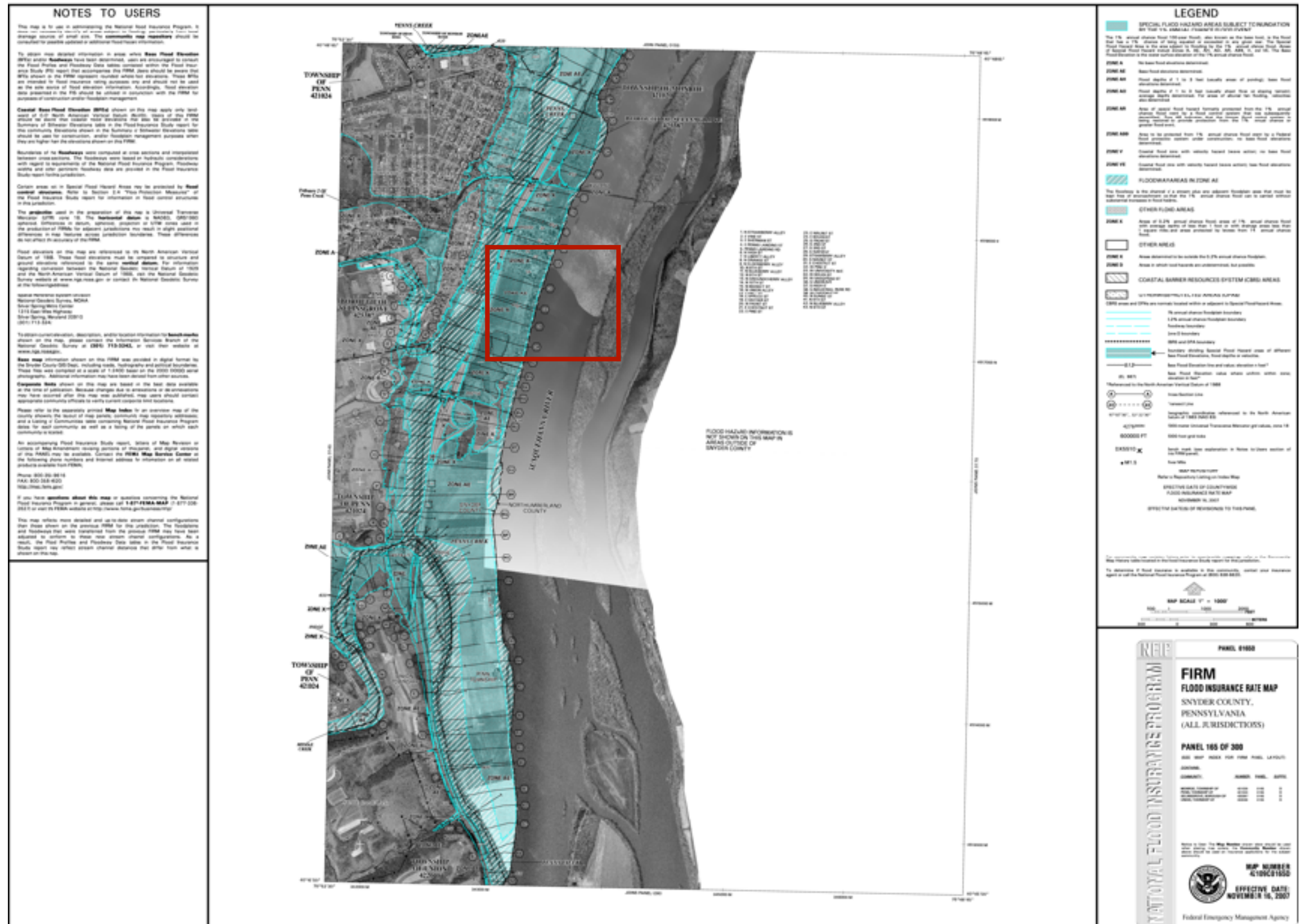


Uncertainty matters even in the decision of elevating a house

Mahkameh Zarekarizi and Klaus Keller

In response, residents are either abandoning or elevating houses



Problem: the entire community is in the flood zone
In response, residents are either abandoning or elevating houses

Elevating

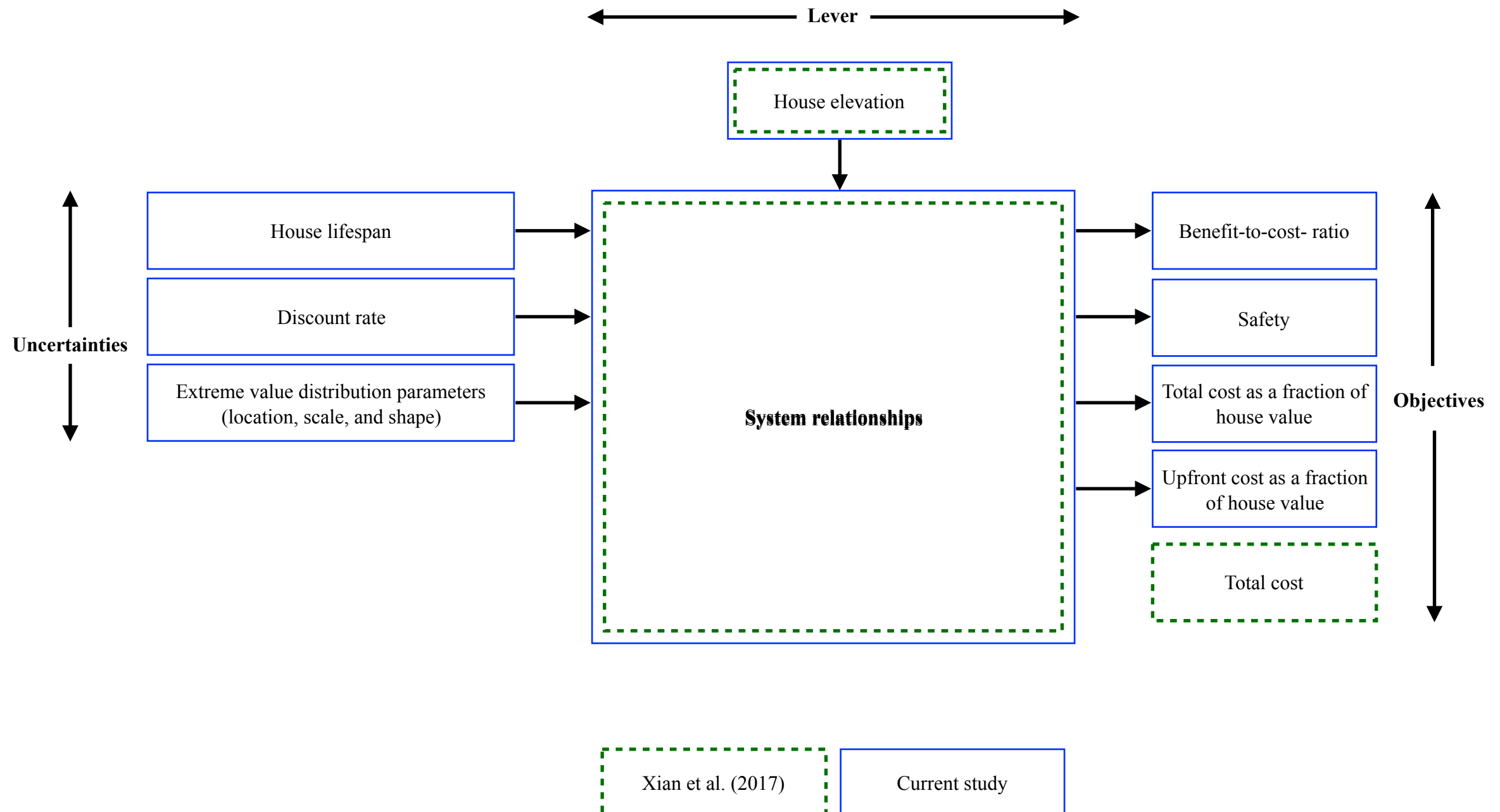


Abandoning



Question: Is elevating cost effective?

These elements are involved in such a decision



Question: Is elevating cost effective?

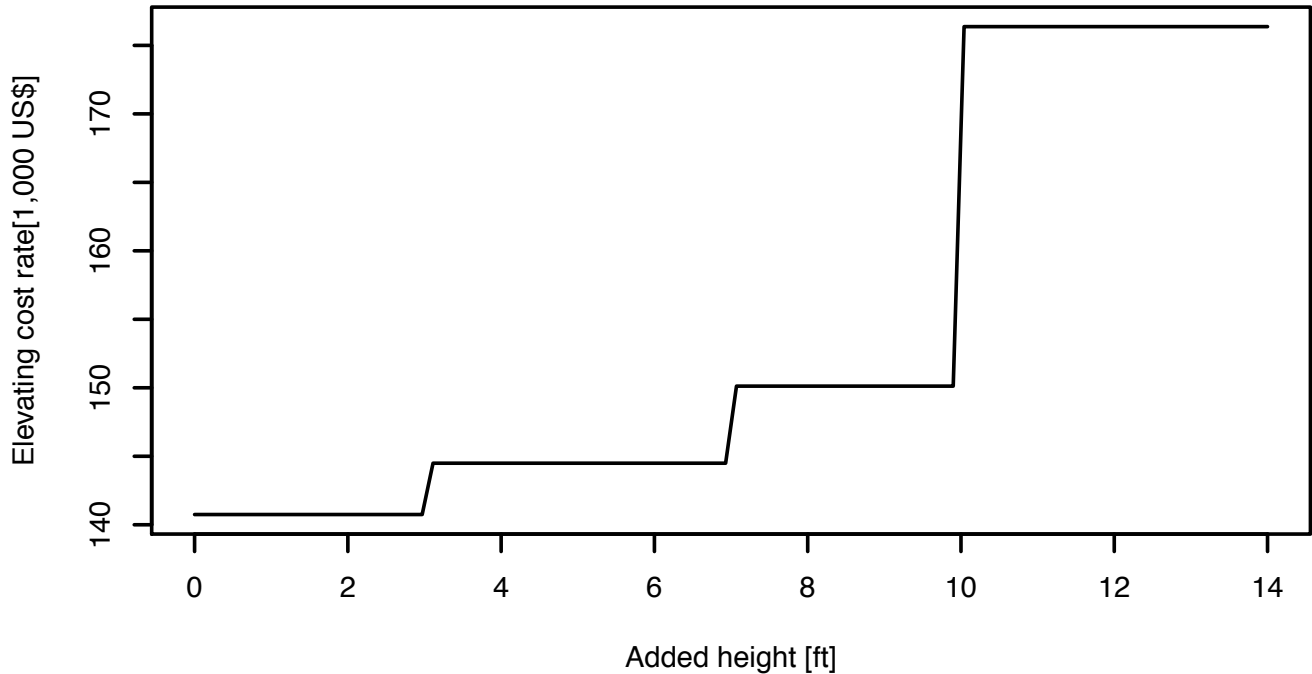
Elevating is expensive!

Component Description	Estimated Unit Cost (for a 2,000 square foot structure)
Cost to elevate over 3 feet up to 7 feet	\$82.50/square foot
Cost to elevate over 7 feet up to 10 feet	\$86.25/square foot
Cost to elevate over 10 feet up to 14 feet*	\$103.75/square foot
Temporary occupant relocation costs during construction, reimbursable by CPRA	\$3,500/structure
Estimated permitting cost	\$2,175/structure
Inspection cost	\$4,300/structure
Survey	\$470
Title search	\$300
Project administration and construction management	\$10,000 flat fee (based on an estimated 200 hours of work)

*10 to 14 foot elevation above grade will require concrete columns; more than 14 foot elevation above grade will require voluntary acquisition.

CLARA table of elevating costs

Elevating cost for a typical 1,500 ft² house

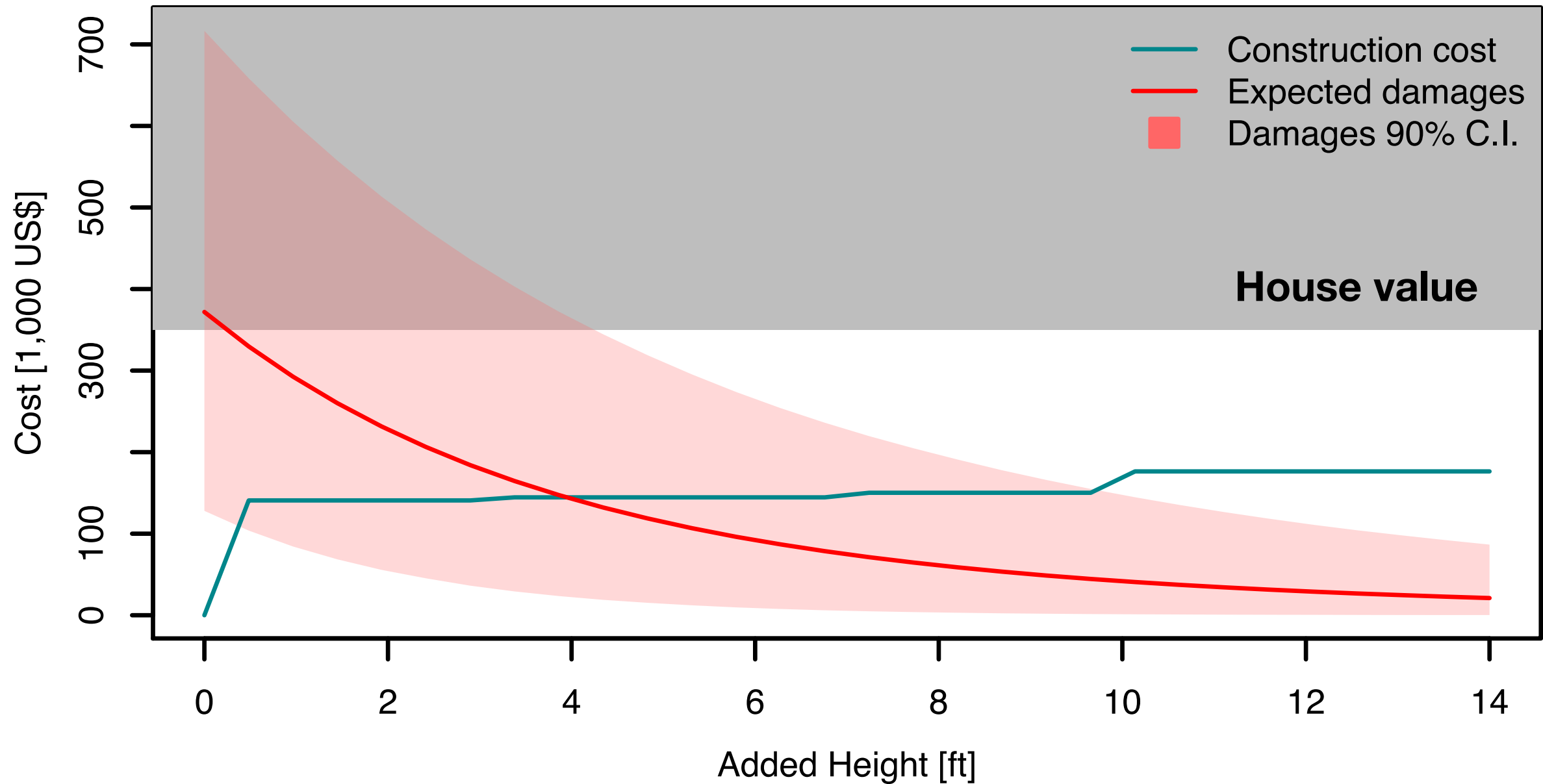


Question: Is elevating cost effective?

