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?

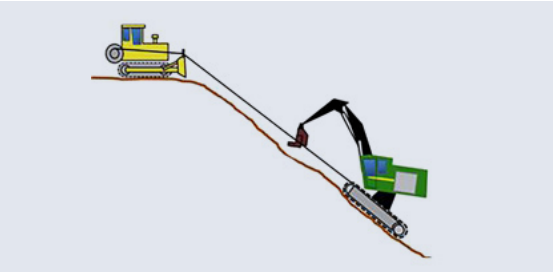
A winch is a powered geared drum that spools the wire rope. Winch systems can have different mechanisms for managing tension and power that aim to provide constant tension. The operator adjusts the winch settings. For example, some have the wire rope tensioned through constant hydraulic pressure or band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

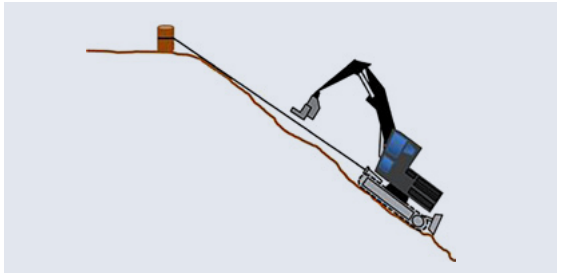
The advantage of the system is the:

- 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.

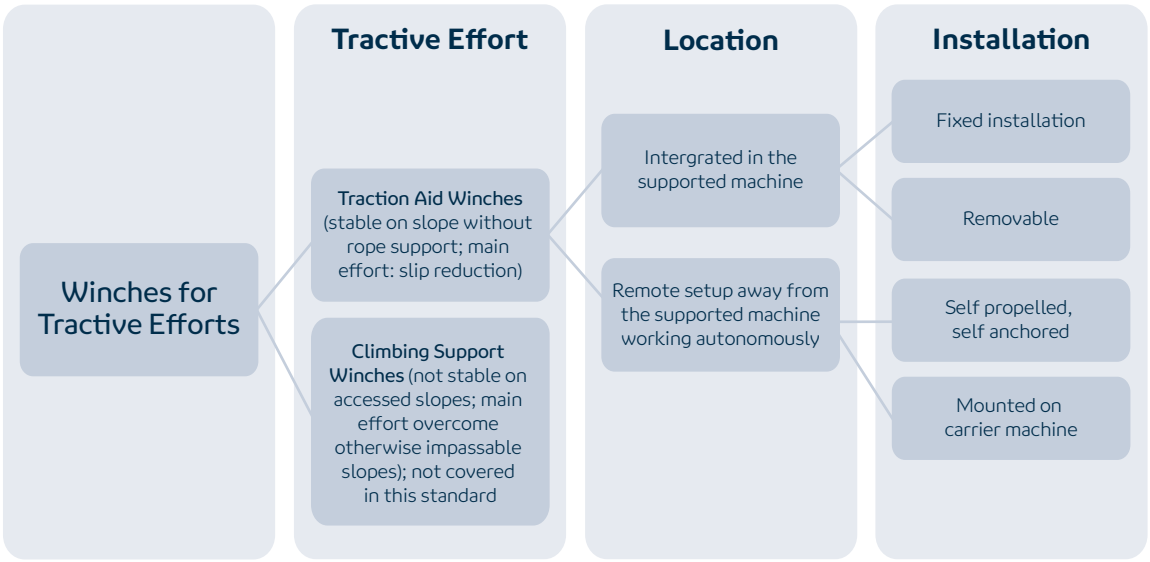
Examples of double rope systems. Left: EMS Tractionline. Right: The Remote Operated Bulldozer ROB.

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.

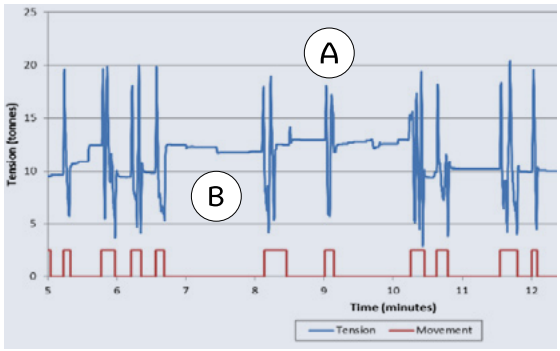
Many factors affect winch tensions

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**



A Spikes are from the machine moving
B Flat sections are the machine felling

Figure 1

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

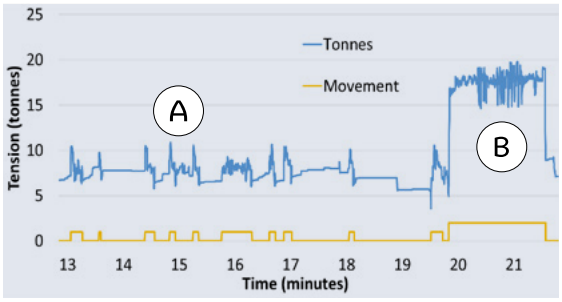


Figure 2

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.

