sediments: release to the water column, conversion to gaseous form (nitrogen only), or burial to deep, inactive sediments.

Table 2 **Sediment Sub-Model State Variables and Fluxes**	
State Variable	Sediment-Water Flux
Temperature	
Particulate Organic Carbon	Sediment Oxygen Demand
Sulfide/Methane	Release of Chemical Oxygen Demand
Particulate Organic Nitrogen	
Ammonium	Ammonium Flux
Nitrate	Nitrate Flux, Denitrification
Particulate Organic Phosphorus	
Phosphate	Phosphate Flux
Particulate Biogenic Silica	
Dissolved Silica	Silica Flux

The primary observations required for application of the diagenesis model are measures of sediment-water fluxes of dissolved oxygen, ammonium, nitrate, dissolved phosphate, and dissolved silica. These should be collected over the course of the year to provide a database of fluxes at various temperatures, deposition rates, and conditions in the water column. Secondary, desirable, observations describe concentrations in the sediments including particulate organic carbon, particulate organic nitrogen, particulate phosphorus (organic and inorganic), particulate biogenic silica, interstitial ammonium, interstitial dissolved phosphate, interstitial dissolved silica, and interstitial sulfide. Data on deposition and burial can also be useful.

Living Resource Modeling

The ultimate goal of eutrophication modeling is to protect precious living resources. Typically eutrophication models compute living-resource criteria such as dissolved oxygen concentration. Computed dissolved oxygen is compared to requirements for species survival and judgments are made about management actions appropriate to meet requirements. Eutrophication models are developing the capability to directly compute living resources for two reasons. First, the resources themselves are of interest. Stakeholders prefer to hear how many fish they might catch rather than conditions will be right for fish. Second, living resources interact with and influence their environment. Filter feeders remove particulate matter from the water column and deposit it in the sediments. Submerged aquatic vegetation (SAV) damps waves and

retards sediment re-suspension. Accurate modeling of the water column requires representation of the organisms that influence conditions in the water column.

The CE-QUAL-ICM model incorporates living resources including zooplankton (two groups, Cerco and Meyers 2000), benthic filter feeders (multiple groups, Cerco and Meyers 2000), benthic deposit feeders (Cerco and Meyers 2000), SAV (multiple groups, Cerco and Moore 2001), and subtidal benthic algae (Cerco and Seitzinger 1997). Any or all of these can be implemented in the Curituck Sound study. Implementation will depend on local significance of the process and availability of sufficient data. For zooplankton, this data should include spatial and temporal observations of zooplankton biomass by size class (microzooplankton and mesozooplankton). For benthos, the temporal and spatial distribution of deposit- and filter-feeding biomass is required. SAV modeling requires observations of SAV distribution, species composition, and local abundance (e.g. mass per unit area). Incorporation of benthic algae requires observations of the spatial distribution of biomass (as chlorophyll) and, preferably, measures of algal production. Caution is advised that application of these processes should occur only if supporting data area available.

The CE-QUAL-ICM model continues to undergo additional development and addition of new capabilities. Concepts of future development included addition of modeling capabilities for ecologically important features such as littoral zones (tidal flats), and wetlands and interactions with coupled Eulerian-Lagrangian Models (ELM) of organism motion. As these developments occur, they can be incorporated into the Currituck Sound Water Quality Model in follow-up studies.

The ERDC has the capability to provide include all of the water quality modeling capability described in this document on Currituck Sound and the adjacent waters. The capabilities of CE-QUAL-ICM that are applied to this study are dependent upon the sponsor's desire. As additional capabilities are included the level of effort (and cost) is increased. This SOW was developed with some assumptions as to what level of modeling would be applied for this study. The approach that is proposed for Currituck Sound is to apply CE-QUAL-ICM in an eutrophication model configuration. The sediment diagenesis and benthic processes sub-models will also be included in this application. Should the sponsor desire, SAV could (and probably should) be added to the modeling package.

