**Report:** **Amended 3 August 2020**

# Pinehaven Stream Flood 8 December 2019 at Chatsworth Road Gauge Site and Its Implications for Flood Frequency Estimates in The Catchment.

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27 July 2020

**Peer Review:**

G.Horrell, 27 July 2020

**Contents:**

A.I. McKerchar [ Journal of Hydrology ( NZ ) 30 ( 2 ), 65 – 76 ].

f. Regional Flood Frequency Analysis for Small NZ Basins ( 1991 ) – Part 2. Flood Frequency Groups C.P. Pearson [ Journal of Hydrology ( NZ ) 30 ( 2 ) 77 – 92 ]

g. Estimation of Mean Annual Floods in N.Z. ( 2012 ) G.A.Griffith & A.I.McKerchar [ Journal of Hydrology ( NZ ) 51 ( 2 ) 111-120

h. A Method of Estimating Design Peak Discharges ( Tech Publication 61 ) Planning & Technical Division, Water & Soil Division Ministry of Works ( NZ ).

i. G.Horrell ( 8 November 2018 Revised July 2020), " Assessment of Pinehaven Stream 23 July 2009 Flood Peak.

k. Towards Prediction of Extreme Floods in New Zealand ( 2019 ) G.A. Griffith, Shailesh K. Singh and A.I.McKerchar [ Journal of Hydrology ( NZ ) 58 ( 2 ) 105 – 116 ]

**Acknowledgements**

G.Horrell, Dr. G.Griffith, A.Ross, S.Pattinson, D. Longstaff

**Preamble:**

In the early hours of the morning 8 December 2019 a heavy rainstorm occurred In the Hutt River catchment resulting in an intense burst of some 53mm of rain falling on the Pinehaven Stream catchment between 3 am and 5 am. The duration of that rainfall matched the estimated time of concentration for the catchment as at the Chatsworth Rd. gauge site. The average annual recurrence interval for this events 53 mm in 2 hours is estimated from HIRDS V4 ( Historic ) at the Pinehaven Reserve to have been in the order of 30 years. As far as can be ascertained, the distribution of rainfall depths and resulting intensities were reasonably evenly distributed throughout the catchment.

This rainfall subsequently produced a significant flood event which resulted in flooding in Pinehaven. Flood profiles were surveyed in the vicinity of the Chatsworth gauge site [ i.e. the Gauge ], at the Dutch Reform Church footbridge weir [ i.e. the Weir ] some 3.6m downstream from the gauge. Information obtained from this survey work has enabled

1. estimates to be made of the peak flow that occurred around 6.30 am on the morning of 8 December 2019, and
2. enabled a revision to be made of the Greater Wellington Regional Council's rating curve for the Gauge, which previously had lacked a reliable high stage event or events., and
3. provided a basis on which to upgrade flood frequency relationships previously compiled ( or reported ) variously by the Greater Wellington Regional Council [ GWRC ] and MWH ( 2008, 2009 ) and Sinclair Knight Mertz [ i.e SKM ] ( 2010 ).

R.J.Hall & Associates Ltd. were engaged by Save Our Hills Upper Hutt Incorporated [ SOH inc ] to review the flood profile survey data that they had obtained from this event and use it to make the

determinations identified in 1., through 3. above. This summary report is provided in response to that request.

**Summary of Findings:**

## 1.0 Flood Estimates - Chatsworth Rd, Gauge Site : 8 December 2020

An estimate of the peak flow over the Weir has been made based on first principles for critical flow conditions using the Euler Energy Equation and the methodology set out in F.M.Henderson ( 1966 ) " Open Channel Flow". Further to that an XL spreadsheet has been set up based on the cross section surveyed at the Gauge, again using the Euler Equation in order to relate the recoded Gauge height to the flow estimate obtained over the weir.

These calculations yield a peak flow in the order of **11.5 to 11.8** cumec for the 8 December 2019 flood event at the site. The maximum stage height for this event has been measured at **1510** mm on the Gauge.

## 2.0 Revised Rating Curve for the Pinehaven Stream at the Chatsworth Road Gauge Site.

A series of 11 gauging's have been undertaken are available for the Chatsworth Road site between 15 August 2008 and 30 August 2009. These gauging's have flows ranging from 876 l/s to 1685 l/s with gauge readings ranging from 408mm to 790mm. These gauging's are for all intents and purposes modest and well short of the likely mean annual flood. The GWRC rating curve provided to S.Pattinson [ SOH ] by GWRC dated 15 August 2008 includes a high stage value of 9104

l/s for a gauge height of 1600mm. It should be noted that this high stage value is simply an extrapolation of the gauging's previously undertaken at relatively modest flows and is not the result of actual measurement.
Accordingly, little confidence can be placed on the reliability of this particular rating curve.

The peak flow estimates made as part of this study have enabled an actual high stage discharge value and associated gauge height to be employed in order to obtain an improved rating curve for the site. It is opined that in the absence of an automatic water level recorder at this site the GWRC can use the methodology employed and described here to obtain further stage / discharge points in the future as flood events occur which will enable the revised rating to be further upgraded as information becomes available.

