FMA 2011 Annual Conference Presentation

Improving Synthetic Storm Runoff Hydrographs
by
Adjusting Watershed Parameter Estimation Methodologies

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Roadmap of the Presentation

- Brief Review of Most Used Synthetic Unit Hydrograph Methods.
- Summary of Clark Method Parameter Estimation Methodologies for California, and the Concerns.
- Introducing the Improvement Ideas of the Harris County Methodology.
- Recommendations for Improving the California's Methodologies.

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SCS Method Parameters

- $U_p = C \dfrac{A}{T_p}$ (C = 484)
- $T_p = \dfrac{\Delta t}{2} + t_{lag}$
- $t_{lag} = 0.6 t_c$

Parameters to estimate: t_{lag} (or t_c)

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Snyder Method Parameters

- $$\frac{U_p}{A} = 640\frac{C_p}{t_p}$$
- $$t_p = C_t\left(\frac{LL_c}{\sqrt{S}}\right)^{0.33}$$

Parameters: C_t and C_p may be regression functions of watershed characteristics.

Clark Method Parameters

- Parameters to estimate: ***t_c* & *R***

Linear Reservoir Routing -

$$\begin{cases} Continuity\ Equation: \dfrac{dS}{dt} = I_t - O_t \\ Linear\ Reservoir: S_t = RO_t \end{cases}$$

$$Time - Area\ Relationship: \frac{A_t}{A} = \begin{cases} 1.414\left(\dfrac{t}{t_c}\right)^{1.5} & for\ t \le \dfrac{t_c}{2} \\ 1 - 1.414\left(1 - \dfrac{t}{t_c}\right)^{1.5} & for\ t > \dfrac{t_c}{2} \end{cases}$$

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Available Methodologies for Estimating T_c and *R* in California

- Northern California - *Fitzpatrick (1970) [DWR,1971, 1976]*
- Southwestern California - *USACE HEC (1967)*
- Southeastern California - *Mayer (1987)*

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Regression Equation for Northern California (Fitzpatrick, 1970)

- $T_c + R = 10^K (DA^{0.211} \times 10Y3D^{0.732} \times 1.093^{El.In.} \times 0.873^C)$
- Loss-rate: $L = 3.5 P^{0.4}$, (P: rainfall rate in/hr)
- R / T_c and K => Distribution Maps

DA: Drainage Area (mi^2)
K Log(Residual)
10Y3D: 10-Year, 3-Day Precipitation (in)
El.In.: Basin 10% and 85% Average Elevation
C: Soil Cover Index.

