

Do floodplain delineations decrease property values?

Evidence from New York City after Hurricane Sandy

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1. Introduction

After hurricane Sandy struck the east coast in late October 2012 and caused about \$19 billion in damages to NYC alone and \$32 billion statewide, the Federal Emergency Management Agency (FEMA) reassessed and released new Flood Insurance Rate Maps (FIRMs). The new maps place significantly more property in NYC in the 1 percent and 0.02 percent flood zone, also known as the 100-year-flood zone and 500-year-flood zone respectively (Ramey 2015). The city is appealing the new maps, because properties designated as in the flood zone have expensive required flood insurance and future developments in the flood zone will have to protect against flood hazards, making them more costly. There was an 83 percent increase—with 400,000 residents now in the zone, up from 218,000 previously (Fig. 1). The city has hired a private consultant firm, Arcadis, to analyze the flood zones and show FEMA's maps have overstated the risks. People are concerned that the new maps put unnecessary burden on residents through the increased cost of insurance and the decreased value of the property. Insurance premiums cost \$5,000 to \$10,000 per year and are not implemented until the maps are finalized (Ramey 2015). However, people in support of the new maps believe politicians think in the short-term, and perhaps the decision to appeal the maps was a political one (Lehmann 2015). It makes sense for politicians to prioritize home affordability over natural disaster preparation because it is more likely to affect them in the next election. However, there is no doubt that properties not previously in the flood zone were devastatingly flooded during Sandy.

In this analysis, I used property sales data from the past decade along with maps of the old and new proposed FIRMs to estimate how property values were affected that were once outside the flood zone and are now inside the flood zone in New York City. I also analyze if it

differs significantly whether the property is newly added to the .02 percent, 1 percent, or high velocity wave + 1 percent flood zone. Theoretically, if property owners have to pay insurance for being located in the flood zone, the value of the property will decrease because a) the insurance is expensive and that property is less desirable; and b) there is a negative behavioral response because people are less likely to buy a property for a higher price if there is a greater chance it will be damaged in a storm event—in other words, people became more cognizant of flood risk after Sandy.

Flood risk will continue to become more relevant in the future. Climatologists believe with high certainty that the rate of sea level rise is accelerating. Changes in sea level are caused by global temperature forcing, generally over very long periods of time. Anthropogenic climate forcing is relatively instantaneous on a geologic time scale. The Intergovernmental Panel on Climate Change reports with high confidence that over the period 1901 to 2010, global mean sea level rose by an estimated 0.19 meters [0.17 to 0.21], and the rate since the mid-19th century has been larger than the average rate of the past two millennia. When this is considered alongside the fact that coastal areas generally have a gradual slope, it translates into many meters of lost coastal area underwater. In addition, climate change results in increasing trends in extreme precipitation and greater risks of flooding at a regional scale, especially during storm surges (IPCC 2014).

Related to sea level rise, one of the processes that has and will continue to affect coastlines with increased frequency is the intensity of storms, but this is a relatively low-confidence claim. However, it is not controversial that as settlements become relatively lower in elevation as sea level rises, a given storm will do more costly damage. As sea level rises, it

decreases the buffer area between the land and a storm coming off the water, increasing the potential to do damage. The areas of the world most vulnerable to sea level rise are in “Low Elevation Coastal Zones”, which are defined as areas along the coast less than 10 meters above sea level. Although these areas constitute only 2 percent of the world’s land area, they contain 10 percent of the world’s population (600 million) and 13 percent of the world’s urban population (360 million) (McGranahan et al. 2007). This includes United States cities such as Miami, New Orleans, and New York, and analyzing the costs that are incurred when people realize an area is suddenly more vulnerable than once thought is a concrete method of showing some cost associated with sea level rise.

