BIOGRAPHICAL SKETCH

Dr. Rory Nathan is the Principal Hydrologist with Sinclair Knight Merz, and is an Honorary Research Fellow at both the University of Melbourne and Monash University. He is the Australian representative on the ICOLD floods committee and lead author of the national guidelines for the estimation of large to extreme floods. He has published over 130 research papers on environmental and engineering hydrology in refereed journals and conference proceedings. He has won several national and international awards for his research publications, including being named national "Civil Engineer of the Year" by the Institution of Engineers.

ABSTRACT

This paper broadly describes the range of flood estimation procedures used currently in Australia. It presents the context for the range of different approaches used, and discusses the overall rationale for transitioning from the use of flood frequency analyses for the estimation of frequent floods, through to the use of rainfall-based procedures for the estimation of extreme events. The importance of reconciling differences between the different approaches used is emphasised. The different frameworks used to undertake flood simulation are discussed, and the relative advantages between deterministic, joint probability, and continuous simulation approaches are briefly mentioned.
**Introduction**

> Flood estimation in Australia governed by guidelines "Australian Rainfall and Runoff" published by the Institution of Engineers:
  > o Divided into 8 books covering hydrologic, meteorologic, and hydraulic aspects of flood estimation
  > o Book VI is concerned with the "Estimation of Large to Extreme Floods"
  > o Book IV (II) covers Flood Frequency Analysis
  > o Remainder currently under (slow) process of revision
> Scope of document covers the estimation of events between 2 yr ARI flood up to the PMF.
> These are guidelines, not prescriptive, and they can be departed from with justification
Event classes

Flood Peak

Large Rare Extreme

PMF is upper limit of floods that could reasonably be expected to occur

Credible Limit of Extrapolation

PMP Design Flood (at the AEP of the PMP)

Annual Exceedance Probability (1 in Y)

PMF vs Probability-Neutral PMP Flood

> The guidelines differentiate between a flood derived from the PMP under probability-neutral assumptions (“PMP Design Flood”) and that under upper limiting assumptions (“PMF”)

Distribution of flood sizes from largest possible rainfall (the PMP)

PMF Design Flood

Upper limit of floods derived from PMP under reasonably likely combination of factors

PMP

Frequency

Flood Magnitude (m³/s)
**Event classes**

- Flood Peak

<table>
<thead>
<tr>
<th>Annual Exceedance Probability (1 in Y)</th>
</tr>
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<tbody>
<tr>
<td>50</td>
</tr>
<tr>
<td>Large</td>
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</table>

- Fewer observations
- Increasing uncertainty
- Increasing prescription required
- Increasing need for rainfall-based procedures

**Stochastic variability vs. uncertainty**

<table>
<thead>
<tr>
<th>Method: Calibration</th>
<th>Extrapolation</th>
<th>Simulation</th>
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<tbody>
<tr>
<td>Basis: Data</td>
<td>Data &amp; hydrologic knowledge</td>
<td>Modelling hypotheses</td>
</tr>
<tr>
<td>Dominant Feature: Stochastic variability</td>
<td>Parameter uncertainty</td>
<td>Model uncertainty</td>
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</table>
Summary of Rainfall Procedures

Regional pooling (space for time) of observed data

At-site analysis (e.g., LPIII)

Generalised (but site-specific) PMP estimates

Interpolation

Regional Pooling

1. Data collation
2. Standardisation
3. Allowance for correlation
4. Fitting of statistical model(s)

Easier to apply to rainfalls than streamflows
Flood Frequency Analysis (FFA)

- Current procedures effectively same as Bulletin 17B, but draft revision recommends range of distributions (GEV, GPO, GUM, LP3, EXP) and fitting of parameters by Bayesian calibration

- Literature on theoretical advantages extensive, but in practice the factors that most dominate are:
  - Relevance of gauged site to point of interest
  - Length of available record
  - Quality of streamflow gauging extrapolation
  - Stationarity of flood producing factors in the catchment
  - Availability of historic events (prior to collection of systematic record) and paleo evidence

- Little point giving undue attention to theoretical advantages of a particular FFA method if data availability is poor
Flood Simulation Concepts

- Rainfall Input (design storms)
- Runoff production (loss model)
- Rainfall excess
- Hydrograph formation (routing model)
- Flood output

Flood Simulation Approaches

**DETERMINISTIC**
- Design event simulation
  - Design rainfall event (ARI=Y)
  - Storm runoff production, flood hydrograph formation
  - Design flood event (ARI = Y ??)

