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A Loss Avoidance Study of Amphibious Housing

Snehanjali Sumanth[a], Elizabeth English[b]

[a]University of Waterloo School of Architecture, 7 Melville St. S, Cambridge, ON N1S 2H4, [b]University of Waterloo School of Architecture, 7 Melville St. S, Cambridge, ON N1S 2H4

Abstract

Louisiana's coastline is losing wetlands at a rate if 16.57 square miles a year, equal to the loss of a football field of coast every hour." Located outside the boundaries of Louisiana's levee system, five major hurricanes and the BP oil spill have slowly eroded Leeville. Since 1932, Leeville has lost approximately 70% of its land area. This paper looks at the benefits of implementing flood mitigation systems in Leeville by conducting a Loss Avoidance Study* for a house that is being fitted with a Buoyant Foundation. Buoyant Foundations are a type of Amphibious foundation that allow an otherwise fixed structure to float on rising floodwater and prevent it from getting damaged due to the forces of floodwater. By conducting this study, we can understand the benefits of implementing buoyant foundations in areas prone to intense floods such as Leeville and encourage further use of this technology as a method of flood mitigation.

Keywords: Leeville, Louisiana, flood mitigation, levee, loss avoidance study, Amphibious Architecture, Buoyant Foundation, Pre-Mitigation Flood Depth, Building Losses, Contents Losses, Displacement Costs

1. Introduction

1.1.Leeville

Leeville is located in southern Louisiana between Port Fouchon, the largest oil port in the United States and Golden Meadow, the first town within the levee system. At one point, Leeville was a vital connecting point from Port Fouchon to Golden Meadow through LA-1, a state highway in Louisiana. However, a recent constriction of an elevated highway which will eventually connect Port Fouchon directly to Golden Meadow bypasses Leeville, completely isolating it outside the boundaries of the levee system. Leeville was once lush with orange groves and cotton fields, but years of storm surges and the influence of the oil industry has weathered away its surface to give way to wetlands that are marked with inlets of water.

Oil was discovered in Leeville in the 1930's and led to an industrial boom in a town once known for its orange groves. In 1960, Port Fouchon, now the largest oil port in the country, accelerated the influence of oil on Leeville and it served as a vital connection point to Port Fouchon through the LA-1. However, the boom surpassed Leeville, isolating it and causing its current degradation. After Hurricane Ike struck in 2008, washing out the LA-1, construction on an elevated highway began and cut Leeville off as a connecting point to Port Fouchon. The elevated highway is expanding to run past the levee system, further isolating Leeville. A canalization system servicing the early oil industry and aiding fishing access creates more edge area in the interaction between land and water as it allows for sediments to be eroded from the depths of the land.

Fig. 1. Past and Future Land Maps of Leeville (LA1 Coalition, 2012)

