Nov. 1, 2004

CIEG 440 Water Resources Eng'g.

Probability / Statistics

Hydrologic Phenomena like the weather are non-linear and are:
- random
- obey the chaos theory,

That is, we have a low chance of predicting when and how much it will rain.

Climatologists will say that long range weather forecasts can be made with a 50% chance of being accurate. Flip a coin.

Therefore, water resources engineers employ factor of safety into design to reduce risk and increase reliability.

- Risk - Design a culvert to pass a 100-yr. flood instead of a 50-yr.

- Reliability - Build an over-flow spillway in the event that an outlet pipe at a stormwater detention basin overflows.

Return Period / Recurrence Interval (T)

$$T(\text{yrs}) = \frac{1}{p}$$

where p = probability

T = 10 yr flood = $\frac{1}{p}$, $p = 0.10$ or 10%

T = 100 yr Flood = $\frac{1}{p}$, $p = 0.01$ or 1%

So, a 10-yr. flood = 10% (0.1) chance of occuring in any given year.

A 100-yr flood has a 1% chance of occuring in any given year.

This does not mean that the Q_{10} will occur only once every 10 years. We can have a 10-yr flood in 2 yrs.

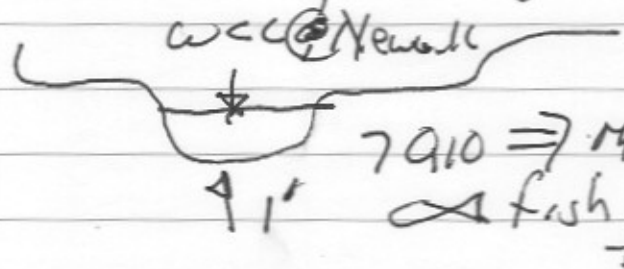
Witness, the Red Clay Creek in northern Delaware where a 500-yr. flood occured in Sep. 2003 (Henri) and a 100yr. flood occurred in Sep. 2009 (Jeanne)

T (yrs)	P
1	1.0 (100%)
2	0.5 (50%)
5	0.2 (20%)
10	0.1 (10%)
25	0.04 (4%)
50	0.02 (2%)
100	0.01 (1%)
500	0.002 (0.2%)

Flow	Criteria	RCC @ Woodale Gage (cfs)	WCC @ Newark (cfs) Gage
Q_{10}	Storm Sewer Design	4,700	7,200
Q_{50}	Culvert Design, Low Traffic Roads, Footbridges	7,800	11,800
Q_{100}	Bridges, Culverts (High Traffic) Floodplain Delineation Stormwater Detention Basins	9,400	14,200
Q_{500}	Dam Safety	14,3000	22,000

Drought

7Q10 flow - Low flow likely to occur for 7 days in a row once every 10 yrs.

- The 7Q10 flow is exceeded 98% of the time.
- The 7Q10 flow is likely to occur 2% in any given year, or 0.02(365) ≈ 7 days
- The 7Q10 flow is set by regulatory agencies like the DE DNREC and Delaware River Basin Commission (DRBC) as the minimum flow that must be left in a stream to protect fishery.
- At the WCC@Newark gage, the City of Newark must contain withdrawals at their intake when/as the stream flow declines below the 7Q10 = 7 mgd.
- 

- Because of the 7Q10, the City of Newark is building a new reservoir.

Water Supply Intake	7Q10
Brandywine Creek @ Wilmington	49 mgd
White Clay Creek @ Stanton	17 mgd

r. White & Lower Egypt Creek at Wooddale Streamgage

Tropical Storm or Hurricane	Date	Peak Flow	Estimated Return Interval
Jeanne	9/28/04	11,500 cfs	> 100 yr.
Henri	9/15/03	18,400	> 500 yr.
Floyd	9/16/99	7,600	50 yr.
Donna	9/12/60	4,800	10-yr.
Agnes	6/22/72	9000	< 10-yr.

Precipitation Volume and Return Period in northern Delaware
(source: U.S. National Weather Service)

Return Period / Duration	Total Volume
2-yr / 24-hr.	3.2 in.
5-yr / 24-hr.	4.2 in.
10-yr / 24-hr.	5.2 in
25-yr. / 24-hr.	5.5 in.
50-yr. / 24-hr.	6.5 in.
100-yr / 24-hr.	7.5 in.

CIEG 490 Water Resources Engineering

$$f(n) = \frac{N!}{n!(N-n)!} p^n (1-p)^{N-n}$$

Ex. Along the Red Clay Creek, what is the probability ($f(n)$) that a 100-yr flood occurs 2 x (twice) in 4 years.

$p = 1/100 = 0.01$

$N = 4$ yrs

$n = 2$

$$f(2) = \frac{4!}{2!(4-2)!} (0.01)^2 (1-0.01)^{4-2}$$

$$= \frac{4(3)(2)(1)}{(2)(1)(2)(1)} (0.0001)(0.9801)$$

$$= \frac{24}{4} (0.0001)(0.9801)$$

$$f(2) = 0.0005 = 0.05\%$$

There is a 0.05% probability that a 100-year flood occurs twice in 4 yrs. or 1 in 2000 chance.

Return Intervals can be calculated for floods & drought flows using the Weibull Distribution.

1. Print out peak flows & low flows for each year from stream gage see www.usgs.gov.
2. Rank the flows from high to low
3. Calculate probability $(p) = \frac{M}{N+1}$
   M = Rank, N = # of years

Year	Peak Flow (cfs)
1965	15,000
1966	9,790
1967	70,000
1968	44,300
1969	15,200
1970	9,190
1971	97.40
1972	58,500
1973	33 100
1974	25 200
1975	30 200
1976	14100
1977	54 500
1978	12 700

Rank	Flow	Weibull $p = \frac{M}{N+1}$
1	70000	1/15 = 0.067
2	58500	2/15 = 0.133
3	54500	0.200
4	44300	0.267
5	33100	0.337
6	30200	0.400
7	25200	0.467
8	15200	0.533
9	15000	0.600
10	14100	0.667
11	12700	0.733
12	9790	0.800
13	9740	0.867
14	9190	0.933

4. Calculate the 10-yr, 50-yr, 100-yr flood by plotting p on the y-axis and flow on the x-axis on semilog paper.