NYCPLANNING

COASTAL CLIMATE RESILIENCE

Urban Waterfront Adaptive Strategies

NYC Dept. of City Planning
December 20, 2012

Urban Waterfront Adaptive Strategies
A guide to identifying and evaluating potential strategies for increasing the resilience of waterfront areas.

Project Goals

- To identify the range of possible adaptive strategies to increase the resilience of urban coastal areas to coastal hazards associated with sea level rise, such as high tides, storm surge, and erosion.
- To understand the type and magnitude of costs/benefits associated with each strategy.
- To set up a framework for evaluating the effectiveness and appropriateness of various approaches for various types of coastal areas.

Alley Pond Creek, Queens

Upper Bay

The coastal zone is large and diverse. Different areas face different risks and will require different strategies.

Rockaways, Queens

Williamsburg, Brooklyn

Sea level rise has associated sudden and gradual impacts that will impact different areas in different ways.

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Gradual

Regular inundation	Low-lying areas; wetlands
Increased erosion	Soft shorelines; weakened structures

Sudden

Higher storm surge	Current flood zones
Flooding	Expanded flood zones
Wave forces	Areas exposed to open ocean

NOTE: sea level rise may also cause salt water intrusion which could lead to enhanced corrosion of underground structures and foundations. This element is not a focus of this study.

1 Understand the Vulnerabilities

Create Coastal Area Typologies that are representative of the range of uses, densities, conditions of the city's coastal zone.

Example: Low-density oceanfront beach

2 Identify Specific Adaptive Strategies

At the scale of the site, neighborhood and reach.

Example: Elevating a building

3 Develop Resilient Approaches

Presents a cohesive strategy which may be a combination of individual strategies.

Example: Flood proofing of private homes and building an off-shore barrier reef.

4 Evaluation Framework

Set up a framework on how to evaluate the overall costs and benefits of strategies for different kinds of neighborhoods.

Example: Implementation challenges, un-tested strategy, potential impacts on streetscape

The Coastal Area Typologies will be used to understand the type and ranges of ***vulnerabilities*** *and* ***risks*** of the ***built environment*** to existing coastal hazards and to impacts of sea level rise.

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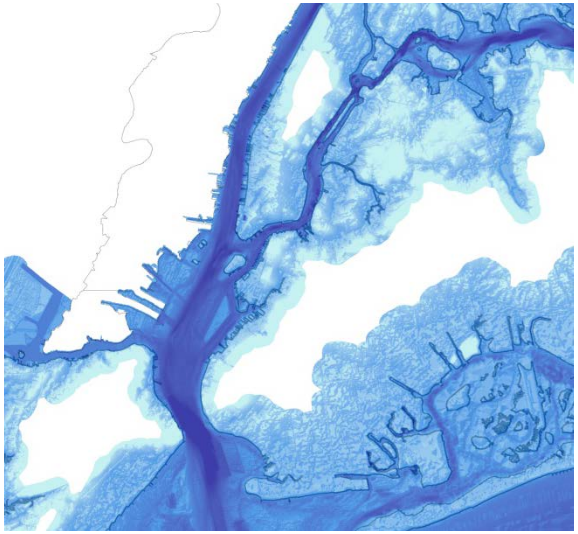
Exposure to wave forces



Land elevation

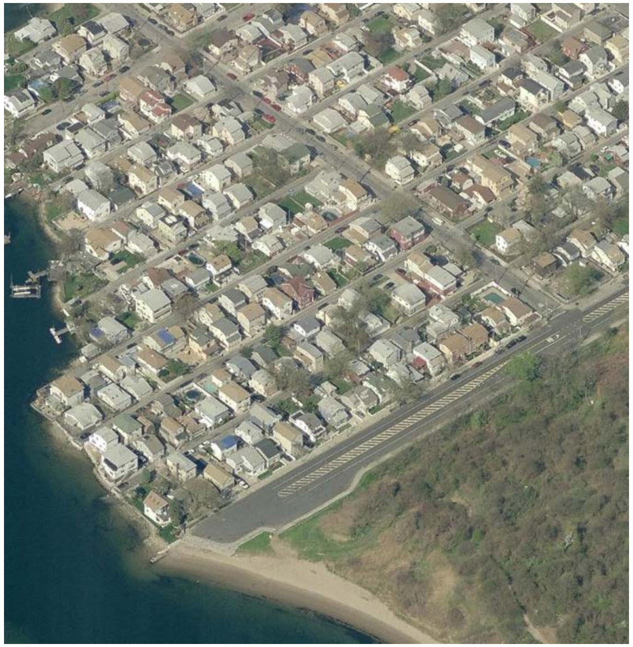
Land uses

Vulnerability refers to the characteristics of an affected area that causes hazards to create unwanted consequences.

Risk is the (financial or operational) impact of the hazards on an affected area, given their vulnerability and the probability of an event.

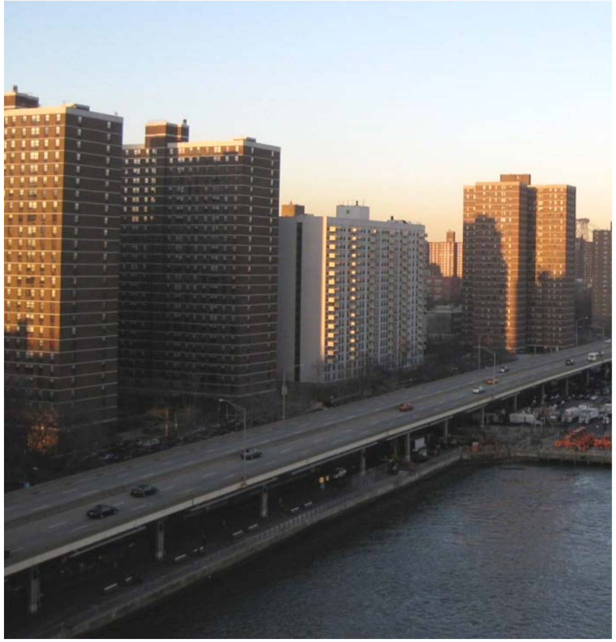
The ***built environment*** is all the physical structures and landscapes that form the city.

And the range of physical characteristics that make strategies more or less appropriate by affecting either the costs or benefits.



Density

Soil types



Shoreline infrastructure

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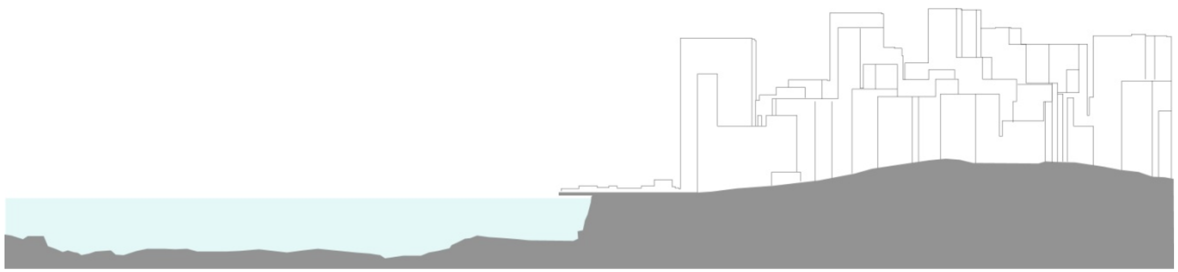
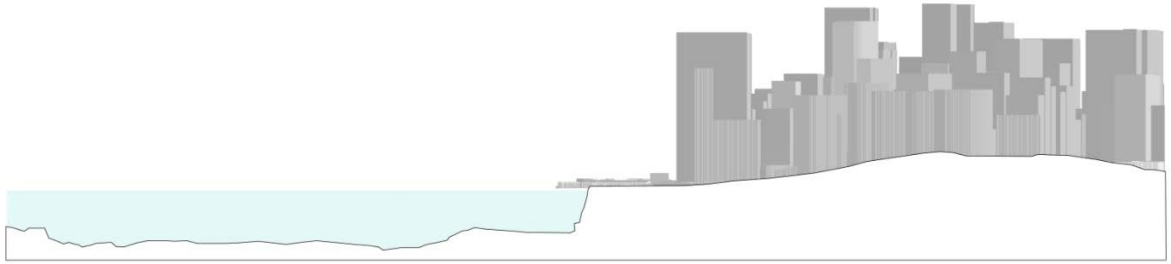
To identify the range of these factors we looked at two different systems:



Geomorphology:
Physical coastal landforms and geographic features.



Land Use:
The types of uses and structures, and the intensity of uses.

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Glacial Formations

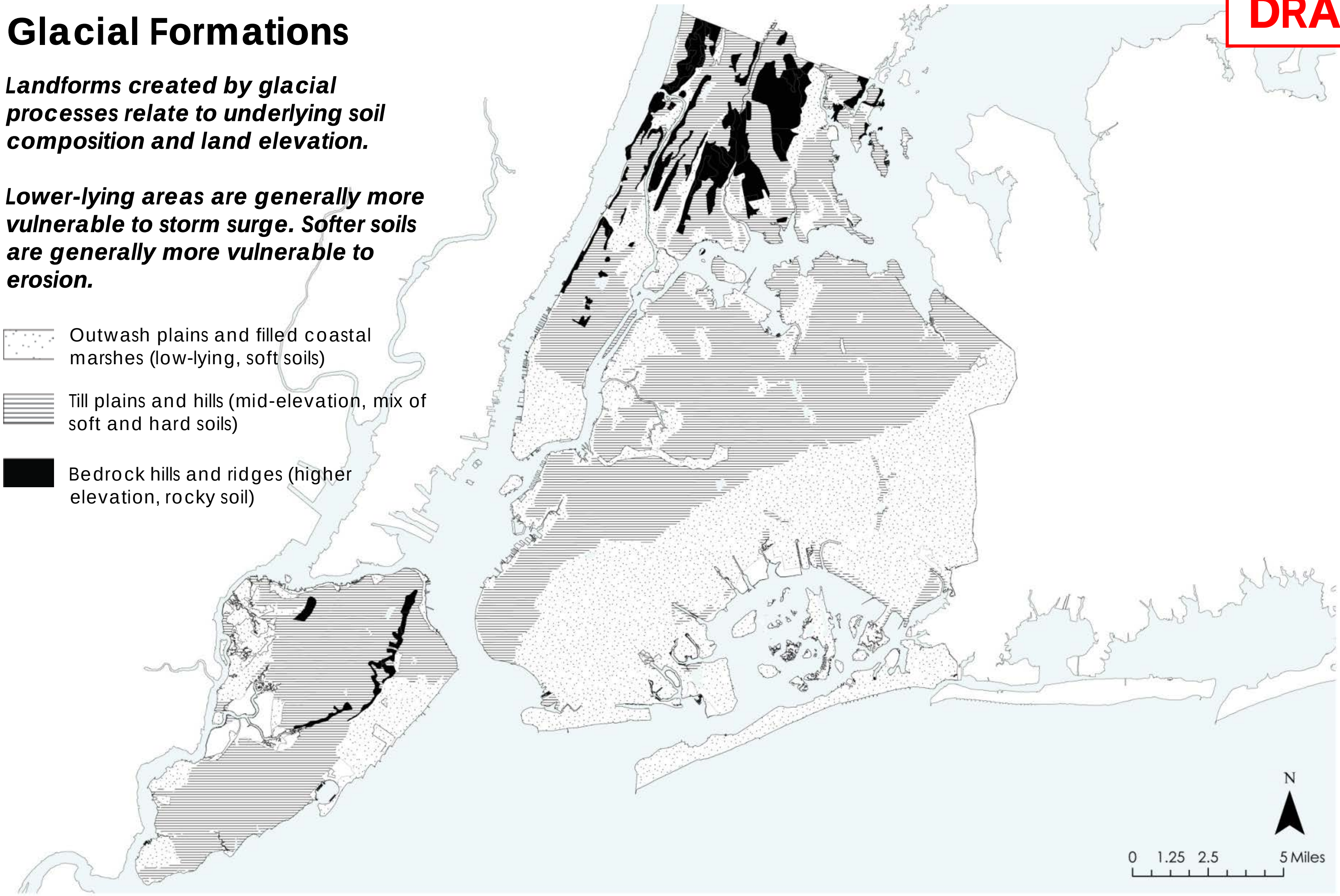
Landforms created by glacial processes relate to underlying soil composition and land elevation.

Lower-lying areas are generally more vulnerable to storm surge. Softer soils are generally more vulnerable to erosion.

Outwash plains and filled coastal marshes (low-lying, soft soils)

Till plains and hills (mid-elevation, mix of soft and hard soils)

Bedrock hills and ridges (higher elevation, rocky soil)



Sources: Reconnaissance Soil Survey, New York City Soil and Water Conservation District, 2005

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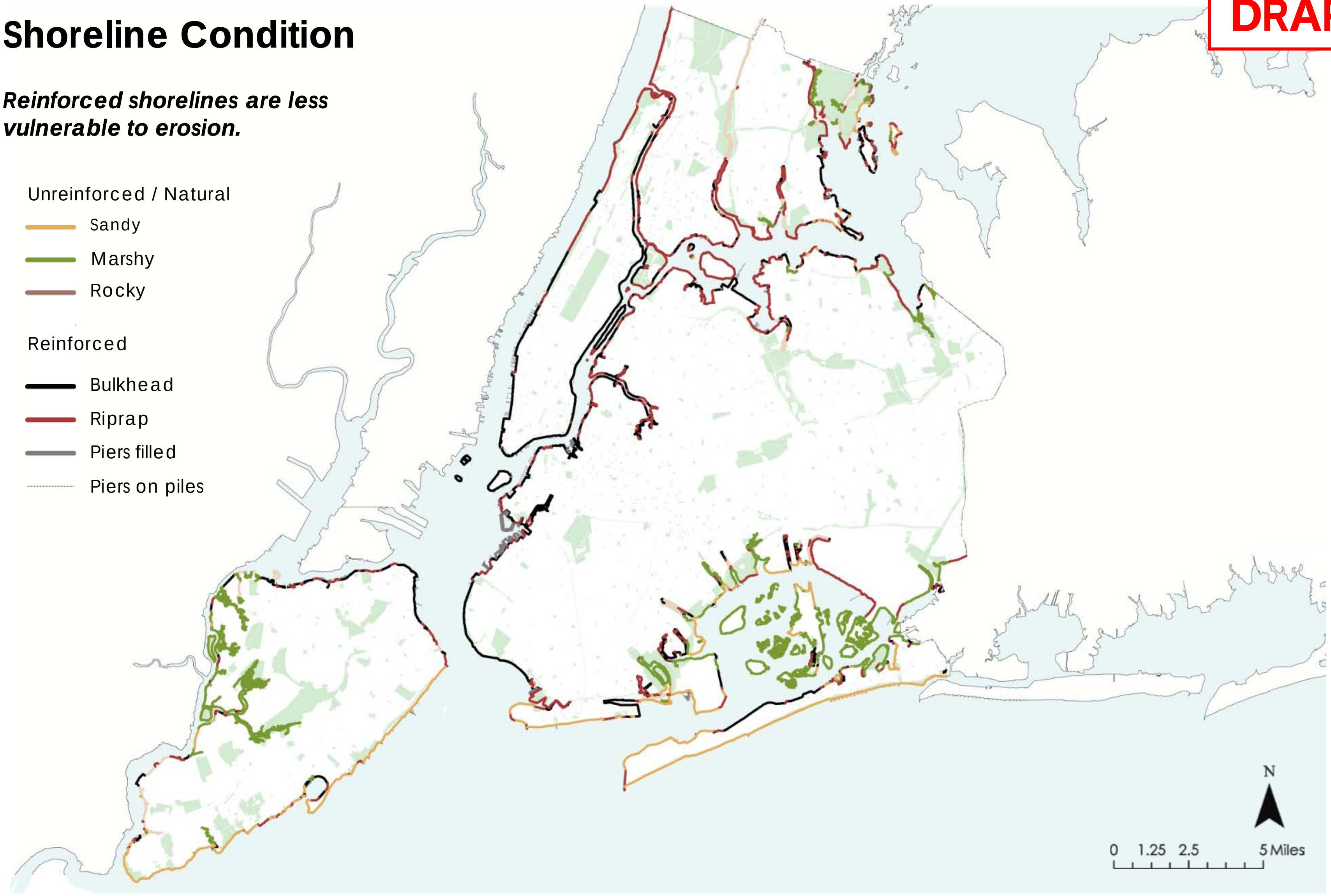
Shoreline Condition

Reinforced shorelines are less vulnerable to erosion.



Sources: Department of City Planning, based on aerial survey, 2011

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Exposure to Wave Forces

Areas with a greater distance to an adjacent shoreline ("fetch") are more exposed to waves.

