FFMP 2017 Salinity Study

April 30, 2020

The purpose of this document is to provide more detailed information on the Salinity Study that was identified in the 2017 Flexible Flow Management Program (FFMP2017). It is not meant to define, change, add, subtract or limit any part of the FFMP 2017 agreement.

Introduction

The management of flow of the Delaware River has evolved over time to address changing environmental values and management priorities over the last 35 years. On October 21, 2017, the Parties to the 1954 Supreme Court Decree (Delaware, New Jersey, New York, New York City, and Pennsylvania) (Decree Parties) entered into an agreement, the 2017 Flexible Flow Management Program (FFMP2017). FFMP2017 is a two-part, ten-year agreement, which builds on the experience gained over 10 years of similar programs. During the first five years, the Decree Parties agreed to study and investigate different aspects of the FFMP2017, assess their effectiveness, impacts and benefits under current and future stressors, and evaluate alternatives for achieving the program's goals and objectives.

Sections IV.2 and IV.3 of FFMP2017 focus on three major issues: 1) detaching releases from the New York City Delaware Reservoirs from the position of the salt front during drought emergency; 2) increasing New Jersey's Diversion during all drought conditions; and 3) increasing or optimizing lower basin storage for flow augmentation (i.e., alternate operations, structural modifications, new infrastructure). These three studies will be evaluated in relation to estuary salinity, aquatic and fishery resources, water-supply availability for multiple purposes, flood mitigation, and projections of future sea level rise as well as topics identified in Section IV.6. A variety of alternatives under scenarios of current and future environmental conditions will be tested through modeling and may include sea level rise and long-term trends in climate and hydrology. Specific scenarios will be developed in separate scopes of work for each study.

Opportunities for stakeholder/public involvement and input will be provided through the Delaware River Basin Commission (DRBC) Regulated Flows Advisory Committee (RFAC) and through individual Decree Party forums.

Purpose and Scope

The purpose of this study is to evaluate the impacts and conditions resulting from "detachment of releases from the New York City Delaware Reservoirs from the position of the salt front during drought emergency and to replace the benefit that New York City releases have with respect to the salt front with an alternative methodology or methodologies that will provide comparable protection for existing resources within the Basin" (Section IV.3.a.i, FFMP2017).

In 1982 The Interstate Water Management Recommendations of the Parties to the U. S. Supreme Court Decree of 1954 to the Delaware River Basin Commission pursuant to

Commission Resolution 78-20, also known as the Good Faith Agreement or Good Faith, established a salinity vernier, attached to the location of the salt front, using minimum flow objectives for the Montague and Trenton gauging stations during drought emergencies. Under the Good Faith Agreement, the City of New York is responsible for sustaining the vernier at Montague through releases from its Delaware Basin Reservoirs.

The GFA adopted a more stringent salinity standard and also contained 14 recommendations, a conservation release program, and a reservoir management program. In addition, the GFA recommended construction or modification of new and existing storage facilities, the establishment of water conservation measures, and the reduction of consumptive water use. Although the Decree specifically dealt with the New York City Reservoirs and upper-basin flows, the Good Faith Agreement included additional lower-basin flow-management concerns, particularly those related to preserving and managing fresh water inflows into the estuary. The recommendations were implemented through a series of Delaware River Basin Commission (DRBC) Dockets and modifications to the Delaware River Basin Water Code. Since adoption, the GFA has been periodically modified, including the addition of enhanced conservation releases and the establishment of a program to reduce reservoir spills. The package of GFA recommendations and subsequent modifications represented fundamental changes in how the water resources of the Delaware River were managed from the program established by the Decree.

The central features of the GFA were recommendations for the management of basin resources during normal and drought conditions and the conservation release program. The drought management plan included drought-response stages (rule curves) based upon the combined storage in the Cannonsville, Pepacton and Neversink reservoirs and associated phased reductions in compensating and conservation releases, out-of-basin diversions by New York City and New Jersey, and the flow objective at Montague. These features were accompanied by a linkage between the flow objective at Montague and the location of the salt front. A similar flow objective program was established for the Delaware River at Trenton. In addition, a complementary drought management program was established for times when combined storage in the New York City reservoirs are normal, but the lower basin is experiencing drought conditions. The basin-wide and lower-basin drought operating plans were incorporated in the Delaware River Basin Water Code. The GFA contained a suite of actions designed to address a repeat of the 1960s drought and modifications to any one feature of the water management program should consider its relationship to the others.

The Decree Parties seek to examine the foundation and efficacy of the salinity vernier as defined in the Good Faith Agreement and to identify and analyze alternatives. This study will specifically include:

- an evaluation of the salt front (its location and variability),
- impacts to the aquatic and fishery resources,
- the effect of projections of sea level rise on salinity under various conditions,
- and additional considerations as identified in Section IV.2 of the FFMP2017.

The resulting analyses and conclusions from this and the other FFMP2017 identified studies will be used to inform Decree Party negotiations for Phase II of the FFMP2017 agreement.

The following sections outline the individuals, models, and tools that are intended to be used for the salinity study and a process by which a baseline level of protection can be prescribed while alternatives can be identified and evaluated to achieve these defined objectives.

Interagency Salinity Study Team

A multidisciplinary, multiagency team has been assembled to provide objective recommendations based on sound science to the Decree Party Workgroup (DPWG). The salinity interagency team (Team) is comprised of representatives from the Delaware River Basin Commission (DRBC), Department of Energy – Los Alamos National Laboratory (DOE-Los Alamos), Office of the Delaware River Master (ODRM), US Army Corps of Engineers (USACE), and the US Geological Survey (USGS). The Team has developed tasks to accomplish the salinity study and to address questions raised by the DPWG related to this study.

The Team members include:

DRBC - Amy Shallcross - John Yagecic - Namsoo Suk - Fanghui Chen	ODRM - Kendra Russell USACE - Laura Bittner - Robert Lowinski DOE – Los Alamos - Phil Wolfram	USGS - John Warner - Tom Suro - Mark Nardi - Joe Duris - Chris Gazoorian - Heather Galbraith

Procedure

The tasks outlined below were excerpted from current studies, which are funded through a variety of sources. These current studies will be leveraged to the extent possible; however, resources are constrained by the purpose, scope and timeframe of the other works.

The DPWG questions were divided into two categories: 1) dynamics; and 2) freshwater inflow/management. The work will be accomplished by the Team using multiple tools in parallel and then integrating results through collaboration. The Team proposes to use a multi-pronged modeling approach for the scenario analyses. This will provide several benefits which include, but are not limited to:

- Informed Model Runs
    - Screening tools can inform more complex models. Scenario evaluation can be narrowed to most promising.
    - More complex models to provide scenarios information for use as inputs to PST.
- Model Verification
    - Suite of models can be used to verify results. Results can also be used to inform model parameters.

- Results availability
    - Different groups working at the same time allows preliminary results to be available sooner and groups are able to inform and advise each other.
- Coarse and Refined Outputs
    - Utilizing multiple tools and multiple complexities will result in varied outputs. These may be available at different times needed for decision makers.
- Backup Tools
    - If a tool proposed is determined to provide unacceptable results, other tools can be considered and may already be ready to use.

Tasks

Phase 1: Model and scenario development

Each model considered for use is included in the model matrix (Appendix A).

- Model development
    - Common assumptions (includes portions of DRBC TASK 4, see Appendix B for entire January, 2019 DRBC proposal):
        - The models that will be used to answer the dynamics questions and/or management questions need to have a common set of drivers/forcings and shared data. *Examples for estuary models include, but are not limited to, sea level (current and predicted); boundary conditions (salinities from the ocean, Chesapeake and Delaware Canal, and the Delaware and Schuylkill rivers - constant or time-varied); consumptive use (current or projected); hydrology (period of record, future deterministic); among many others. Examples for upstream models include, but are not limited to, changes in the source and/or timing of salinity repulsion releases.* The Team will compile *a list of drivers of the models, outline the options for different assumptions and make recommendations with supporting analyses*[1].
        - This information and recommendations will be provided to the DPWG for input and feedback. The team will work with the DPWG to build a set of assumptions that will be used in the scenarios, including information in the form of parameters, patterns, or time series to serve as inputs to the system model, PST.
    - Calibration: Preliminary Calibration/Validation; evaluate model performance.
        - All models that will be used (USGS - COAWST, DOE - MPAS-O/E3SM, DRBC - EFDC, DRBC - PST, USACE - CWMS and others) will go through a calibration and validation process and will be compared with the results of other models if needed.

[1] The italicized text in the tasks of this document is from the January, 2019 DRBC proposal (Appendix B).

