REGIONAL FLOOD METHODS

Update on Pilot Studies

Australian Rainfall and Runoff
A guide to flow estimation

ENGINEERS AUSTRALIA

OVERVIEW

- Project team
- RFFA methods in ARR 1987
- Pilot study results for Victoria
- Status reports for other states

PROJECT TEAM

- Dr Ataur Rahman
- Mr Khaled Haddad
- Associate Professor James Ball
- Mr Erwin Weinmann
- Professor George Kuczera
- Mr Mark Babister
- Dr William Weeks
- Dr David Kemp
- WA Representatives

METHODS IN AR&R 1987

- Probabilistic Rational Method
  - Vic & Eastern NSW
  - Frequency factors depend on elevation for six zones A-F for Eastern NSW.
- Multiple regression relationship
  - Western NSW
- Quantile Regression
  - ACT

METHODS IN AR&R 1987

- Qld
  - No general method meets the primary criterion of being based on sufficient observed flood data.
  - Main Roads Department Rational Method - not easy to apply.
  - Department of Primary Industries Rational Method - based on little/no observed streamflow records.

METHODS IN AR&R 1987

- SA - South East Region
  - Probabilistic Rational Method (Based on observed data from 20 catchments).
  - Department of Agriculture Method - Index type approach (based on floods data from 6 small agricultural catchments).

METHODS IN AR&R 1987

- SA – Northern and Western Region (Based on very little observed data)
  - Rational Method
  - Bankfull frequency method – Method of western NSW by McDermott and Pilgrim (1983).
  - Regional Flood Frequency Method – Based on records of 3 catchments.

METHODS IN AR&R 1987

- WA
  - Five regions.
  - Rational method & Index flood method.
  - Methods were based on data from 12-28 catchments.
- NT
  - Methods were based on limited data.
  - Rational method.

METHODS IN AR&R 1987

- Western Tasmania
  - Regional flood frequency method.
- Eastern Tasmania
  - No design information based on observed data is available. Turner's (1961) procedure is suggested.

METHODS TESTED

- Probabilistic Rational Method
- Quantile Regression Technique
  - Ordinary least squares (OLS); and
  - Generalised least squares (GLS).

PROBABILISTIC RATIONAL METHOD

C_Y is the central component of PRM

$$Q_Y = 0.278\, C_Y I_{t_c,Y} A$$

Limitations:

- Location based interpolation for C_Y
- Limited independent testing.
- Limited data on prediction uncertainty.

PROBABILISTIC RATIONAL METHOD

Advantages of PRM:

- Easy to apply
- Simple regional approach with meaningful independent variables
- C_Y integrates effects of other flood generation and attenuation factors in the equation.

QUANTILE REGRESSION

- QRT can be expressed as:

$$Q_T = aB^b C^c D^d$$

  - B, C, D, … are variables (catchment area, main stream slope, rainfall intensity) and a, b, c, … are regression coefficients to be estimated by:
    - OLS (traditionally)
    - GLS (preferable)

PRM and QRT

- PRM was developed
  - $FF_Y = C_Y/C_{10}$
  - C_{10} contour was mapped using MAPINFO
- QRT - OLS method was developed using SPSS
- QRT - GLS method was developed using Statistical Package R.
- Independent testing was undertaken.

INTRODUCTION

Typical problems in streamflow data collation include:

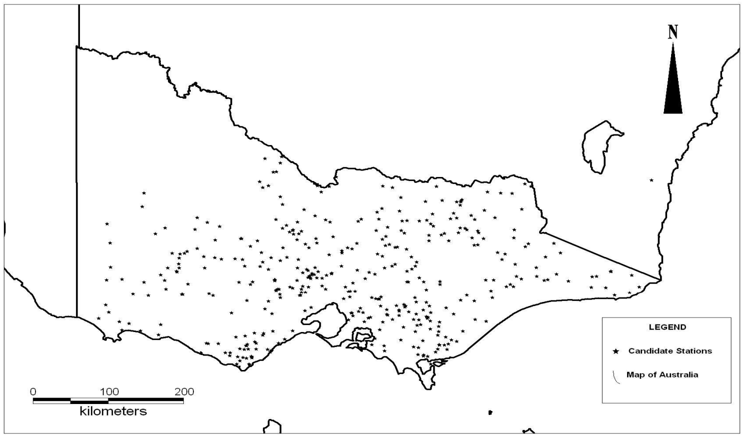
- Unrepresentative sites;
- Missing records; and
- Outliers, trends and rating curve extrapolation errors.