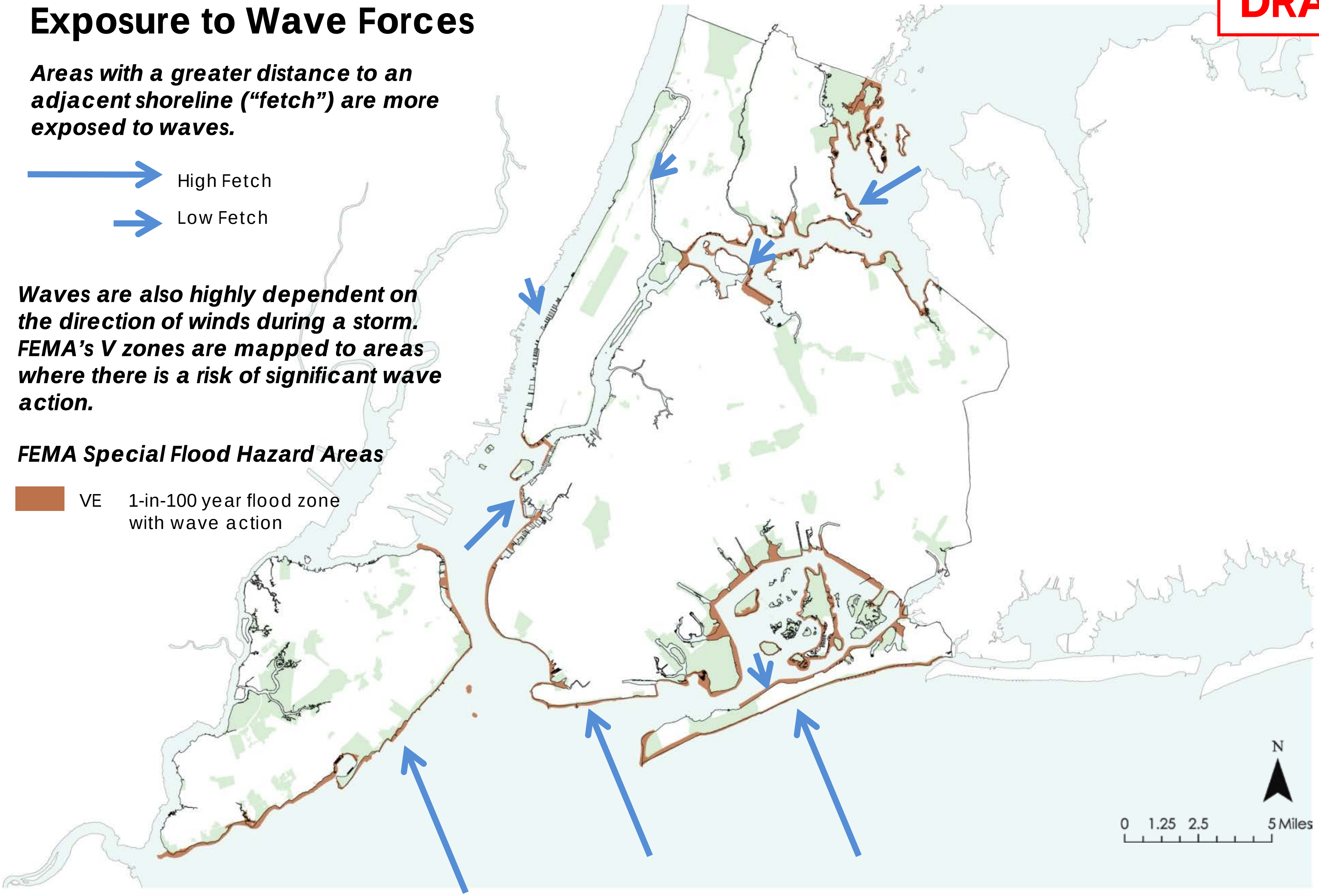
High Fetch

Low Fetch

Waves are also highly dependent on the direction of winds during a storm. FEMA's V zones are mapped to areas where there is a risk of significant wave action.

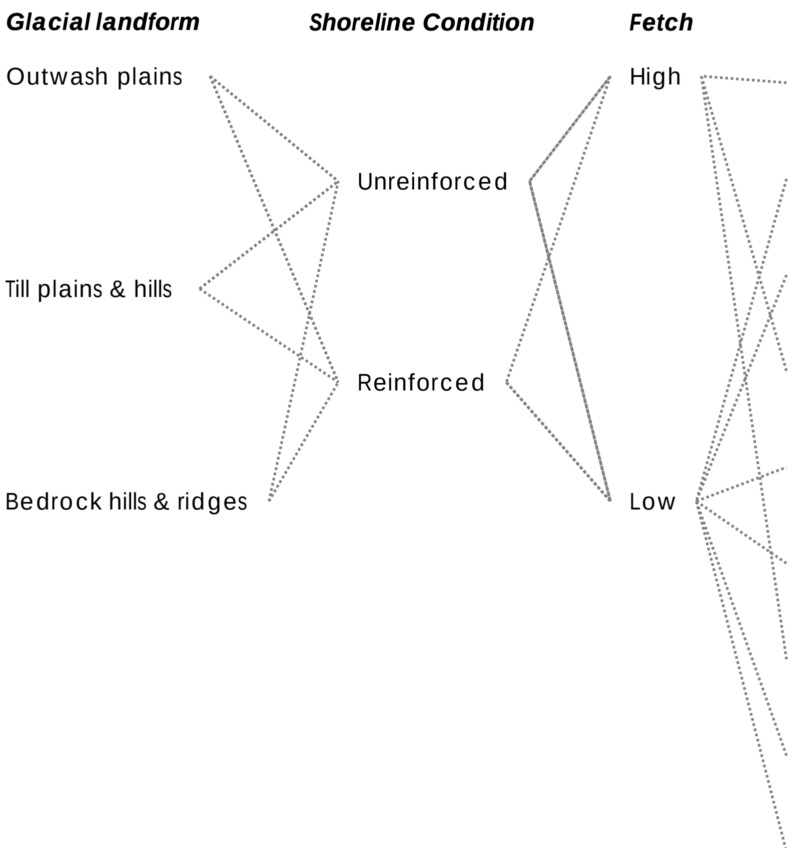
FEMA Special Flood Hazard Areas

VE 1-in-100 year flood zone with wave action



Geomorphology Categories

High Medium Low



	Exposure to: Surge	Erosion	Wave Forces
1. Exposed outwash plains / High Fetch / Low elevation / Unreinforced soft shorelines	High	High	High
2. Sheltered outwash plains / Low Fetch / Low elevation / Unreinforced soft shorelines	High	Medium	Low
3. Sheltered outwash plains / Low Fetch / Low elevation / Reinforced shorelines	High	Low	Low
4. Exposed outwash plains / High Fetch / Low elevation / Reinforced shorelines	High	Low	High
5. Sheltered till plains & hills / Low Fetch / Medium elevation / Reinforced shorelines	Medium	Low	Low
6. Sheltered till plains & hills / Low Fetch / Medium elevation / Unreinforced shorelines	Medium	Medium	Low
7. Exposed till plains & hills / High Fetch / Medium elevation / Unreinforced shorelines	Medium	Medium	High
8. Sheltered bedrock / Low Fetch / High elevation / Unreinforced shorelines	Low	Low	Low
9. Sheltered bedrock / Low Fetch / High elevation / Reinforced shorelines	Low	Low	Low

NOTE: Doesn't include combinations not present in NYC.

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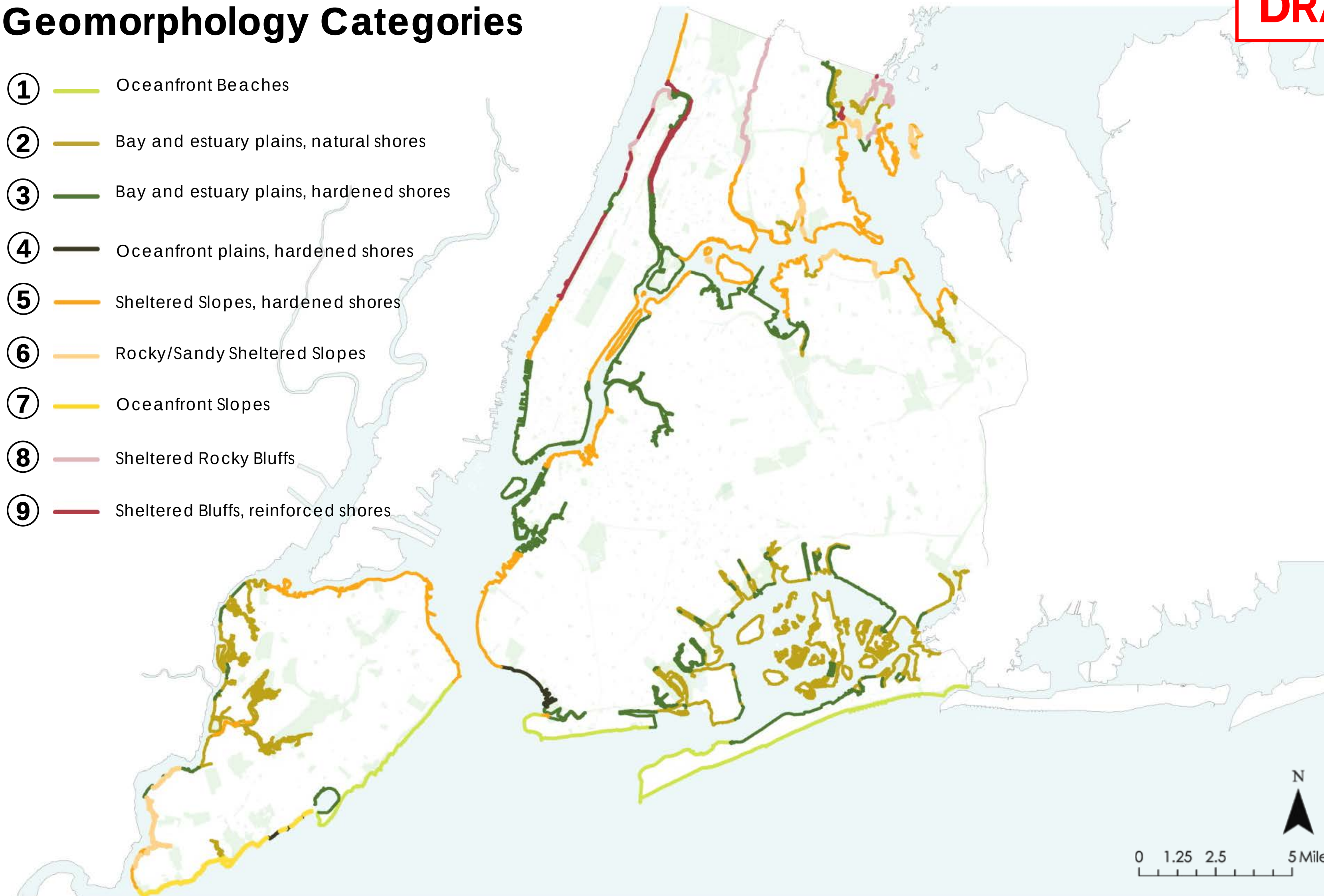
Geomorphology Categories



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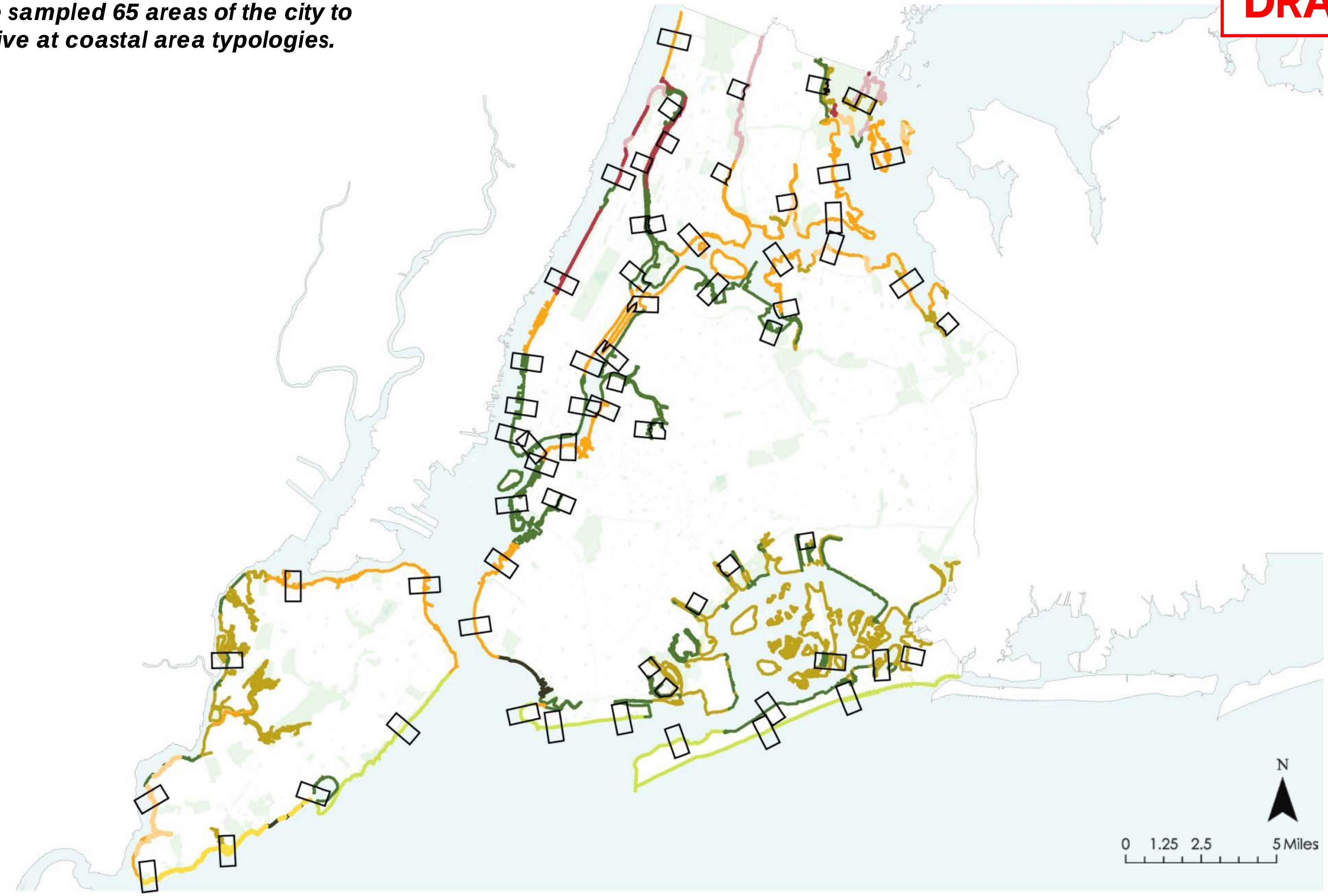
We sampled 65 areas of the city to arrive at coastal area typologies.



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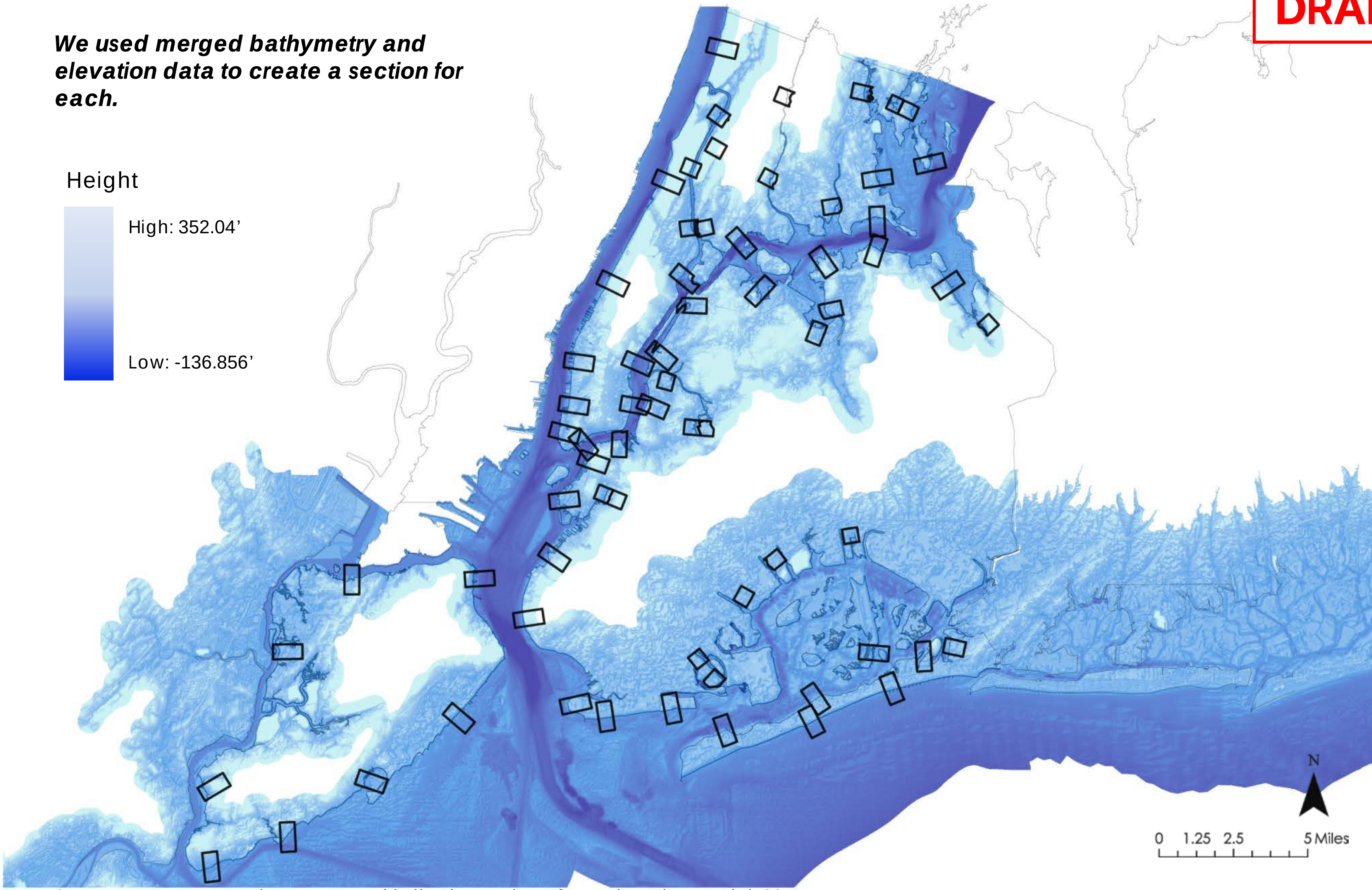
We used merged bathymetry and elevation data to create a section for each.