        - Where possible, model outputs can be verified to ensure their applicability to the appropriate questions. Where applicable, results from different models can be compared to evaluate assumptions made.
        - Results will be shared with DPWG and feedback requested.
    - Develop and conduct sensitivity simulations and diagnostic runs as needed.
        - All models that will be used (USGS - COAWST, DOE - MPAS-O/E3SM, DRBC - EFDC, DRBC - PST, USACE - CWMS and others) will go through this process.
    - Model Refinement/Recalibration
        - All models used will go through this process.
- Metric identification (includes portions of DRBC Task 3)
    - Identify metrics that will aid decision making, based on DPWG questions, history, available studies, and recent negotiations.
    - A suite of meaningful metrics will be identified for the baseline and evaluation of alternatives and establishing program goals (e.g. number of drought days, location of salt front during a repeat of the 1960s drought, river recreational use, main stem and tributary fisheries habitat). Commissioners, Decree Parties, DPWG and stakeholders will be consulted to inform a final set of metrics. This task will be completed by DRBC with assistance from ODRM in coordination with DPWG and stakeholders.
- Flow Management Alternatives Development (includes portions of DRBC Task 5)
    - Alternatives: Develop a set of flow management alternatives with the DPWG and interested stakeholders to be simulated in the models. This will be accomplished by the DPWG, facilitated and advised by DRBC and ODRM, by holding several meetings to brainstorm ideas and then distill a list of alternatives for consideration.
        - The alternative flow management options will focus on how to maintain the current level of overall basin protection provided by the Vernier, also known as the L5 Montague Flow Objective.
        - *Ideas for alternatives will be developed to determine if the existing level of protection provided by the Montague Vernier can be replaced with new or modified operations or operational components or combinations thereof and a different L5 Montague Flow Objective, not linked with the salt front. Such operations and operational components may include, but are not limited to, 1) new flow objectives; 2) timing of releases (e.g. pulsed); 3) drought definitions; 4) NYC's and NJ's Diversion; 5) reallocation or optimization of current storage and/or additional storage; 6) ERQ[2] factors, volumes and guidelines for its use, and 7) others.*
    - Screening-level modeling
        - DRBC models, DRB-PST and DRB-PST/DYNHYD-TOXI5, will be used to assist with development and selection of alternatives and provide

[2] Calculation of the value of the ERQ is outside the scope of this study. ERQ volumes will be evaluated as agreed upon by the Decree Parties.

screening-level outputs and guide which alternatives merit further modeling by evaluating the impact of selected alternatives and/or scenarios on the Delaware River basin.

- DPWG questions anticipated to answer:
    - What is the frequency of the salt front @ certain locations (RM 110 intake, RM 98 groundwater, downstream (NJAW))?
    - How are the number of overall drought days impacted by the management change?
    - How is overall risk of drought shared among the decree parties
    - A set of metrics quantifying stresses or additional stresses applied to down basin reservoirs

- (includes portions of *DRBC Task 6) "work with DRB-PST to test model assumptions developed under Task 4 and evaluate indicator parameters and metrics for comparisons. This phase will result in the definition of baseline scenario(s) and a standard set of screening level metrics. Next, alternative program components will be identified with the DPWG, coded and tested for simulation individually and as sets. These preliminary screening level simulations will be conducted with DRB-PST and presented to the DPWG. The DPWG will then be engaged in developing groups of alternative components to simulate in the second phase. "*
- DRBC, shall coordinate with the DPWG the selection and integration into PST of screening sub-models, including but not limited to salinity, stream water temperature tools.

- Define and refine scenarios
    - The combination of alternatives plus the drivers and assumptions selected will form the scenarios.
    - An agreed upon set of scenarios will be defined and refined by the Team working in coordination with DPWG and stakeholders.
    - The number of scenarios evaluated by any of the models will be at the discretion of the team members as schedule, budget and resources allow.
    - Scenario refinement shall include delivering of corresponding input information/files that will allow the evaluation of their impact on the overall Delaware River basin as simulated using PST/screening models and in conjunction with the selected metrics.

Phase 2: Scenario Analyses

(Includes portions of DRBC Task 6)

- Dynamics questions scenario analyses
    - USGS - COAWST Scenario simulations (baseline scenarios, scientific guidance on processes evaluation)

        - DPWG questions anticipated to answer:
            - What are the main contributing factors or mechanisms that results in movement of salt front in upstream direction? How sensitive is the salt profile to fresh water releases and other controlling factors?
            - How can we rate these factors in their importance and effects? Can we rank them based on their probability of occurrence and their level of impact?
            - What is the flowrate (or minimum flow or releases) required to keep the 250 ppm salt front from extending upriver beyond the typical river mile range during months of low flow?
            - What is the longitudinal and lateral distribution of salinity along the channel width and channel depth during low flow scenarios?
            - Where is location of the salt front under sea level rise assumptions and other extreme events?
            - Water quality changes if any need to be identified
    - DOE - MPAS-O/E3SM scenario simulations (Long-term simulations, climate and coastal processes changes)
        - DPWG questions anticipated to answer:
            - Where is location of the salt front under sea level rise, extreme events, such as significant hurricanes, floods and droughts?
    - DRBC - EFDC Scenario simulations
        - DPWG questions anticipated to answer:
            - What is the longitudinal, distribution, distribution along the channel width and channel depth?
            - Where is location of the salt front under sea level rise, extreme events?
- Flow management scenario analyses
    - DRBC - EFDC Scenario simulations (Further alternatives refinement, 3d estuary impacts)
        - DPWG questions anticipated to answer:
            - What is the average location and variability of the salt front during the different seasons?
            - Where is the location and variability of the salt front under older flow management rules?
            - Where is location and variability of the salt front under current flow management rules?
            - Where is the location and variability of the salt front during drought?
            - What is the location and variability of the salt front under alternative operational scenarios
            - What is the frequency of the salt front @ certain locations (RM 110 intake, RM 98 groundwater, RM 92.2, downstream (NJAW))?

      - Are there any changes in water quality?
  - USACE - CWMS Scenario simulations (Potential for upstream or downstream impacts, changes in storage)
    - DPWG questions anticipated to answer:
      - How are the watershed, endangered species, cold and warm-water and migratory resources, and water supply users impacted by the management change?
      - Any changes in WQ, potential changes in recreational and economic
  - Delineation of ecological and other impacts of changing the volume, source and/or the timing of salinity repulsion releases through existing or new models

Phase 3: Reporting

(Includes portions of DRBC Task 7)

- Individual reports will come out by each researcher or agency as results are available and as specified through their projects and funding sources. This information will be shared through the specified channels of the initiating project. Therefore, results and work may or may not be released before Decree Party negotiations occur.
- A synthesized report or unifying document could be completed with additional resources (currently not specified). The DPWG has decided that the need and specifications of this document will be decided at a later time after results from the initial studies are available. Who will do this work and how it will be resourced will be decided at that time.

Coordination and Communication

(Includes portions of DRBC Task 1 and 2)

- Set up a common site for data and code sharing for the Team's use.
- Quarterly meetings will occur between the Team to have technical discussions and collaborate on modeling results and potential implications to other ongoing modeling efforts.
- Progress meetings with the DPWG and Team will occur at regular intervals. In addition, meetings will occur to provide an opportunity for input and feedback on items such as, but not limited to, model assumptions and alternatives development.
- Meetings with RFAC, SEF and other stakeholders will occur to present study results or to solicit public input.
- In person meetings will occur on an as needed basis.

Ecology

There were multiple ecology questions from the Decree Parties about how the current program may provide additional ecologic benefits and how potential changes to the current salinity vernier procedures could impact the current ecologic benefits. To help address these, the

DPWG agreed that a literature review should be tasked to SEF through RFAC. This will occur separately from the work listed in these tasks but coordination will occur as needed. SEF's work in this regard will not supplant the ecology related activities referred to earlier in this document.

Comparable Protection

Sections IV.2, IV.3, and IV.6 of FFMP 2017 identified the salinity study and issues for consideration; specifically, Section IV.3.a.i included language that any alternative methodology considered "will provide comparable protection to the existing resources within the Basin". Additionally, Section IV.3.b. included the requirement that any changes identified by any of the FFMP2017 studies "provide for comparable protection for existing resources and uses within the Basin to avoid significant adverse impacts". A specific definition or approach to define comparable protection was not included in the agreement. Flow management in the Delaware River Basin has evolved over the last century seeking to meet multiple objectives and balance water supply, water quality, recreation, aquatic resource, wastewater assimilation, drought management, and estuary needs, so any alternative potentially affects an array of existing and critical uses. As studies and alternatives are developed and completed additional issues may arise that require further investigations as part of this study to ensure that comparable protection is maintained.

Questions currently unanswered

Some of the questions posed by the DPWG are not currently addressed in the existing suite of models that will be used. These include: erosion, corrosion, tourism, health to humans, and desalination. For each of these there may be an opportunity to conduct literature reviews similar to what is described for ecology or to develop surrogate metrics from the existing models. This work is not currently ongoing. If it is determined to move forward, who will do this work and how it will be resourced will be decided at that time. Additional information and clarity of the question would be needed at that time as well.

Appendix A: Interagency Salinity Study Team Model Matrix

Appendix B: DRAFT DRBC proposal (December 2018)

