Cyclone Gabrielle

Post Event Woody Debris Assessment – Hawke's Bay

Supplementary Report Including Northern Beaches

Prepared for **Scion Research**

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1 EXECUTIVE SUMMARY

The Cyclone Gabrielle weather event resulted in large masses of woody debris being spread across Hawke's Bay. Media and public commentators have called this material 'slash'. Slash is the term for woody material that is left as waste after a plantation forest is harvested. The media's use of this term, and the public's perception, suggest that most of the woody debris that caused damage to infrastructure came from waste that was not cleared after harvesting the plantation forest. Hawke's Bay Forestry Group (HBFG) asked for a report in March 2023 to independently measure large woody debris (LWD) content along the coastal and inland catchment areas, describing it by species, probable source, volume per hectare, and total volume accumulated (Herries, 2023).

This report used a modified Line Intersect Sampling (LIS) method to measure the volume of woody debris. This method is a common way to estimate how much woody debris is left after clear-cut logging, and has been used since 1964 by foresters. The modification was to account for the non-random direction of the LWD pieces due to water or wave movement. This was done by using a plot shaped like an equal-sided triangle with random plot locations and random starting direction of the first side of the triangle.

The mapping of woody debris shows 241 ha of coastal woody debris in Hawke Bay, and 14ha of inland debris accumulations in selected catchments. A network of 328 plots was set up at random locations for measurement. Because of access limitations, Herries 2023 reported measurement of only 81 survey plots with little or no road access to northern Hawkes Bay (Field Survey 1).

In July 2023, Scion Research asked for more plots to be added to the network in cooperation with the Ministry for the Environment (Field Survey 2). As many roads were open again, 128 plots were set up from July 24 to 27, 2023. These concentrated on the north coast of Hawkes Bay.

Average volume of 428 m3/ha (11.3 % probable limit of error (PLE)) and that 8 % of the LWD had signs of originating from harvest residue. 18 % of the pine had root ball attached and came from mid-slope failure and/or streambank erosion, while 25 % was pine with no root ball or harvest evidence. This category of material may have been harvest waste, but due to the large areas of mid-rotation pine forest lost to erosion and the smaller diameter (compared to harvest material), it is likely it originated from younger, standing wood sources (Figure 20). Pine made up 51 % of the LWD across Hawke's Bay. 73 % of the LWD was 3 m or less in length, and only 1 % was longer than 12 m. 31% of the LWD was willow or poplar. This material probably originated from flood-protection willow and poplar plantings along the streambanks originally established to prevent erosion during flooding. This shows the severity of the event and the vulnerability of the Hawke's Bay floodplains.

2 INTRODUCTION

2.1 BACKGROUND

Cyclone Gabrielle impacted Hawke's Bay from 13th – 14th February 2023. It was one of the most intense storms to impact New Zealand in recorded history. During the most intense 12-hour period of Cyclone Gabrielle, 400 mm of rain fell with a peak intensity of 56 mm per hour at the Glengarry Hawke's Bay Regional Council site. The highest measured 24-hour rainfall period during Cyclone Bola was 419 mm at Te Puia Springs. This indicates that Cyclone Gabrielle was a much more intense storm than Cyclone Bola during their respective peaks, as it affected parts of Hawke's Bay. Prior to this event was a sustained, record-breaking, wet 6-month period for Hawke's Bay from July 2022 to January 2023. The impact of heavy rainfall during Cyclone Gabrielle was in addition to already saturated soils.

As a result of this extreme weather event, large masses of woody debris have been deposited across Hawke's Bay. Commentators from the media and the public have referred to this material as 'slash'. Slash is defined as woody material left as waste after harvest of plantation forest. The implication of this categorisation by the media, and resulting public impressions, is that the majority of woody debris suggested as the cause of damage to infrastructure came from waste left behind after the harvesting of the plantation forest estate. Hawke's Bay Forestry Group (HBFG) commissioned a report to independently quantify large woody debris (LWD) content along the coastal, and inland catchment areas, characterising it by species, likely source, volume per hectare, and total volume accumulated (Herries, 2023).

Mapping of woody debris indicate 241 ha of coastal woody debris within Hawke Bay, with 328 random plots allocated for sampling (Figure 1). A total of 81 plots were installed from the 3rd to 24th March 2023 (Field Survey 1). Sampling effort focused on the river mouths and inland rivers. Plots were selected from the random pre-planned plot network, starting closest to the river mouth and working outward. The number of plots collected at each catchment had elements of time and access constraints with some sites visited by helicopter. Plots were abandoned where hazardous or disturbed by clean-up activity.

Scion Research commissioned an extension of the plot network in coordination with the Ministry for the Environment in July 2023 (Field Survey 2). With road access restored in many areas, a total of 128 plots were installed from 24th to 27th July 2023. Sampling effort focused on the gaps in the original sample due to access constraints in the northern reaches of Hawke Bay. Plots were selected from the initial 328 plot random pre-planned network, starting closest to the river mouth and working outward.

This report presents the combined summary of the two field surveys.

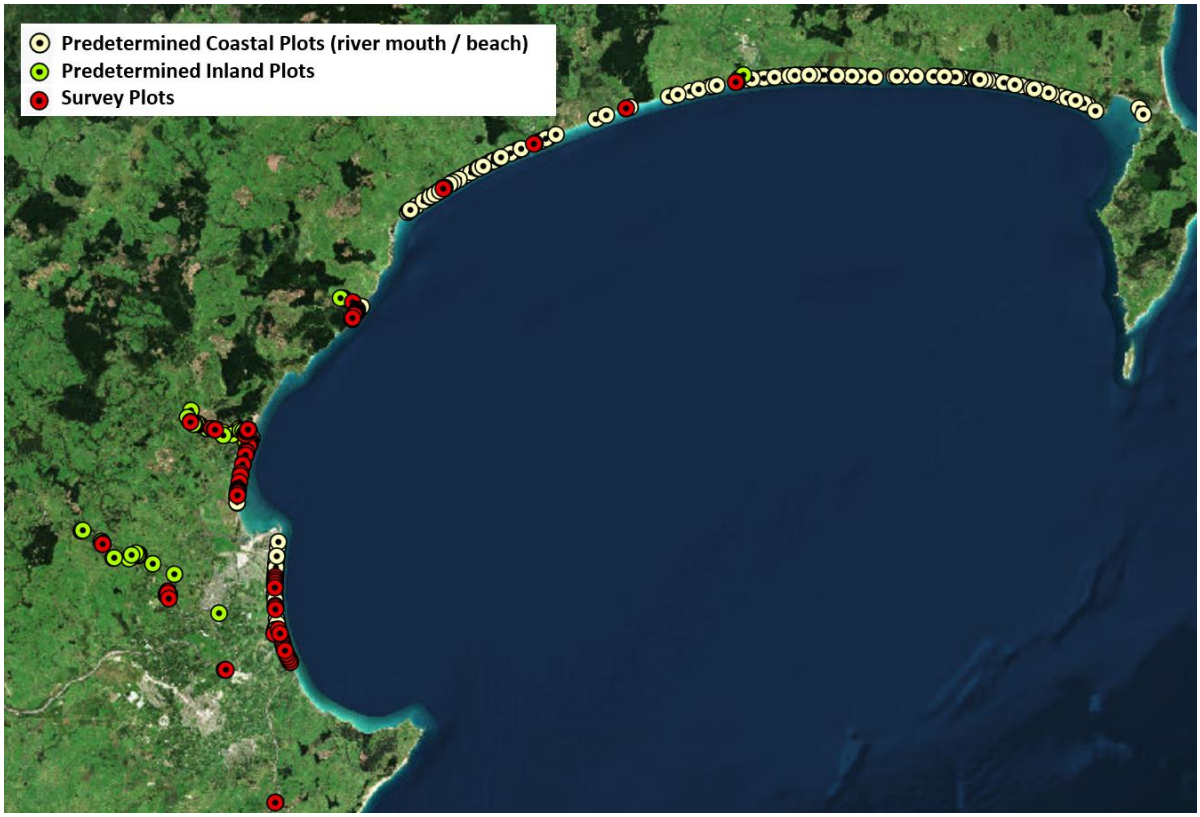


Figure 1 - Predetermined random sample locations, with actual surveyed sites in March 2023 shown in red.

2.2 OBJECTIVE

This study was commissioned to establish a robust data set for accurately categorising LWD volume and proportion by species, in areas where it has had community impact; such as beaches, infrastructure, streambanks, and properties across the Hawke's Bay region.

This supplementary report aims to assess sample locations which were omitted from the March 2023 survey due to access restrictions.

3 METHODOLOGY

For completeness the Methodology section is extracted from Herries, 2023. The following recommendations (Herries, 2023) were implemented, and the methodology has been extended to include;

- Transect edge plots where the transact extends outside of the mapped debris extent, a fold back transect mirage plotting methodology was implemented (Section 3.3.2).
- Weathered wood that was clearly aged beyond Cyclone Gabrielle is recorded separately. This classification was undertaken to help to distinguish debris from previous events (Section 3.3.4).
- Piece length data is collected with categorisation into length bins (e.g., <1m, <3m, <6, <9m, <12m, >12m etc.) (Section 3.3.6)

3.1 MAPPING WOODY DEBRIS POST EVENT

Using post event aerial and satellite imagery along the length of the coastline and river catchments, areas of likely wood debris accumulation were mapped in ArcGIS. Sampling locations for plots were then applied across the mapped area as described in section 3.3.8 Initial priority was given to the coastline areas, then subsequent river catchments areas from the river mouth inland based on the mapping criteria outlined in Table 1. Areas were stratified by river mouths (within approx. 1km of the mouth of river) which were to be the focus for the study, then inland, followed by beaches. Areas were split and aggregated by the main river confluence of influence, referred to as locality.

Plot locations were then provided in GPX, Shapefile, and PDF Map formats for field survey.

Table 1 - Mapping criteria used in woody debris sampling strata.

Mapped Strata	Mapping Criteria	Coverage
Coastal River Mouth	Concentrated wood debris accumulation areas > 0.1ha, eg. 50*20m. May have sporadic gaps between debris up to 10m to map accumulated aggregate areas of impact.	Full coastline of Hawke's Bay and within +/-1km of major river mouths.
Coastal Beach		Full coastline of Hawke's Bay outside of +/-1km of major river mouths.
Inland Rivers		Mapped from river mouth by stream. Aropaoanui – 5km Esk – 8km Tutaekuri – 20km Ngaruroro – 8km Tukituki – 14km

3.1.1 Satellite or Aerial Photography Sources

Various qualities of imagery sources became available post the storm event. Initially use of Planet Labs Monitoring 3-4m resolution near daily satellite imagery was used, due to timely access on the first fine day after an event. For Cyclone Gabrielle this provided imagery from 18th of February onwards. Most of the coastline imagery was mapped using this imagery from the 20th of February 2023. While the imagery provided a medium-resolution image, this enabled a quick assessment of the entire coastline and catchment areas assessed for accumulated woody debris.