A significant flood event occurred in this catchment 23 July 2009 which had a gauge height recoding of 1577mm ( GWRC ). A stage reading of 1577 mm using the revised rating curve indicates a peak flow in the order of **12.5 cumec**. In the absence of measured flood depths over the Weir from this event it is not possible to directly check this result but based on the cross sectional geometry of the channel at the Gauge and estimate of the cross sectional area of the flow at the peak enables a uniform flow estimate to be made using the XL spreadsheet referred to in 1.0 above. This exercise yielded a peak flow of **13.0** cumec which given the uncertainties present is never-the-less reasonably consistent with the value derived from the revised rating curve. On that basis it is opined that the 23 July 2009 event would have peaked at between **12.5 and 13.0** cumec. A review of the Tasman Vaccine rain gauge record for this event in conjunction with that sites rainfall depth – duration – frequency estimates from NIWA HIRDS V4 ( historic ) data indicates that the rainfall recurrence interval for this event was in the order of 50 to 80 years depending on whether the critical duration of the 66.5mm of rainfall was 3 hours or 2 hours respectively.

## 3.0 Revised Flood Frequency Curve for the Chatsworth Road Gauge Site.

In order to assist in the design process and provided guidance on the likely frequency of occurrence of flood events it is customary to compile “at a site” flood frequency curves [ FFC ]. The most reliable FFC are those developed from hydrometric stations with long flow records. In the absence of such records reliance has to be placed on empirical methods of which are many and varied. A critical requirement in either case is to ensure that the results obtained reflect reality. There are two broad tests that can be applied to assist this process

( a ) Checking that the annual probability [ AEP ] of exceedance obtained for the flood peaks have reasonable parity with the annual exceedance of the rainfall event that gives rise to them recognising that they will not necessarily be the same, and

( b ) Checking to see that the frequency with which out of channel flood spread predicted to occur from the FFC derived is consistent with what a knowledge of the capacity of channel being considered actually is and the typical frequency with which such flooding is known to have occurred historically.

[ D.H.Pilgrim, I.Cordery; pers comm. *Graduate Course in Surface Hydrology University of NSW, Kensington, Australia ( 1979 )* ].

In the absence of such checks the reliability of the derived FFC can be very easily compromised leading unwittingly to either over design or under design with no ability to differentiate between either of such outcomes.

Given that the Pinehaven catchment at Chatsworth Road ( or elsewhere for that matter ) has an operational hydrometric station it is necessary to revert to empirical methods in order to obtain a workable FFC. To this end R.J.Hall & Associated Ltd. have used six different methods in order to develop a suitable FFC for the catchment at the Chatsworth Rd. Gauge site. These methods are

[ A ] Pinehaven FFC developed from the NIWA ( 2018 ) FFC for the Mangaroa River at Te Marua, using Rational Method runoff coefficient ratios obtained from both catchments and an area ratio raised to the power of 0.8, and

[ B ] Pinehaven FFC developed using " m " and " Qr " values derived from the Mangaroa River at Te Marua that were then modified using the Rational Method runoff coefficient and area ratio relationship [ Qm = 2.78E-3 x Cm x Ir x A ], utilised in [ A ] above, and

[ C ] Pinehaven FFC using the MWH ( 2009 ) flood frequency estimates that were based on the McKerchar and Pearson ( 1989 ) procedure modified using the Rational Method runoff coefficient and area ratio relationship utilised in [ A ] above, and

[ D ] Pinehaven FFC using the McKerchar and Pearson ( 1989 ) procedure but using a mean annual flood value of 6.2 cumecs derived from both methods [ A ] and [ B ] above rather than that calculated from the mapped ( Qma / A^0.8 ) and a q100 value set at 2.4, and

[ E ] Pinehaven FFC derived from Water & Soil Division MOWD Technical Memo 61 ( 1980 ), and

[ F ] Pinehaven FFC developed from the Rational Method using a runoff coefficient derived from an analysis of the 8 December 2019 flood event.

The results of these FFC are plotted in a log – normal form with the average annual recurrence interval T ( years ) plotted along the " X ' axis and with the corresponding flood peak, $Q_T$( cumecs ) plotted along the vertical, " Y " axis. Refer Fig. 1. Shown also on this graph are the GWRC / MWH FFC developed from the Hystra rainfall – runoff model and their Rational Method obtained from the *GWRC Pinehaven Stream Flood Hydrology report 2009, Appendix B, Revision of Rainfall – Runoff Model and Design Flood Estimates ( 5 November 2009 ).*

Fig.2. Is a replication of Fig.1. but with the estimated peak discharges for the 23 July 2009 ( 12.5 – 13.0 cumec ) and 8 December 2019 ( 11.7 cumec ) added. In addition, the estimated recurrence intervals for each storm's critical duration and depth are plotted in order to provide for the Pilgrim/ Cordery check described above. In applying this test Method [ C ] above could not satisfy these criteria for the 8 December 2019 flood peak of 11.7 cumec and accordingly that particular FFC has been rejected.

