Report: Pinehaven Stream
ARI 100 Hydrological Assessment
Various Development Scenarios

Prepared For: Save Our Hills (Upper Hutt) Incorporated
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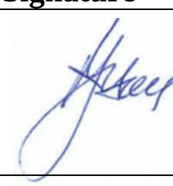
R.J. Hall	Author / Review	05.11.2019		FINAL
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1.0 Executive Summary

Save Our Hills (SOH) requested that R.J. Hall & Associates Ltd (RJH) independently investigate whether Jacobs' (2016) reworkings of the Pinehaven flood modelling corrected the future development hydrology error by SKM (2010):

"[In] SKM's modelling of future development … there was not the expected increase in flood volume. SKM used hydrology provided by MWH. However, MWH have not provided an explanation as to why there is no increase in future development flood volumes. Therefore, SOH's concerns are upheld that the effects of future development on flood extent are not modelled correctly." (Beca "Pinehaven Stream Flood Mapping Audit" 13 July 2015, p17)

"During the audit, I noted an error in the way that future development had been modelled. This was subsequently corrected. … As raised by Submitter #12 [SOH], my 2015 audit noted that there was a discrepancy in the … 'future development' scenario in the Pinehaven catchment. … there was no anticipated increase in flood volume. This suggested that the future hydrology … had not allowed for the additional runoff generated by increased impervious areas post-development … showing a less than expected difference between existing and 'future development' flood extents provided by GWRC [RJH Figure 4 below] *…. GWRC's consultants (Jacobs) updated the 'future development' hydrology, and sent me the results for comment. This included an updated flood extent difference map to indicate the effects of unmitigated future development. … I am satisfied that Jacobs' reworking of the future development hydrology is appropriate."*

Statement of Evidence of Michael Charles Law 30 Aug 2017 paras. 40, 60, 61 - Upper Hutt City Council (UHCC): Hearing for Proposed Plan Change 42 – Mangaroa and Pinehaven Flood Hazard Extents

RJH conclude that Jacobs (2016) has not resolved SKM's error regarding the effects of future development on flood extent.

Regarding SKM's (2010) pre- and post-development comparison map (RJ Hall Figure 4 below) the Beca auditor Michael Law suggests it should show a post-development increase in runoff volume of about 5.6% (see Appendix 4). Inexplicably, based on Jacob's results published in their Table 1 (RJH Figure 8), this reduces to about 1% in Jacobs (2016) reworking.

In contrast, RJH find increases in post-development runoff volumes for the various Development Scenarios DS1, DS2 and DS2A in a 100-year storm to be in the order of about 500% (see RJH Table 4 below, where an allowance for climate change is included for both pre and post development), and potentially up to 738% (see RJH Table 2 below, no climate change in the pre-development case).

RJH find that Jacobs' pre- and post-development flood extent comparison maps are materially no better than SKM's (2010) comparison map. By back-calculating Jacobs' figures (RJH Appendix 5), we find a CN value of 96 for the pre-development hydrology, which means the existing forested hills are treated by Jacobs as being more or less impermeable, and the runoff characteristics between pre and post development are almost indistinguishable. The effect of this is that when these pre and post hydrographs are applied to the hydraulic model it is to be expected that this error will generate almost identical pre and post flood extents. In essence this fundamental error by SKM persists also in Jacobs' 2016 reworking.

The current modelling by MWH, SKM, Beca and Jacobs grossly over-estimates the baseline (OS) pre-development case and grossly under-estimates the likely impact of the post-development case. Consequently the modelling is unreliable as a basis for assessing future developments for increases in peak flow and flood volume.

Hydraulic neutrality rules in UHCC District Plan Change 42 (PC42) are dependent on reliable pre- and post-development assessments of unmitigated stormwater runoff. They will be ineffective for controlling increased stormwater runoff from future Guildford development if based on the current modelling by Jacobs (2016).

Pinehaven and Silverstream communities, instead of being protected by PC42 rules from increases in flooding due to future Guildford development, will actually be exposed to significant increases in flood risk to life and property from future developments such as those proposed in Guildford scenarios DS1, DS2 and DS2A.

We conclude Jacobs' error can only be remedied by rejecting the hydrological and hydraulic modelling to date and doing it again using reasonable and representative runoff hydrographs for pre- and post-development situations.

2.0 Introduction and Background

In 2010 SKM released a report " Pinehaven Stream Flood Hazard Assessment " compiled on behalf of the Greater Wellington Regional Council (GWRC) and the Upper Hutt City Council (UHCC). This report included flood maps derived for an 100 year ARI flood on the Pinehaven Stream. These maps depicted the expected extent of flood in such an event with the catchment as it was at that time and also for a future urban development scenario in the catchment (RJH Figure 4 below).

These maps used flood hydrographs derived from a hydrological model by MWH (2008 / 2009) in a combination 1D and 2D hydraulic model compiled by SKM. In viewing SKM's (2010) comparison map (RJ Hall Figure 4 below), SOH noticed there was little difference in pre- and post- development flood extents. The community raised this issue with the GWRC who responded by engaging Beca in 2015 to undertake an independent audit of the whole plan including consideration of this pressing issue. The Auditor (Michael Law) acknowledged this irregularity but was unable to provide an explanation as to why it should simply be dismissed.

This response did not lie well with the Pinehaven Community who pressured the GWRC to address the matter and provide the necessary explanation. For Sub-catchment B, while the post development hydrograph peak flow exceeded that of the pre development hydrograph there was no obvious difference in runoff volume represented by the area contained within the body of the hydrograph (RJH Figure 5 below) notwithstanding the fact that extensive urban development was being considered on the Pinehaven hills in the upper catchment.

In 2016 the GWRC engaged Jacobs (formerly SKM) to undertake a further review, the results of which are contained in a memo to the GWRC dated 23 June 2016 titled "Pinehaven Developments Scenarios 1 and 2". Jacobs in this Memo set out the brief given them by GWRC, in particular they were requested to *"Resolve the Future Development item in Table 4.1 – Hydraulic Modelling in Section 4.2 of the report 'Pinehaven Stream – Flood Mapping Audit', Beca, 13 July 2015."*

This particular issue centres on the form of the pre and post development hydrographs, specifically the scale of the respective peak flows and the runoff volume expected in each case. In essence this is a matter relating to the conversion of rainfall into runoff i.e. an hydrological modelling exercise the results of which feed into an hydraulic model which eventually produces flood maps. Jacobs (2016) noted that they themselves did not produce the hydrographs which they used in their study, these being provided by the GWRC. They also noted that the hydrographs both pre and post development were for an ARI 100 year, 2 hour storm, without climate change applied to the rainfall and with no hydraulic neutrality measures being applied to the post development outflows.

The Jacobs (2016) study examined a baseline situation with the catchment in its present state as at 2009 i.e. the OS Scenario, and two others, the DSI Scenario (1,665 new dwellings on Guildford land on the Pinehaven hills) used by SKM but in Jacobs' study without the effects of climate change included, and a "lower level of development" DS2 scenario. Jacobs tabulated the various peak discharges and runoff volumes for each of 15 sub-catchments of the Pinehaven Catchment for each of these two scenarios, the results of which are set out in Table 1 of their 2016 Memo to GWRC (see RJH Figure 8 below for Jacobs' Table 1).

What is immediately obvious from viewing this table is that there are only very minor differences between the runoff volumes for the various scenarios (OS, DS1 and DS2) being examined. This result is for all intents and purposes not materially different to the situation derived by SKM in 2010 and which the Pinehaven Community were deeply concerned about.

SOH requested that R.J. Hall & Associates Ltd independently investigate this matter to determine whether or not Jacobs (2016) reworkings of the flood modelling for the future development scenarios corrected the error that M. Laws acknowledged (but simply dismissed without resolving or investigating further) in Beca's "Pinehaven Stream Flood Mapping Audit" (2015).

In order to answer that question R.J. Hall & Associates Ltd carried out their own assessment of pre and post development runoff for an 100 year ARI rainstorm for the two development scenarios DS1 and DS2 used by Jacobs (2016), and in addition a further development scenario, viz. DS2A.

On the basis of our study we conclude that Jacobs (2016) have not resolved this issue and in point of fact, because they were using hydrographs supplied to them by GWRC, in effect they never actually addressed that issue at all. The figures for peak flow and runoff volume are GWRC's not Jacobs.

Further, as will become apparent when reading through the RJ Hall report, there are significant increases in runoff to be expected from the various development scenarios DS1, DS2 and DS2A in any storm over this catchment, which contrasts strongly with the situation depicted by SKM (2010) and Jacobs (2016). The reason significant increases in flood volume do not show in SKM's 2010 comparison map of pre- and post- development flood extents (RJH Figure 4 below) is that the blue baseline pre-development flood extents have been grossly over-estimated, and the green post-development flood extents have been grossly under-estimated.

In order for Jacobs to satisfy the requirement in their brief from GWRC to resolve the 'Future Development' hydrology [see Jacobs Memorandum 23 June 2016] it is opined that Jacobs should have independently developed a set of hydrographs to be used for generating reworked flood maps. It is only in this way that they could have gauged the accuracy of the pre- and post-development hydrograph volumes.

Instead, Jacobs simply used hydrographs supplied to them by the GWRC:

"The hydrological modelling of scenarios and generation of the hydrographs was undertaken by GWRC and provided to Jacobs." (Jacobs Memo, 23 June 2016, p1)

Consequently, Jacobs' Memorandum (2016) does not fulfil the brief to resolve the future development hydrology, and the future development hydrology error in the Pinehaven flood modelling has not been addressed or corrected by Jacobs.

M. Law's review (01 March 2017) of Jacobs' reworking (23 June 2016) states:

"I have not reviewed the modelling or raw results of the additional model runs, and so my comments are restricted to the memo [Jacobs, 23 June 2016] *and accompanying maps … The revised peak flows and flood volumes provided by Jacobs indicate that peak flows will increase by about 3% and flood volumes by about 6% in the affected sub-catchments if development proceeds. The increase in flood volume is about the same as I estimated it would be in … the 2015 audit."*

M. Law does not explain how a 6% increase in flood volume was calculated. According to Jacobs' figures for DS2 in Table 1 of Jacobs' memo (see RJ Hall Figure 8 below) increases in flood volumes for affected sub-catchments B, C, E and I are 1.4%, 1.0%, 1.2% and 1.2% respectively. As mentioned above, we find actual increases being in the order of about 500% to 700%, and conclude that the error in the Pinehaven flood modelling is significant and has not been resolved.

This current study by RJH presents the results of an hydrological analysis of peak flow and runoff volumes from Sub-catchment B of the Pinehaven catchment for three possible development scenarios namely DS1 (the entire sub-catchment B), plus DS2 and DS2A (both are along and adjacent to the ridge of sub-catchment B) in response to an ARI 100 year 12 hour rainstorm using a nested storm pattern.

The hydrological rainfall – runoff HEC HMS has been employed on the various development footprints with and without development in Sub-catchment B and estimates made of the likely response of adjoining Sub-catchments A, C, E and I by pro-rata using the respective Sub-catchment development scenario footprints relative to that of Sub-catchment B.

This work was undertaken at Save Our Hills (Upper Hutt) Incorporated (SOH) request by R.J. Hall and Associates Ltd. in collaboration with SOH for the purposes of re-evaluating previous work undertaken variously by Montgomery Watson Harza (MWH), Sinclair Knight Merz (SKM), Becca and Jacobs in order to determine the scale and nature of unmitigated runoff from future possible urban development in the Pinehaven catchment headwaters.

The results of this study demonstrate:

- That the infiltration capacity of the forest floor in this catchment has high infiltration rates arising from a combination of the weathered and fractured nature of the underlying bedrock, the presence of a thick mantle of weathered regolith, a good layer of forest litter and thin topsoil without the presence of grazing animals. It is also opined that the history of original native forest clearance, pine plantation establishment and harvesting and regeneration of forest cover over substantive areas of the catchment slopes, valley floor and ridges and associated disturbances have combined with these other characteristics to provide the high infiltration rates that are present and which have been quantified through field infiltration testing;

- Parameters that are to be used in hydrological modelling exercises of the kind being employed in these various studies need to be representative of those actually present in the catchment and it is one role of a technical audit to be satisfied that that is the case;

- It is opined as a result of this study that there has been a significant underestimation of the likely scale and form of losses (initial abstraction and continuing losses) during the rainfall events evaluated in these earlier studies. A direct consequence of under-estimating losses in the pre-development case means that the runoff in those cases is over-estimated. This has the effect of under-estimating the likely impact of the post-development case. For all intents and purposes the earlier studies conclude that the unmitigated effects that will be generated are likely to be minor where in reality that will not be the case (refer section 4.0 and Figure 14);

- Sub-catchments A, B, C, E and I total some 95 ha in the DS2A development scenario and constitute approximately 48% of what is referred to as the Guildford development area (some 198 ha. in total) located along the Pinehaven catchment ridgeline with the balance of that development land being located in hills above Silverstream, and Stokes and Whitemans Valleys. Given that situation and on the basis of the estimates made for Sub-catchments A, B, C, E and I in the Pinehaven catchment it could be expected that the total post-development runoff for the DS2 and DS2A scenarios when applied to the whole Guildford development could conceivably be double that occurring off the DS2 or DS2A developed areas in the Pinehaven Stream catchment (refer Appendix 3);

- The efficacy of any subsequent work which relies on the hydrological results derived from these earlier studies should in the light of this assessment be questioned and at this point cannot be relied upon.

Background:

Guildford Timber Company (GTC), owner of about 300ha of forest on the hills around Pinehaven and Silverstream, published a concept for a master-planned new town [Figure 1 - Guildford], prepared by Boffa-Miskell and SKM (c. 2007).