Sources: RAMPP, seamless topographic/bathymetric surface elevation model, 2011, NAVD

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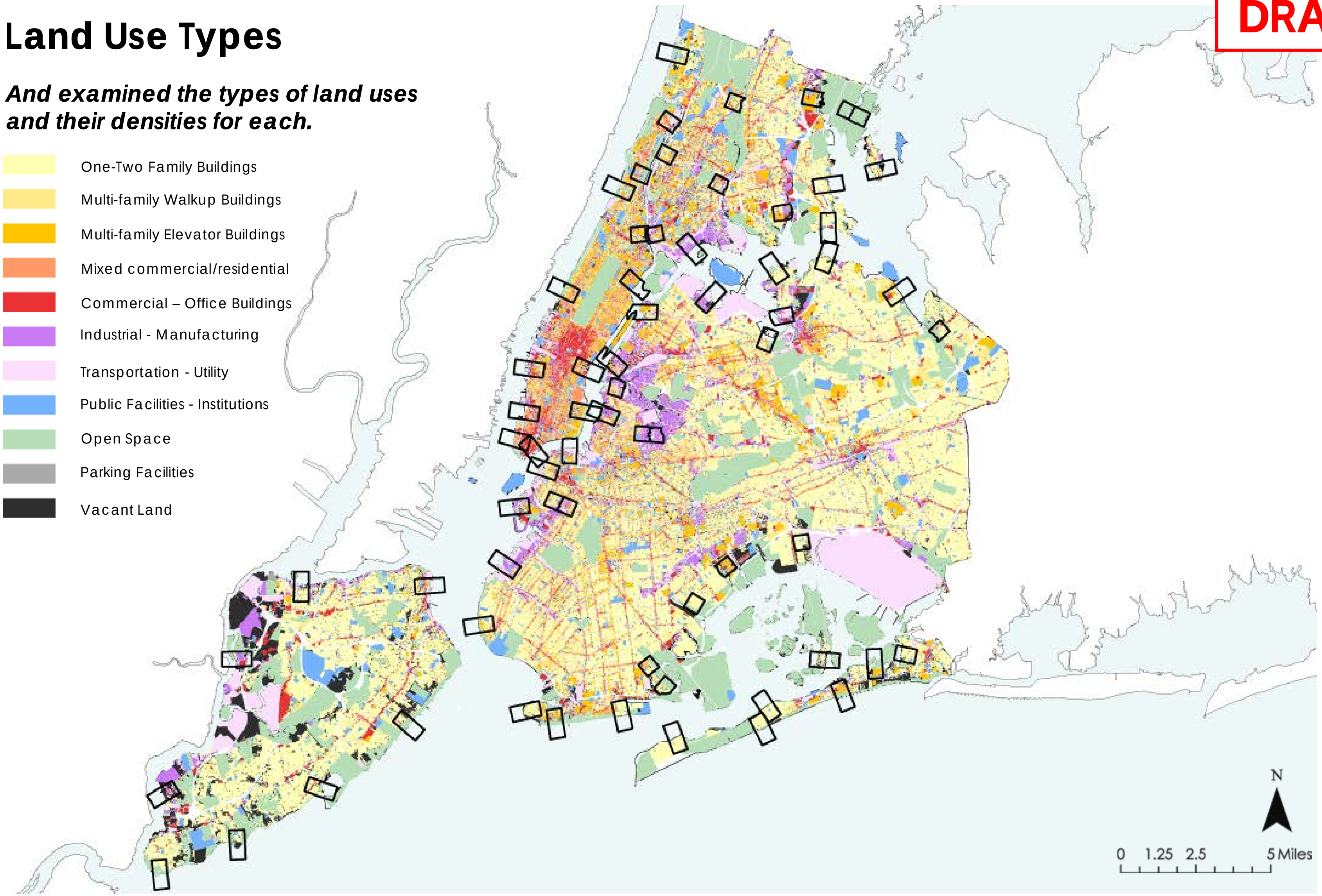
Land Use Types

And examined the types of land uses and their densities for each.



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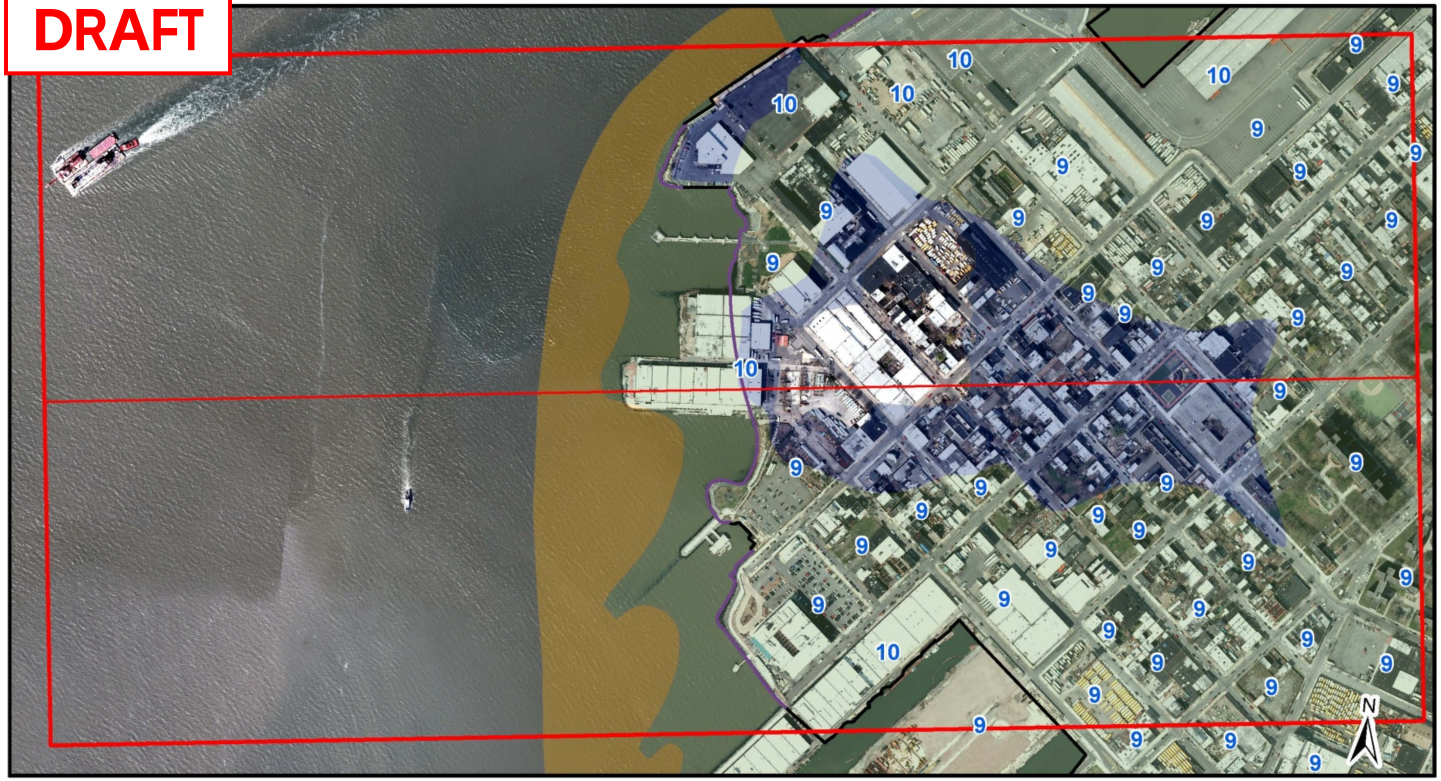
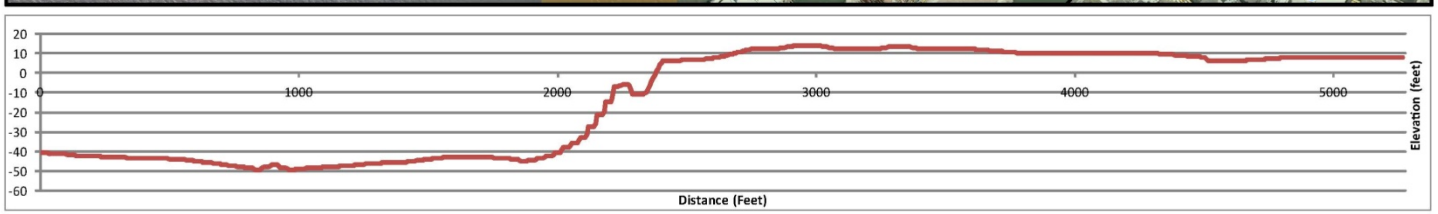




Shoreline Categories		Natural Shoreline	
Piers	Riprap	Marsh	Sandy Shoreline
Bulkhead		Rocks	Undefined

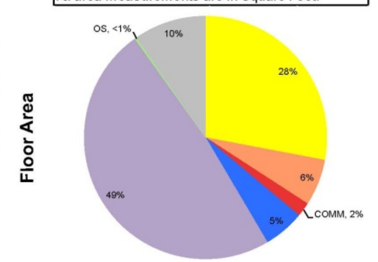
Flood Zone Categories: VE; A; AE; 500 Year

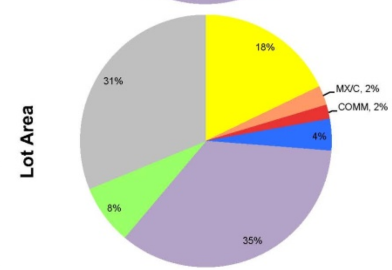
Base Flood Elevation (Feet): 8

Coastal Strategy Grid #21 Upper Bay

Land Use	*Floor Area*	Lot Area	Floor Area Ratio
Residential	*1,275,958*	1,027,835	1.24
Mixed-Use/ Commercial	*282,163*	143,575	1.97
Commercial & Office	*86,233*	104,057	0.83
Community Facility	*248,995*	233,135	1.07
Industrial	*2,218,499*	2,008,671	1.10
Open Space	*8,204*	438,438	0.02
Other	*440,989*	1,793,369	0.25
Total (Excluding Open Space and Other)	*4,111,849*	3,517,273	1.17

All area measurements are in Square Feet.





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Land Use Types

A	**All Open Space**	FAR 0
B	**Low / Medium Density Industrial**	Largest share of Lot Area & Floor Areas is Industrial or Open Space
C	**Industrial / Low Density Residential**	Residential FAR <1 Residential & Industrial >75% of Lot Area/Floor Area
D	**Industrial / Medium Density Residential**	Residential FAR >1 (Highest is 2.14) Residential > 25% Floor Area Industrial > 25% of Floor Area
E	**Low Density Residential**	Overall FAR <1 % Lot Area Residential >60%
F	**Medium Density Residential**	Overall FAR 1-2 Residential & Mixed Use >50% of Total Floor Area
G	**High Density Residential / Commercial**	Overall FAR 2 – 7 (Highest is 6.63) Residential > 25% of Floor Area Residential/Commercial 15-50% of Floor Area Commercial <50% of Floor Area
H	**Very High Density Commercial**	Overall FAR >7 (Highest is 13) Residential <25% of Floor Area Commercial >75% of Floor Area

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		A	B	C	D	E	F	G	H
		Open Space	**Low/Medium Density Industrial**	**Industrial/Low Density Residential**	**Industrial/ Medium Density Residential**	**Low Density Residential**	**Medium Density Residential**	**High Density Residential / Commercial**	**Very High Density Commercial**
1	**Oceanfront Beaches**	Orchard Beach (#527) *(also Breezy Point; Great Kills Park)*				Midland Beach (#459); Belle Harbor South (#433); Sea Gate (#49); Manhattan Beach (#56)	Coney Island West (#54); Rockaway Beach (#530)		
2	**Bay and estuary plains, natural shores**	Pelham Bay Park (#290) *(also Jamaica Bay, portions of Staten Island West Shore)*	Kreisherville (#491) *(Also Gowanus Bay, Flushing Creek)*			Douglaston (#351); Broad Channel (#393); Edgemere (#405); Far Rockaway (#400); Canarsie (#98)	Marine Park (#71); Starrett City (#531); Coop City (#273)		
3	**Bay and estuary plains, hardened shores**		Bloomfield (#506); Bowery Bay (#318; Newtown Creek East (#529)		Gowanus East (#528); Gowanus West (#24); Red Hook (#21); Newtown Creek West (#2); Greenpoint North (#7); Long Island City(#306); Mott Haven (#205); Greenpoint West (#10); Sherman Creek (#144);	Gerritsen Beach (#68); Great Kills (#471); Howard Beach North (#361); Belle Harbor North (#412)	East Harlem South (#156); East Village (#166); East Harlem North (#152); North Corona (#325)	Chelsea (#120), Soho/Tribeca (#117)	Battery Park City (#115); Lower Manhattan (#171)
4	**Oceanfront plains, hardened shores**				*Gravesend Bay*		*Bath Beach*		
5	**Sheltered Slopes, hardened shores**		Flushing Bay (#331); Port Morris (#290); Sunset Park South (#30)	Mariner's Harbor (#516)	DUMBO (#15); Edgewater (#526)	Throggs Neck (#258); Whitestone (#340); Country Club (#266); City Island (#297); College Point (#335)	Bay Ridge (#35); Astoria (#310)	Brooklyn Heights (#18); Kips Bay (#163)	
6	**Rocky/Sandy Sheltered Slopes**			Westchester Creek (#248)	Lower Bronx River (#218)	Riverdale (#191)			
7	**Oceanfront slopes**	*Butler Manor Woods*				Prince's Bay (#478); Tottenville (#484)			
8	**Sheltered, rocky bluffs**	*Inwood Hill Park*					Norwood (#224)		
9	**Sheltered bluffs, reinforced shores**						West Harlem (#134); Morris Heights (#199)	Upper West Side (#126)	

1E Low-Density Residential / Oceanfront Beaches

Belle Harbor South #433

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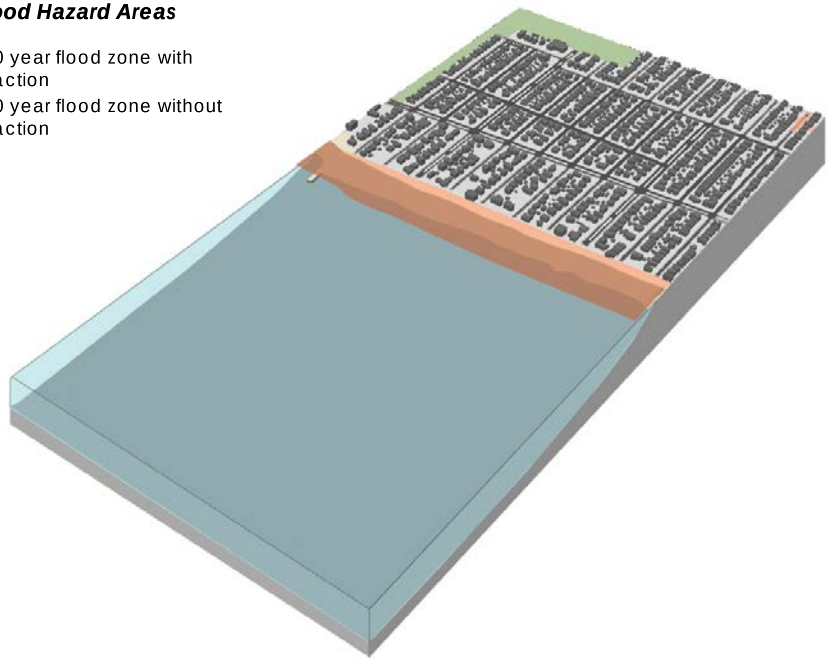
FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action



Land Use / Density Factors

Building Types	1-2 story detached homes 1-2 story semi-detached homes Community Facilities
Open Space	Beach Neighborhood Park
Infrastructure	Roads
Density	XX du per acre 18,241 ft^2 built floor area/acre (0.42 FAR)[1]

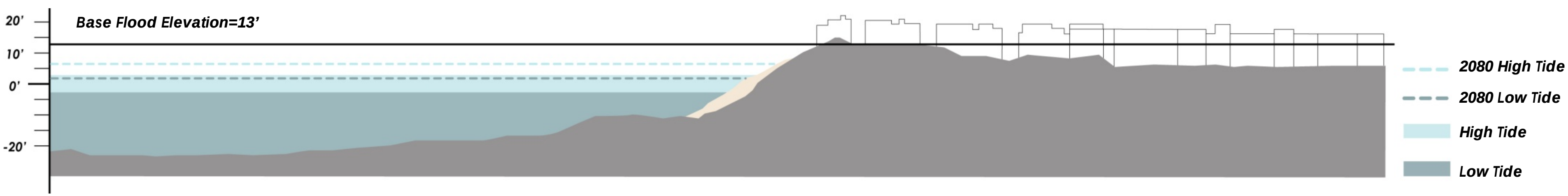
Hazard Exposure

Gradual	Regular inundation	MED [2]
	Increased erosion	MED
Sudden	Storm Surge	HIGH
	Wave Forces	HIGH
	Erosion	HIGH

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

[2] The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise.

All elevations in NAVD.



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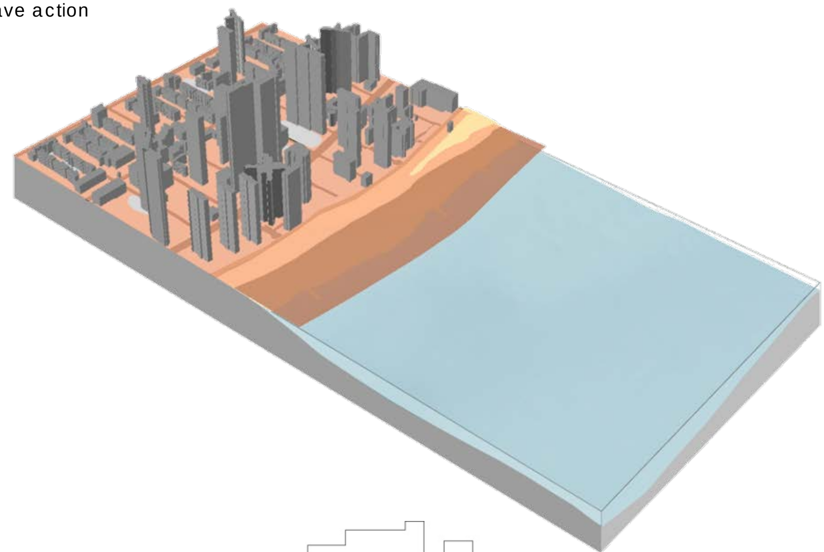
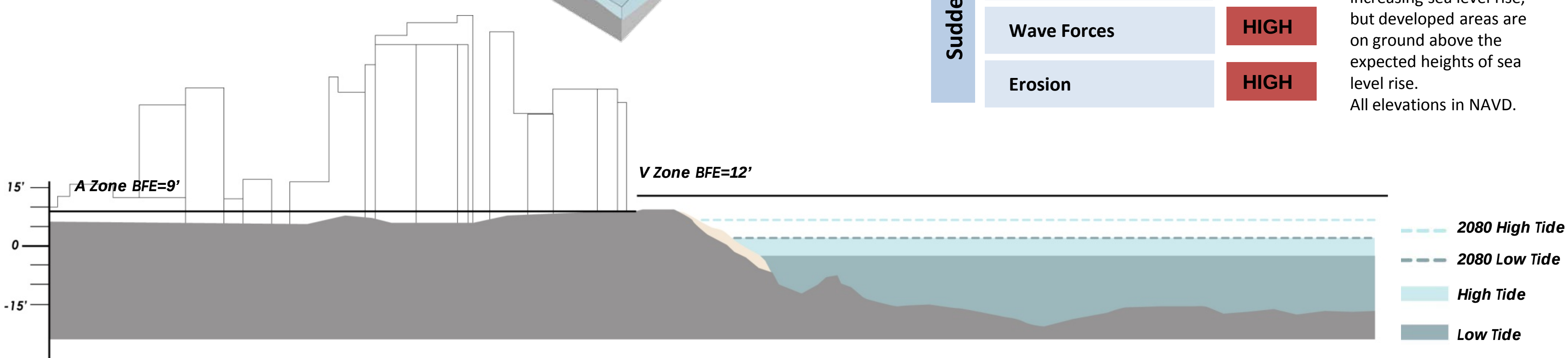
1F *Medium Density Residential / Oceanfront Beaches*

Coney Island West#54

FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action





Land Use / Density Factors	
Building Types	Residential/commercial buildings 10 story residential buildings Community facilities
Open Space	Parking, Neighborhood Parks, Athletic Fields
Infrastructure	Roads, Boardwalk
Density	XX du per acre 67,984 ft^2 built floor area/acre (1.56 FAR)[1]

Hazard Exposure

Gradual	Regular inundation	MED [2]
	Increased erosion	MED
Sudden	Storm Surge	HIGH
	Wave Forces	HIGH
	Erosion	HIGH

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

[2] The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise.

