Before Independent Hearings Commissioners

At Wellington

Under	The Resource Management Act 1991
In the matter of	Applications for resource consents, and a Notice of Requirement for a Designation by Wellington Water Limited on behalf of Upper Hutt City Council, for the construction, operation and maintenance of the structural flood mitigation works identified as the Pinehaven Stream Improvements Project

Statement of Evidence of Alexander Keith Ross

Dated 27 July 2020

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Statement of Evidence of Alex Ross

1.0 Qualifications and Experience

1.1 My full name is Alexander Keith Ross.

1.2 At the time the applications for this project were prepared I was a resident on Pinehaven Road. I have lived there for 8 years.

1.3 I am a retired Civil Engineer with in excess of 40 years experience in Civil Engineering Works associated with Local Government.

I trained at Silsoe College in the United Kingdom (now part of Cranfield University) in Agricultural Engineering. I have a New Zealand Certificate in Civil Engineering issued in 1972, and was a Registered Engineering Associate from 1977. I was a member of the Institute of County Engineers, later Association of Local Government Engineers.

My relevant employment experience is detailed below.

I worked for the Hawke's Bay Catchment Board on flood protection and drainage Schemes for the Te Aute Swamp for the Waipa Rivers Board, and the flood protection and drainage scheme for Omaranui Swamp. I was also involved in taking hydrological measurements for the Board.

1.4 I was employed by Hauraki Plains County Council as Assistant County Engineer, where I was in charge of the design and construction of drainage schemes for three Land Drainage Boards.

1.5 I was employed by Egmont County Council as County Engineer for 13 years in charge of design and construction of all works including roads; stormwater; water supply both urban and rural; bridges and culverts.

1.6 After the 1989 Council restructuring I was employed by South Taranaki District Council as Technical Services Manager in charge of all design and contract works including stormwater and roading.

1.7 I joined Apex Consultants in 1999 as Quality Manager for the company and obtained AS/NZS ISO 9001:1994 certification for the company, which was later upgraded to ISO 9001:2000. During this time I wrote several activity management plans including the Stormwater Activity Management Plan for South Taranaki District Council.

1.8 I worked for six months on secondment to Rangitikei District Council as Asset Manager and reviewed their roading, water and wastewater asset management plans.

1.9 I also reviewed the Waitomo District Council asset management plans for water, wastewater, stormwater, and roading.

1.10 I retired in 2010.

1.11 My evidence relates to a Notice of Requirement ('**NOR**') for Designation and associated resource consent applications for the construction, operation and maintenance of the structural flood mitigation works identified as the Pinehaven Stream Improvements Project ('**the Project**'). Wellington Water Limited ('**WWL**') has lodged the resource consent applications and NOR on behalf of Upper Hutt City Council ('**UHCC**').

1.12 I am familiar with the area that the Project covers, and have been involved with the Project since it was notified to the public, and prior to that notification with Plan Change 42 by UHCC.

1.13 The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence to follow. The reasons for the opinions expressed are also set out in my evidence to follow.

2.0 Scope of evidence

2.1 My evidence addresses the following matters:

a History

b Infiltration

c Model Calibration

d Upper Reaches of Pinehaven Stream

e Hydrology Model

f Quality Assurance

g Economic Considerations

j Evidence from other witnesses.

3.0 History

3.1 On review of GWRC flood maps which showed my property underwater in a 0.1% AEP. My experience suggested the maps did not appear to be correct. I investigated further and found that not only was 300mm of freeboard shown as floodwater added to the flood maps also a 100mm depth of water was shown as flooding.

3.2 In my experience freeboard shown as floodwater and minimal flood water levels are not usually shown on flood maps. More investigation showed that the anticipated flood peak flow would have been handled by the existing stream channel and secondary flow in the road gutter. This showed, in my opinion that there was obviously something wrong in the GWRC calculations of peak flood flow.

3.3 For UHCC PC42 I submitted that UHCC should remove the 300mm freeboard shown as flood water from the flood maps [compare 2007 Mangaroa River flood map]. I was relying on reason and common sense to prevail, unfortunately that did not happen and the flood maps were adopted despite numerous objections from residents. In hindsight mixing the Mangaroa and Pinehaven plan changes into one plan change "muddied the waters" so much that many of the arguments from my perspective appeared unclear to the Commissioner. This may have been deliberate strategy by UHCC in order to get the plan change adopted expediently.

3.4 The Pinehaven Stream works application is where WWL are acting as project managers for UHCC and GWRC seeking permission from UHCC and GWRC to carry out works designed by the consultants who also produced the flawed flood maps in the first place. The reports in relation to the Pinehaven Stream work were reviewed by the same reviewer [Michael Law, Beca] who ~~that~~ glossed over the fact that changing the infiltration from a green-field site to a proposed construction of 1600 houses made no difference to flood volumes.

3.5 The problem with the flood maps is the excess run off that the consultants have allocated to the forested and bush clad hills surrounding Pinehaven. These forested and bush clad hills make up about 80% of the catchment area. If the infiltration factor used in the GWRC calculations for their prediction of runoff is too low considerably more runoff will be predicted. *The model used 5 mm initial followed by 2 mm per hour for infiltration.*

3.6 I carried out infiltration tests in the forest and bush areas at the top of Pinehaven road in July 2019. Most (87%) tests gave results greater than 500mm per hour, which is detailed in the report I compiled ""Report on Infiltration Tests carried out on the Pinehaven Stream Catchment During July 2019" [attached at Appendix A]

4.0 Model Calibration

4.1 GWRC stated in their evidence (MWH Report) that they had calibrated their model to a surveyed debris line flood of between one to two year recurrence interval on 31 July 2008. This was updated later after a flood on 23 July 2009. *A very small flood* which has been scaled up to a 1 in 100 year flood *(a very Large Flood)* in order to produce the flood maps.

