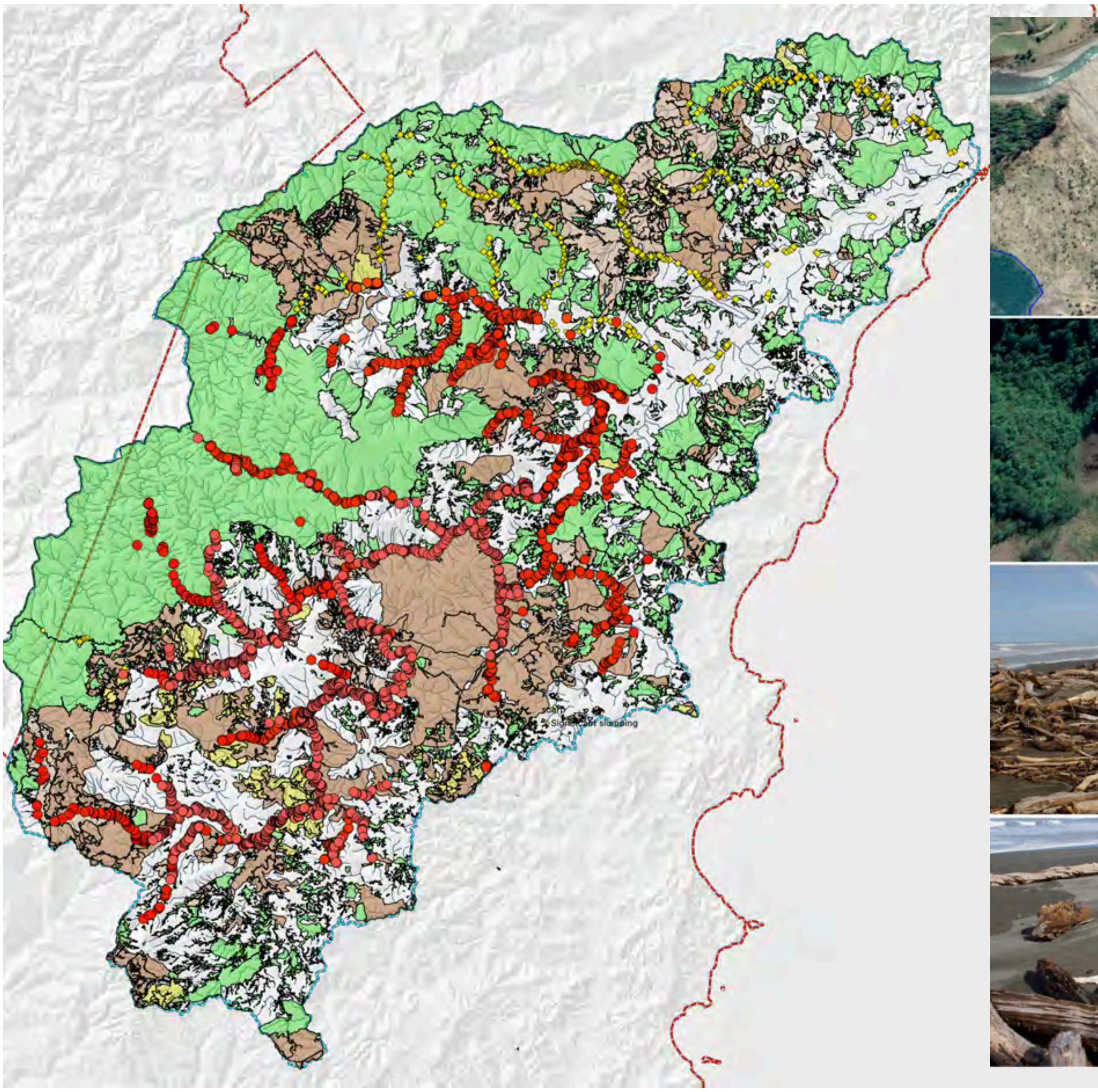
An assessment of Woody Material on Tikapa Beach after the July 2020 storm and potential sources within the Waiapu



Final report v3.5

Te Kaunihera o Te Tairāwhiti
GISBORNE
DISTRICT COUNCIL

Dr Murry Cave
Principal Scientist
Gisborne District Council
January 2021

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Final Report

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Executive Summary

The June–July 2020 storms, particularly that of 20-21st July resulted in the deposition of woody material on beaches across the region and refocussed national attention on the Tolaga Beaches in the Uawa Catchment. A helicopter flight as part of the food delivery at East Cape identified a range of other beaches with issues including, Tikapa Beach, Tokomaru Bay, and the south end of Waipiro Bay. Rapid assessments were undertaken at Tokomaru, Waipiro, and Anaura but getting on the ground at Tikapa Beach was delayed for a number of reasons including the closure of Waiomatatini Road, and the need to focus on landslide dam risk.

There was also media coverage about Tikapa Beach and reference was made to the effort put in by the forestry industry to clean up Tolaga Beach raising the question of whether the forestry companies should also clean up Tikapa. Although Waiomatatini road was closed, 4WD access was possible and the beach was visited on Sunday 23rd August 2020 to obtain a wood count at one location, and to get a better impression of overall woody material. A second visit was made with community members in October to undertake more log counts. Additionally, an analysis of potential sources of the debris has been taken of the Waiapu Catchment using satellite imagery.

This report confirms the view of the local community in establishing that wood waste material is having a significant visual and environmental impact on Tikapa Beach south of the Waiapu River. The situation is, however, rather different from that at Tolaga Bay in the Uawa catchment where successive assessments of the wood waste has pointed to the dominant role of pine-based woody material on the beach. An assessment of the quantities and types of wood waste at Tikapa was undertaken after the Queens Birthday storm of 2018 and that assessment has been repeated in 2020. These assessments, confirmed that the proportions of the different types of woody waste differs significantly from Tolaga Bay and also that the characteristics of the woody material is different.

The aggregate percentages of wood waste at Tikapa Beach in 2020 was pine at 41%, Indigenous 35%, willow and poplar 17% and other material such as fence posts and battens 7%. This contrasts with Tolaga Bay where 77.5% was pine, just over 5% was indigenous, just over 5% was willow or poplar and 12% was other material such as farm posts. One other difference not picked up is the difference in age of the woody material on Tikapa compared with Tolaga. Tolaga Bay beach has a far greater proportion of fresh material. At Tikapa Beach far more of the material comprised weathered logs irrespective of whether or not those were pine or indigenous. This same contrast was evident during a site inspection of the Tapuaeroa River where a lot of the material was weathered indicating that it had been in the catchment for some time (**Figure Seventy**). It is thus likely that much of the material observed in this assessment had been mobilised previously, most likely in 2017 (Cyclone Cook) or in 2018 (Queens Birthday storm), and was incrementally migrating to the beach during flood events.

Based on the situation in 2017 (Cave *et al* 2017) it was anticipated that it would not be possible to establish primary sources for the woody debris in the catchment and on the beach. It remains impossible to track woody material directly from a source to the beach. What could be established, however, was that the primary “hotspot” sites were on land that failed and thus caused woody material to mobilise which then migrated to watercourses and from there downstream. These hotspots comprised areas of indigenous forest and scrub, as well as pine. Further, there were multiple slope failure mechanisms as well as spatial differences in the distribution of the hotspots depending on land cover type and as a result, the volume of logs mobilised differed between hotspots.

The data shows that the southernmost Mata River catchment had far more slope failures and also generated a far greater volume of material than did the Tapuaeroa River catchment. This is not, in itself, surprising since the 21st July storm in particular was centred on Te Puia in the south of the Waiapu Catchment.

In the case of indigenous woody material, the main mechanisms for mobilising wood to the river system were threefold;

- the re-activation of gullies or the ongoing erosion of gullies adjacent to indigenous forest by attrition over time,
- the incremental addition of indigenous trees and scrub within stream banks resulting from small-scale scour, and
- mobilisation from large slips which are either re-activations or fresh slips that have toes connected to the stream.

For pine forests the failure mechanisms were more varied. While some were generated by gully erosion or by incremental failure of stream banks, ten out of fifteen failures were associated with forestry landings (skid sites) and roadways, as well as birds-nests in vulnerable locations and clear-felled slopes directly connected to waterways.

For those associated with landings, there are a few key elements for consideration.

Firstly, a number of the landing failures were strongly associated with severe pre-existing slope failures. The siting of operation sites such as landings and the construction of forestry roads on these pre-existing slope failures has exacerbated the risk of failure post-harvest or in the case of Aorangiwai during second rotation. In the case of the Aorangiwai failure, the landslide appears to have been triggered by a water table and a hairpin bend on a roadway directing water onto the headscarp of the pre-existing failure.

Secondly, most of these landing failures are associated with birds-nests that have been perched on the edge of landings. Birds-nests on landings were a key contributor to the landing failures identified in the Uawa Catchment following the Queens Birthday storms in 2018 due to the additional weight they put onto the edge of the landing during storms. This assessment suggests that landings remain vulnerable well after harvest and in some instances the lake of maintenance of roadways and water tables post harvest has increased the level of vulnerability.

Thirdly, at some other forestry sites, and the recent harvest in Mangahaweone stream is a case in point, little care has been taken with slash and reject harvest residues at the harvest time. As a result all of the watercourses within the forest have become chocked with harvest residues that can be re-mobilised during storm events.

Finally, at other sites and Whakoau Stream is a case in point, harvest residues have been stowed on or close to the flood plain and as a result such sites are vulnerable during rainfall events that cause floods. This was the case in the Whakoau during Cyclone Cook when large volumes of harvest residues were mobilised and the large slash catcher installed downstream to capture any escaping logs was overwhelmed by the volume of material.

Generally, it was considered that pine plantation plantings were a solution to the type of gully erosion that was exacerbated by Cyclone Bola, in part because they were a fast growing species. On the other hand, this solution was predicated on such forests providing permanent cover but this has proved not to be the case with almost all pine plantations put in following Cyclone Bola converted to production forests. Consequently, all of the potential benefits that pine as a permanent cover afford are reduced once they become harvested as the gullies they were intended to protect again become exposed to the risks of erosion but the risk is also potentially exacerbated by the modifications to slopes necessitated by the infrastructure necessary to achieve harvest.

As a consequence, the areas of pine forest within the Waiapu are vulnerable to erosion post-harvest. Numerous reports and technical papers point to a "window of vulnerability" after which second rotation forest starts to move towards a closed canopy. Aorangiwai and other sites suggest, however, that the risk continues even when second rotation forests move to a closed canopy. This was the case in the Uawa catchment even in areas lacking the degree of gully erosion characteristic of the Waiapu. It is expected that in the Waiapu, as was the case in the Uawa; the forestry infrastructure that is retained in second rotation forests become a locus of risk because of their impact on drainage on roadways and the increased stress placed on slopes by birds nests on landings.

The easiest solution to this problem is to firstly identify sites of high risk within pine forests approaching harvest age and then to create suitable buffers to ensure that the areas around gullies are protected from the impacts of harvest. Secondly, harvest planning should assess the pre-existing geotechnical risks of roadways and landings to ensure that vulnerable sites are avoided.

Conclusions

1. The woody material that covered Tikapa Beach in 2020 (and in previous events such as the 2018 Queens Birthday storm) is characterised by a varied mix of vegetation types with pine comprising 41%, indigenous 35%, willow and poplar 17% and other material such as fence posts and battens 7%.
2. This mix of material contrasts with the Tolaga Bay beaches in Uawa where pine material dominates. Tikapa Beach also differs in that far more of the wood waste is weathered indicating a long residence time in the catchment.
3. Analysis of relative land cover for indigenous and pine to August 2020 shows that indigenous cover was 38% which exotic pine cover was 29% which suggests that as pine wood, at 41%, is a disproportionate contributor of material to the beach.

4. Pine logs can be seen shedding from areas of recent harvest and are the logical source of the cut logs identified on Tikapa Beach. This shedding appears to be driven by;
    a. The siting of roadways and landings in areas with pre-existing landslides or high slope instability potential which then collapse,
    b. The harvesting of pine stands that were planted to the rivers edge,
    c. the migration of harvest residues from unstable birds nests,
    d. Locating birds nests on riverbanks or flood plains that have then inundated or been scoured by the river during flood.
5. It is considered appropriate that landslide and/or slope stability geotechnical risk assessments are routinely used during the design of harvesting infrastructure and assessed in the consenting process.
6. Forest management plans need to take into account the risks associated with harvest including those associated with large-scale harvest within catchments that then leaves them vulnerable to failure during storms.
7. Pine trees have been sourced from large-scale gullies where pine has been planted in an effort to mitigate erosion risk. Further work is required to fully assess the performance of pine as a long-term stabilisation treatment for these large-scale gullies but it appears that the benefits that do accrue are largely lost during the harvest cycle.
8. A key source of indigenous material being shed into the catchment are persistent large-scale gullies, typically occurring in areas that have not been previously cleared for pastoral farming.
9. Indigenous vegetation has also been sourced from stream banks that have been scoured by stream flood flows.
10. Large slips or landslides not associated with gullies have also generated volumes of indigenous vegetation that have been mobilised to the catchment.
11. It is presently difficult to verify where all the willows and poplars have been sourced but some instances smaller scale gullies have been identified that were planted with willow and poplar for stabilisation reasons but have subsequently failed. Some instances were observed where willow previously planted on the banks or flood plains of streams had failed but not been removed and would thus be vulnerable to mobilisation during flood events.
12. Areas in closed canopy (largely mature harvestable) pine represent 73% of all pine forest land cover (32,00 6.75 Ha) while open canopy pine occupies 18% of all pine forest while only 9% of all pine/exotic plantations has been recently harvested. This indicates that a rapid increase in the area of harvest can be expected over the next few years. In turn this suggests that the area of ground vulnerable to failure and thus mobilisation of harvest residues during severe weather events will increase by several orders of magnitude over the next few years.
13. The National Environmental Standards for Plantation Forests (NESPF) do not require harvest consents for all forests in the Tairawhiti Region unless the forests meet certain criteria. All very high risk [Red Zone] and certain activities

on high risk land [Orange Zone] requires a consent but elsewhere harvest is a permitted activity[1]. Each of the hotspots in pine forest considered in this assessment did meet the criteria (8e +7e) except for the Aorangiwai failure that occurred on the boundary between LUC 6e and 7e. Based on the assessment undertaken here it is considered, however, that failures are possible in moderately erosion prone land under the ESC system and thus the NES Plantation Forestry may not adequately address the risks that forest harvest poses to the Waiapu Catchment. Undertaking a full high-resolution landslide risk assessment is beyond the scope of this project.

[1] https://www.mpi.govt.nz/dmsdocument/27930-Resource-Management-National-Environmental-Standards-for-Plantation-Forestry-Regulations-2017-March-2018

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Appendices

1.0 Introduction

The June and July 2020 storms, particularly that of 20-21st July resulted in the deposition of woody material on beaches across the region and refocussed national attention on the Tolaga Beaches in the Uawa Catchment. A helicopter flight as part of the food delivery at East Cape identified a range of other beaches with issues including, Tikapa Beach, Tokomaru Bay and the south end of Waipiro Bay. Rapid assessments were undertaken at Tokomaru, Waipiro, and Anaura but getting on the ground at Tikapa Beach was delayed for a number of reasons including the closure of Waiomatatini Road, and the need to focus on landslide dam risk.

There was also media coverage about Tikapa Beach and reference was made to the effort put in by the forestry industry to clean up Tolaga Beach raising the question of whether the forestry companies should also clean up Tikapa Beach. Although Waiomatatini road was closed, 4WD access was possible. Accordingly, a visit was finally made to Tikapa on Sunday 23rd August 2020 to obtain a wood count at one location and to get a better impression of overall woody material. A second visit was made with community members in October to undertake further log counts. Additionally, an analysis has been taken of the Waiapu Catchment using recent satellite imagery (**Figure One**) to assess possible sources of material complementing the database of imagery collected during recent helicopter flights in the region (**Figure Two**). Photograph locations are shown in **Figure Three**.

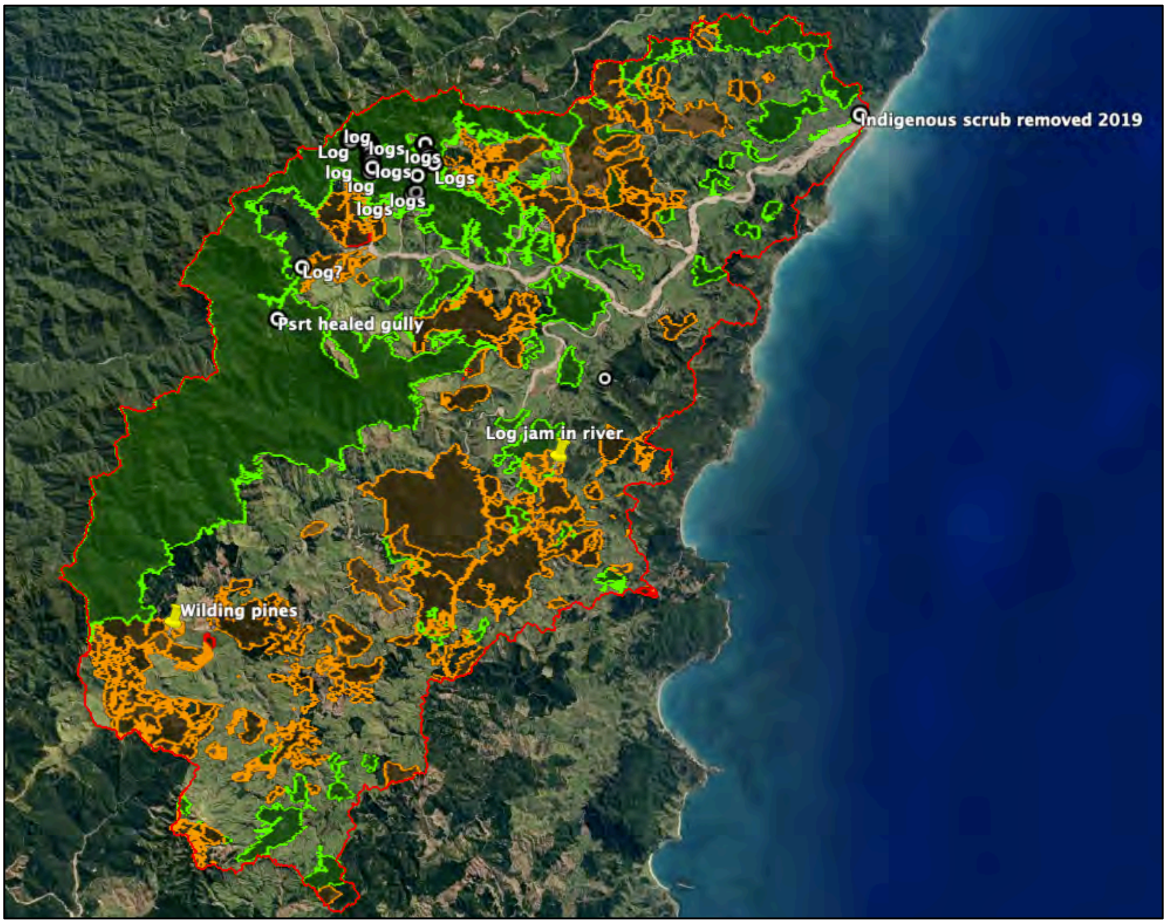

Figure One. *Initial analysis of satellite imagery for Waiapu Catchment showing areas of indigenous vegetation (green) and exotic pine and other canopy species (brown) and the location of areas of significant wood generation. The land use has been mapped based on 8th of November 2019 5m resolution satellite coverage adjusted to the 27th of August 2020 were possible.*

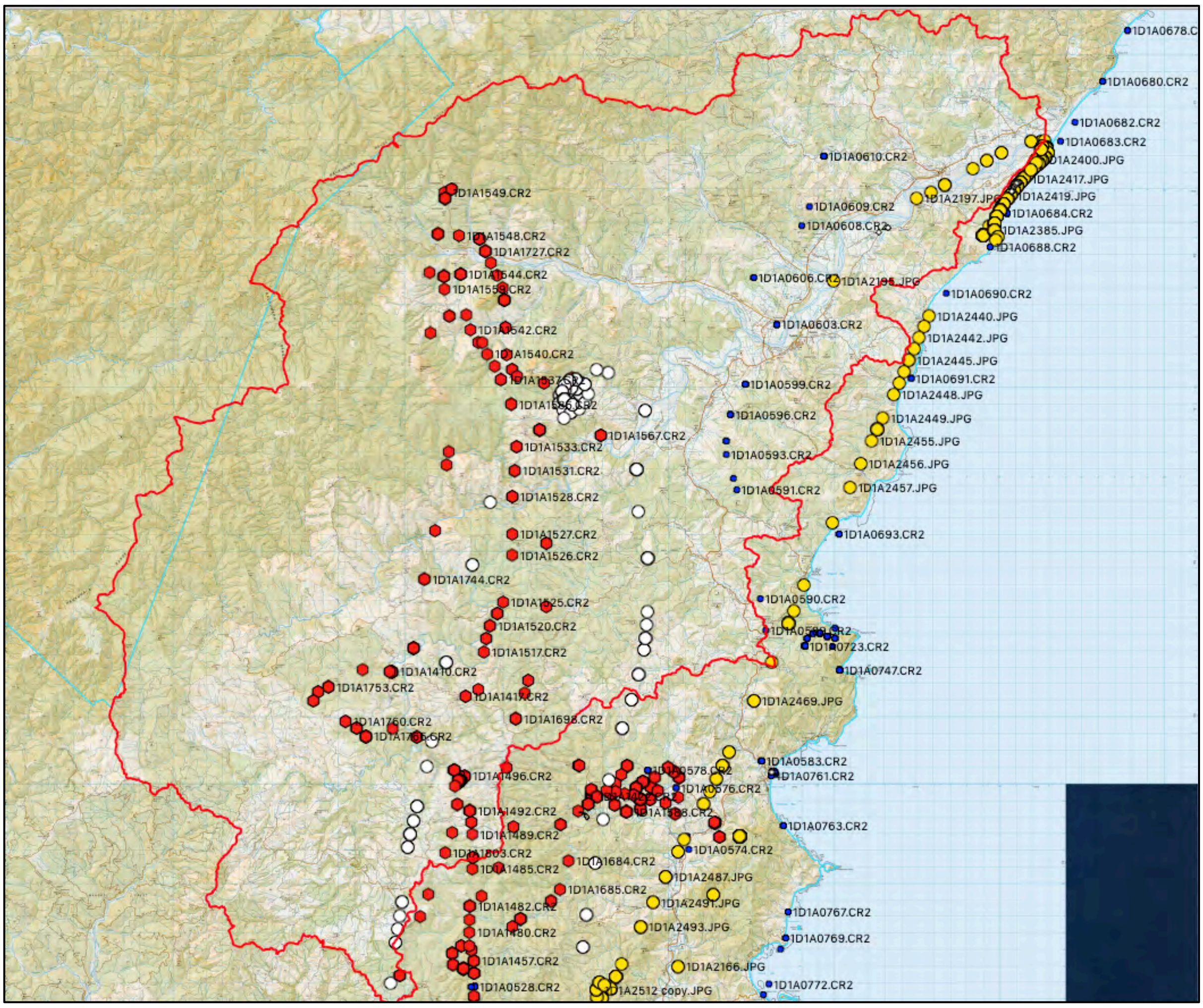

Figure Two. *Map of Waiapu Catchment showing location of photographs taken July and August. Tikapa Beach is at top right.*

Figure Three*. Tikapa Beach Photograph locations (on site images from 23082020 in red).*

2.0 Overflight imagery

The photos taken during the flight to East Cape on the 21st of July 2020 showed that there was a significant volume of wood washed up on Tikapa Beach that appeared fresh. It is important to note, however, that any aerial assessment can only differentiate between material that has not been remobilised (ie is a weathered grey colour) and material that has either remobilised *in situ* or been freshly added to the beach stock (**Figure Four**).

