AMPHIBIOUS ARCHITECTURE:

WHERE FLOOD RISK REDUCTION MEETS CLIMATE CHANGE ADAPTATION

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FLOAT WHEN IT FLOODS

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WHAT IS AMPHIBIOUS ARCHITECTURE?

- **Amphibious architecture refers to buildings that sit on dry land like ordinary buildings, except when there is a flood, in which case they are capable of rising and floating on the surface until the floodwater recedes.**

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- **A buoyancy system beneath the house displaces water to provide flotation as needed, and a vertical guidance system allows the rising and falling house to return to exactly the same place upon descent.**

WHAT IS AMPHIBIOUS ARCHITECTURE?

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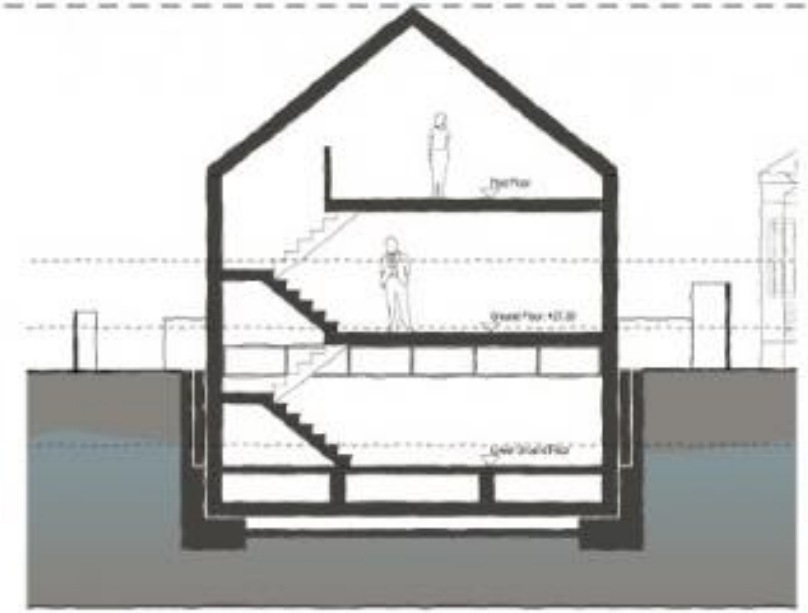
- **Amphibious construction is an adaptive flood risk reduction strategy that works in synchrony with a flood-prone region's natural cycles of flooding, rather than attempting to obstruct them.**

Maasbommel, Netherlands

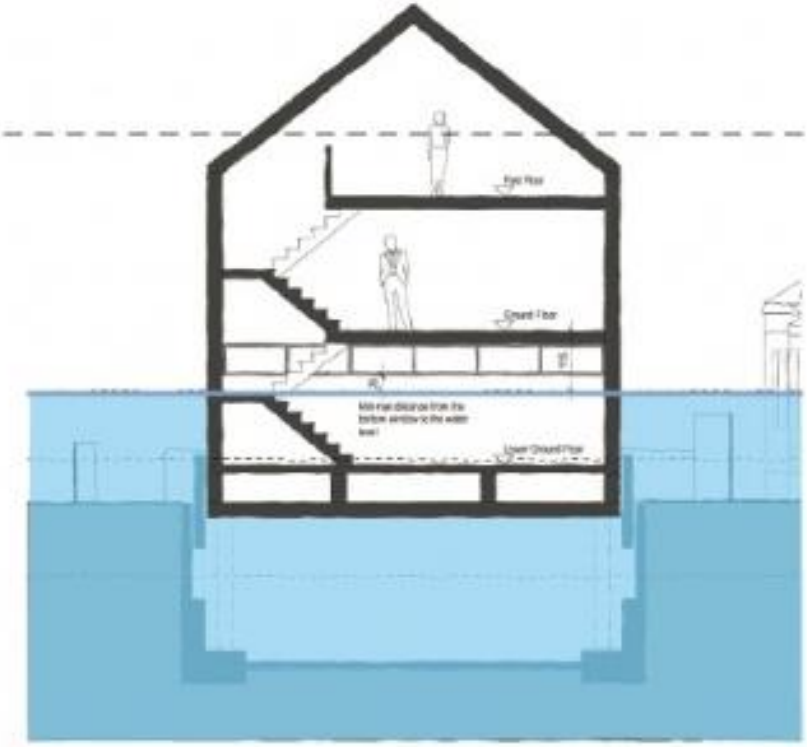
Maasbommel, Netherlands

Maasbommel,
Netherlands

Bangkok, Thailand, by SiteSpecific Architects



Before a flood



During a flood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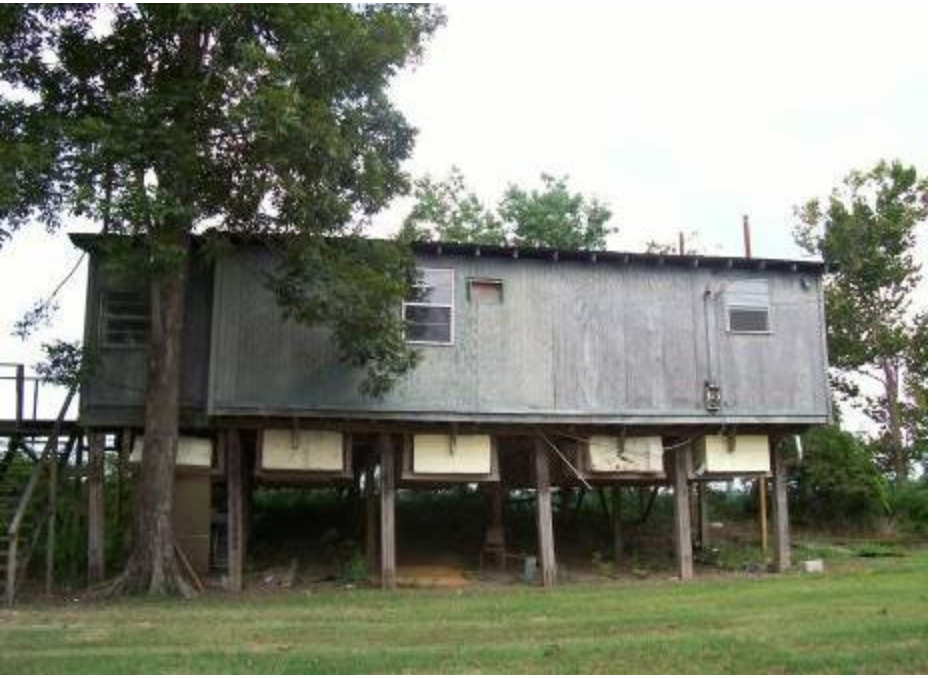
LOUISIANA

For about 40 years, amphibious houses at Old River Landing in rural Louisiana have been rising and falling reliably with the level of flooding of the Mississippi River.

AMPHIBIOUS FOUNDATIONS ARE NOT NEW!



Dry in September . . . The same house . . . Floating in February

Old River Landing,
Pointe Coupee Parish, LA

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Pointe Coupee Parish, LA

After the spring 2011 flood. Amphibious house on left is undamaged. Note waterline on elevated house on right.

WHAT IS THE BUOYANT FOUNDATION PROJECT?

A Buoyant Foundation is a particular type of amphibious foundation that is specifically designed to be retrofitted to an existing house that is already slightly elevated off the ground and supported on short piers.

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WHAT IS THE BUOYANT FOUNDATION PROJECT?

A Buoyant Foundation is a particular type of amphibious foundation that is specifically designed to be retrofitted to an existing house that is already slightly elevated off the ground and supported on short piers.

The system consists of three basic elements: buoyancy blocks underneath the house that provide flotation, vertical guidance posts that prevent the house from going anywhere except straight up and down, and a structural sub-frame that ties everything together.

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They are best suited to large, flat floodplain areas, to regions that are protected by levees where flooding is due to overtopping, to coastal regions well-protected by barrier islands or peninsulas, and to similar flood situations where the water is primarily rising rather than fast-flowing.

