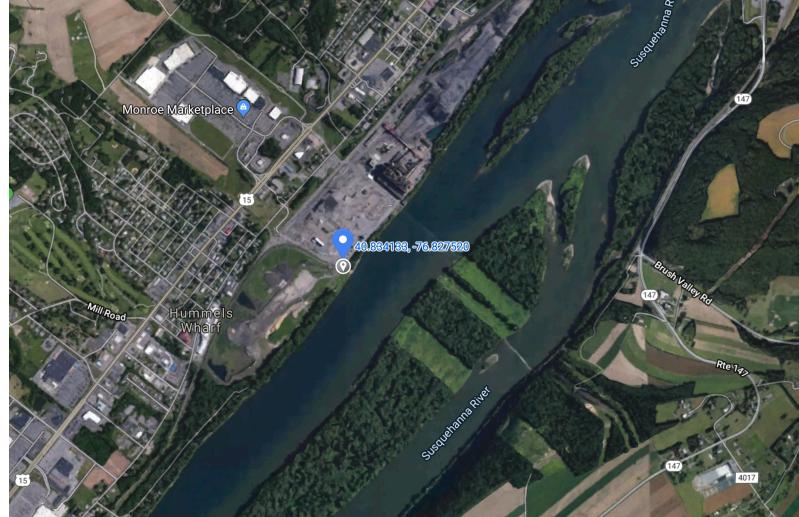
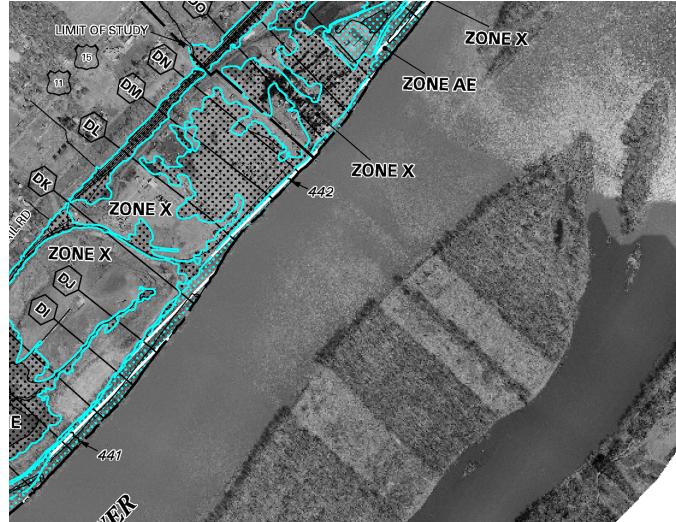


On the optimality of FEMA's recommendation for flood hazard mitigation

Areal image



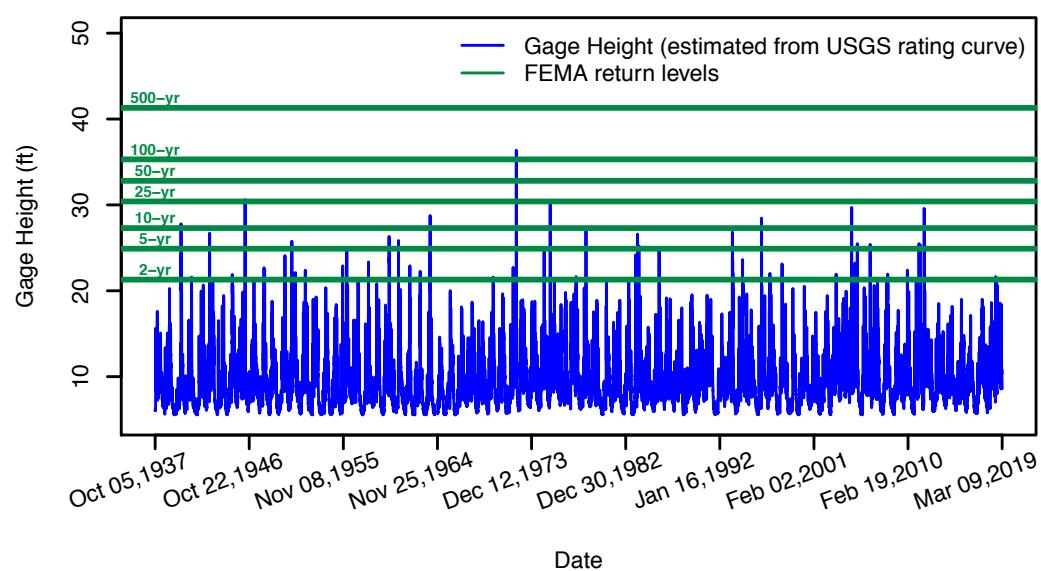
FEMA Flood zones



Typical houses in AE Zone

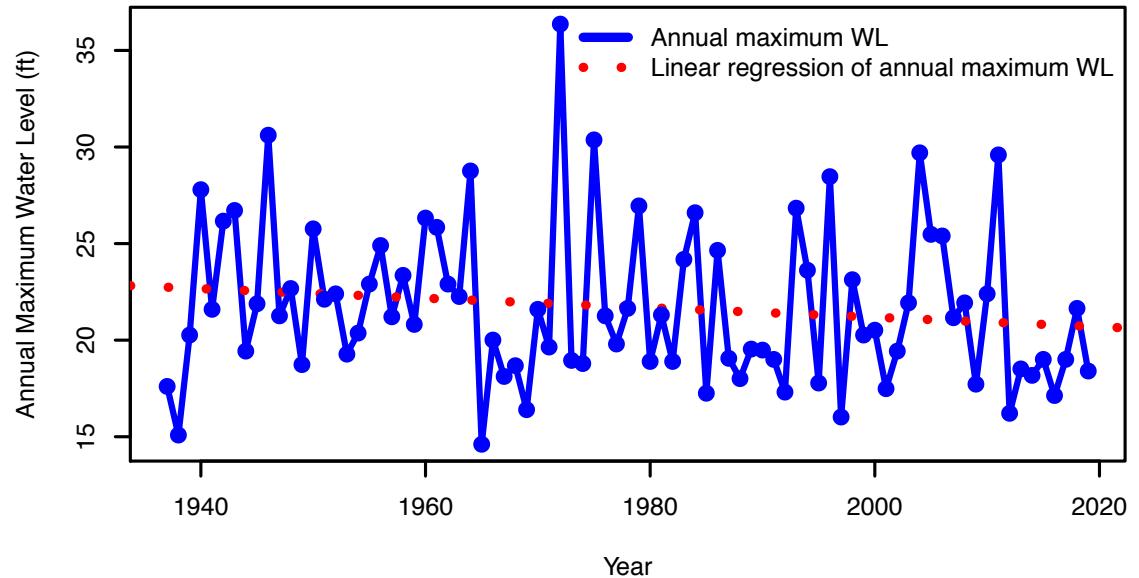


USGS 01554000 Susquehanna River at Sunbury, PA



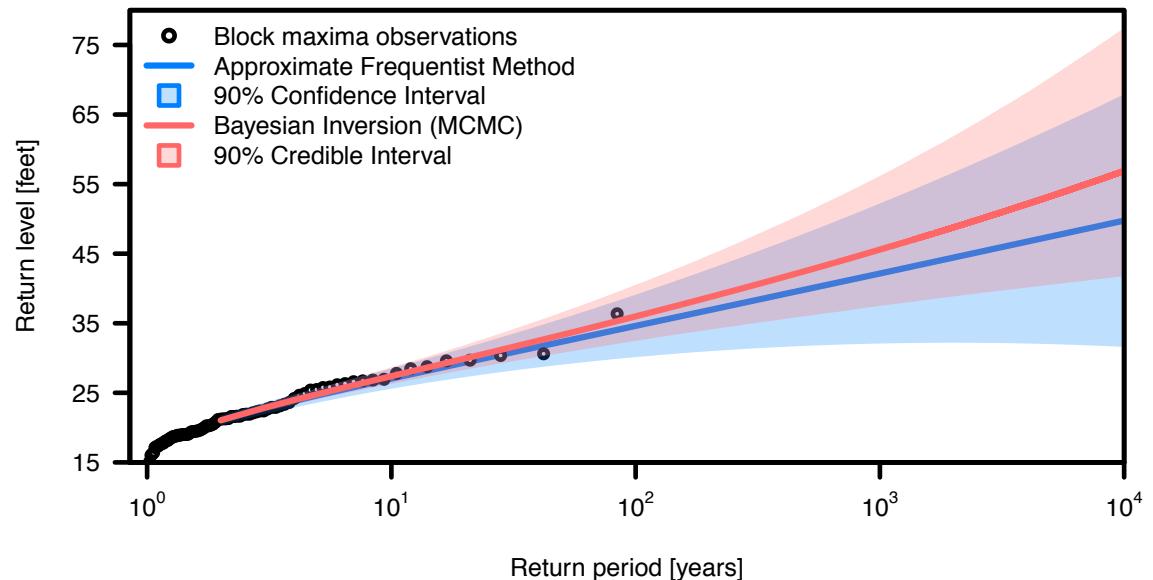
Flood Frequency Analysis (Block Maxima)