Is ‘very small flood’ referring to 31 July 2008? According to Bob Hall, the 23 July 2009 flood was about 35-40 year ARI (Graeme Horrell says 28-year ARI).

The MWH Report states
6.2.1 23 July 2009 Event
Recorded flow data for this flood event have been supplied by GWRC. The peak flow is extimated (sic) to be 8.8 m3/s. It must be noted that due to the short period of record and lack of certainty about the conversion of high measured water levels to flow (rating curve), the 8.8 m3/s estimate may be revised in the future when new information is available.

4.2 This model is 12 years out of date. To compound this error there have been several larger floods in the catchment and GWRC have not collected any flood data from them. GWRC have even removed a depth gauge from the catchment in 2013 thus loosing years of useful record.

4.3 Applicants response to Section 92 request which shows reluctance to use the 8 December 2019 event to assist with calibrating / validating the model. The response is produced below from P35 Notified Officers Report GWRC.

- The applicant responded that the 8 December 2019 event was a 1-in-30-year event for the two hour duration. Mr Law agreed with this.
- The applicant advised that there were no model outputs for a directly comparable flood, so they compared the flooding observations to the modelled 1-in-10-year and 1-in-100-year events as presented in the PSFMP.

Mr Law commented the focus of the assessment was on flood extents with no mention of flood levels along the stream. He considered that if post flood surveys of trash marks, flood photographs and anecdotal reports were conducted by the council's (do you mean UHCC?) or WWL then they should have been compared to the modelled water levels. The applicant has advised that no post-flood surveys or trash markings were undertaken by WWL. Mr Law noted he was disappointed that there was no post-flood survey undertaken against which to calibrate the model.

Mr Law commented that the annotated maps (which maps are these?) appear to be overlain on the PSFMP maps, which hampers direct comparison (due to climate change allowances). He requested Jacobs run the Pinehaven model to provide a comparison with the December 2019 event. He noted this could be done with the December 2019 event hydrology, or (as that would be highly resource intensive) he later suggested it would be possible to use the 1-in-10-year with climate change design rainfall scenario which would be comparable to the December 2019 event. The applicant provided this to GWRC in the updated Flood Hazard Assessment on 15 June 2020, and it is discussed further in subsections (h) and (i) below.

(h) The applicant noted that the Pinehaven Stream flood model's hydrological method used the Initial Loss – Continuous Loss model to represent the infiltration capacity of the catchment, and the catchment had not been treated as 'bare'. This hydrological method used does not use a CN value, and there were some concerns raised by the way the back-calculation in Mr Hall's report (which formed part of submission 11) had been undertaken.

Mr Law generally agreed with the applicant's comments. In relation to the validation of the model he considers the 8 December 2019 event provides an opportunity for additional detailed validation.

(i) The applicant did not consider that the hydrological input into the model needed to be re-done and model re-run and commented that '*the hydrological input to the model is from a calibrated and validated model of the rainfall-runoff processes in the catchment. While no model is perfect… MWH have demonstrated that the inputs to the hydraulic model are robust and suitable for the purposes of the Pinehaven Stream.*

4.4 The errors can be seen using the GWRC 10 year flood map and comparing it with a 25 year actual flood occurrence that happened on 8 December 2019. The flood extents should be a lot less in a 10 year storm than a 25 year storm even with an allowance for climate change. This is obviously not the case on the flood maps and the applicants are "mudding the waters" using climate change and water depths as low as 2mm as a strategy to obfuscate the issue.

4.5 The flood maps show that the runoff is greatly exaggerated and this is why GWRC stated that the Pinehaven Stream channel has less than a 1 in 5 year flood capacity instead of the 1 in 25 year storm capacity that much of the stream channel coped with on 8 December 2019.

4.6 As a result the WWL proposes to widen the stream channel, not just widen but triple the size. This is because the runoff modelled bears no resemblance to what actually occurs as evidenced by the flood of 8 December 2019.

4.7 If the stream works as proposed are constructed they will in reality be able to cope with much larger floods, certainly greater than a 1 in 50 year flood and probably as much as a 1 in 100 year flood.

4.8 However these benefits from the works will be masked by the flawed flood maps which will still show properties in the flood zone when the $40,000,000 to be spent by the Councils could show much larger benefits. Conversely, the cost of the work could be reduced if the stream works were sized for an actual 25 year flood plus climate change.

5.0 Upper Reaches of Pinehaven Stream

5.1 In the application it was stated that the Pinehaven Stream Flood Management Plan includes proposed structural works within the lower reaches of the Stream as well as in the upper catchment.

5.2 However, the residents now find out that no works are proposed in the upper catchment where there are several problems that need addressing. This despite the cost ballooning out from $10M to now over $40M when interest on loans is factored in. (See photograph attached).

5.3 I understand that GWRC is only responsible for the stream up to the Pinehaven Reserve. I assume this is why there is no work occurring to fix the problems in the upper catchment, as this part is controlled by UHCC. Yet UHCC ratepayers bear the majority of the cost.

