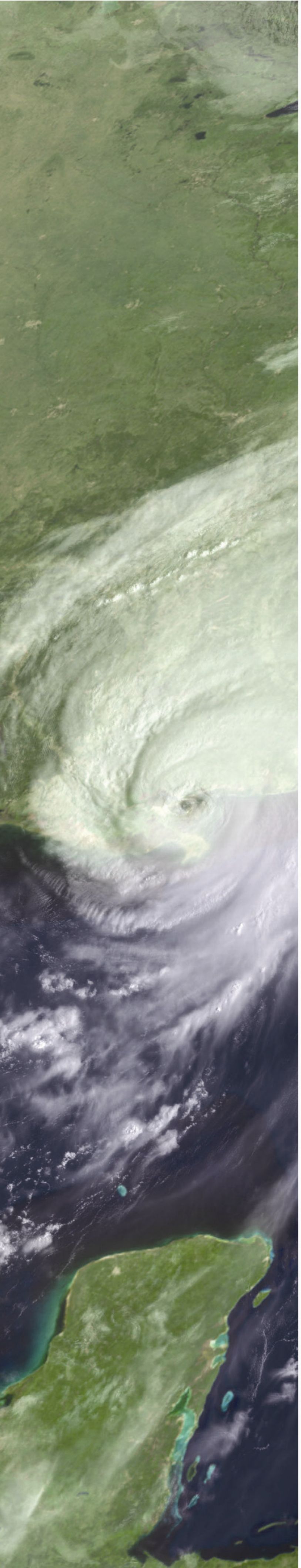

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2008 Supplement to the 2006 Evaluation of the National Flood Insurance Program's Building Standards

Introduction

The purpose of this analysis was to provide a supplement to the *2006 Evaluation of the National Flood Insurance Program's Building Standards*[1] and, further, to determine the cost-effectiveness of including freeboard[2] within the foundation height of new residential buildings constructed in floodplains. The incorporation of freeboard will effectively reduce the potential flood risk to the building. This analysis was conducted to determine the benefits associated with constructing coastal houses higher than the current National Flood Insurance Program (NFIP) requirements mandate. In addition, the analysis was conducted to establish which factors should be considered when determining how many feet above the minimum required elevation a house should be constructed at in order to maximize the cost-effectiveness of the additional height.

The report will demonstrate the cost-effectiveness of utilizing additional freeboard in the construction of a house and point out the factors that impact the cost-effectiveness of freeboard. Foundation types, house size (i.e., layout) variations, flood hazard conditions, and costs of construction were all evaluated in order to determine which factors should be specified as the primary considerations in determining how much freeboard is economically justified. In almost all situations studied, freeboard proved cost-effective for both 1 and 2 feet above the minimum requirements. In some situations, 3 and 4 feet of freeboard were still deemed cost-effective. In addition to cost-effectiveness, a general discussion of risk reduction (i.e., damages avoided) is provided, as well as some of the engineering considerations that should be evaluated when selecting the appropriate foundation type.

Background

The NFIP was instituted by congressional order in 1968 to assist in regulating floodplains. The NFIP divides the Special Flood Hazard Area (SFHA – 1-percent annual chance floodplain) into V Zones (i.e., areas of high-velocity wave action) and A Zones (i.e., some wave action, but primarily inundation and low-velocity floodwaters). Due to the differences in risks associated with these zones, this report will use these zones as a method of differentiating flood risk levels and as a proxy for different methods of construction. It is also important to further differentiate the risk level within different portions of the A Zone. The A Zone has been subdivided into the Coastal A Zone and the A Zone (see **Figure 1**). Each of these zones is defined by the depth of the stillwater and wave height during a design event flood.

The design event used for designation of the zones is a flood event with the annual probability of exceedance of 1 percent. The 1-percent annual chance flood event is

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[1] *Evaluation of the National Flood Insurance Program's Building Standards*, American Institutes for Research, Christopher P. Jones, William Coulbourne, Jamie Marshall, and Spencer M. Rogers, Jr., December 2006.

[2] Freeboard is defined by the American Society of Civil Engineers (ASCE) in ASCE 24-05, *Flood Resistant Design and Construction*, as "additional height used as a factor of safety in setting the minimum elevation of a structure, or floodproofing measures applied to a structure, to compensate for factors that may increase flood heights and for uncertainties inherent in determining flood frequencies and flood elevations."

commonly referred to as the 100-year flooding event. However, in order to avoid confusion, the annual percent chance will be used throughout this report. The stillwater elevation plus the wave heights is referred to as the "base flood elevation" (BFE). The term "BFE" is used throughout the report to designate the minimum elevation of construction allowed by the NFIP.

