Economic Impact of Sea Level Rise

Purpose: To evaluate options for an HRPDC study of economic impacts related to sea level rise.

1 Introduction

Measures of economic costs and benefits play an important role in public policy evaluation and adaptation resource allocation in response to sea level rise. A well done economic analysis can provide an organized and transparent assessment of potential damage to localities and the region as a whole, and assist in determining what stakeholders might be impacted by those costs.

A number of methodological and practical challenges have hindered the uptake of economic tools to support sea level rise adaptation assessments. Economic analysis of adaptation measures requires information on impacts, both physical and economic, that are distributed unevenly across time, location, and systems, and can potentially be non-marginal (such as the devastation many communities experienced in the wake of Hurricanes Katrina and Sandy) (Li, Mullan, and Helgeson 2014).

The Direct Damage Estimation Analysis for this region should be conducted, both because of the straightforward nature of the analysis, and because of the strength of the results. Additionally, the other analysis techniques would require the completion of such an analysis before they may be conducted. It should also be noted that estimating the Economic Drag Created by Sea Level Rise (also called a full damage estimate) would be extremely sensitive to the assumption used, and thus the results of even a rigorous analysis in this vein would be highly speculative.

Damage forecasts conducted by other agencies appears in the appendix of this document, and both categories the type of analysis featured in this forecast and asses the quality/strength of the final estimates produced.

2 Direct Damage Estimation Analysis

2.1 Description

The goal of this analysis would be to characterize the existing baseline potential damages associated with storm surge flooding, as well as characterizing the storm surge property damage associated with SLR.

The total impact of flooding (i.e., damage) in a community depends on the depth of the floodwater and the type and number of assets exposed to flooding. Defining assets at risk and assessing the cost of impact is a non-trivial exercise as there are many types of assets, each of which can differ as to their vulnerability. The most readily quantifiable assets included: residential, commercial and public properties. Further estimates might be made as to the at-risk contents of these properties, value of regional agricultural crops, and personal property that might be lost.

2.2 Data Requirements

Estimates of elevations throughout the geography of interest, which have already been produced for the Hampton Roads region from the LIDAR Data set

Avoiding the complications of judging different scenarios of SLR, the Hampton Roads PDC would use static measures of SLR (1 foot, 2 foot, 3 foot) coupled with storm surge of a 10-year and 100-year storm to develop inundation maps.

Graphical information system (GIS) data on assets-at-risk within the region, including:

- Parcel Type (Residential, Commercial, Industrial, Public, Agricultural)
- Building Type
- Assessed Value of Land and Buildings
- Adaptations on site including sea walls
- Placement of building within the parcel
- LIDAR data for elevations throughout the region
- First floor elevations

2.3 Potential Uses

To develop an estimate of the property damage under a variety of likely scenarios within the region, which would help to inform the level of adaptation that both government agencies and private property owners would consider.

2.4 Quality of Results

This analysis produces tangible results in terms of property values impacted by flooding/storm surge. Significant soft and indirect costs would be omitted from this analysis, potentially biasing this analysis resulting in cost estimates below. The final result would give a reliable order of magnitude for the potential property damage/loss from both storm surge and from recurrent flooding.

2.5 Length of Time for Analysis

This analysis would take approximately 160 hours, in addition to the efforts already in progress to improving the GIS modeling for the region using the recent LIDAR data .

2.6 Pros

- Straightforward analysis, focusing specifically on damage to buildings and property lost to recurrent flooding
- Coincides with work already in progress within the HRPDC to improve inundation mapping for the region

2.7 Cons

- Omits many of the direct costs a region would experience as a result of significant storm surge (infrastructure repair, overtime for emergcy personnel, debris removal, etc.). These costs may total as much as 50% to 75% of the property damage developed in the analysis.[1]
- Does not examine any distributional impacts that may result from SLR, including impacts specific to particular industries, social economic groups, or the resilience of particular neighborhoods within the region.
- Does not examine any potential economic drag that will be experienced as a result of lost employment, population, and/or capital investment.