Appendix C: Interagency Salinity Study Team Schedule

Appendix A: Interagency Salinity Study Team Model Matrix

** Columns in grey were considered but not included in modeling tasks*

Primary POC	USACE	DRBC	DRBC	USGS	LANL	USGS	USACE	USGS
Model	**HEC group/CWMS**	**DYNHYD/TOXI5 Linked with DRB-PST**	**EFDC-Fine-Grid**	**COAWST**	**Los Alamos Model for Prediction Across Scales Ocean (MPAS-O)**	**WATER**	**CH3Dz**	**DSS**
Dimensional	1D	One dimensional (Branched around major islands)	Three-dimensional	3D	2D / 3D	1D	3D	2D flow models
Boundaries (RM extents)	Entire Basin	DYNHYD/TOXI5: RM 0 ~ 134 (i.e., mouth of Bay to head of tide). DRB-PST: Headwaters to Delaware Memorial Bridge. Combined: Headwaters to mouth of bay.	Fine grid is under development. The upstream boundary is near Trenton at RM 134 (i.e., head of tide). Open boundary downstream is extend from the mouth of Bay (i.e., RM 0) to the contential shell.	Seaward boundary is ~20 km offshore of Cape May, and extends landward through the Bay up the DE River to Trenton	Global to portion of 200m to 1km-resolvable upstream rivers depending upon scale	Entire basin - no limitation on stream size. Includes tidal areas, but with no accounting for tides.	Trenton to Atlantic Ocean C&D Canal down through Chesapeake to Annapolis, MD	East and West branches, Neversink, and Mainstem to Montegue gage
Expense	No cost for software or calibrated models. Funds would be needed to create alternatives.	$0	Being completed as part of Designated Use Study. (Wm. Penn, NJDEP, PA-pending, EPA 106 Grant, DRBC Budget). Additional funding could expedite progress.	Model has been used by researchers at WHOI, USGS, and Rutgers for process studies of waves, salt flux, and sediment transport. Expenses needed to cover modeler to run realistic scenarios and compare to observations.	High-performacne Computing code (expensive)	Model already completed as part of DRB Water Census focus area study. Equipped for climate, water use, and land-cover scenario testing. Currently requires ArcGIS 10.0, but base model is being recoded in Python. Funds would be needed to integrate with multiple HRUs.	If USACE can provide, no expense.	Expense associated with hiring a programmer to code a new module
Time to run	Less than 1 Hour	About 2-minute CPU for 1-year simulation. About 6-8 hours for **period of record** simulation with DRB-PST.	Two fine-grid models are under development. One set the downstream boundary at the mouth of the bay and will be linked to EPA WASP8 water quality model; the other fine-grid model sets the downstream open boundary 40-45 miles further on the continental shelf. It will be used for evaluating the impacts to salinity based on flow management,climate change, seal level rise, as well as for other purposes. There are vertical 8 to 10 vertical layers in the navigation channel. It is expected to take about 24-hour CPU for a one-year simulation with the model that covers part of the ocean and with a maximum of 20 vertical layers.	~3 days to run ~200x1400x16 grid for 1 year on 180 processors (supercomputer). Future runs depend on the number of vertical levels, and number of multiple processors.	days to weeks to months	~1 hr CPU for 5000 km2 basin. No reservoir regulation included - intended to be used with DRBCs reservoir management system.	Several Hours to do a Yearly Simulation. Tested at 14 hours to run 18 months simulation	Defaults are hard-coded and require no additional run time; new models take ~15 min per species of interest
Availability	Available	Now	Fine grid model is under development. We may include and refine the grids that cover floodplain (marsh areas) areas. This may be important when evaluating the impact due to sea level rise in the future.	code is open source. Application specific grid and forcings are avaialble, but need time to be evaluated more closely.	open source	Database and model available from Science Base. Docmented in1 OFR, 1 SIR, Climate Science, and Hydrological Processes.	Evaluating availability from USACE	Open source
Data input needed	Gridded Precip for entire DRB, Snowmelt data, Riverine Flows, Reservoir Operations, Soil Infiltration	Bathymetry, water surface elevations at open boundary (Bay mouth and C&D canal at Chesapeake City), freshwaterinflows/withdraws (including 22 tributaries, about 70 municipal and industrial dischargers, and 8 intakes).	Bathymetry; water surface elevations at two open boundaries (The first open boundary located either at the mouth of the bay or on the continental shelf about 40 to 45 miles from the mouth of the bay and second open boundary is C&D canal at Chesapeake City); freshwater inflows/withdraws (including 31 major tributaries, 71 major municipal and industrial dischargers, and 8 major intakes); salinity and water temperature (as initial and boundary conditions); weather conditions (including wind speed and direction, solar radiation, humidity, cloud cover, air pressure, air temperature, precipitation, and evaporation).	Needs bathymetry (from NCEI or CONED). Needs river flow at Trenton, flows (or tide) at CD canal. Surface: wind and heat fluxes, Patm, Evap, Precip, RH, and cloud cover (get this from NAM). At offshore needs: tides, surge level, salt, temp (from ADCIRC and HYCOM).	Inland forcing (river flows with salinity and temperature); ocean-mouth forcing (tides, salinity, stratification, huricanne wind / pressure forcing); in-domain information (accurate bathymetry and vegetation datasets to assess variable bottom drag, meterological forcing of heating / precip / wind over the estuary)	Database published in Science Base - includes historical precipitation and temperature record for 1980-2011. An older data record has been estimated for DRBC, to include historical drought and pluvial decades. Climate change factors and land-use forecasts included in database for 2030 and 2060 - also in Science Base. Drivers include 1-km resolution DayMet daily precip and temperature, sampled by approximate 10-km2 areas. Other physiographic data include 10-m rasters of topographic wetness interval, SSURGO soils, and land cover data which are sampled by hydrologic response unit for individual simulations.	Bathymetry, freshwater inflows from tributaries, water withdrawals, point source discharges into river, background salinity, water temperature, tidal water levels at mouth of Delaware Bay and Chesapeake at Annapolis, surface wind speed and direction for entire grid domain, surface heat exchange between water and air	OASIS model, modelled depth and velocity data, climate data (once we get the temperature model coded back into the DSS), habitat suitability criteria for key species

Appendix A: Interagency Salinity Study Team Model Matrix

***** *Columns in grey were considered but not included in modeling tasks*

Is data input available?	Yes	Yes	Yes. Currently, we are using data from five weather station for the entire model domain and may consider using multiple weather stations. Extension of model domain into Atlantic Ocean is under consideration for ocean boundary salinity.	Yes, data can come from several sources, for hindcasts or real-time.	Some for hindcasts but future inputs are derived from E3SM climate model	yes	Yes	Yes
Outputs (spatial component)	Streamflows, water surface elevations, velocities	DYNHYD simulaties water surface elevation, current velocity, and flow. Toxi5 simulates Chlorides	Water surface elevation, current velocity, salinity, water temperature, bed shear stress, flow rate and associated fluxes.	water levels, and 3D gridded fields of velocities, salitnity, temperature, sediment, flows, ..	water levels, salinity, 3D velocity	Streamflow and water budget	Computed tides & salinity at specified output grid cell locations	Potentially available habitat for key species: currently depth and velocity with temperature models built but still needing to be incorporated into the DSS
Timestep	1 Hour	30 seconds for DYNHYD and 15 minutes for TOXI5. Communication with DRB-PST is based on daily averaged output and accessed every time step for the Vernier	~10 seconds.	~ 10 sec	10 s to 10 min	Hourly, but reports daily. Daily precipitation is randomly distributed as hourly, with a set seed.	1 Minute	daily
Finite element/finite difference	N/A	Finite difference	Finite difference	Finite difference	finite volume / mimetic finite difference	NA	Finite Difference	???
Grid spacing	N/A	1 - 24 km	In the fine-grid model, main stem grid cells range from finer (on the order of 60 x 350 m) at the head of tide to coarser (on the order of 3500 x 3300 m) at the Bay mouth, with an average of 770 x 1100 m; In the area of interest for the Decree Party (i.e., RM 70 - 110), main stem grid cells range from 90 x 340 m to 510 x 1230 m, with an average of 220 x 660 m.	Varies along the domain. Cross bay ~300m and reduces to ~40m in river. Along channel ~400m in bay and reduces to ~100 in river. Grid is 184 (x-dir) and 1379 cells (y-dir) and between 8 and 20 vertical levels	200 m / 1km to 300 km (coastal to global); climate simulations will only support 1km finest resolution with huricanne simulations supporting O(100m) resolution	NA	Varies 34,524 cells in 3D grid	1 m2
Estuary/Riverine Environment	Primarily riverine but models include tidal estuary down to Reedy Point	For estuary	Estuary and tidal-influenced river environment.	more estuarine and tidal river.	estuarine + large rivers	Tidal areas included, but no tidal influences incorporated	Estuary but uses riverine inputs	Currently riverine, but could potentially be adapted to estuarine
What is it currently used for?	Assist COE with water control management decisions at their 5 reservoir projects in DRB	PCB TMDL, Spill impact assessment. Linked with DRB-PST model for flow management program assessments	Dissolved Oxygen (DO) standard revisement and waste load allocation.	DE Bay applications are to study waves, momentum balance in the bay, and salt fluxes in the bay.	DOE cliamte modeling; research	DRBC using to plan infrastructure and water allocations	Assess saltwater intrusion and hydrodynamics of the Delaware in response to the Delaware Deepening Project	Determine how different flow management strategies influence available habitat for key recreational and imperiled species
Wet and dry capability	No	No.	Yes	yes	in progress	no	No	If I'm understanding what this is referring to, it's only for instream modelling (not floodplain)
Bathymetry utlized (year)	Varies by location. Bathymetry for estuary portion from the DEMs developed for the 2011 FEMA storm surge model	Bathymetry in Zone 2 ~ 5 (RM 48 ~ 134) was based on USACE survey data collected in late 1980s and early 1990s. Bathymetry in Zone 6 (RM 0 ~ 48) was based on a Digital Elevation Model (DEM) developed by National Ocean Service (NOS), which was derived from 17 surveys conducted from 1945 to 1993.	Bathymetry is based on a Digital Elevation Model (DEM) developed by USACS in 2011, which covers the entire Delaware River and Chesapeake Bay watershed and their adjacent coastal area. Topographic and bathymetric data in the DEM were obtained from numerous sources, including: the USGS National Elevation Data (NED); the NOAA National Ocean Service (NOS), Office of Coast Survey (OCS), and National Geophysical Data Center (NGDC); the USACE; and the individual states. Navigation channel dredging (i.e., deepen from 40 ft to 45 ft) is incorporated. The water depth in C&D canal is set to be 35 feet below MLLW.	not sure, but can be updated easily. Think it is from here: https://www.ngdc.noaa.gov/mgg/bathymetry/estuarine/	SRTM / CONED	No	1996	2005 and 2010 with existing bathymetric lidar flown for entire mainstem
Datum used	NAVD88	Data were based on NGVD 1929. NOS-DEM was based on the Mean Low Water (MLW). Model datum was NGVD 1929.	NAVD 1988	your choice	derived from bathymetry datasets used	NAVD88	NGVD29	UTM Zone 18N NAD83 CORS96 GEOID09

