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New Zealand Winch-Assisted Harvesting

Best Practice Guide

Foreword

The New Zealand forestry industry has seen a huge shift from manual to mechanised harvesting in the past few years, greatly reducing risks to manual fallers and breakers-out.

However, mechanised harvesting creates its own critical risks, particularly if machines and the people who operate them are working on steep and more difficult terrain.

With winch-assisted technology now widely used around New Zealand, the forestry industry identified the need for a Best Practice Guide. This Guide will set a benchmark for winch-assisted harvesting on steep slopes.

Safetree was pleased to be able to lead the development of this Guide, with funding support from ACC and WorkSafe.

We would also like to thank the team of forestry, safety and machinery experts who volunteered their time and expertise to create this Guide.

This Best Practice Guide will be maintained by Safetree and it is our intention to make updates as winch-assisted harvesting technology develops. Please provide any feedback you have to info@safetree.nz

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Comments and suggestions to brett@brettgilmoreconsulting.com.

Disclaimer

Winch-assist harvesting is now well established in New Zealand after rapidly expanding.

The guide was developed using existing guides and manuals within New Zealand and overseas. The steering committee and steep slope harvester machine operators gave technical input.

The purpose of the guide is to promote best practice for winch-assist operations. Best practice changes and improves over time as winch-assist systems develop and knowledge and experience are gained.

Legal obligations for companies, contractors and operators are set out in the Health & Safety at Work Act (2015) and specific guidance for Winch-assist in the Approved Code of Practice (ACOP) for Forest operations.

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ACC He Kaupare. He Manaaki. He Whakaora. prevention. care. recovery.

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Contents

Part B – Other factors for a well run winch-assist operation

The Best Practice Guide's purpose

The purpose of this guide is to assist operators, contractors, and supervisors:

- ✓ Improve understanding of winch-assist systems.
- ✓ Guide what is best practice.
- ✓ Help improve the safety of winch-assisted harvesting operations.
- ✓ Achieve best environmental outcomes.
- ✓ Improve productivity.

Duty of care

The Winch-Assisted Harvesting Best Practice Guide aims to contribute to a safer work environment.

The Best Practice Guide helps fulfil the duty of care requirements within the H&S at Work Act 2015 on Persons Conducting a Business or Undertaking (PCBU). These require PCBUs to provide and maintain a safe work environment, safe plant and structures and safe systems of work. Everyone is required to play their part, including employers, workers, and machine designers and manufacturers.

Symbols used in the guide

Warnings:

Warnings specify hazards associated with a task, location, or equipment.

Experienced operators' advice:

Experienced operators' have emphasised important information.

Examples of good and poor practice:

Part A
The winch-assist system

Chapter 1

Overview of winch-assist ground-based harvesting

In this chapter you will find out:

- ✓ What is winch-assist harvesting.
- ✓ Why use winch-assist systems.

What is a winch-assisted harvesting system?

Winch-assist is a ground-based harvesting system that uses wire rope(s) attached to a machine to operate in a broader range of conditions, often on steeper slopes. A common New Zealand use of winch-assist is steep slope felling or shovelling with a tracked excavator. However, a range of other machines can be successfully winch-assisted including skidders and forwarders. Winch-assist is often called cable-assist or tethered.

The Best Practice Guide uses the term winch-assist because it is in the Approved Code of Practice for Health and Safety in Forest Operations (ACOP). The term traction aid, also widely used, has an important difference from winch-assist. Traction aid uses a rope to support a machine capable of operating on the slope, but winch-assist gives access to terrain that could not otherwise be operated without the support of a winch and wire rope.

Why use winch-assisted harvesting?

A big drive has been to improve safety, productivity, operational flexibility, and forest owner returns. There is a global trend toward more mechanised harvesting systems. Winch-assist is specifically designed to extend the operating range of machines on steep slopes.

Safety
An initial driver for winch-assisted harvesting systems was to improve felling safety. Machines protect workers from many of the risks associated with manual felling. The forest industry has invested heavily in mechanisation, and winch-assist technology has been encouraged by forest companies. WorkSafe's position on new technology is that companies should adopt it when it better manages risk. The move to winch-assist has been an important safety step to protect workers through new technology.

Cost and Productivity
On average, cable logging is more expensive than ground-based operations. Winch-assisted harvesting increases the operating range of ground-based machinery. It can also be used to support cable logging operation through mechanised directional felling for extraction, bunching and shovelling. Through careful planning, it can reduce infrastructure costs like roading, landing number and size.

However, there's a significant capital investment and higher operating costs associated with winch-assist harvesting over other ground base operations.

The supporting winch-assist machine may not always be required and often needs to be relocated, so their utilization is likely lower than other machinery on a harvesting site. When done effectively, there's substantial productivity improvements and financial benefits.

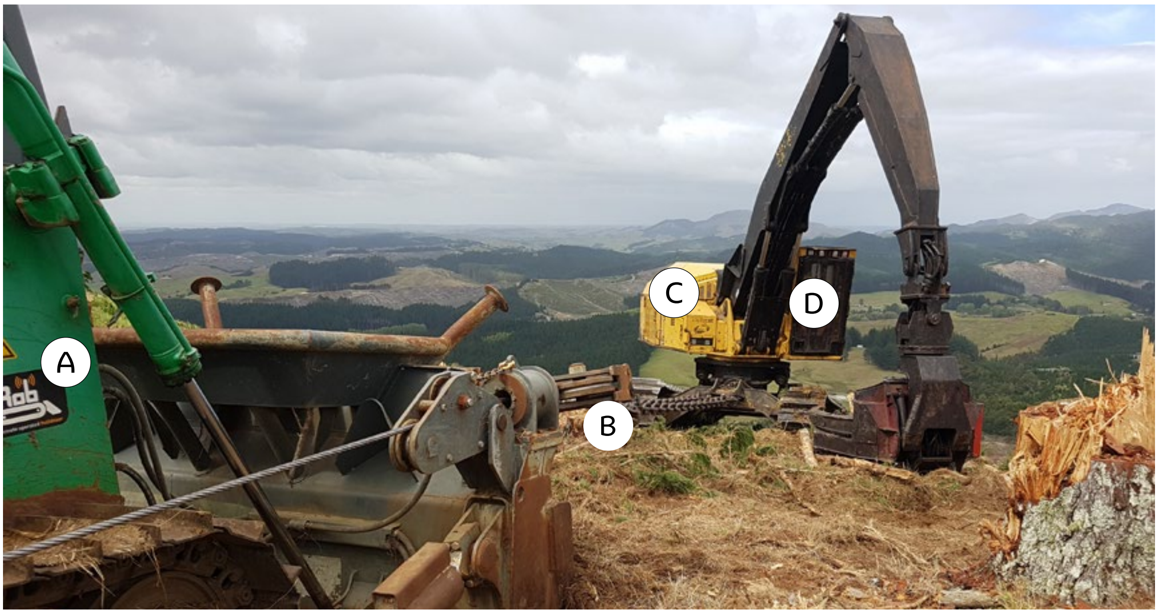
Environment
There can be environmental benefits, but this depends on the site and its management. Winch-assist improves machine traction, and with good operators and site conditions, deep soil disturbance is often significantly less than operating machinery without winch-assist support. Where cable assist replaces cable logging, less roading and landing earthworks may be required.

However, winch-assist allows harvesting machinery to operate on steeper slopes where previously no machine could have worked. Machines have a higher level of soil disturbance and compaction compared to manual felling. However, soil type and weather conditions, and operator skill play a big part in getting a light environmental footprint.

System parts

Irrespective of whether you are using the winch-assist system to fell, skid, shovel or forward, there are four essential parts. These are the:

1. Operator.
2. Steep Slope Harvesting (SSH) machine.
3. Winch on the harvesting machine or an anchor machine.
4. Rigging.



A Winch anchor machine

B Rigging

C Steep Slope Harvesting (SSH) machine

D The operator

Chapter 2
The operator

In this chapter you will find out:

- ✓ What it takes, from professional operators.
- ✓ What training you need.
- ✓ How to manage fatigue and emergencies.
- ✓ Ways to work with hand fallers.

Being a winch-assist operator is a challenging job. It's not for everyone. You are a professional in a million-dollar setup.

This chapter covers the important aspects of having what it takes for the job, the training needed, and aspects of self-care, including fatigue management, when to stop, and working alone.

Mechanised felling with a winch-assist machine is not possible everywhere, and another critical part of this chapter is working with the hand feller.

Having what it takes

Experienced operators were surveyed anonymously on their views around what it takes to be a good operator. They said:

1. A planning mind, always thinking multiple steps ahead.
2. Trusting the machine and your ability
3. Knowing limits of the machine and oneself.
4. Experience and competence, and never complacency.
5. Having patience and being calm under pressure.
6. Always consider the whole job and ways to make it all go smoother.
7. Goal setting and taking pride in your work.

Important messages experienced operators want to pass on

1. Check your gear and trust it – anchor, electronics, rigging and machine!
2. Work within your limits.
3. Plan and have a Plan B. Be adaptive to changing situations.
4. There are places you don't winch-assist. Don't be forced to go there.
5. Stay focussed. Take regular breaks and stop operating if you've lost concentration.
6. Take your time. Don't let production pressure affect your decisions.
7. Ensure you can see the ground, and look up as well as down.
8. Make sure you can always get out of where you've gone.
9. Look how the winch rope(s) lay. That's where they take you back up the slope.
10. Know when to stop and leave the remainder for hand felling, even if it is just a few trees.
11. Always keep things clean for the hand fallers, just in case they need to finish things off.

Things that affect an operator's work

Headspace
mind on task, avoids distractions, rushing, complacency, or fatigue.

Attitude
healthy knowledge and respect for hazards, listens to supervisor, follows plan.

Competency
experience and skills with the machine, and harvest sites.

Planning
time spent pre-planning, thinking about next steps, adapt to change.

Hazard ID
quality maps and felling plans, identifying changing conditions and unforeseen hazards; knows how to manage and when to stop. Knows when to ask for help.

Equipment
know the physical capabilities of each machine and the harvest block.

Supervisor's competency and attitude
understands the plan and how to implement, recognises when adjustments are needed, acts to implement, communicates with the operator; avoids a production-only attitude.

! Delay steep slope work until a suitable machine or operator is available.

Winch-assisted operator's training requirements

Operators for winch-assisted felling are often trained and experienced mechanical felling operators.

The operator, after training, must be able to:

- Demonstrate knowledge, and safe operation of the winch-assisted system.
- Set up a new winch-assist line.
- Conduct daily pre-start and maintenance checks.
- Identify site hazards and describe how associated risks are controlled.
- Describe factors that influence harvester stability.
- Minimise both total loads, as well as shock loading on the cable(s).
- Shutdown/isolate the winch system in an emergency situation.

General mechanised operator training requirements

- The operator must be suitably trained or under supervised training.
- The operator must have competency assessed regularly. The assessment should be organized by the employer, or if self-employed, by the operator. The assessment should be undertaken by a person who sufficiently understands winch-assisted operations.
- All training must be documented.
- Trainee mechanised fallers must receive adequate supervision. The level of supervision is determined by the level of competency demonstrated by the trainee.

Unit standards for winch-assisted felling

The following NZQA unit standards have been specifically developed for winch-assist systems:

Unit Standard #	Description
30583	Establish an anchor for cable-assisted forestry machine
30584	Demonstrate knowledge of cable-assisted forestry machine operation
30585	Operate cable-assisted forestry machine
30586	Manage cable-assisted forestry machine operation

A fully trained operator, depending on the machine type and harvesting method, may hold the following NZQA Unit Standards:

Unit Standard #	Description
1231	Prepare wire ropes for harvesting operations
6935	Operate an excavator based tracked machine in a forestry situation
6941	Demonstrate knowledge of forest mechanised harvesting
6945	Fell trees using a mechanised harvesting machine
6947	Bunch tree lengths for extraction or processing
17771	Carry out line shifts in a cable harvesting operation using a mobile tailhold machine
22994	Demonstrate knowledge of factors that affect the performance of forestry workers
24590	Operate a self-levelling machine in a forestry situation
30587	Shovel and Bunch tree stems or logs

Some operators may not hold some unit standards, e.g. 1231 and 17771 in a groundbase crew. If the operator doesn't have the specialist skills then someone trained or qualified should be available to assist, e.g. rope splicing or line shifts.

Example – Winch-assisted operator training programme

Winch-assist training typically starts will learning skills on mechanised felling machines, and as competency is reached, training is progressed to steeper terrain and finally to winch-assisted harvesting.

Mechanised Faller Classification	Skill Development and Supervision	SBOs Frequency by Contractor
Trainee Operator Less than 6 months experience or 500 hours on the machine. Will be working towards the following qualification: Forest Operations Advanced – Mechanised Tree Felling.	As a minimum the operator will have spent 20 working days (160 hours) felling/shovelling on slopes less than 22 degrees before undertaking further training on slopes exceeding 22 degrees. An Intermediate or experienced operator will supervise and support until competency is achieved.	Training notes shall be kept. These should record date, training and observations. SBOs will occur monthly by a suitably qualified or experienced person. The Contractor or plant supplier will provide reference material such as operator manuals to the trainee.
Intermediate Operator More than 6 months experience and 500-1000 hours on machine.	An experienced operator will supervise and assist. The operator shall be given sufficient time to become familiar with a new machine's controls and capabilities.	Training notes shall be kept. SBOs* will occur monthly for the first 3 months, then quarterly by a suitably qualified or experienced person. The contractor will provide reference material like operator manuals to the trainee.
Experienced Operator > 12 months experience. Holds a Forest Operations Advanced – Mechanised Tree Felling certificate plus the winch-assist unit standards 30583-87, or be in a signed training agreement with a provider to achieve these.	The operator's competency is periodically assessed for by a suitably qualified or experienced person. Indirect supervision is provided to an experienced operator.	The Contractor or plant supplier will provide reference material like operator manuals. SBOs* will initially occur quarterly by a suitably qualified or experienced person until competency achieved. Then 6 monthly.

* Top Spot assessments are equivalent to an SBO.

Operator fatigue plan

Winch-assisted harvesting can be demanding, especially on steep ground and in tough conditions. It is essential to maintain concentration. A fatigue plan helps the operator manage their work health and be 'fit for work'.

It helps if you eat and drink well, have a good night's sleep, exercise, and take work breaks.

Get training on fatigue, so you know what to look for and how to manage it.

Safetree Fatigue Management Guidance

safetree.New Zealand/wp-content/uploads/2016/11/Fatigued_-Or-Fit-for-work_-.pdf

The following may help develop a fatigue management plan:

- Incorporate a minimum 15-minute break every 3 hours or two 30-minute breaks per day. Microbreaks of 5 minutes per hour often work well.
- Limit work to no more than:
  - 13 hours per day, excluding rest breaks, but including travel.
  - 65 hours in 7 days, including travel time.
  - 6 successive days.
- Keep a log of hours worked.

- Look after yourself. Take breaks and stop operating if you've lost concentration.
- Do not operate the machine if fatigued.
- Don't do unsafe work, and don't let production pressure affect your decisions.

Working alone procedure including a no response action plan

Working alone is work done in a location where a worker can't physically see or talk to other workers. This could expose them to additional risk should the work go not as planned especially where assistance from others is not readily available. An example of working alone in steep slope harvesting is an operator pre-falling before the main crew set up at the harvest site.

There must be a documented Working Alone Procedure, including a No Response Action Plan. The procedure must be known and understood by the crew and operationally followed.

A good place to confirm the plan for each day is during the tailgate meeting.

The operator needs to:

- Confirm their point of contact and the contact's location.
- Ensure that their whereabouts are known.
- Communicate their plans.
- Have an RT or cell phone for communication. A registered EPIRB gives an additional option.
- Make minimum hourly check-ins with a contact person.
- If the work plan changes, inform the contact person.

Establish an alternative communication plan where there is poor cell phone reception.

Chapter 3
Winches

In this chapter you will find out:

- ✓ The different winch types and how they work.
- ✓ That traction aid is not winch-assist.
- ✓ Your machine skills could impact winch tensions.

This chapter is about the winch. Not about how they are anchored or repositioned which is discussed in Chapter 5.

What is a winch?

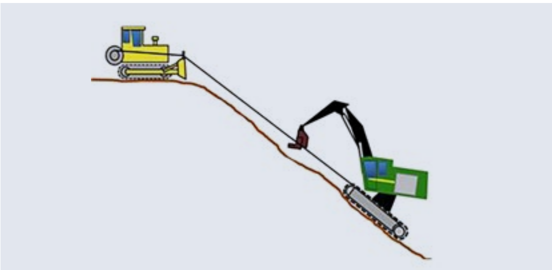
A winch is a powered geared drum that spools the wire rope. Winch systems can have different mechanisms for managing tension and power that aim to provide constant tension. The operator adjusts the winch settings. For example, some have the wire rope tensioned through constant hydraulic pressure or band brakes applied to the drum.

Some drums pivot under load, which acts as a shock absorber within the rigging system.

There are two options for the winch location:

- On the anchor machine.
- On the steep slope harvesting or extraction machine.

Winch Anchor Machines



The winch(es) are mounted and powered by a mobile anchor. The winch anchor machine is typically a modified excavator or a bulldozer. The complexity and cost of fitting a winch to the anchor machine make them purpose-built machines. The harvesting or extraction is done by a second machine working on the slope.

Anchors can range from small units that deliver a pulling power of 5 tonnes up to larger systems more common in New Zealand that deliver pulling of 18-23 tonnes.

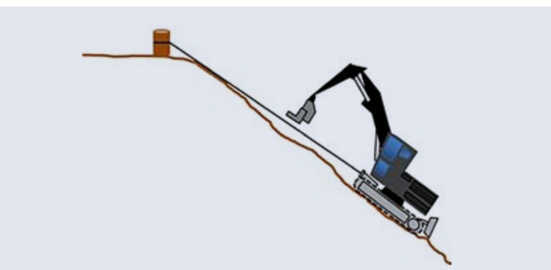
The advantage of the system is the:

- Winch anchor machine is mobile and can assist with a line shift.
- Two machines can easily disconnect so either machine can do other work or work with a different machine, e.g. the steep slope harvesting machine can shift between winch-assist and other operations.
- Winch anchor machine can still operate as a dozer and or a digger.

These are a few examples of commercial models available, top left: Eco-Forst T-WINCH 30.2. Top right: T Max. Below left: Electrical and Machinery Services (EMS) Tractionline and below right: DC Equipment's Falcon winch-assist.

Winch on the steep slope harvesting machine

The second option is the winch mounted on the steep slope harvesting (SSH) machine. They can either be integrated into the chassis or have a winch mounted onto the machine. It is a one-machine winch-assist system when anchored to stumps or deadmen, although it can also be supported by a second anchor machine that does not have the winch on it.



The advantages of the integrated systems:

- It is a one-machine system.
- The rope doesn't move along the ground because the rope is spooled on the SSH machine.
- Flexibility in the anchor type, e.g. a stump, deadman, or mobile anchor.

The only New Zealand made winch integrated SSH machine is the ClimbMax. In Europe, most have the winch mounted on the SSH.


Left: ClimbMax Steep Slope Harvester. Right: HERZOG ALPINE Synchrowinch.

Single and double rope (two-line) systems

Winch-assist can be single or double rope systems. There are advantages and disadvantages in both systems, and the choice comes down to the merits contractors can see for their operations.

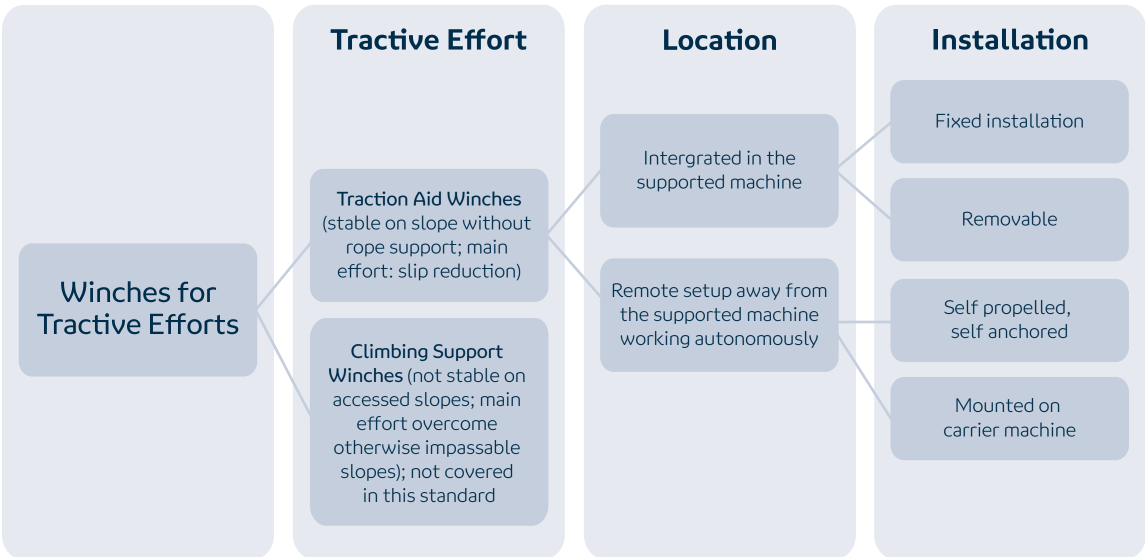

Examples of double rope systems. Left: EMS Tractionline. Right: The Remote Operated Bulldozer ROB.

The difference between 'traction-aid' and 'climbing support winches'

The ISO standard 19472-2:2021(E) Machinery for Forestry; Winches – Part 2: Traction aid winches was published in January 2022. The ISO standard distinguishes traction aid winches and climbing support winches, as seen in the diagram below. Traction aid is where the rope is added to reduce machine slip, but the supported machine is both stable and still able to move on the slope without support from the rope.

This is different from how many operators use winch-assist in New Zealand. Winch-assist is often used to help access terrain that would otherwise be impassable. The term 'climbing support' has been coined by the standards review committee to differentiate between the ISO 19472 traction aid systems that have been designed, manufactured, and employed in the northern hemisphere with those manufactured in New Zealand.

The standard is significant because of the implications around differences in the Safe Working Load (SWL). The ACOP requirement is for a winch-assisted operation's rigging to be tensioned up to at least 1/3rd of the ropes rated breaking strength. The ISO standard allows for wire rope to be operated at a tension up to 1/2 the rope's minimum breaking strength, recognising it is only for traction aid.



Good winch features

The following are good features for winches used in assisted operations.

- A winch specific emergency stop procedure.
- A pre-set maximum line pull that does not exceed the safe working load of the wire rope (33% of breaking limit).
- A winch auto-stop mechanism designed if the anchor machine loses power or when the drums' minimum wire rope length is reached.
- A winch braking system can hold the steep slope harvesting machine if power, traction, or stability are lost.
- Chartered Professional Engineer or manufacturer certified winch attachment points and tow hitches.
- Systems that in 'real time' monitors, records and relays to the steep slope harvesting machine cable tension and winch rope details like rope off and remaining on the drum.
- The manufacturer's service schedule for the winch and its ancillaries' parts.

Winch tension monitoring systems

Cable-assist machines should have a tension monitoring system. Wire rope has a Safe Working Load (SWL), and without a monitor, the tension in the rope cannot be managed. The operator needs to set the tension and view the current tension setting.

Like in cable logging, tension is difficult to measure directly as a load cell cannot easily be put into the rigging system, so monitors indirectly measure tension. Three examples are:

1. Putting a small deflection ('bight') in the rope using three sheaves and measuring the pressure on one of the sheaves.
2. Measuring the hydraulic pressure in the winch drum.
3. Using a sheave in the rigging system, where the rope passes through a known change in direction.

All three require careful calibration to reflect the tension in the rope accurately. Torque varies with the diameter of the winch drum. For example, when using hydraulic drum pressure, 'the effective diameter', or the number of wraps on the drum, must be calibrated correctly.

A three sheave deflection winch tension monitor system.

Many factors affect winch tensions

Winch-assisted operations are complex, and the forces involved are relatively large. The operator sets the desired tension. A good operating practice is to use the lowest possible winch setting required for the job. This creates the least amount of stress and risk in the system.

Increased loading known as shock loading, can be common when using winch-assist.

A frequent cause of shock loading is lag in the system's response time to machine movement. While shock loading cannot be avoided entirely, understanding it helps to avoid overloading. The example winch-assist tension graphs below show some limitations in managing tensions.

1. **Moving the machine causes most 'shocks' and not from felling or shovelling**

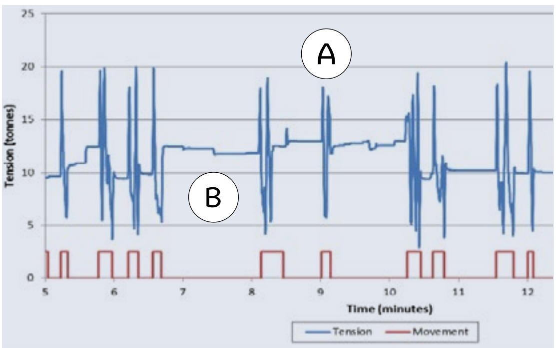


Figure 1

A Spikes are from the machine moving

B Flat sections are the machine felling

Tracked machines, especially when moving downhill, can generate a large pulling force combined with traction and gravity! There is often a small lag between when the machine is pulling the rope, and when the winch can adjust its tension. This shows up on the tension charts as a spike with tensions going both up and down.

Also shown on Figure 1 is when the machine was moving (orange line). This confirms that nearly all sudden spikes are from machine movements, not from the felling or shovelling activity.

2. The tension depends on the operator setting

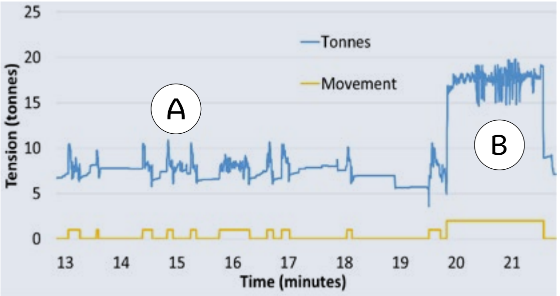


Figure 2

A Machine working downhill

B Machine heading up the slope

Operators can choose from tension settings as low as a few tonnes, all the way up to the safe working load (SWL).

Figure 2 shows the operator choosing a tension of about 6-7 tonnes while working downhill, and then at the 20-minute mark, increasing the setting to 18 tonnes to help the machine go back up the hill. This change in setting is much larger than the smaller shock loads.

Figure 3 chart shows the operator of a two rope system (blue and orange lines) changing their setting from about 4.5 tonnes up to 8 tonnes. For example, this might be required as the slope gets steeper or the soil conditions become wetter. The chart shows that dual-wire systems share the load evenly.

