Caroline County
Board of Supervisors Agenda
Executive Summary

Meeting Date: **March 8, 2022**

Title: **New Business – Approval of Task Contract for Hydrodynamic Model Recommendation (Rappahannock River Water Intake Permit)**

(Check Mark)

____	Consent	____	Closed Meeting
x	Action	____	Public Hearing
____	No Action (Information Only)	____	Ordinance
____	Resolution	____	PowerPoint Presentation

Summary: As indicated in the attached memorandum from Director of Public Works/Utilities Joseph Schiebel, staff and the County's environmental engineering consultant (Hazen and Sawyer) have concluded that it is necessary to conduct a hydrodynamic model study to evaluate potential impacts to aquatic resources as part of the County's application for a surface water intake permit from the Rappahannock River.

The Virginia Institute of Marine Science (VIMS), an organization that recently performed similar studies on behalf of Prince George County and Chesterfield County, will complete the study for Caroline instead of Hazen and Sawyer. VIMS appears to have the full confidence of the Virginia Marine Resources Commission (VMRC), the state agency charged with approving the County's Joint Permit Application for a surface water intake permit from the Rappahannock.

More detail is included in Mr. Schiebel's memorandum and accompanying attachments.

Budget Impact: The cost of the study is $72,708. The proposed source of funds is the FY 2021/2022 Undesignated General Fund Balance.

Requested Action from Board of Supervisors: 1) approve attached task contract with Virginia Institute of Marine Science (VIMS); and 2) authorize appropriation from the FY 2021/2022 Undesignated General Fund Balance to the FY 2021/22 Utility Fund for this purpose.

County of Caroline
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Public Works/Utilities
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MEMORANDUM

Caroline County, VA
All-America City
2009

To: Charles M. Culley Jr.
County Administrator

From: Joseph C. Schiebel
Director of Public Works/Utilities

Date: March 2, 2022

SUBJECT: Task Contract – Three-dimensional Particle Tracking Hydrodynamic Model Study - Rappahannock River Intake

The Joint Permit Application (JPA) for the Rappahannock River withdrawal was submitted to DEQ on March 24, 2020. As part of this process, the Virginia Marine Resource Commission (VMRC) reviewed our application and has requested that the County complete a three-dimensional partial tracking hydrodynamic model study to evaluate potential impacts to the aquatic resources based on their consultation with the Virginia Institute of Marine Science (VIMS).

VIMS has recently performed similar intake modeling studies for Prince George County and is in the process of doing one for Chesterfield County. So while we have raised reasonable concerns with the hydrodynamic model, there is now a precedent for this modeling approach on similar intake projects.

Staff now believes that this model study is an implied regulatory requirement at this time and leaves us with no choice but to proceed with the modeling as requested by VMRC to secure our permit. Accordingly, VIMS has provided a proposal to perform the hydrodynamic model, which will provide the information requested by VMRC.

Therefore, staff recommends that the Board of Supervisors approve the proposal for the Hydrodynamic model by VIMS and appropriate $72,708. from the unencumbered fund balance for the payment of this study.

Attached:

VIMS Proposal
Recommendation Letter from Hazen & Sawyer

Hazen
Hazen and Sawyer
1555 Roseneath Road
Richmond, VA 23233

February 7, 2022

Joseph C. Schiebel
Director, Department of Public Utilities/Works
Caroline County
12613 Mill Creek Road
Ruther Glen, VA

Re: Rappahannock River Water Supply Project – Hydrodynamic Model Recommendation

Dear Mr. Schiebel:

Caroline County is pursuing a new surface water intake to withdraw water from the Rappahannock River to provide public water supply for the County and its local partners. The water supply project will reduce future groundwater withdrawals and meet the County's long-term water supply planning needs to support continued growth in the County.

Permit approval from multiple state and federal agencies is needed to authorize construction of a river intake in the Rappahannock River. To obtain regulatory approval for the project, a Joint Permit Application (JPA) was prepared and submitted to the Virginia Marine Resources Commission (VMRC). Consistent with recommendations from prior research and the design of prior river intakes in Virginia, the proposed river intake includes a protective screen design intended to minimize impacts to fisheries and aquatic resources.

