PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: info@ffr.co.nz
Web: www.ffr.co.nz

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Development of the Jackson Beckham Felling Wedge for Directional Tree Felling

Authors:
Brett Vincent,
Daniel Jackson,
Michael Beckham.

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Disclaimer

EXECUTIVE SUMMARY

The Steep Land Harvesting Programme developed by Future Forests Research Limited and co-funded by the Primary Growth Partnership has the objectives of improving the safety and productivity of tree harvesting of New Zealand's steep terrain forests.

Part of this programme is to increase the use of grapple yarding through improved payload and grapple control (Objective 2.2). One of the projects in this area is to improve directional tree felling to reduce breakage and improve grapple payload through alignment of felled trees.

An earlier project investigated the use of a hydraulic tree felling wedge to determine if it was successful in improving the accuracy of directional tree felling. Following on from this initial work this project was aimed at trialling and further developing the Jackson Beckham Mechanical Felling Wedge. This is an innovative tree felling wedge, developed as a response to the need for the logging industry to adopt safer and more efficient tree felling systems.

This report details the initial production trials of the wedge, and recommendations for further development. These initial trials showed that the Jackson Beckham Wedge did improve the accuracy of directional felling of trees. Measured tree data showed that using the Wedge to directional-fell trees reduced breakage, and in good conditions resulted in a 6% increase in tree length to the first break compared to similar sized trees felled with conventional wedges.

The Jackson Beckham Mechanical Felling Wedge can help to improve the safety of manual tree felling and increase extraction productivity.

INTRODUCTION

One of the programme objectives of the Steep Land Harvesting Programme developed by Future Forests Research Limited (FFR) and co-funded by the Primary Growth Partnership is to increase the use of grapple yarding through improved payload and grapple control (Objective 2.2). One of the projects in this area is to improve directional tree felling to reduce breakage and improve grapple payload through alignment of felled trees.

Brett Vincent of Tramroad Limited was assigned by Future Forests Research Ltd to investigate a mechanical tree felling wedge developed by Daniel Jackson and Michael Beckham, of Whangarei (the Jackson Beckham Mechanical Felling Wedge). The aim of the project was to establish whether the felling wedge can improve the accuracy of directional tree felling and reduce breakage to improve cable extraction productivity and increase harvesting value recovery.

An earlier report examined the initial trials with the Hydrawedge hydraulic tree felling wedge (Vincent, 2013). This report documents the development of the Jackson Beckham Felling Wedge, the trials undertaken, and summarises the issues identified with the felling wedge. The report also provides project direction for further development of the felling wedge to use the power from a chainsaw to provide assistance to the felling wedge.

BACKGROUND

The Jackson Beckham Mechanical Felling Wedge (Wedge) is an innovative tree felling wedge, developed as a response to the need for the logging industry to adopt safer and more efficient tree felling systems.

This project was initially instigated in an attempt to minimise the common hazards faced by tree fallers in their day-to-day logging operation, such as felling trees on difficult angles or in difficult positions. Current manual tree felling has a poor safety record of injury and death to workers. The potential for injury is obvious when felling even individual trees, but increases exponentially when tree driving is undertaken. With multiple trees falling in various directions, tree driving is potentially a very dangerous practice where guidelines are often ignored. However, tree driving is a common practice in the New Zealand logging industry and is sometimes necessary in order to get particular trees to fall, or to fall in the desired direction.

It was proposed that the Wedge would substantially lessen the risk of injury when felling trees, as it has the potential to offer a faster, stronger and more controlled lift of the tree than conventional wedges. It was anticipated that in many instances tree driving should no longer be necessary, as the Wedge will fell large trees in the desired direction.

Wedge Design and Operation

The Wedge is designed to be carried and used by individual fellers so they always have it at the ready. It is simple, yet strong. The design essentially consists of one plate. This single plate is cut in the centre and is joined at one end by a hinge thereby forming the shape of a wedge which can be wound open by means of a jacking bolt which penetrates the cut plate at the other end.

An initial prototype of the Wedge was built and trialled. While these initial trials proved very successful, modifications were required. The modified prototype was constructed and made available for trialling by Future Forests Research Ltd.

It is foreseen that once prototyping and operational trials are completed, a local (New Zealand) engineering company will be commissioned to manufacture a number of units to be commercially available to the New Zealand logging industry.

The Developers

The Wedge has been designed and manufactured by an experienced tree faller, Daniel (Dan) Jackson, and an engineer, Michael (Mike) Beckham, both from Whangarei.

Dan Jackson has 15 years' experience working in the forestry industry, 12 years of which were spent felling trees. He is currently an Assessor/Trainer within the forestry industry and is completing a National Certificate in Health and Safety.

Mike Beckham is Workshop Manager at a Whangarei engineering firm. He is a qualified Fitter-Turner with 17 years' engineering experience.

The development of the wedge arose from Dan Jackson's experience as a tree faller. He saw the need for a tool that could fell large or difficult trees and fell them in the direction desired. The aim was to develop a tool that could assure the tree faller a measure of safety when felling trees. Dan Jackson teamed up with Mike Beckham in mid-2012 and together they have developed the first (or alpha) prototype of the Jackson/Beckham Mechanical Felling Wedge.

Benefits of the Wedge

The Wedge (Figure 1) will bring the following benefits to the New Zealand logging industry:

1. **Safety** – by enabling tree fallers to control the direction of trees being felled, potentially reducing the need for tree driving and reducing safety hazards.

2. **Production** – by enabling more controlled felling, better aligned trees for extraction and improving extraction payloads.

3. **Cost –** reducing production costs as a result of increased productivity and safety.

4. **Return on investment** – providing a quick payback as a result of increased productivity.

Figure 1: The prototype Jackson Beckham Felling Wedge

METHOD

Project Objectives

Brett Vincent of Tramroad Limited was assigned by FFR to work with the developers, Dan Jackson and Mike Beckham in getting the prototype Wedge to a commercialisation stage. Brett worked with a number of tree fallers in trialling different techniques to ascertain "proof of concept" for the Wedge. A lot of discussions were had with the tree fallers about the concept, use and accuracy of the Wedge, and their ability to work with it. Ideas were discussed with logging contractors and other forest industry people in order to improve the current prototype.

The objectives of the project were to:

- improve the accuracy of directional tree felling;
- reduce felling breakage and thus enhance productivity and value recovery;
- eliminate tree driving and the hazard of driving-related accidents and deaths; and
- provide project direction to steer the further development of a productive, lightweight powered felling wedge.

Trial Process

The trial process was designed to use the Wedge as an assistant tool to the use of conventional felling wedges. The trial was to prove the concept that a felling assistance tool can improve directional felling and therefore decrease breakage and increase production. A secondary objective was to determine the ability of the Wedge to eliminate tree driving.