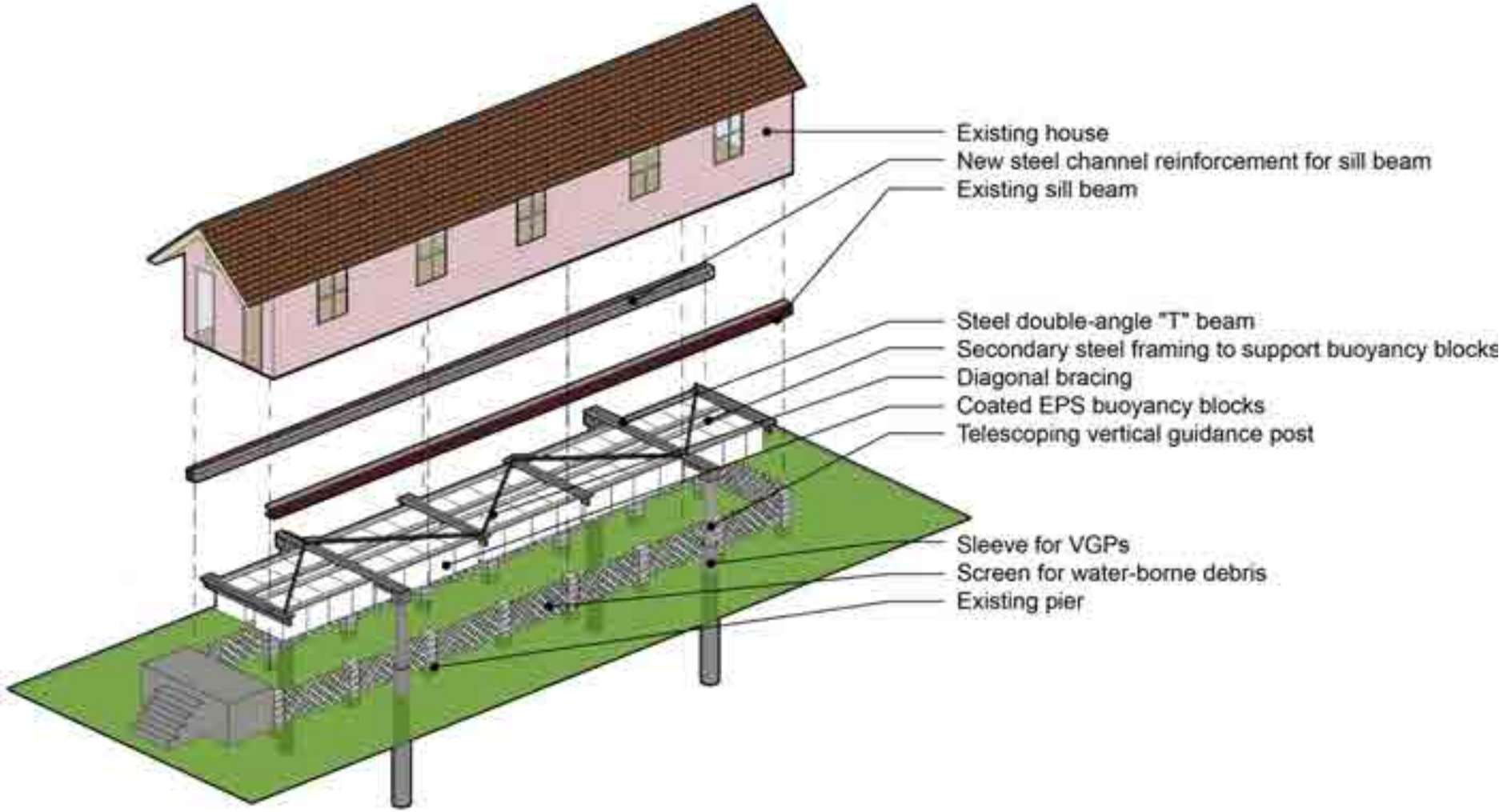
BUOYANT FOUNDATIONS
CREATE HOMES THAT FLOAT IN A FLOOD

Advantages

- Temporarily elevates house to exactly the height required to stay above water
- House otherwise remains close to the ground
- Therefore, less susceptible to wind damage
- Accommodates both soil subsidence and rising sea level
- House looks essentially the same as before
- Preserves traditional architecture
- Neighborhood retains original character
- Half the cost of permanent static elevation

TESTING THE PROTOTYPE AT LSU

"We have major concerns that this type of development does not meet minimum National Flood Insurance Program (NFIP) criteria (44 CFR Part 60.3) which local governments must adopt in order to participate in the program and make flood insurance available. . . . The local floodplain management regulations must be met in order for the entity to continue to participate in the NFIP. . . . We have concerns about a concept being promoted and publicized that would jeopardize a community's good standing in the NFIP. With that in mind, I would highly recommend that LSU withholds any information to the public until the recommended concept meets all local regulatory requirements."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Screen for water-borne debris
Existing pier

ANIMATION OF ASSEMBLY

The Buoyant Foundation Project

SO WHY FIGHT FLOODWATER WHEN YOU CAN FLOAT ON IT?

BFP applied to a New Orleans shotgun house

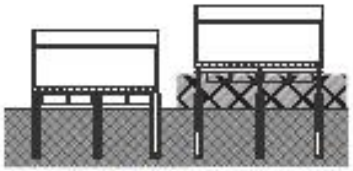
TILT HOUSE

Lower 9th Ward, New Orleans

PERTH-ANDOVER, NB, CANADA

North Side of Lake Street between Clark and LaSalle 1857, Chicago. "The sidewalks of Chicago are...remarkable. With almost every block of buildings there is a change of grade."

Clark Street 1857, Chicago. "...it was a continual succession of ups and downs."

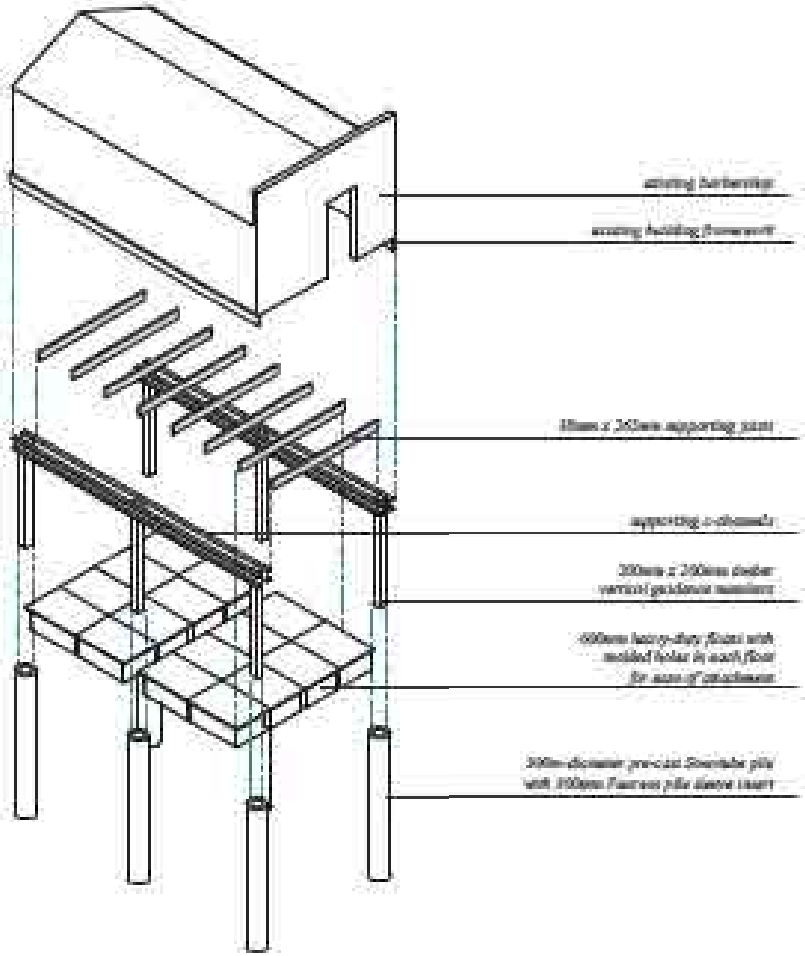


commercial building in normal conditions *commercial building during flood conditions*

First amphibious retrofit implemented to local barbershop setting the standard for flood mitigation.

Further development of the amphibious prototype funded by the government and investors in the local economy.

Full expansion and revitalization of the downtown commercial core with amphibious retrofits and waterfront boardwalk.