Appendix A: Interagency Salinity Study Team Model Matrix

***** *Columns in grey were considered but not included in modeling tasks*

Is the C&D canal incorporated? What point source discharge and withdrawals are incorporated?	No C&D, no point source discharges or withdrawals	C&D canal is incorporated and ends at Chesapeake City. About 70 municipal and industrial dischargers and 8 withdrawls are incorporated.	C&D canal is incorporated and ends at Chesapeake City. 71 major municipal and industrial dischargers and 8 major withdrawls are incorporated.	A lateral point source. Other point sources include DE River at Trenton. Could include some other major tributaries to DE River.	No plan to do so given the finest resolution for short time scale scenarios planned; although in fully coupled climate mode it could be incorporated via the river model and water management operations (not currently done)	if it was in the Water Census water use database.	Yes, 58 point source discharges & the 3 Philly Water Withdrawal Locations (same as DRBC's DYNHYD5 Model	No
What calibration has been done? Has any been completed using data/dye studies near Ben Franklin Bridge?	Calibration of streamflow and river water levels from USGS/NOAA gages for the Aug 1955, Jan 1996, Mar-Apr 2005, June 2006, Aug-Sep 2011 events is completed. Calibration of streamflow from USGS/NOAA gages for time periods that include high and lows flows (2016, 1997-2002, 1983-1985, and 1963 to 1965) is ongoing.	Calibration was condcuted using the measured water surface elevations at 11 NOAA stations and ADCP-current data collected at 11 transects for the period of September 2001- March 2003. Dye studies conducted by Philadelphia Water Department in August 2014 near Ben Franklin Bridge is after the DYNHYD model development task and thus not yet incorporated. Toxi5 was calibrated wtih 2001-2003 data and 1965 data.	Fine-grid model is under development and will go through similar calibration and validation processes as the coarse-grid model.	Calibration based on 2017-2019 observations. Working on 2011. Work is focused on wave dynamics in Bay. Waves were found to be an important process to get mass flux into the Bay.	This is in progress: only tidal stage has been used so far although a more complete suite of NOAA and USGS data for validation needs to be used.	used streamflow at 58 USGS gaged sites for 2001-2010; regional calibration of ten Hydrologic Response Unit parameters - not basin specific.	Hydrodynamics (Tides) & Specific Conductance, 2001-2003 & 1965, Not based on dye studies. Based upon NOAA tide stations & Continueous USGS Specific Conductance WQ Stations	Some pieces of the DSS have been validated, some are currently being validated, and others, no.
What other water quality parameters are included?	No WQ parameters	DYNHYD itself does not include any water quality parameter, but was linked to the EPA-TOXI5 model to simulate volatile organic compounds (1998) chloride (1998, 2003) and PCBs (2003, 2006, 2010). Also applied for Athos oil spill, vinyl chloride spill events.	EFDC includes its own water quality module. DRBC is using a separate water quality model (i.e., EPA-WASP8) for modeling the eutrophication processes. Water quality parameters in WASP8 includes, but not limited to, CBODu, NH4, NO3, DON, PON, PO4, DOP, POP, DO, and algae.	Could include sediment dynamics and vegetation in present COAWST framework. ROMS has several water quality models for NPZD, and we have linked output to be used by WASP.	salinity and temperature for now; sediment transport is planned	none	None	In the process of linking temp to DSS and ecosystem services in biofiltration
How frequently has the model been run? How much has it been utilized in DRB?	Developed end of 2017, enhancements being added in 2020	It is being used for the waste load allocation related to the PCB TMDL for the Delaware River estuary (both Phase 1 and 2).	The fine-grid model is under development and will be utilized to revise DO standard and waste load allocation in the Delaware River estuary (regulatory purposes for DE, NJ, PA) and assess SLR impacts to salinity/chlorides (Water Supply Planning - 2060).	many users globally, NOAA ports daily, several case studies (whoi, ruters, etc). Don't think DRBC has used it.	coastal applications relatively new (over last several years)	used by DRBC. Used in coordination with SUNY and National Park Service. Used to look at projected changes in water budget and streamflow changes as a function of forecasted land cover	Infrequent last used in 2013 for DRBC/COE Study	Run many times in the DE (in fact, was designed specifically for the DE)
Can this account for sea level rise? If so, how?	Yes, tidal boundary at Reedy Point can be manipulated to represent an elevated stage due to increased sea level.	DYNHYD5 cannot simulate the wetting-and-drying process. By rasing bounday forcing tide alone may over-predict sea level rise impact. Model simulations may be used to develop a new flow related regression equation for DRB-PST if the Trenton Vernier (and/or Montague Vernier) are retained for future negotiations.	Yes. Rising sea level at the mouth and contential shell can be used to specify open boundary condition. EFDC has the wetting-and-drying capability to simulate water rising to (or receding from) land or marsh areas due to sea level rise, storm surge, and ebb/flood tide processes. EFDC incoporates vegetation resistance formulations to simulate flow in vegetated environments.	possibly, but need to make assumptions. Don't want to just 'fill the bathtub', but can account for elevated water levels. Will need to update grid to incorporate topography if inundation is the science question	Through offshore free surface forcing (development in progress); complete implementation in E3SM beyond scope of immediate project	includes current boundary of coastline.	Yes, change input water levels at Atlantic Ocean Boundary and Chesapeake Boundary	It currently doesn't, but it probably could?
Can this provide distribution of salinity at C&D canal, Philly, Trenton. etc?	No WQ component to it	DYNHYD was linked to the EPA-TOXI5 model to simulate salinity in the estuary.	Yes.	yes	Timeseries outputs at these locations can be added	no	Yes	In its current format no; however, new modules could be added
Has this been connected with other models?	Not models external to USACE. CWMS is a suite of HEC models including HMS, ResSim, RAS, & FIA all integrated ~~with each other~~ in a common user interface	Yes,DYNHYD5 is connected to EPA-TOXI5 and DRB-PST	EFDC hydrodynamic module has been connected to internal or external water quality and sediment transport modules/models for numerous engineering and environmental studies. It has also be connected to wave models (e.g., SWAN) to simulate wve-induced current and mixing in the near-shore area. Currently, DRBC is connecting EFDC to the EPA-WASP8 model for eutrophication/DO study.	yes - we have spent a considerable effort to develop a coupled modeling system for coastal applications that need ocean+waves+sediment. ROMS+SWAN or WaveWatch + Sediment (=WRF but not really needed here).	E3SM (which is a fully coupled earth system model that includes WaveWatchIII coupling, E3SM Atmosphere Model)	Connect with land cover forecasts (Chesapeake Bay Land Cover Model) and DRBC Planning Support Tool	No	No

Appendix A: Interagency Salinity Study Team Model Matrix

***** *Columns in grey were considered but not included in modeling tasks*

Does this extend into the trbituaries?	Yes, whole DRB is model domain including all major tributaries to Delaware	Partially. DYNHYD5 includes 22 tributary inflows. Some of the inflows were set at the confluences between the individual tributary and main stem.	Yes, the fine-grid model is extended into 31 major tributaries up to the DRBC nutrient monitoring stations or the heads of tide (approximately 1 to 5 miles).	not yet, probably not that easy to extend up small tribs. Could couple to a river model.	some partial extension into tributaries will be considered dependeing upon scale	yes - no limitation on size of tributaries. Calibration and validation included streams from 2-928 km2.	No grid does not, but flows from the largest tribs accounted for as a boundary condition	East and West branches and the Neversink
Is constituent transport include in addition to salinity?	No	No.	Yes.	yes, : temp, dye, sediment, biological tracers.	yes; tracers, BGC (needs coastal calibration)	no	No	no
Does this model include salinity? If not, is there an option to add?	No, HEC-RAS does have limited WQ capabilities that could be added, if desired ~~part of HEC-RAS component of modeling suite could be added~~	DYNHYD itself does not simulate salinity, but can be linked to another model, such as the EPA-TOXIC5 to simulate salinity.	Yes. EFDC includes salinity.	yes already there	yes	no	Yes	no, but theoretically could be added
Can impacts to fisheries and aquatic resources be quantified?	~~Not currently~~ Once calibration of low and high flows is completed, scenarios showing impacts to fisheries and aquatic resources could be possible	DYNHYD5 could be linked to the EPA water quality model (e.g., WASP) that can quantify the impacts to fisheries and aquatic resources.	EFDC water quality module or its linkage to an external water quality model (e.g., WASP8) can be used to quantified the impacts to fisheries and aquatic resources.	yes - benthic changes of sed erosion	not directly	if they can be tied to streamflow	Just salinity levels	yes
Can reservoir operations be adjusted within the model?	Yes, Reservoir Operations from the 5 COE projects and over dozen others including the 3 NYC reservoirs are included in the models	No.	EFDC can handle hydraulic control structures, such as resevior and dam operation, withdraw/return flow. Currently, DRBC-EFDC development is not intented to cover the upstream reserviors.	no	not without land coupling to hydrological / land model ATS (planned); use in E3SM has some support for water resource management operations that is coming online in ICoM project-- can discuss more as helpful to determine appropriate engagement with broader group	yes - as part of DRBC's PST	Yes, indirectly by modifying freshwater inflows at Trenton & Schuylkill boundaries	through OASIS input, yes
What drivers beyond Decree Parties exist to run this model?	COE Headquarters Mandated	It has being used for the PCB TMDL and associated waste load allocation for the Delaware River estuary. Daily automated program simulates the hydrodynamic model for the most recent ~140 days and 8 days into the future. (https://onlinelibrary.wiley.com/doi/abs/10.1111/jawr.12185)	The development of EFDC-WASP8 models by DRBC is going to be used as a management and regulatory tool for revising DO and other state variable standards, allocating waste loads, assessing spill impacts within the Delaware River estuary.	NOAA, ONR, USGS, Universities, 100's of international users, etc.	DOE cliamte modeling datasets, e.g. CORE-II; NOAA, universities, USGS, private consultings	Water Census and other cooperators in KY, research with universities on stream delineation, water budget, soil management.	Developed and used to access potential salinity impacts for the Delaware Navigation Channel Deepening Project	NPS, USGS

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The Impacts of Flow Management and Sea Level Rise on Salinity Control
Delaware River Basin Commission Services in Support of the FFMP Studies

INTRODUCTION

Since the 1970s, the Decree Parties have relied on the Delaware River Basin Commission (DRBC) to provide independent technical and scientific information to inform policy decisions related to drought, flow management and salinity. As the agency responsible for the planning, management, conservation and use of the water resources in the Delaware River Basin, DRBC has the local knowledge, data, models and resources necessary to evaluate many hydrologic, operational and water quality issues in a responsive, timely and cost-effective manner.