We need to look at expected damages

Elevating is expensive but so are the expected damages!

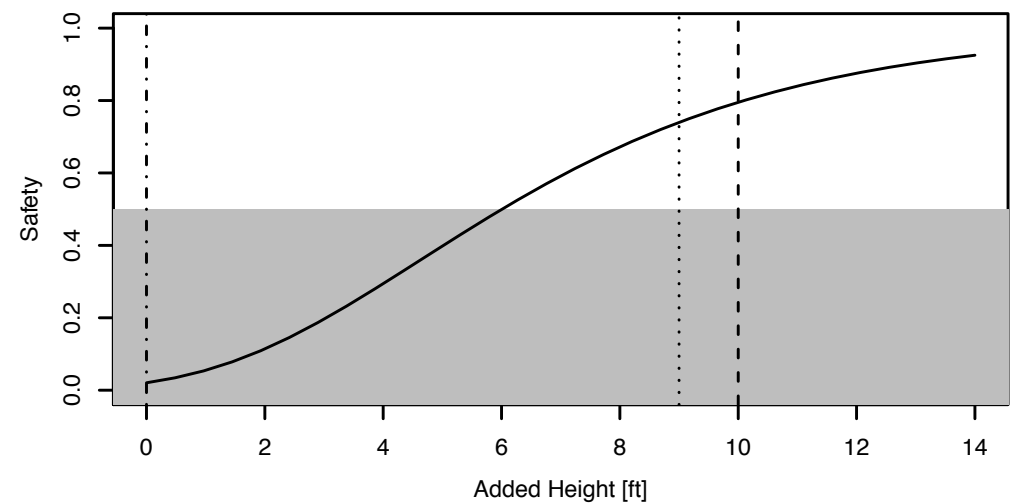
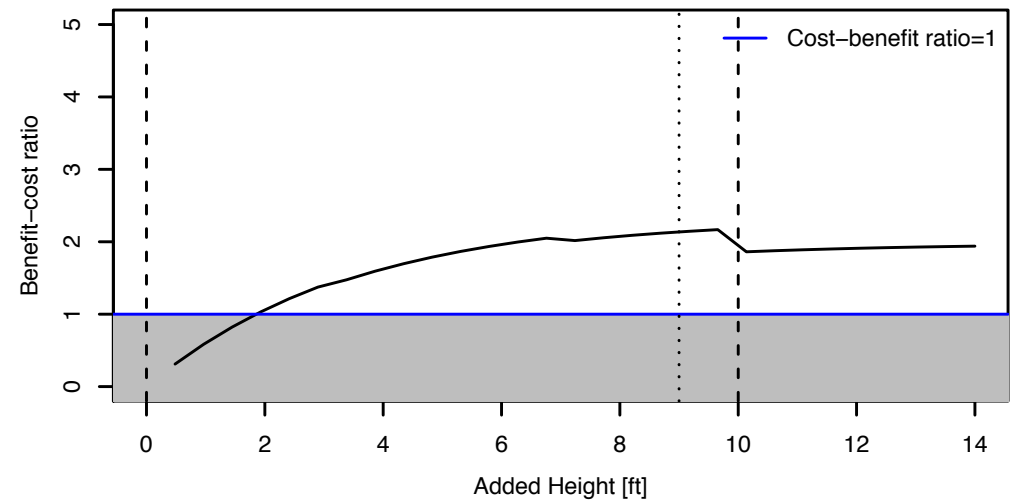
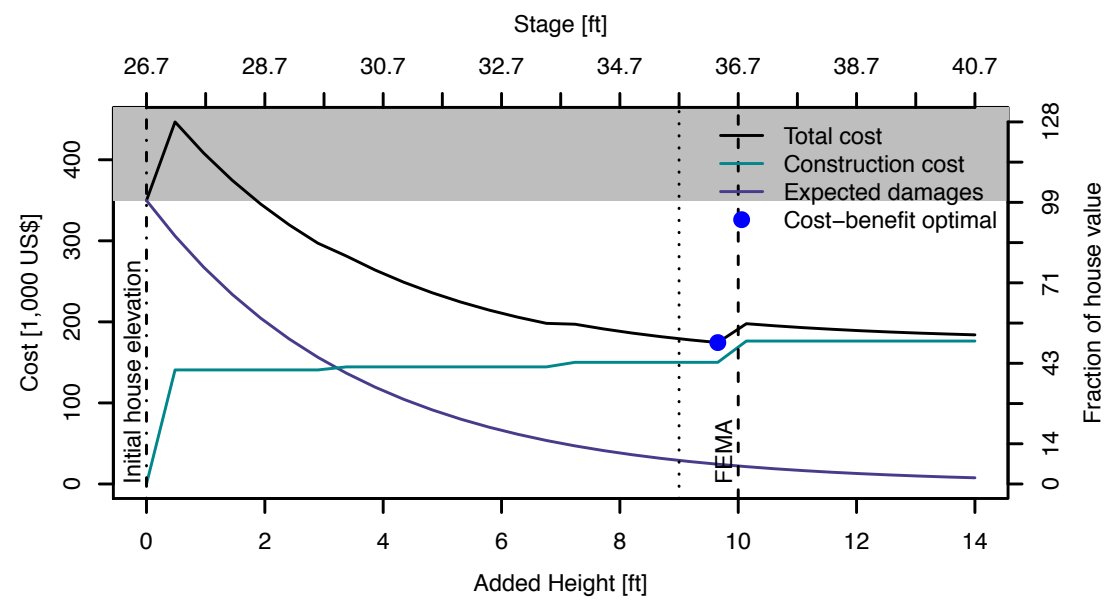
Flood return levels are derived from GEV function



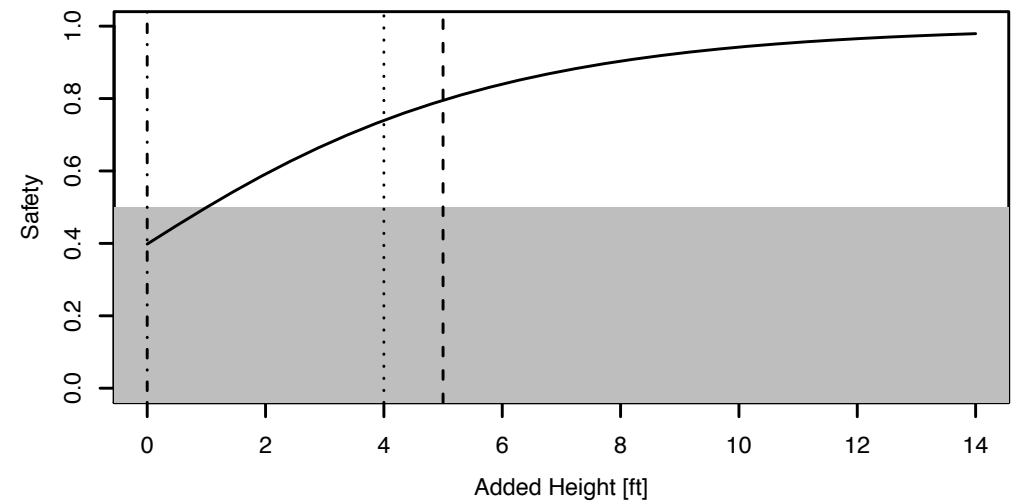
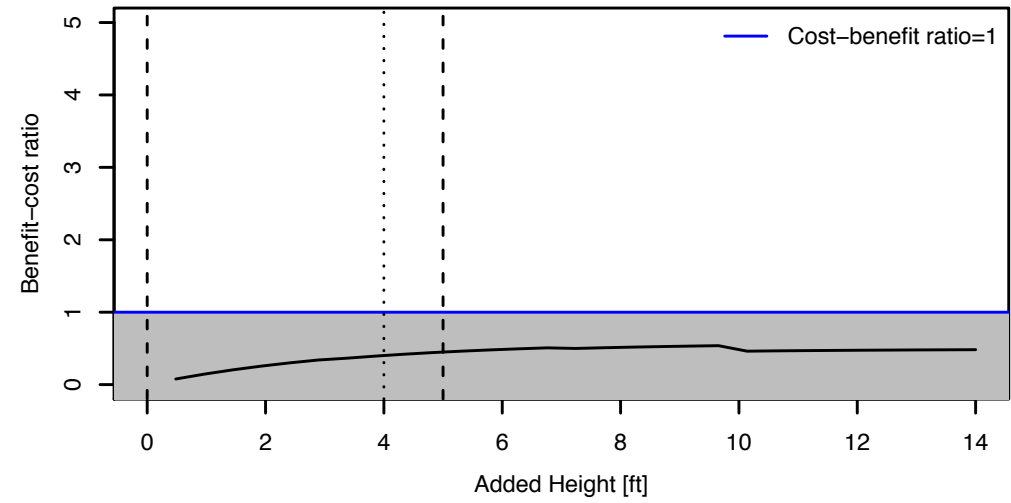
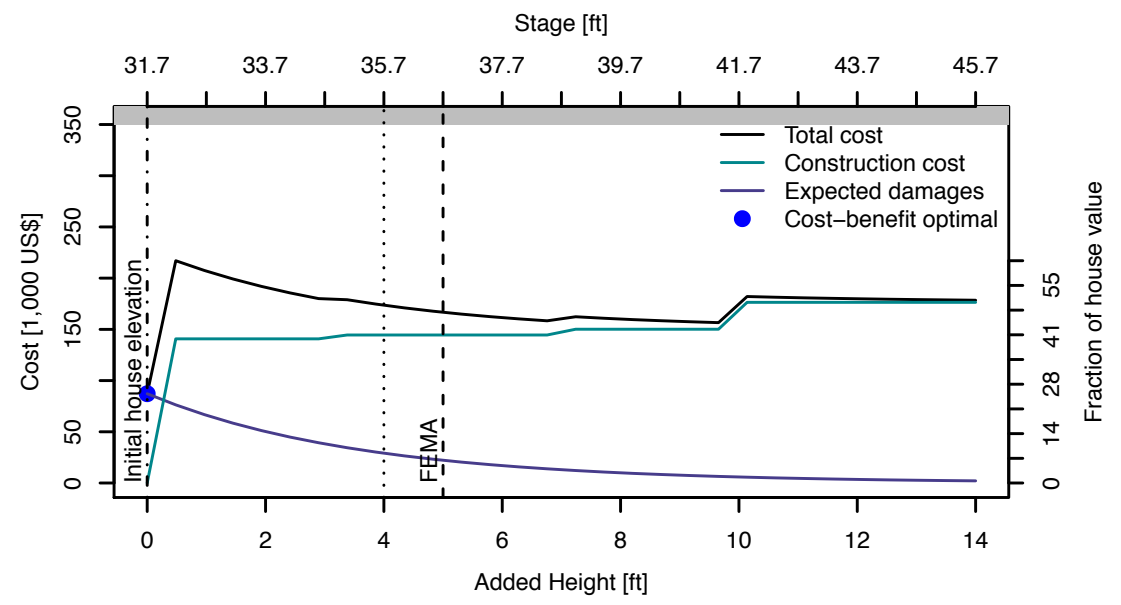
Question: Is elevating cost effective? It depends!

Elevating a house in some cases are cost effective!