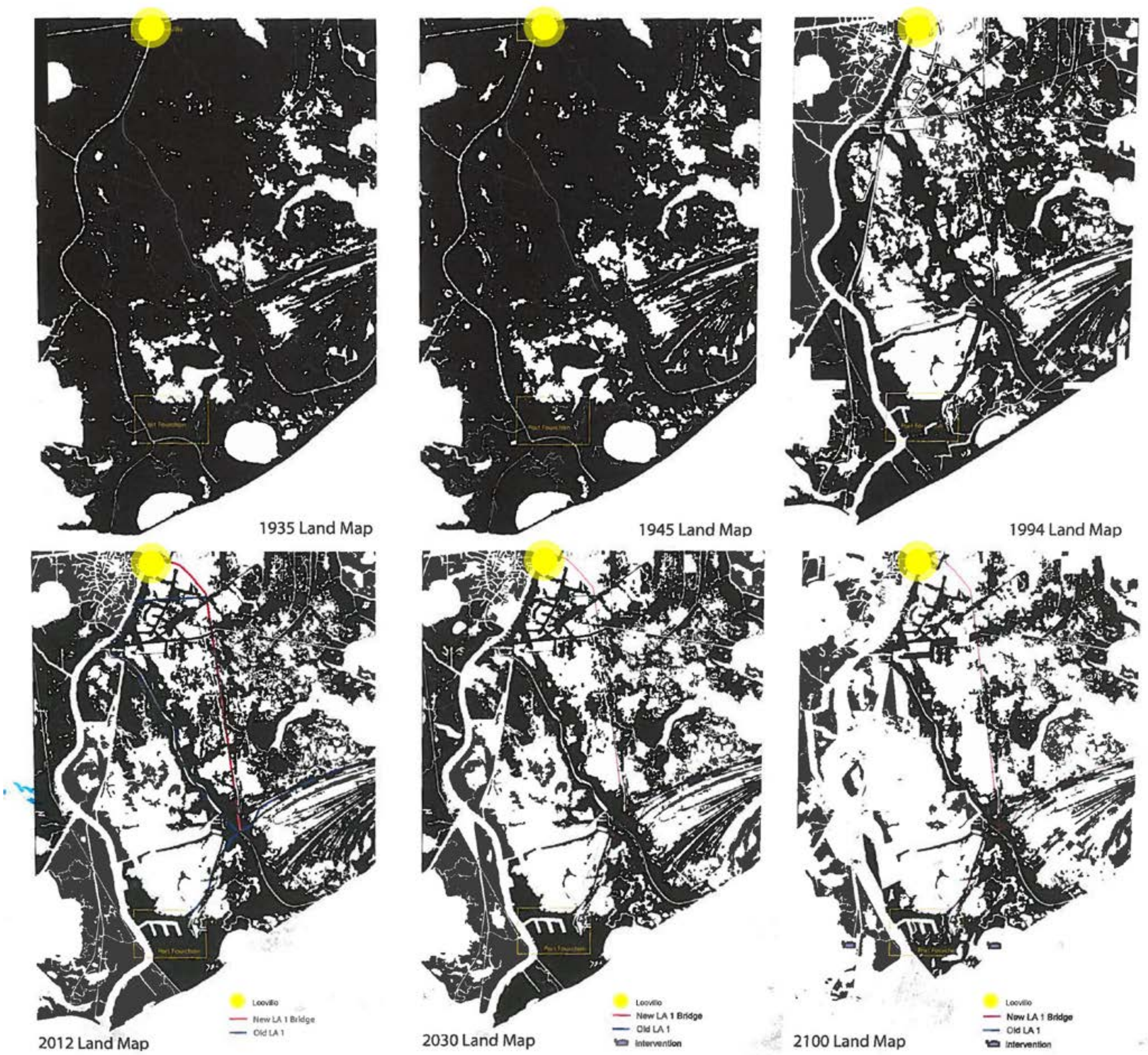

Fig. 2. Past and Future Land Maps of Leeville (Doyle, 2014)

Fig. 2. Leeville, Louisiana (Author: Ivee Wang, University of Waterloo)