5.4 After submissions closed on 18 December 2019 the Applicants changed the design, designated areas and the modelled depth of flooding. It appears reasonable that this design work should have been carried out prior to any notification, so that residents and submitters know exactly what is proposed. Since 20 July 2020 submitters have had just one week to re-evaluate all the changes. This short timeframe is unreasonable given the limited resources of the submitters compared to the Applicants.

6.0 Infiltration and Runoff

6.1 When rainfall falls on the land the resulting stormwater runoff depends on catchment characteristics, on land usage, on the degree of urbanisation etc. These factors also influence the amount of infiltration. Soils have varying capacities to infiltrate water. Influencing factors are soil type, degree of saturation and nature of ground cover. Activities that change the soil surface or alter its properties [e.g. compaction of soil during subdivision development] also have an effect.

6.2 The infiltration tests I undertook in July 2019 were to establish a reasonable estimate for the infiltration rate on the various land and soil types in the Pinehaven Catchment [refer Appendix A].

6.2.1 The infiltration test results show that existing pine forest and regenerating bush (which make up about 80% of the Pinehaven catchment) have exceptionally high infiltration rates. Double-Ring Infiltrometer (DRI) tests on pine forest and regenerating bush areas at Elmslie Road, Pinehaven gave infiltration rates between 512 – 900 mm/hr, and single ring infiltrometer tests in the pine forest and regenerating bush areas of Sub-catchment B on Guildford land gave an average infiltration rate of 603mm/hr consistent with the results of the DRI tests at Elmslie Road.

6.2.2 On grassed Pinehaven Reserve areas and residential lawns in the developed urban portion of Pinehaven catchment, DRI test results all gave infiltration rates of just 1 – 2 mm/hr. Along with impermeable areas of roofs, roads, footpaths and driveways, the urban areas will provide the majority of the stormwater runoff in the Pinehaven catchment due to their negligible infiltration capacity.

6.3 The infiltration test results show that the forest and bush areas in the Pinehaven catchment have much higher infiltration rates than assumed in the flood model calculations by GWRC of just 5mm initial abstraction and 2 mm/hr ongoing infiltration losses. Consequently, GWRC's peak flood calculations, volumes, and extent of flooding shown on the GWRC flood maps for the Pinehaven catchment are grossly exaggerated because their calculations grossly under-estimate infiltration losses and grossly over-estimate runoff.

6.4 Extract from M Laws Technical Review

50 SOH (with Mr Ross) have undertaken their own studies[4] of infiltration and hydrological inputs for the upper valley, Elmslie Road and Pinehaven Reserve. These concluded that the average infiltration rate was in the order of 600 mm/h. This exceeds the historical 1% AEP (100-year ARI) 10-minute rainfall intensity of 114 mm/h for Pinehaven extracted from NIWA's HIRDS5 (High Intensity Rainfall Design System) Version 4, and would result in no surface runoff if applied directly to the calculation of flood flows.

6.5 This statement is not correct. As the rainfall would also fall on the urban portions of the catchment, lawns and grassed areas driveways and roads and .would certainly produce run off which would produce flow.

[4] Pinehaven - submission (11_3) Save Our Hills - Report on Infiltration Tests_Alex Ross (18-12-2019)

7.0 The Hydrological model

7.1 The inputs to this model are critical to the design of the Pinehaven Stream works. Unfortunately, the modelling for the flood maps is reliant on poor calibration.

The Opus Report Greater Wellington Region Climate Change Impacts Scoping Study to GWRC states:

2 Review of Existing Modelling

2.1 Hydrology

2.1.1 Assessment of hydrology quality used

The quality of the hydrological inputs to any computational hydraulic model are critical to the reliability and accuracy of the results. It is therefore essential to assess the accuracy and reliability of the hydrological inputs to the model.

Although it is estimates of design flows or design hydrographs which are used in hydraulic models, these are invariably derived from measurements of the water level in the river. These water level measurements are then converted to flow information using a rating curve.

Consequently, the reliability of any hydrological inputs to a flood model is a function of:

- *The length of the flow record and therefore the robustness of any analysis of the frequency and magnitude of flood events. This then affects the reliability of any design flood estimates;*
- *The accuracy with which water levels are recorded; and*
- *The accuracy of the rating which is used to convert the water level information to flows.*

2.1.3 Accuracy of rating curves

With most flow records therefore it is actually the water level in the river which is measured quasi-continuously not the actual flow. The current 'standard' is to measure water level every 15-minutes, although this temporal resolution is often considerably longer during early records because of limitations in the technology available. These water level readings are then converted to estimates of flow using a rating curve i.e. essentially a calibration which relates the water level to the volume of flow. The rating curve is developed by undertaking a series of measurements of the actual flow in the river and recording the particular water level at the time. A relationship is then derived (i.e. the rating curve) which allows all thewater level measurements to be converted to estimates of flow.

The accuracy of flow estimates in any river is therefore a function of both the accuracy of the water level measurements (currently accepted to be ±1mm under normal conditions) and the accuracy of the rating curve.

The accuracy of a rating curve depends on a range of variables including the stability of the channel, the number of actual flow gaugings used to define the curve, and the range of the flows gauged. While flows measured using industry best practice are usually regarded as being ±8%, the uncertainty increases during higher flows (i.e. floods). This is because of the rapidly changing water level, and difficulties in measuring accurately both depth and velocity. Consequently, during flood events the uncertainty of flow estimation can increase to ±30%.