9 feet below BFE



4 feet below BFE



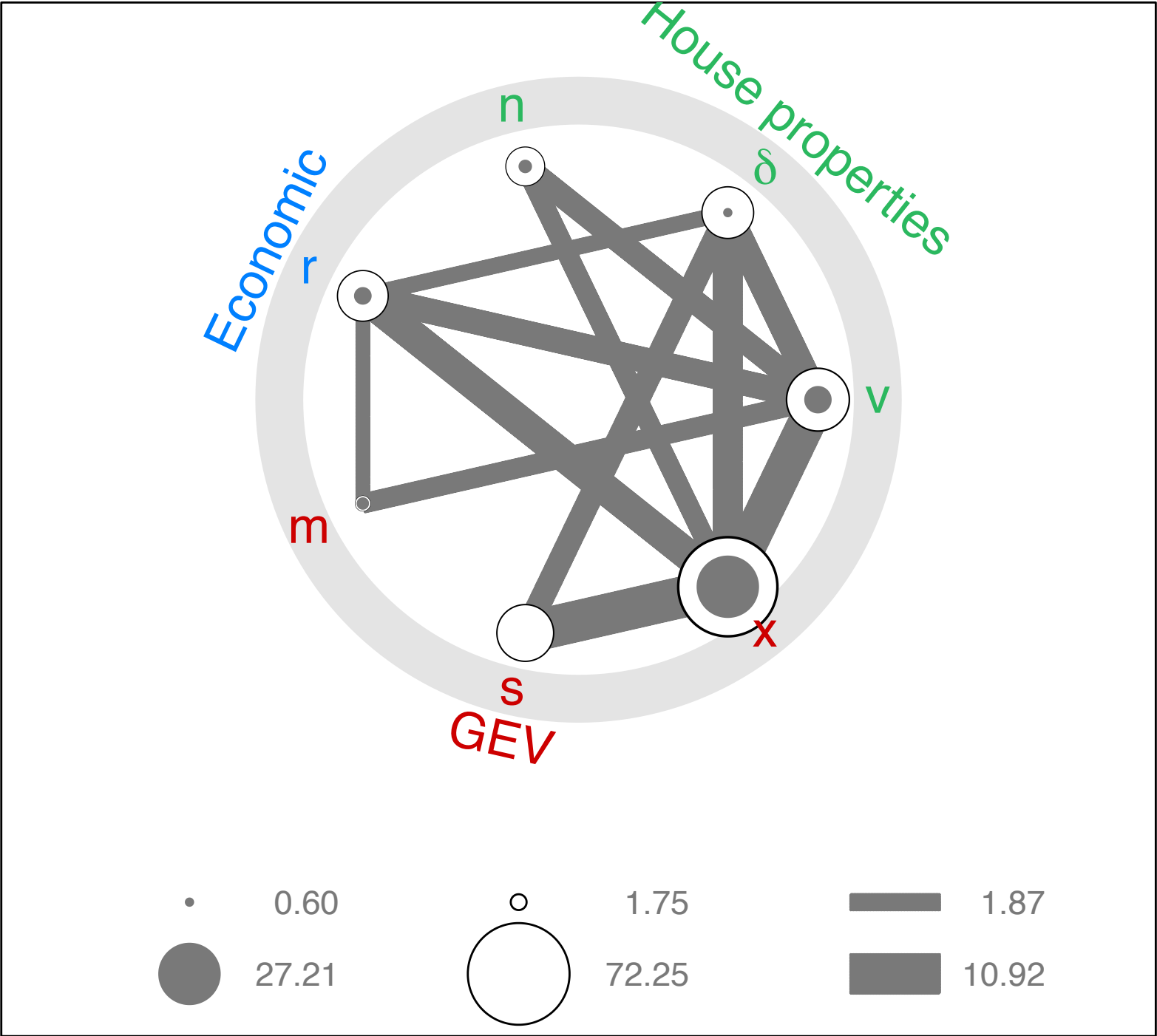
What does it depend on? House characteristics!

GEV shape parameter matters the most

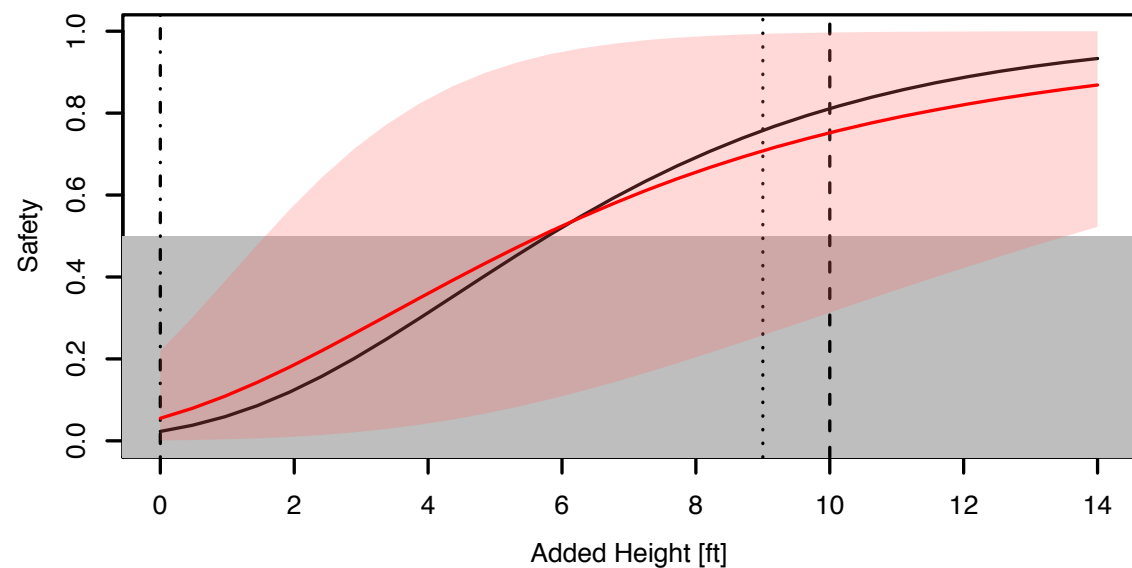
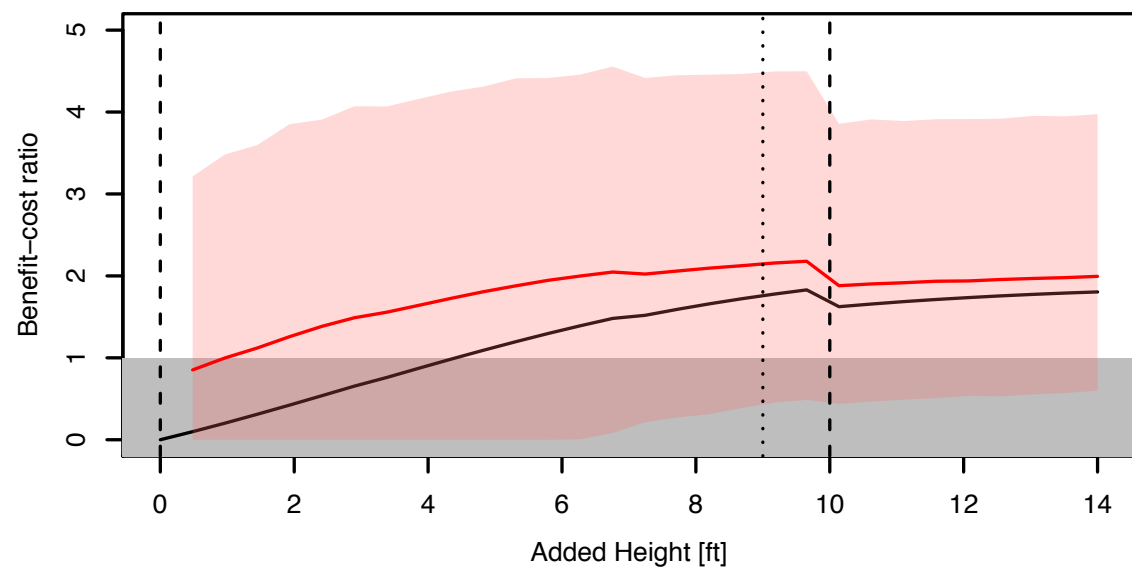
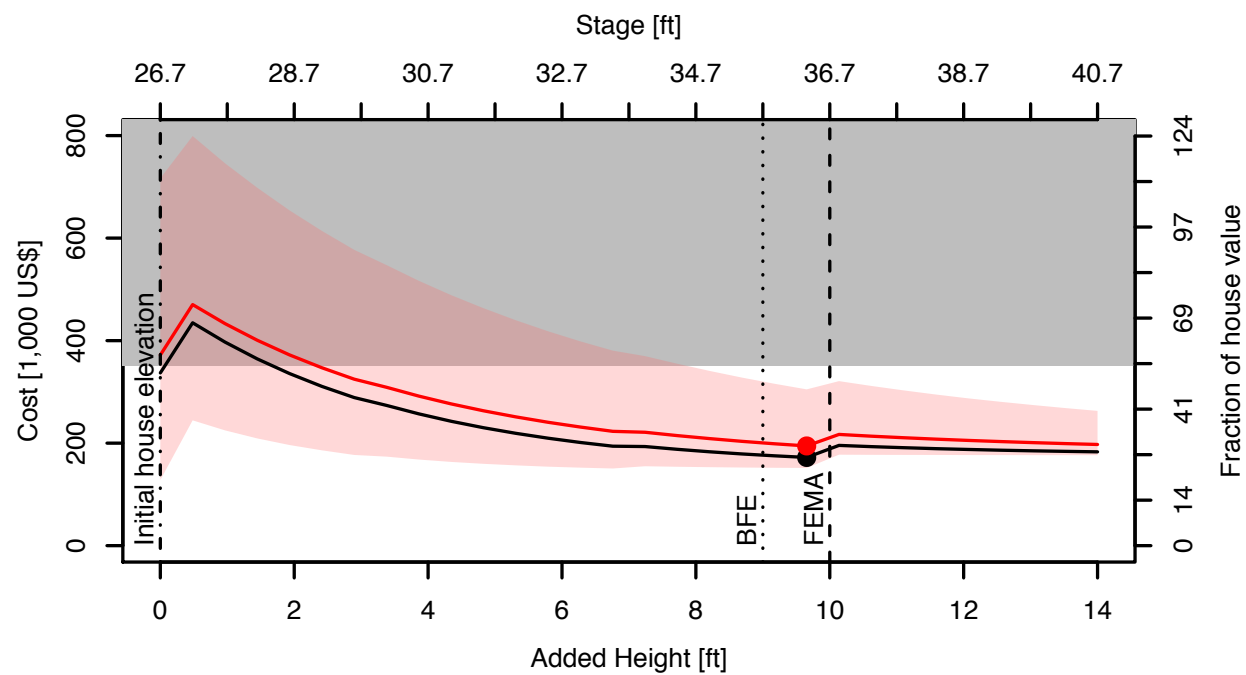
Sobol Sensitivity Analysis

Most sensitive
parameter is GEV
Shape parameter

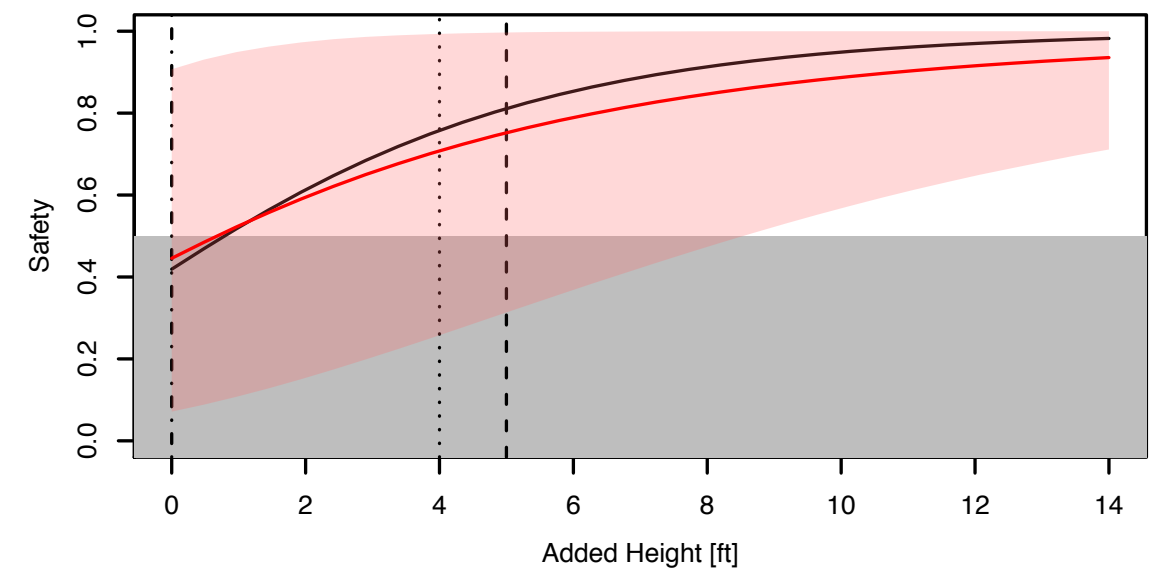
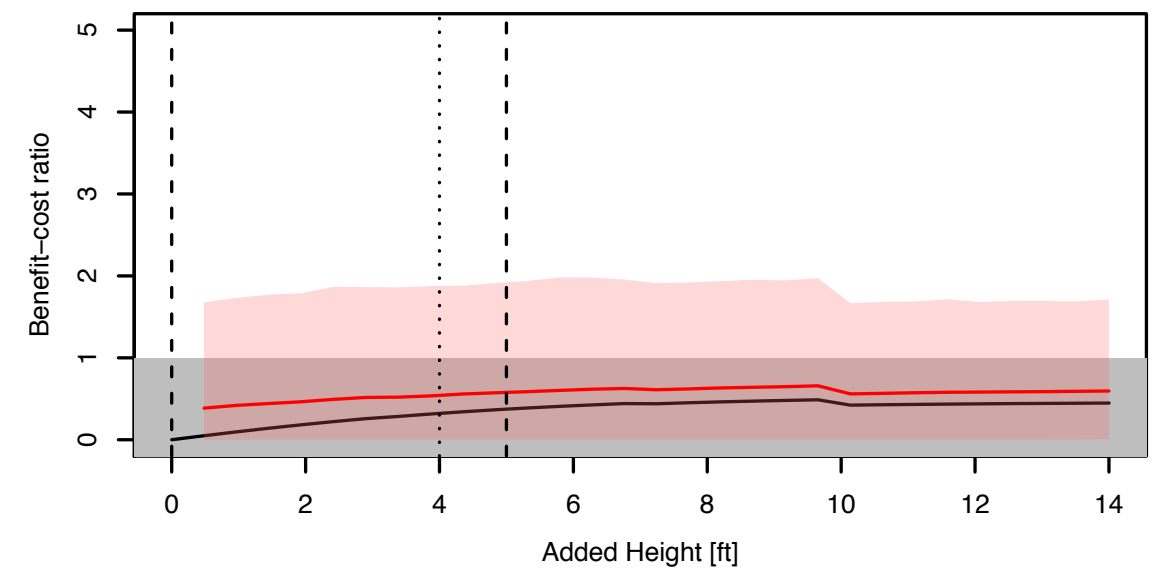
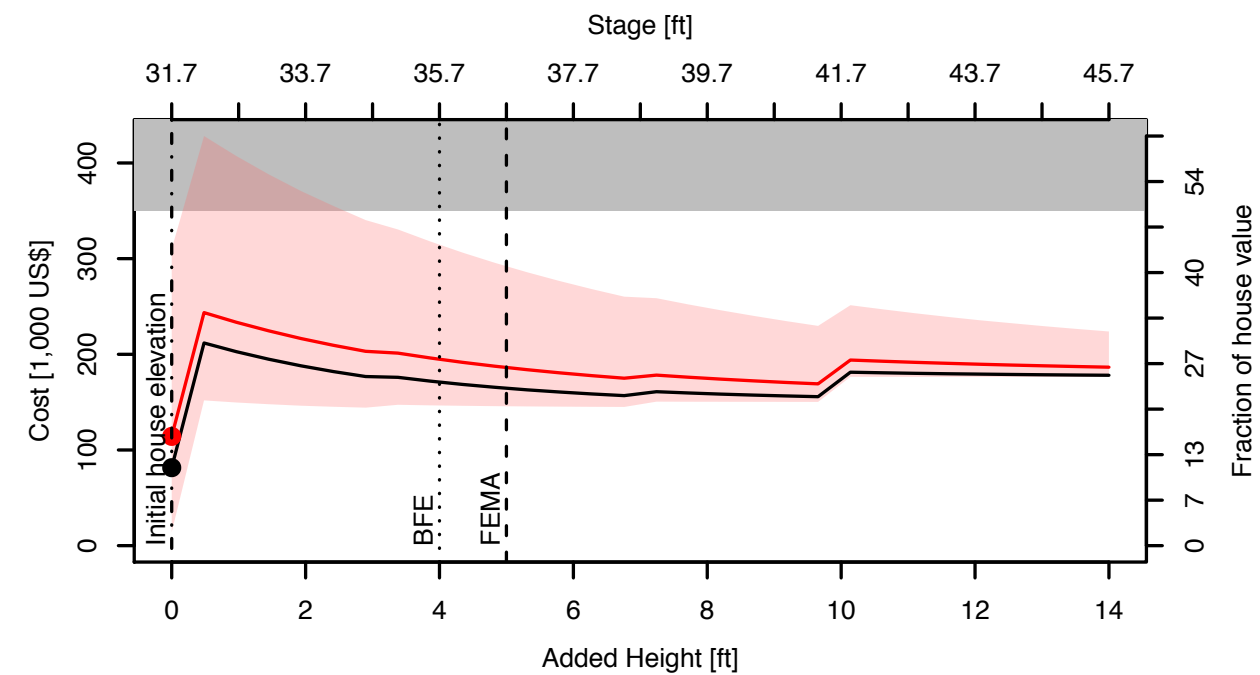
Expected damages