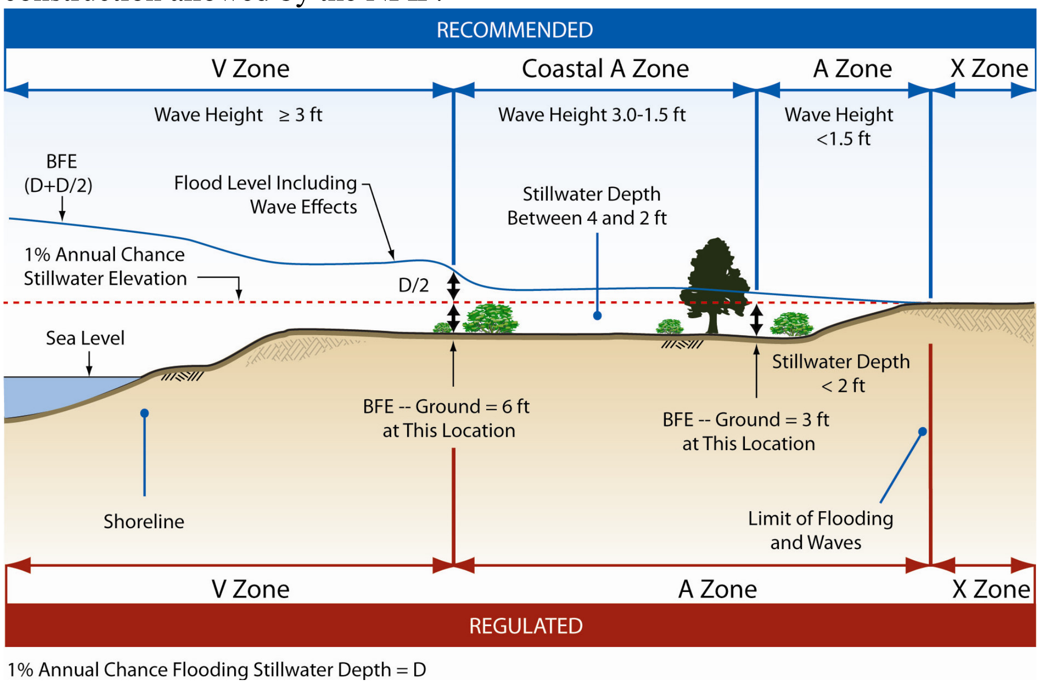


Figure 1 | Coastal Floodplain Zones

The NFIP requires that buildings built within V Zones are constructed to a height such that the bottom of the lowest horizontal structural member supporting the lowest floor is located at the BFE. When buildings are located within Coastal A and A Zones, the NFIP requires that they only have the top of the lowest floor located at the BFE. The focus of this report is to quantify the benefits of building additional foundation height above the BFE in order to reduce the risk of flooding. This additional height is referred to as "freeboard" and is typically evaluated in 1-foot increments.

One reason freeboard was introduced into building codes was to account for the inherent uncertainties associated with flood maps. Flood maps reflect the data collected at the time of mapping and should be considered a "snapshot in time." Changes to the land following the mapping (development or erosion) can drastically impact stillwater elevations and wave heights. It should also be noted that the elevations shown on a coastal flood map have been rounded to the nearest whole foot. Therefore, there is the potential that the modeled flood height is slightly higher than what is shown on the map. In addition, freeboard can provide protection against changes in water elevation due to sea-level rise. These uncertainties associated with flood maps do not make them flawless, but the information contained in them should be considered credible nonetheless.

Freeboard requirements may be dictated by local building codes or floodplain management ordinances, and the use of 1 foot of freeboard has been included in the 2009 version of the International Residential Code (IRC) for V Zones and Coastal A Zones. Although the use of freeboard is not required by all local authorities, it remains important to consider that the additional height above the BFE may provide financial benefits based upon reduced flood insurance premiums. The reduced flooding risk is reflected in those flood insurance premiums and, as consumers become more educated on the benefits of freeboard, the additional height may offset the initial cost of construction. The report is designed to evaluate for a homeowner the relationship between the increased costs of construction for freeboard versus future savings from reduced flood damage and reduced flood insurance premiums.

Study Parameters

The study was conducted using similar data to the *2006 Evaluation of the National Flood Insurance Program's Building Standards*. Four house layouts were selected (See **Table 1**) and then multiple foundations were evaluated for each house layout (See **Table 2**). The foundations were evaluated at multiple elevations above BFE and evaluated against a house constructed at BFE or a baseline structure. The house foundation costs were evaluated in each flood zone and modeled using a foundation that is allowable within those particular flood zones, based upon NFIP regulations. These houses were further evaluated in multiple flooding situations, based upon data from different coastal locations around the United States in order to determine whether the changes in flooding characteristics and local construction costs impacted the cost-effectiveness of the construction above BFE.

