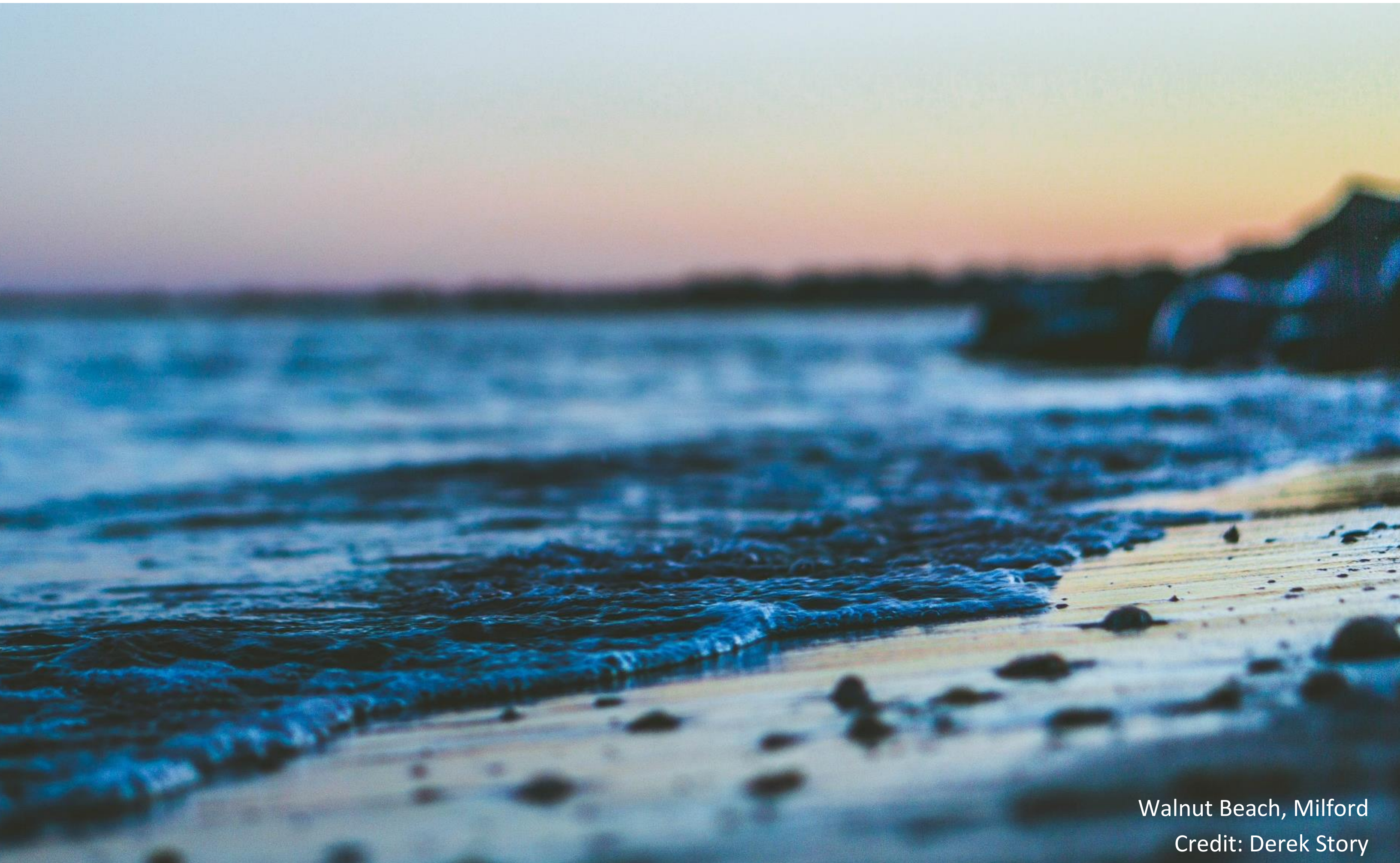

Walnut Beach, Milford
Credit: Derek Story

Real Estate Values, Tax Revenues, and Climate Change – Induced Retreat from Flood Zones

An analysis of hypothetical retreat from the Connecticut shoreline.

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More information about CIRCA can be found at circa.uconn.edu.

Some data provided by Zillow through the Zillow Transaction and Assessment Dataset (ZTRAX). More information on accessing the data can be found at http://www.zillow.com/ztrax. The results and opinions are those of the author(s) and do not reflect the position of Zillow Group.

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Executive Summary

Inundation events have been a fact of life for many years along the coastline of Connecticut, but rising sea levels are putting greater pressure on local governments to develop strategies for greater coastal resiliency. One tool for reducing coastal vulnerability is shoreline retreat, accomplished by buying flood-prone homes and returning the land to natural cover. Buyout programs utilize public funds for purchase and demolition, and for maintaining the resulting open space in perpetuity. The challenges to such draconian, yet permanent, solutions are numerous, but in the face of predictions of a twenty-inch sea level rise by 2050, removal of the most vulnerable structures is inevitable, one way or another.

Among the many obstacles to buyout programs are the direct project costs which are generally covered by federal and/or state funding sources and the anticipated loss of property tax revenue which accrues to the local government. Less often considered are the potential gains that can counteract a share of these financial losses.

There are several ways in which local governments can benefit:

1. Removal of vulnerable structures in the flood plain reduces demands on local emergency services and utility infrastructure.
2. Retreat projects are likely to improve a municipality's bond rating as such projects are viewed favorably by the financial sector that seeks resiliency planning evidence.
3. Natural uses of the vacated land may provide greater flood plain protection for the remaining flood plain residents, thus further increasing a town's resiliency.

Removals can have significant market impacts on the value of surrounding homes, which in turn will increase property tax revenue:

4. Neighborhood quality may improve from the removal of decaying structures suffering from repetitive flooding and its replacement with open space.
5. When the new open space also provides park-like attributes, values may increase even further.
6. Once dwellings closer to the water are removed, the value of neighboring houses may increase due to improved views and shoreline amenity access.

Direct benefits can accrue to homeowners in the flood plain

7. Retreat activities add points to a town's FEMA Community Rating Status (CRS), thus reducing flood insurance premiums for all residences in the flood plain. A direct benefit to town residents, the indirect effect may be increasing housing values and thus tax revenues.

In addition, the long run impacts on tax revenues will not be as severe as may be anticipated. Retreat is not equivalent to losing a structure's tax revenue in perpetuity. In the absence of demolition, the value of these vulnerable houses will be decreasing (likely quite rapidly) over time as flooding increases. When retreat is combined with relocation projects within the same jurisdiction but away from the flood plain, a new source of property tax revenue can be generated.

Our research compares lost tax revenues to some of these countervailing gains through a set of policy simulations informed by empirical estimations. There are four simulation scenarios, including two that are locationally defined on sea level rise predictions and two defined in terms of contiguous projects targeting lower valued properties. All scenarios target small mostly non-conforming lots to add a measure of realism, as such properties are less likely to undergo mitigation investment (such as structure elevation) instead of buyout. The four scenarios are defined as:

Scenario 1: Widespread retreat within the Sea Level Rise (SLR) projection of 20 inches by 2050 (532 properties)

Scenario 2: Widespread retreat within the projected Special Flood Hazard Area (9420 properties)

Scenario 3: Based on Scenario 2 but with a contiguity requirement and assessed property values less than $250,000 (30 contiguous projects ranging from 11 to 244 properties)

Scenario 4: Based on Scenario 2 but with a contiguity requirement and structure assessed values less than $60,000 (33 contiguous projects ranging from 7 to 317 contiguous properties)

For each scenario, lost tax revenue in the first year is calculated as well as the present value of lost tax revenue over a 50-year time horizon based on assumptions about the declining value of flood-prone properties over time. Comparison is made to estimated gains associated with mechanisms 4 through 7). Those directly benefiting local government (1, 2, and 3) are beyond our ability to measure.

Parameter estimates necessary to calculate gains are derived from an empirical model of housing price determination using a extensive compilation of data on residential sales transactions in coastal Connecticut towns over the past two decades. We characterize viewsheds by constructing measures of distance to Long Island Sound and width and amount of uninterrupted water views for each home in the coastal floodplain, statistically testing how different levels of these attributes are valued in the market. Estimates of the value home buyers place on waterfront status rely on a manual scouring of digital parcel boundary maps, property by property, identifying those with coast or bay frontage, those located across the street from the coast frontage, and those with river frontage. Estimated parameters from the literature are used to capture values of neighboring open space.

For the broad retreat scenarios 1 and 2, average lost tax revenue per property in the first year is about $7,000 with a net present value loss over a 50-year horizon averaging about $90,000. For retreat Scenarios 3 and 4 that target lower valued properties, lost tax revenue per property averages $4,000 in the first year and $60,000 in net present value. Under a set of rather conservative assumptions, we estimate valuation changes accruing to nearby homes and find this source of tax gain offsets up to 14% of lost tax revenue. There can be additional benefits totaling as much as 22% of the towns lost tax revenue but that accrue directly to homeowners through reductions in flood insurance premiums. Beneficial rate reductions are available to all residences in towns that participate in FEMA's Community Rating System and undertake resiliency activities such as buyout programs.

The housing market analysis yields additional insights that can be helpful in informing the likely success of other resilience strategies. After employing extensive measures to control for confounding influences, we estimate an average price discount of about 2.5% from being in the SFHA. In comparison, coast front homes see a 40% premium, and across the street from the coast, see a 27% premium. This relatively small effect is likely due in part to the limited information buyers have about flood risk before purchase and the often misleading signals given by flood insurance pricing policies. An understanding of the extent and ways in which homeowners perceive flood risk and act on those perceptions must necessarily underlie any resiliency planning.

Section 1. The Consequences of Flood Risk

Sea level rise is now broadly recognized as a major threat to the nation's coastline (National Climate Assessment, 2019). The combination of rising seas and more frequent and heavier storm events is already resulting in increases in periodic and severe flooding in many coastal communities. Defending against *current* levels of flood risk is challenging, but scientists predict this trend will continue, possibly at an increasing rate over this century, leading not just to more frequent and deeper flooding but chronic inundation in some areas.

This study focuses on rising flood risk and the Connecticut coastal housing market, the evolution of which is fundamentally tied to the well-being of its residents, the viability of local businesses, and the revenues that fund local government. A study by the Union of Concerned Scientists (UCS) calculated the number of homes along the U.S. coastline (by state, community, and zip code) that were predicted to suffer chronic inundation due to sea level rise at various points along an 80 year time horizon (Union of Concerned Scientists, 2018a). 'Chronic inundation' is defined as experiencing at least 26 floods per year even in the absence of heavy rains or storms (Dahl et al. 2017). According to their estimates, 4500 homes housing 10,000 people, valued at $3.4 billion and generating tax revenues of about $52 million in coastal Connecticut towns will be exposed to chronic inundation by 2045, well within the terms of a 30-year mortgage taken out today. UCS calculations suggest that by 2100 each of the above statistics will have increased by about five-fold, with 25,000 Connecticut houses chronically flooding.

Drawing on flooding forecast maps generated specifically for Connecticut by the Connecticut Institute for Resilience and Climate Adaptation[1] and counting housing units using digitized town maps, we estimate a level of vulnerability in the same ballpark but based on slightly different definitions. Frequent inundation is one measure, but another relates to flooding from storm surges, best captured with reference to FEMA's Severe Flood Hazard Area (SFHA) defined as a 1% or greater probability of annual flooding. The public is likely more aware of the SFHA which is updated on a periodic basis, plays a key role in building regulations, and forms the basis of flood insurance rate determination. Sea level rise will increase predicted flood heights throughout the SFHA and will expand its geographic extent.

The appeal of the shoreline - be it waterfront, water views, or water access - has been a major force in the U.S. housing market for more than a century. But it is widely believed that rising flood risks and frequent flooding events will - either gradually or suddenly - erode coastal housing values. Evidence of declining coastal home prices is already apparent in both research studies (First Street Foundation, 2019) and in the financial media (Flavelle, 2018; Leefeldt, 2018). As flooding becomes more severe and

[1] O'Donnell's research provided the basis for sea level rise projections and led to a mandate for periodic recalibration, both set out in Governor's Bill S.B. 7, introduced into the 2018 legislative session, and enacted into law as Public Act 18-82. The methodology is set out in O'Donnell, 2019.

frequent, incentives for maintaining structures disappear, hastening their loss of value. Foreclosures and abandonments follow. When these predictions become realities in Connecticut, vulnerable homeowners' consequences will be devastating as a family's house is typically its most valuable asset.

The consequences are more far-reaching, though. Surrounding home values may suffer from a decaying neighborhood. With falling property values on a broader scale comes a loss in local tax revenues, which provide over 70% of the revenues for Connecticut towns. If not made up from other sources, lost tax revenue affects municipality-level services provided to non-flooded areas. What's more, it reduces the ability of local governments to undertake adaptive actions to address flooding of public infrastructure (roads, bridges, power, and sewage treatment plants, etc).

At least two additional forces at work are likely to put downward pressure on coastal housing values – the flood insurance market and the lending market.

FEMA's National Flood Insurance Program (NFIP), by far the major flood insurer in the U.S., has operated at a substantial deficit for more than a decade as one catastrophic climate event after another has caused payouts to vastly exceed premiums. Flood insurance rates are now legislatively mandated to move towards full actuarial values, based on FEMA maps of flood risk, even as these maps themselves are being redrawn to reflect more accurately the effects of rising seas (Kousky, et al., 2016) and potentially higher rates for many will result if NFIP's proposed Risk Rating 2.0 pricing plan is enacted (Congressional Research Service, 2021). As risks increase for houses not adapted to withstand flood damage, premium rates will increase too, further applying downward pressure on prices buyers will be willing to pay for at-risk properties

A similar process of recognition and reassessment is ongoing in the financial sector. After years of ignoring the growing risk to investments in coastal areas, financial institutions are now taking steps to internalize climate risks into their lending policies. In past housing recessions, most families continued to make mortgage payments on houses that had lost value in the well-founded belief that the market would ultimately rebound. Devaluation due to rising seas can only get worse, leaving the lending sector with billions of dollars of worthless assets on their books. Facing this prospect, financial institutions are beginning to deny thirty-year mortgages in areas predicted to suffer chronic inundation (Flavelle, 2020a; Union of Concerned Scientists, 2018b).