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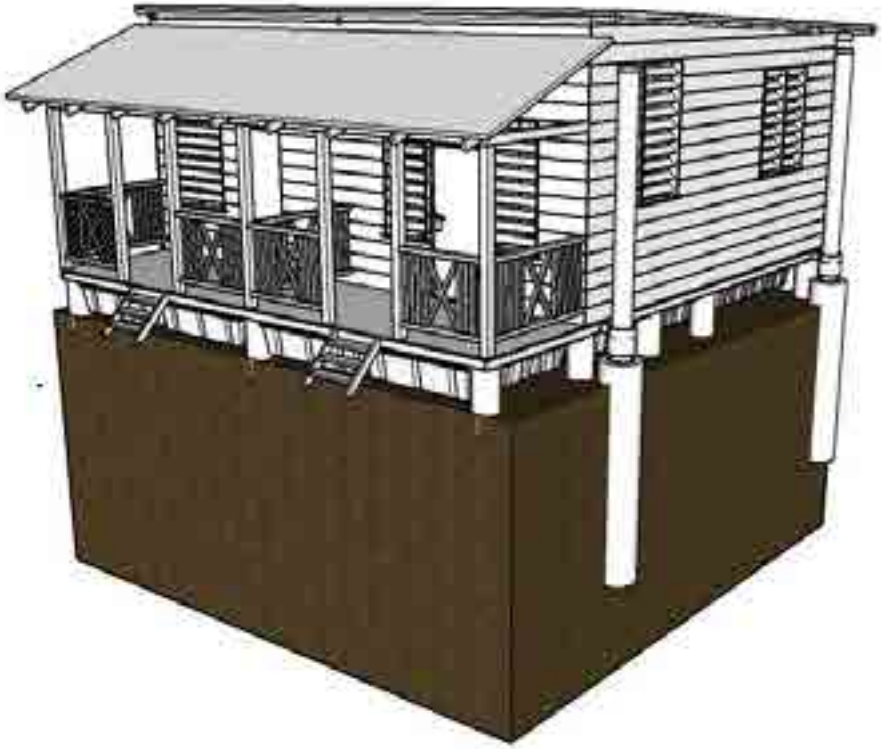
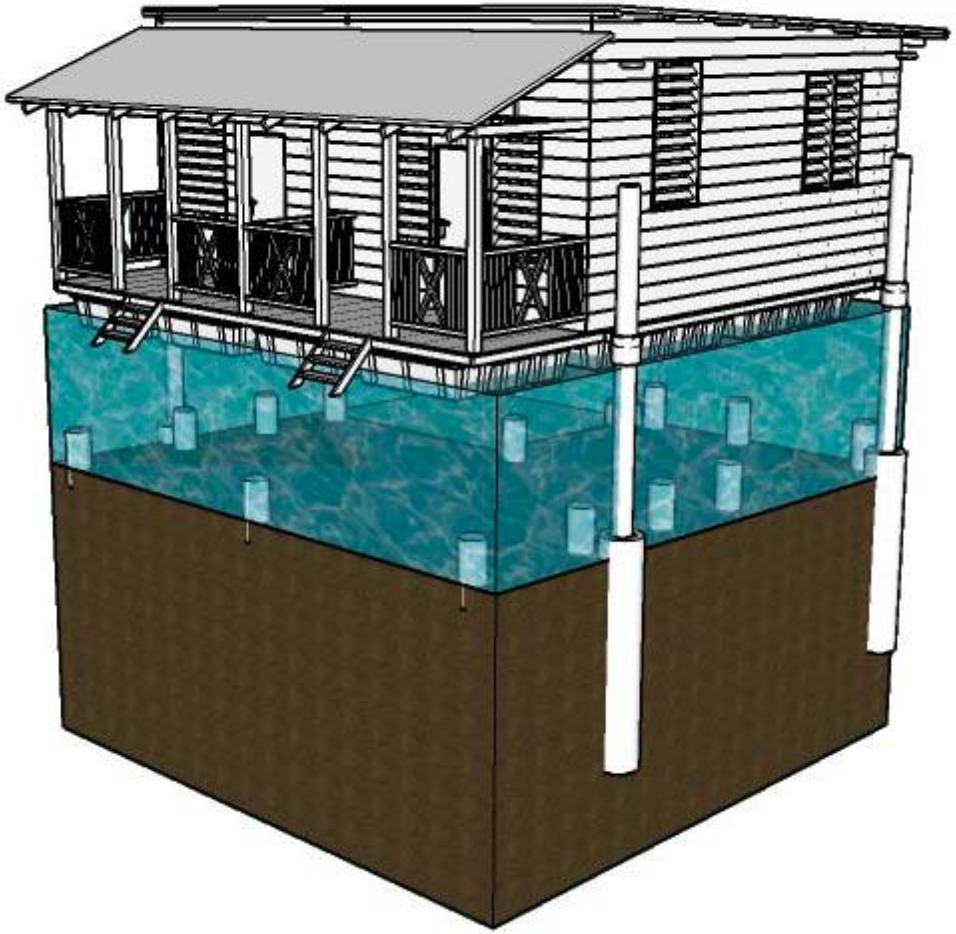
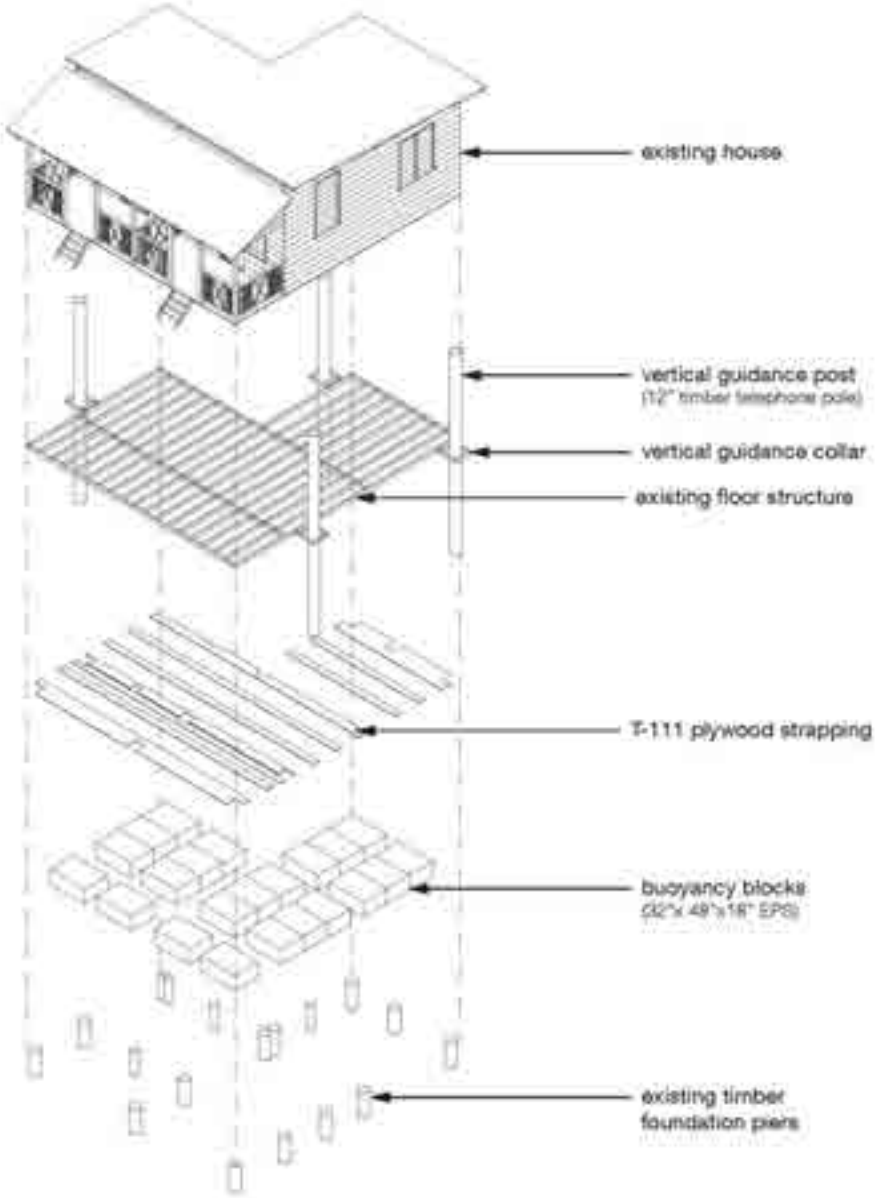






