

DROUGHT RISK

DROUGHT FLOWS

THE RELEVANT FLOWS FOR CERTAIN USES ARE[RICKERT AND MCKENZIE (1977)]:

- DROUGHT FLOWS--
 - oxygen depletion
 - algal blooms
 - thermal discharges

- FLOODS
 - erosion
 - pathogen transport and contamination
 - poison transport and contamin

IN THE EAST, LOW FLOWS OCCURS DURING LATE SUMMER, EARLY AUTUMN, SO CONCENTRATION EFFECTS ARE AGGRAVATED BY HIGH WATER/AIR TEMPERATURES

WITH RESPECT TO ECOLOGICAL DISTURBANCES, WE WANT TO KEEP THE FREQUENCY LOW ENOUGH SO THAT SPECIES PERSIST. THE RELEVANT ISSUES ARE DISCUSSED IN,

- CLEMENT S CLIMAX THEORY
- MACARTHURS S COLONIZATION THEORY
- PERSISTENCE THEORY
 - influence of diversity
 - absence of benthal invertebra
good indicators of recent disturbance

- higher animals too mobile and subject to migration/invasion

IF A REACH IS DENUDED OF FISH, THEY CAN USUALLY RE-ESTABLISH THEMSELVES IN A FEW WEEKS BY MIGRATION FROM UPSTREAM AND DOWNSTREAM REACHES [HYNES (1970)].

BENTHAL INVERTEBRATES MOVE DOWNSTREAM BY NOCTURNAL DRIFT AND UPSTREAM DURING BRIEF FLYING ADULT STAGE. THEY GENERALLY REQUIRE SEVERAL MONTHS TO REPOPULATE A DENUDED REACH [HYNES (1970)].

THUS, FOR DENUDATION OF A LIMITED REACH AN ALMOST ANNUAL EVENT IS ACCEPTABLE.

THIS DOES NOT APPLY TO INTERMITTENT STREAMS FOR WHICH THERE IS LITTLE DATA.

THE USUAL DROUGHT FLOW IS THE ANNUAL 7-DAY AVERAGE LOW FLOW:

- VELZ (1970)--IT ACCOUNT FOR THE WEEKEND SHUT-DOWN OF INDUSTRY
- VELZ (1947)--SHOULD USE AS AVERAGING PERIOD THE TIME-OF-TRAVEL ALONG THE RIVER BECAUSE THIS REPRESENTS THE SYSTEM S RESPONSE TIME.
- SHOULD ALSO CONSIDER OTHER AVERAGING PERIODS

- response time of microbes to increases in inputs
- frequency of scour events due reservoir drawdowns and thunder storms
- durations that result in actual denudation of benthos (7-day average may be too large a filter)
- durations that match water quality standards, especially for point sources

NOTES:

1. DURING ANY AVERAGING PERIOD SOME FLOWS ARE LESS THAN THE AVERAGE AND THESE LOW FLOWS MAY PERMIT UNINTENDED HARM.

RETURN PERIODS [RIGGS (19??)]

THE OEPA USES RIGGS METHOD. FIRST, RANK ORDER THE ANNUAL SMALLEST 7-DAY AVERAGE DROUGHTS FROM SMALLEST TO LARGEST:

- WHAT GETS YOU INTO TROUBLE?
 - for floods, flows larger than designed for, use exceedance probabilities
 - for droughts, flows less than designed for, use nonexceedance probabilities

example drought return period calculation

year	flow (cfs) (T_Q)	ranked ed flow (cfs) (T_Q)	rank (m)	non- exceeda ncd probabi lity (P_o)	return period (T_D)
1981	10	5	1	0.143	7.00
1982	20	7	2	0.286	3.50
1983	20	10	3	0.429	2.33
1984	5	15	4	0.571	1.75
1985	15	20	5	0.714	1.40
1986	7	20	6	0.857	1.17

CONSIDER THE TABULATED DROUGHT FLOWS.

A FLOW OF 5 CFS OR LESS OCCURS ONLY ONCE IN 6 EVENTS SO ITS NON-EXCEEDANCE PROBABILITY IS

APPROXIMATELY $1/6$. SIMILARLY, FLOWS EQUAL TO OR LESS THAN 7 CFS OCCUR TWICE IN 6 YEARS, SO ITS NON-EXCEEDANCE PROBABILITY IS $2/6$.