3 Property Value Analysis

3.1 Description

While property damage is one cost of sea level rise, another result of the risk of flooding and storm surge results from lower home values. Decreases in real estate transactions and prices have been tied to increases in the cost of flood insurance by several news sources.[2]

This impact is important because of the role property values play in both individual wealth and on locality revenues, and thus developing accurate evaluations of this effect would be a useful for policy makers. One interesting result of previous research, is that the decrease in market value from living in a floodplain tends to be smaller than what a pure financial analysis would suggest. This effect persists until significant flooding within the floodplain. Once this happens, the price of housing quickly adjusts to the level that is more consistent with the Net Present Value cost of flood insurance.

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[1] Gaddis et al. 2007, P208

[2] Appelgate 2014

This suggests that home owners do not appropriately evaluate the risk of flooding until an area has recently experienced a flooding event.

This analysis would use repeated sales of properties both within and outside of the floodplain to assess the effect of flood insurance on home price values. An additional part of this effort would be to measure the extent which home prices had fully accounted for the risk of flooding, and what potential impact would develop if behavior changes as result of flooding.

Additionally, this research would need to examine the differences in impact that may result from recurrent flooding versus a singular significant flood. These might have very different impacts on the impact on property values, as well as the permanence of any changes in behavior that resulted from a flooding event.

3.2 Data Requirements

The first key information requirement would be a complete data set of home transactions for the region over a significant period of time. This data set would need to include many identifying features of the properties, including number of bedrooms/bathrooms, square footage, school district, lot size, and construction materials.

Additional information would be required when looking at parcels that are waterfront/waterview, as they require a more detailed model to analyze the effects of sea level rise/flood risk on property values.

High quality information on flood insurance rates throughout the region would be required to analyze the extent that flood insurance rates have been fully incorporated into market prices. Areas where flood claims have occurred during the first data set would be another useful data point for analyzing how prices have incorporated flood insurance rates on either side of a flooding event.

3.3 Potential Uses

This information would answer an ongoing question about the impact that increasing flood insurance rates will have on regional property values. Additionally, this research would estimate the decrease in value of those properties that might occur after a major storm surge event, which would equate to potential savings from adaptation.

3.4 Quality of Results

These results would be very reliable assuming that full data sets are obtainable for both real estate transactions and flood insurance.

3.5 Length of Time for Analysis

This analysis would be extremely time intensive because of several issues

- Data collection would require reaching out to several different sources, including REIN (the region's multiple listing service), each city and counties assessor's offices/GIS, and several sources to determine accurate information on the extent/depth of flooding in the region.
- Data cleaning and matching would be time intensive
- Significant effort would be needed with GIS to create information for waterfront and waterview properties
- The regression analysis would be intensive

As a result, this analysis may require almost 960 hours to complete.

3.6 Pros

- A topic of interest for both real estate professionals and planners in the region
- This analysis has not been done for a significant metropolitan region, and thus might be useful to advocate for federal funds for adaptation.
- This information is important for policy makers, both in planning for adaptation and recovery after a significant flooding event.
- Estimates the projected change in revenue for localities.

3.7 Cons

- Extremely data intensive, and without large, complete data sets, this analysis will not be possible
- Labor intensive (and possibly computing intensive) analysis. This has not been done at a metropolitan area scale. A possible remedy issue would be to conduct analysis for a single school district in three or four of the localities within the region, to test the methodology and quantify the value added by this analysis.

4 Economic Impact from Adaptation

4.1 Description

Adaptation actions can be distinguished as being private or public, autonomous or planned, and stand-alone or integrated, and can vary in their timing, approach, and scale. In addition, adaptation can occur at different scales – from local, project-level measures, to sectoral or regional planning, and national policy.

For example, for infrastructure decisions, standard engineering-based methods can be used to estimate the cost of climate resilient design; the expected benefits of the measure can be calculated based on projected probability of flooding occurrence and estimates of avoided repair cost, and direct and indirect economic losses from service interruptions (Li, Mullan, and Helgeson 2014).

While analyzing the cost of putting in any individual adaptation should result from straightforward engineering assessments, evaluating the benefits presents a more significant challenge from both an engineering and economic perspective. Adaptations occur not as a single decision, and a whole system of adaptions may either support or undermine the efforts within the region.