Table 1 | Baseline Building Parameters

Building Case	Length (ft)	Width (ft)	Number of Stories	Footprint Size (sf)	Building Size (sf)
1	50	30	1	1,500	1,500
2	50	30	2	1,500	3,000
3	60	40	1	2,400	2,400
4	60	40	2	2,400	4,800

Table 2 | Flood Zones and Foundation Types Analyzed

Flood Hazard Zone	Building Sizes	Foundation Types	Lowest Floor Elevation (ft)	Flood Conditions	Building Combinations Analyzed
V	4	Timber Pile Concrete Pile Masonry Pier	BFE BFE + 1 BFE + 2 BFE + 3 BFE + 4	4 Location Scenarios	192
Coastal A	4	Timber Pile Concrete Pile Masonry Pier 8" Masonry Pier 12" Masonry Pier Fill and Concrete Slab-on-Grade	BFE BFE + 1 BFE + 2 BFE + 3 BFE + 4	4 Location Scenarios	384

A	4	Timber Pile Concrete Pile Masonry Pier 8” Masonry Pier 12” Masonry Pier Fill and Concrete Slab-on-Grade	BFE BFE + 1 BFE + 2 BFE + 3 BFE + 4	4 Location Scenarios	384

Development of Data

Each of the foundations designs were developed using the FEMA 550, *Recommended Residential Construction for the Gulf Coast*. This document provided foundation assumptions for each of the foundation types. The soil in all scenarios was assumed to be dense sand in all locations. Scour was assumed in both V Zones and Coastal A Zones. Sour is common in areas of high water velocities or more generally the V and Coastal A Zones. When utilizing timber piles, concrete piles and masonry piers it was assumed that adjustments to the size or number of piles/piers would be required based upon the size and height of the house. These modifications were dictated by the combination of foundation heights and foundation material properties.

In order to comply with applicable NFIP regulations in the V Zones the lowest horizontal structural member was set to the BFE for the baseline houses. The houses in the Coastal A and A Zones were modeled so that their baseline elevation was the top of the first floor which was constructed to BFE. All of the remaining house models were developed in 1-foot increments up to 4 feet above BFE or baseline model.

Table 3 illustrates the percent increases in the cost of construction when freeboard is included into the design of a structure.

Table 3| Percent Increases in Cost of Construction for Freeboard

Flood Zone	Freeboard (ft)	Cost of Freeboard (% increase)
V Zone	**BFE + 1**	**0.4–1.8**
	BFE + 2	**0.8–3.6**
	BFE + 3	**1.3–5.4**
	BFE + 4	**1.7–7.2**
Coastal A Zone	**BFE + 1**	**0.5–3.9**
	BFE + 2	**0.7–4.8**
	BFE + 3	**1.1–6.1**
	BFE + 4	**1.4–8.1**
A Zone	**BFE + 1**	**0.2–2.3**
	BFE + 2	**0.3–4.5**
	BFE + 3	**0.7–6.8**
	BFE + 4	**0.9–9.1**

Cost Models Utilized:
The costs for each house were developed by calculating the approximate cost for each of the four baseline structures and then removing the cost of the foundation elements. The costs to construct each of the foundations were calculated using RSMeans 2008 cost data and then added back to each of the houses (to represent the structure above the foundation). The difference between the cost to construct the house at BFE and the costs associated with constructing the house with each freeboard scenario was used in order to run the Benefit-Cost Analysis (BCA).

A range of construction location factors from approximately .80 to 1.20 (1.0 = the national average) were applied to the various locations in order to evaluate the impacts of various construction costs on the cost-effectiveness of freeboard. The various locations also provided opportunities to evaluate the influence that the Community Rating System (CRS) classification might have upon the cost-effectiveness of freeboard. CRS ratings between 7 and 9 were used in the analysis.

Flood Insurance Premiums
Each structure was evaluated using a flood insurance premium model based upon 2008 flood insurance premium rate tables. 2008 NFIP flood insurance premium data was collected and a simplified chart was developed in order to assess each house a flood insurance premium. The chart also evaluated the reduced premiums associated with increases in freeboard. In order to determine the potential benefits associated with freeboard, the maximum allowable coverage was calculated for each house—for both the structure and its contents. Flood insurance premiums were calculated to be the value of the structure up to a maximum of $250,000 and, for the contents, 30 percent of the building replacement value up to a maximum of $100,000. An approximate contents value of 30 percent of the building replacement value was utilized. Although the 30-percent value reflects past FEMA guidance, this value is being evaluated and, in instances where the contents value is documented to be higher, an increased value can be applied. Due to the contents value not being applied to the construction cost, this assumption would provide additional benefits if the house was constructed higher and flooding damage was prevented. As stated above, the CRS classification was evaluated in the study and discounts to flood insurance premiums were evaluated in order to determine the potential impacts of the CRS classification to the overall cost-effectiveness of including freeboard.

Data Analysis
In order to compare the benefits associated with constructing the houses at each freeboard scenario, the FEMA *Mitigation BCA Toolkit* was used to evaluate the cost-effectiveness of construction of the additional freeboard height. Both Versions 2.0 and 3.0 were used in order to provide additional data and an opportunity to look for variations in data trends between the versions. The Benefit-Cost Ratios (BCR) were developed for every house and then compared based upon location, foundation type, and amount of freeboard. The final trend analysis and data used in the Data Analysis and Conclusion sections were developed using Version 3.0 since it represents the most current depth-damage information at the time of the study.