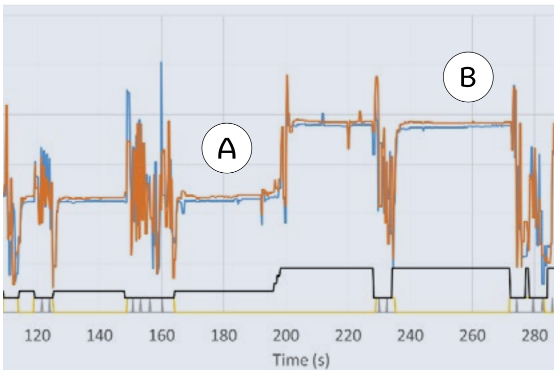
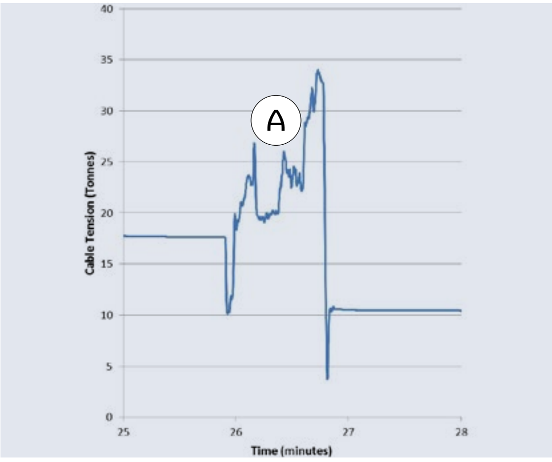


Figure 3

A Initial tension

B Operator increased winch tension

3. Extreme winch tensions do arise from operator errors



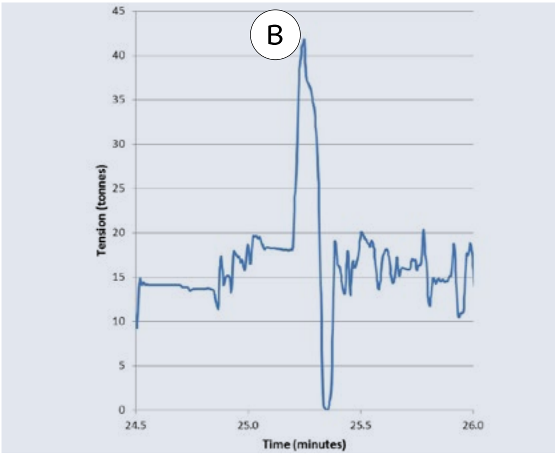


Figure 4 and Figure 5

A Machine 'stuck' behind an obstacle

B Operator had brake on and drove down the hill

Figures 4 and 5 show that operator decisions can potentially lead to serious risk. Left: The steep slope harvesting machine was stuck behind an obstacle, so the operator put the tension up to its highest setting then used the boom to generate an extra force to solve the problem. The graph spiked to 34 tonne, which is well over the SWL.

Right: The operator still had the system on a manual feed setting and began to move the machine downhill. When the winch is either off or in a manual setting, the winch won't adjust to an increase (or decrease) in rope tension. The graph shows over 40 tonnes on the rope when both gravity and the steep slope harvesting machine's traction were pulling on the winch.

4. Redirects (rub trees or stumps)

Redirects add friction and result in the rope tension being different above and below the redirect. For example, if a winch applies a rope tension, the pulling power of the rope reduces after going around the redirect. See the section 'How redirects change rope tension' on page 61.

Shock loading results in higher tensions than the operator setting.

Guidelines when working with winches

- Record winch operating hours for operational machinery and rigging. servicing and replacement schedules.
- Before operating, make sure all safety systems are operating.
- Don't override safety controls.
- Use a constant tension system. Never allow slack to develop in the line.
- Use a mechanism or system to prevent accidental operation of the assisted machine when the winch is in manual mode.

Chapter 4

Steep slope harvesting machines

In this chapter you will find out:

- ✓ What is a steep slope harvesting machine and their features.
- ✓ What affects traction, and how a cable improves it.
- ✓ Things that affect stability.
- ✓ Ways to help reduce machine rollover.

What are steep slope harvesting machines?

Steep slope harvesting (SSH) machines are purpose-built for working on steep slopes. In New Zealand, the most common winch-assisted SSH machine is the excavator-based feller-buncher that has replaced manual felling in many situations. However, SSH machines can be skidders, forwarders, excavators, and specialised tracked or wheeled harvesting machines. This leads to many makes and models. SHH can have a chassis built on tracks or wheels. The cab can often level. The power unit may be part of the cab /upper structure or on the chassis.

Felling and processing SSH machines are either wheeled harvesters or a tracked harvester/feller-director/feller-bunchers. They have either levelling or non-levelling bases. Levelling machines are more comfortable than non-levelling, especially when slewing during felling or shovelling.

Log or tree extraction SSH machines typically are levelling, or non-levelling tracked excavator forwarders, wheeled forwarders, clam bunk skidders, or four or 6-wheeled rubber-tyred grapple skidders.

Excavator base vs wheeled machines

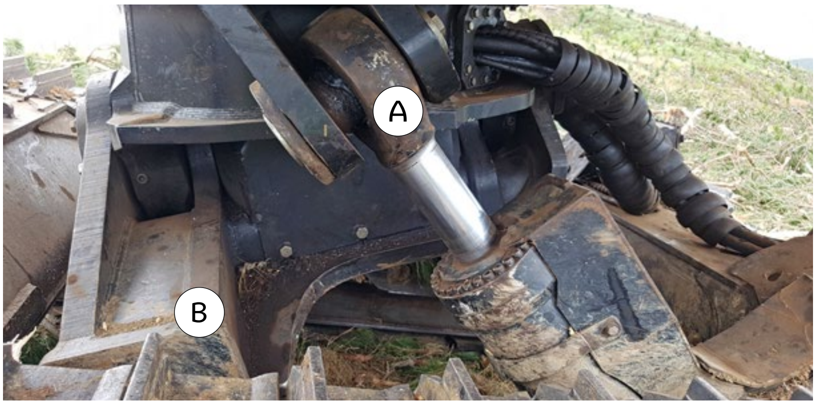
In New Zealand, excavator-based machines are commonly used for felling and shoveling as they typically have more power, move larger trees, and have more traction in steeper terrain or poorer soils. However, their rigid base reduces the tracks contact on uneven terrain, such as when shallow rock is present. In these situations, sudden loss of traction and stability can occur.

Wheels are better on undulating terrain. A major advantage is getting over obstacles like stumps that excavator-based machines struggle with. Wheeled machines tend to have significantly better vision than excavators because the boom is set high.

Levelling vs non-levelling cabs

A levelling cab is essential for winch-assisted operations on very steep slopes. A leveling cab redistributes the centre of gravity uphill to improve stability, especially on slopes over 33 degrees (65 percent). It has been shown that they reduce rollover risk.

Studies have also shown that productivity and operability is enhanced when using a levelling cab.

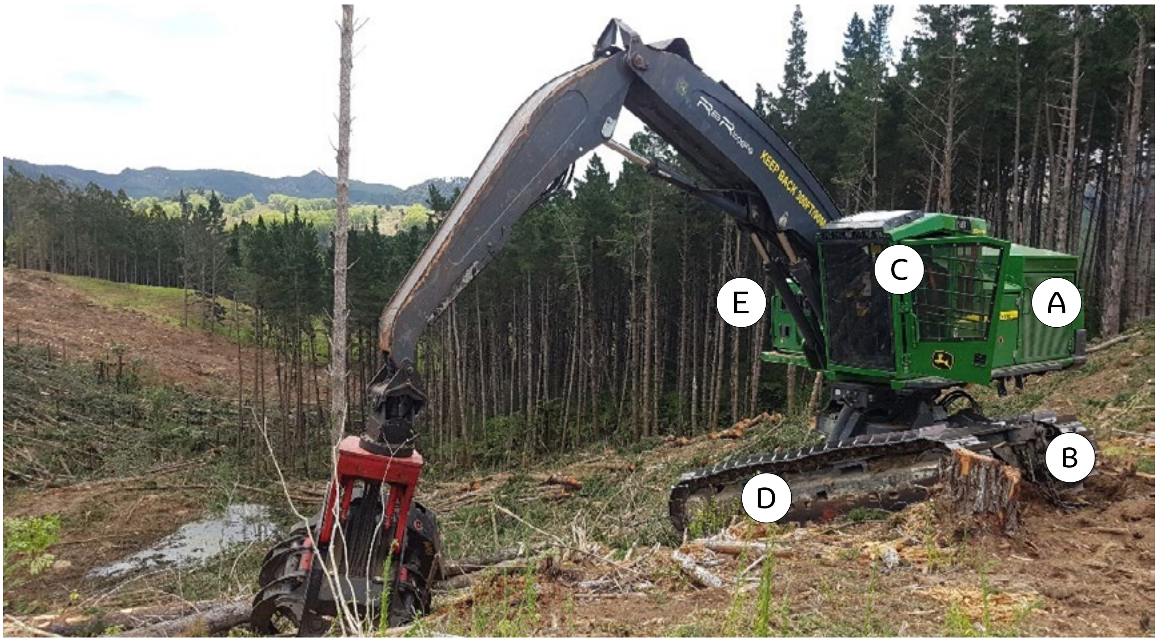


Hydraulic rams A and a pivot B levels the cab.

Machine features to safely and effectively work on steep slopes

Steep slope harvesting machines are purpose built for their work environment.

General operation



A Engine designed to work on the maximum slope limit

B Cable attachment points engineered for the expected loads

C Minimum 2 (preferably 3) emergency exits with two accessible from the outside

D Adequate traction and slew power for steep slopes

E Fluid systems designed to operate on steep slopes

Also:

- Emergency back-up system to ensure stability should the winch, wire rope, or anchor fail.
- Designed and tested to operate continuously for steep winch-assist.

Cabin

A Fully integrated/ automatic fire suppression system

B Minimum four-point seat belt harness (lap 75mm + shoulder 50mm)

C Comms system

D Fire extinguisher

Also:

- Noise levels less than of 85 dBA otherwise hearing protection.
- Aircon (15-25^{oc}).
- A place to secure all water and food containers.
- No loose or dangerous material inthe cab.

Upper structure – external

A Compliant forestry cab with ROPS, FOPS, and OPS

B 19mm polycarbonate or equivalent front window

Also:

- Over-riding and functional braking system in the event of loss of machine power.
- Guarding that protects the steep slope harvesting machine's mechanical operation.
- Company safety/emergency stickers.

Undercarriage

Extended (>50mm) single grouser track shoes for tracked machines and chains or bands for rubber tyred machines.

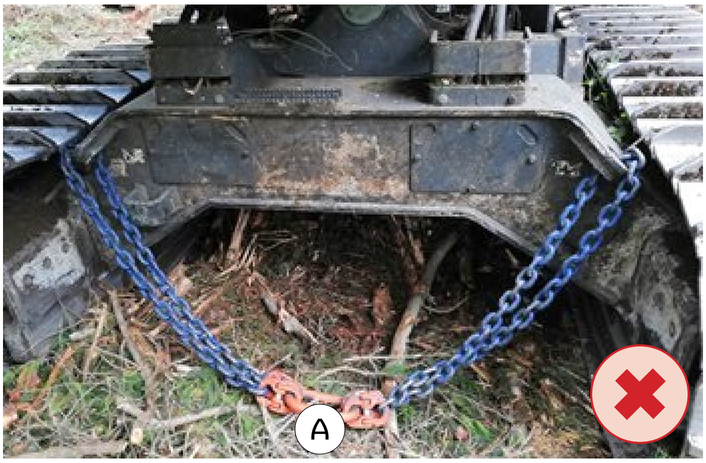
Machine attachment points

A low frame-mounted attachment point is usually best. Do not sling around the lower structure.

Sharp edges can damage the rope or chain and the machine structure could also be damaged.

Cable attachment points engineered for the expected loads.

A certified heavy duty towing hitch.



A Risk of extreme side loading of chain link

Electronic systems

The following are recommended:

- A winch monitor, with audible alarms, showing the hydraulic temperature or over-temperature light, cable tension and overloads, remaining available rope length, and when the minimum number of cable wraps is reached, rope length in use and spooling errors.
- Hour meter that tallies the number of hours the winch and cable operated to monitor cable use and life.

Remote control systems that incorporate safety redundancies.

Prevent accidental operation of the Steep Slope Harvesting machine when the winch is in manual mode.

Inclinometers can have digital readouts or mechanical.

Camera display of obstructed view areas for the operator including winch.

Take care of aerial and electronics, they can be damaged.

Chapter 5

The anchor and repositioning

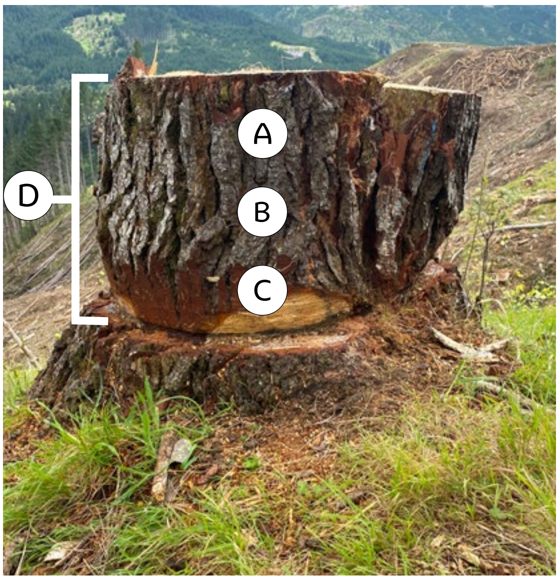
In this chapter you will find out:

- ✓ Different sorts of anchoring systems.
- ✓ Why anchors fail and how to stop this from happening.

Types of anchors

Stumps

Stumps have been very commonly used in cable logging operations and are an option for integrated winch-assisted SSH machines. Refer to section 14.3 of the ACOP. Regularly inspect stumps because they can work loose under shock loading. Stump monitors give the operator with an alarm signal should the stump start to move. There needs more research on stump anchoring for SSH machines as stump requirements have come from cable logging operations. For example, the need for notching stumps with synthetic strops for SSH application.



A Minimum stump diameter of 500mm
B Only use fresh stumps in strong soils
C All stumps must be notched
D 30cm of solid wood above the notch

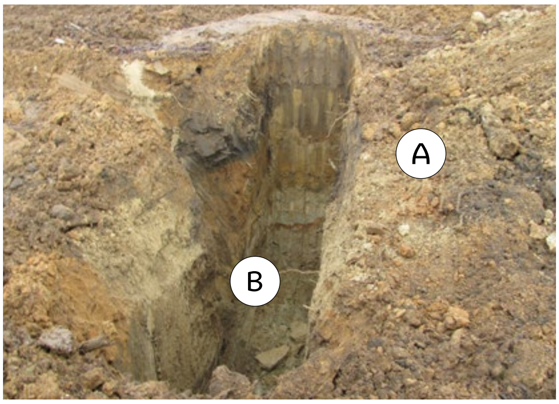
Also:

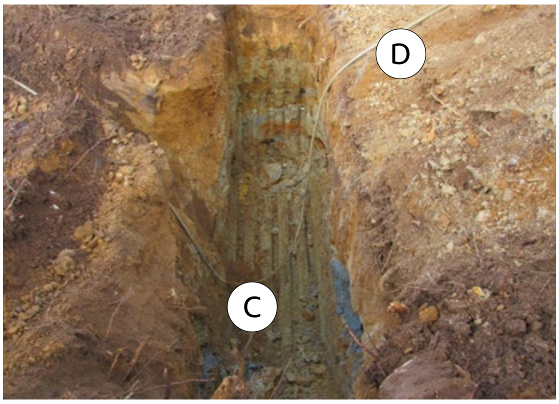
- A stump monitor alarm should be fitted.

Shock loading stumps can loosen or pull them out.

Deadmen

Deadmen, like stumps, can also be used to anchor integrated winch-assisted machines. Deadmen are typically strong if installed in accordance with section 14.3.5 of the ACOP.



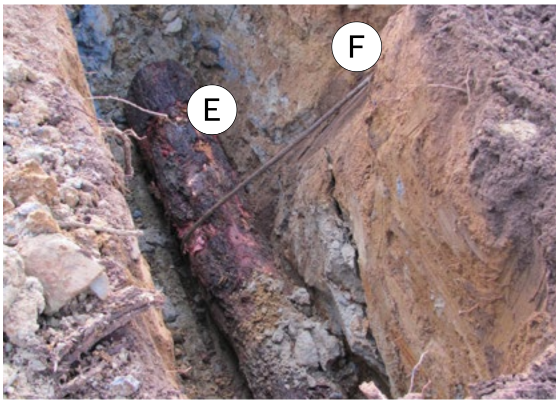


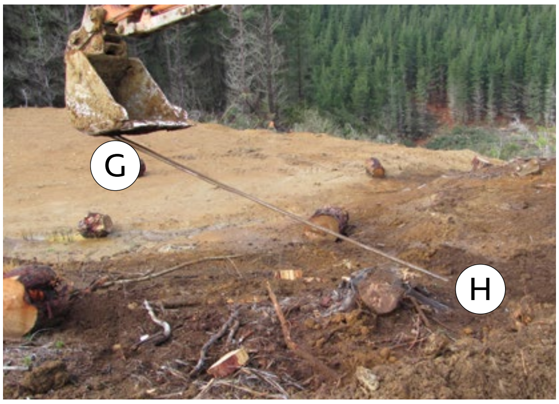
A Dig the trench at right angles to the pull

B Make at least 4 m deep and about 7 m long

C Lay a strop in the trench

D The strength rating of the deadmen strop should be at least equal to the winch rope





E Use green logs at least 50 cm in diameter

F The notch stops the log being pulled straight up

G The two strop ends must be equal before shackling

H Compact as you backfill

Rocky soil and fill can cause strops to wear and fail.
Always use suitable fill and periodically check strops.

Anchor machines

These are either bulldozers, excavators, or purpose-built winch anchors. Machine anchors are popular because they are mobile. This means the steep slope harvesting machine can quickly shift between winch-assist and other operations without modification.

The most common anchor in New Zealand is an excavator. The winch(es) are mounted at the machine's rear, with the wire rope(s) coming up over the top of the boom.

The two largest excavator-based winch-assist manufacturers, DC Equipment and EMS, have an additional sheave mounted on the boom just above the bucket to bring the rope close to the ground and significantly reduce any lateral instability issues. The bucket is dug into the ground to provide the extra holding strength required to make it a safe anchor. A significant advantage is that they can lift the rope for a line shift.

Bulldozer anchors have a sturdy base and low centre of gravity. The blade must be pushed into the ground to provide the extra strength as a solid anchor. If positioned correctly, the bulldozer blade will move deeper into the ground if pulled forward, so the holding strength increases with minor movement.

Left: the single winch DC Equipment's Falcon winch assist. Right: The twin drum EMS Tractionline. Below left: the Remote Operated Bulldozer (ROB). Below right: Eco-Forst T-WINCH 10.2.

Why anchors fail

The following things can make anchors fail:

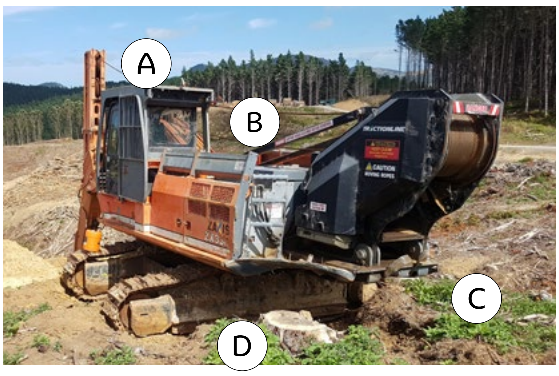
- Poor anchor positioning, including an anchor machine not on level ground and blade or bucket not dug in correctly.
- Weak soil strength.
- Overloading the anchor.
  - Anchors aren't strong enough.
  - SSH machine pulling from a too wide lead angle.
  - Shock loading from the steep slope harvesting machine.

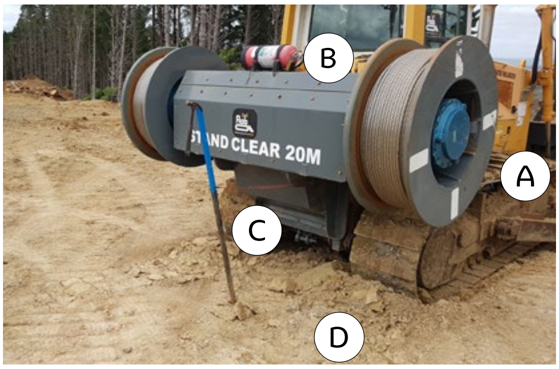
If the soil is weak, there are three common ways to strengthen the anchor:

- Put the blade into the ground behind a stump. The holding strength of the stump will improve anchoring. Not too close behind the stum. Otherwise, the root system could get cut, and this gives the stump its strength.
- Tie off to a stump behind the machine.
- If an excavator, reposition the bucket deeper or in a different location.

Most anchoring failures are a combination of factors – poor machine positioning or cable angles, and high loading.

Guidance for safe machine anchoring





A Install a tension monitor that relays to the steep slope harvesting machine operator

B Use camera(s) to show steep slope harvesting machine operator cable spooling

C Use an anchor movement alarm

D Position safe and securely, eg. avoid soft road or landing edges

Do not exceed the anchoring capacity of the anchor machine. Improve by anchoring back to stumps as well.

Don't move the anchor and steep slope harvesting machine at the same time. One machine needs to be stationary and stable during line shifts.

This bucket and blade should have been in deeper.

Additional guidance for excavator anchors

- **A** Dig bucket into firm soil so it won't pull out
- **B** Bucket can be normal way or reversed
- **C** Lead angle within manufacturers limits
- **D** Low cable exit points to prevent overturning
- **E** Boom and stick angle between 90-110 degrees

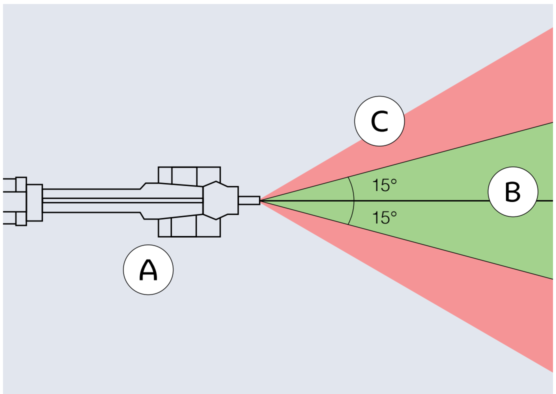
! Machine anchors do move. Put the blade or bucket behind a stump. Check the anchor is holding each set up. Do a straight pull test.

Repositioning the anchor

The anchor often needs repositioning to help keep it in line with the steep slope harvesting machine as the block progressively gets felled.

Anchor lead angle

The lead angle is typically the angle from the anchor's fairlead to the steep slope harvesting machine.



A Reposition the anchor or use rub trees to maintain correct lead angle

B Maximise in-line pull. Minimise the amount of side pull

C Follow any manufacturer's specifications about the horizontal and vertical lead angle

Guidance on the lead angle for an excavator

There's no one answer. It depends on the site and the current conditions, the machine, and how the machine is anchored. Follow the manufacturer's specifications on the horizontal and vertical lead angle of the cable exiting the fairlead.

Lead angle	Soil type	Comment
Up to 15 degrees	Loose or uncompacted fill	Maintaining bucket stability is a limiting issue.
Up to 30 degrees	Good	Keep to this limit when operating for longer periods as the soil may loosen over time. Also, for steep slopes when higher shock loading might be expected.
Up to 40 degrees	Good	The anchoring hole is deep enough (approx. 1.25m), the soil is strong, and the machine is designed for the forces.
Up to 90 degrees	Very strong	Increasing sideways forces could generate forces large enough for failure on the bucket/boom/ sheave unless manufacturers have modified their equipment design to accommodate such large angles.

Chapter 6
Rigging

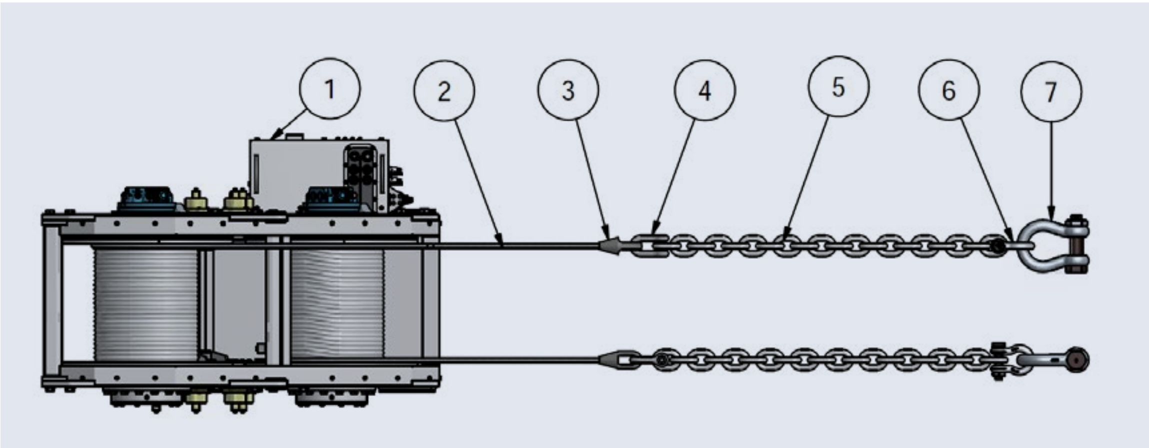
In this chapter you will find out:

- ✓ About wire rope and the different connectors' strength.
- ✓ Why bending a rope can severely damage it.
- ✓ What rigging guidance needs to be followed.

Rigging connects the anchor to the steep slope harvesting machine. This chapter describes the different parts of the system.

Parts of a rigging system

A rigging system has several main parts. These are the winch, wire rope, chain, connectors, and shackles. There are many different options, and some of these are shown. Rigging is only as strong as its weakest link, so all components need matching with their strength characteristics.



1= winch, 2= rope, 3= rollover shackle, 4= hammerlock, 5= chain, 6= chain shackle, 7= steep slope harvesting machine shackle.

Rigging is only as strong as its weakest component.

Wire Rope

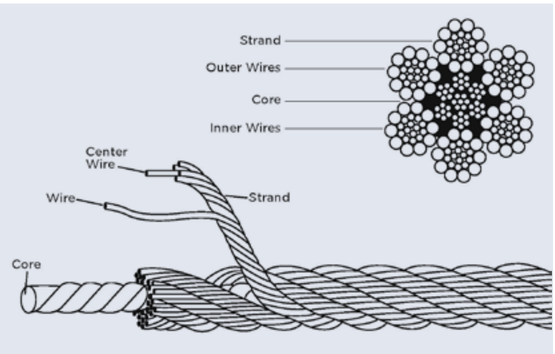
This section describes the basics around wire rope and guidance around its use. Chapter 11 covers wire rope inspections and maintenance.