One example of this would be shoreline hardening, which would prevent erosion at one site, but exacerbate erosion to the shorelines in proximity to the adaptation. The greater the length of shoreline which is hardened/armored, the greater level of erosion experienced by those areas which are not armored. Thus evaluating adaptation has often assumed regional efforts or choices, or ignored every other adaptation effort other than the one considered.

The first step in this effort would be identifying the adaptations under consideration, and then the projected impact on flooding that result from those adaptations. The flood prevention/damage prevention would then be applied to maps developed while doing the first analysis (that of direct property damage), which would provide a dollar value of benefit. The cost of the adaptation plus the expected value of the benefit would allow for a net present value and an internal rate of return to be calculated for a variety of adaptations.

An additional step may consider the benefits outside of property protection. Beach nourishment provides a positive benefit by creating a tourism amenity, while a sea may potentially limit access to the water and views, which might lower property values impacted by the sea wall.

Lastly, the analysis may include the impact to the economy of paying for region wide adaptation measures. This would be modeled in two ways using the region's REMI software: treating the cost of adaptation as both a decline in investment resources (to quote Neumann and Strzpeck 2014 "a series of indirect effects of impacts on the diversion of resources from productive to defensive capital") in the region and as a decline in consumption expenditures in the region.

4.2 Data Requirements

The data requirements for this analysis involve significant information that would most likely need to be developed by an engineer consulting firm, regarding the most appropriate types of adaptation, the cost, and the potential protection provided by those adaptations. While some attempts have been made to apply standard costs of adaptation strategies to the Hampton Roads coastline, there was no attempt to develop how these adaptations would work in concert with one another. Instead, the protection provided by these adaptations was treated as binary (shoreline was either protected fully or not protected at all). This oversimplification would lead to a weak analysis.

4.3 Potential Uses

This analysis would answer the most important question related to sea level rise: which adaptations to sea level rise pass the cost benefit analysis. This then allows policy makers to evaluate the potential return on investment of a particular adaptation strategy.

4.4 Quality of Results

The results of this analysis would match the quality of the engineering data/forecasting of the adaptations. If high quality analysis tailored to Hampton Roads is procured, then this could accurately map out the adaptations for the region moving forward.

If that data is not available, the analysis may proceed using a set of general estimates that have been developed for other regions, but the results would be comparatively weaker. In this case, analysis would likely still point to a path and give an order of magnitude for the benefits, while still leaving potential for future research to develop the path forward.

4.5 Length of Time for Analysis

This length of time required for this analysis would depend strongly on the quality of data procured. Higher level data including the cost of adaptations and their impact in lowering region wide flooding/property damage would limit the in-house research needs; would allow analysis to proceed rapidly (~160-320 hours). If instead, it is left to the HRPDC to determine cost and the degree to which particular adaptations protect the region, than this project would become a much more significant undertaking (~960 hours)

4.6 Pros

- This analysis would answer the cost-benefit question when it comes to various types of adaptation.

4.7 Cons

- It might be impossible to get the level of data required to produce actionable results. Lower quality data on the cost and appropriateness of various adaptation techniques for the region would both lengthen the study and would require a future study to detail the appropriate policy responses.

5 Economic Drag Created by Sea Level Rise

5.1 Description

While the property damage estimates described in section 2 may be described as the 'Typical Analysis' of the economic impact from SLR, researchers admit that it does not capture the full economic cost of SLR. A broad class of indirect effects, however, is largely ignored, even in the better studied sectors. Effects of coastal storms, for example, include not just property value losses but also business interruption and long-term capital losses that are omitted in the current set of estimates.

Additionally, it is difficult to value the productive nature of infrastructure regionally, as typically public infrastructure aims at producing the greatest total benefit – without an effort to maximize revenues; without a market determined revenue stream the analyst would be required to estimate the productivity of regional infrastructure, which adds uncertainty to the analysis.

Lastly, as SLR impacts the region, there is the potential for population decline and interruption of employment, which would have long term impacts on the regional economy.