Houses were grouped by flood zone and analyzed accordingly. V Zone houses were evaluated using the V Zone BCA module and A Zone houses were evaluated using the A Zone module. Coastal A Zones were evaluated using the V Zone module instead of the A Zone module. This decision was made due to these houses being impacted by wave heights of 1.5 to 3 feet. (This level of wave action has been noted to significantly increase damage to structures.)

The standard FEMA depth-damage curves were used without modification. Depth-damage curves provide an association between the depth of flooding within the home to the subsequent damages expected to be incurred by the structural components of the house and contents within the house.

Costs associated with displacement from the house in the event of a storm were calculated using FEMA standard values. Assumptions used in the model were $1 of rent per square foot of damaged house for housing costs following a disaster and, in addition, $500 per month to cover utility bills, storage costs, and other costs associated with temporary housing following a disaster. (A one-time $500 cost is also included in order to cover any deposits that may be required for temporary housing.)

The evaluation of the flooding risk was evaluated over a 30-year period. This number was based upon an assumed 30-year mortgage used to finance the house. In addition, a 7-percent discount rate was used, which is a standard value used for FEMA economic analyses.

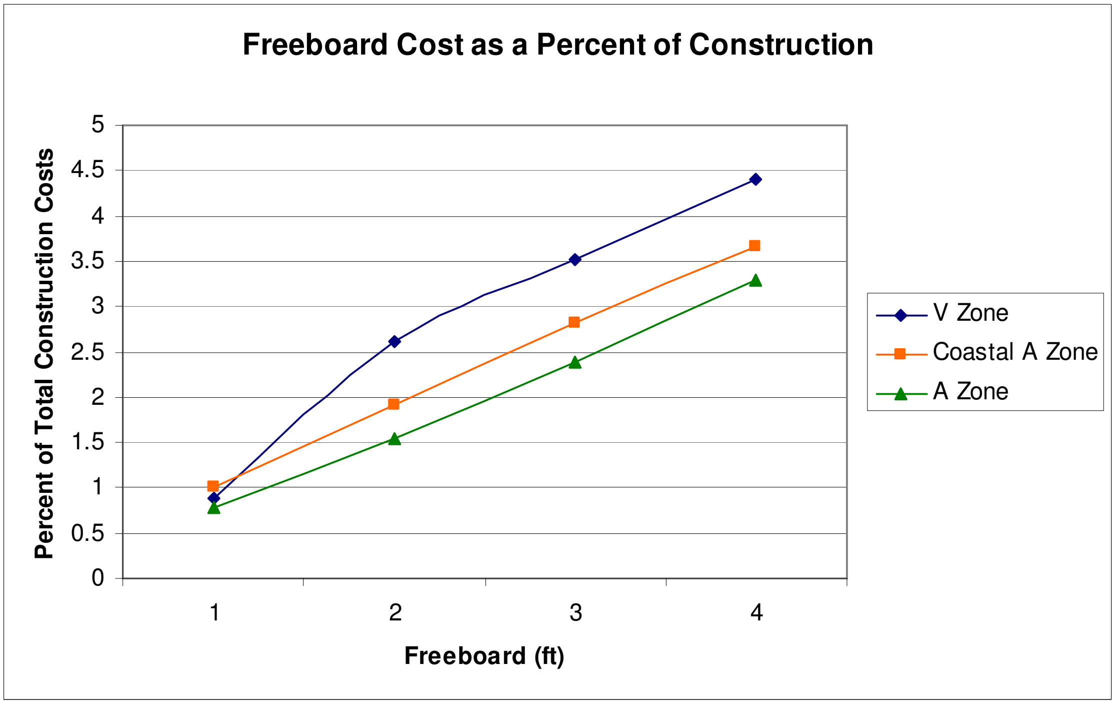
The benefits and costs of construction were evaluated in order to develop a BCR. The BCRs were developed by dividing the present value benefits by the cost of freeboard construction. A BCR above 1.0 is considered to be cost-effective. In order to evaluate the complete benefits associated with freeboard, the calculated reduction in flood insurance premiums was added to the damages avoided benefits. This combined benefit was divided by the cost of freeboard construction. Although the flood insurance premium reduction is not normally included in such studies (from a societal point of view, premium reductions should be comparable to damages avoided), it was determined that it would be included in this analysis in order to assess the costs and benefits of freeboard to a homeowner. (A homeowner will enjoy both benefits—reduced flood insurance premiums and damage/displacement costs avoided.)

The data was then displayed in graphical format and trends were evaluated by comparing the area of the houses (in square feet), their locations and foundation types, and the flood zone in which each is located. As expected, the most benefits were seen in houses located within the V Zones and Coastal A Zones. This suggested that houses that are subject to the highest risk will gain the most benefits from incorporating the use of freeboard into their design.

