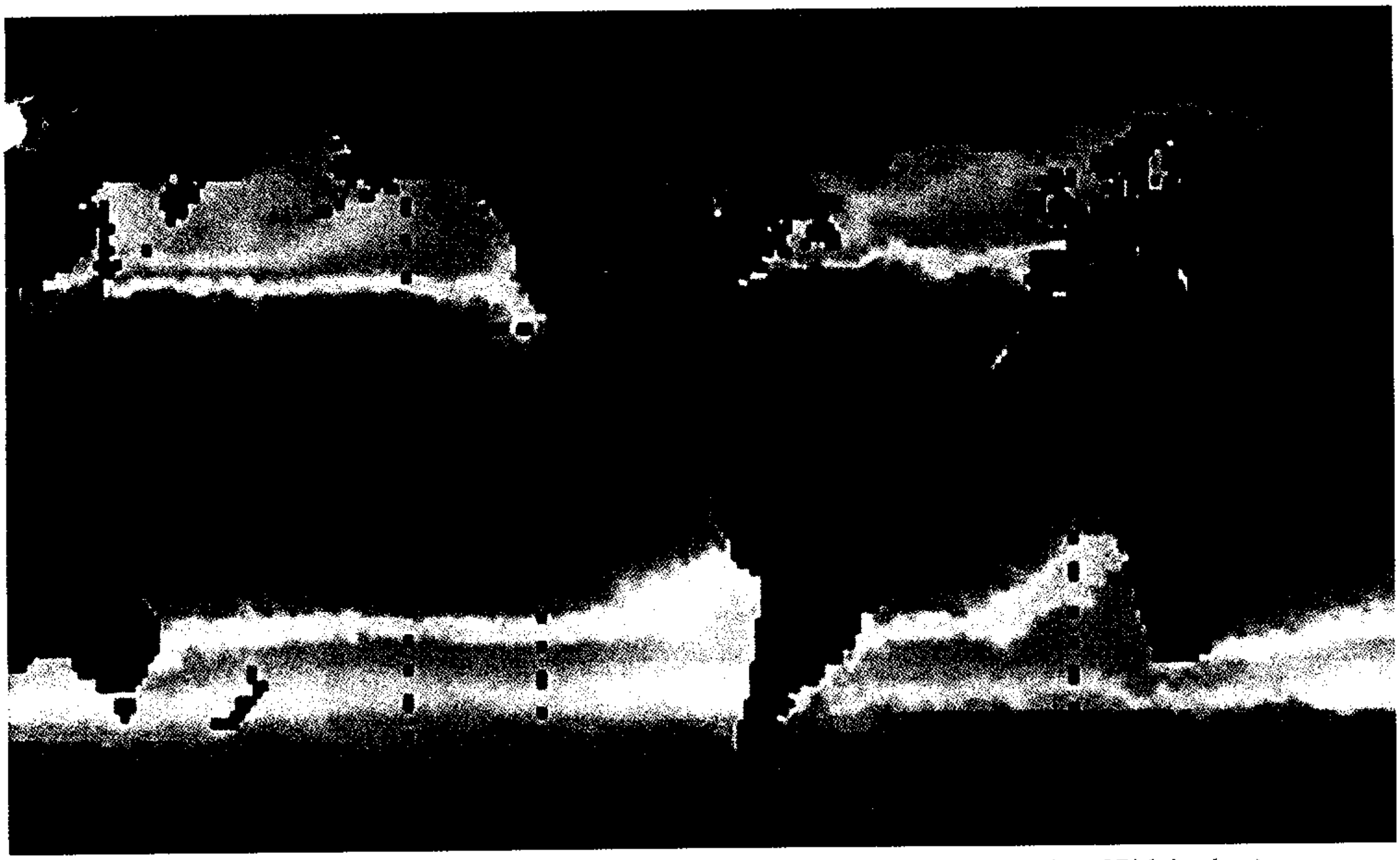

(image courtesy of FEMA El Nino Loss Reduction Center/ http://www.fema.gov/nwz97/elnino.htm)

Winter '97/'98: Year of the Great El Niño?

San Diego, CA

March 11-13, 1998

Floodplain Management Association

Technical Program Chair: Lisa Vomero Inouye
A & M Engineering Consultants of California

Chair: Clark Farr, County of Kern, CA

Executive Director: Laura Hromadka

Exponent

A STATISTICAL LOOK AT THE DECEMBER 1997 STORM EVENT IN LAGUNA BEACH, CALIFORNIA

By

Theodore V. Hromadka, Ph.D., Ph.D, P.E., P.H.