1. Extract annual maximum water level



2. Fit the annual maximum data to GEV distribution

Method: Markov Chain Monte Carlo

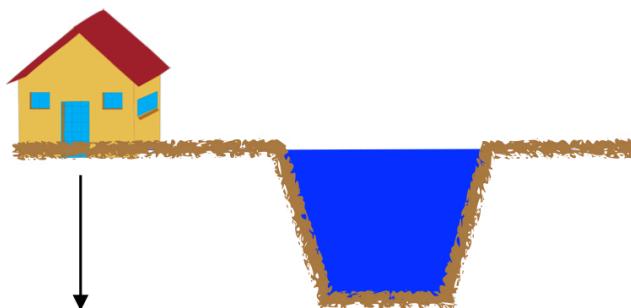
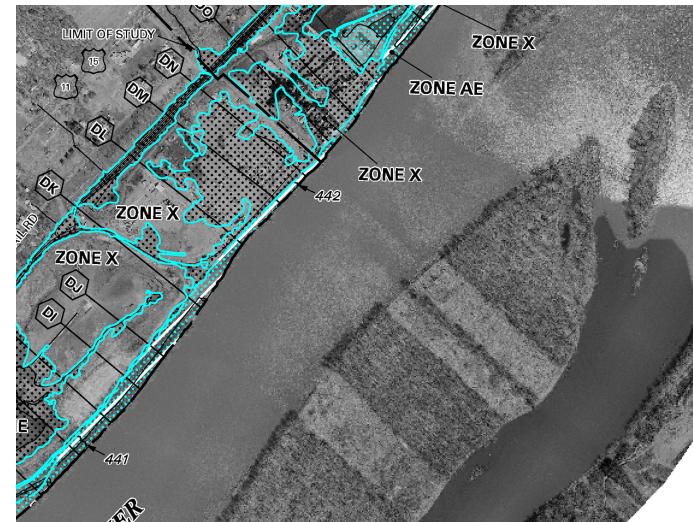


FEMA recommends elevating this house by two feet. But is that cost effective?

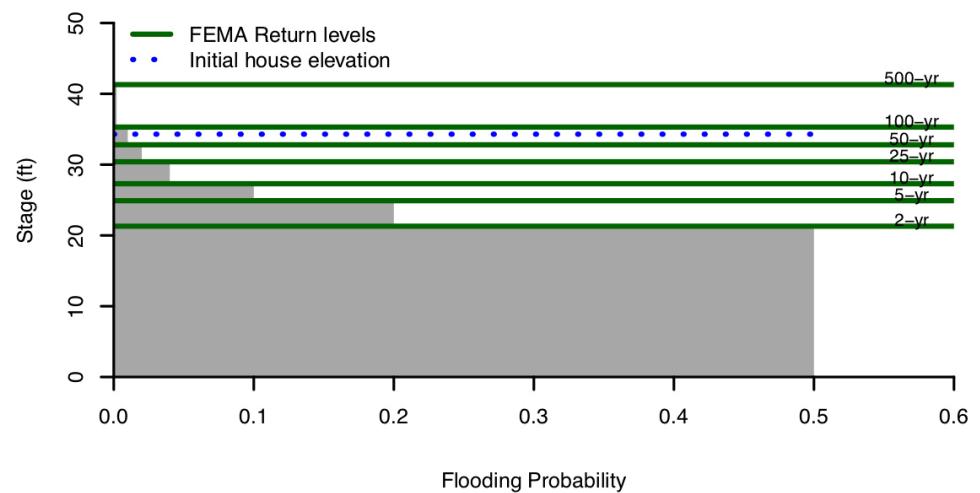
Areal image



FEMA Flood zones



This hypothetical house
Is 1 feet 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:

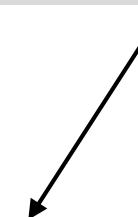
- FEMA recommendation is not cost effective for all houses
- The level to which a house should be elevated is dependent on:
 - The current elevation of the house; not just the zone
 - The house size, house value, and house age.
 - If uncertainties are taken into account, the recommended elevation increases

- Our research questions:

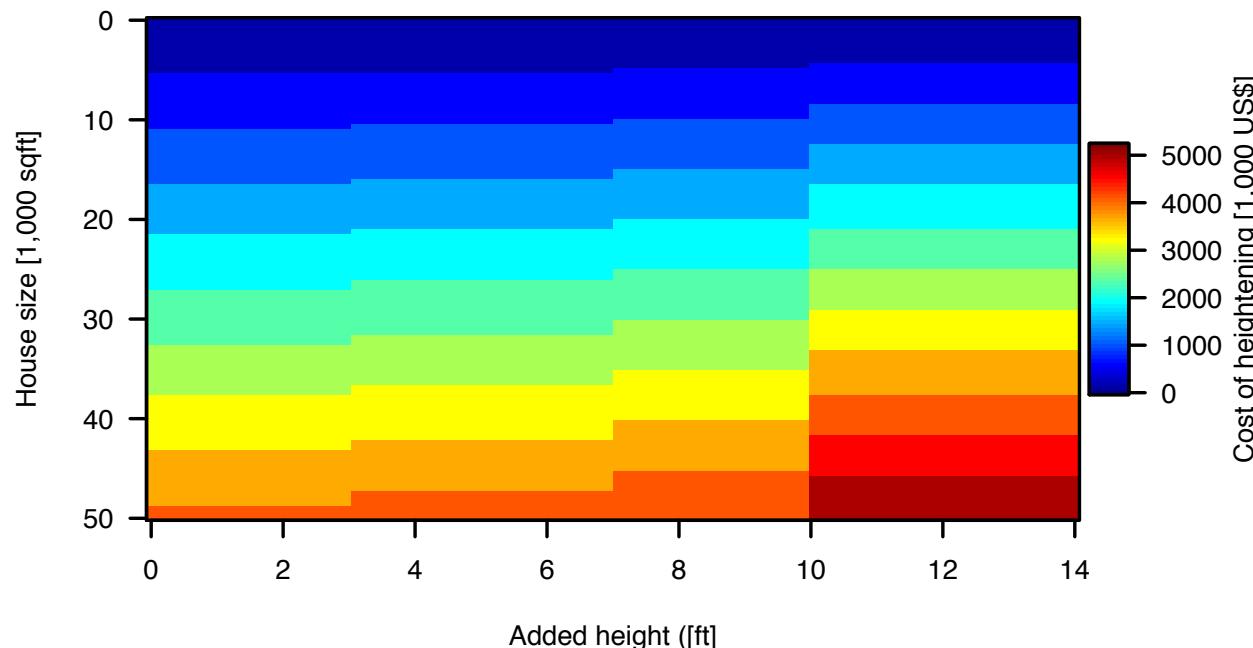
- Is one foot above BFE cost optimal? What are uncertainties taken into account?
- What is an optimal elevation under uncertainties?
- Would a better estimation of BFE lead to a different recommendation?

Question: Is FEMA's recommendation cost effective?