SELECTION OF CANDIDATE STATIONS

Initially 415 candidate catchments selected from Victoria based on the following criteria:

1. Catchment Area (up to 1000 km^2)
2. Record Length (initially 10 years was cut-off)
3. Regulation
4. Urbanisation
5. Landuse change
6. Quality of data

LOCATIONS (Vic)

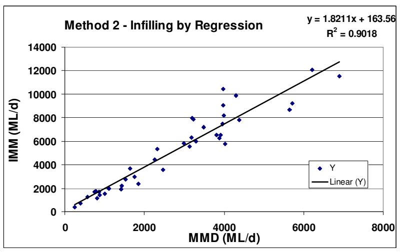


Study area and geographical distributions of the candidate study catchments

INFILLING MISSING RECORDS

- Method 1: Comparison of monthly instantaneous maximum (IM) data with monthly maximum mean daily (MMD) data for the year with data gap

INFILLING MISSING RECORDS



- Method 2: Regression of annual maximum mean daily flow series with annual instantaneous maximum series of the same station

INFILLING MISSING RECORDS

- 273 data points from 187 stations were filled by Method 1
- 60 data points from 44 stations were filled by Method 2
- 10% of stations did not have any missing records.
- Only 7.5 % of data points were infilled.

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TREND ANALYSIS

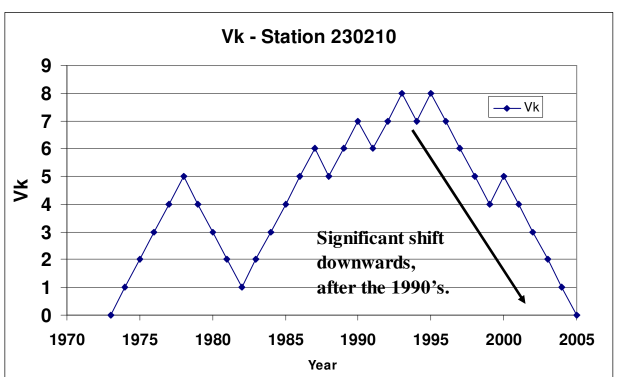
Two tests applied, Mann Kendall & Distribution Free CUSUM Test

- Mann – Kendall test - checks for trends in time series; and

CUSUM test - examines whether the mean values in two parts of a record are different.

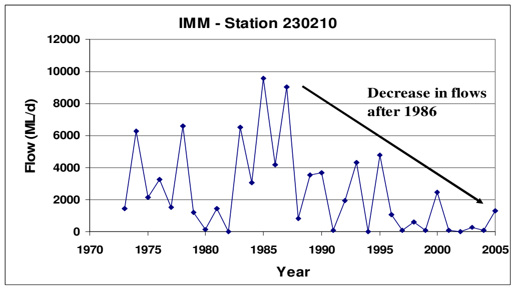
TREND ANALYSIS

Mann Kendall test showed 21% of stations have decreasing trend after 1990s



TREND ANALYSIS

It was also useful to plot time series data as below.



This shows 10-15 years of significant downward trend

TREND ANALYSIS

Conclusions developed were

- Inclusion of sites with short records questionable
- Cut-off length introduced → minimum record 25 years
- A significant shift from ARR1987 (where minimum record length of 10 years was considered).