This analysis requires estimating a significant number of factors regarding the regional economy which is unobservable[3], and then using these estimates to forecast the impacts of flooding. The layers of estimates/forecasts lead to numbers that are highly sensitive to assumptions.

5.2 Data Requirements

It is impossible to fully outline the data required to develop this analysis.

One key piece of data would be a combination of interviews and surveys to see how SLR would affect investment decisions among the region's major industries and employers.

Secondly, information would need to be gathered from the HRTPO regarding the level of service provided by regional infrastructure that may be impaired by SLR, and to use this to develop an estimate of social return from this infrastructure.

[3] Unobservable data/numbers are which it is impossible to measure the true value no matter how sophisticated the survey or analysis conducted. Researchers attempt to minimize the use of unobservable data because it is impossible to check its veracity.

Lastly, a review of flooding impacts in developed countries would need to be conducted to estimate the potential impact on regional population created by SLR.

5.3 Potential Uses

A fuller accounting of the costs of SLR would be used with adaptation scenarios to produce new cost-benefit analyses. As the potential costs of storm surge or recurrent flooding would be higher, this would lead to a greater chance that any given adaptation would be more viable from an economic perspective.

5.4 Quality of Results

The reason that these analysis are rarely done, is that the results are both speculative and highly uncertain. While property damage is (relatively) easy to visualize and measure, declines in economic activity related to SLR will be significantly harder to justify. Furthermore, these estimates will be highly sensitive to the assumptions made while conducting this analysis.

Furthermore, it is likely that there would be inflection points within the range of flooding, weakening the applicability of these results to a variety of situations. As an example, localized recurrent flooding would have an impact within the region, but would not necessarily create significant drag for the entirety of the region.

5.5 Length of Time for Analysis

This analysis would be a significant undertaking, and would take at least 1000 hours to complete.

5.6 Pros

- Properly conducted, this study would do a more thorough job of capturing the complete costs of SLR, and thus would allow for the proper level of adaptation to be identified.

5.7 Cons

- This study would take a significant number of person hours.
- The results of this study would not be robust as it would be extremely sensitive to assumption.
- Given the quality of the results, and the length of time required to conduct a more complete analysis, it might not pass a cost-benefit analysis.

6 Conclusions and Recommendations

There are many different guidelines and attempts to measure the economic impact of climate change in general, and SLR in particular. This paper briefly examines the mechanics of several of those methodologies. When making recommendations on research methodologies to pursue, the HRPDC uses a no-regrets framework, which requires both actionable results as well as minimal potential for underutilization of either time or money.

Currently, the economic department recommends moving forward with a direct damage estimation analysis. The HRPDC has already begun efforts that will allow that analysis to move forward, and there are several examples already conducted by other regions that can serve as a guide to conducting this analysis in Hampton Roads.

Additionally, this paper recommends that efforts are made to assess the availability of the data to conduct a property value analysis. This analysis would provide excellent value, and could serve as a model for other regions.

	DATA Availability/Quality	Labor Intensity Clear/Clear Methodology	Quality and Applicability of Results
Direct Damage Estimation	Green	Green	Green
Property Value Analysis	Yellow	Green	Green
Economic Impact of Adaptation	Yellow	Green	Yellow
Economic Drag from Sea Level Rise	Red	Red	Red

Table 1: Evaluation of Methods of Analysis

As a future step, this paper recommends that the HRPDC begin looking for grants to solicit for engineering analysis of adaptions that may be executed in the region, so that an analysis of adaptation methods may be conducted in the near future. The U.S. Army Corps of Engineers in the North Atlantic Coast Comprehensive Study both outlined current research into SLR adaptation strategies in Norfolk and outlined several strategy options that could be pursued. It also indicated what needed to be accomplished within the context of a preliminary financial analysis for adaptation in

Norfolk.[4] This analysis would allow staff to evaluate the viability and applicability of conducting an analysis of this type at the regional level.

Lastly, staff recommends against the HRPDC or other local government entities funding/attempting an study focused on estimating the full economic drag of Sea Level Rise. A project of this type combines high costs in terms of time and research dollars with an output that is sensitive to assumptions, and thus could create worse decision making if it were incorporated into planning. While it is an interesting and important question, there have been no rigorous estimates created for storms which have already occurred; much less attempts to produce credible estimates about future flooding events.