In their response to the JPA, VMRC requested that the County complete a three-dimensional particle-tracking hydrodynamic model study to evaluate potential impacts to aquatic resources based on consultation with the Virginia Institute of Marine Science (VIMS). VIMS has recently performed similar intake modeling studies on behalf of Prince George County and Chesterfield County. While we have raised reasonable concerns with VMRC and VIMS about the need for a hydrodynamic model, there appears to be a precedent for this modeling approach on similar intakes, and the modeling study is an implied regulatory requirement at this stage.

VIMS has provided the attached proposal to perform a hydrodynamic model to provide the information requested by VMRC. It is recommended that the County proceed with the hydrodynamic model as proposed by VIMS. Hazen will continue to assist the County with regulatory coordination and review of the model by VIMS. Proceeding with the model will help support the County's goals for securing a long-term water supply source.

Sincerely,

Christopher W. Tabor, PE
Associate Vice President

Apply a Particle Tracking Model to Analyze Impacts of Water Intake on Ichthyoplankton Mortality in Tidal Freshwater Region of the Rappahannock River

A Proposal Submitted to

Hazen and Sawyer
1555 Roseneath Road, Richmond, VA 23230

by

Virginia Institute of Marine Science
School of Marine Science
William & Mary
Gloucester Point, Virginia 23062

Project Duration: April, 2022 – October, 2022

Jian Shen
Principal Investigator

Qubin Qin
Co-Principal Investigator

Troy Tuckey
Co-Principal Investigator

Courtney K. Harris, Chair
Department of Physical Sciences

Mark Luckenbach
Associate Dean of Research and Advisory Services

Connie Motley, Director
Office of Sponsored Programs

February 6, 2022

Introduction

Caroline County, Virginia, is seeking to develop a new water supply source in the upstream Rappahannock River that will include the construction of a new water intake. The currently proposed intake is sized to meet the average daily water demand of 7.9 million gallons per day (mgd) and a maximum daily demand of 13.9 mgd, based on projected water demands for the planning year 2035. The proposed intake location is approximately 30 km upstream of the Route 301 bridge over the Rappahannock River near Port Royal. The location of the water intake is influenced by tide, the impacts of the intake on the mortality of ichthyoplankton and the ecosystems in the tidal freshwater region of the Rappahannock River are not well known. Because of the interaction of tide and freshwater discharge, it creates a difficult situation for accurate analyses of environmental impacts of the intake if the impacts are only evaluated locally.

One of the key potential impacts of the intake operation on marine resources is causing an increase in the mortality of fish eggs and larvae. Because of the complex geometry and large variations of freshwater discharge in this tidal freshwater region, the tidal flow can transport ichthyoplankton back and forth and increase mortality. However, ichthyoplankton transport pathways and retention time in this region are unknown. It is unclear if ichthyoplankton spawned in this freshwater region will be affected by the intake. To provide sound scientific-based information for the environmental assessment, a numerical modeling approach can be used to simulate ichthyoplankton dispersion and changes in mortality caused by the intake.

The Virginia Institute of Marine Science (VIMS) will support Caroline County in conducting the modeling study. We propose to develop a fine-resolution model to simulate tidal flow and larval transport processes. With the use of the model, the changes in hydrodynamic conditions in terms of currents and water exchange can be evaluated, which will provide good information for understanding the impacts of intake on the ecosystems of the adjacent region and ichthyoplankton transport. **We will use a particle tracking model to simulate the movement of fish eggs and larvae and to accurately evaluate probabilistic increases of mortality due to the intake under different hydrological conditions**. The model results can provide information for an accurate risk assessment.

Approaches

1. Hydrodynamic Model Development

As no available model is suitable for this study, we are planning to develop a fine-resolution model for this region. We will use the numerical model to analyze the impacts of the intake under different hydrological conditions (e.g., high flow vs. low flow) during fish spawning periods assumed to occur in the region. Although the intake is located in the tidal freshwater region, it is influenced by the tide. Tide variation along the river depends on the tide propagation from the River mouth and tidal refraction due to the length of the river and depth. To accurately simulate the tide and tidal induced transport in the model domain, the model needs to include the entire Rappahannock River. Therefore, the tide and salinity boundary conditions can be provided, which are available at the mouth, and tide characteristic and salinity data along the river can be used for the model calibration. We plan to apply the SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model) model to the Rappahannock River. SCHISM uses a semi-implicit time-stepping scheme applied in a hybrid finite-element and finite-volume framework to solve Navier-Stokes equations and uses a Eulerian-Lagrangian method to treat the momentum advection. In the vertical dimension, the model uses a highly flexible and efficient hybrid coordinate system (Zhang et al., 2015). This model has been applied to the James River and Chesapeake Bay (Liu et al., 2018). An example of the model grid is shown in Figure 1. It can be seen that a model grid with very high resolution can be placed in the area of interest. The unstructured grid model is flexible and is capable of simulating complex changes in geometry with 5-10 m resolution. We are planning to use the SCHISM model as the baseline model, and fine grids will be placed in the intake region so that the construction structure of the intake can be directly represented by the model grid. The model will be forced by real freshwater, tide, salinity, and wind, and will be calibrated for surface elevation and salinity.

