RECLAMATION *Managing Water in the West*

A Case Study: Calculating a Precipitation Frequency Curve Using L-Moment Statistics with Emphasis on the Uncertainties in the Analysis

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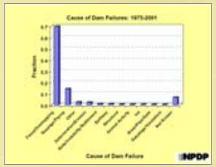
MOTIVATION

- Rainfall-produced floods can overtop dams which result in dam failure if adequate releases through the spillways and outlets can not occur.
- Three such significant disasters resulting from inaccurate forecasting of flood conveyance requirements include (Jansen 1983):
  - South Fork (Johnstown), United States
  - Oros, Brazil
  - Panset and Machhu II, India



(NPDP 2011)

BACKGROUND

OVERTOPPING ASSESSMENT

- Initial Risk Assessment – If the dam can safely pass the current PMF without overtopping, then overtopping is not considered a failure option for that dam.

PMF – Probable Maximum Flood – The 'maximum runoff condition resulting from the most severe combination of hydrologic and meteorological conditions considered reasonably possible for a drainage basin' (USDOI 1987)

- If the dam does not safely pass the PMF – higher level study needed.

Rainfall-based statistics (i.e. precipitation frequency) and rainfall-runoff routines are needed as input for the method of analysis and modeling required to produce a Hydrologic Hazard Curve (HHC). An HHC is an estimated relationship of flood magnitudes (or volumes) to annual exceedance probabilities (AEPs) up to the PMF. From an HHC, flood peaks may be compared with spillway discharge capacities to determine the risk of overtopping.

INTRODUCTION

HYDROLOGIC HAZARD

The probability of failure during some hydrologic event due to an undersized spillway needs to be determined at East Park Dam, CA.

East Park Dam (USDOI 2011):

- Thick-arch concrete dam
- Structural height of 139 ft.
- Crest length of 266 ft.
- Crest Elevation 1,198.68 ft.
- Reservoir with a capacity of 50,900 acre-ft
- Reservoir storage for irrigation

OBJECTIVE

Create a precipitation frequency curve for use as input into a rainfall-runoff model which will, in turn, be used to create a Hydrologic Hazard Curve. Flood peaks may then be compared with spillway discharge capacities to determine the risk of overtopping.

METHODOLOGY

Regional statistics calculated from the L-Moments method will be used to create the precipitation frequency curve. As a regional statistics method, this scheme allows space for time substitution (Hosking and Wallis 1997).

PRECIPITATION FREQUENCY

- Input – Annual maximum 1-day precipitation totals from the NWS COOP rain gauge network (determined from the NCDC Summary of the Day precipitation product)
- Region for statistical analysis – Area with similar climatological characteristics as that of the East Park watershed

STEPS TO COMPUTE PRECIPITATION FREQUENCY CURVE

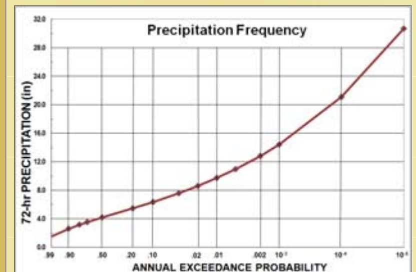
1. The rain gauges with discordant data were removed to form a statistically homogeneous dataset.
   Total = 92 rain gauges, ~3,000 station-years of data
2. L-Moment ratios (L-Cv, L-skewness, L-kurtosis) were computed for the gauges in the dataset. These ratios were used to find a common set of distribution parameters, defining a single probability distribution function for the region (i.e. the regional growth curve).

Generalized Logistic Distribution Parameters

ξ	α	*k*	*h*
0.951	0.186	-0.156	-1

3. Scale the regional growth curve by a point precipitation value representative of East Park Dam to find the at-site growth curve. The areal average of the East Park watershed = 2.80" (the at-site growth curve for 24-hr precipitation)
4. The 24-hr at-site growth curve scaled to a 72-hr storm, based on historical record of extreme storms. Scale factor = 1.75 (Corrigan et al. 1999)
5. The 72-hr at-site growth curve scaled to the 100 mi^2 watershed. Scale factor = 90.25% (Corrigan et al. 1999) (the basin growth curve)
6. The basin growth curve extrapolated from 3,000 years to the PMP.

PMP – Probable Maximum Precipitation – 'theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of year' (Hansen et al.1988)
Note: no defined return period



Precipitation Frequency

1/AEP	1-AEP	Rainfall (in)
100	0.99	9.73
200	0.995	10.97
500	0.998	12.83
1,000	0.999	14.42
2,000	0.9995	16.19
5,000	0.9998	18.84
10,000	0.9999	21.12
20,000	0.99995	23.65
50,000	0.99998	27.45
100,000	0.99999	30.70
111,000	0.999991	31.23

The precipitation frequency curve for East Park Dam, CA, extrapolated to the PMP, 31.23."

UNCERTAINTIES IN THE ANALYSIS

1. Annual maximum precipitation observations do not capture all large events.
2. The creation of a statistically homogeneous dataset removes discordant data points (i.e. those gauges with significantly high precipitation amounts).
3. Assume that it is appropriate to scale the 24-hr storm to a 72-hr storm.
4. PMP published in 1999; using storm data from 1905-1986. No recent data incorporated.
5. Assumption of stationarity: The past precipitation is representative of the future.

REFERENCES

Corrigan, P., D.D. Fenn, D.R. Kluck, and J.L. Vogel, 1999: *Probable Maximum Precipitation for California.* Hydrometeorological Report No. 59, National Weather Service, 392 pp.

Hansen, E.M., D.D. Fenn, L.C. Schreiner, R.W. Stodt, and J.F. Miller, 1988: *Probable Maximum Precipitation Estimates – United States between the Continental Divide and the 103rd Meridian.* Hydrometeorological Reports No. 55A, National Weather Service, 242 pp.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional Frequency Analysis – An Approach based on L-Moments.* Cambridge University Press, 224 pp.

Jansen, R.B., 1983: *Dams and Public Safety, A Water Resources Technical Publication.* U.S. Government Printing Office, 332 pp.

National Performance of Dams Program, cited 2011: Historic Record of Dam Performance. [Available online at npdp.stanford.edu/npdphome/Historic%20Performance%20of%20Dams.pdf]

U. S. Department of the Interior, Bureau of Reclamation, 1987: *Design of Small Dams, A Water Resources Technical Publication.* 3rd ed. U.S. Government Printing Office, 860 pp.

U. S. Department of the Interior, Bureau of Reclamation, cited 2011: Orland Project. [Available online at http://www.usbr.gov/projects/Project.jsp?proj_Name=Orland%20Project]