The DRBC is proposing the following project to review the impacts of different proposals that may impact the Commission's responsibilities for flow management and salinity control. The project capitalizes upon existing and on-going investigations and efforts by the DRBC for various purposes. Those purposes include estuary designated uses, water quality standards, sea level rise, climate change, lower basin flow augmentation, consumptive use assessments and water supply planning. The proposed project involves the use of DRBC's existing and developing models to study the effects of flow management (reservoir operations, storage, diversions) and climate change (hydrology, sea level rise) on salinity in the Delaware River Estuary. The models to be used were developed, or are being developed, to answer specific questions about flow management and/or water quality in the river and estuary. DRBC's models are public domain, run on a personal computer and will continue to be supported, maintained and evolved to answer water resource questions in the basin.

It is recommended that this project be conducted in collaboration and coordination with the salinity study specified in the 2017 Flexible Flow Management Program Agreement. This proposal can be modified and adjusted in consultation with the Decree Parties. The results of this project will provide vital technical information for the Commissioners and Decree Parties in their review of impacts to flow management, water quality management and salinity control as they related to DRBC's responsibilities.

This proposal is organized into seven parts:

- Introduction (this section)
- Purpose
- Background and history
    - The Salt Front Location
    - Historic Location and Concentrations
    - Trends and Future Conditions
    - Salinity Management
    - With and Without the Vernier
    - Levels of Protection
- Proposed models and tools

- Proposed approach
- DRBC's project team
- Disclaimer

PURPOSE

The 2017 Flexible Flow Management Program (FFMP 2017)[1] is a two-part, ten-year agreement, related to provisions of the 1954 Supreme Court Decree (Decree), the 1982 Good Faith Agreement (GFA) and Section 2.5.3-2.5.6 of the Delaware River Basin Water Code. During the first five years of FFMP 2017, the Decree Parties, in Section IV.3 of the Agreement, outlined the intention to:

> "evaluate the impacts and conditions resulting from the following:
>
> i. detachment of releases from the New York City Delaware Reservoirs from the position of the salt front during drought emergency and replacing the benefit that New York City releases have with respect to the salt front with an alternative methodology or methodologies that will provide comparable [level of] protection for existing resources within the Basin.
> ii. The increase in the New Jersey Diversion during drought conditions (basinwide and/or lower basin).
> iii. The increase in available storage for the lower basin from either the optimization of existing storage or the development of new storage in the basin in accordance with the mutually adopted GFA and water planning efforts conducted by the Decree Parties."[2]

"Detachment of releases" is related to the directed releases made to meet the Montague Flow Objective (MFO) during drought emergencies (L5), which is dependent upon the location of the salt front (SF) and season. This flow objective, informally known as the Montague Vernier, was established in 1983 as part of the Delaware River Basin Drought Management Plan[3], developed in response to the 1960s drought to improve the basin's drought resiliency. The drought management plan is documented in the Delaware River Basin Water Code (Sections 2.5.3 through 2.5.6) and the FFMP 2017 (in part). The plan consists of many components and includes water quality (salinity) standards, drought definitions; reservoir rule curves; phased reductions in reservoir releases flow objectives and diversions; water conservation; and emergency procedures.

The proposed project will focus on the three study topics listed above and in Sections IV.3 of FFMP 2017. An assessment of the potential impacts and conditions resulting from detachment, NJ's drought diversion and available storage will require modeling studies of reservoir operations and salinity. Various flow management options and assumptions will be examined to determine the extent to which the individual and collective goals of the Decree Parties may be met and how those goals affect the

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[1] https://webapps.usgs.gov/odrm/ffmp/FFMP2017.pdf
[2] FFMP 2017 Section IV.3.
[3] Sections 2.5.3 through 2.5.6 of the Delaware River Basin Water Code, incorporated with Resolutions 83-13 and 88-20 revised.

Commission's responsibilities for flow management and salinity control. Alternative flow management options will be identified and tested individually and conjunctively under current conditions and current conditions with sea level rise, among other variables listed in Sections IV.2 and IV.6.

There are additional study items in Section IV of FFMP 2017, the Office of the River Master (ODRM) Balancing Adjustment and the calculation of the Excess Release Quantity), which are outside the scope of DRBC's project. It is anticipated that the Office of the Delaware River Master will conduct the evaluations of the Balancing Adjustment and calculation of the Excess Release Quantity. Although those studies are outside the scope of this proposed project[4], DRBC will evaluate the outcomes of those studies when they become available and as resources allow.

Background text removed

PROPOSED APPROACH

DRBC is proposing a project scope of work, similar to the 1981 Level B study[5], in respect to salinity control and flow management. The Level B study was a large planning effort to review the DRBC Comprehensive Management Plan for the Water Resources of the basin and informed the evaluations of options for the Good Faith Agreement.

For this project, DRBC efforts will focus on flow management, flow augmentation storage[6], salinity, future demand projections[7], and seal level rise. It is anticipated that this work will be performed with DRBC's existing or approved resources, be completed using the aforementioned models and build on

[4] The Decree specifies that "a quantity of water equal to 83 per cent of the amount by which the estimated consumption during such year is less than the City's estimate of the continuous safe yield during such year of all its sources obtainable without pumping. In any such year the City's estimate of anticipated consumption shall not exceed by more than 7 1/4 billion gallons the actual consumption in any previous calendar year; and its safe yield in any such year, obtainable without pumping, shall be estimated at not less than 1355 m. g. d. after the Neversink and East Branch reservoirs are put into operation; and at not less than 1665 m. g. d. after the Cannonsville reservoir is put into operation." DRBC does not have the resources to develop an appropriate model of the entire NYC to independently calculate the safe yield of the NYC system.
[5] https://www.nj.gov/drbc/library/documents/Level-B-Study_May1981.pdf. See pages 30-40.
[6] Limited to options listed in the Good Faith Agreement. Others as resources allow.
[7] 2060

other on-going projects, such as the Designated Use Study and Water Supply 2060. However, additional funding or resources may be needed to expedite progress or should the number and variety of model simulations become too burdensome.

The project is comprised of seven major tasks with the acknowledgement that there are many subtasks, not explicitly specified. Due to the iterative nature of identifying, testing, and refining alternatives, there is likely to be significant cross-over among tasks and much of the work may be performed in parallel. For instance, assumptions may be revisited, or additional metrics may be identified after reviewing model results. The major task categories include:

1. Decree Party Coordination;
2. Public Participation;
3. Existing Resource Condition Assessment and Metrics;
4. Model Assumptions and Scenarios;
5. Alternatives Development;
6. Modeling Analyses – Scenario and Alternatives Testing
7. Documentation

Each task is described in more detail below. A preliminary list of deliverables and proposed schedule are also provided. Given that the project will be conducted with limited existing resources, the deliverables and schedule are subject to change.

TASK 1: Decree Party Coordination

The DRBC is committed to working with the Decree Parties and the Office of the Delaware River Master to conduct this project. To be successful, a like commitment would benefit the overall project goals. The Decree Party Work Group (DPWG) and River Master Advisory Committee (Principals) will be consulted on a regular and on-going basis for input on model assumptions, scenario definitions, alternatives development, refinements, and reports. Intermediate work products will be presented regularly at meetings of the DPWG in an interactive forum. It is anticipated that quarterly progress reports will be made to the Principals and Commissioners at milestones and decision points. As in the past, DRBC will keep preliminary work products confidential and deliberative until the Decree Parties and then Commissioners approve of a plan to both engage with and/or report to the public.

Deliverables:

1. DPWG Meetings: participation, presentations and materials
2. Principals Meetings: participation, presentations and materials
3. Progress Reports, including presentations
4. Coordination with the Commissioners, Principals, DPWG and ODRM

TASK 2: Public Participation

DRBC already provides a forum for public participation through its Regulated Flow Advisory Committee (RFAC) and Subcommittee on Ecological Flows (SEF) (or other subcommittees as needed). The DRBC will advertise, facilitate and provide staff support for these public meetings in accordance with the incorporating resolutions. Additional meetings may be supported upon request and as resources allow. On a limited basis, staff will provide support to stakeholders on the use of DRB-PST. As resources allow, staff may also use the USGS Delaware REF-DSS in support of SEF to assess the guidelines on the rapid flow mitigation and thermal guidelines and a refined set of flow management alternatives.

When approved for release by the Commissioners or the Decree Parties, study results will be presented at public meetings (RFAC, SEF) either in power point, as memorandum or both. Public input will be documented for the Parties through the meeting summaries. Suggestions from the public will be discussed with the Parties and incorporated into the analyses as deemed necessary.