All elevations in NAVD.

1F Low Density Residential / Bay and estuary plains, natural shores

Edgemere #405

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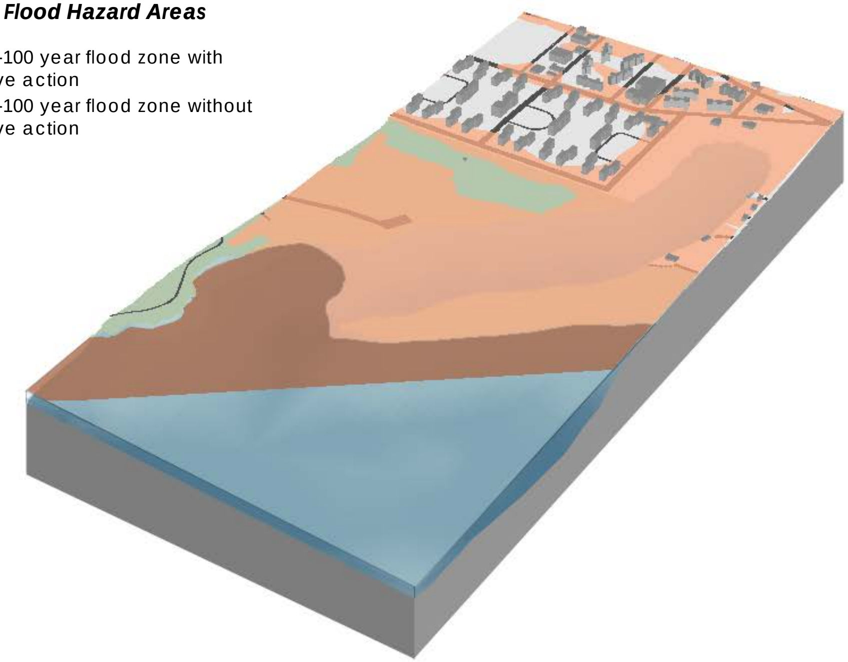
FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action



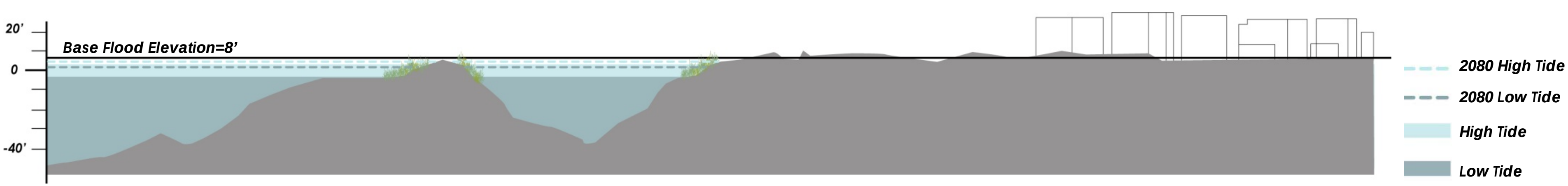
Land Use / Density Factors

Building Types	1-2 story detached homes 1-2 story semi-detached homes Community Facilities
Open Space	Beach Neighborhood Park
Infrastructure	Roads
Density	XX du per acre XX ft^2 built floor area/acre (XX FAR)[1]

Hazard Exposure

Gradual	Regular inundation	MED
	Increased erosion	HIGH
Sudden	Storm Surge	HIGH
	Wave Forces	LOW
	Erosion	MED

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.



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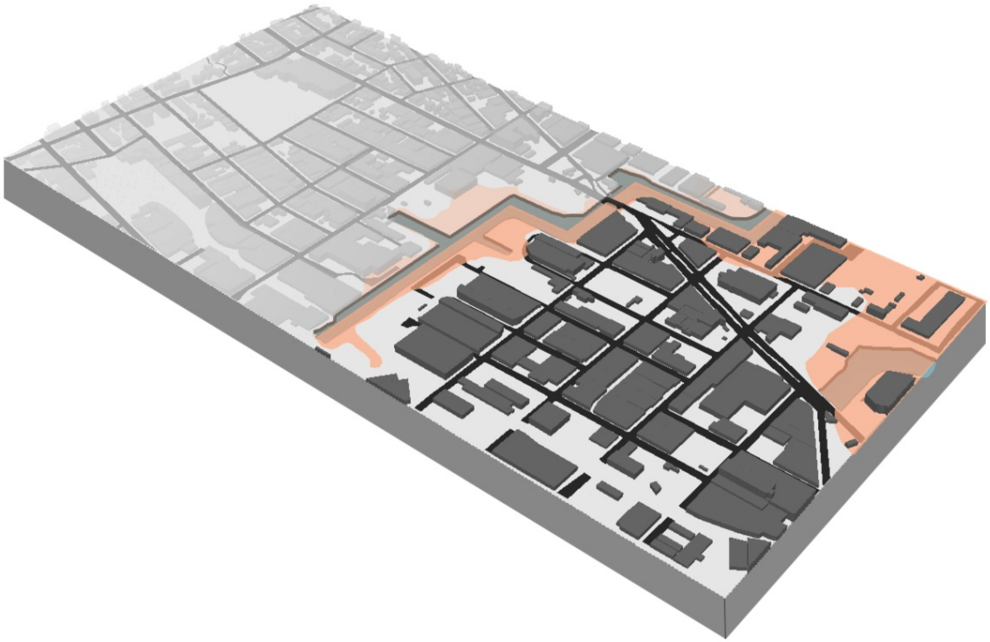
3B Low/Medium Density Industrial/ Bay and estuary plains, hardened shores

Newtown Creek East #529

FEMA Special Flood Hazard Areas

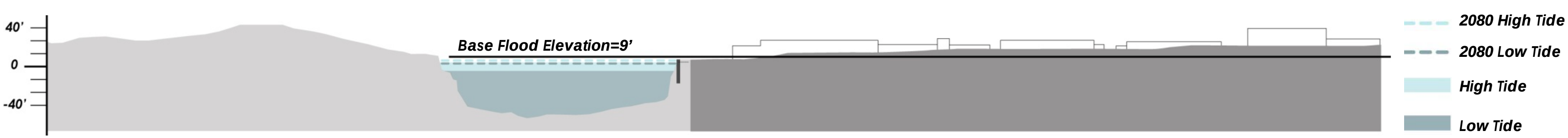
AE — 1-in-100 year flood zone without wave action



Land Use / Density Factors	
Building Types	1-2 story industrial Community facilities
Open Space	Parking, Vacant Land
Infrastructure	Roads, Elevated Rail Tracks
Density	XX du per acre XX sq ft built floor area per acre

Hazard Exposure		
Gradual	**Regular inundation**	**MED**
	Increased erosion	**MED**
Sudden	**Storm Surge**	**HIGH**
	Wave Forces	**LOW**
	Erosion	**LOW**

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.



3D Industrial/Medium Density Residential / Bay and estuary plains, hardened shores

Red Hook #21

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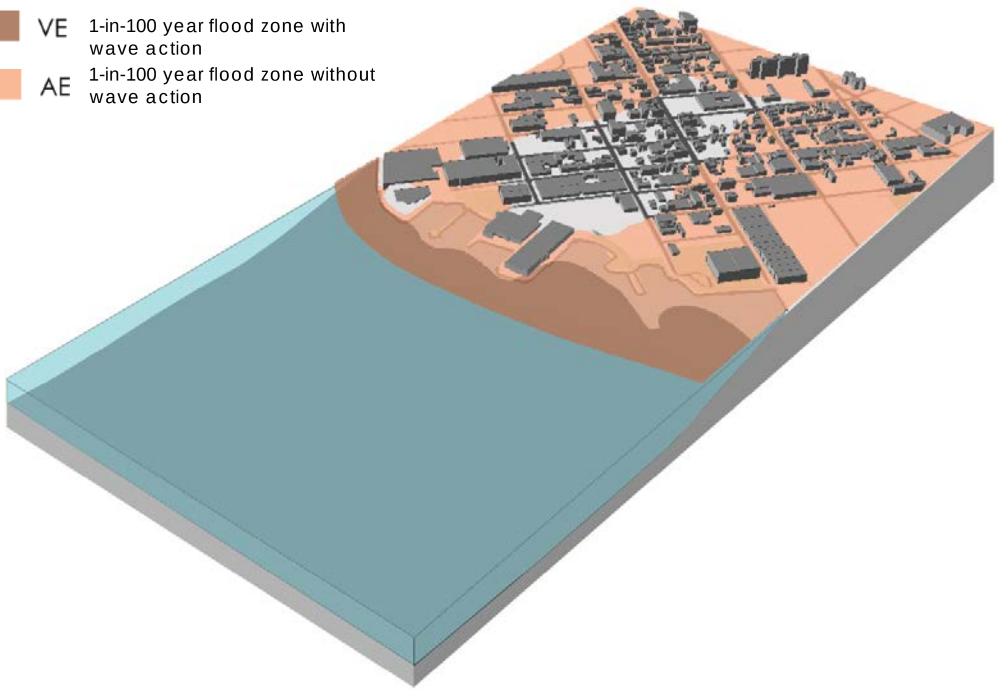
FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action

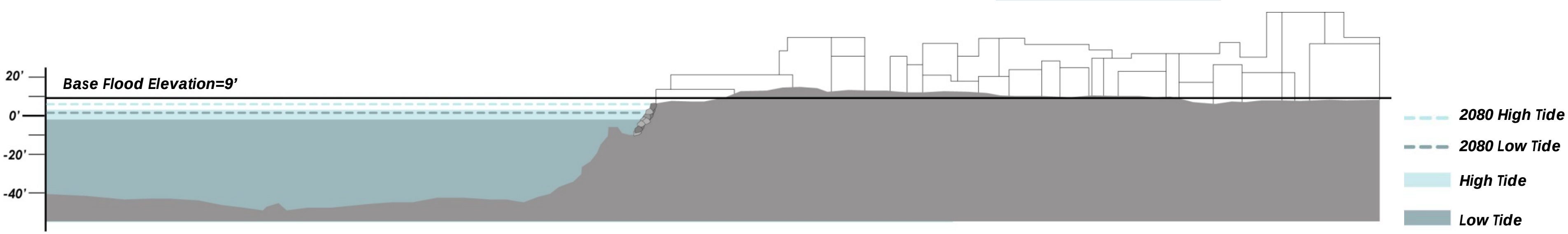


Land Use / Density Factors	
Building Types	1-2 story industrial 3-6 story residential/commercial 10-story apartment buildings Schools
Open Space	Parking, Neighborhood parks
Infrastructure	Piers, Roads
Density	XX du per acre 50,763 ft² built floor area/acre (1.17 FAR)[1]

Hazard Exposure

Gradual	Regular inundation	HIGH
Gradual	Increased erosion	MED
Sudden	Storm Surge	HIGH
Sudden	Wave Forces	MED
Sudden	Erosion	LOW

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.



3F *Medium Density Residential / Bay and estuary plains, hardened shores*

East Harlem South #156

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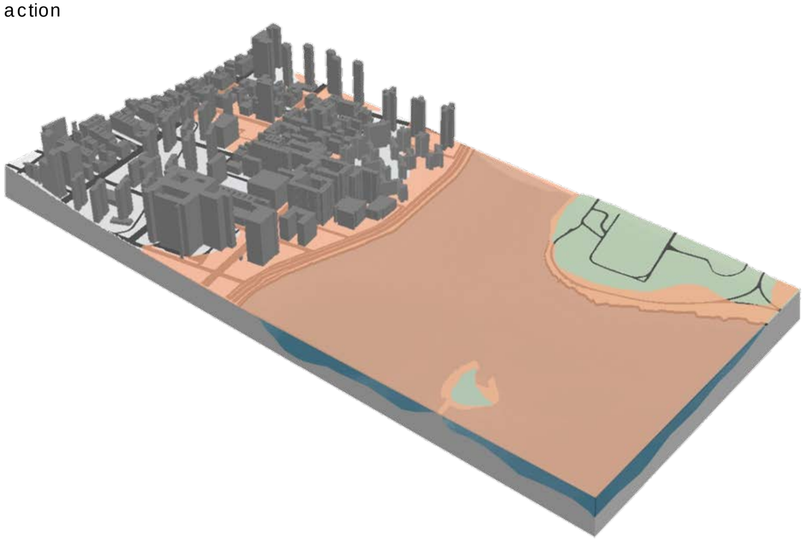
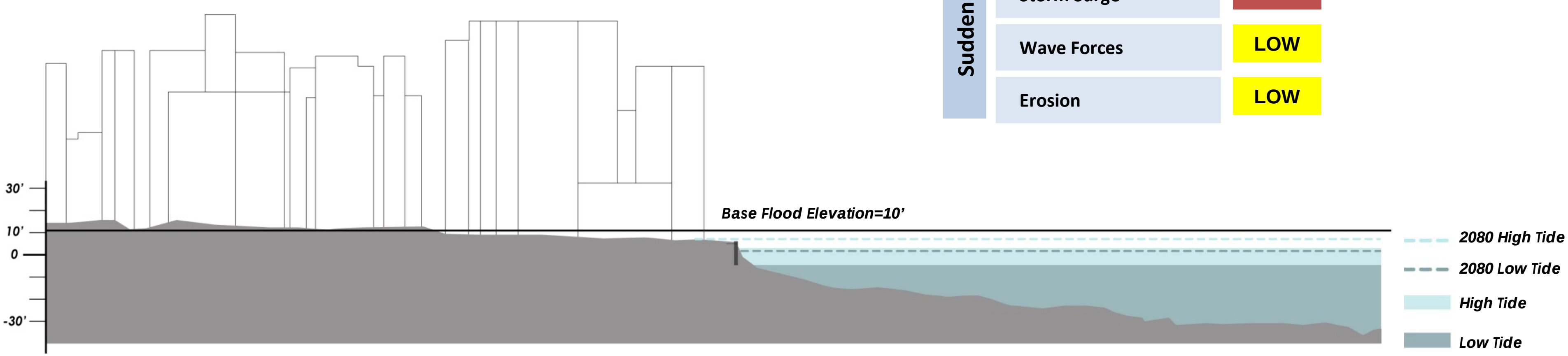
FEMA Special Flood Hazard Areas

AE — 1-in-100 year flood zone without wave action





Land Use / Density Factors

Building Types	Residential/commercial buildings 10 story residential buildings Community facilities
Open Space	Parking, Neighborhood Parks, Athletic Fields
Infrastructure	Roads, Rail Tracks
Density	XX du per acre 116,932 ft^2 built floor area/acre (2.69 FAR)[1]

Hazard Exposure

Gradual	Regular inundation	HIGH
	Increased erosion	MED
Sudden	Storm Surge	HIGH
	Wave Forces	LOW
	Erosion	LOW

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

3H Very High Density Commercial / Bay and estuary plains, hardened shores

Lower Manhattan #171

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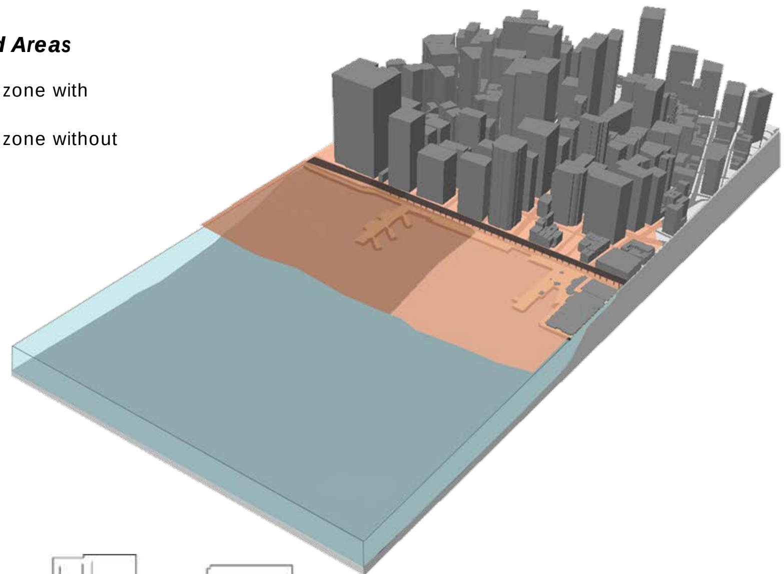
FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action



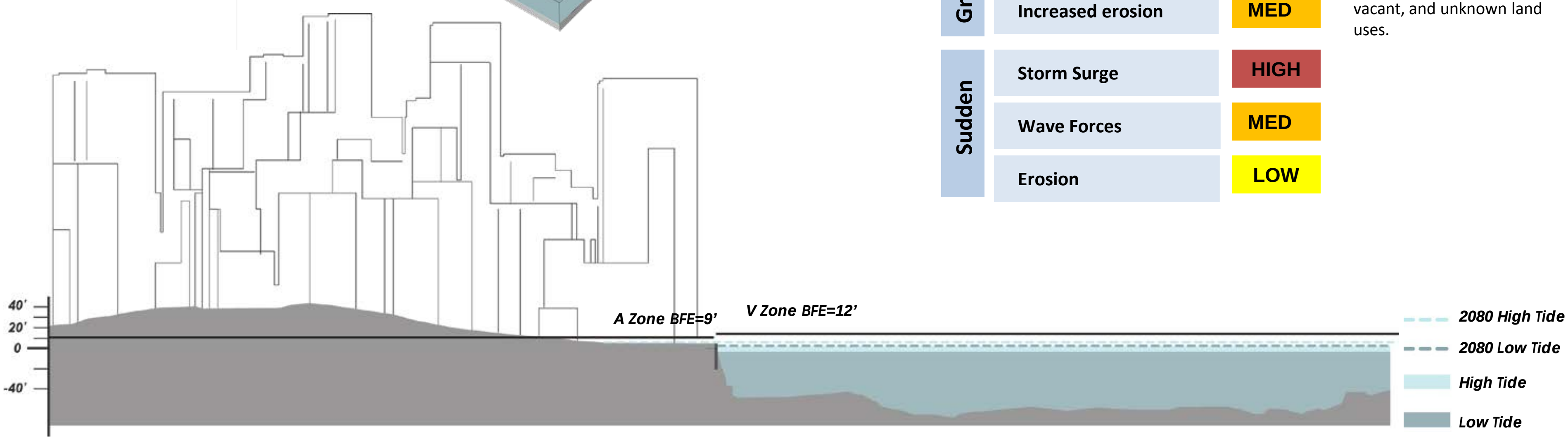
Land Use / Density Factors

Building Types	Commercial/office towers Residential/commercial towers 4-6 story commercial
Open Space	Public piers and esplanade Sidewalk plazas
Infrastructure	Elevated highway, Subways, Piers
Density	XX du per acre 501,425 ft^2 built floor area/acre (11.48 FAR)[1]

Hazard Exposure

Gradual	Regular inundation	HIGH
	Increased erosion	MED
Sudden	Storm Surge	HIGH
	Wave Forces	MED
	Erosion	LOW

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.