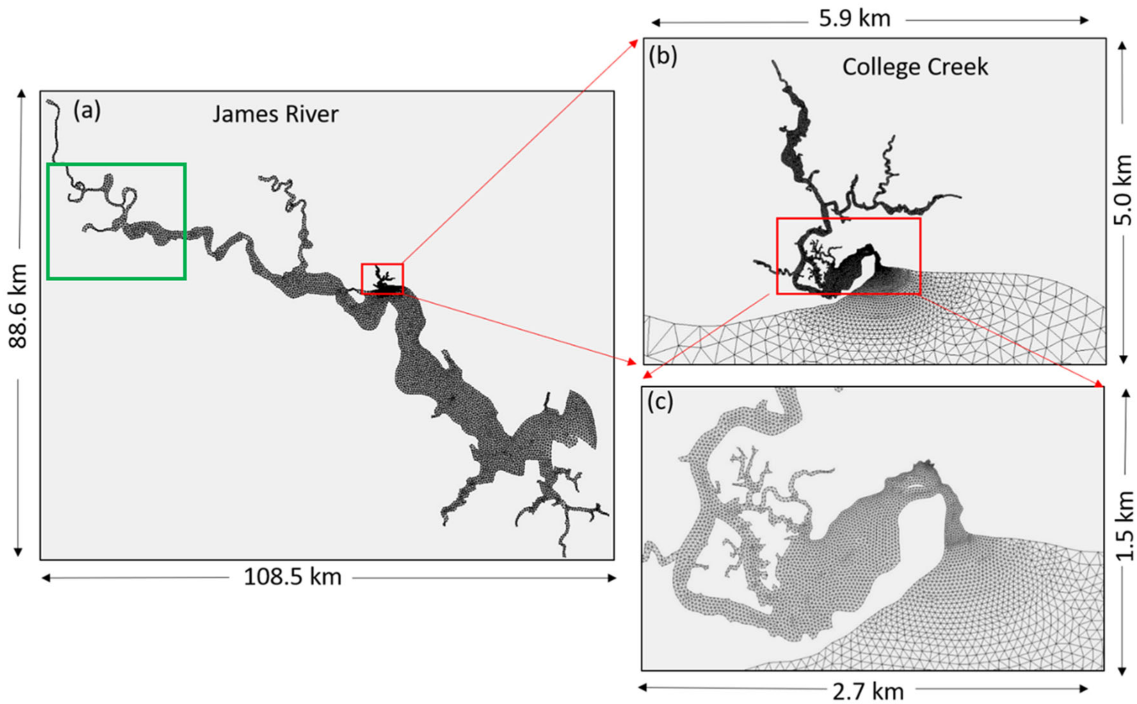

Figure 1. The James River model grid with high resolution near the vicinity of College Creek (Green box indicates the area that needs model grid refinement).

2. *Particle Tracking Model*

We have developed a particle tracking model to simulate the transport of fish eggs and larvae. The Particle Tracking Model (PTM) is a Lagrangian particle tracker designed to allow the user to simulate particle transport processes. The model has been successfully applied to the freshwater region of the James River to study the impact of intake on fish eggs and larvae. The model includes the algorithms that appropriately represent transport, settling, mixing, and behavior (swimming and settling) processes. Each particle is used to represent an individual or a cluster of ichthyoplankton. Different densities and mortality rates of eggs and larvae of different species can be added to the model to simulate physical and biological behaviors. Multiple scenarios of particles representing ichthyoplankton will be conducted from different locations at different times corresponding to different freshwater discharge conditions. The percentage of mortality of ichthyoplankton can be estimated.