NCR	60	65	70	75	80	85	90
C	1	2	3	4	5	6	7

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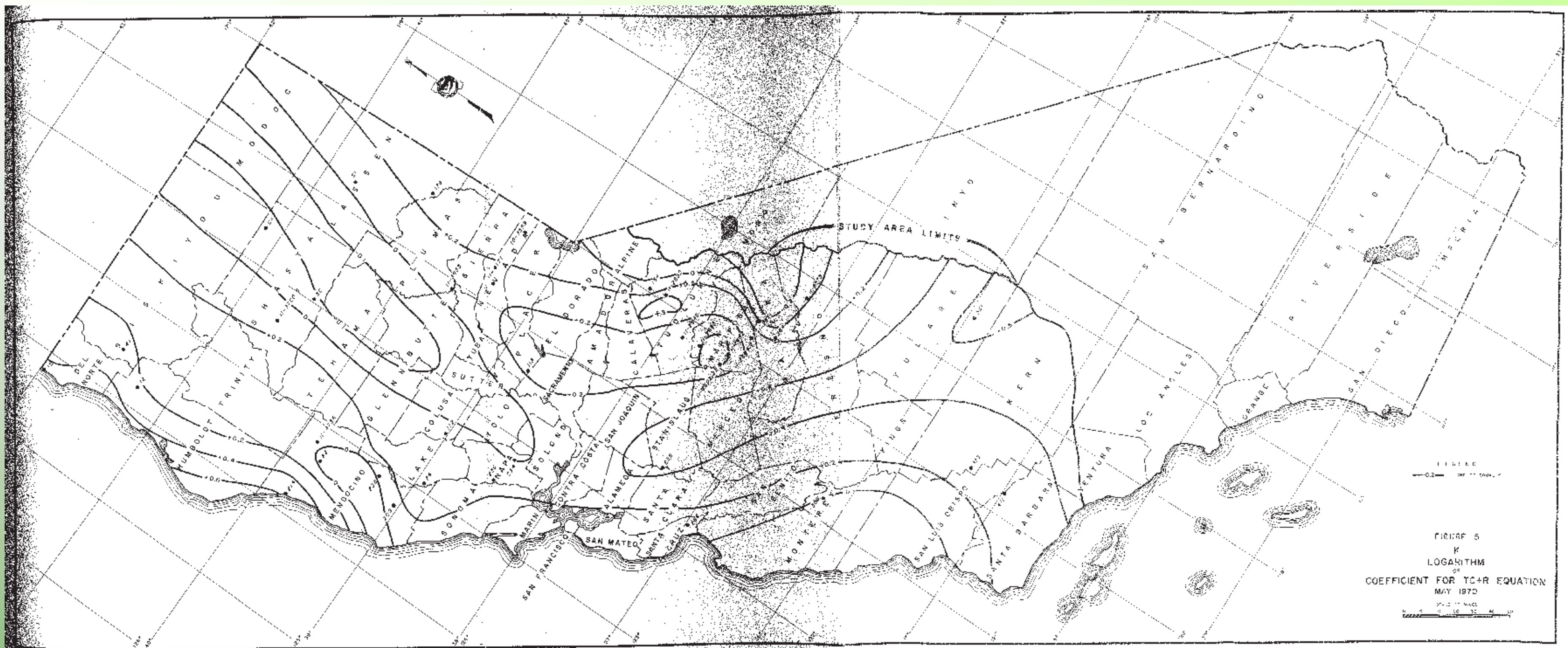
Log *K* Map for T_c + *R* Equation



(Source: James Arthur Fitzpatrick, 1970, 'Unit Hydrographs for Small Ungaged Watersheds in Northern California', Thesis of California State University, Sacramento.)

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Regression Equation for Southwestern California (HEC, 1967)

- $T_c = a\,(DA \cdot L_c)^{.25}$, L_c: median stream length (mi)
- $R / T_c = 0.8$
-