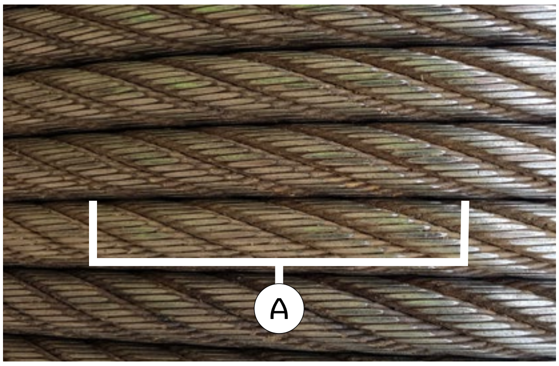
Nearly all 'wire rope failure' incidents are caused by failed end connectors, failure due to poor practice like overbending the rope, or equipment design problems.

Parts of a wire rope

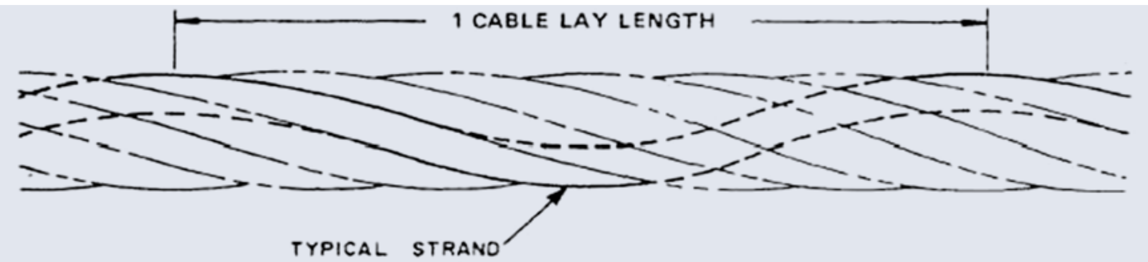
A rope consists of individual wires twisted into strands. These preformed strands are then twisted around the core to complete the rope.

The core supports and maintains the shape of the rope. The rope's cable 'lay length' is one full twist of the rope which is about 15cm for a 1 inch or 1 1/8th inch rope.





A One cable lay length



Different ropes, different properties

Ropes behave differently depending on construction. The combination of the above factors creates ropes with varying properties. There are four fundamental properties to differentiate rope: strength, abrasion resistance, crushing resistance and fatigue resistance.

- Strength increases through larger diameter ropes or swaging.
- Abrasion resistance, or the outer wires' ability to resist wearing away and deformation, increases by fewer or larger outer wires, Lang lay construction and higher carbon content in the metal.

- Crushing resistance, or the ability of the rope to resist deformation, is improved with a strand or IWRC core, swaging, and higher carbon content in metal.
- Fatigue resistance, or the rope's ability to resist bending and twisting, is increased by more wires, smaller wires, fibre cores, and Lang lay construction.

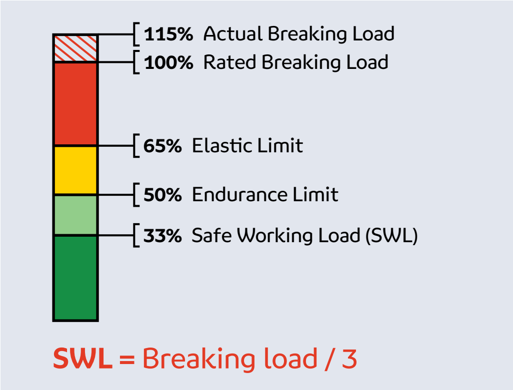
Use the manufacturer's specified rope.

Wire rope strength and the safe working limit

A rope's strength will depend on its properties and type. All ropes have a breaking strength rating.

The ACOP provides the following guidance:

- The SWL to have a factor of safety of three – so the SWL is one third of the rope's breaking strength.
- Operations not to exceed the SWL.



Definitions

Safe Working Load: Refers to the maximum weight a wire rope can handle without the rope incurring damage. It is currently 33% of the rated breaking load.

Endurance Limit: Occurs at 50% of the wire rope's minimum breaking strength. When a rope is strained repeatedly past this limit, it reduces lifespan, and failure may occur even if the tension does not reach the elastic limit or breaking strength.

Elastic Limit: The load limit at which the wire rope will, when the load is removed, return to its original length without incurring damage. It is defined as 60 to 65% of the minimum breaking strength. If a strain is applied beyond this limit, the wire rope is damaged immediately, e.g. if the SSH moves without the WAM engaged. For a larger shock load that exceeds the elastic limit, cease operations and replace the rope.

Wire rope and bending fatigue

Bending occurs when it goes around something including block sheaves, redirect stumps and logs. Bending can significantly increase the stress on the rope because the many wires that make up the rope are forced to stretch at different rates when going around the bend.

This happens because of the difference in diameter between the inside and the outside of a rope. Bending wear on blocks increases exponentially as the ratio of the sheave diameter to rope diameter decreases.

Follow manufacturers' directions, or if unavailable, a minimum sheave to rope ratio of 16 :1 is recommended.

Bending also increases the tension in the rope due to the rope tension plus the force created by the bending.

For cable logging applications, a block diameter of 20 times the diameter of the rope is often recommended to keep the additional stress to about 10%. Such a stress loading needs to be included in the factor of safety.

Shock loading, redirects, and bending can all increase rope tension beyond the SWL.

Sheave/Rope Diameter Ratio	Tension in outer wires of rope
10 times	+27%
12 times	+21%
14 times	+17%
16 times	+14%
18 times	+12%
20 times	+10%
24 times	+8%
30 times	+5%

Small diameter ratios create an unacceptable increase in stress

Acceptable diameter (account for in the SWL)

Bending creates an uneven stretching of the rope. The tighter the bend, the more rope damage.

Wire rope and ground contact

Ideally, wire rope should not have ground contact. However, initial rope testing research showed that external wear from ground contact does not significantly affect winch-assist rope due to winch-assist ropes moving at relatively low speed. The rope is also on top of the ground with no sharp angles.

However, depending on anchor placement and system type, the winch-assist rope is dragged often through the edge of landings and roads. This is because the anchor machine needs to sit back far enough so the steep slope harvesting machine can be lowered off the slope, and the road and landing edges often lack anchoring strength because they are in fill.

Also, this creates an erosion and sedimentation problem if the site is not remediated.

Pulling a rope through the ground runs the risk of it bending sharply around a hidden rock (or similar), or that grit/clay works its way into the rope, decreasing its useable life.

A Ropes are carving through bund and landing fill

B Rub logs help keep the rope above dirt

Guidance for wire rope

- Visually check all connections daily.
- If a sheave is used, make sure they have a minimum of 16:1D/d ratio.
- Joining splices should not be used to repair broken or damaged winch ropes.
- Use blocks where possible. Avoid running wire over sharp bends or redirect stumps or trees.
- Avoid cable drag over abrasive surfaces like rock and through the soil.
- Minimise shock loading. Shock loading rope and rigging reduce its life.
- Wire ropes used for winch-assist should not be used for log extraction or hauling.
- Review tension log data daily and whenever shock loading is known or suspected. Stop operations and inspect the wire rope for damage.

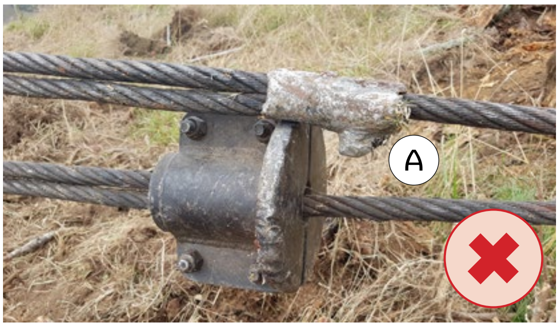
Beware of shock loading or dragging a cable over rock.

Connectors

Connectors are used to join the wire rope to the anchor and the steep slope harvesting machine.

There are various types and most have advantages and disadvantages. There is no 'best' connector.

Common end connection options



Left: The stopper should be to the right of the second or slave ferrule to stop it from being forced into the block. A challenge with pressed ferrules is that the soft ferrule metal wears easily if dragged along the ground.

A Ensure that cable connections do not contact sheaves

Always grommet or bolt shackle ends.

Logger's eye splice

The logger's eye splice is the most common end connector in winch-assisted harvesting operations due to quick splicing time and its popularity in cable harvesting operations. It also pulls easily through the block and is easy to inspect.

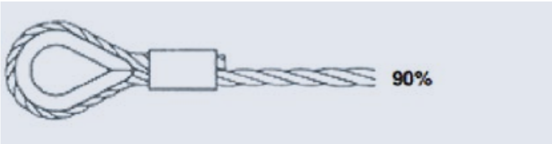
However, the spliced eye is not the strongest connector (~80% efficiency). Using a thimble adds strength and prevents eye deformation (up to 90% efficiency). Balancing strands is not as critical as thought. Eye splices failed at the last tuck at similar tensions, whether balanced or not.

Logger's eye with rollover shackle and hammerlock link.

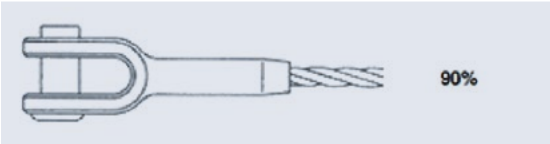
Tuck loggers eye splice three times on one side and two on the other (ACOP).

Ensure no eye-to-eye splices.

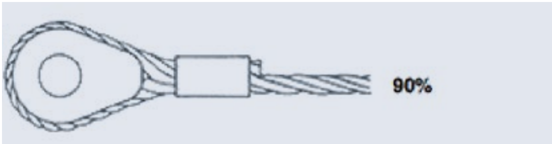
Different connector's strength compared to the wire rope



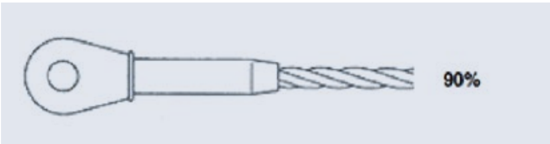
DIN 3093 Aluminum Splice with HD Thimble



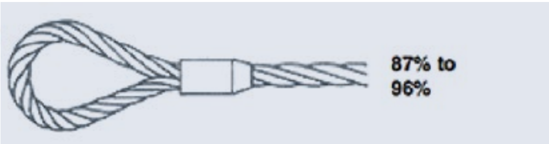
Open Swaged Socket



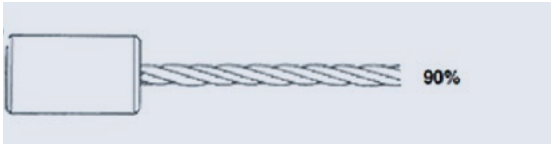
DIN 3093 Aluminum Splice with Solid Thimble



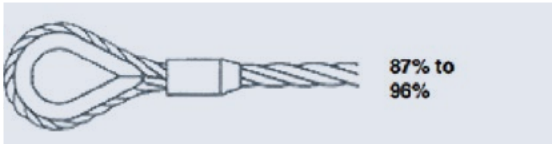
Closed Swaged Socket



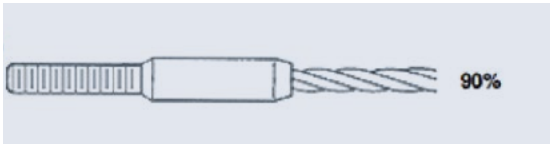
Flemish Eye with steel sleeve



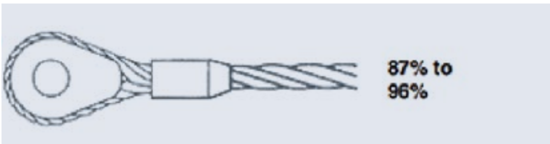
UNI-LOC™ Button



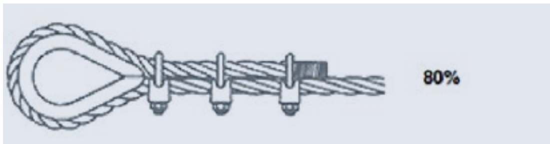
Flemish Eye with steel sleeve and HD Thimble



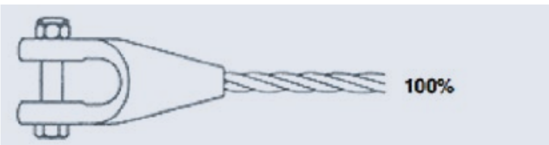
UNI-LOC™ Threaded Stud



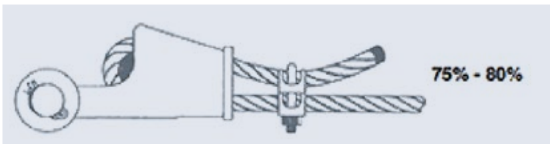
Flemish Eye with steel sleeve and Solid Thimble



Forged Wire Rope Clips



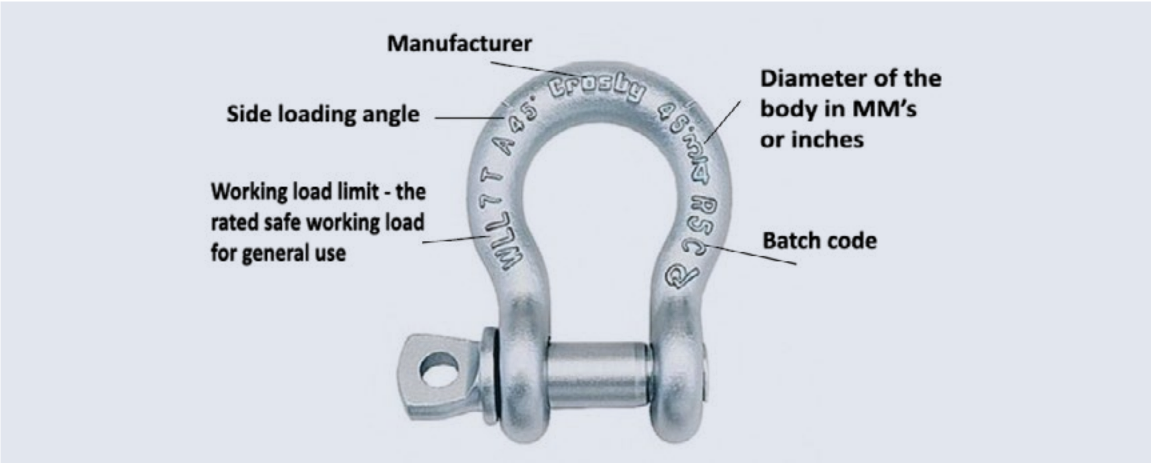
Open Spelter Socket (Closed not shown)



Wedge Socket

Shackles

Shackles need to be rated to match the SWL requirements for the rope. The safe working load, the Working Load Limit (WLL) is marked on the shackle.



Use shackle with visible WLL markings.

Guidance for connectors

- Check end connectors daily.
- Use a rigging register. Maintain a schedule and document inspections, maintenance, replacements and incidents. The register must list each component's rated breaking limit, the SWL and the safety factor.
- Every connector's rating must match or exceed the wire rope safe working load.
- All rope eyes must be married and spliced with a minimum of three tucks per strand.
- An approved wire rope company must form swaged eyes.
- Anchor strop strength must be equal or greater than that of the winch rope.
- Ensure that cable connections do not contact sheaves. Use a second pressed metal ferrule where the ferrule could run into blocks or sheaves.
- Use a heavy-duty chain segment to prevent or reduce wire rope wear close to the steep slope harvesting machine.
- Replace rigging as per the manufacturer's requirements.
- Prevent shock loading to the wire rope and other system components.

Chapter 7

Common operational situations

In this chapter you will find out how to:

- ✓ Use redirects (rub trees or stumps).
- ✓ Manage the boundary between winch-assist and hand falling.
- ✓ Anchor winch excavators on a narrow ridge.
- ✓ Use uphill winch-assisted systems.

Redirects (rub trees or stumps)

It is best to stay in lead by moving the anchor machine. Sometimes this is not possible, e.g. in broken country with side ridges. Most operators use redirects.

They are also commonly referred to as rub trees or stumps or 'side-washing' in North America. Redirects help maintain the felling machine directly up and down the face. Some manufacturer guidelines specifically allow for it but give restrictions.

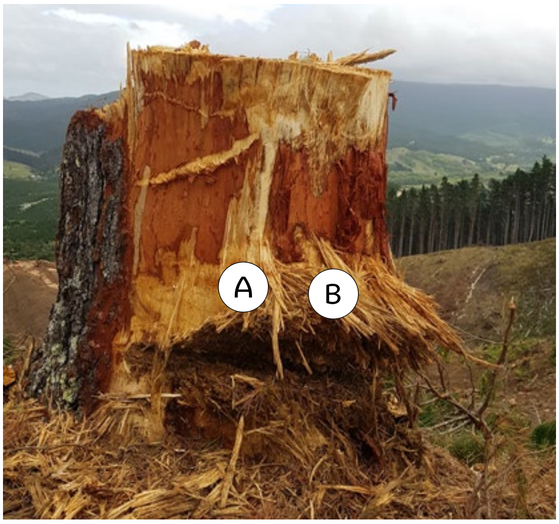
A Redirect stumps and trees

B High redirects are more likely to cause falling or leaning trees

Redirects help:

- Maintain a proper lead angle.
- Enable the steep slope harvesting machine (SSH) to cover more ground each machine anchor shift as multiple corridors are worked without moving the machine back to the anchor.
- Control where and how the SSH descends and ascends a slope, e.g. when there's broken ground.

Hazards created by redirects



A Redirects can cause the rope to cut / bind

B Redirects can create high temperatures from friction

Also, redirects can:

- Move or fail, causing a wire rope shock load, or steep slope harvesting machine instability.
- Binding can lead to rope tension being different above and below the stump, causing inaccurate tension readings.
- Increase hazard zones, e.g. rub trees.

How redirects change rope tension

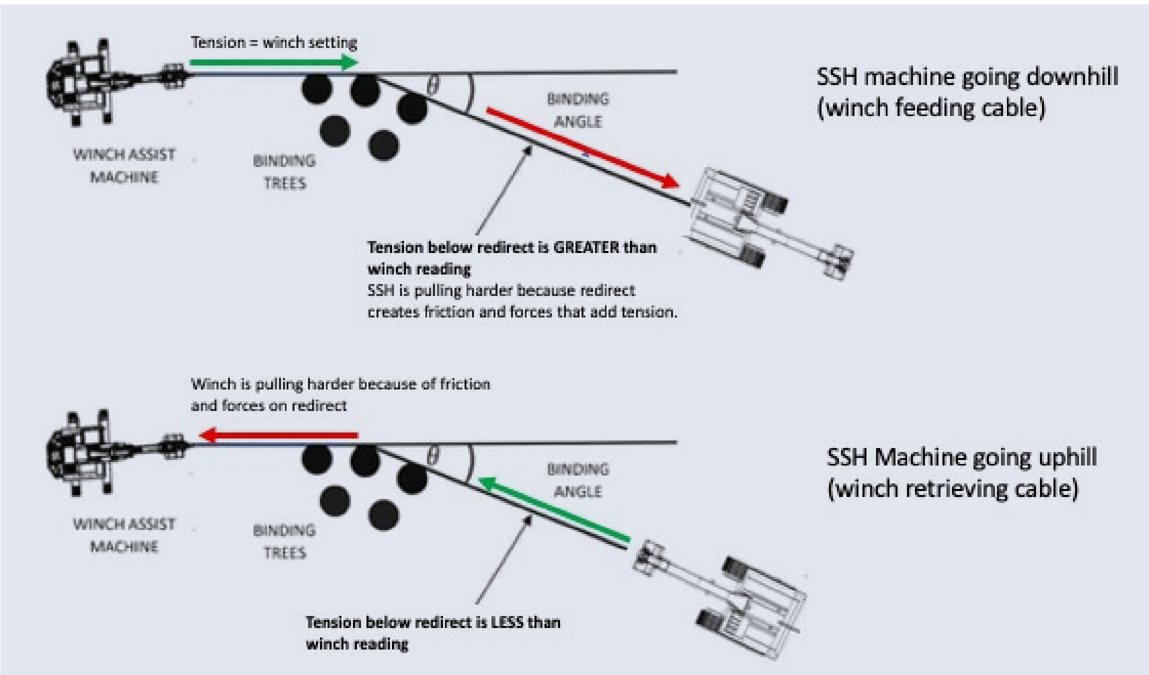
Redirects add friction and result in the rope tension being different above and below the redirect. For example, if a winch applies a rope tension, the pulling power of the rope reduces after going around a redirect. The greater the redirect angle, the less tension goes to the SSH when being pulled uphill.

The stump's friction takes 25% of the rope's tension under load. However, if the SSH is moving downhill, the machine has to drag the rope around the stump that is restricting its free movement. This means more tension is below the stump than above it at the winch anchor machine. This is because the winch can still spool off rope unrestricted. Don't use higher tension settings when moving downhill and using a redirect.

In the table below, if the winch is set at 20 tonnes and there is a 30-degree redirect, the actual tension on the cable below the setup could be 25 tonne so operating above the ropes safe working load.

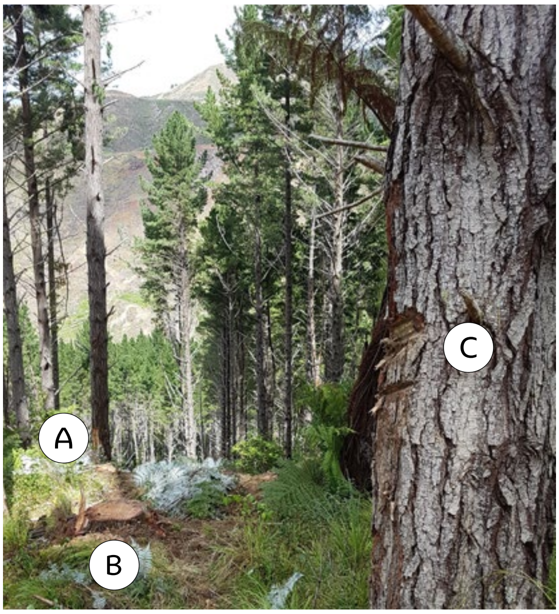
BINDING ANGLE (DEGREES Θ)	TENSION (TONNES) When machine is tracking downhill				
	5	10	15	20	TENSION MONITOR READOUT
10	5.4	10.8	16.1	21.5	ACTUAL TENSION VALUES
20	5.8	11.6	17.4	23.1	
30	6.2	12.4	18.7	24.9	

The table gives indicative tensions only. Other factors can affect tension too.



Working in steep broken country that requires redirects

Working in steep broken country is challenging even for skilled operators. An example would be a steep face with lots of narrow gullies. The steepness makes the SSH machine have less traction, and the narrow gullies need redirects, so the machine is going up and down them, not sidling. Position the rope carefully to avoid unintentional redirects.



- A Use a redirect on the left side of the ridge if going right, otherwise there will not be enough room for the machine to pull up and over the ridge coming back up.
- B Re-cut stumps low on narrow ridges.
- C On ridges with flat sections, use redirect trees, otherwise the ropes will ride off the stumps. Two tree lengths apply for standing trees.

Stump failure increases the risk of rollover if redirecting across a steep side ridge.

Watch where your rope(s) run and what they run over. Wherever the rope runs that's where they will take you back up!

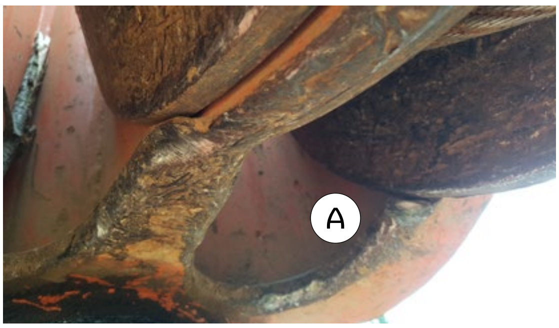
Moving up, then getting the rope over a redirect no longer needed

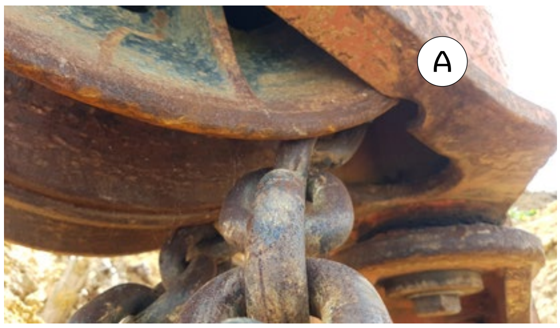
Coming back up the winch rope in steep and broken country creates additional challenges. Redirected ropes need lifting over stumps. In easy country, this is straightforward. The machine moves around them or lifts the rigging over them.

In steeper country, this can be much harder. Carefully plan where your redirects are placed. For example, use a redirect on the left side of the ridge if you're heading right. Otherwise, there is not enough room for the machine to pull up and over the ridge coming back up. If the stump is too close to the ridgetop, it becomes difficult to get up and around it safely.

On steep country rigging is usually lifted over stumps with the attachment. Weight needs taking off the winch rope. Be aware that redirect binding creates tension in the rigging. Spooling off rope can create significant hazards at the winch anchor like misfeeding and ropes riding off sheaves. Ropes get cut this way.

After spooling off a little slack, use the head to create slack at the rigging. Then lift over the redirect stump.





A Don't spool off too much. Slack can cause the wire not to feed correctly onto the fairlead sheave(s) as seen on two different machines. This can cut the rope.

Take care when shifting off redirects.

Binding from redirects significantly reduces anchor winches pulling power.

Ensure you can climb back on top of the ridge by using a redirect stump, and not left hanging off to the side. In difficult country, ensure you can get out of where you went down.

Redirecting using blocks

Blocks reduce:

- Friction and don't create the changes in tension like stumps or rub trees.
- Rope wear.
- Permanent rope damage like twisting which may affect rope life and spooling onto the drum.

Blocks can be challenging to manage, especially on twin rope winches where there is a need for double blocks. Also, multiple stump redirects are difficult, as is re-shifting winch ropes when moving back up the rope.

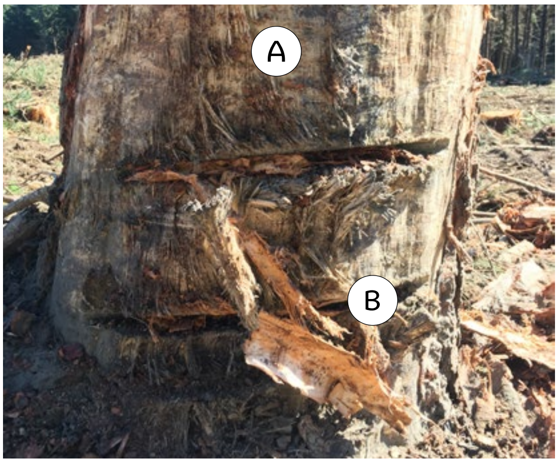
If the block is attached to a looped chain, then the SSH can carry it and put over a stump. It can then also be lifted back over the stump when the SSH returns uphill.