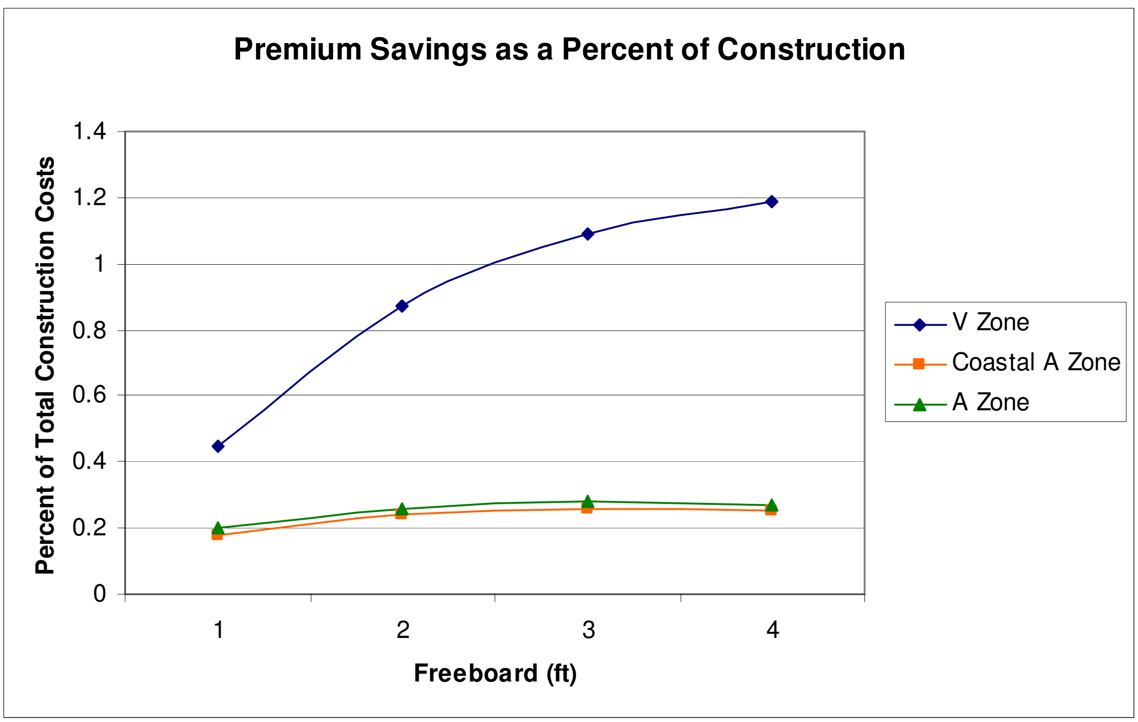
Graphical Analysis

The following graphs visually illustrate the average costs associated with including freeboard into the design of a house. Each graph includes a separate line for each flood zone.

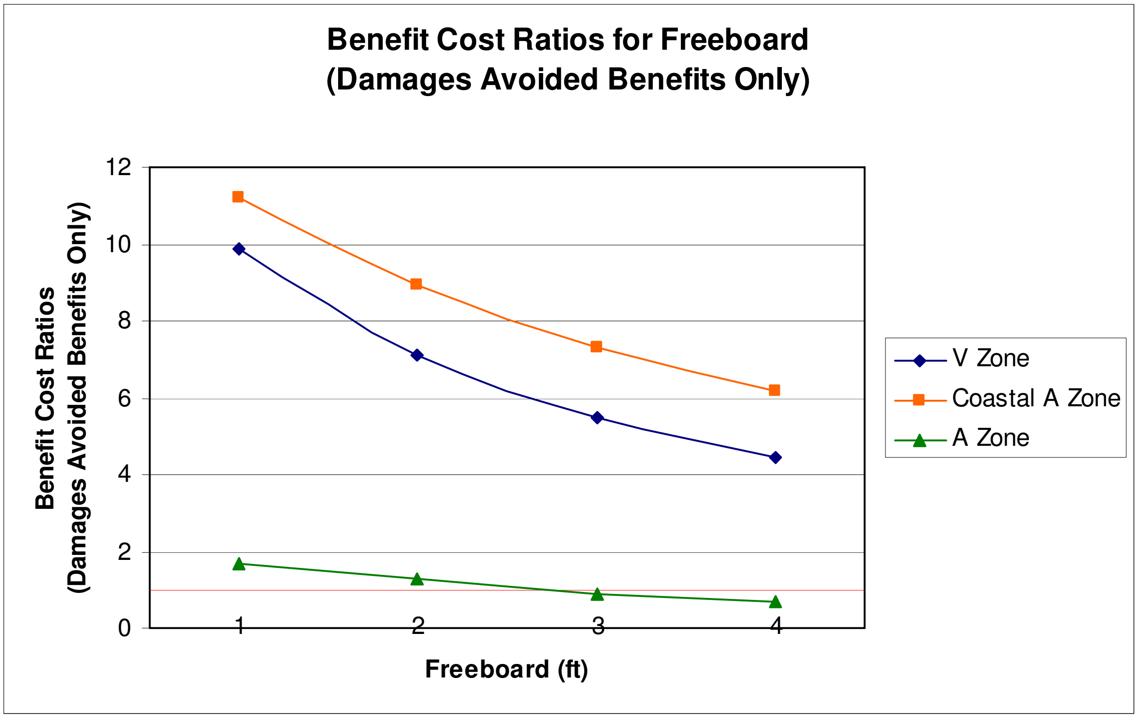
- **Graph 1** illustrates the average cost of freeboard as a percent of the total construction costs and compares each foot of freeboard. The total cost of construction is the cost associated with building the entire house at freeboard. The cost of constructing the house at BFE was subtracted from the cost of constructing the house at freeboard. This difference in cost was divided by the cost of constructing the house to freeboard and then taken as a percentage.
- **Graph 2** illustrates the average potential flood insurance premium savings of freeboard. The average potential flood insurance premium was divided by the total cost of construction at freeboard. The average potential flood insurance premium savings is shown as a percentage of the total cost of construction at freeboard.
- **Graph 3** illustrates the average Benefit Cost Ratio for damages-avoided benefits of freeboard. The initial analysis was conducted solely by evaluating the potential avoided damages based upon the annual potential for flood damage as a function of the flood hazard data and the elevation of the house.
- **Graph 4** illustrates the average Benefit Cost Ratio for the total benefits (i.e., damages-avoided benefits plus the potential flood insurance premium savings) of freeboard. In addition to the avoided damages illustrated in **Graph 3**, the potential flood insurance premium savings were annualized and included in the overall benefits per foot of freeboard. This was divided by the additional cost of freeboard and graphed per foot of freeboard.
- **Graph 5** is a comparison chart of the Benefit Cost Ratios for the damages-avoided benefits and compares them to the Benefit Cost Ratios for the total benefits (i.e., damages-avoided benefits plus the potential flood insurance premium savings) of freeboard. This is a comparison graph for the information shown in **Graphs 3** and **4**.