Figure Four. *Oblique aerial image of area from Waiapu River mouth (far right) to Whakariki Point showing fresh and/or remobilised woody waste (brown).*

The 21st July 2020 overflight merely indicated that there had been woody material either remobilised or deposited and did not provide any quantifiable assessment as to the type of material or volumes. Accordingly a second flight was undertaken on the 14th of August 2020 with 453 georeferenced images taken of the beach between the mouth of the Waiapu River and Whakariki Point. The entire stretch was also continuously videoed for further reference. Not all of these photographs are useable due to wind-induced vibration while shooting from the open door of the helicopter but 67 images were selected as showing the range of materials present along the beach (**Figure Five**) with 23 of these further selected for additional assessment.

The river mouth area is shown in **Figure Six** below and shows an area of fresh-looking woody material deposited on both the true right riverbank and on the esturine end of Tikapa beach. The material on the river bank provides a good indication as to the extent of the flood event that triggered the wood influx indicating that the flood did not extend onto the grassed dune area inland of the beach. The material at the esturine end is extensive and occurs as two ridges which suggests that there has either been two separate flood events or that a storm surge has reworked material.

Given the location, storm surge wave action is less likely than having more than one flood event since initial deposition.

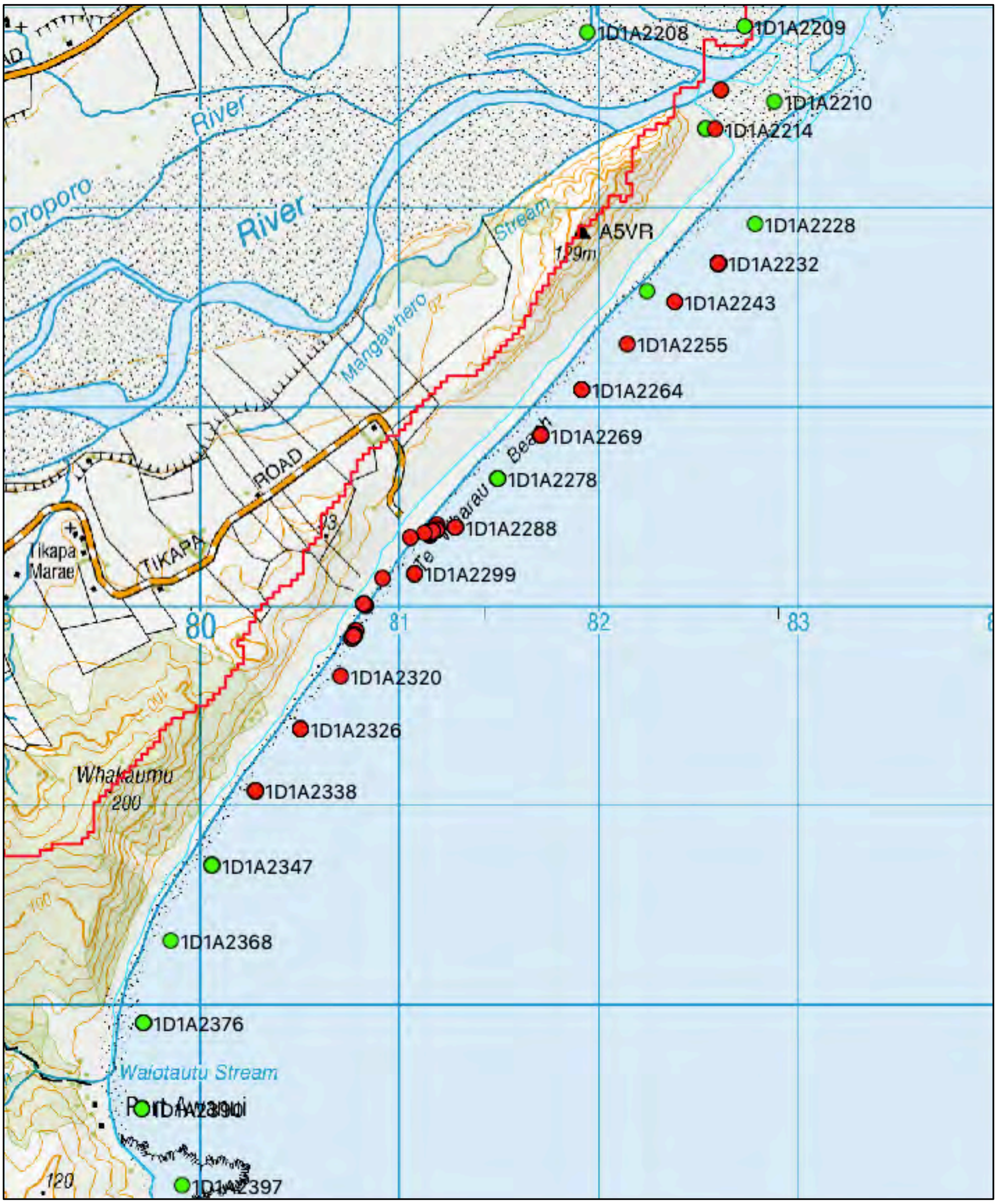

Figure Five. *Location of key images used in this assessment.*

A point midway between the river mouth and the Tikapa roadend is shown in **Figure Seven** below. This shows a pronounced trimline between fresh-looking woody debris and woody debris inferred to be older beyond the trim line. The debris is relatvely thin over much of the image but is more extensive in the south.

Figure Six. View of the beginning of Tikapa Beach from the Waiapu River mouth showing extensive woody debris which from its brown colour will have been recently deposited.

Figure Seven. *View of Tikapa Beach midway between the river mouth and the Tikapa roadend showing a thin strip of woody debris below a trimline with more extensive debris in the south.*

The south end of the beach is shown in **Figure Eight** below. This image shows a broad area of smaller wood material than is present further north along the beach. The older grey-weathered wood from prior events also contains a predominantly finer grained suite of wood but does include a number of larger pieces. Of the c.11 pieces counted in this image, only one occurs at the edge of the newly deposited wood waste but lacks the brightness typical of newly deposited material. This piece is a long resident[1] pine log and is inferred to be reworked material from a prior event such as 2018. Other larger material include long pine stems with rootballs (Windthrow/riverthrow/slips), indigenous logs and willow/poplar branches.

Figure Eight. *The south end of Tikapa Beach near Whakariki Point showing the broad area of fine grained wood waste ("dross").*

As well as the larger beach view images shown above, a suite of more detailed images were taken and these have been assessed to see if thay can indicate the proportions of the types of material present.

Figure Nine shows a small area of beach around one third of the way between the river mouth and the Tikapa roadend. This shows a large area of brown wood waste reflecting being either remobilised on the beach or deposited on the beach during the July 2020 storms, most likely the event around the 20th-21st July. At the top of the image is more scattered grey wood material that is comprised of finer dross and small branches.As can be seen in the image, much of the fresher material is quite fine grained "dross" with scattered larger material and one obvious long log. The long log

[1] A long resident log is one that has been harvested and stored somewhere within a harvest area and has be mobilised from that site at some stage and remained in the catchment for some time having the ends worn to rounded or cone shapes over time.

has a worn root ball (windthrow/riverthrow) and when examined closely has an obvious spiral grain. This suggest that the log is not pine which typically has a straight grain and it is also unlikely to be willow which would not yield such a long straight length but beyond that it is not possible to identify the log down to class of material. Two smaller long resident pine logs are visable as are smaller branched material with root balls which are most likely to be indigenous scrub species such as Manuka, and some highy eroded dark coloured wood pieces of indigenous origin. One fence batten and a red plastic container are also present.

Figure Nine. *View of the beach approximately one third of the way from the river mouth to the Tikapa roadend showing the mix of material present.*

A closer view of the area close to the Tikapa roadend is shown in **Figure Ten**. This image shows a distinct separation into three zones down the beach profile with grey-weathered material from previous events higher on the beach, then a zone of largely finer dross material in the middle band and a larger log dominated lower zone. Two obvious large diameter short logs are evident in the top right of Figure Ten. When examined closely, the brighter one of these has an obvious cut end and is inferred to be a pine sloven but the adjacent log appears to be indigenous. There is an obvious long resident pine log in the middle right of the image which is close to a mix of other larger material including one grey-weathered branched log which has a cut end and is inferred to be a willow.

On the left hand end of the image is a long log with no obvious root ball but does have a spiral grain and so is unlikely to be a pine log. Interestingly, there is a fence batten lying across this log at the left end while immediately above it is a long resident pine log. Below this material is a log with no obvious root ball but with a straight grain and is hence most probably a long-resident pine log. Adjacent material includes an obvious piece of willow, a weathered pine stump, other highly-weathered larger diameter logs of probable pine origin, a poplar branch, and some moderately weatherer small diameter straight grained material which is most probably pine. One long small diameter piece of wood with a root ball is probably manuka or kanuka.

Figure Ten. *View of the woody material close to the Tikapa roadend showing the mix of material present (described in detail above).*

A view of the woody material 250m south of the Tikapa roadend is shown in **Figure Eleven**. This shows a similar zonation of the beach to **Figure Ten** but there is a greater proportion of larger material present. At bottom left a long pine log with a root ball is evident indicating a windthrow/waterthrow origin while an adjacent short dark red coloured log is of indigenous origin. A long-resident pine log with a cut end is evident at the bottom right.

Overall a majority of the visible larger logs appear to be pine in origin and the majority of these appear to be long-resident logs rather than windthrow/waterthrow. While present, willow/poplar and indigenous material is subordinate in this particular image.

Figure Eleven. *View of woody debris on Tikapa Beach c.250 metres south of the Tikapa roadend as described above.*

3.0 Beach Counts 2020

A single beach count was undertaken around 650m south of the Tikapa roadend on the 23rd August 2020. It was anticipated that this would provide the basis for a subsequent citizen science project to undertake a full assessment of the log population on the beach. At present, however, the access to Tikapa Beach is constrained by the closure of Waiomatatini Road to all but local residents with 4WD vehicles or for essential work. By necessity therefore, this beach assessment is limited in scope until full access to the beach is available.

3.1. Site visit 23rd August 2020

Tikapa Beach was visited on the 23rd of August when low tide was in the early afternoon which maximised the time available to assess the population of woody material on the beach. Offsetting this, however, was the time required to traverse Waiomatatini Road which in turn reduced the time available to undertake an assessment. As a result the assessment was limited to a qualitative assessment at the Tikapa roadend and a log count around 600m south of the road end.

3.1.1 Roadend assessment

The qualitative assessment at the roadend comprised a basic overview of the different types of large wood waste available but without any log counts to provide a statistical analysis. The observations are summarised in **Figures Twelve** and **Thirteen** below and show that the roadend material comprises a mix of indigenous, willow/poplar and pine. Two prominent pine logs have cut ends although it is notable that one of the pine logs is cut at one end but has a root ball at the other. It is possible that this log has been cut on the beach following its deposition, however, the other log has clearly been cut at both ends and sourced from a harvest operation.

Figure Twelve*. View on large wood waste at the Tikapa roadend showing primarily willow logs in the foreground with one small indigenous log at bottom right, a large indigenous log above close to the sea and other smaller indigenous pieces at middle right of the image.*

Figure Thirteen*. View on large wood waste at the Tikapa roadend showing cut pine logs prominent in the foreground and an indigenous log on the right of those and a long-resident pine log further on the right of the image. Foreground logs are a mix of indigenous and willow with a large indigenous log in the background.*

What is immediately apparent overall when looking at the material at the Tikapa roadend is that the proportions of wood types is profoundly different from that washed up on north Tolaga Beach during the June and July 2020 storms. At Tolaga cut pine and long-resident pine logs are dominant in the wood waste mix whereas the Tikapa wood population is more evenly mixed.

It was decided that a log count at the roadend might introduce a bias into the analysis as it was evident that locals had been cutting logs for firewood. As a result a site around 600 metres to the south was selected for the plot.

3.1.2 Beach count 600m south of the roadend

The wood count followed the methodology established by Cave *et al* (2017) following Cyclone Cook. This involved pegging out a 10m by 10m plot and counting all woody material within the plot greater than 15 cm diameter, with the area covered by either sand or woody material smaller than 15cm estimated. The material was categorised as the following; Indigenous, windthrow/riverthrow[2] pine, clean cut pine, long-resident pine logs, slash sized material, farm waste and general rubbish/waste. The plot count shows that 36% was indigenous, 14% was willow/poplar, 5% comprised farm posts and battens, and the remaining 46% a mix of pine wood dominated by slash (ie small) sized material. Long-resident logs comprised 12% and windthrow/riverthrow logs 11% (**Figure Fourteen**).

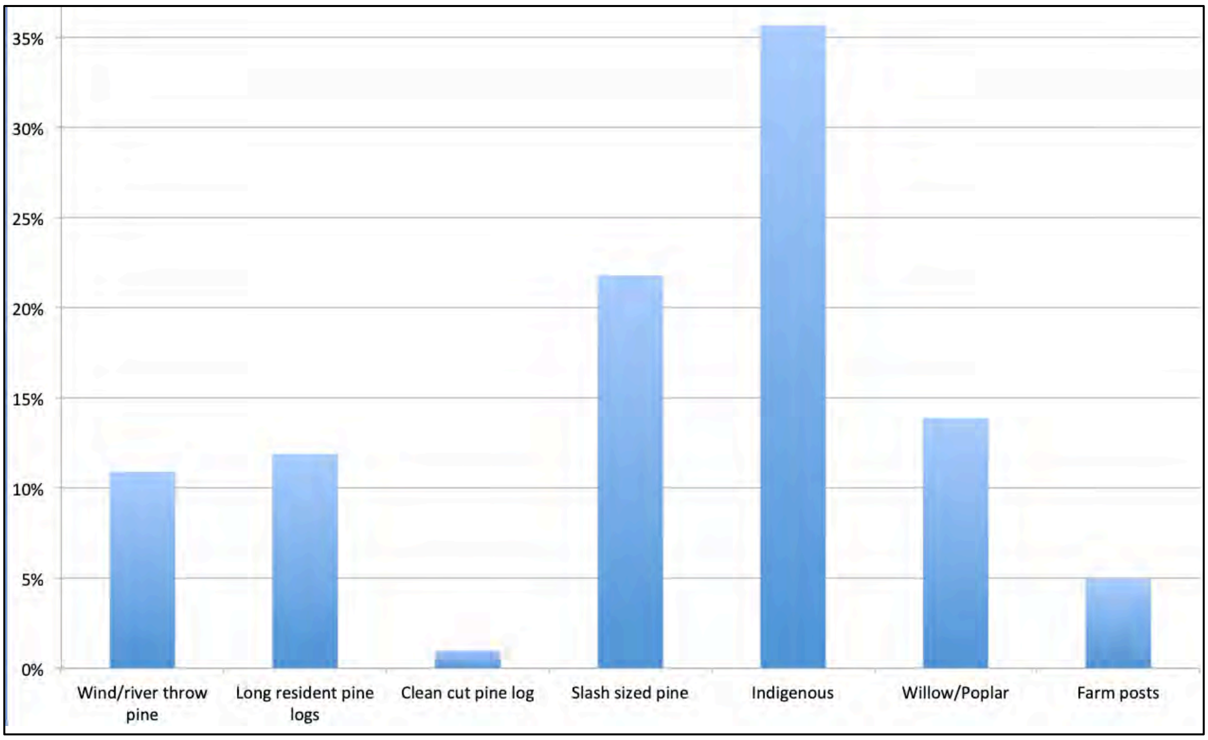

Figure Fourteen. *Proportion of wood types at the 600m south plot site.*

[2] While all such material is often just considered "windthrow" the mechanism for relocation of pine with root ball material can include windthrow, trees dislodged by landslides, or trees eroded from the banks of rivers and streams.

The proportion of all pine wood aggregated is shown in **Figure Fifteen**. As this indicates 54% of all woody material other than aggregated pine material. Furthermore, if just the pine data is examined (**Figure Sixteen**) it can be seen that 46% of the material is slash (ie small-sized branches) while 24% is windthrow/riverthrow pine and 28% is cut pine mainly comprising long-resident logs. In other words, only 28% of all pine or 16% of all wood types can be considered to be associated with potentially non-compliant forest harvest activity.

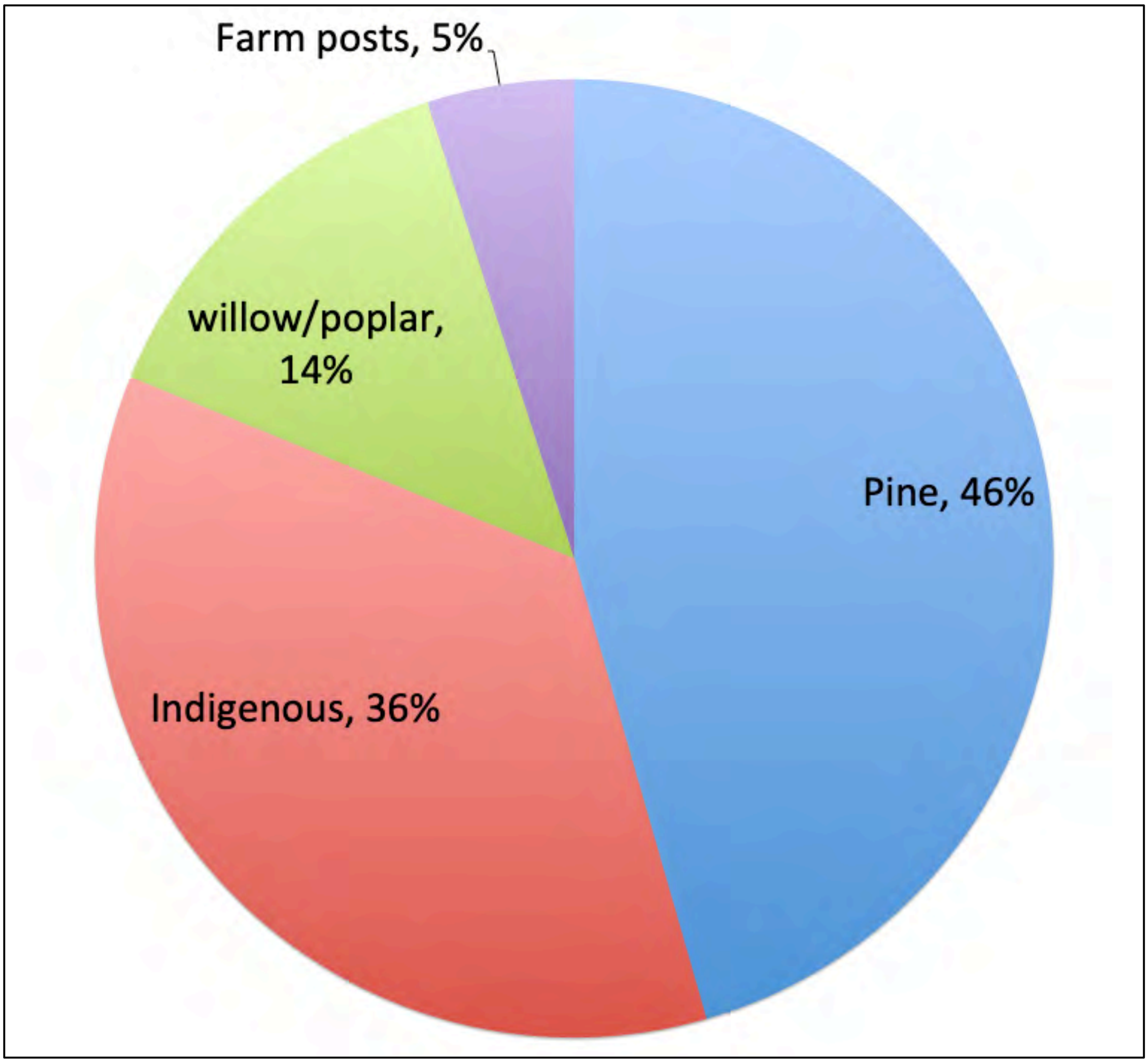

Figure Fifteen. *Pie chart showing the different types of wood material with all pine aggregated.*

3.1.3 Site visit 20th October 2020

A number of log counts distributed over the beach is necessary to establish a statistically valid assessment of the quantities of woody material on the beach. Accordingly, arrangements were made to have members of the local Ruatoria community undertake an assessment of the woody material on the beach (**Figure Sixteen**). This was arranged through Lisa Beach from the Eastland Institute of Technology (EIT) office at Ruatoria. Three plots were counted north of the Tikapa Road (**Figure Seventeen**).