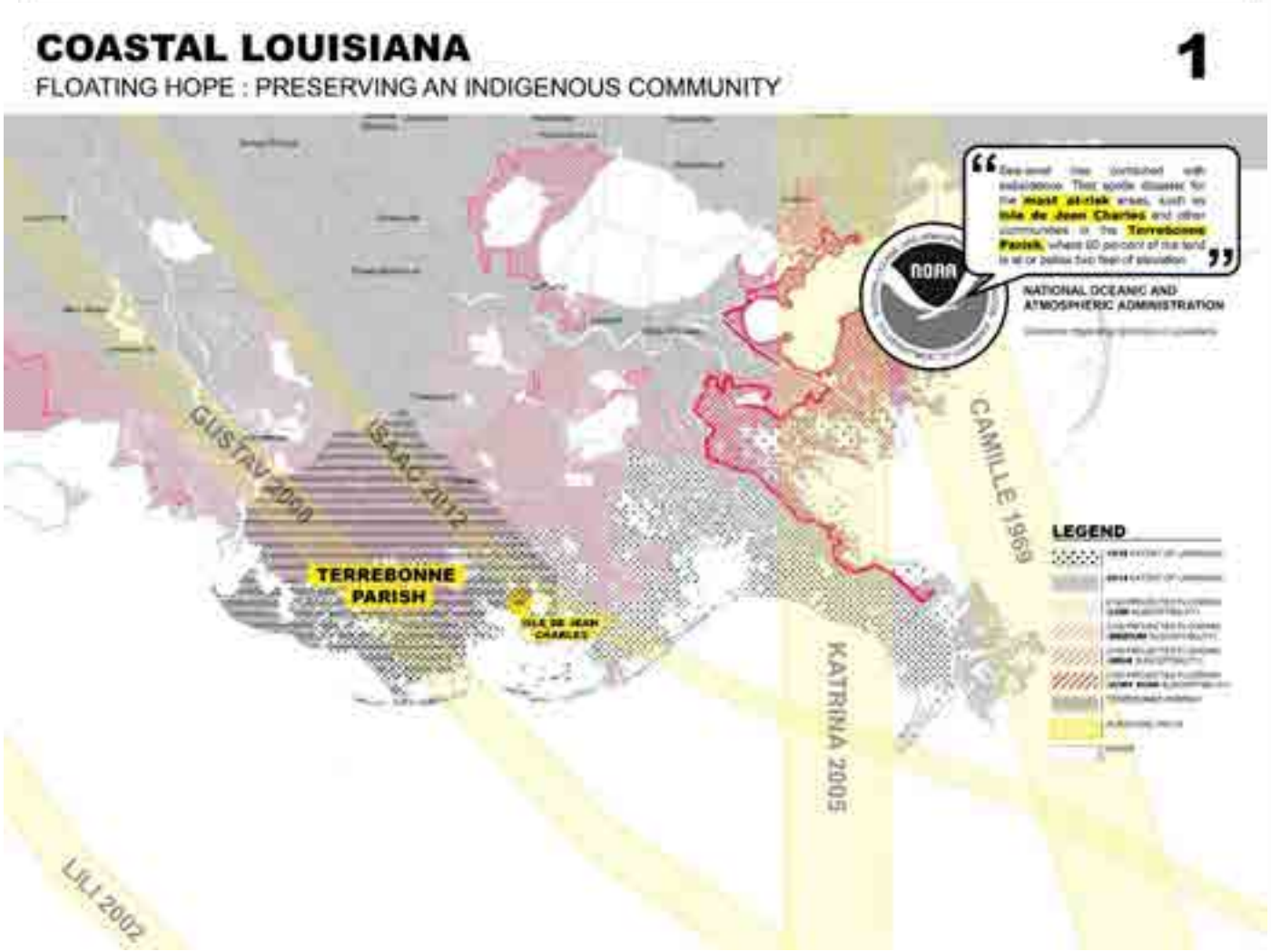
PORT MARIA HOUSE-EXPLODED AXONOMETRIC

SCALE 3/32" = 1'0"

LOUISIANA IS EXPERIENCING A COASTAL CRISIS

Potential to lose an additional 800 – 1,750 square miles of land over the next 50 years

FLOATING HOPE:
PRESERVING AN INDIGENOUS COMMUNITY



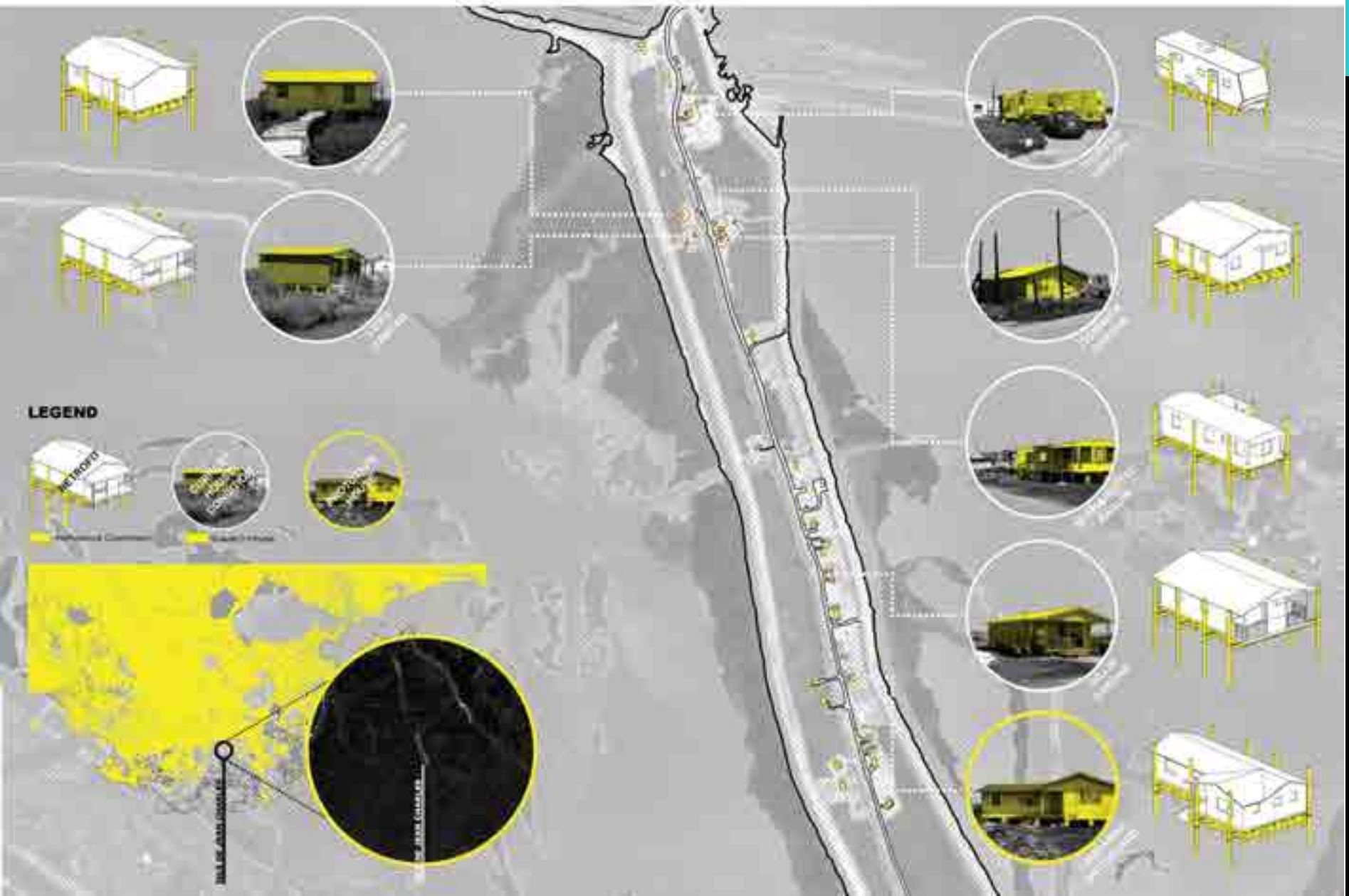
Coastal Louisiana, front line against threats of sea-level rise and coastal erosion, suffers the highest rate of land subsidence in the world. Isle de Jean Charles is at ever-increasing risk. As surrounding wetlands revert to open water, the frequency and severity of flood events has skyrocketed. The island is inadequately protected by its ring levee and is outside of an authorized new levee alignment. This combination of factors threatens to overwhelm the island and its remaining inhabitants.

“The people who live on the island want to stay on the island. My plan is to get the community back together. We want a community where we can all live and intermarry and continue on with our community and culture.”

- Chief Albert Naquin

SUBJECT HOUSES

FLOATING HOPE : PRESERVING AN INDIGENOUS COMMUNITY

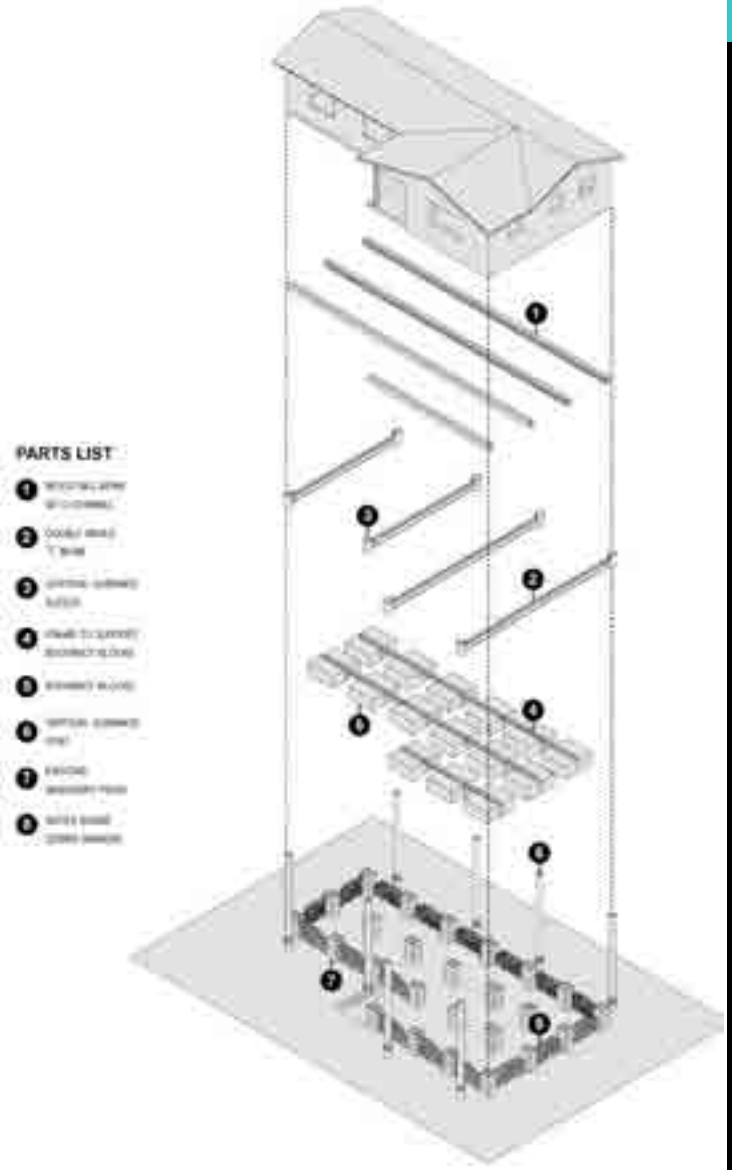


FEMA OKAYS BFP?