Examples can be seen in Figure 2 and Figure 3, where woody debris is showing up clearly in imagery.

Figure 2 - Coastline assessed with an image from the 20th of February showing the woody debris appearing in the 3-4m imagery at Aropaoanui Beach. Image Source: Planet Labs LLC

When additional aerial photography or higher resolution satellite imagery became available throughout the project, it was used to validate the previous mapping extents as being sufficient for establishing the sampling frame for the wood debris survey (example Figure 4) and providing a consistent approach across the region.

Figure 3 - Example of extracted coastline from imagery gathered on the 20th of February, with enlarged view of the Mohaka River mouth, and example of mapping the woody debris area (yellow polygons) impacted on the beach. Randomised sample locations are also shown (yellow circles).

Figure 4 – Validation of woody debris mapping using varying resolutions of imagery, 3-4m GSD Planet, 0.5m (LINZ 2023A) provided satellite imagery, and 0.1m aerial imagery (LINZ 2023B) of the coastline of Aropaoanui Beach showing woody debris accumulation (yellow), and sample plots (yellow points).

3.2 Drone Aerial Photo Mapping

When areas were not likely to have other imagery sources or the debris was quickly changing (i.e., being chipped, removed from site or continuing to wash away), drone imagery was captured where time allowed during the project; Figure 5. This allows for additional imagery analysis and documentation of areas in the future analysis.

Drone Flight Specifications: mapping grid flight for creation of an ortho-mosaic, with a 70 % overlapping swath. Typically, above ground level flight height targeted a ground sampling distance of 1-3cm/pixel with flight heights from 40-120m above ground, depending on the drone camera specifications.

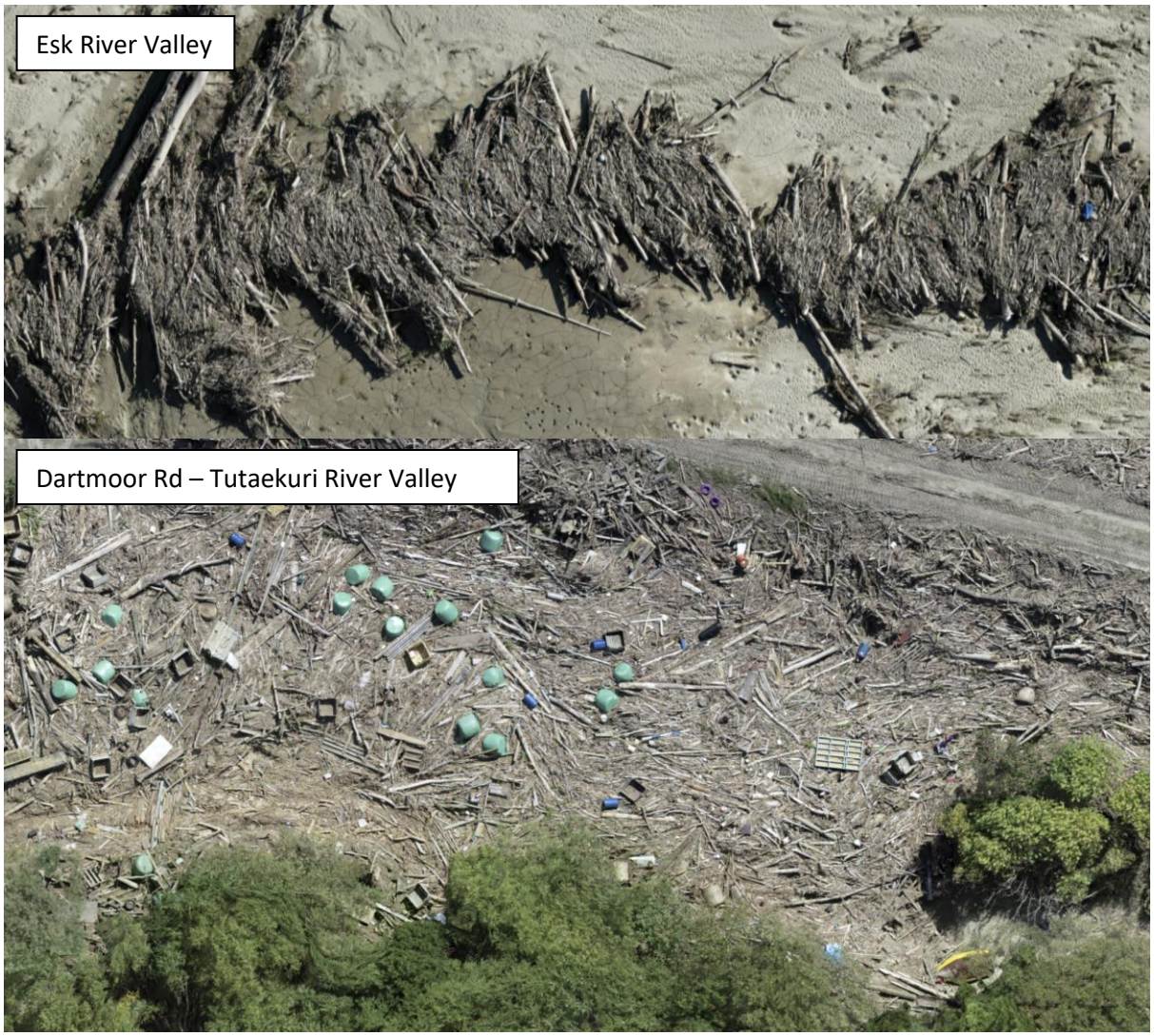


Figure 5 – Examples of drone imagery used to document discreet woody debris piles in various locations in river catchments around Hawke's Bay.

3.3 SAMPLING METHODOLOGY REVIEW

3.3.1 Line Intercept Sampling Method History

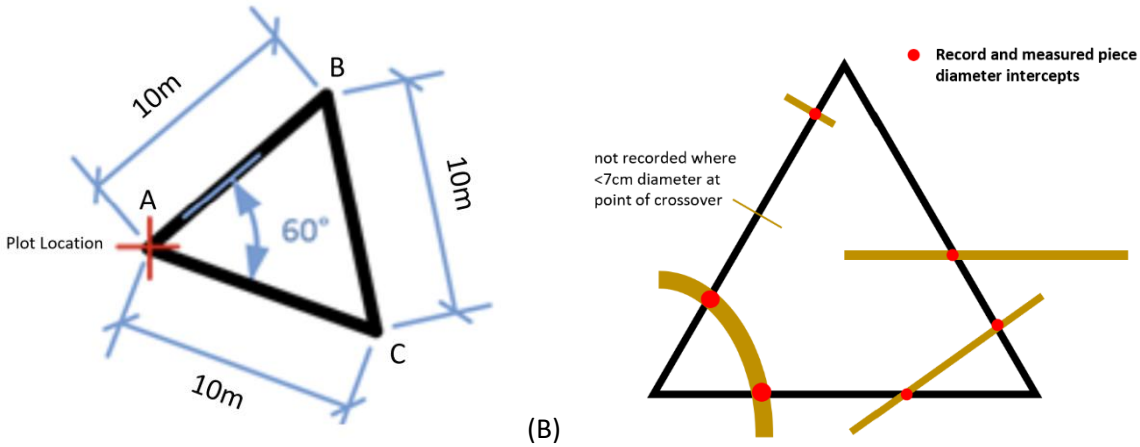
Due to nature of the LWD, the Line Intercept Sampling (LIS) technique was adapted from that used for cutover waste assessment as per training guidance in "NZQA Unit Standard 6956 – Carry Out Waste Assessment in Cutover Forest".

Since its original description for merchantable cutover residue assessment (Warren and Olsen, 1964), LIS is used to quantify wood lying on or near the ground. LIS continued to develop, as a simple and practical method (Bailey, 1970; Wagner & Wilson, 1976; Hall, 1986; Bell et al., 1996).

Proof of its mathematical basis (De Vries, 1973) and practical aspects of LIS to overcome bias and improve precision (Wagner, 1982; Pickford & Hazard, 1978; Bell et al., 1996) have seen it adapted worldwide for woody debris in forestry settings. Therefore, LIS is a peer reviewed and well-established method for measuring the volume of woody debris effectively.

3.3.2 Line Intercept Sampling Process

To remove the bias of piece orientation, an equilateral triangle sample plot was used. Each side of the triangle is 10 m, with each plot being a total length of 30 m (horizontal length), as per Figure 6. Where slope of the transect is greater than 5 degrees, a slope adjusted distance is applied to each side of the triangle.



(A) (B)

Figure 6 - (A) Line Intercept Sampling Equilateral Triangle (B) Measure and Record Piece Diameters at Crossover

The diameter of each LWD piece intersected by a line was measured at the point wherever it intercepts the line. A lower limit diameter of 70 mm is used; all material greater than or equal to 70 mm was recorded and measured. Comments were made alongside photos collected of each of the three lines per plot. There was no minimum length restriction, as the statistical likelihood of the line intersecting the piece accounts for length without arbitrary bias towards longer pieces. This also ensure inclusion of harvest slovens, and log bucking waste.

To further address the bias in debris accumulation orientation, each equilateral triangle sample has a random orientation based on a random bearing between 0 and 90 degrees (Figure 7).

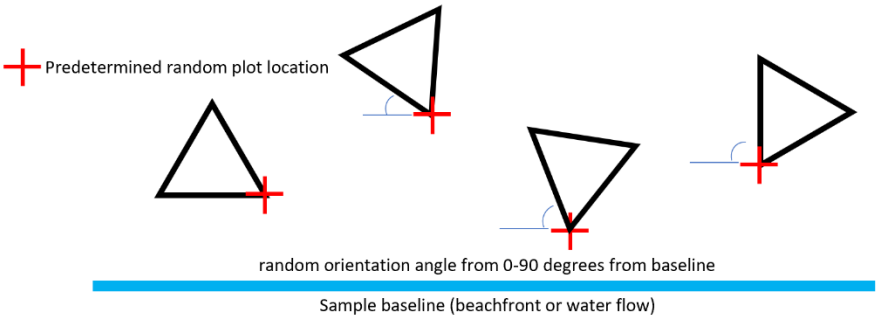


Figure 7 - Sample orientation to a baseline to ensure sample remains unbiased to direction of accumulation of woody debris.

Where the transact extends outside of the mapped debris extent, a fold back transect mirage plotting methodology is implemented, whereby the edge of plot is folded back on itself into the sample area as shown in Figure 8.