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



Cost of heightening = $f(\text{house size}, \text{added height}) + \text{initial cost}$



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)



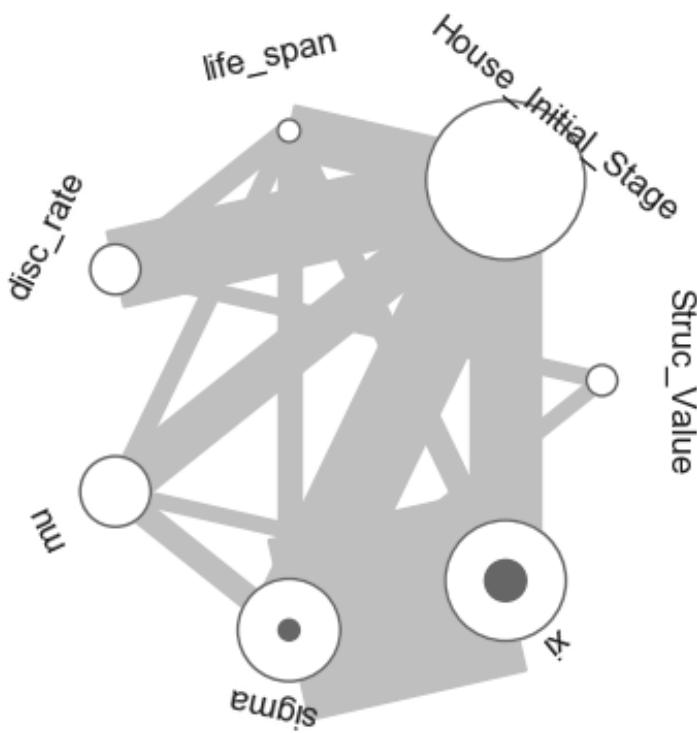
**f(house value , elevation , life span ,
flood return levels)**

Question: Is FEMA's recommendation cost effective?

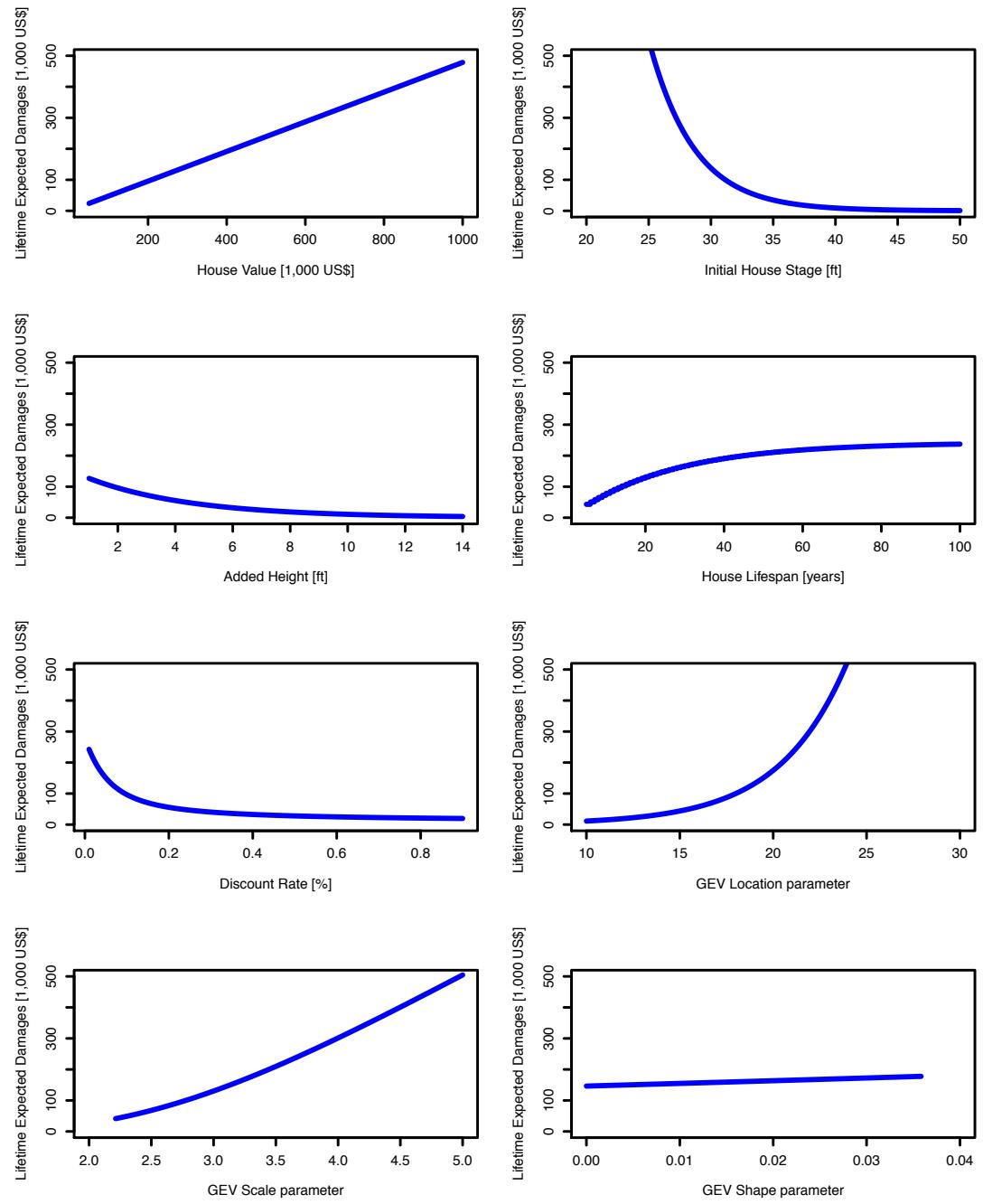
Total cost =
cost of heightening the house
+ present value of expected damages



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



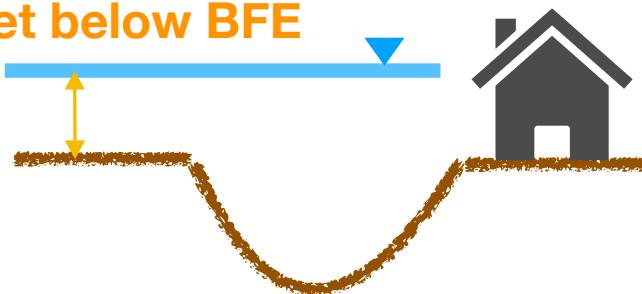
Sensitivity of lifetime expected damages
Figure under construction



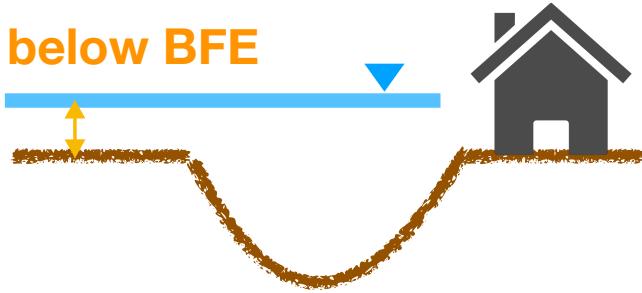
Question: Is FEMA's recommendation cost effective?

Let's consider three hypothetical houses

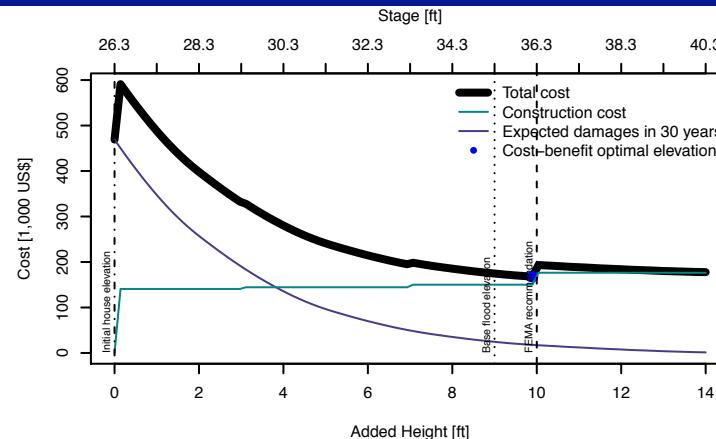
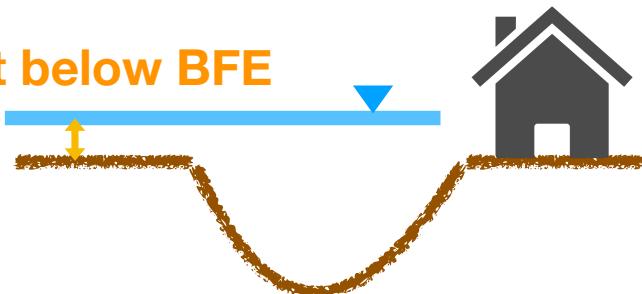
9 feet below BFE