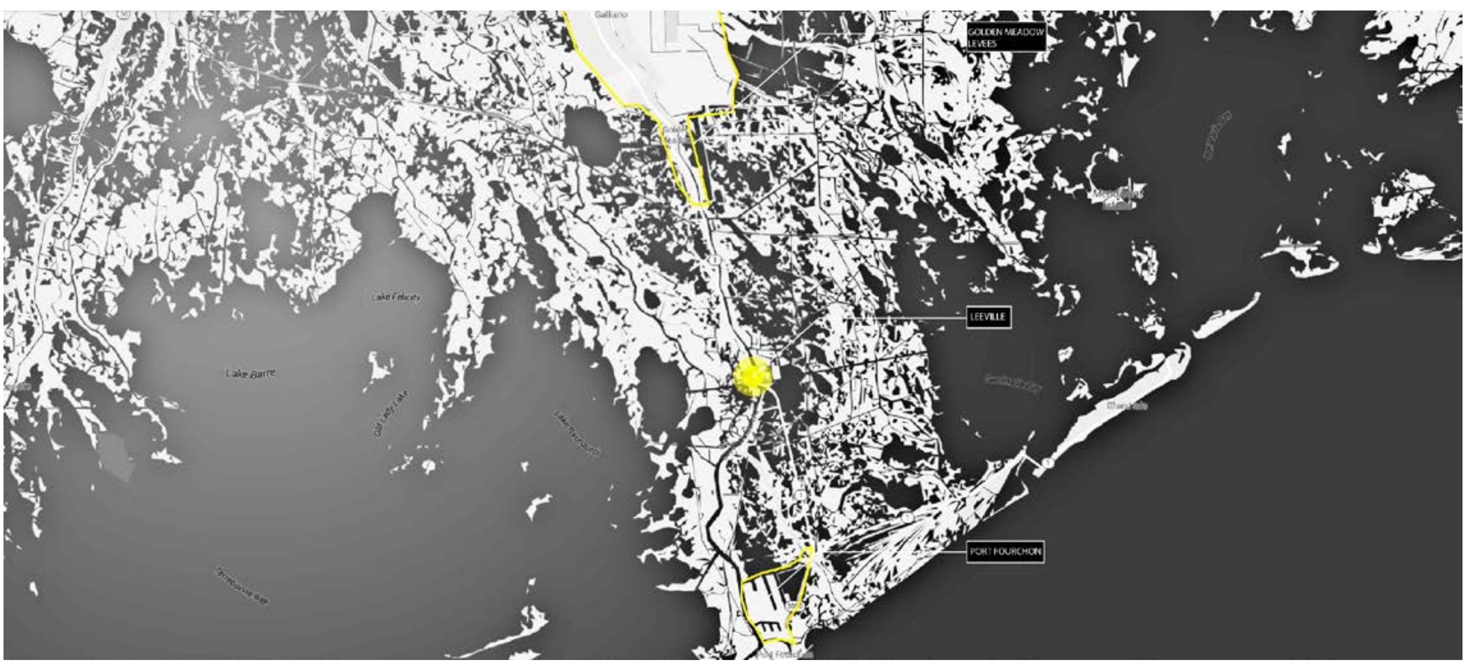

Fig. 3. Leeville, situated outside the levee system and on-route to Port Fouchon (Author: Ivee Wang, University of Waterloo)

Another set of industries that also contains a large social aspect of Leeville is its fishing and ice industry. These industries that thrive on an edge condition of land and water are now the driving industries of a land once cherished by oil but now left behind, tarnished by it. With the alarming rate of disappearing wetlands, Leeville will begin to battle staying afloat and maintaining its connection with the network of industry and electricity infrastructure that lies behind the levee system.