Principal Engineer

Exponent

Failure Analysis Associates

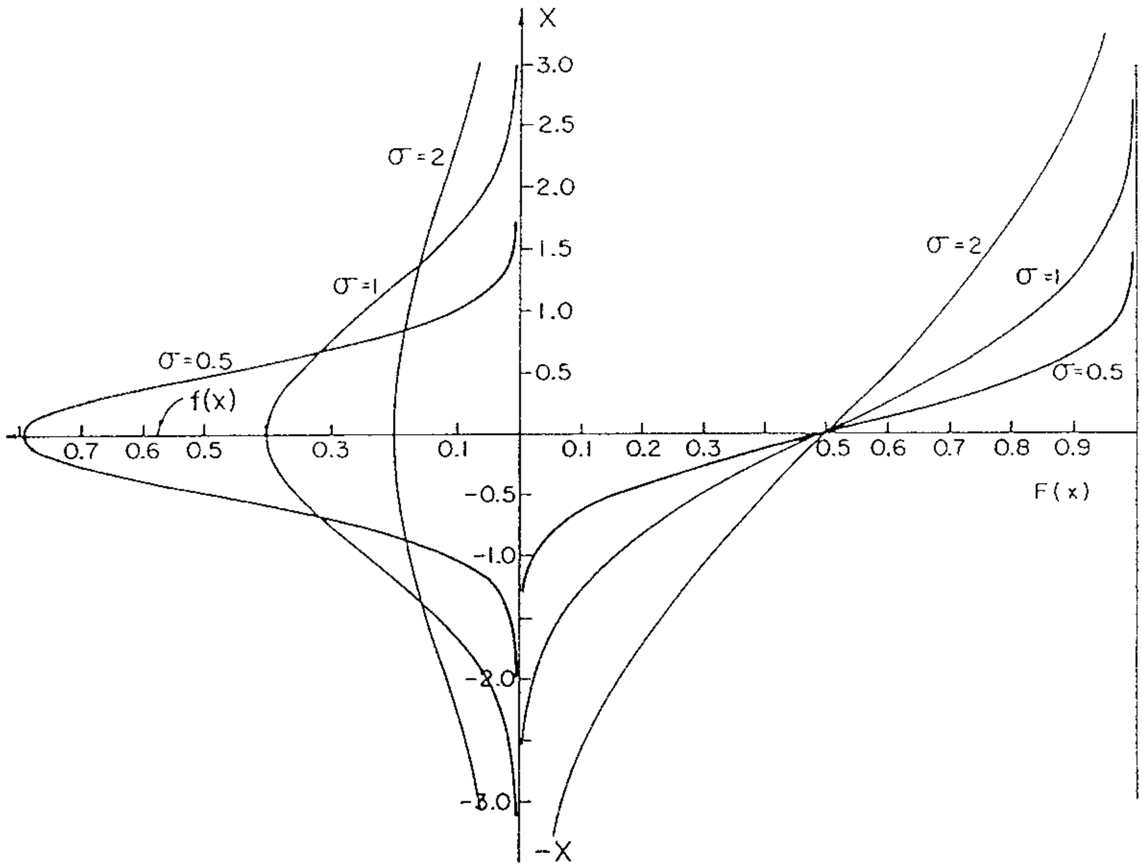

Figure 7. 1. Normal probability density curves (left side of graph), and normal probability distribution curves (right side of graph) for $\mu = 0$ and three values of σ, 0.5, 1.0 and 2.0.

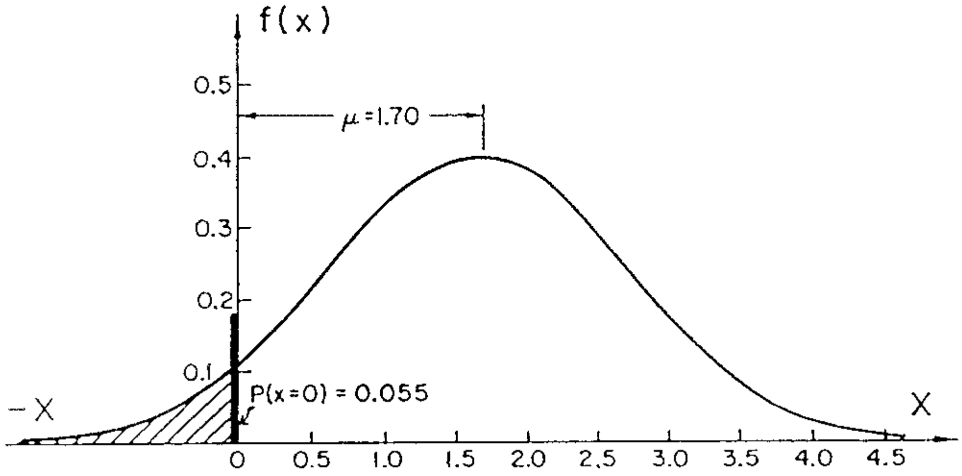

Figure 7.2. The negative part of a normal probability density function, conceived as being equal to the probability mass p (x = 0), as a truncated normal distribution.

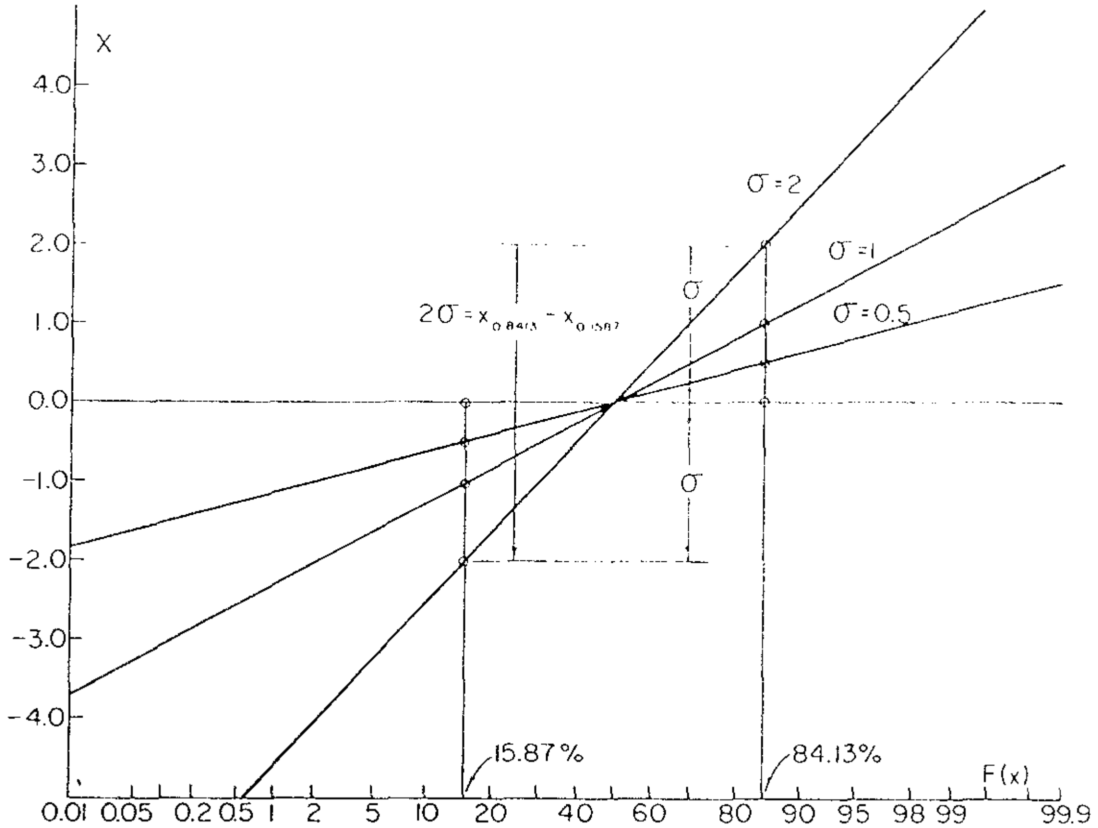

Figure 7.3. Normal probability distribution functions, with the mean of $\mu = 0$, plotted as straight lines, for $\sigma = 0.5$, 1.0, and 2.00, in cartesian-probability scales, respectively for x and F (x).