Use blocks rated for the expected load and forces, e.g. uphill winch-assist systems.

Ensure block redirects are correctly installed.

Use a block with an attached looped chain for redirects

Guidance for redirecting

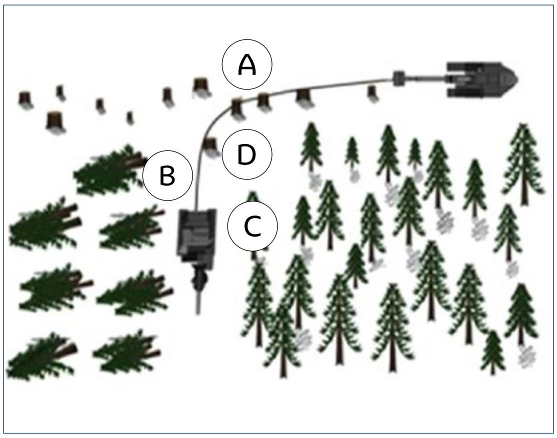


A Use stumps that are large and strong so they won't move and create rope bending fatigue.

B Position the rope low.

Also:

- Avoid redirects during high fire hazard.
- Consider using blocks with redirect trees.
- Check a redirect stump frequently, to confirm its stability.



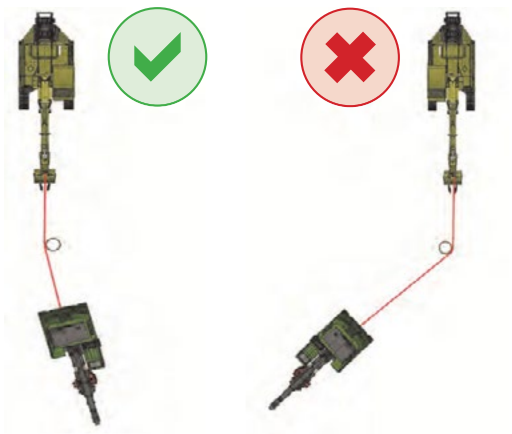
A Use multiple stumps or stems. A single stump failure could result in shock-loading. Even though multiple redirects will cause rope wear and reduce anchor winch power, it is safer than a single stump.

B Position the winch rope to avoid unintentional redirects.

C Avoid using trees. They can be more unstable than stumps.

D Keep the redirect angle as wide as possible.

! Minimise using standing trees for redirects.



Avoid angles over 45 degrees. Stumps can pull out or cut through.

Managing the boundary between mechanised and hand felling

In steeper and more challenging broken country, mechanised felling may not be safe or possible. This could include inaccessible anchor locations or areas below bluffs, rock or terrain that mechanised machines cannot go on, or slopes exceeding 45 degrees. This is considered the absolute upper limit for any winch-assist operation. The felling plan needs to identify hand felling areas. It isn't always clear, especially if the boundaries aren't obvious ones.

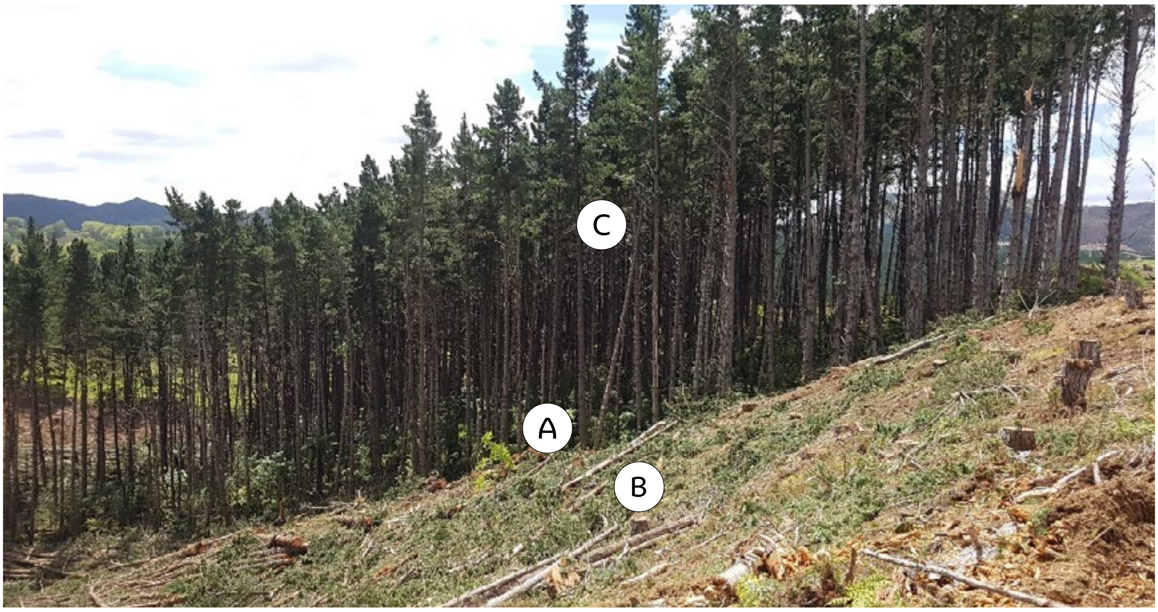
Ideally, the hand fallers fell before the winch-assisted operation starts in the setting. However, often it isn't until the winch-assisted machine is on the slope that the operator can work out the hand felling boundary, leaving the hand felling until later. Otherwise, if hand felling occurred first, the winch-assist operator may not harvest all the remaining trees.

Guidance for managing the boundary where hand felling follows mechanised

Managing the boundary between mechanical and hand felling is essential.

- Communicate the harvest plan with the hand fallers and involve them in the planning processes.
- Map out the area to be hand felled.
- Have the hand fallers work first if possible.
- Minimise 'unnatural hazards' if the hand fallers come in last. These are hazards that have been made by the winch-assisted machine that would otherwise not be there.

Always make boundaries as safe as possible for the hand fallers.



A Keep hand fallers escape routes open on the boundary

B Fall away from the boundary. No branches or tops in the hand falling area

C Leave a clean boundary canopy, with minimal broken branches. These are hard to see because they are still green

Also:
- Redirect (rub) trees must be felled by the winch-assist machine.
- Remove risks identified by hand fallers.
- Eliminate other hazards that could be between standing and felled trees.
- Inform the hand fallers of boundary hazards.

Have the hand fallers work first if possible. Even when you think you can get all the wood, fell as if you might not.

Anchoring excavators on narrow tracks or ridges

Narrow ridges are common in many parts of New Zealand and can cause difficulty when setting up winch-assisted machines. There is not enough space for the winch-anchor machine to be in line with the steep slope harvester (SSH) requiring an alternative anchoring method.

A solution is to sit the excavator perpendicular (90 degrees) to the lead angle and use the bucket to redirect the load from the SSH. Unlike the standard winch-anchor machine anchoring where the anchoring is through machine, boom and bucket, most of the rope's force goes on the bucket:

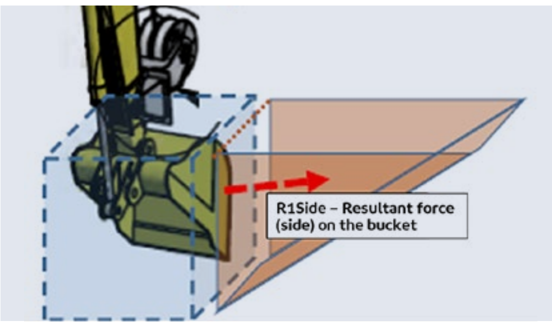
- The strength of the soil that the bucket is dug into holds the SSH machine's forces
- Digging the bucket deeper and using solid ground creates more holding force
- Locating the bucket further back from the edge improves holding force and the rope will cut through the ground.

Increasing sideways forces could generate forces large enough for failure on the bucket/boom/sheave unless manufacturers have modified their equipment design to accommodate such large angles.

It may also be challenging for the SSH machine to access on or off the ridge. A solution is to sit the winch-anchor machine far enough back or use redirects.

A Excavator is back far enough to allow the felling machine to be on the rope as it moves over the edge

B Ensures the bucket is in strong natural soil or in hard ground on a track



The orange wedge of soil holds the force from the steep slope harvesting machine!

The soil around the bucket is susceptible to loosening over time. Use solid ground and not uncompacted fill.

Uphill winch-assisted systems

Depending on the location, a common situation is where a mobile machine cannot access the top of the winch-assisted harvesting slope or cut an access track.

This occurs for many reasons including crossing into a different property, no physical way of access, environmental reasons, or a different age class of trees.

Winch on the steep slope harvesting machine

Steep slope harvesting (SSH) machines with winch mounts, like the Climbmax can use suitable stump(s) or tree anchor(s). This is a system advantage.

- Drag strawline directly from the SSH to the stump.
- Pull up the winch line.
- Securely anchor and back up anchor, if needed.
- Attach a stump movement monitor.

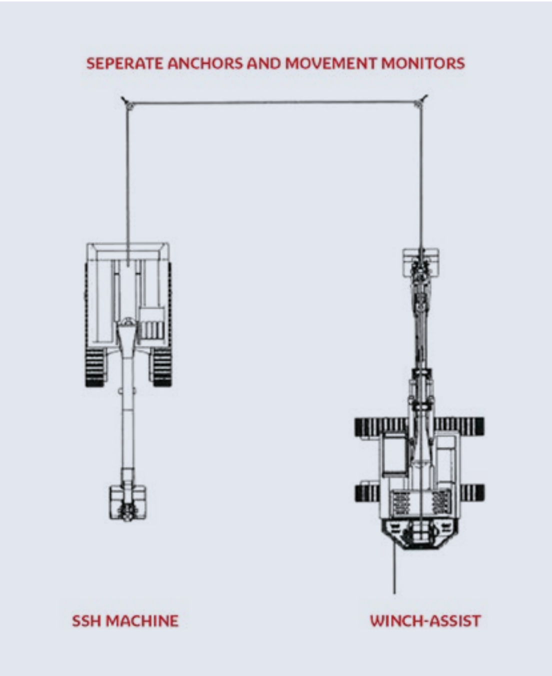
Winch anchor machines (WAM)

A solution for WAM machines is for the winch rope to be fed through blocks at the top of the winch-assist harvest area back to the SSH machine.

The system integrity depends on the:

- Quality of the stump or tree anchors. Each anchor may need to have backups, e.g. 2 or more stumps
- Using correct rigging, e.g. the right size and type of blocks, shackles, and strops

Forces on the anchor and rigging are significantly increased. If a single anchor was used, and the tension on the SSH machine was 18 tonnes, then the force at the stump, block, strops, and shackles would be double at 36 tonnes.



Anchor or anchor rigging failure may result in SSH machine destabilisation or rollover.

Work area exclusion zones

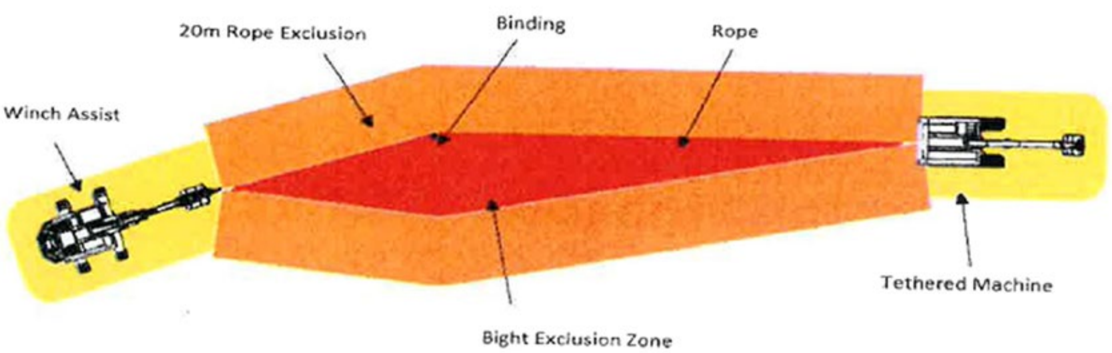
Operational work exclusion zones differ depending on the harvest site. These should be determined as part of the site safely plan. The following are indicative work area exclusion zones.

Minimum 6m

- Behind and to the side of a stump or deadman anchor.
- Around the winch anchor machine.
- Around the SSH machine (depending on the operation).

Minimum 20m

- Either side of the winch rope if operating without redirects.
- Beyond the extent of the bight if using redirects (see diagram).



Serious hazards exist from winch-assisted harvesting rigging and system.

Part B

Other factors

(for a well-run winch-assist operation)

Chapter 8

Risk assessment and management

In this chapter you will find out:

- ✓ Some of the hazards and risks you need to manage.
- ✓ Ways to reduce them.
- ✓ Some useful reference material.

Hazards and risks

Hazards have the potential to cause harm including serious injury or death.

Risks are what could happen if someone is exposed to a hazard.

Risk considers both the likelihood and consequences of exposure. Risks can be to people, environment, and property.

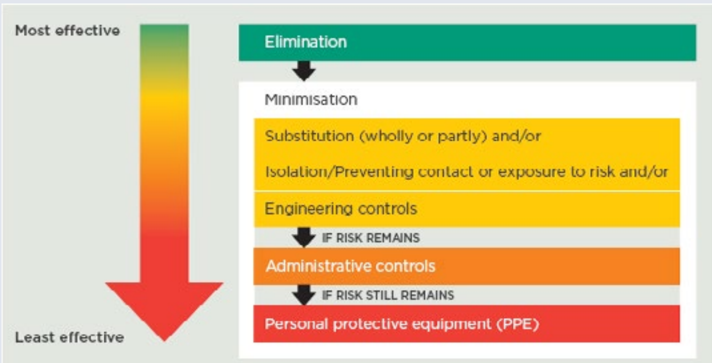
Risk management process

The risk management process should include the following steps:

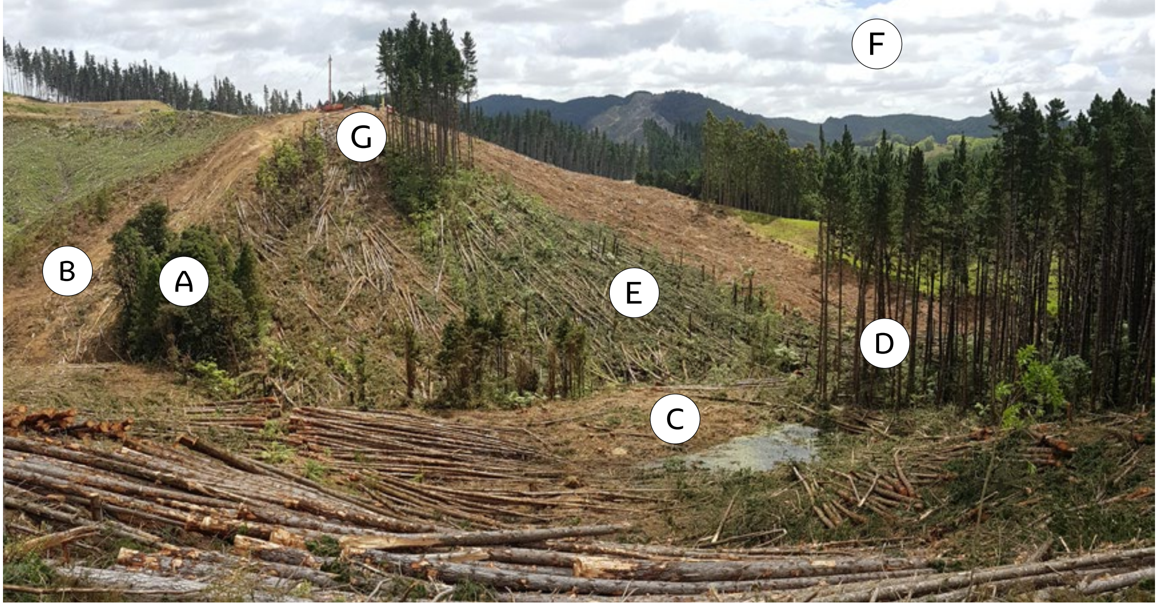
A risk assessment will help decide:

- How severe is a risk.
- How likely it is to occur.
- Whether existing control measures are effective.
- What additional action needs taking.
- How urgently it needs doing.

The following table provides information on each of the steps in the above diagram.

Process	Consideration
Identify Hazards	Find out what could cause harm or damage to people, property and the environment. For example: – Physical work environment including site factors – People and tasks – Work design and planning – Plant and equipment
Assess Risks	Understand the harm that could be caused by the hazard, how serious the harm may be, and the likelihood of it happening.
Eliminate Risks	It is best to try and **eliminate risk**. If eliminating the hazards and associated risks is not reasonably practicable, you must **minimise** the risk by one or more of the following control methods: 
Control Risks	If it is not reasonably practicable to eliminate the risk, implement effective control measures to **minimise risk**. (Refer to the hierarchy of control measures in the above diagram). Ensure the controls are: A Fit for purpose B Suitable for the nature and duration of the work C Installed, set up and used correctly D Understood by those exposed to the hazard. Also consider whether your preferred control measures introduce new hazards or unintended consequences.
Monitor / Review	Monitor controls, and periodically review them. This helps ensure they remain fit for purpose, are being implemented correctly and are working effectively. Also, consider if there are any new risks. Where relevant and available, reviews should include inspection, consultation, testing and analysis of records and data.

Potential hazards



A Native vegetation and fish habitat

B Soil and rock type

C Rivers and wetlands

D Diameter and height, and spacing of the trees

E Steepness and ruggedness of the area

F Amount of rainfall and storms

G Rolling debris

Risk likelihood/consequence matrix

A common way to determine the likelihood and consequence of a risk is through a standard risk matrix. It is a way to assess the potential seriousness of a possible incident. Once the risks are understood, appropriate controls or protection can be put in place. The greater the risk, the stronger the controls need to be. The following is an example of a risk matrix.

Likelihood Increasing

Consequence Increasing	Negligible	Unlikely	Possible	Likely	Almost Certain	Certain
Catastrophic	Medium	High	Extreme	Extreme	Extreme	Extreme
Extreme	Medium	Medium	High	High	Extreme	Extreme
Major	Low	Medium	Medium	High	High	Extreme
Moderate	Low	Low	Medium	Medium	High	High
Minor	Low	Low	Low	Low	Medium	Medium
Insignificant	Low	Low	Low	Low	Low	Medium

Bowtie risk assessment

The bowtie diagram is a form of risk assessment. It helps to visualise the risks, causes and controls on a single page.

The centre of the bowtie is a main hazard. To the far left are potential threats or causes for the central hazard. To the far right are potential consequences if the central hazard happened. For example, in the bowtie diagram below, injury and machine damage can be caused by weather and site conditions, who is doing the work, how it's planned and what equipment you are using. As a consequence of injury and machine damage is a trapped or injured operator, a damaged machine including fire, an environmental incident, and a legal problem.

Preventative controls on the left side interrupt the threat so it either does not occur, or if it did, does not result in an injury or machinery damage. For example, in the top left gold box is poor site conditions and weather. There's several preventative measures that include stopping work by either not working or moving to safer part of harvest area. Recovery controls on the right side make sure that if the central hazard does happen, it either does not escalate into an actual incident, or if it did, the impact of the incident is minimised. For example, the recovery controls for a trapped and injured operator are one or more of the recovery controls which include: multiple access to the cab, and having someone onsite that can give first aid.

Cause or threat	Prevention controls			
Physical work environment				
Poor site conditions eg. high wind, rain, soil type and moisture, slope	Avoid or reduce operating in high-risk conditions	Follow the adverse weather policy. Check the weather forecast. Meet the environmental standards		Cease work – leave or move to safer part of block
People and their tasks				
Impairment eg. fatigue, health, drug and alcohol	Follow fatigue management plan. Health checks	Complete 'fit for work' on the day (unit 22994)	Cease or suspend work	Monitor operator logbooks
Operator lacks competency, is inexperienced or inadequate supervision	Work practices are monitored (SBO)	Follow business induction, training and operational requirements		In-cab device to monitor working slope & rope tension
Rules, policy, guidance not followed eg. ACOP/good practice guides/regulations/ manufacturer's documents		Stop work, reassess plan and risk controls		Practices/guidance is periodically reviewed
Work design/planning				
Work plan poor or flawed	Have detailed and agreed harvest plan for block. Eg. slope map, no go zones	Review felling plan daily. Monitor via SBO/ site visits		Operator awareness of site hazards/risks & how to manage them
Plant & equipment				
Mobile anchor moves or tips over	Follow process to monitor anchor integrity/stability	Test initial position stability	Install auto stop braking mechanism	Minimum of 1 layer wrap on winch drum
SSH tips over while repositioning	Follow manufacturer's guidance	Move one machine at a time. De-tension rope		Develop procedure to manage machine repositioning
Anchor machine power loss		Check machine daily		Install over-riding drum braking system
Harvester forwarder, or skidder power loss				Install over-riding braking system to stabilise machine
Winch-assist system failure eg. rope, connector, or fitting	Comply with the CP ENG certification and the Worksafe fact sheet		Active operational monitoring eg. rope, fitting & connector checks	Manage rope 'bight'
Machine failure through general machine wear & tear	Undertake required inspections specified by the designer, manufacturer or supplier			
SSH hit by object and cabin penetrated	Cab guarding meets industry standards. Structural damage assessed and repaired in a timely manner		Ensure 'working alone' process in place	

Note: Using this guide will help develop preventative and recovery controls for many of the threats and consequences. Winch-assist contractors are advised to complete their own risk assessment.

Personal injury and/or machine damage

Recovery controls				Consequences
Investigate incident	Minimum 2 (preferably 3) emergency exits with two accessible from the outside. Follow Emergency Response Plan (ERP) including emergency procedures		Provide first responder assistance	Trapped or injured operator that can't exit machine
	Follow ERP safely	Recover machine	Ensure fire suppression available. Test periodically	Machine fire damaged
			Find alternative work or temporary stand crew down	Machine damaged (no fire)
		Notify relevant persons/ authorities	Provide first responder assistance. Ensure site is frozen	Worksafe notifiable event
	Undertake remedial work		Advise management. Seek advice	Environmental damage
				Prosecution, fine, notice, or another liability
Assess risks and plan and implement alternate work methods				Loss of production

Emergency plan

General emergency plan

- Follow the crew emergency response procedures.
- If a winch-assisted machine operates across multiple crews, then the emergency plan followed is with the machine's crew.
- Display emergency procedure stickers prominently on the worksite and in all vehicles and machines.
- If an emergency occurs, ensure emergency services are contacted and dispatched as soon as practical.
- GPS Emergency location coordinates must be current for each work site for emergency services. These are often on the harvest map or plan or written up on the crew container white board.
- Know your nearest Emergency meeting point (if that system is used) or the identified helicopter landing area.

! Know the emergency plan.

Emergency preparedness

- Test check-in procedures.
- Inspect and test escape hatches. Schedule drills to ensure that the operator can fit through the hatch.
- Have a plan for evacuating an operator off the hillside.
- Have a plan for repairs and delivering heavy parts to a downslope machine.
- If possible, move machines to safe areas to perform maintenance. Ensure machines are de-energised and stable.
- Clean and inspect build-up of flammable materials or leaks within the engine compartment.
- Fire suppression systems should work in any orientation.
- Have procedures for using and maintaining a handheld tool for the operator to cut their way out in the event of a rollover or rescue procedures for crews to cut operators out.
- Check that the two escape hatches can be accessed outside the cab.
- Know what to do if there's a loss of communication between the WAM and the mobile plant being assisted.

A machine in an unstable position

Evaluate different scenarios and come up with emergency plans for the most likely. Make them part of the general emergency plan. An emergency plan could have the following:

- Stay in the cab. Exiting the cab often is a poor decision as it may increase the risk of personal safety.
- Secure yourself against injury should machine movement occur.
- Establish radio contact with your supervisor or onsite contact.
- Identify your location, explain the situation, request assistance.
- Evaluate the situation, e.g. will releasing the load improve or reduce machine stability? Will raising or lowering the blade/boom/attachments increase or decrease the likelihood of a rollover?
- If the evaluation comes up with some solutions, attempt to improve the situation, e.g.
  - Activate the blade braking device on the assisted machine if available.
  - Activate the track or wheel brakes on the steep slope harvesting machine.
  - Use the head's grapple to hold on a tree or stump or set the head or heel rack (if available) into the ground to provide further braking resistance.
- Wait for assistance to arrive.
- Exit the cab only if safe to do so once the assisted machine is fully immobilised.
- If your assessment determines the least risk option is to exit the cab, first survey the area for hazards, e.g. uneven ground, falling or rolling debris, unstable logs. Communicate your plan before exiting.

When to stop winch-assisted felling?

Operators must be clear about under what conditions operations should cease. These might include:

- Changes in weather that increase the risk to an unacceptable level, e.g. high winds, heavy rain, thick fog, darkness.
- Changes on the felling face, e.g. saturated or unstable soils, storm damage, rock, steepness.
- Damaged equipment, e.g. radios, electronics, hydraulics, damaged safety features.
- Fatigue, e.g. unable to maintain concentration or focus.
- Operator confidence.

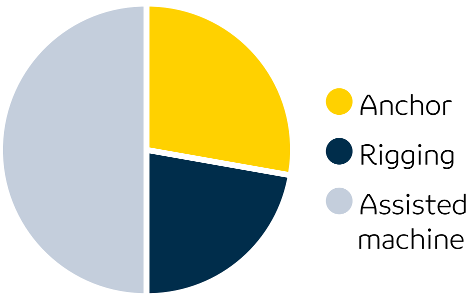
Unplanned events, or changed plans, can lead to accidents. If something changes, stop work, and review the plan with others.

Don't be pressured into felling more when you have decided to stop.

Winch-assist incidents

It's best practice to consider findings from accidents and incidents and apply these learnings to operations. The Forest Owners Incident Reporting and Information System (IRIS) records incidents for a range of activities and periodically publishes its findings. Analysis of IRIS data shows the recent WAM incidents are split between the key three components.

Winch-assist incidents



Anchor set up, and anchor components were about **a third** of all incidents. This included winch components, controllers and site factors. Anchor lead angles incidents were included.

Rigging related incidents were about **one in five** incidents. This included ropes, chains, connectors, and unintentional factors like binding and redirects.

Assisted machine (most commonly a harvesting machine) accounted for **half** the incidents. This covered harvester stability, trees falling onto the machine, other felling issues, cab and operator specific incidents like slips, trips and falls.