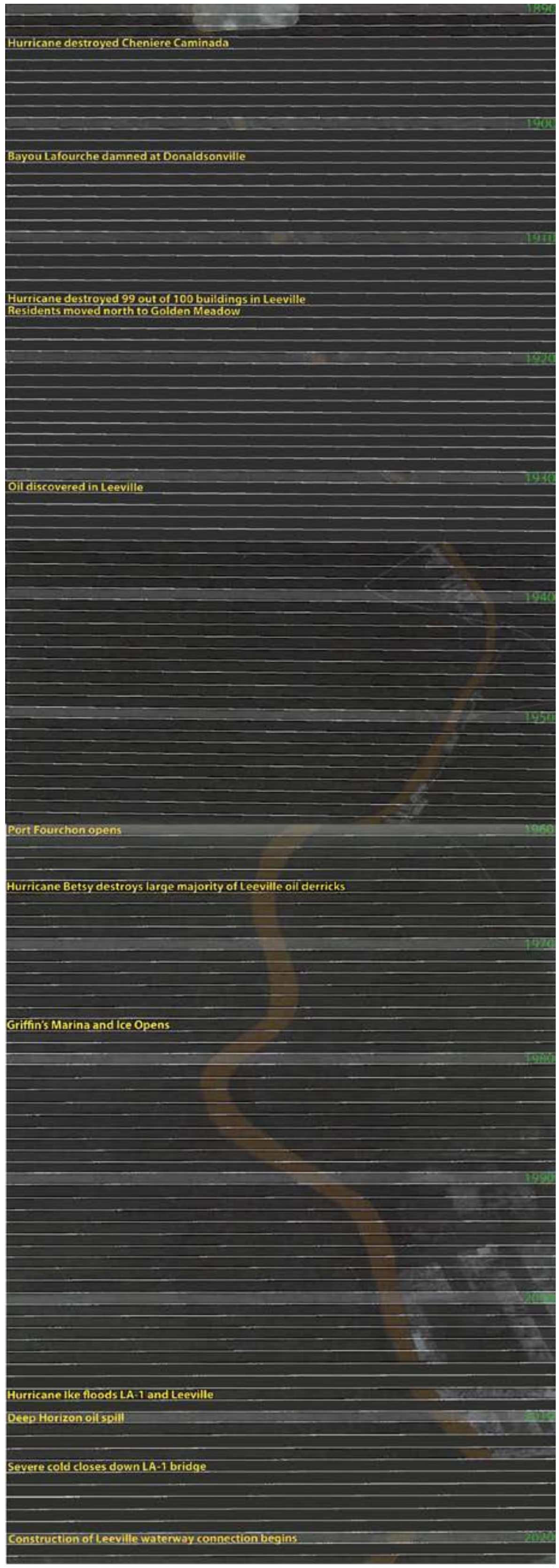

Fig. 4. Timeline of Leeville (1890 - 2020) (Doyle, 2014)

1.2. Amphibious Architecture

Amphibious architecture refers to an alternative flood mitigation strategy that allows an otherwise-ordinary structure to float on the surface of rising floodwater rather than succumb to inundation. An amphibious foundation retains a home's connection to the ground by resting firmly on the earth under usual circumstances, yet it allows a house to float as high as necessary when flooding occurs (The Buoyant Foundation Project). 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. Amphibious construction is a flood mitigation strategy that works in synchrony with a flood prone region's natural cycles of flooding, rather thank attempting to obstruct them. Amphibious foundations make homes resilient; resilient homes are the bases for resilient communities.

1.3. Buoyant Foundation

A buoyant foundation is a particular type of amphibious foundation that is specifically designed to be retro-fitted 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 guideposts that prevent the house from going anywhere except straight up and down, and a structural sub-frame that ties everything together. It basically works like a floating dock. A steel frame that holds the flotation blocks is attached to the underside of the house. The posts that provide vertical guidance are installed not far from the corners of the house. Utility lines have either self-sealing 'breakaway' connections or long, coiled 'umbilical' lines. When flooding occurs, the flotation blocks lift the house and the vertical guideposts resist any lateral forces from wind and/or flowing water. Any house that can be elevated can be made amphibious. (English, 2009)

2. A Case Study - The Buoyant Foundation Project

The Buoyant Foundation Project has documented and studied a house in Leeville to begin working on installing a Buoyant Foundation. This house will serve as a case study in a Loss Avoidance Study for implementing Buoyant Foundations in Leeville. The site is situated along Old Highway 1, a road that runs through the middle of Leeville. It sits with its back to Bayou Lafourche. The house is a 1086 square foot rectangular base and is elevated off the ground from 17” to 24” along the rising slope.

Fig. 4. Case Study House Location (Author: Ivee Wang, University of Waterloo)

Fig. 5. (a) Current house conditions; (b) Render of elevated house during flood after installation of a Buoyant Foundation (Author: Ivee Wang, University of Waterloo)

3. Loss Avoidance Study

A loss avoidance study is a technical assessment of a property fitted with flood mitigation technology and determining what losses would have occurred has it not been retrofitted. It is a comparative study that is measured in dollars and proves the success of implementing flood mitigation technologies (Bourdeau, 2015).

In this paper, I will be conducting a Loss Avoidance Study for the house described above. It is currently under design development for a buoyant foundation retrofit.

3.1.Current Conditions

This Loss Avoidance study will be conducted by comparing the losses in a scenario of flooding in its current condition - elevated off the ground from 17” to 24” - with the costs of fitting the house with a buoyant foundation.