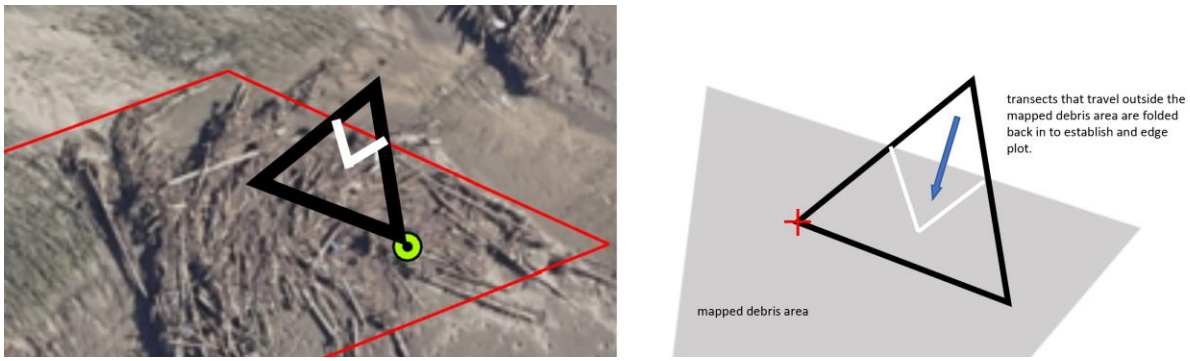


Figure 8 - Edge plot mirage methodology for narrow debris piles or where transects fall into areas outside of the mapped debris extent.

3.3.3 Measurement of Pieces

Diameter is to be measured to the nearest cm in line with the woody debris orientation as shown in Figure 9.

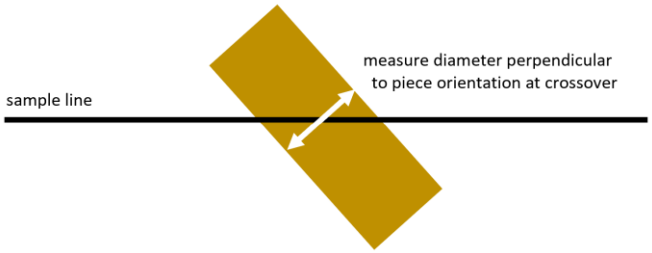


Figure 9 - Measurement of diameter of each intersecting pieces

3.3.4 Classification of Debris

Each intercept diameter measured will be classified into the following (See Table 2).

Table 2 - Classification of Debris

CODE	CLASS
N	Native Species
CH	Conifer (e.g. Pine/Douglas) Plantation Harvest Residue *evidence of flush cuts / slovens / processor damage / branches cut off / cut stumps*
CT	Conifer (e.g. Pine/Douglas) Plantation Full Tree Residue *evidence of full tree slippage of preharvest standing trees / full tree lengths / root plates visible / branches attached.*
CN	Conifer (e.g. Pine/Douglas) Non-Plantation *old man's pine, streambank large old open grown pine.*
CO	Conifer (e.g. Pine/Douglas) Other *no evidence of harvest residue (CH) or full tree lengths (CT)*
PT	Posts / Timber / Bins
PW	Poplar or Willow
E	Eucalyptus
O	Other *other orchards species (apple, avocado, citrus etc), cut firewood, and where possible make comment species / type comment.*

Debris is to be classified for its link to the target event (Table 3). Weathered wood that is clearly aged beyond the event in question should be recorded separately and distinct from fresh woody debris likely from the target event. If the survey is to be completed sometime after the target event an additional classification is available where debris is likely from a more recent event.

Table 3 - Classification of Debris Link to Target Event

CODE	DEBRIS EVENT LINK
Fresh	Likely from target event
Too Fresh	Likely from another event after the target event
Weathered	Likely from a previous event

3.3.5 Species Identification

To ensure expert and objective species identification were made of the LWD, an independent, expert farm forester and ex-Hawke's Bay regional councillor (Alec Olsen), and a technical forest contractor (Ian Robertson Contracting and Interpine Group Ltd) were employed to conduct plotting and characterisation of the LWD.

3.3.6 Piece Length Assessment

Piece length data is collected with categorisation into length bins. While the LIS does not require length to calculate volume, reporting on piece length enables categorization of volume and potential impact or recovery activity. (Table 4).

Table 4 – Piece Length Class

CODE	PIECE LENGTH CLASS
<1m	Less than 1m
<3m	Greater or equal to 1 m, but less than 3 m
<6m	Greater or equal to 3 m, but less than 6 m
<9m	Greater or equal to 6 m, but less than 9 m

<12m	Greater or equal to 9 m, but less than 12 m
>12m	Greater or equal to 12 m

3.3.7 Calculating Woody Debris Volume and Summary

Volumes were calculated using the following LIS formula (Wagner, 1968).

Volume of debris: $Volume\ m^3/\ ha = (\pi^2/8*L)*sum(d^2)$

Where:

V= volume per unit area (m3/ha)
d= piece diameter at intersection (cm)
L= length of the sample line (m)

The resulting dataset yields volume per hectare by woody debris type. This yield of woody debris was applied to the mapped area of woody debris.

3.3.8 Randomised LIS Sampling Plot Locations and Intensity

Satellite imagery was used to pre-identify areas of woody debris depositions. Due to the nature of the material in isolated piles or long narrow beach accumulation, the plot placement was adapted from one of two approaches.

A. Predefined Plot Locations

The preferred method, in which random plots using geo-spatial plot sample tools (e.g., GeoMaster Assessment Planner) identifies plots which were navigated to using a GPS. Plots were placed using a random sampling approach (best suited for narrow width of the sample areas and yet to be determined time and resources). These plots are defined in mapped debris areas as described in 3.1.

B. Onsite Random Systematic Grid Plot Locations

A systematic interval between plots (e.g., every 25 m or 50 m) along the baseline (beachfront or river flow). This included taking photos using a mobile device, and/or drone imagery, video or mapped orthophoto to aid in later mapping of area in hectares of woody debris.

3.3.9 Field Plot Sampling Methodology Workflow in Practice

1. Determine the baseline (beach orientation, river flow direction)
2. Locate predefined plot locations using a GPS as outlined in 3.3.8 above, mark with stick paint mark – POINT A.
3. Record the GPS Location of the plot.
4. Determine plot orientation from base line with a random number between 0 and 90 (select from Appendix A).
5. Using a 30 m tape or measured survey rope, hold the tape/rope at 0m and 30m at Point A. Lay out the first transect of 10 m from the start point to POINT B. Then complete the triangle by pulling the remaining tape out to 20 m POINT C.
6. Record wood debris diameters where piece at intercept is =>70 mm and classify each piece by debris type, link to event, length class.
7. At each corner, check slope of transect and where greater than 5 degrees add an additional length to transect as per Table 2, recording any additional wood debris.

8. Record as depth of the pile per transect 10 m length which was not able to be assessed (if you measured all the pieces then depth will be 0 m). Record to nearest 0.5 m
9. Continue to measure wood debris each side of the triangle.
10. Take photos along each side of the transect, and any other items of interest for future reference.

Figure 10 - Example of LIS plots laid out and photos taken of each side of the transects being surveyed. Source: H. Scown

4 RESULTS

4.1 WOOD DEBRIS MAPPING AND SAMPLE PLOT ALLOCATION

Mapping approximately 280 km of coastline from Cape Kidnappers to Mahia Peninsula identified a total of 241 ha of woody debris piles on coastal beaches and river mouths. An additional 14 ha of inland woody debris were mapped in key catchment rivers impacted by the event, with a total of 255 ha of mapped debris piles across the region for the study (Herries, 2023) (Figure 11).

Figure 11 – Woody debris detected in post event satellite imagery to set sampling frame for survey.

From the mapped area, 328 random plots were allocated for potential survey, of which only 81 plots were collected in March 2023 due to access challenges during the first survey (Figure 12). This supplementary report to Herries 2023, targets areas underrepresented during field visits in March 2023. Figure 13Figure 12, shows the additional 143 plots surveyed from 24th to 27th July 2023, that were collected on the northern beaches of Hawkes Bay during Survey 2.

During Survey 2, field crews compared the debris accumulation to that provided in their field maps from the satellite imagery taken just after the event.

Table 5 shows successfully measured plots tally of 128 where debris was not deemed to have changed since Cyclone Gabrielle, with 8 plot locations having already been cleaned up, 6 where debris extent had changed, and 1 site unmeasurable due to significant hazardous location.

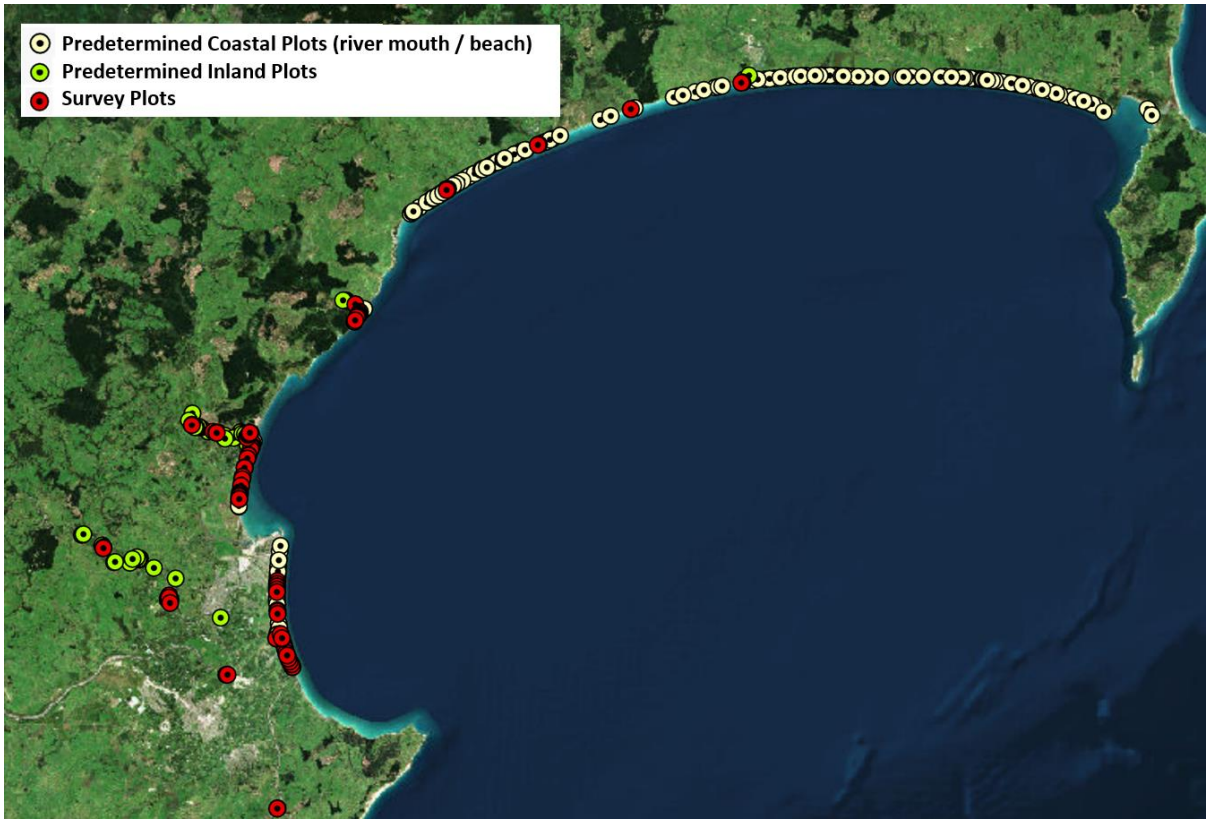


Figure 12 - Predetermined random sample locations, with actual surveyed sites shown.