Near an intake, flows are typically complex, having high swirl levels and vortices because of water pumping. We will place high resolution model grids near the intake to simulate complex flow near the intake. The structure of the intake construction, such as the intake outlet and temporal Coffer Dam, can be directly represented by the model grid with a size of about 1-5 m. Mortality due to the intake can be better simulated using the high-resolution model.

3. *Data Analysis and Scenario Design*

VIMS scientists have conducted data analysis for Virginia tributaries. Fish community data from the VIMS Striped Bass Seine Survey (seine survey, hereafter) will be used to characterize fish species in Chesapeake Bay river systems. The seine survey has been conducted since 1965, though the time series for this analysis was restricted to more recent years as the abundance of fishes in Chesapeake Bay river systems has changed over time (e.g., a decline of American shad). We will use the available data over the most recent 20 years (1999 – 2018) for this study. The possible concentration and density of larvae will also be empirically estimated. We will determine release locations and design simulation scenarios for review. We will communicate with scientific advisors to the County to discuss these proposed simulation scenarios before running simulations during the course of the project, and will use inputs from scientific advisors to the County to revise and finalize simulation experiments. Each scenario will target a specific location or multiple locations of release under a specific hydrological condition.

4. *Model Result Analysis*

We will analyze changes in hydrodynamic conditions and mortalities of egg and larval stages due to the intake. Changes in hydrodynamics will be analyzed by comparing changes in currents in the area adjacent to the intake. The impacts of the intake on transport and mortality of fish eggs/larvae will be conducted based on particle tracking model results. Each particle is used to represent a certain number of fish eggs/larvae in the estuary. By releasing particles at different locations during spawning periods and by tracking the movement of these particles, transport of fish eggs or larvae and percent increases in mortality due to the intake will be estimated. A number of scenarios will be conducted for the intake impacts under different hydrological conditions. By analyzing model results under these different hydrological conditions, the theoretical impacts of the intake on the marine resource and environment can be evaluated.

Scope of Work

1. Develop a numerical model and modify the model algorithm of particle tracking

   This project will develop a new unstructured grid model for the Rappahannock River with high resolution. The model grid will include the entire Rappahannock River with a focus on the tidal freshwater region so that tide and estuarine circulation that is caused by interactions of the tide, freshwater discharge, and salinity can be well simulated. The model will be forced by tide and salinity at the mouth of the Rappahannock River, USGS flow at the headwater of the River, as well as surface wind. The model grid will follow the geometry of the river. The resolution of the grid will be sufficiently fine to represent the structure of the intake so that mortality due to the intake can be directly simulated. As there are no available data on the currents, the model will be calibrated for tide and salinity at NOAA and DEQ monthly monitoring stations.

A project meeting will be held to report the model setup, assumptions, and data used for model calibration. County scientists and their advisors will review and discuss in detail and provide comments and suggestions for the model setup. VIMS and County scientists and their advisors will come to an agreement on the modeling approach. VIMS will revise the model setup accordingly and start the model development after the meeting.

<u>Estimated work load: 40%</u>

2. Conduct particle tracking simulation

The calibrated high-resolution model will be used to represent the intake location within the water column and to simulate fish eggs/larvae transport and direct withdrawal from the river. We have successfully applied models to study the impact of intake on ichthyoplankton at James River for both counties of Prince George and Chesterfield. We will use the same scenarios for this study. The flow period will be determined based on the analysis of flow data to determine low flow, mean flow, and high flow. The maximum daily demand of 13.9 mgd will be applied for model scenario simulations. We propose the following described below to be simulated (note that dates for simulation will be revised based on the results of flow analysis):

<u>Scenario 1:</u> about 10,000 (or more, depends on the revised model grid) passive particles are released around the intake on 4/11/2017;

<u>Scenario 2:</u> about 10,000 passive particles are released upstream of the intake on 4/11/2017;

<u>Scenario 3:</u> about 10,000 passive particles are released downstream of the intake, but still in the Rappahannock River on 4/11/2017;

<u>Scenario 4:</u> about 10,000 passive particles are released continuously at the head of the Rappahannock River of the model grid over a period of 21 days (4/11/2017-5/1/2017), and the daily release number is proportional to the freshwater discharge of the Rappahannock River.

