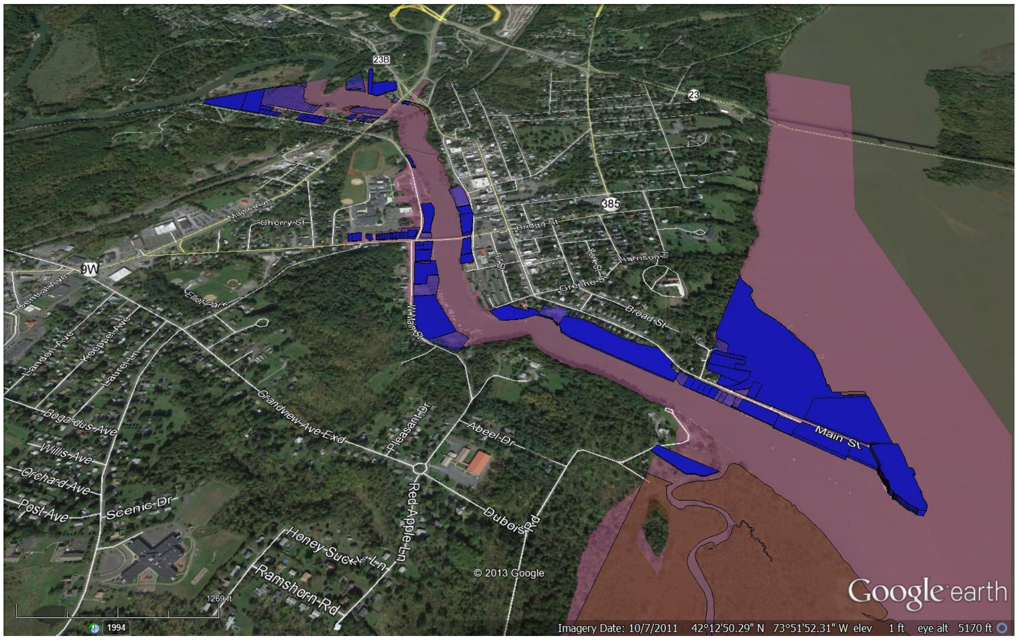
Benefit Cost Analysis for Adaptation to Sea Level Rise and Storm Surge in Catskill, NY:

Use of the COAST Approach™ to Evaluate Elevations, Flood Proofing, Flood Walls, and Strategic Relocations



COAST model scenario of buildings damaged in a 100 Year Storm arriving in the year 2025, with 6.5 inches of sea level rise and a total water elevation of by 11.04 feet, if no action is taken, in the Village of Catskill.

- **Estimates one-time damage to building values from a 100-year storm in the years 2025, 2055, and 2100 if no action is taken.**
- **Indicates which parcels are pedicted to be permanently inundated by sea level rise on a daily basis, if no action is taken, by the years 2025, 2055 and 2100.**
- **Utilizes sea level rise scenarios provided by Scenic Hudson, and flood heights from the effective FEMA Flood Insurance Study.**
- **Includes predictions for all cumulative expected damage to building values from all storms, up to the years 2025, 2055, and 2100.**
- **Includes cost estimates and benefit-cost ratios for three proposed adaptation scenarios**

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SCENIC HUDSON

Hudson River Estuary

DEPARTMENT OF ENVIRONMENTAL CONSERVATION · NEW YORK STATE

NEIWPCC
New England Interstate Water Pollution Control Commission

Executive Summary

Catalysis Adaptation Partners of Freeport, Maine worked with Scenic Hudson and a task force of the Village of Catskill, to use the COAST modeling tool to:

- Conduct a vulnerability assessment for the Village from the threat of future storm surges, made worse by sea level rise over time.
- Calculate a prediction of cumulative damages to real estate over time if no action is taken.
- Calculate a prediction of one-time damages from 100-year storms that might occur in the future.
- Evaluate three sets of actions, or scenarios, that Village might pursue to mitigate future damages, with benefit-cost analysis.

The COAST Vulnerability Assessment, with stakeholder-derived inputs, predicts:

- By the year 2100, the COAST model predicts that there will be $17.2 million in cumulative damages to buildings over time in Catskill, from all storms, as sea level increases by 5.00 feet above today's level.
- By the year 2100, the COAST model predicts that 30 parcels will be permanently inundated by the Hudson River and Catskill Creek, as sea level increases by 5 feet over today's level, with a total taxable assessed value of $3.8 million.
- During a 100-year storm that might occur in the year 2055, the COAST model predicts $3 million in damages from this one-time event, significantly higher than from Superstorm Sandy, as it would arrive on top of a sea level increased by 1.79 feet over today's level.

The Catskill Flooding Task Force asked that COAST to be used to test three sets of adaptation strategies, to protect the waterfront area (cost estimates for each action developed in collaboration with Parsons Brinckerhoff).

- 1 – The "Bushnell Greenway" scenario, emphasized a relocation approach with buyouts of parcels vulnerable to sea level rise and flooding, both now and in 2055. A greenway could be created along the creek in the areas of recurring flooding.
- 2 - The "West Main Street Floodproof/Elevate" scenario, emphasized an accommodation approach, allowing floodwaters to move onto the waterfront. Damage would be minimized by the floodproofing and elevation of buildings, and the elevation of West Main Street.
- 3 – The "West Main Street Waterfront Relocate" scenario, emphasized strategic relocation of most of the structures now located on the east side of the road, to new bulk-headed and filled, elevated waterfront access areas. The scenario also called for elevation of buildings mostly on the west side of the road, and elevation of West Main Street itself.

The COAST model was run again for each scenario to estimate avoided damage over time as if each adaptation action had been implemented. Benefit-cost relationships were then established to compare the relative fiscal efficiency of each adaptation option, where "benefits" are the cumulative avoided damages during each scenario. The highest benefit cost ratio was in Scenario 2, with positive ratios when looking at either discounted or non-discounted dollar figures (benefit-cost ratio = 2.91, by year 2055, with non-discounted dollars). In general, benefit-cost ratios in Catskill are low, because adaptations are relatively expensive for the amount and scale of the properties being protected. For instance, in the Kingston project also conducted by Scenic Hudson, benefit-cost ratios were higher because of protection provided to the multi-million dollar sewage treatment plant.

Contents

Methodology and Assumptions Used for COAST Model Analysis

Initial development of the COAST software tool was funded by the US Environmental Protection Agency. It is used to predict damages from varying amounts of sea level rise and storm surge under a range of candidate adaptation action scenarios that users construct. The software was run for Scenic Hudson and the Village of Catskill by Catalysis Adaptation Partners, LLC (Catalysis), whose principals designed the software, and who use it to help communities around the country. COAST is used to calculate the potential damage from one particular storm in the future, as well as to calculate the cumulative potential damage from all storms that may occur over a period of years, from today until a point in the future, under a range of adaptation scenarios stakeholders may wish to consider.