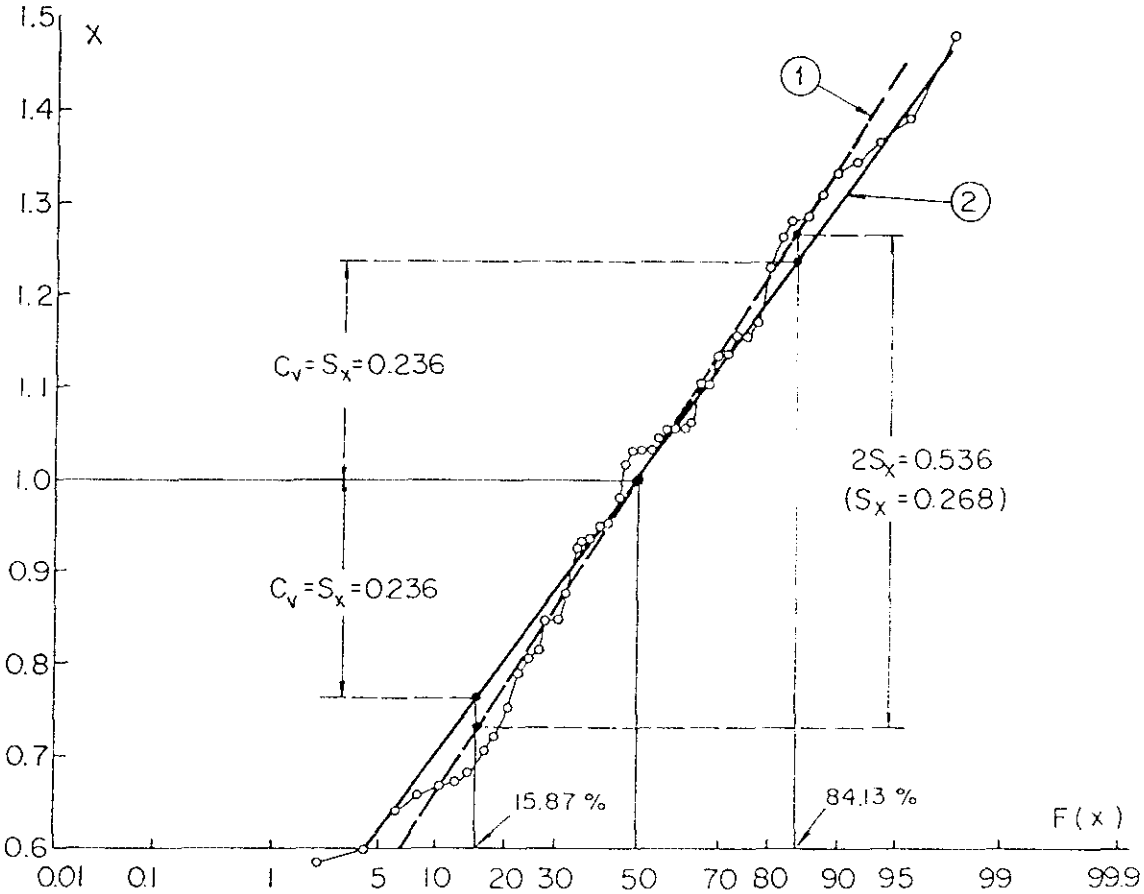

Figure 7.4. The graphical fit of normal probability function (1) to the empirical distribution of annual runoff (given in modular coefficients) of the Willamette River, near Albany in Oregon, N = 48 (1893 – 1941), with $\bar{x} = 1.00$ and $s_x = 0.268$, against the function (2) fitted by the method of moments, with $\bar{x} = 1.00$ and $s_x = 0.236$.

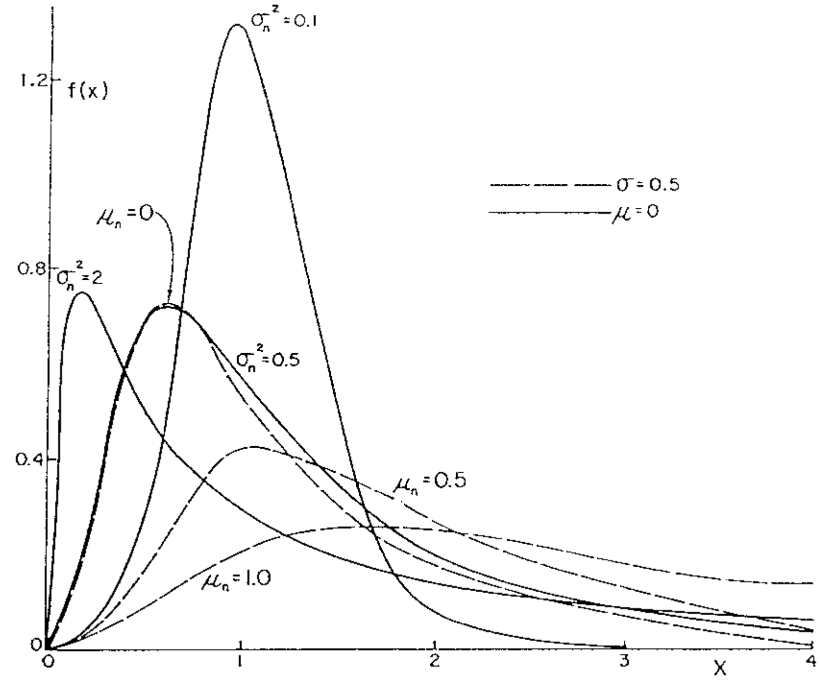

Figure 7.5. Six lognormal probability curves: $\mu_n = 0$, 0.5, and 1.00, for $\sigma_n^2 = 0.5$, and $\sigma_n^2 = 0.1$, 0.5, and 2, for $\mu_n = 0$.