Figure 13 – 143 survey plots installed 24-27 July 2023.

Table 5 - Tally of Survey 2 additional plots measured and status debris present.

Locality	Measured	Cleaned Up	Debris Washed Away	Hazardous
Mahia	9	1		
Mohaka	39	6	1	
Nuhaka	45			
Waihua	6		2	
Waikari	7			1
Wairoa	2	1	1	
Whakaki	20		2	
TOTAL	**128**	**8**	**6**	**1**

The total area of mapped debris by strata and locality, as well as the number of ground survey plots per hectare, are shown in Table 6 and Table 7. These tables combine the data from Survey 1 and 2, with a total of 209 plots measured. Figure 14 displays the images taken during the survey using ESRI Survey123. Appendix E contains detailed field plot reports for future reference.

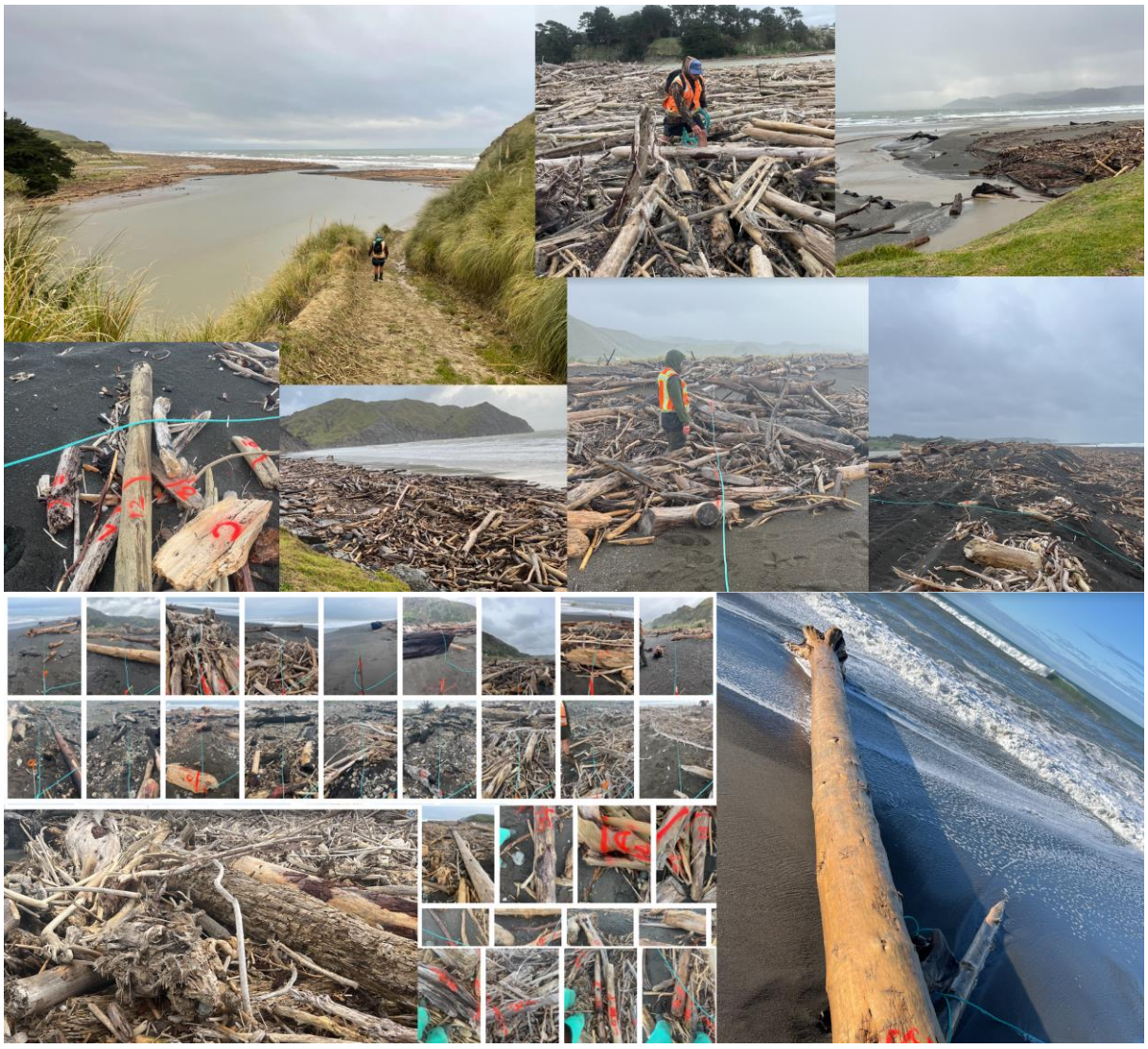


Figure 14 - Field Survey 2 images gathered using Survey123

Table 6 - Accumulated Strata of Mapped Woody Debris and Plots Sampled

Wood Debris Strata	Locality	Area (ha)	%	Plots	ha/plot
Coastal River Mouth +/- 1km of River Mouth	Aropaoanui River	7.1	9%	7	1.0
	Esk River	5.5	7%	4	1.4
	Mohaka River	9.0	12%	28	0.3
	Ngaruroro / Tutaekuri River	12.9	17%	9	1.4
	Nuhaka River	4.0	5%	9	0.4
	Ridgemount River	0.4	1%	0	na
	Tukituki River	2.5	3%	3	0.8
	Waihua River	1.1	1%	7	0.2
	Waikari River	16.7	21%	10	1.7
	Wairoa River	10.1	13%	4	2.5
	Waitaha River	8.7	11%	0	na
	TOTAL RIVER MOUTH	**78.0**	**31%**	**81**	**1.0**
Coastal Beach	Esk South	16.5	10%	14	1.2
	Mohaka North	3.1	2%	6	0.5
	Mohaka South	22.4	14%	7	3.2
	Te Awa / Awatoto	21.8	13%	8	2.7
	Mahia	5.9	4%	9	0.7
	Nuhaka North	10.3	6%	18	0.6
	Nuhaka South	28.5	18%	18	1.6
	Waihua South	1.4	1%	0	na
	Waikari South	11.0	7%	0	na
	Wairoa South	7.6	5%	0	na
	Whakaki	34.2	21%	20	1.7
	TOTAL BEACH	**162.7**	**64%**	**100**	**1.6**
Inland Rivers	Aropaoanui River	0.2	1%	1	0.2
	Esk River	4.9	35%	12	0.4
	Ngaruroro River	0.4	3%	2	0.2
	Tukituki River	0.1	1%	1	0.1
	Tutaekuri River	8.6	61%	12	0.7
	TOTAL INLAND	**14.2**	**6%**	**28**	**0.5**
TOTAL		**254.9**	ha	**209**	**1.2**

Table 7 - Accumulated Locality of Mapped Woody Debris and Plots Sampled

Wood Debris Region	Locality	Area (ha)	%	Plots	ha/plot
Aropaoanui River	Aropaoanui River Mouth	7.1		7	
	Aropaoanui River Inland	0.2		1	
		7.3	3%	**8**	**0.9**
Esk River	Esk River Mouth	5.5		4	
	Esk South Beach	16.5		14	
	Esk River Inland	4.9		12	
		26.9	**11%**	**30**	**0.9**
Mohaka River	Mohaka River Mouth	9		28	
	Mohaka North Beach	3.1		6	
	Mohaka South Beach	22.4		7	
		34.5	**14%**	**41**	**0.8**
Ngarururoro / Tutaekuri River	Ngarururoro / Tutaekuri River Mouth	12.9		9	
	Te Awa / Awatoto Beach	21.8		8	
	Ngarururoro River Inland	0.4		2	
	Tutaekuri River Inland	8.6		12	
		43.7	**17%**	**31**	**1.4**
Nuhaka River	Nuhaka River Mouth	4		9	
	Nuhaka North Beach	10.3		18	
	Nuhaka South Beach	28.5		18	
		42.8	**17%**	**45**	**1.0**
Mahia	Mahia	**5.9**	**2%**	**9**	**0.7**
Ridgemount River	Ridgemount River	**0.4**	**0%**	**0**	**na**
Tukituki River	Tukituki River Mouth	2.5		3	
	Tukituki River Inland	0.1		1	
		2.6	**1%**	**4**	**0.7**
Waihua River	Waihua River Mouth	1.1		8	
	Waihua South Beach	1.4		0	
		2.5	**1%**	**8**	**0.3**
Waikari River	Waikari River Mouth	16.7		9	
	Waikari South Beach	11		0	
		27.7	**11%**	**9**	**3.1**
Wairoa River	Wairoa River Mouth	10.1		4	
	Wairoa South Beach	7.6		0	
	Whakaki Beach	34.2		20	
		51.9	**20%**	**24**	**2.2**
Waitaha River	Waitaha River Mouth	**8.7**	**3%**	**0**	**na**
	TOTAL	**254.9**		**209**	**1.2**

4.2 Line Intersect Sampling of Wood Debris

4.2.1 Hawke's Bay

A total of 81 plots were installed from the 3rd to 24th March 2023, and an additional 128 installed from the 24th to 27th July 2023. The 209 plots sampled focused initially on the river mouths, and then coastal beaches with some limited inland rivers surveyed. Plots were selected from the random pre-planned plot network, starting closest to the river mouth and working outward. The number of plots collected at each catchment had elements of time and access constraints with some sites visited by helicopter. Plots were abandoned where hazardous or disturbed by clean-up activity.

These represent a plotting intensity of 1.2 ha per plot of mapped woody debris across Hawke's Bay. Sampling intensity varied due to plot access with survey 2, reducing the plotting intensity from 3.2 ha per plot, and importantly filling in the gaps where little data was able to be collected on the northern beaches due to access challenges (closed and blocked roads).

Plots show an average of 428 m3/ha in the woody debris piles mapped across the region with a probable limit of error (PLE) of 11.3 % (95 % confidence interval of the mean expressed over the mean) (Table 8).