It is likely that in the end, the less affluent will suffer the most from rising seas. Low-income households in the flood plain often do not purchase flood insurance either because of its cost or because they are unaware of the extent of risk or the possibility of insuring against it. For these families, flooding can mean losing everything. Even for those with insurance, payouts often yield far less than would be needed to rebuild safely. As NFIP rates continue to move to full actuarial values, participation in the flood insurance program will likely be further discouraged in poorer communities.

Homeowners living in less affluent towns may suffer disproportionately for yet another reason. The financial sector is reconsidering the risks involved in financing coastal municipalities whose infrastructure and tax base may both be at risk. (Moody's Investors Services, 2017, 2021; Walsh, 2017;

S&P Global Ratings, 2018). Bond ratings are being restructured to take into account the resiliency of a municipality's built-environment. It is a cruel irony that less affluent localities with fewer resources to direct toward resiliency projects will have little to show in this regard and will find it even more difficult to borrow the resources needed for mitigation and adaptation in the future (Deas et al. 2017).

Even if current sea level rise forecasts turn out to be overestimates, there seems little doubt that reversing the trend is unlikely. Ultimate outcomes may depend on the success of mitigation and adaptation strategies. While government officials can adopt regulations and provide incentives, they have no *direct* control over adaptation and mitigation actions for already built houses. Instituting policies that prohibit new development of increasingly vulnerable land is of little value along our shoreline because there is little developable land left in the flood-prone areas. More rigorous building standards will therefore apply principally to rebuilding and substantial renovation.

Homeowners can make decisions to rebuild or renovate in order to incorporate adaptive design features (e.g. elevation and flood-proofing). An alternative strategy, *retreat* from already developed but particularly at-risk areas, requires voluntary agreement to buyouts, and thus also depends on homeowner decisions. Buyers' decisions about where to purchase a house, and homeowners' decisions when considering adaptation/mitigation actions, will necessarily depend on their assessment of the financial implications. Understanding how climate change and sea-level rise affect households' decisions requires understanding the connection between these threats and the housing market – and how this connection is evolving.

Our principal task in this project is to explore the implications of retreat strategies. However, it quickly became clear to us that the first step must necessarily be a better understand of the housing market in coastal Connecticut. We needed to look for evidence of the extent to which the housing market may be providing signals to potential buyers about the costs and risks of living in the flood plain. Our work is based on more accurate and more extensive data types than have typically been incorporated in studies of its kind, some of which we have calculated ourselves from technical data sources and some of which have been acquired directly from coastal towns as they shared their flood plain insights with us. Nonetheless, each analysis is, to a greater or lesser extent, hampered by data difficulties which we discuss and which we are hoping to address through further cooperation with local officials.

Throughout this study, we seek clues as to how aware households (and particularly buyers in the market) are of the flood risks associated with location. Prices will respond to risks, insurance costs, and stringent flood plain regulations only if buyers have the necessary knowledge. Still, information about flood risk is not currently easy for households to obtain. Not only is the price response a signal of awareness, but it is also a motivation for homeowners to take mitigating actions because they know their investment can be recouped when they sell. Our initial study of the housing market provides a jumping off point to estimate the benefits of coastal retreat. Towns are known to be hesitant to facilitate buyout programs because of the loss in property tax revenue, but surprising results might arise from a careful study of the complex environment in which, whether or not action is taken, nothing will stay the same.

Section 2: The Regulatory Environment of the Housing Market

Just how complex is living in the flood plain, and who are the players? Homeowners are the ultimate decision-makers, but multiple governmental entities play essential roles. In this section, we describe the environment in which homeowners and buyers in the flood plain must navigate, as well as the challenges faced by local governments as they attempt to increase their town's resiliency. These considerations are central to our analysis as we estimate housing price effects associated with flood plain risk and gains that might come from shoreline retreat.

The Federal Role in Mapping and Flood Insurance

Starting broadly, the Federal Emergency Management Agency (FEMA) provides the overarching policy framework for flood plain management in the U.S. One of FEMA's roles through the National Flood Insurance Program (NFIP) is to produce Flood Insurance Rate Maps (FIRMs). These maps designate flood zones for use in determining flood risk and flood insurance premiums. [2] The Special Flood Hazard Area (SFHA) denotes areas with a 1% or higher annual probability of inundation and a 26% chance of flooding over the life of a 30-year mortgage'. The SFHA is the target of restrictive flood plain regulations and the focus of this project's research.

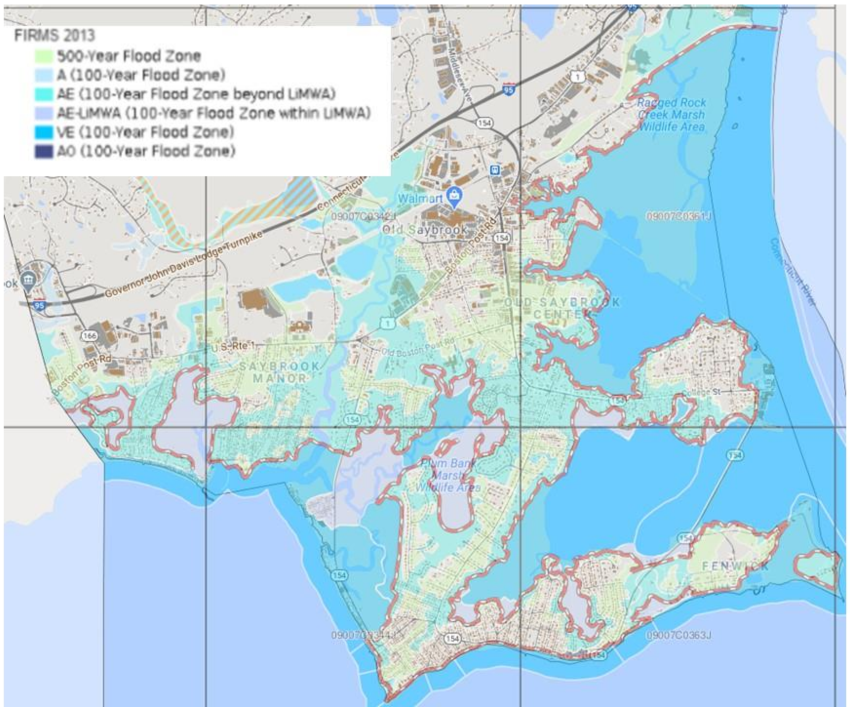
Within the SFHA, there are currently two relevant designations with V zones, areas where the flood exposure includes wave action with heights of at least 3 feet, and A zones where inundation concerns dominate. Evidence that severe damage can occur with wave heights as low as 1.5 feet has led to the recent mapping of the "limit of moderate wave action" line. The area seaward of this line but still within the A zone now has an official FEMA designation as a LiMWA or Coastal A zone. Connecticut incorporated this zone into its building codes in the flood plain (Ifkovic, 2018). Figure 1 depicts the flood zone delineations for Old Saybrook where most of the town south of Rt 95 is in some flood zone designation or another. The LiMWA boundary is delineated by the heavy red dashed line. Additional maps predicting flood inundation that were used for this study are based on O'Donnell (2019) and CIRCA's Sea Level Rise and Storm Surge Viewer.[3]

There is even further variability within these zones, specifically in the base flood elevation (BFE). BFE is the minimum height of surface water from a flood event predicted to be reached or exceeded with a 1% chance in any year. BFE is a measure relative to mean high tide (approximately) and not relative to the housing site's ground elevation. Roughly speaking, BFE minus ground elevation yields an estimate of how high the house's lowest inhabitable floor must be to avoid the 1% annual flooding probability.

[2] Private flood insurers have entered the market in the last few years, but the NFIP remains the major insurer. Private companies appear to be 'cherry-picking' the least vulnerable properties (often in the 500 year zone outside the SFHA) leaving the riskiest to the federal insurer.
[3] Maps of predicted flood inundation based on O'Donnell (2019) research can be found at: https://circa.uconn.edu/sea-level-rise-and-storm-surge-viewer/

Locations in which BFE's have been calculated are designated VE or AE zones and make up most of the SFHA in our shoreline towns.

Figure 1: FEMA Flood Zones, Old Saybrook, CT



Source: Town of Old Saybrook, https://oldsaybrookct.mapgeo.io/

In a simple world, an NFIP insurance premium rate would reflect a house's flood risk. With this information, buyers would have a good indication of flood risk, and homeowners could consider adaption activities that would lower flood risk and save on insurance costs. But flood insurance rate determination has been extremely complicated. Not only does a premium depend on characteristics of the structure, such as number of stories, existence of basement/crawlspace, and structure elevation, but rates have been subject to numerous discounts, subsidies, and exceptions that have overridden all other calculations. These 'overrides' include, but are not limited to,

- The 'Pre-FIRM' subsidy which applies to houses that have been continuously insured and built before, and not substantially altered since, the first FIRM map drawn for the area (anywhere from 1979 to 1981 in our shoreline communities) and
- Grandfathered rates for Post-FIRM houses that were in-compliance with elevation requirements at time of construction and were continuously insured since

Consequently, premiums vary dramatically house by house and cannot be easily understood by buyers or simulated by researchers.

The overall structure of NFIP's insurance rates has been changing during our study period and the rates themselves have been on the legislative radar for years. The Biggert-Waters Act of 2012 attempted to eliminate all exceptions and move all rates to full-risk levels. Before taking effect, it was replaced by the Homeowner Flood Insurance Affordability Act of 2014, which reversed some of the Biggert Waters changes but instituted a process by which rates would gradually increase to full-risk levels over time. These dates are of particular interest as they bracket the two most destructive storms (Sandy and Irene) to damage coastal Connecticut in this century.

Remapping flood zones and BFE's has occurred periodically to reflect rising sea levels and increases in storm frequency and surge. However, the Pre-FIRM and grandfathering clauses tend to blunt their immediate effect. New mapping projects are underway, and new insurance rating schemes are being considered (Congressional Research Service, 2021), which will likely extend the geographical range of the SFHA and more rapidly move insurance rates towards actuarial values.

The Federal Role in Flood Plain Regulations

FEMA plays another important role by setting minimum flood plain management regulations that must be enforced locally for the residents of that locality to be eligible for NFIP flood insurance. The requirements apply to newly constructed or substantially renovated structures and include the elevation of the structure at least to BFE (base flood elevation). The term 'substantially renovated' is defined as repairs or alterations that cost 50% or more of the structure's market value. The '50 % rule' forces owners of non-compliant houses to undertake considerable extra expense if they wish to make substantial changes in their home or if their home has suffered significant storm damage.

Local Government's Role

Localities bear the burden of enforcing NFIP requirements while also enforcing what are sometimes conflicting local zoning regulations such as local height restrictions or minimum setbacks. In addition, localities can impose stricter regulations than FEMA in a few important ways. Over time FEMA has encouraged states to adopt 'freeboard' (extra feet) to the BFE elevation requirement, as this has been found in post-storm studies to be one of the most effective ways of reducing storm damage. In anticipation of remapping and sea level rise, the state of Connecticut now requires structural elevation to exceed BFE by at least one foot, and some Connecticut towns have added further 'freeboard' requirements.

Localities also have the authority to stipulate over what period the 50% rule will be applied as well as what projects require permits and thus are subject to this calculation. The 'look-back' period varies from town to town and ranges from 1 year to the structure's 'lifetime' (or the period since the requirement started). The 50% rule is intended to move a town's housing stock towards greater resilience, but where the 'look-back' period is one year, homeowners often stage renovation projects to avoid bringing their house into compliance. With exceptionally long 'look-back' periods, unsuspecting buyers, with no knowledge of the intricacies of flood plain regulations, can purchase a home where there is no possibility of making any changes, no matter how slight, without requiring mitigation actions. When faced with the daunting costs of elevation, some undertake unpermitted projects that can lead to defective construction which once discovered must be dismantled. All of this must be monitored and enforced by local flood plain managers.

Towns can also qualify for discounts in insurance rates by participating in FEMA's Community Rating System (CRS). A town can earn points by meeting and exceeding NFIP regulations (e.g. increasing freeboard requirements), tracking repetitive loss properties, generating flooding information and warnings, maintaining extensive documentation, including accurate elevation records, and undertaking buyout programs. The reward is a percent discount of up to 45% in NFIP insurance premiums for homeowners in the locality. As of July 2020, nine Connecticut coastal towns qualified for discounts, ranging from 5% to 15%.

What Our Research Intends to Achieve

This project's original intention was to explore the implications for real estate values and tax revenues of climate change-induced retreat. Such an analysis cannot be empirical. It must take the form of a hypothetical simulation, as only one retreat project has taken place along the Connecticut shoreline.[4] However, empirical work can inform the simulation and, in the process, provide further insights valuable to the public sector as it tackles the challenges posed by increasing climate-induced flooding.

The intent of this project, then, is two-fold. First, we provide an initial analysis of the housing market in the flood plain to test hypotheses about homeowners' and homebuyers' responsiveness to market signals. The shoreline's appeal has been a significant force in the U.S. housing market for more than a century. Although far from complete, this section's description of life in the flood plain highlights factors that undermine that appeal, especially for those with neither views nor direct access to the water and those without the resources to manage the added costs inherent in flood plain living.