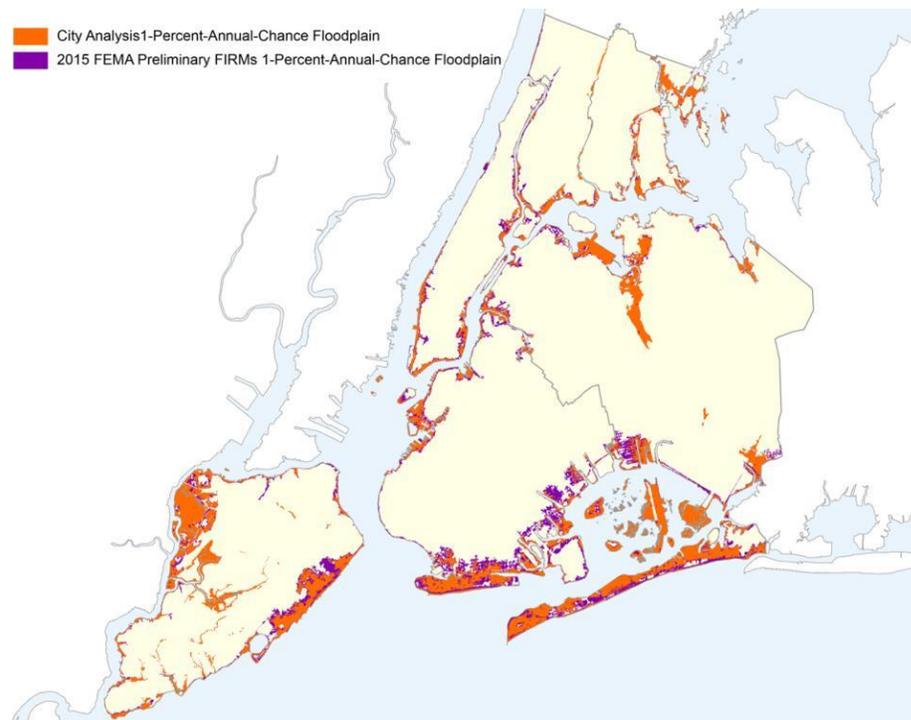


Fig. 1

1 percent flood risk map showing the differences between FEMA’s version and New York City’s version. FEMA’s new map (purple) places about 400,000 residents in the flood zone, compared to 218,000 previously (*New York Daily News*).

In 2002, about US\$1.9 trillion worth of assets below the 100-year extreme sea level were concentrated in the following 10 coastal port cities: Miami, New York-Newark, New Orleans, Osaka-Kobe, Tokyo, Amsterdam, Rotterdam, Nagoya, Virginia Beach and Guangzhou (Hanson et al. 2011). The economic advantages that drive coastal urbanization seem to not take environmental impacts into account, but with new flood planning and increased costs that correctly mirror the risk of flooding, we might see some change. In a place like Manhattan, it is more likely for leaders to invest in structural mitigation than abandon the city, unlike in smaller flood-prone towns (Lehmann 2015). Accurate up-to-date flood maps are fundamental for this to occur.

The slow pace of climate change typically makes property value losses difficult to estimate and to tie directly to sea level rise. A regression of property value on average sea level rise would have to take place over many years to get enough variation in sea level rise, and it would be difficult to control for other confounding factors that vary over time. This paper takes advantage of an abrupt and dramatic flood map change— that has never happened to my knowledge in the past on such a large scale—in one of the world’s most important urban centers. This background is not to say that the explicit reason for FEMA’s new maps is principally sea level rise, it could be that nothing about the sea level changed, but FEMA realized they miscalculated previously, or were not adequately assessing the existing risk (even if the risk did not change). This research paper cannot determine the reasons for the change, but will attempt to quantify the loss in property value regardless. For my purposes, it is irrelevant what the reason behind the sudden shift was, because with the sea level rise that will occur within the next century, flood risk maps will have to change somewhere down the line. This research may give

us a baseline for what to expect will happen to property values when additional properties are inevitably placed in zones they previously were not in. In 2081–2100 relative to 1986–2005, the mean sea level rise will likely be in the ranges of 0.26 to 0.55 m for RCP2.6, and of 0.45 to 0.82 m for RCP8.5 (IPCC 2014). This means an increase of about 1.5 - 2.7 feet in a business-as-usual emissions scenario.

I found that the sale price of a property newly placed in any flood zone after 2015 decreases by 8.6 percent on average. The sale price of a property newly placed in the 0.2 percent flood zone (the 500-year-flood) decreases by 8.9 percent on average, and the sale price of a property newly placed in the 1 percent flood zone (the 100-year-flood) decreases by 8.2 percent on average. I had expected that the greatest flood risk would result in the largest decrease in value. However, my results show the opposite. Perhaps the most significant drop in value is the initial placement in a flood zone, no matter what zone. Since many properties that were placed in the 1 percent flood zone for the first time were already in the 0.2 percent zone, it makes sense that this average comes out lower because the new decrease in sale price was less noticeable.

I also examined four different property value subgroups, and found that the effect on sale price of a property when newly placed in any flood zone is heterogeneous across property values. On average, a low end property, categorized as a sale price between \$30,000 and \$284,921, decreases by 15.8 percent when newly placed in any flood zone, while the highest end properties show no significant effect. In addition, I found that the largest decreases occur when a low end property is newly placed in the 100-year flood zone and the 100-year + high velocity wave zones, with 16.9 percent and 18.8 percent sale price decreases, respectively.

The rest of the paper is organized as follows: Part 2 covers past studies on flooding and property value, Part 3 describes the data used in this analysis, Part 4 shows the estimation strategy, Part 5 analyzes the results, and Part 6 concludes.