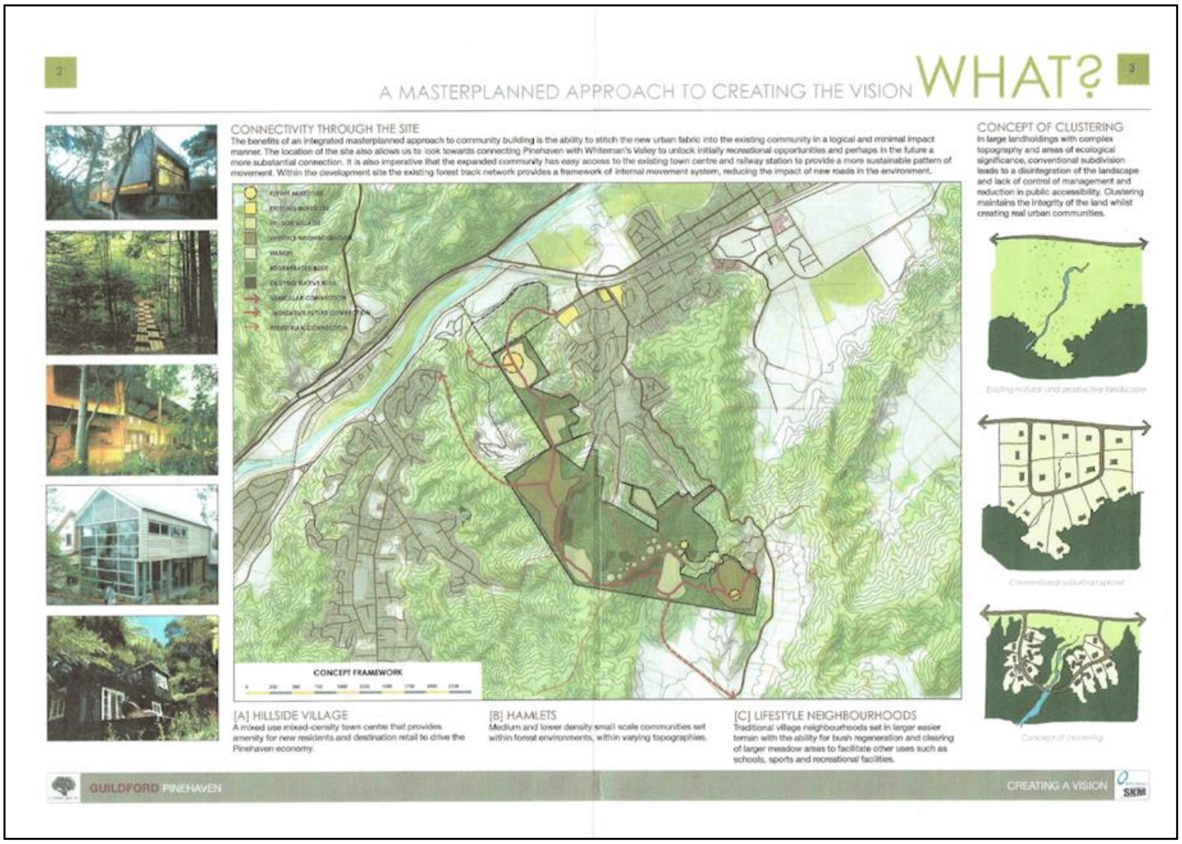


Figure 1 Guildford (Source. A3 flyer circulated in Pinehaven by GTC, 2007)

In 2008, MWH published the "Pinehaven Stream Flood Hydrology" report for Greater Wellington Regional Council (GWRC). This report (revised 25 Nov 2009) identified 15 sub-catchments of the Pinehaven Stream. Part of Guildford land is on sub-catchments A, B, C, E and I in the upper catchment (see Figure 2 and Figure 3).

SKM (2010) reported the impact on flooding of a Guildford "future development scenario" [referred to later by Jacobs as DS1]. SKM stated that unmitigated runoff from 1,665 new dwellings on 750m² lots (each lot having a connected impervious area of 40%) on sub-catchments B, C, E and I would have only "minor" impact on flooding compared with the existing [OS1] ARI 100-year flood extents (Figure 4).

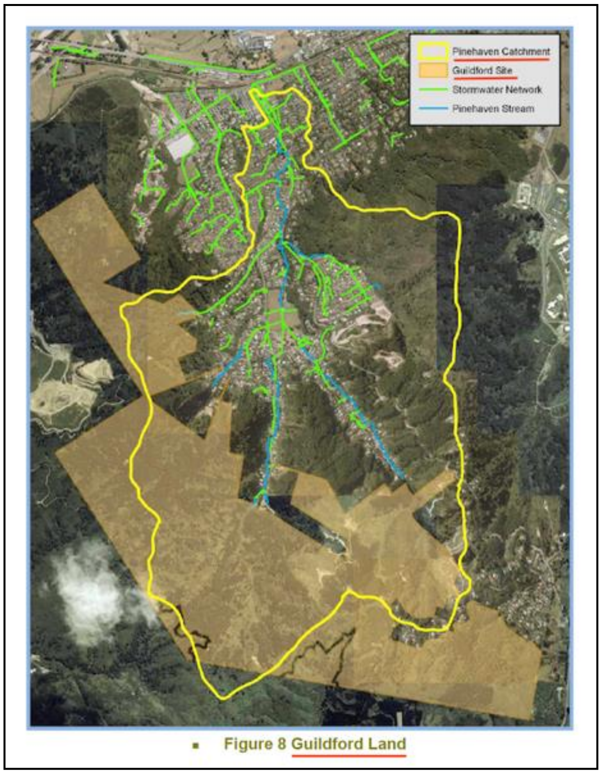


Figure 2 - Guildford Land (Source. SKM(2010))

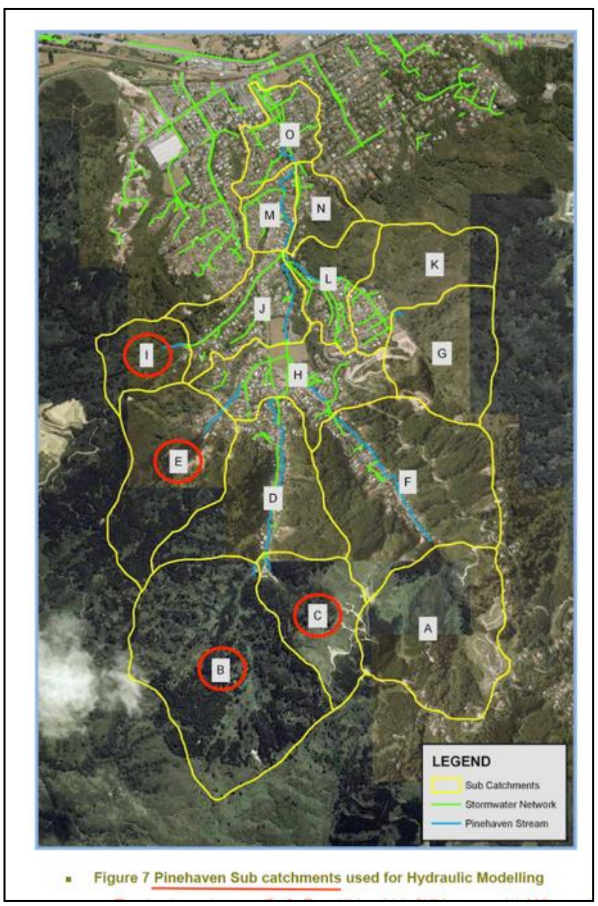


Figure 3 – 15 sub-catchments, Pinehaven Stream (Source. MWH(2009))

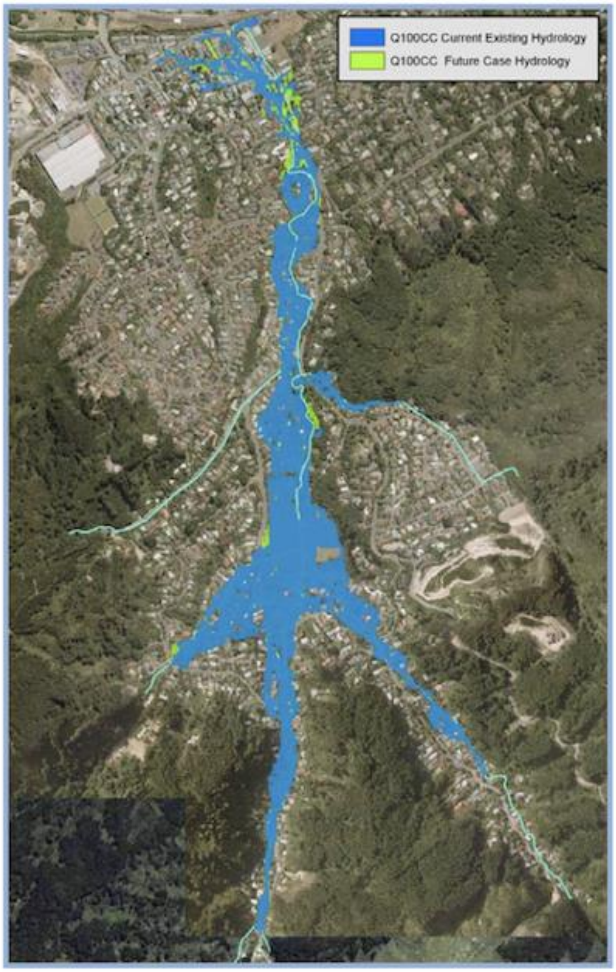
NB: SKM's 2010 'future case scenario' (DS1) assumed 1,665 new dwellings on sub-catchments B, C, E and I, each lot being 750m2 and each lot having a CIA (connected impervious area) of 40%.

[Note that the CIA increases to about 52% when roads and footpaths are allowed for, and the assumed DS1 development covers the entirety of sub-catchments B, C, E and I.]

6.3. Future Development in the Catchment

In this investigation the future development in the catchment was also analysed in the 100 year storm with the predicted impacts of climate change and the 10 year storm without climate change. For details on how the future case hydrology was developed refer to section 3.2.

The modelled flood extents associated with the 100 year storm including climate change for the current existing hydrology are compared with the flooding extents from the future case hydrology in Figure 19.



The model results show that there is the potential for future development to increase flooding in the catchment as connected impervious areas can have a much faster runoff response, with less catchment losses than vegetated catchments. However this comparison of the 100 year rainfall event also shows that the change in extents are minor and may be possible to be mitigated. The steep topography of the catchment appears to constrain the overflows in the upper catchment and thus the minor differences observed are in the lower catchment in the vicinity of Whiteman's Road. The comparison of the modelled inundation depths between current existing and future case hydrology for the 100 year storm results in less than 100mm increase in inundation depths across the catchment.

- **Figure 19 Current Existing vs. Future Case Comparison of Predicted Flooding Extents in the Q_{100} with Climate Change.**

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Figure 4 - Comparison of blue pre-development (OS) and green post development (DS1) flood extents, as assessed by SKM (Source. SKM - 2010)

An audit by Michael Law (Beca, 2015) provided pre- and post-development [DS1] hydrographs for sub-catchment B (Figure 5) and estimated the increase in post-development [DS1] peak flow to be 18%, with the runoff volume increasing 5.6%.

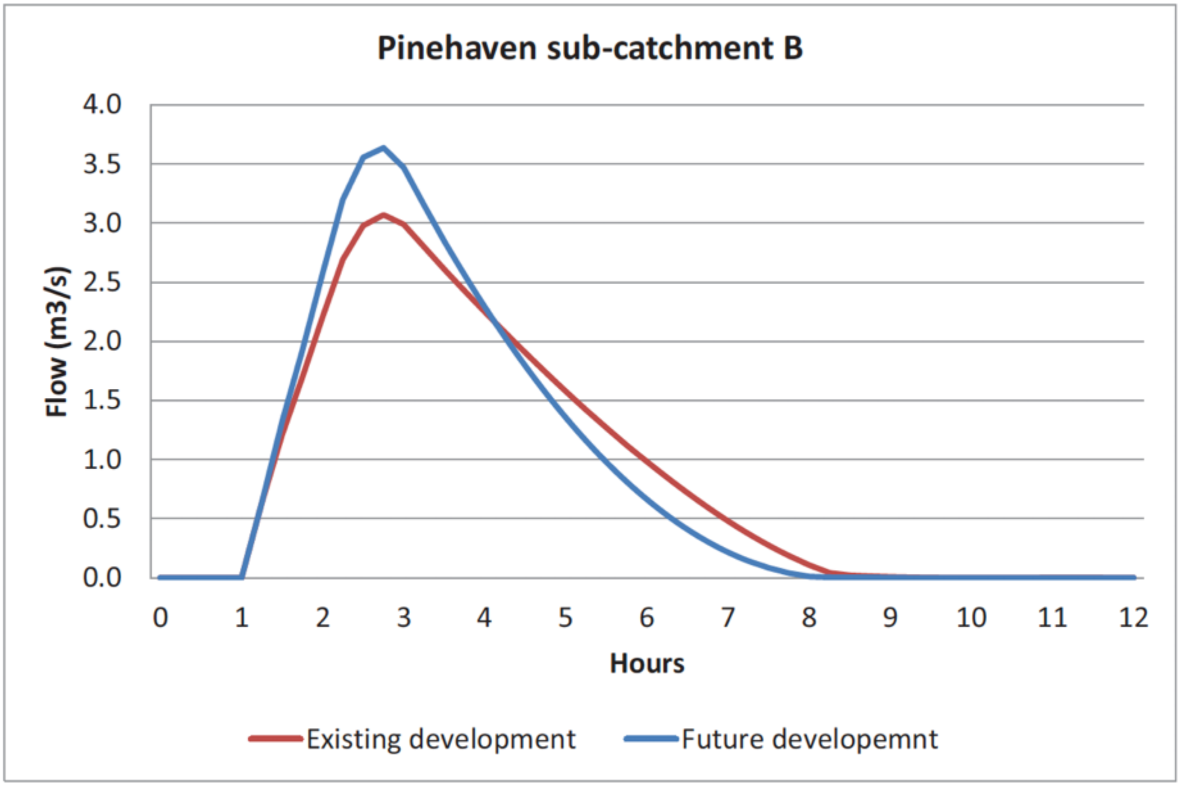


Figure 8.1 – Existing and maximum probable development hydrographs

Figure 5 - Beca "Pinehaven Stream Flood Mapping Audit" (13 July 2015) Sub-catchment B Hydrographs - Existing Hydrographs (OS1, with Climate Change (CC) and Future (DS1, with CC))

In 2016, Jacobs (formerly SKM) introduced a new future development scenario on Guildford land - DS2 which assumes "a lower level of development" than DS1 but with the same parameters of 750m2 lots, each with a connected impervious area of 40%. In March 2016, Upper Hutt City Council (UHCC), without prior consultation with the public, signed a "Land Swap" proposal with GTC. In a 'Memorandum of Understanding Relating to Land Exchange' UHCC proposes to swap the Silverstream Spur (a 35ha public reserve), for 132ha of GTC's steep forested hillsides. The DS2 development by Guildford would not include the steep hillsides but be confined to gentler slopes along ridges remaining in GTC ownership (Figure 6a, 6b, 6c, 7a, 7b).

5.0 The proposed land swap

Enabling road access onto the ridge from the valley floor will be the keystone to achieving the proposed vision.