Safetree Reference: How to... manage forestry risks

safetree.nz/wp-content/uploads/2017/03/Managing-risk-in-forestry_March-2017.pdf

Regulations

Two recent regulation examples that will impact on winch-assisted harvesting are the General Risk and Workplace Management (2016) and the Plant and Structures Regulations currently under development (at 06/22). The former requires businesses to manage risks associated with remote or isolated work, working under raised objects and falling objects.

The latter will likely require plant registration (design and item of plant), periodic inspection and installation of safety devices.

Harvesting activities must meet many regulatory requirements including the Health and Safety at Work Act 2015. Refer to chapter 11, page 113.

Chapter 9

Steep slope harvesting and the environment

In this chapter you will find out:

- ✓ How winch-assist can affect the environment.
- ✓ Why winch-assist can create a lighter footprint on the ground than an unassisted machine.
- ✓ Ways to improve environmental outcomes.

Environmental challenges of winch-assisted systems

Environmental problems usually only occur when things are pushed, rushed, wrong options are chosen, or when people don't know or care.

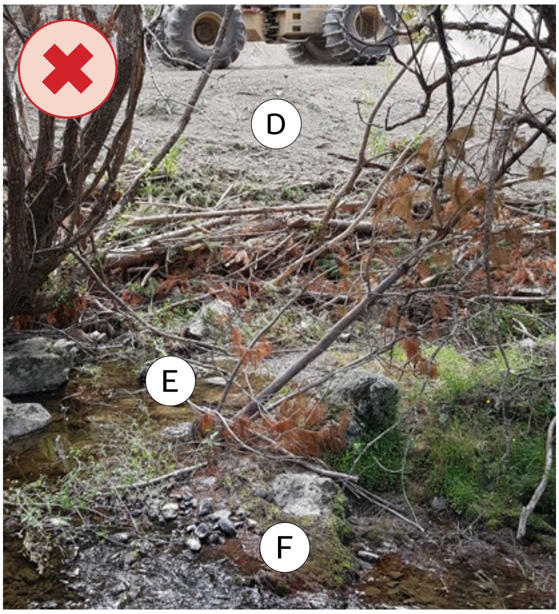
Many companies aim to fully mechanise felling and extraction for health and safety and other benefits.

At times, this has put pressure on environmental outcomes. Winch-assist puts machines in places previously not accessible. For example, shovel logging, especially uphill, can lead to heavy rutting.

- It was logged in the wet so the SSH had poor traction.
- The good soil has gone and the tracks struggle to grow grass.
- The tracks channeled rainwater and they've scoured.

Many parts of New Zealand have thin and relatively fragile soils, and when exposed to heavy rainfall, it can create erosion and sedimentation. Ground-based equipment can potentially damage soils through excessive rutting or compaction. Rutting on steep slopes may also cause water redirection or concentration and result in erosion and sedimentation. Soil damage will affect the growth of the next rotation.

Poor winch-assist planning creates environmental risks, especially where winch-assist is in conjunction with traditional ground-based grapple extraction. This typically leads to downhill logging and extraction. Tracks are often a significant source of sediment, which can impact waterways. Also, mid-slope contour tracks may be needed, especially where the slope is longer than the winch rope. These open steep slopes to erosion, often by soil slip.



A The winch-assist operator did a good job

B An extraction track was built in a perennial river

C The loggers didn't remove the crossing

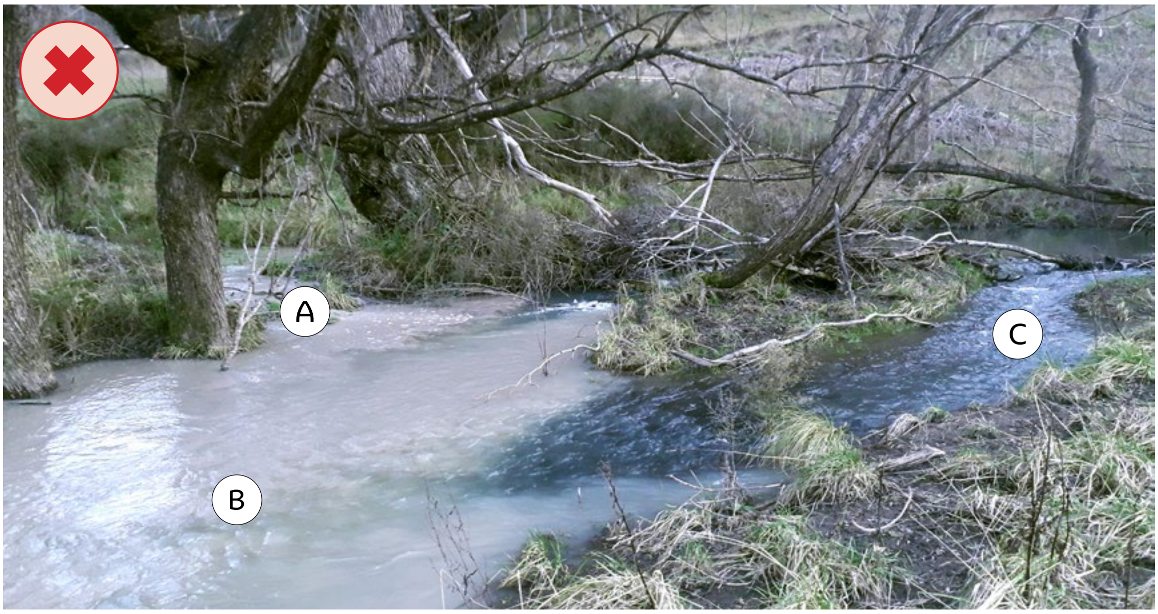
D The track is too close

E Debris in a river

F The river turns to mud when it rains

Also:

- Downhill logging to the waterway created environmental non-compliance.
- Improved planning and operational management could have created a much better outcome.

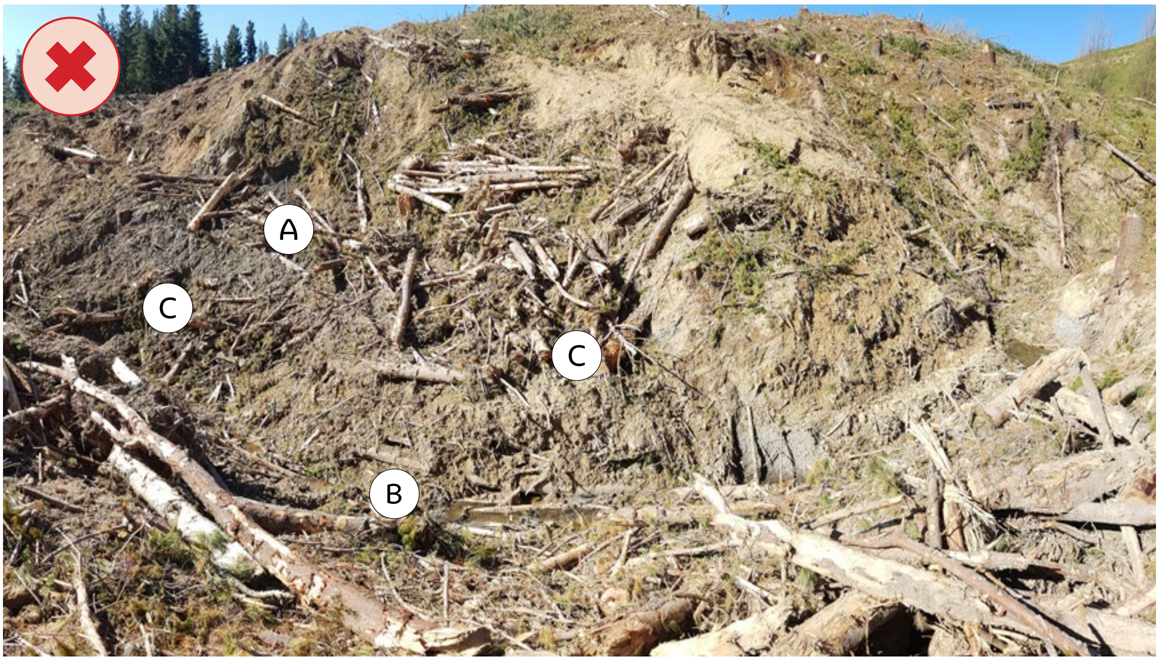


A A light rainfall created sediment into the side creek that went into the main river

B The river has silt over the stones and is not good habitat for fish, even a km downstream

C The trout river upstream is clean and good for fish

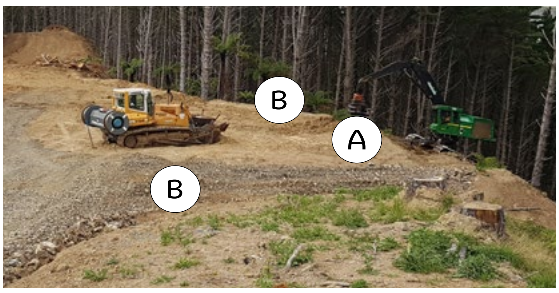
Machine felling does not always give the best environmental outcome, especially for the tricky areas that machines either struggle to access or require tracking.



This small 0.2 ha area could have been hand felled, then extracted with the hauler, rather than tracked and machine felled, leading to NES-PF non-compliance.

- A The track was cut for the felling machine
- B The creek has fill in it
- C Logging slash is in or could slip into the workway

Winch-assist rope is often dragged through the edge of landings and roads. This is because the anchor machine needs to sit back far enough so the steep slope harvesting machine can be lowered off the slope, and the road because landing edges are often built of fill that lacks good anchoring strength. This creates an erosion and sedimentation problem if the site is not remediated after harvesting.



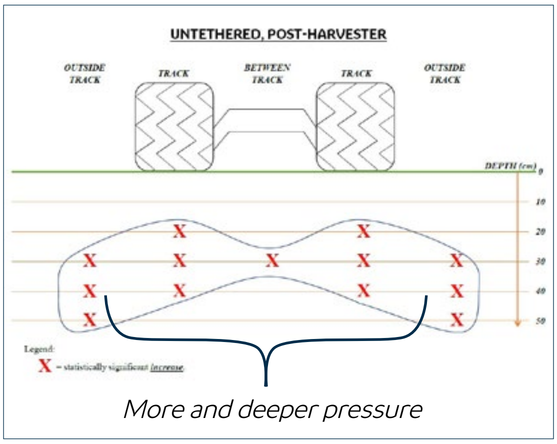
- A Ropes are carving through bund and landing fill. These need to be rehabilitated after harvesting
- B The road and landing have been engineered to control water, and reduce sedimentation as required by the NES-PF

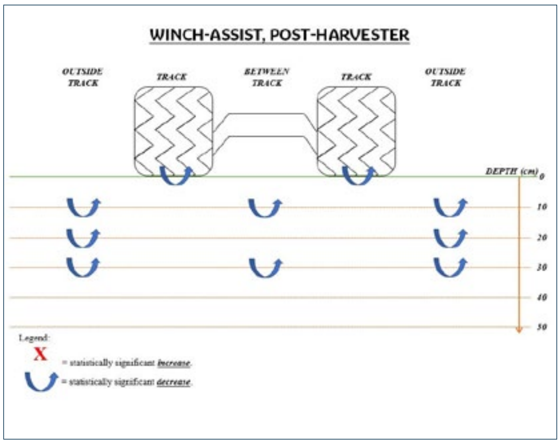
Winch-assist has a lighter footprint than other ground base systems

Winch-assist decreases the machine's tracks pressure on the soil. It also improves how pressure is distributed. These increase machine mobility and stability. The reduction in ground pressure and reduced track slip and rutting also helps reduce soil disturbance.

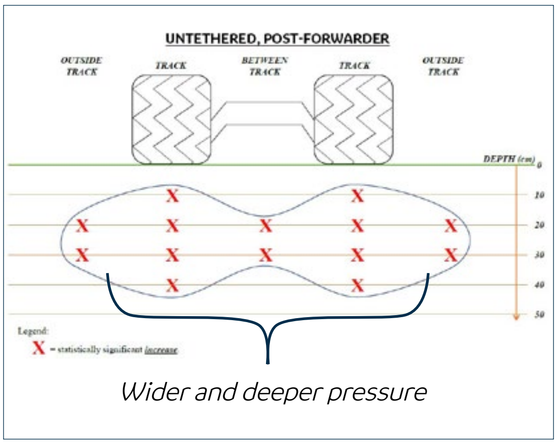
When moving downhill, tracks are engaged better throughout their entire length giving better mobility. Also, ground pressure concentrations decrease, creating less soil disturbance and more stability.

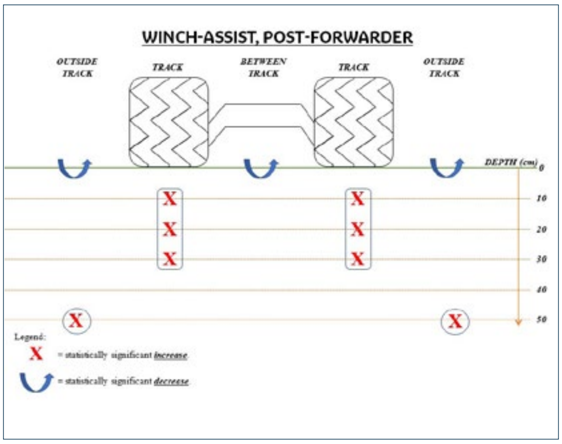
Uphill operation is improved by better distributing ground pressures.





Left: This diagram shows the pressure distribution from the machine's tracks. Right: on winch-assist both the amount of pressure reduces and the impact of soil pressure in deeper soil.





Left: An untethered forwarder has a much wider and deeper pressure distribution than a winch-assist, at right.

Five critical environmental questions for operators

Operators can make a big difference in how the job finally looks. Maintaining the soil for future forests, and reducing the impact on our waterways for kaimoana, are important operator responsibilities.

1. Is it too wet to work without heavily damaging the soil through slipping?
2. If ruts were made, would they concentrate water and scour out?
3. Could your ruts lead to sediment in a waterway?
4. Are your company's wet weather guidelines right for the location you are in, or are you stopping when it is too wet?
5. What thing can you do to minimise your machine's impact on the soil?

Don't work when it's too wet. You'll make a mess—work easier areas if possible.

Put slash on your tracks. It's easy to do.

Environmental guidelines

The National Environmental Standard for Plantation Forestry (NES-PF) requires a management plan for almost all forestry earthworks and all harvesting. Putting in tracks for the anchor machine or extracting logs is considered to be earthworks.

What the management plan says and what happens in the field need to be the same. Operations in the field need to meet the requirements of the NES-PF permitted activity conditions or the resource consent.

- Planning must incorporate the potential environmental risks of winch-assist. Understanding the impact of winch-assist on steep environmentally sensitive soils is fundamental to the task.
- Communicate site-specific environmental requirements to the harvesting contractor. Incorporate into operational paperwork.
- Monitor operations and stop when working would cause unreasonable soil compaction and erosion and sedimentation. Resume when site conditions are satisfactory. Closely monitor operations where soil compaction or erosion and sedimentation are likely to be an issue.
- Limit loss of traction. Operators must reduce slipping, e.g. maintain a constant tension and not push the machine too hard, instead rely on the rope.
- Use slash across any ruts to reduce the impact on the soil when the harvest area is not hauler logged.
- Use tire tracks on wheeled machines to help prevent wheel slip or spin.
- Rehabilitate winch-assisted machine ruts as they are finished. There is unlikely to be a cleanup machine.
- Use winch-assist on less steep ground than normal if without it would otherwise cause unreasonable soil damage.

The rope gives extra traction and reduces rutting and slipping.

Chapter 10

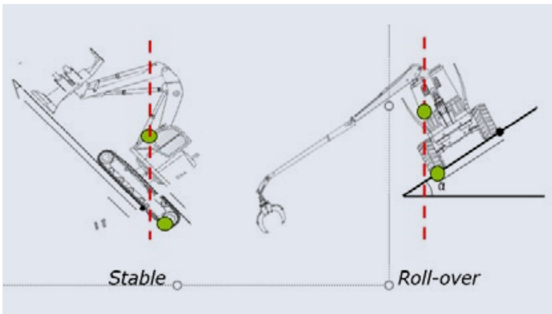
Stability and traction

In this chapter you will find out:

- ✓ How gravity changes stability.
- ✓ Things to watch out for that affect machine stability.
- ✓ How traction changes with slope and soil conditions.
- ✓ Why a winch improves traction.

Stability

Stability measures how likely it is for an object to roll-over when pushed or moved. Stable objects are difficult to fall over, while unstable objects topple over very easily. A machine rolls over when they are out of balance. That's technically when the centre of gravity is 'outside' the base, or edge, on which it balances.



Machines rarely just fall over, and an operator can often act to stabilise the machine. The risk of a rollover increases on slopes of more than 50% (28 degrees).

! Beware of SLIP-SLIDE-TIP.

What affects stability

A loss of traction is the most significant cause of a loss of stability. Any factors that reduce traction efficiency impact traction. Refer to the 'what affects traction' section.

- Most rollover accidents are caused by loss of traction. The steep slope harvesting machine begins to slide, and then the tracks/wheels hit an object like a stump, log or rock. This leads to a change in stability and rollover.
- A change in slope can also affect stability because the machine's weight and centre of gravity may change rapidly, e.g. dropping off the road near the anchor onto the felling area.
- The machine type and where the load's position influences stability too.

Loss of traction causes most rollover accidents.

Traction

Traction is the 'grip' the machine has on the slope. The primary purpose of the winch-assist is to help improve traction. Maintaining traction is essential to control the machine's stability.

The section explains what affects traction and explains in detail how soil strength, slope steepness and the cable itself can affect a machine's ability to climb.

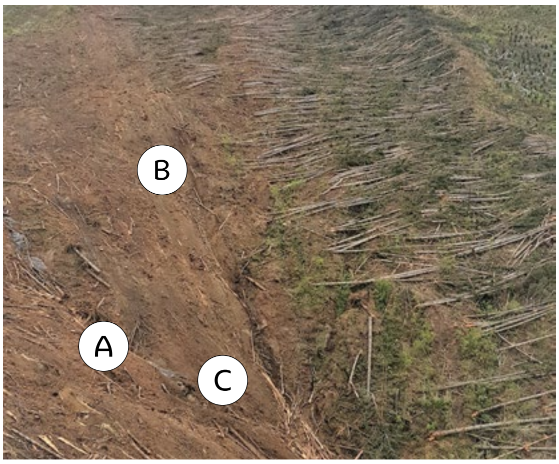
What affects traction

Traction constantly changes. Four main factors can affect traction. Some of these can combine to either make traction significantly better or worse. Two factors we can't change, and these are the:

- Harvest area's site considerations like the soils, geology, slope, aspect, windthrow, and terrain features.
- Environmental factors like rainfall, sunshine, wind, fog or darkness.

The other two factors the contractor and operator have some influence over and can adjust or modify. These are the:

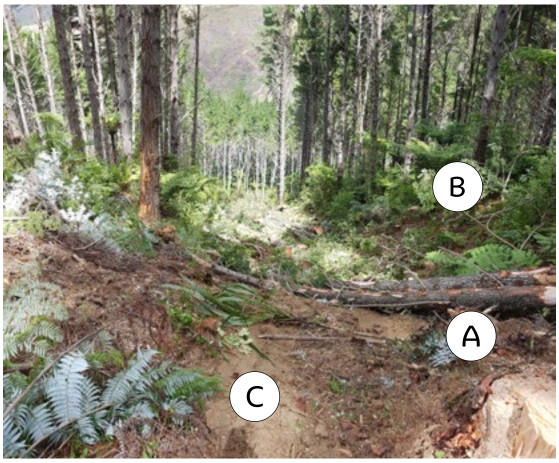
- Machine, e.g. type and weight, grouser size, machine limitations, and maintenance.
- Operator experience and care, e.g. amount of tension applied by the winch through the cable.



A Terrain – boulders, rock, thin soils and gullies

B Wet locations – aspects that get less drying, or poorly drained soils

C Steep slopes especially over 35% (20 degrees), and long steeper slopes



A Windthrow, stumps, and woody debris

B Dense scrub that obscures a ground view

C Soil like clay or black soil, that are worse when wet

Also:

- Strong winds and poor visibility
- Heavy rainfall, or increasingly wet weather conditions

Common natural hazards are stumps, holes, rocks, drop-offs, windthrow and thick scrub.

Loss of traction

Slipping indicates the tracks are losing traction. Slipping reduces soil strength because the tracks cut through the slash and vegetation that help support the machine. During high slip, the spaces between grousers can become packed with soil, and they stop biting into the ground. Machines can slide even on moderate slopes of 30-40% (17-22 degrees).

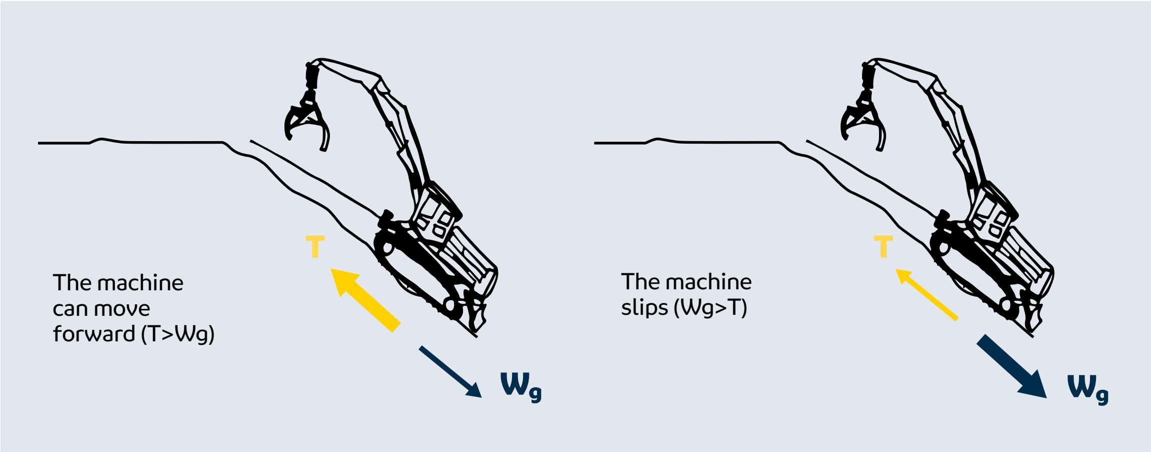
Loss of traction can lead to machine rollover.

Why traction changes with slope

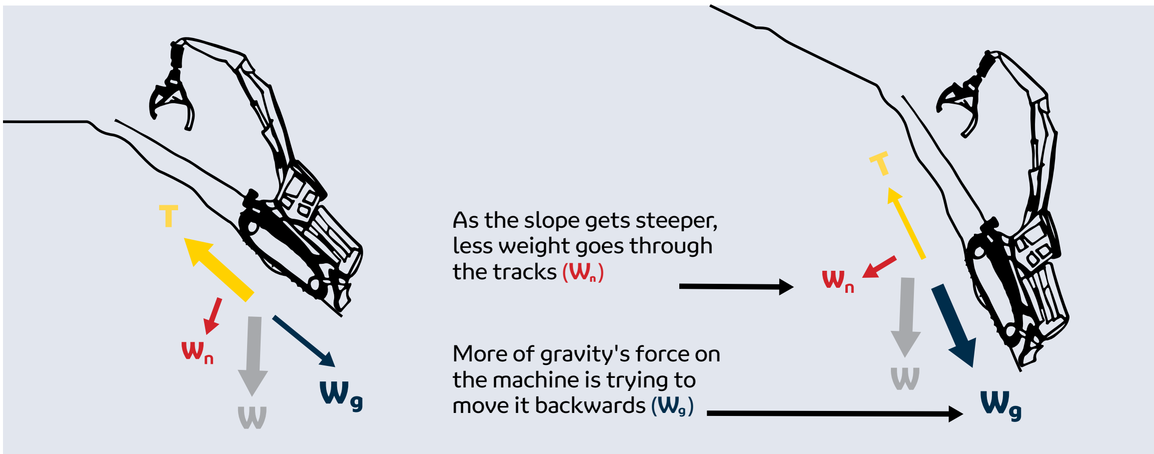
Slope affects traction. As the slope increases, the machine's tracks are more likely to slip.

This is because the steep slope harvesting machine must fight gravity to climb. Gravity is trying to slide it down the slope.

1. Traction is lost when the force of gravity (Wg) is greater than the machine's ability to go forward (traction force or T).



2. Traction reduces as slope increases.

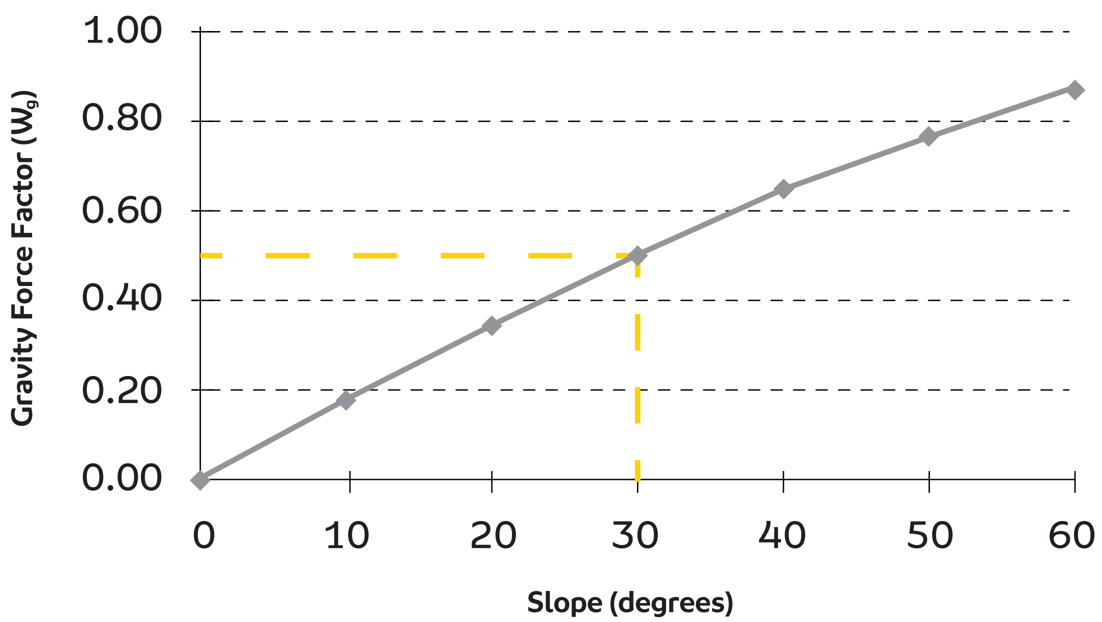


Machines are much less likely to slip on a flatter slope than a steep one, all things being equal. The reason is due to how gravity behaves. On a flat surface, gravity pulls down directly. On a steepening slope, less of gravity's force gets to go directly down through the tracks. The force directed on the tracks is called gravity normal force or W_n.