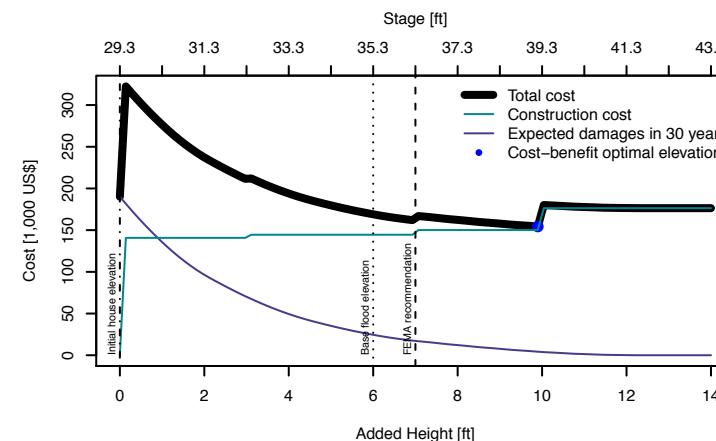
6 feet below BFE



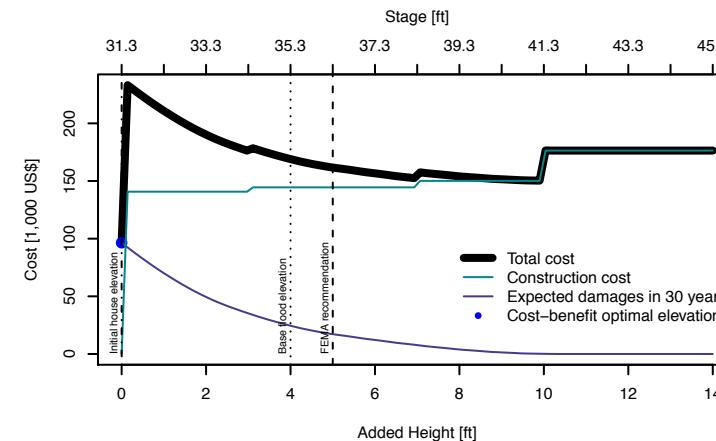
4 feet below BFE



Is cost effective



Is not cost effective

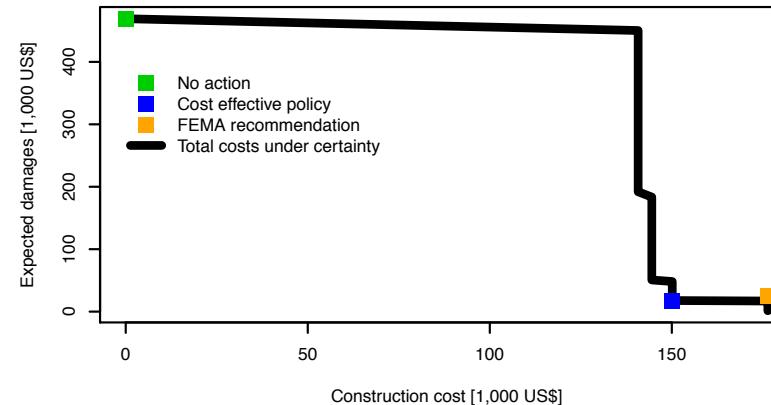
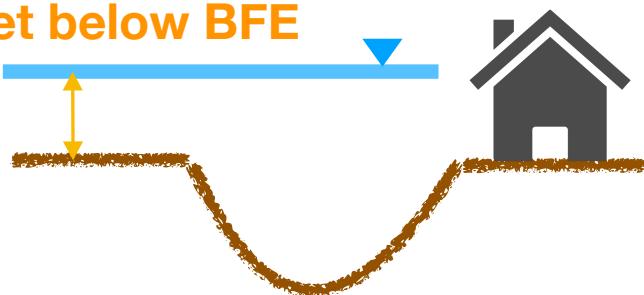


Is not cost effective

Question: Is FEMA's recommendation cost effective?

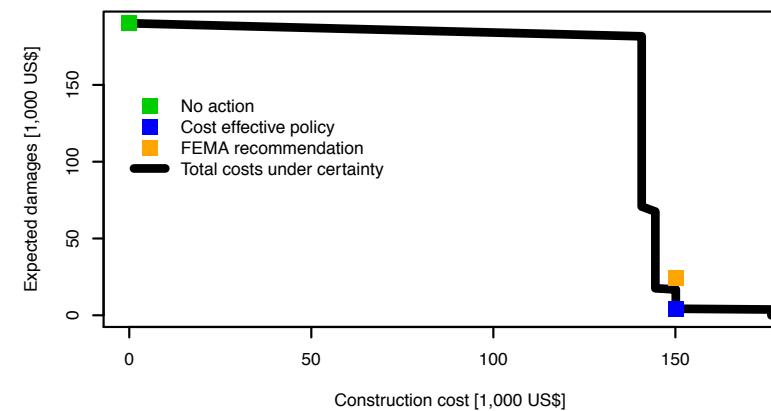
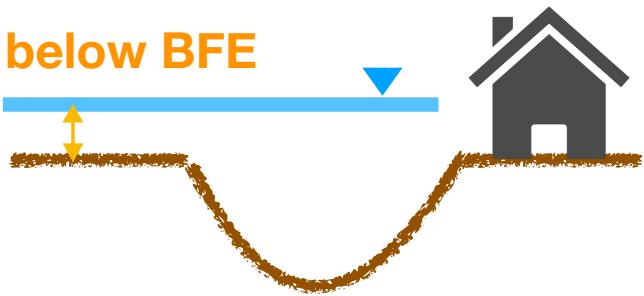
Let's consider three hypothetical houses

9 feet below BFE



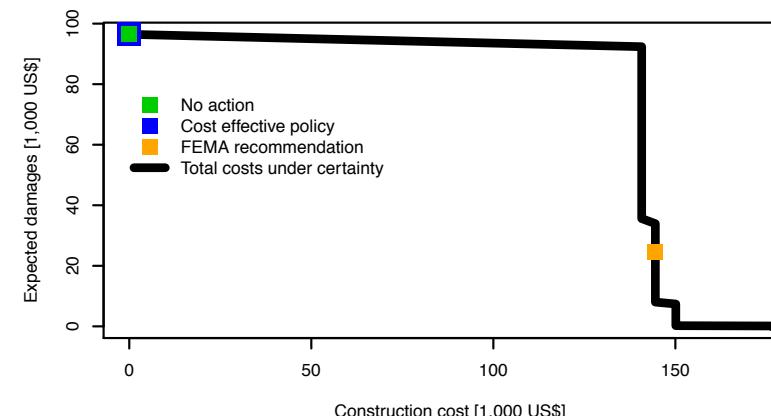
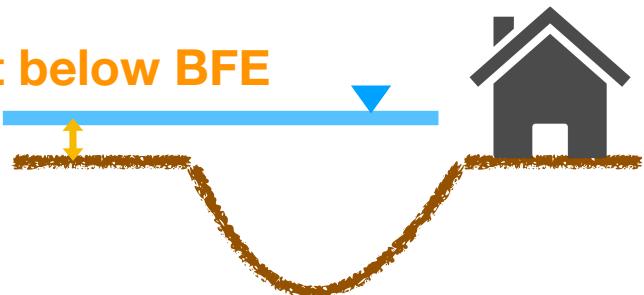
Is cost effective