The council-owned Silverstream Spur is the most suitable location to develop a road link from the valley, as the contours allow for a route that would sidle up the south side of the spur to join the rolling ridgetop land in the Guildford Block.

It is therefore proposed that all or part of the 35-hectare Silverstream Spur be transferred to the Guildford Timber Company and, in return, 132 hectares of the Guildford Block, on the slopes south and east of Pinehaven, would be transferred to the Upper Hutt City Council. Figure 2 shows the areas of proposed land swap.

In proposing this land swap, the Guildford Timber Company seeks to work in partnership with the council and other stakeholders to achieve a range of mutually beneficial outcomes for the company, the council and the Upper Hutt community. This could include the establishment of a community trust which could assist in the design and development of the park for environmental and heritage conservation, public recreation and enjoyment. The trust could take on partnership role made up from representatives from the community, iwi, the Guildford families, the Council and other stakeholders.

Figure 6a - The Proposed Land Swap (Boffa Miskell - October 2015, p6)

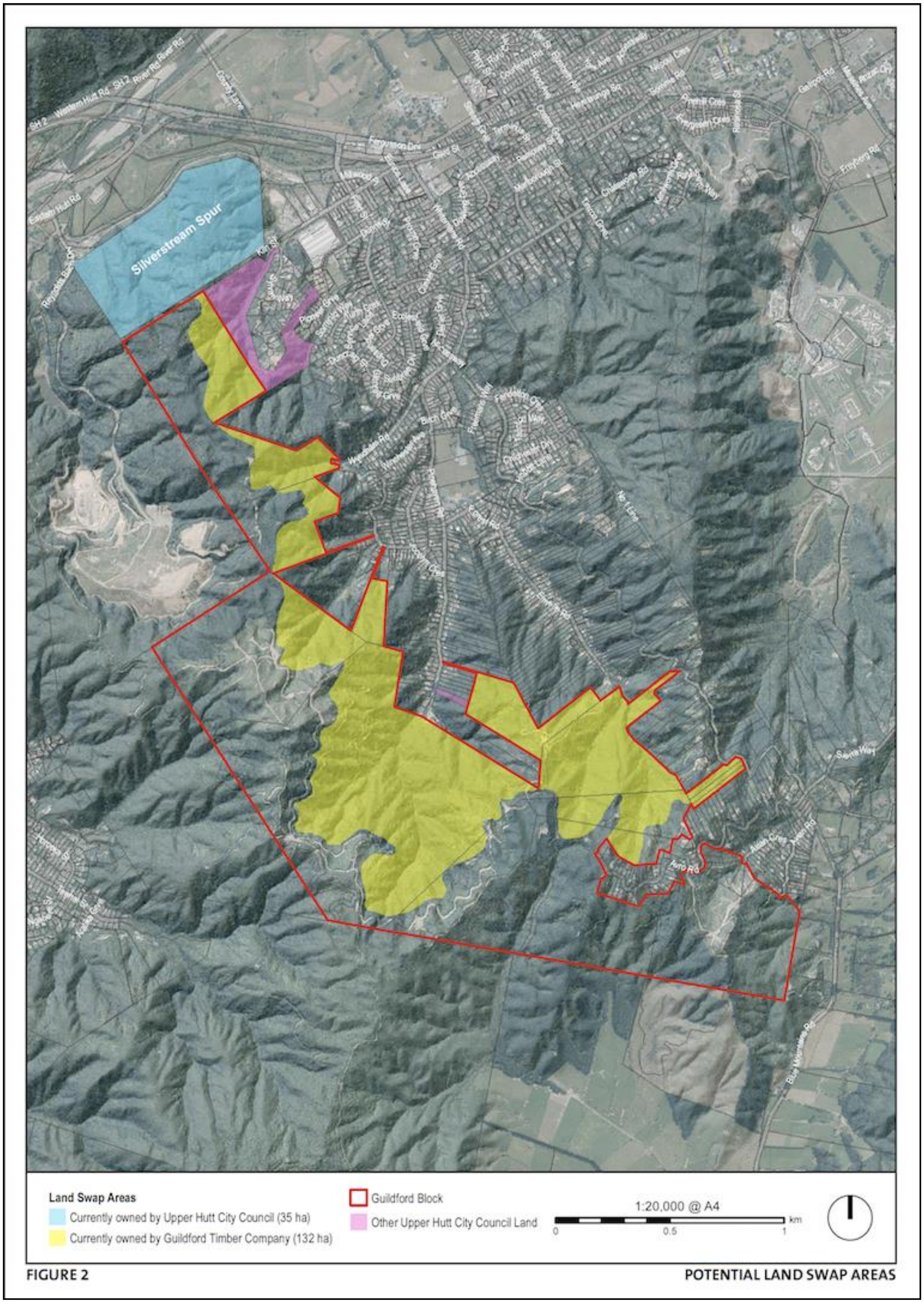


Figure 6b - The Proposed Land Swap (Boffa Miskell - October 2015, p7 Fig.2)

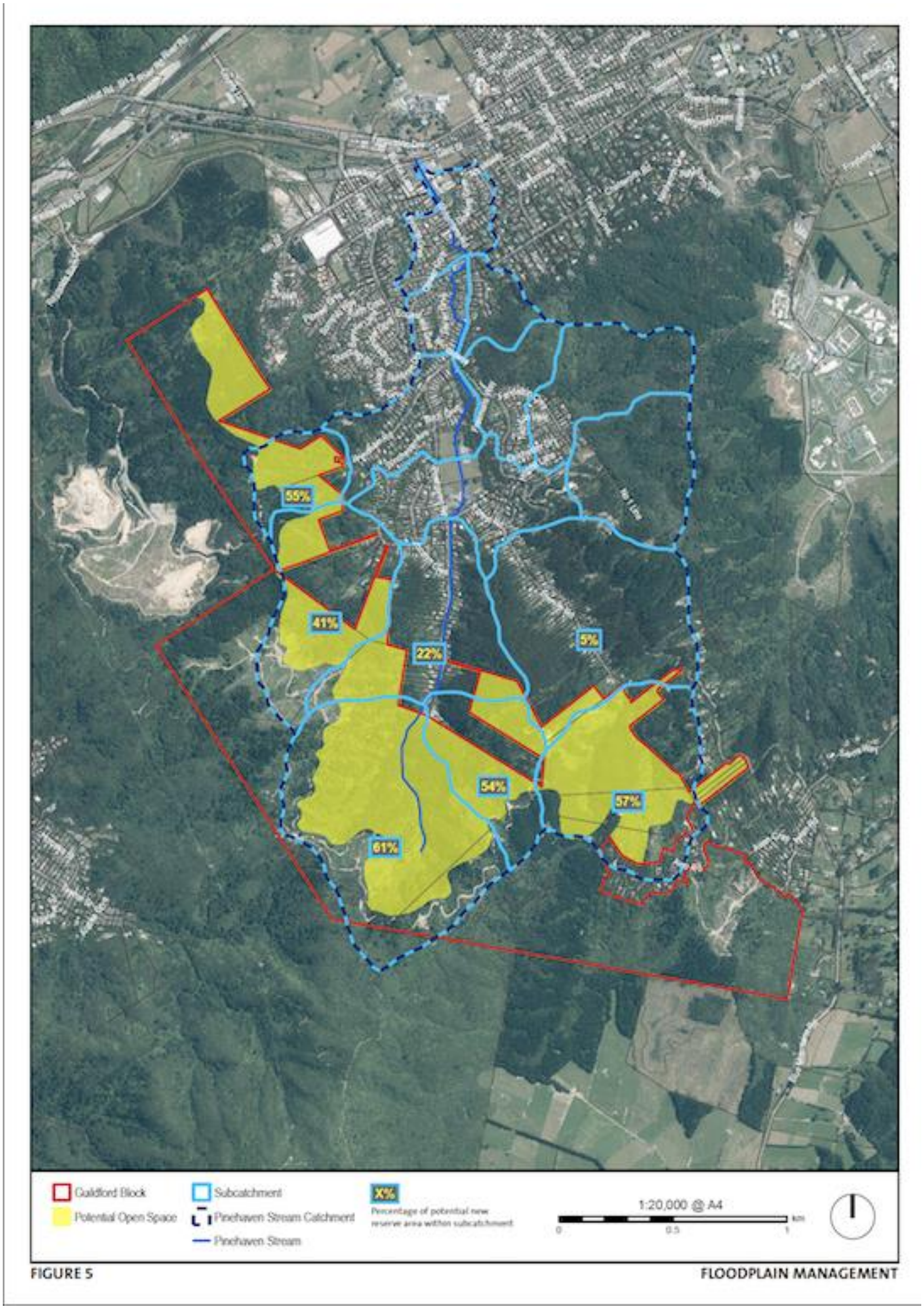


Figure 6c - The Proposed Land Swap (Boffa Miskell - October 2015, p11 Fig.5)

Southern Growth Area (Guildford Timber Company land)

This area extends along the south-western hills behind Pinehaven, from Silverstream Spur (the Council-owned land beyond the end of Kiln Street), towards Avro and Avian Roads in the Blue Mountains.

This land has long been established as a pine plantation, and covers an area of approximately 330 ha. It is owned by the Guildford Timber Company (GTC), which intends to gradually retire the land from its current use as a commercial forest. GTC have begun considering other future uses, including development for housing and protection of some parts of the site that have visual or ecological value.

Responding to both topography and indigenous vegetation on the site, GTC have been investigating a concept that includes development of clusters of housing on the higher and less steep land beyond the Silverstream and Pinehaven ridges. A conceptual illustration of potential development is shown below.

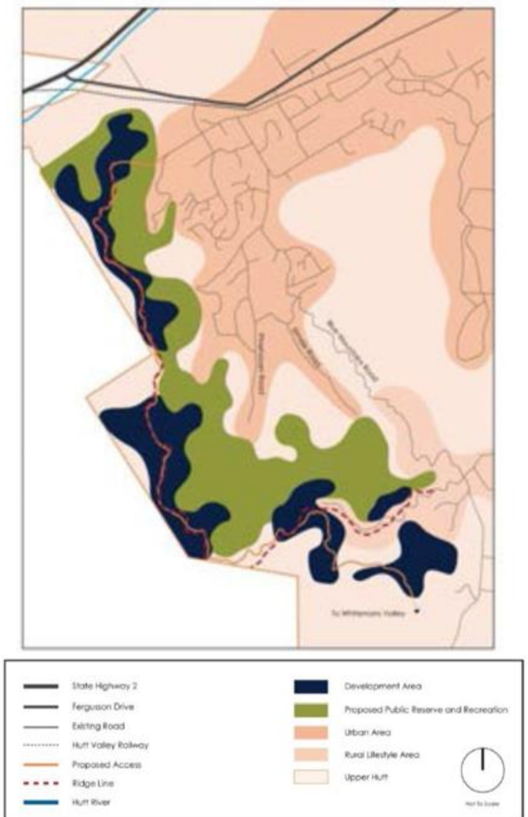


Figure 4.15: Development at Guildford – broad concept

**Note that this is not the final configuration of development on this site – it is a conceptual map only. As investigations into the feasibility of development on the site proceed more detail will evolve.*

Figure 7a - Guildford Development (UHCC Land Use Strategy - Sept 2016, p79)

Access to the potential development is proposed via Council-owned land on Silverstream Spur which could be achieved through a land swap. In exchange for access, the land swap would convert large areas of the slopes above Pinehaven into a public recreation resource. This would preserve the vegetation cover on the slopes above Pinehaven, recognising that these provide much-valued visual amenity benefits to the nearby residential areas and reduce the risk of increased stormwater runoff as the protected land includes a large amount of the Pinehaven Stream catchment. It would also make a significant contribution to the city's recreation assets.

GTC and the Council have entered into a Memorandum of Understanding in respect of the land swap so that both parties can investigate the possibility and feasibility of it occurring.

There are a number of ecological, amenity, physical and topographical features of the site which would require sensitive development considerations. The exact nature of the development and location of housing is yet to be determined, but it is anticipated that the likely yield from the development would be around 1000 dwellings. More information can be found in GTC's document "Guildford Timber Land Swap" prepared by Boffa Miskell, which can be found on the Council's website.

Due to the amount of land under consideration, the location needs to be considered as a key strategic housing location for the next 30 years.

If this development was to proceed, a Plan Change would be required to rezone the land for residential use. A Plan Change would require a full assessment of all aspects of development of the land, as required by the Resource Management Act. At that stage, detailed consideration would be given to land development issues including (but not limited to) land stability, traffic/roading, servicing, design and layout including regard to visual and natural amenity values, earthworks, hydrology and staging. The impact of any development on adjacent land uses, taking into account their particular sensitivities (for example, the heritage and operational aspects of the Silver Stream Railway) would also be considered.

Figure 7b - Guildford Development (UHCC Land Use Strategy - Sept 2016, p80)

Jacobs (2016) assessed the overall existing (OS) runoff volume to be 202,450m^3, increasing overall to 206,430m^3 for DS1 (2% increase), and increasing overall to 203,610m^3 for the "lower level of development" DS2 (0.5% increase) (Figure 8).

3. Results and Discussion

3.1 Comparison of Flows and Volumes

Table 1 below shows the peak runoff flowrates and total volumes from each of the subcatchments for the OS, DS1 and DS2.

Subcatchment	Peak Runoff (m^3/s)			Total Volume (m^3)		
	OS	DS1	DS2	OS	DS1	DS2
A	2.258	2.258	2.270	21,780	21,780	21,990
B	2.751	2.832	2.774	33,080	35,060	33,560
C	1.430	1.466	1.438	11,340	12,030	11,460
D	1.905	1.905	1.908	18,920	18,920	18,990
E	2.000	2.056	2.014	18,010	19,020	18,220
F	2.434	2.434	2.434	28,360	28,360	28,360
G	1.582	1.582	1.582	13,240	13,240	13,240
H	1.684	1.684	1.684	13,300	13,300	13,300
I	0.843	0.860	0.848	4,830	5,120	4,890
J	1.342	1.342	1.342	9,510	9,510	9,510
K	1.455	1.455	1.455	12,310	12,310	12,310
L	1.079	1.079	1.079	7,130	7,130	7,130
M	0.666	0.666	0.666	3,870	3,880	3,880
N	0.765	0.765	0.765	4,330	4,330	4,330
O	0.465	0.465	0.465	2,440	2,440	2,440
Total				**202,450**	**206,430**	**203,610**

Table 1. Peak Flowrates and Total Volumes for Pinehaven Subcatchments

Figure 8 - Assessment of Peak Flows and Runoff Volume for Future Development Scenarios DS1 and DS2 - without allowance for climate change (Jacobs (2016))

According to Jacobs', the total runoff volume from sub-catchments B, C, E and I is 67,260 m^3 in the OS (existing) condition, 71,230 m^3 in scenario DS1 (5.9% increase), and 68,130m^3 in scenario DS2 (1.3% increase) (Figure 8 above - Jacobs "Table 1").