**PROBABILITYSTIC**
- Monte Carlo simulation (+ Total prob. theorem)
  - Sample of stochastic storm rainfall events
  - Storm runoff production, flood hydrograph formation
  - Derived flood frequency curve

**COMPREHENSIVE**
- Continuous simulation
  - Complete time series of rainfall (& other climate factors)
  - Catchment rainfall-runoff response
  - Complete streamflow time series

Increasing complexity in process description
Decreasing applicability of traditional design information
### Deterministic ("Design Event" Approach)

<table>
<thead>
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<th>Rainfall Depth</th>
<th>AEP</th>
<th>Season</th>
<th>Probability</th>
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</tbody>
</table>

Stochastic variability represented by single "probability-neutral values

- Fixed rainfall input
- Seasonal losses
- Temporal pattern
- Seasonal drawdown

#### Outflow

- 1:Y flood

#### Time

### Probabilistic (Monte Carlo Simulation)

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Stochastic variability

- Rainfall input
- Seasonal losses
- Temporal pattern
- Seasonal drawdown

#### Outflow

- 1:Y AEP rainfall

#### Time

Mimics Mother Nature

Outflow
**Probabilistic (Monte Carlo Simulation)**

**Rainfall Input**
- Rainfall depth
- Season
  - Probability
- Seasonal Losses
  - AEP
- Temporal Pattern
  - Probability
- Seasonal Drawdown
  - AEP

**Stochastic Variability**

**Flood Event Model**
- 1:Y AEP Rainfall
- Time

**Mimics Mother Nature**

**Design Event Approach**
- Deterministic
  - Likelihood of flood peak assumed to be the same as its rainfall

**Monte Carlo Approach**
- Stochastic
  - Likelihood of flood peak calculated using joint probability theory

**Outflow**
- 1:Y flood

**Achieve remarkable success**

9
**Continuous simulation**

Stochastic variability

- Rainfall
- Temperature
- Snowpack

Simulation Model

Derived flood frequency analysis

Flow peak

**Method selection**

- Flood frequency analyses:
  - difficulty with extrapolation to rare floods
  - … and to locations of interest,
  - but valuable use of at-site data.

- Continuous simulation:
  - also limited by length of available record
  - … unless using (complex) stochastic data generation
  - well suited to handling complex interactions

- Monte-Carlo approaches:
  - Good extension of traditional flood event models
  - Makes extended use of available design information
  - Need to focus on dominant stochastic influences
Reconciliation between different flood estimation approaches very valuable and very important.

Particularly if independent data / methods used (e.g., flood frequency approaches and rainfall-based approaches)

Reconciliation b/w Monte Carlo Simulation and FFA, d/s of a large dam
Reconciliation b/w Monte Carlo and FFA d/s of two correlated storages

Monte Carlo simulation of uncertainty

Uncertainty function of:
- AEP of PMP
- Model parameters
- Pragmatic assumptions

SKM

achieve remarkable success
Conclusions

> Australian design practice firmly wedded to risk-based concepts, though many areas where more confidence is required in reducing uncertainty in analyses.

> Guidelines based on use of flood frequency analysis of at-site data, transitioning to rainfall-based procedures for more extreme events.

> Important emphasis placed on reconciliation of estimates from different data sets and procedures.

> Draft chapter on revised flood frequency methods recommends range of distributions (GEV, GPO, GUM, LP3, EXP) and fitting of parameters by Bayesian calibration (i.e., move away from B17B procedures).

> The flood guidelines are currently under revision, and will be encouraging practitioners to move towards Monte-Carlo and continuous simulation techniques.