6 feet below BFE



Is not cost effective

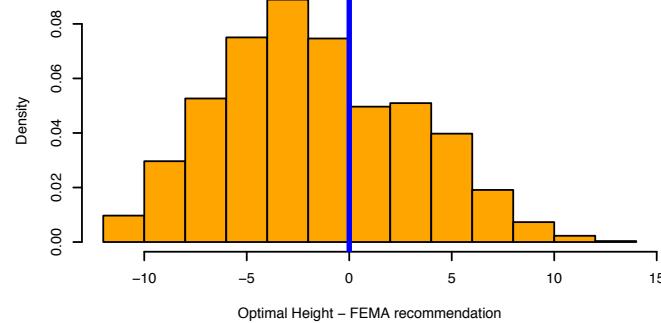
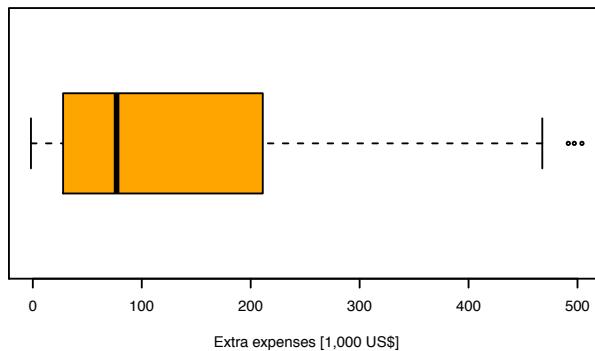
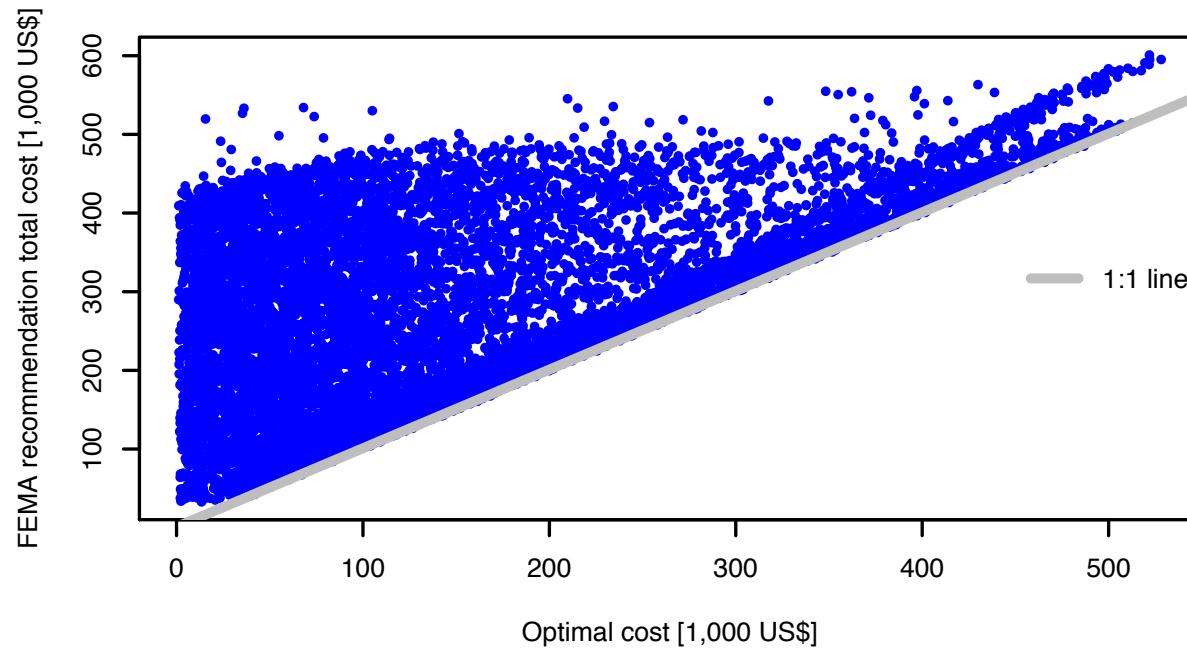
4 feet below BFE



Is not cost effective

Question: Is FEMA's recommendation cost effective?

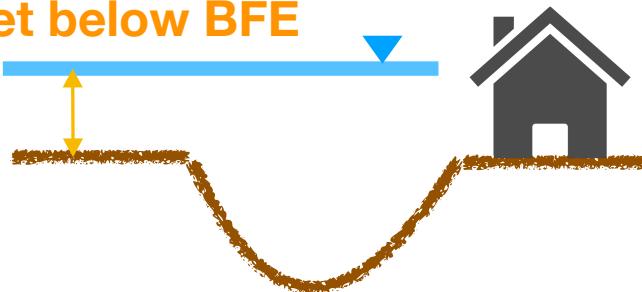
- Let's create 10,000 hypothetical houses and see in how many of them FEMA is optimal
- FEMA's recommendation is cost effective in less than 1% of the houses.



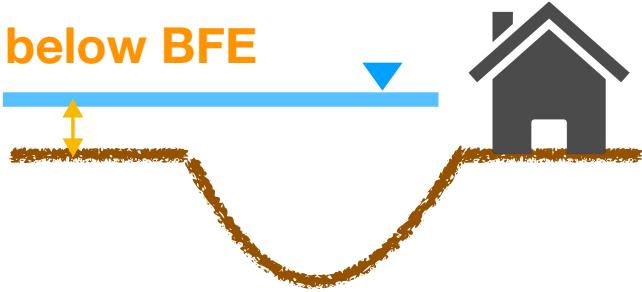
Question: Is FEMA's recommendation cost effective? What is cost is not the only objective?

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

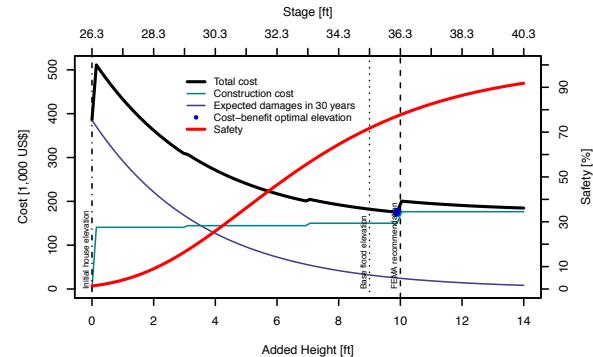
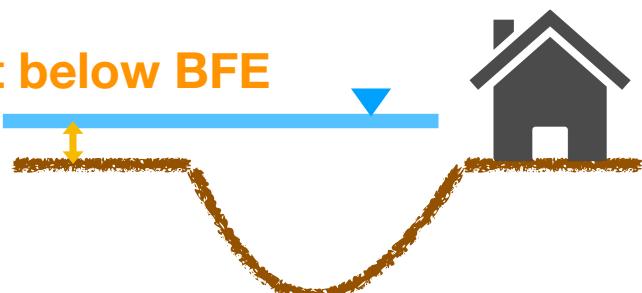
9 feet below BFE