YES!!

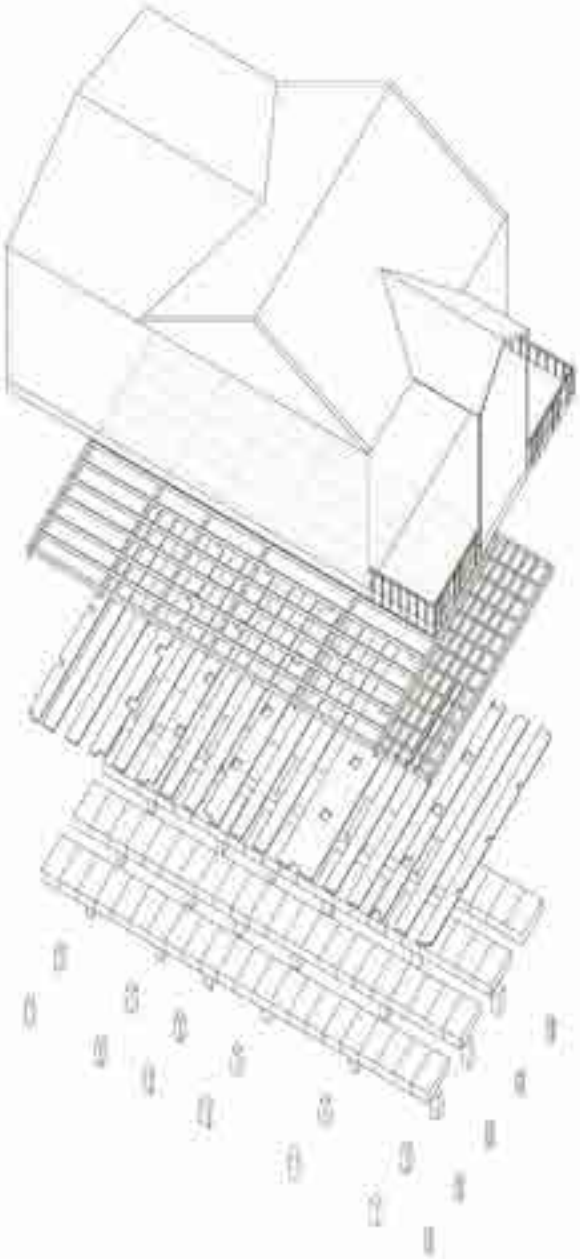
“This technique [amphibious construction] would be allowed under the NFIP regulations on pre-FIRM non-substantially damaged/improved structures as the NFIP regulation [cited above] only applies to new construction and . . . substantially improved structures."

LAURAMAE BROUSSARD




Gilmer
Gilmer


CAMP MADELYN




CAMP MADELIN

LOSSES AVOIDED RATIO

The Losses Avoided Ratio is the ratio of the calculated Losses Avoided to the calculated Mitigation Cost.

Losses Avoided = Costs of building repair + contents damage + displacement
Losses Avoided Ratio = Losses Avoided / Mitigation Cost

The losses avoided ratio for a pre-mitigation flood depth of **0.5m**
= $38,930 / $30,280
= **1.28**

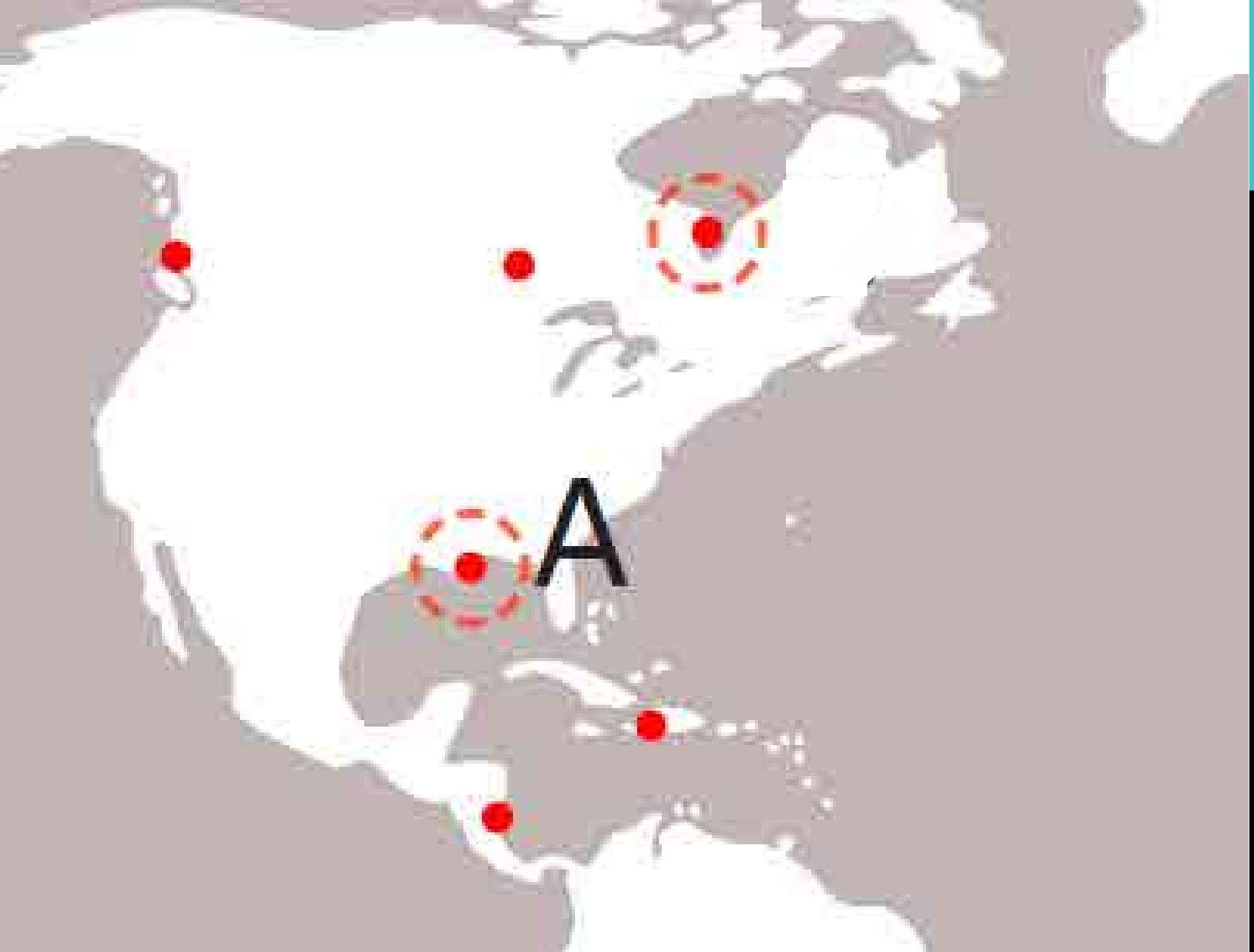
The losses avoided ratio for a pre-mitigation flood depth of **1m**
= $62,430 / $30,280
= **2.06**

The losses avoided ratio for a pre-mitigation flood depth of **1.5m**
= $78,021 / $30,280
= **2.58**

A ratio greater than one indicates that applying the mitigation strategy to the house in question is expected to be beneficial or that it has performed successfully.