Figure 9 - DS2 (shaded orange) - Approximate location and area 23.7 ha (Source: Save Our Hills Upper Hutt Incorporated - August 2019 – based on subtracting the proposed 'Reserve' area from sub-catchment B as described by Boffa Miskell 2015 – see RJH Figures 6a, 6b and 6c above)

SOH, on behalf of the local community, challenge these reported "minor" increases in post-development runoff volumes for DS1 (extensive low density development) and DS2 (low density development confined to the ridges – Figure 9) and engaged R J Hall and Associates Ltd to investigate them. GTC's master-planned concept (Figure 1) includes medium density development on the ridges, suggesting a higher percentage of connected impervious area than DS2. Therefore, SOH suggest that a third development scenario DS2A (Figure 10) should be considered, which assumes medium-density development on the ridges and a slightly larger development footprint than DS2 (suggested by 'blobs' in GTC 2007 and UHCC 2016) since no legal definition has yet been given to the boundaries of proposed "Land Swap" parcels.

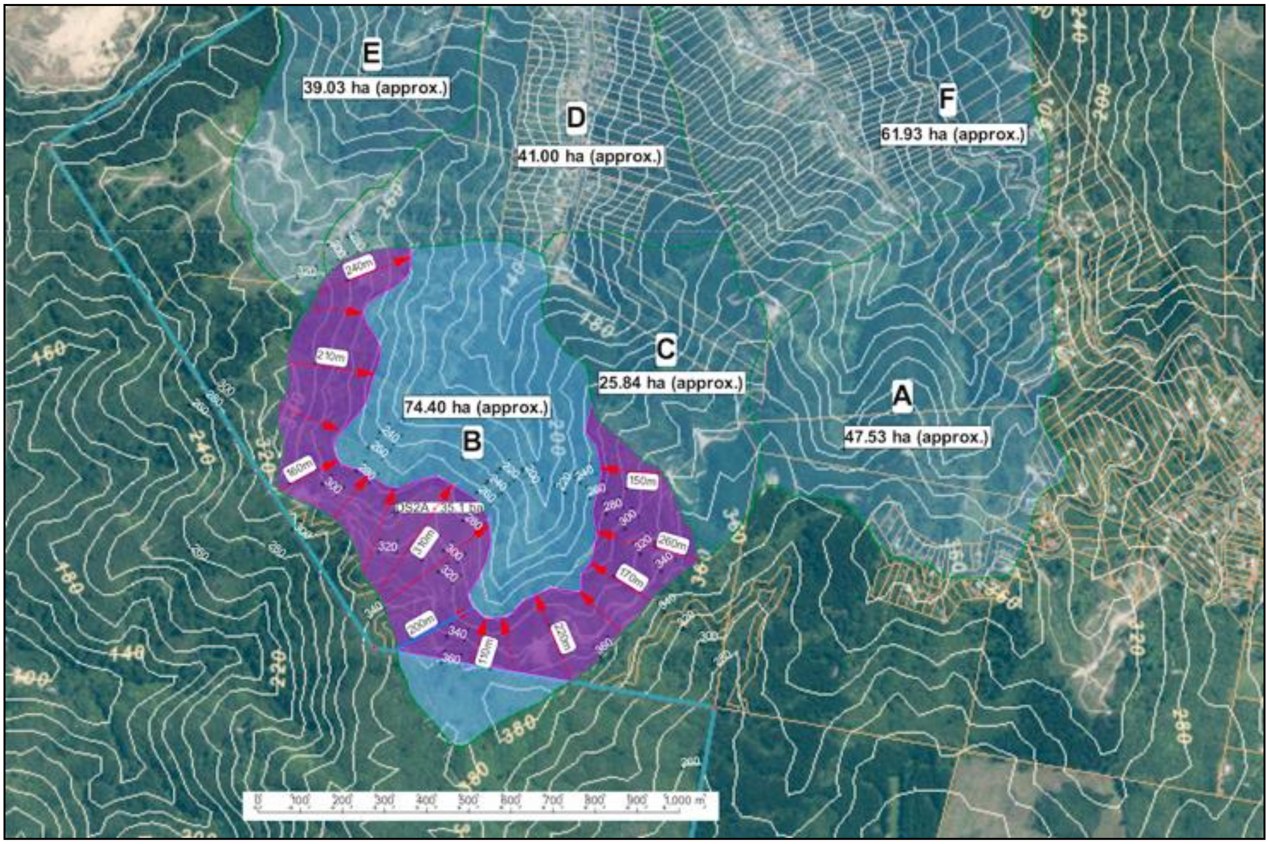


Figure 10 - DS2A (shaded purple) - Approximate location and area 35.1 ha (Source: Save Our Hills Upper Hutt Inc., Aug 2019 - based on medium density for combined 'blobs' in GTC 2007 and UHCC 2016 – see RJH Figures 1, 7a, 7b and Appendix 3)

Recap: - SKM carried out an assessment for the Greater Wellington Regional Council (GWRC) in 2010 for an hypothetical future case urban development scenario (DS1) to consider its impact on flooding in the catchment. That study concluded that the unmitigated runoff from 1665 new dwellings each on 750 square metre lots spread over sub-catchments B, C, E and I (CIA of 40 %, rising to 52 % when roads are included) would have "minor" impact on flooding.

Jacobs (2016) concluded that the unmitigated runoff from the original scenario DS1 (CIA 52 % including roads) would only result in about a 6 % increase in runoff volume for sub-catchments B, C, E and I where development was being assessed (e.g. Sub-catchment B, DS1 post development runoff volume 35,060 m^3, pre-development runoff, 33,080 m^3). A similar approach was applied to peak runoff where it was concluded that for sub-catchment B peak flow would increase by only 3% in the DS1 scenario (from 2.751 to 2.832 m^3/s).

A reworking of this future case scenario in 2016 by Jacobs for GWRC assessed a reduced development area confined to the ridges (DS2). For this smaller DS2 development Jacobs reported that post-development runoff volume would be 33,560 m^3, about a 1.5% increase compared with a pre-development runoff volume of 33,080m^3, and a peak flow increase of 0.8% (from 2.751 to 2.774 m^3/s). Jacobs did not assess the impact of possible medium-density development on the ridges.

The upper parts of the Pinehaven catchment where the effects of development were being considered i.e. in sub-catchments B, C, E and I are presently well forested, a combination of pine plantations and regenerating bush and scrub. The upper catchment is steep, but with gentler slopes on the ridges where Jacobs' (2016) Development Scenario DS2 is located. The soils comprise a thin layer of topsoil over regolith in the order of 1.0 to 1.5 metres in thickness which in turn has accumulated on heavily fractured and weathered greywacke and argillite. The fracturing is associated with the proximity of this bedrock to the Wellington Fault.

The floor of the forest is clothed in a thick mantle of litter and is not grazed. Originally this catchment was covered in stands of native podocarp mixed hardwood native forest which was subsequently clear felled. In the 1930s, pine plantations were established, and they were harvested in the 1970s. Currently, mature pines and regenerating bush cover about 80% of the catchment.

It is evident from an inspection of road cuttings that root mats have penetrated through the soils overlying the bedrock and well into the bedrock itself exploiting fractures within that rock mass. It is considered that the combined effects of both removing and planting vegetation in association with decay of root systems and the regolith and weathered fractured bedrock would facilitate good infiltration rates on gentler ridge slopes during rainstorms. With that in mind, the assumptions made by MWH and SKM/Jacobs do not seem credible that the hydraulic characteristics of these forested sub-catchment surfaces would be in essence not much different to the low permeability surfaces widely present in a post-development state.

This study has been undertaken to re-assess the likely effects of development on runoff rates and volumes independently from the assessments undertaken variously by MWH, SKM, Beca and Jacobs referred to above.

3.0 Methodology

R. J. Hall & Associates Ltd have undertaken an assessment of the runoff (e.g. peak flows, runoff volume) that might be expected from Sub-catchment B of the Pinehaven Stream catchment in an ARI 100 year 12 hour rainstorm. Sub-catchment B is the largest sub-catchment in the upper catchment. It is reasonable to assume that results from an assessment of sub-catchment B would be indicative of results that could be expected from sub-catchments A, C, E and I.

In this present assessment, Sub-catchment B is considered in its existing condition (as at 2009 when it was assessed by MWH) and if urban development were to occur along and adjacent to the ridge line at the head of the catchment. Details of the various characteristics which have been considered in making this assessment and which influence runoff are set out below. Summary tables of the modelling parameters are presented in Appendix 1 and Appendix 2. Three development scenarios are evaluated, identified variously as DS1, DS2 and DS2A. The estimates of peak flow and runoff volume in each case are estimated at the notional downstream exit point for runoff from each of the three developed areas. The runoff generated off these development footprints with the catchment in the pre-development condition are identified as OS1, OS2 and OS2A respectively.

The analysis has proceeded on the basis that the OS1, OS2 and OS2A cases are assessed for the ARI 100 year rainfall both with and without climate change. This approach has been adopted in order that the full effects of climate change in the types of developments considered in the DS1, DS2 and DS2A scenarios are more obvious. The post-development scenarios DS1, DS2 and DS2A include an allowance for climate change using a factor of 1.16 applied to rainfall. This enables the community to better understand the likely effects on themselves of each development with respect to climate change.

Finally, an estimate of the gain for each scenario is made; here gain is described as the ratio of the post-development runoff volume over the pre-development runoff volume expressed as a percentage.

The assessment has employed the hydrological model HEC-HMS on sub-catchment B using ARI 100 year rainfall depth of 10, 20, 30 min, 1, 2, 6 and 12 hours obtained from HIRDS V4 (Historical) along the ridge line at the head of the catchment (refer Appendix 2), and from this compiled a 12 hour nested storm rainfall profile of the form prescribed in the Cardno publication “ Reference Guide for Design Storm Hydrology “ prepared for Wellington Water Ltd (Cardno, 9 April 2019). As noted in the preceding paragraph the rainfall applied to the OS1, OS2 and OS2A runs was carried out both with and without the effects of climate change, whereas those for runs DS1, DS2 and DS2A were scaled up by 16% to allow for climate change effects. [Excluding climate change in the OS cases aligns with Waikato Regional Council TR2018/02 (p8) “pre-development data should not be adjusted for climate change while post development rainfall data should be adjusted for climate change ”].

The hydrological model employs the SCS method and in line with the procedure set out in Cardno (2019) initial abstraction is set at 0.1S. A series of single-ring infiltration tests were carried out in a forested catchment area in Elmslie Road, Pinehaven, and also in Sub-catchment B. The infiltration rates in the two areas were very similar. In July 2019, double-ring infiltrometer tests were carried out in the same forested locations in Elmslie Road as the previous single-ring tests to provide representative infiltration rates for the forest floor in Sub-catchment B. Double-ring infiltration rates ranging from 516 to 912 mm / hr. and averaging 743mm / hr. were obtained.

A CN of 37 was adopted on the basis of these test results assuming an AMC II condition with the soils in good hydrological condition, well forested and not grazed and reference to the US Dept. of Agricultures publication Part 630 Hydrology: National Engineering Handbook (2007), Chapter 7 Tables 7 - 1 and 7 – 2. This approach is consistent with Appendix B of Cardno (2019) which recommends a CN value for forested areas on Soil Type A at 26, rising to 46 on Soil Type B. Applying this CN value to the OS1, OS2 and OS2A scenarios produced ARI 100 yr 12 hour (no climate change) peak runoff values of 2.7, 1.0 and 1.3 cumec respectively giving ARI 100 year specific discharges of 3.6, 3.7 and 3.7 cumecs per square kilometer. An independent check was then carried out on the neighboring Mangaroa River ARI 100 year specific flood discharge at the Te Marua hydrometric site which yielded a value of 3.45 cumec / square kilometer [" Mangaroa River Flood Hazard Assessment" GWRC - Mangaroa Hydraulic Modelling Report AC04609 / Rev F, 6 November 2015). Further to that, the Waikato Regional Council procedure set out in TR2018/02 requires an adjustment to the pre-development CN number for the effects of compaction on soil which is expected to occur as a consequence of development on the pervious area that will be present in the subdivision once development takes place. The effect of such compaction is accounted for by raising the CN number for these areas which, in combination with the associated impervious areas that result in the development, yields a composite CN for the post -development condition. A CN number of 64.5 has been adopted for the post-development pervious areas which in conjunction with a CN number of 98 for the impervious areas yields composite post-development CN numbers of 82, 82 and 90 for development scenarios DS1, DS2 and DS2A respectively.

As noted above three future development scenarios were considered in this assessment, variously DS1, DS2 and DS2A. The ARI 100 year 12 hour nested storm runoff from these scenarios in terms of both runoff volume and peak runoff were compared with those for the pre-development condition on the respective footprints OS1, OS2 and OS2A and from that their various yields calculated, the results of which are set out in Table 1 to Table 4 inclusive.

4.0 Development Scenarios - Results

4.1 Pre development without climate change (Table 1 and Table 2)

Table 1 - Results - 100 year ARI Peak Runoff from the Developed Areas

	Peak Runoff (m3/s)								
	DS1 - Extensive Low Density (74.4 ha)			DS2 - Low Density Along Ridge (23.7 ha)			DS2A - Medium Density Along Ridge (35.1 ha)		
Sub-catchment	OS1*	DS1†	DS1 Gain	OS2*	DS2†	DS2 Gain	OS2A *	DS2A †	DS2A Gain
A	1.7	12.1	700%	0.6	4.0	630%	0.8	6.6	792%
B	2.7	18.9	700%	1.0	6.3	630%	1.3	10.3	792%
C	0.9	6.6	700%	0.3	2.2	630%	0.5	3.6	792%
E	1.4	9.9	700%	0.5	3.3	630%	0.7	5.4	792%
I	0.5	3.6	700%	0.2	1.2	630%	0.2	2.0	792%

* existing situation - no climate change

† 16% added to rainfall for climate change (ARI 100yr)

Table 2 - Results - 100 year ARI Runoff Volume from the Developed Areas

	Runoff Volume (m3)								
	DS1 - Extensive Low Density (74.4 ha)			DS2 - Low Density Along Ridge (23.7 ha)			DS2A - Medium Density Along Ridge (35.1 ha)		
Sub-catchment	OS1*	DS1†	DS1 Gain	OS2*	DS2†	DS2 Gain	OS2A*	DS2A†	DS2A Gain
A	9,835	62,717	638%	3,163	20,000	632%	4,651	34,330	738%
B	15,405	98,235	638%	4,954	31,327	632%	7,285	53,771	738%
C	5,342	34,065	638%	1,718	10,863	632%	2,526	18,646	738%
E	8,075	51,494	638%	2,597	16,421	632%	3,819	28,186	738%
I	2,940	18,749	638%	946	5,979	632%	1,390	10,263	738%
Total	41,598	265,261		13,377	84,591		19,671	145,196	

* existing situation - no climate change

† 16% added to rainfall for climate change (ARI 100yr)

NB: “pre-development rainfall data should not be adjusted for climate change while post-development rainfall data should be adjusted for climate change” refer Waikato Regional Council - 'Waikato Stormwater Runoff Modelling Guideline" Technical Report 2018/02, p8.