2. Background on flooding and property value

This analysis contributes to existing literature on flooding and property value loss. Multiple studies have performed hedonic price analyses to examine changes in property values after a major flood event (Kousky 2004, Daniel 2009, Bin et al. 2004). However, by only looking at the lost property value after a major flood, the lost value incurred by just being at greater risk of a flood even if the flood has yet to occur is ignored. Vanessa E. Daniel et al. used data from the Netherlands near the Meuse River and found that a house in a location that was affected by one or both of the floods in 1993 and 1995 has a value that is 7.4 percent lower compared to a house that was not affected by the floods. However, they found the effect of being close to the river increased the value by 2.7 percent, showing that houses affected by flooding but also near the river only decrease by 4.7 percent (Daniel et al. 2009). In 2004, Okmyung Bin and Stephen Polasky used data from 1992 – 2002 in Pitt County, NC, which experienced severe flooding from Hurricane Floyd in 1999. They found that property values were reduced by 5.7 percent when in a flood zone, and that after the hurricane this effect more than doubled in places that actually flooded (Bin et al 2004). This shows that an actual flood has a significant effect on behavior, perhaps because it increases information, news coverage, and awareness. Kousky also studied whether flood risk is reassessed after a severe flood by looking at properties in the 100-year-flood zone before and after the flood from the Missouri and Mississippi Rivers in 1993 (Kousky 2004). Her analysis is similar to mine in that she uses panel data and a property fixed effects

model. In this way she isolates the effect of flooding, because all properties compared were already in the flood zone in both panels. Interestingly, she found that after the flood property prices in 100-year flood zone did not change significantly, but in the 500-year flood zone it declined by between 2 and 5 percent. Additionally, all property prices in municipalities located on the rivers fell after the flood, possibly because the whole area became stigmatized (Kousky 2004). A possible reason that the 100-year flood zone property values showed no significant effect could be that homebuyers are required to be made aware if they are located in this flood zone, but not the 500-year zone. Therefore, the actual flood may have provided new information to those in the 500-year zone, whereas those in the 100-year zone were already accounting for the risk and had the proper insurance (Kousky 2004).

In 2008, Bin used geographic information systems (GIS) data and property value data to estimate the impact of sea level rise on North Carolina's coastal plain real estate (Bin 2008). He used high resolution topographic technology to identify property that will be underwater given different mean sea level rise scenarios. He found that the impacts of sea level rise on coastal property values vary across different portions of the North Carolina coastline, most significantly in Dare County, where the residential property value risk ranged from 2.98 percent to 14.69 percent of the total residential property value. Bin also discusses why coastal property value depreciation is significant. Population growth on the coast has been accompanied by unparalleled growth in property values. According to the Heinz Center, a typical coastal property is worth from 8 percent to 45 percent more than an otherwise comparable inland property (Heinz 2000).

Contrary to my results, Rae Zimmerman found that no statistically significant variation in value between flood prone and non-flood prone lands (1979). His possible explanations for this

result include property buyers have a lack of information, do not incorporate flood information into their decisions, or the National Flood Insurance Program fully mitigates the difference. However, his paper was also written before wide knowledge of sea level rise. A possible flaw in this analysis is that Zimmerman compares properties in the flood zone to similar properties not in the flood zone, but there may be confounding factors. For example, proximity to water is correlated with being in the flood zone as well as a higher property value (Daniel et al. 2009). I attempt to resolve this problem by looking at the difference in property values after a dramatic shift of the flood zone line. By using building, apartment, and neighborhood fixed effects in my estimations, confounding factors like proximity to water do not change. In most of these studies, the researcher tried to compare property sale prices among similar properties by analyzing factors that have an effect on property value including environmental amenities, type of house, year built, and distance to highway among others. My paper takes advantage of a natural experiment in which I can compare within clusters because the flood zone shifted in a drastic way.

3. Data

3.1 Property Sales

My property sales data come from the New York City Department of Finance annualized sales data available for download online. These documents display yearly sales information from 2003 to the present including neighborhood, borough, address, square footage, and sale price. As Table 1 shows, I have sales records from 1,242,822 properties from all 5 boroughs. Some sales are unrecorded and appear as \$0 in my dataset, while others are strange and unreasonable prices

such as \$10. To handle this problem, I eliminated sales less than \$30,000 in my regression because the effect I am looking for is more accurately captured among properties sold for a reasonable amount. I am concerned that for properties less than \$30,000, other factors affected the price that I am unable to account for in my estimating equations. I also encountered a similar problem at the other end of my data; if some properties sold for unreasonably high prices because of an unobservable effect, I want to eliminate them as well. For example, if a very famous person lived there, maybe people are willing to pay an unreasonable price for that property regardless of flood zone. The highest sale price in my data set is about \$4 billion, but I capped most of my analyses at \$6.75 million because 99 percent of my data is below this. I also analyzed the effect on different subsets of sale prices, and to look at the effects at the highest end of sale prices I increased this cap.

Table 1
Descriptive statistics, property sales data

Percentiles		Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	1,211,762
25%	0	0	Sum of Wgt.	1,211,762
50%	284921		Mean	754788.5
		Largest	Std. Dev.	1.09E+07
75%	570000	2.20E+09		
90%	999000	2.80E+09	Variance	1.18E+14
95%	1815000	3.33E+09	Skewness	152.0715
99%	6750000	4.04E+09	Kurtosis	36535.54

1,211,762 observations measured in USD with a maximum of 4.4 billion and a minimum of 0.

