

Assessing the Effects of Storm Surge Barriers on the Hudson River Estuary Scope of Work for Workshops and Research

Scientific Workshop

We will hold one full-day workshop, with the following general plans (a separate detailed Workshop Plan will be distributed and finalized with the Project Advisory Committee):

When: September, 2019; exact date TBD

Where: Hudson River Foundation, New York City

Approach: Combination of presentations and discussions to distill key implications for studying the potential effects of NYC Harbor surge barriers. Coordinate workshop with any related USACE work (e.g. conceptual biological models) through sharing information, cross-participation, etc.

Content: (a) diving deeper into the science for a small number of topics that have risen to the top of the list of concerns; and (b) taking stock of relevant lessons learned at other locations that have built surge barriers.

Specific Topics (subject to revision based on additional conversations with the PAC)

- Surge barrier gates and potential biological effects (e.g.. larvae, marine mammals) – the effects of rapid turbulent flows through gates remains poorly understood and broader experience from biologists, engineers and prior case studies will be particularly useful to understand the potential effects.
- Tidal marshes – water level fluctuations and waves during storms strongly influence marsh sedimentation and edge erosion. A particular interest for the Hudson River NERRS sites, and regarding all the Hudson's tidal marshes, is the effect when tides are attenuated and large storm surges are prevented by a storm surge barrier system.

Participants

We will plan to have 20-30 people total, generally scientists and engineers with relevant topical expertise, plus interested Project Advisory Committee representatives.

Experts

We hope to invite 5-10 expert speakers – scientists and engineers with knowledge of the topics above and/or experience studying specific surge barrier systems. These invitees may come from anywhere in the world – we have \$2500 for travel expenses, but will seek additional funding where needed. For these invited speakers, we will also provide a webinar format option if they prefer to participate remotely. The total number of speakers will be dependent on funding.

Invited participants

Additional regional scientists will be invited, including experts on related topics and some scientist invitees from our Scoping Session. Project Advisory Committee organizations are invited to send one attendee each. The lead organizer of the Corps of Engineers June workshop on conceptual modeling of biological impacts will be invited.

Research Topics within this Project

Research on physical influences of gated surge barriers on the Hudson and potentially also other parts of the New York/New Jersey Harbor estuary system will be performed at Stevens Institute of Technology under this study. The time available this spring/summer for this research is 3 months for a doctoral student and about 0.5 to 1.0 months for PI Orton. Work will need to be completed by November 2019 at the latest because this is a one-year catalyst project.

A survey was conducted among those that attended or expressed interest in the March 25 Scoping Session to get a better sense of interest in potential research topics. Those survey results (**Appendix A**), along with the planning team's professional judgment, helped inform the candidate priorities put forward here (with corresponding topic number). Also, total effort estimates are given for each research topic, as a percentage of total during the project (100%).

Proposed research focus with existing funding (NERRS)

(70% effort) Topic #2. Study duration of storm tides and gate closures (55% high-priority votes)
(10% effort) Topic #1. Study gate closure frequency and its future evolution (48%)
(20% effort) Topic #3. Inter-comparisons of existing model results (19%)

Possible additional research, if funding is available (under discussion with NYSERDA)

(80% effort) Topic #8. Study how barrier gate closures influence estuary physical changes (51%)

Research Topics – More Information

Below are brief summaries of research topics and the rationale for each. **Appendix B** gives additional details and references regarding methods.

Topic #2. Study duration of storm tides and gate closures (70% effort¹)

Rationale – the gate closure duration strongly influences the effect on the estuary during storms. Storm frequency (or return period) and peak water levels have been studied

¹ Approximate percent effort is given, as compared with 100% effort total available during the project (based on the total time budgeted for research in the project). The final set of research topics will total roughly 100% effort.

extensively for this region, but duration has not and for that reason is poorly understood. Our region's more common storms are extratropical cyclones, which often have a multi-day duration spanning several high tides. Multiple-day closures could present a challenging problem for balancing flood mitigation and water quality, or for river water backup behind the barrier.

Approach – historical tide gauge data can be analyzed to create datasets of both peak water level and surge duration. These data can be used for a purely empirical/historical analysis. Also, a more comprehensive analysis can be performed by adding synthetic storm event data (standard practice for coastal flood risk assessment; FEMA, 2014b; Orton et al., 2016), and performing joint extreme value probability analysis of the relationship between high water levels and their duration. This approach would enable the analysis to include unusual events that are not reflected in our limited historical record. The possible study topic of resulting residence time or water quality impacts is presented in a separate topic area below.

Topic #1. Study gate closure frequency and its future evolution (10% effort)

Rationale – the gate closure frequency strongly influences the effect of a surge barrier system on the enclosed estuaries. The HAT Study alternatives with cross-harbor surge barriers (Alt 2 and 3a) also include shorefront residual risk reduction features, so that the gates will not need to be closed during frequent low flood events (e.g. weak nor'easters). However, sea level rise will cause the number of floods per year to increase, leading to a requirement for either more frequent closures or additional risk reduction measures (e.g. retreat, construction of higher shorefront barriers).

