

Water New Zealand 31<sup>st</sup> October 2013

## High intensity rainfall estimation in New Zealand

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Statistics of extreme rainfall play a vital role in engineering practice from the perspective of mitigation and protection of infrastructure and human life from flooding

River flood flow analysis are preferred, but analysis of rainfall data is often more convenient due to the finer spatial nature of rainfall recording networks

#### Origins

Rainfall frequency analysis as a design tool has developed over the years in New Zealand

2010

- Seelye1947Robertson1963
- Tomlinson HIRDS V1 1980
- Thompson HIRDS V1 1992
- Pearson and Henderson 1998
- Thompson HIRDS V2 2002
- Thompson HIRDS V3





Tomlinson manually read daily raingauges 1980 940 180 automatic raingauges Conversion of annual maximum: daily manual to 24 hour maximum, 1.14 daily manual to 48 hour maximum, 1.07 daily manual to 72 hour maximum, 1.04 Extreme value type 1 (EV1) - Gumbel distribution Some values fitted extreme value type II (EV2) "outliers' Estimated any duration storm rainfalls for any return period up to 100 year



Tomlinson's, South Island map of 24-hour rainfall (mm) of return period 5 years.

## Thompson

1992

#### Converted Tomlinson's 1980 maps, graphs and tables into a computer based procedure

#### User enters location coordinates to obtain a table-with 10 durations from 10 minutes to 72 hours and up to the 100 year period



First version of the High Intensity Rainfall Design System, "HIRDS

### Pearson and Henderson 1998

- Looked in detail at the Tomlinson (1980) "outliers" removed from the EV1 (Gumbel) frequency analysis.
- 1933 manually read daily raingauges
  - 150 automatic raingauges
- Frequency analysis on 1, 6, and 24 hour durations
- Fitted the Generalised Extreme Value (GEV) distribution to the annual maximum series, using the method of L-moments (Hosking 1990).
- Concluded that for hydrological design that deleting "outliers" and using the EV1 distribution leads to underestimation of design storm rainfalls for many New Zealand regions.
- For these regions annual maxima of 24-hour rainfalls tend toward the Extreme Value Type II (EV2) distribution.





Dimensionless (maxima divided by mean) Gumbel plot of 83 series of eastern Southland annual maximum 24-hour duration storm rainfalls, with fitted EV2 (curve) and EV1 (line) distributions 1693 Thompson manually read daily raingauges
682 automatic raingauges

#### 2002

Conversion of 1, 2 and 3 day annual maximum same as Tomlinson

Used an index rainfall the "median" annual maximum rainfall for each duration

The regional growth curves were derived using a generalised extreme value distribution combined with probability weighted moment estimation.

Mapped regional frequency growth curves that are common to every site within a prescribed region

Mapping of the index rainfall involved fitting a trivariate thin-plate spline to three independent variables longitude, latitude, and site elevation.

Design rainfalls for any site are simply the product of the index rainfall (median) and the regional rainfall growth curve

Version 2 was also a computer based procedure requiring site coordinates.

# Latest versionThompson2010Elements of HIRDS version 3



0 50 100 200 Kilometres ├------

### Thompson

## 2010

2177 manually read daily raingauges1036 automatic raingauges

- Very similar to Thompson 2002, Regional Councils data included
- Closed sites in close vicinity combined
- The introduction of data stratification based upon 3 principal meteorological processes, convective, stratiform and a mixture of both.
- A regional dimensionless growth curve based on the Generalised Extreme Value (GEV), and using goodness of fit test for the GEV (Ailliot et al., 2009), Gumbel (EV1), and Generalised Logistic (GLO) distributions rather than probability weighted moments used in HIRDS version 2.
- Mapping of median annual maximum rainfall and parameters of the regional growth curves, covered New Zealand using thin-plate smoothing ANUSPLIN splines (Hutchinson 1995, 2000), at a 2km x 2km grid, and using L moments statistics, resulted in 10 surfaces each representing the 10 durations from 10 minutes to 72 hours, and were extended to a maximum Average Recurrence Interval (ARI) of 100 years.



Web address

http://hirds.niwa.co.nz/

#### **Cropp wettest raingauge in New Zealand**

12,000 mm per year







#### **Cropp Hut**

#### Duration Rainfall depth (mm)

ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	<b>48h</b>	72h
1.58	0.633	12.6	21.2	28.6	48.0	80.8	184.2	309.9	521.5	692.8	818.1
2.00	0.500	13.6	22.7	30.8	51.6	86.3	195.3	327.0	547.3	727.2	858.6
5.00	0.200	16.9	28.3	38.3	64.2	105.9	233.8	385.3	635.1	843.7	996.3
10.00	0.100	19.5	32.8	44.3	74.3	121.2	263.3	429.6	700.8	931.0	1099.4
20.00	0.050	22.5	37.7	51.0	85.4	138.0	295.1	476.8	770.2	1023.2	1208.2
30.00	0.033	24.3	40.8	55.2	92.6	148.7	315.2	506.2	813.2	1080.4	1275.7
40.00	0.025	25.8	43.2	58.4	98.0	156.7	330.1	528.1	844.9	1122.5	1325.5
50.00	0.020	26.9	45.1	61.1	102.4	163.2	342.1	545.7	870.3	1156.3	1365.3
60.00	0.017	27.9	46.8	63.3	106.1	168.8	352.3	560.4	891.6	1184.5	1398.7
80.00	0.012	29.5	49.5	66.9	112.2	177.8	368.8	584.5	926.1	1230.4	1452.9
100.00	0.010	30.8	51.7	69.9	117.2	185.1	382.2	603.8	953.8	1267.2	1496.3

#### **HIRDS version 3 assessment**

#### **by Regional Councils**

#### Background

 The previous HIRDS version 2 was not fully accepted by many Regional Councils

 Jeff Watson of Horizons wanted version 3 validated by Regional Councils to prove it was "fit for purpose" before it was released.