Model Preparation for the Village of Catskill

Step 1 - Load accurate elevation data.

A LiDAR (Light Detection and Ranging) image of the area was used, serving as a highly accurate map of land elevations. With this data layer the COAST model could identify the ground elevation of any point in the study area. LiDAR data for the Village consisted of a grid millions of squares, each 1 meter by 1 meter, with a single elevation value in feet for each square.

Step 2 – Load tax map parcels and assessed building values from the Village.

Property values were provided by the Real Property Tax Service of Greene County. Care was taken to ensure the LiDAR images and tax map layers had the same coordinate system and units (feet) for both vertical and horizontal positions.

The Task Force identified that the assessed values provided by Greene County were generally low and needed to be adjusted to better reflect market conditions. The Village staff had determined that on average, the amounts of the assessed values of properties in Catskill were only 58.8% of the actual selling price amounts in recent years (a term known as the sales ratio). For the purposes of modeling dollar damages to real estate, all assessed values provided were divided by 0.588, to reflect this sales ratio, and to provide a more realistic estimate.

Step 3 – Determine water levels and probabilities.

When floods occur in Catskill, the water heights are not uniform throughout the Village. As you go up Catskill Creek from Bridge Street to the Village limits, flood heights increase as the bottom of the creek goes uphill. Therefore, for the COAST software analysis, the Village waterfront was divided as follows:

(1) Area 1: Hudson River waterfront, and Catskill Creek waterfront from the Hudson River upstream to Bridge Street;
(2) Area 2: Catskill Creek waterfront from Bridge Street upstream to Route 9W; and
(3) Area 3: Catskill Creek waterfront from Route 9W upstream to the Village limits.

As determined by Scenic Hudson, the starting values of the high tide level (MHHW or Mean Higher High Water) for Catskill in Areas 1 and 3, were 2.76 feet (NAVD 88 units). The starting value for the high tide level in Area 2 was 2.71 feet. As set by Scenic Hudson, the “North of Kingston, Rapid Ice Melt” scenario was added to the model for sea level rise above today’s level, as follows:

By the year 2025, an additional 0.54 feet (6.5").
By the year 2055, an additional 1.79 feet (21.5").
By the year 2100, an additional 5.00 feet (60").

An "exceedance curve" was also established that states the relationship between storms of different recurrence intervals, sizes, and probability of occurring in any given year. In each of the three study areas, the predicted flood heights from the FEMA Flood Insurance Study were averaged. Catalysis, in consultation with Scenic Hudson, used the predicted storm heights and probabilities from the effective FEMA Flood Insurance Study for Greene County, May 16, 2008; Volumes 1-3, FIS# 36039CV001A, 36039CV002A, 36039CV003A. The following values were used to populate the exceedance curve :

Storm Event	Recurrence Interval	Probability in Any Given Year	Surge Height Above MHHW[2] (NAVD 88 units)			Overall Elevation of Flood Waters in Feet (NAVD 88 units)		
			Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
500 Year Storm[1]	Once every 500 years	0.002	10.24	19.29	24.74	13	22.0	27.5
100 Year Storm[1]	Once every 100 years	0.01	7.74	14.29	17.24	10.5	17.0	20.0
50 Year Storm[1]	Once every 50 years	0.02	6.74	12.29	15.24	9.5	15.0	18.0
10 Year Storm[1]	Once every 10 years	0.10	4.74	7.29	9.74	7.5	10.0	12.5

[1]From the FEMA Flood Insurance Study for Greene County, May 16, 2008; Volumes 1-3, FIS# 36039CV001A, 36039CV002A, 36039CV003A.
[2]The MHHW level for Areas 1 and 3 in 2014 is 2.76 feet (NAVD 88 units). The MHHW level for Area 2 is 2.71 feet (NAVD 88 units). Values were derived from NYHOPS tidal datum by Scenic Hudson.

These water levels were established for the creation of simulated storms, with identified sea level rise curves added to change over time.

Step 4 – Provide a depth-damage function

Finally, COAST needs a guide to calculate amounts of damage to be incurred by each asset, depending on flooding depth during each storm event. A "depth-damage function" was incorporated from the US Army Corps of Engineers, and was based on the Army's damage measurements from years of studying floods and the associated insurance claims. In the model parameters, it was assumed that once the daily high tide (mean higher high water) with no storm surge, reached a depth of one foot at the center of a parcel, the entire value of the building or buildings would be permanently lost due to sea level rise, if no action was taken.

Step 5 – Ensure asset data are appropriately structured

COAST creates flood scenarios over many years and measures flood depth at the center of each parcel polygon. In the case of multiple buildings on one lot, and with the version of the software being used at the time, there unfortunately was no way to apportion building value between separate buildings. The municipal tax parcel database aggregated "building value" for all buildings on a lot. Therefore, for the purposes of this model, the aggregate building value was assigned to the group of buildings on each multibuilding lot. Implications of this are that if the model showed the centroid of the parcel as flooded, it calculated damage to all buildings on the parcel using the depth-damage function, as if it were one flooded building. This may have overestimated damage on some parcels.

Limitations of these COAST Model Results

- A uniform mean higher high water elevation for Catskill for each of three areas was entered in the model. Variation in tidal surface elevations that might actually occur within each of these areas was not accounted for.
- On the open river coast, the effects of waves, wind, and erosion are not considered in the COAST model, as it calculates new high tide levels due to sea level rise, using only still water flood elevations on the existing terrain.
- Model output was not evaluated for the hydrologic connectivity of inundated areas. Certain low-lying areas not directly connected to tidal waters may appear flooded in some COAST results in Catskill, which may not necessarily be what occurs in actual flood events.
- Values for individual buildings were not available, as assessing records combined the values of all buildings on a particular lot into one number. Loss of building value for the lot was assumed to occur when flood waters reached the centroid of the parcel polygon.
- When the daily high tide level (MHHW) with sea level rise was projected to reach depths from zero to one foot, without any storm surge, permanent damage was assumed <u>not</u> to occur, to reflect and take into account uncertainty in the modeling. Only when daily MHHW depths reached 1 foot or more at the centroid were building values entirely removed.
- Assessing records did not reflect which buildings may have already been elevated on pilings or flow-through flood-proofed foundations, if any. Sea level rise damage would be overestimated for these structures. However, it should be noted that an elevated structure protected from water damage at its base could still lose its value and utility after sea level rise, because street and utility accesses leading up to the building are lost to daily tidal flooding.