Approach – given an input of a threshold water level for neighborhood flooding, one can compute the number of expected events requiring closure per year for the present and also how this number changes with future sea level rise. The threshold that triggers gate closure may be defined by several factors, including the resulting flooding caused inside the estuary, costs of lost port commerce, and environmental concerns. The Corps will also be studying gate closure frequency, and we will collaborate to ensure our approaches are compatible or complementary.

Topic #3. Inter-comparisons of existing model results (20% effort)

Rationale – stakeholders were interested in seeing a closer examination of existing modeling results to study and seek to better understand the models and their differences. Models may have differences in estuary stratification, or in the turbulent mixing or tide dissipation caused by surge barrier gates, even when resolved with high resolution.

Approach – seek to match up periods with similar forcing for the existing models and model runs (Stevens NYHOPS and the Corps AdH) as well as possible, so their results can be compared and differences can be studied. The Corps modeling was for 1995, and it would be a large

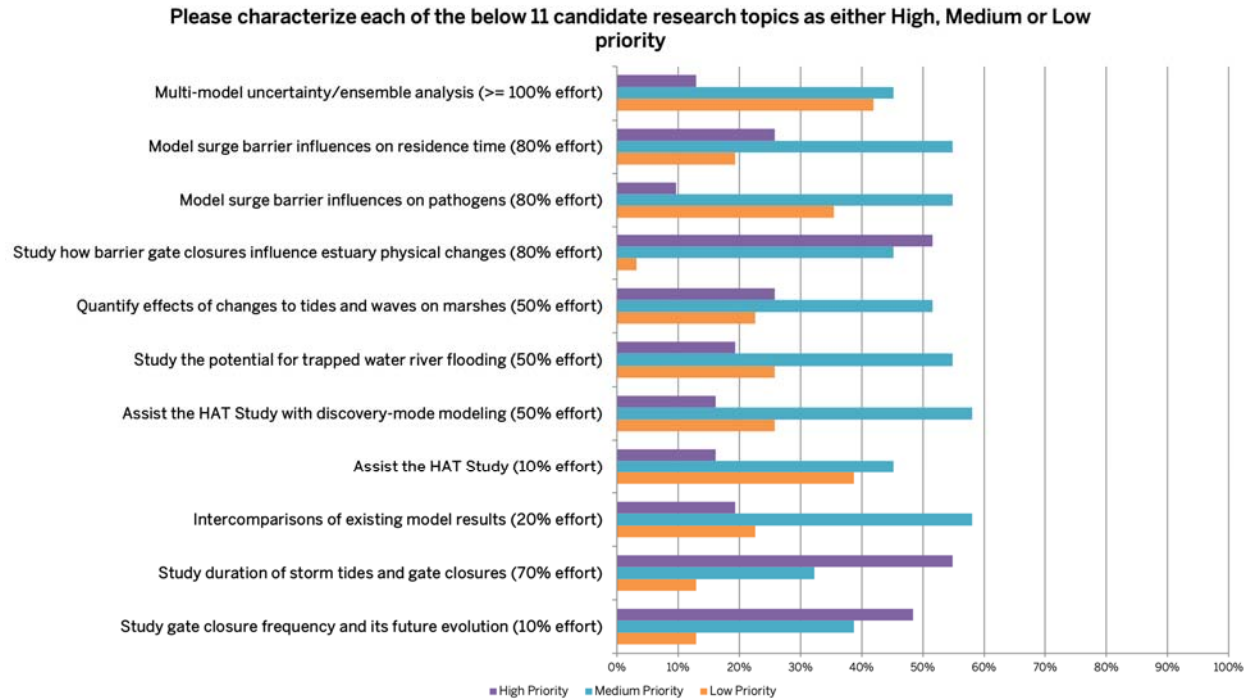
effort to simulate weather and tidal forcing conditions for the same year. Existing tide modeling results could be used to study salinity, stratification and salt intrusion including the regions near the barriers and regions up the entire length of the estuary. This would likely require finding Corps model results and requesting data/graphics for a period with similar (mean) streamflows and weak meteorological forcing (e.g. August/September).

Topic #8. Study how barrier gate closures influence estuary physical changes (80% effort)

Rationale – Most analysis so far has focused on the influence of surge barrier infrastructure on estuary physical conditions when gates are open, during normal conditions (Orton & Ralston, 2018; USACE, 2019). However, periodic gate closure can also have an aggregate impact on estuary conditions, and this impact will increase if the frequency of closure increases with sea level rise.

Approach – Simulate conditions causing a range of gate closure frequencies and durations (e.g. back-to-back nor'easters), then evaluate the influence on estuary conditions. Evaluate the changes to mean and extreme conditions of the estuary, in terms of salinity, temperature, stratification and salt intrusion. A better understanding of the relationship between estuary changes and closure frequency could help the Corps work backward to an appropriate maximum frequency for gate closures, which would also help determine the required elevation (and cost) of on-shore residual risk/high frequency measures.