5B *Low/Medium Density Industrial/ Sheltered slopes, hardened shores*

Sunset Park South #30

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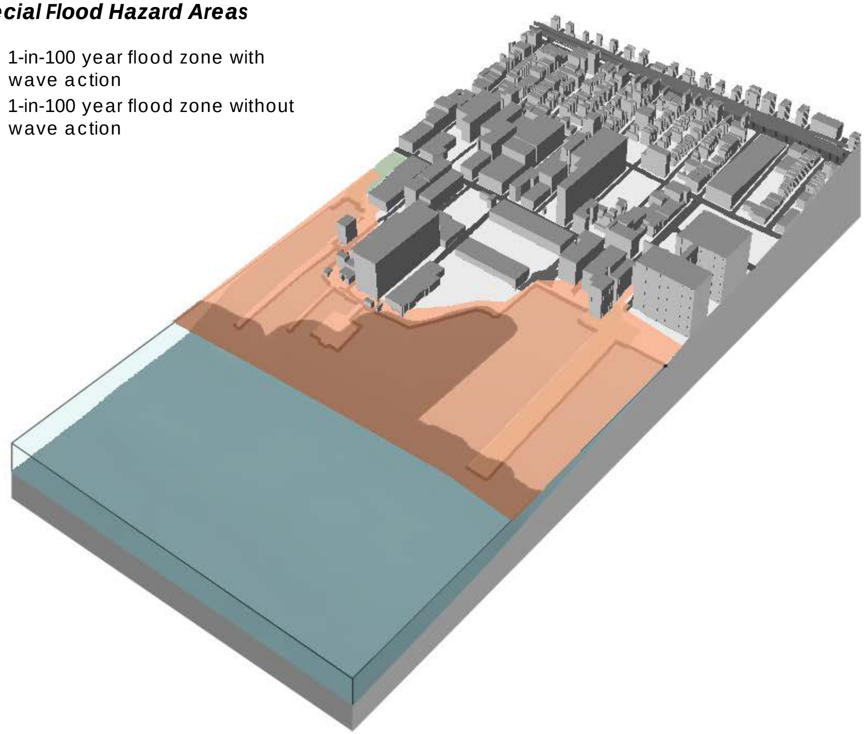
FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action



Land Use / Density Factors	
Building Types	1-2 story industrial 3-6 story residential/commercial 10-story apartment buildings Schools
Open Space	Parking, Neighborhood parks
Infrastructure	Piers, Elevated highway, Roads, Rail tracks
Density	XX du per acre 54,262 ft^2 built floor area/acre (1.24 FAR)[1]

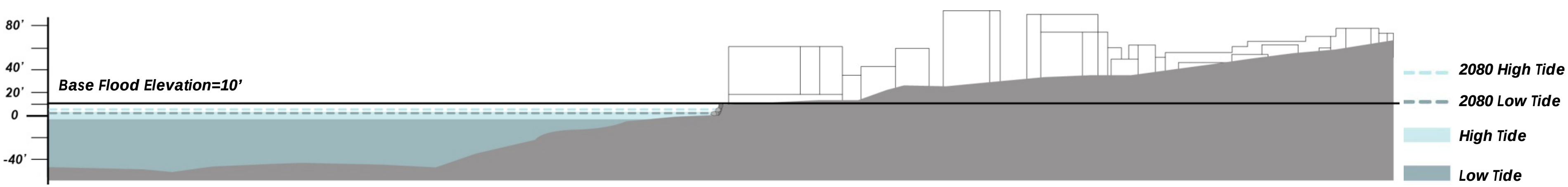
Hazard Exposure

Gradual	**Regular inundation**	**LOW**
Gradual	**Increased erosion**	**LOW**
Sudden	**Storm Surge**	**MED**
Sudden	**Wave Forces**	**LOW**
Sudden	**Erosion**	**LOW**

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.

[2] The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise.

All elevations in NAVD.



5E Low Density Residential/ Sheltered slopes, hardened shores

Country Club #266

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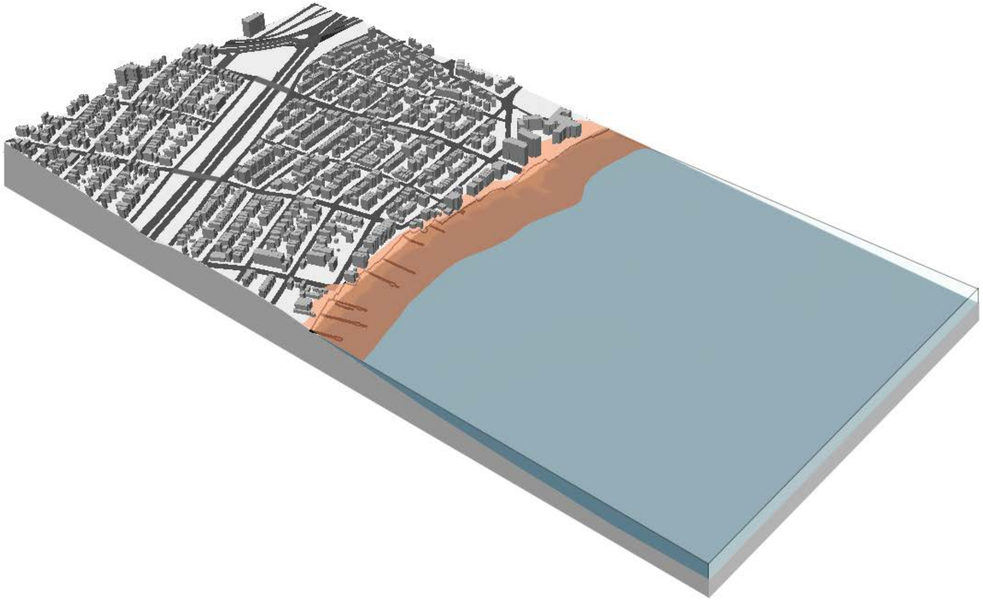
FEMA Special Flood Hazard Areas

- VE — 1-in-100 year flood zone with wave action
- AE — 1-in-100 year flood zone without wave action

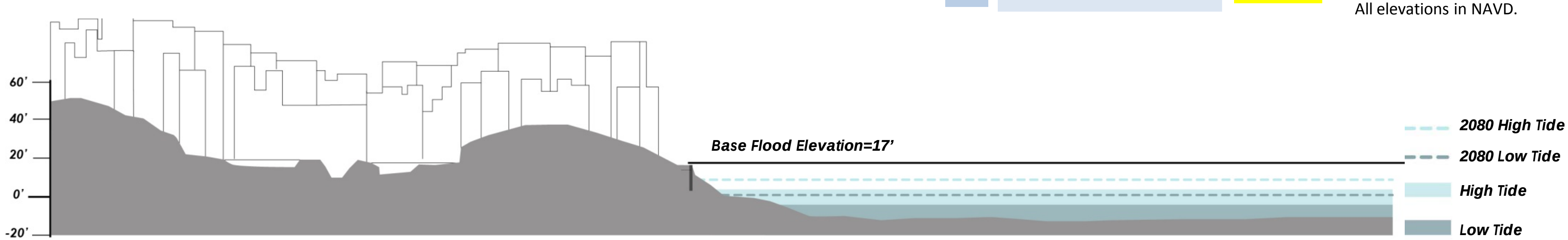


Land Use / Density Factors	
Building Types	1-2 story detached homes 1-2 story semi-detached homes 3-4 story residential/commercial Community Facilities
Open Space	Parking, Vacant Land, Beach
Infrastructure	Roads, Highways, Piers
Density	XX du per acre 29,858 ft^2 built floor area/acre (0.69 FAR)[1]

Hazard Exposure

Gradual	Regular inundation	LOW
	Increased erosion	LOW
Sudden	Storm Surge	MED
	Wave Forces	LOW
	Erosion	LOW

[1] FAR based on total floor area over total lot area, excluding open space, vacant, and unknown land uses.
[2] The beach may be regularly inundated due to increasing sea level rise, but developed areas are on ground above the expected heights of sea level rise.
All elevations in NAVD.



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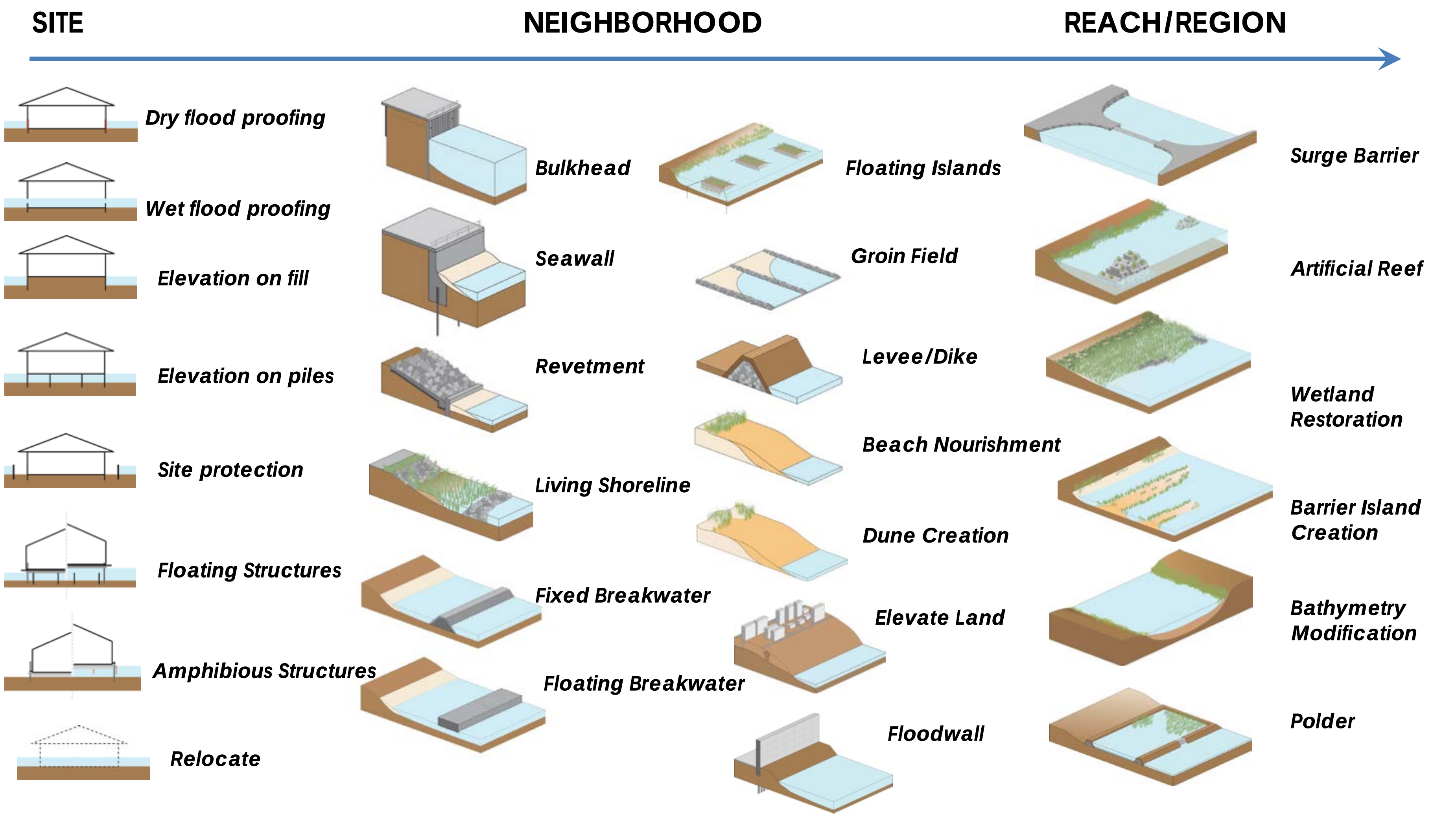
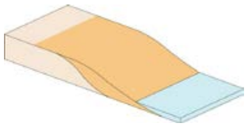
There are many potential adaptive strategies at various scales.



For each strategy, the catalog will provide the following key pieces of information.



Beach nourishment

Risk Reduction:
- Reduces risk from frequent inundation and low and high surge events.
- Can reduce risk from strong wave action, though must be replenished after.
- Protects inland area from erosion though the beach itself is susceptible to erosion.

Best-suited for:
- Flat to moderately sloped areas.

Doesn't work for:
- Shorelines with high erosion rates.

Cost:
- Estimated $7-$18 per cy or $50-600 per linear foot

Issues/Barriers:
- Low initial costs, but requires continual monitoring and maintenance every 2-3 years (typical).
- Can be significantly eroded by large storm events.
- Need a source for sand.
- Temporary disturbance of near-shore environment.

Benefits:
- Supports recreational activities.
- Less environmental damage than other coastal structures.
- Easily modified or changed.

Questions for further inquiry:
- What is the highest level of surge protection that is feasible for beach nourishment?
- What are the environmental consequences of beach re-nourishment?
- What are innovative approaches to beach nourishment?

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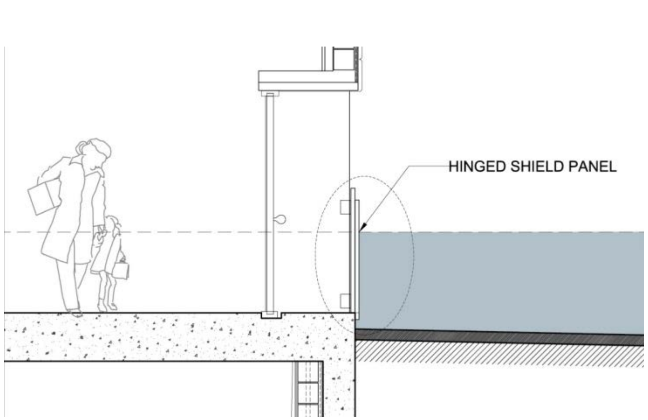

Florida

Georgia

Install shield panels to protect doors and windows

Risk Reduction:
- Limits or prevents water infiltration through or around doors and windows.
- Provides protection up to a certain height or force.

Best-suited for:
- Buildings with a flood elevation lower than the height of the panel

Doesn't work for:
- High flood elevations

Cost:
- To be determined.

Issues/Barriers:
- Aesthetically challenging to incorporate into a building.
- May be difficult to implement with certain envelope systems.
- Removable panels require adjacent storage space.

Benefits:
- Provide some protection against flood-borne missiles.
- Can quickly be positioned in anticipation of flooding.

Questions for further inquiry:
- ***To what extent do shield panels provide protection against wave action?***
- ***Can shield panels compromise the building envelope by transferring flood loads across the façade?***
- ***How much protection does a shield panel provide if the façade has limited waterproofing potential?***

Strategies can reduce risks from multiple hazards.

● *Yes* ○ *No* ◐ *Potentially*

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	Regular inundation		Erosion	Storm Surge		Wave Forces
	HIGH	LOW		HIGH	LOW	
Bulkhead	●	●	●	◐	●	◐
Seawall	●	●	●	●	●	●
Beach nourishment	●	●	○	●	●	●
Levees/ Dikes	●	●	●	●	●	●
Revetments	○	○	●	○	○	●
Living Shoreline	●	●	●	○	◐	◐
Breakwaters	○	○	●	○	○	●
Artificial reefs	○	○	●	○	○	●
Vegetation floating islands	○	○	●	○	○	●
Surge Barrier	◐	◐	○	●	●	●

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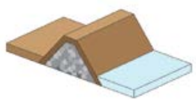
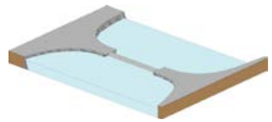
These strategies can be combined at various scales.

1 *Take protective measures beyond the scale of the neighborhood*

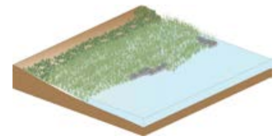
Includes these options:



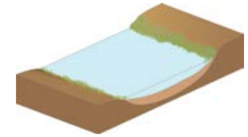
Levee/Dike



Surge Barrier



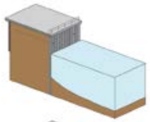
Wetland restoration (?)



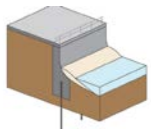
Bathymetry modification (?)