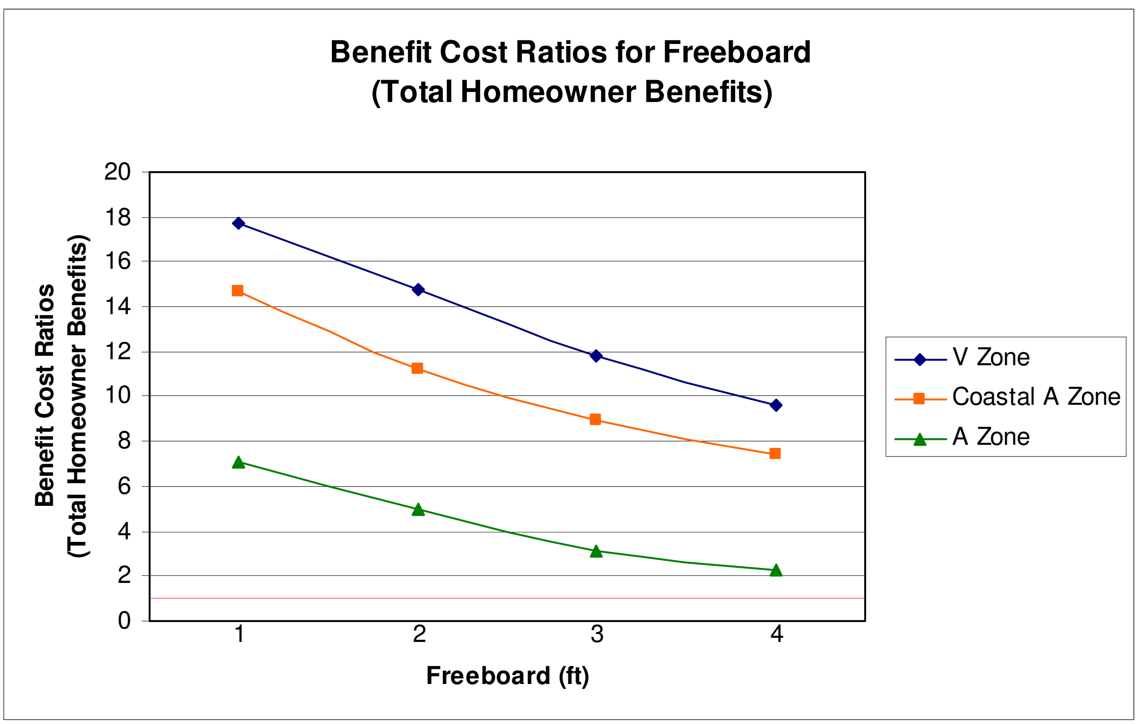
Graph 1 | Freeboard Costs as a Percent of Total Construction Costs