As the slope gets increasingly steeper, less force goes through the tracks (W_n), and more force is trying to pull the machine backwards (W_g), as seen in the diagram below. The equations are:

Normal force (W_n) = machine weight x cos (slope angle)

Gravity's force (W_g) = machine weight x sin (slope angle)



At 30 degrees, the gravity's pull on the machine is already 50% of the machine weight!

How to measure slope

Slope is easier to measure over long distances than short ones. However, the slope immediately around the machine is what's really important to know especially if it is steep. The dominant or long-distance slope gives an indication of overall steepness. A recent study indicated that the machine's slope is often different than the terrain slope.

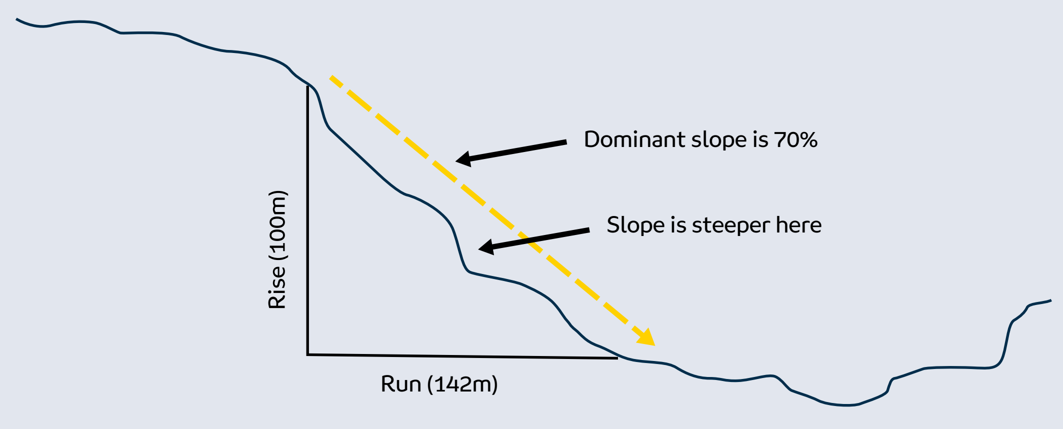
Slope is commonly referred to in two types of measurement units. These are degrees and percent. While degrees are often still used in New Zealand, percent is recognized internationally. See page 100 for degree/percent comparisons.

Calculating Slope

Slope can be measured off a contour map:

- It is best to start on a contour and finish on one.
- Measure the ground distance (also called the 'run') between the contours.
- Next count the number of contours (called the 'rise').
- Dividing the rise by the distance will give you the slope in %.

In the following example the map scale was 1:10 000 and the contour interval was 10m. If there were 10 contours crossed the rise, is 100 metres (10 contours multiplied by 10). If the ruler distance was 14.2mm, then this equals 142 metres on the ground. The slope is 100/142 x 100% = 70%.



Dominant slope = Rise divided by run **100/142 = 0.7 or 70%** **70% = 35deg**

How steep is too steep?

Many factors other than slope affect safe machine operations e.g. soil condition, operator skill, the machine, and the roughness of the slope. Operators say productivity drops on slopes greater than 42 degrees.

The following chart gives some indication of boundaries.

Slope (degrees)	Slope (%)	Consideration
17°	30%	This is considered a limit for when a wheeled ground-based machine can start to slide under poor conditions.
22°	40%	This is considered a limit for a tracked ground-based machine. It can start to slide under poor conditions.
28°	50%	Most purpose built forestry machines, with good operators in good conditions can work up to this limit. Beyond this slope it is wise to consider using winch-assist.
35°	70%	This is considered the absolute upper limit for ground-based machines without winch-assist. Only under very favorable soil strength condition, with a purpose built steep slope harvesting machine and a very experienced operator, and then only traversing directly up or down the slope.
42°	90%	A realistic upper limit for all winch-assist operations.
45°	100%	Considered the absolute upper limit for any winch-assist operation. If any part of the rigging fails, a machine roll-over would be difficult to avoid.

The following table shows that on steep slopes maintaining traction is essential, otherwise the anchor and rigging can carry loadings higher than the SWL of the rope. If the SSH machine slipped and created a shock loading too, then the weight would be much higher.

Traction is lost when the force of gravity (W_g) is greater than the machine's ability to go forward (traction force or T).

Slope (degrees)	Gravity's force trying to pull it backwards (% of machine weight)	Gravity's force trying to pull it backwards (tonnes, on 45t SSH machine)	Winch tension Average operational setting	Tonnes>W_g Good soils 90% Traction efficiency	Tonnes>W_g Poor soils 50% Traction efficiency
30°	50%	23	8	19	3
35°	57%	26	8	13	-1
40°	64%	29	8	8	-6
42°	67%	30	8	6	-7
45°	71%	32	8	3	-10
50°	76%	35	8	-2	-14

Assumes the machine's weight is 45 tonnes, plus 2 tonnes of working force to shovel or hold a tree, and all other things are constant like the traction efficiency and the soil conditions.

The ability for the machine to go forward **is limited** without addition winch pull (tonnes)	(light yellow)
The machine can't move forward and requires additional winch pull (tonnes)	(dark yellow)

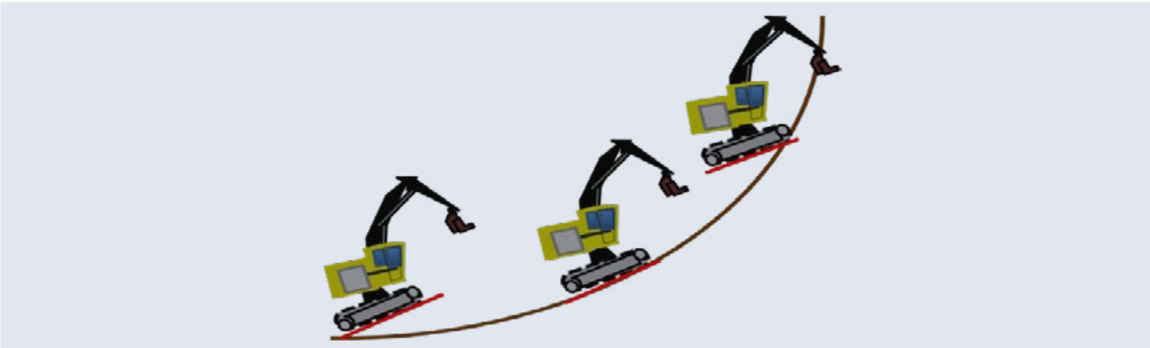
! SSH machines must only be operated in locations and with techniques that assure stability.

The difference between machine slope and terrain slope

The machine's angle or steepness can be different from the terrain steepness. The main reasons are the resolution in the terrain slope data and the operator's skill. Even with LiDAR slope maps, each pixel, or smallest coloured square, maybe 10m x 10m. A machine's track base is much less than a pixel or the dominant slope. Good operators on steep terrain manage slope by using minor slope changes like flatter areas for the machine.

The University of Canterbury studied 22 machines during normal steep-terrain operations and recorded both terrain and machine slope:

- Terrain and machine slope are nearly always different.
- Machine slope was higher than terrain slope except for steep sites.
- On steep slopes, machine slope was less due to operator management.



Machine slope can rapidly change on broken ground. Watch for holes, drop-offs, and old tracks.

Why traction changes with soil strength

Understanding soil strength is important because it affects traction and stability. Weak soils can make working on flatter terrain tough going, yet strong soils on steep terrain can work well. Regularly evaluate soil and its ability to provide good traction.

Saturated soils are very weak.

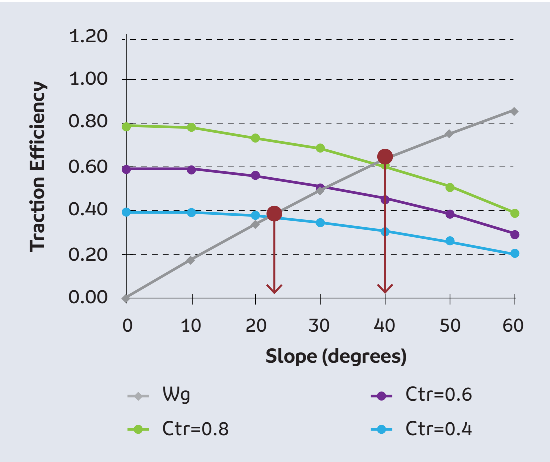
Strength varies between different soils.

Even the same soil's strength changes depending on wetness.

How do you know the strength of soil?
Traction efficiency (CTR) is the interaction between the track type on the soil composition. The following is a guide for traction efficiency:

- **40% – Weak soil =** sandy, loose, or wet soil. They are easy to move with a shovel.
- **60% – Firm soil =** shovel goes in when you use your foot.
- **80% – Strong soil =** tightly bound gravelly soil with clay. Hard for a shovel to go in.

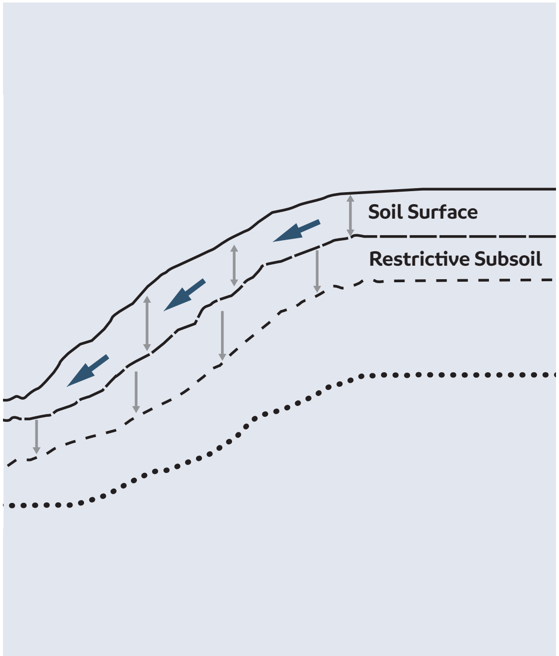
For example, extended grousers can increase the traction efficiency on weak soil as it penetrates further into the ground to increase its holding capacity. Conversely, extended grousers can decrease traction efficiency on strong soils as they ride on the tips of the grousers.



Poorer traction due to wet or weak soils means machines should only work on less steep terrain.

Tracked machines typically have a tractive efficiency of between 0.4 and 0.8. The difference in the value depends on the soil and track type. A weaker soil gives the machine less traction before it slips. In the example, it is the difference between working on a slope less than 22 degrees or one of 40 degrees.

Watch for springs or where water runs just below the soil surface. In ash and papa (mudstone) country, water runs where the soil hits the papa rock. This creates a slippery surface called a greasy back.

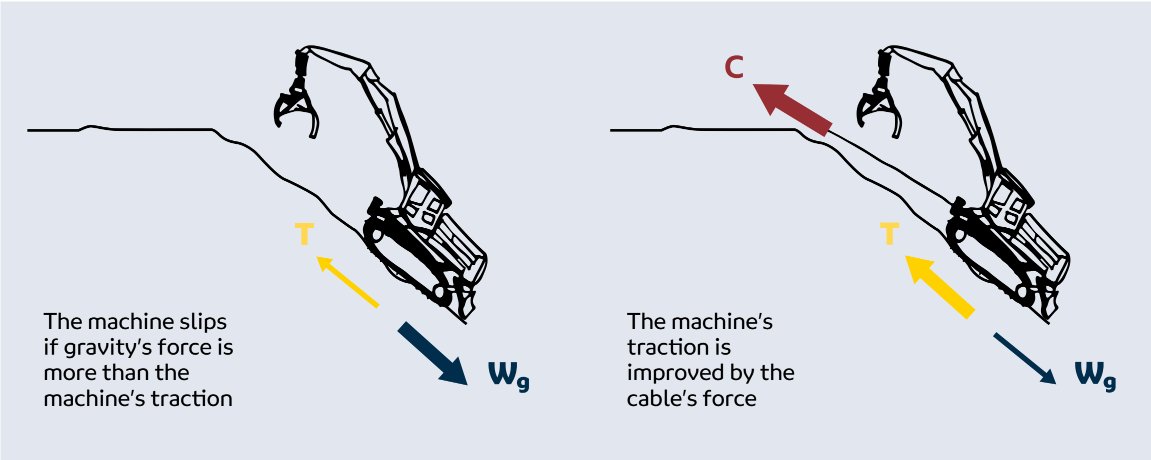


Left: When water hits a restrictive subsoil (blue arrows), it creates slippery conditions.
Right: Track slipping creates safety and environmental concerns.

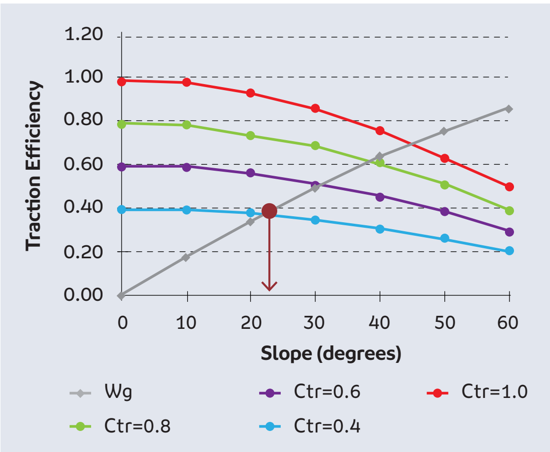
If it is too wet, don't work.

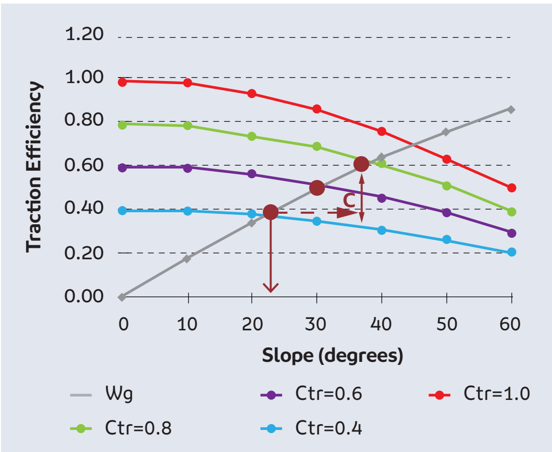
How traction assist increases slope capability

The force in the cable offsets some of the gravity force acting on the steep slope harvesting machine. Also, a cable better distributes weight on the tracks. This increases traction because it gives additional traction force.



Left: With no cable tension, if gravity's force on the machine, W_g was greater than the machine's traction, T, then the machine would slip. With cable tension, the machine's traction is improved. This is because of the winch-assist force, C.





The graphs above show the effect of cable assistance on the operating slope for a 45 tonne machine.

Left: without a cable, on weak soil (0.4) a machine can work up to about 22 degrees.

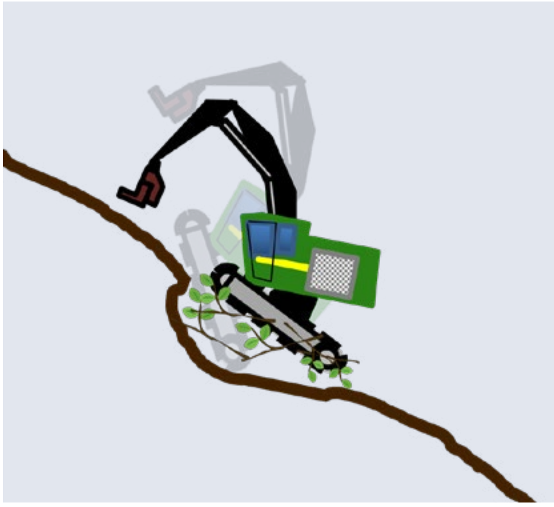
Right: on the same soils with cable assistance, of approx 8 tonnes, the machine can now retain traction at 31 degrees. With 12 tonnes of assistance, traction is maintained to 36 degrees.

Some tables and spreadsheets can help calculate the forces on winch-assisted machines.

Why traction increases with a slash mat

Using some slash can increase traction on most soils. This is because slash can help bind the soil and increase its strength. It is good for the environment too, because slash helps reduce wheel rutting, erosion and sediment.

Slash can also be used to fill holes to smooth terrain.



Slash mats can slip on high clays soils.

Larger woody debris can reduce traction through slipping.

Guidelines to help prevent machine rollover

Moving – all machine types

A Only turn around on a steep slope when there's a flat and wide bench

B Cut and move away woody debris that could affect traction and stability

C Keep boom stationary when moving otherwise weight and traction on each track changes

D Keep the saw head or grapple close to the ground to provide quick stability support

E Going over steep terrain lower boom and head and use for stability

F Before moving into the harvest area, pre-tension ropes to immediately support the machine. Check lead angles are OK

G Keep tracks parallel to the slope so the grousers or tyres provide resistance to sliding

Also:

- Avoid terrain that could affect traction and stability.
- Remove dense understory that blocks a clear view of the ground.
- Keep within the lead angle.
- Check rope and connectors are secure and not damaged.

Felling – all machine types

A Work straight up or down the slope, never across it

B Cut stumps off low to the ground

C Fell, lift, and lay trees that are within safe reach

D As slope increases fall narrower strips for machine stability

A Make machine stable before swinging wood.

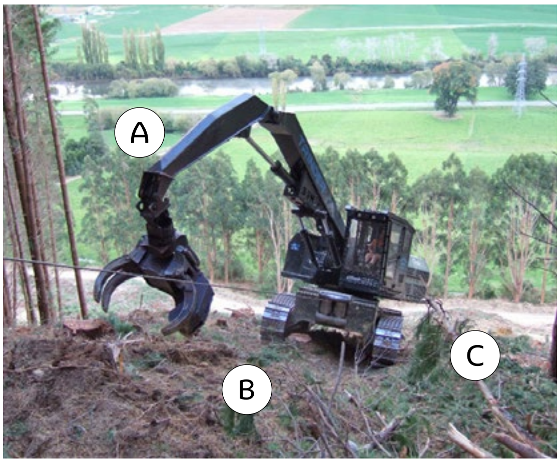
B Keep to the machine's cutting diameter and lifting limits.

Also:

- Lift trees no higher than necessary and not more than 3 m.
- Avoid swinging trees to the downhill side of the machine.

- Avoid lifting the boom straight up and tilting trees back over the machine (to the downhill side).
- Position cut timber from 10 o'clock to 2 o'clock when working uphill.
- Face the boom downhill on slopes greater than 30 degrees.
- Use multiple cuts only to fall a tree directionally. The equipment must have sufficient pushing power to direct the tree against its lean. Sufficient holding wood should be maintained until the machine is positioned to make the final cut.

Tracked machine – moving



A Ensure the boom is facing the right direction before engaging the winch.

B Keep the tracks parallel to the slope so the grousers provide resistance to sliding.

C Use single bar grousers for the best traction.

Chapter 11

Planning winch-assist operations

In this chapter you will find out:

- ✓ What makes a good plan.
- ✓ Planning starts well before the felling starts and finishes after the machinery leaves.
- ✓ Your role in the planning process, whether planner, contractor, or operator.

All blocks need careful harvest planning. This chapter goes through how to make a good plan. Planning is much more than just the company paperwork the contractor gets at the start of the job.

Planning should start well before the machines arrive and end after the machines leave. Risk management needs to integrate into all levels of planning.

The steps in good winch-assist planning.

The harvest plan

The planner must understand harvest options and keep up with the rapid evolution of techniques. Planners need to consider all phases from falling, extraction, processing, and loading.

It is essential to understand pre-existing erosion features and erosion prone material (loess, air-fall tephra, unconsolidated marine sand). Plan for re-working ruts so they don't turn into erosion gullies.

Winch-assisted extraction down an ephemeral water way creates a pathway for sediment to reach a stream.

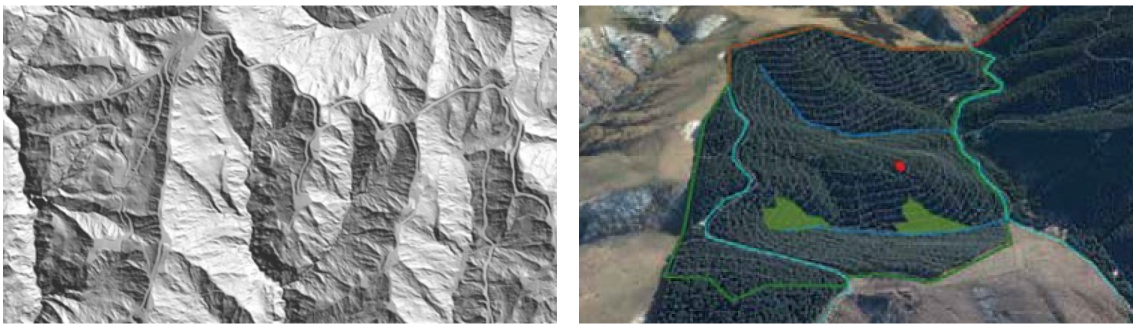
The office or 'paper' plan

The office plan's purpose is the first cut at harvest layout by piecing together information that helps develop the plan. It consists of collecting data that helps understand the block and things that affect layout design like the type of equipment available, extraction method, extraction distances, and the crew's capability. There are six steps to a good office plan.

1. Understand the block

Use data to find out as much information about the block before you visit the field.

- Geology.
- Soil type and soil depth, and strength and susceptibility to rainfall.
- Topography like slope and length, and terrain features like rocky outcrops, incised gullies and benches.
- Ground Roughness.
- Terrain Stability / Classification.
- Aspect.
- Climate and potential timing for operations.
- Infrastructure including old tracks.
- Ground cover and debris.
- Forest resource including stem size, stocking, height.



Old tracks can easily be seen with LiDAR, even with the trees still standing.

2. Know different winch-assist options and methods

There has been a swift expansion to winch-assist since 2010 and the change is still rapidly happening. Planners need to keep up with the changes. Forestry and harvest companies need to lift staff knowledge. Learning opportunities include industry conferences, University of Canterbury harvest courses, and regional wood councils for field days.

3. Understand the crew and their machines

Winch-assist planning isn't generic ground base planning that was typical in the past. Slopes are steep. If known, incorporate information on the crew and the machine types. They are experts in their fields.

- Understand the crew's knowledge, skill and ability and account for it in the plan.
- Use individual contractor's preferences when designing blocks.
- Know the machine capability, and if you don't, learn from operators and contractors.
  - Machine capability on different terrain, soil and slope.
  - How different ground conditions and other factors affect stability and mobility.
  - Machine technical specifications, e.g. manufacturer's rope length, slope limits.
  - Economics vs. safety.
- Don't push or exceed the operator or machine limits. Recognise that some areas are not suitable for mechanical operations. Designate these as 'NO GO' Zones and develop an alternate harvest solution.

4. Identify hazards

Identifying site hazards and understanding the risks is a critical part of your work. Refer to the hazard and risk chapter that identifies winch-assist hazards.

5. Understand laws, regulations and standards

Understanding the legal requirements is critical. Consents and approvals may also be required. Laws and regulations include:

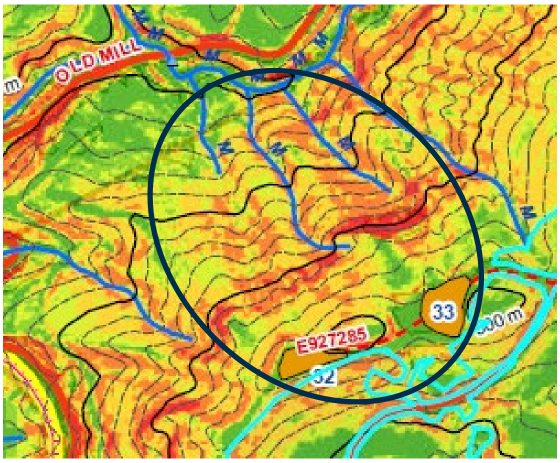
- The Health and Safety at Work Act (2015) and related regulations. They set out health and safety responsibilities and focus on managing work risk. It requires those who create the risk to manage the risk.
- The National Environmental Standards for Plantation Forestry (NES-PF). These forestry specific environmental regulations include harvesting, harvesting tracks and temporary river crossings. Most activities are permitted in low and moderate risk areas without consent if they comply with the permitted activity regulations. Part of that is having an earthworks and harvesting management plan available at the council's request.
- The Heritage New Zealand Pouhere Taonga Act for activities that could disturb or modify archaeological sites. Obtain an authority from Heritage New Zealand if you might damage, modify or destroy an archaeological site.
- The Approved Code of Practice for Safety and Health in Forest Operations (ACOP) provides guidance to undertake any forest activity.

6. Create the office plan

Work with the knowledge gained in the above five steps to develop a plan. This includes draft planning notes and maps. Use for the plan's field verification.

- Locate proposed roads and infrastructure.
- Identify what needs to go uphill rather than downhill, e.g. shovelling more than about a tree length uphill, is very challenging.
- Locate critical anchor and 'corridors'.
- Locate proposed harvesting trails.
- Determine if redirects are needed.
- Identify any possible winch-assist 'no-go' zones.
- Determine if any manual or hand-felling is needed and how this ties in with machine felling.
- Produce maps.
  - Harvest maps.
  - Slope maps useful for operators and preferably electronic. If paper, then at a scale matching the block's base data resolution, e.g. 1:5000 minimum scale, or prefered at 1:2500.
  - LiDAR maps.
  - Aspect maps, especially if this helps determine different soil moisture patterns.
- Identify the initial components of a hazard mgmt plan.

Walk the harvest block to identify hazards.



Use slope maps in conjunction with other mapping tools like LiDAR. The steepest section may limit the setting. For example, is this area a steep soil slope, or is it a rock bluff band?

The field verified plan

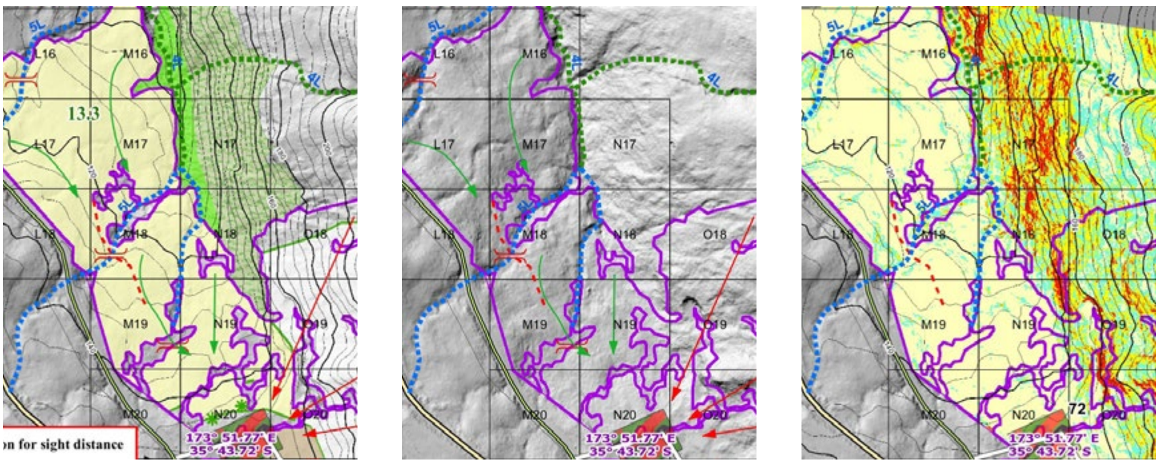
The office or 'paper' planning notes and maps needs field confirmation. The field plan needs to be site specific rather than general. There is no substitute for 'walking the block'.