2 *Prevent flooding of neighborhood through protective shoreline measures.*

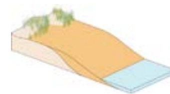
Includes these options:



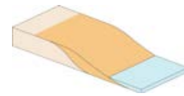
Bulkhead



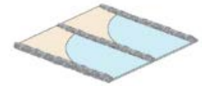
Seawall



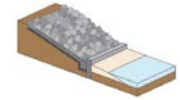
Dunes



Beach nourishment



Groin field

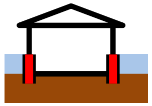


Revetment

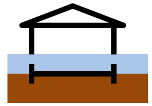
Levee/Dike

3 *Protect individual structures and assets through site-specific measures.*

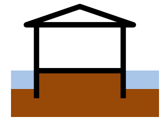
Includes these options:



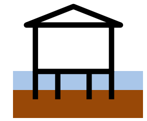
Dry flood proofing



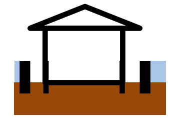
Wet flood proofing



Elevation on fill



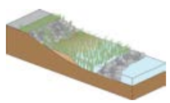
Elevation on piles



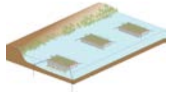
Site protection

4 *Reduce impact of flooding through wave attenuation and protect structures through site-specific measures.*

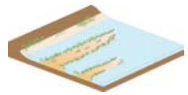
Includes these options:



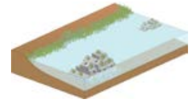
Living shoreline



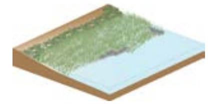
Floating islands



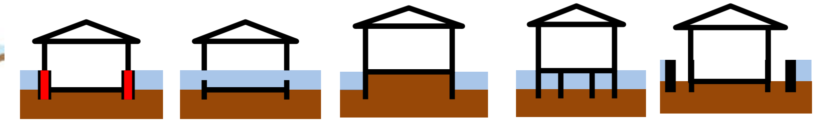
Barrier islands



Reefs



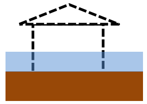
Wetlands



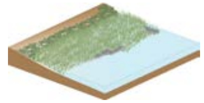
Site-specific measures

5 *Strategically retreat from at risk areas.*

Includes these options:



Relocate



Wetlands

Each comes with its own share of costs and benefits.

● *High* ◐ *Medium* ○ *Low*

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Strategies	Financial Cost		Potential External Costs (Environment, Public Space, etc.)	Potential External Benefits (Environment, Public Space, etc.)
	Initial	Annual		
Bulkhead	●	○	◐	◐
Seawall	●	○	●	◐
Beach nourishment	○	●	◐	●
Levees/ Dikes	●	◐	●	◐
Revetments	○	○	○	○
Living Shoreline	●	◐	◐	●
Breakwaters	○	◐	○	○
Artificial reefs	○	◐	○	●
Vegetation floating islands	○	◐	○	●
Surge Barrier	●	◐	●	◐

And its own hurdles in implementation.

High Medium Low

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Strategies	Regulatory	Political	Technological	Time
Bulkhead	High	Low	Medium	Medium
Seawall	High	Medium	High	Medium
Beach nourishment	Medium	High	Medium	High
Levees/ Dikes	High	Medium	High	Medium
Revetments	Low	Low	Low	Low
Living Shoreline	High	Medium	High	High
Breakwaters	Low	Medium	Low	Low
Artificial reefs	Low	Medium	High	High
Vegetation floating islands	Low	Medium	High	High
Surge Barrier	High	High	Medium	High

At a regional scale, strategies are most suitable for certain types of areas.

Suitable Unsuitable Potentially Suitable

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Strategies	Belle Harbor South #433	Lower Manhattan #171	Red Hook #21	Tottenville #484	Midland Beach #459	Sunset Park South #30	East Harlem South #156	Coney Island West #54	Newtown Creek East #529
Bulkhead/ Seawall									
Beach nourishment									
Levees/ Dikes									
Revetments									
Hybrid Bulkhead									
Living Shoreline									
Breakwaters									
Artificial reefs									
Vegetation floating islands									

To be determined

Suitable - Addresses hazards presents in a cost-effective way and technically feasible given area characteristics.

Unsuitable – Would not address relevant hazards, is not likely to be cost-effective, and/or is not technically feasible.

Potentially Suitable – May be suitable but requires further inquiry or additional strategies in concert.

APPENDIX

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1 *Reach strategies*

Maeslant Barrier, Rotterdam, the Netherlands

On the Water Palisade Bay, Architecture Research Office

Surge Barriers

- Fixed surge barriers (in combination with levees)
- Mobile surge barriers (in combination with levees)

Landforms

- Constructed wetlands
- Bathymetry modification
- Constructed barrier islands
- Polders

Other

- Inland retreat of wetlands
- Redundancy, multiple lines of defense
- Enhanced emergency evacuation

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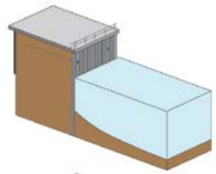
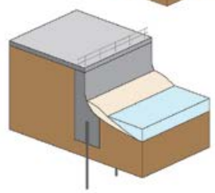
2 *Neighborhood strategies*

Bulkhead

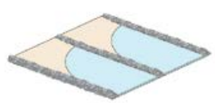


Seawall

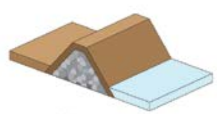


Revetment

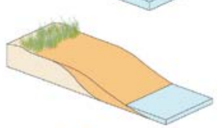
Groin Field



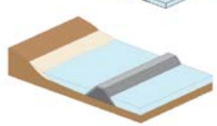
Levee/Dike



Beach Nourishment



Fixed Breakwater



Floating Breakwater

Shoreline armoring strategies

- Seawalls
- Bulkheads
- Revetments
- Groins
- Beach nourishment
- Levees and dikes

Wave attenuation

- Fixed breakwaters
- Floating breakwaters

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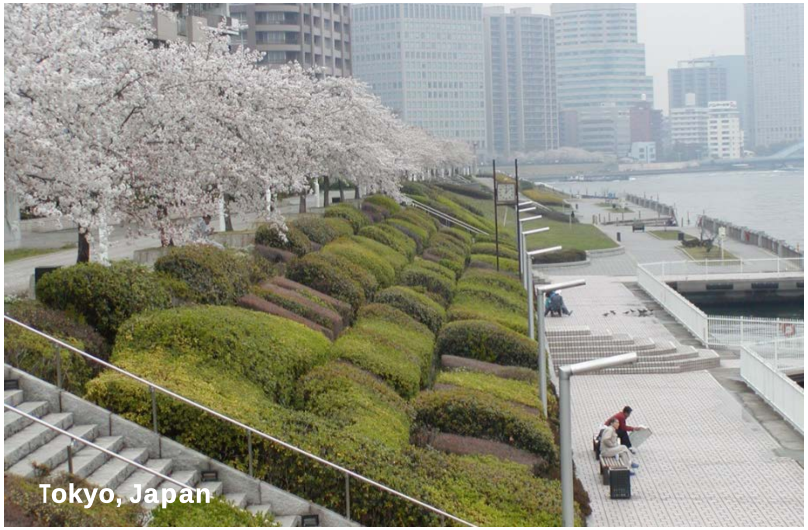
2 *Neighborhood strategies*

Hafen City, Hamburg, Germany



Tokyo, Japan

Elevate

- Elevating multiple buildings
- Elevating streets
- Elevated pedestrian access areas and public spaces

Flood accommodation

- Floodable parks and open spaces
- Water retention

Enhanced shoreline protection

- Multi-use levees /Superlevees
- Retrofitting elevated shoreline structures as flood barriers

Shoreline protection / Wave attenuation + Habitat

- Living shorelines
- Artificial reefs
- Floating islands/breakwaters

Strategic Retreat

- Relocation
- Acquisition programs
- Rolling easements / Setbacks
- No-rebuild

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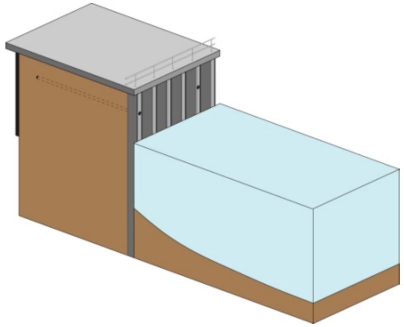

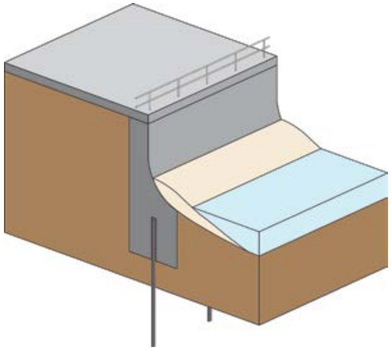

Bulkheads / Seawalls

- Bulkheads are vertical retaining walls intended to hold soil in place and allow for a stable shoreline.
- Seawalls are structurally similar, but designed to resist heavy wave forces and prevent flooding of upland areas.
- Different forms include cantilevered, anchored, gravity, relieving platforms, and cofferdams. Common materials are sheet pile, concrete, or timber.

Seawall, Galveston, TX

Bulkhead, East River, New York

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Bulkheads / Seawalls

Risk Reduction:
- Bulkheads protect site from erosion. They are not designed to protect from major flood events but do manage daily and monthly fluctuations in tide levels.
- Seawalls protect from erosion and provide site and upland protection from coastal surge.

Best-suited for:
- Areas where space in high demand.

Doesn't work for:
- Cantilevered or anchored bulkheads require hard, dense soils suitable for pile-driving.

Cost:
- Estimated $5,000 to $15,000 per linear foot for a new sheet-pile bulkhead.

Issues/Barriers:
- Significant environmental disturbance for undisturbed sites.
- Can exacerbate erosion of adjacent soft shorelines.
- Require high level of engineering.
- Extensive permitting process.
- Incremental raising of bulkheads or seawalls to account for sea level rise presents many regulatory challenges and site design constraints.

Benefits:
- Less space intensive.

Questions:
- ***How can the repair and maintenance of existing bulkheads take into account rising sea levels?***

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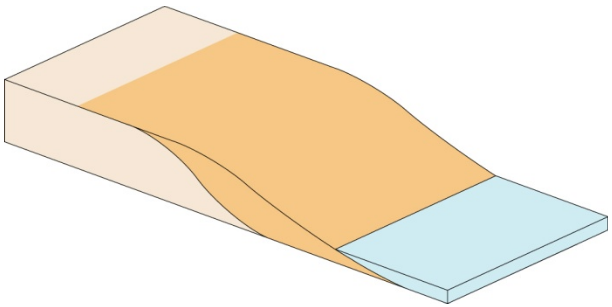

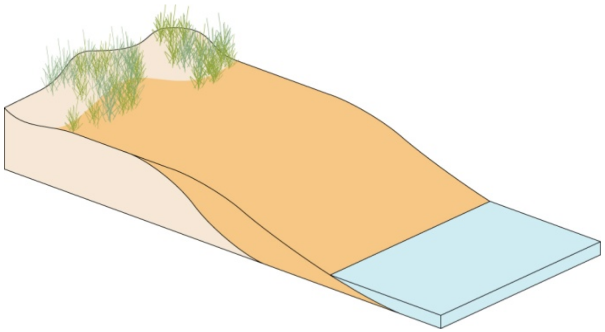

Beach nourishment

- Addition of sand to the shoreline to protect upland property and infrastructure.
- Different forms of beach nourishment can include creation of a berm, dune and grasses, feeder beach, nearshore berm or dune stabilization.

Rockaway Beach

Sandbridge, Virginia Beach

Sand Motor, The Netherlands

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Beach nourishment

Risk Reduction:

- Reduces risk from frequent inundation and low and high surge events.
- Can reduce risk from strong wave action, though must be replenished after.
- Protects inland area from erosion though the beach itself is susceptible to erosion.

Best-suited for:

- Flat to moderately sloped areas.

Doesn't work for:

- Shorelines with high erosion rates.

Cost:

- Estimated $7-$18 per cy or $50-600 per linear foot

Issues/Barriers:

- Low initial costs, but requires continual monitoring and maintenance every 2-3 years (typical).
- Can be significantly eroded by large storm events.
- Need a source for sand.
- Temporary disturbance of near-shore environment.

Benefits:

- Supports recreational activities.
- Less environmental damage than other coastal structures.
- Easily modified or changed.

Questions:

- ***What is the highest level of surge protection that is feasible for beach nourishment?***
- ***What are the environmental consequences of beach re-nourishment?***
- ***What are innovative approaches to beach nourishment?***

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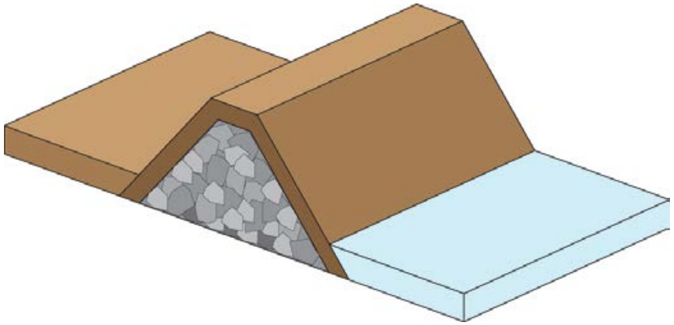

Levees/Dikes

- Levees (also called dikes) are earthen embankments that provide protection from flooding.
- Concrete floodwalls on top of levees are used to increase the height of surge protection.
- “Superlevees” are larger levee structures that can support buildings on top.

Tokyo, Japan

New Orleans

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Levees/Dikes

Risk Reduction:
- Levees can offer protection from a high surge elevation, and when combined with armored rip-rap, can resist heavy storm waves.

Best-suited for:
- When protection from high surge elevation is desired and there is sufficient land area available.

Doesn't work for:
- When space is in high demand.

Cost:
- New levees are estimated to cost $2,000 per linear foot with annual maintenance costs of $200.

Issues/Barriers:
- Requires a lot of space. Potentially raises land condemnation issues.
- Significant environmental disturbance of shoreline and nearshore.
- Extensive permitting process.
- May block waterfront views.

Benefits:
- Can be strengthened or modified to accommodate rising sea levels.
- Land area on top of the levee can sometimes be used for other functions, like paths, roadways, or structures.

Questions:
- ***How can existing waterfront roadways be adapted into levee structures?***

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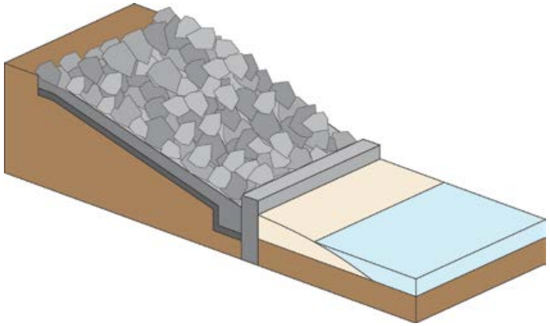

Revetments

- Stone rubble or concrete blocks placed on a sloped surface to protect the underlying soil from erosion and reduce the forces of wave action.

Hudson River, Manhattan

Lake Michigan, Chicago

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Revetments

Risk Reduction:
- Protect shoreline from erosion even in areas that experience high wave action.
- Often used in concert with seawalls, bulkheads, or levees to add additional armoring protection.
- Do not on their own protect from coastal surge.

Best-suited for:
- In combination with other structures or where there is already a high bank elevation.

Doesn't work for:
- Most effective with stable foundation soil.

Cost:
- Estimated $2,000 to $5,000 per linear foot.

Issues/Barriers:
- Significant environmental disturbance for undisturbed sites.
- Extensive permitting process.

Benefits:
- Very low maintenance required if constructed properly.
- Reduce degree of erosion on adjacent sites than bulkheads.
- More opportunity for intertidal vegetation and habitat.
- Can be more flexible than other strategies.

Questions:
- ***How can revetments be designed to promote the growth of intertidal habitat? In what conditions is this feasible?***
- ***How can existing revetments be adapted to protect from surge?***

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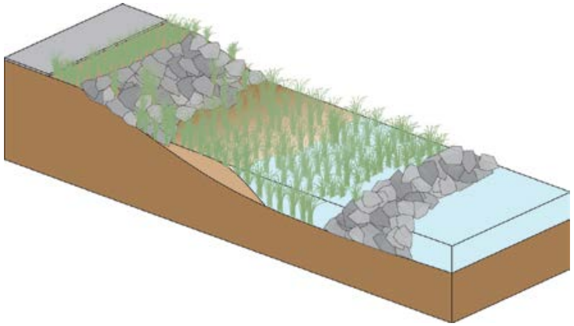

Living Shorelines

- A more natural bank stabilization technique that uses plants, sand, and limited use of rock to provide shoreline protection and maintain valuable habitat.
- Living shorelines need to include the use of coastal vegetation and usually, but not always, a low-lying structure.

Harlem River Park

Maryland

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Living Shorelines

Risk Reduction:

- Protects shorelines from erosion.
- May reduce risk from frequent inundation and periodic low surge flooding, although not typically used to do so.

Best-suited for:

- Flat to moderately sloped areas with moderate fetch (up to 10 miles).

Doesn't work for:

- Areas with steep slopes or high wave energy.

Cost:

- ?

Issues/Barriers:

- Lack of clear guidelines for implementation.
- More space intensive than typical bulkheads.
- Structural features may prevent wetland migration and may lead to loss of adjacent sandy beaches.

Benefits:

- Retains intertidal habitat.
- Can retain stormwater and improve water quality.

Questions:

- ***How can Living Shorelines survive in high wake conditions?***
- ***What can they do to mitigate the impacts of coastal flooding?***
- ***How might they be designed to work with sea level rise?***

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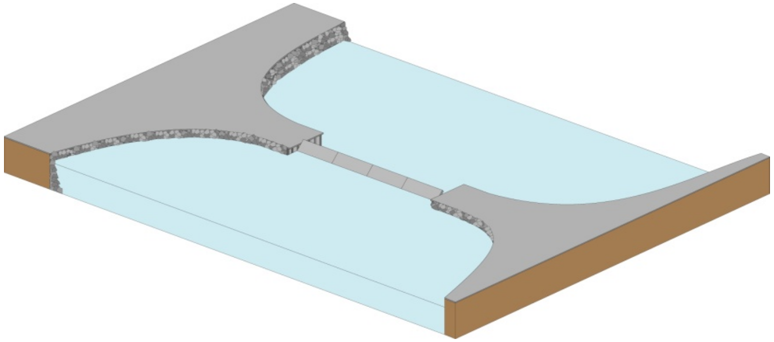

Surge Barriers

- Surge barriers cross a waterway to protect coastal areas from surge.
- They are usually integrated into a larger flood protection system including levees and pumps.
- Movable surge barrier remain open in normal conditions to allow water and vessels to pass, but can be closed when water levels rise due to storm surge.
- Various types of flood gates include floating gates, vertical lifting gates, and flap gates.

Stamford, CT

London, Thames Barrier

New Orleans, Lake Borgne

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Surge Barriers

Risk Reduction:
- Provide a high level of protection from even the highest level of storm surge.

Best-suited for:
- Bays with proximate shorelines.

Doesn't work for:
- Exposed oceanfront shorelines.

Cost:
- Costs vary widely depending on types and components. Estimated range of $2 - $11M per linear foot based on costs of existing barriers.*

Issues/Barriers:
- Require extensive maintenance and monitoring.
- Can create navigation conflicts.
- Altering water flow changes the chemical, physical and biological properties of estuarine system by altering water flow (temperature, salinity, suspended matter, nutrients); use of movable rather than fixed barriers can reduce these impacts
- Potential for increased river flooding from backed-up water on the landward side of the barrier, although this can be prevented with proper monitoring and design.
- Relatively inflexible once built.
- Extensive permitting process and high level of engineering required.