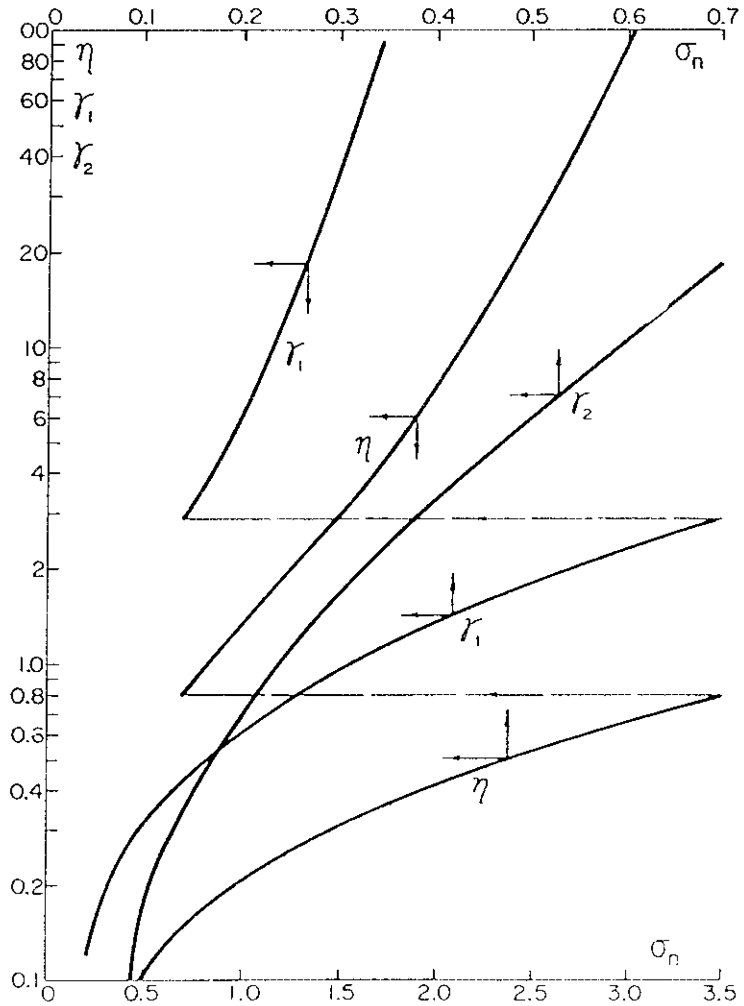

Figure 7.6. Relations of the coefficient of variation η, the skewness coefficient γ_1, and the kurtosis γ_2 to the standard deviation of logarithms σ_n.

TABLE 7.2

DISTRIBUTION FUNCTION	PROBABILITY DISTRIBUTION, OR PROBABILITY DENSITY, OR MASS FUNCTION	RANGE OF VARIABLE VALUES	PARAMETERS OF THE FUNCTION	MEAN μ	VARIANCE σ^2	3rd CENTRAL MOMENT μ_3
BINOMIAL	$f(x) = \binom{n}{x} p^x q^{n-x}$ $q = 1 - p,$	Integers $0 \leq x \leq n$	n, p	np	npq	$npq(1-2p)$
POISSON	$f(x) = \frac{\lambda^x e^{-\lambda}}{x!}$	Integers $0 \leq x \leq \infty$	λ	λ	λ	λ
STANDARD NORMAL	$f(t) = \frac{1}{\sqrt{2\pi}} e^{-t^2/2}$	$-\infty$ to $+\infty$		0	1	0
NORMAL	$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$	$-\infty$ to $+\infty$	μ, σ	μ	σ^2	0
LOGNORMAL 2-PARAMETER	$f(x) = \frac{1}{x\sigma_n\sqrt{2\pi}} e^{-\frac{(\ln x - \mu_n)^2}{2\sigma_n^2}}$	0 to $+\infty$	μ_n, σ_n	$e^{\mu_n + \sigma_n^2/2}$	$\mu^2(e^{\sigma_n^2} - 1)$	$\mu^3(C_v^6 + 3C_v^4)$
GAMMA 1-PARAMETER	$f(x) = \frac{x^{\alpha-1} e^{-x}}{\Gamma(\alpha)}$	0 to $+\infty$	α α = Shape Parameter $\alpha > 0$	α	α	2α
GAMMA 2-PARAMETER	$f(x) = \frac{x^{\alpha-1} e^{-x/\beta}}{\beta^\alpha \Gamma(\alpha)}$	0 to $+\infty$	α, β α = Shape Parameter, $\alpha > 0$ β = Scale Parameter, $\beta > 0$	$\alpha\beta$	$\alpha\beta^2$	$2\alpha\beta^3$
GAMMA 3-PARAMETER	$f(x) = \frac{1}{\beta\Gamma(\alpha)}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1} e^{-\left(\frac{x-\gamma}{\beta}\right)}$	Bounded on Left by γ	α, β, γ α = Shape Parameter β = Scale Parameter γ = Lower Boundary	$\gamma + \alpha\beta$	$\alpha\beta^2$	$2\alpha\beta^3$
BETA I 2-PARAMETER	$f(x) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B_1(\alpha, \beta)}$ $0 \leq x \leq 1$	0 to 1	α, β $\alpha > 0;\ \beta > 0$	$\frac{\alpha}{\alpha+\beta}$	$\frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)}$	
BETA II 2-PARAMETER	$f(y) = \frac{x^{\alpha-1}(1+x)^{-(\alpha+\beta)}}{B_2(\alpha, \beta)}$ $0 \leq x \leq \infty$	0 to $+\infty$	α, β $\alpha > 0;\ \beta > 0$	$\frac{\alpha}{\beta-1}$ for $\beta > 1$	$\frac{\alpha(\alpha+\beta-1)}{(\beta-1)^2(\beta-2)}$ for $\beta > 2$	
DOUBLE EXPONENTIAL 2-PARAMETER	$F(x) = e^{-e^{-\alpha(x-\beta)}}$ for $y = \alpha(x-\beta)$; $F(x) = e^{-e^{-y}}$	$-\infty$ to $+\infty$	α, β α = Shape Parameter β = Scale Parameter	$\beta + \frac{0.5772}{\alpha}$	$\frac{\pi^2}{6\alpha^2}$	
BOUNDED EXPONENTIAL 3-PARAMETER	$F(x) = e^{-\left(\frac{x-\gamma}{\beta-\gamma}\right)^\alpha}$	Bounded on Left by γ, Unbounded on Right	α, β, γ $\quad x \geq \gamma$ β = Location Param. $\beta > \gamma$ α = Scale Param. $\alpha > 0$ γ = Location Param. $\gamma \geq 0$	$\gamma + (\beta-\gamma)\cdot\Gamma\left(1+\frac{1}{\alpha}\right)$	$(\beta-\gamma)^2\left[\Gamma\left(1+\frac{2}{\alpha}\right) - \Gamma^2\left(1+\frac{1}{\alpha}\right)\right]$	
CHI-SQUARE $\chi^2 = \xi$	$f(\xi) = \frac{1}{2^{n/2}\Gamma(n/2)} \xi^{\frac{n}{2}-1} e^{-\frac{\xi}{2}}$	0 to $+\infty$	n n = Degrees of Freedom	n	2n	8n
STUDENT-t	$f(t) = \frac{1}{\sqrt{n\pi}} \frac{\Gamma\left(\frac{n+1}{2}\right)}{\Gamma(n/2)} \left(1+\frac{t^2}{n}\right)^{-\frac{n+1}{2}}$	$-\infty$ to $+\infty$	n n = Degrees of Freedom	0	$\frac{n}{n-2}$	0
FISHER-z	$f(z) = \frac{2m^{m/2}n^{n/2}}{B\left(\frac{m}{2}, \frac{n}{2}\right)} \frac{e^{mz}}{(me^{2z}+n)^{(m+n)/2}}$	$-\infty$ to $+\infty$	m, n	$\frac{n}{n-2}$ for $n > 2$	$\frac{2n^2(m+n-2)}{m(n-2)^2(n-4)}$ for $n > 4$	