The Vulnerability Assessment

COAST was then run under a "no action" scenario for the Village of Catskill to calculate the losses of building value from sea level rise and storm surge, for the years 2025, 2055 and 2100 (11, 41 or 86 years from now). Results are summarized in tables on the following pages. A google earth map was also created for the Village, with the flooding depth and dollar damage estimate available for each individual parcel flooded by a 100 year probability storm surge with sea level rise, for each scenario. The google earth files (*.kml format) are available and can be distributed to property owners or any other interested parties for use in personal or public planning for sea level rise and storm surge.

Key Findings of Vulnerability Assessment – If No Action is Taken

- By the year 2055, the COAST model predicts that there will be $6.3 million in cumulative damages to buildings over time in Catskill, from all storms, as sea level increases by 1.79 feet above today's level.
- By the year 2100, the COAST model predicts that there will be $17.2 million in cumulative damages to buildings over time in Catskill, from all storms, as sea level increases by 5.00 feet above today's level.
- By the year 2055, the COAST model predicts that 7 parcels will be permanently inundated b'y the Hudson River and Catskill Creek, as sea level increases by 1.79 feet over today's level, with a total taxable assessed value of $1.7 million.
- By the year 2100, the COAST model predicts that 30 parcels will be permanently inundated by the Hudson River and Catskill Creek, as sea level increases by 5 feet over today's level, with a total taxable assessed value of $3.8 million.
- During a 100-year storm that might occur in the year 2055, the COAST model predicts $3 million in damages from this one-time event, significantly higher than from Superstorm Sandy, as it would arrive on top of a sea level increased by 1.79 feet over today's level.

Note that the sea level rise curve used for these estimation purposes was just one of many options. Stakeholder process early in the community modeling stage can identify a range of sea level rise scenarios to examine in the 'no action' and 'action' scenarios. More or less aggressive curves would produce different cumulative expected damage results.

COAST Model for Catskill

Modeled Water Levels and Vulnerability Assessment Results For the 100 Year Storm with Sea Level Rise in the Years 2025, 2055 and 2100

	Predicted Elevation of 100 Year Storm Flood Height from FEMA Effective F.I.S. NAVD88 (ft.)[1]			Model of Sea Level Rise Above MHHW in 2014 (ft)[2]	Model Total Flood Elevation for Each Scenario NAVD 88 (ft.)			COAST Model Expected Damage to the Value of All Buildings & Improvements From This Single Storm Incident in the Scenario Year ($ Million)[4]				COAST Model Cumulative Expected Value of All Buildings and Improvements Located on Properties Permanently Inundated by Sea Level Rise if No Action is Taken, by this Year ($ Million)[3]				COAST Model Cumulative Expected Damage to the Value of All Buildings & Improvements From Sea Level Rise and All Storms, 2014 to Scenario Year ($ Million)[3]			
Year	Area 1	Area 2	Area 3		Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	**Total Village**	Area 1	Area 2	Area 3	**Total Village**	Area 1	Area 2	Area 3	**Total Village**
2025	10.5	17	20	0.54	11.04	17.54	20.54	1.4	0.7	0.2	**2.3**	0.09	0	0	**0.09**	1.0	0.5	0.07	**1.6**
2055	10.5	17	20	1.79	12.29	18.79	21.79	1.7	1.0	0.3	**3.0**	1.4	0	0	**1.4**	3.9	2.0	0.3	**6.3**
2100	10.5	17	20	5.00	15.50	22.00	25.00	2.7	2.7	0.7	**6.1**	2.7	0.09	0	**2.8**	9.7	6.1	1.4	**17.2**

[1] *Tidal state is included in FEMA FIS predicted flood elevations for the 100 year storms.*

[2] *Elevation of Mean Higher High Water (MHHW) in year 2014 is 2.76 feet in Areas 1 & 3, and 2.71 feet in Area 2 (NAVD 88).*

[3] *No Discount Rate applied.*

[4] *See kml files and spreadsheet for complete list predicted depths and damages to individual properties.*

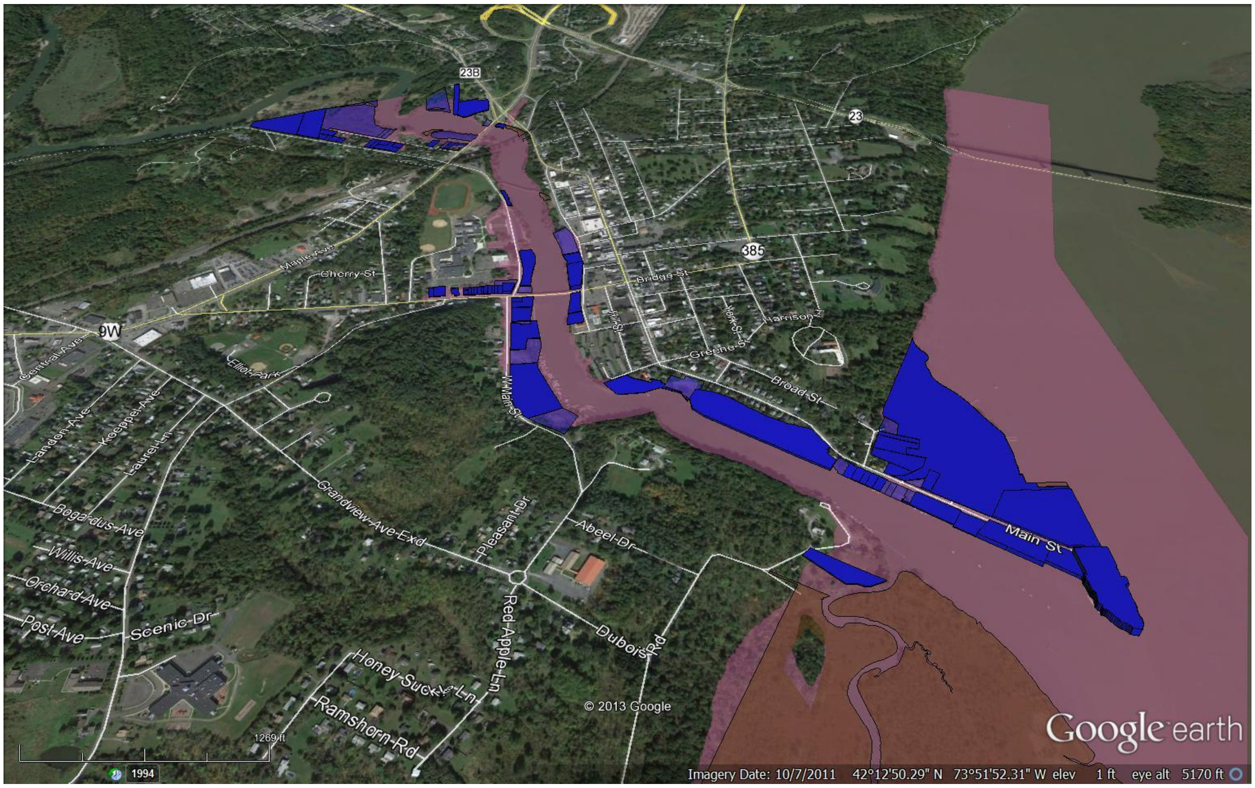
COAST Model for Catskill
Modeled Water Levels and Vulnerability Assessment Results
For Sea Level Rise Only, Without Any Storm Surge
in the Years 2025, 2055 and 2100