RATING CURVE ISSUES

Q_E = annual maximum flood series data point (reported value)

Q_M = maximum measured flow

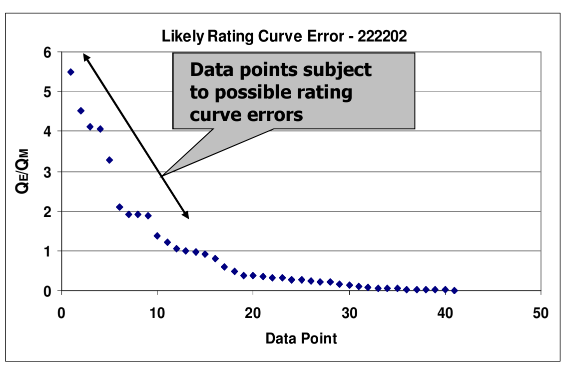
$$Rating\ Ratio\ (RR) = \frac{Q_E}{Q_M}$$

RR ≈ 1 - considered to be free of rating curve extrapolation error.

a RR value >> 1 indicates potential rating curve error

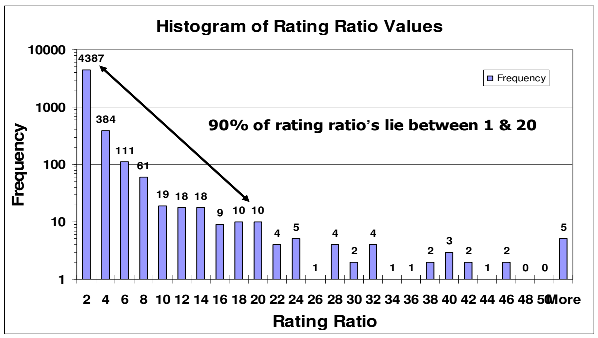
RATING CURVE ISSUES

Graph shows typical example



RATING CURVE ISSUES

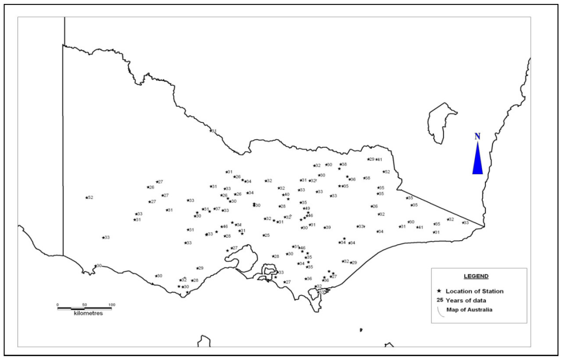
- A rating ratio of 20 may be adopted?
- Any station with RR>20 would be excluded.



AT-SITE FLOOD FREQUENCY

- A LP3 distribution was fitted to each stations annual maximum flood data
- Bayesian parameter fitting procedure was adopted.
- FLIKE was used.

VICTORIA PILOT STUDY



Locations of the study 133 catchments

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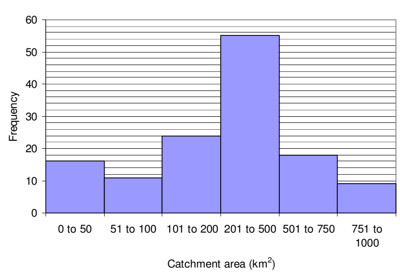
CATCHMENT AREAS



Range: 3 – 997 km^2

Mean = 319 km^2

12% catchments < 50 km^2,

20% catchments < 100 km^2 and

80% catchments < 500 km^2.

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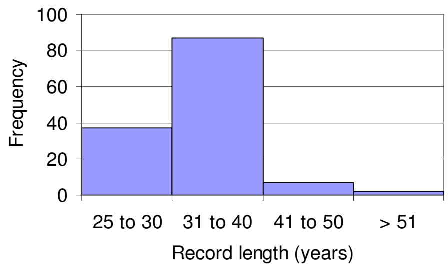
STREAMFLOW RECORDS