Plantation pine/conifer accounted for 51 % of the total survey volume per hectare (217 m3/ha) with the next highest classification being poplar/willow at 31% (131 m3/ha)

Pine/conifer harvest slash accounted for 8 % of the total survey volume per hectare (32 m3/ha)

Table 8 - Average Volume Per Hectare by Wood Debris Strata, Locality and Classification

	Plantation Pine/Conifer									
Average m3/ha	Pine/Conifer OTHER	Pine/Conifer FULL TREE	Pine/Conifer HARVEST SLASH	Pine/Conifer OLD PINE	POPLAR WILLOW	NATIVE	EUCALYPT	POST/TIMBER	OTHER	TOTAL m3/ha
Coastal River Mouth	107	69	36	41	90	19	5	3	40	**410**
Aropaoanui River	123	21	22	4	215	20	0	1	18	425
Esk River	194	201	46	107	225	8	6	7	18	812
Mohaka River	101	99	46	33	37	14	13	1	67	412
Ngaruroro / Tutaekuri River	33	0	22	0	118	5	0	4	37	218
Nuhaka River	95	44	23	0	6	21	0	5	1	193
Tukituki River	0	0	5	0	353	2	0	0	0	359
Waihua River	60	16	6	86	45	24	0	10	9	255
Waikari River	241	88	91	111	41	8	0	5	66	651
Wairoa River	99	92	6	34	264	90	0	2	26	613
Coastal Beach	96	81	33	13	147	29	1	5	17	**422**
Esk River	145	17	19	12	99	33	2	1	19	346
Mahia	164	134	29	8	137	48	1	2	13	536
Mohaka River	63	132	47	5	62	62	5	2	3	381
Ngaruroro / Tutaekuri River	97	19	17	0	136	32	1	17	27	345
Nuhaka River	82	101	30	19	68	9	0	2	21	333
Wairoa River	77	55	45	15	369	29	1	8	17	616
Inland	155	91	16	14	207	5	0	10	10	**509**
Aropaoanui River	48	270	0	0	140	0	0	0	0	457
Esk River	174	144	2	10	61	11	0	4	21	428
Ngaruroro / Tutaekuri River	157	39	31	20	343	0	0	17	3	609
Tukituki River	0	0	0	0	127	0	0	0	0	127
TOTAL m3/ha	**108**	**77**	**32**	**25**	**131**	**22**	**3**	**5**	**26**	**428**
% of TOTAL m3/ha	25%	18%	8%	6%	31%	5%	1%	1%	6%	
	51%			**49%**						
	Combined Plantation Pine/Conifer			Other						

Table 9 - Average Volume Per Hectare as % Total Wood Debris by Strata and Classification

	Plantation Pine/Conifer									
Average m3/ha as %	Pine/Conifer OTHER	Pine/Conifer FULL TREE	Pine/Conifer HARVEST SLASH	Pine/Conifer OLD PINE	POPLAR WILLOW	NATIVE	EUCALYPT	POST/TIMBER	OTHER	TOTAL m3/ha
Coastal River Mouth	26%	17%	9%	10%	22%	5%	1%	1%	10%	**410**
	52%			**48%**						
Coastal Beach	23%	19%	8%	3%	35%	7%	0%	1%	4%	**422**
	50%			**50%**						
Inland	30%	18%	3%	3%	41%	1%	0%	2%	2%	**509**
	51%			**49%**						

Table 10 - Average Volume Per Hectare by Wood Debris Locality and Classification

	Plantation Pine/Conifer									
Average m3/ha	Pine/Conifer OTHER	Pine/Conifer FULL TREE	Pine/Conifer HARVEST SLASH	Pine/Conifer OLD PINE	POPLAR WILLOW	NATIVE	EUCALYPT	POST/TIMBER	OTHER	TOTAL m3/ha
Aropaoanui River	114	53	20	3	205	18	0	1	16	429
Esk River	163	92	16	24	101	21	2	3	19	441
Mahia	164	134	29	8	137	48	1	2	13	536
Mohaka River	90	109	46	25	44	28	11	1	48	402
Ngaruroro / Tutaekuri River	105	22	25	9	224	10	0	13	19	428
Nuhaka River	85	89	29	15	56	12	0	3	17	305
Tukituki River	0	0	3	0	296	1	0	0	0	301
Waihua River	60	16	6	86	45	24	0	10	9	255
Waikari River	241	88	91	111	41	8	0	5	66	651
Wairoa River	82	63	37	19	346	42	1	7	19	615
TOTAL m3/ha	**108**	**77**	**32**	**25**	**131**	**22**	**3**	**5**	**26**	**428**
% of TOTAL m3/ha	25%	18%	8%	6%	31%	5%	1%	1%	6%	
	51%			**49%**						
	Combined Plantation Pine/Conifer			Other						

Table 11 - Average Volume Per Hectare as % Total Wood Debris Region and Classification

	Plantation Pine/Conifer									
Average m3/ha as %	Pine/Conifer OTHER	Pine/Conifer FULL TREE	Pine/Conifer HARVEST SLASH	Pine/Conifer OLD PINE	POPLAR WILLOW	NATIVE	EUCALYPT	POST/TIMBER	OTHER	TOTAL m3/ha
Aropaoanui River	26%	12%	5%	1%	48%	4%	0%	0%	4%	**429**
	43%			**57%**						
Esk River	37%	21%	4%	5%	23%	5%	0%	1%	4%	**441**
	62%			**38%**						
Mahia	31%	25%	5%	1%	26%	9%	0%	0%	2%	**536**
	61%			**39%**						
Mohaka River	22%	27%	11%	6%	11%	7%	3%	0%	12%	**402**
	61%			**39%**						
Ngaruroro / Tutaekuri River	25%	5%	6%	2%	52%	2%	0%	3%	4%	**428**
	36%			**64%**						
Nuhaka River	28%	29%	9%	5%	18%	4%	0%	1%	6%	**305**
	66%			**34%**						
Tukituki River	0%	0%	1%	0%	98%	0%	0%	0%	0%	**301**
	1%			**99%**						
Waihua River	24%	6%	2%	34%	18%	9%	0%	4%	3%	**255**
	32%			**68%**						
Waikari River	37%	14%	14%	17%	6%	1%	0%	1%	10%	**651**
	64%			**36%**						
Wairoa River	13%	10%	6%	3%	56%	7%	0%	1%	3%	**615**
	29%			**71%**						

The average size of pieces measured was 193mm, with a std deviation of 132mm (Table 12, Figure 15, Figure 16).

Table 12 Diameter Distribution by Classification

	Plantation Pine/Conifer								
Avg Diam (mm)	Pine/Conifer OTHER	Pine/Conifer FULL TREE	Pine/Conifer HARVEST SLASH	Pine/Conifer OLD PINE	POPLAR WILLOW	NATIVE	EUCALYPT	POST/TIMBER	OTHER	Total
All Plots	195	288	245	190	167	188	224	123	179	**193**
			224							