TABLE 7.2 (continued)

DISTRIBUTION FUNCTION	4 th CENTRAL MOMENT μ_4	SKEWNESS $\frac{\mu_3}{\sigma^3}$ γ_1 or C_s	EXCESS $\frac{\mu_4}{\sigma^4}-3$ γ_2-3, or E	MODE m, and p (m)	MEDIAN M, and p (M)	REMARKS
BINOMIAL	$3n^2p^2q^2 + npq(1-6pq)$	$\frac{1-2p}{\sqrt{npq}}$	$\frac{1-6pq}{npq}$			p and n must be known and $\binom{n}{x} = \frac{n!}{x!(n-x)!}$ Events must be independent.
POISSON	$\lambda(3\lambda+1)$	$\frac{1}{\sqrt{\lambda}}$	$\frac{1}{\lambda}$	Mode is Largest Integer Less Than Or Equal to λ		Skewness is always positive. $\lambda = pn$, and $\lambda > 0$, must be known. Events must be independent.
STANDARD NORMAL	3	0	0	$m = 0$ $p(m) = \frac{1}{\sqrt{2\pi}}$	$M = 0$ $p(M) = \frac{1}{\sqrt{2\pi}}$	Mean is zero, and variance in unity. Standardization by $t = (x-\mu)/\sigma$.
NORMAL	$3\sigma^4$	0	0	$m = \mu$ $p(m) = \frac{1}{\sigma\sqrt{2\pi}}$	$M = \mu$ $p(M) = \frac{1}{\sigma\sqrt{2\pi}}$	μ = any real number, σ = any positive number, a change in μ shifts curve horizontally; a change in σ raises or lowers the peak.
LOGNORMAL 2-PARAMETER	$\mu^4(C_v^{12}+6C_v^{10}+15C_v^8+16C_v^6+3C_v^4)$	$C_v^3 + 3C_v$	$C_v^8+6C_v^6+15C_v^4+16C_v^2$	$m = \frac{\mu}{(1+C_v^2)^{3/2}}$ $p(m) = \frac{(1+C_v^2)^{1/2}}{\mu\sqrt{2\pi\ln(1+C_v^2)}}$	$M = \frac{\mu}{\sqrt{1+C_v^2}} = e^{\mu_n}$ $p(M) = \frac{\sqrt{1+C_v^2}}{\mu\sqrt{2\pi\ln(1+C_v^2)}}$	$\infty \leq \mu_n \leq \infty$; $0 < \sigma_n \leq \infty$. μ_n = mean of ln x; σ_n = standard deviation of ln x. Skewness is always positive.
GAMMA 1-PARAMETER	$3\alpha(\alpha+2)$	$\frac{2}{\sqrt{\alpha}}$	$\frac{6}{\alpha}$	$m = \alpha - 1$ for $\alpha > 1$		Definition of Γ-function: $\Gamma(\alpha) = \int_0^\infty x^{\alpha-1}e^{-x}dx$
GAMMA 2-PARAMETER	$3\alpha\beta^4(\alpha+2)$	$\frac{2}{\sqrt{\alpha}}$	$\frac{6}{\alpha}$	$m = \beta^2(\alpha-1)$ for $\alpha > 1$		
GAMMA 3-PARAMETER	$3\alpha\beta^4(\alpha+2)$	$\frac{2}{\sqrt{\alpha}}$	$\frac{6}{\alpha}$			$f(x) = \frac{1}{\beta\Gamma(\alpha)}\left(\frac{x}{\beta}\right)^{\alpha-1}e^{-x/\beta}$ $\gamma = \mu - \sigma\sqrt{\alpha}$ $\beta = \sigma/\sqrt{\alpha}$ for $\gamma = 0$ $\alpha = 4/C_s^2$
BETA I 2-PARAMETER				Mode is: $= (\alpha-1)(\alpha+\beta-2)$ for $\alpha > 0$ $\beta > 0$		Definition of B-function $B(\alpha,\beta) = \int_0^1 x^{\alpha-1}(1-x)^{\beta-1}dx = \frac{\Gamma(\alpha)\Gamma(\beta)}{\Gamma(\alpha+\beta)}$ β in this case is parameter.
BETA II 2-PARAMETER				Mode is: $m = \frac{\alpha-1}{\beta-1}$ for $\alpha > 1$		β in this case is parameter.
DOUBLE EXPONENTIAL 2-PARAMETER		Constant 1.29857 ≈ ≈ 1.3	Constant 1.500	$m = \mu - 0.5772\alpha^{-1}$ $f(m) = \alpha e^{-1} = 0.368\alpha$ $F(m) = e^{-1} = 0.368$	$M = \frac{\beta + 0.3665}{\alpha}$	$\sigma = \frac{\pi}{\alpha\sqrt{6}}$; $\beta = \mu - 0.450\sigma$; $\alpha = 1.281\sigma^{-1}$; $f(x) = \alpha\exp[-\alpha(x-\beta) - e^{-\alpha(x-\beta)}]$.
BOUNDED EXPONENTIAL 3-PARAMETER				$m = \gamma + \beta\left(1-\frac{1}{\alpha}\right)^{1/\alpha}$ for $1/\alpha < 1$	$M = \gamma + \beta(\ln 2)^{1/\alpha}$ for $\frac{1}{\alpha} < 1$	$m < M$ for $1/\alpha > 0.30685$ $m = M$ for $1/\alpha = 0.30685$ $m > M$ for $1/\alpha < 0.30685$ for $x = \beta$; $F(\beta) = e^{-1} = 0.3678$
CHI-SQUARE $\chi^2 = \xi$	$12n(n+4)$	$\sqrt{\frac{8}{n}}$	$\frac{12}{n}$			$\chi^2 = \sum_1^n \frac{(x_i-\mu)^2}{\sigma^2} = \xi$
STUDENT-t		0		$m = \mu = 0$	$M = \mu = 0$	As $n \to \infty$ distribution converges to normal distribution.
FISHER-z				$m = \frac{m-2}{m}\frac{n}{n+2}$ for $m > 0$		This function is independent of σ. $z = \frac{1}{2}\ln F$; F = Fisher's statistics = ratio of variance estimates for two samples, with m and n degrees of freedom, respectively.