One key point emerges. The housing market can only reflect the level of knowledge and awareness of the participating parties. If buyers are only vaguely aware of flood risk, have no knowledge of the complex regulations governing substantial renovations, or have a limited idea of the current and future cost of flood insurance, the amount they are willing to pay for a house will not reflect the risks and ultimate expense. Where buyers are uninformed, market signals will not exist. Without awareness, the market will not provide accurate signals of the downside of owning property in the flood plain. Discussions with town officials suggest that the level of awareness varies considerably along the Connecticut shoreline. Some towns experienced significant storm damage in either Sandy or Irene or both, leading to a large percentage of rebuilt, elevated houses. In these areas, elevation is a key feature in real estate advertising, and non-elevated homes sell at a discount. Other towns report that buyers often appear oblivious to flood risks and the costs of living in the flood plain. This awareness is key to the economic analysis of resiliency efforts. Earlier, we noted that homeowners are the ultimate decision-makers for residential mitigation or retreat activities. Homeowners will be more likely to undertake adaption/mitigation activities if they are convinced that the market will reward them when they sell their house. And they will be more likely to agree to a buyout program if they understand that the value of their house will continue to fall as flood risk increases. Thus, our first goal is to seek evidence that buyers in the housing market react to flood risk.

[4] The project is in West Haven, but even this project cannot contribute to our analysis as the consequences for the surrounding market have yet to play out.

Section 3: Assembling a Database

One of the accomplishments of this project, and by far the most time-consuming, has involved identifying the critical factors that might be affecting variation in housing prices and collecting, digitizing, and calculating how to define those factors. Our current data compilation is richer than has been incorporated in past work on this topic.[5] Many important policy questions are as yet unanswerable given limited access to important data.

A. The Scope of the Study

Our analysis focuses on single-family, detached housing, which constitutes the largest residential land use along the Connecticut shoreline. The remaining categories of residential use include condos, camps, and mobile homes where land ownership is separate from structure ownership. Multifamily structures account for a third category with very differing attributes. Because they either involve rental units or joint decision making, decision making criteria are difficult to characterize.

Of the 24 municipalities along the Connecticut shoreline, we drop the three most westward (Greenwich, Darien, and Stamford). They are heavily influenced by the New York City suburban housing market with price ranges that far exceed those along the rest of the shoreline and have different budgetary pressures both individually and as a community. Substantial variation remains both within and across the remaining 21 municipal boundaries.

Although sales data are available over several decades for many towns, the more remote the sale date, the less trustworthy are the transaction details. What's more, other key aspects of the regulatory and physical landscape become increasingly difficult to characterize as we move back in time. Our analysis includes sales transactions beginning in 1998 and continuing through 2020.

B. Transaction Data, Housing Description, and Location

Our analysis requires knowledge of the housing stock: types of houses, their appraised and assessed values, the prices they have sold for overtime, and - of particular importance - their exact location. ZTRAX, a commercial product of Zillow, is an often-used source of such data by economists because it provides data on individual housing sales for many years and includes sales price, sales date, structure characteristics, and lot sizes, as well as extensive information on the financial details of each transaction. (Zillow, 2020)

Before using the ZTRAX data, many corrections and adjustments were made. Observations with missing important attributes were dropped as were sales whose price did not reflect market value (such as non-arms-length transactions, foreclosures, etc.) Appendix A describes the rather tedious process of

[5] Most past work has studied areas of the country with far larger flood plains (e.g. Florida, the Carolinas, and Texas) but quite different terrain and history. As a consequence, much of that work is not just less detailed than ours but also not very applicable to Connecticut's particular geography and socio-economics.

purging from the dataset all transactions that, for one reason or another, do not qualify as full market value.

To improve the accuracy of two of our key variables, municipality-provided data were used to verify or correct sales price (using town specific reporting systems such as Vision Government Solutions) and to improve the accuracy of locational data.[6] Exact house location is essential for measuring flood risk factors but also enables the calculation of important descriptors such as commuting distance to New York City and distances to highway entrances, railroads, airports, the nearest beach, and the nearest brownfield site. Surrounding land use is captured by measures of percent of developed land and percent of forest within a half-mile radius of the house, and distance to nearest high-intensity development.

C. Separating the Negative Flood Risk Effect from the Positive Water-Related Amenities

Testing hypotheses about the effect of flood risk on house prices is plagued by high correlation between location in the flood zone and the positive amenities of being near the water. Because Connecticut's shoreline is exceptionally complex and the terrain within the flood plain varies in elevation in unpredictable ways, the correlation between risk and amenities is not perfect. While most waterfront properties and those with water views are in the flood plain, some are not, simply because ground elevation varies considerably even along the coast. Conversely, only a small portion of houses in the flood plain have water views, and many do not even have easy access to the shoreline. Creating measures of this heterogeneity is the first step in identifying risk effects separately from amenity effects.

C.1. Measures of Amenities

Water-related amenities generally fall within three categories: waterfront, water view, and water access. Often researchers will quantify access by measuring the distance to the shoreline. We do include distance measures to the coastline, nearest public beach, and closest waterbody (be it the Sound, a bay, or river), but we don't stop there. Waterfront is the amenity that is associated with the largest price premium. To provide a uniform, complete, and informative set of waterfront variables, we manually scanned each town's parcel boundary map to identify three categories of interest:

- 'Coast front' includes properties bordering Long Island Sound or large bays with open access to the Sound.
- 'Riverfront' includes houses on navigable rivers and coves farther from the Sound.
- 'Waterfront across street' includes properties that do not border the water, but are situated across a road from an open beach or rocky shoreline, devoid of any structures.

The most challenging amenity to measure, and the second most important in terms of a price premium, is water view. Four measures of the house's 'viewshed' are calculated for each house within a 1 km distance to the shoreline. These complex calculations (described in Appendix B) depend on three sources of data:

- LiDAR data (National Oceanic and Atmospheric Administration)

[6] The ZTRAX Q&A's admit that the ZTRAX coordinates are not the best that can be provided due to limits in redistribution rights, and that it is necessary for the researcher to correct the address coordinates.

- Digitized maps of structure footprints (Connecticut Environmental Conditions Online, Connecticut Department of Energy and Environmental Protection)
- Digitized map of Long Island Sound (National Hydrography Data Plus High-Resolution data, US Geological Survey)

Using the high-resolution elevation surfaces available from these sources and working from carefully specified viewpoints, the viewshed analysis considers all obstructions to view, including other buildings, vegetation, and high ground. These calculated viewsheds are intersected with the Long Island Sound (LIS) polygon generating four different measures: LIS view area (in square feet), LIS view angle (in degrees), number of slices of LIS view, and LIS view distance (in feet up to 1 mile).

C.2. Measures of Flood Risk and Associated Data Challenges

In addition to the apparent confounding effects due to correlation with favorable amenities, there is the equally complex problem of defining flood risk and determining how prospective buyers might form perceptions of that risk.

FEMA's flood plain designations provide objective predictions of flood risk and, to the extent they are known and understood by buyers, may be good proxies for risk perceptions. Using FEMA's flood plain maps, which vary over the time frame of our analysis, we determine for each transaction whether the house sold was in the FEMA-designated SFHA (Special Flood Hazard Area) at the time of sale. The SFHA is significant because it is within this area that localities must enforce the National Flood Insurance Program's (NFIP's) floodplain management regulations. If a house resides in the SFHA, Connecticut law requires that this fact be disclosed to a buyer at closing, and if the transaction includes a federally backed loan, then purchase of flood insurance is mandatory. Whether buyers are fully aware of the consequences of being in the flood plain in time to make well-informed purchase decisions remains an open question, especially for those buyers not required to purchase insurance. Approximately 85% of the house purchases in our data involved mortgage financing.

Flood risk is not homogeneous throughout the SFHA. In principle, the distinction between types of flood zones would further define predicted levels of risk. But the VE zone is so closely correlated with waterfront as to make statistically identifiable results challenging to obtain, and the LiMWA designation is too new to apply to our study period. We do calculate the depth of expected flooding, measured as base flood elevation (BFE) minus ground elevation, as a possible indicator of flood risk, but this is relevant only for houses that have not been elevated.[7] Media attention focusing on areas that suffered damages during the storms of 2011-12 may have resulted in a greater perceived risk in those areas. To explore this possibility, we include data on the height of flood surge from Superstorm Sandy.

Except for Sandy surge data, these flood risk measures rely on FEMA flood plain maps which are periodically redrawn, an activity that has become much more frequent over the last decade as flooding

[7] Unfortunately, we do not yet have data on elevated structures but in the final section we discuss the possibilities of using such data to modify the BFE-ground elevation variable, to simulate insurance premiums, and, most importantly, to model homeowners' structural elevation decisions.

predictions accelerate. Sales transactions are therefore linked to the SFHA status according to the relevant FEMA map.

Because the Connecticut shoreline terrain is characterized by rapidly changing elevations, there are cases where ground elevations may be above BFE in isolated locations within otherwise flood-threatened areas. In such circumstances, homeowners can prove their localized ground elevation with engineering data and obtain a Letter of Map Amendment (LOMA) exempting their house from SFHA regulations. To improve the flood plain status variable's accuracy, we undertook the substantial task of obtaining copies of all Letters of Map Amendment for the study period. We ultimately shared our work with Connecticut's Department of Energy and Environmental Protection. Taking account of LOMAs reduced the number of houses within the SFHA by 311 sales.

C.3. How Flood Insurance Might Enter the Picture

Much of the literature addressing ways to encourage mitigation behavior mentions the size of insurance premiums as a potential motivating strategy. Although structural elevation can reduce insurance costs, this advantage is irrelevant for houses eligible for discounts. At least to date, the many discounts and peculiarities in NFIP's calculation of flood risk premiums have obscured risk and benefits of mitigating behavior. Although we are in the process of pursuing new data sources, at this time the absence of data on key determinants such as structure elevation and Severe Repetitive Loss[8] properties makes insurance cost simulation impossible. There is no obvious function of house characteristics that map directly to insurance rates.

There is an indirect means of exploring the effects of flood insurance costs on house prices. Any real estate purchase that involves federally backed loans (and most involving financial institutions of any kind) requires the concurrent acquisition of flood insurance. Whether the flood insurance premium is perceived as an indicator of flood risk or just a cost of locating in the flood plain, buyers with mortgages may be more aware of this cost. If so, we may find a more substantial negative flood plain effect for these transactions.

D. Sources of Data and Data Refinement Processes

Table 1 reports the original data sources for the factors we have discussed in this section. Data was collected for the following 21 municipalities (in order from west to east): Norwalk, Westport, Fairfield, Bridgeport, Stratford, Milford, West Haven, New Haven, East Haven, Branford, Guilford, Madison, Clinton, Westbrook, Old Saybrook, Old Lyme, East Lyme, Waterford, New London, Groton, Stonington.

In total, the dataset contains over 107877 sales transactions in the 21 municipalities over the period from 1998 through 2020. Summary statistics for these data elements are presented in Table 2.

[8] Repetitive Loss and Severe Repetitive Loss are FEMA designations for properties that have experienced multiple insurance claims from flooding over time. Locations of RL and SRL houses are not legally obtainable from FEMA.

Table 1. Data Sources

Data	Source	Time (or Acquired Time)
Tax assessment data and transaction records	ZTRAX	1998-2020
Special Flood Hazard Zone	National Flood Hazard Layer	Sept. 2012 (Effective since 2008), Mar. 2017, April 2019
Hurricane Irene Surge	FEMA Modeling Task Force	2018
Hurricane Sandy Surge	FEMA Modeling Task Force	2019
Waterbody	National Hydrography Dataset High Resolution data (NHDPlus HR)	2017
Shoreline and estuary	CUSP NOAA	2017
Elevation	NED 30meter	2016
Landcover	NLCD	2002, 2008-2015
School districts	US Census TIGER/line Shapefiles	2017
Streets and roads	US Census TIGER/line Shapefiles	2018
Railroads	US Census TIGER/line Shapefiles	2015
Highway exists	Tele Atlas North America	2018
LiDAR 2012 CT coast	NOAA	2012 post sandy
LiDAR 2006 CT coast	NOAA	2006
LiDAR 2016 CT coast	CT ECO	2016
Building footprints	CT ECO, originator: Quantum Spatial	2012
Parcel polygons with address	Individual municipalities or regional Council of Governments	Acquired 2019
Brownfield	CT DEEP Brownfields Inventory	2017
Census Blocks with median income	United States Census Bureau	2017
Municipal boundaries	DEEP GIS database	2017