Flooding on the Peguis Reservation, 2011

Assiniboine River Flooding, 2011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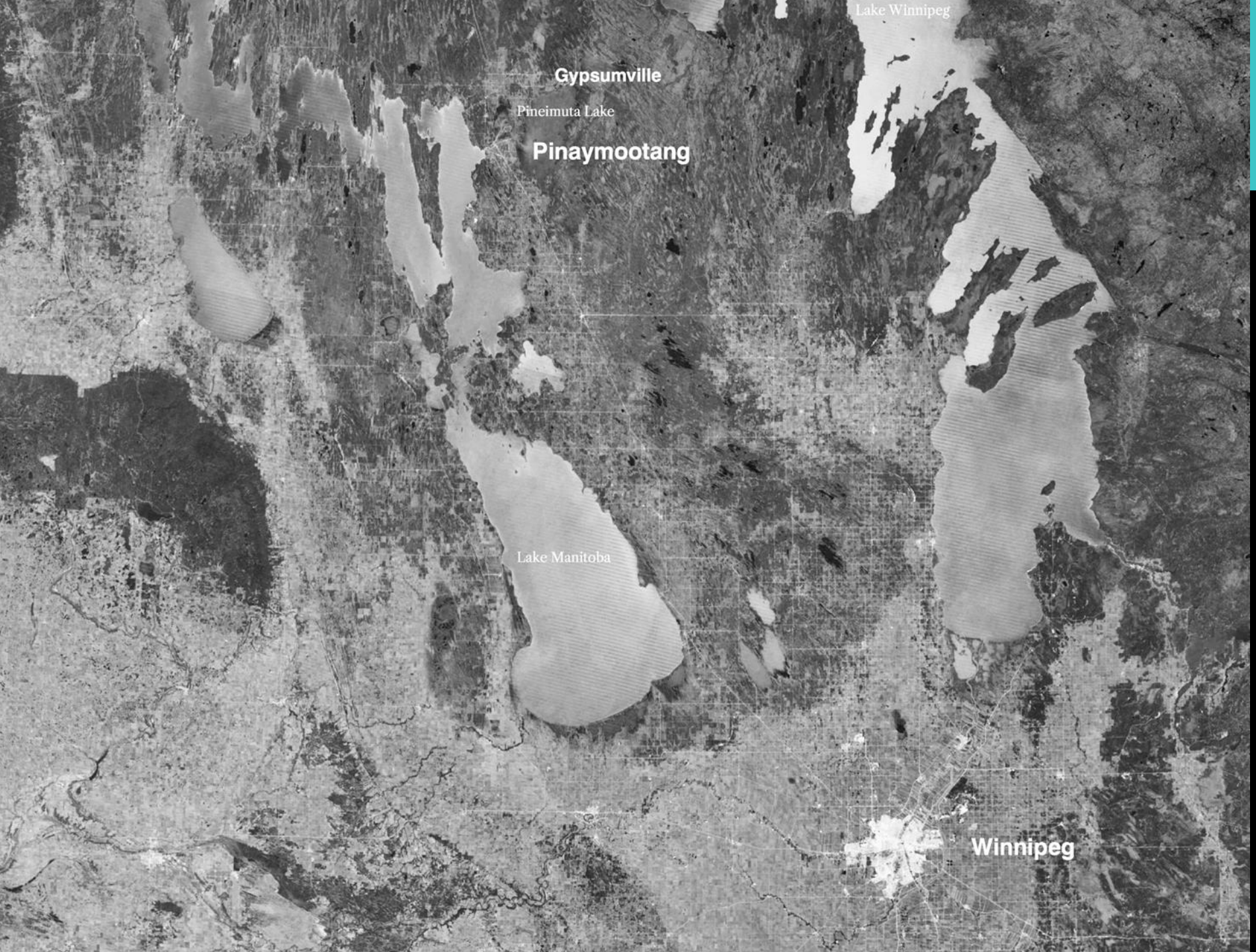
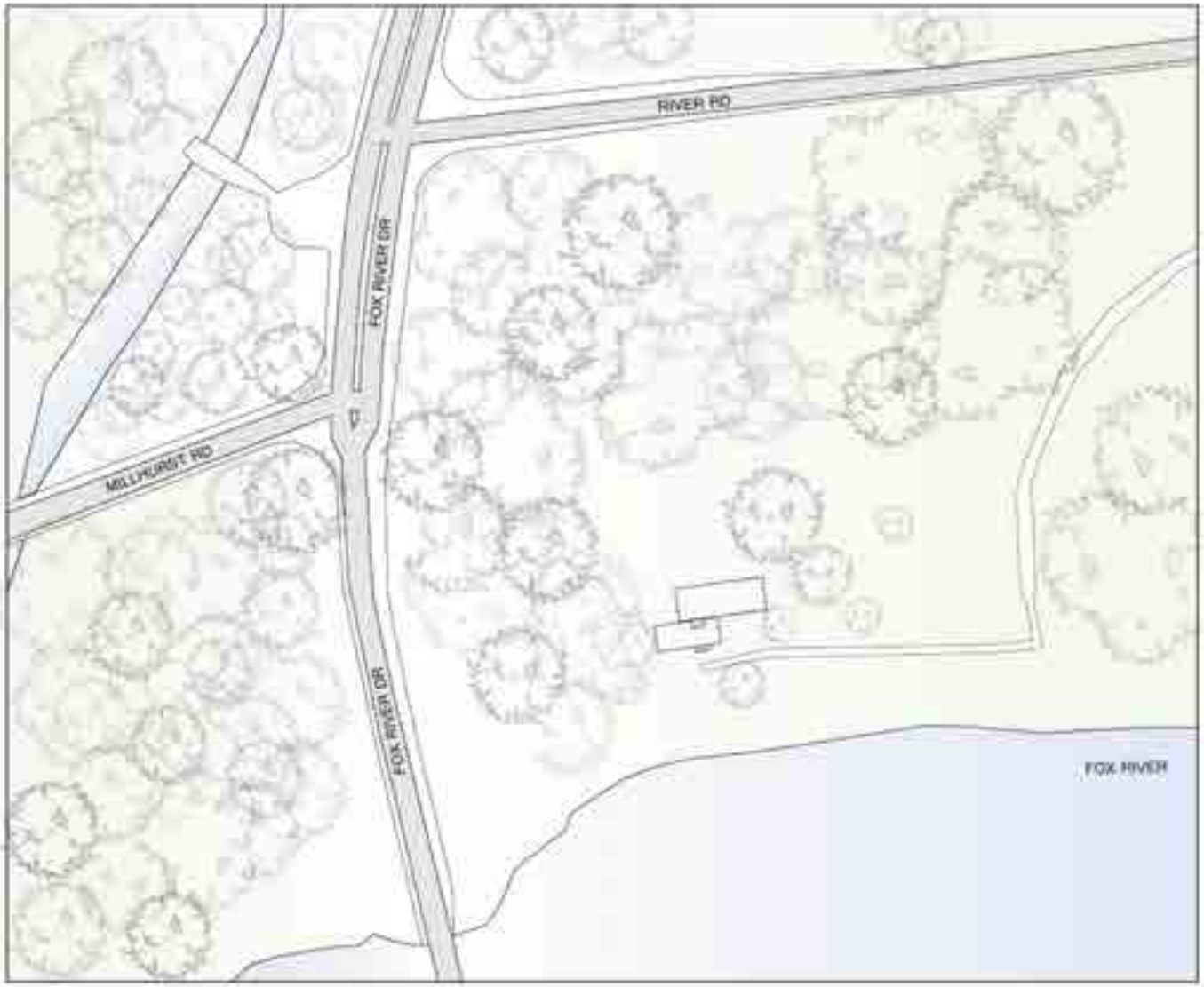

Lake Winnipeg
Gypsumville
Pineimuta Lake
Pinaymootang
Lake Manitoba
Winnipeg

SUMMARY

		Losses Avoided Ratio for Flood Depth			
Building Replacement Value	*Flood Mitigation Cost*	*0m*	*0.5m*	*1.0m*	*1.5m*
$70,000	$10,000 ($10 / sq.ft)	1.10	3.46	7.91	10.02
	$25,000 ($25 / sq.ft)	0.44	1.38	3.16	4.01
	$40,000 ($40 / sq.ft)	0.28	0.86	1.98	2.51
$120,000	$10,000 ($10 / sq.ft)	1.90	4.82	10.24	12.76
	$25,000 ($25 / sq.ft)	0.76	1.93	4.10	5.11
	$40,000 ($40 / sq.ft)	0.47	1.21	2.56	3.19
$250,000	$10,000 ($10 / sq.ft)	3.96	8.37	16.32	19.90
	$25,000 ($25 / sq.ft)	1.58	3.35	6.53	7.96
	$40,000 ($40 / sq.ft)	0.99	2.09	4.08	4.97



'PHIBIOUS FARNSWORTH

SITE PLAN

Static house, under normal conditions

Static house, during extreme flood

House with Buoyant Foundation System retrofit, during extreme flood

ANIMATION OF ASSEMBLY

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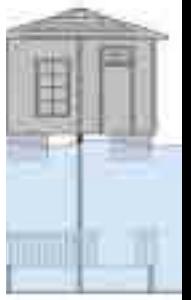
Farnsworth House / Amphibious Retrofit



'PHIBIOUS FARNSWORTH


ICAADE2017
THE SECOND INTERNATIONAL CONFERENCE ON
AMPHIBIOUS ARCHITECTURE, DESIGN AND ENGINEERING
June 25 - 28 2017
University of Waterloo
Waterloo, Ontario, Canada
www.icaade.org