All plots used the same methodology developed for the assessment of logs on Tolaga Bay beach following ex-tropical Cyclone Cook and consistently used for all subsequent GDC-supervised beach counts on Tairawhiti beaches. This involves selecting multiple sites on the beach on a semi random basis. The only selection criteria was that the 10m^2 area selected had to be fully covered with logs as much as possible. This is not always possible, however, and in those cases the percentage area covered by either sand or fine grained woody dross was measured. Each piece of wood was compared with an identification chart, counted and then sprayed with "dazzle" to ensure there was no double counting.

It is understood that the Eastland Wood Council also undertook a count of logs on Tikapa Beach at some stage. The results and methodology of that count is unknown, however, and no signs of "dazzle" paint were observed during the October visit.

Figure Sixteen. *The Ruatoria EIT team on site after plotting a 10m^2 log area of logs on Tikapa Beach. Note the "dazzle" marks on the logs.*

The first (middle) plot site was counted by all of the group under Council supervision to ensure that the group could correctly identify the different wood types, were recording correctly and were confident in the results. The groups then split into two with one group moving north to occupy an additional site while the other group moved south to do the same. The counts at these sites were not supervised. The results of the October survey were then collected and collated and the results are shown in **Figures Eighteen** and **Nineteen** below.

Figure Seventeen. *Location of the log plots on Tikapa Beach showing the 23rd of August plot (MC August) in the south and the three October plots undertaken with the team organised by the Ruatoria EIT to the north of the Tikapa access road. The white dots represent photo locations for the 20th of October and the red dots represent photo locations from the 23rd of August 2020.*

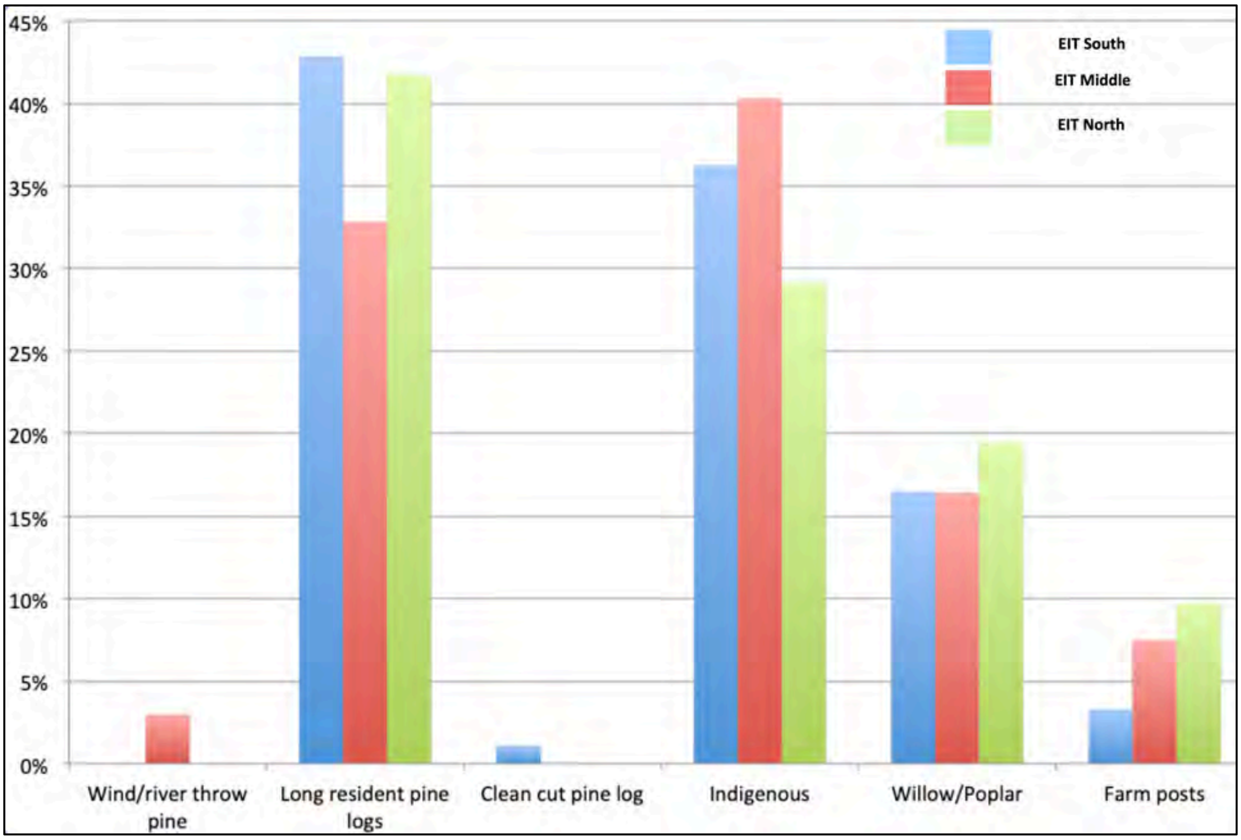

Figure Eighteen. *Plot of log types on Tikapa Beach recorded during the 20th October visit showing the concentrations of pine types vis indigenous, willow/poplar and farm posts/battens.*

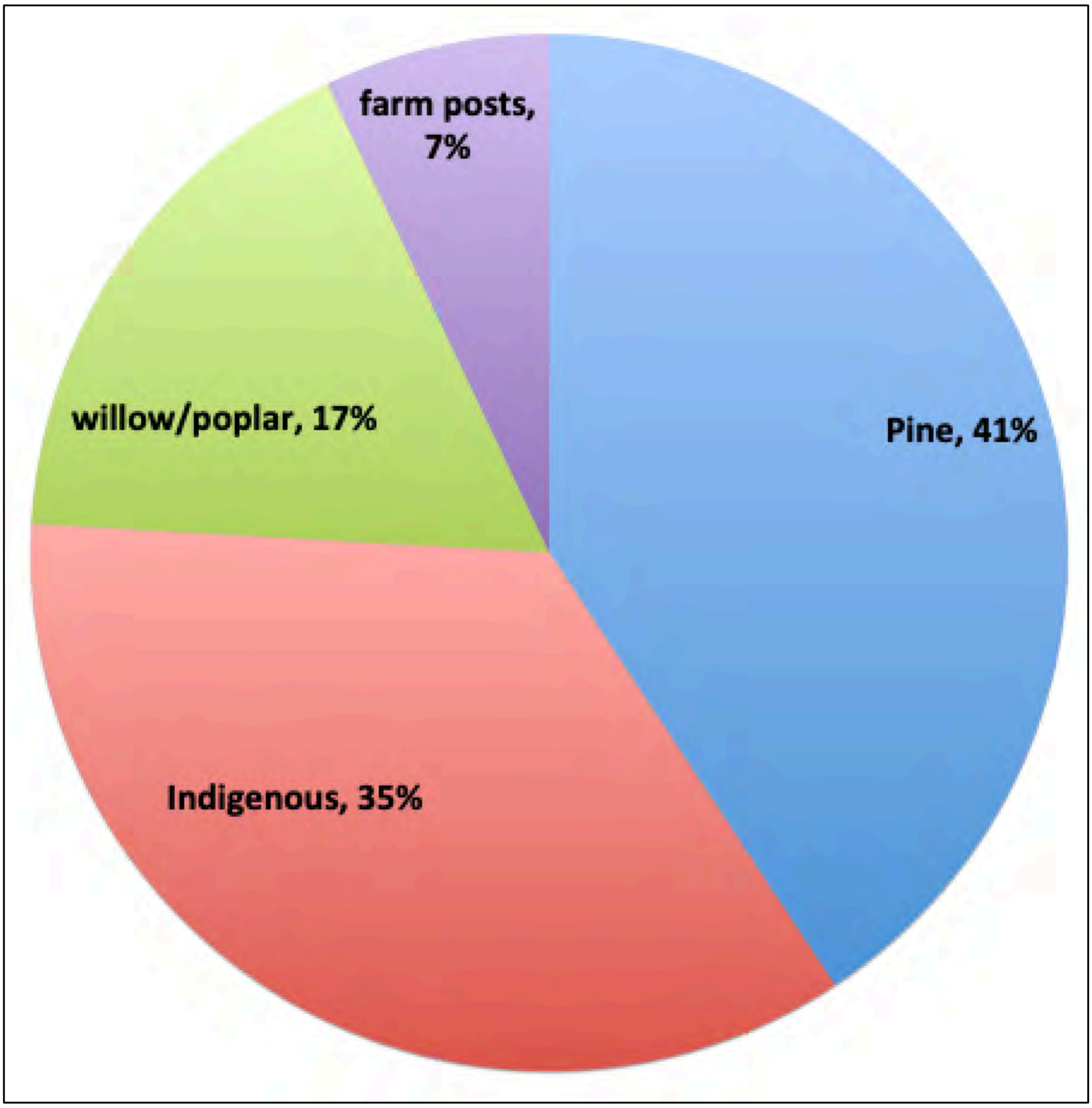

Figure Nineteen. *Pie chart showing aggregated wood types from all three plots undertaken on the 20th of October with all pine types combined.*

The results are consistent with the results of the log count in August with pine types the largest class at 41% (46% in August), significant indigenous at 35% (36% in August), willow/poplar at 17% (14% in August) and farm posts/battens at 7% (5% in August). To allow for a comparison with Tikapa in 2018 and Uawa in 2020, the 23rd of August and 20th of October log plots were aggregated (**Figure Twenty**). This results in a slight change to the percentages shown in **Figure Nineteen** with total pine at 43%, indigenous at 36%, willow/poplar at 16%, and farm posts/battens at 6%.

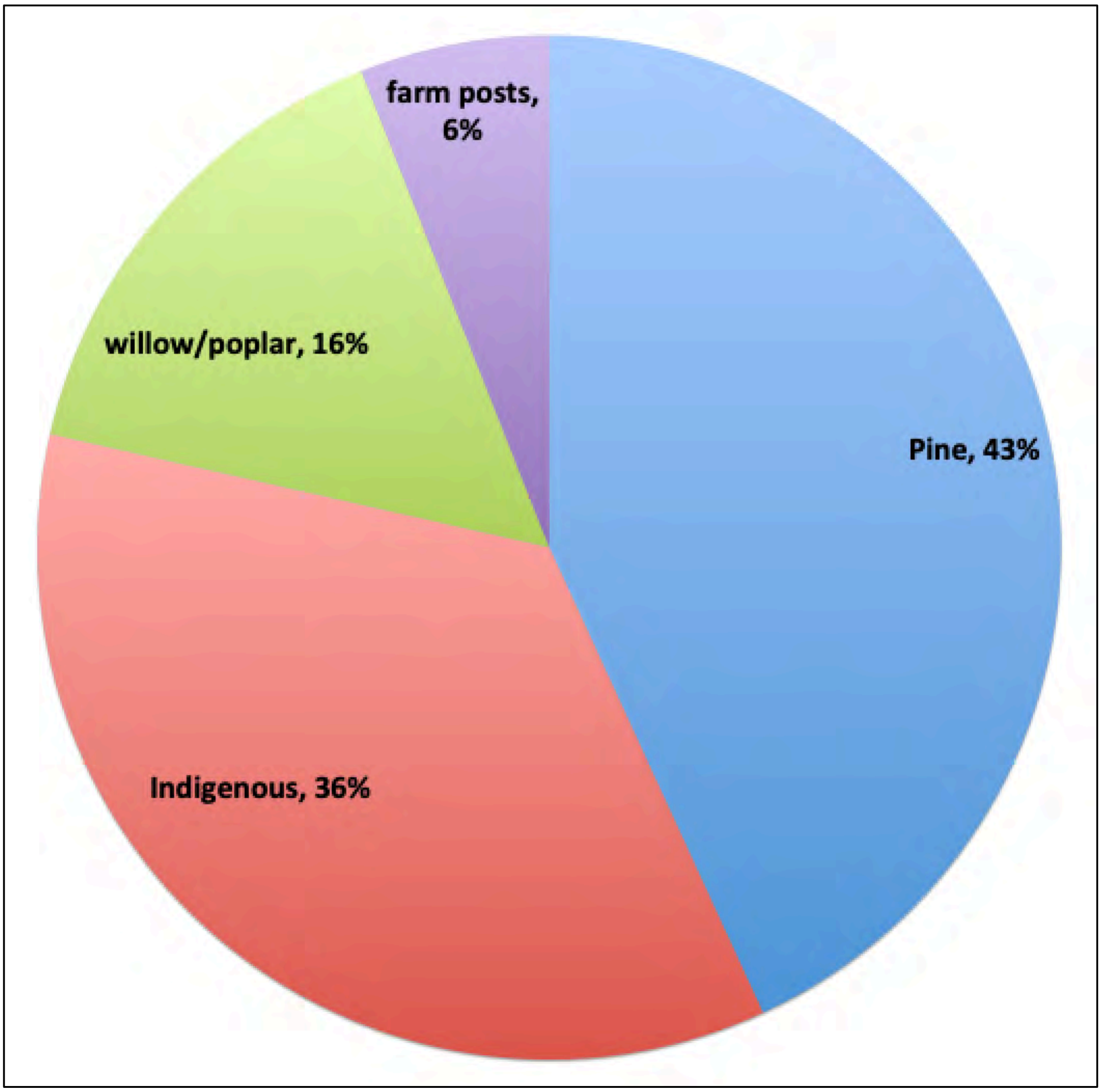

Figure Twenty. *Pie chart with the wood classes for the August and October log plots aggregated*

3.2 Comparison with Tikapa Beach in 2018

Tikapa Beach was adversely impacted by the Queens Birthday storms in 2018 and a wood count was undertaken at that time as part of the investigation into that event (**Figure Twenty One**). This showed that in 2018, 47% of the material were pine logs (43% in 2020), 19% was willow/poplar (16% 2020), 31% was indigenous (36% 2020), while farm posts and battens were 2% (6% 2020). The comparison between 2018 and 2020 indicates that the mix of material deposited on the beach was consistent in both events (**Figure Twenty Two**).

3.3 Comparison with Uawa in 2020

The 600m south Tikapa wood count undertaken in 2020 (MC August in **Figure Seventeen**) has been compared with the 2020 Uawa wood counts undertaken by the Uawanui cadets at four sites on North Tolaga Beach. As this analysis showed, all of the Tolaga Beach sites were dominated by pine categories with indigenous, willow/poplar and farm posts and battens making up a relatively minor amount of the total. There is one category at Tolaga (burnt pine) which is obviously absent at Tikapa since that category identifies material burnt after the 2018 and 2019 storms. In addition, finer sized slash material is a minor component at Tolaga and is excluded from the counts. A direct comparison between one Uawa plot and Tikapa is shown in **Figure Twenty Three** below.

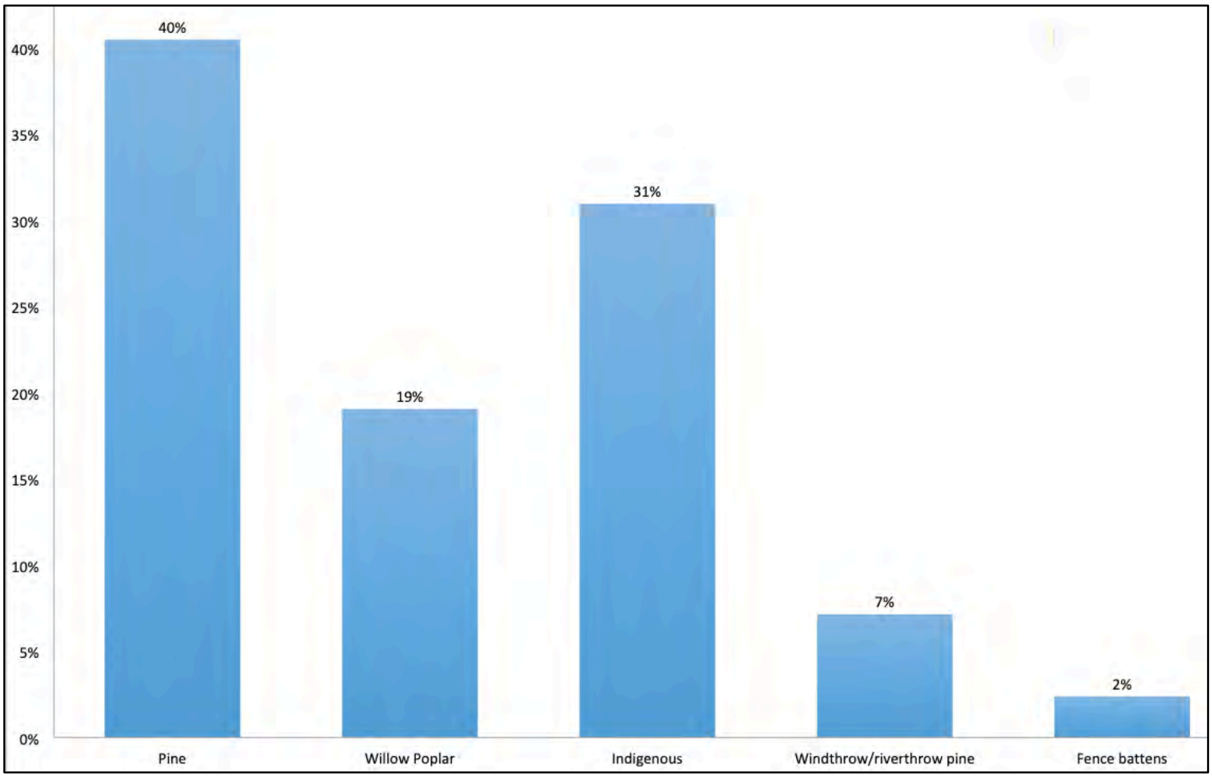

Figure Twenty One*. Tikapa Beach wood counts for the 2018 Queens Birthday storm.*

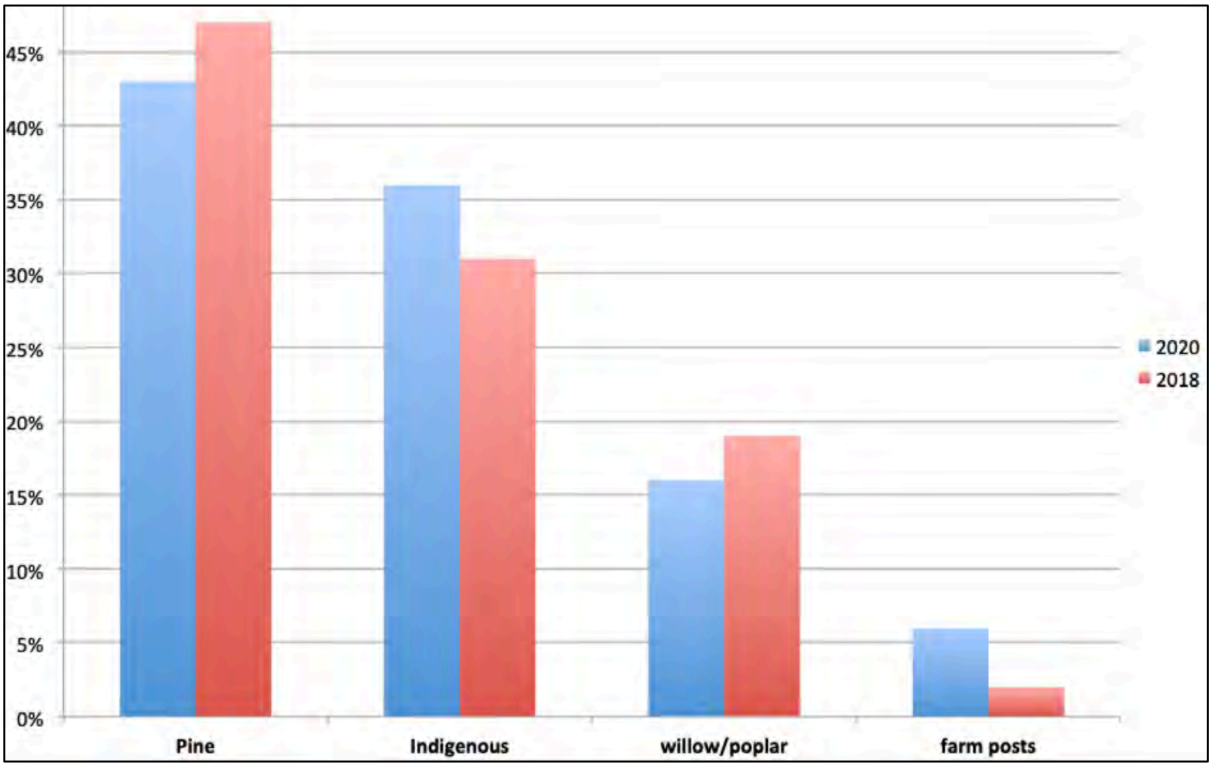

Figure Twenty Two*. Tikapa Beach wood counts for 2018 Queens Birthday storm vs July 2020. Note, wind/river throw pine omitted.*