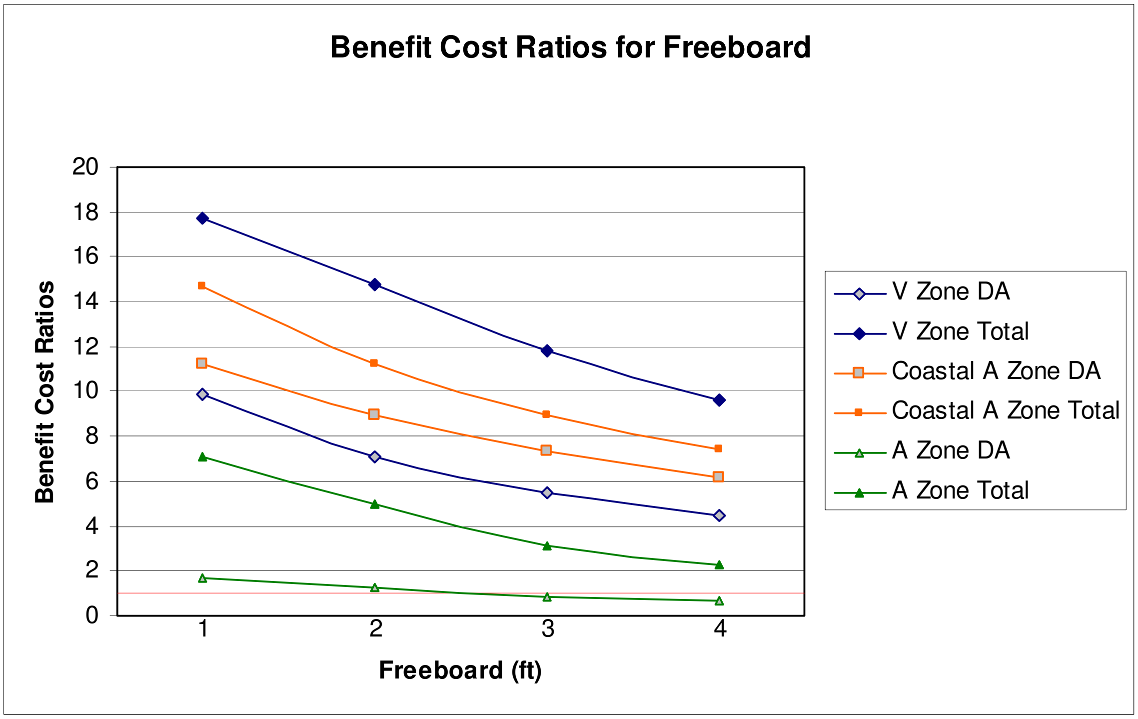
Graph 2 | Flood Insurance Premiums as a Percent of Total Construction Costs



Graph 3 | Benefit Cost Ratios (Damages-Avoided Benefits Only) of Freeboard. The red line illustrates a Benefit Cost Ratio of 1.0.



Graph 4 | Benefit Cost Ratios (Total Homeowner Benefits) of Freeboard – This Benefit Cost Ratio represents the combined damages-avoided benefits plus the flood insurance premium savings. The red line illustrates a Benefit Cost Ratio of 1.0.



Graph 5 | A Comparison of the Benefit Cost Ratios for Damages-Avoided Only (DA) Versus the Benefit Cost Ratio Total (i.e., the combined damages-avoided benefits plus the flood insurance premium savings) **.** The red line illustrates a Benefit Cost Ratio of 1.0.

Limitations of the Models

It is important to consider that the BCA did not account for inconsistencies in flood hazard data. The flood hazard data used within the models was calculated for a design event. However, if higher flood elevations occur with an increased frequency, then additional freeboard becomes more beneficial. The potential for higher-than-predicted flood elevations suggests that when considering hazard resistance, it should be remembered that, although 1 and 2 feet of freeboard are most cost-effective in many situations, 3 and 4 feet of freeboard may prove to be more beneficial.

Conclusions

The BCA data suggested that in every location constructing above the BFE is cost-beneficial. The BCR did show some overall trends based upon various factors and have provided some insight for the cost-effectiveness of where the house is located. The factors that could influence the decision of how much freeboard to include are:

- Local regulations
- The flood zone in which the house is located
- Local flooding hazard conditions (i.e., elevations for flood probabilities)
- Local foundation construction practices
- Cost of construction

Payback Periods for Including Freeboard

Further calculations conducted using the data suggested that the savings in flood insurance premiums were providing a payback period of less than 5 years in most cases in V Zones and less than 8 years in most cases in Coastal A Zones and A Zones. Exceptions to these findings occur with more costly foundation options. These foundation options include some high concrete pile configurations and some 12-inch masonry wall situations. The similarities in payback periods for Coastal A Zones and A Zones are primarily a function of the increased costs associated with the increased risk in Coastal A Zones versus the reduced costs of construction associated with A Zones. The payback periods are important to consider when the average homeowner spends approximately 5 to 7 years in a house. The increased cost of construction will be recouped by the average first homeowner of the house. The average payback period calculation does not consider the primary advantage of constructing a house with freeboard integrated into its design, which is the reduced flooding risk. The payback period calculation was developed in order to prove to homeowners the cost-effectiveness of including freeboard even if a flood event does not occur during the first several years after a house is constructed.

Foundation Design Considerations

While timber piles, in many cases, provide the most cost-effective foundation material, it should be noted that in some situations timber piles present design limitations. Due to the material properties of timber, it is possible that (because of high flood elevations) timber piles will no longer prove to be a viable foundation material due to the lengths required to exceed both the flooding conditions and scouring below pre-flood ground. The material properties of timber make it subject to bending when the ratio of pile length to pile diameter becomes excessive. In the past, this issue has been remedied by cross-bracing the piles. Post-disaster evaluations have suggested that houses that rely on cross-bracing for stability are significantly damaged if it is lost during the storm, as houses become unstable once cross-bracing is lost. This design limitation inherent in the timber piles may require a builder to select another foundation material in order to achieve the proper house elevation.