Table 2. Summary Statistics for Original Sample

Variables	Mean (S.D.)		
	All	In Flood Plain	Outside Flood Plain
Housing Price	470432.514	621580.120	451562.704
	(417916.701)	(553222.123)	(393757.117)
Flood Plain (SFHA DFIRM)	0.111	1.000	0.000
	(0.314)	(0.000)	(0.000)
Base Flood Elevation (ft)	0.839	7.505	0.006
	(2.950)	(5.279)	(0.264)
Sandy Surge (ft)	0.104	0.907	0.004
	(0.552)	(1.379)	(0.120)
Irene Surge	0.052	0.355	0.014
	(0.427)	(1.073)	(0.219)
Ln (LIS View Area)	0.781	3.561	0.434
	(3.193)	(6.180)	(2.370)
Ln (LIS View Angle)	0.121	0.595	0.062
	(0.615)	(1.320)	(0.419)
LIS Viewshed Slice No.	0.189	0.936	0.096
	(1.366)	(3.194)	(0.864)
LIS Viewshed Distance (ft)	5058.962	4220.792	5163.603
	(996.502)	(2020.259)	(713.321)
Coast Front	0.012	0.078	0.004
	(0.110)	(0.268)	(0.063)
River Front	0.007	0.043	0.003
	(0.086)	(0.202)	(0.055)
Waterfront Across Street	0.004	0.020	0.002
	(0.061)	(0.139)	(0.041)
Building SQFT (living space)	1842.986	1804.144	1847.835
	(936.464)	(903.946)	(940.337)
Building SQFT (total space)	3819.792	3378.023	3874.944
	(2099.690)	(1823.644)	(2125.215)
Lot SQFT	22414.416	14738.464	23372.709
	(34912.971)	(27315.103)	(35632.511)
Building Age	58.041	61.578	57.599
	(31.751)	(32.309)	(31.653)
Ground Elevation	78.868	17.811	86.490
	(67.793)	(30.058)	(67.330)
Sewer Service (dummy)	0.688	0.681	0.689
	(0.463)	(0.466)	(0.463)
No of Buildings	1.037	1.046	1.035
	(0.283)	(0.310)	(0.280)
No of Stories	1.604	1.675	1.595
	(0.557)	(0.574)	(0.555)
Total Rooms	6.739	6.485	6.771
	(1.835)	(1.775)	(1.840)
Total Bedrooms	3.202	3.087	3.216
	(0.863)	(0.914)	(0.855)
Total Calculated Bath Count	2.071	2.097	2.068
	(0.966)	(0.968)	(0.966)
Air Condition	0.106	0.121	0.104
	(0.307)	(0.326)	(0.305)

Fireplace Number	1.206	1.195	1.207
	(0.381)	(0.322)	(0.388)
Pool	0.011	0.008	0.012
	(0.106)	(0.090)	(0.108)
Garage No. of Cars	0.223	0.140	0.234
	(0.576)	(0.470)	(0.587)
Distance along I-95 to New York City	64.404	63.843	64.474
	(27.869)	(28.952)	(27.730)
Ln (Distance to the Coastline)	3.799	2.526	3.958
	(1.199)	(1.376)	(1.074)
Ln (Distance nearest Highway Exit)	0.731	0.830	0.719
	(0.336)	(0.316)	(0.336)
Ln (Distance nearest Highway)	2.568	2.774	2.542
	(0.883)	(0.947)	(0.872)
Ln (Distance to the Railroad)	3.805	3.729	3.814
	(0.899)	(0.725)	(0.918)
Ln (Distance nearest Public Beach)	1.002	0.598	1.052
	(0.500)	(0.444)	(0.484)
Ln (Distance nearest Brownfield site)	4.486	4.605	4.471
	(0.775)	(0.708)	(0.782)
Ln (Distance to nearest Waterbody)	2.180	1.606	2.252
	(0.771)	(0.865)	(0.727)
Ln (Distance nearest High Intensity Development)	2.025	1.613	2.077
	(0.970)	(0.940)	(0.961)
Ln (Distance nearest State Park)	1.240	1.238	1.240
	(0.474)	(0.467)	(0.475)
Ln (Distance nearest Airport)	5.163	5.047	5.177
	(0.740)	(0.901)	(0.717)
Ln (Distance nearest Coastal Barrier Resources System)	4.687	4.119	4.758
	(0.855)	(0.988)	(0.809)
Ratio of agricultural land within .5 mile	0.025	0.023	0.025
	(0.042)	(0.042)	(0.042)
Ratio of developed land within .5 mile	0.536	0.471	0.544
	(0.252)	(0.225)	(0.254)
Ratio of forest within .5 mile	0.239	0.172	0.248
	(0.227)	(0.157)	(0.233)
Ratio of open space or wetland within .5 mile	0.199	0.334	0.183
	(0.171)	(0.211)	(0.157)
N	107877	11973	95904

Notes: Distance along I-95 to New York City measured in miles and used in linear form; other distance variables measured in feet and used in log forms. Airports in the area are small; distances reflect noise dis-amenity and not transport advantages. High intensity developed areas include dense commercial/industrial uses, apartment complexes, row houses, etc, where 80-100% of land cover is impervious (https://www.mrlc.gov/sites/default/files/metadata/landcover.html.) The Coastal Barrier Resources Act encourages the conservation of hurricane prone, biologically rich coastal barriers by restricting federal expenditures that encourage development (https://www.fws.gov/cbra/Act.html.)

Section 4: Analyzing the Effect of Flood Risk on the Housing Market

As a precursor to an analysis of retreat scenarios, we first analyze empirical relationships between market prices and property characteristics. The estimated parameters will be used in the retreat scenarios and to address a central policy question: Is there statistically significant evidence that home buyers in towns along the shoreline are aware of and respond to variations in flood risk.

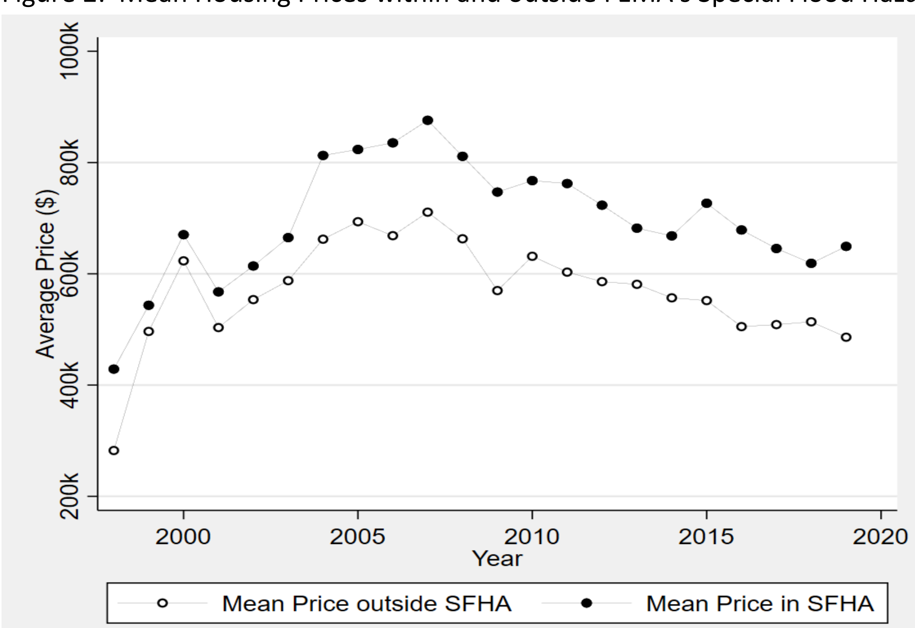
Locational factors such as waterfront or accessibility are well-known to be reflected in housing prices. Whether flood risk is also capitalized into these prices is an empirical issue. If not, homeowners will be reluctant to undertake expensive mitigation activities and be less likely to participate in buyout programs, as they will fail to appreciate that future flood risk will depress their house's value *irreversibly*. In what follows, we look for statistical evidence of a price response to flood risk.

The Estimation Strategy

Hedonic regression is a well-established statistical approach that economists have used for decades to analyze the relationship between housing prices and characteristics. There are many modifications that can be made in this general approach, some to improve the robustness of estimators and to reduce potential bias due to correlation among characteristics. Given how many important characteristics are related to location, a complex correlation pattern is likely to arise.

Our challenge is separating the expected conflict between the strong amenity effect of being close to the water and the heightened flood risk that this location presents. The strength of the shoreline amenity effect is illustrated in Figure 2 below. Over the entire study period, average price in the SFHA exceeds that outside the SFHA within our 21 coastal towns.

Figure 2: Mean Housing Prices within and outside FEMA's Special Flood Hazard Area



In Section 3, we took the first step in a strategy to address the problem of correlation by measuring as many amenities and risk factors as possible to tease out estimates of the competing effects. In this section, we describe the estimation method that uses this extensive data to the best advantage. Our strategy is to employ a quasi-experimental design to reduce potential biases in the parameter estimates of the flood risk and amenity effects. We focus on flood plain status – i.e. being in or out of the Special Flood Hazard Area (SFHA) - as the primary flood risk indicator. Our design involves identifying a 'comparable' non-SFHA transaction to match each SFHA property transaction. Formally, we employ a nearest-neighbor matching algorithm[9]. Each flood zone transaction is matched with a similar non-flood-zone transaction, where similarity is based first on the following discrete criteria:

- Same year of transaction
- Same loan status category (mortgage or not)
- Same category of median income within Census block group (high-income or not) [10]
- Same urban status (where 'urban=1' for New Haven, Bridgeport, and New London)
- Same coastal-proximity band (defined by 10th percentiles of the distribution of distance from coastline).

Once these discrete matches are enforced, the matching algorithm searches for the nearest non-SFHA neighbor for each SFHA transaction based on the 'Mahalanobis distance', where nearest neighbor is defined on the following continuous attributes:

- ln of LIS view area,
- ln of LIS view angle,
- ln of LIS viewshed distance,
- relative ground elevation (deviation from the town mean),
- distance along I-95 to New York City (miles),
- ln of distance to the coastline (feet),
- ln of distance to the nearest Brownfield site (feet),
- ln of distance to the nearest highway (Census defined primary/secondary roads) (feet),
- ln of distance to the nearest highway exit (feet),
- ln of distance to the nearest railroad (feet),
- ln of distance to the nearest public beach (feet),
- ln of distance to the nearest waterbody (feet),
- ln of distance to the nearest high intensity development area (feet),
- ln of distance to the nearest state park (feet),
- ln of distance to the nearest airport (feet),
- ln of distance to the nearest Coastal Barrier Resources System (CBRS) (feet),
- ratio of developed land within a half-mile radius,
- ratio of forest land within a half-mile radius,

[9] Dehejia and Wahba 1999; Rubin, 2006; Ho et al. 2007; Stuart 2010; Alix-Garcia et al. 2015; Imbens and Wooldridge 2009; Johnston and Moeltner 2019.

[10] The measure is based on median household income by Census block group (2017) with the high-income category being defined as a median income greater than $150,000 per year.

- ratio of open space or wetland within a half-mile radius,
- building square footage (sqft),
- lot size (sqft),
- building age,
- number of structures on property,
- number of baths,
- garage capacity (number of cars),
- fireplace number,
- number of bedrooms,
- number of floors in the structure.

This process results in a 'matched' sample containing the 'treated' observations (all 11,973 transactions in the SFHA) and the set of 'control' observations that provide matches for each treated transaction (7,430 non-SFHA observations). As is obvious from these numbers, some controls are used to match more than one SFHA property transaction.

The matched sample forms the basis of a weighted[11] hedonic regression of house price on $SFHA$ status and our long list of covariates describing the structure, lot, and location characteristics. The regression also includes a set of fixed effects including temporal fixed effects measured in quarters from 1998*Q1* through 2020*Q4*, monthly seasonal fixed effects (January through December), and municipality fixed effects by town[12], the latter being included as a regression control for unobservables that are time-invariant, such as neighborhood-specific amenities that are unchanging and hard to measure.

The Results of the Estimation

Table 3 shows parameter estimates for a subset that are key to our investigation. Some ancillary characteristics associated with house and location are also presented to highlight their consistency with expectations and their robustness across specifications. The full set of results for all covariates is presented in Appendix C.

The first column shows estimated coefficients from applying ordinary least squares to the full (non-matched) dataset. Because matching is not involved, all 107,877 transactions are used, including the 11,973 in the SFHA and 95,904 located outside the flood plain. The results from applying the matching method can be found in Column 2. These are based on 19,403 transactions, as 88,474 non-SFHA transactions are not included because they are not sufficiently similar to houses in the flood plain and therefore cannot be considered valid 'comparables'.

[11] Weights are generated in the matching process.
[12] Municipality boundaries and school districts are identical.

Table 3. Key Estimated Coefficients using Ordinary Least Squares and Matching Regression

Variables in Model	Ordinary Least Squares	Matching Regression
SFHA	-0.014	-0.0245+
	(0.0226)	(0.013)
Ln(View area)	0.0004	0.001
	(0.0025)	(0.002)
Ln(View angle)	0.0214*	0.0271**
	(0.0088)	(0.009)
Coast front	0.426***	0.391***
	(0.0284)	(0.031)
River front	0.302***	0.270***
	(0.0373)	(0.037)
Waterfront across street	0.312***	0.271***
	(0.0403)	(0.038)
Square footage living	0.274***	0.284***
	(0.0200)	(0.042)
Square footage total	0.145***	0.144**
	(0.0227)	(0.050)
Lot size	0.0547***	0.0628***
	(0.0051)	(0.010)
Age	-0.00327***	-0.00312***
	(0.0003)	(0.000)
Age squared	0.0000134***	0.0000154***
	(0.0000)	(0.000)
Rooms	0.0135***	0.0149***
	(0.0018)	(0.004)
Air conditioned	0.0666***	0.0832***
	(0.0050)	(0.012)
Distance to NYC	-0.00522***	-0.00503***
	(0.0012)	(0.001)
Distance to coast	-0.0607***	-0.0513***
	(0.0094)	(0.011)
Distance to brownfield	0.105***	0.156***
	(0.0126)	(0.024)
Distance to dense development	0.0287***	0.0264**
	(0.0045)	(0.009)
Distance to state park	0.0538*	0.0662+
	(0.0261)	(0.035)
Distance to airport	0.0453*	0.0978**
	(0.0188)	(0.031)
Distance to CBRS	-0.0261*	-0.0644***
	(0.0132)	(0.017)
N / R^2	107,776 / 0.817	19,272 / 0.830
Standard errors in parentheses	Significance + p<.1, * p<.05, ** p<.01, *** p<.001	

The estimated coefficients of important structural characteristics are both statistically significant and surprisingly similar in magnitude whether estimated using OLS or the matching procedure. The estimated coefficients associated with some of the distance variables exhibit a similar pattern.