3.2.Pre-Mitigation Flood Depth

This is the flood depth that would occur with the house in its current condition (elevated off the ground 17”-24”). This can be found by subtracting the height of the Finish Floor Elevation before mitigation (FFE) from the High Water Mark (taken from analyzing data of previous flood conditions). Three High Water Marks will be used in the Loss Avoidance Study to determine the success of installing a Buoyant Foundation System.

Table 1. High Water Marks and Pre Mitigation Flood Depths for FFE = 3ft

High Water Mark	Pre Mitigation Flood Depth
4.5 ft	*1.5 ft*
6 ft	*3 ft*
7.5 ft	*4.5 ft*

4. Three Categories of Losses Avoided

The LAS looks at three categories of losses that can be avoided if the house was fit with a buoyant foundation:

- Building Repair Costs
- Contents Losses
- Displacement Costs

4.1.Depth of Damage Calculation for Building Repair Costs

Building Repair Costs look at the Building Replacement Value to understand the losses that occur through damage to structural, electrical, mechanical, drywall, cabinets and flooring. To calculate the total sum of losses avoided in building repair costs, the Building Replacement Value, Square Footage and Flood Depth need to be determined and then assessed using a Depth of Damage Calculation.

- Building Replacement Value (BRV) = $70,000
- Square footage (SF) = 1084 sq.ft

Table 2. Residential Building Depth Damage Function (Bourdeau, 2015)

Building Type	1 Story without Basement	2 Story without Basement	Mobile Home
Flood Depth in Feet	*Percent Damage*	*Percent Damage*	*Percent Damage*
-1.5 ≤ > -0.5	2.5	3	0
-0.5 ≤ > 0.5	*13.4*	9.3	8
0.5 ≤ > 1.5	***23.3***	15.2	9.4
1.5 ≤ > 2.5	32.1	20.9	63
2.5 ≤ > 3.5	***40.1***	26.3	73
3.5 ≤ > 4.5	***47.1***	31.4	78

To calculate the building repair costs, the depth of damage percent acquired from Table 2 is multiplied by the Building Replacement Value of $70,000. The percent damage for each pre mitigation flood depth is marked in red in Table 2.

Table 3. Depth of Damage Calculation for BRV = $70,000

Pre Mitigation Flood Depth	Percent Damage	Building Repair Costs
Flood Depth in Feet	*Percent Damage*	*Cost in dollars*
1.5	23.3	**16,310**
3	40.1	**28,070**
4.5	47.1	**32,970**

4.2.Depth of Damage Calculation for Contents Losses

Calculating the Contents losses gives us the cots of repairing damages that occurred to furniture, appliances, electronics, equipment, clothing, power tools and lawn mowers. To calculate losses occurred through damage to contents, the Contents Value (CV) of the house must be determined. Its value is estimated to be 30% of the Building Replacement Value (BRV)

- Building Replacement Value (BRV) = $70,000
- Contents Value (CV) = 30% of BRV
  = 0.3 x $70,000
  = $21,000

The derived CV is then plugged into a Contents Depth Damage Function:

Table 4. Contents Depth Damage Function (Bourdeau, 2015)

Building Type	1 Story without Basement	2 Story without Basement	Mobile Home
Flood Depth in Feet	*Percent Damage*	*Percent Damage*	*Percent Damage*
-1.5 ≤ > -0.5	2.4	1	0
-0.5 ≤ > 0.5	8.1	5	12
0.5 ≤ > 1.5	***13.3***	8.7	66
1.5 ≤ > 2.5	17.9	12.2	90
2.5 ≤ > 3.5	***22***	15.5	90
3.5 ≤ > 4.5	***25.7***	18.5	90

Table 5. Depth of Damage Calculation for CV = $21,000

Pre Mitigation Flood Depth	Percent Damage	Building Repair Costs
Flood Depth in Feet	*Percent Damage*	*Cost in dollars*
1.5	13.3	**2,793**
3	22	**4,620**
4.5	25.7	**5,397**

4.3.Depth of Damage Calculation for Displacement Costs

These are the costs required to provide living expenses while homeowners are out of the house while re- pairs are being made. This includes rental expenses and meals. Displacement costs are based on the average house- hold size of 2.70 people[1] and on the GSA per-diem rates for lodging and meals in SE Louisiana.