During the trial the tree faller had control of the felling site, the tree felling process and the use of the Wedge. Brett Vincent acted as an assistant/observer to carry the Wedge and make safety observations. If the tree faller considered that the Wedge should not be used because of safety concerns or production issues, then Brett Vincent moved aside until it was safe enough or the tree faller had the time to continue with the trial work.

RESULTS

Trial: Day One

In November 2013, Brett Vincent made an initial visit to Whangarei to meet Dan Jackson and Mike Beckham, to talk through their ideas and concepts for the Wedge.

The trial was undertaken at a forest site that Dan had selected close to Whangarei. Arriving on the job site, the first observations from the skid site suggested that the piece size of the block was 1.8 tonnes average. The process required to fall the trees and demonstrate the use of the Wedge and its capabilities was discussed with Dan and Mike.

After initial discussion Dan suggested moving to an area of heavier leaning trees. No machine was available to use to assist felling if difficulties in tree felling were experienced.

The piece size of the first tree chosen was close to 4.0 tonnes weight. The scarf and first quarter cut were placed in with a conventional tree faller's wedge to hold the tree. The second quarter cut was placed and the Wedge inserted into the tree (Figure 2). The Wedge failed to lift the tree over. The tree did not move at all, nor did it look like moving without some serious power behind it. It was decided to fall the tree in a different direction.

Two other trees were tried and the Wedge failed to lift either of them over. The position in the stand was changed from falling against the tree lean to working with the lean. After adjusting position the Wedge managed to lift a number of trees over to enable operator training for future trial days.

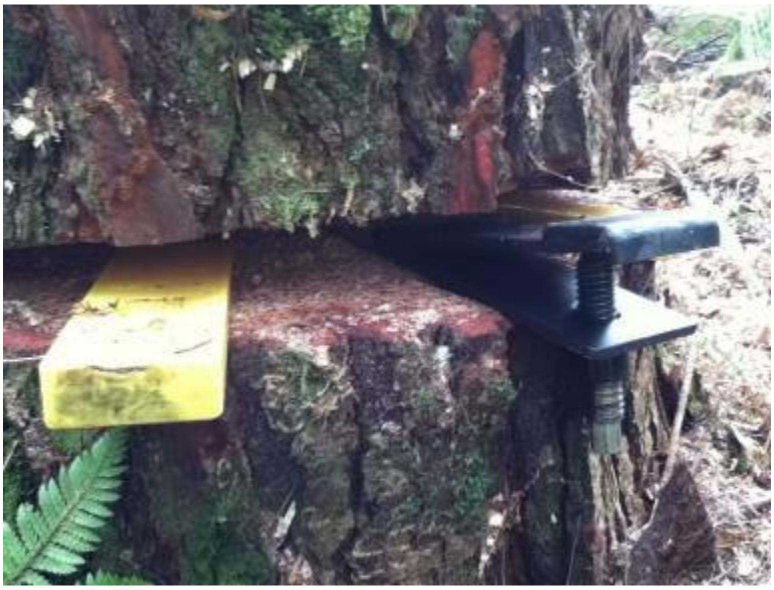

Figure 2: First prototype of the Wedge (right)

Improvements Arising From Day One

The mechanical faults and the issues that the wedge had presented whilst completing the first trial day were assessed:

1. Thickness of the Wedge plates was causing the Wedge to flex too much (Figure 3).
2. The thin plastic tip on the end of the Wedge came free after the first couple of trees (Figure 4).
3. The Wedge had limitations in lifting larger trees that had significant lean.
4. Difficulty in inserting the Wedge due to the size of the hinge pin.
5. Back plate to allow the Wedge to be driven in was too lightweight.

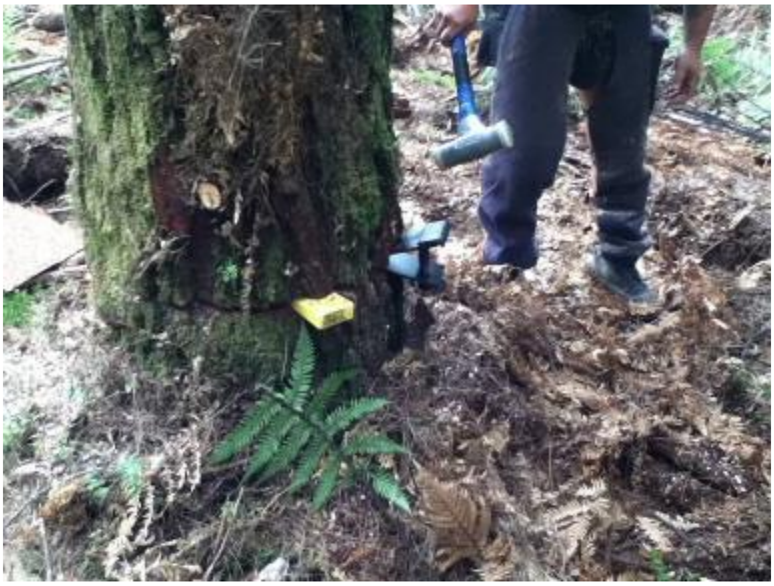

Figure 3: Wedge showing plates bending under the tree weight

Proposed modifications to the wedge as a result of the first trial day were discussed with the developers.

The improvements suggested resulted in producing two prototype wedges: one with heavy plate steel (Heavier Wedge) and one with lighter plate steel (Lighter Wedge). Both had the same sized threads and pins. The plastic wedge ends were attached differently on each wedge. Overall each was stronger in its design in order to reduce the damage to the Wedge that would occur during typical tree felling operations.

Figure 4: Plastic end missing and bent plates

Trial: Day Two

Day Two was completed in a roadlining harvesting operation outside of Rotorua. The crew had one tree faller who held all the appropriate tree felling Unit Standards.

Figure 5 shows that the Lighter Wedge (bottom) is shorter and is made of lighter plate steel. The Heavier Wedge (top) was heavier and longer and was made from thicker plate steel.

The first task was to understand the strengths and limitations of each of the Wedges.

Each Wedge was trialled to ascertain the design improvements to be made. Sledge hammers and ¾-inch drive sockets were used on them. Brett even adjusted the back cuts to be sloping inwards and enlarged.