Deliverables:

1. Facilitation of RFAC and SEF meetings
2. Meeting Summaries
3. Limited technical support for stakeholders (DRB-PST, USGS Delaware REF-DSS)
4. Presentations and memoranda of study results for the public as requested

TASK 3: Existing Resource Condition Assessment and Metrics

The intent of this task is to provide foundational knowledge about existing basin resources and develop metrics for comparisons of model simulations. Information evaluated will include main stem flows, estuary salinity, and storage. Through the process of compiling information for comparisons, a suite of meaningful metrics will be developed for the baseline and for the evaluation of alternatives and establishing program goals (e.g. during a repeat of the 1960s drought, the salt front remains below RM 100, even with SLR of 3 feet by 2060; FE Walter recreation program not impacted by the drought management program). Example metrics are provided in Appendix A; however, Commissioners, Decree Parties and stakeholders will be consulted to inform a final set of metrics for comparisons.

DRBC compiles many different assessments of the conditions of basin water resources. As part of this task, staff will compile and summarize the conditions of existing resources, focusing on main stem flows, estuary salinity and water supply storage. DRBC will reference existing reports such as Delaware River and Bay Water Quality Assessments[44] (Requirement 305(b) of the Clean Water Act), the Atlas of Existing Water Quality for Special Protection Waters[45], chloride trends[46], the Boat Run[47], and others based on the existing resources definition determined by the DPWG. Gaps in data, such as lack of wintertime specific conductance measurements, will be identified and used to qualify the characterization of existing conditions. Using model results from Task 6, staff will also summarize the simulated conditions of

[44] http://www.state.nj.us/drbc/about/public/publications/index.html
[45] https://www.nj.gov/drbc/programs/quality/spw_ewq-atlas.html
[46] https://www.nj.gov/drbc/library/documents/WQAC/032918/panuccio_chloride-trends.pdf
[47] https://www.nj.gov/drbc/programs/quality/boat-run.html

existing resources, focusing on main stem flows, estuary salinity and water supply storage, under FFMP 2017, existing conditions and with sea level rise. Model simulations will be compared using the metrics in Tables 1A-1C in Appendix A and/or others as identified, including time-series or probability plots of specific events of reservoir storages, diversions, flows, and salt front location and others as identified.

Once existing resource conditions are characterized (observed and simulated), a facilitated process will be conducted with the Decree Party Work Group to develop a suite of metrics to be used for the comparison of alternatives and scenarios. Table 3 presents a preliminary list of metrics that may be expanded or modified. While refining the metrics and through the process of evaluating alternatives (Task 6), DRBC will assist the Parties in identifying the goals and objectives of future flow management programs. These goals can be summarized and presented at RFAC or a facilitated process may be conducted for the public through RFAC.

Deliverables:

1. Memorandum characterizing salinity and salinity issues in the estuary;
2. Memorandum characterizing status of additional resources (as needed) in the basin based on available data;
3. Suite of Metrics for comparisons; and
4. Memorandum on goals and/or criteria for future flow management programs (optional).

TASK 4. Assumptions and Scenarios

All models have assumptions and the combinations of the assumptions, along with the alternatives, form the scenarios. Examples of assumptions include, but are not limited to, sea level (current and predicted); boundary conditions (salinities from the ocean, Chesapeake and Delaware Canal, and the Delaware and Schuylkill rivers - constant or time-varied); consumptive use (current or projected); hydrology (period of record, future deterministic); among many others. DRBC staff will compile a list of assumptions in the models, outline the options for different assumptions and make recommendations with supporting analyses. As appropriate, staff will perform sensitivity testing on model assumptions. Due to the many possible combinations of assumptions, the extent of the sensitivity testing may be limited.

Once all assumptions are identified and tested, staff will work with the Decree Parties to build the sets of assumptions that will be used in the scenarios. For instance, the existing conditions scenario may be current sea level, 2016 consumptive use (most recent available data), current inflow file, etc. A future condition scenario might be sea level rise of 3 feet, 2060 water use projections, 2060 deterministic hydrology (from WATER), 2060 land use, etc. Table 2 in Appendix A presents an example matrix of potential scenarios.

Deliverables:

1. Memorandum on model assumptions and sensitivity analyses; and
2. Memorandum on recommended scenario assumptions (current and future baselines) and associated matrix (Planning Year, Consumptive Use, Sea Level Rise, Etc.)

TASK 5: Alternatives Development

The primary purpose of the FFMP2017 Studies are to determine the effects of detachment and New Jersey's diversion on salinity and storage. Detachment is likely to change the distribution and duration of freshwater flows into the estuary, and thus the timing and persistence of chloride concentrations as well as the location of the salt front. To manage those effects, alternative flow management options will be needed to maintain the current level of protection provided by the Montague Vernier, also known as the L5 Montague Flow Objective. Also, if or when detachment is implemented, a replacement will be needed for the L5 Montague Flow Objective

Ideas for alternatives will be developed to determine if the existing level of protection provided by the Montague Vernier can be replaced with new or modified operations or operational components or combinations thereof and a different L5 Montague Flow Objective, not linked with the salt front. Such operations and operational components may include, but are not limited to, 1) new flow objectives; 2) timing of releases (e.g. pulsed); 3) drought definitions; 4) NJ's Diversion; 5) reallocation or optimization of current storage and/or additional storage;7) ERQ[48] volumes and guidelines for its use, and 7) others. Other options may be identified through research into how salinity is managed in other estuaries, for what purposes, and the criteria used to assess success, but outside resources would need to be procured to do so. Table 3 in Appendix A contains samples of the types of alternatives that may be evaluated. As with the scenarios, DRBC will work with the DPWG to develop alternatives for consideration and simulation.

The scenarios and alternatives will first be evaluated (simulated) with the screening level models. DRBC proposes using DRB-PST for preliminary screening of various scenario/alternative combinations. For more promising scenario/alternative combinations that interest the Parties, DRB-PST/DYNHYD-TOXI5 will be used as a secondary screening tool. Task 6 provides more detail on the modeling.

Deliverables:

1. Memorandum defining alternatives to be simulated
2. Matrix of alternatives to be simulated at the primary screening level (DRB-PST)
3. Matrix of alternatives to be simulated at the secondary screening level (DRB-PST/DYNHYD-TOXI5)
4. Matrix of alternatives to be simulated for sea level rise (EFDC 3D).

TASK 6: Modeling Analyses

DRBC proposes a multi-phased approach to the modeling analyses. The DPWG will be consulted regularly for their input for avenues of investigation. Staff will work iteratively with the DPWG by providing information on initial assumptions, scenarios, alternatives to be tested and preliminary model

[48] Calculation of the value of the ERQ is outside the scope of this study. DRBC will evaluate proposals with different ERQ volumes as agreed upon by the Decree Parties.

results and then incorporate comments and feedback. As with most modeling analyses, it is anticipated that this will be collaborative process.

The first phase will involve significant amounts of work with DRB-PST to test model assumptions developed under Task 4 and evaluate indicator parameters and metrics for comparisons. This phase will result in the definition of baseline scenario(s) and a standard set of screening level metrics. Next, alternative program components will be identified with the DPWG, coded and tested for simulation individually and as sets. These preliminary screening level simulations will be conducted with DRB-PST and presented to the DPWG. The DPWG will then be engaged in developing groups of alternative components to simulate in the second phase.

The second phase involves simulations of the baseline and a smaller set of alternatives with DRB-PST/DYNHYD-TOXI5. DRB-PST/DYNHYD-TOXI5 simulates the physical processes affecting chlorides in the estuary. Baseline model assumptions may also be verified with the more detailed DRB-PST/DYNHYD-TOXI5. It is necessary to limit the amount of simulations performed with the DRB-PST/DYNHYD-TOXI5 because of computational time.

The third phase involves simulations with the EFDC 3D model. This model will be used to address questions about sea level rise. EFDC 3D is currently under development and should be completed by the end of 2020. Due to computational constraints, it is anticipated that only a small number of alternatives simulations will be completed with this model.

The fourth phase involves the simulation of a discrete set of alternatives with alternative hydrology representing climate change. Alternate hydrology will be generated with the USGS WATER model. These analyses will primarily be conducted with DRB-PST, but the other models may be employed for a limited set of simulations.

The fifth phase involves the evaluation of the rapid flow change and thermal mitigation guidelines developed through SEF. Simulations of various options will likely be conducted with DRB-PST. The Delaware REF-DSS may also be used as resources allow.

The last phase will involve outside technical review of the body of work, if desired. The DYNHYD-TOXI5 model was developed with input, guidance and approval of an expert panel and stakeholder involvement. Similarly, the EFDC 3D model is under development and under review by an expert panel and very active stakeholder involvement. DRBC does not have the resources to convene an outside expert panel specifically for this project. However, if an outside panel is engaged, DRBC will address their comments to the extent that resources allow.

Deliverables:

1. DRB-PST version with final FFMP program options
2. DRB-PST/DRNHYD-TOXI5
3. EFDC 3D for sea level rise simulations
4. Memorandum summarizing model results including metrics tables and time-series plots
5. Memorandum summarizing the advantages and disadvantages of alternatives

6. Memorandum with Decree Party Recommendations
7. Memorandum describing evaluations for SEF
8. Response to technical review comments (if needed)

TASK 7: Documentation

DRBC will be developing memorandum and other documentation during the conduct of this study. The materials will be considered preliminary and deliberative until approved by the DPWG for distribution to the public. A draft report summarizing the body of work will be compiled for review by the DPWG. DRBC will incorporate comments from the DPWG into the draft report and then issue a final draft for review by the Commissioners and Principals. Upon approval by the Commissioners and Principals, DRBC will publish the document on its website.

If desired, the document will first be published as a preliminary report and DRBC will solicit public comment via an RFAC meeting. DRBC and the DPWG will then review the public comments and determine if additional analyses are needed. Those analyses will be completed, discussed and incorporated into the document. A response to comment themes document will be prepared and included in the report. A revised report will then be prepared for review and published on the website when final.