To evaluate flow effort, we will also conduct scenarios as follows:

Scenario 5: One-time release during high flow (release location will be around the intake)

Scenario 6: One-time release during low flow (release location will be around the intake)

Scenario 7: One-time release during high flow (release location will be upstream of the intake)

Scenario 8: One-time release during low flow (release location will be upstream of the intake)

Scenario 9: One-time release during high flow (release location will be downstream of the intake)

Scenario 10: One-time release during low flow (release location will be downstream of the intake)

Scenario 11: Continuously release during high flow (release location will be at the head the Rappahannock River of the model grid)

Scenario 12: Continuously release during low flow (release location will be at the head the Rappahannock River of the model grid)

Besides, additional scenarios will be conducted for fish ichthyoplankton. The vertical velocity and swimming velocity will be varied for the simulations based on Table 1. The behaviors represent the characteristics of the fish ichthyoplankton in the James-Appomattox River system.

Table 1. Particles, vertical velocity, and the representatives.

Particle	**Vertical velocity (cm/s)**	**Representative**
Passive	0	Neutrally buoyant eggs
Active	-1	Demersal eggs
Active	-0.3	Demersal eggs
Active	-0.1	Demersal eggs
Active	-0.01	Demersal eggs
Active	-0.001	Demersal eggs
Active	1	Larvae
Active	10	Larvae

In previous projects for the James-Appomattox River system, we have conducted several test runs by releasing 100,000 particles for evaluation, the results are almost identical to those using proposed particles in terms of percentage of mortality. Using fewer particles will greatly speed the model simulation given a short period for the project.

<u>Estimated work load: 40%</u>

3. Analyze model results and prepare the model report

The morality for each scenario will be estimated for the intake. These results will be compared to the results without intake and different scenarios. Detailed model set-up will be provided and model results will be analyzed and presented in the report. We will present our findings to the County and scientific advisors in the County. After receiving feedback and comments, we will finalize the report including all detailed processes for the modeling exercise.

Estimated work load: 20%

Required data and information

Some of the basic data are needed from the County for the model development:

1. Details of the construction of the intake (location, size, shape, etc.). We prefer GIS shape file;
2. The County has a bathymetric survey in the vicinity of the proposed intake with resolution about 2200 feet along the river and 50-foot cross-section intervals. This data set (or other available bathymetric survey) can be used for representing the bathymetry in the vicinity of the proposed intake
3. Pumping rates and operation methods;
4. Any additional information that may be useful for this project.

Budget

A 5-weeks is budgeted for a faculty member at VIMS to oversee the project, work on the methodology, develop the Rappahannock River model, analyze the model results, and prepare the model report. A two-and half month time is allocated for a Research Scientist to develop and calibrate the model, conduct the scenario simulations, analyze the results, and prepare the report. A half-month time is allocated for a faculty member in the fisheries department at VIMS to conduct the background study, provide the background information, design the model simulation scenarios, and review the model results. A $300 is budget to travel to the Rappahannock River as site investigation before generate model grids.

An estimation of total budget is $72,708 including $34,686 for personnel costs, $13,874 (40.0%) for fringe benefits, and $23,448 (47.6%) for facilities and administrative costs. We budgeted $500 for computer supplies to archive data and $200 for travel to survey the intake site.

Schedule and deliverable

We are currently working on model simulations for Chesterfield County and HRSD. We plan to start this modeling project in April.

Tasks 1: April - June
Tasks 2: June - July
Tasks 3: August - October

We plan to discuss model set-up and scenario simulations with county scientists in June. We will present results to county scientists in August and prepare and submit report in before middle of September. We will revise report to address comments in October.

References

Liu, Z, Zhang, Y.J., Wang, H., Huang, H., Wang, Z., Ye. F., Sisson, M., 2018. Impact of small-scale structures on estuarine circulation. Ocean Dynamics, 68: 509-533.

Varnell, L.M., D.A. Evans, D.M. Bilkovic, and J.E. Olney, 2008. Estuarine surface water allocation: a case study on the interactive role of science in support of management. Environmental Science & Policy 11, 602-612.

Zhang, Y.J., Ateljevich, E., Yu, H.C., Wu, C.H. and Jason, C.S., 2015. A new vertical coordinate system for a 3D unstructured-grid model. Ocean Modelling, 85: 16-31.