4.2 Pre development scenarios with climate change (Table 3 and Table 4)

Table 3 - Results - 100 year ARI Peak Runoff from the Developed Areas

	Peak Runoff (m3/s)								
	DS1 - Extensive Low Density (74.4 ha)			DS2 - Low Density Along Ridge (23.7 ha)			DS2A - Medium Density Along Ridge (35.1 ha)		
Sub-catchment	OS1†	DS1†	DS1 Gain	OS2†	DS2†	DS2 Gain	OS2A †	DS2A †	DS2A Gain
A	2.5	12.1	485%	0.9	4.0	450%	1.2	6.6	542%
B	3.9	18.9	485%	1.4	6.3	450%	1.9	10.3	542%
C	1.4	6.6	485%	0.5	2.2	450%	0.7	3.6	542%
E	2.0	9.9	485%	0.7	3.3	450%	1.0	5.4	542%
I	0.7	3.6	485%	0.3	1.2	450%	0.4	2.0	542%

† 16% added to rainfall for climate change (ARI 100yr)

Table 4 - Results - 100 year ARI Runoff Volume from the Developed Areas

	Runoff Volume (m3)								
	DS1 - Extensive Low Density (74.4 ha)			DS2 - Low Density Along Ridge (23.7 ha)			DS2A - Medium Density Along Ridge (35.1 ha)		
Sub-catchment	OS1†	DS1†	DS1 Gain	OS2†	DS2†	DS2 Gain	OS2A †	DS2A †	DS2A Gain
A	14,182	62,717	442%	4,558	20,000	439%	6,716	34,330	512%
B	22,214	98,235	442%	7,139	31,327	439%	10,503	53,771	512%
C	7,703	34,065	442%	2,475	10,863	439%	3,642	18,646	512%
E	11,644	51,494	442%	3,742	16,421	439%	5,506	28,186	512%
I	4,240	18,749	442%	1,363	5,979	439%	2,005	10,263	512%
Total	59,984	265,261		19,277	84,591		28,361	145,196	

† 16% added to rainfall for climate change (ARI 100yr)

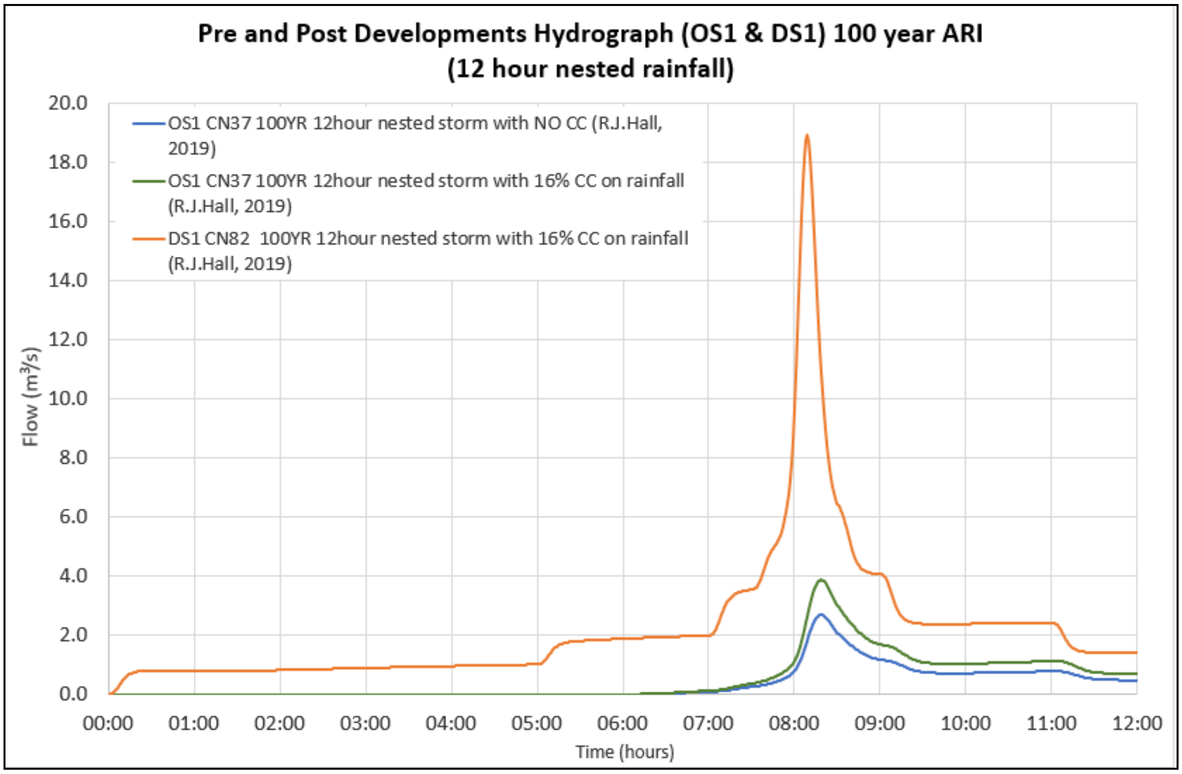


Figure 11- Pre and Post Development OS1 and DS1 Hydrographs

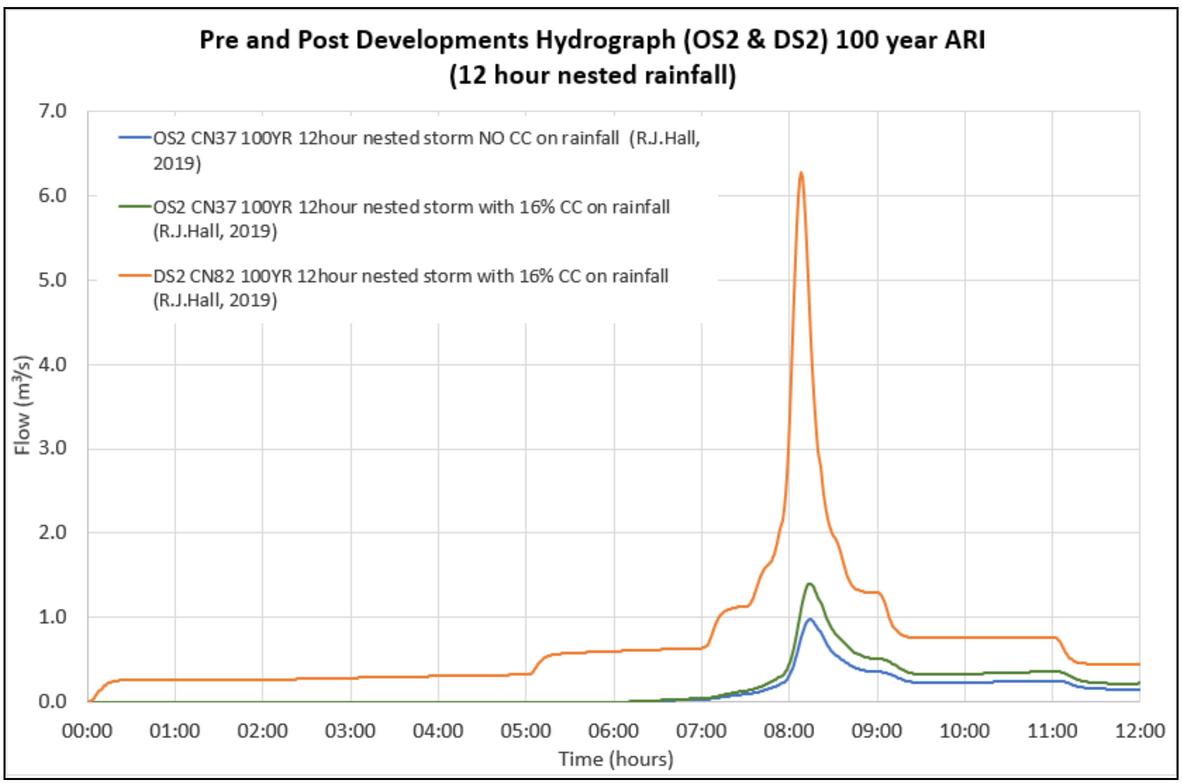


Figure 12 - Pre and Post Development OS2 and DS2 Hydrographs

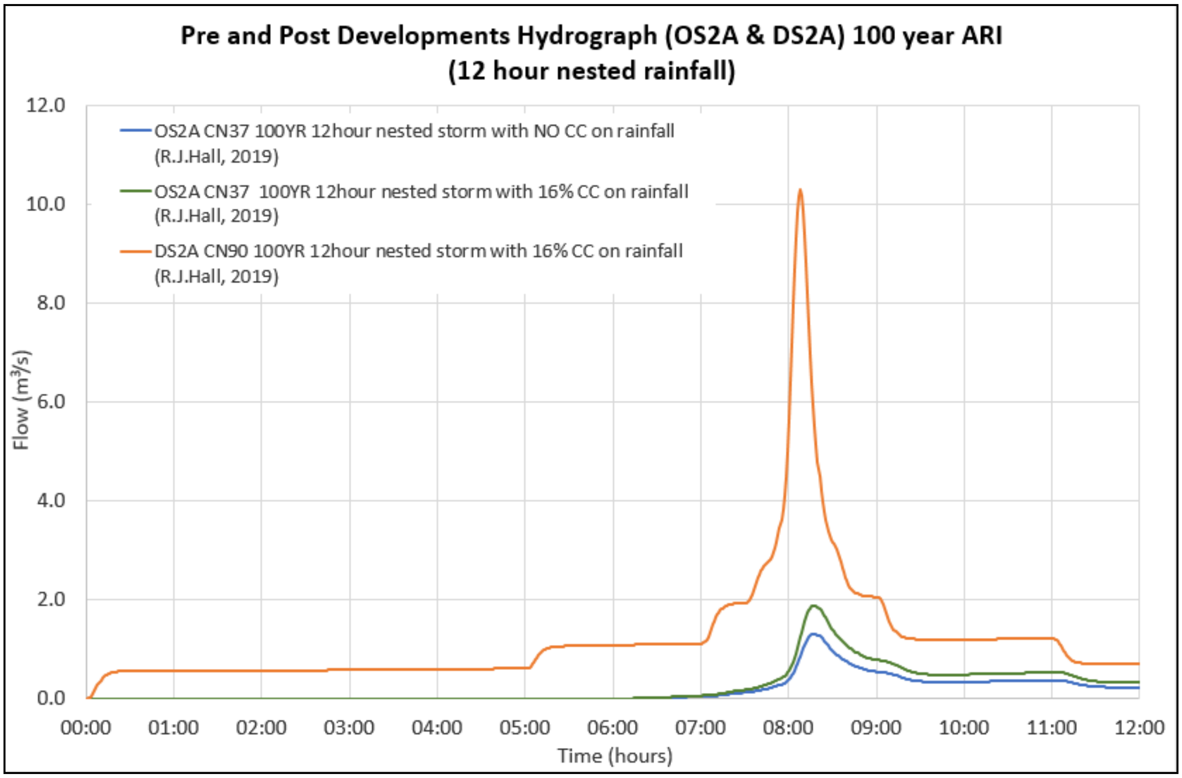


Figure 13 - Pre and Post Development OS2A and DS2A Hydrographs

The earlier studies by SKM, Beca and Jacobs conclude there will be only 1,160m^3 increase in flood volume in the DS2 scenario, i.e. 202,450 m^3 increasing to 203,610 m^3, an increase of about 0.5% (see Figure 8 above) from unmitigated runoff from future Guildford development in the upper Pinehaven catchment.

This present study finds (when the pre-development case is assessed <u>without</u> climate change) the increase in unmitigated runoff for the DS2 scenario is 71,214 m^3 (i.e. 13,377 m^3 increasing to 84,591 m^3, a gain of 632%), and for the DS2A scenario it is 125,525 m^3 (i.e. 19,671 m^3 increasing to 145,196 m^3, a gain of 738% - see Table 2 above). The 0.5% increase in flood volume supposed by Beca and Jacobs will, in reality, be more than 600% increase in flood volume.

When the pre-development case is assessed with an allowance for climate change, the increase in unmitigated runoff for the DS2 scenario is 65,313 m^3 (i.e. 19,278 m^3 increasing to 84,591 m^3, a gain of 438%), and for the DS2A scenario it is 116,834 m^3 (i.e. 28,362 m^3 increasing to 145,196 m^3, a gain of 511% - see Table 2 above). The 0.5% increase in flood volume supposed by Beca and Jacobs will, in reality, be more than 400% increase in flood volume.

The reason these significant increases in flood volume do not show up in SKM's 2010 comparison map of pre- and post- development flood extents (Figure 4 above) is that the blue baseline pre-development flood extents have been grossly over-estimated, and the green post-development flood extents have been grossly under-estimated.

The significant discrepancies in the baseline modelling in the earlier studies by MWH, SKM, Beca and Jacobs mean that the hydraulic neutrality provisions in the proposed Plan Change 42 will not be effective if the current flood modelling is used as the baseline for assessing post-development increases in peak flow and flood volume.

The flood modelling in the earlier studies by MWH, SKM, Beca and Jacobs should be independently examined and corrected before any reliance is placed upon it as the baseline modelling for assessing post-development runoff of future Guildford development in the upper Pinehaven catchment or any other such development proposal.