An import feature of the ADCIRC-CH3D-ICM modeling suite is that all linkage software required to fully utilize the modeling system has been developed and tested during the successful completion of previous modeling studies. Examples of the previous modeling studies are outlined in Table 3. Citations for these and other relevant studies are included in the References section at the end of this document. In addition, many of the projects undertaken and the personnel involved during the development of the technology are listed in the reference section. A critical aspect to the timely and successful completion of the proposed project is the selection of a coordinated team of modelers with varied and extensive experience. A review of the projects list and reference section below clearly demonstrates that the modeling team presented herein more than meets these qualifications.

Table 3 **ADCIRC - CH3D - CE-QUAL-ICM Modeling Studies**				
Study	Sponsor	Models Applied		
		ADCIRC	CH3D	CE-QUAL-ICM
Chesapeake Bay Environmental Model Package	EPA		**X**	**X**
Suspended Solids and Living Resouce Interactions (Potomac River and upper Bay)	US EPA and Baltimore District		**X**	**X**
Chester River Eutrophication Model	Maryland Dept. of Environment		**X**	**X**
Choptank River Eutrophication Model	Maryland Dept. of Environment		**X**	**X**
Patuxent River Eutrophication Model	Maryland Dept. of Environment		**X**	**X**
Delaware Inland Bays Water Quality Modeling Study	Delaware Dept. of Natural Resources and Environmental Control		**X**	**X**
San Pedro Bay/Port of Los Angeles	LA District	**X**	**X**	**X**
San Juan Bays Estuaries	Jacksonville District	**X**	**X**	**X**
Passaic River Flood Tunnel Diversion Study	New York District		**X**	**X**
New York Harbor DMMP	New York District	**X**	**X**	**X**
Pascagoula Channel Deepening	Mobile District	**X**	**X**	**X**
Gulfport Channel Deepening	Mobile District	**X**	**X**	**X**
Lake Washington Water Quality Modeling Study	King County, WA		**X**	**X**
St.Johns River, FL	St. John's River Management District			**X**

The regional and local HM and WQ grids will be developed, linked, and tested. The regional grid will be calibrated to available water-surface and current measurements. The need to include the Chesapeake Bay or represent it as a water body will be assessed at this time. The tide and current boundaries developed for the local CH3D grid using the ADCIRC-CH3D boundary linkage routines will be tested via comparison with measured water-surface elevations and currents. The CH3D-ICM linkage will be validated via volume and mass conservation tests. A series of simulations utilizing the entire modeling suite will be performed. These tests will investigate the flushing characteristics of Currituck Sound as a function of tidal, atmospheric and freshwater discharge forcing. Finally, preliminary results of the model tests, including recommendations for modification of the ongoing data acquisition effort, will be provided to the Currituck Sound Study working groups via a letter report.

The modeling suite will be calibrated and verified utilizing existing field measurements and those collected during the course of the study. Baseline hydrodynamic and water

quality conditions will be developed, from which scenarios can be defined to address future modification to hydrology, hydrodynamics and water quality of the Sound for purposes of developing restoration alternatives. In addition, the impact of sediment re-suspension and suspended solid concentrations on light attenuation within Currituck Sound will be investigated. The complete model suite, as a predictive tool for evaluating the response of the ecosystem to restoration alternatives, will be applied to two, or perhaps three, mitigation scenarios. Model results will be provided to the various working groups and a Task 2 letter report prepared.

Project management and coordination will be maintained throughout the modeling study for purposes of providing information required by all of the working groups. Representatives of the modeling team will meet with the District and involved working groups as needed. A final report including the results of the present study, working group recommendations and an assessment of future modeling efforts will be prepared.
In particular, the option and cost associated with 1) performing additional restoration scenarios in concert with the living resources working groups and 2) delivery of the modeling suite to the District or an allied agency with the necessary training will be discussed.