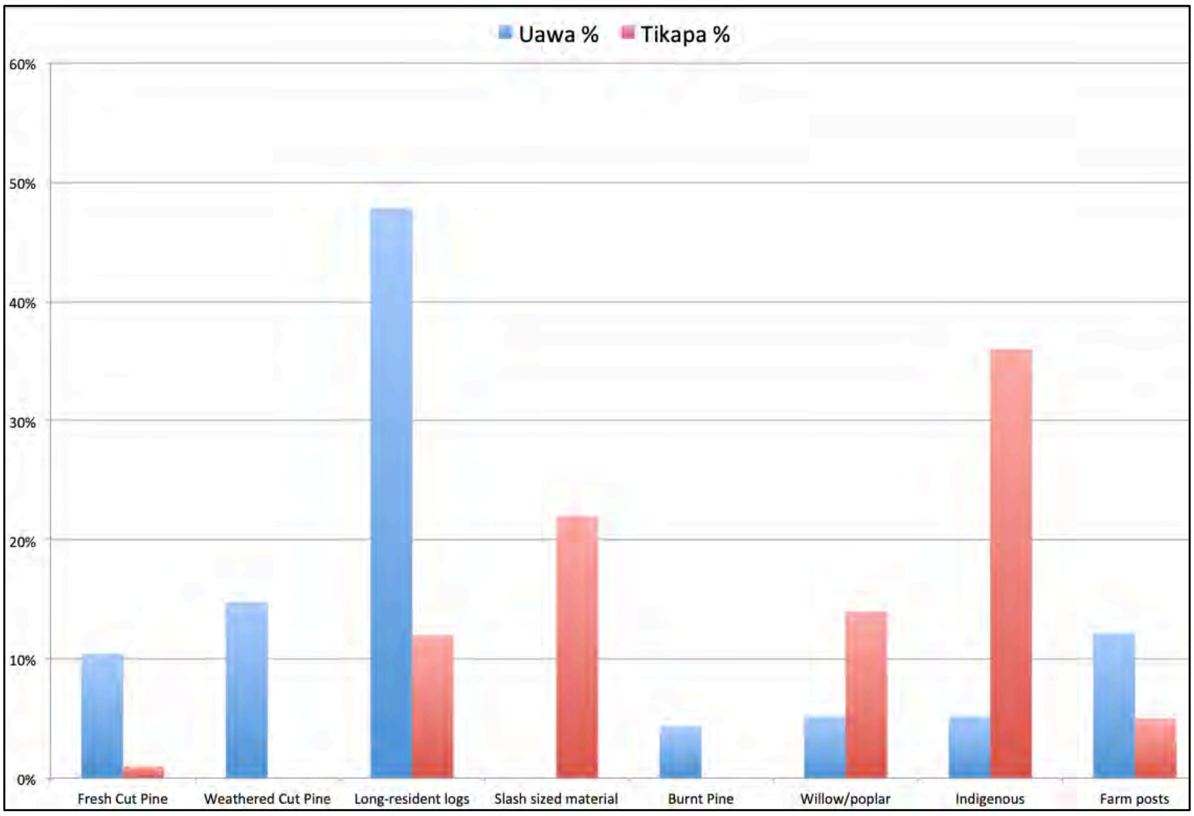

Figure Twenty Three. *Comparison between Uawa (Blue) and Tikapa (red) wood types. As this shows there are significant differences between the types of wood material deposited on Tikapa and Tolaga Bay beaches during the June-July 2020 storm events.*

4.0 Source Tracking in the Waiapu

Following the initial satellite analysis shown in **Figure One** above was completed, new satellite imagery dated the 27th of August, 30th August, 13th September, 16th September, and 2nd October 2020 was released. This has allowed for a more accurate assessment of log distribution within the catchment (**Figure Twenty Four**) and shows that logs were widely distributed through all parts of the catchment.

The assessment is incomplete as the new satellite imagery does not cover the entire catchment and particularly does not extend to the coast. Thus it is not presently possible to directly track July 2020 material from the source to the beach. Further, it is not possible using the log distribution alone to determine the likely source of the logs. To establish this, the latest version of the land cover database (LCDB v5.0) was first analysed but was not used after reviewing the dataset as it was found to be inaccurate at the scale of the assessment required. Further, the dataset was up-to-date to 2018 and did not reflect changes that had occurred between 2018 and 2020, for example, forestry harvests between 2018 and 2020.

Consequently the main land cover classes (Indigenous, indigenous scrub, exotic plantation forests, recently harvested pine forest, replanted open canopy, willow/poplar) were digitised primarily from the 27th of August 2020 satellite imagery and used in the assessment. The key land cover classes are shown in **Table One** below. Given that post July 2020 storm log mobilisation occurred in all sub catchments it could be anticipated that the percentage of wood waste on Tikapa Beach would be consistent with the area under each type of land cover. The percentage of Indigenous cover within the catchment is comparable with the percentage of indigenous material on Tikapa Beach, however, the percentage of exotic pine material is significantly over-represented on the beach.

	Indigenous	Exotic
Land cover	38%	29%
Tikapa Beach	36%	43%

Table One *Percentage Indigenous and Exotic (Mature, recent harvest and open canopy pine) land cover in the Waiapu compared with the percentage of each type of wood waste on Tikapa Beach. As this indicates the percentage of indigenous wood waste on Tikapa Beach is consistent with the percentage indigenous land cover, whereas pine wood waste is significantly over represented relative to percentage land cover.*

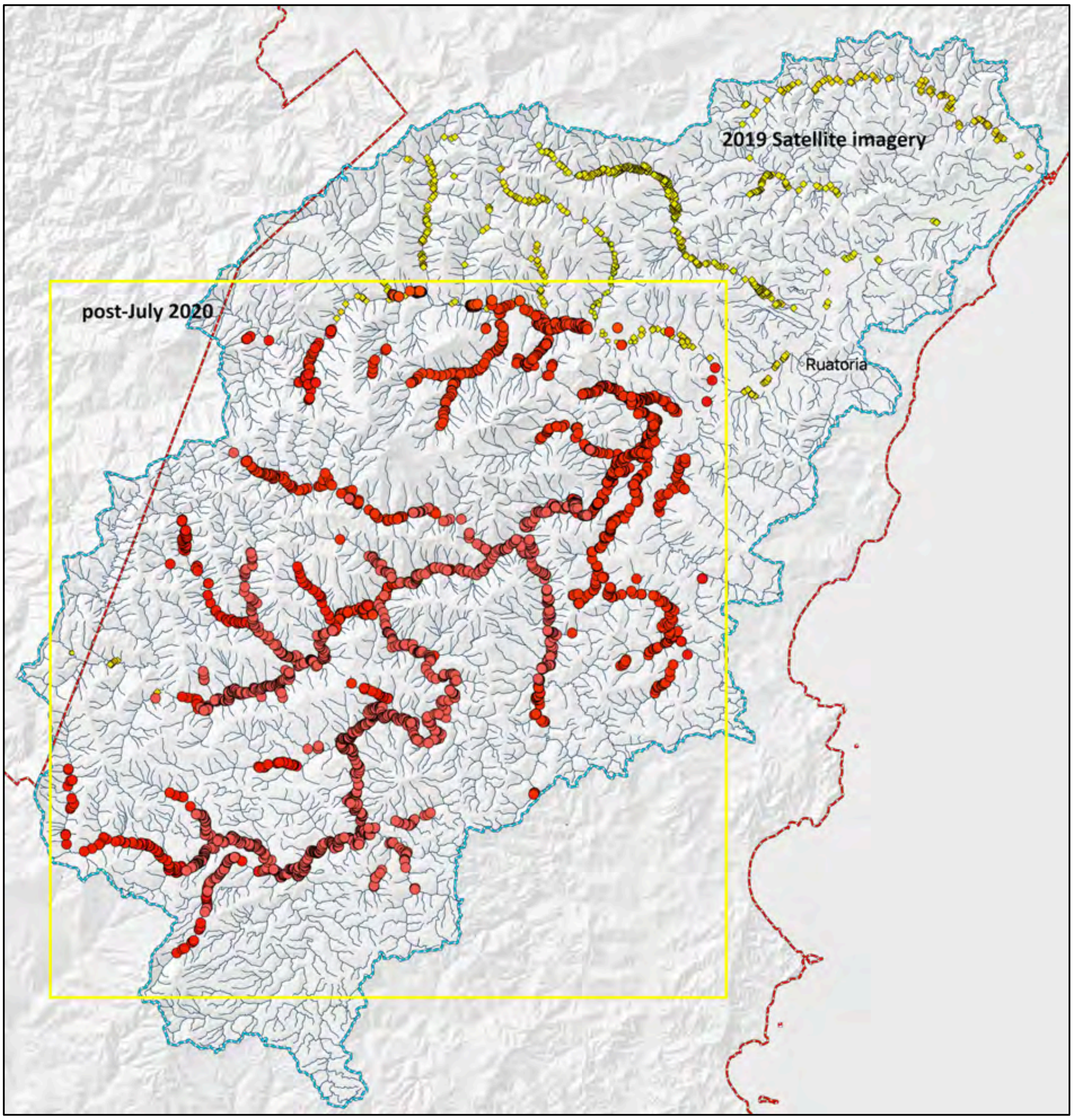

Figure Twenty Four. *Map showing the area covered by post-July 2020 satellite imagery (yellow box), the distribution of logs in the Waiapu catchment post the July 2020 storm (red circles), and distribution of logs within the catchment from 2019 satellite imagery (yellow diamonds).*

Plotting the area of each different land cover gives a good indication of the probable source of wood waste on the beach. The same log distribution from **Figure Twenty Four** is compared with the distribution of Indigenous vegetation cover for the Waiapu catchment in **Figure Twenty Five** below. This shows that areas of indigenous forest, particularly the true right tributaries of the Tapuaroa River (Mangatoitoi Stream, Mangatangaruru Stream, and Mangarata Stream) and also some true left tributaries of the Mata River (Waingakia, Mangaropo and Makokoia Streams) contributed material (**Figure twenty Six**). Equally, however, **Figure Twenty Five** shows that a considerable amount of logs in the headwaters and other tributaries of the Mata which lack significant indigenous forest and scrub cover.

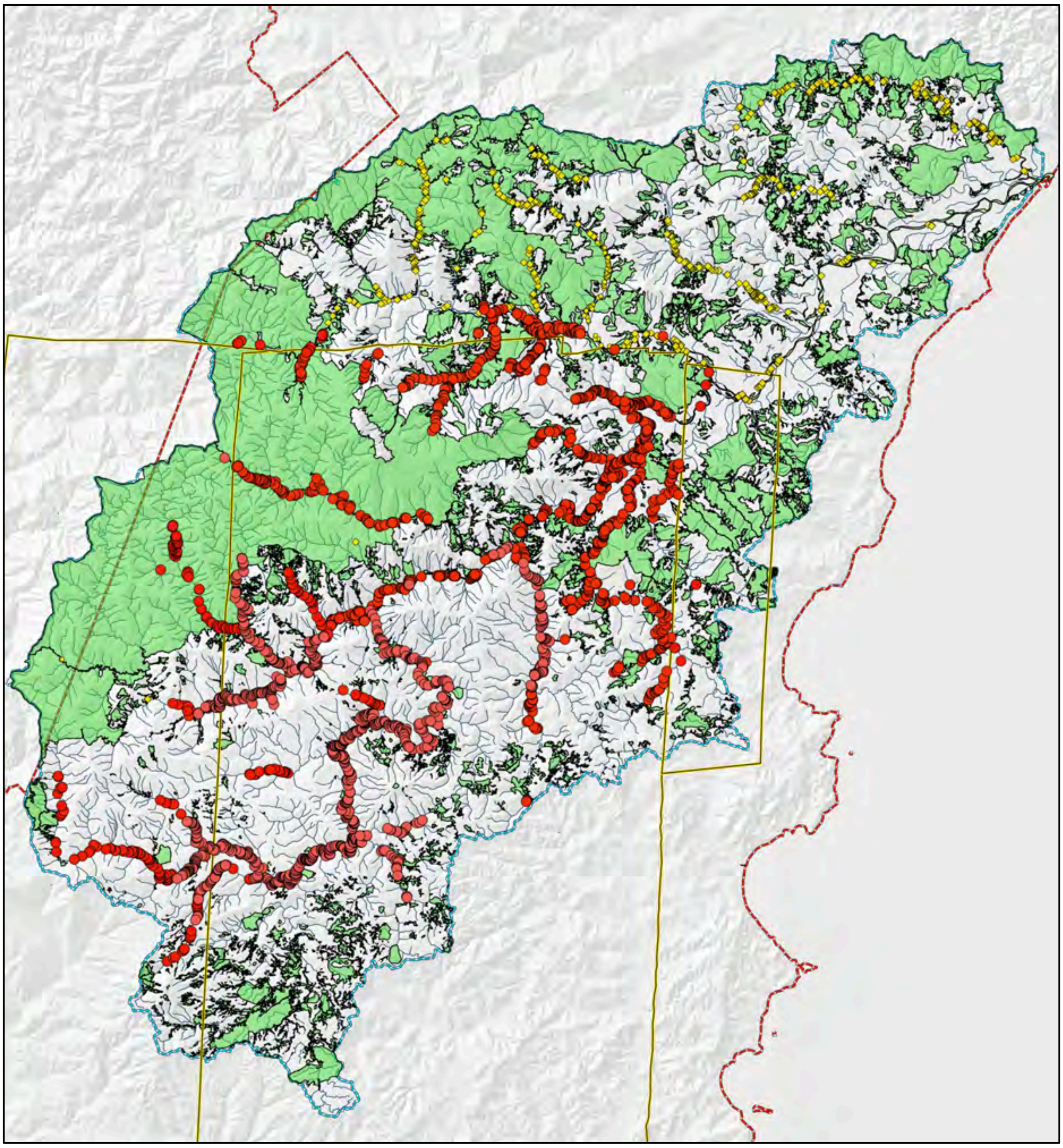

Figure Twenty Five. *Map showing the same log distribution data as **Figure Twenty Four** overlain by the area of significant indigenous land cover showing that the true right tributaries of the Tapuaroa and some true left tributaries of the Mata are likely sources of the indigenous woody debris in the Waiapu River and most probably is also the source of indigenous material on Tikapa Beach.*

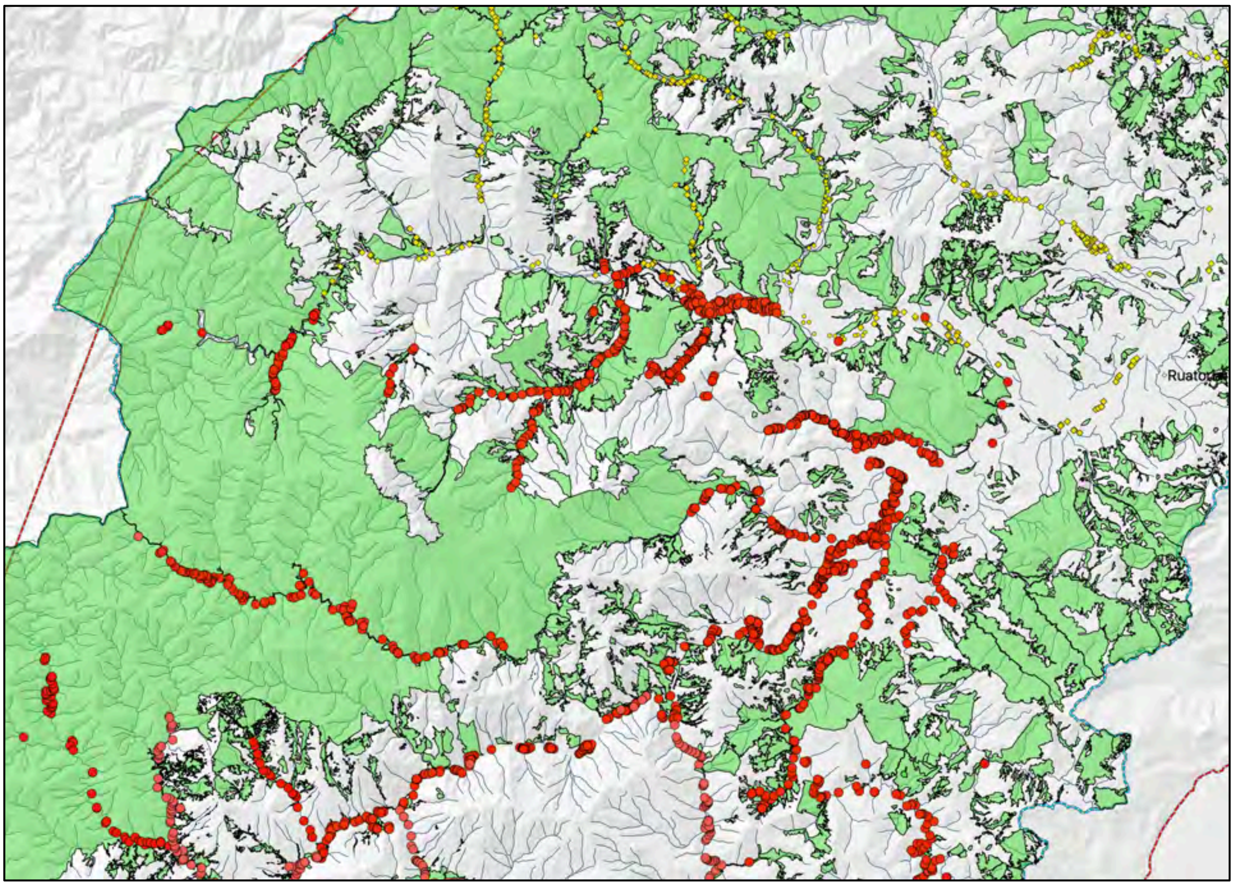

Figure Twenty Six. *Detail of* ***Figure Twenty Five*** *showing the main tributaries with indigenous vegetation with the log pathways in the rivers. As was the case in Figure Twenty Five, the red circles represent post July 2020 imagery while the yellow diamonds are plots based on 2019 imagery. Note; the town of Ruatoria is on the far right of this map.*

Similarly, a plot of all exotic pine plantation forests, open canopy (replanted or new plantings on pasture) and recently harvested pine for the Waiapu catchment has been overlain with the log distribution shown in **Figure Twenty Four**. This shows that the exotic forests in the upper Mata River and tributaries such as the Waitahaia, Whakoau, Mangamatukutuku and Mangatarata were a significant source of pine logs, harvest residues and displaced whole trees within the catchment following the July 2020 storms (**Figure Twenty Seven**).

Furthermore while some of this material can be traced to areas with either recent harvests or open canopy pine, this was not always the case. The analysis shows that the Ihungia Rivers and its headwater streams were also significant contributors of logs despite no significant harvests occurring in the sub catchment indicating slope failures in standing pine forests. Other areas, including the Aorangiwai and Mangaerewa tributaries on the true left of the Mata River, and Makarika Stream on the true right lower down the Mata River also contributed material (**Figure Twenty Eight**).

Further north the Mangapekapeka tributary of the Tapuaeroa River also contributed logs. Lack of good quality satellite imagery precludes determining whether or not areas of recent harvest in Ruatoria forest further up the Tapuaeroa River contributed woody debris during 2020.

The 2019 satellite data shows that open canopy pine forest in the northern pine forests adjacent to the Mangaoparo River and probably also the Waiorongomai

Rivers contributed pine material to the Waiapu catchment during 2019 (and also probably during the 2018 Queens Birthday storm). It is likely that this material contributed to the population of weathered (long-resident) logs observed on Tikapa Beach in 2020.