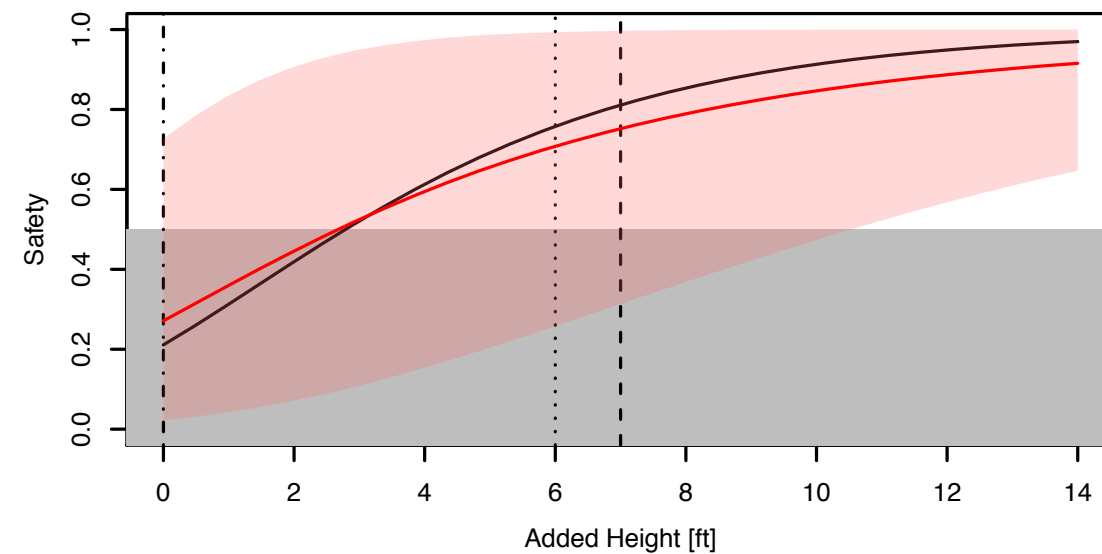
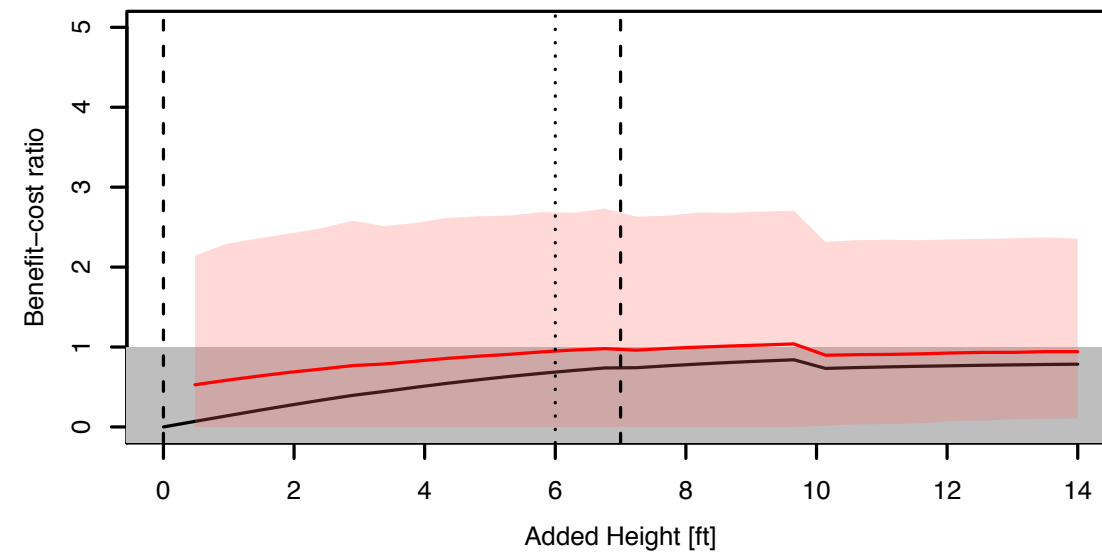
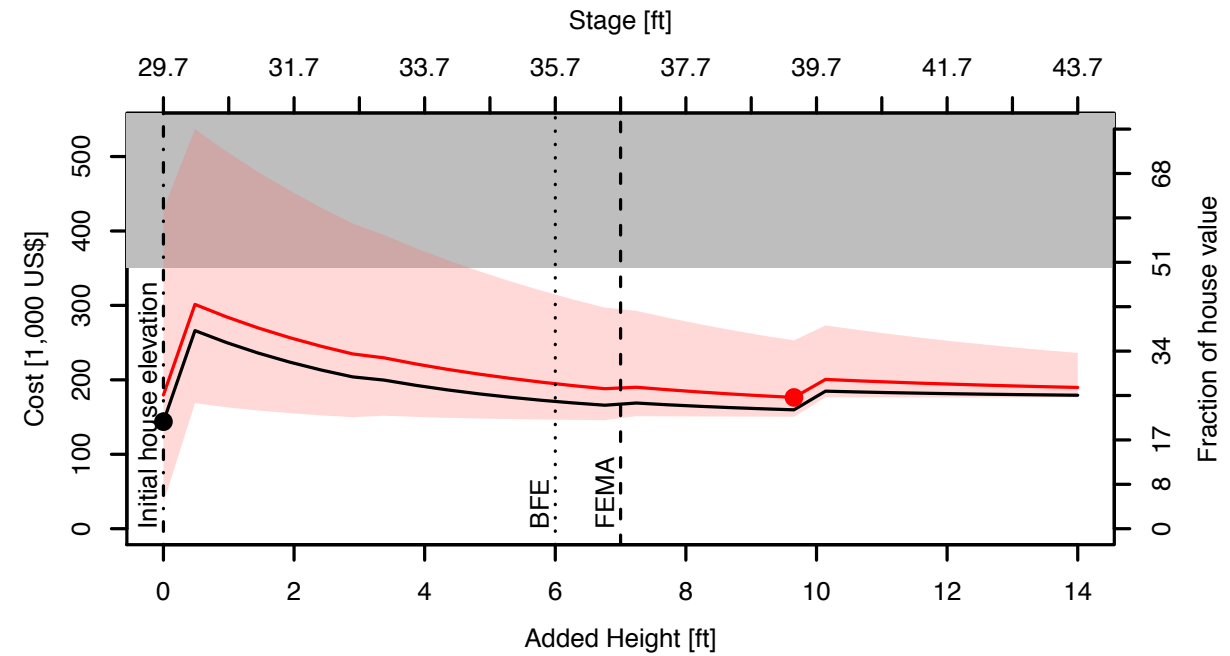
9 feet below BFE



4 feet below BFE



6 feet below the BFE



In some cases the decision might change due to uncertainty

Conclusion

- **Elevating a house is very expensive but so are the expected flood damages**
- **Uncertainty in parameters can change the decision of elevating a house or not**
- **FEMA's recommendation is not always cost optimal!**
- **In 60% of the houses, elevating is not cost optimal**