3.2 Flood Maps

The 2015 Flood Insurance Rate Map (FIRM) is available for download from the Federal Emergency Management Agency's online database. It depicts flood risk information including the 1 percent flood risk zone (100-years-flood), the 0.2 percent flood risk zone (500-years-flood), high velocity wave risk zone (which is also always a 1 percent flood risk zone) and minimal flood risk areas. The FIRM published by FEMA is the standard used for all National Flood Insurance Program (NFIP) initiatives including flood zone management, mitigation, and insurance purchases. The maps establish the insurance premiums for different properties, although owners do not have to pay insurance until the FIRM becomes official (FEMA 2015)

Table 2

Descriptive statistics, flood zone data in 2015

2015 Variable	Obs	Mean
1% flood zone	1,212,344	0.0456199
0.2% flood zone	1,212,344	0.033314
high velocity wave + 1% flood zone	1,212,344	0.0002161

Binary observations with a value of 1 for being in the flood zone in question in 2015 and a 0 otherwise.

The 1996 FIRM I used is available from the New York GIS website. This website includes files for every county in the state. The flood zone information supplied is the same as the 2015 FIRM. I am using the 1996 map because it is available, and I could not locate the 2011 version, which was the last version before Sandy hit. I am making the assumption that the flood map in 1996 has almost the same zones as the flood map in 2011 did. This is acceptable for my

analysis because the flood maps barely changed from the 80s until the dramatic changes of this year (Ramey 2015).

Table 3

Descriptive statistics, flood zone data in 1996

1996 Variable	Obs	Mean
1% flood zone	1,212,344	0.0213289
0.2% flood zone	1,212,344	0.0222354
high velocity wave + 1% flood zone	1,212,344	0.0005139

Binary observations with a value of 1 for being in the flood zone in question in 1996 and a 0 otherwise.

Table 2 and 3 show descriptive statistics for flood zone data in both years used in my analysis. In 1996, about 2.1 percent, 2.2 percent, and 0.05 percent of properties were in the 1 percent, 0.2 percent, and high velocity wave + 1 percent flood zones, respectively. In 2015, about 4.5 percent, 3.3 percent, and .02 percent of properties were in the same respective zones. Figure 2 shows a sample of what the maps in ArcMap looked like – shown here is Manhattan in 2015 with color coded flood zones.

FIRMs are created through the combined effort of engineers, mapping specialists, surveyors, and scientists. They take into account the amount of development in the area, the types and strength of storms that historically have affected the area, and onshore and offshore elevations (FEMA 2015). Most relevant for this paper are storm surge analyses, which use a specific model called the ADCIRC (Advanced CIRCulation) as well as the Simulating Waves Nearshore (SWAN) model. This analysis gives stillwater elevations for the 100-year flood. This

storm surge calculation does not account for waves, so onshore wave models called “Wave Height Analysis for Flood Insurance Studies” are also used, and take into account additional factors like wind speed and vegetative cover (FEMA 2015). In-depth specifics of this process can be found at <http://www.region2coastal.com/resources/coastal-mapping-basics/>.