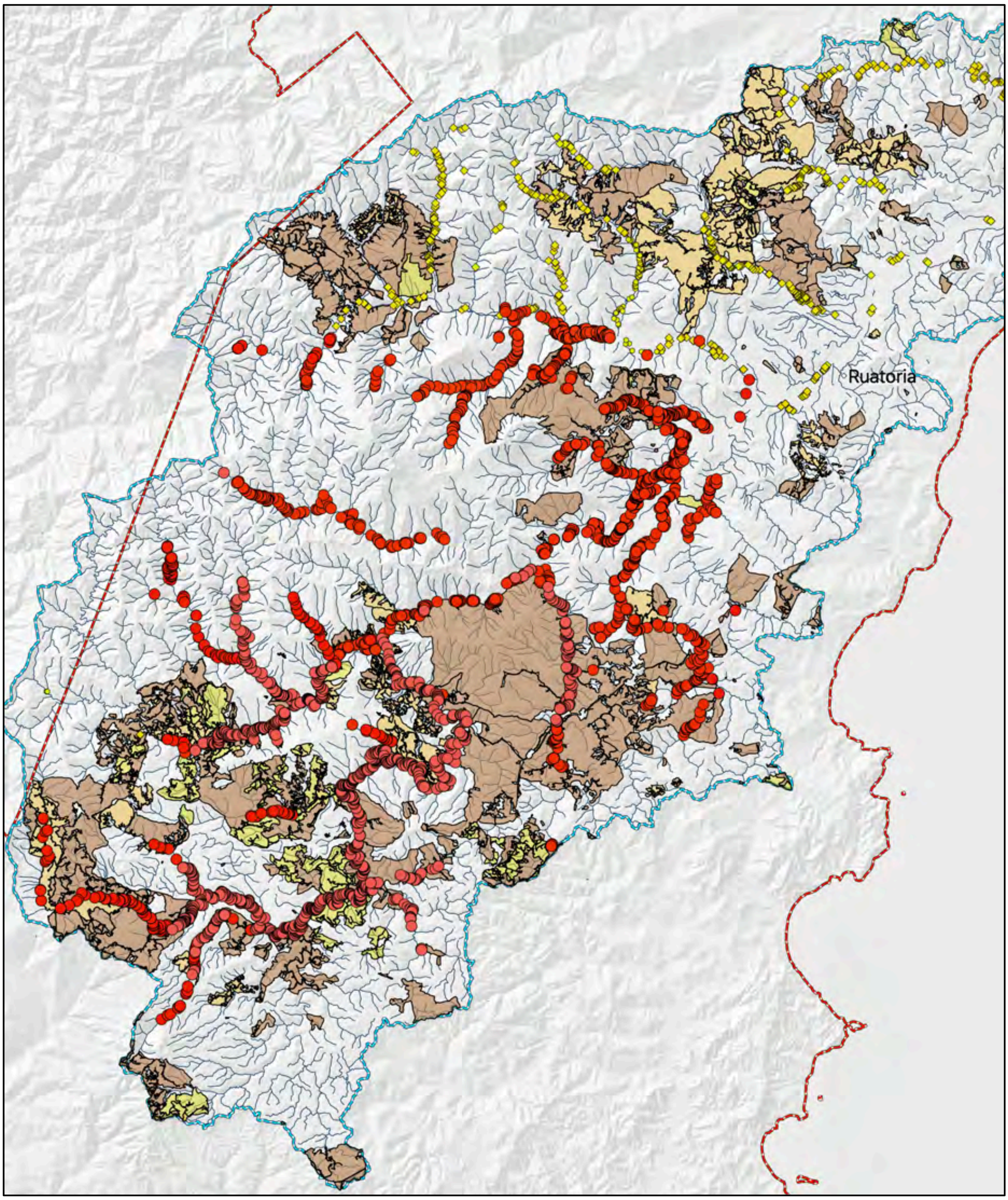

Figure Twenty Seven. *Map showing the same log distribution data as* ***Figure Twenty Four*** *overlain by the area of significant Exotic forest land cover in the Waiapu catchment showing that the upper Mata River itself and the true right tributaries of the Mata are likely sources of the Pine woody debris in the Waiapu River and thus most probably is also the source of a large proportion of the pine material on Tikapa Beach.*

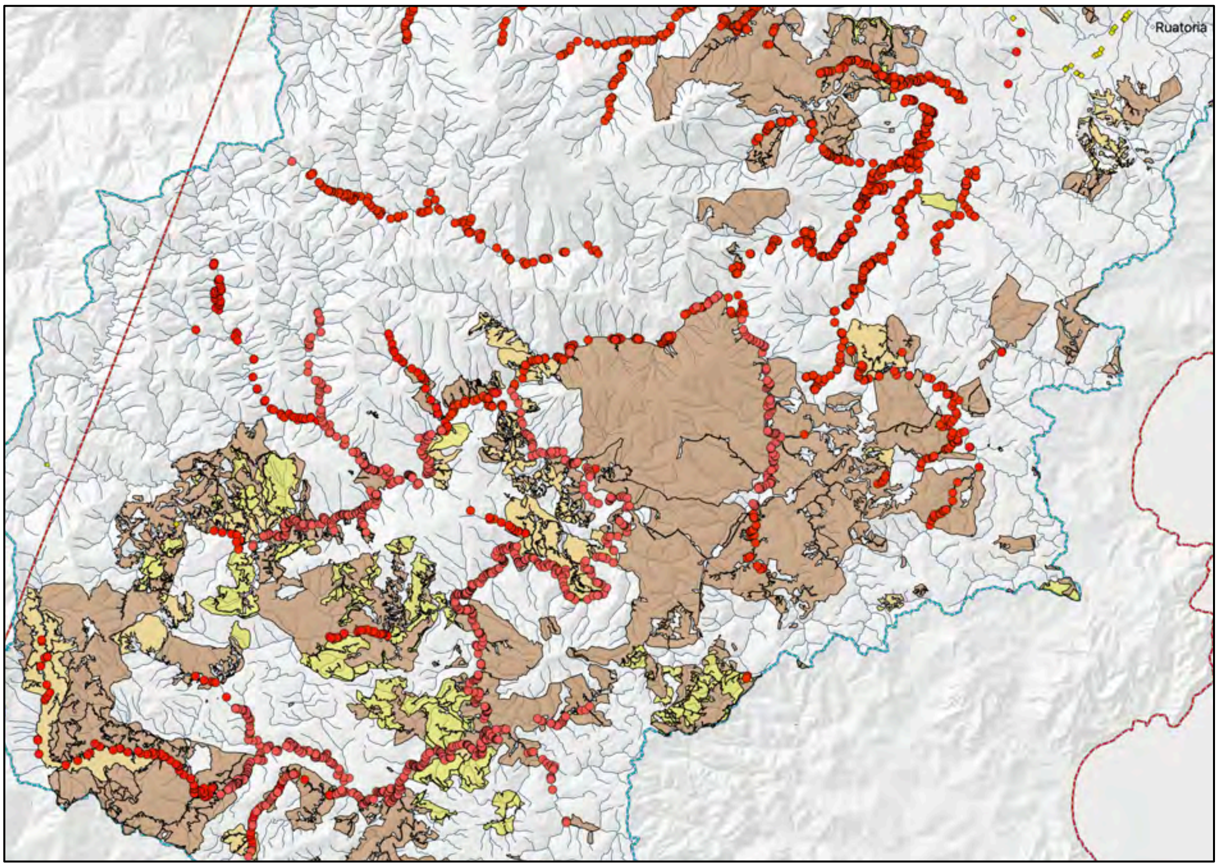

Figure Twenty Eight. *Detail of* ***Figure Twenty Five*** *showing the main tributaries with exotic vegetation with the log pathways in the rivers. Note; the town of Ruatoria is on the top right.*

5.0 Site Specific analysis

The satellite analysis has allowed for some specific hotspots, or significant failure sites that have contributed logs or harvest residues to the catchment to be identified (**Table Two**). These are not the only contributors of woody material to the catchment but are the most obvious sources of wood supply identified in this assessment. In addition, without verification on-the-ground, it is not possible to determine whether or not a large proportion of the logs observed in the catchment below the hotspots were the result of slope failures during the July 2020 storm events. It is likely that some will relate to prior events such as the Queens Birthday storm of June 2018 and some to the Cyclone Cook event of 2017.

In some instances these can be attributed to the shedding of trees from active gullies in both indigenous and exotic pine forest cover. In other cases, however, it is clear that trees and other woody material have been sourced from erosional failures of the river or stream banks during flood scour or other natural impacts arising from flood events. On the other hand, it is also evident that the failure of skid sites or landings has resulted in harvest residues being discharged into the waterway. In addition, several sites show where considerable volumes of logs have been left on or at the base of slopes where it has then been mobilised during flood flow. In one instance, it appears likely that poor drainage or poor drainage maintenance on a forestry road has contributed to a significant failure highlighting the importance of ongoing forest infrastructure maintenance.

What is also evident from **Table Two** below is that the majority of sites are in the Mata sub catchment and its tributaries in the south of the Waiapu Catchment. Three sites have been in the Tapuaeroa sub catchment and its tributaries while other tributaries of the Tapuaeroa such as the Mangaoporo and Waiorongomai have not been assessed as primary sources as no satellite imagery for those sub catchments was available for the period following the July 2020 storms.

Sources	Vegetation class	Watercourse
Broad slip on edge of creek shedding logs	Indigenous	Mangarata Stream, Tributary Tapuaeroa River
No obvious failures. Incremental contribution along stream banks	Indigenous	Mangatoitoi Stm, Tapuaeroa R.
Active Gully shedding pine trees	Pine	Mangapekepeke Stm,Tapuaeroa
No obvious failures. Incremental contribution from stream banks	Pine	Mangaaorewa Stm, Tapuaeroa
Gully with movement of logs	Indigenous	Waingakia Stream, Mata River
Slip with logs mobilised post July 2020 storm	Indigenous	Waingakia Stream, Mata River
Fresh mega slip dated between 15042020 & 08082020 mixed indigenous & pasture with trees & scrub shed to river	Indigenous	Waingata Stm, Waitahaia R, Tributary Mata R
Debris flow from landing with slash to river	Pine Open canopy	Waimata Stream, Mata River
Large failure from landing near trig A7UY	Recent pine harvest	Waitahaia R, Tributary Mata River
Slash from recent harvest in river, large number of felled to waste trees & cut logs on slope. Ref Cyclone Cook Report	Recent pine harvest	Whakoau Stm, Mata River
Logs from vulnerable birds nest in river. Ref Cyclone Cook Report	Recent pine harvest	Whakoau Stm, Mata River
Significant tension cracks mobilising logs on skid site.	Recent pine harvest	Whakoau Stm, Mata River
Log jam in pine	Recent Pine Harvest	Mangahaweone trib of Mangatarata Stm, Mata River
Log jam in recent harvest	Recent Pine Harvest	Mangahaweone trib of Mangatarata Stm, Mata River
Large gully in pine shedding logs	Pine	Ihungia R, Tributary Mata River
Gully shedding logs near Waitahaia Road	Pine	Waitahaia R, Tributary Mata R.
Gully shedding logs east of Waitahaia Road	Pine	Waitahaia R, Tributary Mata R.
Large scale failure of landing Stevensons forest with probable excess drainage from watercourse	Pine	Aorangiwai Stm, Mata River
Area of pine trees being shed to river from active stream bank slips	Pine	Whakoau Stm, Mata River
Recent slip in recent harvest,	Pine	Whakoau Stm, Mata River

Table Two. *Summary of the key hotspots or site-specific sources for wood waste in the Waiapu catchment. Note; not all of these sites are described in detail below.*

5.1 Tapuaeroa Sub Catchment

5.1.1. Indigenous logs Mangarata Stream Tapuaeroa Headwaters

Satellite imagery for this site is available covering multiple days following the July 2020 storms. The imagery for the 21st August, 13th and 16th of September and 2nd of October 2020 have been used to plot the distribution of logs in the Mangarata sub catchment at the head of the Tapuaeroa river (**Figure Twenty Nine**).

A detailed view of an active slip in indigenous vegetation downstream of an obvious gully is shown in **Figure Thirty** below and shows a considerable number of logs in the streambed and also on the face of the slip. A slip that initiated on the site of a re-vegetated former slip but has significantly increased in size since the June 2018 Queens Birthday storm is present in the adjacent tributary on the true right of the Mangarata Stream (**Figure Thirty One**).

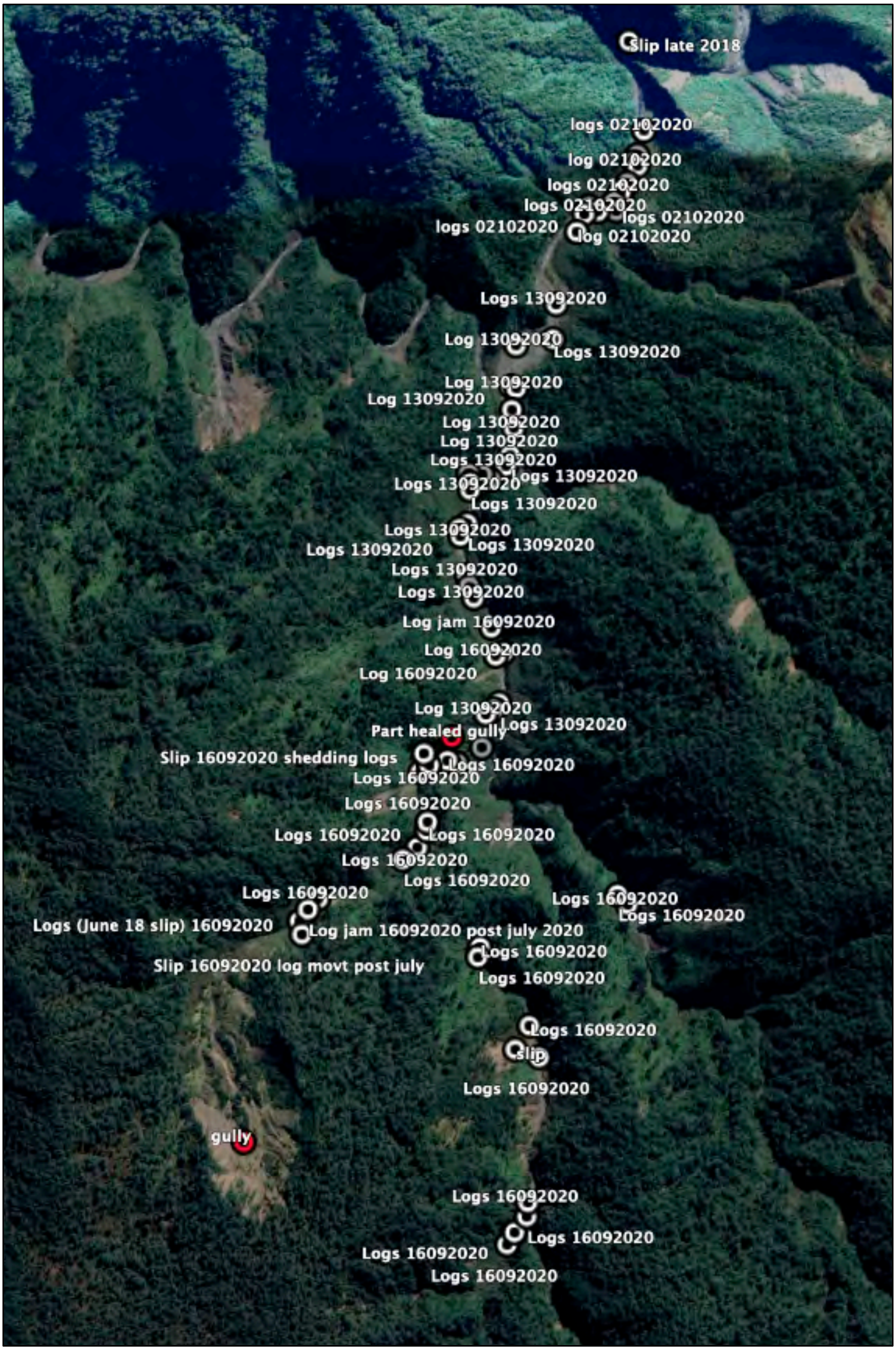

Figure Twenty Nine. *Satellite imagery of the Mangarata stream in the headwaters of the Tapuaeroa River showing the main gully as well as the distribution of logs downstream from the gully as well as from slips in the adjacent tributaries.*

Figure Thirty. *View of slip immediately downstream of the gully in Mangarata Stream showing a significant volume of indigenous logs in the streambed. Logs are also visible on the face of the slip.*

Figure Thirty One. *View of an adjacent tributary of the gully in Mangarata Stream showing indigenous logs in the streambed. Logs are also visible on the face of the slip.*

5.1.2 Incremental contribution of indigenous from Mangatoitoi stream bank failure

Satellite imagery dated the 8th of August 2020 was used to plot the distribution of logs in Mangatoitoi Stream. This stream is a tributary of the Mokoiwi Stream which in turn discharges into the Tapuaeroa river (**Figure Thirty Two**). There is no immediately obvious cause of the migration of the logs in the uppermost reaches of the stream. There area couple of small slips immediately upstream, however, these seem too small to generate the volume of logs in the stream.

More promising is a debris flow that has its toe in the stream around 1km below the highest set of logs (**Figure Thirty Three**). Again, however, despite this debris flow having a path of around 1.2km, all but the lowest 250m is in pasture. Hence it is unlikely to have generated all of the logs seen further downstream. Furthermore, this debris flow predates the July 2020 storm events and does not appear to be relatively inactive. Two other small slips reaching the stream are evident below the debris flow (**Figure Thirty Four**) and these may have contributed some material although logs are present above these slips and they are too small to have contributed to all of the woody material in the streambed below.

Most likely the logs of logs observed in the streambed have been generated from a series of slips and debris flows along the length of the stream although none were individually capable of generating the volume of logs observed.

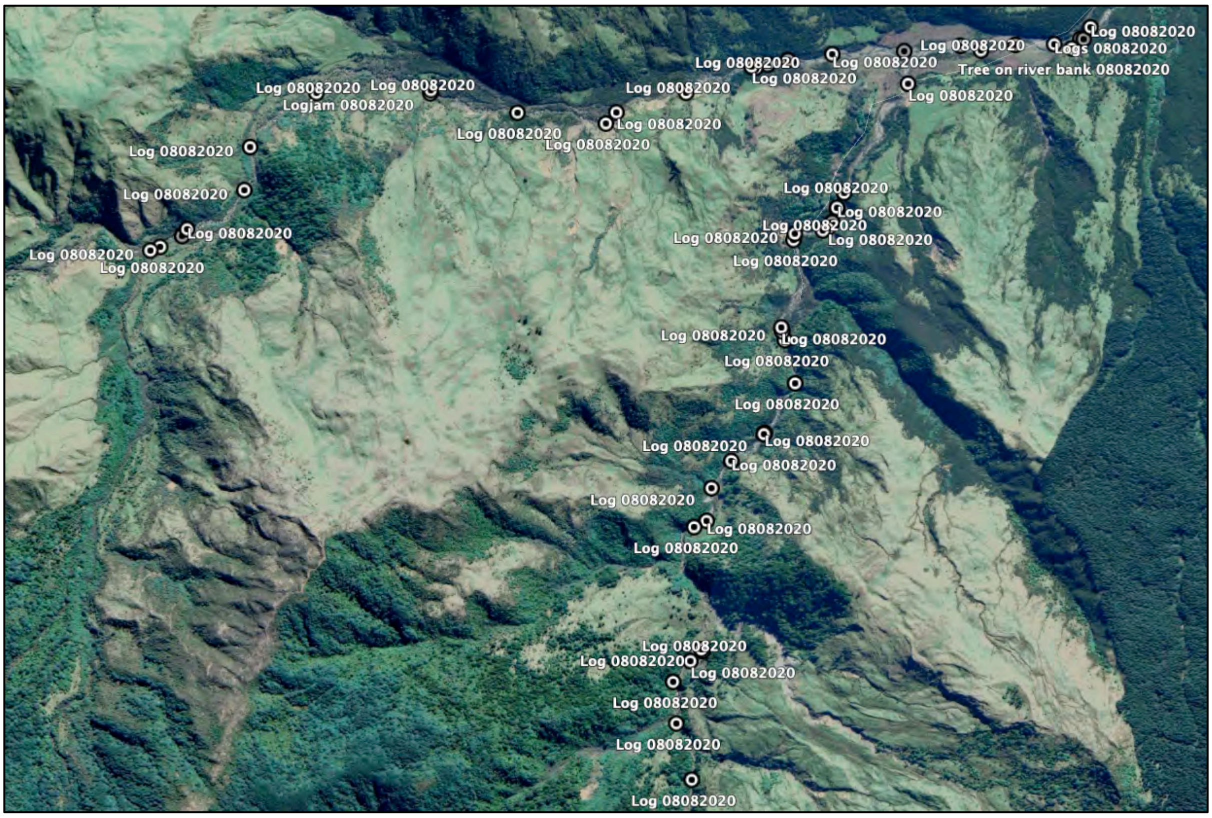

Figure Thirty Two. *View of headwaters of Mangatoitoi Stream showing the distribution of logs downstream to the Mokoiwi stream confluence.*