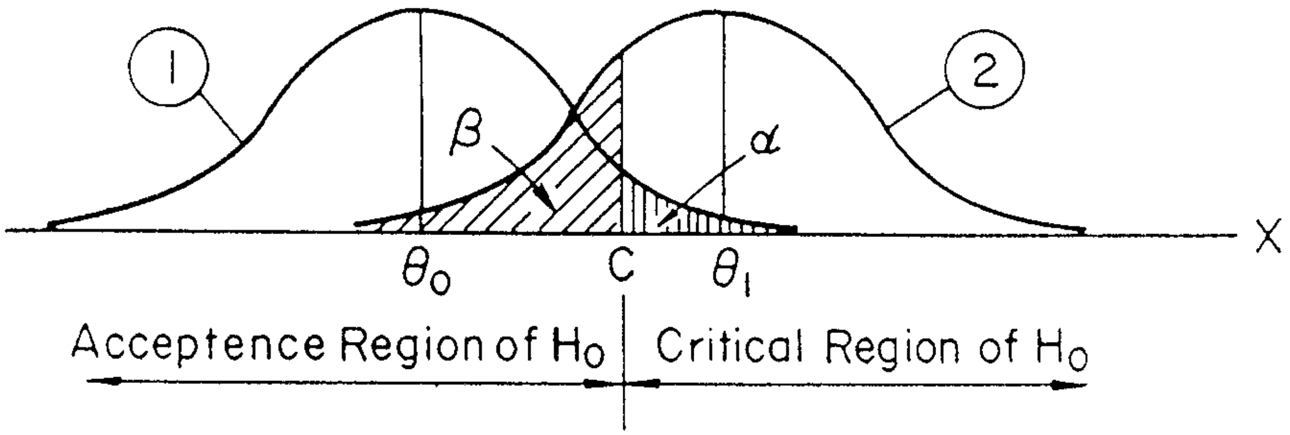

Figure 10.1. Schematic representation of the acceptance and rejection (critical) regions in the test of hypotheses: (1) distribution of $x = \Theta$ assuming H_0 ($\Theta = \Theta_0$) is true, and (2) distribution of $x = \Theta$ assuming H_1 ($\Theta = \Theta_1$) is true.

Table 10.1
Definition of Types of Errors Associated with Testing Hypotheses

Decision	True Situation	
	Hypothesis H_0 is true	Hypothesis H_1 is true
Accept hypothesis H_0	Correct decision	Type II error
Reject hypothesis H_0	Type I error	Correct decision

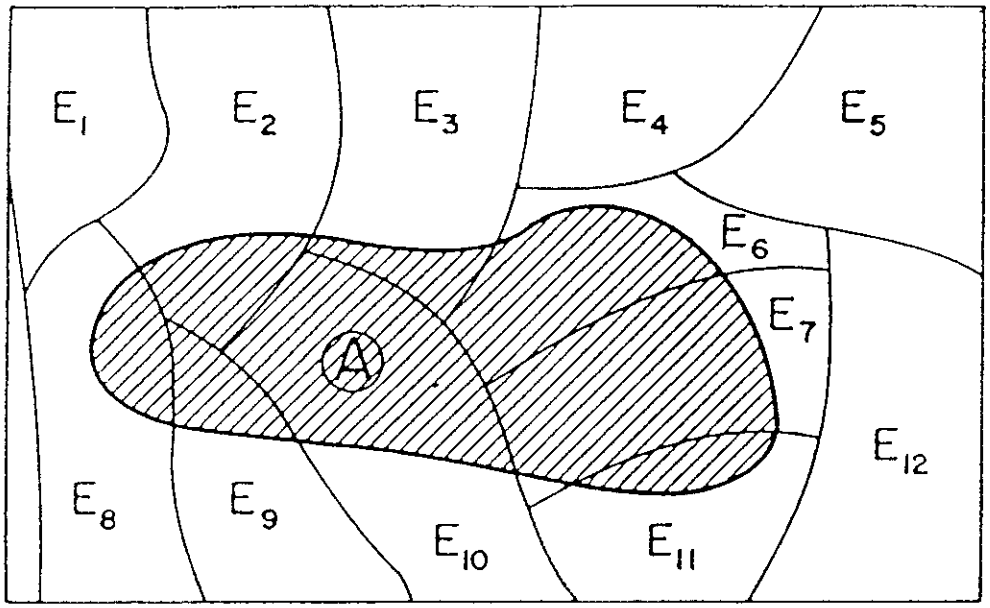

Figure Venn diagram for the representation of the theorem of total probability in the form of geometric probabilities.