Type of Area	*a*
Mountain	.5
Foothill	.4
Valley	.3

- $Loss = K\,(Rain)^{.7}$, *K*: varies with soil perviousness

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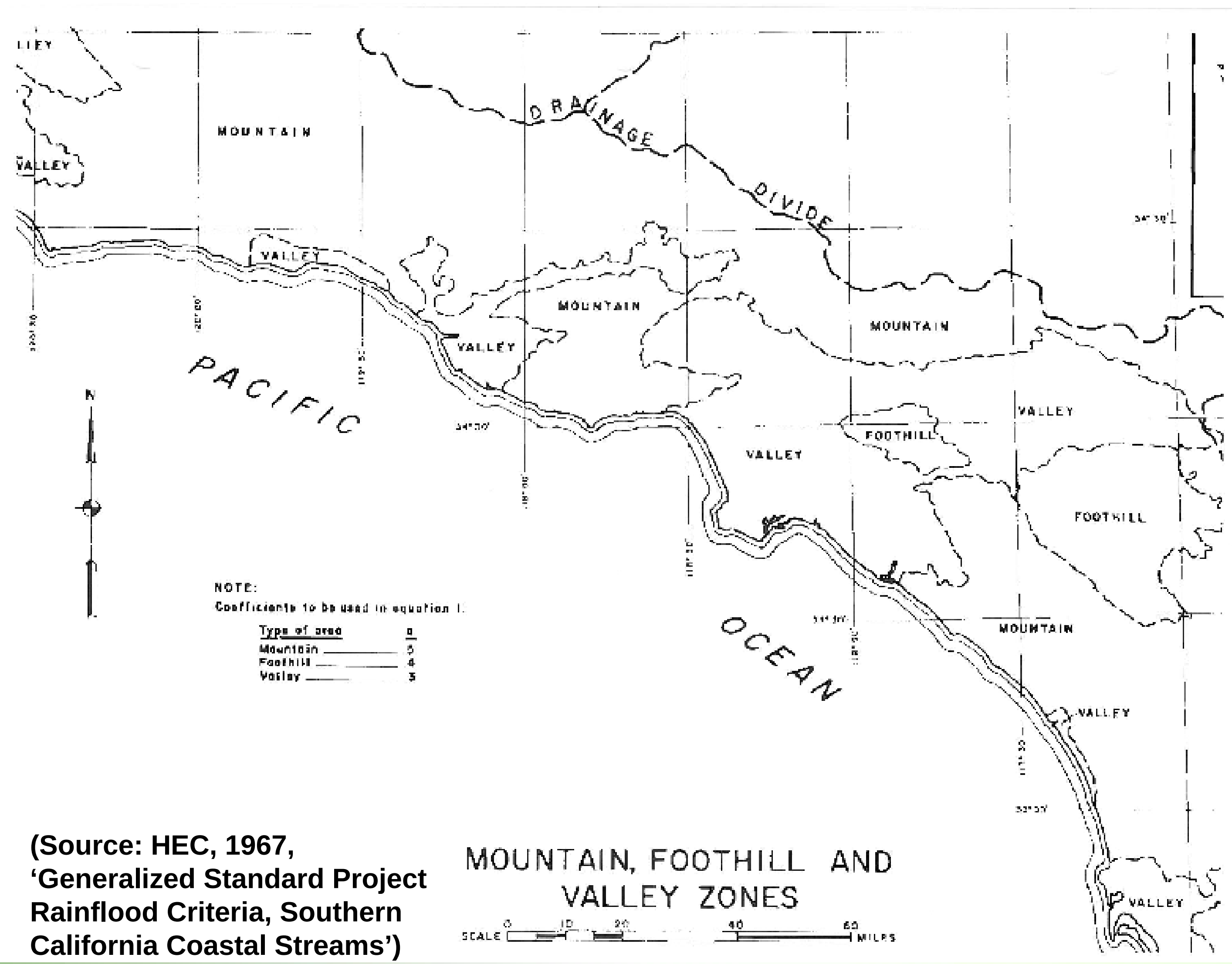
Mountain, Foothill, and Valley Zones



(Source: HEC, 1967, 'Generalized Standard Project Rainflood Criteria, Southern California Coastal Streams')

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Regression Equation for Southeastern California (*Three Regions*, Mayer, 1987)

- ***Region 1 – Eastern Slope of Sierra Nevada***

$$\ell n(T_c) = .58 - 1.974\ \ell n(A_r) + .536\ \ell n(A) + .674\ \ell n(\tau) + \text{residual}$$