NOTE THAT ALDROUGHTS ARE COUNTED, EVEN IF THEY HAVE THE SAME FLOW. ACTUALLY, DUE TO MEASUREMENT ERRORS AND ROUNDING, THE FLOWS ARE NOT THE SAME. THE FACT THAT THE SAME FLOW HAS TWO DIFFERENT NON-EXCEEDANCE PROBABILITIES IS A MEASURE OF SAMPLING ERROR.

IN ORDER TO AVOID BIAS DUE TO SMALL SAMPLE SIZES, ASSIGN A NON-EXCEEDANCE PROBABILITY USING GUMBEL'S OR HAZEN'S EQUATION:

- GUMBEL--

$$P_o = \frac{m}{n+1}$$

where, m = the rank of the drought for smallest;

n = the number of drought events;

P_o = the non-exceedance probability.

THE NON-EXCEEDANCE PROBABILITY IS THE PROBABILITY THAT A DROUGHT EQUAL TO OR LESS THAN THE TABULATED FLOW WILL OCCUR. THIS ARE ANNUAL EVENTS, SO IT IS THE PROBABILITY THAT THE EVENT OCCURS IN A RANDOMLY CHOSEN YEAR.

WITH RESPECT TO RETURN PERIODS, NOTE THAT A FLOW EQUAL OR LESS THAN 5 CFS OCCURS ONLY ONCE IN THE 6 YEAR RECORD, SO ITS RETURN PERIOD IS APPROXIMATELY 6 YEARS.

THIS IS THE RECIPROCAL OF THE APPROXIMATE NON-EXCEEDANCE PROBABILITY ($1/6$).

TO AVOID BIASING DUE TO SMALL SAMPLE SIZES, USE GUMBEL S ESTIMATOR:

$$T_D = \frac{1}{P_o} = \frac{n+1}{m}$$

- HAZEN

$$P_o = \frac{m-0.5}{n}$$

$$T_D = \frac{1}{P_o} = \frac{n}{m-0.5}$$

DROUGHT DATA CAN BE FITTED BY SEVERAL STATISTICAL DISTRIBUTIONS. THERE IS NO THEORETICALLY CORRECT DISTRIBUTION, SO THE CHOICE IS ENTIRELY BASED ON EMPIRICAL GOODNESS-OF-FIT CRITERIA.

FOR FLOODS, THE USUAL (3 PARAMETER) FORMULA (HYDROLOGY COMMISSION, 1967, 1976) IS THE LOG PEARSON TYPE III. THIS IS ALSO USED BY OEPA FOR DROUGHTS

ANOTHER COMMON (2 PARAMETER) MODEL IS GUMBEL S FORMULA.

ALL FORMULAS CAN BE WRITTEN AS,

$$x = \bar{x} + Ks_x$$

THE STATISTICS FOR THE RANKED FLOWS
ARE :

$$\overline{7Q} = 12.83 \text{ cfs}$$

$$s_{7Q} = 6.49 \text{ cfs}$$

$$\overline{\log 7Q} = 1.0537$$

$$s_{\log 7Q} = 0.2488$$

GUMBEL S METHOD

$$Q_{T_D} = \bar{Q} - \frac{\sqrt{6}}{\pi} [\gamma_E + \ln[\ln(T_D)]]$$

$$Q_{T_D} = \bar{Q} - \{ \{ 0.4501 + 0.7797 \ln[\ln(T_D)] \} \} s_Q$$

where, γ_E = Euler s Gamma ;

$$= 0.57722.$$

FOR OUR DATA SET, AND OF 10 YRS,

$$Q_{T_D} = 12.83 -$$

$$(0.4501 + 0.7797 \ln \ln 10) \times 6.49$$

5.69 cfs

FOR OTHER RETURN PERIODS WE WOULD
HAVE :