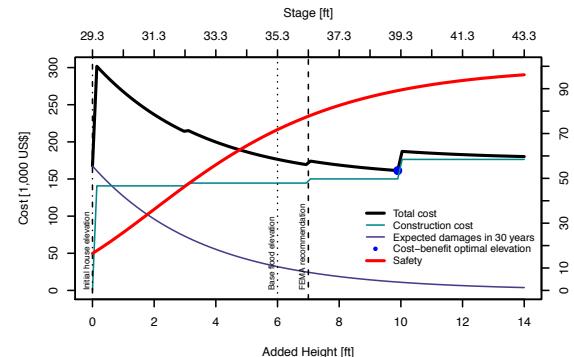
6 feet below BFE



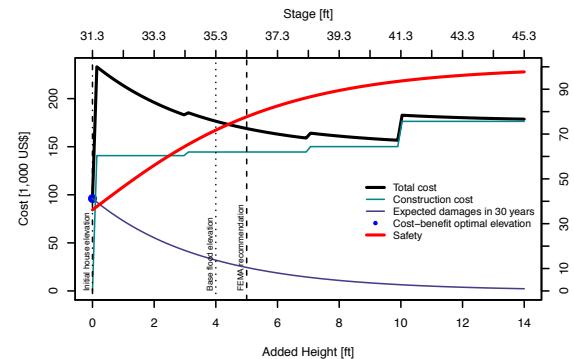
4 feet below BFE



FEMA safety: 77%
Cost optimal safety: 77%

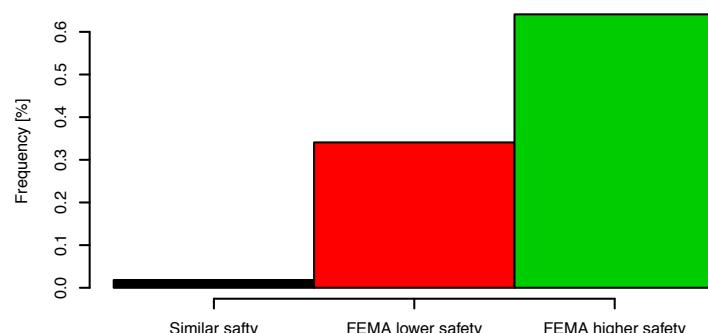
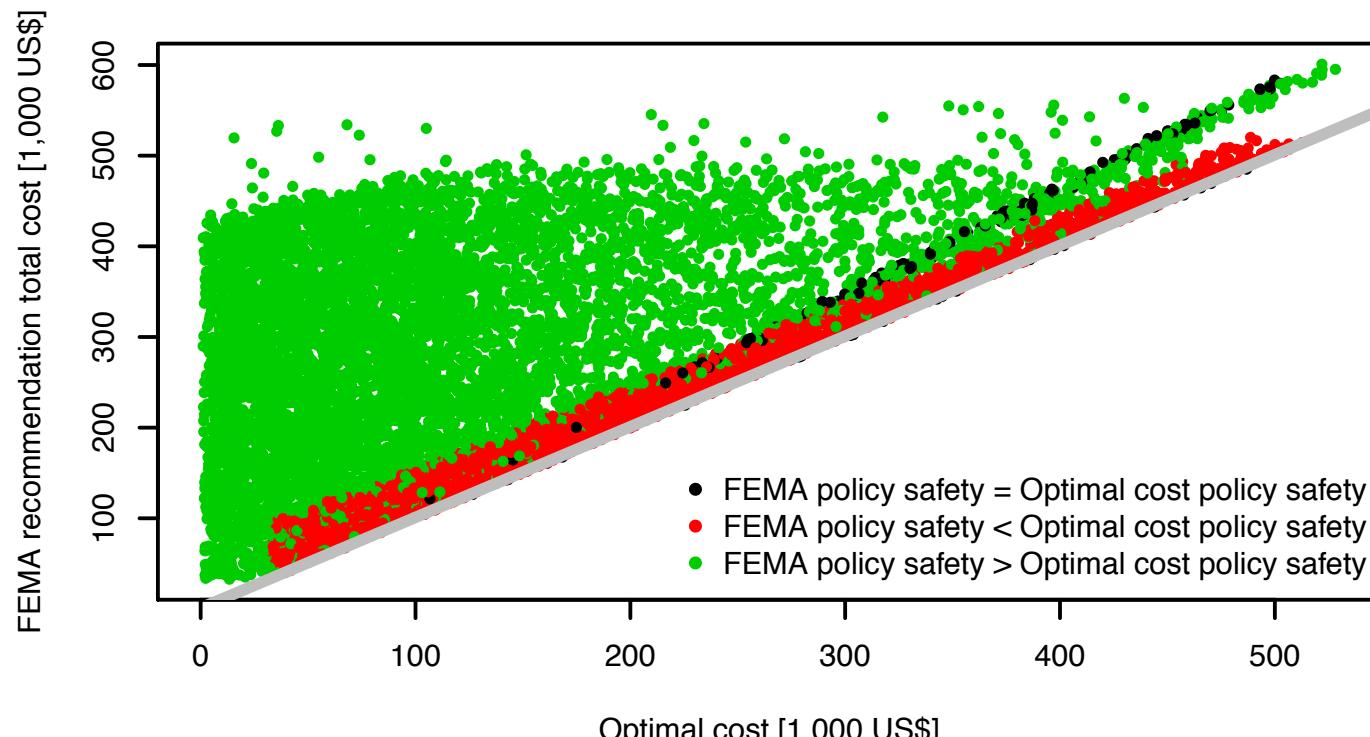


FEMA safety: 77%
Cost optimal safety: 89%



FEMA safety: 77%
Cost optimal safety: 36%

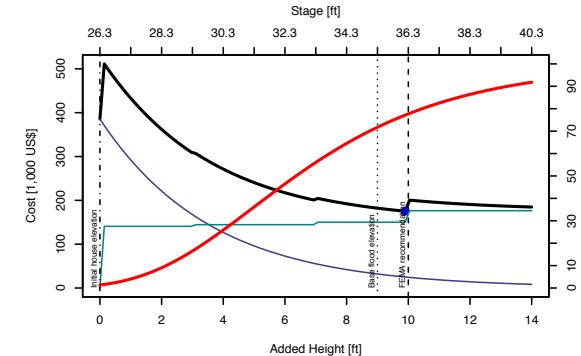
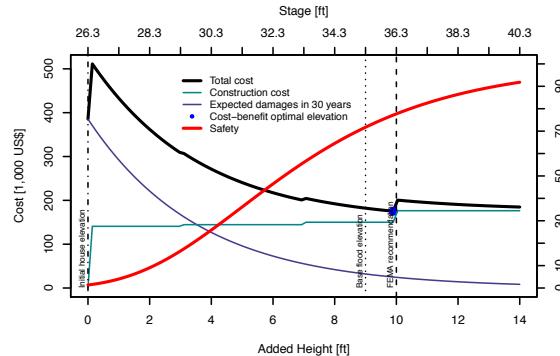
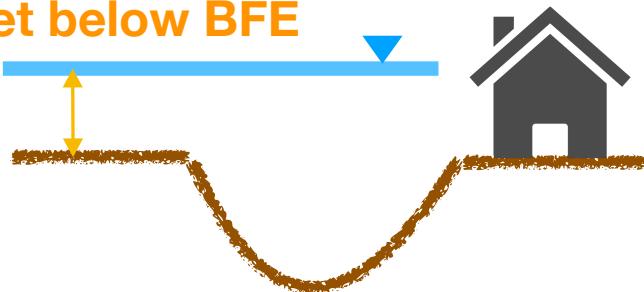
Question: Is FEMA's recommendation cost effective? What is cost is not the only objective?



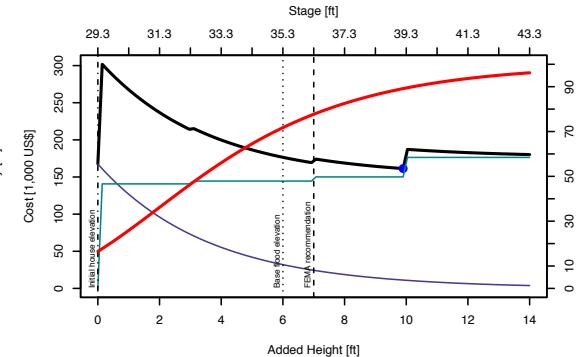
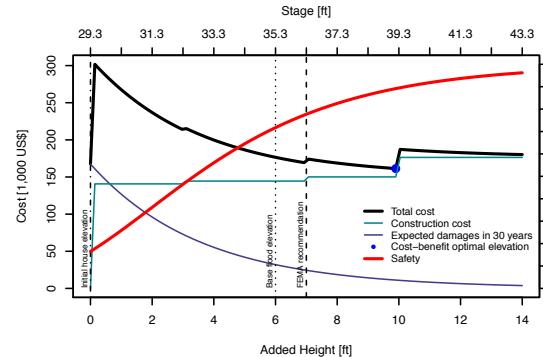
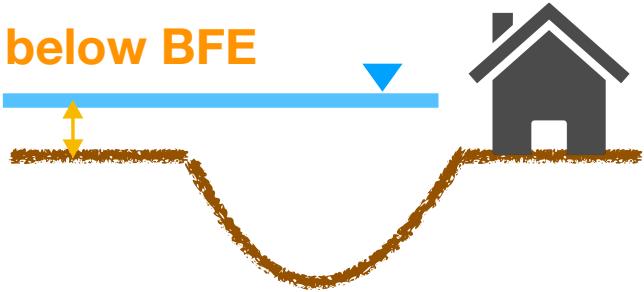
Question: Is FEMA's recommendation cost effective? What is cost is not the only objective?

What is we add safety as another objective?