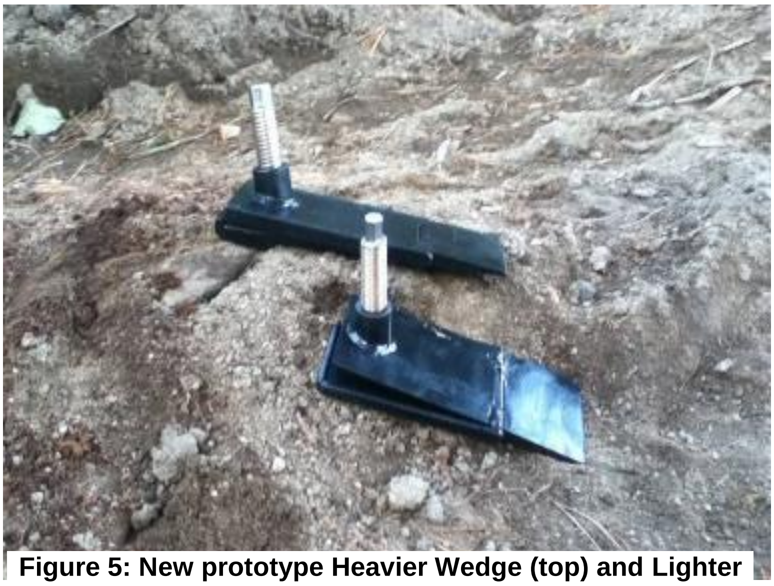

Figure 5: New prototype Heavier Wedge (top) and Lighter Wedge (bottom) for Trial Day Two

Lighter Wedge

The lighter Wedge failed immediately. It was made lighter to allow a smaller hinge pin to be inserted into the back cut without opening up a larger slot. The thin plate steel flexed and was unable to handle the estimated 2.0 tonne piece size of the trees.

Heavier Wedge

The heavier Wedge took the loads and impact better than the lighter Wedge. It held up against the 4-kg sledge hammer and the large tree piece size. With some of the larger trees a larger ratchet, from ½ inch to ¾ inch drive, was used (Figure 6).

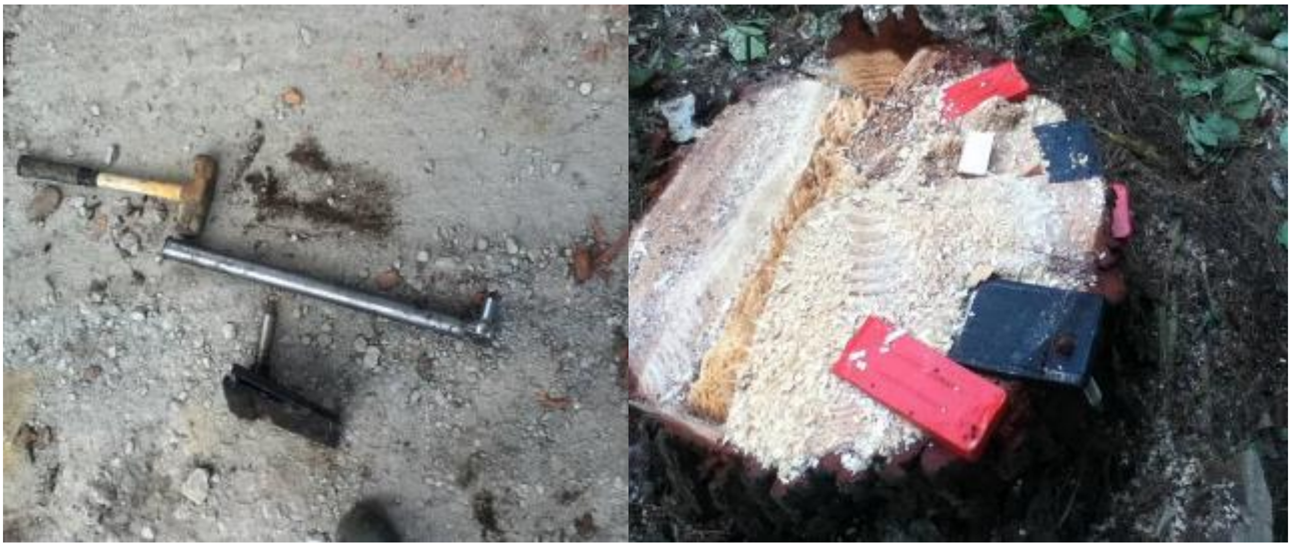

Figure 6: Tools used on the larger wedge (left) and using both wedges (right)

Larger slots had to be cut in the tree for insertion of the Wedge (Figure 7).

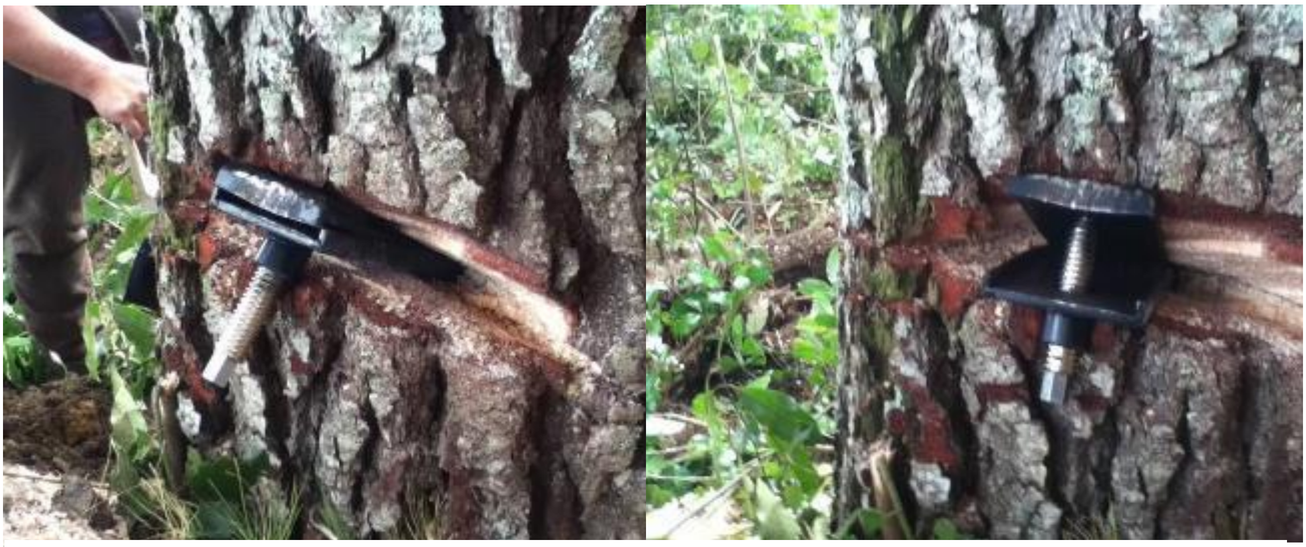

Figure 7: Sloping back cut (left) and enlarged back cut (right) trialled for effectiveness

Failings

The ends of both Wedges were broken off during Trial Day Two. Both internal threads failed and locked the screws tight. The two Wedges were put through some tough tests as could be seen from the marks on them. The hinges were strong on both units but the backing plates and main plates were bent on both Wedges (Figure 8). Both Wedges certainly struggled on Trial Day Two with the size of the trees.

Improvements Arising From Day Two

The following improvements from Trial Day Two were proposed:

- Strengthen the screw mechanisms.
- The screw should be the same size on the smaller Wedge as the larger Wedge.
- Improve the plastic wedge tip attachment as both were broken on the first tree felled.
- Side gussets to add a lot of strength to both units.
- Some calculations were required to be made for the screw to match the power produced through the ratchet.