The robustness of estimates of the magnitude of various design storm events is directly related to the length and reliability of the hydrometric record. Consequently, as the critical hydrometric records get longer the estimates of the design storms is likely to alter and they should become more robust.

Therefore, at least once every 10 years the magnitude of the design events used in the various hydraulic models should be reviewed against the latest hydrological data.

7.2 "Even where there is good calibration data, it is still good practice to undertake a 'common sense' check of flood extent areas against observations from known events" was also stated in the Opus report.

8.0 Hard Data on the Pinehaven Stream

8.1 The initial MWH Hydrology report stated that there was less than one year of recorded flood flow data for the Pinehaven Catchment, and that GWRC installed a flow recorder on the Pinehaven Stream at Chatsworth road in August 2008 (it was removed in 2013). In this short period of time there has been only one flood event worthy of use for calibration purposes. This event was 23 July 2009. During this event the rain gauge within the Pinehaven catchment malfunctioned providing no records for the storm. The absence of data is noted in the following extract from *M Laws Report for PC42:*

Unfortunately, stream flows and water levels were not recorded in the catchment prior to MWH's hydrological modelling in 2008, which meant that the derived flow hydrographs in their report were derived from general hydrological methods rather by calibration against observed events. Temporary flow and water level measurement was installed for a period during 2008 and 2009, during which a small flood event was recorded on 23 July 2009. This event was used to calibrate the hydrological modelling in the 2009 update to the report, but it is noted that the July 2009 event had an ARI of about 10 years; significantly lower than the 1976 event.

GWRC reviewed MWH's hydrology and did not find any major issues, although they acknowledged the absence of data against which to calibrate the modelling.

MWH's derived flow hydrographs were used in the coupled 1D/2D hydraulic modelling of the Pinehaven catchment by SKM (now Jacobs) in 2009.

The modelled flows were calibrated against the relatively small flood events of 31 July 2008 (Mean Annual Flood) and 23 July 2009 (10-year ARI).Ideally, the model should be calibrated against a larger flood event. In the absence of recorded water level and flow data for the catchment, calibration against the hydrological response of a monitored catchment with similar hydrological characteristics would increase confidence in the modelled flow hydrographs.

The calculated peak flows have been cross-referenced against regional methods for estimating peak flows, and similar results found. It is six years since the hydrological modelling was carried out, and consideration should be given to reviewing the hydrology as a longer period of rainfall data becomes available, as predictions for the effects of climate change evolve, and as the understanding of the hydrological response of the Pinehaven Stream (and similar catchments) improve.

It is six years since the hydrological modelling was undertaken. Flood maps are periodically updated in line with council long term plans, or in response to *significant new data becoming available. At such time, the hydrology should be updated to account for longer rainfall records and more storm events. More robust hydrology could be provided by calibration against recorded flow data, especially for a large flood event. In the absence of recorded data, calibration against the hydrological response of a similar catchment should be considered when the hydrology is reviewed.*

8.2 The following extract shows that the modeller is not confident of the results due to the poor calibration of the model. The hydrological inputs to the model have not changed since the original model was built.

Extract from MWH Report by M. Harkness

6.4 Rainfall-Runoff Model Limitations

The major limitation of the rainfall-runoff modelling process for the Pinehaven Stream is the lack of calibration data. Although a single calibration point was available, it was a relatively minor flood event. The use of the model to simulate extreme flood events will therefore carry relatively high uncertainties. This uncertainty is reduced by comparing modelled output with peak estimates from other methods as summarised in Section 7.

A number of recorded flood hydrographs is preferred for calibration purposes to ensure estimates of peak flows and hydrograph shape are as accurate as possible.

It is recommended that GWRC make use of data from its recently installed flow recorder on the Pinehaven Stream and check/re-calibrate the rainfall-runoff model after a number of years or flood events have been recorded.

8.3 The flow data was provided by GWRC to MWH (M. Harkness) and the estimated peak flow was 8.8 m^3/s. (*MWH 2009 Revised hydrology appendix B section 6.2.1 23 July 2009 event*). However this estimate is unreliable due to the fact that there is only a short period of record; the lack of certainty in converting high measured water levels to flow (the rating curve). SKM in their report *Pinehaven Flood Hazard Investigation 2010* state in order to provide a reliable rating curve a minimum of three or four high flood events are required.

8.4 Fortunately the storm of 8 December 2019 provided an opportunity to use the flood data for calibration. However, GWRC has ignored this opportunity and it has been left for submitters at their cost to do the Councils work for it.

8.5 The major limitation of the rainfall runoff modelling process for the Pinehaven Stream is the lack of calibration data (neither GWRC or WWL have instigated stream flow data collection in the years since the original model was constructed). Although one calibration event has been used by the modellers there are uncertainties around the accuracy of the recorded data as the high flow rating is unconfirmed (the modellers used 1.2m and the actual recorded water depth in the stream was 1.6m - *see SKM Pinehaven Flood Hazard Investigation Report 2010)*

8.6 P.Kinley in his evidence (at paragraph 6.1 (c)) states:

The model had been calibrated to an observed flood event. This means the model parameters had been adjusted to achieve a good fit of the model outputs to an observed flood event, and shows that the model accurately represents the physical processes within the catchment.