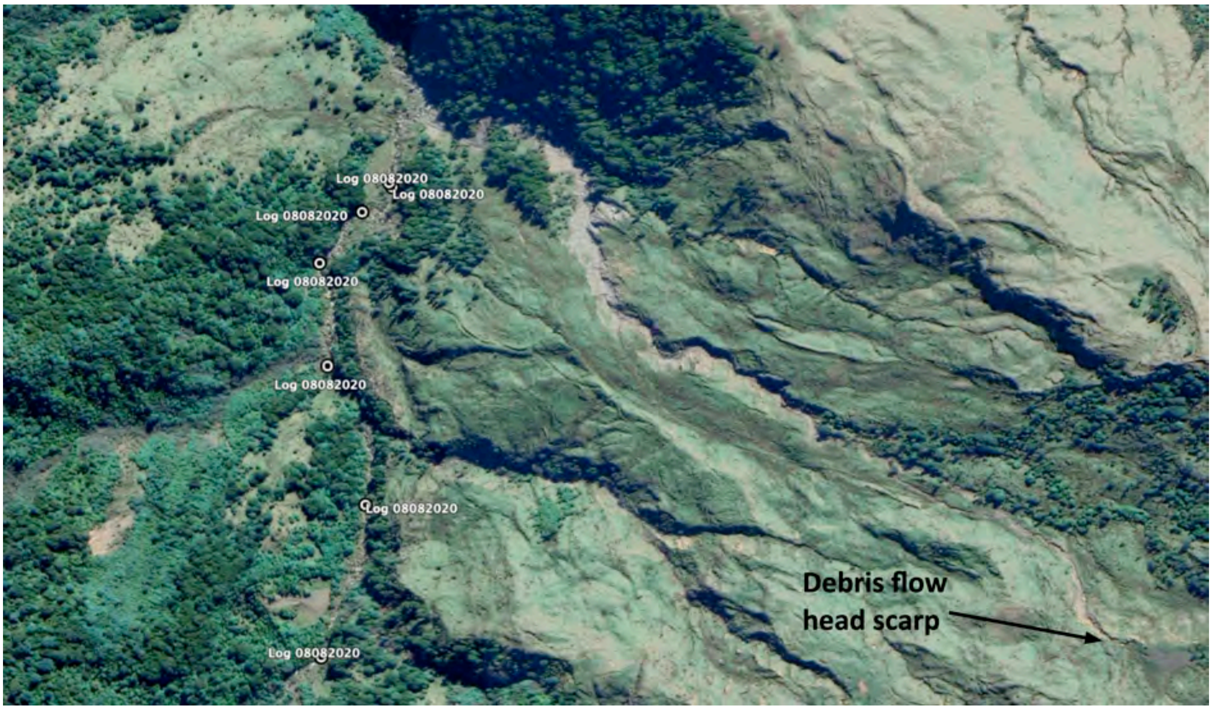

Figure Thirty Three. *View of a debris flow at the headwaters of Mangatoitoi Stream.*

Figure Thirty Four. *View of a slip in Mangatoitoi Stream that was enlarged during the July 2020 storms.*

5.1.3 Active Gully system in pine forest Mangapekepeke stream

The earliest satellite imagery for this large gully system is dated 10th December 2002 at which stage the adjoining ground was largely in pasture or pasture that has recently been planted with pine (**Figure Thirty Five**). These conversions from pasture to pine have been seen as a tool to stabilise gullies with Marden *et. al.* (2005) indicating that size and shape of a gully was a key determinant of stabilisation with the larger gullies (>10Ha) not stabilising over a 28 year period.

Figure Thirty Five. *View of gullies in Mangapekepeke Stream in the Tapuaeroa sub catchment in 2002. A linear gully forms the headwaters of the stream while a large amphitheatre gully occupies the true left with smaller amphitheatre gullies are evident on the true right. The area adjacent to the linear gully in the headwaters has been planted in pine while the remaining areas are in pasture.*

In the case of Mangapekepeke stream, however, the main gullies including those less than 10 ha in area increased in size between 2009 and August 2020 with all showing signs of recent shedding of trees in August 2020. One such gully on the true right side of Mangapekepeke stream with freshly mobilised pine trees and soil is shown in **Figure Thirty Six** below.

Of the 12 gullies mapped in Mangapekepeke stream, eleven showed the shedding of significant fresh pine trees in August 2020 while in the last gully in an area of indigenous cover at the foot of the stream, did not show active shedding of trees.

One gully on the true left of Mangapekepeke stream had significantly reduced in size since 2002 but even this gully showed signs of recent erosion and loss of mature pine trees in August 2020 (**Figure Thirty Seven**). The distribution of logs within the stream is shown in **Figure Thirty Eight**.

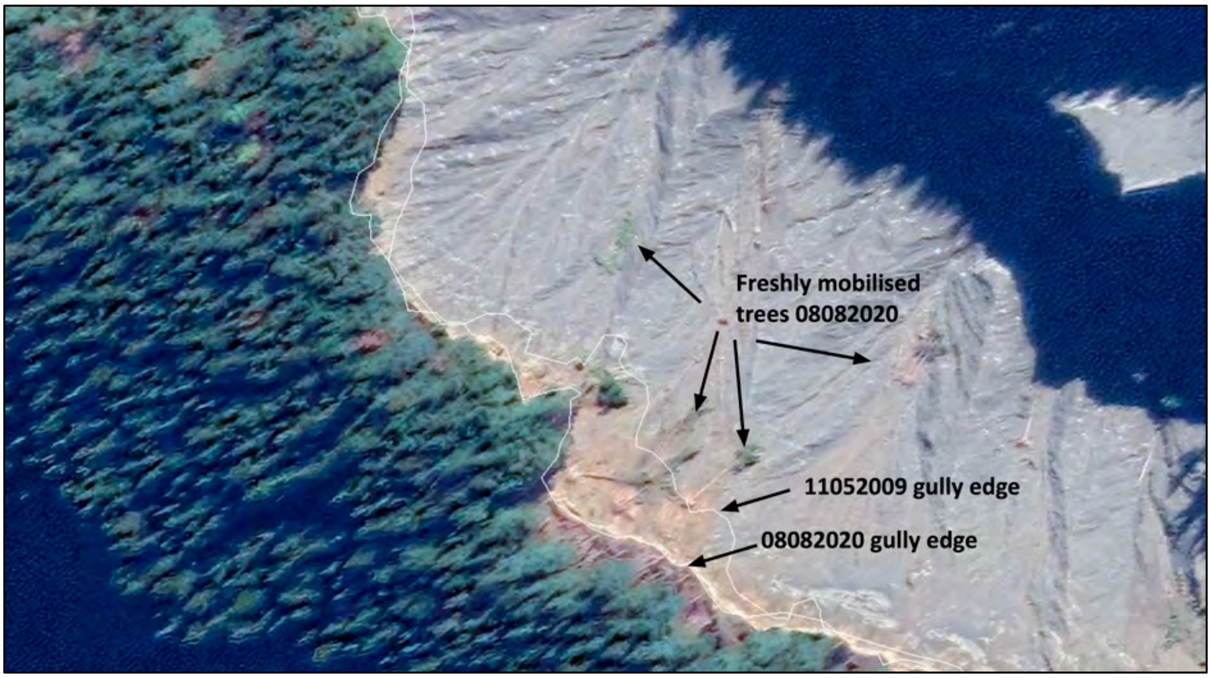

Figure Thirty Six. *View of a 7.85 ha gully on the true right of Mangapekepeke Stream in the Tapuaeroa sub catchment in 2002 showing the extent of gully enlargement between 2009 and 2020, and signs of fresh erosion of soil with mobilised fresh trees in August 2020.*

Figure Thirty Seven. *View of a partially revegetated gully on the true left of Mangapekepeke Stream showing signs of recent movement in August 2020 with mobilised pine trees.*

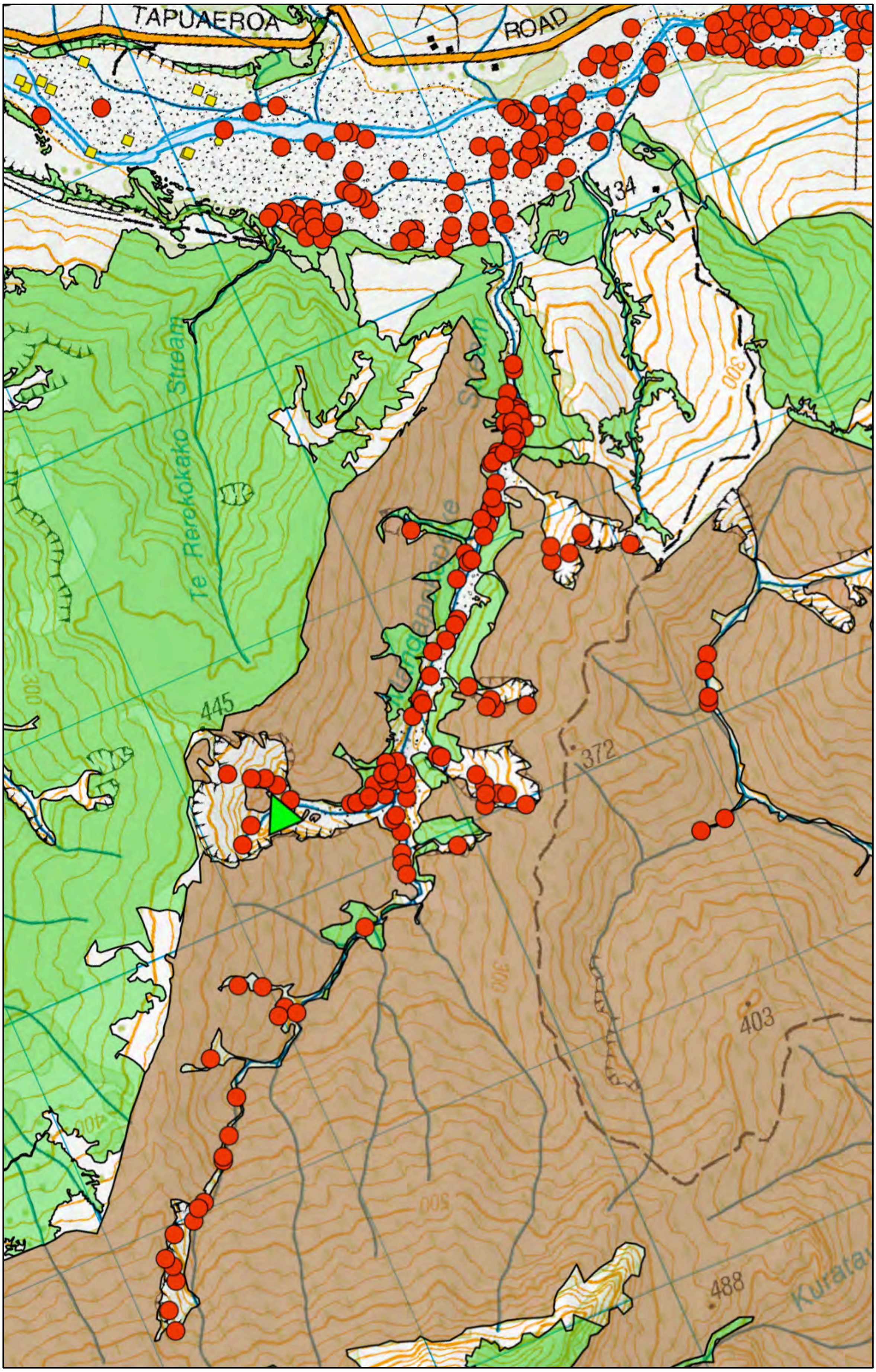

Figure Thirty Eight. *View of Mangapekepeke Stream in the Tapuaeroa sub catchment the distribution of logs based on satellite imagery dated 8th August 2020.*

5.2 Mata River Sub catchment

5.2.1 Large landslide in regenerating Indigenous, Waingata Stream, Waitahaia River

Satellite imagery from the 8th of August 2020 shows a large-scale fresh landslide (**Figure Thirty Nine**) in regenerating indigenous scrubland with scattered larger indigenous trees that was intact in the previous imagery dated 21st May 2020 (**Figure Thirty Forty**). This has resulted in sediment being pushed into the river and there are scattered logs distributed downstream in the river (**Figure Forty One**).

Figure Thirty Nine. *8th August 2020 satellite imagery of a large fresh landslide in the Waingata Stream tributary of the Waitahaia River.*

Figure Forty. *21st May 2020 satellite imagery showing the pre-landslide vegetation cover comprising some open pasture, indigenous scrub and larger indigenous trees.*

Figure Forty One. *8th August 2020 satellite imagery of the Waingata Stream tributary showing the distribution of logs downstream of the landslide.*

5.2.2 Recently Harvested Skid Site Failure Waitahaia River

High resolution satellite imagery for this site is available on the 21st of May (**Figure Forty Two**) and the 8th of August 2020 (**Figure Forty Three**). On the 21st of May 2020, the satellite imagery shows an intact skid site albeit with a slip at river level that had been active since 2011. The site has a stack of cut logs left on the edge of the skid and there is an apron of harvest residues immediately below. There are also logs visible lower in the slope and on the riverbank opposite.

By the 8th of August 2020, the skid site has failed resulting in a slip to the river occupying approximately 4.5Ha. Assessment of low resolution Sentinel satellite data indicates that the failure occurred at some stage between the 14th of June and the 11th of July 2020. A more precise timing of this failure in not possible, however, since the visible spectrum images between those dates are obscured by heavy cloud.

Analysis of available satellite imagery dating back to the 5th of May 2007 shows that the mature pine forest had been planted on a former area of instability (**Figure Forty Four**). Aerial photographs from 1981 show that the site was a large active slip with an obvious headscarp. It is likely that constructing a roadway and skid on a highly vulnerable site would have been a contributing factor in this site failure and that it would be appropriate for landslide risk assessments to be routinely used during the design of harvesting infrastructure and assessed in the consenting process.

Figure Forty Two. *Satellite image of a landing in the Waitahaia River dated 21st May 2020 showing a slip at river level but a stable landing above. Logs are evident on the slip at river level and on the river bank opposite.*

Figure Forty Three. *Satellite image of the same landing in the Waitahaia River dated 8th August 2020 showing the collapse of the landing with a significant slope failure to river level.*

Figure Forty Four. *Satellite image of the site of the landing failure that occurred in the Waitahaia River between 21st May 2020 and 8th of August 2020. This shows the outline of the slope failure that occurred during the storms of July 2020 with signs of the earlier slope failure marked by an area of poor growth. Other areas of instability with poor pine cover are evident on either side of the 2020 failure.*

5.2.3 Gully in Indigenous Waingakia Stream Mata River

Satellite imagery dated 30th August 2020 shows an active 6.7 Ha gully with a significant volume of logs displaced to the stream (**Figure Forty Five**) with further logs also shed from a slip in indigenous further upstream (**Figure Forty Six**). Earlier imagery dated 8th November 2019 also shows a large number of logs in the stream below the gully which are most likely the result of the October 2019 storms.

Further, assessment of the position of logs over successive time-stamped satellite images points to this site being one where active shedding is an ongoing process rather than the result of one storm. This is similar to what has been observed in the Uawa catchment following Cyclone Cook in 2017, the Queens Birthday storms in 2018 and subsequent smaller storm in 2019 as well as the July storms of 2020.

Figure Forty Five. *Satellite imagery dated 13th September 2020 showing an active gully in indigenous forest shedding logs to Waingakia Stream.*

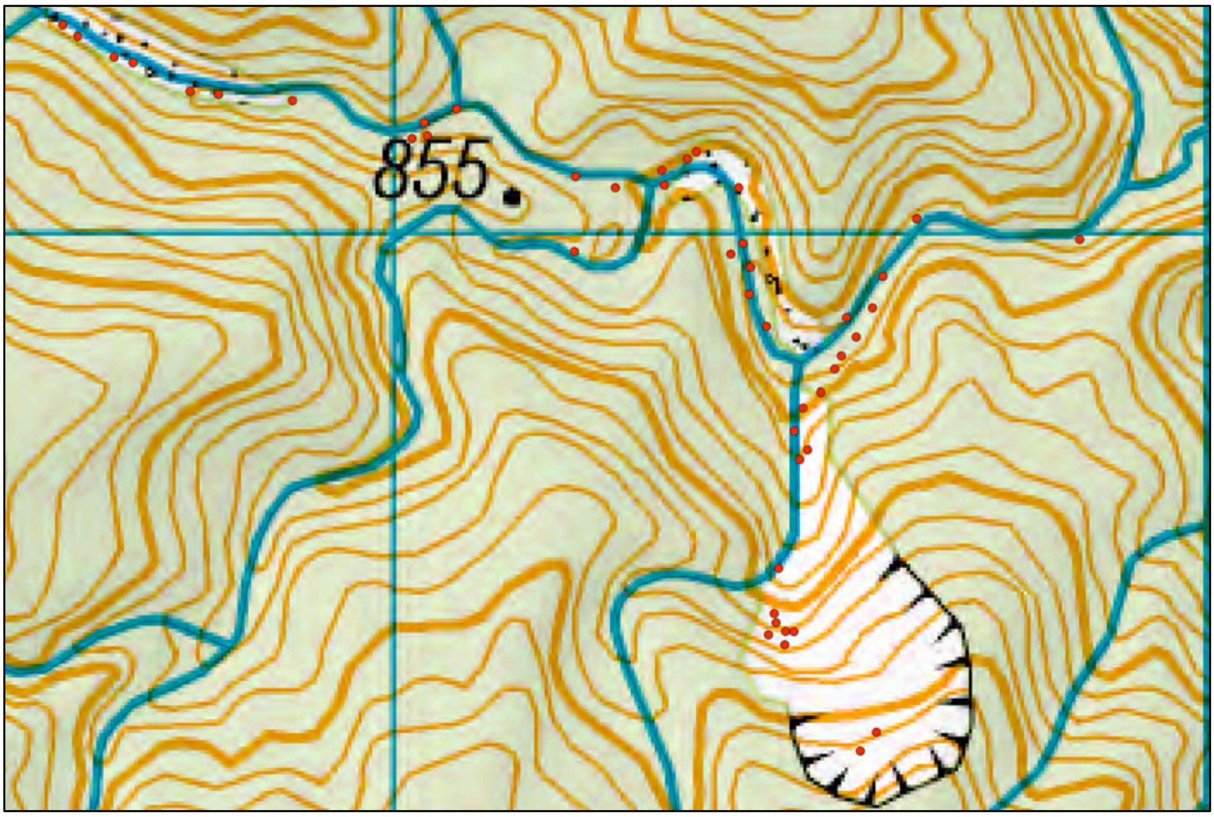

Figure Forty Six. *Distribution of indigenous logs in Waingakia Stream being shed from an active gully and a slip further upstream.*

5.2.4 Debris flow and landslide from birdsnest on landing to Waimata Stream

This site has a history of instability dating back to the period between 2011 and 2015 when the area was harvested. A headscarp close to the landing is present in the post harvest period on the 25th of November 2015 but has no connection with Waimata Stream. By July 13th 2018, however, this slip had been reactivated and now extended to river level while on the eastern end of the landing a narrow debris flow gully had formed (**Figure Forty Seven**).

Figure Forty Seven. *Satellite image dated 13th of July 2018 showing a recently activated landslide on the lefthand side of the landing and a debris flow on the righthand side. Note mature pine left standing below the landing.*

Notably, mature pine at the landing had not been harvested and remained stable. Further satellite imagery dated from 13th July 2018 and 16th September 2020 showed that the debris flow has not been active since 2018. The landslide on the lefthand side of the landing had also remained inactive between July 2018 and May 2020 but had reactivated by the 8th of August 2020 while small-scale slips associated with the debris flow are now evident (**Figure Forty Eight**).

Figure Forty Eight. *Satellite imagery for the Waimata Stream landing dated 13th July 2018, 12th September 2019 and 8th August 2020 showing the slip and debris flow in 2018 post dating the Cyclone Cook storm, a stable period in 2019 and reactivation of the slip in 2020 with small slips associated with the 2018 debris flow.*

5.2.5 Slash from recent harvest and birdsnest Whakoau Stm, Mata River

Satellite imagery dated 27th August 2020 was used in the assessment of this site since the 8th of August imagery has a key area in shadow. The area was harvested over 2016 – 2017 and was impacted by the Cyclone Cook event at the end of Easter 2017 (Cave *et al* 2017). Issues in this area were identified during a visit on the 13th of December 2016 and a limited degree of remediation was carried out in early 2018 following Cyclone Cook and the supply of the Cave *et al* 2017 report to the forestry Industry.

This site assessment relates to the period from 2019 after the clean up undertaken in 2018 to the period following the storms of July 2020. The 15th of April 2018 satellite imagery gives a good indication of the situation in a key potential source of woody debris from this pine harvest area (**Figure Forty Nine**).

This figure shows the presence of a large number of logs lying on the slope between the landing and the stream. At least one large log is evident in the stream itself and downstream of this slope there are a large number of logs in vulnerable sites. The 27th August 2020 satellite imagery indicates that a large log remains in the same position as a log in **Figure Forty Nine** but also that there are a significant number of logs in the stream below which were not present before the July 2020 storms (**Figure Fifty**). The Whakoau Stream site highlights the issues around forestry harvests that do not meet industry best practice guidelines. The site has a range of high-risk issues, such as a large number of logs on slopes prone to ongoing mobilisation, birds-nests of logs placed on the flood plain and large scale harvesting on unstable slopes. These factors make this site a probable source of logs in the river for several years to come.

