CE311S Laboratory 4
Levee Design Based on the Binomial Distribution

Purpose

Using a binomial distribution model, you will investigate how a often a levee protecting against floods fails, and thus how the height of a levee affects: 1) its performance over different design lives; 2) its return period of a levee being overtopped; and 3) its construction cost.

Introduction

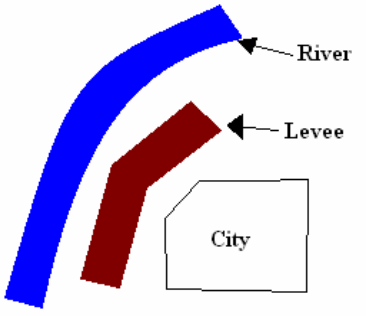
Levees are constructed of compacted earthen materials and are built as flood control structures. A levee's design height is usually based on the maximum annual flood level for the area. It also depends on the amount of money available to pay for construction and the amount of risk the client wishes to accept in the event that the levee fails (i.e. expected losses).

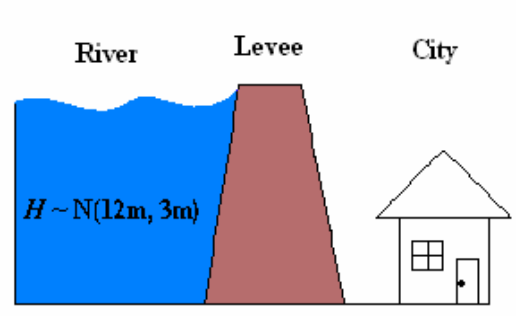
Both federal and state governments offer relief aid for areas destroyed by floods. However, the agencies controlling these funds have set specific standards to reduce the probability that an area will be flooded so that the amount of aid that they must extend is reasonable. In order to be eligible for future Federal Emergency Management Agency (FEMA) funds or the equivalent state funds, certain guidelines for levee construction must be met. The standards are:

> **Federal Standard:** a 99% reliability (1% failure rate) over a 20-year design life.
> **State standard:** a return period of 500 years for a 20-year design life.

A levee fails whenever water spills over it (when it is "overtopped"). A return period, as defined here, is the average time between events which overtop a levee.

You have been hired by the City of Bodine to determine if their levee needs to be upgraded for eligibility to the state or federal programs. The current levee height is 15 meters. Based on historical records of the river heights, the maximum annual water height (H) has a normal distribution with a mean of 12 meters and a standard deviation of 3 meters. You will test the current levee design for eligibility as well as other potential designs to compare their performance and cost.





Tutorial

The number of years in which the levee fails over its lifetime can be modeled as a binomial random variable. A binomial event arises from a succession of independent, identical Bernoulli trials. See tutorial for the Bernoulli Sequence on the Lab web page.

Procedure

Part I: Levee performance for Different Design Lives

With a partner, you will use the program "Levee Design.exe" to calculate the probability of overtopping at least once during a given levee's design life, the return period of this event, and the levee's construction cost.

1. Open the program "Levee Design.exe" and click on run (⇨).
2. In the table below, enter the input values arising from your results. Click on the "Next Trial" button and record the output data in Table 1. Repeat for design lives of 20 and 100 years.
3. Change the height of the levee and run experiments for design lives of 1, 20, and 100 years. Record the output data in Table 1 (located at the end of this lab report). Try four different levee heights.
4. Use the program to determine the levee height necessary to meet the state standard and the levee height necessary to meet the federal standard given in the introduction and record in the last line of Table 1.

Part II: Simulation of Levee Performance Over Twenty Years: The city has made available to you a new simulation program. With this program you can monitor how different levee designs perform over a five-year period. You can simulate several five-year periods to monitor a levee over a period greater than five years. For instance, to simulate a 50-year period, a total of 10 simulation sets would be run.

1. Open the program "Levee Simulation.exe" and click on the toolbar's run (⇨) button.
2. Enter the current levee height of 15m and a design life of 20 years. Click on the "Simulate 5 Years" button. Each year's performance will be sequentially displayed. Record the results for the first five years in the table below.
3. Click on the "Simulate 5 Years" button again and record the results for years 6 through 10 (i.e. 1 = year 6, 2 = year 7…). Repeat until you have 20 years of performance data.
4. Click the "Clear Display" button and repeat the simulation for 20 years twice: once using the levee height you found in Part I for the federal standard and once using levee height you found for the state standards.

Table input values:

0 = Levee overtopped (failed) 1 = Levee intact (no failure)

Current Design: Levee Height = 15m, Design Life = 20 years (3 pts)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Overtop?																				

Federal Standard Design: Levee Height = _____m, Design Life = 20 years (3 pts)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Overtop?																				

State Standard Design: Levee Height = _____m, Design Life = 20 years (3 pts)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Overtop?																				

***Questions*:**

1. Based on the data you collected in Part I, provide qualitative and quantitative descriptions about how the following parameters are related.

(a) What is the relationship between construction cost and levee height? (2 pts)

(b) What is the relationship between P(Overtop) and construction cost? (2 pts)

(c) What is the relationship between return period and levee height? (2 pts)

2. The city council would like to know the reliability of the current 15m high levee.
   (a) Calculate the probability that the current levee will be overtopped by the river in a given year. Check your calculation with your output from Part I. (Hint: What is the distribution of the maximum annual water height of the river?) (15 pts)

(b) Calculate the probability that the current levee will be overtopped at least once during a 20-year design life. Compare your estimate with your output from Part I. (15 pts)

3. If the levee overtops, the City of Bodine has two possible sources of relief funds. However, the levee must meet the governments' criteria in order for the city to be eligible for these funds. Assume that both sources provide the same amount of disaster relief money. Also, you may only receive aid from one source, not from both. Compare the current levee design with the designs required for the federal and state standards by recording the information in Table 2.

Table 2

Levee Design	Levee Height (m)	Design Life (years)	P(Overtop) During Design Life	Return Period (years)	Construction Cost ($)
Current		20			
Federal Standard		20			
State Standard		20			

Based on the values you collected in Part I, what recommendation do you make to the City of Bodine? Should they keep the current levee height, design to the federal standard, design to the state standard, or design according to your best judgment? Compare the advantages and disadvantages of each of the three and explain your final decision. (10 pts)

4. According the binomial model, should the performance of the levee during any five-year period be different, on average, from any other five-year period? Using the data collected in Part II, compare how the current levee, with a height of 15m, performed over the first 5-year period, the first 10-year period, and the entire 20-year period. Does this agree with your answer from the first part of this question? Why or why not? (15 pts)

5. Is the simulated performance from Part II of the lab what you expected for each levee design simulated? Include with your answer the levee performance you expected (this can be garnered from Part I). (20 pts)

(a) Current Levee Design

(b) Federal Standard

(c) State Standard

Table 1 (10 pts)

Levee Height (m)	Design Life (yrs)	P(Overtop) During Design Life	Return Period (yrs)	Construction Cost ($)
15	1			
15	20			
15	100			
	1			
	20			
	100			
	1			
	20			
	100			
	1			
	20			
	100			
	1			
	20			
	100			
Federal/ Standard				
	20			
State Standard				
	20			