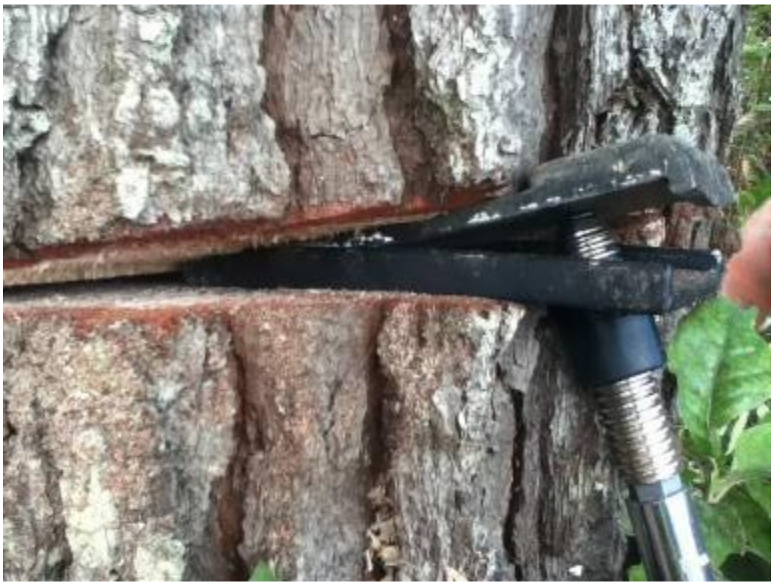

Figure 8: Flex in the plates and slot cut out for insertion

After Trial Day Two both Wedges were returned to the developers for modification. During December 2013/January 2014 the Wedge was redesigned to be more robust to work every time and withstand the stresses placed on it during daily tree felling operations.

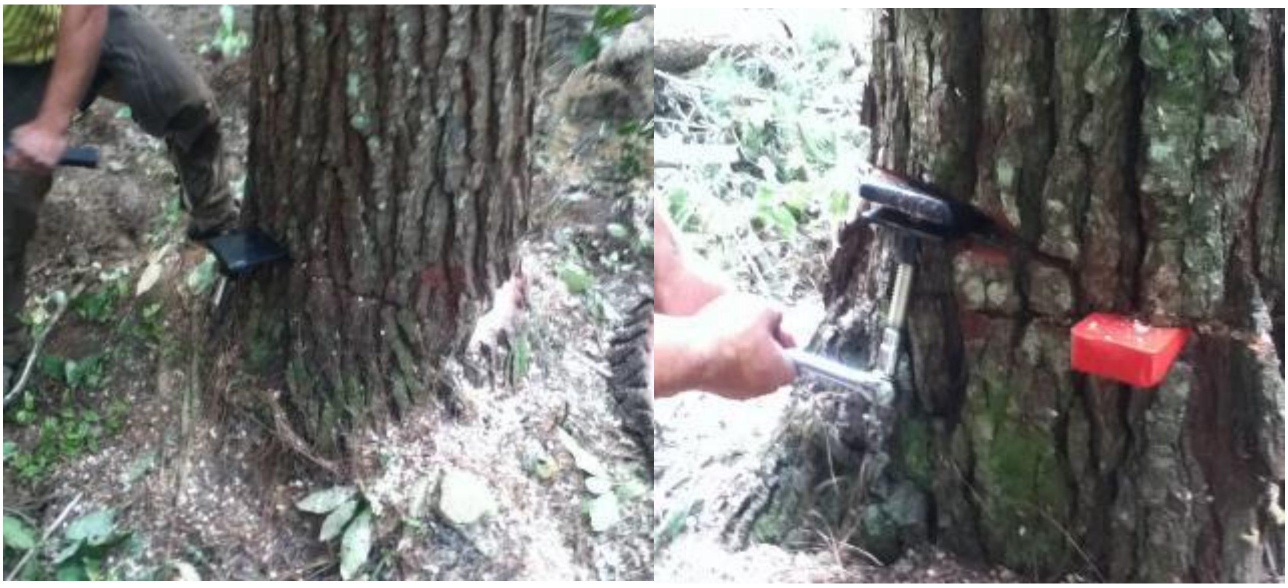

Figure 9: Using the hammer to drive in the wedge (left) and used with a conventional wedge (right)

Trial: Day Three

In early 2014 the redesigned (second prototype) Wedge was available for further trials. It looked more powerful, stronger and more robust. The changes made were to make it out of one solid plate split in the middle. The backing plate was stronger, allowing the Wedge to be driven in with a hammer without bending (Figure 10). In initial trials the Wedge worked very well, with sufficient strength in the plates to wedge every tree over with ease.

In the afternoon work session, the Wedge was trialled with edge trees. Realising the limitations of the Wedge from past experience, trees within the capability of the Wedge were selected (Figure 11). On a couple of occasions the Wedge struggled to lift the trees before tipping over.

Figure 10: The second prototype Wedge

From the testing of the second prototype, it was decided to use the Wedge in both a ground-based and a hauler operation measuring tree length driving vs. non-driving felling techniques to minimise breakage.

Improvements Arising From Day Three

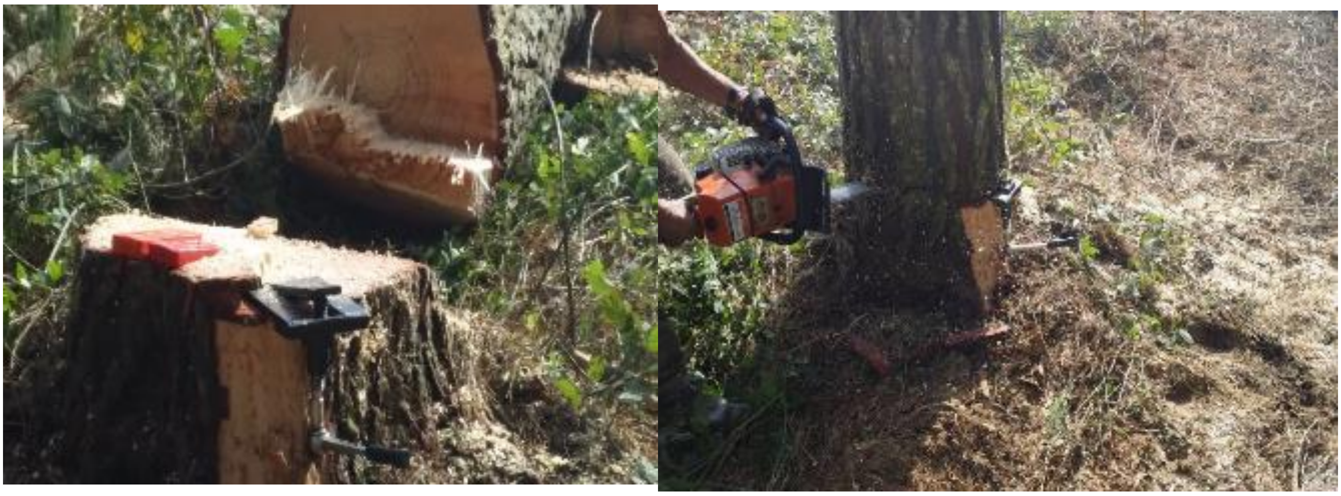

Figure 11: Bark cleaned and slot opened in the back cut for full Wedge insertion (left) and Wedge lifting trees over successfully with conventional wedges (right)

The Wedge was sent back to the developers for one further improvement. The angle of the thread was such that it would jam against butt fluting of the tree, and therefore full insertion could not be achieved. The felling technique was adjusted to suit by cutting the fluting away from the tree base, so full insertion could be achieved. It was suggested that the angle on the pin be increased by 5 degrees.