Reserved materials

Areal image



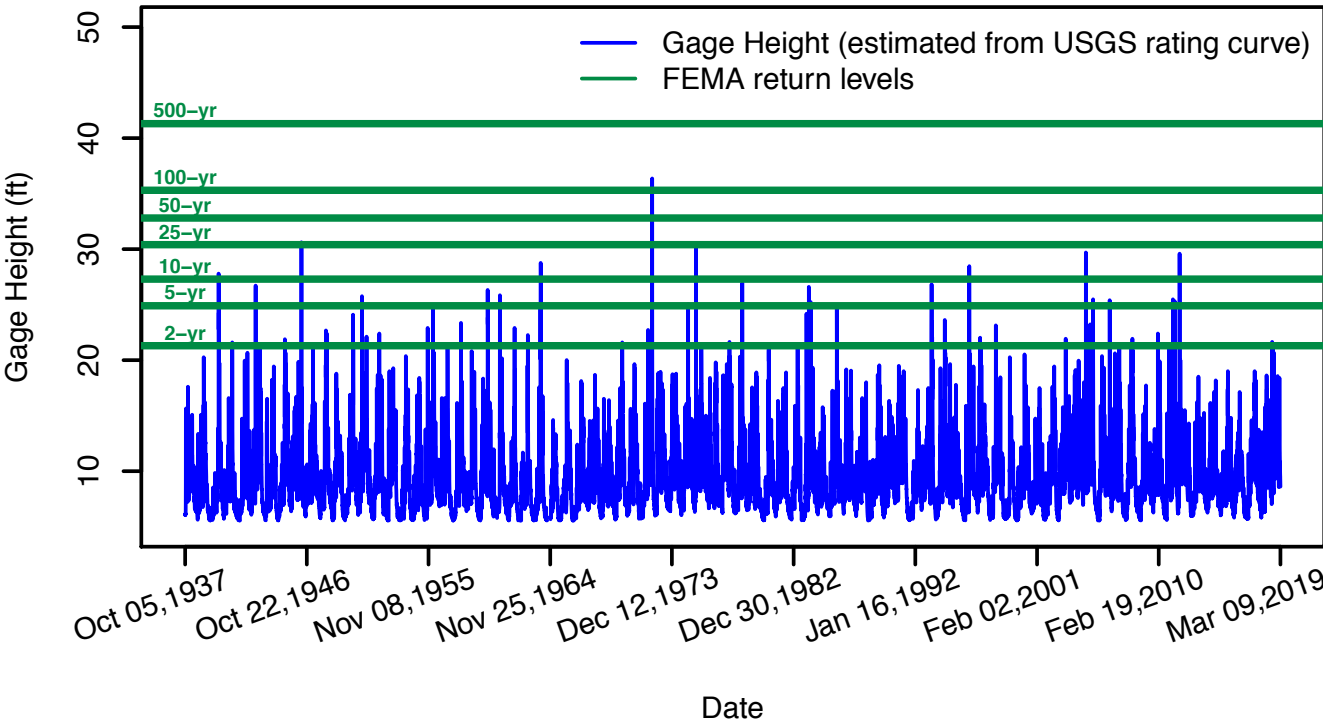
FEMA Flood zones



Typical houses in AE Zone

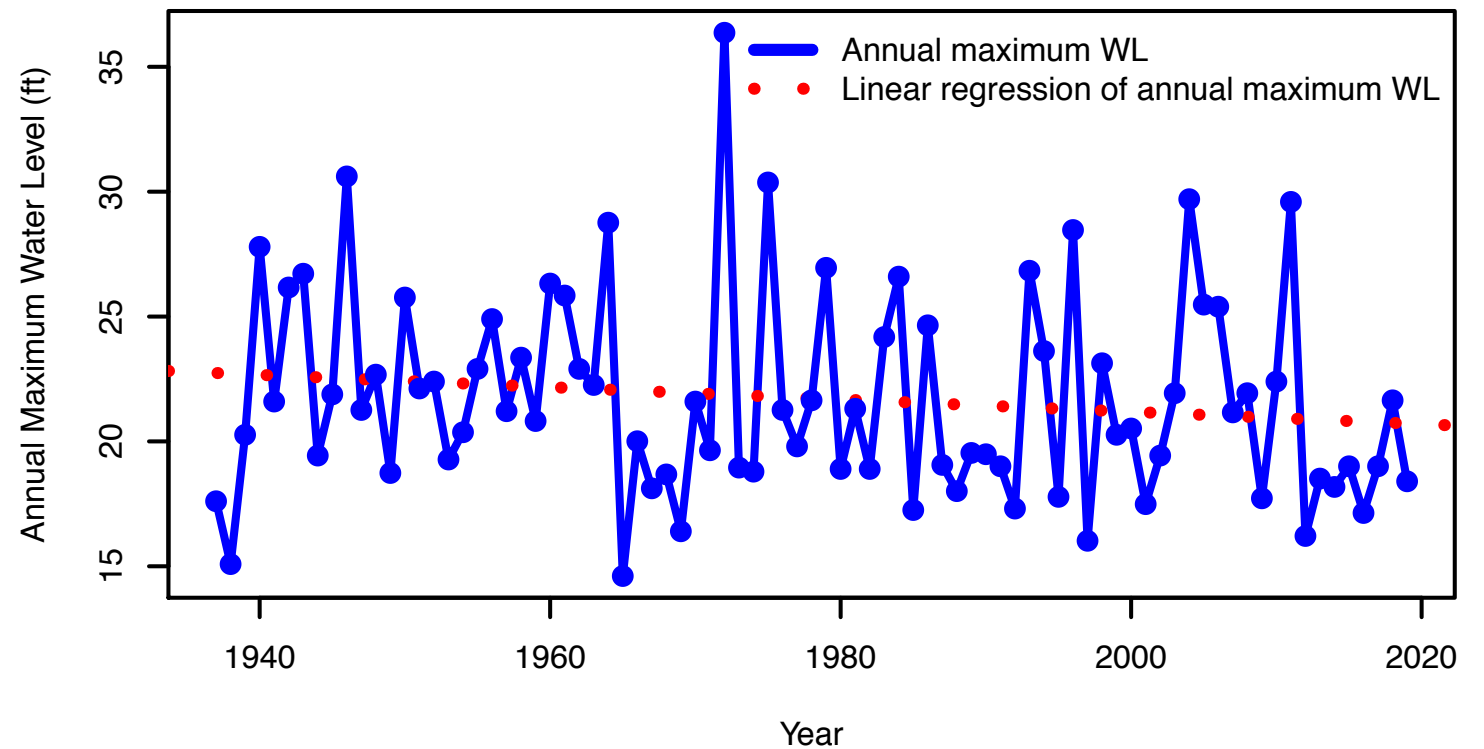


USGS 01554000 Susquehanna River at Sunbury, PA



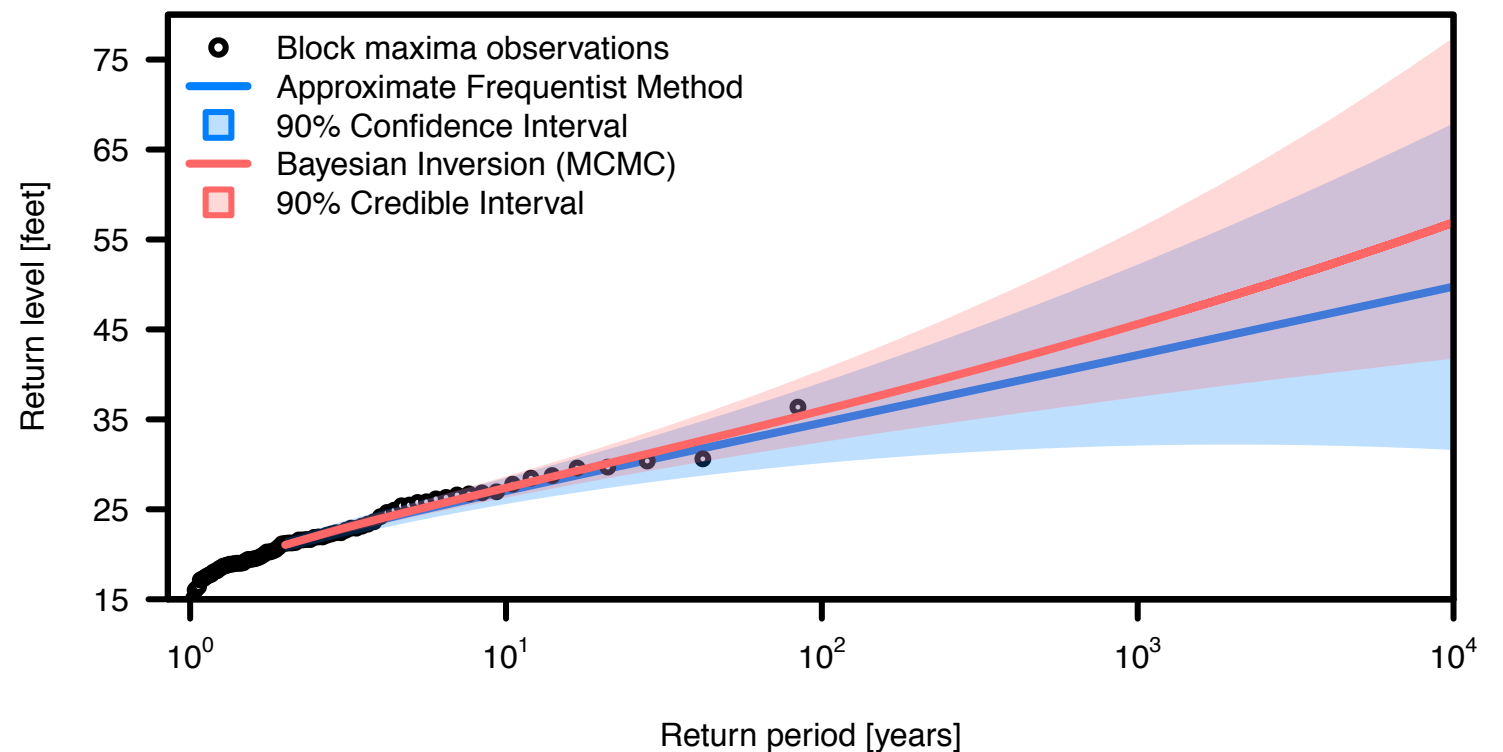
Flood Frequency Analysis (Block Maxima)

1. Extract annual maximum water level



2. Fit the annual maximum data to GEV distribution

Method: Markov Chain Monte Carlo

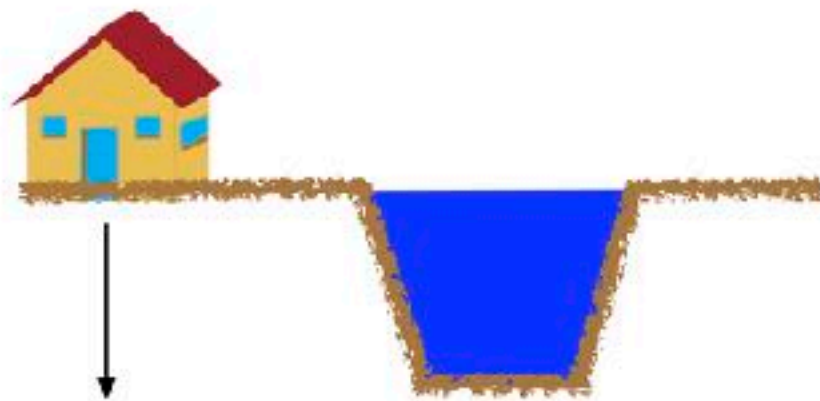


FEMA recommends elevating this house by two feet. But is that cost effective?

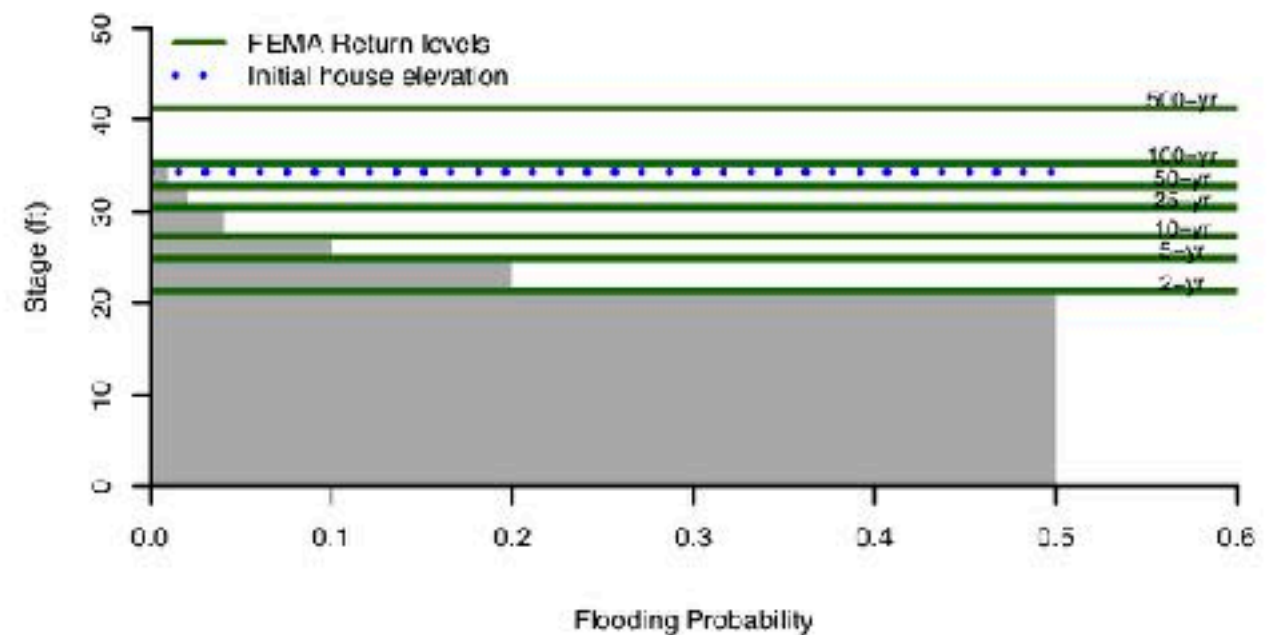
Areal image



FEMA Flood zones



This hypothetical house
is 1 foot below FEMA's
base flood elevation



The Problem, our hypothesis, and research questions

- Problems with FEMA's recommendation:

- It is merely based on the zone of the house
- It recommends elevating to at least one foot above BFE. It does not provide an exact instruction for homeowners
- It is based on old base flood frequency estimates
- Elevating the house is very expensive

- Our hypothesis:

- FEMA recommendation is not cost effective for all houses
- The level to which a house should be elevated is dependent on:
 - The current elevation of the house; not just the zone
 - The house size, house value, and house age.
 - If uncertainties are taken into account, the recommended elevation increases

- Our research questions:

- Is one foot above BFE cost optimal? What is uncertainties are taken into account?
- What is an optimal elevation under uncertainties?
- Would a better estimation of BFE lead to a different recommendation?

Question: Is FEMA's recommendation cost effective?

Total cost = cost of heightening the house + present value of expected damages

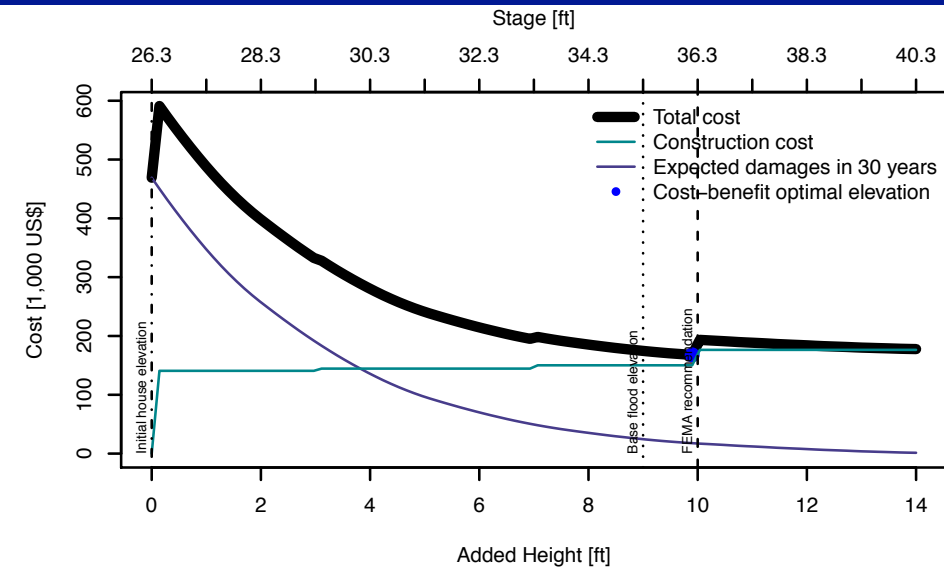
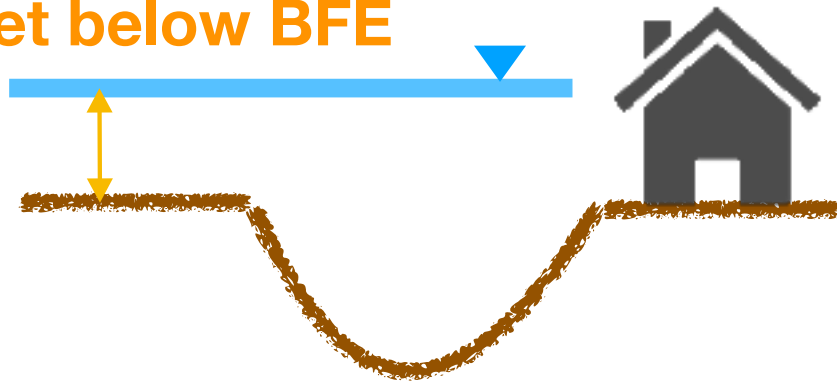
↓
f(Expected Annual Damages (EAD) ,discounting rate)

↓
**f(house value , elevation , life span ,
flood return levels)**

Question: Is FEMA's recommendation cost effective?