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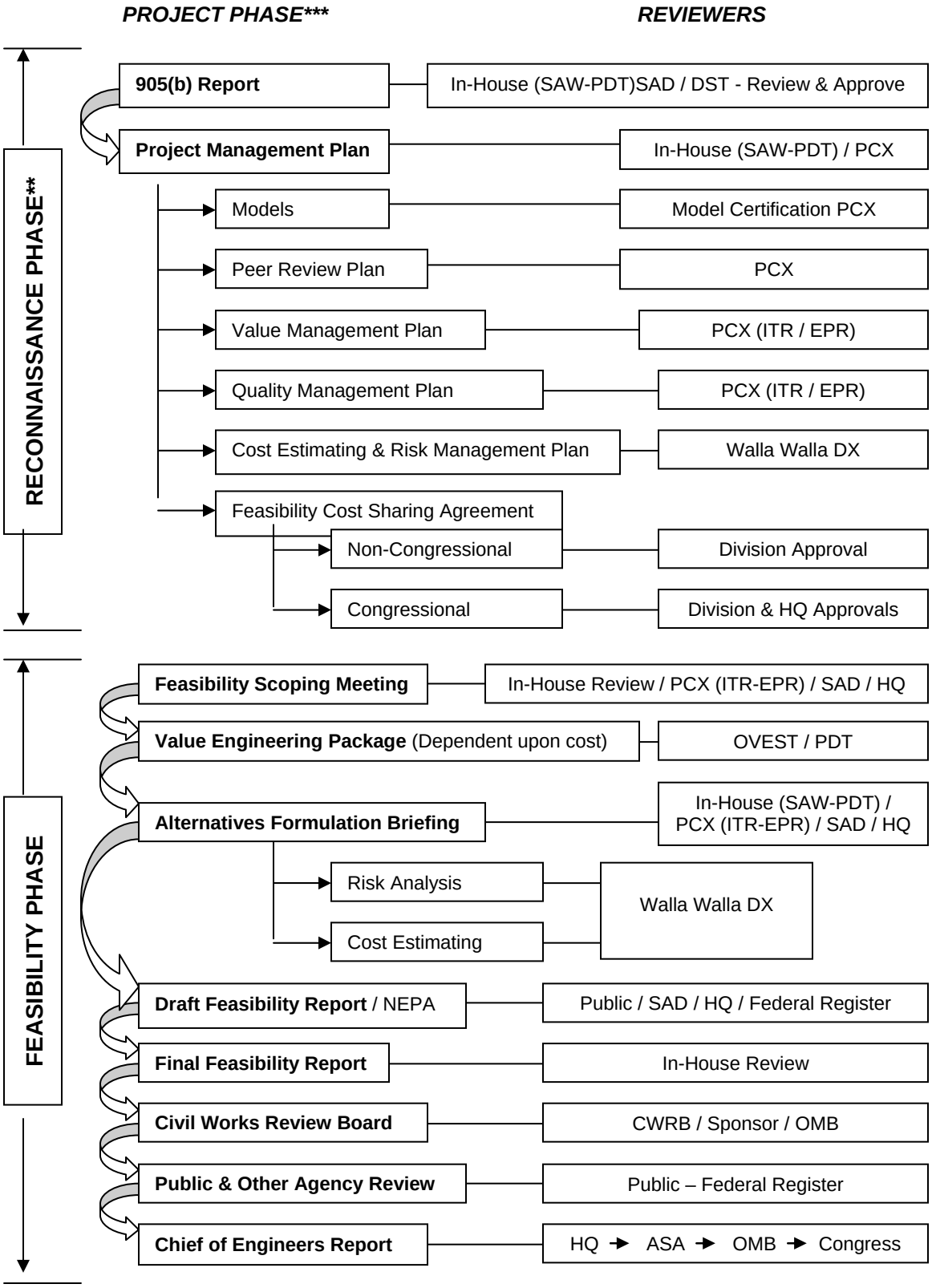
ATTACHMENT 2

PEER REVIEW PLAN

PEER REVIEW PLAN*



***** Reference External Peer Review Decision Checklist in Section b., questions 1 - 5: if any changes occur in checklisted items, the vertical team will determine if External Peer Review (EPR) will be required. A decision regarding EPR is requested in writing from SAD and HQ Regional Integration Team Leader (RIT).

**A Scoping Letter during the Reconnaissance Phase provides the Public the opportunity to share any known concerns.

***The Project Delivery Team (PDT) includes the non-Federal Sponsor, stakeholders, and resource agencies.