5.0 OS1 and DS1 Hydrograph Comparisons (Jacobs (2016) and R.J.Hall and Associates Ltd (2019))

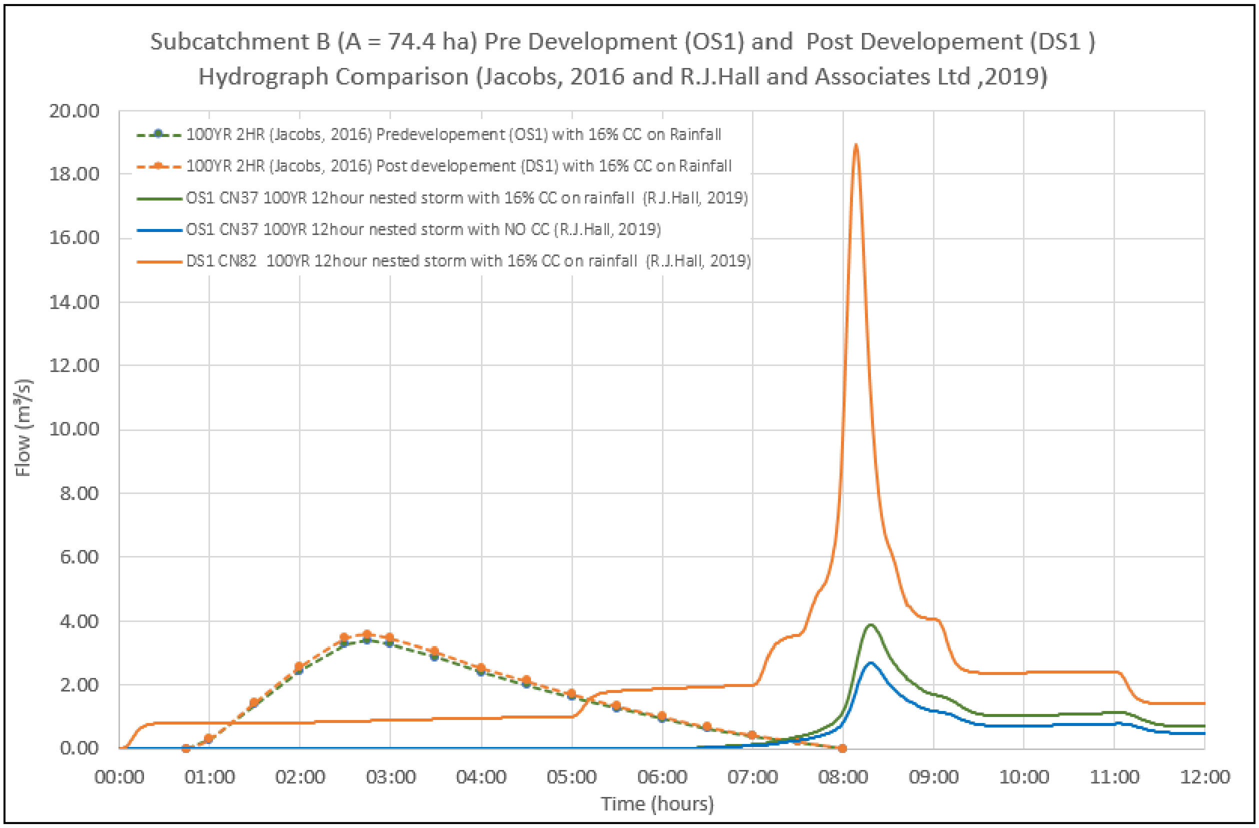


Figure 14 - Pre and Post Development OS1 and DS1 Hydrograph Comparison (Jacobs, 2016 and R.J.Hall and Associates Ltd, 2019)

6.0 Conclusion

A reappraisal of the hydrological implications of three development scenarios in the Pinehaven catchment have been undertaken for an ARI 100 year 12 hour nested rainfall pattern applied to these three development scenarios namely DS1, DS2 and DS2A with runoff volumes and peak flows compared with those for development footprints of OS1, OS2 and OS2A in the un-developed condition. The purpose of this exercise was to allow a comparison to be made between previous work undertaken variously by MWH (2008, 2009), SKM (2010) Beca (2015) and Jacobs (2016) on behalf of Greater Wellington Regional Council. This earlier work consistently showed that the unmitigated runoff from the DS1 and DS2 scenarios would have relatively minor effects, a result which did not lie comfortably with the knowledge that the developments being considered are situated in a forested catchment where post-development runoff logically could be expected to be significantly greater than that in a similar sized rainstorm in the pre-development condition. The development areas being considered in these three scenarios are located along the ridge line at the head of the Pinehaven Catchment referenced as sub-catchments A, B, C, E and I. The approach taken was to evaluate peak flow and runoff volumes for each of the three scenarios in the post development condition and again from their footprints for the pre-development condition using Sub-catchment B as a seed. The hydrological model HEC HMS was employed for that purpose and then the responses for Sub-catchments A, C, E and I derived on a pro-rata basis using the ratio of the developed footprint for each case over that of the Sub-catchment B developed footprint to derive representative values for each situation including the existing pre-development situation.

This present analysis shows that the post-development runoff volume and peak discharges for each of the development scenarios DS1, DS2 and DS2A greatly exceed their respective pre-development values for the design storm being considered.

This result is markedly different to that derived from the earlier work by MWH (2008, 2009), SKM (2010), Beca (2015) and Jacobs (2016) undertaken on behalf of Greater Wellington Regional Council. This difference is seen in a substantive reduction in runoff in the pre-development situation particularly evident in the runoff volumes and as a marked increase in runoff peak flows in the post-development situation. The principal reason for this result is considered to arise as a consequence of the application of unrepresentative initial abstraction and continuing losses for the soils in the sub-catchments being examined that were being applied in the earlier work, in effect the values selected and used in that work are not representative of the soils and current land use in the catchment and grossly underestimate the losses that can be expected from such soils and land use.

A second reason is that, in the earlier studies, the post-development runoff has not been assessed at source.

A third reason is that, in the earlier studies, the unmitigated runoff has been assessed for a 2hr storm.

Sub-catchments A, B, C, E and I are part of what is referred to as the Guildford development but that development although located along the Pinehaven catchment ridge line nevertheless extends beyond the Pinehaven catchment boundary (refer Appendix 3). When those parts of the Guildford development are included in the assessment using the results derived for the pre and post development situations as described above, it is provisionally estimated that the total increase in runoff (peak flows and runoff volume) in the DS2A scenario for example when applied over that greater area will be in the order of twice what it would be for the Pinehaven Sub-catchments A, B, C, E and I alone. This occurs because the Guildford development area is estimated to be in the order of 198 ha whereas the summed area for Sub-catchments A, B, C, E and I is in the order of 95 ha.

The results of this analysis have implications for hydrological characteristics beyond increases in peak runoff and volume. The high infiltration rate identified for the forested catchment means that substantial volumes of water during rainstorms percolate into the catchment soils and are steadily released over time and support stream flow. If development on the style and scale are undertaken in this catchment in the manner examined in this report then there are likely to be significant impacts on normal and low flow stream flow because of the loss of infiltration opportunity on the developed areas during rainstorms of all intensities, durations and recurrence intervals.

The results of the earlier studies by MWH, SKM, Beca and Jacobs were used to provide and validate hydrological inputs to hydraulic models in order to demonstrate the likely scale of effects on the distribution and passage of flood water arising from an ARI 100 year rainstorm in the Pinehaven catchment.

Given the substantive discrepancies in those earlier studies in the hydrological pre- and post-development runoff values for peak flow and runoff volume that have been revealed in this present study, no reliance should be placed on the efficacy of the flood mapping results that were associated with that earlier work by MWH, SKM, Beca and Jacobs.

R.J.Hall

CMEngNZ (Civil) CPEng Int PE (NZ)., MNZSESOC.

ME (Nat Res) BE (Civil) NZCE (Civil)

R.J.Hall & Associates Ltd.

References:

- Beca: "Pinehaven Stream – Flood Mapping Audit" 13 July 2015
- Boffa Miskell: "Guildford Timber Land Swap – Land Swap Discussion Document Prepared for Guildford Timber Company", 21 October 2015
- Jacobs: "Memorandum - Pinehaven Developments Scenarios 1 and 2" - 23 June 2016
- Law, M. (Beca): Letter dated 01 March 2017, from M. Law to Alistair Allan (Greater Wellington Regional Council) – Response to Jacobs 22 June 2016 revised Pinehaven development scenario update [titled Pinehaven Development Scenarios 1 and 2 (June 2016 memo)]
- Law, M.: "Statement of Evidence of MICHAEL CHARLES LAW, 23 August 2017" - Proposed Plan Change 42 to the Upper Hutt City Council District Plan (2004) – Mangaroa and Pinehaven Flood Hazard Extents
- MWH: "Greater Wellington Regional Council - Pinehaven Stream Flood Hydrology" 4 November 2008, revised 25 November 2009
- SKM: "Pinehaven Stream Flood Hazard Assessment – Flood Hazard Investigation Report, Volumes 1 and 2, Revision E, 25 May 2010
- Upper Hutt City Council: "Land Use Strategy 2016 – 2043", adopted September 2016

Appendix 1 – HEC HMS Modelling Parameters

Appendix 1: HEC HMS Modelling Parameters

Hydrological Model Set Up (for modelling Sub-catchment B, Pinehaven Stream)

Software	Version	Loss Method	Transformation Method	Initial Abstraction	Curve Number	AMC	Time of Concentration	Rainfall Method	Nested Storm	Time Intervals
HEC-HMS	4.3	SCS Curve Number	SCS Unit Hydrograph	Absolute value (mm)	Varies	II	Lag = 0.6 x Tc	Specified Hyetograph	12 hr (peak at 67%)	5 min

Parameters used in HEC-HMS model

	OS1	DS1	OS2	DS2	OS2a	DS2a
BASIN						
Total Area (ha)	74.4	74.4	23.7	23.7	35.1	35.1
Impervious Area (ha)	0	38.1	0	12.3	0	26.7
Pervious Area (ha)	74.4	36.3	23.7	11.4	35.1	8.4
LOSS						
Initial Abstraction (mm)	43.25	43.25	43.25	43.25	43.25	43.25
Pervious Curve Number (Op. 1)	37	37	37	37	37	37
Pervious Curve Number (Op. 2)	37	65	37	65	37	65
Impervious Percentage	0	52	0	52	0	76
TRANSFORM						
Graph Type	Std	Std	Std	Std	Std	Std
Lag Time, 2/3 Tc (min)	0	0	0	0	0	0

Rainfall

12 Hour, 100YR Nested Storm - See "NestedStorm" worksheet

12 Hour, 100YR Nested Storm +16% (CC) -See "NestedStorm" worksheet

Appendix 2 – HEC HMS – Pinehaven Sub-catchment B – Inputs

Appendix 2: HEC-HMS - Pinehaven Sub-catchment B - Inputs

Rainfall - HIRDS v4 (Historical Data) - Location: Top of Sub-catchment B

Storm Duration		10 mim	20 min	30 min	1 hr	2 hr	6 hr	12 hr	24 hr
ARI 100yr	(no CC)	19.5	27.4	33.6	47.4	66.8	112.0	151.0	199.0
		1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
ARI 100yr	16% CC	22.6	31.8	39.0	55.0	77.5	129.9	175.2	230.8

Development Scenario DS1 - Extensive Low-Density Development - Lot sizes 750m2

OS1 (Pre-Development)						DS1 (Post-Development)								
Area (km2)	Tc (min)	Lag time (min)	CN	Ia (mm)	Impervious Area %	Pervious Area (km2)	Impervious Area (km2)	Tc (min)	Lag time (min)	Pervious CN	Impervious CN	Composite CN	Ia (mm)	Impervious Area %
0.744	24	16	37	43	0	0.363	0.381			64.5	98	82	2.5	0
							51%							

Weigthed Ia = (0.1 x Str x Ar) + (0mm x Ai) + (5mm X Ap)

Weighted Ia = 0 + (0mm x 51%) + (5mm x 49%) = 2.5 mm

Development Scenario DS2 - Low-Density Development Along Ridges - Lot sizes 750m2

OS2 (Pre-Development)						DS2 (Post-Development)								
Area (km2)	Tc (min)	Lag time (min)	CN	Ia (mm)	Impervious Area %	Pervious Area (km2)	Impervious Area (km2)	Tc (min)	Lag time (min)	Pervious CN	Impervious CN	Composite CN	Ia (mm)	Impervious Area %
0.237			37	43	0	0.114	0.123			64.5	98	82	2.4	0
							52%							

Weigthed Ia = (0.1 x Str x Ar) + (0mm x Ai) + (5mm X Ap)

Weighted Ia = 0 + (0mm x 52%) + (5mm x 48%) = 2.4 mm

Development Scenario DS2A - Medium-Density Development Along Ridges - Average Lot size 350m2

OS2A (Pre-Development)						DS2A (Post-Development)								
Area (km2)	Tc (min)	Lag time (min)	CN	Ia (mm)	Impervious Area %	Pervious Area (km2)	Impervious Area (km2)	Tc (min)	Lag time (min)	Pervious CN	Impervious CN	Composite CN	Ia (mm)	Impervious Area %
0.351			37	43	0	0.084	0.267			64.5	98	90	1.2	0
							76%							

Cardno - Appendix B - Curve Number table:
Pervious CN37 = Forest (in Good condition)
- Mid-way between Soil Group A (CN28) and Soil Group B (CN46)

Cardno - Appendix B - Curve Number table:
Pervious CN64.5 = Urban Open Space (in Good condition)
- Mid-way between Soil Group B (CN59) and Soil Group C (CN72)