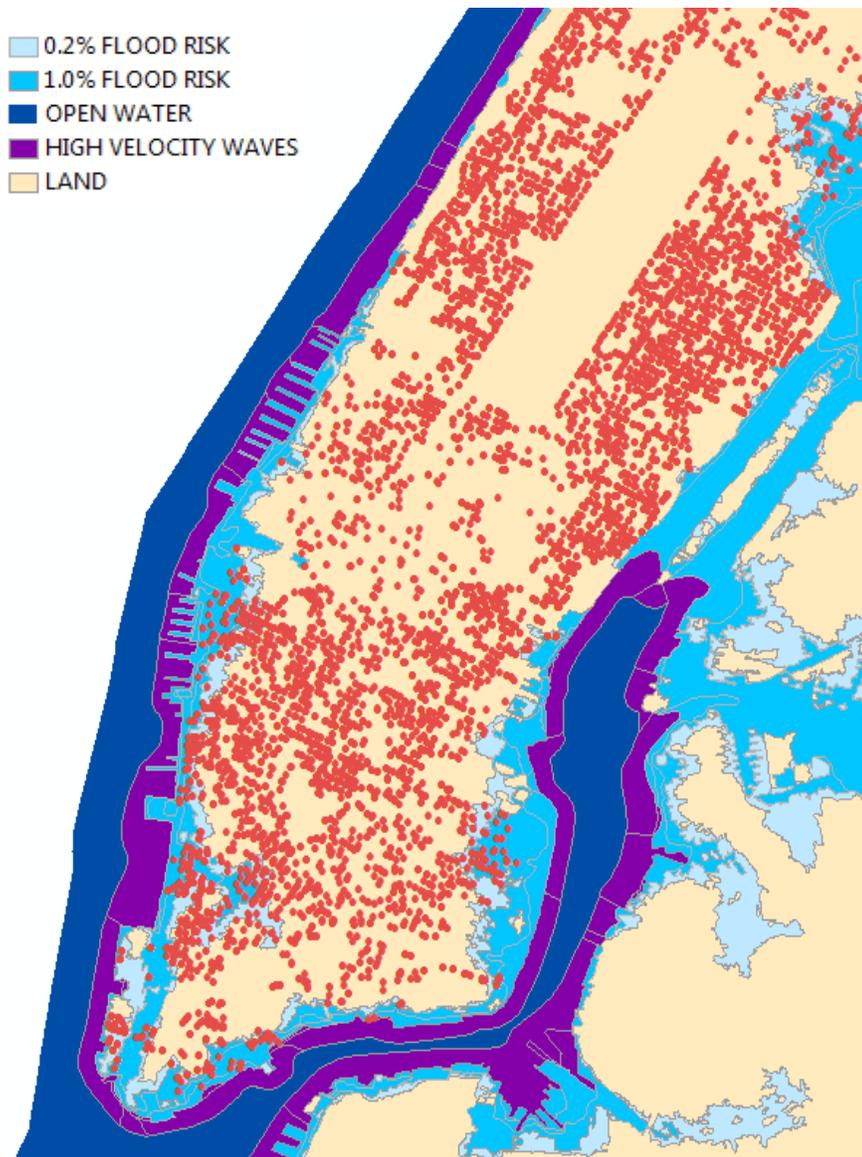


Fig. 2

A sample view of the FIRM and property sales in Manhattan, 2015. Includes 1.0 percent flood risk area + high velocity waves, 1.0 percent flood risk, and 0.2 percent flood risk. Red dots represent properties sold in 2015.

3.3 Matching the Data

To combine the flood zone data for each observed sale price, I used ArcMap to join layers of flood zones and geocoded properties with the help of a GIS specialist. An example is shown in Fig. 2 above, which depicts Manhattan flood zones and property sale locations in 2015 alone. A more in-depth explanation of the merging process can be found in the data appendix.

4. Estimation

To explore the effect of different flood zone placement on property value, I use a series of difference in difference (DD) models. A naive OLS regression would mean regressing property value on whichever flood zone it is in, but this does not have the benefit of looking at properties that are otherwise the same and isolating just the effect of the change in zone. It would look at a cross section instead of a difference over time with a treatment and a control group.

By using DD models with fixed effects, the comparison between each property before and after new flood maps were released is isolated because other factors that could change property values are controlled for by looking at how property values change in the city as a whole during the same time period. If there are other variables that are correlated with both property values and being in the new flood zone it would bias the analysis, but I cannot think of any plausible stories, aside from actually flooding during Sandy which I discuss later. The equations used for the first three regressions (1 - 3) is the most general model, capturing the average percent change in property sale price regardless of which new flood zone it was placed in, and includes the largest range of sale prices.

$$\ln\text{saleprice}_{abny} = \alpha + \gamma_y + \delta_n + \beta_1 \text{Any_Flood_2015}_b * \text{post_2015}_b + \epsilon_{abny} \quad (1)$$

$$\ln\text{saleprice}_{abny} = \alpha + \gamma_y + \delta_b + \beta_1 \text{Any_Flood}_{2015_b} * \text{post}_{2015_b} + \epsilon_{abny} \quad (2)$$

$$\ln\text{saleprice}_{abny} = \alpha + \gamma_y + \delta_a + \beta_1 \text{Any_Flood}_{2015_b} * \text{post}_{2015_b} + \epsilon_{abny} \quad (3)$$

In the equations above, the dependent variable is the logged sale price in apartment a, building b, neighborhood n, and sale year y. γ_y is year fixed effects, δ is neighborhood, building, or apartment fixed effects in equations 1, 2, and 3 respectively, and ϵ_{abny} is an error term. The coefficient of importance is β_1 , showing the effect on the interaction between the sale occurring after the new FIRM was released (post_{2015}) and being in any flood zone in 2015.

To analyze the effect of specific flood zones, I used a different version of the equations above that parse out the effects of the different zones in 2015:

$$\ln\text{saleprice}_{abny} = \alpha + \gamma_y + \delta_n + \beta_1 \text{Flood}_{2015_1_b} * \text{post}_{2015_b} + \beta_2 \text{Flood}_{2015_2_b} * \text{post}_{2015_b} + \beta_3 \text{Flood}_{2015_wave_b} * \text{post}_{2015_b} + \epsilon_{abny} \quad (4)$$

$$\ln\text{saleprice}_{abny} = \alpha + \gamma_y + \delta_b + \beta_1 \text{Flood}_{2015_1_b} * \text{post}_{2015_b} + \beta_2 \text{Flood}_{2015_2_b} * \text{post}_{2015_b} + \beta_3 \text{Flood}_{2015_wave_b} * \text{post}_{2015_b} + \epsilon_{abny} \quad (5)$$

$$\ln\text{saleprice}_{abny} = \alpha + \gamma_y + \delta_a + \beta_1 \text{Flood}_{2015_1_b} * \text{post}_{2015_b} + \beta_2 \text{Flood}_{2015_2_b} * \text{post}_{2015_b} + \beta_3 \text{Flood}_{2015_wave_b} * \text{post}_{2015_b} + \epsilon_{abny} \quad (6)$$