Field verification should also incorporate ideas and suggestions from the supervisor, contractor and operator. Involving them helps make a better plan. They may not be able to come out with you, so give sufficient time for them to assess the plan and request any changes.

However, this is often not always possible as the layout may be several years before harvest, crew scheduling is not known, contractor equipment changes or the block is tendered.

Field check:

- Confirm if soil, geology, terrain and other site features match the plan's base information.
- Visit proposed landing, road and track locations and confirm these are acceptable.
- Agree that winch-assist is the prefered harvest method, and review the office plan.
- Confirm plan layout, e.g. how to harvest gullies.
- Walk challenging areas, especially those that could impact traction and stability, e.g. poor or wet soils, bluffs or rocky areas.
- Decide on any NO GO zones, and how to manage these.
- Visit and confirm identified hazards along with agreed control measures, e.g. steep faces, rockfall, fences, powerlines, houses, council roads. Additional safety plans may be needed, e.g. Temporary Traffic Control, Electrical Hazard Management Plan.
- Visit key terrain control points, e.g. anchor locations, redirect points.
- View restricted areas and discuss how these are managed, e.g. historic sites, ephemeral or permanent streams.
- Discuss ways to reduce environmental risk, e.g. erodible soils and damage caused by machines on steeper slopes.
- Confirm what maps to supply.



The harvest, hill shade and slope maps, along with the boundary between cable and groundbase provides an operator with valuable information. The maps are also on the operator's cellphone and GPS located.

If the contractor is known, get their advice as they are experts.

Pre-harvest planning

The pre-harvest meeting and sign-off operationalises the plan. The meeting is generally between the forest and the harvesting company.

It typically involves the harvesting manager or supervisor and the contractor. Any changes going forward need to be justified and approved.

Harvest plan meeting and sign-off

The pre-harvest sign-off is a formal agreement around how the block is harvested. It is also a legal requirement under the HSWA section 34 duties to consult, co-operate and coordinate activities. Section 2.4.4 of the ACOP covers the principal's duties on identifying and jointly determining measures to control site specific hazards. The meeting will go through the harvest plan and maps, specific plan requirements, stand information and site hazards. The specifics differ between companies. Both parties must agree on the plan.

Sign-off is simplified if the contractor has been involved in the field verification of the harvest plan. There should already be an agreement on most aspects of the job. Where they have not been involved in the planning, follow the steps identified in the field verification process above. If necessary, refine the plan.

Give maps to the contractor, foreman and operator that show essential information for their jobs. These should be at the scale they want. Electronic maps are most useful. These incorporate into phones or tablets apps with a GPS location, e.g. Avenza. Make sure operators understand the maps.

Decide or confirm operational aspects like how to open up the block and hazard management. Confirm the machinery and crew skills are suitable for the plan.

Get all the information and maps you need to help make good operational decisions.

Ensure you've been involved in the overall planning.

Contractor felling plan sign-off

The harvest plan shows WHAT needs felling. The felling plan describes HOW it is felled. Best practice is to mark up features of the felling plan on a suitable map, e.g. a slope or contour map at a scale of 1:5,000.

The contractor needs to decide how the block is felled, like anchor locations and main corridors. They need to consider:

- Terrain, e.g. soil, steepness, and gullies.
- Trees, e.g. volume, stocking, piece size, and tree lean.
- Machine or operator capability issues, e.g. under training, give easier areas.
- Felling method. In mixed method felling, the order of hand felling is a key consideration.
- Hazards.
- NO GO zones or protected areas, e.g. waterways, native vegetation, bluffs.
- Block adjacency or neighbour issues, e.g. roads, powerlines, fences.
- Road closure or traffic management requirements.
- 'Wet' and 'dry' weather options.
- Shared boundaries with adjacent harvesting operations.

Planning during operations

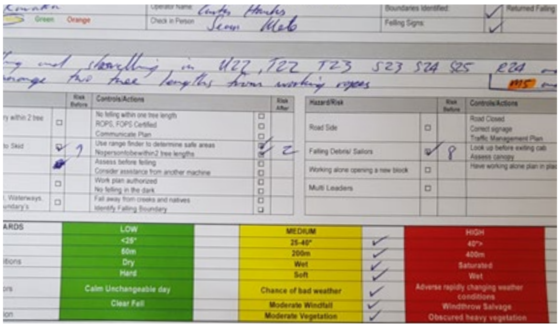
Day-to-day planning during the job is essential. Think ahead.

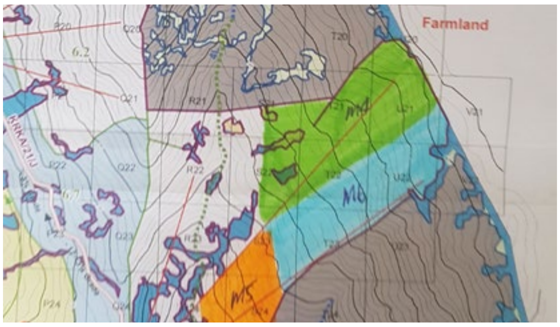
Plan for the day

- Ensure everyone knows the day-to-day plan. Have tailgate meetings to discuss and agree on the plan. Get everyone to confirm their understanding by signing the meeting record.
- Discuss safety, environment, production and other important information:
  - Harvest changes that could affect machine operations, e.g anchor shifts, lead angles, or rope redirects.
  - Any situations or challenges that apply to the current day, e.g. traffic management, or interaction between different parts of the operation.
  - Hazards and their controls.
  - Machine and rigging inspection, maintenance and servicing.
  - An alternative plan if conditions change, e.g. rain, or wind.
  - Operators understand when to call for assistance and when to suspend work.
  - Emergency response procedures.
  - Check everyone is fit for work and if there's anything that could affect the job. See the operator and crew chapter.

FISC has detailed information that helps prepare for daily crew meetings.

safetree.nz/resources/tailgate-resources/





Examples of a felling plan map and daily plan

Stop felling if hazards can't be managed as planned.

Always have a Plan B in case things don't go according to the plan.
Consider alternatives to mech felling on challenging sites including hand felling, delayed felling, pull over with the yarder ropes, or leave standing.

Operational coordination

Clear operational coordination is critical. This could come from the harvesting PCBU, the woodlot manager, or the woodlot owner. They visit the operation to make sure harvesting is according to the plan.

Three additional important tasks are to:

- Ensure production pressure isn't compromising safety and environmental standards.
- Keep current on conditions at the worksite, e.g. machine breakdowns, staff changes, new equipment, and production factors.
- Work with the harvest planner and the contractor to ensure any plan changes are agreed upon and signed off.

Post-harvest review of the planning

Reviewing the job after completion is a great way to incorporate learning into future operations. The planner and contractor should assess the block and discuss what worked and didn't and how planning and layout can be improved going forward.

Planning responsibilities

Harvest planners must:

1. Plan all blocks and thoroughly field verify.
2. Involve the contractor in the planning process.
3. Understand the crew and machinery capability.
4. Meet and sign-off the plan before work starts.
5. Provide useful planning notes and maps.
6. Learn from each job to improve the plan's quality.

Contractors must:

1. Plan ahead.
2. Every day have a crew pre-start meeting to discuss and agree on the day's plan.
3. Make sure everyone knows their part.

Supervisors must:

1. Make sure the plan is followed.
2. Approve modifying the plan when there are good reasons.
3. Monitor the work.

Operators must:

1. Follow the plan, suggest and get confirmation of plan changes.

Chapter 12

Machine and rigging inspection, servicing and maintenance

In this chapter you'll find out about:

- ✓ Regular inspections for:
  - Winch-assist machine.
  - Supported machine.
  - Ropes and connectors.
  - Non-winch-assist machine anchor.
- ✓ Servicing, including annual inspections.
- ✓ Guidance to help safely undertake repairs and maintenance.

This chapter provides an overview of general inspection, servicing and maintenance for the winch, the steep slope machine (harvester, forwarder, skidder) and rigging. Irrespective of the machine's brand, the chapter highlights the important things to check. There's a significant risk for the machine operator if a system failure occurs. Also, machinery damage is often expensive and time consuming to fix.

There are three ways the machine can fail and any of the three can create significant hazards. These can be structural, mechanical, and control element failures.

Structural components don't move. Mechanical ones move, e.g. they rotate, extend, retract. Control elements are the devices and systems that cause the mechanical parts to start, stop, change speed or direction.

It is best practice for the operator to be familiar with safety critical elements and for the machine owner to oversee and support regular inspection, service and maintenance of these.

Note: The guidance does not replace the Original Equipment Manufacturers' (OEM) requirements and recommendations. If in doubt always refer to OEM manuals, guides and induction materials.

Regular Inspections

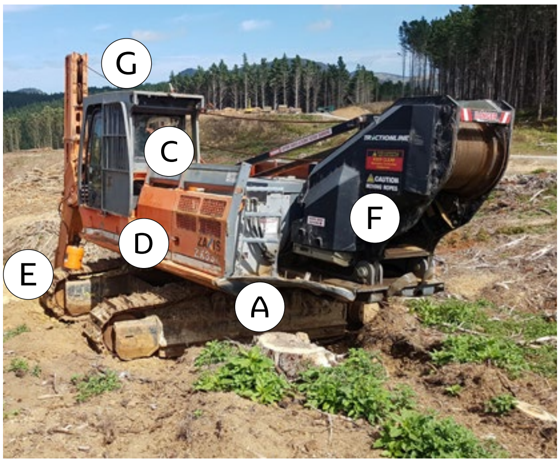
Winch-anchor machine

The winch machine should be checked daily. The things to check will depend on the type of WAM and the manufacturer's requirements, e.g. anchor winch or winch on the steep slope machine.

Look carefully, especially in areas that are subject to:

- Wear and tear.
- Changing forces and tensions.
- Areas that are known to need maintenance.

On the following pages, photos show examples of components that should be regularly inspected.



A No fluid leaks

B Fairlead rollers

C Electronics working

D Fuel and oil levels OK

E Anchored and braked?

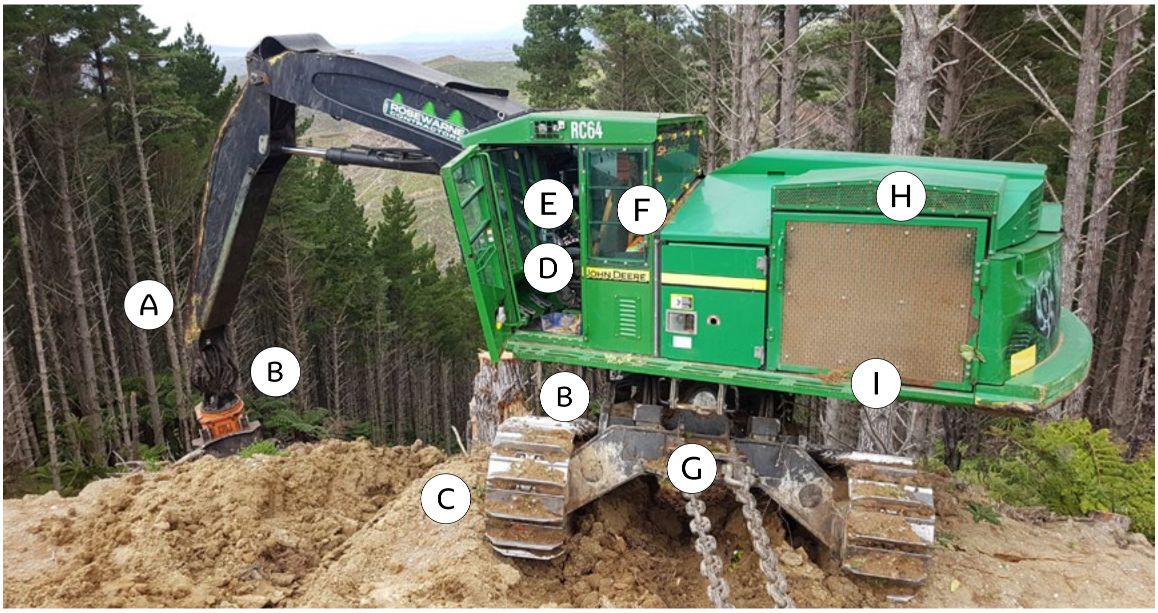
F Winch mounts/ attachment points OK

G Tower/guides/ sheaves

Also:

- No metal or hose cracks.

Steep Slope Harvester (Harvester, Forwarder, Skidder)



A Boom and attachment OK

B No fluid leaks

C Track gear good

D Controls working OK

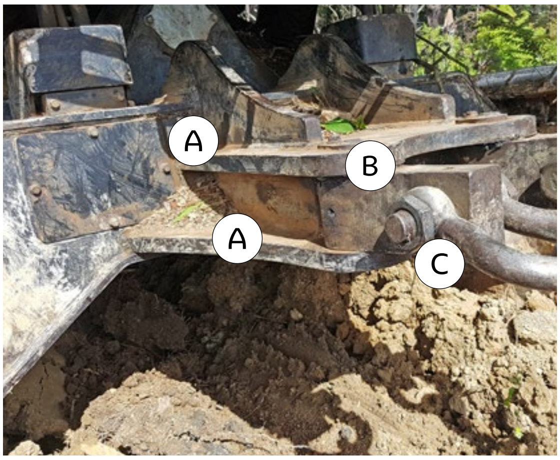
E Electronics working, e.g. radio, remote control system

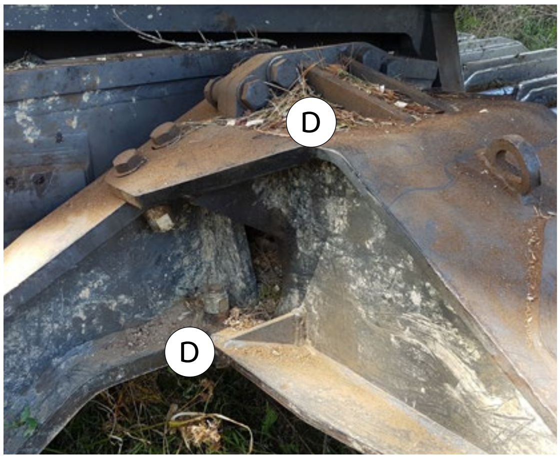
F Windscreens clean?

G Winch mounts/ attachment points OK

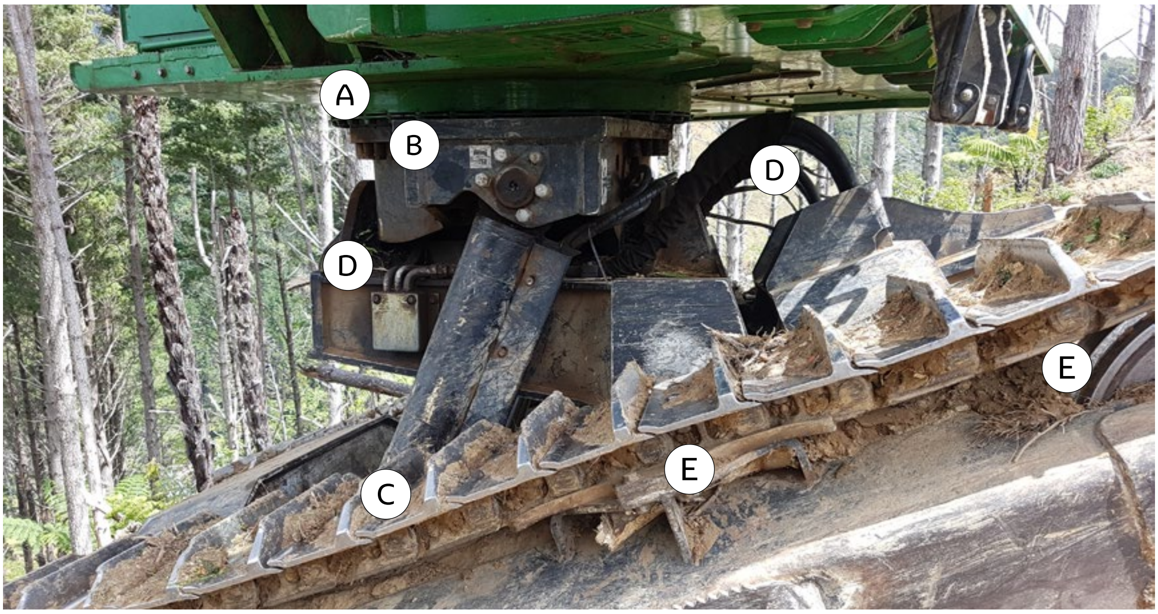
H Fuel, oil and water levels OK

I No guarding damage





- A Winch-assist attachment welds no cracks
- B Pivots pins no cracks and greased
- C Shackle has grommet of bolt, shackle wear OK
- D All winch mounting bolts tight and not sheared off



- A Slew bearing OK (noise, play, etc.)
- B Turret bolts tight and none snapped
- C Grousers OK
- D No fluid leaks, hydraulics
- E Rollers, sprockets and idlers all good?

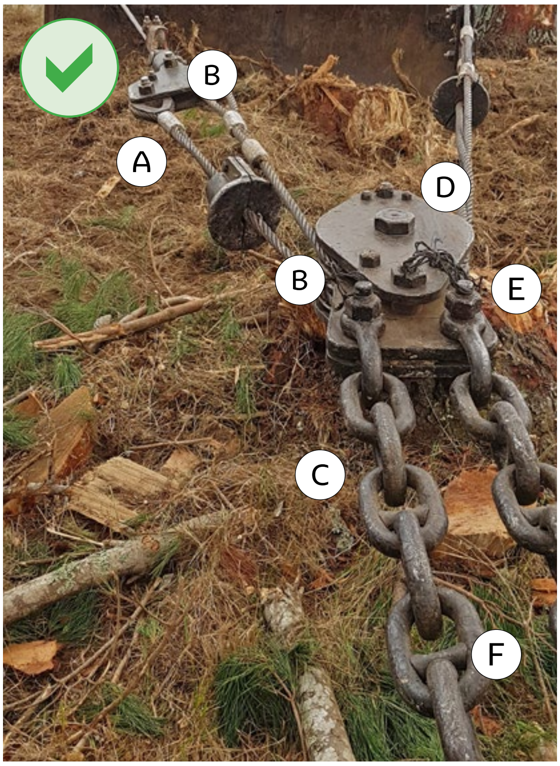
Connectors

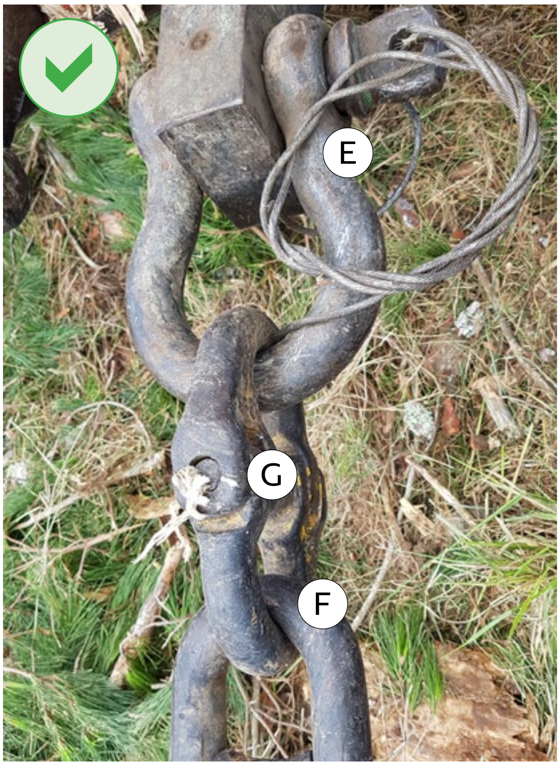
Thoroughly check the rope connection points, fasteners, chain, shackles, and hammerlocks. Rigging wears out over time. Make sure that all parts in the tether system still meet the manufacturer's tolerances. The type and amount of rope and rigging wear and tear will vary depending on the location, terrain, and soil types. Specifics around wire rope are discussed in a later section.

Daily inspect every connector and wire rope attachment point for wear or damage:

- Inspect the chain regularly for wear or damage, e.g. measure the chain's length and the links hole diameters to check for stretch using a simple gauge. Replace the chain if it appears worn, damaged, or stretched beyond the manufacturer's recommended limits.
- Inspect the wire rope connectors for surface wear, nicks, cuts, broken wires. Replace accordingly. Some types of cable, e.g. swaged, may appear fine when they are worn out, so know the wire's characteristics.
- Keep a list of all rigging components, their breaking loads and deployment date.

Stop work and check connectors and rigging if a stress event or damage occurs. Assess, and replace the component immediately, if necessary.





A Ferrules good?

B Other connectors in good condition?

C Chain bridle good?

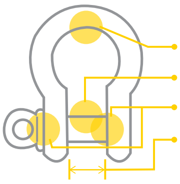
D Blocks OK

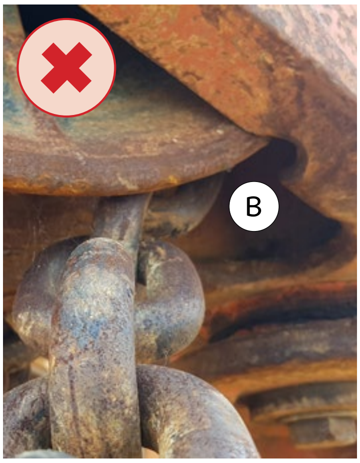
E Shackles with grommets or bolts, wear OK?

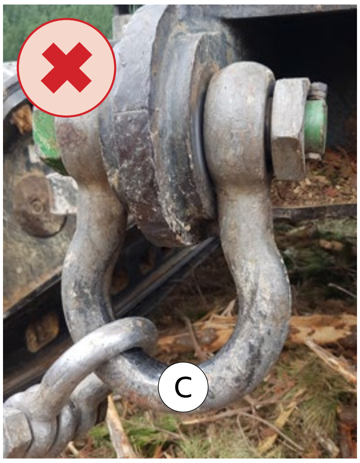
F Chain wear OK? Stretched, worn, bent or gorged out?

G Hammerlock good?

Never replace a shackle pin with a bolt. It will bend.







A Hammerlock worn by rubbing against machine. This happens when going to flatter slopes below steeper ones

B Excavator anchor fairlead shows significant wear caused by a rope riding off the sheave

C Shackle is worn here but elsewhere too?

End Connector Inspection

Some common types of end connectors:

These connectors should be installed correctly and in good working condition. Make sure to inspect pressed eyes, thimbles, ferrules and other metal components for excessive abrasion and fatigue cracks. The following are best practice guidelines examples for correctly installing end connectors:

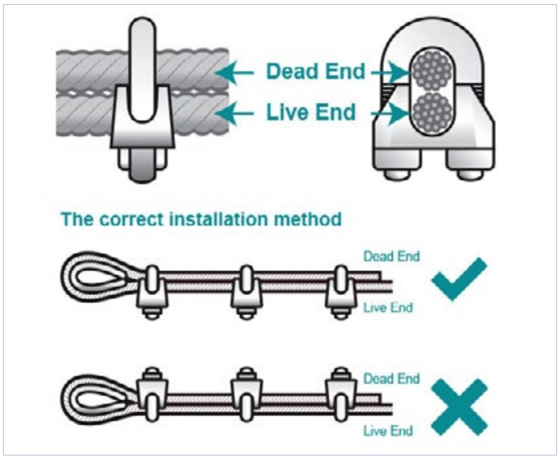
Loggers eye splice

A loggers eye splice should be tucked three times on one side and two on the other (ACOP, 2012)

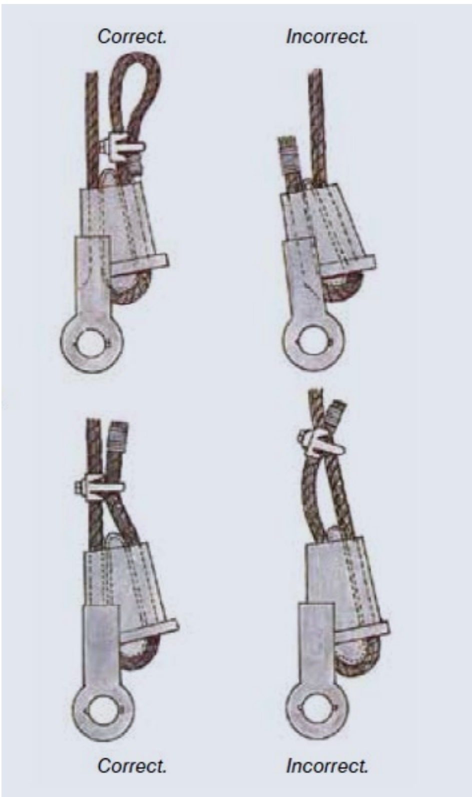
Split wedge ferrules

The strands of wire rope should protrude roughly 1/4" past the top of the wedge button. Once the first load is applied, the wedge will seal firmly into the wedge button.

Wedged sockets and Cable Clips



Remember the saying "Never saddle a dead horse!"



Wire Rope Inspections

What causes wire rope failure?

Ropes can fail through abrasion, tensile overload, and temperature damage.

1. Abrasion occurs when the rope rubs an external source like a rock outcrop, a different section of the rope, or a component of the rigging.
2. Tensile overload occurs when the rope experiences an axial load that overwhelms its strength. The result may be a loss of rope strength or even rope failure.
3. Wire rope can also be damaged by exposure to extreme temperatures, which can occur when the rope rubs against trees or stumps during operations.

How to extend a rope's life

Reduce or eliminate the three points listed above that shorten a rope's life.

1. Abrasion damage

- Avoid running the rope on the ground, over rocks, or around sharp bends.
- Use a heavy-duty chain segment near the harvesting machine and in other high-wear areas.
- Move the anchor or anchor machine as needed to prevent cable contact at ground breaks.
- Before every use, inspect the wire rope for surface wear, nicks, cuts, broken wires, or changes in diameter.
- Take care when lifting/repositioning wire rope. Use mechanical attachments to grab a chain segment rather than the rope.
- Don't run over the rope with wheels or tracks.

2. Tensile overload

- Working tension affects rope life. Use a tension monitoring and recording system. Review tension log data daily, and whenever shock loading is known or suspected to have occurred.
- Avoid loading or shockloading the rope, or the weakest rigging link, above the safe working load specified by the manufacturer.
- Cease operations and replace the rope if tension ever exceeds the elastic limit. If tension exceeds the rope's endurance limit, its lifespan is reduced.