The key variables for our purposes are the viewshed and shoreline amenity descriptors, as well as the central variable – flood plain status. Not surprisingly, our three water-related descriptors are highly statistically significant and not dissimilar across models. Focusing on the matching model, waterfront properties on Long Island Sound or the bays with open access to the Sound command a significant premium of approximately 47%[13] over similar but non-waterfront properties. The premium for riverfront properties and properties across the street from the oceanfront (with no structures between the street and the Sound) is approximately 30%. This difference is an entirely novel finding in the literature.

Of the multiple viewshed measurements calculated, the size of the viewshed *angle* appears to be the most successful at capturing the water view amenity. The wider the view, the more valuable the property. However, the collinearity among our four viewshed variables may be masking further dimensions of importance. The OLS and matched regression results are once again similar and, in the matched sample, significant at the 95% level. Table 4 provides help interpreting the estimated coefficients in this specification. [14] Price changes are given for two levels of change in viewshed angle, applied to two different viewshed starting points and for houses of two different initial values.

[13] The percentage changes are transformed from the log-price regression coefficients, since the changes in the waterfront variables are not marginal (i.e., from 0 to 1). To be exact, if the coefficient is β, the percentage change should be [100*(e^{β}-1)].

[14] Interpreting the size of these coefficients is complicated by an initial transformation necessary given that the natural log of 0 is undefined.

Table 4. Examples of Estimated Effects for Coastal-related Amenities

Initial housing Value	$617,995 (about the AE zone average)		$473,406 (about the sample average)	
Initial view angle	0°	30°	0°	30°
Change in view angle	Change in property value (percentage changes are in parentheses)			
+1° (marginal)	+$13,292 (2.15%)	+$618.0 (0.1%)	+$10,182 (2.15%)	+$461.6 (0.1%)
+30°	+$68,709 (11.1%)	+$12,977 (2.1%)	+52,634 (11.1%)	+$9,940.5 (2.1%)

Note: These results are conditional on holding other view variables and waterfront variables constant. Even though it is impossible to hold the view area constant when changing view angle, the view area coefficient is small and not significantly different from zero.

Evidence of a Response to Flood Risk Factors

Our analysis uses SFHA status as the indicator of flood risk. We did consider two other flood risk indicators, but each had problems that limited their usefulness. We thought that surge levels from Superstorm Sandy might lead to a greater awareness of flood risk. At best, this is a tenuous measure of perceived risk, but it has an even more significant flaw. Areas particularly hard hit by Sandy and suffering the most damage in housing stock saw the most rebuilding and structure elevation. Consequently, houses purchased post-Sandy in such areas may be viewed as less prone to flood risk.

Net BFE (base flood elevation minus ground elevation) is another, more accurate measure of flood risk, although this measure is less likely to be perceptible by buyers. Once again, structure elevation complicates interpretation. Net BFE is not a measure of flood risk for elevated houses, and houses will be more likely to be elevated in areas with the greatest inundation risk as elevation provides flood protection. With the planned acquisition of better data on elevated houses, we should be able to add much more to this discussion.

In Table 3, the flood risk indicator is flood plain status, denoting whether the transacted house is located in the SFHA or not. Not surprisingly, we find no significant evidence of SFHA status's effect in the naïve OLS model using the full sample of 107,877 transactions. It would be econometrically ideal if flood plain status were assigned to sales transactions randomly, but as that is obviously not the case, the matching exercise aims to control for factors correlated with flood plain status so as to better untangle its effect on price. Comparing the OLS estimates with the matching results suggests that we have had at least some success in doing this. Using the matching technique, the estimated effect of being in the SFHA is a decrease of about 2.45% in price (statistically significant at 10 percent level with p value close to .05), holding constant the long list of covariates we have included in the specification.

It is possible that because buyers assuming loans must purchase flood insurance, such buyers might be more sensitive to flood plain status. Table 5 reports results from re-estimating the model separately for transactions with and without loans. For the loan group, the price discount associated with being in the SFHA is about 2.17% (similar to the magnitude and at the same significance level as the full matched sample estimate). The estimate for the transaction-without-loan group, while slightly larger in magnitude, is not significantly different from zero even at the 90% level of confidence. This difference in statistical significance may result because the insurance requirement ensures that loan recipients are uniformly more aware of the flood risk compared to those who purchase without a mortgage. The significant negative effect for those with mortgages reflects the fact that flood insurance adds to the annual carrying cost of a house, causing buyers to be willing to pay less for a house in the flood plain (all else equal). Given that approximately 85% of transactions depend on mortgages, our results suggest that rising flood insurance rates may further encourage buyers to take account of SFHA-related costs and, albeit indirectly, the risk of living in the flood plain.

Table 5. Comparison of Model Results – with and without transactions

Variables in Model	Transactions with Loan	Transactions w/o Loan
SFHA	-0.0217+	-0.0356
	(0.012)	(0.025)
view angle	0.0264*	0.0288+
	(0.012)	(0.016)
waterfront_ocean	0.402***	0.349***
	(0.032)	(0.060)
waterfront_river	0.269***	0.250***
	(0.045)	(0.056)
waterfront_street	0.247***	0.308***
	(0.046)	(0.050)
square footage living	0.288***	0.310***
	(0.045)	(0.050)
square footage total	0.145**	0.124*
	(0.054)	(0.050)
lot size	0.0597***	0.0868***
	(0.011)	(0.019)
age	-0.00257***	-0.00554***
	(0.000)	(0.001)
age squared	0.0000122***	0.0000332***
	(0.000)	(0.000)
rooms	0.0172***	-0.00112
	(0.004)	(0.008)
air conditioned	0.0699***	0.0853***
	(0.012)	(0.024)
distance to NYC	-0.00448***	-0.00722***
	(0.001)	(0.002)
distance to coast	-0.0469***	-0.0773***
	(0.012)	(0.021)

Table 5 continued

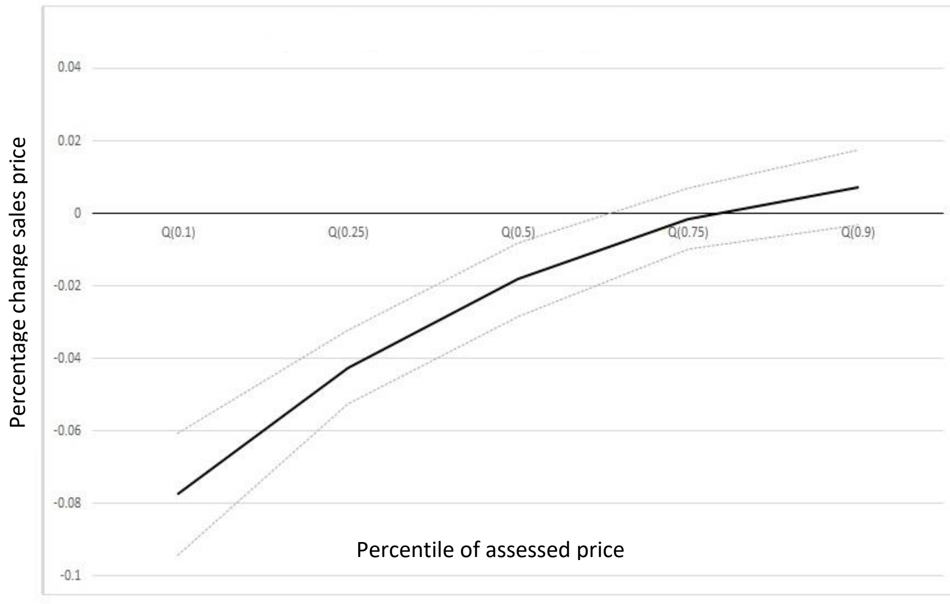
distance to brownfield	0.146***	0.172***
	(0.023)	(0.037)
distance to dense development	0.0255**	0.028
	(0.009)	(0.017)
distance to state park	0.0677+	0.072
	(0.036)	(0.046)
distance to airport	0.102***	0.129**
	(0.030)	(0.049)
distance to CBRS	-0.0626***	-0.0703**
	(0.018)	(0.024)
N	14,423	4,442
R^2	0.866	0.828

Standard errors in parentheses
+ p<.1, ** p<.01, *** p<0.001

Exploring Further Dimensions

Of particular interest is how flood risk might affect different socio-economic groups. Looking at a graph of the SFHA effect by housing value quartile (Figure 3), we see that SFHA status has a depressing effect on price for low-valued houses, as defined by their assessed values. There are at least two contributing factors likely at work here. Low-priced properties are unlikely to be found close to the shoreline because the land itself is highly valued. Instead, these low-priced houses are the most likely to suffer from the regulations and risks of being in the flood plain without shoreline amenity benefits. What's more, these low-valued houses are more likely to be owned by more impoverished people constrained by the 50% rule from making substantial improvements and people often unable to afford flood insurance.

Figure 3. The flood zone effect on different quantiles with quantile regression



Interpretation of Statistical Results

Our extensive data collection and construction, the use of a statistical matching method, and the robustness of coefficient estimates for standard hedonic covariates over multiple specifications contribute to our confidence in the results. The strong effect of waterfront and at least one view shed measure correspond in magnitudes to anecdotal observations of these effects and suggest that our statistical description of the housing market is plausible. If we accept this, results concerning SFHA status indicate that house prices respond, at least over some ranges of prices, to the risk/and or costs of flood plain location. The effect is small, however, less than 2.5 %. Although not greater in magnitude, the greater significance of results for transactions involving loans, relative to those that do not, lends support for the argument that the cost of flood insurance rather than the simple awareness of flood risk may be the more compelling factor.

This analysis is hampered by one serious shortcoming in the data. As yet, we are unable to take account of structural elevations. As explained in detail in Section 2, current SFHA building regulations require new houses to be constructed on stilts, pilings or vented sub structures such that lowest inhabitable floor is above BFE plus required freeboard. The requirement also applies to substantial renovations (the '50%' Rule). Both perceived flood risk and insurance cost will be greatly affected by structure elevation. Any truly complete analysis of response to flood risk must be able to account for this structure characteristic. Our efforts to date as well as our plans for the future construction of a complete inventory of elevated houses are discussed in Section 6.

Section 5: Shoreline Retreat

In many places along the shoreline, hardscape solutions and structural elevations will be insufficient to fend off flood risk of the predicted magnitude even as soon as 2050. Increasingly scientists have identified managed retreat as an imperative in the most vulnerable areas, as this strategy moves people away from high-risk areas, permanently eliminating their risk.

The Mechanics of Buyout Programs

Federal grants to fund buyouts have been available since 1989. Some sources such as FEMA's Hazard Mitigation Grant Program (HMGP) and HUD's Community Development Block Grants-Disaster Recovery (CDBG-DR) activate only in response to a disaster declaration, providing an alternative to repairing damaged homes. FEMA's Pre-disaster Mitigation Program (PDM) and Flood Mitigation Assistance (FMA) facilitate buyout programs that can be carefully planned and implemented before disaster strikes.

The one buyout program that has occurred in our study area was funded, not by any of the above, but by a more minor program within the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture. The Emergency Watershed Protection - Floodplain Easement (EWPP-FPE) Program provided the means of purchasing 13 properties[15] in the Old Field Creek neighborhood of West Haven beginning in 2016. This neighborhood was suffering repeated inundation events, causing flood damage and mold problems. A quote from one of the voluntary participants provides insight into the motivations needed to accomplish resident cooperation: "… I couldn't afford to stay there anymore… I'd put all my savings into remodeling the house. We were told that over a period of five years, flood-hazard insurance would double. Putting my house on stilts would cost $150,000. I'd loved the fact that deer would come right up to the house, but I had financially no way of surviving." [16] It took a good deal of effort by the town and its grant writer to accomplish this buyout, and a fair amount of desperation on the part of residents to make this happen, which explains in part why examples of buyouts are so rare.

One of the most significant obstacles is the time it takes to accomplish a buyout. The acquisition process begins with local authorities identifying properties and obtaining letters of intent from willing households. The locality then prepares a detailed application sent through the state to FEMA, which applies its benefit/cost criteria. With acceptance comes buyout offers based on pre-disaster market value. In a successful project the local government then moves forward to take title, demolish the structure and return the land to natural vegetation, with most but no more than 75% of the costs borne by the federal grant program. The length of time between initiation and closing can be as much as two or three years for the homeowner.

For many homeowners, it is traumatic to leave a home and neighborhood after many years or even generations. Finding an affordable new home presents further challenges. In some cases of extreme and long term flooding, FEMA has allocated a shortfall allowance recognizing the difference in home

[15] The original application included more than 30 homes, but in the end only 13 made it through the full process.
[16] See https://www.ecori.org/climate-change/2016/7/18/program-helps-floodplain-homeowners-relocate for a description published in a Southern New England environmental news outlet.

price between the repetitive loss areas and areas outside the flood plain. The now-famous New York state program (the NY Rising Buyout Program) also tried to overcome this obstacle by offering additional incentives in high-risk communities. These were easier to attain if the community agreed to move *en masse* and if households relocated in the same county (Freudenbert, et al, 2016).

Despite these obstacles, there are many places in the U.S. where flooding is already so severe and repetitive that homeowners are desperate for buy-out options. But local authorities have been reluctant to undertake the management task given limited staff and tight budgets and the reluctance to forfeit the revenue by reverting taxable real estate into public open space. This is of particular concern in Connecticut, where localities depend on property tax revenues for an average of 71% of their budgets.