Appendix A: Post-Scoping Session Survey Results – Ranking Possible Research Tasks



	Low Priority	Medium Priority	High Priority	Total
Multi-model uncertainty/ensemble analysis (>= 100% effort)	41.94% 13	45.16% 14	12.90% 4	31
Model surge barrier influences on residence time (80% effort)	19.35% 6	54.84% 17	25.81% 8	31
Model surge barrier influences on pathogens (80% effort)	35.48% 11	54.84% 17	9.68% 3	31
Study how barrier gate closures influence estuary physical changes (80% effort)	3.23% 1	45.16% 14	51.61% 16	31
Quantify effects of changes to tides and waves on marshes (50% effort)	22.58% 7	51.61% 16	25.81% 8	31
Study the potential for trapped water river flooding (50% effort)	25.81% 8	54.84% 17	19.35% 6	31
Assist the HAT Study with discovery-mode modeling (50% effort)	25.81% 8	58.06% 18	16.13% 5	31
Assist the HAT Study (10% effort)	38.71% 12	45.16% 14	16.13% 5	31
Intercomparisons of existing model results (20% effort)	22.58% 7	58.06% 18	19.35% 6	31
Study duration of storm tides and gate closures (70% effort)	12.90% 4	32.26% 10	54.84% 17	31
Study gate closure frequency and its future evolution (10% effort)	12.90% 4	38.71% 12	48.39% 15	31
Answered				31
Skipped				0

Appendix B: Methodological Details

Climate change effects

PI Orton is a member of the NY Panel on Climate Change, serving on the expert teams for sea level rise and coastal flooding. NPCC projections (Gornitz et al., 2019; Orton et al., 2019) can directly be tapped to study the frequency of barrier closures for various flood prevention goals over the long-term, the influence of climate change on this frequency, and effects of such closures on the estuarine system.

Modeling methods

Computational modeling of estuary circulation and storm tides can be performed using both the three-dimensional Stevens Estuarine and Coastal Ocean Model (e.g., Blumberg et al., 1999; Georgas & Blumberg, 2009) or the widely-used two-dimensional coupled modeling system ADCIRC (ADvanced CIRCulation model) /SWAN (Simulating Waves Nearshore) (Booij et al., 1996; Luettich et al., 1992). SECOM can be used on the NYHOPS model domain (e.g., Orton et al., 2016) as is done operationally (Georgas et al., 2016a; Georgas & Blumberg, 2009) or on higher-resolution grids such as for Hoboken at resolutions as high as 3m (e.g., Blumberg et al., 2015). ADCIRC may be run on the FEMA Region II unstructured numerical grid covering the Northwestern part of the Atlantic with resolution of up to 70 m in the NYC region (Brandon et al., 2016; FEMA, 2014a; Orton et al., 2015), or a modified version of the same grid that was developed with higher resolution of about 40m in the NYC region for the SIRR study (City of New York, 2013).

A unique advantage of the NYHOPS model is its accuracy and historical record for capturing (generally forecasting) stratification and the location of the salt front along the Hudson. The location of the salt front was forecast accurately with an r^2 of 0.83 in a recent two-year period. In a 1979-2013 reanalysis simulation, average indices of agreement were 0.99 for water temperature (1.1C RMSE, 99% of errors less than 3C), and 0.86 for salinity (1.8 psu RMSE, 96% of errors less than 3.5 psu) (Georgas et al., 2016b). Analyses of the influences of surge barrier plans on stratification and on salt intrusion can easily be performed under a wide range of conditions, tapping the existing simulation archive from 1979-2013 (Georgas et al., 2016b) and for the aforementioned storm surge and rainfall flood assessments.

Probabilistic assessment of coastal flooding

The Project PI has created probabilistic flood hazard assessments to quantify annual probabilities of coastal flooding (storm surge plus tide) and flooding from rainfall, tides, storm surge and sea level rise (Orton et al., 2015; Orton et al., 2018; Orton et al., 2016). Data from these pre-existing studies can be used here to quantify future frequencies for flood and barrier gate closure.

The relationship between storm tide maxima, surge duration, and possibly also river flood timing can be studied using statistical models. Extreme value distributions can be fitted for marginal distributions for each variable (Orton et al., 2018; Orton et al., 2016), and copulas can be used to form a multivariate probabilistic model that addresses correlation and timing between rain and river water level (e.g., Lian et al., 2013; Wahl et al., 2015). Copulas and distributions can be fitted using maximum likelihood approach, and a set of different but widely-used extreme value distributions and copula types will be evaluated for best-agreement using a least-squares criterion (e.g., Lian et al., 2013). The resulting copula models can be utilized to create time series (e.g., Wahl et al., 2016) for streamflow and storm surge (plus time-varying tide) for synthetic storm sets that are associated with a range of return periods. These can help more comprehensively test out and plan for barrier gate closure management.