In the equations above the additional interactions terms represent the three different flood zones examined. All six equations make the parallel trend assumption, meaning that without the treatment, the trend in property values would be the same in both groups. I use neighborhood, building, and apartment fixed effects because the goal is to compare properties newly placed in

the flood zone to the same property before it was in the flood zone, using properties that are similar but not in the flood zone as a control. In this way I controlled for unobservable differences that may bias the estimate.

In all estimates, I expect the sign of β to be negative for 2015 because it is difficult to think of scenarios in which the movement of a property into the flood zone causes the value to increase. I am testing the null hypothesis that $\beta = 0$, so with a negative estimate with enough statistical significance to reject the null, I can conclude that I have evidence for the negative hypothesized effect of flood risk zones on property value.

My results could be threatened if there are changes in the treatment group alone aside from the treatment itself. For example, maybe properties added to the flood zone were already declining in value due to the spreading awareness of climate change, so my model would essentially place the treatment at a point in time that is too late to capture the full effect. Alternatively, in many cases these properties actually flooded during Sandy, and it might be the physical flood that decreased that value rather than the placement in the zone. However, if this is the case it does not make my results any less meaningful.

5. Results

The most important result is evidence of an 8.6 percent decrease in sale price on average for new placement in any flood zone after January 2015 on new FIRMS. Table 4 shows results for all properties. The first three columns are neighborhood, building, and apartment fixed effect models for placement in any flood zone, while the last three columns have the effects separated by flood zone placement. The average decrease of 8.6 percent with building fixed effects and 7.5

percent with apartment fixed effects are significant at the 99 percent confidence level. However, much less data (only about 200,000 observations) was used for the apartment fixed effect model because the apartment was not always recorded. The most staggering result from the separated zone regressions (columns 3 – 6 in table 4) are the average decreases of 37.4 percent and 39.2 percent for properties newly added to the high velocity wave zones, both significant at the 99 percent confidence level. However, as discussed in the data section above, not many properties are actually in this zone, so it affects fewer people. I clustered standard errors at the zipcode level where possible to allow for the error to be correlated within a zipcode but independent across zipcodes. When using neighborhood fixed effects, the errors cannot be clustered this way, and so I used robust standard errors.

Table 4
Effect of placement in various flood zones after January 2015 on new FIRMS

	Neighborhood Fixed Effects	Building Fixed Effects	Apartment Fixed Effects	Neighborhood Fixed Effects	Building Fixed Effects	Apartment Fixed Effects
After 2015*any flood zone	-0.049 (0.037)	-0.086 (0.027)**	-0.075 (0.028)**			
After 2015*1% flood				-0.083 (0.018)**	-0.080 (0.034)*	-0.071 (0.038)
After 2015*0.02% flood				-0.002 (0.021)	-0.089 (0.027)**	-0.078 (0.035)*
After 2015*1% flood and waves				0.046 (0.233)	-0.392 (0.041)**	-0.374 (0.034)**
Sale year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	12.686 (0.023)**	12.608 (0.014)**	12.771 (0.009)**	12.686 (0.003)**	12.608 (0.007)**	12.771 (0.009)**
R ²	0.04	0.07	0.22	0.04	0.07	0.22
Observations	795,706	795,706	172,157	795,706	795,706	172,157

* $p < 0.05$; ** $p < 0.01$

Dependent variable is percent change in sale price. Each column is a single regression corresponding to equations 1 – 6. The fixed effects used in the column are denoted at the top of each column. Standard errors in parentheses are clustered at the zipcode level for column 2 and otherwise are robust.

To examine heterogeneity across property sale price groups, I split the regressions into four value ranges based on sale price summary statistics (refer to Table 1). The groups are roughly the 0 – 50th percentile, 50th – 75th percentile, 75th – 90th percentile, and 90th + percentile.

The low end group is half the data because I drop everything below \$30,000 which is a large chunk of the data. As I explained earlier, the effect I am looking for is more accurately captured among properties sold for a reasonable amount. I am concerned that for properties less than \$30,000, some other factors affected the price that I am unable to account for in my model, such as unrecorded values (\$0) or in-family purchases for much lower than market value. Table 5 shows evidence that low end properties suffer the most with a drop of about 15.8 percent when located in a new flood zone. Meanwhile, there is no statistically significant effect at the high end. The mid-range effects vary between 4.5 and 3.5 percent decreases in sale price. All regressions in Table 5 are clustered by zipcode.