Pressure to use retreat strategies is increasing, though. With growing natural disaster spending, federal agencies are putting more pressure on states to invest in mitigation activities. The Army Corps of Engineers is threatening to withhold project aid in locations where mitigation actions are not being pursued and are purportedly considering the necessity of side-stepping the voluntary requirement for buyouts by invoking eminent domain (Wetlands Watch, 2020; Flavelle, 2020b). Perhaps the most prominent emerging obstacle comes from the financial sector. At the household level, thirty-year mortgages in potentially vulnerable areas see increasing scrutiny. At the municipal level, restructured bond ratings penalize local governments that have undertaken little in the way of mitigation activity.

Accounting for the Benefits of Retreat

Recognizing that local government resistance is often the greatest obstacle to retreat, attempts are being made to identify ways to recoup tax revenue losses (Wiley, 2018). Among them are strategies to relocate displaced homeowners to new developments within the same jurisdiction and expand the tax base to make up for losses in the flood plain. This is a strategy pursued in the New York Rising project, but one that at this point is beyond our ability to assess.

Even where internal relocation is impossible, there are additional ways in which localities may benefit from shoreline retreat.

1. Removal of vulnerable structures in the flood plain reduces demands on local emergency services and utility infrastructure.
2. Natural uses of the vacated land may provide flood plain protection for the remaining surrounding residences (Nature Conservancy, 2020). FEMA is encouraging localities to consider these and other environmental benefits such as improved groundwater recharge.
3. The resulting open space may also provide parks and recreational opportunities to town residents, raising the value of neighboring real estate and in turn raising tax revenues.
4. The value of neighboring houses may also increase due to improved views and shoreline access once houses closer to the water are removed.
5. Neighborhood quality may improve from the removal of decaying structures suffering from repetitive flooding. Anything that raises neighboring property values raises property tax revenue.

6. Retreat activities can reduce flood insurance premiums for the entire town by adding points to the town's Community Rating Status (CRS).
7. Retreat projects could improve a municipality's bond rating as such projects are viewed favorably by the financial sector that seeks evidence of resiliency planning.
8. The present value of the tax revenue lost from structure demolition will be smaller than towns may be calculating. Should they not be demolished, the value of these vulnerable houses will be decreasing (likely quite rapidly) over time as flooding becomes more prevalent.

Only local authorities can calculate their specific estimates of infrastructure and emergency services savings and benefits from improved bond ratings. And without the help of scientists, evaluation of any resulting flood plain or groundwater protection is beyond our capabilities. We do make a rough estimate of the flood insurance premium savings, but this section's major focus will be on tax revenue gains through effects on neighboring properties as these gains accrue to the towns. This question cannot be answered directly through empirical work because of the lack of retreat experiences. Instead, we use parameters estimated in our analysis of housing prices and in other studies of real estate markets to simulate impacts under a set of retreat scenarios.

Defining Scenarios

Developing plausible retreat scenarios is a challenge. The obvious starting place would be to identify areas where flooding has already become a persistent problem. Lists of Repetitive Loss (RLP) and Severe Repetitive Loss (SRLP) properties would be a good starting point, but it is currently illegal for FEMA to release these addresses. An alternative is to focus on areas that scientists predict to change dramatically in terms of rising sea levels or more frequent flooding in the coming decades. This is the basis for our approach.

In the following scenarios we use two alternative flooding criteria drawing on CIRCA research (O'Donnell, 2019):

- The first identifies all single-family detached residential houses in our study area that are located within the area predicted to suffer at least 20 inches of sea level rise (relative to Mean Higher High Water/MHHW) by 2050.
- The second identifies single family detached residential houses whose location is predicted to be within the SFHA by 2050.

These criteria produce too many target properties to be useful, but adding further criteria is a task fraught with controversy.

Maps of flood risk were the starting point for the post-Sandy buyout programs in the New York City metropolitan area (Freudenbert, 2016), but these much-studied programs added socio-economic considerations when choosing target sites, including income, race, and housing tenure. Citizens can easily misinterpret motivations for targeting neighborhoods based on race and income in the light of historical spatial and resource disparities. However, it is true that in considering buyouts, the households with lower incomes (and wealth) tend to have fewer resources available to repair and maintain structures or adapt them to reduce risk. So, they face rising and particularly burdensome flood risks and insurance premiums. Flooding has particularly severe consequences for such households, and buyout options may provide the only alternative to financial disaster. What's more, some funding sources such as the USDA program require that a substantial portion of buyout money be used in low to moderate-income neighborhoods.

To recognize the seriousness of the problem yet avoid a political minefield, we consider criteria that focus on the value of the property rather than the income of the household. This has the added advantage of being more practical, as low-valued houses cost less to buy out and are the exact properties most likely to suffer from the unintended consequences of rules like the 50% rule. All of these point to homeowners willing to participate in a buyout program making more acquisitions possible. Recall that buyouts are a matching process where funding must meet willing homeowners. Our first criterion restricts the total assessed value of the property to be less than $250,000. By law, Connecticut municipalities must assess properties at 70% of their appraisal (i.e. estimated market value), so our cut-off is equivalent to including only properties with estimated market values less than approximately $357,000.

A drawback of using this criterion is that it will necessarily target towns where housing is simply less valuable because of location along the shoreline and not necessarily because of structural quality or maintenance level. What's more, towns with lower valued housing will have less financial resources to use for retreat. A recent study of buyout locations nation-wide found them most prevalent in the more impoverished neighborhoods of relatively wealthy counties (Mach, et al, 2019). The well-off county governments had the resources to manage the buyouts but chose the county's more impoverished areas to target. In Connecticut, where local governments are at the town level and therefore smaller and more homogeneous, this strategy is less feasible.

A second approach is to target properties for which the structure itself is of low value. For this criterion, the cap is $60,000 (equivalent to appraised structure value of approximately $86,000). The aim here is to identify structures in poor repair that might signal the kind of decay that comes from increasing flooding events and lack of incentives for maintenance. Not surprisingly, the set of towns represented remains only a subset of the 21 in our study area, as decaying housing in towns on high valued land are more likely to be bought up and redeveloped. Even with this added consideration, properties that are truly waterfront *never* qualify as they are continually assessed at higher valuations, but some houses across the street from the waterfront are removed, transferring that status to the second row of houses. With rising seas, this huge waterfront premium will eventually erode, but it is still significant enough to make such properties costly to buy out.

Two additional criteria are considered. Even in the less affluent towns, valuable land near the shoreline is likely to be redeveloped/renovated and possibly elevated to raise value and lower insurance costs. However, there are many properties in our study area where lots date back decades and are, by today's zoning regulations, 'non-conforming'. Minimum lot size varies over and within towns, but we choose 10,000 square feet as a lot size that will be non-conforming almost anywhere along the shoreline. Such a small lot makes rebuilding for flood resistance technically difficult and not profitable given the limitations on the resulting house size.

Flooding of properties on septic systems rather than public sewer service has serious environmental consequences, so adding information about septic system dependence is another useful criterion. Strict application is not desirable as it eliminates all candidates from those localities that provide universal sewer service. Consequently, we do not apply this criterion to such towns. In towns with partial sewer service, we give priority to septic system properties.

Finally, in addition to some of the criteria discussed above, we recognize that for a buyout project to generate secondary benefits for an area, the resulting open space must be contiguous. Maintaining contiguity in purchased properties is a cost-effective approach, as the resulting open space has limited environmental and amenity value if it is not a self-contained entity. In the third and fourth scenarios posed here, the concept of 'project' is employed where a project must be made up of contiguous properties and at a reasonable scale to be viable.

The four scenarios are described as follows:

Scenario 1 – 2050 Sea Level Rise, full retreat

- Property is in the 2050 projected area for a 20 inch increase in sea level
- House is built on a non-conforming lot (i.e. lot size less than 10,000 square feet)

Scenario 2 – 2050 Flood Plain, full retreat

- Property is in the 2050 projected SFHA
- House is built on a non-conforming lot (i.e. lot size less than 10,000 square feet)

Scenario 3 – 2050 Flood Plain, Low valued properties

- Property is in the 2050 projected SFHA
- House is built on a non-conforming lot (i.e. lot size less than 10,000 square feet)
- The total assessed value of the property (structure and lot) is $250,000 or less
- Projects are defined based on contiguity and project scale and priority is given to properties on septic rather than public sewer

Scenario 4 – 2050 Flood Plain, Low valued structures

- Property is in the 2050 projected SFHA
- House is built on a non-conforming lot (i.e. lot size less than 10,000 square feet)
- The assessed value of the structure is $60,000 or less
- Projects are defined based on contiguity and project scale and priority is given to properties on septic rather than public sewer

We are not proposing that any of these scenarios would or should be carried out in full, but the magnitudes indicate the extent of the problem and the costs involved. Table 6 reports the number of houses removed in each scenario and the average appraised and assessed values. Appraised value is the locality's best estimate of market value. The distinction is important because market value is what we analyzed in Section 4 and because it is the price that homeowners would need to be compensated for agreeing to the buyout. Assessed value is the portion of appraised value that is taxable and, by state law, is calculated as 70% of appraisal.

Table 6. Number of removed properties with their average appraised and assessed values by scenario

	Mean Total **Appraised** Value of Removed Properties	Mean Total **Assessed** Value of Removed Properties	Number of Removed Properties
Scenario 1: SLR 2050, full retreat	$346,444	$242,511	532
Scenario 2: SFHA 2050, full retreat	$485,040	$339,528	9,420
Scenario 3: SFHA 2050, low valued properties, contiguous projects	$236,181	$165,327	2,049
Scenario 4: SFHA 2050, low valued structures, contiguous projects	$260,940	$182,658	1,235

Note: A small number of these removals are not included in Table 8's gains estimates because of data limitations.

Obtaining Estimates of Retreat Gains and Losses

The first column of numbers in Table 6 is our best guess at the cost of buying out the targeted homeowners. For most buyout projects in the U.S., state or federal grants have paid this cost, along with the cost of demolition and land rehabilitation.[17] In the results that follow, we assume that localities will not be responsible for this expense. Instead, we focus on the lost tax revenue from each of our four scenarios and then attempt to demonstrate some potential gains that may accrue from retreat.

Lost Tax Revenue for Scenarios 1 and 2

For each property identified for removal, the current assessed value is multiplied by the town's mill rate to obtain an estimate of the lost tax revenue in the first year after demolition. The total and average lost tax revenue for properties meeting the criteria set out for Scenario 1 and Scenario 2 are reported in Table 7. We note the implausibility of a scenario such as scenario 2, but it is included to highlight the scope if retreat is used as the overarching single policy lever against the risk of rising seas.

[17] Most federal buyout grants cover no more than 75% of this cost. The remainder usually comes from non-profits, other government sources and sometimes is assumed at least in part by the homeowner.

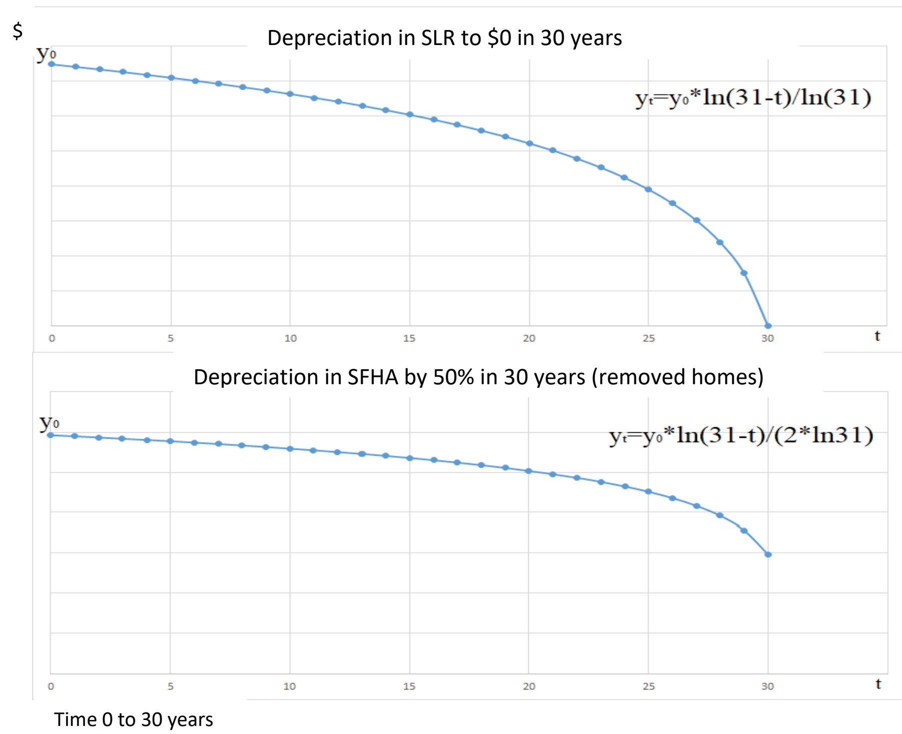
Table 7. Lost Tax Revenue from Removing Properties in Scenarios 1 and 2

Scenarios	Number of Removals	Total Lost Assessed Value in Year of Removal	Total Lost Tax Revenue in Year of Removal	Present Value of Stream of Lost Tax Revenue Through 2050
Scenario 1: SLR 2050	532	$ 124,717,480	$ 3,426,196	$ 42,676,740
Scenario 2: SFHA 2050	9420	$ 2,741,587,076	$ 71,623,369	$ 996,651,821

The properties targeted are those most likely exposed to intensified and more frequent flooding events over time. If the property were not bought out and removed, its market value, and therefore assessed value, would decline over time. The last column above estimates the present value of the stream of lost tax revenue through 2050. This estimate depends on assumptions about the pattern of flood-induced depreciation over this period which we explain below.