7 Bibliography

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[4] U.S. Army Corps of Engineers 2015. North Atlantic Coast Comprehensive Study, Norfolk Virginia Focus Area Analysis.

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I. Appendix: Examples of Research and Analysis

1 "North Atlantic Coast Comprehensive Study (NACCS)". Army Corps of Engineers, September 1, 2013.

   i. Government Document
   ii. Economic Analysis of Adaptation
   iii. This reviewed the City of Norfolk by Watershed, and evaluated the feasibility of a variety of adaptations for each independent watershed. This document did not provide the necessary information regarding the level of benefit provided by the adaptation or the cost of the various adaptations, though provided the information and planning for these efforts.

2 Neuman, James E. et al. "Joint effects of storm surge and sea-level rise on U.S. Coasts: new economic estimates of impacts, adaptation, and benefits of mitigation policy," Climatic Change. Vol 129: 337-349, December 2014.

   i. Academic
   ii. Direct Damage Estimation, Economic Analysis of Adaptation
   iii. Used the National Coast Property Model to estimate the damage from a variety of SLR scenarios; this model examines 150Mx150M blocks and includes elevation and property value data at that level. For adaptation, it would estimate the risk of flooding within each decade and damage relative to property values, then would either choose abandonment of the parcel, elevating building, or status quo based on relative costs.

3 "MID-ATLANTIC HURRICANE SCENARIO ANALYSIS REPORT" National Protection and Programs Directorate Office of Cyber and Infrastructure Analysis. September 2015.

   i. Government Document
   ii. Direct Damage Estimation, Economic Drag from Sea Level Rise
   iii. This study looked at the impact to critical infrastructure, industry, and industry from a significant storm. It also produced state level impacts to GDP from a storm, using the information developed in the report. Excellent guide for the variety of issues stemming form significant flooding which need to be examined in an Economic Drag Analysis.

4 Bin, Okmyund et al. "Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd," Land Economics, University of Wisconsin Press, vol. 80(4).

   i. Academic
   ii. Property Value Analysis
   iii. Excellent example of a property value analysis where the parcels are do not have amenities associated with flood risk.

5 Okmyung Bin & Thomas W. Crawford & Jamie B. Kruse & Craig E. Landry, 2008. "Viewscapes and Flood Hazard: Coastal Housing Market Response to Amenities and Risk," Land Economics, University of Wisconsin Press, vol. 84(3), pages 434-448.

i. Academic
ii. Property Value Analysis
iii. Extends property values analysis method to situations where the risk of flooding are tightly connected to the value of the property (water access or beachfront properties).

6 Wilson, Jeff et al. "Forecasting Economic Damages from Storm Surge Flooding: A Case Study on the Trantramar Region of New Brunswick." Atlantic Climate Adaptation Solutions Association. October 2012.

i. Government Document
ii. Direct Damage Estimation, Economic Impact of Adaptation
iii. Excellent example of direct damage estimation for a region, using GIS as the backbone of the analysis. The adaptation piece was less well developed, using beach nourishment as the sole adaptation option. HRPDC direct damage estimation efforts would closely follow this methodology when allowed to do so by data availability.

7 Hallegatte, Stephane et al. "Assessing climate change impacts, sea level rise, and storm surge risk in port cities: a cast study on Copenhagen," Climate Change 104:113-37

i. Academic
ii. Direct Damage Estimation, Economic Drag from SLR, Economics of Adaptation
iii. Uses the experience of Katrina to make assumptions on the distribution of property damage within Copenhagen (Residential $27-$35B, Commercial $25-$29B, Infrastructure $15-$18B, and Public building $6-8B). Also uses the water depth to measure the extent of damage to building, similarly to the New Brunswick case study. Moves from the direct costs to a 'total cost' analysis that contains significantly more assumptions, and may be considered speculative. For the adaptation estimation, it examined building Dikes for the entire 50 kM coastline of the region, at heights of 1, 2, and 3 meters.