3. Temperature

- Heat affects rope strength. For IWRC wire rope, temperatures over 93°C reduces the rope's strength.
- Look for wood charring where the rope has contacted a tree or stump. Charring occurs at 120 to 150°C.

Who should inspect wire rope?

A competent person needs to inspect a rope. They consider the different types of deterioration and assess the 'combined effect' of the wear on the rope. This requires knowledge and experience.

When to inspect a rope

Use the rope manufacturer's recommendation for rope inspections and discard requirements, e.g. Some manufacturers recommend end for ending rope after 1000 hours and replacing rope after 2000 hours.

Otherwise:

- Inspect the rope's working length monthly, or at minimum of every 500 hours, unless there is a reason to do it before that.
- ISO 4309:2017 provides useful recommendations on rope care, maintenance, inspection, and discard criteria.
- Inspect ropes and connectors after an incident involving visible damage to the rope or suspected shock loading above Safe Working Limit (SWL).

Check the rope thoroughly. If you are unsure about something, get a second opinion.

Joining splices should not be used to join broken or damaged winch ropes.

What to look for, and when to discard?

If significant changes in a rope's condition are seen, the rope may need replacing. If the damaged section is near the working end, it may be possible to remove the damaged section. This shortens the working length of the rope.

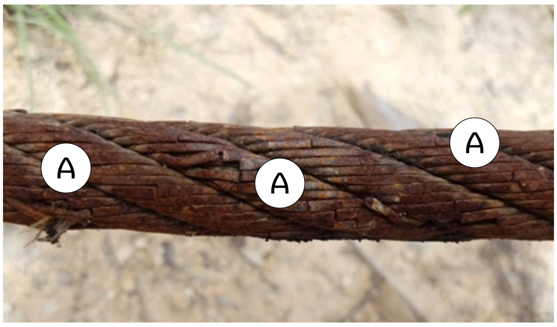
The ISO 4309-2017 document explains in detail rope inspection and when to discard. Always inspect a rope with the tension off. If you see breaks on the outside, there will usually be more broken on the inside.

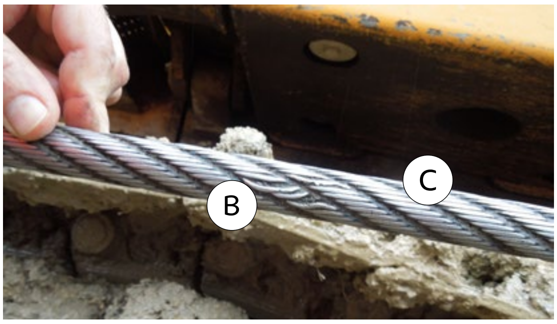
The 9 key points of ISO's discard criteria are:

1. Randomly distributed visible broken wires and valley wire breaks.
2. Local groups of visible broken wires.
3. Visible broken wires near the rope termination.
4. Local decrease in diameter (core failure).
5. Uniform decrease in diameter (wear).
6. Internal corrosion.
7. External corrosion.
8. Deformations.
9. Thermal damage.

Replace ropes if there are concerns. Visual inspection only shows the condition of the outer wires, only 20% of the rope's area. A marlinspike helps see more, but for only small sections.

Always consider swapping the rope out sooner than later to give it a second life in a less safety critical work area.



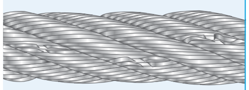
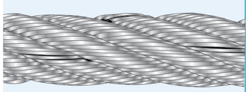
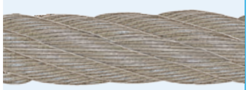


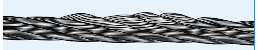
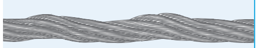
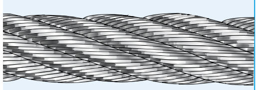
A Randomly distributed visible broken wire

B Local group of visibly broken wires

C External wear

Below are some common defects and their discard criteria as outlined in ISO 4309:

DEFECT	DISCARD CRITERIA
 Breaks: crown wire	Discard or remove section if: • 6 or more randomly occurring wire breaks are found over a lay length, or • 3 or more breaks occur in a single strand in one lay, or • 2 or more wire breaks occur at termination points.
 Breaks: valley wire	Discard or remove section if: • 2 or more valley wire breaks occur over a lay length, or • 2 or more wire breaks occur at termination points.
 Corrosion	Discard rope if wire surface is heavily pitted and slack, and corrosion cannot be wiped away. Perform internal inspection if signs of internal corrosion (such as corrosion debris exuding from between strands) are visible. Discard if internal corrosion is confirmed.

DEFECT	DISCARD CRITERIA
 Flattened portion	Flattened portions wear more quickly. Inspect them more frequently for broken wires and corrosion damage.
 Changes in rope diameter	Discard the rope or remove the section if there is an obvious localized decrease in diameter caused by failure of a core or rope centre, or by a sunken strand. When non-localized changes in diameter are found, discard the rope if the changes in diameter exceed 7.5% of nominal diameter.
 Waviness	Discard the rope or remove the section if the gap (g) between the underside of the rope and a straightedge is 1/10 of rope diameter (d) or greater.
 External wear	External wear will cause the diameter to decrease and will result in broken wires. See discard criteria for wire breaks and changes in diameter, above.

Source: FPInnovations 2017, "Wire rope integrity in winch-assisted harvesting operations"

Magnetic Rope Test (MRT)

The ISO 4309:2017 standard describes the Magnetic Rope Test (MRT). MRT is a non-destructive test that examines the rope both inside and out. The MRT machine looks at the whole rope cross-section, including broken external wires.

Because of operating conditions, an MRT is problematic for tether ropes.

MRT is better suited for rope that run off the ground, e.g. on gondolas and ski lifts.

A thorough and regular visual inspection is best suited to forestry applications. If done well, the inspection can identify vulnerable sections of rope. Typically, these sections have suffered abrasion, tensile overload, or friction (temperature) induced fatigue.

Servicing

The following advice should be followed:

- The anchor and the steep slope harvesting machine must be serviced according to the Original Equipment Manufacturer's (OEM) specifications, recommendations or instructions.
- The machine owner is responsible for ensuring specified components are replaced in accordance with manufacturer's recommendations.
- All sensors, alarms, and controls fitted by the manufacturer must be monitored and in working condition.
- Structural repairs or modifications must be approved by the OEM or their local representative and may require inspection and approval by a certified professional engineer. This includes repair to an operator protective structure.
- The machine owner should keep servicing records.

Manufacturers recommend doing a pull test before starting work and after completing daily checks, and hitching is done. Refer to your operator manual for instructions, including tension pre-sets and instrumentation to monitor.

The inspection form below gives an example of a regular weekly or monthly check. Manufacturers will often provide their own inspection forms.

OPERATOR DAILY / MONTHLY CHECKS			
Date: __________ Machine Model: ___________ Machine Hours: ________ Winch Hours: ________	Daily (8 hrs)	Monthly (160 hrs)	Notes
Independent or integrated Winch Machine			
Rollers and Sheaves (check for movement, wear, damage)	○		
Rollers and Sheaves (grease)	○		
Sheaves (check for damage cause by lead angle rub)	○		
Tension monitor (visual check that rollers are turning)	○		
Winch Mountings (visual inspection of bolts and/or weld integrity)	○		
Fairlead and Boom (wear, damage, cracks, loose bolts)		○	
Fluids – Check all oils, water and fuel levels. Check for leaks (hoses, pipes and tanks)	○		
Grease / Lubricate points (as per Manufacturer's instructions)	○		
Electronics/Software (Various prestart checks and warning features checked)	○		
Movement sensor check (attachment points and cable tightness). Pull the lanyard to active the anchor/ motion switch, the warning sign should be activated on the main screens in the machine cab	○		
Supported Machine (Harvester, Forwarder, Skidder)			
Drawbar (check for wear, cracks and that pins are in correctly)	○		
Drawbar (winch mounting bolts tight and not sheared off)	○		
Fluids – Check all oils, water and fuel levels. Check for leaks (hoses, pipes and tanks)	○		
Operator Protection (in good condition)	○		
Electronics/Software – Various prestart checks and warning features checked	○		
Fuel, oil and water levels OK	○		

OPERATOR DAILY / MONTHLY CHECKS			
Date: __________ Machine Model: __________ Machine Hours: ________ Winch Hours: ________	Daily (8 hrs)	Monthly (160 hrs)	Notes
Slew bearing OK (noise, play etc.)		O	
Turret bolts tight and none snapped)		O	
Emergency exits functioning		O	
Ropes and Connectors			
Hammerlocks (check for wear and cracks and check that pins are in correctly)	O		
Shackles (visually check for cracks or galling on pins and grease)	O		
Wedge Socket (visually check pins for wear, cracks, and galling – change if necessary)	O		
Wedge socket (suggest cutting 50cm off rope as internal defects difficult to identify, refit, clip)		O	
Stud Link Chain (visually check for cracks, bad nicks or cracks or damage from grapples or hot saw chains – change if any major defects	O		
Rope (check for wear around connectors)	O		
Rope (zero the rope distance counter)	O		
Rope (visual inspection of working length)		O	
Other End Connectors (check for wear and tear)	O		
Non-WAM Anchors			
Deadman (4m deep, 5m long and > 50cm diameter, in-lead)	O		
Stumps (fresh, >50cm or multiple stumps, strong soils, not excessively worn by rope or socketing due to tension)	O		
Stumps (movement monitor device if any potential concerns)	O		
Mobile Anchor (sufficient size/weight, blade in the ground, in-lead, (device employed to monitor movement)	O		

Note: For further guidance on non-winch-assist machine anchor types refer to the Cable Logging BPG and section 14.3 of the ACOP.

safetree.New Zealand/resources/best-practice-guidelines

Check your anchor, machine and rigging thoroughly. Don't take shortcuts and 'tick the boxes' with maintenance or service checks.

Annual Inspections

- All mobile plant with an integrated or attached winch system should have an initial annual inspection.
- The inspection can be in isolation or as part of warranty or a service agreement provided by the OEM.
- After the initial inspection, a documented inspection should be carried out every two years.
- If the OEM specifies components requiring more frequent calibration or checking, their requirement and recommended interval should be followed.
- A competent person familiar with the plant and systems should do inspections. A competent person could be:
  - The OEM or their local representative.
  - A qualified technician approved by your service agent.
  - A person with suitable product knowledge, e.g has specific PLC programming and technical knowledge.
  - A chartered professional engineer.
- The inspection should cover:
  - All mechanical aspects, e.g. winch mounting, brakes, sheaves, rollers and bearing condition.
  - Function tests of systems, e.g. the movement sensor, hydraulic and communication systems.
  - Alert systems, e.g. engine oil pressure, high temps, low hydraulic level).
- Use an inspection checklist provided by the OEM due to differences in machines and operating systems.
- The machine owner should provide previous servicing and inspection records to the person conducting the inspection.
- The machine owner should get a copy of the inspection result, including any recommended corrective actions.

Second-hand plant

If purchasing second-hand plant:

- Ensure that the machine's structural, mechanical, and control elements meet the same standards expected of new equipment.
- A competent persons should inspect the machine to assess that all safety and operational features are working as designed by the OEM.
- Once the inspection is completed, it is recommended future inspections meet the service and annual inspection requirements within this guide.
- Ask for servicing and inspection records, operating manuals and induction materials.

All secondhand bases converted to a WAM should undergo a "pre inspection" to ensure all safety and operational functions work as the OEM intended. Visually inspect and check:

- Hydraulic hoses and components.
- Mounting points and critical welds.
- Hydraulic bypass test on all cylinders.
- Leak tests on all cylinders.
- Measure play in all pins and bushings.
- ROPS, OPS, FOPS.

Second-hand plant generally changes hands on an "as is basis". This does not prevent the buyer or seller entering into an agreement regarding future warranties.

Repairs and Maintenance

Repair and maintenance need careful management otherwise there are serious risks including severe injuries.

Repairs and maintenance shouldn't need to be done on slope, only remedial work. It is always best if you can safely get the machine to level ground with nearest access possible for maintenance vehicles.

Major and minor repairs

Repairs should be identified as major or minor. A major repair must be done otherwise a part of the winch-assist system will fail. Minor repairs are important to fix, however, the problem will not directly cause a machine failure. Major work should be approved by the OEM or their local representative. Major changes are always major repairs and need signing off by a chartered professional engineer. Minor work is non-structural and does not change or alter any part of the winch system, e.g. replacing a damaged sheave.

Use a lockout system

The guide recommends using a lockout system that prevents machines or their energy sources from being accidentally turned on. Lockout is essential for operators and mechanics to safely and confidently work on machines.

Common steps include:

- Shut down machinery and ensure that a responsible person removes and maintains possession of the ignition/master key.
- Apply brakes, swing locks, etc.
- Place the transmission in the manufacturer's specified park position.
- Lower to the ground or secure each moving element like the booms, grapple, bucket, saws, to prevent a release of stored energy.
- Engage hydraulic safety locks when applicable.
- Relieve pressure on hydraulic or air systems by bleeding tanks or lines.
- Place lockout device.

Before the lockout device(s) are removed and the machinery started, check that the site is safe.

If the steep slope harvesting machine is being worked on down the slope, then the winch-assisted system needs to be locked out to eliminate the risk from the anchor machine. Make sure trees or debris on the uphill side of the machine are stable.

Energy is a hazard and comes in many forms. It could be electrical, pneumatic, hydraulic, mechanical and stored energy like heat. Isolate or remove all energy before starting maintenance.

Only work on the machine if it is stable, has zero energy, and it's locked out.

Repairing machines on unlevel ground
Sometimes machines cannot be repaired on level ground. Have a procedure or system to ensure the machine's stability before shutting down for remedial work or repair. This will create a consistent and safe approach to repairs.

This should include:

- Ensuring all parts of the machine have zero energy before starting work.
- Having the winch wire anchored.
- Putting the blade down (where applicable) or the boom/arm lowered with all attachments on the ground in a safe state.
- No lose debris upslope of the machine that could come down.
- Operator or mechanic safety, e.g. access to a harness if working on top of machine, or suitable guarding / fall protection installed.

The following accidents have occurred doing R&M on harvesting machinery:

- Arm became trapped in processor.
- Technician crushed and fatality injured during repairs to a logging processor head.
- Hose blew off just missing my head.
- Slips, trips and falls off cabs, tracks, and other machine parts.
- Crushed fingers.

Six key safety considerations for machinery repairs
The following table is a guide to safely work on machines.

	Six key safety considerations for machinery repairs	Responsibility
PREVENTION CONTROLS	SKILLS and COMPETENCY and TOOLS and RESOURCES	
	Worker has the skill set and experience to do this job correctly and safely.	Operator
	Correct tools and operator manuals are available.	Foreman, Operator
	PPE (e.g. gloves, eyewear) is available and worn.	Operator
	A suitably experienced person available to assist (if required).	Foreman
	External Service providers have received site access instructions (i.e. R/T Instruction or meet at gate) and contractor provides site induction.	Foreman, 3rd party
	TIME PRESSURE	
	If there likely to be a production impact, advise the foreman. This may need to be escalated to the forest owner/manager.	Operator, Foreman
	If the machine will be out of commission for an extended period, the foreman will ensure that any temporary manual work is planned, organised and undertaken by competent persons. Risks will be assessed and supervision provided (if necessary).	Foreman
	When testing a repair, keep body parts clear of nip / crush points. If multiple workers are assisting, every worker must be crystal clear about their role in the diagnostics / live check.	Operator, Mechanic
	WORK AREA	
	Raised objects must be appropriately supported. Ensure that no raised object can fall and crush any person assisting with or in the vicinity of the RandM task.	Operator
	Assess the work area for Falling objects. Ensure that no overhead hazard can fall on and injure any person assisting with or in the vicinity of the RandM task.	Operator
	Check that the machine is free of trip, slip, fall hazards.	Operator, Mechanic
	(Hydraulic fluid, diesel and oil leakage increase the chances of slipping on or falling from mobile plant or into moving parts).	Operator
	If there is a chance that another machine / vehicle will come into the work zone, Isolate (tape off) the work area.	Operator
	If the machine has broken down in an area difficult to access and repair, can it be recovered to a safer location before the repair is undertaken? Foreman is involved in any decision involving the recovery of a machine.	Foreman
	Weather conditions – if poor light, visibility fog, rain, dust, heat will affect your ability to complete the task safely, then delay the work until conditions are suitable.	Operator

	Six key safety considerations for machinery repairs	Responsibility
PREVENTION CONTROLS	**MOBILE PLANT AND EQUIPMENT PREPARATION**	
	If more than one person is involved in the task, 1 PERSON will take charge. That person will ensure each person clearly understands what is expected of them.	Operator
	The person doing the work knows how to engage the machine's lock-out / de-energise / disable features. Lockout prevents a machines or its energy sources being accidentally turned on. Lockout is essential for operators and mechanics to safely and confidently work on machines.	Operator, Mechanic
	Stored energy is released before starting the job (tension or fluid pressure). A sudden or unexpected release of hydraulic fluid release onto the body can result in severe injury including blood poisoning.	Operator
	Clothing or hair is not at risk of getting entangled.	Operator
	Important: Modern mobile plant may have as many as 5 energy systems to consider before starting RandM work (e.g. hydraulic, pneumatic (air), mechanical, electrical (incl computer) and heat. And always respect gravity!	
	SPECIFIC RISKS	
	Hot Work (e.g. welding, gas work) MUST be managed to prevent fire. Fire season requirements (including notification) are to be followed.	Operator, Foreman
	Smoking is an ignition source. No smoking while refueling or around petrol, diesel, or oil.	Operator
	Manual handling – if components or liquids > 25kg are being handled, share the load, break the load into small units or use another mechanical device to lift or assist.	Operator
	PREVENTATIVE MAINTENANCE	
	Daily Checks and Servicing are undertaken in accordance with manufacturer and company requirements.	Foreman, Worker, 3rd Party
RECOVERY	**WORKING ALONE**	
	If a worker is working alone, an effective call-in arrangement must in place. (e.g. includes weekend or after-hours work).	Foreman, Worker
	FIRST AID and EMERGENCY RESPONSE	
	Minor injuries (e.g. cuts / puncture wounds) must be treated with appropriate first aid to prevent infection.	First Aider, Worker
	In the event of an accident follow your emergency procedures. Review Emergency Procedures after an event (as part of the accident investigation).	Foreman, Worker

If Prevention Controls fail, it is critical that effective Recovery Controls are available to manage issues. Recovery controls are the things that manage an accident.

Appendix 1: References

BC Forest Safety (2015) *Slope Logging Resource Package – Assessing Risks and Planning, Mechanical Harvesting on Steep Slopes*. Version 4

FPInnovations (2018) *Winch-Assist Harvester: Best Practice Manual*. Special Paper SP-533

FPInnovations, Amishev, Hunt and Boswell (2019) *Best Management Practices For Winch-Assist Equipment Version 2*

FPInnovations, Steep Slope Initiative. (2017) *'Wire Rope Integrity In Winch-Assisted Harvesting Operations – A Guide To Wire Rope Handling And Inspection For Machine Operators*

Hancock Forest Management (2017) *Interim Best Practice Guideline – Cable Assisted Steep Slope Harvesting*

ISO 4309, *Cranes – Wire Ropes – Care and maintenance, inspection and discard* (2017 – Fifth edition)

Parker, FPInnovations (2017) *The Effect of Machine Position on Stability when Operating on Steep Slopes*. Tech report no. 60.

Pedofsky and Visser (2019) *Assessment of Winch-Assist Skidder In Gisborne, New Zealand*

Rayonier Matariki Forests (2020) *Safe System of Work Production Tree Felling (incl. Winch-Assisted)*. Version 2

Safetree (undated) *Steep slope risk assessment – Risk identification and assessment form*

Washington State Department of Labor & Industries, (2019) *Best Management and Operating Practices for Steep Slope Machine Logging*. Technical Report Number 98-02-2019

Worksafe NZ (2016) *Fact Sheet – Winch-Assisted Harvesting On Steep Slopes*

Visser, Rayonier Matariki report (2018) *Lead angle for Winch-Assist operations – a Review of Practices and Limits*

Visser, Raymond and Harrill (2014) 'Mechanised Steep Terrain Harvesting Options' *NZ Journal of Forestry, November 2014, Vol 59, No.3*

Visser (2019) *Steep Terrain and Winch-Assist Harvesting Workshop*

Appendix 2: Examples of steep slope risk assessments

A steep slope risk assessment document is a systematic system that both guides risk and mitigation of risk, as well as records that a formal risk assessment has been undertaken. Two examples are provided here. The second is a simplified version of the first.

Steep slope harvesting risk assessment[1]

This form is to be used in conjunction with the ACOP, the company safety plan, as well as the contractor's health and safety plan. It should be completed for a Harvest Setting when:

1. Any equipment is going to be operated on soils with low strength (e.g. very wet, or very loose) and on dominant slopes over 40% (22 deg), or
2. A crawler tractor, or a basic excavator base with grapple / felling/ processing head is going to be operated on dominant slopes over 40% (22 deg), or
3. Forestry equipment specifically designed for use on slopes (e.g. self-levellers; high and wide with custom grousers) is going to be operated on dominant slopes over 50% (27 deg).

The dominant slope for the harvest setting is ___ % / deg *(cross out unit that does not apply).*

Logging Contractor: ____ Date: ________

Forest / Compartment: ___________________ Harvest Area/ Landing: ____________

1 DRAFT developed by R. Visser (SOF, UC) and Wayne Dempster (Rayonier) March 2017 based on consideration of (a) the BC FSC Steep Slope Logging Resource Package, (b) the SafeTree Steep Slope Risk Assessment form, and (c) NZ operating conditions.

Practices and Controls:			
Compounding Steep Slope Risk Factors:			**If YES – what practice to eliminate or minimise risk is required:**
Unstable ground (e.g. fill slopes, slips, slumps) covering more than 25% of area.	YES	NO	
Ground roughness (e.g. boulders, rocky outcrops, depressions) covering more than 25% of area.	YES	NO	
Shallow soil over bedrock, or exposed areas of bedrock covering more than 25% of area.	YES	NO	
Wind-throw covering more than 25% of area.	YES	NO	
High stumps, and or deep slash that can interfere with machine operations.	YES	NO	
Large trees (i.e. > $3m^3$) that are difficult to handle on slope.	YES	NO	
List other risk factors:			
Mapping / Planning:			
Where feasible, are the above steep slope risks identified on the map?	YES	NO	
Are all areas over 40% (22 deg), 50% (27 deg) identified on the harvest planning map?	YES	NO	
Are contiguous areas > $800m^2$ over 100% (450) identified as machine no-go areas?	YES	NO	
Machines to Operate on Steep Slope:			
Description	**Will it be winch-assisted?**		**Features for working on steep slopes:** (e.g. tilting cab; extended grouses; extended tracks; chains or belts on wheels; telescoping boom)
1:	YES	NO	
2:	YES	NO	

Operator Training, Competency, Fatigue and Communication

Operators that will be operating under this risk assessment are:

(1) ____________________ (2) ____________________ (3) ____________________

Do the operator(s) have the correct unit standards to operate on the dominant slope identified for this harvest area?	YES	NO
Have the operator(s) been deemed competent to operate on the dominant slope identified for this harvest area?	YES	NO

Fatigue – In addition to the fatigue management plan, what steps are taken to ensure the operator will remain focussed on the task?

Isolation – Communication system (i.e. RT?) ______; Check-in with (name) ________ at a frequency of __ min.

Assistance – What equipment is available to assist the machine on slope in case of a breakdown or emergency?

Weather – The suitability of operating on steep slopes should be reconsidered after rainfall events, high winds or other adverse weather conditions. Who is responsible?

Site – Any site specific requirements and notes:

Signatures

This form is accurate to the best of my knowledge: ____

Date: _______________

Person completing risk assessment: ____

Operator Name: ____

Operator Name: ____

Foreman / Contractors (counter-sign if operator is assessor) ______________________________ safetree™ You are the key

Steep slope risk assessment

Risk identification and assessment form.

Forest owner:		Logging contractor:		Date:
Forest:		Compartment:		
Mean tree height:		Tree species:		

Steep slope risk assessment and identification table

RISKS	LOW RISK	MEDIUM RISK	HIGH RISK	Comments
Slope and slope length (tracked machine)	☐ 22° to 27° and slope length <50 metres	☐ 22° to 27° and slope length >50 metres	☐ >27° and slope length >10 metres	
Slope and slope length (wheeled machine)	☐ 19° to 24° and slope length <50 metres	☐ 19° to 24° and slope length >50 metres	☐ >24° and slope length >10 metres	
Terrain stability/ classification	☐ No instability indicators and slopes <27°	☐ Instability indicators and slopes <27°	☐ Slopes >27°	
Ground roughness: boulders, outcrops, depressions	☐ <17° of steep slope area covered by roughness features	☐ <17° to 27° of steep slope area covered by roughness features	☐ >27° of steep slope area covered by roughness features	
Soils	☐ Well drained (e.g. gravel, coarse sand)	☐ Moderately drained (fine sand, silt indicators of sub-surface flows)	☐ Poorly drained or staurated (clay, silt) high water table	
Soil depth	☐ >30 cm to bedrock	☐ 15 to 30 cm to bedrock	☐ Thin soil (less than 15 cm) or bedrock exposures	
Pre-existing and post harvest debris	☐ Open understory, not windthrow	☐ Moderate windthrow, understory, stumps <30 cm	☐ Heavy windthrow, understory, stumps >30 cm	
Human factors: State of mind	***Consider operator focus, alertness, understanding of plan and how to implement, confidence, stress level, physical and mental workplace distractions, well fed and well rested. AVOID complacency, fatigue, rushing***			
Risk ranking	☐	☐	☐	
Operator competency	*Does the operator have adequate training and experience to complete this work? Has the operator demonstrated successful operations using this machine on sites with similar attributes and timber?*			
Risk ranking	☐	☐	☐	
Duration of exposure	*How long will the operator be working on a specific steep slope site? Also consider shift length, number of consecutive shift days, etc...*			
Risk ranking	☐	☐	☐	
Worker isolation – time for assistance to reach operator	☐ <15 minutes	☐ 15 to 30 minutes	☐ >30 minutes	
Weather conditions	☐ Calm day, change unlikely	☐ Chance of changeable weather	☐ Adverse rapidly changeable weather	

4 ticks in high risk or 5 ticks in medium risk, results in a ***"NO GO SITUATION"*** unless additional measures are taken.

Manager/Contractor/Foreman:..**Signature:**..

Version control

Version Date	Changes Made	Reason For Changes
May 2022	Initial version	
August 2022	P.130 and P.132 including adding MRT	Update to cover ISO 4309-2017

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