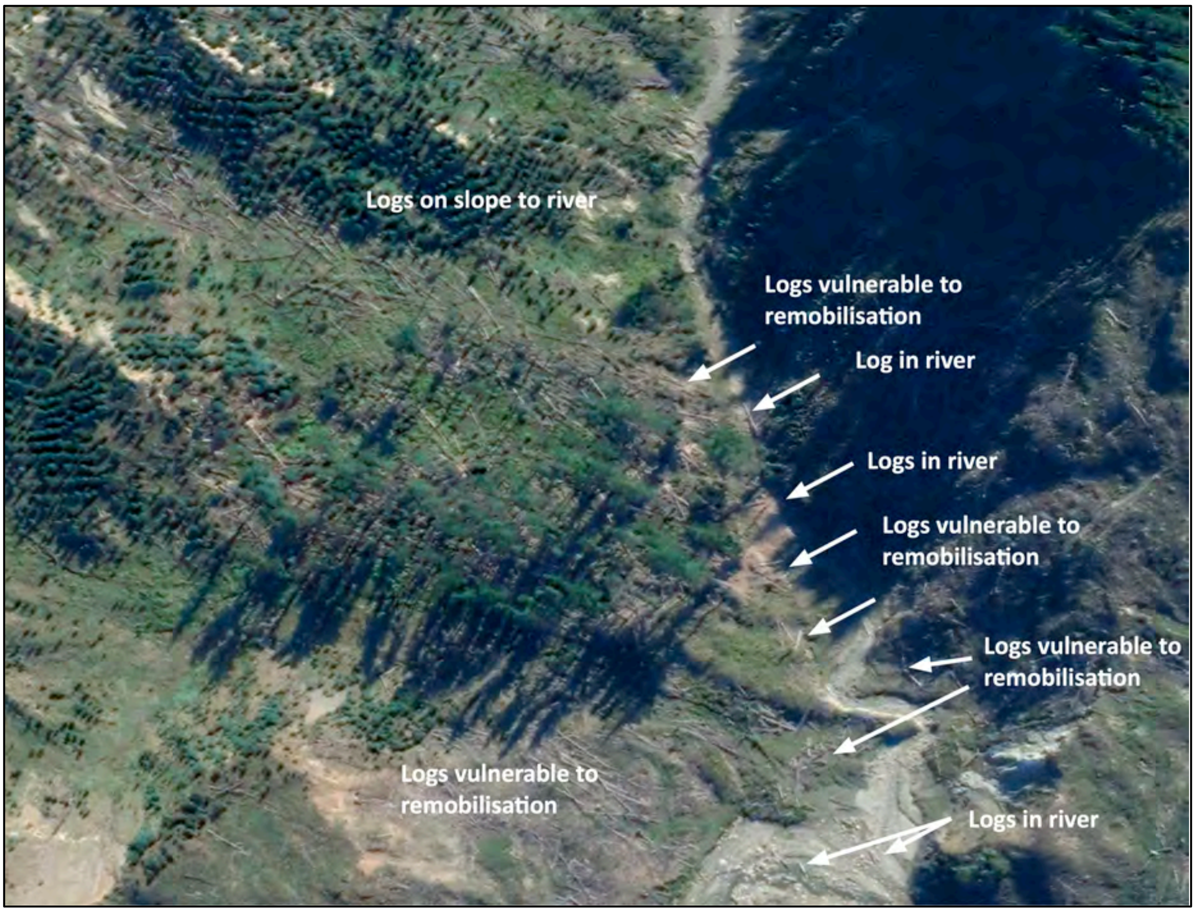

Figure Forty Nine. *Satellite image of the Whakoau Stream upstream from near Bremnar Bridge (15th April 2018) showing the presence of a vulnerable slope with many logs from prior harvest distributed between a landing out of picture at top left as well as the position of logs in the area downstream.*

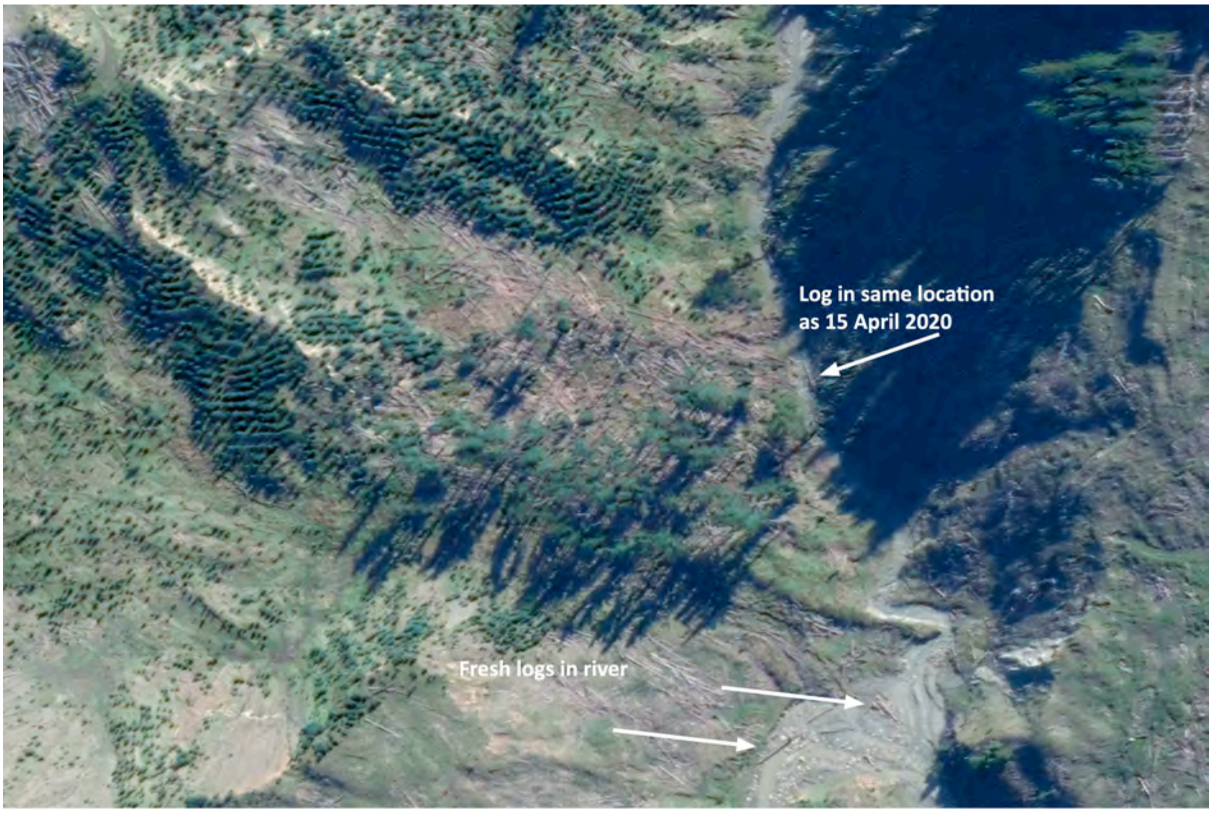

Figure Fifty. *Satellite image of the Whakoau Stream upstream from near Bremnar Bridge dated 27th of August 2020 showing that at least one log remains in the same location but also that there are newly mobilised logs in the river below the slope that is shedding logs.*

5.2.6 Significant tension cracks mobilising logs on skid site. Whakoau Stream

Immediately upstream from the Whakoau site is another landing that satellite imagery from the 8th of November 2019 shows to be intact (**Figure Fifty One**). Over the middle of 2020, however, the landing is marked by tension cracks which by the 8th of August 2020 has resulted in logs and soil being mobilised down slope (**Figure Fifty Two**) and there are indications of active slope failure at the site by the 16th of September 2020 (**Figure Fifty Three**).

It is not evident that this site is presently contributing a significant volume of logs to the catchment. The presence of birds-nests immediately upslope and adjacent to the slope failure indicated by the tension cracks suggests, however, that this site will a probable contributor of harvest residues to the catchment over the next few years. Remediation of the site to mitigate the risk of failure is an appropriate course of action.

Figure Fifty One. *Satellite image of a landing in Whakoau Stream dated 8th of November 2019 showing no sign of failure. The slip at both ends of the site seems to date from around 2016 when the roadway was constructed.*

Figure Fifty Two. *Satellite image of the same landing in Whakoau Stream dated 8th of August 2020 showing tension cracks and signs of logs mobilised from the slope below the landing after the 21st May 2020 sitting below the landing on the flood plain. Note also displaced trees from the standing forest on the left of the image.*

Figure Fifty Three. *Satellite image of the same landing dated 16th of September 2020 showing the slumping at the site in more detail (with less shadow than the 8th of August image). Note the collapsed trees on the slip face and in the river at the toe of the slip upstream of the landing.*

5.2.7 Log jams in recent harvested forest Mangahaweone tributary, Mata River

Harvesting of this forest that is surrounded by pasture started in 2015 and was completed before July 2018. The harvesting is notable for the extent to which logs are distributed on all slopes and within the Mangahaweone Stream down to the confluence with the Mangatarata Stream tributary of the Mata (**Figure Fifty Four**).

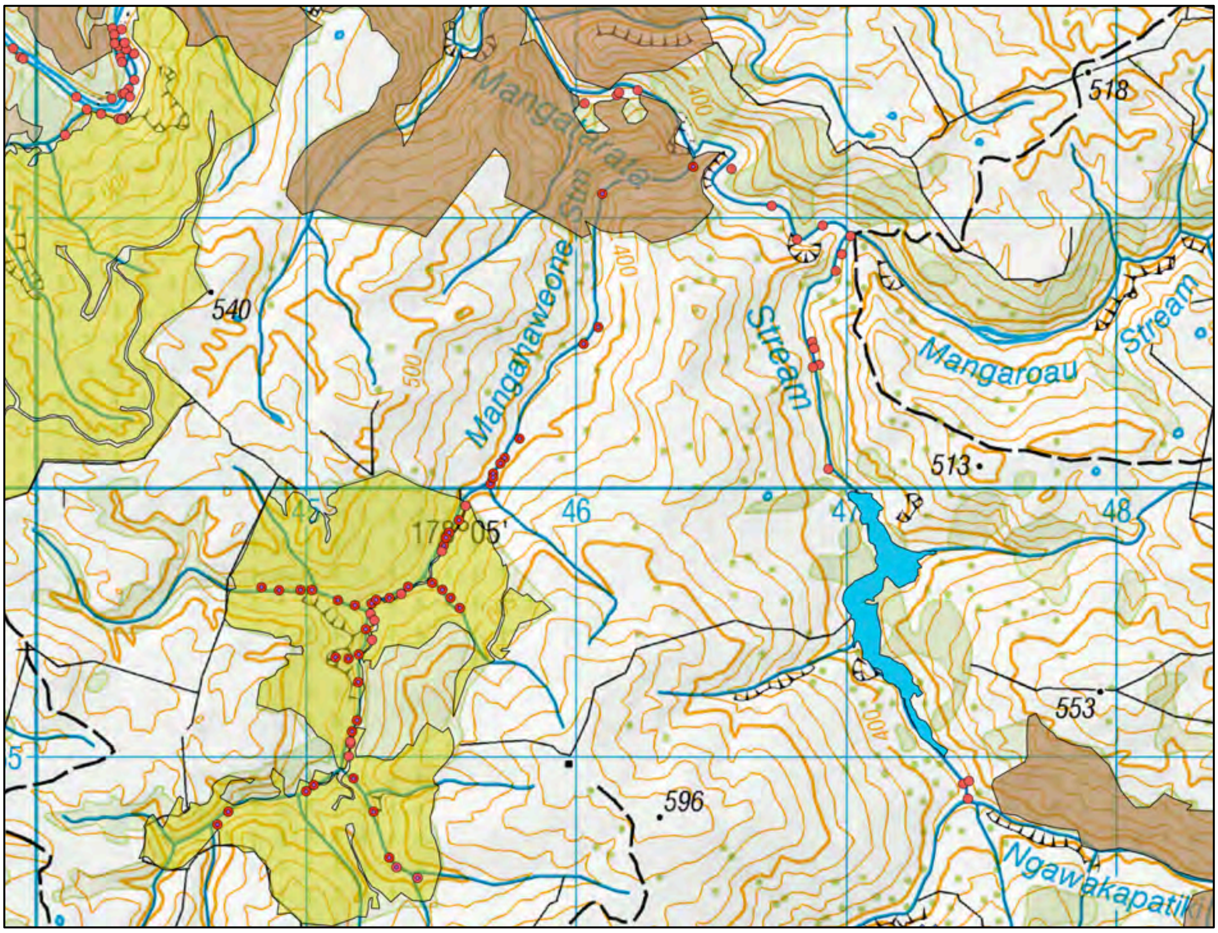

Figure Fifty Four. *Map of the recently harvested forest in Mangahaweone Stream and the distribution of logs in the streams and migrating down to the Mangatarata tributary of the Mata River. Note the small lake in the adjacent stream which formed as a result of an earthflow on the boundary between Matanui and Fernside stations.*

The extent of logs in the streambed is shown in **Figures Fifty Five** and **Fifty Six** below. **Figure Fifty Five** shows two log jams in the main stem of the Mangahaweone Stream on the 27th of August 2020 while **Figure Fifty Six** shows the extent of logs in a small true left tributary immediately upstream of the log jams on the 13th of September 2020. While one group of logs in **Figure Fifty Six** clearly relates to a fresh slip the other areas of logs are not related to slope failures. Assessing the position of these logs in both figures over time does not point to a significant extent of downstream migration over the period from 13th July 2018 to the 9th of September 2020 that is the latest available satellite imagery. Some movement of individual logs is occurring but generally the log jams themselves have remained in place[3]. This site is, however, a significant reservoir of logs with potential to mobilisation in the future.

[3] This area was prone to significant movement prior to harvest. Kerry Hudson *pers comm*.

Figure Fifty Five. *Satellite image of Mangahaweone Stream 27th August 2020 showing the log jams in the main stem.*

Figure Fifty Six. *Satellite image of Mangahaweone Stream on the 16th September 2020 showing the extent of logs within a true left tributary of the stream.*

5.2.8 Large gully in pine shedding logs Ihungia River, Tributary Mata River

This area in the Ihungia river catchment was planted in the late 1990s-2000 and is likely to be harvested within the next few years. Analysis for the period 2007 and 2020 indicates that the gully has been relatively stable over this period with the gully increasing in size from 42.5 ha in 2007 to 43.5 ha in 2020. Some pine encroaching onto area previous in the active gully has occurred, however, while elsewhere some gully retreat has occurred. Satellite imagery for 25th November 2011, through to the 16th September 2020 all show logs being shed from the gully, however, the volume of material in the stream bed at the base of the gully is greatest after the July 2020 storms.

Figure Fifty Seven. *Distribution of logs in the vicinity of a large (43.5 ha) relatively stable gully in the Ihungia river sub catchment. This area was planted in pine some time in the late 1990s-2000 period.*

5.2.9 Gullies shedding logs near Waitahaia Road Waitahaia River

There are several gullies on the true right side of the Waitahaia River on either side of Waitahaia Road which were planted in pine in the period late 1990s to around 2005 (**Figure Fifty Eight**). The gullies have been designated WTR1 to WTR4 (Waitahaia True Right 1 to 4 upstream to downstream) to assess the effectiveness of the pine plantings as a gully treatment. The plantings appear to have been reasonably effective in stabilising the gullies with some showing signs of recovery but with the larger ones show a relatively small increase in size between 2007 and 2020 (**Figure Fifty Nine**).

Gully WTR1 has shown the most improvement decreasing in size from 3.54 ha down to 2.58 Ha while gully WTR3 has shown less of an improvement decreasing in size from 1.32 ha down to 1.1 ha. Gully WTR4 has also shown a decrease down in size from 5 ha to 4.33 Ha over the period. Gully WTR2 on the other hand has increased in size over the period from 3.18 Ha to 3.41 ha. Furthermore, while the overall area of the gullies may have decreased, all of them show signs of recent slipping at the head scarp with trees displaced and mobilised down slope to the streams[4]. Generally, it appears that gully recovery has been the result of good tree growth on easier parts of the gully but this has been at the expense of head scarp retreat.

Figure Fifty Eight. *Satellite image of the Waitahaia River at Waitahaia Station dated 5th of May 2007 showing a downstream gully that has been recently planted in pine while the adjacent gullies upstream have older closed canopy pine. To aid assessment of the site the gullies have been designated as WTR1 to WTR4 (Waitahaia True Right 1 to 4).*

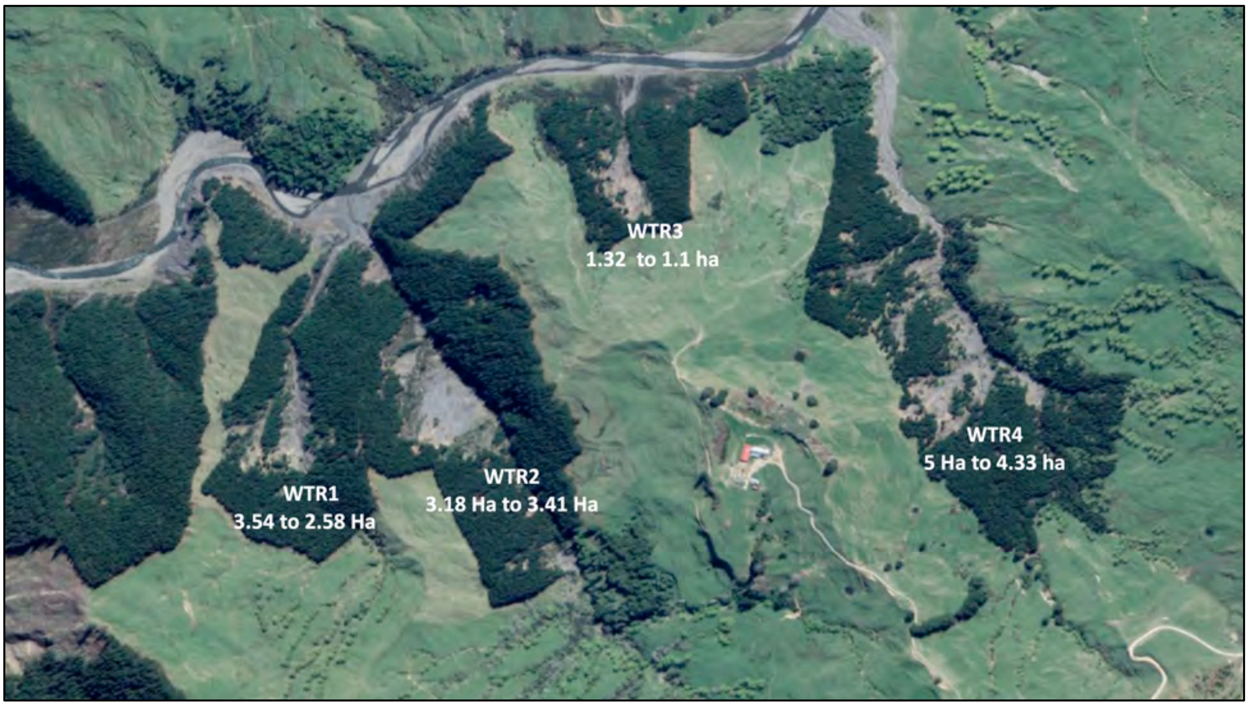

Figure Fifty Nine. *Satellite image of the Waitahaia River dated 8th of August 2020 with the change in area of each gully from 2007 shown.*

A detailed view of gully WTR 1 is shown in **Figure Sixty** below and shows an area of recent erosion and loss of trees as well as an area on the right hand side where an earthflow has caused the pine trees to tilt westwards with at least one falling to the gully floor and others close to collapse. Similar headscarp migration is evident in WTR3 (**Figure Sixty One**) and WTR4 (**Figure Sixty Two**).

Figure Sixty. *Satellite image of gully WTR1 in the Waitahaia River dated 8th of August 2020 showing the earthflow affected pines on the right and trees mobilised from the lefthand side of the eroding headscarp.*

Figure Sixty One. *Satellite image of gully WTR3 in the Waitahaia River dated 8th of August 2020 showing trees that have collapsed from the eroding headcarp on the left of the gully.*

Figure Sixty Two. *Satellite image of gully WTR4 in the Waitahaia River dated 8th of August 2020 showing significant number of trees mobilised from the eroding headscarp on the left side of the gully.*

5.2.10 Aorangiwai Stream Stevensons forest Landing and roadway failure

This site was one of the more dramatic failures from the July 2020 storms. Soon after the storm of 21st July had eased, a report was received from Ernslaw of a landslide in Stevensons Forest on the Aorangiwai River. As the report indicated that a landslide dam had formed downstream of the failure an initial site inspection was undertaken on the 27th of July but the area could not be visited overland due to slipping on the access road. Accordingly an inspection by helicopter was undertaken on the 28th of July and an initial report prepared on the 29th July (Cave 2020).