Trial: Day Four – Ground-Based Setting

The third prototype Wedge was sent back to Brett to organise use of the Wedge in a ground-based setting of approximately 2.0 tonne piece size. The morning work session was spent falling trees using conventional wedges without the assistance of the Wedge, and the afternoon work session was spent falling with the assistance of the Wedge.

Morning Session

Brett assisted the tree faller as an observer and helped with wedging using conventional wedges. Mean tree height for the block was 39.1m. Terrain was flat to undulating. Soil type was pumice. Weather was fine with light westerly winds.

Felled trees were measured for large end diameter (led), tree length (using a range finder), and small end diameter (sed) at the breakage point. Not all trees were measured, as some trees could not be safely accessed. Range finder measurements of trees were to the nearest whole metre.

Six tree drives were completed, where each drive comprised one tree onto one, which resulted in 12 wedged trees being measured. Each drive had a wedge in the front tree and was driven out from the tree behind sometimes with assistance of additional conventional wedges (Figure 12).

A total of 23 felled trees were measured. Results showed the average length of conventionally wedged trees was 27.4m. Tree diameters averaged 56.5 cm led and 23.7cm sed (Appendix 1).

Later in the morning work session the trees were felled on already fallen stems increasing the likelihood of breakage. Stumps also caused breakage on some single trees.

Figure 12: Driving trees during Day Four morning session

Afternoon Session

In the afternoon work session the Wedge was used for all the conventional tree drives. Brett and the faller worked together with Brett acting as observer. The use of the Wedge and where it could be best used was discussed. In the felling of all trees, conventional wedges were used to assist the Wedge in tipping the trees over.

In the afternoon session the Wedge was used on a number of trees. All other factors and variables were the same as for the morning session.

A total of 18 trees were measured. Results showed the average length of trees felled using the Wedge was 29.1m. Tree diameters averaged 53.9 cm led and 23.1cm sed. Using the Wedge in similar sized trees to those felled with conventional wedges resulted in a 6.2% increase in tree length to the first break.

No measurements were taken at the landing after extraction had taken place, as there was very little breakage at breakout (during extraction). There were no production influences as the tree felling was undertaken on a Saturday.

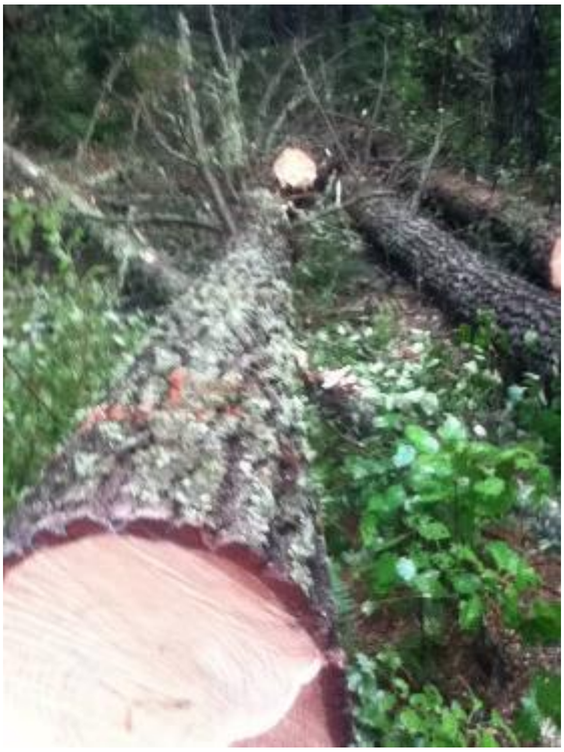

Figure 13: Laid wood down during Day Four afternoon session

Trial: Day Five – Hauler Setting

The Wedge was sent back to the developers for some strength improvements to the threaded pin. The fourth prototype Wedge was received back and a one-day trial in a cable harvesting operation was organised. The piece size was estimated to be just under 3.0 tonnes. A setting that provided the need for the Wedge was selected.

The operating plan was to complete a morning work session with the faller as an observer and assist him in using conventional wedges either to wedge trees over or drive trees.

Morning Session

Mean tree height for the block was 43.5m. Terrain was steep. The forest has been grown on clay and marine based soils. Weather was raining with light westerly winds.

Similar to the ground-based trial, the length of felled trees to the first break was measured using a range finder. The breakage point was found for each tree and the tree length back to the faller at the butt was measured using the laser rangefinder. Range finder measurements of trees were to the nearest whole metre. Due to the steep terrain sometimes this proved difficult, and safety certainly was a factor during data collection. Consequently, not all trees were measured, only those that could be reached safely.

In total six tree drives were completed, which resulted in measuring five wedged trees. Each drive comprised one tree onto one. Each drive had a wedge in the front tree and was driven out from the tree behind, sometimes with assistance of more conventional wedges.

Results of the measurements of a total of 16 felled trees resulted in average measured tree length for the conventional wedged tree sample of 26.4m. Tree diameters were 63.5cm led and 30.3cm sed (Appendix 2).

Afternoon Session

During the afternoon session the Wedge was used for all the conventional tree drives. The tree faller worked together with Brett as the observer. For each tree the use of the Wedge was discussed and agreement was reached as to when it could be used. In all trees conventional wedges were used to assist the Wedge in getting the trees over.

The afternoon session resulted in only three trees where the Wedge was used. All other factors and variables were the same as for the morning session.

A total of 18 felled trees were measured. Results showed the average length of trees felled using the Wedge was 26.5m. Tree diameters averaged 61.6cm led and 31.3cm sed. Using the Wedge in similar sized trees to those felled with conventional wedges resulted in only 0.5% increase in average tree length.

Figure 14: Wedge struggling to lift a tree

No results were taken from skid measurements after extraction had taken place. The trial was completed on a Monday, but the faller was far enough ahead that production pressure did not influence him.

During the afternoon session one tree, which was 5.0 tonne piece size, sat back on the one conventional wedge in the back cut.