$$\ell n(R) = 1.353 + .653\ \ell n(A) + \text{residual}$$

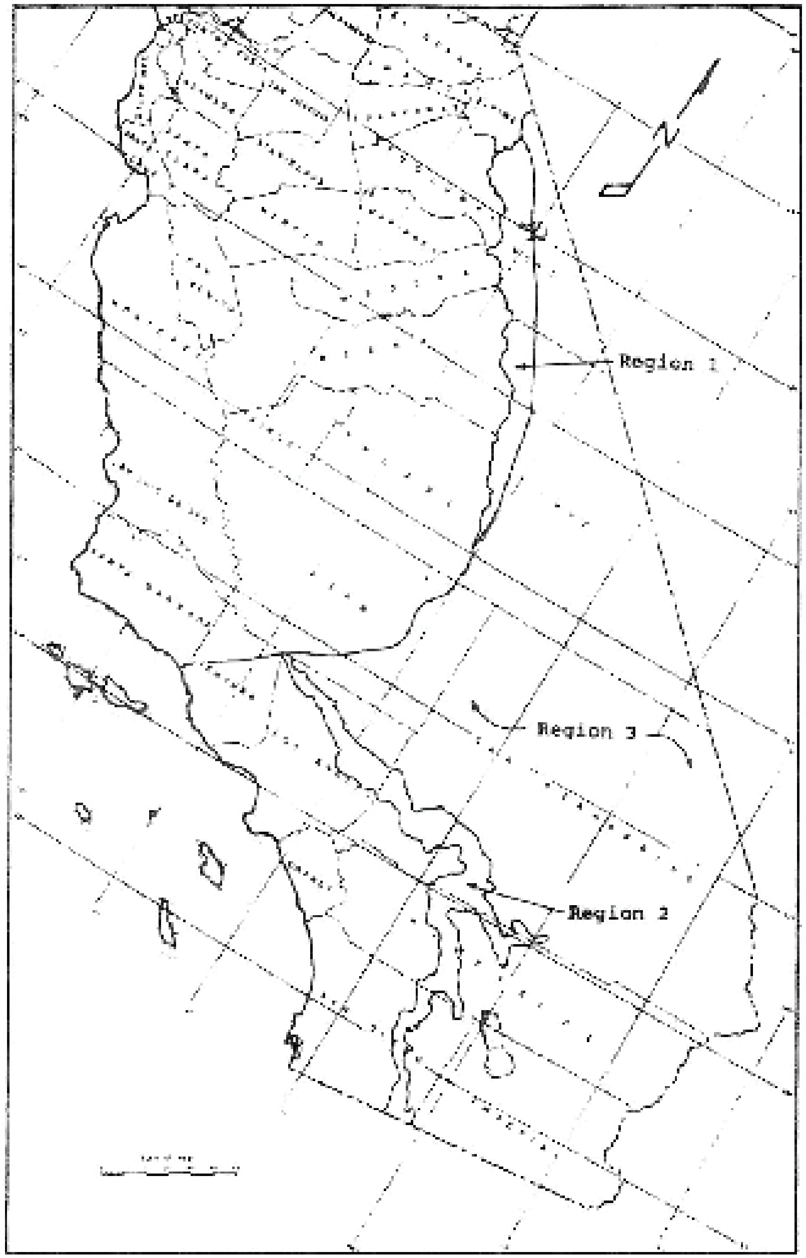
A_r = Ratio of area below lakes to total drainage area

$\tau = \frac{\sqrt{|L_c^2 - W_L^2|}}{W_L}$, Watershed eccentricity,

L_c = Length from mouth to centroid

W_L = width at centroid $\perp L_c$

Hydrologic Regions of Southern Eastern California



(Source: Rodney Gerard Mayer, 1987, 'Unit Hydrographs for Small Ungaged Watersheds in Southeastern California', Thesis of California State University, Sacramento.)

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Regression Equation for Southeastern California (Mayer, 1987)

- ***Region 2 – Northern and Eastern Slopes of Transverse Ranges and Eastern Slope of Peninsular ranges***

$$\ln(T_c + R) = -26.1 + .314 \ln(A) + 3.19 \ln(E_{1085})$$

$$\ln(R / T_c) = -6.23 + 6.11 \ln(h) + 2.80 \ln(R_c)$$

* Recommended Average T_c= 1.8, R = 4.9

E_{1085} = Avg. elevation of 10% and 85% points (ft)

h = Elevation difference between outlet and divide (ft)

R_c = A / A_c, Circularity ratio, A_c = Area of circle with the same perimeter as the watershed

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Regression Equation for Southeastern California (Mayer, 1987)