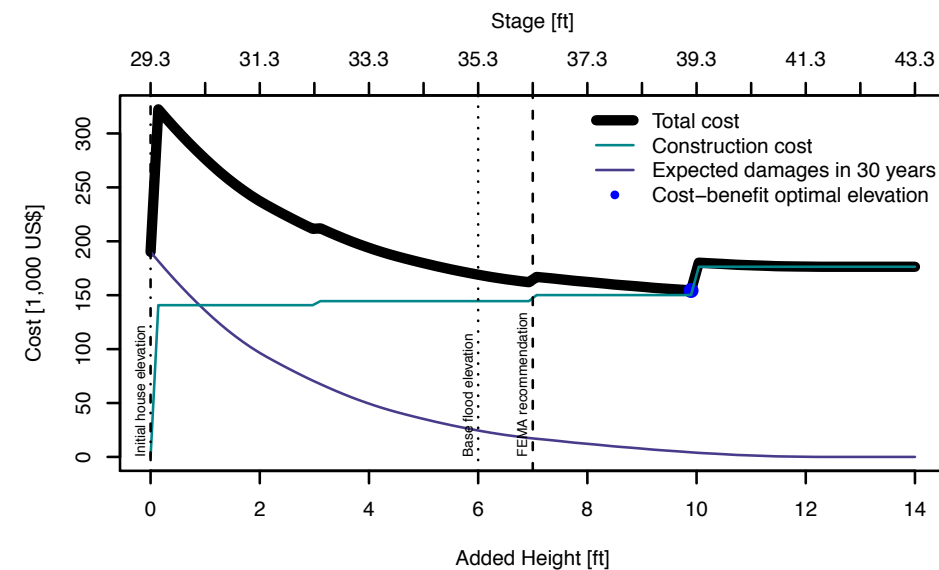
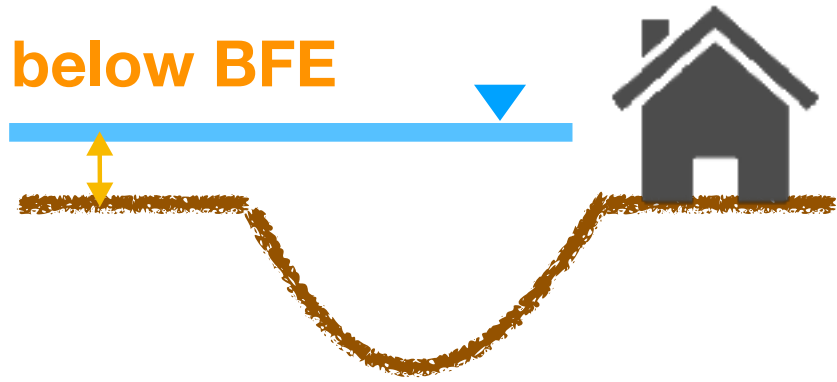
Let's consider three hypothetical houses

9 feet below BFE



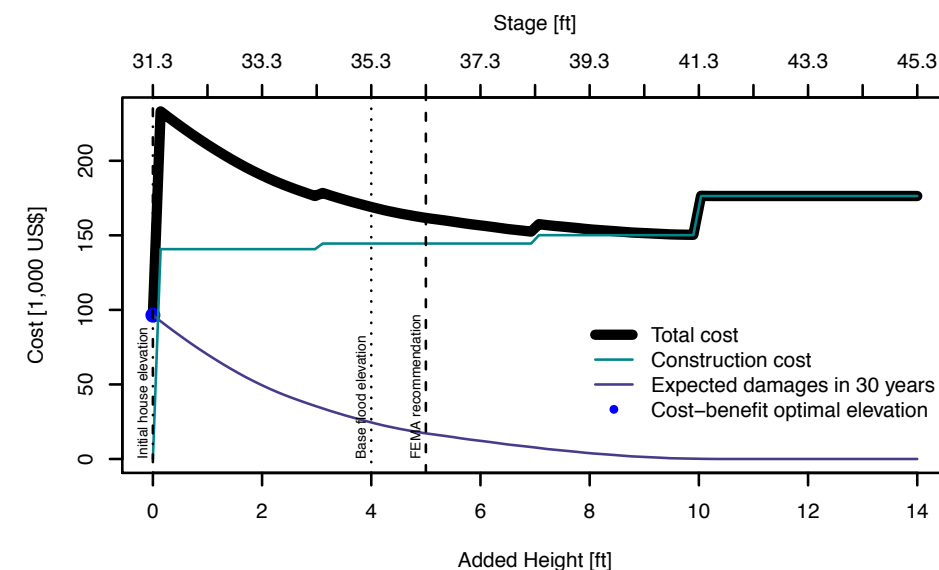
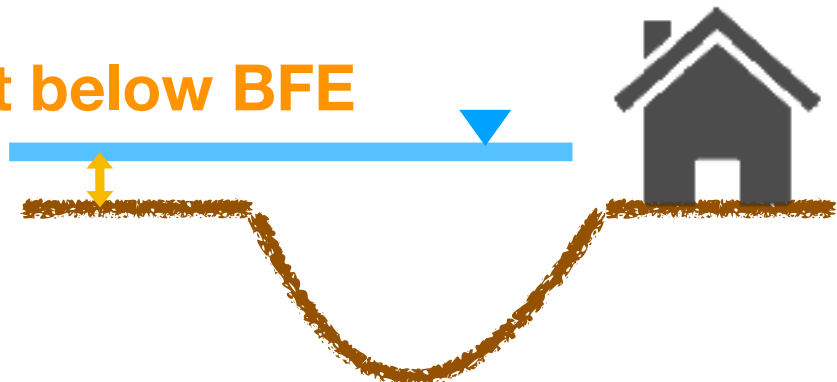
Is cost effective

6 feet below BFE



Is not cost effective

4 feet below BFE

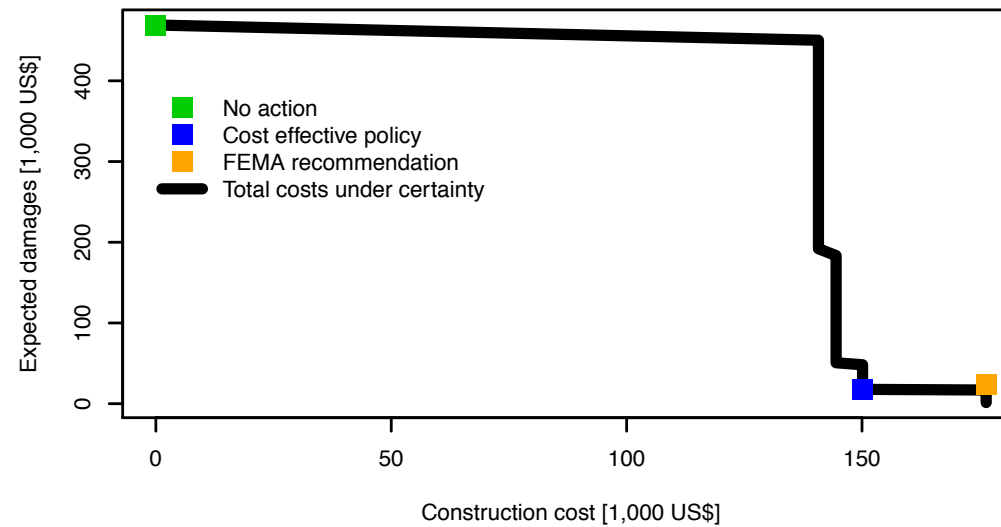
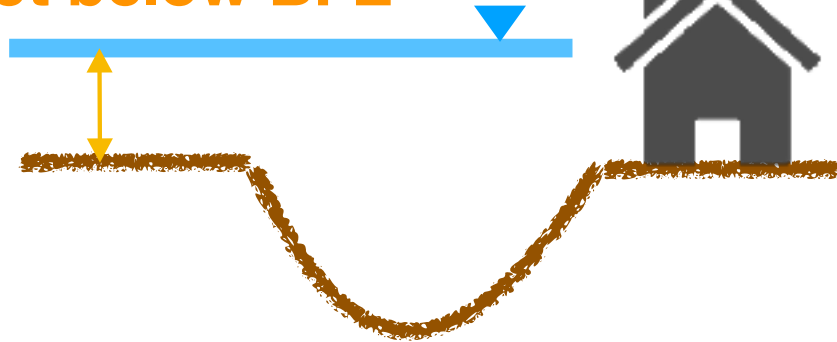


Is not cost effective

Question: Is FEMA's recommendation cost effective?

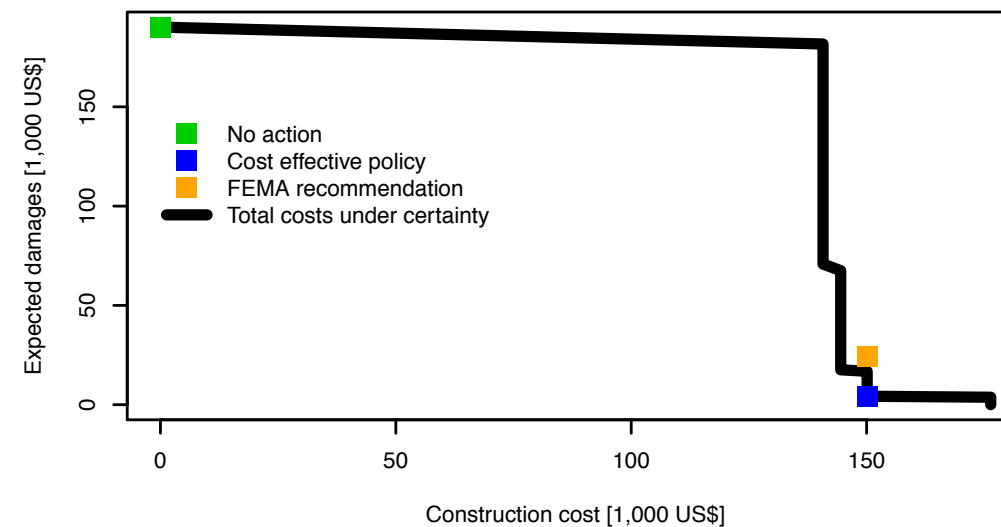
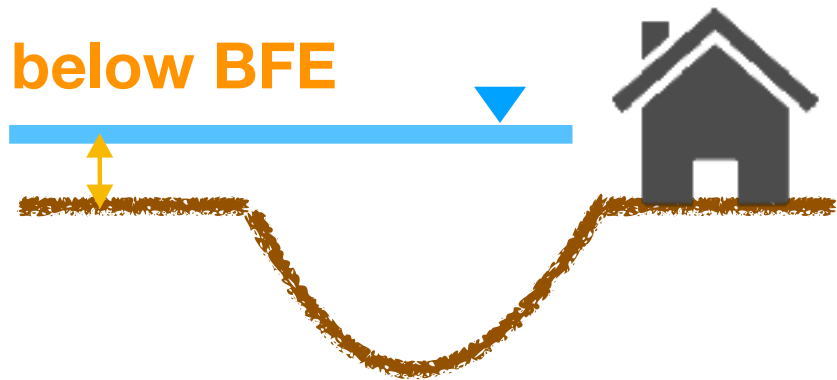
Let's consider three hypothetical houses

9 feet below BFE



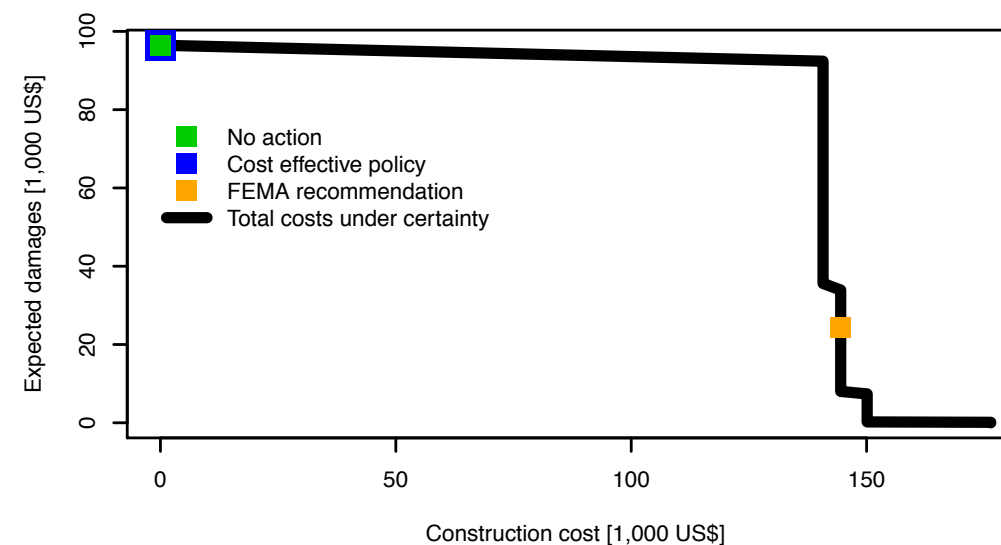
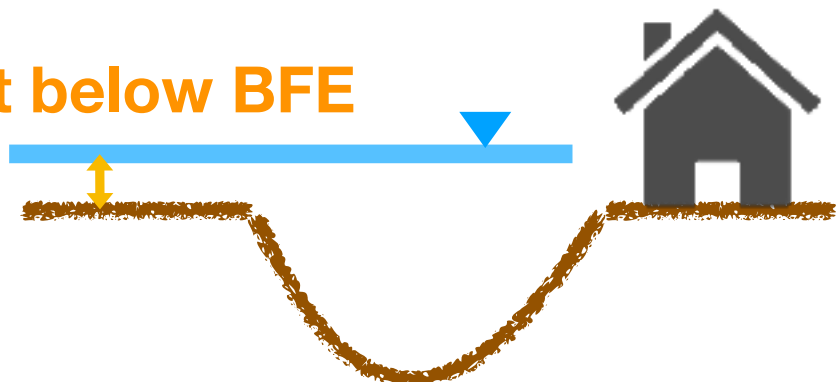
Is cost effective