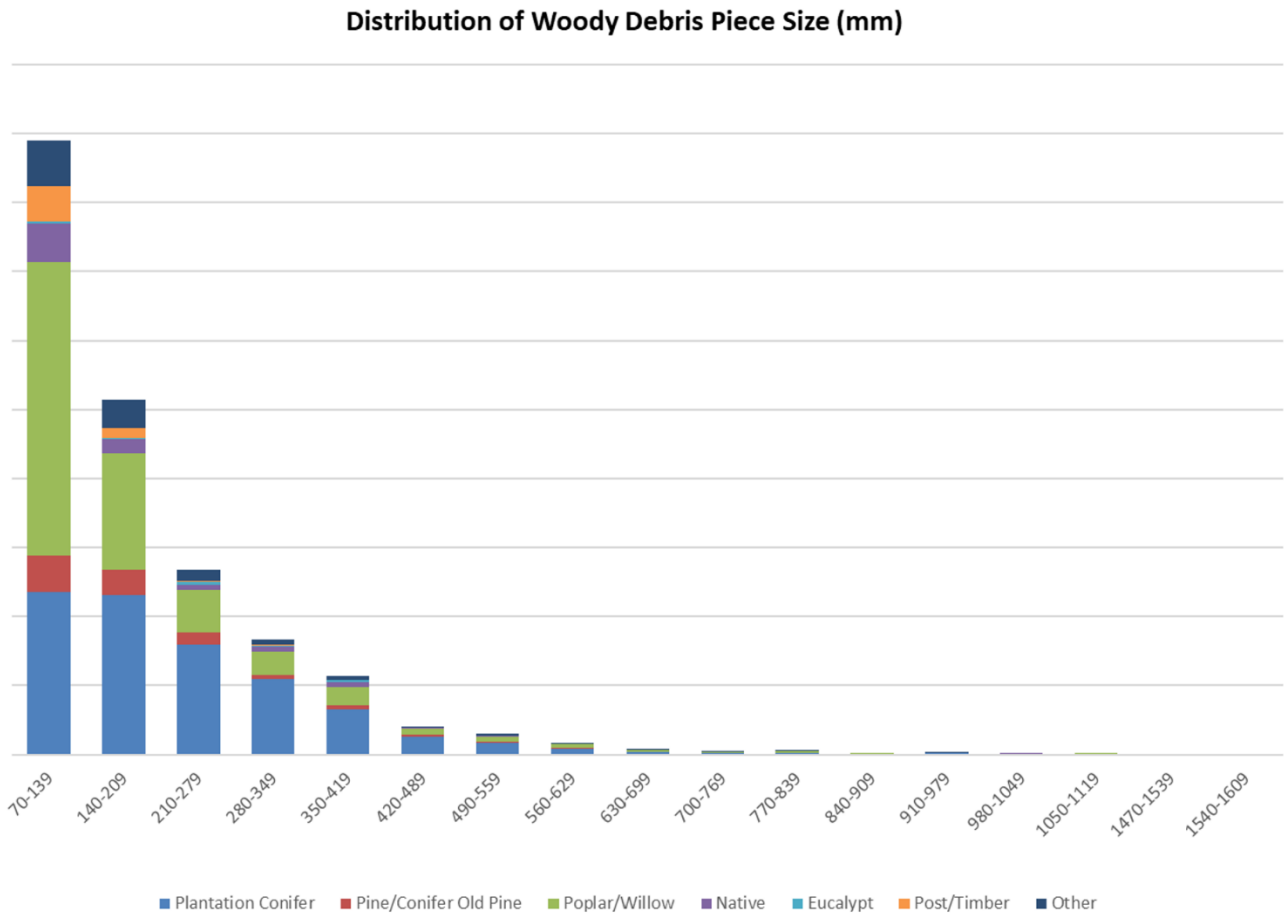


Figure 15 - Distribution of woody debris by diameter

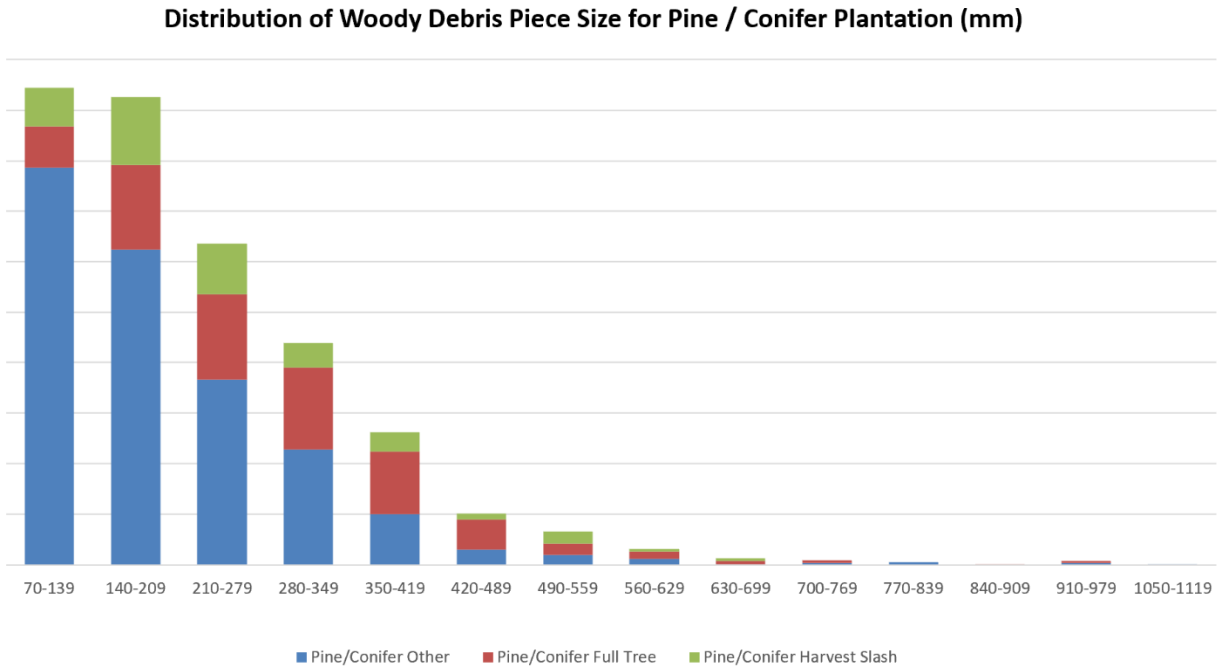


Figure 16 - Distribution of woody debris by diameter for pine/conifer

Survey 2 collected a length classification for measurement debris. Derived from the 128 plots measured, 73 % of debris is less than 3 m, with only 1 % greater than 12m.

Table 13 Length Distribution of Pieces (Survey 2 Only)

	Length Class					
Piece Classification	**<1m**	**<3m**	**<6m**	**<9m**	**<12m**	**>12m**
Pine/Conifer OTHER	35%	49%	12%	2%	1%	0%
Pine/Conifer FULL TREE	11%	27%	31%	18%	10%	3%
Pine/Conifer HARVEST SLASH	18%	42%	27%	11%	2%	0%
Pine/Conifer OLD PINE	20%	65%	13%	1%	0%	1%
POPLAR WILLOW	31%	39%	19%	7%	3%	1%
NATIVE	44%	35%	15%	7%	0%	0%
EUCALYPT	24%	24%	29%	12%	12%	0%
POST/TIMBER	74%	26%	0%	0%	0%	0%
OTHER	65%	32%	2%	0%	0%	0%
All Classes	**32%**	**41%**	**17%**	**6%**	**3%**	**1%**
Accumulative %	32%	73%	90%	96%	99%	100%

4.2.2 Aropaoanui

The Aropaoanui catchment woody debris deposition was measured to be 7.3 ha. 8 plots were measured, representing a plotting intensity of 0.9 ha per plot of mapped woody debris.

Plots show an average of 429 m3/ha in the woody debris piles mapped across the Aropaoanui catchment with a PLE of 59.3 %.

Plantation pine/conifer accounted for 43 % of the total Aropaoanui survey volume per hectare (186 m3/ha), with the highest classification being poplar/willow at 48 % (205 m3/ha).

Pine/conifer harvest slash accounted for 5 % of the total Aropaoanui survey volume per hectare (20 m3/ha).

4.2.3 Esk

The Esk catchment woody debris deposition was measured to be 26.9 ha. 31 plots were measured, representing a plotting intensity of 0.9 ha per plot of mapped woody debris.

Plots show an average of 441 m3/ha in the woody debris piles mapped across the Esk catchment with a PLE of 28.9 %.

Plantation pine/conifer accounted for 61 % of the total Esk survey volume per hectare (271 m3/ha), with the next highest classification being poplar/willow at 23 % (101 m3/ha).

Pine/conifer harvest slash accounted for 4 % of the total Esk survey volume per hectare (16 m3/ha)

Pine/ conifer with root ball attached (full-tree) accounted for 21 % of the total Esk survey volume (92 m3/ha).

4.2.4 Mahia

The Mahi coastal catchment woody debris deposition was measured to be 5.9 ha. 9 plots were measured, representing a plotting intensity of 0.7 ha per plot of mapped woody debris.

Plots show an average of 536 m3/ha in the woody debris piles mapped across the Mahia catchment with a PLE of 47 %.

Plantation pine/conifer accounted for 61 % of the total Mahia survey volume per hectare (327 m3/ha), with the next highest classification being poplar/willow at 26 % (137 m3/ha).

Pine/conifer harvest slash accounted for 5 % of the total Mahia survey volume per hectare (29 m3/ha)

Pine/ conifer with root ball attached (full-tree) accounted for 25% of the total Mahia survey volume (134 m3/ha).

4.2.5 Mohaka

The Mohaka catchment woody debris deposition was measured to be 34.5 ha. 41 plots were measured, representing a plotting intensity of 0.8 ha per plot of mapped woody debris.

Plots show an average of 402 m3/ha in the woody debris piles mapped across the region with a PLE of 23 %.

Plantation pine/conifer accounted for 61 % of the total Mohaka survey volume per hectare (245 m3/ha), with the next highest classification being poplar/willow at 11 % (44 m3/ha).

Pine/conifer harvest slash accounted for 11 % of the total Mohaka survey volume per hectare (46 m3/ha).

Pine/ conifer with root ball attached (full-tree) accounted for 27 % of the total Mohaka survey volume (109 m3/ha).

4.2.6 Ngaruroro/Tutaekuri

The Ngaruroro/Tutaekuri catchment woody debris deposition was measured to be 43.7 ha. 31 plots were measured, representing a plotting intensity of 1.4 ha per plot of mapped woody debris.

Plots show an average of 428 m3/ha in the woody debris piles mapped across the region with a PLE of 41.2 %.

Plantation pine/conifer accounted for 36% of the total Ngaruroro/Tutaekuri survey volume per hectare (152 m3/ha), with the highest classification being poplar/willow at 52 % (224 m3/ha).

Pine/conifer harvest slash accounted for 6% of the total Ngaruroro/Tutaekuri survey volume per hectare (25 m3/ha).

4.2.7 Nuhaka

The Nuhaka catchment woody debris deposition was measured to be 42.8 ha. 45 plots were measured, representing a plotting intensity of 1 ha per plot of mapped woody debris.

Plots show an average of 305 m3/ha in the woody debris piles mapped across the region with a PLE of 27 %.

Plantation pine/conifer accounted for 66 % of the total Nuhaka survey volume per hectare (203 m3/ha), with the next highest classification being poplar/willow at 18 % (56 m3/ha).

Pine/conifer harvest slash accounted for 9% of the total Nuhaka survey volume per hectare (29 m3/ha).

Pine/ conifer with root ball attached (full-tree) accounted for 29 % of the total Nuhaka survey volume (89 m3/ha).

4.2.8 Tukituki

The Tukituki catchment woody debris deposition was measured to be 2.6 ha. 4 were measured, representing a plotting intensity of 0.7 ha per plot of mapped woody debris.

Plots show an average of 301 m3/ha in the woody debris piles mapped across the region with a PLE of 169.3 %.

Plantation pine/conifer accounted for 1% of the total Tukituki survey volume per hectare (3 m3/ha), with the highest classification being poplar/willow at 98% (296 m3/ha).

Pine/conifer harvest slash accounted for 1% of the total Tukituki survey volume per hectare (3 m3/ha).

4.2.9 Waihua

The Waihua catchment woody debris deposition was measured to be 2.5 ha. 8 plots were measured, representing a plotting intensity of 0.3 ha per plot of mapped woody debris.

The plot showed an average of 255 m3/ha in the woody debris piles mapped across the region with a PLE of 92 %.

Plantation pine/conifer accounted for 32 % of the total Waihua survey volume per hectare (82 m3/ha), with the next highest classification being old pine non plantation at 34% (86 m3/ha).

Pine/conifer harvest slash accounted for 2 % of the total Waihua survey volume per hectare (6 m3/ha).

4.2.10 Wairoa

The Wairoa catchment woody debris deposition was measured to be 51.9 ha. 24 plots were measured, representing a plotting intensity of 2.2 ha per plot of mapped woody debris.

Plots show an average of 615 m3/ha in the woody debris piles mapped across the region with a PLE of 32 %.

Plantation pine/conifer accounted for 29 % of the total Wairoa survey volume per hectare (181 m3/ha), with the highest classification being poplar/willow at 56 % (346 m3/ha), and native with 7 % (42 m3/ha).

Pine/conifer harvest slash accounted for 6% of the total Wairoa survey volume per hectare (42 m3/ha)

4.2.11 Waikari

The Waikari catchment woody debris deposition was measured to be 27.7 ha. 9 were measured, representing a plotting intensity of 3.1 ha per plot of mapped woody debris.

Plots show an average of 651 m3/ha in the woody debris piles mapped across the region with a PLE of 60 %.

Plantation pine/conifer accounted for 64% of the total Waikari survey volume per hectare (353 m3/ha), with the next highest classification being old pine non plantation at 17 % (111 m3/ha) followed by poplar/willow at 6 % (41 m3/ha).

Pine/conifer harvest slash accounted for 14 % of the total Waikari survey volume per hectare (91 m3/ha). This was the highest region for harvest slash present.

5 DISCUSSION AND RECOMMENDATIONS

5.1 FINDINGS AND DISCUSSION

The results of this study show that large woody debris presenting evidence of harvest activity, i.e., flush cuts / slovens / processor damage / branches cut off / cut stumps and classified as pine or conifer harvest slash accounted for approximately 8% of the total woody debris measured the Hawke's Bay following the Cyclone Gabrielle weather event. The LWD also has a significant proportion (18%) of pine with root ball attachment.

Conifer without harvest evidence or root ball attachment cannot be attributed to mid slope failure or streambank failure with certainty. However, the implication of finding a higher proportion of pine material with root ball attachment (18%) versus pine material with evidence of harvest (8%) indicates that it is statistically more likely that pine material of unknown origin was in standing tree form immediately prior to the cyclone. Evidence of harvest is easily recognisable even on aged material from an earlier event.

Given that the root ball and subsequent stem material attached is the widest, most structurally stable part of a tree, tops and large branches likely broke away from the stem in its journey downstream. Therefore, it is likely that much of the pine of unknown-origin was brought down in floodwaters after mid-slope failure or streambank erosion caused by mechanical failure of waterlogged soil and prolonged intense rainfall.

Where there are significant areas of indigenous forest, or flood-protection willow/poplar plantings on erodible sites within the catchment, significant volumes of indigenous or willow/poplar woody debris have been measured in the LWD.

It has been shown that sediment loads after rain events are reduced when pastoral land is converted to close-canopy tall woody vegetation (Basher & Dymond, 2013; Fahey & Marden, 2000; Fransen & Brownlie, 1996; Page et al., 1999; Phillips et al., 2012). To this end, pine forest plantings were incentivised on the most erodible sites in Hawke's Bay Catchment Board and NZ Forest Service extension projects and following Cyclone Bola through the Erosion Control Funding Programme (ECFP) on the East Coast.