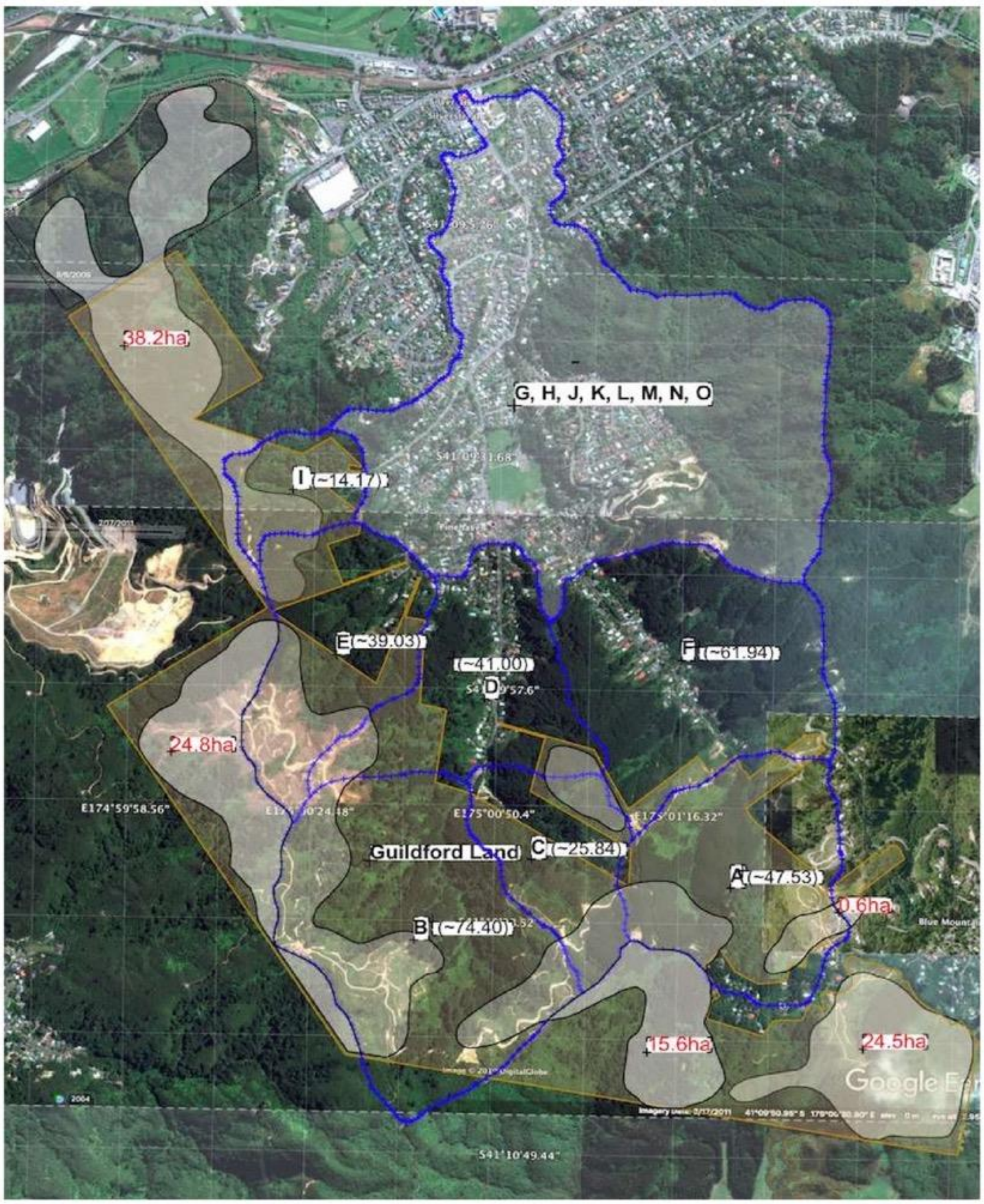
Weigthed Ia = (0.1 x Str x Ar) + (0mm x Ai) + (5mm X Ap)

Weighted Ia = 0 + (0mm x 76%) + (5mm x 24%) = 1.2 mm

Appendix 3 – Guildford Timber Company - Development Concept

Compiled by Save Our Hills from various source information in the public realm by MWH, SKM, Boffa Miskell, Jacobs, Greater Wellington Regional Council (GWRC) and Upper Hutt City Council (UHCC).

Potential GTC Development OUTSIDE the Pinehaven Stream catchment area



Proposed GTC Development
(Concept development areas combined from Guildford 2007 flyer and UHCC 2016 Land Use Strategy)

GTC Development areas outside the Pinehaven Stream catchment area:	
Location:	GTC Development areas outside of the Pinehaven Stream catchment area: (ha) approx.
Hills above Silverstream	38.2
Hills above Stokes Valley	24.8
Hills above Whitemans Valley	40.7
Sub-total (ha) approx.	**103.7**

Location:	DS2A - development in Pinehaven Stream catchment area (ha) approx.
Sub-total (sub-catch A, B, C, E & I) (ha) approx.	**94.6**

Possible Total Development Area (ha) approx.	**198.3**

<u>SOH (September 2017) Hearing Statement – Guildford Future Development:</u>

The following 4 pages are from Save Our Hills' (SOH) hearing statement - Upper Hutt City Council (UHCC) – on proposed Plan Change 42: Mangaroa and Pinehaven Flood Hazard Extents, held at UHCC on 27th – 29th September 2017 (statement edited October 2019).

It is an analysis by SOH (S. Pattinson, Registered Architect, B. Arch, M. Arch, ANZIA) of the possible number of new dwellings indicated in Guildford Timber Company's (GTC) flyer titled "A Master-Planned Approach to Creating the Vision" circulated to Pinehaven residents (2007). A GTC Director indicated publicly in 2015 and 2016 that GTC still want to develop this vision.

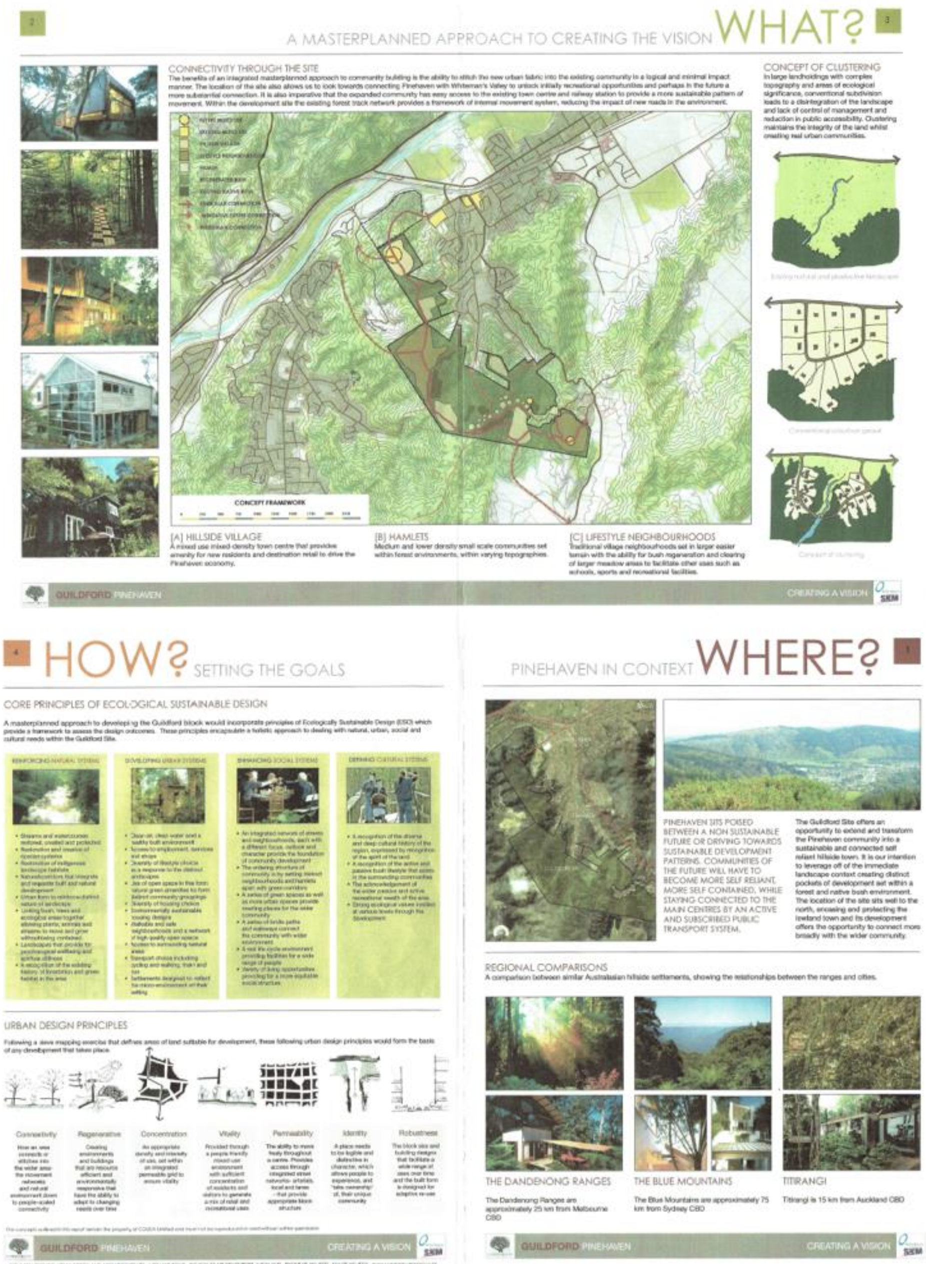
GTC's "A Master-Planned Approach to Creating the Vision" includes a significant amount of medium density housing. No official figures have been released by GTC or UHCC of the total number of new dwellings in GTC's vision, but they have suggested it is 1,000 to 1,500.

S. Pattinson is qualified to comment on the flyer about GTC's proposed master-planned vision. Following 20 years professional practice experience, S. Pattinson carried out 2 years full-time university research from 2009 to 2011 on medium density housing, visiting over 200 medium density developments in Auckland, Wellington, Christchurch and Melbourne. S. Pattinson estimates from information made publicly available to date by GTC and UHCC that the GTC development area may total 173ha to 198ha consisting of around 3,000 or more dwellings (including apartments and medium density housing) plus retail, shops, offices and schools.

Future Development

To: Hearing Commissioner (Hearing: 27th to 29th September 2017) (edited October 2019)
From: Save Our Hills (Upper Hutt) Incorporated (SOH)

At the hearing, SOH presented information regarding future development intended in UHCC's 'Southern Growth Area' on the Guildford land as described in UHCC's Land Use Strategy 2016-2043, adopted September 2016. SOH have analysed the little information available in the public realm about the intended Guildford development, mainly from a double-sided A3-size flyer delivered in letterboxes to local residents in 2007:



A3-size Flyer about Guildford Concept, delivered in letterboxes to local residents in 2007:

Later information released about the Guildford development in UHCC's Land Use Strategy is vague and adds virtually nothing to the information in the above flyer. At a public meeting in Pinehaven School Hall (2015 and at a Pinehaven Focus Group meeting in Silverstream in April 2016, Ralph Goodwin, a Director of Guildford Timber Company (GTC), commented that GTC still intend to progress the vision conveyed in the above A3-size flyer. No details have been released by GTC or UHCC about the number of houses intended, other than UHCC's 2007 Urban Growth Strategy suggesting about 1,500 dwellings, SKM's future case scenario testing the effect of 1,665 dwellings on flooding, and UHCC's Land Use Strategy 2016 commenting that "*the exact nature of the development and location of housing is yet to be determined, but it is anticipated that the likely yield from the development would be around 1,000 dwellings" (UHCC LUS 2016,* p80).

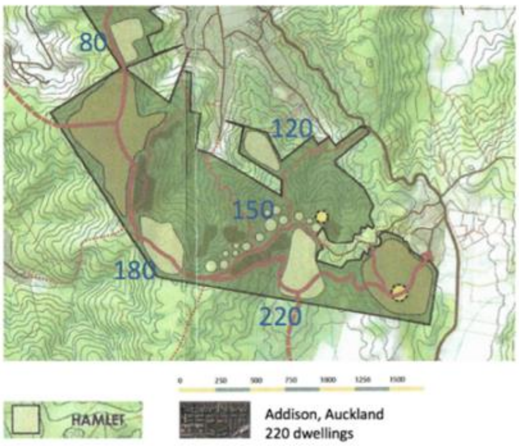
SOH thinks that Council is downplaying the actual intended size of and yield from the proposed development. SOH's analysis of the concept shown and described in the above A3-size flyer suggests the number of dwellings is more likely to be in the range of 2,500 to 3,500, plus possible big-box retail, shops, offices, apartments and schools. This guestimate is based on a careful reading of the descriptions in the A3-size flyer of the various residential and commercial typologies identified in the colour-coded legend, measurement of the land areas on the map associated with each colour, and a reasonable estimate of the densities proposed for each typology based on the descriptions given.

For example, the GTC concept map shows a "mixed-use" town centre. SOH show illustrations of what "mixed-use" means, the proposed area (equivalent to the area bounded in red, from Whitemans Rd to Gloucester St, and Gard St to Chatsworth Rd), and a portion (240 dwellings) of Beaumont Quarter, Auckland, shown at the same scale as the GTC concept map, suggesting GTC's proposed town centre (four times the area of 240 dwellings at Beaumont Quarter) might represent about 800 apartments plus some shops and offices, possibly even some big-box retail).

HAMLETS = 750 ?

On the Guildford concept plan, four "hamlets" are shown, and a scattering of 'clusters', which may total 700-800 dwellings approx.

Addison, Auc



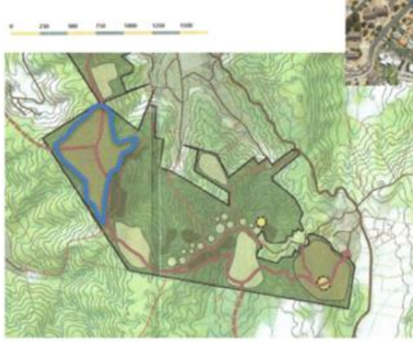
[B] HAMLETS
Medium and lower density small scale communities set within forest environments, within varying topographies.

The GTC plan shows four clusters of "Hamlets", described as "medium density". SOH shows an example of "medium density from Addison, Auckland.

Measuring the shaded areas described as "hamlets", and applying a typical density for this housing typology, SOH estimates that "hamlets" might total around 700 – 800 dwellings.

GTC's "Lifestyle Neighbourhoods" suggest suburban housing, and the area suggests around 800 dwellings (based on comparison with similar housing and area at Port Phillip, Victoria, Aust.)

Quote: "Within the development site the existing forest track network provides a framework of internal movement, reducing the impact of new roads in the environment"



City of Port Phillip, Victoria, Australia

Assume roughly 500 + 300 = 800 'suburban' dwellings, plus maybe a few hundred very low-density lifestyle lots on the steeper land among the trees.

LIFESTYLE NEIGHBOURHOOD

[C] LIFESTYLE NEIGHBOURHOODS
Traditional village neighbourhoods set in larger easier terrain with the ability for bush regeneration and clearing of larger meadow areas to facilitate other uses such as schools, sports and recreational facilities.

So a mixed-use town centre (with possibly about 700-800 apartments), plus ^ medium density hamlets (about 700-800 dwellings), plus lifestyle neighbourhoods (about 800 dwellings) might total about 2,000 to 2,500 dwellings, plus the flyer mentions retail, schools and recreational facilities.

In addition, UHCC's Land Use Strategy 2016 describes a Land Swap which, if carried out, would enable GTC to build further medium-density housing on the Silverstream Spur (35ha).

It is therefore difficult to know just what GTC and UHCC intend the eventual yield from the proposed development to be, but SOH suggests that it would be naïve to assume it is anything less than 2,500 to 3,500 dwellings, plus retail, offices and schools ^ and including medium density development on sub-catchment B.