Displacement Costs/ day (DC) = Lodging Costs/day + Meals/day = $88 + $49/person x 2.70

= **$220.30 /day**

For a household size of 2.70 people, the Displacement Costs would be $220.30/day

To derive the number of days displaced, a Displacement Depth Damage Function is used:

Table 6. Displacement Depth Damage Function (Bourdeau, 2015)

Flood Depth in Feet	*Displacement in Days*
0.5 ≤ > 1.5	45
1.5 ≤ > 2.5	***90***
2.5 ≤ > 3.5	***135***
3.5 ≤ > 4.5	***180***
4.5 ≤ > 5.5	225

Table 7. Depth of Damage Calculation for DC = $220.30/day

Pre Mitigation Flood Depth	Displacement	Displacement Costs
Flood Depth in Feet	*Displacement in Days*	*Cost in dollars*
1.5	90	**19,827**
3	135	**29,740.50**
4.5	180	**39,654**

4.4.Total Losses Avoided

The Total Losses Avoided is determined by adding the three categories of losses avoided.

The Total Losses Avoided for a flood depth of 1.5 feet:
Total Losses Avoided = $16,310 + $2,793 + $19,827
= **$38,930**
So, the Depth of Damage due to Displacement Costs is **$38,930**

The Total Losses Avoided for a flood depth of 3 feet:
Total Losses Avoided = $28,070 + $4,620 + $29,740.50
= **$62,430.50**
So, the Depth of Damage due to Displacement Costs is **$62,430.50**

The Total Losses Avoided for a flood depth of 4.5 feet:
Total Losses Avoided = $32,970 + $5,397 + $39,654
= **$62,430.50**
So, the Depth of Damage due to Displacement Costs is **$78,021**

5. Mitigation Costs

The elements of a Buoyant Foundation used when retrofitting an existing house and their costs as applied to this house are as follows:

- Vertical Guidance Posts = $8,600
- Dock floats = $14/sq.ft
- Marine Plywood = $5.5/sq.ft
- Hurricane ties and fasteners = $0.5/sq.ft

Cost of retrofitting with a Buoyant Foundation System = ($14 + $5.5 + $0.5)/sq.ft + $8,600
= $30,280
So, the cost of retrofitting this house with a Buoyant Foundation is **$30,280**

6. Losses Avoided vs. Cost of Mitigation

The Losses Avoided ratio is the ratio of the calculated Losses Avoided to the calculated Mitigation cost. A ratio greater than one indicates that the applying the mitigation strategy to the house in question is greatly beneficial and performing successfully.

Losses Avoided Ratio = Losses Avoided / Mitigation Cost

For a flood depth of 1.5 feet = $38,930 / 30,280
= 1.28

For a flood depth of 3 feet = $62,430.50 / 30,280
= 2.06

For a flood depth of 4.5 feet = $78,021 / 30,280
= 2.58

7. Conclusion

A Losses Avoided Ratio that is greater than 1 is already indicative of the success of implementing a buoyant foundation system as a flood mitigation technique. This study is a cost comparison of the effects of flooding on a house with and without a buoyant foundation system, but does not take into account other benefits of implementing this system, including not having to evacuate the house as well as not having to repair and replace the house and its contents. This ratio also captures the success of a one time flood, but as seasonal flooding approaches every year, the implementation of a buoyant foundation greatly benefits the house.

The success of the system increases as the intensity of the flood increases. As seen in the calculations, the higher flood depths have a higher loss avoidance ratio. So, even as the flooding increases, the house remains intact for the same price of retrofitting.

In Conclusion, this study shows that implementing a buoyant foundation as a flood mitigation technique on this property in Leeville is extremely beneficial and cost effective. The return on implementing this system is not only the better option financially but also provides relief in facing the damage and despair caused by constant flood surges.

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