Deliverables

1. Draft report
2. Second draft report revised based on DPWG/Principals' comments
3. Final report
4. Public review process (optional)

DRBC TEAM

The DRBC Team consists of highly qualified engineers and professionals in the Operations, Planning and Science and Water Quality Assessment Branches of the organization. These individuals have expertise related to flow management, modeling (hydrologic, hydraulic, hydrodynamic, water quality), water quality assessments and water supply planning.

Project Manager: Amy L. Shallcross, P.E.

Key Staff:

- Fanghui Chen, PhD, P.E., Senior Water Resource Engineer (estuary models, PST)
- Namsoo Suk, Ph.D., Director, Science and Water Quality Management (estuary models)
- Li Zheng, Ph.D., Senior Water Resource Modeler (estuary models)

- John Yagecic. P.E., Manager, Water Quality Assessment (existing conditions, statistics, USGS-DSS)
- Jake Bransky, Aquatic Biologist (SEF, USGS-DSS)
- Chad Pindar, P.E., Manager, Water Resource Planning (water demands, consumptive use, storage)
- SeungAh Byun, PhD, P.E., Water Resource Engineer (water demands, consumptive use, storage)
- Gail Blum, Water Resource Specialist (historic data, PST)
- Water Resource Engineer (WATER/PST) – TBD

DISCLAIMER

There is limited dedicated funding, other than staff salaries, for these studies as they relate to Decree Party matters. DRBC is providing this proposal as a cost efficient and effective option for the salinity study. The project will provide reliable technical and scientific information for the Commissioners and/or the Decree Parties for the evaluation of future FFMP options. DRBC staff will endeavor to perform this work to support the Decree Party studies within its approved resources and budget by utilizing existing staff, data and models, building on work being performed for the Estuary Designated Use Study and prioritizing other relevant work, such as the 2060 Water Supply Planning study. Commissioner member fair share funding or supplemental funding from the Decree Parties would help to support this project.

Appendix A:

Metrics, Scenario and Alternatives Examples

Project Schedule

Table 1A. List of Potential Metrics

ISSUE	METRIC	
Drought Risk	Total Basinwide Drought Days	
	Basinwide Watch	
	Basinwide Warning	
	Basinwide Emergency	
	Total Lower-Basin-only Drought Warning/Emergency Days (while basin-wide conditions are normal)	
	Drought Event Tables (see Tables 1B and 1C)	
NYC Storage	Days PCN Combined Storage <10%	
	Min Usable PCN Combined Storage (BG)	
	Percent of Days PCN storage is below 90% usable threshold	Pepacton
		Cannonsville
		Neversink
	Percent of Days PCN storage is below 85% usable threshold	Pepacton
		Cannonsville
		Neversink
NYC Diversions	Average for entire simulation (mgd)	
	Average 1964-1966	
NJ Diversion	Average for entire simulation (mgd)	
	Average 1964-1966	
NJDOB	NJDOB Maximum Accumulated in any one year cfsd	
	Number of days used	
Lower Basin Storage	Days usable BBN storage < 20%	
	Beltzville MIN usable storage (BG)	
	Number of Days Beltzville Boat Ramps Closed due to Lake Elevation	
	Blue Marsh MIN usable storage (BG)	
	Number of Days (April 1 - October 15) Blue Marsh Below Drought Warning Elevation	
	Nockamixon MIN usable storage (BG)	
	Number of Days Nockamixon Below Acceptable Recreation Level (TBD)	
	Maximum Annual Water Use from FE Walter for Trenton Flow Objective	
Salt Front	Maximum Location (RM)/date	
	Days above RM 92.5	
	Days above RM 92.5 during basinwide drought emergency	
	Days above RM 82.9 during basinwide drought emergency	
Chlorides (1)	Maximum Chloride Concentration in 1964 at Ben Franklin Bridge	
	Maximum Chloride Concentration in 1965 at Ben Franklin Bridge	
	Maximum Chloride Concentration in POR other than 1964-1965	
Flow Objectives	Average 1964 Aug-Nov	Montague Flow (cfs)
		Trenton Equivalent Flow (cfs)
	Average 1965 Jun - Sep	Montague Flow (cfs)
		Trenton Equivalent Flow (cfs)
Minimum Average Monthly Flows (AMF)	Montague AMF min - value (cfs)	
	Montague AMF min - occurrence (mo-yr)	
	Trenton Equiv Flow AMF min - value (cfs)	
	Trenton… AMF min - occurrence (mo-yr)	
Fisheries	Percent of time in Tables	Tables 4G and 4F
		Tables 4G and 4F - 4/1 - 9/30
		Time 4G and 4F, in L2, 6/1 - 8/31
		Time 4G, in L2, 6/1 - 8/31
	Non-drought Days Temperature > 75 degrees	Bridgeville
		Hale Eddy
		Harvard
		Hancock
		Hankins
	Non-drought Days Temperature > 68 degrees	Bridgeville
		Hale Eddy
		Harvard
		Hancock
		Hankins

(1) Depends on use of DRB-PST/DYNHYD-TOXI5 Linkage

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Table 1B. Examle Drought Event Tables

Drought Period	Drought Status		Drought Days			Minimum Storage During Event			
	Basinwide	Lower Basin	Basinwide	LB-only	NYC Combined Storage	Lower Basin Storage	Beltzville	Blue Marsh	Nockamixon
09/27/1930 - 11/18/1930	0	1		53	107.21	20.70	4.65	4.05	12.00
11/19/1930 - 05/29/1931	5	0	192		59.50	17.60	4.00	1.50	12.03
11/02/1931 - 02/18/1932	0	1		109	120.03	23.93	7.06	4.16	12.70
09/29/1932 - 11/12/1932	0	1		45	168.55	24.02	7.43	4.15	12.44
09/24/1939 - 10/31/1939	0	1		38	123.78	26.07	9.14	4.16	12.75
01/17/1940 - 04/11/1940	5	0	86		114.62	29.37	11.62	4.77	12.98
10/22/1941 - 04/17/1942	5	0	178		80.22	27.27	9.78	4.70	12.60
02/21/1944 - 03/30/1944	3	0	39		149.63	30.73	12.98	4.77	12.98
11/08/1944 - 03/10/1945	4	0	123		101.46	27.50	9.80	4.72	12.94
12/09/1949 - 01/03/1950	3	0	26		108.61	30.64	12.98	4.77	12.89
11/15/1953 - 12/14/1953	3	0	30		106.84	29.53	11.78	4.77	12.98
09/02/1957 - 10/19/1957	0	1		48	106.81	20.40	4.65	3.79	11.96
10/20/1957 - 01/03/1958	4	1	76		87.62	19.22	4.65	2.65	11.91
01/04/1958 - 01/23/1958	0	1		20	147.82	28.81	11.06	4.77	12.98
02/26/1958 - 04/10/1958	3	0	44		152.25	30.73	12.98	4.77	12.98
01/03/1962 - 04/05/1962	4	0	93		121.94	30.73	12.98	4.77	12.98
08/27/1962 - 04/13/1963	5	0	230		84.23	29.06	11.16	4.77	12.42
09/26/1963 - 10/10/1963	0	1		15	105.99	25.13	8.88	4.16	12.08
10/11/1963 - 03/14/1964	4	0	156		79.66	16.51	3.31	1.12	12.00
09/18/1964 - 08/01/1967	5	0	1046	2	**0.51**	**5.45**	**1.00**	**1.00**	**3.44**
03/16/1968 - 03/24/1968	3	0	9		169.54	30.73	12.98	4.77	12.98
11/06/1980 - 11/17/1980	0	1		12	107.42	26.58	9.37	4.24	12.98
11/18/1981 - 02/26/1981	0	1	100	1	91.73	26.34	9.20	4.16	12.98
01/26/1983 - 02/11/1983	3	0	17		141.87	30.73	12.98	4.77	12.98
02/02/1985 - 09/27/1985	4	0	238		130.14	29.68	11.26	4.77	12.89
03/06/1989 - 04/12/1989	3	0	38		155.02	30.73	12.98	4.77	12.98
11/05/1991 - 12/04/1991	3	0	30		97.73	30.20	12.45	4.77	12.98
12/31/1998 - 01/28/1999	3	0	29		118.42	30.56	12.81	4.77	12.98
11/14/2001 - 05/22/2002	5	0	190		87.55	30.54	12.79	4.77	12.98
Minimum					**0.51**	**5.45**	**1.00**	**1.00**	**3.44**
Sum			2970	343					

TABLE 1C. Metrics - Drought Event Summary Tables

Program 1		Drought Days	
Begin	End	Basinwide	LB Only
09/27/1930	11/25/1930		60
11/26/1930	05/27/1931	183	
11/02/1931	02/18/1932		109
09/28/1932	11/15/1932		49
09/24/1939	11/02/1939		40
01/17/1940	04/11/1940	86	
10/23/1941	04/16/1942	176	
02/22/1944	03/29/1944	37	
11/08/1944	03/09/1945	122	
12/09/1949	01/03/1950	26	
11/15/1953	12/14/1953	30	
09/02/1957	10/19/1957		48
10/20/1957	01/03/1958	76	
01/04/1958	01/23/1958		20
02/27/1958	04/10/1958	43	
01/03/1962	04/05/1962	93	
08/27/1962	04/13/1963	230	
09/26/1963	10/10/1963		15
10/11/1963	03/14/1964	156	
09/19/1964	08/01/1967	1047	1
03/16/1968	03/24/1968	9	
11/06/1980	11/17/1980		12
11/18/1980	02/25/1981	100	
02/03/1985	09/22/1985	232	
03/07/1989	04/12/1989	37	
11/05/1991	12/04/1991	30	
12/29/1998	01/28/1999	31	
11/15/2001	05/22/2002	189	
Total		**2933**	**354**
Minimum			