However, as can be seen from the extracts quoted above the calibration relied on is at best questionable and at worst misleading.

8.7 P.Kinley in his evidence (at paragraph 6.1 (d)) also states:

The model had been validated against independent methods for estimating peak flood flows. Validating is the process of comparing model outputs to independent data sets and checking how similar the results are. The validation showed the calibrated model produces peak flowrates that are similar to outputs from the independent methods.

8.8 It has been stated that the model was validated against McKercher & Pearson Regional method. This method has accuracy of + or - 28% i.e. it is a very coarse tool. (See McKercher & Pearson 1991) Similarly, it was validated against the Rational method which is very subjective to the 'C' value (infiltration) used. The model also has dubious Mannings 'n' value of 0.2 incorporated for flows in the upper catchment.

I consider that the validations were a self-fulfilling prophesy as their inputs were chosen to give the expected results.

8.9 The attached graph ex R Hall shows how the peak flows have been exaggerated in the model as even the GWRC 8.8 m3/sec peak flow does not fit their own rating curve but does fit the rating curve calculated by the submitters.

9.0 Economic Considerations

9.1 Initially the cost of the project was around $10M split equally between UHCC and GWRC, however that has now ballooned out to over $40M when interest payments on loans raised are taken into account. The majority of the repayments ($35M) are to be paid by Upper Hutt residents. However, the present UHCC does not appear to be worried about the increased cost.

9.2 In my view it would be prudent to get the base hydrology corrected before spending this amount of money when the country is heading towards a recession and justification for the design (4%AEP) will be required, when the works are well over designed due to the flawed hydrology.

10.0 Conclusions

10.1 Every consultant hired by GWRC to work on the Pinehaven Stream has requested in their reports that flood flow data be collected and that the models be updated with the collected data, but this has never happened in the 12 years since the model was produced.

10.2 The result is that the Hydraulic model will have incorporated large uncertainties which is why the model outputs look nothing like the real world when actual floods are compared to the model. This is also why the over designed stream channel is being massively widened with new bridges.

10.3 My conclusion from these reports is that the hydrological input to the Hydraulic model is so unreliable that it should not have proceeded without further data collection in order to produce a reliable rating curve. Also, the model results should have been compared to real world events as a check on the models veracity once the updated rating had been produced.

10.4 Far from being fit for purpose the model is so unreliable that it should be discarded until further data is collected and the flood maps corrected.

10.5 Both WWL and GWRC state that the model is fit for purpose when clearly the errors and uncertainties incorporated within the hydrology and calibration / validation are of such low quality that it is not fit for use to predict flood levels from a storm event.

10.6 The Applications be granted subject to the Hydrology being corrected and input into the hydraulic model to produce a corrected 0.1% ARI and 0.25% ARI flood maps of the total catchment (including the reaches above the Reserve). The Hydrology inputs to be agreed with the Submitters prior to the modelling which should be then validated by SOH data collected from the 8 December 2019 storm..

Appendix A

Report on Infiltration Tests carried out on the Pinehaven Stream Catchment During July 2019

When rainfall falls on the land the resulting runoff depends on catchment characteristics, on land usage, on the degree of urbanisation etc. These factors also influence the amount of infiltration and ground water yield.

Rain storms vary in duration, and the shorter the storm the greater the intensity of the rainfall. This simple observation is very important.

Infiltration is a significant component of hydrologic processes. Soils have varying capacities to infiltrate water. Influencing factors are soil type , degree of saturation and nature of ground cover. Activities that change the soil surface or alter its properties also have an effect.

When the rainfall intensity is less than the infiltration capacity, all of the water reaching the ground can infiltrate into the ground, such that there is no surface run off. But if the rainfall intensity exceeds the infiltration capacity, infiltration will only occur at the infiltration capacity rate, and water in excess of that capacity will be stored in depressions, become surface run off or evaporate. In general, the initial infiltration capacity of a dry soil is high. As rainfall continues, and as the soil becomes saturated , it diminishes to a relatively constant rate.

The tests undertaken were to establish a reasonable estimate for the infiltration rate on the various land and soil types in the Pinehaven Catchment.