These plantings were enacted to mitigate sedimentation impacts primarily attributable to pastoral landscapes in the erosion-prone country and were largely successful. Therefore, in a significant storm event, the most impacted sites, outside of pastoral land uses, will be overly represented by vegetation cover consisting of exotic plantation forests.

By increasing the level of tall, closed-canopy woody vegetation, the overall risk of sedimentation decreases by a factor of 3 to 4 (Fahey & Marden, 2000). The Pakuratahi land-use study (Eyles & Fahey, 2006) states, "Over the 12-year period of record, the total suspended yield from the pasture catchment was over one-and-a-half times that for the catchment going through the forest rotation". Further analysis into the aspect, slope, and vegetation cover, type and so forth of areas that have eroded into the waterway after this event will help guide future land use decisions, and a topic for future work.

Just over half, or 51%, of the LWD volume measured originated from pine plantation forests, and 31% of the volume was from flood-protection willow/poplars. In total, at least 83% of the LWD volume measured originates from unstable, erosion-prone landscapes that vegetation was planted to protect. Most of the time, outside of significant events, this is achieved successfully by these plantings. Therefore, the risk of woody debris from forested catchments is inherent in the risk of significant weather events impacting these fragile landscapes. Solutions to mitigate these risks to the receiving environment should be well thought out and allow for the sustainable use of land in an environmental, economic, and social sense in perpetuity.

The second field survey greatly improved the coverage of areas defined as 'coastal beach' and northern 'river mouths' in Hawke's Bay which were underrepresented in the data collection during the field survey 1 in March 2023. With only a helicopter (Figure 17) to access these areas the measurements had high PLE and uncertainty around the volume and species mix. These areas do have a larger proportion of catchment area in plantations and therefore additional collection at Waikare mouth, Waihua mouth, Mohaka mouth and coast, and Wairoa mouth and coast, Nuhaka and Mahia.

Figure 17 - Helicopter (Hawke's Bay Helicopters - BK117) parked on Wairoa River mouth for plotting. Photo source: H. Scown

The volume of pine LWD with root ball attached measured at Esk, Mahia, Mohaka, and Nuhaka, ranged from 21-29 % respectively. These are the highest recorded catchments of pine with root ball attachment, and this appears to correlate strongly with rainfall data released by Hawke's Bay Regional Council and , National Institute of Water and Atmospheric Research for these catchments (See Appendix D). The LWD measured for Tutaekuri/Ngaruroro catchments were majority willow/poplar (52 %), followed by plantation pine (37 %). Rainfall data appears to show this catchment received significant rainfall; with floodwaters overtopping the stopbanks in many places. Flood-protection willows and poplars planted along the riverbank, especially around Dartmoor/Puketapu area, have been inundated by water and dislodged from the riverbanks (Figure 18).

Aropaoanui catchment was found to have a higher proportion of willow/poplar (48 %) followed by plantation conifer/ pine (43 %). This is consistent with the relocation of the river just inland from the river mouth, where large areas of willows have been removed (Figure 19).

Figure 18 - Tutaekuri River at Hakowhai access entrance, Dartmoor Road. Note the willows on far-right with tight spacing next to interspersed willows, and finally a row of missing and flattened willows can be seen across the river from mid to left. Photo source: H.Scown

Figure 19 – Aropaoanui: showing loss of significant areas of willows alongside the original river course.

Tukituki catchment was notable in that 98 % willow/poplar, a low overall volume per hectare (301 m3/ha), and a low mapped area (2.6 ha) being measured. This is likely due to a combination of lower storm intensity (rainfall) in the catchment (See Appendix D) and low levels of pine plantation within the catchment. This catchment is a good example of where further analysis into the distribution of land uses, storm intensity, and LWD measured in each catchment will help inform better future land use decisions.

Waikari and Nuhaka catchments were notable in that they contained the highest proportion of pine volume within the LWD deposits, 64 % and 66 % respectively. The mean diameter of the measured plantation pine/conifer pieces (other, full tree, harvest) was 224 mm. 14% volume of LWD measured at Waikari was pine with harvest evidence, of which it was solely from fresh scarf cut (felled) pine. Due to the occurrence of smaller diameter scarf face felled pine, it is likely most of the pine material found at the Waikari River mouth originated from a recently waste-thinned plantation forest block(s) that entered the water either by streambank erosion or mid-slope failure (Figure 20).

Figure 20 - Waikari River Mouth - Full Tree Plantation Pine Examples

With length class being recorded in Survey 2, this showed that 73 % of the woody debris is 3m or less in length, with only 1 % being greater than 12 m.

Wairoa and Waikari river mouths were observed to have the highest volumes of 615 and 651 m3/ha respectively. These were also contrasting with 29 % and 64 % Plantation pine/conifer respectively.

5.2 CONCLUSION

In conclusion, Hawke's Bay experienced its wettest 6-month period on record from July 2022 – January 2023. This left the land susceptible to damage by sustained heavy rainfall and wind events. Cyclone Gabrielle was one of the largest weather events to affect New Zealand in living memory, especially in parts of Hawke's Bay.

The severity of this set of conditions led to levels of damage to the landscape affecting all types of standing woody vegetation on the most erodible sites.

The data show that LWD deposits across Hawke's Bay do not contain high levels of harvest residue. Therefore, it is inaccurate to use the catchall term 'slash' when referring to causes of damage to infrastructure across the Hawke's Bay region.

By expanding the plot network to the north Hawkes Bay coast, survey 2 improved the understanding of the woody debris in Hawke Bay catchments. This increased the confidence in the trends, and the additional data collected, such as piece length for example, enhanced the knowledge of the woody debris distributions and effects.

Understanding gained from this study may be applied within wider spatial exercises to determine optimal land use decisions given the erodibility existing within parts of Hawke's Bay landscape and storm events which occur periodically.

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For further information please contact:

David Herries
CTO, Director
B.For.Sc (Hons), MNZIF, Registered Forestry Advisor
Email : david.herries@interpine.co.nz
Mobile : +64 21 435623
Telephone : +64 7 350 3209

Reviewed By
Susana Gonzalez
Remote Sensing Team Leader, Forest LiDAR Engineer
Email : susana.gonzalez@interpine.co.nz
Mobile : +64 21 026 49733
Telephone : +64 7 350 3209

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Further detail on this can be found in a review of the line intercept approach.

- Harvest Cutover Residue Assessment > History | Interpine Innovation
- Cutover Residue Assessment Using Line Intercept Sampling | Interpine Innovation
- Drone based Harvesting Cutover Merchantable Volume Assessment | Interpine Innovation

Downloads

- NZQA Competenz 6956 Unit Module Study Guide:
- EXCEL Sheet – Plot Form and Appendices
- Woody Debris Sampling Methodology (as a PDF)

8 APPENDICES

8.1 APPENDIX A – RANDOM BEARINGS 0 TO 90 AND SLOPE ADJUSTMENT TABLE FOR 10M

Random Number Table Between 0-90				
46	74	90	46	61
88	3	53	75	1
3	3	69	27	70
58	56	59	2	66
22	8	71	57	51
89	64	69	60	38
79	30	85	29	9
90	11	32	60	40
50	82	11	4	74
70	73	66	68	88
1	69	42	83	33
10	2	22	74	70
59	50	63	22	79
66	69	56	77	65
72	47	5	8	27
26	15	88	5	28
62	64	65	61	66
52	59	69	27	81
26	66	44	69	65
2	63	61	52	84
62	2	54	60	73
65	48	45	11	19
6	25	73	72	60
79	16	19	6	85
7	4	43	51	10
38	71	43	22	58
10	14	4	35	1
50	78	4	49	34

Slope	Slope Adjusted 10m Dist. (m)	Extra Length (m)
0	10.00	0.00
5	10.04	0.04
7.5	10.09	0.09
10	10.15	0.15
12.5	10.24	0.24
15	10.35	0.35
17.5	10.49	0.49
20	10.64	0.64
22.5	10.82	0.82
25	11.03	1.03
27.5	11.27	1.27
30	11.55	1.55
32.5	11.86	1.86
35	12.21	2.21
37.5	12.60	2.60
40	13.05	3.05
42.5	13.56	3.56
45	14.14	4.14
47.5	14.80	4.80
50	15.56	5.56
52.5	16.43	6.43
55	17.43	7.43
57.5	18.61	8.61
60	20.00	10.00
62.5	21.66	11.66
65	23.66	13.66
67.5	26.13	16.13
70	29.24	19.24

8.2 APPENDIX B – PLOT FORM PAPER FORMAT

WOODY DEBRIS SURVEY FORM					
Plot Ref			Date & Time		
Location Description:					
Organisation & Plotting By:					
GPS:					
Random Orientation Bearing (0-90):					
Transect	**Slope (Deg)**	**SlopeDist (m)**	**Debris Depth (m)**	**Comment**	
A (A to B)					
B (B to C)					
C (C to A)					
Transect (ABC)	Diameter (cm)	Class/Type	Length Class	Event Link	Comment