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Appendix 4 - Extracts from Michael Law's Audit and Statement of Evidence (relating to SKM and Jacobs Pinehaven 'future development' scenarios)

In Beca's "Pinehaven Stream Flood Mapping Audit" (2015) the auditor, Michael Law, acknowledged but dismissed an error in the way the effect of future development was modelled:

"... it is prudent to assess the effects of possible future development when undertaking flood mapping and hazards studies. To that end, SKM ran the model with reworked hydrographs to represent the additional impervious area associated with the development of 1665 lots of 750 m2 in the upper parts of the catchment. ... However, ***there is no post-development increase in flood volumes. This is unexpected given the increase in impermeable area. MWH were unable to provide an explanation for the lack of increase in flood volume, and so the future development runs of SKM's flood model are potentially compromised in this regard.****"*
Beca "Pinehaven Stream Flood Mapping Audit" 2015, p9 – (emphasis by RJ Hall & Assoc. Ltd)

"The Save Our Hills (SOH) group ... has expressed strongly held concerns ... regarding ... Future development ... SOH noted the small differences between the existing and future development flood extents for the 100-year ARI including climate change event, as shown in Figure 19 of Volume 1 of SKM's Pinehaven Stream Flood Hazard Assessment report [see RJH Figure 4] ... while SKM's modelling of future development resulted in an increase in modelled peak flows, there was not the expected increase in flood volume. SKM used hydrology provided by MWH. However, MWH have not provided an explanation as to why there is no increase in future development flood volumes . Therefore, ***SOH's concerns are upheld that the effects of future development on flood extent are not modelled correctly. However ... the flood maps are unlikely to be materially affected by this apparent anomaly."*** *Beca "Pinehaven Stream Flood Mapping Audit" 2015, pp14,16,17 – (emphasis by RJ Hall & Assoc. Ltd)*

"Figure 8.1 [see RJH Figure 5] shows the change in flood hydrographs for existing development ... and future development ... for sub-catchment B, which is in the southwest of the catchment and drains to the top of Pinehaven Road. Future development increases the peak flow by 18% (from 3.07 m3 /s to 3.64 m3 /s), ... However, ***the flood volume does not increase. This is unexpected, as increasing the impervious area of sub-catchment by 40% to reflect the development would be expected to reduce rainfall losses and increase runoff volume.*** *Similar results were found for sub-catchment E, which drains to Wyndham Road. Assuming a 100-year ARI plus climate change rainfall depth of 87.1 mm for the 3-hour storm, an Initial Loss of 5mm, Ongoing Loss of 2mm/hr, and 40% impermeable area for the affected post-development sub-catchments, then* ***the effective rainfall depths would be 76.7mm (88%) for existing land use, 80.8mm (93%) for post-development land use … only 5.6% increase in effective rainfall post-development. …***

The difference between existing and post-development flood volumes would be expected to be a similar ratio. *… The issue of no increase in post-development flood volume was raised with MWH, but they have not been able to provide an explanation as to why there is not an increase in flood volume. While this does not affect the validity of flood extents defined for current development,* ***it does invalidate the post-development flood extents and reduces community confidence in the flood mapping process."*** *Beca "Pinehaven Stream Flood Mapping Audit" 2015, pp26,27 – (emphasis by RJ Hall & Assoc. Ltd)*

Michael Law (Beca) - Letter (01 March 2017) to Alistair Allan, Greater Wellington Regional Council - M. Law provides his findings of his review of Jacobs' Memorandum (June 2016):

"I have not reviewed the modelling or raw results of the additional model runs, and so my comments are restricted to the memo and accompanying maps …

"The revised peak flows and flood volumes provided by Jacobs indicate that peak flows will increase by about 3% ***and flood volumes by about 6% in the affected sub-catchments if development proceeds. The increase in flood volume is about the same as I estimated it would be in … the 2015 audit."***

In August 2017 Michael Law stated that SKM's error in the flood modelling had been corrected by Jacobs:

"40. During the audit, I noted an error in the way that future development had been modelled. ***This was subsequently corrected."***

"60. As raised by Submitter #12 [SOH], my 2015 audit noted that there was a discrepancy in the way that sub-catchment flow hydrographs had been derived for a 'future development' scenario in the Pinehaven catchment. While there was an increase in peak flow, there was no anticipated increase in flood volume. This suggested that the ***future hydrology*** *had included an allowance for quicker post-development runoff, but* ***had not allowed for the additional runoff generated by increased impervious areas post-development … showing a less than expected difference between existing and 'future development' flood extents*** *provided by GWRC.*

"61. This was acknowledged by GWRC and in March 2017, ***GWRC's consultants (Jacobs) updated the 'future development' hydrology, and sent me the results for comment.*** *This included an updated flood extent difference map to indicate the effects of unmitigated future development. Following discussion and an exchange of correspondence* ***I am satisfied that Jacobs' reworking of the future development hydrology is appropriate.***

Statement of Evidence of Michael Charles Law 30 August 2017, paras. 40,60,61 (emphasis by RJ Hall & Associates Ltd) Upper Hutt City Council (UHCC) – Hearing for Proposed Plan Change 42 – Mangaroa and Pinehaven Flood Hazard Extents

Appendix 5 – Back-calculation for Jacobs' (2016) CN Values for Development Scenarios OS, DS1 and DS2 (Sub-catchment B)

R J Hall Summary (Jacobs' CN values for Scenarios OS, DS1 and DS2 - sub-catchment B):

Scenario OS (pre-development, 74.4ha forest and bush) = CN 96.2

Scenario DS1 (SKM, 2010, post-development, 74.4ha with 52% impervious) = CN 97.5

Scenario DS2 (Jacobs, 2016, post-development, 23.7ha with 51% impervious) = CN 96.7

By back-calculating Jacobs' figures RJ Hall and Associates Ltd find a CN value of 96 for the pre-development hydrology, which means the existing forested hills are treated by Jacobs as being more or less impermeable, and the runoff characteristics between pre and post development are almost indistinguishable. The effect of this is that when these pre and post development hydrographs are applied to the hydraulic model it is to be expected that this error will generate almost identical pre and post development flood extents. In essence this fundamental error by SKM 2010 persists also in Jacobs' 2016 reworking.

R J HALL AND ASSOCIATES LIMITED
Consulting Civil Engineers

File .... Computed RJ HALL REFS SHT 1
Job .... Date........ OF 3
Checked........ Plan ....
Date........ Survey ....

BACKCALCULATION OF CN FOR OS, DS1 & DS2 CASES FROM P & Pe.

CALCULATION SHEET

RAINFALL

Cf GWRC "PINEHAVEN STREAM FLOOD HYDROLOGY"
MWH (4 NOV 2008)

REF UHCC PINEHAVEN RAINGAUGE (1998 – AUTOMATIC)
GWRC TASMAN VACCUVE LTD RAINGAUGE (1980 – AUTOMATIC)

	PINEHAVEN RESERVE	TASMAN VACCUVE.
100YR – 2HR RAINFALL (NO CLIMATE CHANGE)	51 mm	61 mm

75% PINEHAVEN + 25% TASMAN VACCUVE $= ((0.75 \times 51) + (0.25 \times 61))$
$= 53.5$ mm

Cf 25 NOVEMBER 2009 REVISION OF MWH (NOV 2008) REPORT
TABLE 6.2 PINEHAVEN STREAM MODEL CALIBRATION RESULTS.

INITIAL LOSS (IL) = 5 mm
CONTINUING LOSSES = 2 mm
→ LOSSES 2HR STORM $= (5 + 2(2)) = 9$ mm

Cf JACOBS (2016) TABLE 1. SUBCATCHMENT "B"
(MEMO TO GWRC 23 JUNE 2016)

	OS	DS1	DS2
TOTAL VOLUME RUNOFF (m^3)	33080	35060	33560
RAINFALL EXCESS, P_e^* (mm)	44.5	47.1	45.1
Σ LOSSES (IL + CL)	9.0	(6.4)	(8.4)
100YR – 2HR – NoCC RAINFALL =	53.5 mm	53.5 mm	53.5 mm

* SUBCATCHMENT "B" AREA = 74.4 ha

RAINFALL EXCESS = (RUNOFF VOLUME / CATCHMENT AREA) EXPRESSED IN MILLIMETRES.

Corprint – HRLG

CALCULATION SHEET

(OS) $44.5 = \frac{(53.5 - 0.1S')^2}{(53.5 + 0.9S')}$

$2380.8 + 40.1S' = 2862.3 - 10.7S' + 0.01S'^2$

ie $0.01S^2 - 50.8S + 481.5 = 0$

$S' = \frac{50.8 \pm \sqrt{50.8^2 - (4 \times 0.01 \times 481.5)}}{0.02}$

$= \left(\frac{50.8 \pm 50.6}{0.02}\right)$

$= +10$ mm (or $+5070$).

$10.0 = \left(\frac{1000}{CN'} - 10\right) 25.4$

ie $CN' = 96.2$

(DS1) $47.1 = \frac{(53.5 - 0.1S'')^2}{(53.5 + 0.9S'')}$

$2519.9 + 42.4S'' = 2862.3 - 10.7S'' + 0.01S''^2$

$0.01S''^2 - 53.1S'' + 342.4 = 0$

$S'' = \frac{53.1 \pm \sqrt{53.1^2 - (4 \times 0.01 \times 342.4)}}{0.02}$

$= \left(\frac{53.1 \pm 53.0}{0.02}\right)$

$= 6.5$ mm

$6.5 = \left(\frac{1000}{CN''} - 10\right) 25.4$

ie $CN'' = 97.5$ * (THIS IS A COMPOSITE CN VALUE)

R J HALL AND ASSOCIATES LIMITED
Consulting Civil Engineers

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.... Date..................... Survey ....

CALCULATION SHEET

(DS2) $45.1 = \frac{(53.5 - 0.1S''')^2}{(53.5 + 0.9S''')}$

$2412.9 + 40.6S''' = 2862.3 - 10.7S''' + 0.01S'''^2$

$0.01S'''^2 - 51.3S''' + 449.4 = 0$

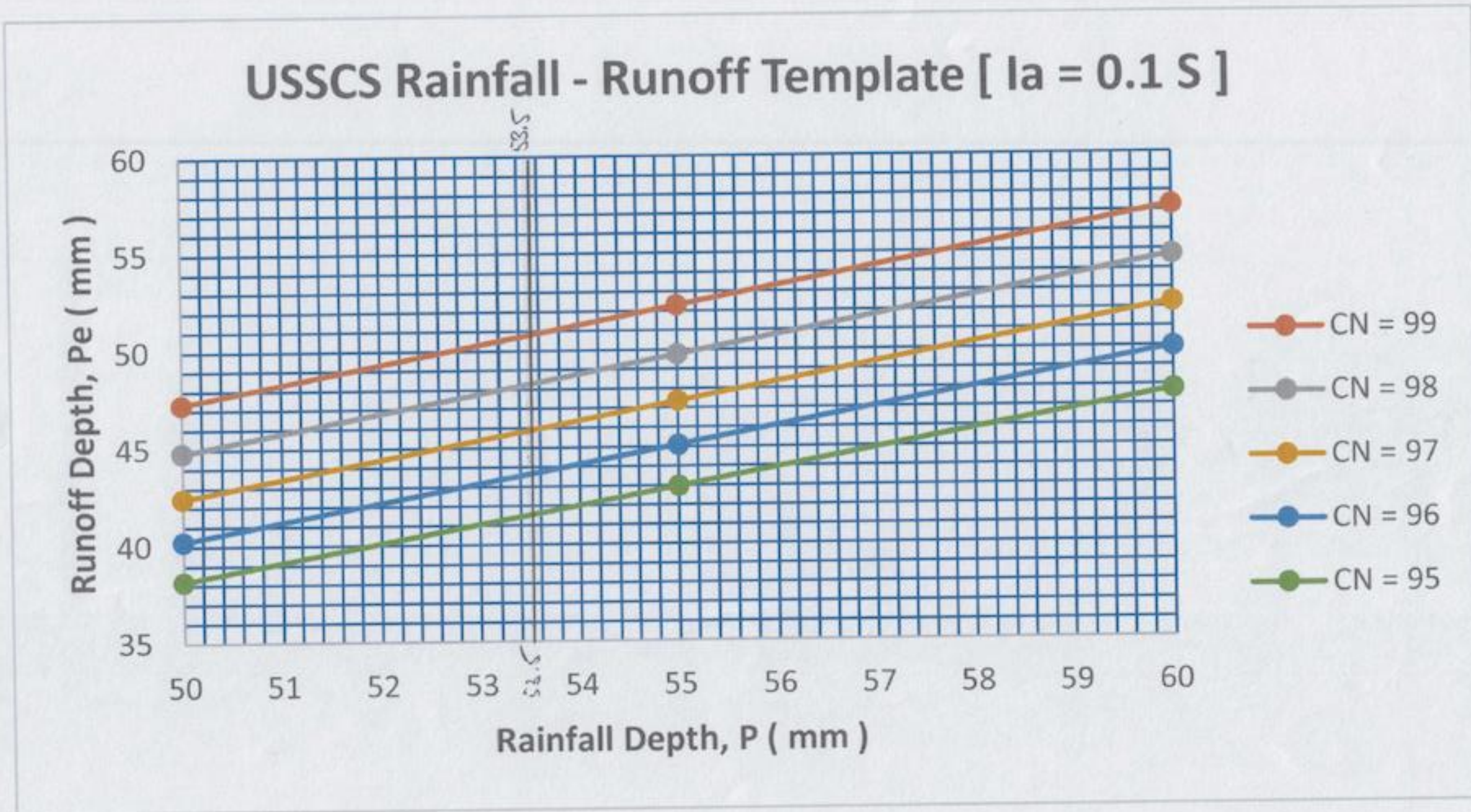
$S''' = \frac{51.3 \pm \sqrt{51.3^2 - (4 \times 0.01 \times 449.4)}}{0.02}$

$= \left(\frac{51.3 - 51.1}{0.02}\right)$

$= 8.8$ mm

$8.8 = \left(\frac{1000}{CN'''} - 10\right)25.4$

$\rightarrow CN''' = 96.7$ (THIS IS A COMPOSITE CN NUMBER)


USSCS Rainfall - Runoff Template [Ia = 0.1 S]
Runoff Depth, Pe (mm)
60
55
50
45
40
35
50
51
52
53
54
55
56
57
58
59
60
Rainfall Depth, P (mm)
CN = 99
CN = 98
CN = 97
CN = 96
CN = 95