

Chesapeake Regional Hydrologic Model

10/2/19

The Chesapeake Bay Program partnership will be producing a series refined hydrologic models designed to incorporate updated weather and watershed data with enhanced modeling practices to simultaneously benefit multiple goals and outcomes. This document will discuss the needs for hydrologic predictions that effect environmental endpoints and the resources available to produce the predictions. A final section will outline a plan for production. This document will be updated frequently as needs, resources, and plans evolve.

Management Needs

The Chesapeake Bay Program partners have need for hydrologic information at various temporal and spatial scales, both on the landscape and in streams and rivers. A variety of predicted metrics and quantities will be needed to answer management questions directly and as input to downstream models.

CBP and TMDL targeting

The Chesapeake Bay TMDL modeling is performed at a spatial scale that is appropriate for setting nutrient reduction targets for large basins, however it is likely that more effective nutrient reduction strategies could be devised given fine-scale transport predictions. Landscape processes on the order of several meters are likely important for determining areas of high nutrient and sediment export and therefore optimal remediation strategies. Riverine processes are needed on a fine scale to the extent that it influences delivery of nutrients and sediment from the landscape. A daily simulation is necessary for calibration of the model against observed data; however, the management questions deal with average annual loads.

Water Supply

DEQ and ICPRB typically use the Chesapeake Bay Program's Watershed model as part of the suite of models used to manage water supply. Cooperating to develop the next generation model should result in a model that better meets CBPO and water supply goals. Water supply efforts are focused on baseflow and need good data on withdrawals. It will be important to simulate droughts, including the droughts of record in 1930, 1966, and 1999-2002. Other low flow and ecological flow metrics will be used and should be a focus of calibration. Low flow management is dependent on reservoir operations and a good understanding of withdrawals and interactions between surface subsurface flows. Near-term hindcasts are useful for management of intakes.

Living Resource Models

Wastewater contains endocrine disrupting compounds that affect living resources. Models that track the quality and quantity of wastewater in the streams can be fitted to living resource models to predict the effects of different management strategies. The wastewater models need NHD100k daily flows and travel time, which would ideally be run in a near-real time operation. Wastewater flows along with population served and treatment type are also necessary.

Ecological flows encompass a range of over 170 hydrology statistics that may be ecologically significant. Trends in these metrics will be matched with fish samples to determine appropriate models linking hydrology to living resources. Much of the fish data are in smaller tributaries, making the NHD100k

scale or finer important to achieve. It would also be important to understand the uncertainty around model predictions of ecological flows.

Habitat prediction models for trout require predictions of temperature and substrate mobilization in addition to hydrology. It has been determined that temperature can vary within reaches at the scale of tens of meters depending on local groundwater contributions and shading. A NHD100k-scale would be useful, but finer scale would be preferred. Spawning success is linked to substrate mobilization events, which will require accuracy in winter and spring high-flow events.

Table 1: Specification of requirements for each major user of the Chesapeake Regional Hydrology Model

Management Priority	TMDL and targeting	Water Supply	Living Resource Models
Direct Customers	CBPO modelers	DEQ, ICPRB, DEP	USGS
Landscape Spatial Scale	Several meters for surface runoff prediction	No preference	No preference
Riverine Spatial Scale	NHD100 or HUC12	NHD100 or HUC12	NHD100 or NHD24
Landscape temporal Scale	Hourly	No preference	No preference
Riverine Temporal Scale	Minutes to hours	Minutes to hours	Hourly
Landscape management metrics	Average annual	None	None
Riverine management metrics	Average annual	1,3,7,30,60,90 day low flow, extreme droughts, eco flows	Wastewater contribution to flows and quality; hourly and daily flows, temperature, and bed mobilization
Temporal extent	1984-current	[1930,1966,1980]-current + forecast	1970-Current
Sensitivities	Climate change, Watershed properties Management actions, land use	Surface and groundwater Withdrawals, reservoir operations, forest loss	Wastewater flow and quality, climate change, stream shading
Parameters	Flow, temperature, oxygen, sediment fractions, species of nutrients and carbon	Flow, temperature, oxygen	Flow, temperature, sediment mobilization

Resources

The Chesapeake Bay Program Office (CBPO) will coordinate the work of developing the Chesapeake Regional Hydrology Model (CRHM) and will be able to devote approximately three full-time employees to the development effort. The CRHM will be hosted on the CBPO's cloud environment, enabling efficient collaboration.

The Interstate Commission on the Potomac River Basin (ICPRB), the Virginia Department of Environmental Quality (DEQ), and the Susquehanna River Basin Commission (SRBC) will participate as suppliers of reservoir operations and withdrawal information and potentially will contribute as developers.

The USGS will develop some of the weather, land use, geomorphological, and stream observation datasets necessary for modeling accurately. The USGS will develop statistical products that can be used as spatial predictors of important metrics and to determine landscape factors that are important for successful modeling of hydrology. USGS Theme 3 products of land use and hydrologic features will be used in the CRHM effort.