6 feet below BFE



Is not cost effective

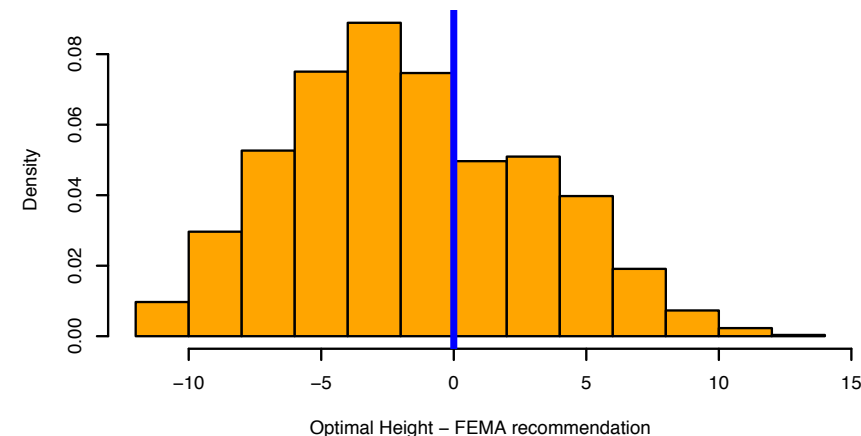
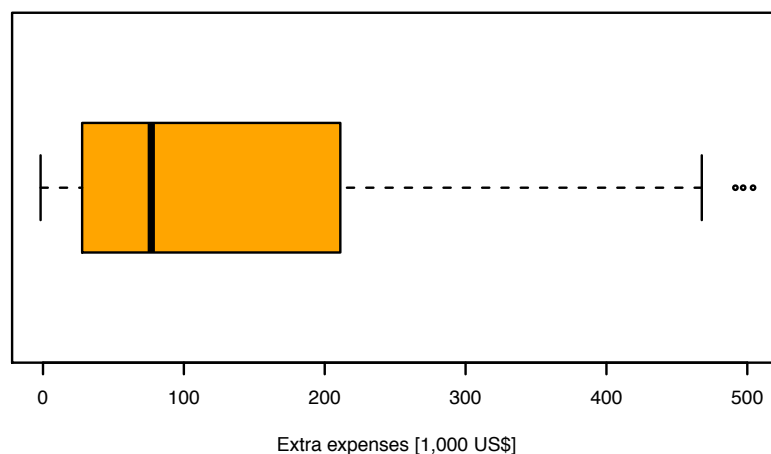
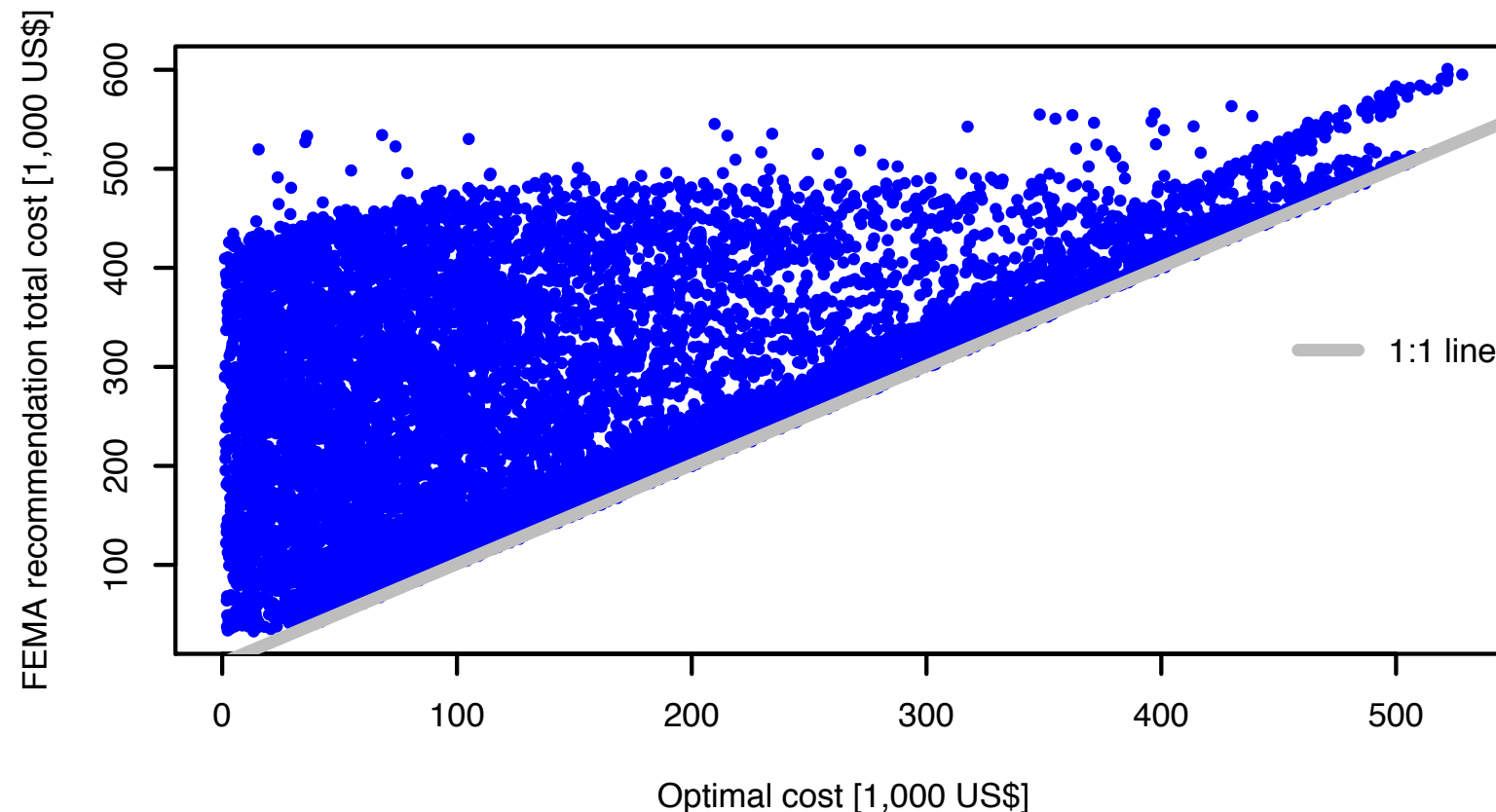
4 feet below BFE



Is not cost effective

Question: Is FEMA's recommendation cost effective?

- Let's create 10,000 hypothetical houses and see in how many of them FEMA is optimal
- FEMA's recommendation is cost effective in less than 1% of the houses.

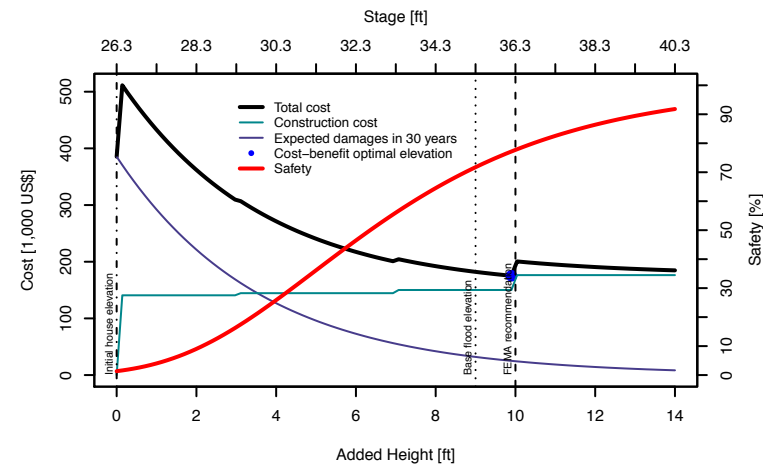
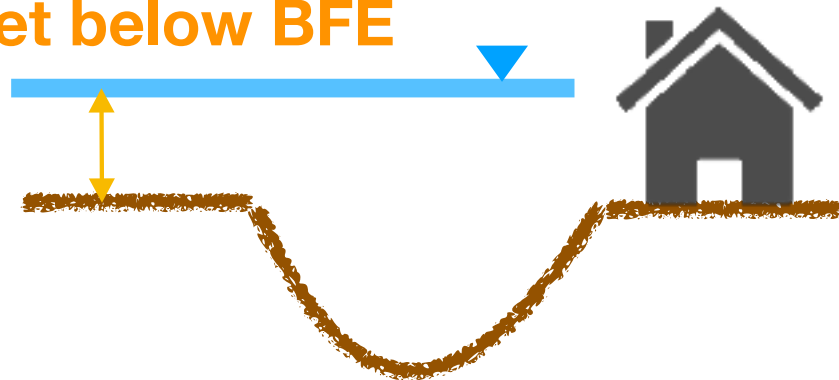


Question: Is FEMA's recommendation cost effective?

What is cost is not the only objective?

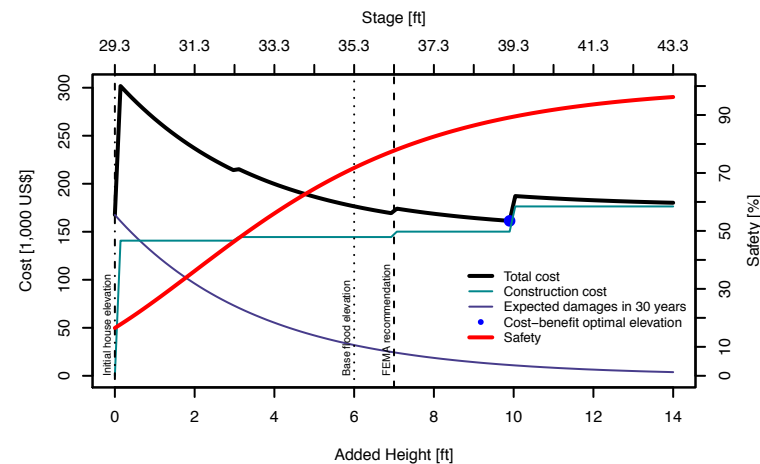
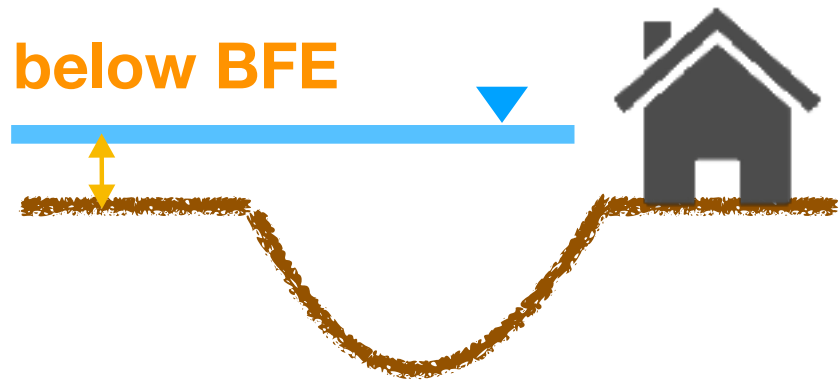
Safety is the probability of not being flooded in the house's lifetime

9 feet below BFE



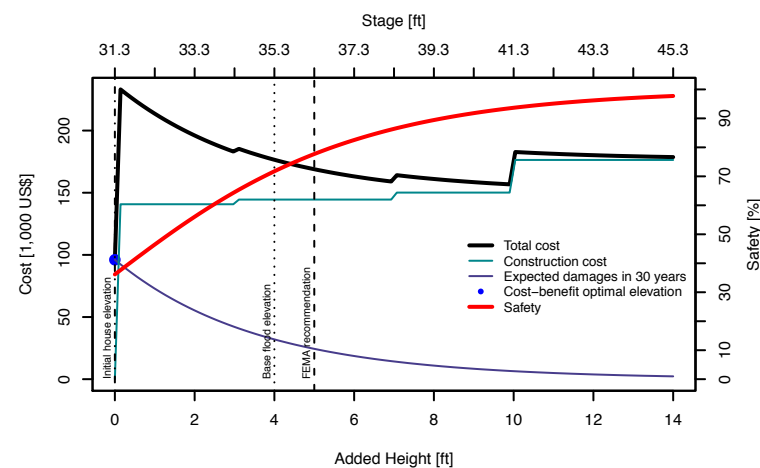
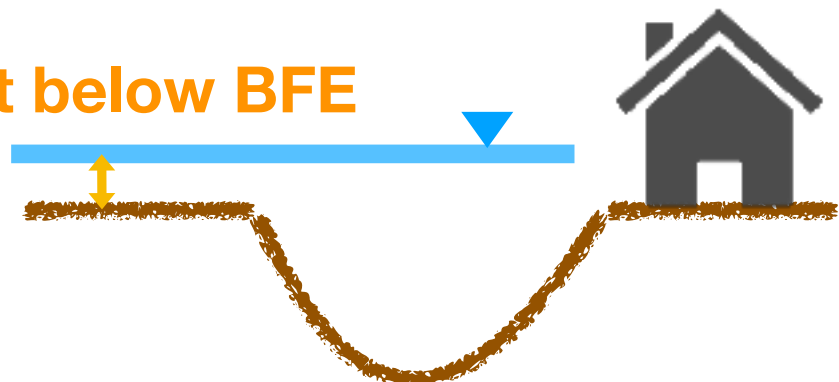
FEMA safety: 77%
Cost optimal safety: 77%