Using a 1.8kg sledge hammer the faller got the Wedge in and lifted the tree. The tree was wedged up and another conventional wedge was used. The Wedge was not fully retracted back and when it was driven into the back cut with the sledge hammer the hinge pin was bent (Figure 15) and the thread housing was cracked, thereby ending the afternoon session prematurely.

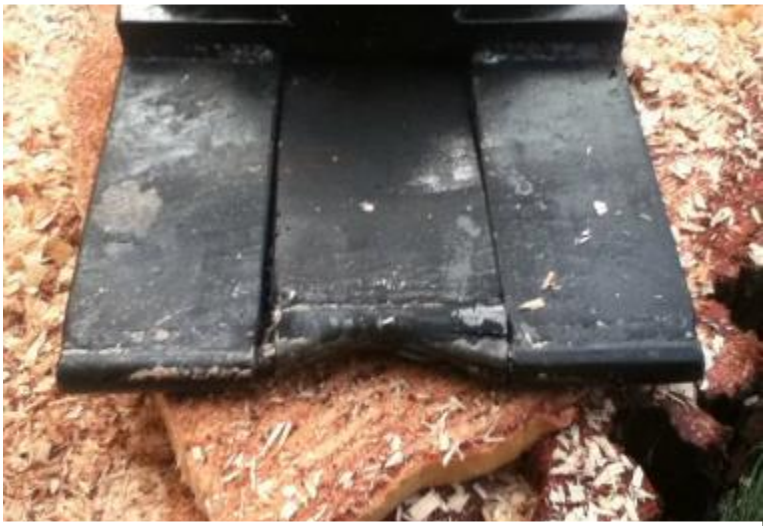

Figure 15: Bent hinge pin on the Wedge

DESIGN ISSUES TO BE ADDRESSED

The design of the Jackson Beckham Mechanical Felling Wedge had a number of issues that became apparent as it was used in these initial trials:

1. **Weight of the current design**.

   The Wedge design would result in a tree faller carrying an additional load of 5kg including the ratchet and socket.

2. **Inserting the Wedge into the back cut.**

   The plates and hinge are bulky when used without a conventional wedge. Insertion proved difficult from a conventional chainsaw chain cut width. The tree faller needed to cut an extra little wedge so the insertion became effective, by tilting the saw as it was pulled out from the back cut. Quarter cuts and split level cuts were used to insert the Wedge before the tree sat back. Once a tree sat back it was impossible to insert the Wedge. Conventional wedges had to be used or a driver tree used to drive the tree down (negating the purpose of the Wedge).

Figure 16: Wedge successfully lifting a tree

3. **Pouch Design.**

   The developers need to design a pouch to carry the Wedge, which would also allow the faller to carry conventional wedges and all his safety equipment.

4. **Ratchet device.**

   Originally the concept was to use a chainsaw bar spanner to wind the Wedge to lift the trees. The bar spanner was too lightweight to undertake this task. The developers need to design a tool that incorporates both a bar spanner and ratchet.

5. **Hinge**.

   The hinge will continue to be a weak point. However adequate training about the use of the Wedge should overcome this problem.

WORKSAFE ASSESSMENT

The developers wanted to consult Worksafe NZ in the design and concept of the Wedge. In early August 2014, the developers met with Karl Bowman and Barry Coles from Northland, who had been asked by Worksafe NZ Northland to assess the Wedge on its behalf.

One day was spent working with the Wedge, establishing new cuts and processes for its use. Karl Bowman and Barry Coles had some positive recommendations for the Wedge which they were going to pass on to Worksafe NZ Northland.

FURTHER IMPROVEMENTS

On conclusion of the Worksafe NZ consultation with Karl Bowman and Barry Coles and from the recommendations of the trial work the following improvement ideas were implemented:

1. Finalise the prototype Wedge design to include:
    - Wider lift plates
    - Grip teeth
    - Narrower pitch on thread
    - Bearing at end of pin to reduce friction
    - Higher grade bronze pin

2. Use the existing hammer and weld a ratchet socket to the end of the hammer.

3. New pouch design for carrying the Wedge.

4. Trial the existing Wedge for a minimum of two days' continuous tree falling. This will establish clear cuts required for the Wedge, and a clear understanding of its capabilities in achieving the goals of reducing tree breakage and eliminating tree driving.

5. Trial the next prototype Wedge, and report.

6. Develop a beta prototype Felling Wedge that is powered using the chainsaw. This design should include remote control operation of the Wedge from a distance.
    - Pneumatic power source
    - Hydraulic power source

FINAL DESIGN

Wedge Design

The final design addressed the issues raised above and included the recommendations from the Worksafe NZ assessment day.

These improvements included:

- Wider lift plates
  The new wider lifting plates allowed more surface area in the back cut.

- Grip teeth
  The grip threads (as shown in Figure 17) provides additional grip to keep the Wedge inside the back cut.

- Narrower pitch on thread
  The narrower pitch on the pin requires less force from the user to lift the tree.

- Higher grade bronze pin
  A high grade bronze pin allows for a lower friction surface to wind the pin.

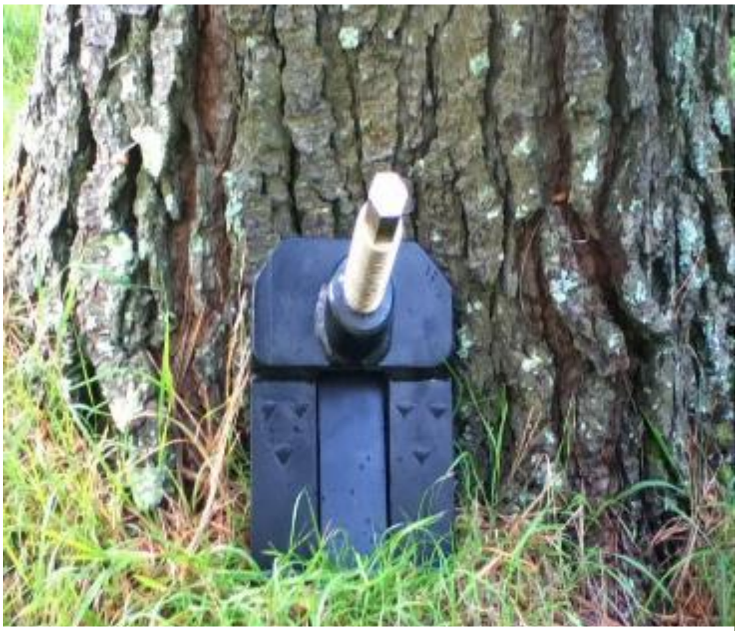

Figure 17: Final Wedge Design showing grip teeth

Combination Hammer Ratchet

An existing metal-handled tree felling hammer is used with a ratchet spanner welded to the end. This makes it a multi-purpose tool that can drive in conventional wedges and also be used to screw the lifting pin of the Wedge. The handle of the hammer and head also give the user a better grip to provide more torque into the Wedge.