Benefits:
- Can protect large areas.

***Questions*:**
- ***What can be used in combination with surge barriers other than levees? Is beach nourishment feasible?***
- ***Can surge barriers be designed to be adaptable over time?***

* Hillen, Coastal Defence Cost Estimates, Delft University of Technology, 2010

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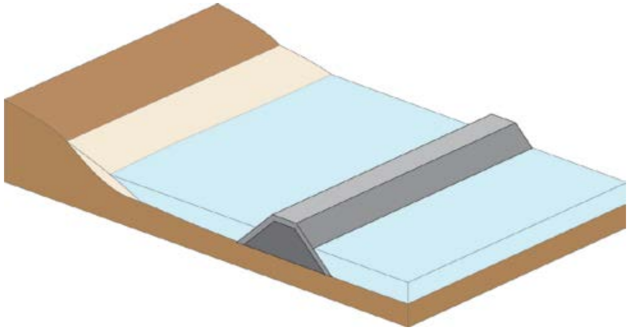

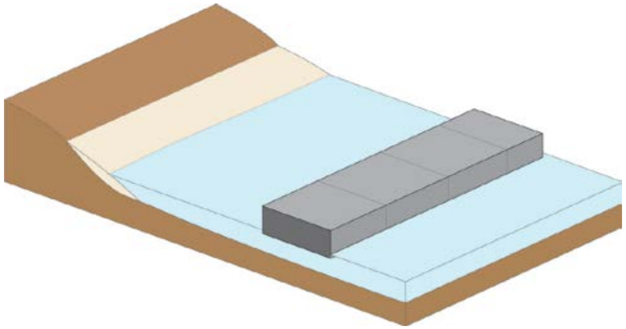

Breakwaters

- Offshore structures, typically parallel to the shore and made of stone, concrete blocks or units.
- Can be fixed or floating, submerged or emerged.

Floating Concrete Breakwater

DRAFT

Breakwaters

Risk Reduction:
- Dissipates and attenuates waves thereby protecting shorelines and upland areas from destructive forces of waves.
- Does not reduce height of surge.

Best-suited for:
- Fixed breakwaters very expensive in deep water (more than 4 feet).
- Floating breakwaters are less effective than fixed breakwaters at dissipating waves higher than 6.5 feet.

Doesn't work for:
- High waves in deep water.

Cost:
- Estimated $175 - $1,750 per linear foot

Issues/Barriers:
- Extensive permitting process.

Benefits:
- Minimize erosion of beaches, wetlands, and shoreline structures.
- Create clam water for recreation.
- In right conditions can function similarly to reefs promote growth of vegetation and habitat creation.

Questions:
- ***How effective are breakwaters at dissipating wave action during a hurricane or nor'easter?***
- ***Where in NYC may breakwaters be and effective strategy for reducing wave action?***

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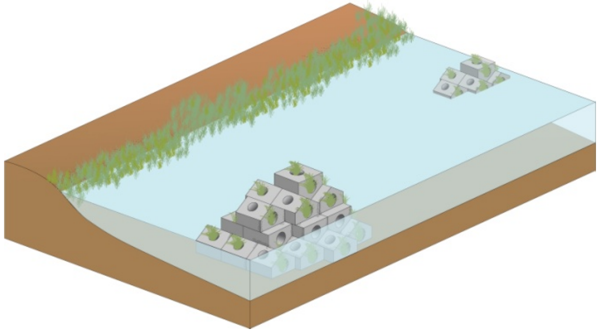

Artificial Reefs

- Artificial reefs are submerged, or partially submerged, structures made of rock, concrete, or other materials, that are designed to provide marine habitat for plants, invertebrates, fish, and birds, while also attenuating waves.

Soundview Oyster Reef, NY/NJ Oyster Restoration Research Project

Reef Balls, Miami Beach

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Artificial Reefs

Risk Reduction:
- Protects shorelines from erosion in areas that experience wave action.

Best-suited for:
- Areas with large shallows and subsurface soils.

Doesn’t work for:
- In areas of very deep water.

Cost:
- ?

Issues/Barriers:
- Relatively untested strategy for coastal hazard mitigation.
- Requires extensive monitoring.

Benefits:
- Offshore strategy with low visual impact.
- Creates or restores habitats.
- Provides educational opportunities.
- Recreational benefits.

Questions:
- ***At what level of wave action are artificial reefs effective?***
- ***At what depths do they become less effective?***
- ***What local conditions make these strategies feasible (wind, wave, soil)?***

NYCPLANNING

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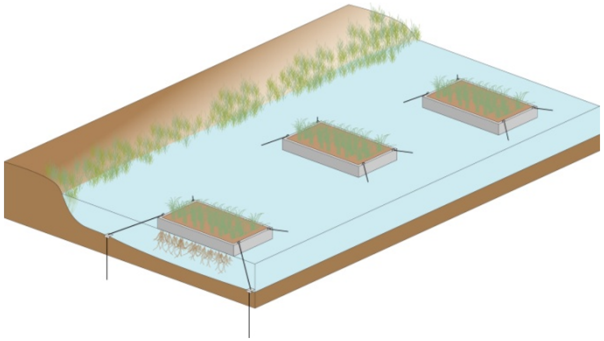
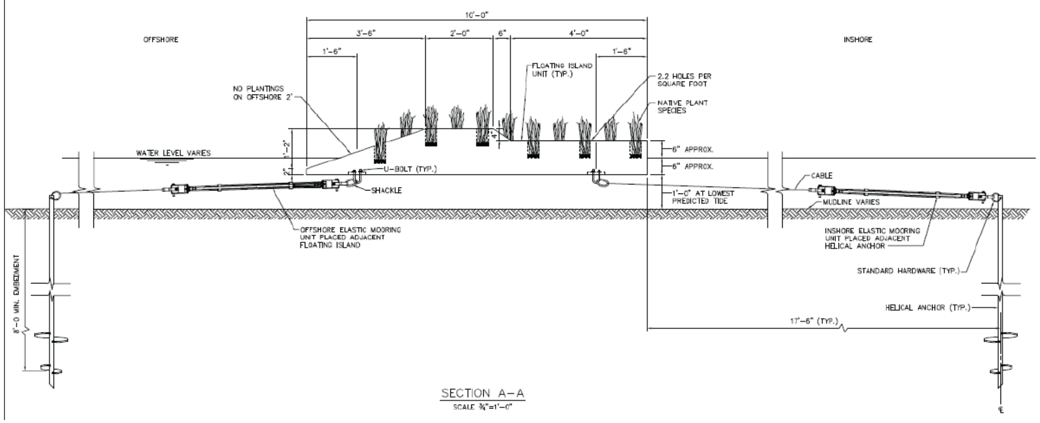


Vegetated Floating Breakwaters (Islands)

- Buoyant, planted mats or structures that can attenuate waves while providing ecological benefits, such as habitat restoration and improved water quality.

Floating Islands, Baltimore Harbor



Planned DEP Pilot in Jamaica Bay

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Floating Islands/ Breakwaters

Risk Reduction:
- Protects soft shorelines from erosive wave forces.

Best-suited for:
- Areas with light to moderate wave exposure.

Doesn't work for:
- Areas with high wave energy.

Cost:

Issues/Barriers:
- Little is understood about the overall effectiveness of vegetative floating breakwaters in coastal hazard reduction.

Benefits:
- Flexible, low cost, and effective on a smaller scale.
- Offers ecosystem services and educational opportunities.

Questions:
- ***In what situation is a vegetative floating breakwater best suited?***
- ***What is their applicability compared to non-planted floating breakwaters?***

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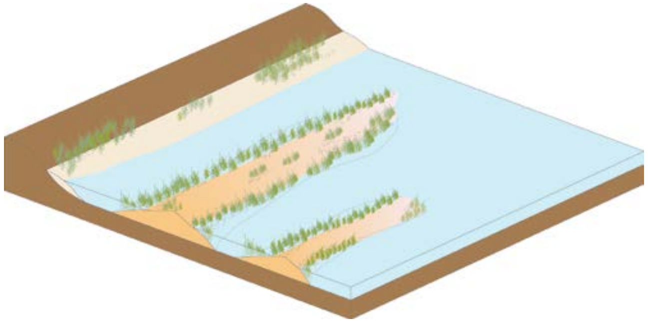
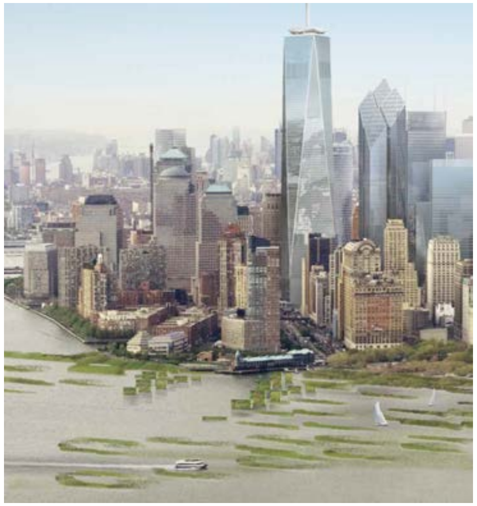


Constructed Barrier Islands

- Constructed Barrier Islands are created with fill offshore.
- Can break up the wave energy generated by storm surges and provide opportunities for development , recreation and habitats.

Fort Pierce, FL



Palisade Bay proposal, New York

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Constructed Barrier Islands

Risk Reduction:

- Protects shorelines from wave forces.
- May reduce risk from coastal flooding.

Best-suited for:

- Shallow water areas where less fill is necessary.

Doesn't work for:

- ?

Cost:

- ?

Issues/Barriers:

- Space Intensive.
- Potential impacts on hydrology and navigation
- Requires large upfront capital investment.
- Extensive permitting process.
- Overall impacts on ecosystem are unknown.

Benefits:

- Provides coastal protection with ecological services and creation of intertidal habitat.
- Offers aesthetic value and potential recreational opportunities.

Questions:

- ***What are the engineering challenges to barrier islands in New York Harbor?***
- ***In what areas in NYC would this be applicable?***
- ***What is the capacity of a barrier island to reduce the risk of storm surge?***

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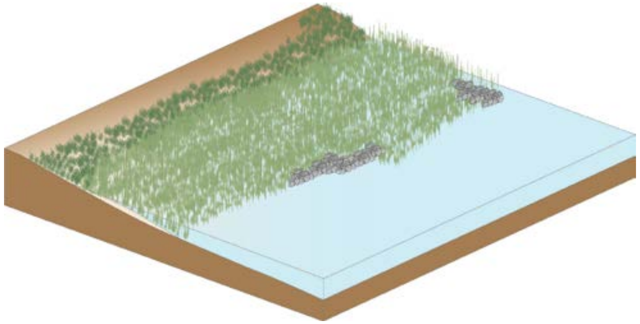

Constructed Wetlands

- A new or restored ecosystem in the intertidal zone that uses plants to retain and filter water while creating wildlife habitat .

Salt Marsh, Brooklyn Bridge Park

Constructed Wetland, Randall's Island

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Constructed Wetlands

Risk Reduction:
- Protects shorelines from erosion
- May reduce risk from frequent inundation and periodic low surge flooding.

Best-suited for:
- Sites with fine grain sediments.
- Sites with light to moderate fetch of less than one mile.

Doesn't work for:
- Areas exposed to high currents or wave energy.
- On steep slopes.

Cost:
- ?

Issues/Barriers:
- Achieving surge reduction requires a mature peat layer, which can take a long time to develop (approx. 30 years)
- Storm surge protection is very site-specific, may be unreliable in all cases.
- Limits certain forms of public access to the water and other construction opportunities.

Benefits:
- Protects natural resources and creates habitat.
- Controls erosion and improves water quality.
- Comparatively low cost.

Questions:
- ***What scale of wetland construction is necessary to have an impact on erosion? Coastal flooding? Storm surge?***
- ***What areas in New York City are best suited for constructed wetlands?***

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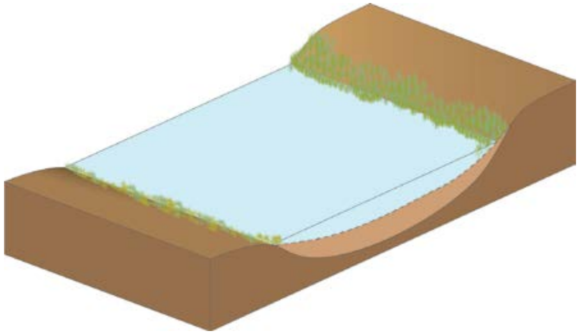
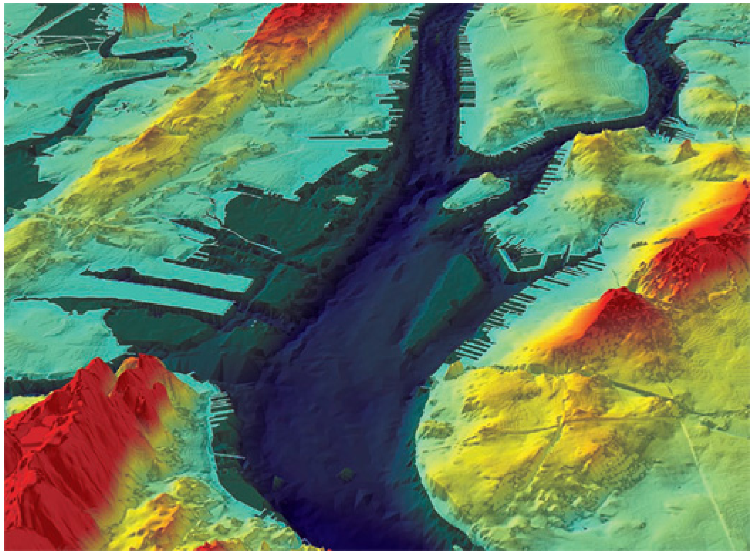


Shallows Restoration or Bathymetry Modification

- Altering the bathymetry of a water body to reduce the extent of storm surge.



New York Harbor Bathymetry

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Shallows Restoration or Bathymetry Modification

Risk Reduction:
- May reduce extent of coastal flooding by altering surge dynamics.

Best-suited for:
- ?

Doesn’t work for:
- ?

Cost:
- ?

Issues/Barriers:
- Strategy is untested in the US.
- Limits navigability.
- Impacts on flooding and sea level rise are uncertain.
- Potential negative environmental impacts and extensive permitting process.

Benefits:
- Could be used in combination with wetland restoration to enhance biodiversity.

Questions:
- ***What scale of shallows restoration is necessary to have an impact on storm surge?***
- ***Has the creation of shallows been used elsewhere to mitigate flood damage? Where might it be appropriate in NYC?***

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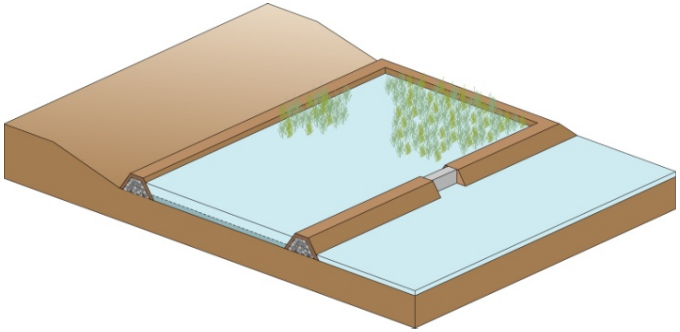
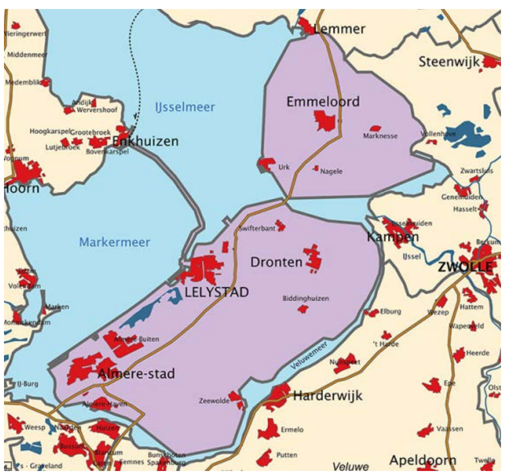


Polders

- A polder is a low-lying tract of land enclosed by levees that form an artificial hydrological entity.
- A traditional Dutch technique that could be used to store and retain flood waters in the event of a coastal surge.



Map of Flevoland Polder in the Netherlands

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Polders

Risk Reduction:

- May reduce extent of coastal flooding by diverting surge.

Best-suited for:

- ?

Doesn't work for:

- Areas with limited space.

Cost:

- ?

Issues/Barriers:

- Strategy is untested in the US.
- Can disrupt natural hydrology and ecosystem.
- High walls may limit access and visibility.
- Requires large areas of undeveloped land.

Benefits:

- Could provide additional space for temporary uses, playfields, farmland, etc.

Questions:

- ***What scale might be necessary for polders to be effective?***
- ***What is the size of an area that could benefit from that scale?***

DRAFT

3 *Site strategies*

Floating House, Amsterdam

Strategies for retrofitting existing buildings

- Elevate
- Structural resilience
- Limit water infiltration
- Accommodate flooding
- Protect building systems

Strategies for new construction

- Dry flood proofing
- Wet flood proofing
- Elevation on fill
- Elevation on piles or open foundation
- Floating/amphibious structures

Site measures to protect from flooding

- Elevate/regrade site
- Floodwall
- Temporary protection

Retreat

- Relocate
- Demolish

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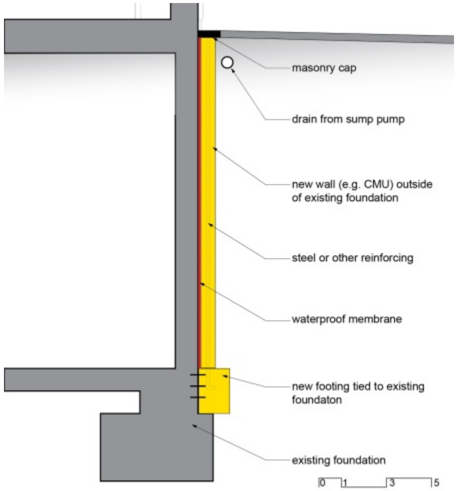

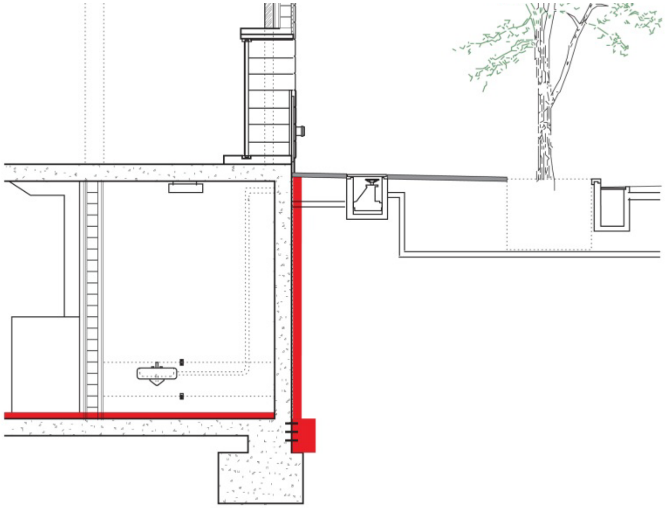

Reinforce foundation

- Adding additional structure increases a building's ability to withstand flood loads.
- Saturated soil imposes significant loads on buildings that are not experience under dry conditions.
- Unequal lateral and buoyant hydrostatic forces can rupture walls or building foundations.
- Foundation failure can significantly or irreparably compromise a building's structural integrity.