Range: 25 to 52 years

Mean: 32 years

CATCHMENT CHARACTERISTICS

Variable	Description
area	Catchment area (km^2)
forest	Fraction of catchment area under forest
Evap	Mean annual areal potential evapotranspiration
Rain	Mean annual rainfall
S1085	Slope of central 75% of main stream
sden	Stream density
I	Design rainfall intensity of 2 and 50 years ARI and 1 and 12 hours duration
QSA	Fraction quaternary sediment area

C_{10} CONTOUR MAP

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C_{10} REGRESSION EQUATION

$$C_{10} = -2.631 - 0.125\log(rain) + 1.02\log(evap) + 0.072\log(S1085) + 0.128\log(sden)$$

rain = mean annual rainfall (mm)

evap = mean annual evaporation (mm)

S1085 = Slope of main stream (m/km)

sden = stream density (km/km^2)

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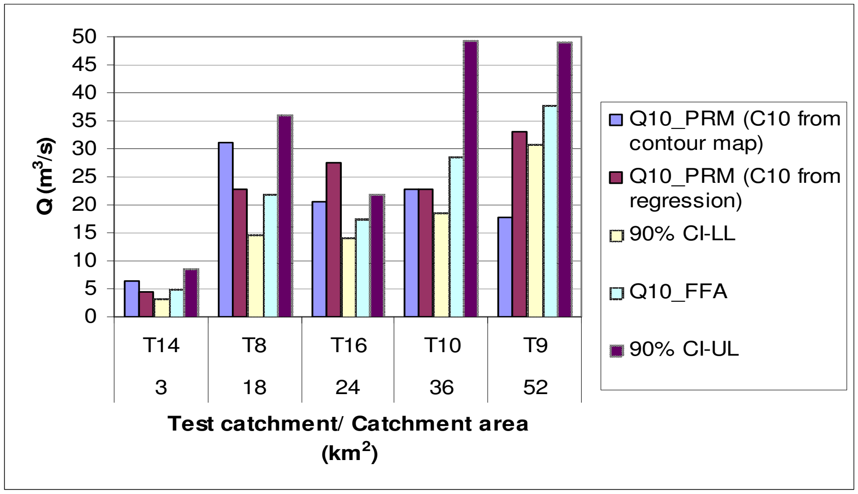
TESTING Q_{10} PREDICTION



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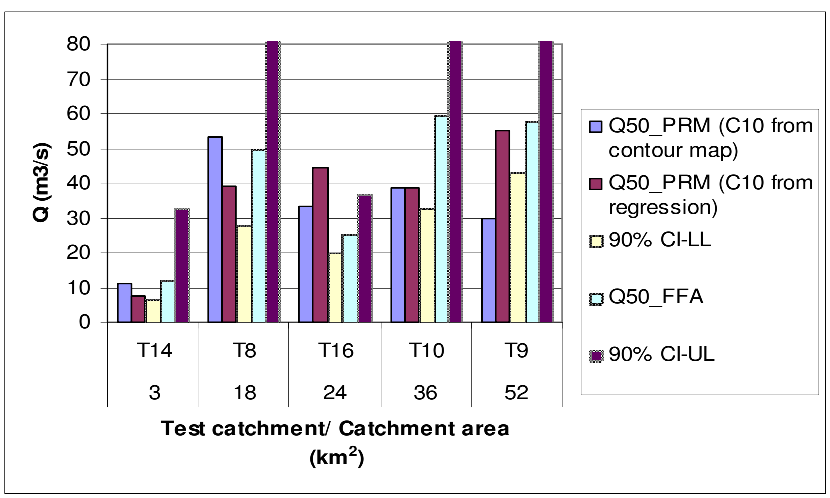
TESTING Q_{50} PREDICTION