The Cave (2020) report concluded that the event most likely occurred during heavy localised rain that fell in the area overnight on the 21st July and that antecedent rainfall had primed the slope for failure. The failure area was about 7.4 Ha and appears to have occurred in an area of pre-existing instability. The report also determined that the lakes that had formed were relatively small and unlikely to fail rapidly but in the event of a failure the volume of water released would be low relative to the capacity of the river below and hence the risk of damage to bridges and other facilities downstream was low.

The loss of trees to the catchment as a result of the landslide was not assessed at that time. An assessment has been made using satellite imagery dated the 8th of August and the 12th of September 2020 and shows that there were a significant number of logs distributed downstream of the landslide (**Figure Sixty Three**). Not all of these logs will have come from the failure however, as a small slip in indigenous on the true left side of the river just downstream of the landslide dams also contributed a small amount of material.

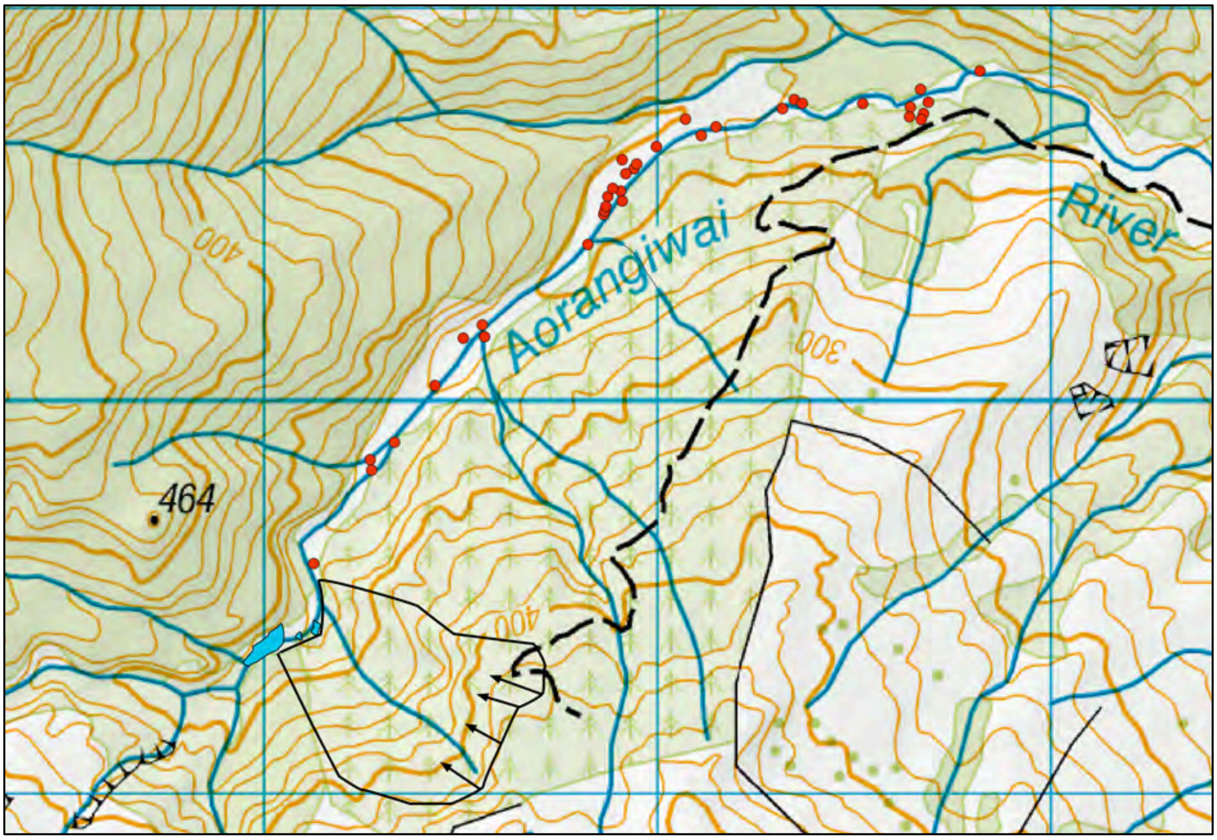

Figure Sixty Three. Map of the Aorangiwai River showing the location of the landslide from Stevensons forest and the distribution of logs identified by satellite imagery dates 8th August and 12th September 2020.

5.2.11 Slip in recently replanted pine, Bremnar Bridge Whakoau Stream Mata River

Satellite imagery from the 8th of August 2020 shows a 0.8 Ha slip on the true left bank of the Whakoau River just downstream from Bremnar Bridge (**Figure Sixty Four**). Imagery from the 21st of May 2020 pre-dates the slope failure but highlights the impact of large volumes of harvest residue logs left on slopes post-harvest when heavy rainfall then occurs (**Figure Sixty Five**). This slip and the other failures higher in the Whakoau River appear to have contributed a significant volume of logs to the catchment (**Figure Sixty Six**).

Figure Sixty Four. *Satellite image dated 8th August 2020 showing a large slope failure on recently replanted slope that has shed a large volume of logs to the Whakaou Stream at Bremnar bridge.*

Figure Sixty Five. *Satellite image of the Whakoau Stream immediately downstream of the Bremnar Bridge dated 21st May 2020 showing the pre-failure presence of harvest residues on the slope.*

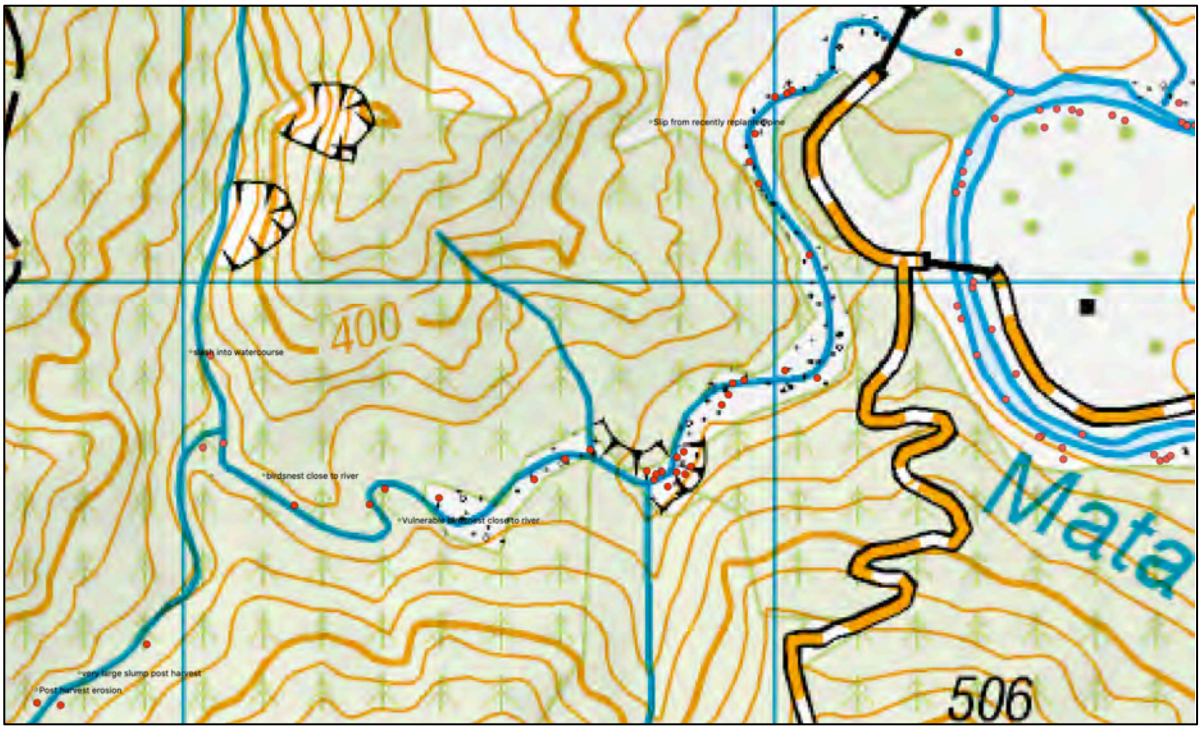

Figure Sixty Six. *Map of the lower Whakoau Stream showing the distribution of logs downstream from the failure sites upstream from the confluence with the Mata River.*

5.3 Evidence of Flood Spread

Flood spread where silt and debris spreads beyond the normal flow banks and onto the adjacent flood plain and low-lying paddocks provides a useful idea of the scale of a flood event. The availability of satellite imagery going back to 2002 in parts of the Waiapu Catchment allows for the timing of flood spread events to be identified. This can help pinpoint where logs have come from during an event and whether or not the woody material seen in a river dates from the most recent event or alternatively are “long resident logs” (logs that have been mobilised previously but remobilised during subsequent events).

Satellite imagery dated 17th of August and 16th of September 2020 show flood spread on the banks of Makatote Stream adjacent to State Highway 35 and just south of Hiruharama Marae (**Figure Sixty Seven**). Prior satellite imagery from the 21st May 2020 does not show any evidence of flood spread in this vicinity. Earlier imagery indicates that this area did not flood during either Cyclone Cook (2017), the Queens Birthday storms (2018) or the October 2019 storms. A small amount of flood spread in Mokoiwi Stream occurred between May and August 2020 occupying an obvious flood channel. Similarly a small flood spread occurred at the mouth of Makomete Stream where it joins State Highway 35 at Waiotaapi (Takapau). During the July 2020 storms a significant amount of flood spread also occurred on the Mata River just west of the Matahiia Road re-occupying in full or in part an area of previous flood spread from the Queens Birthday storm of 2018 (**Figure Sixty Eight**).

Figure Sixty Seven. *Satellite image of the Makatote Stream in the vicinity of Hiruharama Marae on State Highway 35 showing the extent of flood spread from the July 2020 storms.*

Figure Sixty Eight. *Satellite image of the lower reaches of the Mata River dated 16th September 2020 showing the area of 2020 and 2018 flood spread.*

Overall the extent of flood spread during the July 2020 storms does not appear to be as significant as that which occurred during the Queens Birthday storm of 2018 and is not associated with the deposition of a large number of logs.

In contrast, satellite imagery from the 25th of August 2018 shows that there is an area of significant flood with significant numbers of logs spread over the flood plain and pasture in the lower reaches of the Mata River just west of Karewa Road at Aorangi (**Figure Sixty Nine**). Based on the date the most likely origin for this flood spread was the Queens Birthday storm of June 2018. Fresh silt on this flood plain is visible in satellite imagery dated 16th of September 2020 but does not have the same extent as the 2018 flood spread but may have remobilised logs on the flood plain.

*(**Figure Sixty Nine**) image of the lower Mata River at Kawera Road dated 25th of August 2018 showing the flood spread and logging debris from the Queens Birthday storm 2018.*

6.0 Discussion

This report confirms the view of the local community in establishing that wood waste material is having a significant visual and environmental impact on Tikapa Beach south of the Waiapu River. The situation is, however, rather different from that at Tolaga Bay in the Uawa catchment where successive assessments of the wood waste has pointed to the dominant role of pine-based woody material on the beach. An assessment of the quantities and types of wood waste was undertaken after the Queens Birthday storm of 2018 and that assessment has been repeated in 2020. These assessments, confirmed that the proportions of the different types of woody waste differs significantly from Tolaga Bay and also that the characteristics of the woody material is different.

The aggregate percentages of wood waste at Tikapa Beach in 2020 was pine (all pine) at 41%, Indigenous 35%, willow and poplar 17% and other material such as fence posts and battens 7% (See **Figure Nineteen**). This contrasts with Tolaga Bay where 77.5% was pine, just over 5% was indigenous, just over 5% was willow or poplar and

12% was other material such as farm posts. One other difference not picked up is the difference in age of the woody material on Tikapa compared with Tolaga. Tolaga Bay beach has a far greater proportion of fresh material. At Tikapa Beach far more of the material comprised weathered logs irrespective of whether or not those were pine or indigenous. This same contrast was evident during a site inspection of the Tapuaeroa River where a lot of the material was weathered indicating that it had been in the catchment for some time (**Figure Seventy**). It is thus likely that much of the material observed in this assessment had been mobilised previously, most likely in 2017 (Cyclone Cook) or in 2018 (Queens Birthday storm), and was incrementally migrating to the beach during flood events.

Based on the situation in 2017 (Cave et al 2017) it was anticipated that it would not be possible to establish primary sources for the woody debris in the catchment and on the beach. It remains impossible to track woody material directly from a source to the beach. What could be established, however, was that the primary “hotspot” sites were on land that failed and thus caused woody material to mobilise which then migrated to watercourses and from there downstream. These hotspots comprised areas of indigenous forest and scrub, as well as pine. Further, there were multiple slope failure mechanisms as well as spatial differences in the distribution of the hotspots depending on land cover type and as a result, the volume of logs mobilised differed between hotspots.

The data shows that the southernmost Mata River catchment had far more slope failures and also generated a far greater volume of material than did the Tapuaeroa River catchment. This is not, in itself, surprising since the 21st July storm in particular was centred on Te Puia in the south of the Waiapu Catchment.

In the case of indigenous woody material, the main mechanisms for mobilising wood to the river system were threefold;

- the re-activation of gullies or the ongoing erosion of gullies adjacent to indigenous forest by attrition over time,
- the incremental addition of indigenous trees and scrub within stream banks resulting from small-scale scour, and
- mobilisation from large slips which are either re-activations or fresh slips that have toes connected to the stream (toe failure).

For pine forests the failure mechanisms were more varied. While some were generated by gully erosion or by incremental failure of stream banks, (**Figure Seventy One**) ten out of fifteen failures were associated with forestry landings (skid sites) and roadways, as well as birds-nests in vulnerable locations and clear-felled slopes directly connected to waterways.

For those associated with landings, there are a few key elements for consideration.

Firstly, a number of the landing failures (Waitahaia River p.33, Waiamata Stream p.37, and Aorangiwai Stream p.48), were strongly associated with severe pre-existing slope failures. The siting of operation sites such as landings and the construction of forestry roads on these pre-existing slope failures has exacerbated the risk of failure post-harvest or in the case of Aorangiwai during second rotation. In the case of the Aorangiwai failure, the landslide appears to have been triggered by a water table and a hairpin bend on a roadway directing water onto the headscarp of the pre-existing failure.

Secondly, most of these landing failures are associated with birds-nests that have been perched on the edge of landings. Birds-nests on landings were a key contributor to the landing failures identified in the Uawa Catchment following the Queens Birthday storms in 2018 due to the additional weight they put onto the edge of the landing during storms.

Thirdly, at some other forestry sites, and the recent harvest in Mangahaweone stream is a case in point (p.42), little care has been taken with slash and reject harvest residues at harvest time. As a result all of the watercourses within the forest have become chocked with harvest residues that can be re-mobilised during storm events.

Finally, at other sites and Whakoau Stream is a case in point, harvest residues have been stowed on or close to the flood plain and as a result such sites are vulnerable during rainfall events that cause floods. This was the case in the Whakoau during Cyclone Cook when large volumes of harvest residues were mobilised and the large slash catcher installed downstream to capture any escaping logs was overwhelmed by the volume of material.

*(**Figure Seventy**) Photograph of collapsed pine tree resulting from river bank scour (toe failure). Tapuaeroa River immediately upstream of Pakihiroa Bridge (6th January 2021).*

*(**Figure Seventy One**) Photograph of weathered pine log with an obvious cut end. Tapuaeroa River approximately 1km upstream of Pakihiroa Bridge (6th January 2021).*

Generally, it was considered that pine plantation plantings were a solution to the type of gully erosion that was exacerbated by Cyclone Bola, in part because they were a fast growing species[5]. On the other hand, this solution was predicated on such forests providing permanent cover but this has proved not to be the case with almost all pine plantations put in following Cyclone Bola converted to production forests. Consequently, all of the potential benefits that pine as a permanent cover afford are reduced once they become harvested as the gullies they were intended to protect again become exposed to the risks of erosion but the risk is also potentially exacerbated by the modifications to slopes necessitated by the infrastructure necessary to achieve harvest.

As a consequence, the areas of pine forest within the Waiapu are vulnerable to erosion post-harvest. Numerous reports and technical papers point to a “window of vulnerability” after which second rotation forest starts to move towards a closed canopy. Aorangiwai and other sites suggest, however, that the risk continues even when second rotation forests move to a closed canopy. This was the case in the Uawa catchment even in areas lacking the degree of gully erosion characteristic of the Waiapu. It is expected that in the Waiapu, as was the case in the Uawa; the forestry infrastructure that is retained as subsequent rotation forests become a locus of risk because of their impact on drainage on roadways and the increased stress placed on slopes by birds nests on landings. The lessons from the aftermath of 2017 Cyclone Cook and 2018 Queens Birthday storms is that large-scale clear fell harvest exacerbates the risk as such large areas are vulnerable to failure during storms.

[5] Note, however, that some areas such as Ruatoria Forest and Mangawhero were initially planted pre-Bola, Kerry Hudson *pers. comm*.

The easiest solution to this problem is to firstly identify sites of high risk within pine forests approaching harvest age and then to create suitable buffers to ensure that the areas around gullies are protected from the impacts of harvest. Secondly, harvest planning should assess the pre-existing geotechnical risks of roadways and landings to ensure that vulnerable sites are avoided.

7.0 Conclusions

1. The woody material that covered Tikapa Beach in 2020 (and in previous events such as the 2018 Queens Birthday storm) is characterised by a varied mix of vegetation types with pine comprising 41%, indigenous 35%, willow and poplar 17% and other material such as fence posts and battens 7%.
2. This mix of material contrasts with the Tolaga Bay beaches in Uawa where pine material dominates. Tikapa Beach also differs in that far more of the wood waste is weathered indicating a long residence time in the catchment.
3. Analysis of relative land cover for indigenous and pine to August 2020 shows that indigenous cover was 38% which exotic pine cover was 29% which suggests that as pine wood, at 41%, is a disproportionate contributor of material to the beach.
4. Pine logs can be seen shedding from areas of recent harvest and are the logical source of the cut logs identified on Tikapa Beach. This shedding appears to be driven by;
   a. The siting of roadways and landings in areas with pre-existing landslides or high slope instability potential which then collapse,
   b. The harvesting of pine stands that were planted to the rivers edge,
   c. the migration of harvest residues from unstable birds nests,
   d. Locating birds nests on riverbanks or flood plains that have then inundated or been scoured by the river during flood.
5. It is considered appropriate that landslide and/or slope stability geotechnical risk assessments are routinely used during the design of harvesting infrastructure and assessed in the consenting process.
6. Forest management plans need to take into account the risks associated with harvest including those associated with large-scale harvest within catchments that then leaves them vulnerable to failure during storms.
7. Pine trees have been sourced from large-scale gullies where pine has been planted in an effort to mitigate erosion risk. Further work is required to fully assess the performance of pine as a long-term stabilisation treatment for these large-scale gullies but it appears that the benefits that do accrue are largely lost during the harvest cycle.
8. A key source of indigenous material being shed into the catchment are persistent large-scale gullies, typically occurring in areas that have not been previously cleared for pastoral farming.
9. Indigenous vegetation has also been sourced from stream banks that have been scoured by stream flood flows.

10. Large slips or landslides not associated with gullies have also generated volumes of indigenous vegetation that have been mobilised to the catchment.
11. It is presently difficult to verify where all the willows and poplars have been sourced but some instances smaller scale gullies have been identified that were planted with willow and poplar for stabilisation reasons but have subsequently failed. Some instances were observed where willow previously planted on the banks or flood plains of streams had failed but not been removed and would thus be vulnerable to mobilisation during flood events.
12. Areas in closed canopy (largely mature harvestable) pine represent 73% of all pine forest land cover (32,00 6.75 Ha) while open canopy pine occupies 18% of all pine forest while only 9% of all pine/exotic plantations has been recently harvested. This indicates that a rapid increase in the area of harvest can be expected over the next few years. In turn this suggests that the area of ground vulnerable to failure and thus mobilisation of harvest residues during severe weather events will increase by several orders of magnitude over the next few years.
13. The National Environmental Standards for Plantation Forests (NESPF) do not require harvest consents for all forests in the Tairawhiti Region unless the forests meet certain criteria. All very high risk [Red Zone] and certain activities on high risk land [Orange Zone] requires a consent but elsewhere harvest is a permitted activity[6]. Each of the hotspots in pine forest considered in this assessment did meet the criteria (8e +7e) except for the Aorangiwai failure that occurred on the boundary between LUC 6e and 7e. Based on the assessment undertaken here it is considered, however, that failures are possible in moderately erosion prone land under the ESC system and thus the NES Plantation Forestry may not adequately address the risks that forest harvest poses to the Waiapu Catchment. Undertaking a full high-resolution landslide risk assessment is beyond the scope of this project.

8.0 References

Cave, M. P., Davies, N., Langford, J. (2017) Cyclone Cook Slash Investigation. Gisborne District Council October 2017

Cave, M. P., (2020) Tikapa Beach Woody Material July 2020 Storm, Initial draft report Gisborne District Council, September 2020.

Cave, M. P., (2020) Major Earthflow Dam, Stevensons Forest, Aorangiwai River – Rapid Assessment Gisborne District Council July 2020

[6] https://www.mpi.govt.nz/dmsdocument/27930-Resource-Management-National-Environmental-Standards-for-Plantation-Forestry-Regulations-2017-March-2018

9.0 Appendices