TESTS

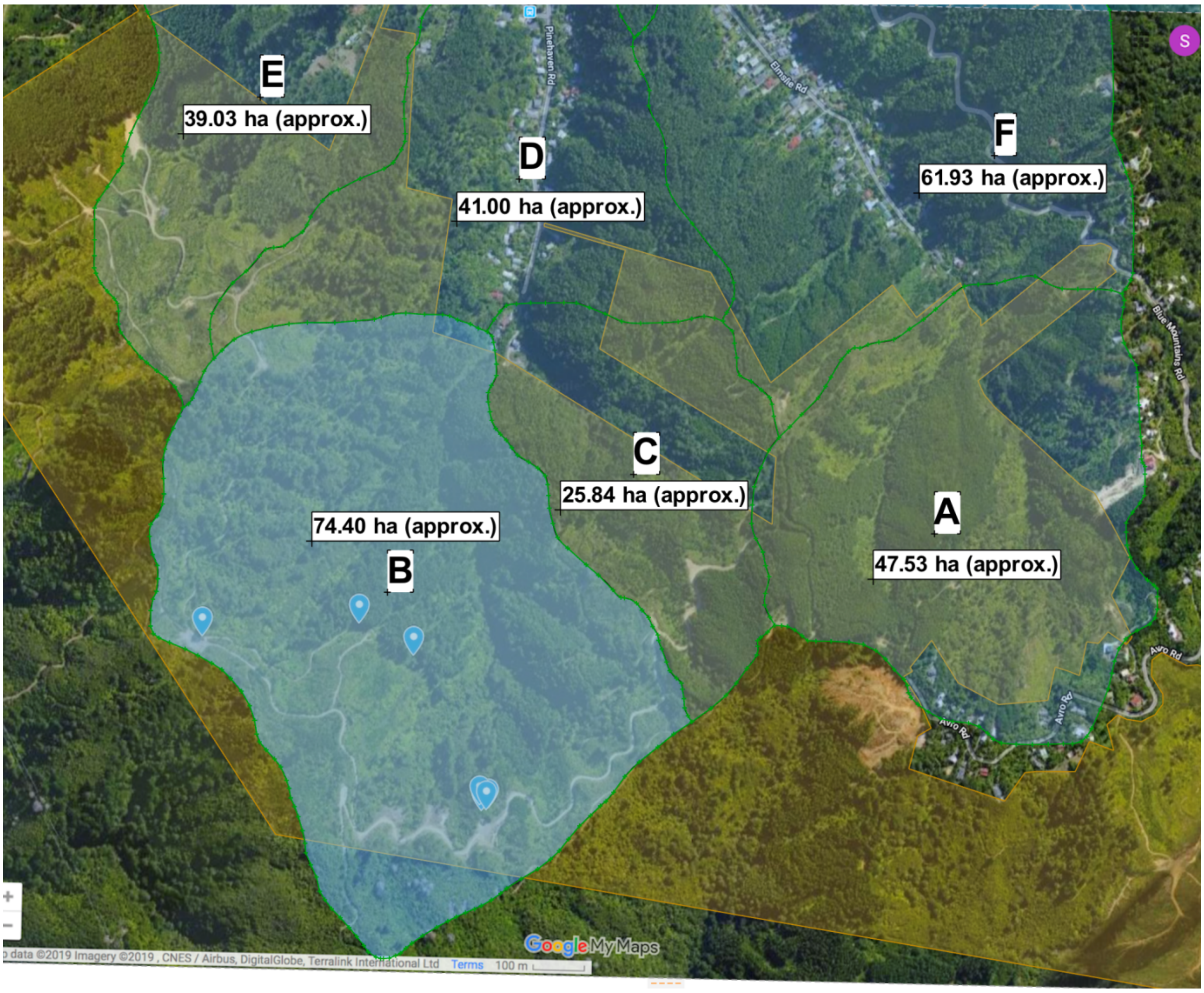
The first tests were carried out using a 100mm diameter uPVC pipe driven into the ground about 70mm and filled with water to a head of 20mm timing how long it took for the water to soak away.

A nominal 100mm Ø PVC pipe x 140mm long was set 70mm into the soil (after clearing the pine needles and leaf litter away). A line had been marked at 70mm from the top inside the pipe (soil level), and another line 20mm above it. 3 or 4 soakings were applied to the soil before timing how long it took for 20mm of water to soak away.

These tests were carried out in several locations in forest, and in regenerating bush. These tests were limited due to the availability of water which had to be carried to the various sites on foot for several kilometres.

The locations of the tests were plotted by GPS app on a cell phone. Then the sites were located on Google maps. This map was then overlaid on a map of the catchment showing other features.

This map is reproduced below.



Soil and rock were observed in road cuttings as transport of the water for the tests proceeded.

Photographs showing tests using single ring infiltrometer.

DOUBLE RING INFILTROMETER

Following the first series of tests a double ring infiltrometer (DRI) was used for the remaining tests . The double ring infiltrometer had a 100mm diameter inner ring, and a 300mm diameter outer ring. The purpose of the outer ring is to keep the water in the inner ring infiltrating vertically into the soil. The rings were inserted into the ground to a depth of 130mm. (which is within the suggested range of 50 - 150 mm described by most methods). The outer ring was filled with water to 100mm above the soil and the inner ring was also filled to the same depth. The timer was started and the depth of water in the inner ring noted at regular intervals whilst keeping the water in the outer ring at the same level as the inner ring by the addition of water. When the water in the inner ring infiltrated the soil it was replenished to the 10 cm mark and the water in the outer ring was also replenished, the depth of water was then measured at the next time interval. The test repeated until the infiltration depths remained constant for the same time interval. The locations of the tests were plotted by GPS app on a cell phone.

In all eight tests were performed on different areas of the catchment and on different ground conditions from forest areas to grassed lawns and reserves.

The photographs below show the various test sites at 27 Elmslie Road, Pinehaven and in the Pinehaven Reserve.

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DRI Test 1 Edge of Pines

DRI Test2 Middle of Pines

DRI Test #3 Regenerating Bush

DRI Test # 4 Back Lawn

DRI Test #5 Mid Lawn

27 Elmslie Road

DRI Test #6 Front Lawn

DRI Test #7 Pinehaven Reserve

DRI Test #8 Pinehaven Reserve

RESULTS OF TESTS

The test results were graphed for tests 1 - 3 of the double Ring Infiltrometer (as shown below), and gave base infiltration rates between 512 - 900 mm/hr for the Bush and forest areas at 27 Elmslie Road.