Year	Model of Sea Level Rise Above Today's MHHW NAVD 88 (ft)[1]	Total Height of Daily High Tide, Without Surge (MHHW) (NAVD 88) (ft.)			Number of Tax Parcels Affected				COAST Model Cumulative Expected Value of All Buildings and Improvements Located on Properties Permanently Inundated by Sea Level Rise if No Action is Taken, by this Year ($ Million)[2]				COAST Model Cumulative Expected Value of All Land Located on Properties Permanently Inundated by Sea Level Rise if No Action is Taken, by this Year ($ Million)[2]				COAST Model Cumulative Expected Value of All Land plus Buildings and Improvements (Total Assessed Value) Located on Properties Permanently Inundated by Sea Level Rise if No Action is Taken, by this Year ($ Million)[2]			
		Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	**Total Village**	Area 1	Area 2	Area 3	**Total Village**	Area 1	Area 2	Area 3	**Total Village**	Area 1	Area 2	Area 3	**Total Village**
2014	0	2.76	2.71	2.76	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**
By 2025	0.54	3.30	3.25	3.30	3	2	1	**6**	0.09	0	0	**0.09**	0.3	0.03	0.001	**0.3**	0.5	0.03	0.001	**0.5**
By 2055	1.79	4.55	4.50	4.55	4	2	1	**7**	1.4	0	0	**1.4**	0.3	0.03	0.001	**0.3**	1.7	0.03	0.001	**1.7**
By 2100	5.00	7.76	7.71	7.76	26	3	1	**30**	2.7	0.09	0	**2.8**	1.0	0.05	0.001	**1.0**	3.7	0.1	0.001	**3.8**

[1] *Elevation of Mean Higher High Water (MHHW) in year 2014 is 2.76 feet in Areas 1 & 3, and 2.71 feet in Area 2 (NAVD 88).*

[2] *No Discount Rate applied. Values taken from Rockland County/Village of Catskill Tax Assessment Database. See kml files for a complete list of permanently inundated individual properties with predicted depths, and which decade permanent inundation is expected to occur.*

Illustrations of COAST Model Output for Sea Level Rise and One-Time Surge Impacts to Buildings



Village of Catskill

COAST Model Results, 100 Year Storm + Sea Level Rise in 2025

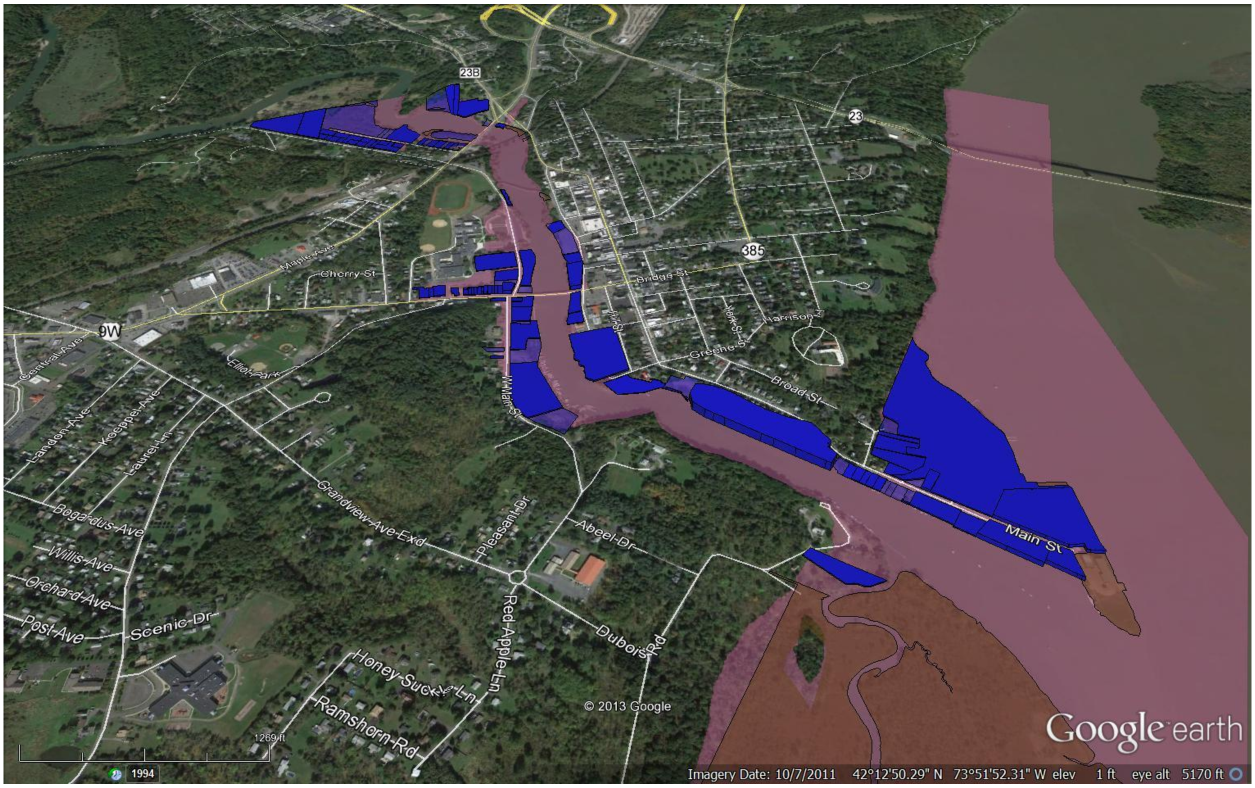
Total Elevation of Area 1 Flooding – 11.04 Feet (NAVD 88)
Total Elevation of Area 2 Flooding – 17.54 Feet (NAVD 88)
Total Elevation of Area 3 Flooding – 20.54 Feet (NAVD 88)

Buildings & Land Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)

Buildings & Land Permanently Inundated due to Sea Level Rise by this Year, if No Action is Taken