5 YRS--

$$Q_{T_D} = 12.83 -$$

$$(0.4501 + 0.7797 \ln \ln 5) \times 6.49$$

7.50 cfs

FOR 15 YRS--

$$Q_{T_D} = 12.83 -$$

$$(0.4501 + 0.7797 \ln \ln 15) \times 6.49$$

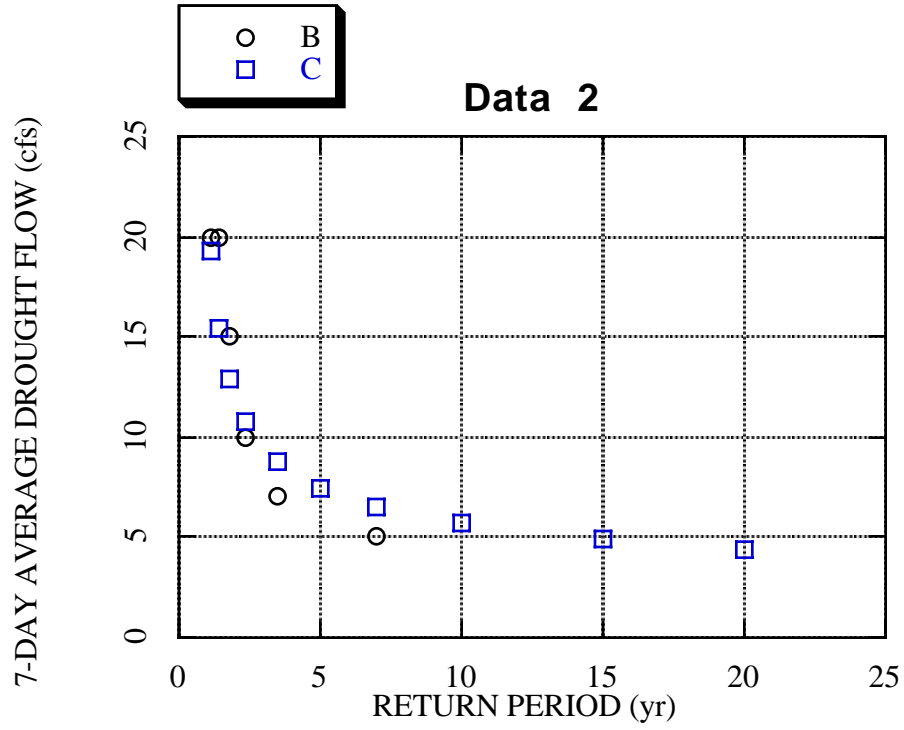
4.87 cfs

FOR 20 YRS--

$$Q_{T_D} = 12.83 -$$

$$(0.4501 + 0.7797 \ln \ln 20) \times 6.49$$

4.36 cfs



LOG PEARSON TYPE III

THE PUBLISHED TABLES FOR THE LOG PEARSON TYPE III FREQUENCY FACTORS ARE FOR FLOODS.

FOR ANY GIVEN FLOW, ALL FLOWS LARGER THAN IT ARE FLOODS, AND ALL FLOWS SMALLER THAN IT ARE DROUGHTS.

THEREFORE, FOR A GIVEN FLOW, THE EXCEEDANCE AND NONEXCEEDANCE PROBABILITIES SUM TO UNITY:

$$P + P_o = 1$$

$$\frac{1}{T_F} + \frac{1}{T_D} = 1$$

$$T_F = \frac{T_D}{T_D - 1}$$

FOR A 10 YR DROUGHT, THE EQUIVALENT FLOOD IS,

$$T_F = \frac{10}{10 - 1} = 1.11\dots$$

THE TABLE ALSO INCLUDES A SKEW COEFFICIENT:

$$C_s = \frac{n \sum_{i=1}^n (x_i - \bar{x})^3}{(n-1)(n-2)s_x^3}$$

FOR THE DATA IN THE EXAMPLE:

$$C_s = -0.427$$

NOTE: IN THE LOG PEARSON TYPE I PROCEDURE, THE MEAN, STANDARD DEVIATION AND SKEW COEFFICIENT ARE CALCULATED FOR THE LOGS OF THE FLOW.

THE CORRESPONDING FREQUENCY FACTOR (K) FOR $T = 1.11$ AND $C_s = -0.427$ IS,

$$K = -1.319 \text{ (linear interpolation)}$$

THE ESTIMATED FLOW IS,

$$\begin{aligned}\log Q_T &= \overline{\log Q} + K s_{\log Q} \\ &= 1.0537 - 1.319 \times 0.2488\end{aligned}$$

$$\log Q_T = 0.7256$$

THE ACTUAL FLOW IS ,

$$Q_T = 10^{0.7256} = 5.32 \text{ cfs}$$

PROBABILITY OF FAILURE DURING A SPECIFIED TIME PERIOD

THE PROBABILITY OF FAILURE IN A GIVEN YEAR IS THE NONEXCEEDANCE PROBABILITY FOR THE DESIGN (USUALLY 7Q10) FLOW.