Patents

A patent for the concept of the thread pin lifting the plates has been filed for New Zealand and worldwide application.

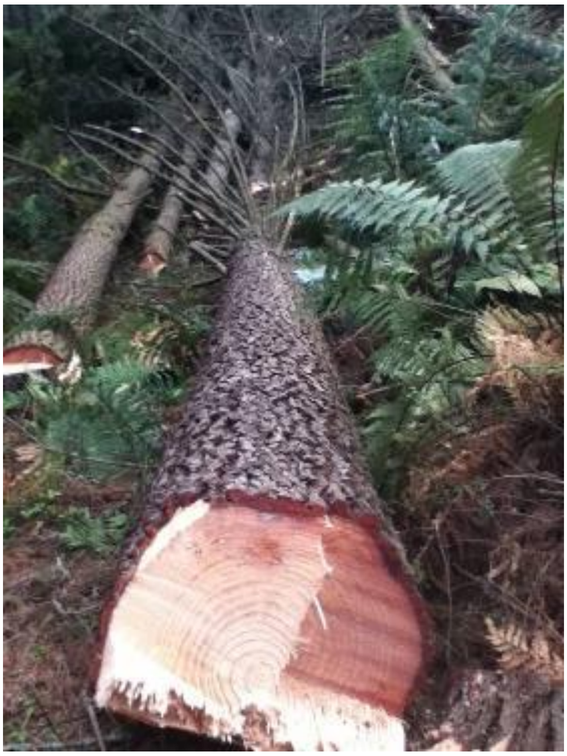

Figure 18: Successful alignment of felled trees using the Wedge

Pouch Design

The developers have designed a pouch to carry the Wedge. One design uses a harness around the tree faller's combination fuel/oil container (Figure 19).

The first prototype will be made up of canvas with Velcro and clips/buckles on straps to go around the bottom of the container.

The design will house the Wedge threaded bolt in the gap between the petrol and oil sections of the combination container. However the pocket will be big enough so the bolt can move around to counteract weight changes when the petrol container is emptier than the oil container.

Figure 19: Pouch design attached to a tree faller's fuel container

A second design is a harness with a modified tree faller's belt at the bottom (Figure 20). The harness has been attached to allow for the extra weight of the Wedge (4.5kg) to be carried around the hips. The harness incorporates the tree faller's radio. The belt also carries the Wedge, four conventional wedges, the hammer ratchet, a first aid kit and a drinking bottle.

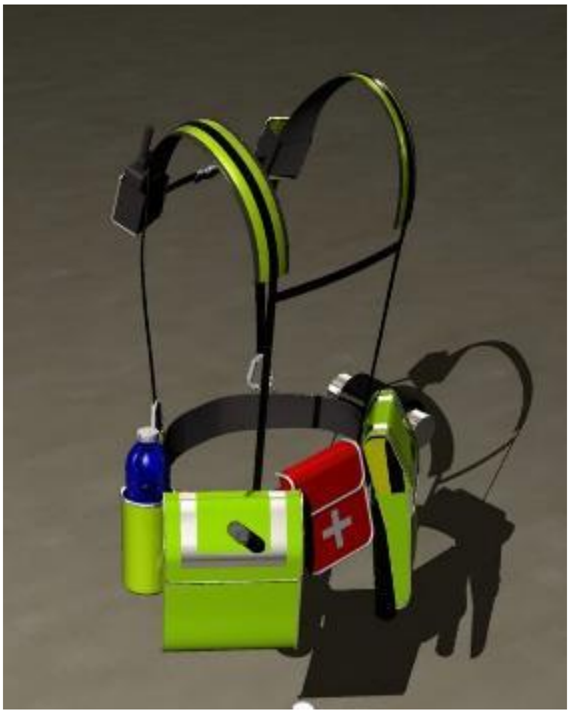

Figure 20: Pouch design on modified faller's belt

Final Trials

The final design of the Wedge was trialled with extremely good results on achieving proof of concept of the original work plan.

Dan completed several weeks' work with the final design Wedge. This allowed him to practice the use of the new design and perfect cutting techniques.

Working with the Wedge allowed Dan to determine which trees to use it on, when he should use it and why he needs to use it.

Dan ceased tree driving whilst he was using the Wedge. Eliminating tree driving was one of the goals of developing the Wedge.

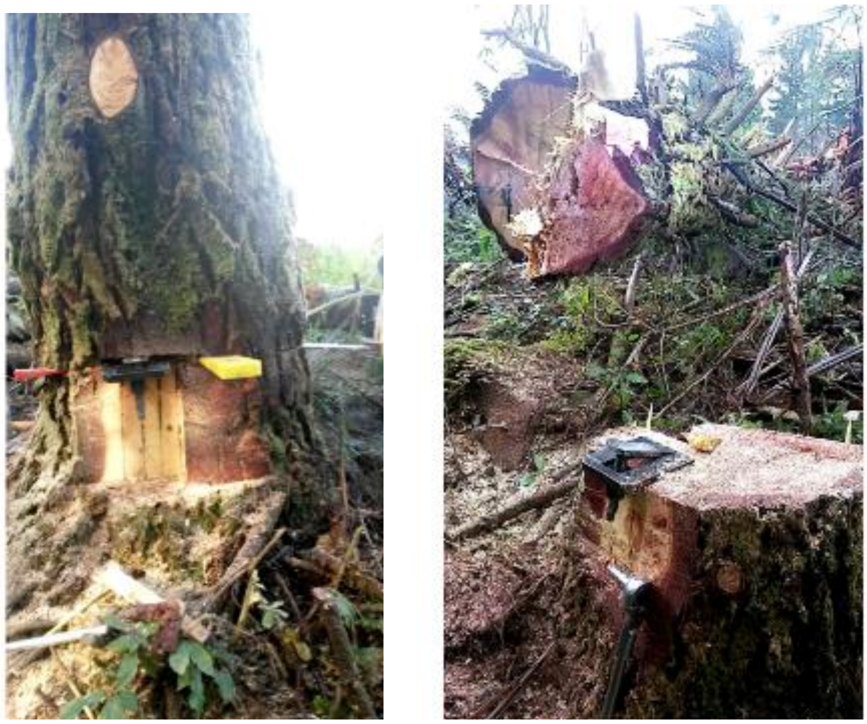

Figure 21: Successful results of use of the Wedge in the last of the initial trials.

DISCUSSION

Proving the concept of using another device for felling assistance required the following questions to be answered. Did the use of the Jackson Beckham Mechanical Felling Wedge:

1. Improve the accuracy of directional felling?

   These initial trials showed that the Wedge did improve the accuracy of directional felling of trees. The measured data showed that directional-felled wood reduced breakage as trees were laid side by side and not crossed over.

2. Reduce felling breakage and thus enhance productivity and value recovery?

   Reduced felling breakage increased merchantable tree length, resulting in fewer pieces to extract and therefore improved extraction productivity.