The graph in Figure 4 reflects two patterns of depreciation for removed properties. The first applies to Scenario 1, for which targeted properties will be repeatedly inundated by 2050 and thus presumably worthless. In Scenario 2 (and in Scenarios 3 and 4 discussed later) properties selected for removal are expected to suffer a less steep decline, losing approximately 50% of their value by 2050 because of the risk or costs perceived to be part of living in the flood plain. Note, however, that any extrapolation of gains and losses into the future are made in 2020 dollars and depend on the assumption that no changes in real (deflated) prices will occur. We apply this depreciation because if a property is ripe for participation in a buyout program it is most likely in tenuous circumstances that threaten its long term market value. In other words, so-called safe homes will not experience this depreciation, but vulnerable homes will.

Figure 4. Assumed depreciation pattern in assessed value for properties to be removed



To get an idea of how losses accumulate year after year we apply each town's mill rate to the depreciated assessed values for targeted properties, yielding estimates of lost tax revenue in each year up to 2050. Using a 5% discount rate, the present value of lost tax revenue can be calculated and is the figure reported in the last column of Table 7.

Tax Revenue Gains in Scenarios 1 and 2

For a number of reasons, buyouts of vulnerable properties can raise the value of neighboring homes.

- Neighboring properties might have improved views,
- Houses with no waterfront status may now fall into the 'across the street waterfront' category, which denotes houses separated from the water by a road but no structures.
- Spillover effects may accrue to neighbors by the removal of houses in poor condition due to frequent flooding.

We first simulate the change in the landscape that would result from the buyout program and then use this simulated landscape to calculate the change in characteristics of neighboring houses. We recalculate viewshed measures for surrounding houses within a 1000-foot buffer of the retreated homes in the new landscape. The new viewshed measures are then valued using estimated parameters from Section 4. Although these parameters were estimated in a market value model, they can be adapted to produce changes in assessed values that are mandated to be 70% of market (appraised) value throughout the state. The respective town's mill rate is then applied to yield the gain in tax revenues reported in Table 8. The present value of the stream of gained tax revenues up to 2050 (using a discount rate of 5%) is also reported in that table. However, in this case, we assume no depreciation in real prices of housing assets over time of houses that do not retreat.

To calculate the tax base gain for neighboring properties from a change in waterfront status, we first select properties that initially have no waterfront status but now qualify for our 'waterfront across street' category. The valuation model follows that described above, but now both waterfront status and viewshed will change. This poses no problem as the hedonic model simultaneously includes both the viewshed variables and waterfront status, and thus the changes to both are accommodated by design.

Finally, we adopt the assumption that before removal, the to-be-removed properties were damaged or have experienced past damage and are likely to be poorly maintained. This was certainly the case in the West Haven retreat project, and without an eminent domain directive, it is the likely case moving forward. So, the removal of such houses will improve the value of neighboring houses. The landscape simulation selects properties within .05 miles from the removed properties, and the valuation assumes that the 1% price discount (suggested by Campbell et al. 2011) will be recovered after the removal. Succinctly, removed lower quality and ill-maintained properties improve neighboring property values in the order of 1%.

These estimated gains to neighbors can be seen in Table 8 for each scenario. The figures report gains in assessed value, gains in tax revenue in the initial period, and the present value of the stream of gains through to 2050. The final column reports estimated gains as a percent of the losses reported in Table 7. The uncertainty over timing complicates interpretation. Tax revenues from removed houses are lost when the title to the property changes hands, but there will be a delay before neighborhood benefits from demolition accrue. However, real estate markets often anticipate changes, so it is difficult to judge how quickly prices might rise in the surrounding neighborhood. Gains in tax revenues will appear only after revaluation but revaluation occurs within three years. The present value calculations, as they stretch over 30 years mute this timing problem somewhat.

The last column in Table 8 offers a rough estimate of relative gains and losses. For Scenario 1, where houses in the 20-inch sea-level rise area are removed, the gains from neighborhood effects are estimated to be in the order of 10% of lost tax revenue initially, but given that the vulnerable houses would have depreciated dramatically over time, the gains make up 14% of net present value of losses when this depreciation is taken into account. The gains for both initial period and present value are much smaller for Scenario 2 which involves many more houses farther from the shoreline and whose demolition would not generate as much gain in terms of views or waterfront status when averaged over the number of removed houses.

Table 8. Gains from Effects on Neighboring Properties, Scenarios 1 and 2

Scenarios	Gain from Improved Views	Gain from Across Street from Waterfront	Gain from Spillover Effects	Aggregated Gain*	Percent of Losses** Offset by Gains
Increase in Total Assessed Value					
Scenario 1: SRL 2050	$ 5,020,575	$ 1,553,875	$ 6,468,118	$ 13,042,567	10.50%
Scenario 2: SFHA 2050	$ 30,890,852	$41,198,332	$36,368,314	$108,457,498	3.96%
Increase in One Period Tax Revenues					
Scenario 1: SRL 2050	$ 138,206	$ 43,222	$ 172,821	$ 354,249	10.30%
Scenario 2: SFHA 2050	$ 827,909	$ 1,093,888	$ 964,554	$ 2,886,351	4.03%
Increase in Present Value of Tax Revenues through 2050					
Scenario 1: SRL 2050	$ 2,124,565	$ 664,431	$3,190,135	$ 5,979,131	14.00%
Scenario 2: SFHA 2050	$ 12,726,993	$16,815,740	$26,004,280	$ 55,547,014	5.57%

* The individual pathway gains are added up here. The interactions across effects across different pathways are not considered in this calculation.
** Losses are found in Table 7.

Losses and Gains in Scenarios 3 and 4

In most respects the process of estimating losses and gains for Scenarios 3 and 4 is identical to that described above. Table 9 reports the loss in assessed value, tax revenue, and present value of stream of tax revenue for Scenarios 3 and 4.

Table 9. Lost Tax Revenue from Removing Properties in Scenarios 3 and 4

Scenarios	Number of Removals	Total Lost Assessed Value in Year of Removal	Total Lost Tax Revenue in Year of Removal	Present Value of Stream of Lost Tax Revenue Through 2050
Scenario 3: SLR 2050	2049	$ 316,504,818	$ 9,279,683	$ 129,119,661
Scenario 4: SFHA 2050	1235	$ 181,203,872	$ 4,878,796	$ 67,884,696

Scenarios 3 and 4 are different from the first two, however, in that they focus on contiguous retreat projects rather than a selection of scattered houses and have value targets for retreated homes. These scenarios add public open space to the landscape that could be cultivated in natural vegetation, used for public recreation, or both. Because of this, we add one additional source of neighborhood benefits that was not included above.

To calculate the tax base gain from increases in neighboring *public* open space, we borrow results from an empirical study focused on just this topic (Irwin, 2002). To match the study's details, we apply Irwin's results to the proportion of the 100-meter buffer around the neighboring property that is transformed into open space by the buyout. Only Scenarios 3 and 4 are designed to result in contiguous and substantial open space, so estimated neighborhood gains now include this added pathway as reported in Table 10.

Table 10. Gains from Effects on Neighboring Properties, Scenarios 3 and 4

Scenarios	Gain from Improved Views	Gain from Across Street from Waterfront	Gain from Spillover Effects	Gains from Open Space	Aggregated Gain, (after adjusting for interactions across effects)*	Percent of Losses** Offset by Gains
Increase in Total Assessed Value						
Scenario 3	$5,341,635	$ 11,245,444	$ 4,285,974	$5,285,471	$ 26,158,523	8.30%
Scenario 4	$5,519,275	$ 10,365,528	$ 3,380,699	$3,485,505	$ 22,751,007	12.60%
Increase in One Period Tax Revenues						
Scenario 3	$ 150,544	$ 344,551	$ 126,083	$ 150,788	$ 771,966	8.30%
Scenario 4	$ 151,351	$ 287,863	$ 93,000	$ 95,387	$ 627,600	12.90%
Increase in Present Value of Tax Revenues through 2050						
Scenario 3	$2,314,231	$ 5,296,591	$ 3,386,288	$7,532,354	$ 18,529,464	14.40%
Scenario 4	$2,326,634	$ 4,425,160	$ 2,190,963	$3,436,907	$ 12,379,663	18.20%

* The individual pathway gains are added up here. The interactions across effects across different pathways are not considered in this calculation.

** Losses are found in Table 9.

From the fifth column of the table 10, it is evident that adding the open space benefit helps recoup losses. In total, as much as 14.5 % of loss taxes are estimated to be recouped through increases in neighboring assessments and subsequent tax revenue in the long term using scenario 4. As we listed earlier, there are other ways localities will gain from retreat, but are beyond the scope of this report. However, it is worth noting that both environmental benefits and local infrastructure savings will be far higher for retreat strategies that are designed as contiguous projects, i.e. scenarios 3 and 4.

Tables 11 and 12 provide data for Scenarios 3 and 4 by project and town based on the requisite criteria, although there are some cases where a property is included that exceeds the value criterion. We do this to maximize the contiguity of the removed homes, but attempt to limit this occurrence. Tables 11 and 12 highlight two things. First, there are often multiple potential sites that result in multiple projects per town. Second, the simulated removals generally account for a small percentage of the towns' overall assessed values, ranging from 0.03% in Westbrook and 0.04% in Fairfield to 2.34% in Old Saybrook for Scenario 3, and from 0.01% in Westbrook to 1.68% in Old Lyme for Scenario 4. It is easy to see that there are opportunities to impact and recoup more value at some sites where surrounding properties outnumber removals by comparing the number of properties removed in column 3 and the number of impacted surrounding properties in column 5.

Table 11. Assessed Values of Retreat Scenario 3

Project	Mean Assessed Value ($) Removed	Number of Properties Retreating	Mean Assessed Value ($) of Surrounding Properties	Number of Surrounding Properties	Removed Value as Share of Total Single Family Homes Value for Town
Branford1	170,956	73	280,116	55	0.60%
Bridgeport1	110,701	95	427,796	35	0.50%
Bridgeport2	73,131	33	97,454	9	0.11%
Clinton1	196,738	48	290,212	70	0.89%
Clinton2	219,522	18	503,080	25	0.37%
Clinton3	180,461	18	600,261	23	0.31%
Clinton4	122,667	27	118,483	24	0.31%
East Haven1	127,834	136	-	0	1.46%
East Haven2	153,747	100	163,636	99	1.29%
Fairfield1	148,272	23	466,132	36	0.04%
Milford1	233,588	36	445,012	38	0.22%
Milford2	191,202	244	525,402	110	1.22%
Milford3	182,355	60	244,966	107	0.29%
New Haven1	126,890	243	172,365	128	2.09%
Norwalk1	256,214	93	423,862	47	0.37%
Norwalk2	221,235	22	347,955	27	0.08%
Old Saybrook1	196,986	190	329,879	80	2.34%
Old Saybrook2	211,485	144	260,016	134	1.91%
Old Saybrook3	191,335	48	341,995	20	0.58%
Old Saybrook4	143,551	49	177,574	62	0.44%
Stonington1	190,402	20	242,432	14	0.23%
Stratford1	110,868	44	-	0	0.18%
West Haven1	144,793	28	125,538	48	0.24%
West Haven2	106,215	33	120,535	58	0.21%
West Haven3	115,796	34	117,424	82	0.23%
West Haven4	130,550	77	118,211	102	0.59%
West Haven5	125,796	11	146,573	36	0.08%
Westbrook1	142,961	71	375,874	20	0.12%
Westbrook2	212,175	13	476,696	30	0.03%
Westbrook3	169,987	18	263,707	45	0.04%
Total	165,327	2,049	269,958	1,564	-

Table 12. Assessed Values of Retreat Scenario 4

Project	Mean Assessed Value ($) Removed	Number of Properties Retreating from	Mean Assessed Value of Surrounding Properties	Number of Surrounding Properties	Removed Value as Share of Total Single Family Homes Value for Town
Branford1	157,888	24	273,458	48	0.18%
Branford2	170,629	7	168,192	26	0.06%
Bridgeport1	80,142	12	117,386	25	0.04%
Bridgeport2	73,142	35	104,349	7	0.11%
Clinton1	289,577	31	524,028	36	0.85%
Clinton2	180,194	16	517,643	21	0.27%
East Haven1	309,214	12	345,383	14	0.31%
East Haven2	270,885	31	338,458	19	0.70%
East Haven3	104,561	41	121,944	57	0.36%
East Haven4	74,554	5	124,283	16	0.03%
Fairfield1	652,173	24	977,192	27	0.19%
Fairfield2	342,460	7	835,563	29	0.03%
Fairfield3	320,984	29	503,749	36	0.11%
Fairfield4	244,615	8	569,375	15	0.02%
Fairfield5	153,780	21	445,945	37	0.04%
Fairfield6	331,900	14	449,064	41	0.06%
Madison1	341,933	12	439,850	4	0.18%
Milford1	252,821	26	365,282	38	0.17%
Milford2	180,228	182	402,776	109	0.86%
Old Lyme1	403,800	53	355,047	36	1.68%
Old Saybrook1	233,966	61	304,900	19	0.89%
Stratford1	95,069	317	-	0	1.12%
Stratford2	110,243	49	-	0	0.20%
Stratford3	112,106	38	-	0	0.16%
West Haven1	94,733	15	115,697	38	0.08%
West Haven2	93,250	7	126,586	35	0.04%
Westbrook1	129,254	8	232,306	29	0.01%
Westbrook2	441,040	7	393,114	31	0.04%
Westbrook3	241,369	20	440,840	15	0.06%
Westbrook4	138,496	64	430,894	8	0.11%
Westbrook5	259,926	28	264,461	27	0.09%
Westbrook6	170,591	15	223,209	57	0.03%
Westbrook7	161,621	16	262,567	47	0.03%
Total (Mean)	182,658	1235	349,989	947	-

Table 13 adds calculations for one final category of benefits, one that accrues not to the town but to the homeowners themselves. Retreat projects count towards NFIP flood insurance premium discounts through the Community Rating System (CRS). Actions undertaken by a town, such as provision of information, collection of elevation certificates, preservation of open space, rigorous enforcement of regulatory standards, undertaking mitigation planning and projects, and acquisition of flood-prone properties all contribute to CRS status. A town that implements a retreat project earns at least a 5% discount in flood insurance premiums that applies to all homeowners in its SFHA. Depending on the size of the project, the discount could be quite a bit more, and if it includes the provision of open space, even more points are earned towards the discount (FEMA, 2018).