**Errata:** Fig 2. Shows the rainfall for the critical duration of the 2009 event as 66mm; this is incorrect, the 66mm is in fact the rainfall total for the storm recorded at the Tasman Vaccine automatic rain gauge just outside the head of the Pinehaven catchment. No record is available for the rainfall that fell on that occasion within the Pinehaven Catchment. Back calculations from a storm hydrograph for that event using the revised ( 2020 ) rating curve for the Chatsworth Rd. staff gauge in conjunction with the stage record for that gauge derived from the SKM ( 2010 ) report and the Horrell Report ( 2018, 2020 ) once allowance is made for baseflow indicates that the rainfall excess on that occasion was in the order of 22 to 23 mm.

[ Note: I consider initial abstraction to be that part of the rainfall that reaches the ground and fills any depressions present, saturates what ever litter is present and brings the voids present in the soil to the point where overland flow commences. ]

Furthermore, once allowance is made for forest and scrub canopy interception on the undeveloped part of the 4.4 sq.km. catchment I estimate to be in the order of 20 to 25 % of incident rainfall, and other losses which include initial abstraction and continuing losses, I provisionally estimate that the event rainfall depth to have been in the order of 56 to 59mm. I note that the preceding June was a very wet month and so too the weeks leading up to the storm on the 23 July. This antecedent rainfall would have had an influence on both canopy interception and the available initial abstraction and accordingly would have affected the rainfall excess for that event which has been estimated from the revised hydrograph.

Since I am back calculating to obtain an estimate of the event rainfall from a stage record, the antecedent rainfall condition at the time of the storm onset would result in the rainfall estimate drifting towards the upper bound depth of 59mm if not exceeding it.

It is noted that stage heights are available for both the 23 July 2009 and 8 December 2019 flood events, both of which caused inundation in Pinehaven per se. As already noted the 2009 event is estimated to have peaked between 12.5 and 13.0 cumec whilst the 8 December 2019 event peaked at about 11.7 cumec. Fig 29 of the SKM report ( 2010 ) shows where flood waters reached on the steps of a house in Birch Grove during the 23 July 2009 event. I understand that a similar situation arose at that site on 8 December 2019 albeit the water level was a little lower, ? 20mm or so lower ( S.Pattinson, SOH, pers comm ).

On that basis of the above I conclude provisionally that the critical rainfall for the 23 July 2009 in the catchment to have had a return period in the order of 35 to 40 years.

**Comment: It is readily apparent from the Pilgrim/ Cordery check that neither criteria can be satisfied by the GWRC / MWH flood frequency curves, there are significant discrepancies between the recurrence intervals for the rainfalls compared to the peak outflows on the one hand and that frequency with which these flood events might be expected are ridiculously high e.g. on average once or twice a year which clearly doesn't happen.**

**In contrast, the FFC developed as part of this study clearly do satisfy both criteria.**

**Footnote**: Rainfall – Depth – Duration – Frequency estimates used in the above methods have been obtained from NIWA HIRDS V4 – Historical on line data for the Pinehaven Stream at the Pinehaven Reserve and the Tasman Vaccine site. No adjustment has been made for climate change.

**Conclusions**

1. The flood event that occurred in Pinehaven on the 8 December 2019 peaked at the Chatsworth Road Gauge site around 6.30 am. At a flow of 11.7 cumec and a gauge height of 1510mm.

2. It is estimated from the FFC developed in this study that this event had an average annual recurrence interval between 20 and 30 years and notionally adopted at 25 years ( AEP 4% ).

3. The actual extent of the flooding that occurred in Pinehaven on that occasion is considered to reliably represent what might be expected in an event with an average annual recurrence interval of 25 years ( AEP 4% )

4. The peak flow associated with the 23 July 2009 flood event is provisionally set at 12.7 to 13.0 cumec with an average annual recurrence interval of 35 years to 40 years ( 2.5% < AEP < 2.8% )

5. In the light of this investigation the FFC's developed and reported variously by GWRC / MWH ( 2008 to present ) and SKM ( 2010 ), relied upon by Becca in their audit ( 2015 ) and Jacobs ( 2016 ) reworking of the flood model in their 2016 review should be considered obsolete and do not form a reliable basis for flood modelling and mapping activities nor for the current stream upgrades being proposed for the lower reaches of the Pinehaven catchment through Pinehaven per se.

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## Appendix

Fig 1. GWRC flood frequency curves ( 2009 ) and R.J.Hall & Associates Ltd. Flood frequency Curves ( 2020 ).

Fig 2. Fig 1. Modified to include details of the 23 July 2009 and 8 December 2019 flood estimates at the Chatsworth Rd. Gauge site ( peak flow and associated recurrence interval, gauge reading and the associated recurrence intervals for the rainfalls for each of these two events)

Fig 3. Updated Rating Curve for the Chatsworth Rd. Gauge incorporating the 8 December 2019 flow of 11.7 cumec.