Program 2		Drought Days	
Begin	End	Basinwide	LB Only
09/26/1930	12/18/1930		84
12/19/1930	05/17/1931	150	
11/03/1931	02/20/1932		110
09/19/1932	11/23/1932		66
09/27/1939	10/31/1939		35
02/02/1940	04/17/1940	76	
11/03/1941	04/06/1942	155	
11/16/1944	12/18/1944		33
09/07/1957	10/20/1957		44
10/21/1957	01/08/1958	80	
01/09/1958	01/23/1958		15
03/21/1958	04/16/1958	27	
09/10/1962	04/15/1963	218	
10/11/1963	10/16/1963		6
10/17/1963	03/19/1964	155	
09/19/1964	10/06/1964		18
10/07/1964	05/29/1967	965	
11/08/1980	12/10/1980		33
12/29/1980	03/06/1981	68	
11/10/1991	12/07/1991	28	
01/12/1999	02/02/1999	22	
11/24/2001	05/15/2002	173	
Total		**2117**	**444**

Program 2		Drought Days	
Begin	End	Basinwide	LB Only
09/26/1930	12/18/1930		84
12/19/1930	05/17/1931	150	
11/03/1931	02/20/1932		110
09/19/1932	11/23/1932		66
09/27/1939	10/31/1939		35
02/02/1940	04/17/1940	76	
11/03/1941	04/06/1942	155	
11/16/1944	12/18/1944		33
09/07/1957	10/20/1957		44
10/21/1957	01/08/1958	80	
01/09/1958	01/23/1958		15
03/21/1958	04/16/1958	27	
09/10/1962	04/15/1963	218	
10/11/1963	10/16/1963		6
10/17/1963	03/19/1964	155	
09/19/1964	10/06/1964		18
10/07/1964	05/29/1967	965	
11/08/1980	12/10/1980		33
12/29/1980	03/06/1981	68	
11/10/1991	12/07/1991	28	
01/12/1999	02/02/1999	22	
11/24/2001	05/15/2002	173	
Total		**2117**	**444**

TABLE 2. Example Scenario Matrix

Options		Hydrology	Landuse	Consumptive Use	Sea Level Rise	NYC Diversion
Scenario	Program	Current, 2060-RCP4.5, 2060-RCP8.5	2011, 2030, 2060	Current, 2030, 2060	1, 3, 6 feet	OST, Pattern, Annual Average
Baseline (Base_0)	FFMP2017	Current	Current	Current	NA	TBD
Scenario 1 (Base_01)	FFMP2017	Current	Current	2060	NA	TBD
Scenario 2 (Base_02)	FFMP2017	Current	Current	Current	6	TBD
Scenario 3 (Base_03)	FFMP2017	2060-RCP8.5	Current	Current	NA	TBD
Scenario 4 (Base_04)	FFMP2017	2060-RCP8.5	2060	Current	NA	TBD
Scenario 5 (Base_05)	FFMP2017	2060-RCP8.5	2060	2060	NA	TBD
Scenario 6 (Base_06)	FFMP2017	2060-RCP8.5	2060	2060	6	TBD
etc.	***	***	***	***	***	***
Baseline (Alt1_0)	Alternative 1	Current	Current	Current	NA	TBD
Scenario 1 (Alt1_01)	Alternative 1	Current	Current	2060	NA	TBD
***	***	***	***	***	***	***
Scenario 6 (Alt1_06)	Alternative 1	Current	2060	2060	6	TBD
etc.	---	---	---	---	---	---
Baseline (Alt2_0)	Alternative 2	Current	Current	Current	NA	TBD
Scenario 1 (Alt2_01)	Alternative 2	Current	Current	2060	NA	TBD
***	***	***	***	***	***	***
Scenario 6 (Alt2_06)	Alternative 2	Current	2060	2060	6	TBD
etc.	***	***	***	***	***	***

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Table 3. Example Alternatives Matrix *

	Montague				Trenton				NJ Diversion Scenario	NJ Diversion Offset	FE Walter		Additional Storage (4)
	Normal	Watch	Warning	Emergency	Normal	Watch	Warning	Emergency			Drought	Recreation	
BASELINE													
Alt_0 FFMP2017	1750	1650	1550	Montague Vernier (1)	3000	2700	2700	Trenton Vernier (1)	FFMP2017 100/100/90/80	DOB, AB	Yes	Yes	No
MONTAGUE													
Alt_1a	1750	1650	1550	FFMP2008 (2)	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
Alt_1b	1750	1650	1550	1100	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
Alt_1c	1750				3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
Alt_1d	1100				3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
etc.	Other Options for the Montague Flow Objective to be Determined												
TRENTON													
Alt_2	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
Alt_2a	1750	1650	1550	FFMP2008	3000	2700	2700	2900	FFMP2017	DOB, AB	Yes	Yes	No
Alt_2b	1750	1650	1550	FFMP2008	3000	2500	2500	2500	FFMP2017	DOB, AB	Yes	Yes	No
Alt_2c	1750	1650	1550	FFMP2008	3,000			Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
Alt_2d	1750	1650	1550	TBD	Trenton Vernier				FFMP2017	DOB, AB	Yes	Yes	No
etc.	Other options for the Trenton Flow Objective to be Determined												
NJ DIVERSION													
Alt_2	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	No
Alt_2a	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	100/100/90/85	DOB, AB	Yes	Yes	No
Alt_2b	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	100/100/100/85	DOB, AB	Yes	Yes	No
Alt_2c	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	100	DOB, AB	Yes	Yes	No
Alt_2d	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	No Offset	Yes	Yes	No
etc.	Other NJ Diversion Options to be Determined												
STORAGE													
Alt_3a	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	FE Walter Mod

Table 3. Example Alternatives Matrix * (Continued)

	Montague				Trenton				NJ Diversion Scenario	NJ Diversion Offset	FE Walter		Additional Storage (4)
	Normal	Watch	Warning	Emergency	Normal	Watch	Warning	Emergency			Drought	Recreation	
Alt_3b	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	Prompton Mod
Alt_3c	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	Cannonsville Mod
Alt_3d	1750	1650	1550	FFMP2008	3000	2700	2700	Trenton Vernier	FFMP2017	DOB, AB	Yes	Yes	Reserve Blue Marsh
etc.	Other storage options to be determined												
COMBINATIONS													
Alt_4a	Example Alt_1b				Ex. Alt_2d				Ex. Alt_2a	Ex. Alt_2d	Ex. No	Ex. Yes	Ex. FEW
	1750	1650	1550	FFMP2008	Trenton Vernier				100/100/90/85	No Offset	No	Yes	FE Walter Mod
Alt_4b	Other options and combintations to be determined												
Alt_4c													
Alt_4d													
etc.													

Notes:

* The alternatives listed are for EXAMPLE purposes only. Actual alternatives to be discussed.

(1) Verniers For description of both the Montague and Trenton Verniers, see Table 2 of the Delaware River Basin Water Code and FFMP2017.

(2) FFMP2008 Until alternative drought emergency flow objective are defined for Montague, the FFMP2008 values are used to represent no Vernier or "Detachment"

(3) Alt_1c Original NYC Proposal is season 2200-2500. Because Discharge Dockets are based on 2500 cfs, the lower limit is 2500 cfs.

(4) Additional Storage Only identified modifications will be addressed in the DRBC at this time. Alternatives may include parts or combinations of FE Walter Mod, New FE Walter Fisheries, Prompton Mod, Cannsonsville Mod, Beltzville Fish Mod, Reserve Blue Marsh

Table 7. Project Schedule

Milestones and Timelines	2019				2020				2021				2022				2023	
	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR
TASK 1. Decree Party Coordination																		
DPWG Meetings	As needed																	
Principals Meetings	As needed																	
Progress Reports																		
Coordination	As needed																	
TASK 2. Public Participation																		
RFAC																		
SEF			As needed															
Technical Support for Stakeholders	As time and resources allow																	
Presentations to Public	As needed																	
TASK 3. Existing Condition Assessment and Metrics																		
Current Condition Assessment		X																
Future Condition Assessment (SLR)									X									
Metrics Set Development	Braninstorming and Testing								X	Refinement						X		
Program Goals and Objectives	Facilitated								X	Refinement						X		
TASK 4. Assumptions and Scenarios																		
Model Assumptions/Sensitivity Analysis	Preliminary		X	Refinement								X						
Scenario Definitions	Preliminary		X	Refinement								X						
TASK 5. Alternatives Development																		
Alternatives Development		X	On-going Iterative Process									X	Refinement			X		
Preliminary Screening	On-going Iterative Process																	X
Screening Level (Depends on results from alternatives developemnt and Task 6)				On-going Iterative Process														X
Detailed Level								On-going Iterative Process										X
TASK 6. Modeling Analysis																		
Preliminary Screening		X	On-going Iterative Process									X	Refinement					X
Secondary Screening												X	Refinement					X
Detailed Level Screening												X	Refinement					X
Climate Change Hydrology	Current - no SLR							Future							New Program			X
DRB-PST version with new program options																		X
DRB-PST/DYNHYD-TOXI5																		X
EFDC SLR Simulations																		X
Memoranda of model results																X		X
Memorandum comparing model results																X		X
Memorandum of DP Recommendations																X		X
Memorandum of SEF Evaluations			As needed (limited)															
Response to Technical Review Comments																X		X
TASK 7. Documentation																		
Formal WG	On-going as needed																	
DP Updates																		
Draft															X			
Second Draft																X		
Final																	X	

Appendix C: Salinity Tasks Schedule