6 feet below BFE



FEMA safety: 77%
Cost optimal safety: 89%

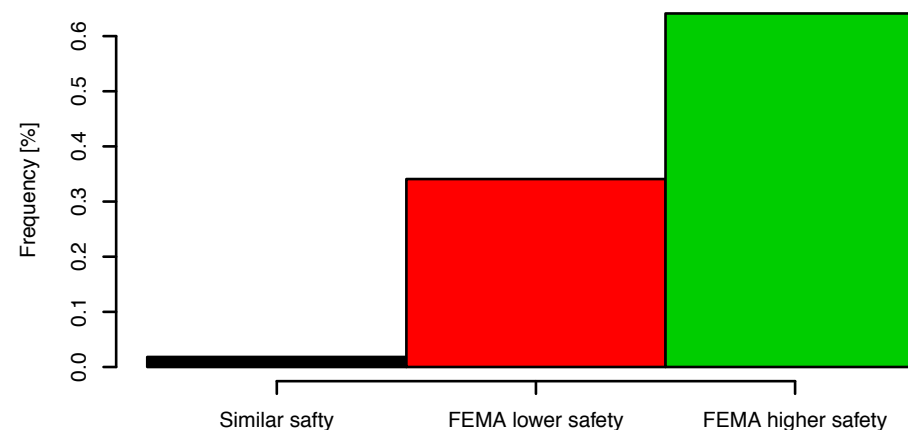
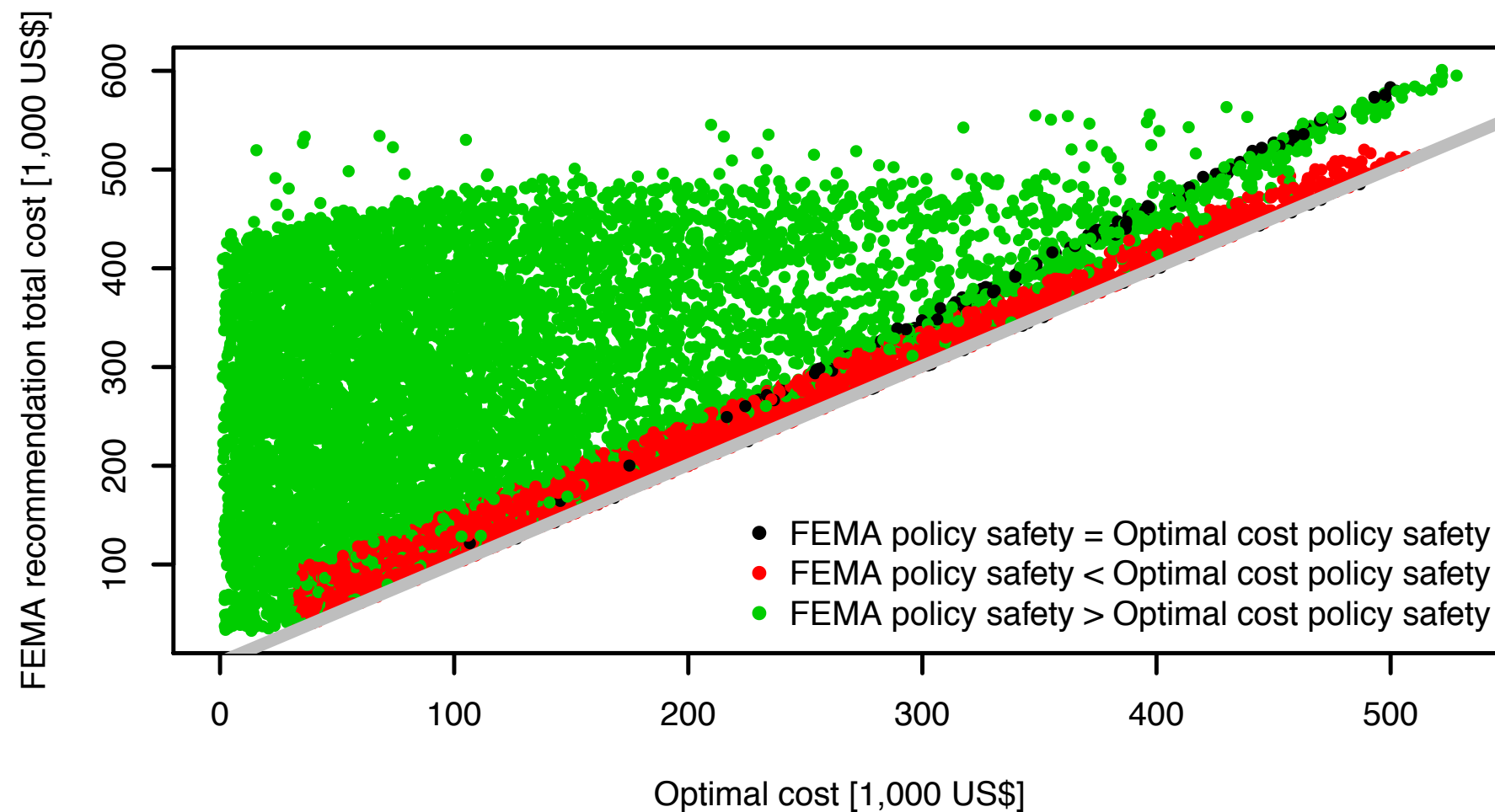
4 feet below BFE



FEMA safety: 77%
Cost optimal safety: 36%

Question: Is FEMA's recommendation cost effective?

What is cost is not the only objective?

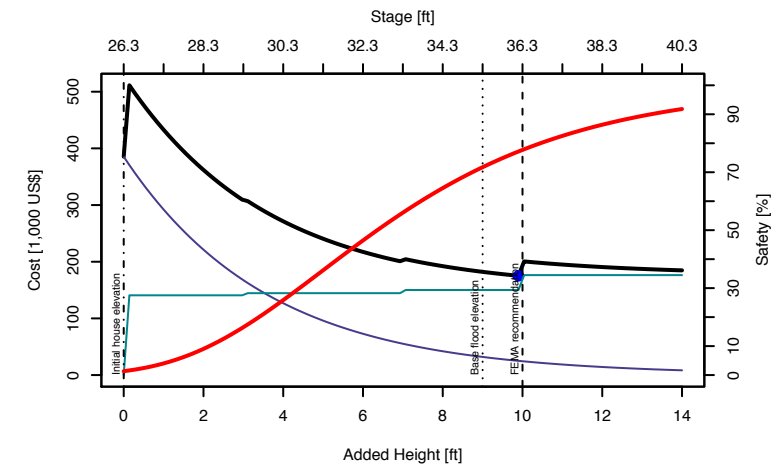
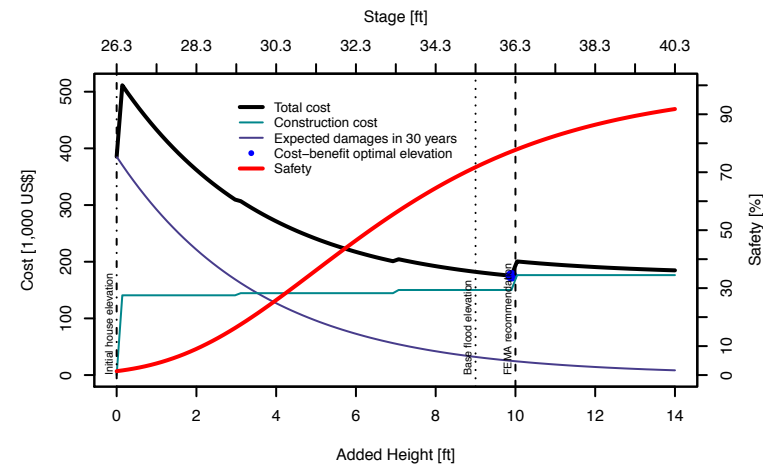
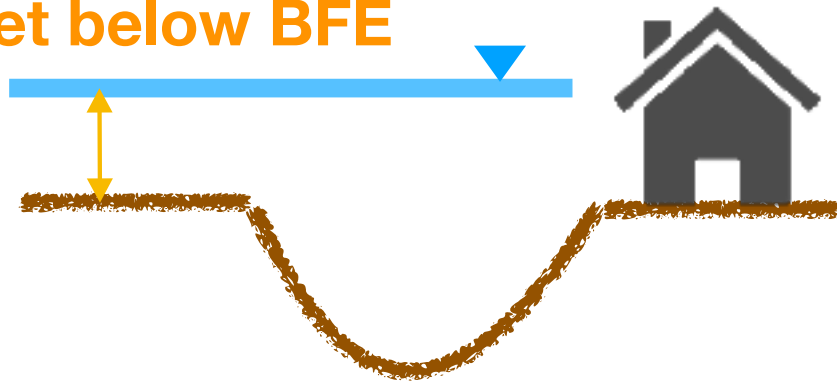


Question: Is FEMA's recommendation cost effective?

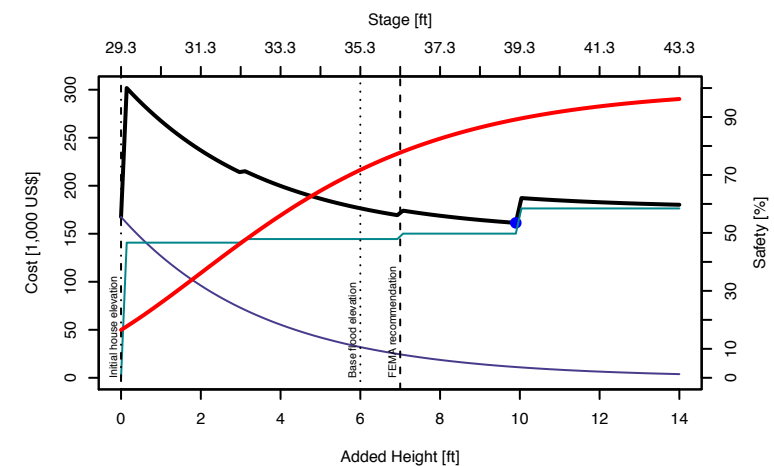
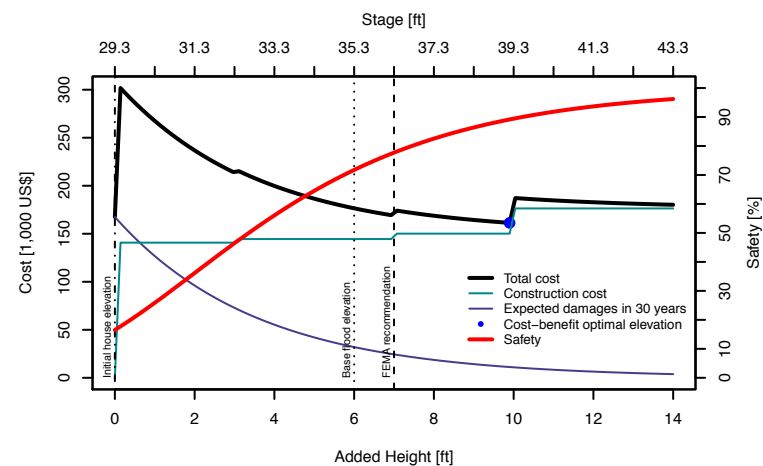
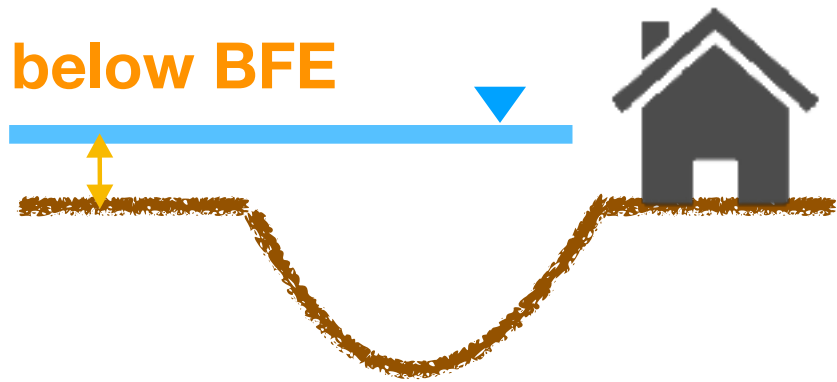
What is cost is not the only objective?

What is we add safety as another objective?

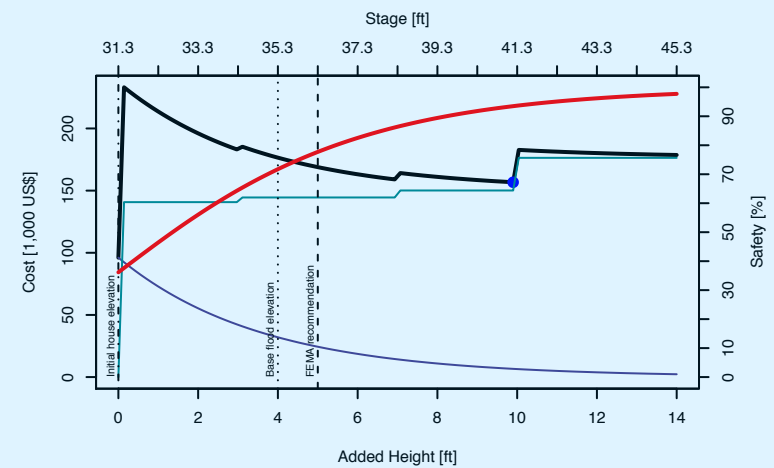
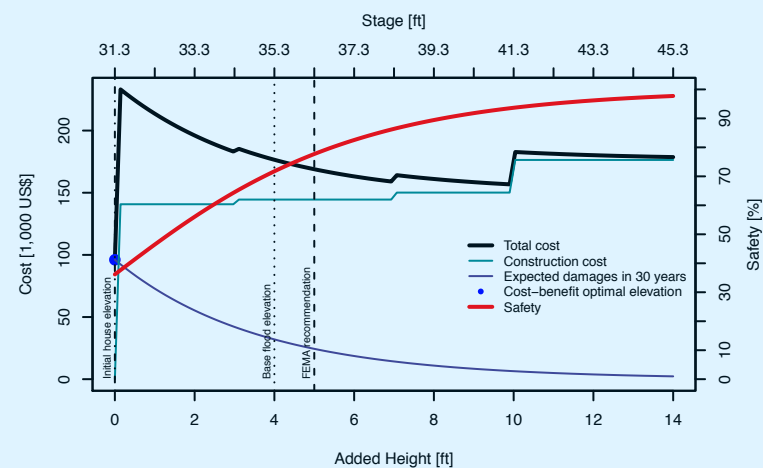
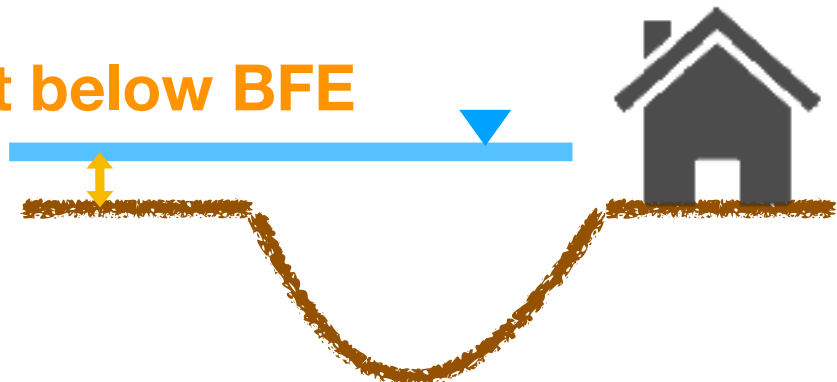
9 feet below BFE



6 feet below BFE



4 feet below BFE



Question: Is FEMA's recommendation cost effective?

What is cost is not the only objective?