THE PROBABILITY OF SUCCESS IN A GIVEN YEAR IS MERELY 1 MINUS THE FAILURE PROBABILITY:

$$P_s = 1 - P_o$$

THE PROBABILITY THAT THERE ARE NO FAILURES IN A SPAN OF N YEARS IS SIMPLY THE SUCCESS PROBABILITY RAISED TO THE NTH POWER:

$$J_s = P_s^N = (1 - P_o)^N$$

AND THE PROBABILITY OF AT LEAST ONE FAILURE DURING THAT SPAN IS,

$$J_{\geq 1} = 1 - J_s = 1 - (1 - P_o)^N$$

FOR A PLANT WITH A 20 YEAR AMORTIZATION PERIOD AND A 10 YEAR DESIGN DROUGHT, WE GET,

$$J_{\geq 1} = 1 - (1 - 0.1)^{20} = 0.878$$

FOR A PERMIT LIFE OF 5 YEARS, WE GET

$$J_{\geq 1} = 1 - (1 - 0.1)^5 = 0.19$$

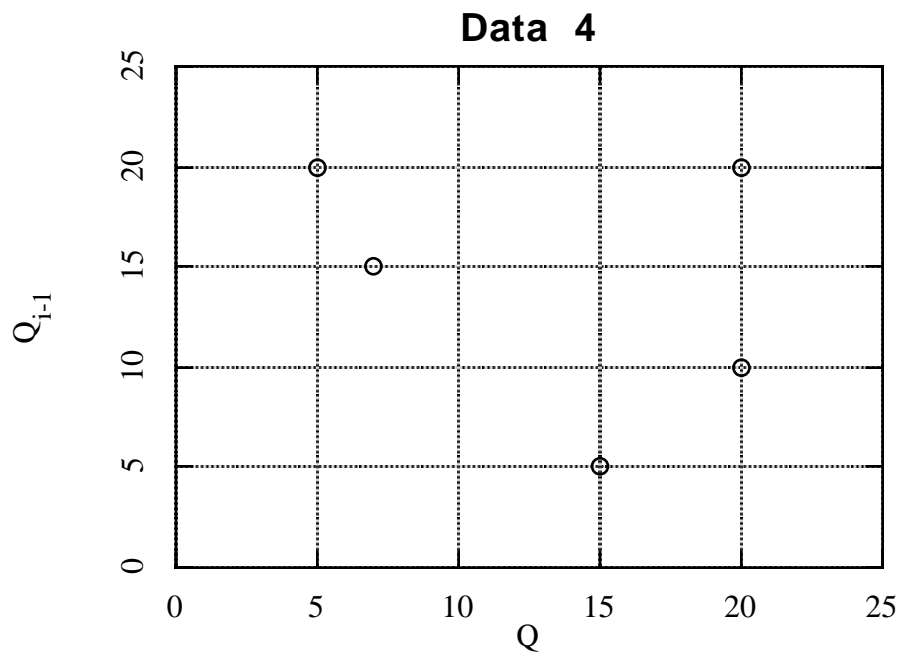
SERIAL CORRELATION

THESE CALCULATIONS ASSUME
STATISTICAL INDEPENDENCE AMONG THE
FLOWS. IF THAT IS NOT TRUE A MORE
SOPHISTICATED APPROACH IS NEEDED.

A SIMPLE TEST FOR SERIAL CORRELATION IS,

correlation between lagged flows

year	Q_i	Q_{i-1}
1981	10	-
1982	20	10
1983	20	20
1984	5	20
1985	15	5
1986	7	15



FOR THIS PLOT:

$$r = -0.314$$

$$r^2 = 0.0988$$

NOTE THAT MOST STREAMS ARE REGULATED. THIS MEANS THAT ALL DROUGHT FLOWS HAVE A SIMILAR MAGNITUDE, AND THERE MAY BE LITTLE DIFFERENCE BETWEEN THE 5-YR AND 100-YR DROUGHT. THUS OUR FAILURE FREQUENCIES MAY BE VERY MUCH HIGHER THAN ESTIMATED ABOVE.