3. Eliminate tree driving and the hazard of driving-related accidents and fatalities?

   Use of the Wedge eliminated the need to drive trees because it had the power to wedge trees over individually. The Wedge reduced the hazards of tree felling by:

   - allowing the operator to watch the top of the tree at all times, keeping focus on the tree instead of hitting conventional wedges;
   - allowing a quieter operation, allowing operators to listen out for felling debris from the top of the tree.

4. Require significant changes in operating techniques?

   It must be made clear to the forest industry that to fully utilise this Wedge all tree fallers will need to adjust how they work. If they find the biggest tree with the heaviest lean then it will not work. It is a device to be used in conjunction with the other tree faller’s equipment (conventional wedges) to fell trees safely to maximise productivity and improve value recovery.

5. Provide direction for further development of a productive, lightweight powerful felling wedge?

   The trials of the Wedge allowed tree fallers to gain insight to provide project direction to steer the further development of a device that allows the tree faller to retreat into the safe zone before the Wedge lifts the tree over.

RECOMMENDATIONS

Design work has started on the next phase of the project, to develop the Beta Prototype of the Felling Wedge. The beta prototype will power the operation of the Wedge and allow the user to operate the Wedge remotely without the need to screw the pin. Initial ideas are focusing on how to incorporate the chainsaw (pneumatic systems, hydraulic systems, or a system using explosive carbon dioxide (cardox) to replace the lifting force of the screw component of the Wedge.

Further development will continue with the Wedge. A clearly defined Work Plan will be developed in order to integrate this improved felling wedge into the New Zealand forest industry. Preliminary drawings for the cardox system have been done. More testing and trial work will be completed after the beta prototype design phase has been completed.

CONCLUSION

In its final design, the Jackson Beckham Mechanical Felling Wedge can complete successfully the task it is required to do. The trials have proved that the final design works well. The theory that good directional felling reduces breakage was found to be correct. Results showed that in good conditions use of the Wedge can align felled trees side-by-side and increase average merchantable tree length by up to 6%.

Giving a manual faller a tool to fell trees directionally all day long will enhance the safety of manual tree felling and increase extraction productivity. From the completed trial work it is clear that this device can be used successfully to eliminate the need to drive trees during felling. The wedge can also be used to tip larger edge trees over in conjunction with conventional wedges.

The Jackson Beckham Mechanical Felling Wedge can help to improve tree faller's safety and should become part of the tree faller's equipment to safely and professionally fell trees.

REFERENCE

Vincent, B. (2013): Development of an Improved Felling Wedge for Directional Felling - Initial Trials. Report No. FFR- H010, Future Forests Research Limited, Rotorua.

APPENDIX 1

Trial Data – Ground Based

Lifting Wedge Trial Data - Ground Based									
	Tree Number	Drive tree	Driven tree	Wedge(s) Used	Single tree	length (m)	LED	SED	Breakage at breakout
Morning Session	1	y	n	y	n	28	63	25	y
Convensional Wedges	2	n	y	y	n	27	63	24	n
	3	y	n	y	n	32	55	25	n
	4	n	y	y	n	27	45	15	n
	5	y	n	y	n	28	45	18	n
	6	n	y	y	n	25	47	22	n
	7	y	n	y	n	29	55	23	n
	8	n	y	y	n	25	53	27	n
	9	y	n	y	n	28	66	26	n
	10	n	y	y	n	29	68	26	n
	11	y	n	y	n	24	79	38	n
	12	n	y	y	n	26	45	20	n
	13	n	n	y	y	27	56	26	n
	14	n	n	n	y	32	50	25	n
	15	n	n	n	y	31	44	12	n
	16	n	n	n	y	28	56	22	n
	17	n	n	n	y	25	59	28	n
	18	n	n	n	y	27	54	23	n
	19	n	n	n	y	26	55	23	n
	20	n	n	n	y	27	62	25	n
	21	n	n	y	y	26	66	26	n
	22	y	n	y	n	26	59	24	y
	23	n	y	y	n	28	55	21	n
						27.43	56.52	23.65	
Afternoon session	1	n	n	y	y	28	55	22	n
Lifting Wedge	2	n	n	y	y	29	56	25	n
	3	n	n	y	y	28	55	22	n
	4	n	n	y	y	30	51	23	n
	5	n	n	y	y	31	44	17	n
	6	n	n	y	y	29	48	18	n
	7	y	n	y	n	29	55	22	n
	8	n	y	y	n	30	59	26	n
	9	n	n	n	y	29	60	27	n
	10	n	n	n	y	28	66	31	n
	11	n	n	n	y	29	44	18	n
	12	n	n	y	y	30	60	31	n
	13	y	n	y	n	33	54	19	n
	14	n	y	y	n	31	55	22	n
	15	y	n	y	n	30	46	16	n
	16	n	y	y	n	26	49	22	n
	17	n	n	y	y	27	55	27	n
	18	n	n	n	y	27	59	27	n
						29.11	53.94	23.06	

APPENDIX 2

Trial Data – Hauler

	Lifting Wedge Trial Data - Hauler									
		Tree Number	Drive tree	Driven tree	Wedge(s) Used	Single tree	length (m)	LED	SED	Breakage at breakout
Morning Session		1	y	n	y	n	23	67	37	
Conventinal Wedges		2	n	y	y	n	25	75	45	
		3	n	n	y	y	27	69	29	
		4	n	n	y	y	25	66		
		5	n	n	n	y	25	63		y
		6	n	n	n	y	25	63		y
		7	y	n	y	n	29	62	25	y
		8	n	y	y	n	25	61	26	n
		9	y	n	y	n	27	44	18	y
		10	n	y	y	n	29	58	23	y
		11	y	n	y	n	25	56	27	y
		12	n	y	y	n	26	66	31	n
		13	n	n	y	y	27	57	27	n
		14	n	n	n	y	28	68	33	n
		15	n	n	n	y	28	71	38	y
		16	n	n	n	y	28	70	35	y
							26.38	63.50	30.31	
Afternoon session		1	n	n	y	y	25	66	31	
Lifting Wedge		2	n	n	y	y	26	56	27	
		3	n	n	y	y	25	68	35	
		4	n	n	n	y	28	49	22	
		5	n	n	n	y	28	53	26	
		6	n	n	n	y	30	55	21	
		7	y	n	y	n	29	62	25	
		8	n	y	y	n	28	61	25	
		9	n	n	y	y	26	79	44	
		10	n	n	y	y	27	70	37	
		11	n	n	y	y	22	69	45	
		12	n	n	y	y	28	58	33	
		13	y	n	y	n	27	55	28	
		14	n	y	y	n	26	52	24	
		15	y	n	y	n	23	44	19	
		16	n	y	y	n	24	76	50	
		17	n	n	y	y	27	70	42	
		18	n	n	y	y	28	65	30	
							26.50	61.56	31.33	