Extent of Flooding from this Amount of Storm Surge + Sea Level Rise

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

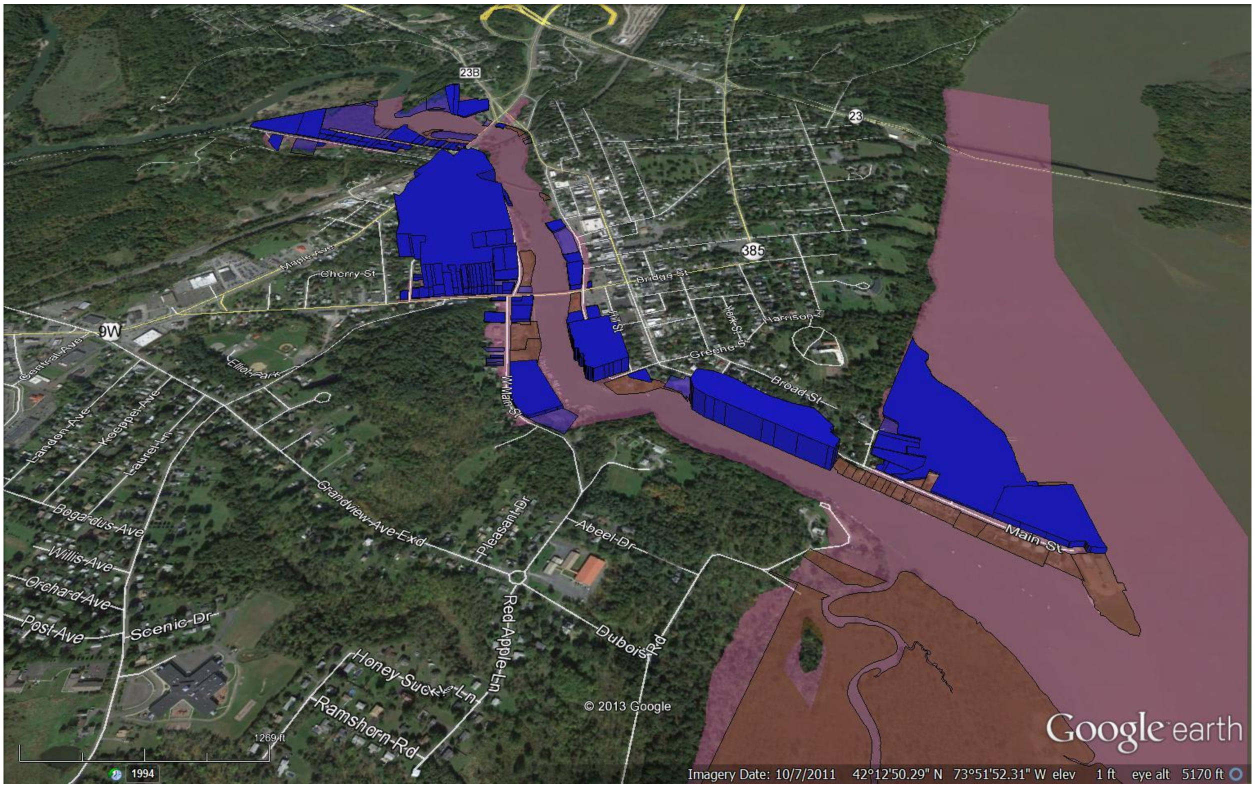


Village of Catskill — COAST Model Results, 100 Year Storm + Sea Level Rise in 2055

Total Elevation of Area 1 Flooding – 12.29 Feet (NAVD 88)
Total Elevation of Area 2 Flooding – 18.79 Feet (NAVD 88)
Total Elevation of Area 3 Flooding – 21.79 Feet (NAVD 88)

- Buildings & Land Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)
- Buildings & Land Permanently Inundated due to Sea Level Rise by this Year, if No Action is Taken
- Extent of Flooding from this Amount of Storm Surge + Sea Level Rise

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*



Village of Catskill — COAST Model Results, 100 Year Storm + Sea Level Rise in 2100

Total Elevation of Area 1 Flooding – 15.50 Feet (NAVD 88)
Total Elevation of Area 2 Flooding – 22.00 Feet (NAVD 88)
Total Elevation of Area 3 Flooding – 25.00 Feet (NAVD 88)

Buildings & Land Damaged by Storm Surge from this Single Event (Height of Bar indicates relative damage amount)

Buildings & Land Permanently Inundated due to Sea Level Rise by this Year, if No Action is Taken

Extent of Flooding from this Amount of Storm Surge + Sea Level Rise

*Predicted flood depths and dollar damages for all individual affected parcels are available in Google Earth *.kml files.*

Adaptation Strategies and the COAST Tool

Do Nothing, Fortify, Accommodate, or Strategically Relocate

Options for responding to sea level rise and storm surge can be divided into four categories.

Doing nothing is the most common, as it simply involves waiting for a storm incident to happen, and responding afterwards.

Adaptation approaches that "*fortify*" use hard or soft structures to prevent flood waters from reaching community assets. Such armoring can be "hard," such as seawalls or bulkheads, or "soft" structures such as geotextile tubes, which are giant fabric sandbags designed to be replaced after storms. Unfortunately, wetlands and beaches in front of such structures can disappear as they are pinched out between the rising water levels and the fortifying structures behind them.

Adaptation approaches that "*accommodate*" modify community assets to reduce the impact of flood waters. Accommodation acknowledges that structures will get wet, but action is taken to make it resilient, such as elevating a structure or its critical systems.