Table 5

Effect of placement in various flood zones after January 2015 on new FIRMS

Building sale price group:	High end	Mid-high end	Mid-low end	Low end
After 2015*Any flood zone	0.007 (0.024)	-0.045 (0.015)**	-0.035 (0.016)*	-0.158 (0.065)*
Sale year dummies	Yes	Yes	Yes	Yes
Constant	14.191 (0.032)**	13.399 (0.009)**	12.764 (0.005)**	11.736 (0.038)**
R^2	0.06	0.05	0.12	0.04
N	112,446	184,192	304,829	201,916

* $p < 0.05$; ** $p < 0.01$

Dependent variable is percent change in sale price. Each column is a single regression corresponding to equation 2, and performed 4 times with different subsets of sale price data, which is labeled at the top of each column. Standard errors in parentheses are clustered at the zipcode level for all columns.

Table 6 shows that these results vary across flood zones as well. The most intense change in property sale price occurs when a low end property is newly placed in 2015 in the 100-year flood + high velocity wave zone, which makes sense because high velocity waves can cause increased damage. However, it is a much smaller zone, so although this result is significant, it does not affect as many properties. Similar to Table 5, low end properties suffer the most with a

drops ranging from 14.1 percent to 18.8 percent when located in a new flood zone. Again, there is no statistically significant effect at the high end. All regression were performed with robust standard errors because statistically significant effects could not be found clustering by zipcode.

Table 6
Effect of placement in various flood zones after January 2015 on new FIRMS

Building sale price group:	High end	Mid-high end	Mid-low end	Low end
After 2015*1% flood	-0.015 (0.040)	-0.015 (0.018)	-0.060 (0.015)**	-0.169 (0.081)*
After 2015*0.2% flood	0.030 (0.034)	-0.059 (0.015)**	0.001 (0.020)	-0.141 (0.064)*
After 2015*1% flood and waves			-0.088 (0.014)**	-0.188 (0.072)**
Sale year dummies	Yes	Yes	Yes	Yes
Constant	14.191 (0.017)**	13.399 (0.007)**	12.764 (0.003)**	11.736 (0.010)**
R^2	0.06	0.05	0.12	0.04
N	112,446	184,192	304,829	201,916

* $p < 0.05$; ** $p < 0.01$

Dependent variable is percent change in sale price. Each column is a single regression, corresponding to equation 5, and performed 4 times with different subsets of sale price data, which is labeled at the top of each column. Standard errors in parentheses are robust for all columns.

The results from Tables 5 and 6 were originally surprising, but concur with some results found by previous research. Vanessa Daniel found that the marginal willingness to pay for reduced risk exposure has increased over time, and it is slightly lower for areas with a higher per capita income (2009). Perhaps those with more wealth, and presumably the ones buying high end properties, do not care as much about flood risk because they can afford to rebuild without as much financial stress.

For the most part, my results concur with past literature, but are perhaps more reliable and in many cases show an effect of greater magnitude. This could be because of the dense urban

location, or because of the publicity of the FIRMs change and the increased attention sea level rise is receiving.

6. Conclusion

6.1 Findings

My analysis uses data from a natural experiment in which FEMA released new FIRMs at the beginning of 2015, placing 400,000 residents in the flood zone – up from 218,000 previously. Using property sales data from 2003 – 2015, I used a difference in difference model with neighborhood, building, or apartment fixed effects to examine the effect on property value. Many studies have been done in the past demonstrating a difference in value between properties in the flood zone and nearby properties not in the flood zone, but a dramatic shift of the flood zone in such a populated area has never happened before to my knowledge. Analyzing different flood zones as well as different property value subgroups, I found that the sale price of a property newly placed in any flood zone after 2015 decreases by 8.6 percent on average. The sale price of a property newly placed in the 0.2 percent flood zone (the 500-year-flood) decreases by 8.9 percent on average, and the sale price of a property newly placed in the 1 percent flood zone (the 100-year-flood) decreases by 8.2 percent on average. I also examined four different property value subgroups, and found that the effect on sale price of a property when newly placed in any flood zone is heterogeneous across property values. On average, a low end property, categorized as a sale price between \$30,000 and \$284,921, decreases by 15.8 percent when newly placed in any flood zone, while the highest end properties show no significant effect. In addition, I found that the largest decreases occur when a low end property is newly placed in the 100-year flood

zone and the 100-year + high velocity wave zones, with 16.9 percent and 18.8 percent sale price decreases, respectively.

6.2 Policy Implications

New York City has appealed the maps, and perhaps if the appeal is accepted (and the maps return to what they were before) the property values will increase again. FEMA maintains that its maps are accurate. Regardless, with sea level rise, FIRMs will have to continue to change in the future to reflect the proper risks. The Dutch have dealt with flooding and sea level rise for a long time and have millions living below mean sea level. Currently, the Dynamic Preservation policy mandates that the coastline of the Netherlands be kept at its 1990 position and that the dunes be able “to withstand a storm event with the probability of exceeding 1 in 10,000 years” (Mulder 2011). The Delta Commission 2008 Report lays out the current recommendations for coastal management in the Netherlands. A series of 12 recommendations includes raising present flood protection level, mandating a cost-benefit analysis for any development in low-lying lands, safeguarding river discharge capacity, and providing beach sediment nourishments (Delta Commission 2008).