In the Tables 13 and 14, we list the savings for homeowners in towns that are selected in Scenarios 3 and 4, should each of these towns choose to become a CRS community. Currently only five of these towns are CRS members. These potential gains are calculated based on the OLR Research Report (Reger, 2016) and corroborated by other reports such as (Howard, 2019). On an aggregate basis these totals could dwarf the one-year benefit gain in revenue reported in Table 10 for any participating town.

Table 13: NFIP Flood Insurance Potential Discounts from Retreat Projects, Scenario 3

Scenario 3	Number of policies	Total insured value	Premiums in force	Assuming 5% discount	Assuming 15% discount
Branford	1,318	$311,988,700	$1,729,628	$86,481	$259,444
Bridgeport	1,728	$344,215,500	$1,758,189	$87,909	$263,728
Clinton	707	$172,305,500	$909,540	$45,477	$136,431
East Haven	1,208	$257,036,800	$1,677,481	$83,874	$251,622
Fairfield	2,567	$683,250,700	$4,294,879	$214,744	$644,232
Milford	3,071	$711,488,100	$3,097,825	$154,891	$464,674
New Haven	977	$238,491,900	$1,394,139	$69,707	$209,121
Norwalk	2,212	$600,363,700	$3,383,993	$169,200	$507,599
Old Saybrook	1,532	$396,043,500	$2,128,753	$106,438	$319,313
Stonington	1,248	$324,003,700	$2,141,066	$107,053	$321,160
Stratford	2,077	$479,503,400	$2,670,599	$133,530	$400,590
Westbrook	603	$161,110,700	$1,005,455	$50,273	$150,818
West Haven	1,069	$224,465,400	$1,112,465	$55,623	$166,870
Totals: Scenario 3	20,317	$4,904,267,600	$27,304,012	$1,365,201	$4,095,602

Authors calculations.

Table 14: NFIP Flood Insurance Potential Discounts from Retreat Projects , Scenario 4

Scenario 4	Number of policies	Total insured value	Premiums in force	Assuming 5% discount	Assuming 15% discount
Branford	1,318	$311,988,700	$1,729,628	$86,481	$259,444
Bridgeport	1,728	$344,215,500	$1,758,189	$87,909	$263,728
Clinton	707	$172,305,500	$909,540	$45,477	$136,431
East Haven	1,208	$257,036,800	$1,677,481	$83,874	$251,622
Fairfield	2,567	$683,250,700	$4,294,879	$214,744	$644,232
Madison	616	$180,217,500	$1,159,598	$57,980	$173,940
Milford	3,071	$711,488,100	$3,097,825	$154,891	$464,674
Old Lyme	568	$153,058,000	$801,094	$40,055	$120,164
Old Saybrook	1,532	$396,043,500	$2,128,753	$106,438	$319,313
Stratford	2,077	$479,503,400	$2,670,599	$133,530	$400,590
Westbrook	603	$161,110,700	$1,005,455	$50,273	$150,818
West Haven	1,069	$224,465,400	$1,112,465	$55,623	$166,870
Totals: Scenario 4	17,064	$4,074,683,800	$22,345,506	$1,117,275	$3,351,826

Authors calculations.

This simulation demonstrates that it is unlikely there are sufficient gains from amenity improvements to offset the revenue losses from a comprehensive buyout program. That is, a program large enough to mitigate impending damages from future flood events. Under a set of rather conservative assumptions, we have shown that, in aggregate, one might expect tax gains associated with valuation changes accruing to nearby homes to offset up to 14% of lost tax revenue. One must remember that this lost tax revenue is only one part of the total public sector costs as it does not include the cost of property purchase. There is significant heterogeneity in sites, and there are likely to exist individual projects along the coast that might come closer to a breakeven point. It is even more likely to approach breakeven if a project can defer other costs like expected infrastructure investments or ongoing flood-related maintenance costs, but these added benefits require the help of individual towns to assess adequately.

Section 6 – Lessons learned and the path forward.

Future Work that Can Improve Our Analyses

The hedonic analysis of Section 4 produced credible estimates of the effect of a variety of shoreline amenities on housing prices which were then used to simulate retreat outcomes in the subsequent section. The hedonic analysis also found evidence of a negative effect of flood plain status on house prices after controlling for coastal amenities. Pursuing this further, we found the effect most convincing for transactions dependent on mortgages. This effect could be attributable to the associated flood insurance requirement which provides important information about flood plain status, information that might otherwise not be readily available to buyers.

Advances in data collection are needed to improve the analysis of the housing market discussed in Section 4. Our inability to identify elevated houses among those sold during our study period compromises the interpretation of SFHA as an indicator of flood risk. Elevating a structure above ground level lowers both the structure's flood risk and its flood insurance premium. Because these elevated structures cannot be separated out in the analysis, the estimated negative effect of flood risk is biased towards zero. We would expect that prices of elevated houses would command a premium over non-elevated houses in the flood plain, but have no way to test this hypothesis.

Being able to identify houses that are elevated to meet FEMA requirements would not only help us more accurately estimate the effect on price of perceived flood risk, it would be of considerable policy interest for other reasons. With such data, we could estimate the size of any price premium elevated houses command on the market providing an estimate of how much of the elevation cost would likely be offset by increased market value. It would also allow us to investigate the circumstances (location, type of house, and type of homeowner) where structural elevation of existing homes most often occurs. Elevation activity, if broadly adopted, could eliminate the need for retreat in some locations where predictions of future flooding are not extreme and infrastructure flooding does not present excessive costs for the public sector. In these cases, policies to encourage elevation will be much less expensive than full scale retreat, even in the long run.

Unfortunately, structure elevation is not a characteristic readily available from any published source, including town tax assessment files. Because of this, studies on this topic are largely non-existent, despite their importance. The next stage of our research will involve a further search for data on elevation activity. Elevation certificates, one source of such data, are engineering reports that accurately document, among other things, the height of the lowest support of a structure above ground level and are used to provide evidence for insurance purposes. FEMA receives these certificates, so our first step will be to request access to these documents from FEMA. Increasingly, towns are keeping records of elevation certificates as well, but as we have discovered, they are often stored in the individual property folders and extracting them requires a laborious search through all properties files. Town permit files can also provide useful data. Permit applications for renovations that involve 'raising' or 'elevating' help identify elevation projects undertaken on already existing structures. Useful in their own right, permit applications will also help point us to the properties whose files are likely to contain elevation certificates. In addition, we know that recently constructed houses will necessarily have been elevated to meet concurrent FEMA standards, but we still need to investigate how far back in time we can count on compliance and rigorous enforcement. Once we are able to identify elevated structures, we will share our findings with town and state officials.

The retreat analysis of Section 5 produced estimates of the amount of lost tax revenues for an array of retreat scenarios. The measurable benefits that might counteract some of these losses fell far short of covering the tax losses[18]. However, there are obvious ways in which this analysis could be improved. Only a portion of the gains from retreat could be measured because several sources fall outside our expertise. Some important factors will require cooperative efforts. Environmental scientists can help us estimate the value of any buffering effect from natural vegetation and dunes that could reduce future risk on remaining structures. Town managers will be the best source for estimates of savings in infrastructure costs. Retreat will eliminate the frequent, and ever increasing, service and maintenance of roads and utilities that would be necessary as sea levels rise in these vulnerable areas. When all the possible types of benefits can be taken into account, there may well be areas for which the present value of benefits from retreat will match or exceed the present value of losses in tax revenue[19].

Defining the retreat scenarios was probably the greatest challenge in this part of the research. We chose criteria that could be defined and defended, yet also somewhat arbitrary and should not be used for targeting buyout areas. Ideally, taking account of historical flooding problems would make good sense. FEMA's Repetitive Loss (RL's) and Severe Repetitive Loss (SRL's) property list would be a good starting point. These addresses remain unobtainable, but this may be changing given recent challenges to the policy. Localities themselves know better than we do the location of perennial flooding problems. Town resiliency reports can be mined in hopes of identifying locations suffering repeated inundation and those where continued provision of emergency services and utilities are under threat.

Socio-economic consequences of flood risk and regulation

The towns and cities along the Connecticut coastline are different from each other in the nature of their housing stock, the socio-economic profile of their communities, and the resources available to affect change (U.S. Census, American Factfinder, 2019). It is often assumed that households in shoreline areas are wealthier than those in interior locations. It is true that five of the twenty-four shoreline municipalities are in the top 10% of Connecticut towns ranked by median household income (and two of

[18] The First Street Foundation (2020) estimated the number of Connecticut residential properties at substantial risk from flooding to be approximately 100,000 or about 10% of 1-4 family structures, rising to about 11% by 2050. Although substantial, these percentages are about average for New England and Mid-Atlantic states in terms of percentage of housing stock, but close neighbors such as Massachusetts, New York and New Jersey face far higher expected losses in flooding damage in absolute terms. Worse off are many states farther south which have larger housing stocks and higher proportions of that stock at risk. Approximately 20% of both Florida's and Louisiana's residential structures are estimated currently to be at substantial risk with predictions growing to 24% in Florida and a devastating 39% in Louisiana by 2050.

[19] We feel it is important to reiterate that our cost estimates focus on lost property tax revenues to towns and do not include the cost of purchasing properties. At the national level, these costs have typically been covered in large part by federal grants and to a lesser extent by state funding.

those are among the ten wealthiest in America), but nine fall in the lower half of Connecticut towns by median income.

Median household income ranges from $55,000 to over $200,000 across shoreline municipalities. Eliminating both the urban areas which tend to have lower average valued residential real estate and the wealthiest towns under the influence of New York City, the remaining shoreline towns exhibit a two-fold difference in median income between richest and poorest. Median housing value statistics offer an even more dramatic comparison. By municipality these range from $170,000 to approximately $1.4 million. Again, eliminating urban areas and towns west of Bridgeport, there is still almost a five-fold difference in median housing value across the remaining towns. Associated with these inequalities will likely be vast differences in the consequences of sea level rise and regulations.

The analysis in Section 4 suggested that low valued houses were the most significantly devalued by being in the flood plain. At least part of this effect may be traced back to the 50% rule. There is some evidence that the 50% rule can have vastly different, and sometimes unintended, consequences depending on household income and house value. In moderate to high income areas, the application of the 50% rule can cause common renovations to transform into major rebuilding and elevation projects. Towns report that homeowners who must incur the fixed costs of elevation, often invest in larger homes, ultimately increasing the value of assets in the flood plain. In contrast, when homeowners cannot afford elevation projects, the 50% rule may prevent them from making any renovations or major repairs, especially since 50% of a low valued structure will mean that the rule will kick-in for far smaller projects. Where renovations are out of the reach of less affluent homeowners with lower valued houses, structures begin to decay. Poorer homeowners in the flood plain may find themselves caught between FEMA compliant regulations that make renovation far too costly and increasingly expensive flood insurance due to the inability to undertake any mitigation. What is more, their decaying asset offers them little hope of selling at a price high enough to cover the costs of moving to a safer location. Risk Rating 2.0, which promises to readjust insurance premiums to actuarial levels, will further penalize homeowners who can afford neither insurance nor mitigation.

Extending our Connecticut shoreline study to consider socio-demographic issues could provide insights into the magnitude of this problem, as well as possible policy options that could help address it. The tension between actuarial rates that would make people aware of the full cost of living in the flood plain and affordable rates that would not cause economic hardship on poorer homeowners was the topic of a two-part National Academy study (National Research Council, 2015, 2016). While the choice to locate in flood plain area should come with an acceptance of responsibility to pay full costs of the decision, information about these costs is not and has never been adequately available to buyers, and the risks themselves have changed dramatically in the time since many of these properties were purchased.

A targeted buyout program could provide some relief. In areas where elevation is a suitable alternative to retreat, buying out individual decaying properties at subsidized prices and then auctioning the property to someone required to renovate/rebuild to FEMA restrictions could provide needed relief to poorer homeowners caught in this trap. This type of program produces income that can be used to partially offset the purchase price and it has the very great advantage of turning a decaying property that generates little tax revenue to one with a much higher market value, thus benefiting local government. The differential impact of flood risk and flood regulations over income groups is part of the broader problem of environmental justice that has risen to the forefront and is a topic that is worth our attention in future work.

The Role of Information

The importance of information has been emphasized throughout this report. Without accurate information on flood risks and regulatory costs, home buyers cannot make good decisions and homeowners have no incentive to undertake mitigation activities. Information is a valuable commodity, but flood risk information is often not readily available or well understood.

It is difficult for a prospective home buyer to learn of a property's flood history. States vary with regard to disclosure laws about flood risk and past flood damage. In "How States Stack Up On Flood Disclosure", the Natural Resources Defense Council (2021) ranks states on the basis of their statutory or regulatory flood information disclosure requirements to potential buyers. The scale from A to F corresponds to the quality of the state's flood hazard disclosure law, where F designates states that have no requirements at all. Connecticut 'earned' a D grade (inadequate) for its minimal information requirement: including SFHA status, along with dozens of other considerations, on the state disclosure form provided at all real estate closings.

One of the best ways to further resiliency in the state might be to require better information about flood risk to all existing and potential homebuyers. People are slow to develop awareness of risks they would rather ignore, but more information may over time provide greater encouragement for mitigation activities and/or more willingness to give up on vulnerable locations.

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