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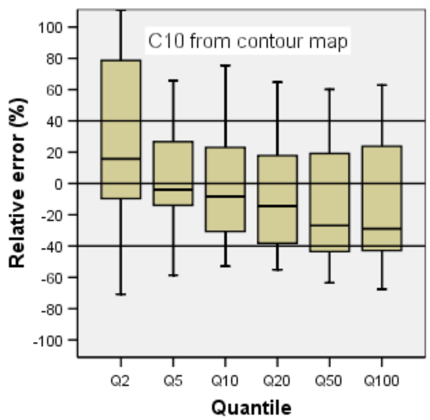
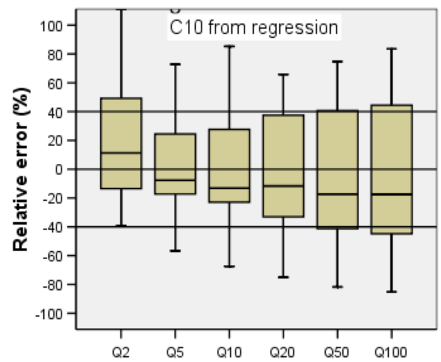
RELATIVE ERRORS

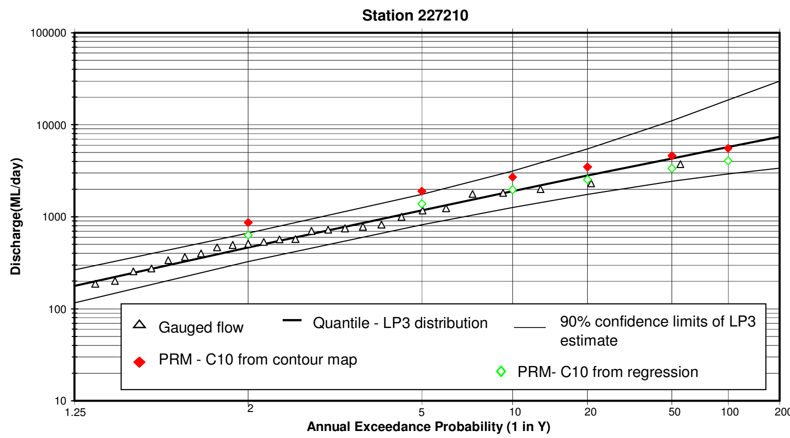




MEDIAN RELATIVE ERROR

ARI (years)	2	5	10	20	50	100
C10-map	28	17	26	30	35	38
C10-equation	31	19	23	36	41	44

FLOOD FREQUENCY PLOT



QRT PREDICTION EQUATIONS

$$\log(Q) = b_0 + b_1 \log(area) + b_2 \log(rain) + b_3 \log(sden) \quad for \ T = 2 \ years$$

$$\log(Q) = b_0 + b_1 \log(area) + b_2 \log(I_{2\_12}) + b_3 \log(sden) \quad for \ T = 5 \ years$$

$$\log(Q) = b_0 + b_1 \log(area) + b_2 \log(I_{2\_12}) + b_3 \log(rain) + b_4 \log(sden) \quad for \ T = 10, 20, 50, 100 \ years$$

Only 4 variables are required:

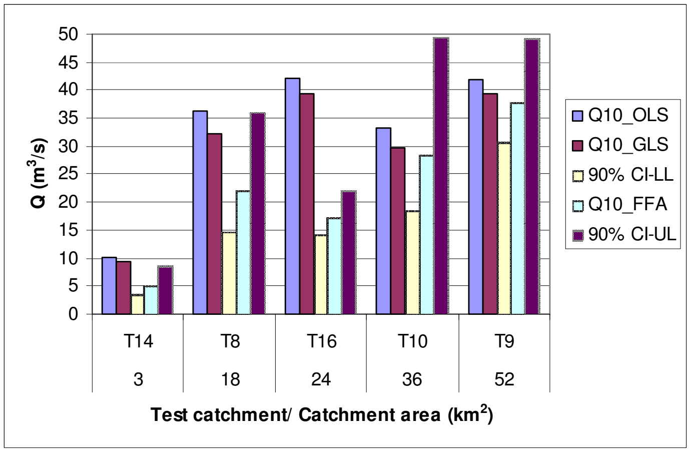
area in all equations

sden in all equations

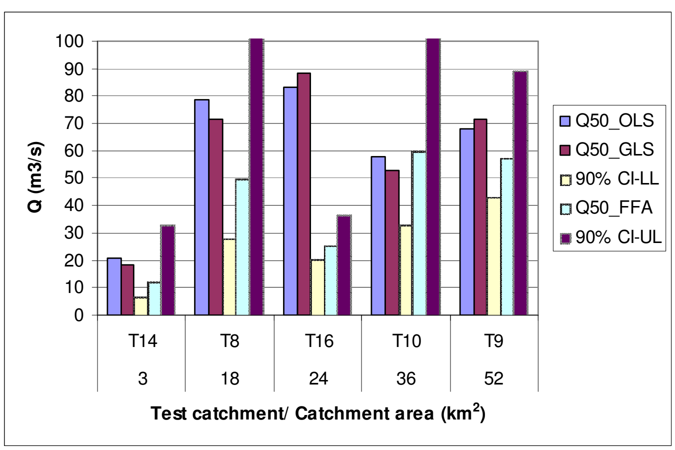
I2_12 for T = 5, 10, 20, 50 and 100 years

rain for T = 2, 10, 20, 50 and 100 years.

TESTING Q_{10} PREDICTION



TESTING Q_{50} PREDICTION



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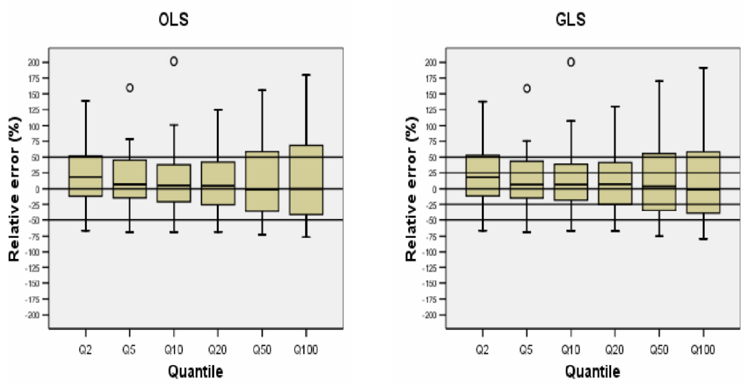

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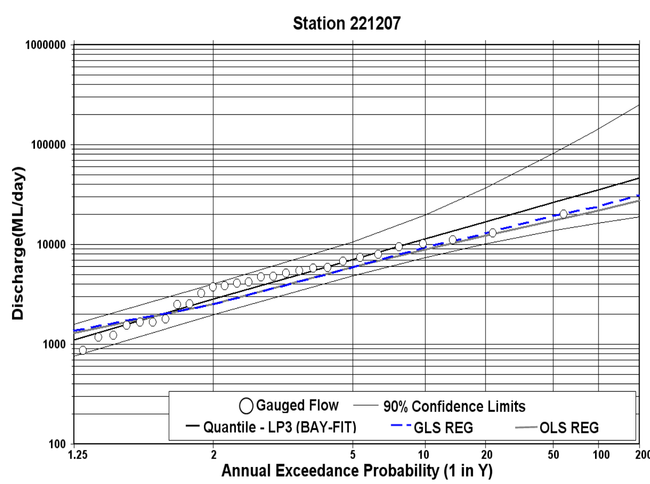
FLOOD FREQUENCY PLOT



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SUMMARY – PILOT STUDY

- The updated PRM can provide design flood estimates with reasonable accuracy.
- C10 values can be obtained from
  - C10 contour map or
  - developed prediction equation (provides less biased results).

SUMMARY – PILOT STUDY

- Median relative error values for the new PRM ranged from 17% to 44%. For 7% cases relative error values > 100%.
- The PRM tends to underestimate flows compared to flood frequency estimates, with 60% of the cases being underestimated.

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SUMMARY – PILOT STUDY

- Prediction equations have been developed for Victoria using OLS and GLS methods.
- Little differences in prediction equations between OLS and GLS.
- GLS procedure provides better estimation reliability.