Similarly the study evaluated the cost-effectiveness of using 8-inch and 12-inch continuous foundations and concrete slab-on-grade foundations on fill in Coastal A Zones. While all three of these foundations are acceptable within the regulatory A Zone, their use in the recommended Coastal A Zone is not advised. These types of foundations would be subject to scour and erosion consistent with high-velocity water and could prematurely fail due to such conditions. In addition, these foundations are discouraged due to changes in flooding conditions or higher-than-expected water levels. If flooding conditions for a particular area are higher than expected, the delineation line of V Zone and Coastal A Zones will move further back into the Coastal A Zone and subject the houses within the Coastal A Zone to V Zone wave conditions (i.e., 3 feet or greater). Post-disaster evaluations of continuous and slab foundations have shown that they perform very poorly in these conditions. An open (pile or pier) foundation is recommended in order to mitigate these situations.

The Impact of Flood Insurance Premium Savings

When considering the benefits of reduced flood insurance premiums it should be noted that these benefits plateau at 3 feet. Further, while the cost of construction is increasing, the premium benefits do not continue to increase. This scenario causes the overall benefits of freeboard at 3 and 4 feet to diminish. It should be noted that in most cases these scenarios still prove to be cost-effective. **Table 4** illustrates the cost of freeboard in comparison to the average flood insurance premium savings as a percent of the total cost of construction. These ranges can be evaluated in order to assess the duration of time it will take to recoup the increased cost of construction associated with incorporating freeboard into the building design.

Table 4 | Summary of Analysis Results

Flood Zone	Freeboard (ft)	Cost of Freeboard (% increase)	Average Premium Savings as a Percent of Total Cost of Construction	Average Payback Period for Additional Cost of Freeboard (years)
V Zone	BFE + 1	0.4–1.8	0.45	2.0
	BFE + 2	0.8–3.6	0.87	2.5
	BFE + 3	1.3–5.4	1.09	2.7
	BFE + 4	1.7–7.2	1.19	3.1
Coastal A Zone	BFE + 1	0.5–3.9	0.18	4.4
	BFE + 2	0.7–4.8	0.24	6.0
	BFE + 3	1.1–6.1	0.26	7.9
	BFE + 4	1.4–8.1	0.25	9.6
A Zone	BFE + 1	0.2–2.3	0.20	3.3
	BFE + 2	0.3–4.5	0.26	4.6
	BFE + 3	0.7–6.8	0.28	6.4
	BFE + 4	0.9–9.1	0.27	8.2

Correlations to the Original Analysis

The original study utilized flood elevations for return periods based on a percentage of the BFE. The percentages were established based on a review of several Flood Insurance Studies throughout the U.S. coastlines. This updated study utilizes actual flood data and elevations from specific locations. Once locations were selected, data was collected using a Flood Insurance Study and a current Flood Insurance Rate Map. Based on this information a BFE and ground elevation were determined for each location. The difference between the ground elevation and the BFE established the foundation requirements for each location. In estimating the foundation costs, the foundations were modified as their height increased. In some instances foundation costs escalated at a nonlinear rate due to design thresholds.

The revised study did not attempt to address the effectiveness of the NFIP or establish construction thresholds for determining the amount of freeboard which a community should enforce. The revised study was intended to focus on the cost-effectiveness of including freeboard into a foundation design and to determine whether the assumptions made in the original study were still valid. Additionally this study addresses concerns that a homeowner may have when deciding how high to elevate their home above the BFE.

This analysis suggested that the data provided in the original study (*2006 Evaluation of the National Flood Insurance Program's Building Standards*) remains valid. Some differences in construction costs and flood insurance premiums were noted, but the overall validation of the study's hypothesis that freeboard is beneficial to homeowners and the community is still valid. Each study was able to arrive at these conclusions independently and was able to conclude that the use of freeboard not only benefits the homeowner with respect to avoided flood damages, but also benefits the homeowner because flood insurance premiums offset the additional costs of construction. Differences in BCRs are the result of differences in construction costs, BCA-tool version differences, and other associated issues, but both study showed general trends that suggest that the use of freeboard is beneficial to incorporate into the design of a house.

Final Considerations

Exactly how much freeboard is necessary for a particular house primarily depends upon the homeowner's decision to weigh the costs of construction versus the rewards. These benefits can be realized as both insurance premium benefits and as reductions in risk. **Figure 2** provides an overview of the decision matrix that the homeowner should consider when determining the ideal amount of freeboard to use.

Freeboard	BFE	BFE + 1	BFE + 2	BFE + 3	BFE + 4
Construction Cost					
Flood Insurance Premium Savings	0	$	$$	$$$	$$$
Risk Level					

Figure 2 | Freeboard Decision Matrix