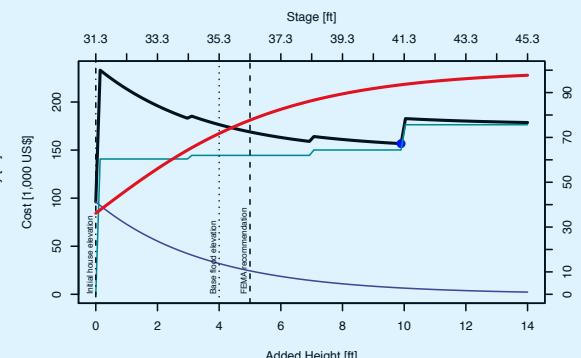
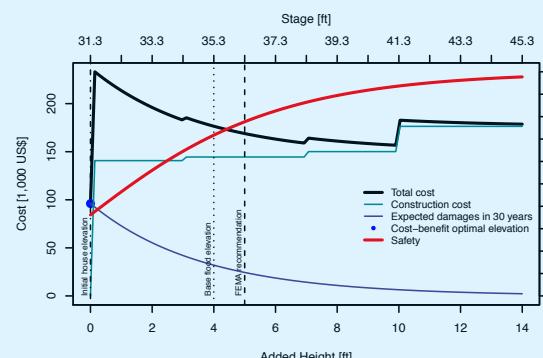
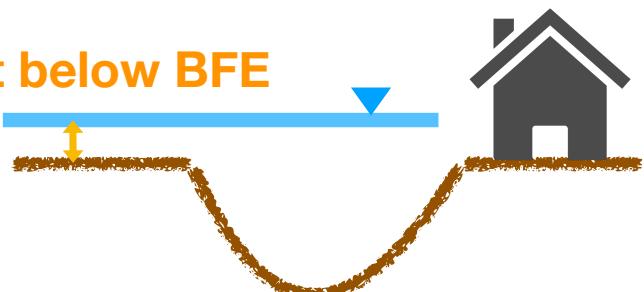
9 feet below BFE



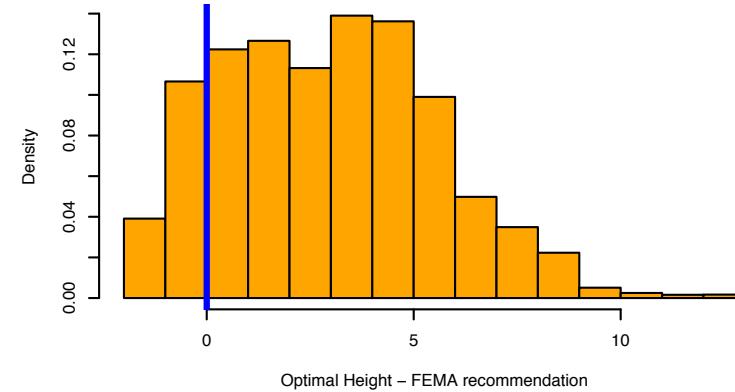
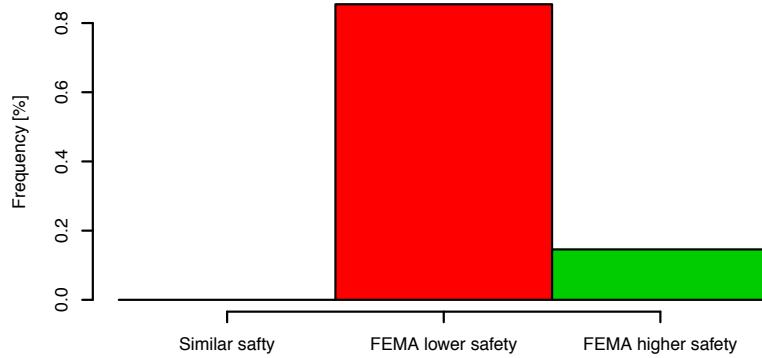
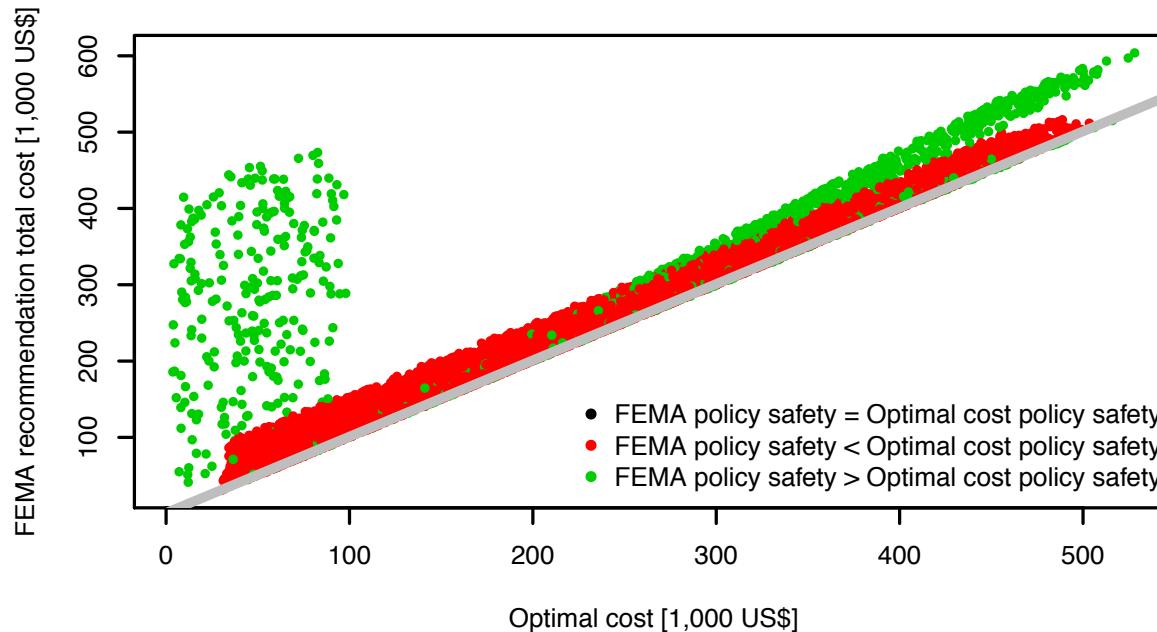
6 feet below BFE



4 feet below BFE



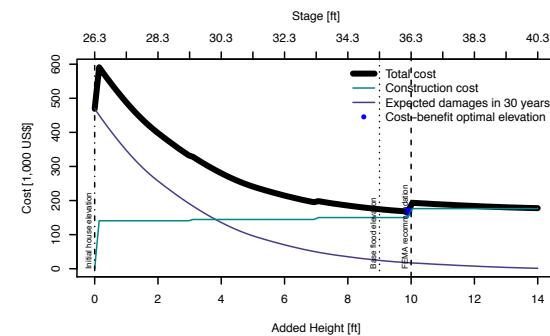
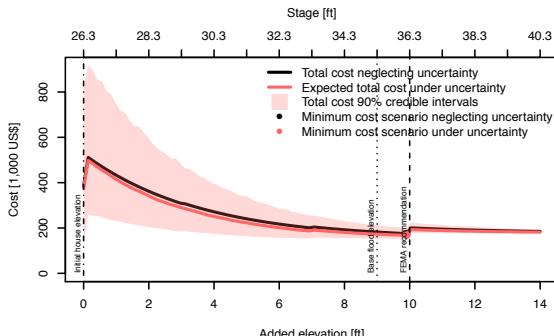
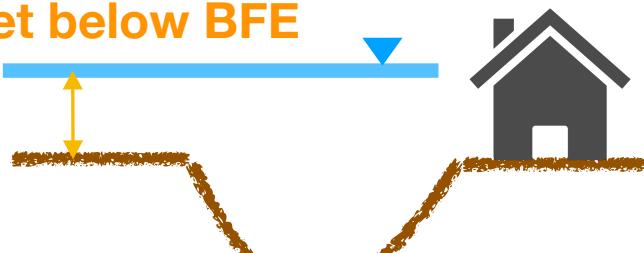
Question: Is FEMA's recommendation cost effective? What is cost is not the only objective?