 HIRDS Version 3 incorporates rainfall intensity data from Regional Councils

## Pilot of HIRDS V3 tested by key Regional Councils

#### Peter Blackwood, Horizons

Craig Goodier, Hawkes Bay Regional Council

Tony Oliver, Environment Canterbury

Toby Kay, Northland Regional Council

Peter West, Environment Bay of Plenty

## Peter Blackwood's comments

- The trends are all good
- I had found that generally HIRDS v2 seemed to underestimate at higher return periods by up to 10-15%. In most cases this software seems to provide an increase to more expected values

 Palmerston North and Pahiatua are exceptions, however there maybe explanations for these

#### Craig Goodier's comments

Waikaremoana

Previously been advised not to use version 2

- He is comfortable with HIRDS ver 1 and used this to compare with ver 3.
- Ver 3 was okay in the longer return periods and longer durations
- Shorter durations with lesser return periods were different to v1, an example was North of Mahia,
- the 1 hour (5 year)
- Ver 3 28.7 mm
- Ver 1 40 mm. Aware it is based on data up to 1977

#### **Tony Oliver's comments**



Overall v3 is a lot better than v2, which generally under estimated by ~ 30%. I Consider achieving agreement within 10 - 15 % for rainfall analysis (including extreme events) is fairly good. Toby Kay's conclusions •It is concluded that HIRDS v3 has reduced the observed difference between rainfall depths calculated from at site frequency analysis of intensity gauges and HIRDS v2.

 HRDS v3 gives rainfall depths 9% greater than v2
 Intensity gauge sites. This is close to the estimated increase in storm rainfall between 2002
 Intensity increase in storm rainfall between 2002
 Intensity increase from frequency analysis – all durations

•HIRDS v3 gives rainfall depths that are 18% greater than HIRDS v2 for daily rainfall sites. This compares with a 9% increase established from at site frequency analysis.

#### Toby Kay's conclusions (cont)

Whilst HIRDS v3 may appear to give conservative estimates in relation to the analysis of daily rain gauge data, depths given by HIRDS v3 correlate well with frequency analysis undertaken for automatic

Gauges. Further Assessment and comparison is recommended for other long term records in Northland, but it seems reasonable at the store to use HIRDS version for all catchments in the Priority Hivers Flood Risk Reduction Project.

## Peter West's comments

- In the Bay of Plenty we've perceived a commonly occurring coastal rain type that causes higher design intensities close to the coast. I can see the desired effect represented on the HIRDS v3 fitted maps.
- General improvement with V3 over V1
- But some gauges not so close, I expect the situation is due to our short record as almost all gauges installed in 1990.



Comparison with Council guidelines for storm water runoff Christchurch city Tony Oliver

**Botanic Gardens** 

- Whilst 1 hour and 48 hour had good agreement
- the 6 12 and 24 hour for 10 to 50 year ARI were 10 to 15 % more for HIRDS v3 than 2009 NIWA study

## Comparison with Council guidelines for storm water runoff

Auckland city

- TP108 (1999) significant heterogenic growth factors
- Revised (2008) now homogeneous
- Further revision (2011) also homogenous
- HIRDS V3 agreed with the TP108 (1999) but not 2008 and 2011 updates
- new updates underestimate the 24 hour 100 year ARI by 30 % when compared to HIRDS V3
- Note a 18 % increase for this duration and ARI occurred in Northland

## Summary - comparison with Council guidelines for storm water runoff

Data length – at site local analysis, used all information

- HIRDS requires a sufficient data length
- comparison over different analysis periods
- last 10 years less stormy, except in Northland, therefore recent raingauges may influence results

- HIRDS joins sites if within 500 m to extend record length

Region of influence – Local analysis may use a different methodology to test for homogeneity for the grouping of rainfall stations in the frequency analysis

#### HIRDS v3 versus HIRDS v2 "differences"

- Approximately 10 additional years of data
- 28% increase in the number of daily manual raingauges
- 52% increase in the number of automatic raingauges
- Region of influence selection is more thorough
- Improved method to determine the shape factor used in frequency distributions

#### HIRDS upgrade

Collaboration with Regional, City and District Councils

• Improve coverage

• Include recent storms

Include historic paper records



Year study completed

## HIRDS upgrade (cont)

- Extend the average recurrence interval to 250 year return period
- Area reduction curves
- Temporal patterns or design storm
- Enable users to download maps from web page
- Provide a comprehensive list of raingauges used
- Interdecadal Pacific Oscillation (IPO) ?

# Combined impact of climate variability (IPO) and change on South Island alpine rainfall



#### International collaboration

- NIWA working with Centre for Ecology and Hydrology, Wallingford, UK, sharing new methods.
- Rainfall intensity also a component of the UNESCO IHP Asia Pacific FRIEND (APFRIEND) project on Flood Design.
- NIWA's 2012 Memorandum of understanding with the Korea Institute of construction Technology (KICT) South Korea.

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