- ***Region 3 – The Basin Ranges, Mojave Desert, and Colorado Desert***

$$\ln(T_c + R) = -.809 + .529 \ln(L_c) + .641 \ln(\tau)$$

$$\ln(R / T_c) = -2.58 - 2.68 \ln(R_c)$$

L_c = Length to centroid of watershed (mi)

τ = Watershed eccentricity

R_c = Circularity ratio

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Concerns of the above Regression Equations for the T_c and R Parameters

- Regression based on *rare / early (decades ago) gage data and geomorphology*.
- Relationship depends too much on *watershed geometry and dimension*.
- *Low coefficient of determination*, r^2 about 0.5.
- *Land use* and *urban development* not considered.
- *Channel and conveyance improvements* not considered.

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Regression Equations for Harris County

(TSARP Study, 2003)

$$T_C = D\,[1 - (0.0062)(0.7\ DCI + 0.3\ DLU_{DET})]\ (Lca / S^{1/2})^{1.06}$$

$$T_C + R = C\ (L / S^{1/2})^{0.706}$$

$C = 7.25$ (*if* $DLU < DLU_{MIN}$)

or

$C = 4295\ (DLU_{DET})^{-0.678}\ (DCC)^{-0.967}$ (*if* $DLU >= DLU_{MIN}$)

$$DLU_{MIN} = 11344(DCC)^{-1.4048}$$

C will not exceed 7.25 → Low R → Overestimate Q_P

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R Adjustment Based On Percent Ponding

RM: Multiplier of R in %, a function of percent ponding (*good for undeveloped areas*) .

Storm Event T_R	RM Factor Equation
5 Year	$RM = 1.31 P^{0.214}$
10 Year	$RM = 1.28 P^{0.199}$
25 Year	$RM = 1.25 P^{0.171}$
50 Year	$RM = 1.23 P^{0.153}$
100 Year	$RM = 1.21 P^{0.132}$
500 Year	$RM = 1.17 P^{0.086}$

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Proposed Adjustment to the Harris County Methodology

- Center around four parameters:

    Percent Ponding (DPP)

    Percent Urbanization (DLU)

    Percent Channel Improvement (DCI)

    Percent Channel Conveyance (DCC)

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R- value Adjustment for 'Developed' Areas

BDF - Basin Development Factor (*Harris County Flood Control District Flood Wise Project*)

$$R = 8.271e^{-0.1167(BDF)}(A^{0.3856})$$

Factors: % Channel Improvements
% Channel Linings
% Storm Drains (Sewers)
% Curb and Gutter Streets

(R decreases when BDF increases)

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Problems with DCC, DLU, and DCI

- Underestimate R when DCC or DLU is low (as a lower C value of 7.25 will be used.)
- When DCI increases, Q_p decreases.
- DCI has no correlation with both DCC and DLU.
- DLU estimated from aerial photos does not account for drainage efficiency differences *between aged and modern developments, streets, and required storm drain dimensions.*

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Proposed Improvements via TSARP

(for Harris County, Texas)

- Remove the C coefficient ceiling (=7.25).

- Redefine DCC as the capability to carry flood flow within the channel banks, to provide DCC and DCI correlation.

- Adjust the methodology such that, when DCI increases, the computed Q_P will increase.

- DSC = a x DCC + (1-a) x DTC (DSC ≤ DCC)

- In estimating DLU, the effectiveness and ages of the drainage infrastructures should be considered
  DLU= 0.7 x (Drainage Infrastructure) + 0.3 x (Imperviousness)

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Conclusions and Recommendations for Improving California's Synthetic Hydrographs

- California's regression equations for T_c & R parameters were based on rare / early (decades ago) gage data and basin geomorphology.
- Relationship too much depends on watershed geometry and dimension. Land use, urban development, and drainage system improvements were not considered.
- Modifying the T_c & R regression equations for valley and flat areas within California with consideration of *Land Urbanization, Channel and/or Storm Drain System Improvement, and Ponding Effect* within each sub-basin.
- *Later or more representative storm events should be used in the Calibration for the model parameters*.

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