The initial single ring tests in Sub Catchment B gave results of :-

Test 1	36 sec
Test 2	56 sec
Test 3	106 sec
Test 4	435 sec

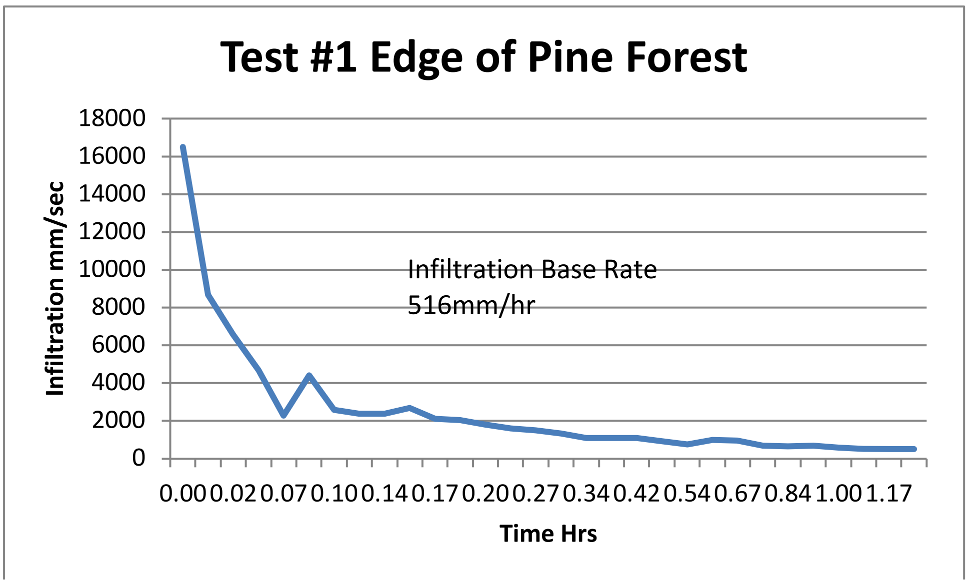
In Regenerating Bush for 20 mm of water to soak into the soil. And

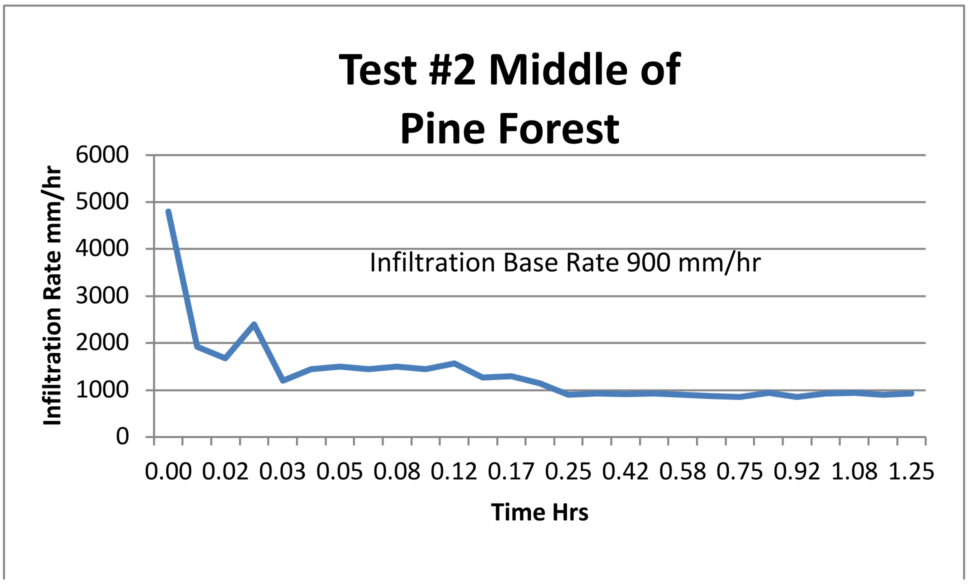
Test 5	60 sec
Test 6	7 sec
Test 7	40 sec
Test 8	85 sec

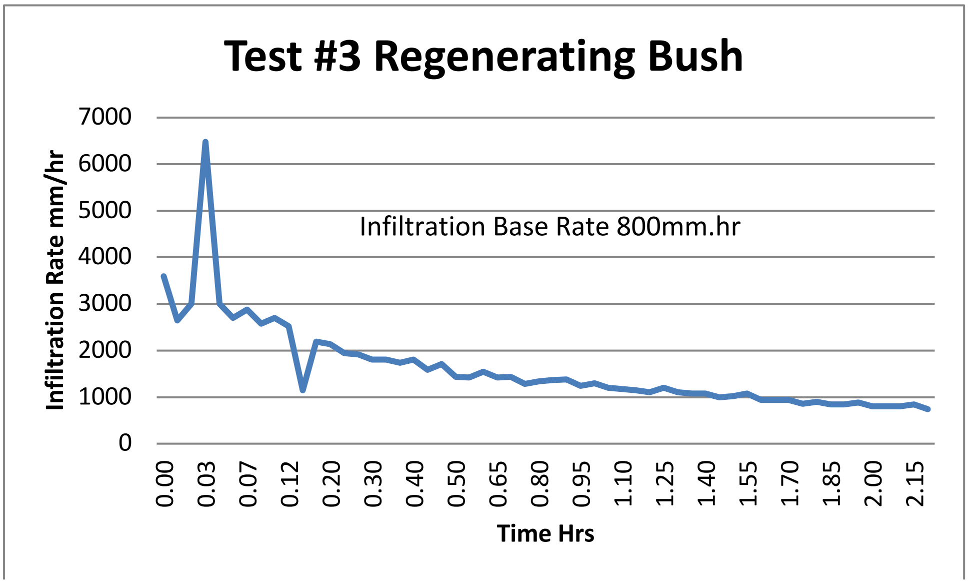
In the forest area for 20 mm water to soak into the soil.