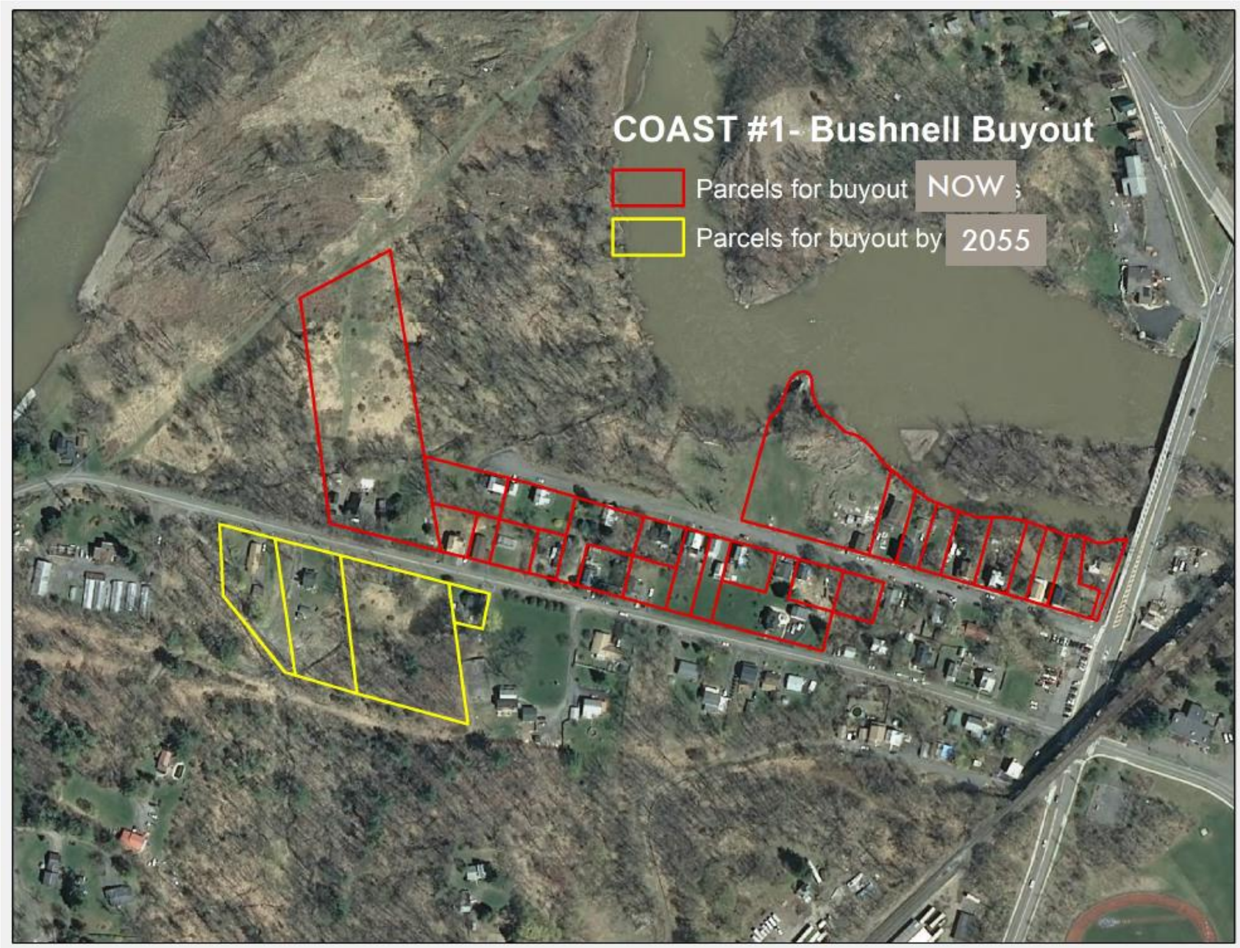
Strategic relocation involves relocating existing structures, people, and land uses away from areas at high risk of flooding to a new location to eliminate the risk of flooding, and allowing wetlands, beaches and natural coastal habitats to migrate landward naturally.

Potential Sea Level and Storm Surge Adaptation Actions		
Fortify	Accommodate	Strategic Relocation
• Revetments • Seawalls • Jetties • Levees • Geotextile Tubes • Automatic Floodgates • Hurricane Barriers	• Dry Floodproofing – Sealing Out Water • Wet Floodproofing – Allowing structures to get wet safely, with minimal damage • Land elevation by fill • Structure Elevations • Dune Restorations • Tidal Marsh Restorations • Tunnel Plugs	• Property Buyouts • Rolling Easements • Relocation of Buildings • Relocation of Infrastructure and/or Facilities • Zoning or Other Regulations to Prevent Fortification, and/or limits on New Construction

Use of the COAST Tool to Perform a Benefit Cost- Analysis for a Proposed Strategies

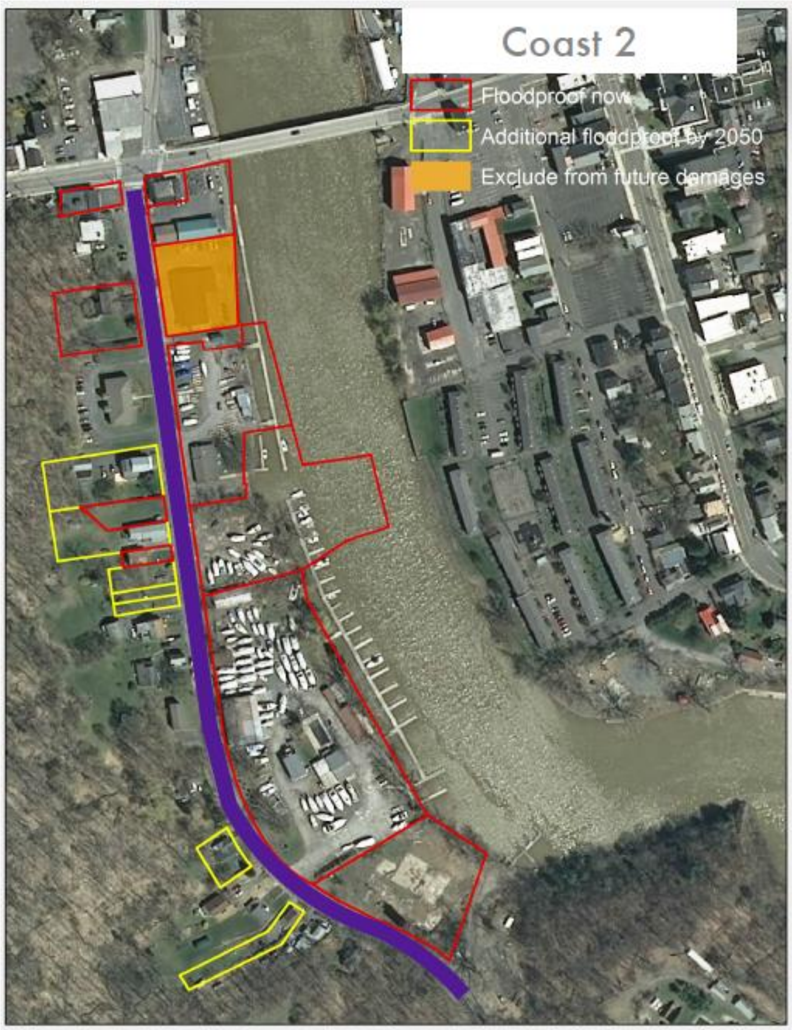
Once an adaptation strategy, or set of strategies, has been identified for a community or portion of a shoreline, the COAST tool can be used to evaluate whether the strategy would be a good investment. This is accomplished via adjustments to the depth damage function to represent avoided cumulative damage if the adaptation strategies were put in place. These avoided damages are then compared to cost of the strategies, creating a benefit-cost ratio. If this ratio is high, i.e., costs are low and benefits are high, then the option may be a good investment and more detailed feasibility plans and construction designs and estimates may be appropriate. The Catskill Flooding Task Force asked that COAST to be used to test three sets of adaptation strategies to protect the waterfront area (illustrations below).