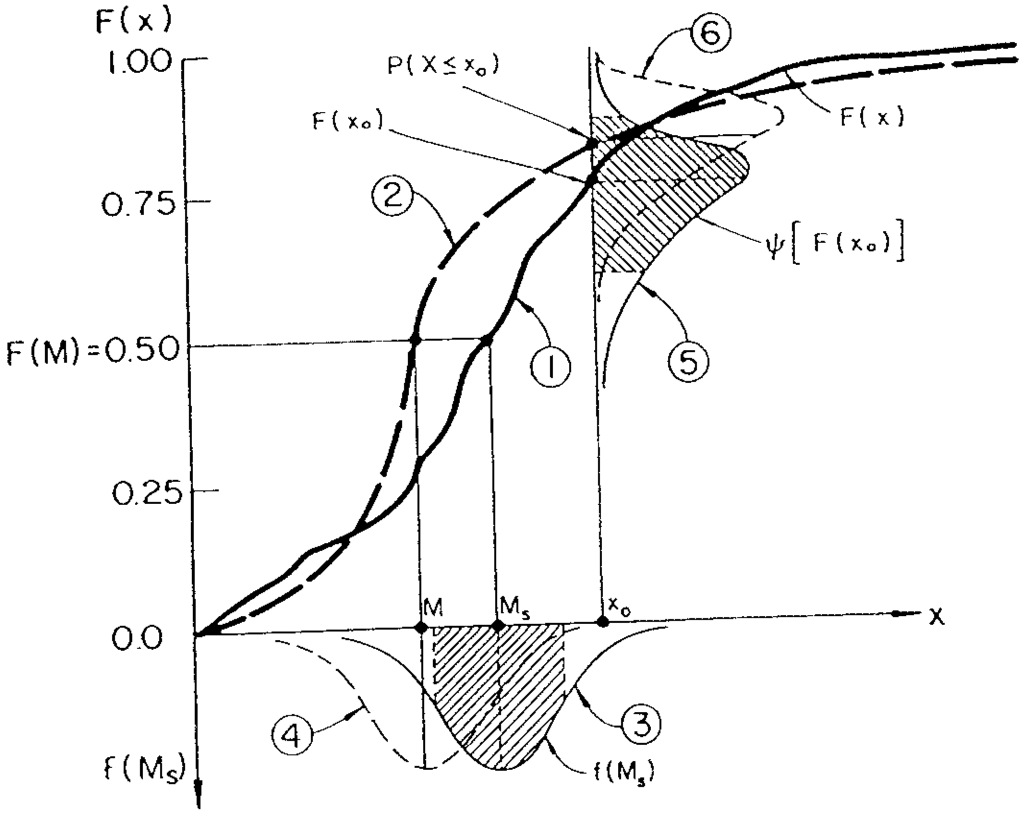

Figure Schematic representation of distributions of sample statistics: (1) sample frequency distribution of random variable x; (2) assumed population distribution of x; (3) probability density curve of the sample median; (4) an equivalent to curve (3), centered about the assumed population median; (5) probability density curve of the sample relative frequency F (x_0) of a given x_0; and (6) an equivalent to curve (5), centered about the population probability P $(x \leq x_0)$ of x_0.

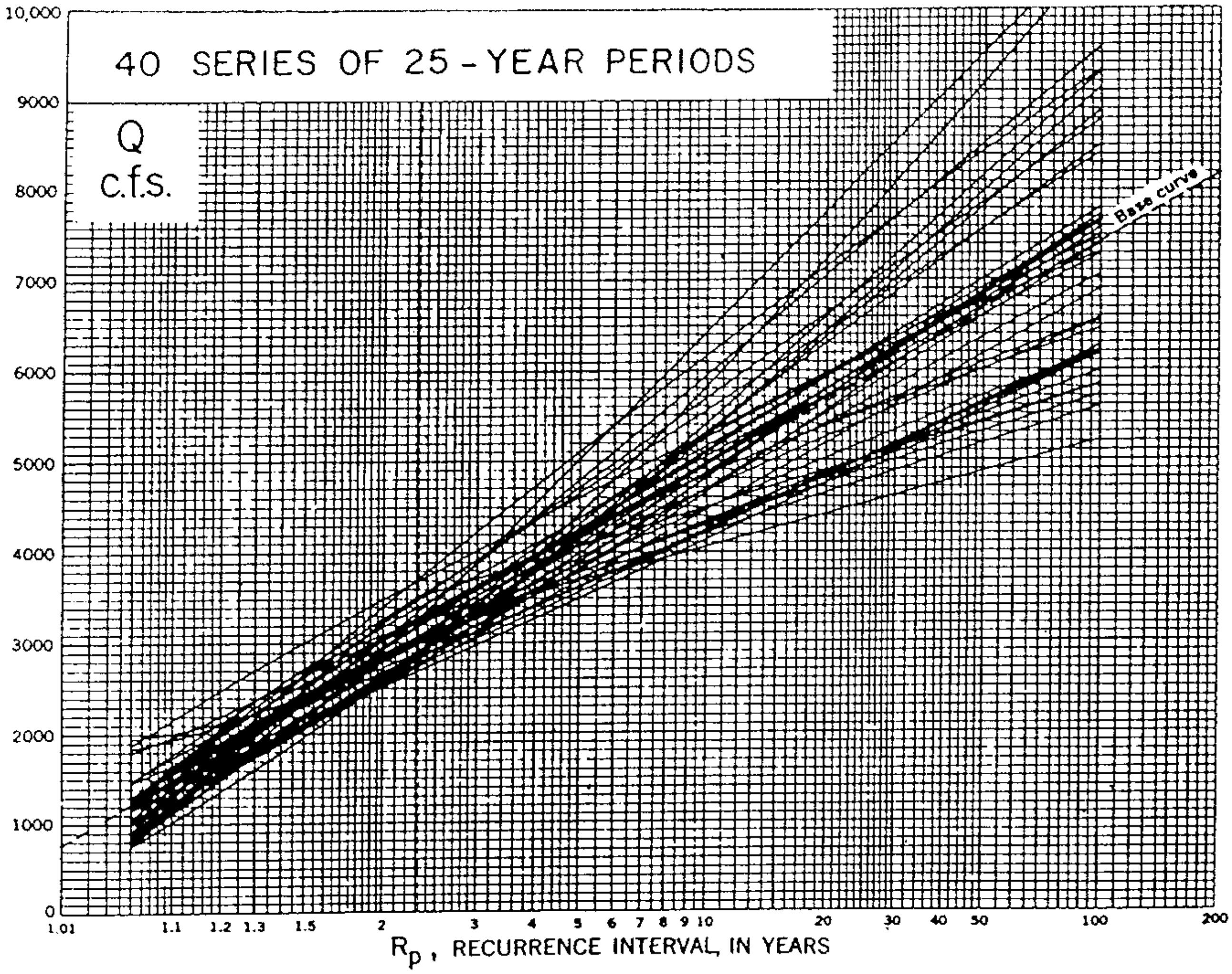

Figure Frequency distributions of 40 samples, each of a 25-year size, of the maximum flood discharges on a Gumbel paper graph. Each sample is drawn from a finite population of 1,000 values without replacement. These values follow the double exponential distribution. [According to Benson, 7]