Setting aside the outlier of Test #6 at 7 sec the average time is 119 sec giving an infiltration rate of 603 mm / hr Which is reasonably consistent with the double ring tests.

The tests on the lawn areas and the Pinehaven Reserve gave consistent results of 1 - 2 mm/hr for the infiltration rate on this type of land cover.







Conclusion

The results show that the forest and bush areas in the Pinehaven catchment have much higher infiltration rates than what was proposed in the flood model calculations by WRC and as such the peak flood calculations, volumes, and extent of flooding shown on the maps based on the catchment as presented in 2019 are grossly exagerated.

The other conclusion from the tests is that the lawns and grassed reserve areas in the developed urban portion of the catchment along with the impermiable areas of roads, footpaths, driveways, and roofs will provide the majority of the run off due to their negligable infiltration capacity.

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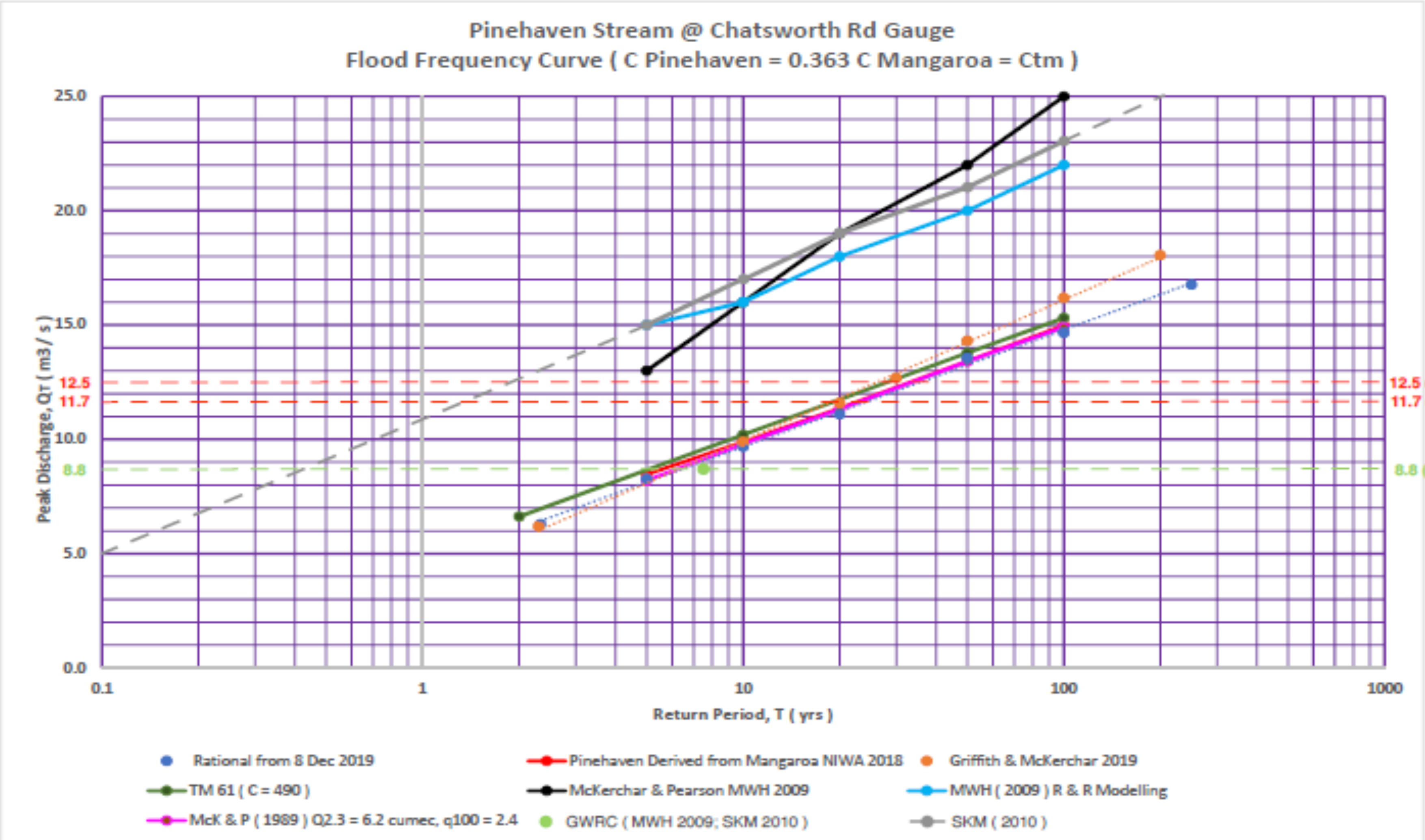
Photograph of secondary flow path caused by undersized culvert and vegetation blocking the channel below the culvert at 122 Pinehaven Road.



Graph from RJ Hall showing Peak Discharge vs Return Period and Highlighting the error in GWRC 8.8m3/sec flood estimates