Illinois

North Carolina

DRAFT

Reinforce Foundation Slab & Walls

Risk Reduction:
- Reduces the risk of structural failure due to saturated soil given any level of flooding.

Best-suited for:
- Buildings with basements in flood zones with still water flooding.

Doesn't work for:
- Buildings facing wave action; attached structures.

Cost:
- To be evaluated

Issues/Barriers:
- Where reinforcing involves thickening the exterior wall, it requires space around the structure for excavation and backfill.
- Doesn't prevent water infiltration unless combined with the installation of a waterproof membrane.
- Does not eliminate the possibility of flooding through the ground floor or through penetrations such as basement windows.

Benefits:
- Can increase structural resilience.
- Does not have negative design or streetscape implications
- Complements other strategies for armoring buildings.

***Questions*:**
- ***Can this strategy be used in all soil conditions/qualities?***
- ***Is there an average DFE above which even reinforced foundations fail?***

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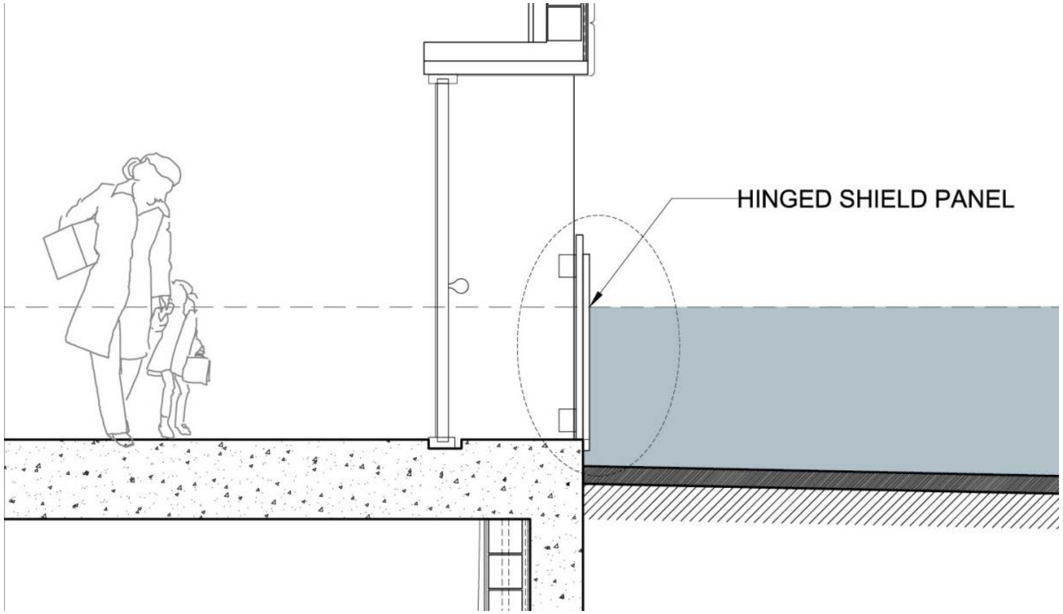

Install shield panels to protect doors and windows

- Guard doors and windows with operable flood-proof panels to limit or prevent water seepage.

Florida

Georgia

Vermont

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Install shield panels

Risk Reduction:
- Limits or prevents water infiltration through or around doors and windows.
- Provides protection up to a certain height or force.

Best-suited for:
- Buildings with a flood elevation lower than the height of the panel

Doesn't work for:
- High flood elevations

Cost:
- To be determined.

Issues/Barriers:
- Aesthetically challenging to incorporate into a building.
- May be difficult to implement with certain envelope systems.
- Removable panels require adjacent storage space.

Benefits:
- Provide some protection against flood-borne missiles.
- Can quickly be positioned in anticipation of flooding.

Questions:
- ***To what extent do shield panels provide protection against wave action?***
- ***Can shield panels compromise the building envelope by transferring flood loads across the façade?***
- ***How much protection does a shield panel provide if the façade has limited waterproofing potential?***

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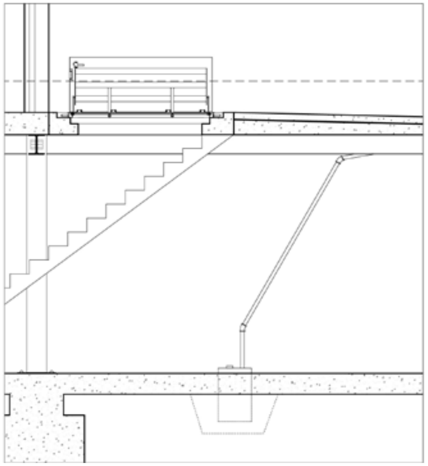

Replace sidewalk vault

- Many New York City vaults were built without either a waterproofing membrane or doors.
- In some cases, replacing a door or closing mechanism may significantly improve the vault's protection against low levels of flooding.
- A full replacement of an old or poorly-maintained vault may be necessary to ensure a building's ability to support flood loads and resist infiltration.

Replaced steel decking

Vault demolition

DRAFT

Replace sidewalk vault

Risk Reduction:
- Replacing doors reduces risk for low levels of flooding.
- Complete replacement can reduce risk of structural compromise and higher floods.

Best-suited for:
- Buildings with old or poorly-maintained sidewalk vaults seeking to renovate.

Doesn't work for:
- Buildings without an existing vault.

Cost:
- Estimated $200-250 per square foot for construction only

Issues/Barriers:
- Requires ongoing maintenance to monitor and repair sidewalk cracks.
- Can be compromised by the use of certain deicing chemicals.
- Does not negate the need to move mechanical equipment out of the basement.
- Temporary disturbance to streetscape during construction.

Benefits:
- Promotes the general upkeep of the building.
- Invisible once complete.
- Improves resistance against groundwater flooding.

Questions:
- ***How many feet of water can the structure of a waterproof vault door support?***
- ***Could sidewalk vaults take on a storm water retention function?***
- ***Are there ways to address energy efficiency and flooding concerns in the same vault replacement?***

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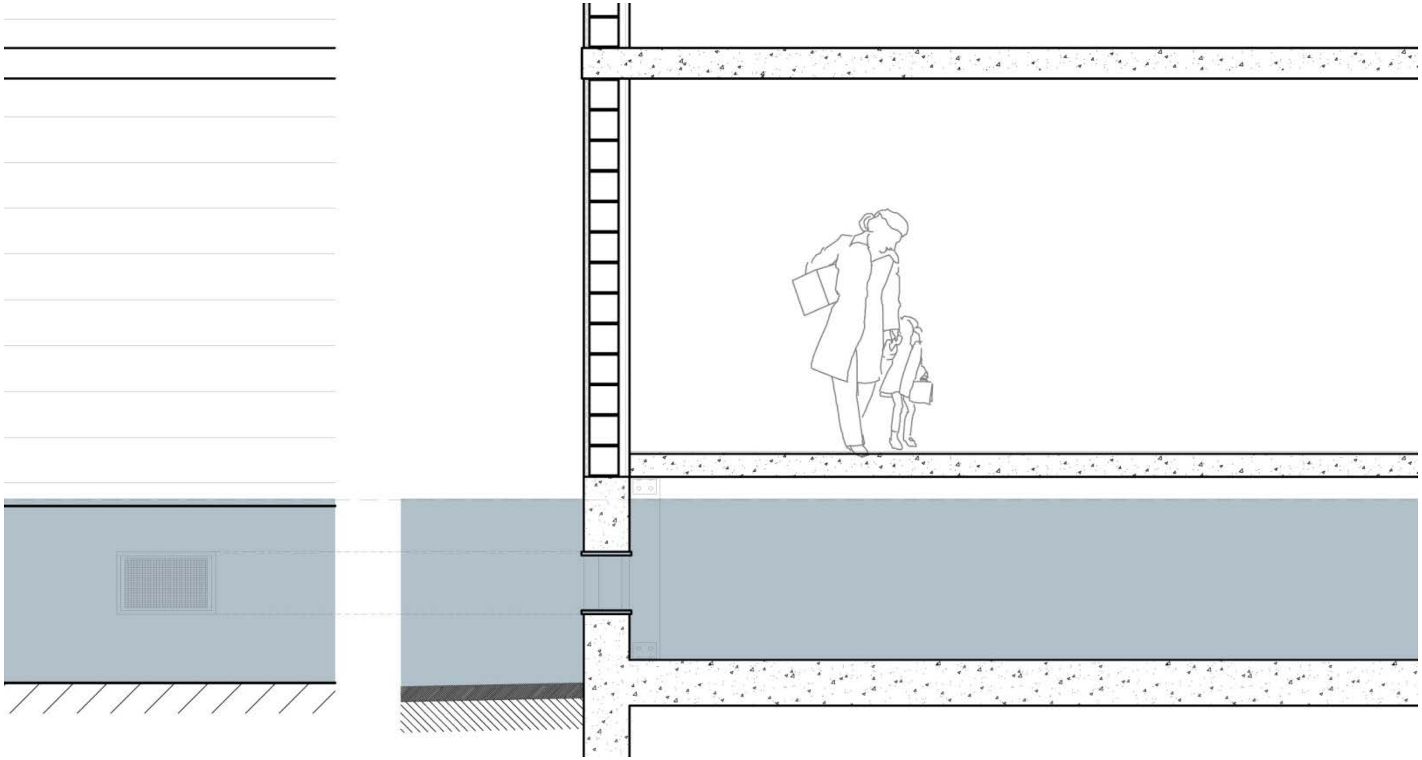

Raise ground floor and incorporate vents

- Allows water to move freely through the structure.
- Relieves hydrostatic pressure for low levels of flooding without sacrificing living space.

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Raise ground floor and incorporate vents

Risk Reduction:
- Relieves hydrostatic and hydrodynamic forces on the structure.
- Accommodates low levels of flooding.

Best-suited for:
- Buildings where the second floor is more than 7 feet above the DFE.
- Frequent flooding scenarios and building subject to wave action.

Doesn't work for:
- Buildings with minimal floor-to-floor heights.

Cost:
- To be determined.

Issues/Barriers:
- Requires vacating the ground floor during construction.
- Eliminates any habitable space below grade.
- Reduces floor-to-ceiling height of the first floor.
- Creates potential compliance issues for accessibility.

Benefits:
- Maintains floor area.
- Accommodates repeated flooding at low levels.
- Provides structural system.

Questions:
- ***What kinds of façade systems can negotiate a raised ground floor and new vents?***
- ***How many buildings have enough floor-to-floor height to implement this strategy?***
- ***Is there an optimal floor area for which this is cost-effective?***

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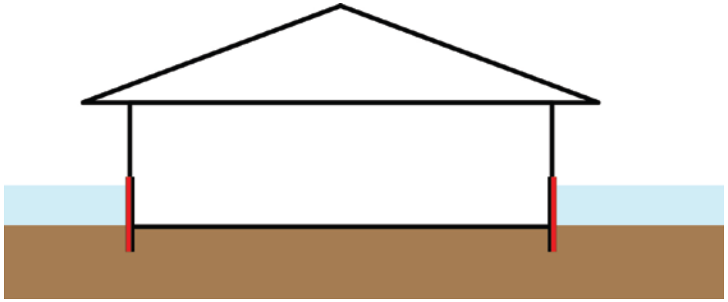

Dry Floodproofing

- In dry floodproofing, water-resistant materials are used, in combination with water-tight gates at entry points, to prevent the infiltration of flood waters and resist hydrostatic forces.
- Different materials include concrete, concrete masonry units, and aquarium glass. Gates often made from sheet metal with reinforcement and rubber joints, or inflatable materials.

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Dry Floodproofing

Risk Reduction:
- Protects buildings from flooding.

Best-suited for:
- Mixed use or community facility buildings in A zones.

Doesn't work for:
- Not allowed by FEMA and Building Code in 100% residential buildings.
- Not allowed by FEMA and Building Code in V zones.

Cost:
- Generally more expensive than wet floodproofing.

Issues/Barriers:
- Above 3 feet, dry floodproofing may not protect from structural collapse.
- Aquarium glass is expensive, other materials limit transparency of ground floor.
- Mechanical/electrical equipment must be protected or elevated.
- Usually used in concert with other strategies (elevation/wet).

Benefits:
- Minimizes impact on streetscape.
- Allows excavation below grade for basements.

Questions:
- ***How can we get a better cost estimate?***
- ***Structural capacity unclear for larger structures.***

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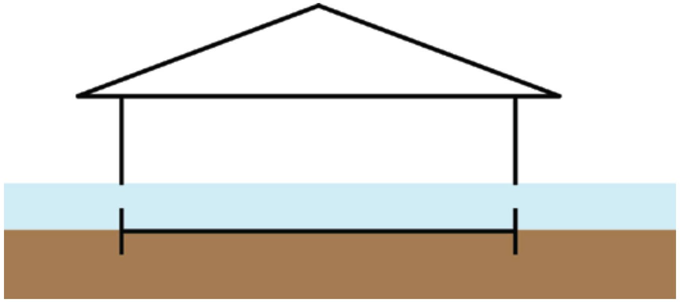

Wet Floodproofing

- In wet floodproofing, water-resistant materials are used, in combination with flood vents or breakaway walls to allow water to enter and hydrostatic pressures to equalize.
- Different materials include perforated holes and marine-grade plywood.

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Wet Floodproofing

Risk Reduction:
- Protects buildings from structural damage due to flooding.

Best-suited for:
- Low design flood elevations.

Doesn't work for:
- Not allowed by FEMA and Building Code in V zones.

Cost:
- Generally less expensive than dry floodproofing.

Issues/Barriers:
- Contents located below the DFE are not protected from flooding.
- Limited uses allowed below the DFE.

Benefits:
- Generally less expensive than dry floodproofing.

Questions:

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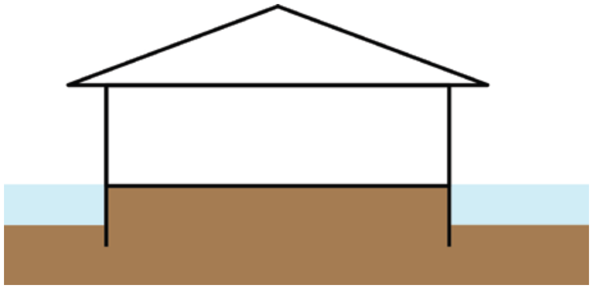

Elevate on Fill

- The building site is raised to a height above the design flood elevation through the addition of fill.

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Elevate on Fill

Risk Reduction:
- Protects buildings from flooding.

Best-suited for:
- Large lots and low design flood elevations.
- Sloped sites.

Doesn't work for:
- Small, infill sites.
- V zones.

Cost:
- Additional cost of fill.

Issues/Barriers:
- For all besides 1-2 family buildings, requires extensive ramping as design flood elevation increases. May make infill development on a narrow lot infeasible.

Benefits:
- Can reduce impacts on streetscape with appropriate landscaping.

Questions:
- ***How can we get cost estimates?***

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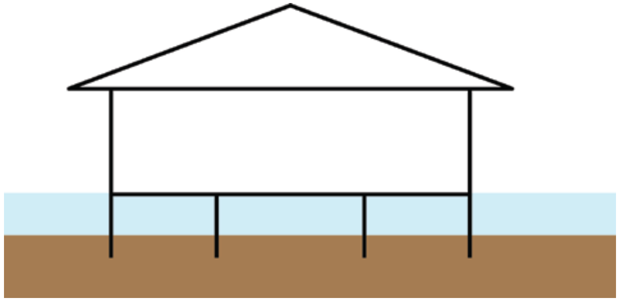

Elevate on Open Structure

- The building is raised above the design flood elevation through construction on piles or piers that are driven into the soil.
- Frequently used along with breakaway walls beneath the design flood elevation.
- Elevator core below the design flood elevation allowed if dry floodproofed.

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Elevate on Open Foundation

Risk Reduction:
- Protects buildings from flooding and associated wave forces.

Best-suited for:
- V zones

Doesn't work for:
- Retail corridors, active streetscapes.

Cost:
- ?

Issues/Barriers:
- Access complicated.
- Uses below DFE are limited and unprotected.
- Streetscape impacts.
- Enforcement.

Benefits:
- High degree of safety
- Allows for waterfront views.

Questions:
- ***How feasible is this for larger structures?***
- ***What are potential uses for below the DFE?***

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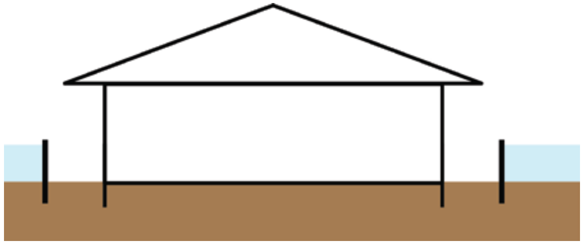

Site Protection

- The use of floodwalls or a berm to prevent water infiltration.
- Can be temporary or permanent.

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Site Protection

Risk Reduction:
- Protects buildings from flooding.

Best-suited for:
- Larger sites with multiple buildings.

Doesn't work for:
- Small sites.
- Areas with wave action.

Cost:
- ?

Issues/Barriers:
- Can end up trapping flood waters behind the wall.

Benefits:
- May be more cost-effective for larger sites.

Questions:
- ***Can end up trapping flood waters behind the wall.***