Description of Three Adaptation Strategy Scenarios for Catskill



Scenario 1 was called "Bushnell Greenway." It emphasized a relocation approach with buyouts of parcels vulnerable to sea level rise and flooding, both now and in 2055. A greenway could be created along the creek in the areas of recurring flooding. Its adaptation elements were as follows:

- Purchase all parcels shown in red now, in a voluntary buyout program.
- Purchase all parcels shown in yellow in 2055, in a voluntary buyout program.



Scenario 2 was "West Main Street Floodproof/Elevate." It emphasized an accommodation approach, allowing floodwaters to move onto the waterfront. Damage would be minimized by floodproofing and elevation of buildings, and the elevation of West Main Street. Its adaptation elements were as follows:

- Adapt all buildings on parcels shown in red now so that their first floors are modified either to:
  1. allow flood waters to flow through (wet-floodproofing) by removing habitable spaces; or
  2. equip all buildings to be able to seal their first floors with water-tight doors, windows, vents, or other openings (dry-floodproofing).

- Elevate all buildings on parcels shown in red in the year 2055 so that their base floor elevation is set at 17.5 feet, which is the current 100 year flood height, with two feet of freeboard, and an additional 60 inches to account for sea level rise.

- Adapt all buildings on parcels shown in yellow in the year 2055, so that their first floors are modified either to:
  1. allow flood waters to flow through (wet-floodproofing) by removing habitable spaces; or
  2. equip all buildings to be able to seal their first floors with water-tight doors, windows, vents, or other openings (dry-floodproofing).

- Raise all sections of roads shown in purple in the year 2055, to a height of 9.76 feet, which is equal to today's high tide plus 60 inches of sea level rise plus 2 feet of freeboard.

Scenario 3 was called "West Main Street Waterfront Relocate." It emphasized strategic relocation of most of the structures now located on the east side of the road, to new bulk-headed and filled, elevated waterfront access areas. The scenario also called for elevation of buildings mostly on the west side of the road and elevation of West Main Street itself. Its adaptation elements were as follows:

- Bulkhead and fill areas now, that are outlined in black with diagonal lines, to a height of 14.29 feet, to create elevated waterfront access areas. The finished grade of these waterfront access areas would be at the current 100 year flood height with two feet of freeboard and an additional 21 inches to account for sea level rise.
- Relocate most/all waterfront structures that are located on the east side of West Main Street into these elevated waterfront access areas outlined in black with diagonal-line fill.
- In the year 2055, add additional bulkhead and fill to raise the waterfront access areas from 14.29 to 17.5 feet. The new finished grade of these waterfront access areas would then be at the current 100 year flood height with two feet of freeboard and an additional 60 inches to account for sea level rise.
- Elevate all buildings on parcels shown in yellow in the year 2055 so that their base floor elevation is set at 17.5 feet, which is the current 100 year flood height with two feet of freeboard, and an additional 60 inches to account for sea level rise.
- Raise all sections of roads shown in red in the year 2055 to a height of 9.76 feet, which is equal to today's high tide plus 60 inches of sea level rise plus 2 feet of freeboard.

Cost Estimates of Adaptations

Catalysis Adaptation Partners in consultation with Parsons Brinckerhoff engineers, developed rough cost estimates for the three scenarios described above. The cost estimates are summarized in tables in the following pages. Costs are shown both in today's dollars, and also with a discount rate applied to expenditures that would occur in the future. A discount rate is often used by economists when thinking about spending money many years from now, as opposed to spending money right away. When comparing two options for spending money to fix a problem, if you are required to spend $10,000 next year versus spending $10,000 immediately, choosing the option of paying next year is often preferred. To quantify the advantage of paying some time in the future, economists will apply a "discount rate" to the $10,000 payment next year. If a 3.3 percent discount rate is used, the $10,000 payment will be reduced to a "net present value" of $9,670 to reflect the advantage of being allowed to pay later.

Scenario 1: Bushnell Greenway. The total estimate for implementing Scenario 1, "Bushnell Greenway," is summarized in the following table:

Project Elements – Scenario 1: Bushnell Greenway	**Estimated Cost**	
	In Today's Dollars ($ millions)	**With Discounting of 3.3% for Expenditures Made in the Future, if any ($ millions)**
Purchase all parcels shown in red now, in a voluntary buyout program.	1.86	1.86
Purchase all parcels shown in yellow in 2055, in a voluntary buyout program.	0.29	0.08
Total Estimate, By 2100	**2.15**	**1.93**
By 2055	*1.86*	*1.86*
during 2056 to 2100	*0.29*	*0.08*

Scenario 2: West Main Street Floodproof/Elevate. The total estimate for implementing Scenario 2, "West Maine Street Floodproof/Elevate," is summarized in the following table:

Project Elements – Scenario 2: West Main Street Floodproof/Elevate	**Estimated Cost**	
	In Today's Dollars ($ millions)	**With Discounting of 3.3% for Expenditures Made in the Future, if any ($ millions)**
Adapt all buildings on parcels shown in red now, so that their first floors are modified either to: 1. allow flood waters to flow through (wet-floodproofing) by removing habitable spaces; or 2. equip all buildings to be able to seal their first floors, with water-tight doors, windows, vents, or other openings (dry-floodproofing).	0.12	0.12
Elevate all buildings on parcels shown in red in the year 2055 so that their base floor elevation is set at 17.5 feet, which is the current 100 year flood height with two feet of freeboard and an additional 60 inches to account for sea level rise.	0.70	0.18
Adapt all buildings on parcels shown in yellow in the year 2055, so that their first floors are modified either to: 1. allow flood waters to flow through (wet-floodproofing) by removing habitable spaces; or 2. equip all buildings to be able to seal their first floors with water-tight doors, windows, vents, or other openings (dry-floodproofing).	0.03	0.0081
Raise all sections of roads shown in purple in the year 2055, to a height of 9.76 feet, which is equal to today's high tide plus 60 inches of sea level rise plus 2 feet of freeboard.	0.81	0.21
Total Estimate, By 2100	**1.66**	**0.53**
By 2055	*0.12*	*0.12*
during 2056 to 2100	*1.54*	*0.41*

Scenario 3: West Main Street Waterfront Relocate. The total estimate for implementing Scenario 3, "West Main Street Waterfront Relocate," is summarized in the following table:

Project Elements – Scenario 3: West Main Street Relocate	**Estimated Cost**	
	In Today's Dollars ($ millions)	**With Discounting of 3.3% for Expenditures Made in the Future, if any ($ millions)**
Bulkhead and fill areas now, that are outlined in black with diagonal lines, to a height of 14.29 feet to create elevated waterfront access areas. The finished grade of these waterfront access areas would be at the current 100 year flood height with two feet of freeboard and an additional 21 inches to account for sea level rise.	0.64	0.17
Relocate most/all waterfront structures that are located on the east side of West Main Street into these elevated waterfront access areas outlined in black with diagonal-line fill.		
In the year 2055, add additional bulkhead and fill to raise the waterfront access areas from 14.29 to 17.5 feet. The new finished grade of these waterfront access areas would then be at the current 100 year flood height with two feet of freeboard and an additional 60 inches to account for sea level rise.	0.41	0.11
Elevate all buildings on parcels shown in yellow in the year 2055, so that their base floor elevation is set at 17.5 feet, which is the current 100 year flood height, with two feet of freeboard and an additional 60 inches to account for sea level rise.	0.90	0.24
Raise all sections of roads shown in red in the year 2055, to a height of 9.76 feet, which is equal to today's high tide plus 60 inches of sea level rise plus 2 feet of freeboard.	0.81	0.21
Total Estimate, By 2100	**2.76**	**0.73**
By 2055	*0.64*	*0.17*
during 2056 to 2100	*2.12*	*0.56*

Calculation of Avoided Damages if Adaptation Actions are Taken – The Benefits

In the next step the COAST model was run three more times for the Village of Catskill, for each of the these three scenarios. From the initial vulnerability assessment we knew what the predicted amount of cumulative damage to the Village's real estate would be over time, if no action were taken. For the three scenarios we adjusted the depth damage function inside the COAST model to test how much less damage would occur if each scenario were implemented. The table below shows how much avoided damage could be achieved from each adaptation scenario.

Scenario	COAST Model **Cumulative Expected Damages** to the Value of Buildings From Sea Level Rise and All Storms		**Avoided Damages** with Adaptation Scenario (No Action Losses Minus Losses with Adaptation in Place)	
	Discounted 3.3% ($ Millions)	Today's Dollars ($ Millions)	Discounted 3.3% ($ Millions)	Today's Dollars ($ Millions)
With No Action				
by 2055	3.33	6.29	$ -	$ -
by 2100	4.68	17.18	$ -	$ -
With Adaptation Scenario 1: Bushnell Greenway				
by 2055	3.20	6.06	0.14	0.24
by 2100	4.45	16.14	0.23	1.03
With Adaptation Scenario 2: West Main Street Floodproof/Elevate				
by 2055	3.20	5.94	0.14	0.35
by 2100	4.43	15.87	0.25	1.31
With Adaptation Scenario 3: West Main Street Waterfront Relocate				
by 2055	3.22	6.00	0.11	0.29
by 2100	4.45	11.70	0.23	5.48

These avoided damages can be considered as the benefit of each adaptation scenario, when creating the benefit-cost ratio.

Key Findings from Cumulative Damage Predictions from Different Adaptation Scenarios

- The prediction of the amount of damage avoided over time by the suite of actions in Scenarios 1 and 2 are remarkably similar.
- The prediction of the amount of damage avoided over time from Scenario 3 is much higher than the first two scenarios, particularly over the later years of the century. Over $5 million dollars is avoided, more than ten times the amount in other scenarios.

Benefit-Cost Ratios for Different Adaptation Scenarios

The prediction of cumulative damage avoided over time by employing an adaptation strategy is considered a benefit. The cost estimate for constructing, maintaining, and/or employing the adaptation strategy is the cost. To compare a series of adaptation strategies, economists and policymakers create a benefit-cost ratio for each. If the benefits outweigh the costs, the project will have a benefit-cost ratio greater than one. The more cost effective options will have a higher number for the benefit-cost ratio.

The benefit-cost ratios for the three adaptation options as calculated by the COAST model, appear in the table below:

	Scenario Cost ($ Millions)		Benefit/Cost Ratio	
With No Action	Discounted 3.3%	Today's Dollars	Discounted 3.3%	**Today's Dollars**
by 2055	$ -	$ -	0.00	**0.00**
by 2100	$ -	$ -	0.00	**0.00**
With Adaptation Scenario 1: Bushnell Greenway	Discounted 3.3%	Today's Dollars	Discounted 3.3%	**Today's Dollars**
by 2055	1.86	1.86	0.07	**0.13**
by 2100	1.93	2.15	0.12	**0.48**
With Adaptation Scenario 2: West Main Street Floodproof/Elevate	Discounted 3.3%	Today's Dollars	Discounted 3.3%	**Today's Dollars**
by 2055	0.12	0.12	1.14	**2.91**
by 2100	0.53	1.66	0.47	**0.79**
With Adaptation Scenario 3: West Main Street Relocate	Discounted 3.3%	Today's Dollars	Discounted 3.3%	**Today's Dollars**
by 2055	0.17	0.64	0.66	**0.46**
by 2100	0.73	2.76	0.31	**1.98**

Key Results of Benefit-Cost Analysis

- The best looking benefit-cost ratio is found in Scenario 2, with positive ratios when looking at both discounted and today's dollar figures, by the year 2055. In smaller municipalities where the waterfront is not highly and densely developed, floodproofing and elevation often show the best ratios.
- Scenario three has the second highest of the benefit-cost ratios.
- While the benefit-cost ratio for scenario one came out very low, it should be noted that only the structural damage was captured in the “cost calculations.” The social costs associated with repeated flooding such as lost wages, clean up, loss of contents, and illness, were not included in the cost estimates.

General Observations

- The COAST tool and approach are designed to help communities evaluate the merits of various options and to show which ideas might merit further study.
- Numbers coming from a run of the COAST model provide powerful motivation to seek funding and to develop political leadership to obtain funding to design adaptation strategies to protect the community – whether the solution will be fortification, accommodation, or strategic relocation – or a suite of strategies with all three elements.
- More rigorous evaluation of potential costs conducted by an engineering firm will be needed before any designs are prepared or actions are taken.
- In cases like Catskill, the COAST tool and approach are designed to help evaluate the merits of various options, and to show which ideas warrant further study. It is not an approach that makes firm recommendations for funding a particular design approach. However, “shopping” for which particular engineered design to construct or planning avenue to pursue *is* an appropriate additional use of the COAST approach – it simply requires clarity of goals and expectations at the

project outset, and appropriate resourcing on the engineering detail and costing inputs to be secured, at the beginning of the process.

- The COAST process is not just about the numbers. The COAST approach is to build a model of the future jointly with a committee of stakeholders. Once the problems of sea level rise and storm surge are discussed with probabilities and damage numbers attached, the vulnerabilities begin to seem real and candidate adaptation actions are evaluated – leading to political momentum.
- Development of this type of model promotes discussions of factors outside of the model, leading to diverse co-benefits and planning outcomes.
- The experience of Catalysis is that when considering adaptations to sea level and storm surge, the most cost-effective option is not always the one chosen. Upon seeing results of a COAST iteration, communities sometimes determine that fiscal efficiency is less important than other values such as maintaining ocean views or protecting natural resources. Importantly, benefit-cost ratios resulting from this work tend to open these tricky conversations about exactly what is most important to a community.