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www.buoyantfoundation.org

ACKNOWLEDGEMENTS

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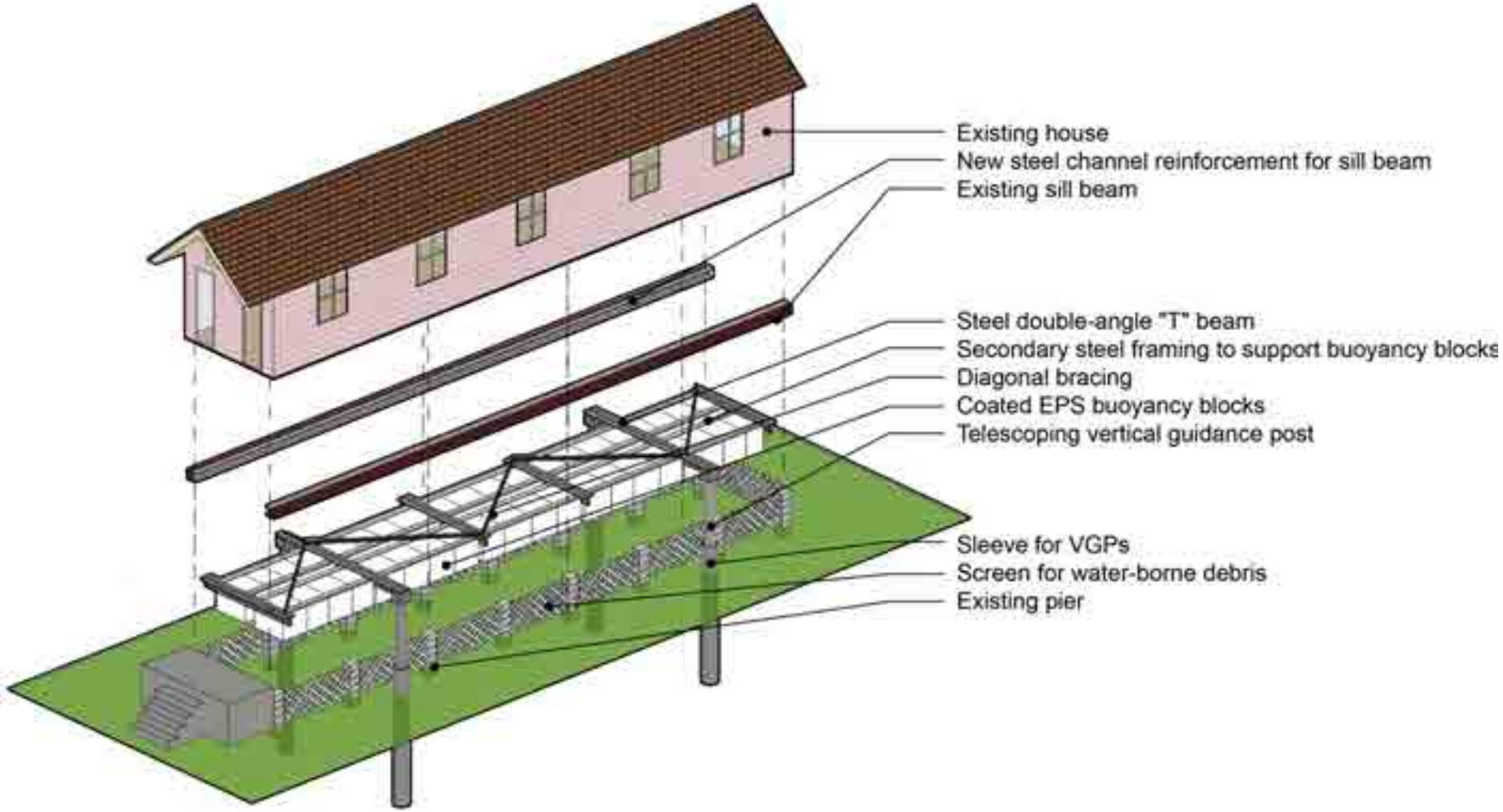
IDRC | CRDI

International Development Research Centre

Centre de recherches pour le développement international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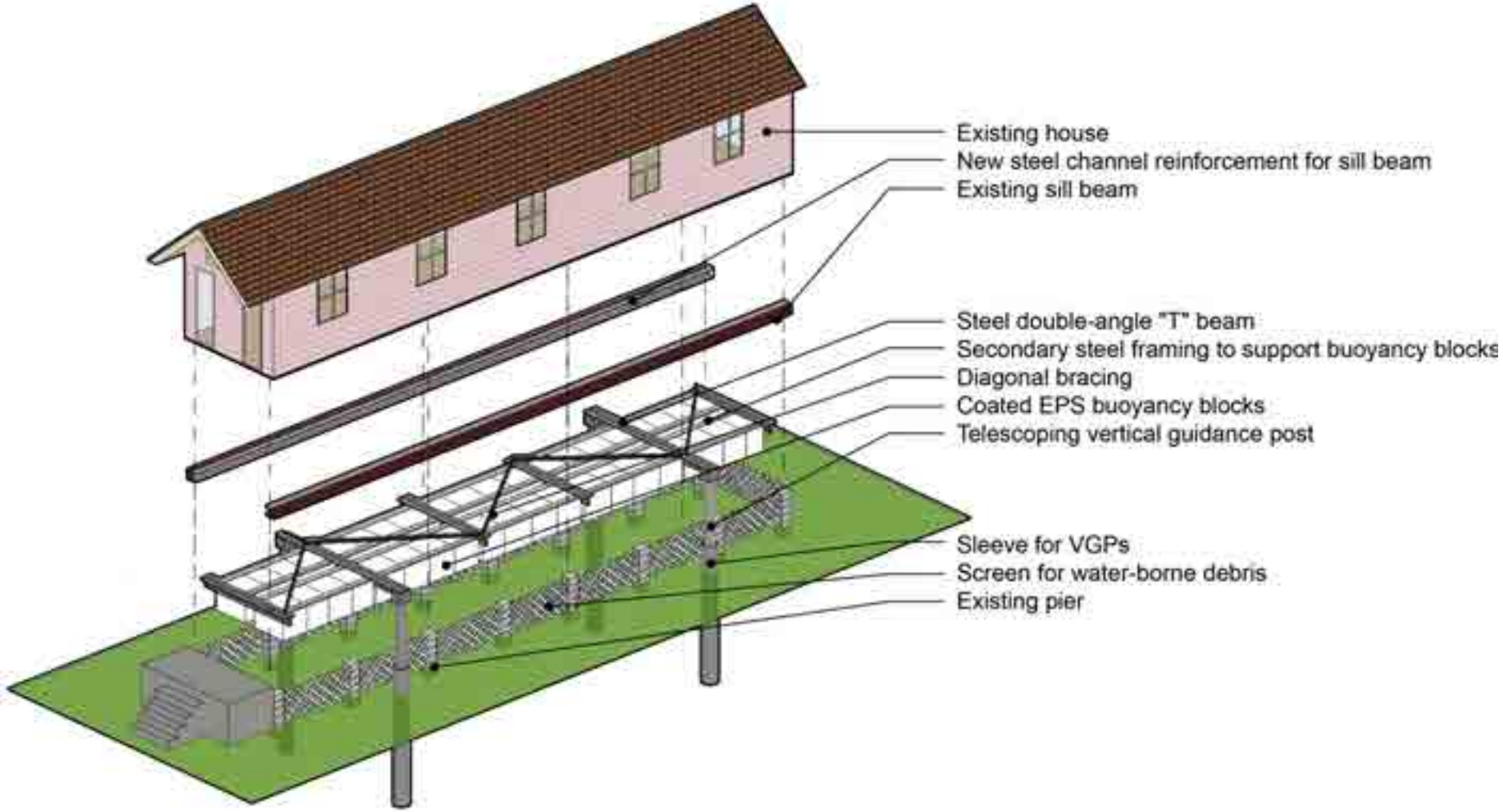
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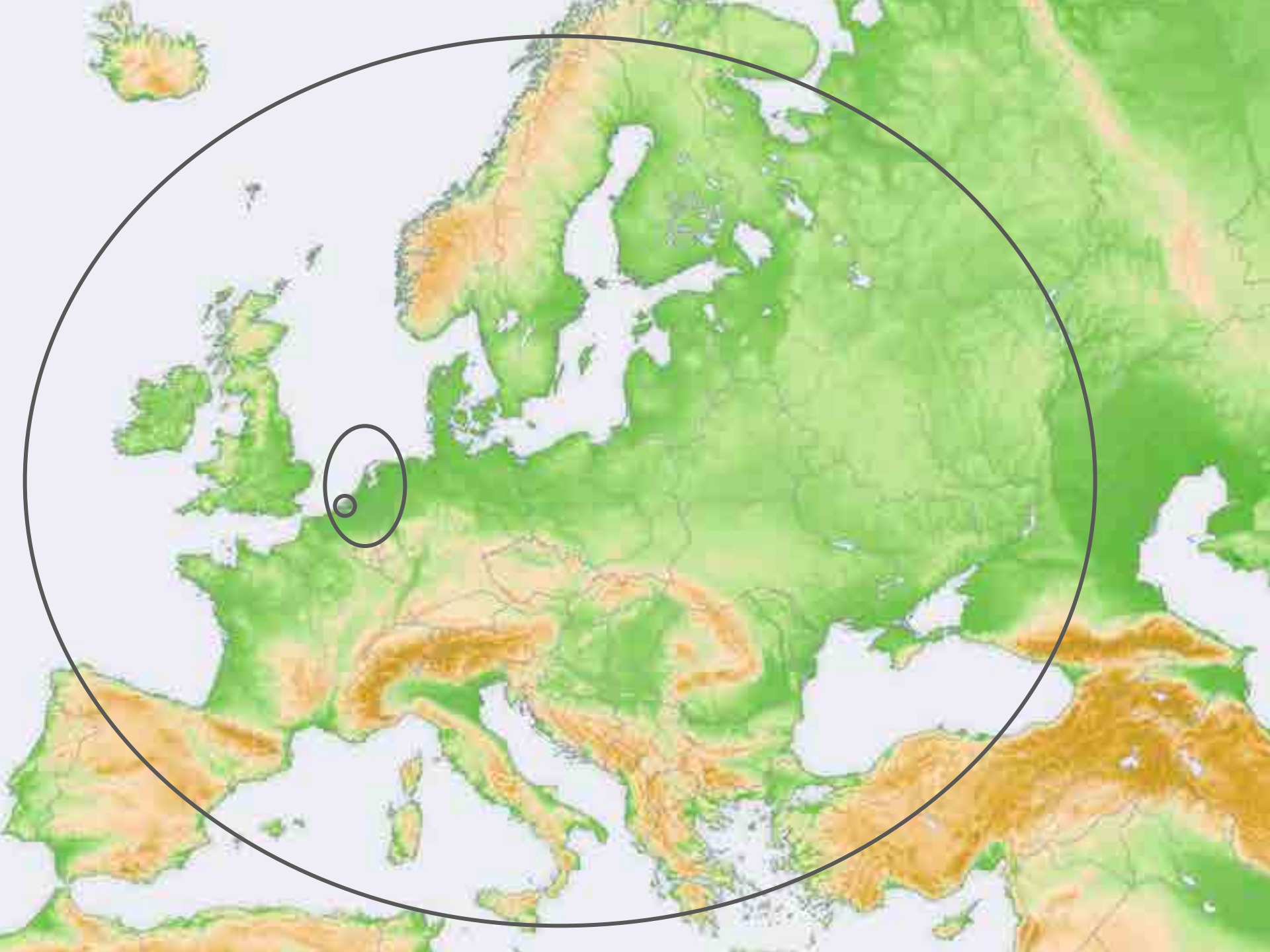

PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

PERMANENT STATIC ELEVATION OF HOUSES

- **Especially after Hurricanes Katrina and Sandy, the US Federal Emergency Management Agency (FEMA) has required many homeowners in flood-prone areas to elevate their houses in order to retain their eligibility for subsidized flood insurance policies from the National Flood Insurance Program (NFIP).**
- **NFIP is critically important in the US because banks require flood insurance as a precondition for providing mortgages to homes in flood zones.**

DISADVANTAGES OF PERMANENT STATIC ELEVATION

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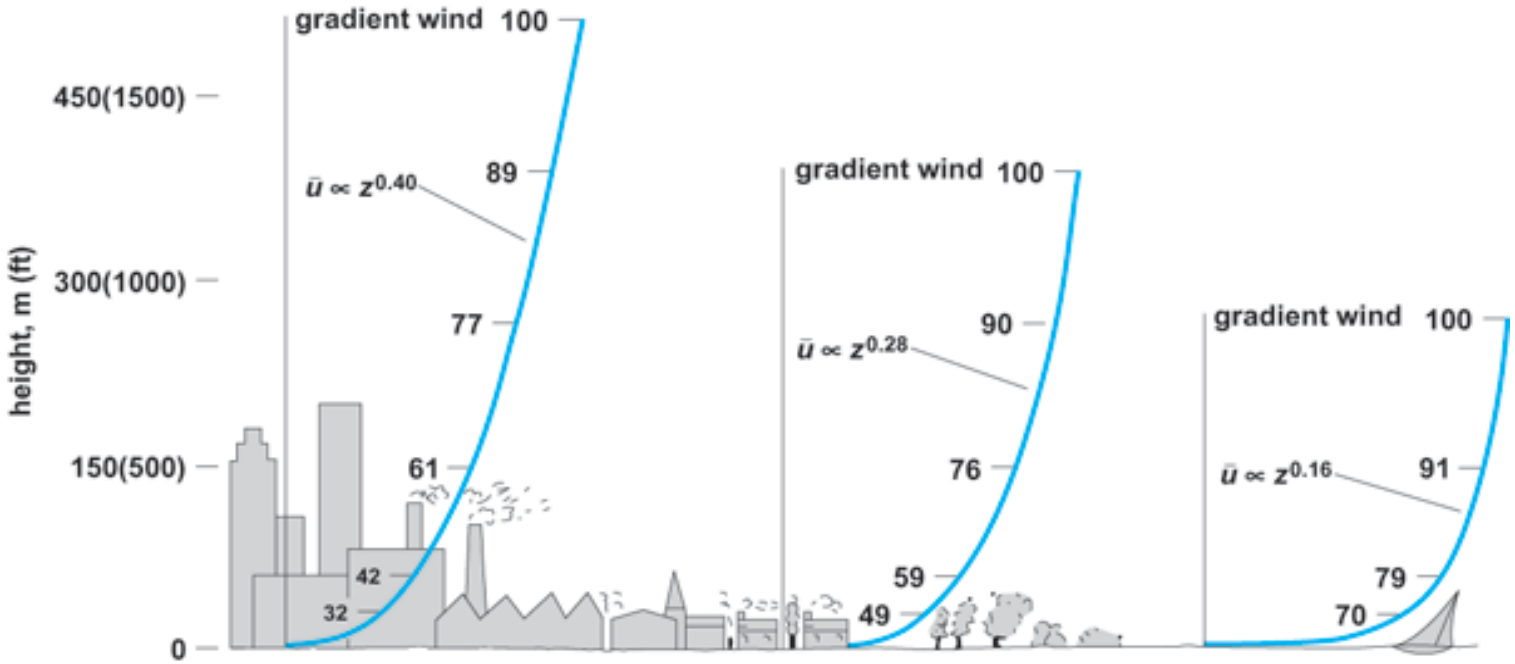
- **Provides insufficient protection from extreme flooding**
- **Increases vulnerability to wind damage**

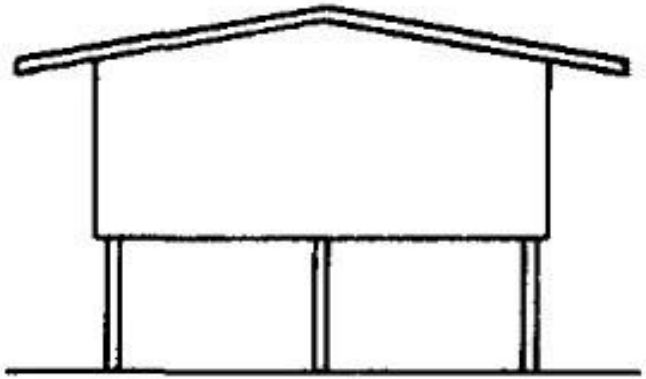
PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

Homes may be exposed to significantly higher wind speeds when elevated.



PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

John Holmes, "Wind Pressures on Tropical Housing":



"The higher pressure coefficients on the elevated house are combined with a dynamic pressure based on the mean velocity at eaves height which is 20-30% higher. Thus the *pressures* occurring in the same windstorm may be expected to be 40-80% higher on the elevated building. This may be why buildings of this type experienced considerably more damage during Cyclone 'Tracy' in Darwin, Australia (1974)."

[*Journal of Wind Engineering & Industrial Aerodynamics* 53.1-2 (1994): 105-23]

PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

Wind Loss – Economic Loss for Variable Roof Heights

- Based on methodology developed at LSU using Hazus-MH economic loss functions representing building, contents and loss of use.
- Loss functions for single story residential buildings are assumed to have a mean roof height (MRH) of 4 m.
- A new mean roof height loss function (L_{MRH}) is calculated from the Hazus 10-m loss function at the MRH wind speed using the power law.
- The MRH wind speed is calculated from the 10-m wind speed generated in the Monte Carlo simulation and used as input to the L_{MRH} to obtain the corresponding loss.

PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

Case Study – Preliminary Analysis

House with a 4m mean roof height will be elevated to a 10m mean roof height

Building Characteristics	
Stories	1
Structure	Wood Framing
Exterior	Siding
Primary Roof Shape	Gable
Roof Slope	6/12
SWR	No
Roof Deck Attachment	6d 6”/12”
Roof-Wall Connection	Toe-Nail
Garage Door	No
Shutter	No
Wind Speed Contour	72 m/s
Terrain	Open Terrain
Surface Roughness, z_0	0.03 m

Case Study	Mean Roof Height	EAL (%)
Current scenario	4 m	2.8%
Elevated scenario	10 m	4.9%

Increase in roof height wind speed 11%
Increase in wind pressure 19%
Increase in expected annual loss (EAL) 75%

This effect becomes more exaggerated the higher the structure is raised above the ground.

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