8.3 APPENDIX C – FIELD PHOTOS

Photos source: H. Scown & I. Robertson

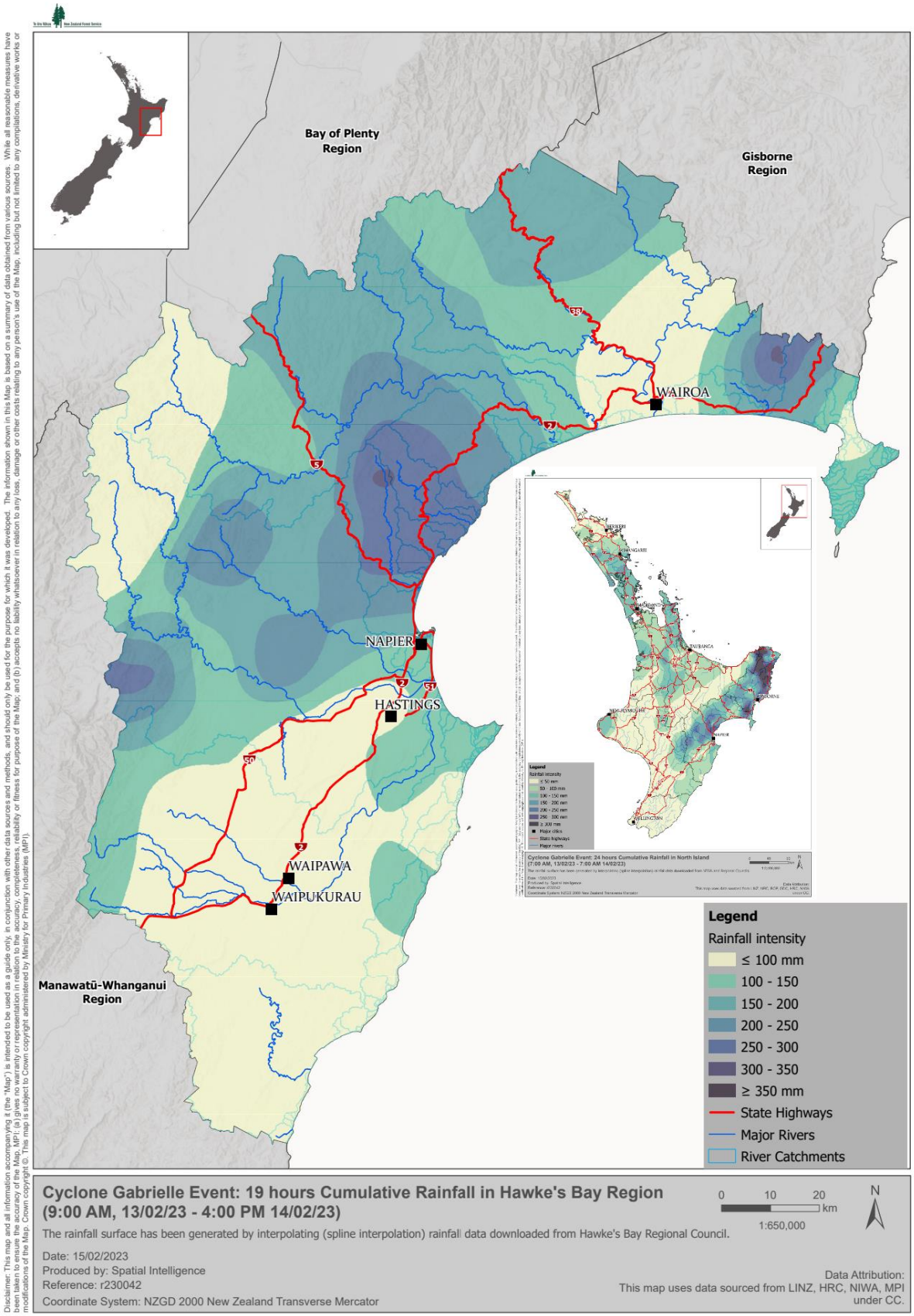
A = Plot transect line photo at Esk River mouth.
B = Close-up of woody debris at Esk River mouth. Note the willow in foreground with alternate branching. Pine in background with branch whorls next to Alec's arm.

C = Two large measured willow logs. Note the epicormic flush growth that occurred since dislodgement from streambank.
D = Wide shot of woody debris at Aropaoanui River mouth, featuring Alec.

E = Orthographic photo of Mohaka River mouth debris. Note the abundance of smaller woody debris.
F = Aerial shot looking Southwest from Waikare River mouth. 15 km long.
G = Alec digging into a willow log to ID. Note the colour and alternating branching.
H = Tutaekuri River inland. Note the large pine log in the mid-ground and branch whorling with internodes.

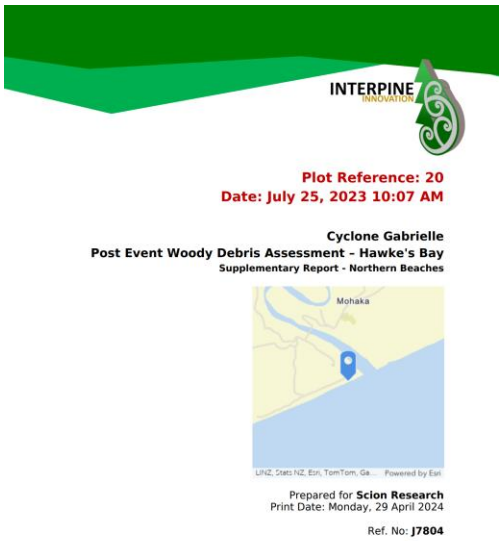
I = Large Pines with root balls attached, Tutaekuri riverbank at Dartmoor Road.
J = Esk River debris pile and pivot irrigator. Note the green/red flushing epicormic growth from willow logs in mix.

8.4 APPENDIX D – CUMULATIVE RAINFALL IN HAWKE'S BAY AND NORTH ISLAND



8.5 APPENDIX E – SURVEY123 FIELD RECORDS AND PHOTOS

143 plot reports (including non-measurable sites) for each site surveyed can be provided and accessed using the link provided below. An example of the report format is shown below. Field crews took photos of all transects, and many of the pieces measured. This can also be made available as a geodatabase on request.


INTERPINE INNOVATION

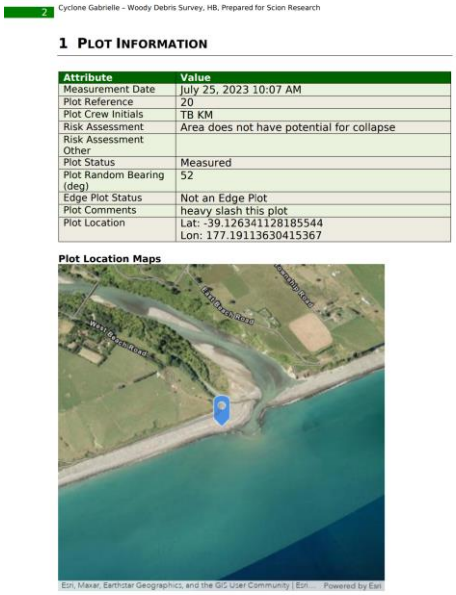
Plot Reference: 20
Date: July 25, 2023 10:07 AM

Cyclone Gabrielle
Post Event Woody Debris Assessment - Hawke's Bay
Supplementary Report - Northern Beaches

Mohaka

Prepared for Scion Research
Print Date: Monday, 29 April 2024

Ref. No: J7804


2 Cyclone Gabrielle – Woody Debris Survey, HB, Prepared for Scion Research

1 PLOT INFORMATION

Attribute	Value
Measurement Date	July 25, 2023 10:07 AM
Plot Reference	20
Plot Crew Initials	TB KM
Risk Assessment	Area does not have potential for collapse
Risk Assessment Other	
Plot Status	Measured
Plot Random Bearing (deg)	52
Edge Plot Status	Not an Edge Plot
Plot Comments	heavy slash this plot
Plot Location	Lat: -39.126341128185544 Lon: 177.19113630415367

Plot Location Maps

Additonal Photos

Shaping Today Natural Resources with Technology of Tomorrow
He rangahau tenei ra he hangarau apopo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+64 7 3503209 info@interpine.nz interpine.nz

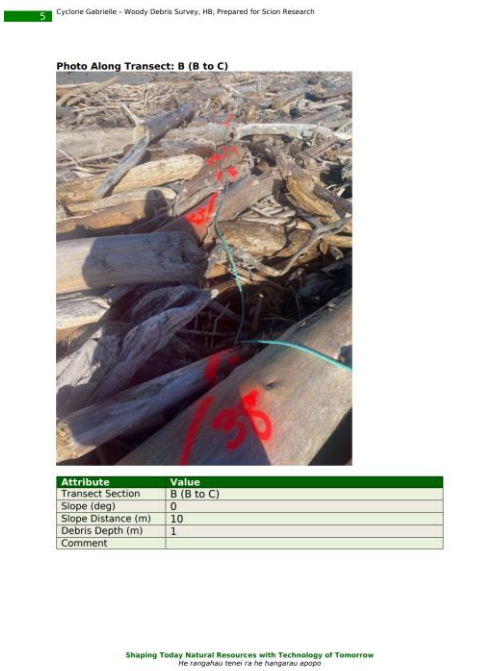
5 Cyclone Gabrielle – Woody Debris Survey, HB, Prepared for Scion Research

Photo Along Transect: B (B to C)

Attribute	Value
Transect Section	B (B to C)
Slope (deg)	0
Slope Distance (m)	10
Debris Depth (m)	1
Comment	

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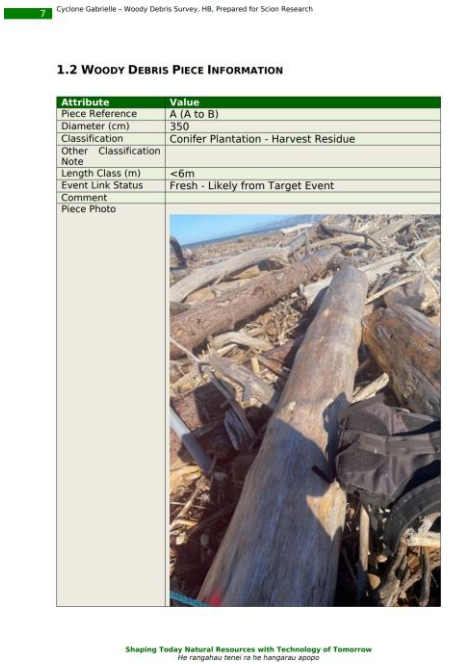
7 Cyclone Gabrielle – Woody Debris Survey, HB, Prepared for Scion Research

1.2 WOODY DEBRIS PIECE INFORMATION

Attribute	Value
Piece Reference	A (A to B)
Diameter (cm)	350
Classification	Conifer Plantation - Harvest Residue
Other Classification Note	
Length Class (m)	<6m
Event Link Status	Fresh - Likely from Target Event
Comment	
Piece Photo	

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Download Link
https://interpine.sharepoint.com/:f:/s/remotesensing/En2aOTlEw6FGjkD4q3_ItswBAAHVpfCwfz4aSn3mfIbUbA?e=Yye9f7

HB Woody Debris Survey - Plot 1 July 2023 - Tc,mc

HB Woody Debris Survey - Plot 5 July 2023 - TB KM

HB Woody Debris Survey - Plot 7 July 2023 - TB KM

HB Woody Debris Survey - Plot 14 July 2023 - TB KM

HB Woody Debris Survey - Plot 19 July 2023 - TB KM

HB Woody Debris Survey - Plot 20 July 2023 - TB KM

HB Woody Debris Survey - Plot 21 July 2023 - TB KM

HB Woody Debris Survey - Plot 24 July 2023 - TB KM

HB Woody Debris Survey - Plot 26 July 2023 - Tc

HB Woody Debris Survey - Plot 27 July 2023 - TB KM

HB Woody Debris Survey - Plot 29 - July 2023 - TB KM

HB Woody Debris Survey - Plot 30 July 2023 - TB KM

HB Woody Debris Survey - Plot 33 July 2023 - Tc

HB Woody Debris Survey - Plot 34 July 2023 - TB KM

HB Woody Debris Survey - Plot 38 - July 2023 - TB KM

HB Woody Debris Survey - Plot 40 July 2023 - Tc,mc

HB Woody Debris Survey - Plot 42 July 2023 - Tc,mc

HB Woody Debris Survey - Plot 44 July 2023 - Tc,mc

HB Woody Debris Survey - Plot 45 July 2023 - TB KM

HB Woody Debris Survey - Plot -49 July 2023 - TB KM

HB Woody Debris Survey - Plot 65 July 2023 - TTB

HB Woody Debris Survey - Plot 68 July 2023 - Tc,mc