In many places, building expensive infrastructure to adapt to climate change is considered a waste of resources, but in New York City it may make the most sense because of the level of development and importance of the city. New York City **plans to spend** \$20 billion over several decades on resiliency efforts (Lehmann 2015). Required flood insurance, the crux of my study, is another tool to manage risk. Sandy was not a once in a lifetime event.

It is challenging to calculate the total welfare lost due to property value decreases because my data set alone does not account for every property affected, but only the ones sold after the new FIRM s were released. An additional 60,000 buildings were added to the zone (Schultz 2014). This means that with an average sale price decrease of 8.6 percent, and an average value of \$754,789 based on my data, the total loss would be \$3.89 billion.

6.3 Concerns and Future Research

My main concern with my analysis is that it simply has not been long enough after the treatment for changes to take effect. The avenues of change are behavioral adjustments and insurance adjustments, meaning there may be a negative behavioral response because people are less likely to buy a property for a high price if there is a greater risk of it flooding, and the insurance is expensive, making that property less affordable. These effects are not measured separately and there is a chance that they both decrease the property value but have different effects on how much it actually costs to live there. For example, paying a high premium for flood insurance could make it so the property value alone decreases, but only the financially better-off citizens can afford to live there because the overall cost increases. Meanwhile, the behavioral effect of being in a flood zone may affect different income classes differently. If an individual is very rich, they may not care if their property is flooded because they can simply pay for repair no matter how much insurance covers, whereas those of lower economic classes are more risk averse. There also could be differences in information exposure if some neighborhoods or economic classes of people are more aware of the risks of sea level rise, storms, and flooding than others. Finally, insurance premiums are not actually mandated until the flood maps are official, but the appeal process is still ongoing. Rational people might assume they will have to

pay insurance in the future and that will decrease the value of the property, but the full affect might not happen until the maps are made official.

As mentioned before, there is probably a more dramatic change in property value among properties that actually flooded in 2012. Adding a layer of the actual flooding during Sandy to my ArcMap analysis and creating a new treatment variable for different levels of damage is the most promising area of further research.

Property value loss does not capture the full economic impact of sea level rise by any means. In a powerful storm event, there will also be a number of other costs including human mortality and social infrastructure destruction. Furthermore, it cannot be assumed that costs increase linearly with sea level rise. (read about Jeffrey's paper here). Most likely, they do not. It is very difficult to extrapolate the results from this paper to what will happen to property values in coastal cities when the sea level rises orders of magnitude more than what we have observed so far. Many of these places won't be in the flood zone anymore, they will be submerged. So the new 1 percent flood zone will be farther back, and maybe this analysis will still apply to those property values, but I my results cannot be extrapolated to predict property values in a century.

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Data Appendix

To assign each property sale with a flood zone in both 1996 and 2015, I first had to get the addresses from the property sale data geocoded because the flood data is georeferenced by location using the State Plane and projection and coordinate system. Stephen Sheppard helped with this stage by using a package in ArcMap that takes the address and attempts to spatially locate it. Instead of geocoding the entire property sale data set which has many repeated addresses because of multiple sales, he sorted by address and created a dummy variable that has a value of “1” for each new address in the list. If the address was the same as the predecessor address, it was given a “0”. Then he sorted the data so the 1’s are on top, which allowed him to only bring unique addresses into GIS for geocoding one time. If a property is sold in 2004 and again in 2010, I still only need to geocode it once. This process was only about 70 percent successful, because ArcMap cannot read and interpret an address as well as the human eye can if it is not in the normal format. In future research, it may be worthwhile to go back and figure out how to format the addresses that were not geocoded to make them possible for ArcMap to geocode in order to get a better success rate.

To get the complete data set needed, I opened both the newly created shapefile of geocoded property addresses and the shapefile of 2015 FIRMs in ArcMap and joined the two layers. I then opened the 1996 FIRM and the joined layer from the previous step, and once again joined these two layers. I exported the resulting table, which consisted of each property’s address, FIRM designation in 1996, and FIRM designation in 2015. My data sets were actually quite large, so I had to do this process in four chunks of data and append them in STATA. Once imported into STATA, the FIRM designations had to be applied to un-geocoded properties by matching them with their geocoded counterparts based on address and zipcode. About 25 percent

of my observations were lost during this process for various reasons, but not so many that my analysis was inhibited. Reasons for dropped observations included ones that were missing a zone designation in either 2015 or 1996, or observations that were unable to be geocoded if ArcMap could not interpret the address given by the Dept. of Finance data set.

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