All will contribute to planning, review, and requirements documentation efforts. Additional meetings or conference calls will be held, perhaps bringing in additional partners such as the Army Corps of Engineers, National Weather Service, or representatives of the USGS' National Hydrologic Model or National Water Model.

Chesapeake Regional Hydrologic Model Plan

The following plan is intended to be living document to be modified as resources and requirements change over time. The CRHM effort will have several phases. A near-term effort will build a finer-scale river simulation from CBP's Phase 6 Dynamic Model. A medium-term effort will produce a finer-scale land and river simulation with the goal of improving the spatial scale of landscape runoff and improving the accuracy of predictions in the rivers. A long-term effort will begin to develop distributed process-based models for prediction. The plan in this document is a rough outline. More detailed plans will be developed for each product. This document is an expression of intent and does not commit any party to a particular action.

CRHM 2020

The CRHM to be developed by the end of calendar year 2020 will be built for the following purposes:

- Provide the living resources models with scale of model output more appropriate to their calibration data.
- Develop methods of river simulation to be used in later models
- Develop new calibration metrics and methods to be used in the CRHM 2020 and future models
- Expand data sets to be used in the CRHM 2020 and future models

The CRHM 2020 will maintain the same landscape simulation of hydrology as the CBP's Phase 6 Dynamic Model (<http://cast.chesapeakebay.net/Documentation/ModelDocumentation>), but with parameters modified through enhanced calibration.

The river simulation, which will be still be modeled using HSPF, will be refined to NHDPlus_V2 100k.

Calibration will be performed to metrics of interest for living resources and water supply with perhaps separate models calibrated for different purposes. Accuracy metrics will be made available.

The output will be hourly for flow, temperature, and sediment for the period 1984-2015. Customers can elect to receive hourly output or supply code to calculate relevant statistics.

Potential enhancements if time allows

- Improved reservoir operations
- Improved water withdrawal information
- Nutrients
- Longer simulation period

Potential fallback products if necessary

- HUC12 scale if NHDPlus_V2 100k not feasible.

CBPO including USGS Theme 3 Partners will

- develop and calibrate the river simulation and links with the land simulation
- explore the potential enhancements listed above with other partners
- scale land use and sediment washoff data for NHD simulation

Water Supply Partners will

- work with CBPO on reservoir operations models
- supply improved water withdrawal information
- participate in model development, as time allows

USGS Theme 1 Partners will

- participate in evaluation of model output
- supply water withdrawal information at the HUC12 level, particularly outside of MD, VA, and PA
- develop input or stream datasets if needed.
- continue to develop flow metrics

CHRM 2023

The CHRM to be developed by the end of calendar year 2023 will be built for the following purposes:

- Provide the CBP with fine-scale predictions of nutrient and sediment sources in the watershed
- Provide an updated model for use in water supply decisions
- Provide the living resources models with improved data for calibration and prediction

Plans for the CHRM 2023 are vague at this point. The land simulation will likely be based on some type of hydrologic response unit structure. The model may or may not be HSPF. The points of emphasis for the simulation will be to better determine areas of high surface runoff pollutant loading and to better incorporate the effects of groundwater. The simulation will likely be informed by empirical models relating watershed characteristics to hydrograph statistics. Fine-scale watershed hydrologic features will be an important consideration. The river simulation method may be brought forward largely unchanged from the CHRM 2020 model or may be further refined to the 100k or 24k levels. Updated reservoir and withdrawal operations will be simulated. Stream shading will be considered in the temperature simulation. Nutrients and perhaps salinity and toxics will be simulated. Companion statistical efforts such as SPARROW, SWAN, other spatially referenced statistical methods will be used to discern the landscape or climate drivers for predicting flows.

The following tasks can be started at any time. They do not have to wait until after the CHRM 2020 model is developed.

CBPO including USGS Theme 3 Partners will

- develop and calibrate the land and river simulation
- develop datasets necessary for the nutrient simulation
- participate in the development of statistics models relevant to hydrology
- investigate calibration and bias-correction techniques.

Water Supply Partners will continue to

- work with CBPO on reservoir operations models
- supply improved water withdrawal information
- participate in model development, as time allows

USGS Theme 1 Partners will

- develop statistical models to directly predict hydrologic endpoints
- develop statistical models to determine important landscape features for hydrologic simulation
- participate in evaluation of model output
- develop input or stream datasets if needed.

CHRM of the future

Pilot-level physically-based distributed models may be developed by 2025 as a test for full Chesapeake watershed simulation in the future. There is currently no significant planning for this effort.

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Figure 1: The 9/18/2019 meeting to begin the planning process for the CRHM was interrupted by a small fire, leading to a pleasant, if not so productive, discussion by the Bay (photo: Jeni Keisman). Thankfully, the fire, which was literally a dumpster fire, was not a metaphor for the meeting.