THREE-HOUR RAIN AMOUNTS GREATER THAN 100-YEAR

FOR THE PERIOD OF RECORD

	LOCATION	YEARS OF RECORD	DATE	AMOUNT	RETURN PERIOD
134	San Juan Guard Station	21	3-4-78	2.50	>100 year
121	Santa Ana	64	3-1-83	2.65	<200 year
163	Yorba Reservoir	42	3-1-83	2.42	<100 year
165	Costa Mesa	42	3-1-83	2.98	>200
173	Villa Park Dam	36	3-1-83	2.43	100-year
**125	Irvine (Sand Canyon)	61	10-1-83	2.37	<100-year
*217	Lambert Reservoir	52	3-20-92	2.44	100-year
239	Westminster	42	1-4-95	2.55	>100-year
8132	Los Alamitos	39	1-4-95	2.68	<200-year
8036	Cypress Pump Station	5	1-4-95	2.87	>200-year
379	Long Beach (Spring Street)	#1	1-4-95	3.42	>2000-year
1180	Gilbert Basin	7	1-4-95	2.48	>100
207	El Toro	33	12-6-97	3.31	1000-year
*217	Lambert Reservoir	52	12-6-97	2.71	<200-year
233	Modjeska Canyon	13	12-6-97	2.45	100-year
256	Lower Silverado	13	12-6-97	2.83	>200-year
263	Corona Del Mar	38	12-6-97	2.91	>200
**274	Irvine (Sand Canyon)	61	12-6-97	3.86	<10,000
1120	Laguna Canyon	7	12-6-97	4.05	<10,000
1130	Laguna Audubon	7	12-6-97	3.81	<10,000
1136	E08 @ Santiago Canyon Road	4	12-6-97	2.86	>200
1141	Upper Aliso Creek	6	12-6-97	3.39	>1,000
1152	Laguna Niguel Lake	23	12-6-97	2.48	>100
1125	San Diego Creek at Campus	7	2-6-98	2.76	200
125	Huntington Beach	16	12-4-74	2.32	100

Not an Orange County rain station. Only one year of record (1995) reviewed by us.

** * Duplicate stations

ORANGE COUNTY:

- Number of Rain Gauges..........................34
- Number of StationYears.........................673
- Number of 100-Year Event Exceedences......24
- Number of 100-Year Events......................7

METHOD 1

- Binomial Distribution

- Probability (24 or more exceedences given independence of gauges) = 10 exp(-6)
  - Gauges are not independent
  - Gauges have variable network density

METHOD 2: AREA COVERAGE STATISTICS

- Probably of point coverage, for exceedence event, = A(T year)/A(region)

- Prob (exceedence) =
  Prob (coverage, and event is “100 year”)
  - Uses current “100 year” estimate values

Percent of Orange County Exceeded by Rainfall Frequencies for Selected Durations

December 6, 1997 Storm			
Return Frequency	Duration		
	2 hour	3 hour	12 hour
5 year	58.0	64.2	67.6
25 year	32.4	28.6	37.2
100 year	21.2	19.2	20.2
200 year	-	-	16.6
500 year	-	-	12.0
1000 year	-	7.6	8.2
2000 year	7.6	-	4.6
5000 year	-	1.8	0.6
10000 year	2.6	-	-
30000 year	0.4	-	-

January 4, 1995 Storm	
Return Frequency	Duration
	3 hour
10 year	60.5
25 year	24.3
100 year	6.6
200 year	0.3

March 1, 1983 Storm	
Return Frequency	Duration
	3 hour
2 year	67.7
10 year	59.3
25 year	32.3
100 year	23.8

December 4, 1974 Storm	
Return Frequency	Duration
	3 hour
100 year	17.5

Table 3.9

Results of applying the eigenvalue method and other methods to application 1 using three quality spaced interior nodes

Time	$\eta = 2$		$\eta = 3$		$\eta = 11$		$\eta = \infty$		Fourth-order subdomain approximation		Adjusted nodal domain integration		Eigenvalue method		Analytic solution	
	0.25[a]	0.50[a]	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50
0.01	0.802	1.041	0.823	0.989	0.851	0.989	0.861	0.981	0.864	1.003	0.864	1.013	0.862	0.979	0.923	0.999
0.02	0.701	0.970	0.716	0.941	0.743	0.941	0.755	0.933	0.760	0.961	0.761	0.967	0.756	0.931	0.789	0.975
0.03	0.627	0.881	0.637	0.876	0.660	0.876	0.671	0.873	0.676	0.898	0.678	0.902	0.672	0.871	0.690	0.918
0.04	0.564	0.796	0.572	0,807	0.592	0.807	0.602	0.807	0.606	0.828	0.608	0.830	0.603	0.806	0.615	0.846
0.05	0.508	0.718	0.515	0.739	0.533	0.739	0.543	0.743	0.546	0.759	0.548	0.759	0.544	0.742	0.553	0.772
0.10	0.302	0.427	0.310	0.461	0.327	0.461	0.335	0.472	0.331	0.469	0.331	0.468	0.335	0.471	0.336	0.474
0.15	0.179	0.254	0.187	0.285	0.202	0.285	0.209	0.295	0.202	0.287	0.201	0.285	0.209	0.296	0.205	0.290
0.20	0.107	0.151	0.113	0.176	0.125	0.176	0.131	0.185	0.123	0.175	0.123	0.174	0.131	0.185	0.125	0.177
0.25	0.063	0.090	0.068	0.109	0.077	0.109	0.082	0.116	0.075	0.107	0.075	0.106	0.082	0.116	0.076	0.108
0.30	0.038	0.053	0.041	0.067	0.048	0.067	0.051	0.072	0.046	0.065	0.046	0.064	0.051	0.073	0.047	0.066

[a] Value of X.