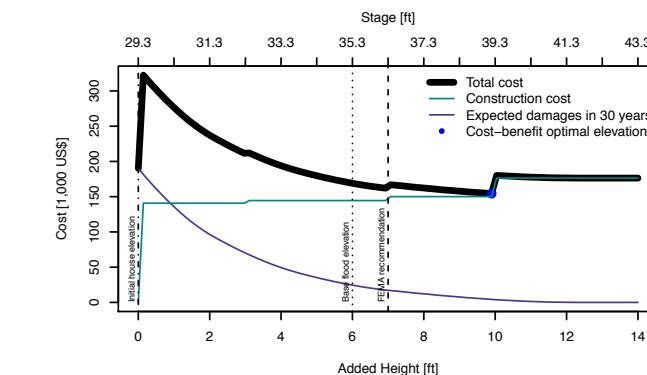
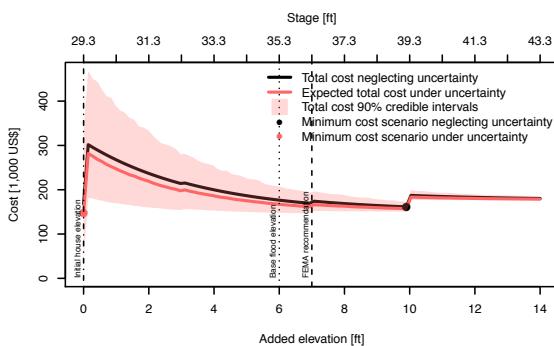
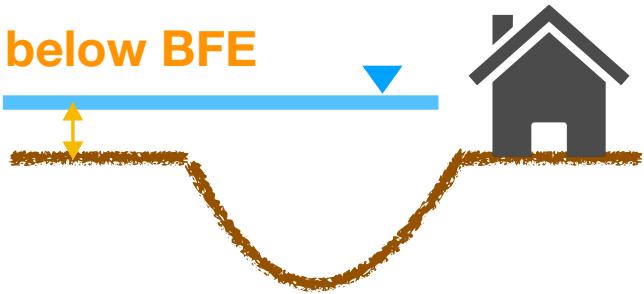
Question: What about uncertainties?

Let's consider three hypothetical houses

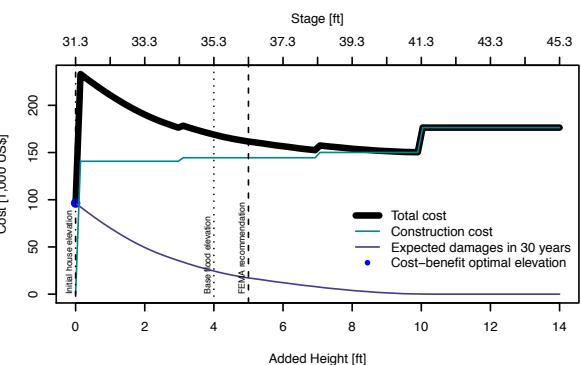
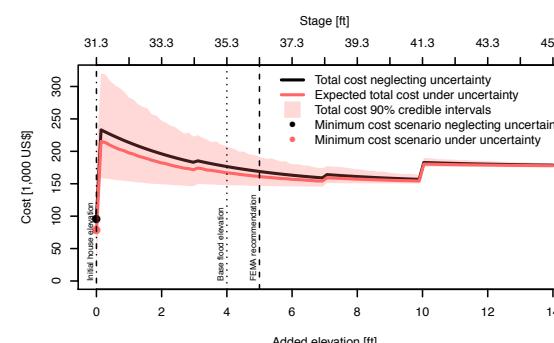
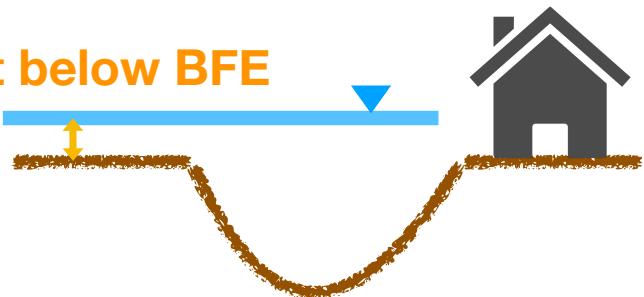
9 feet below BFE



6 feet below BFE



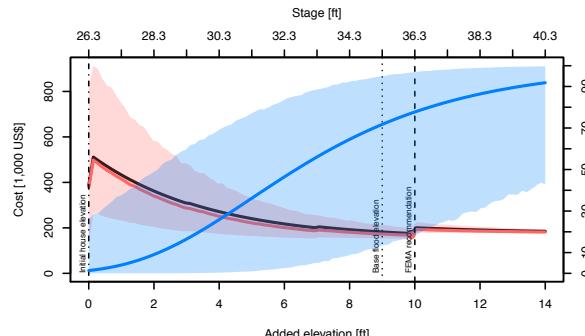
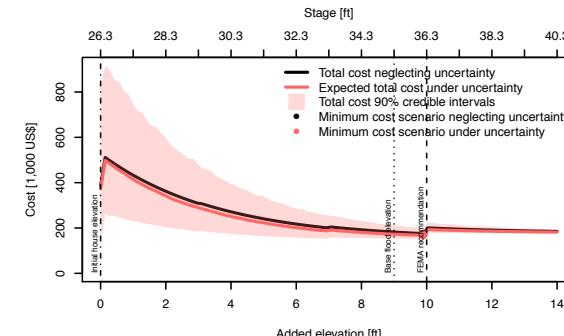
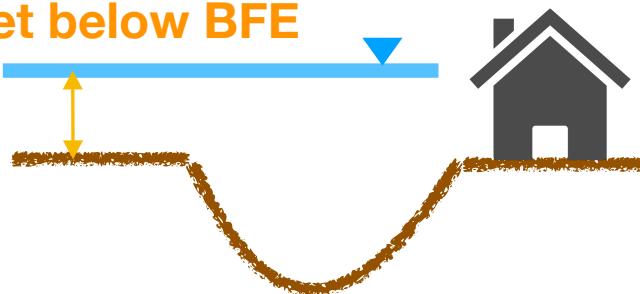
4 feet below BFE



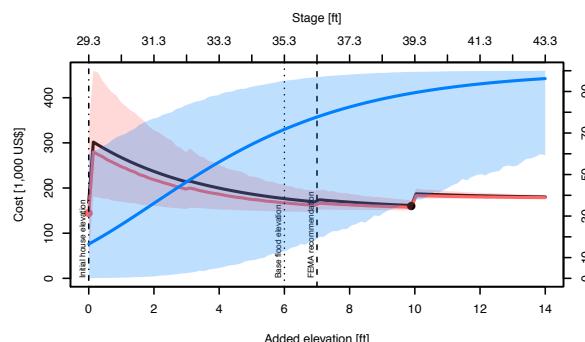
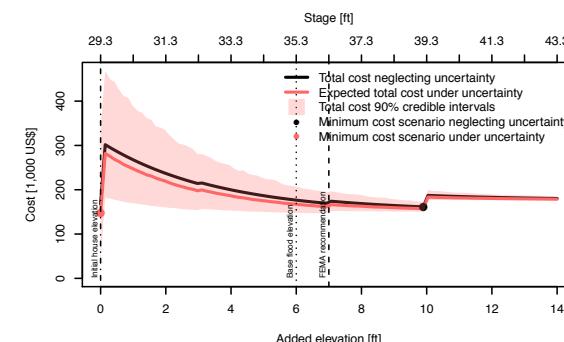
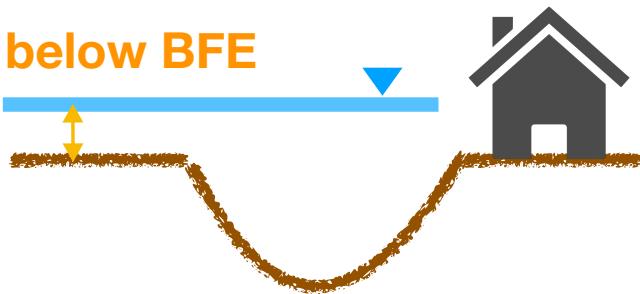
Question: What about uncertainties?

Let's consider three hypothetical houses

9 feet below BFE



6 feet below BFE



4 feet below BFE