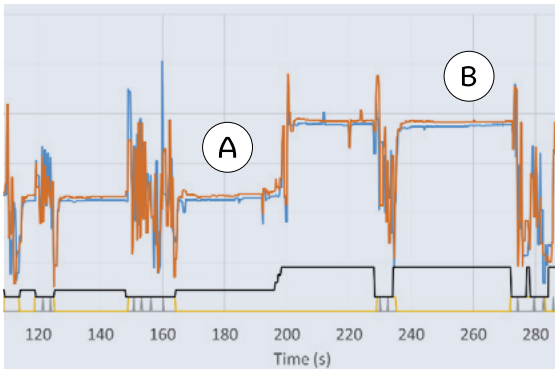
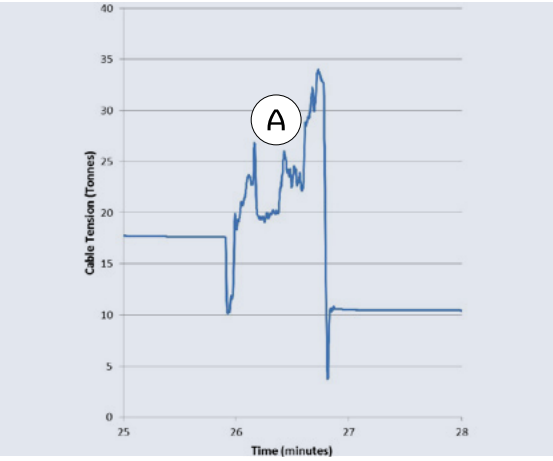


Figure 3

A Initial tension
B Operator increased winch tension

3. Extreme winch tensions do arise from operator errors



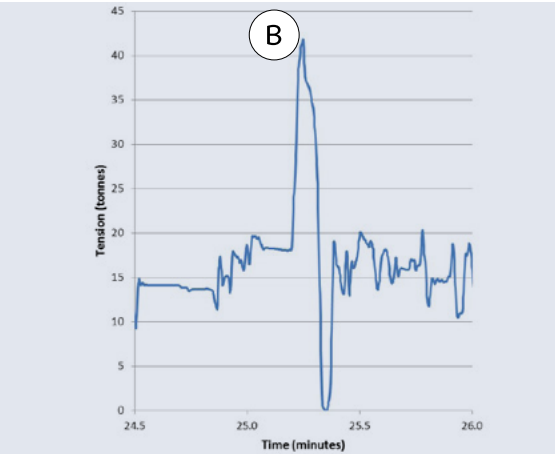


Figure 4 and Figure 5

A Machine 'stuck' behind an obstacle

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.

B Operator had brake on and drove down the hill

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.

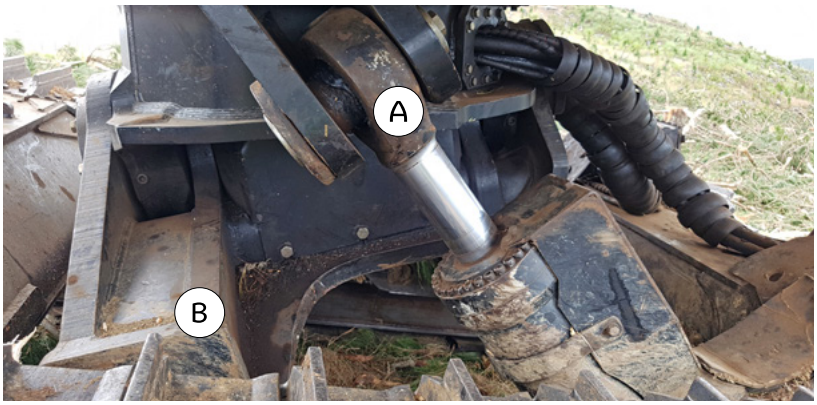
In these situations, sudden loss of traction and stability can occur.

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.

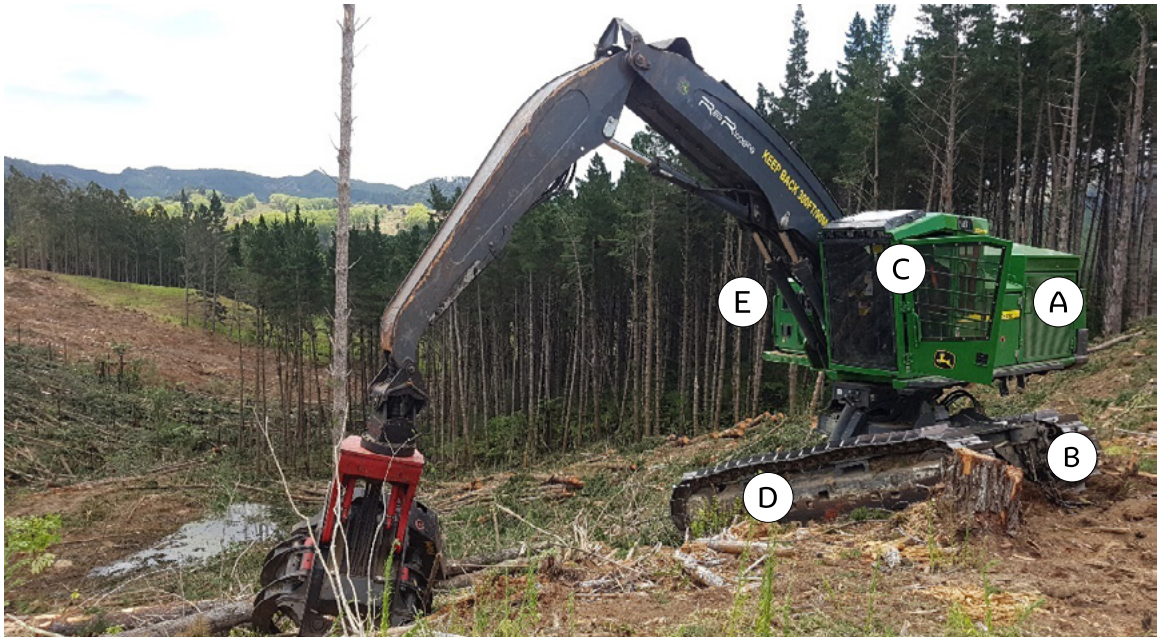


Hydraulic rams A and a pivot B levels the cab.

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.

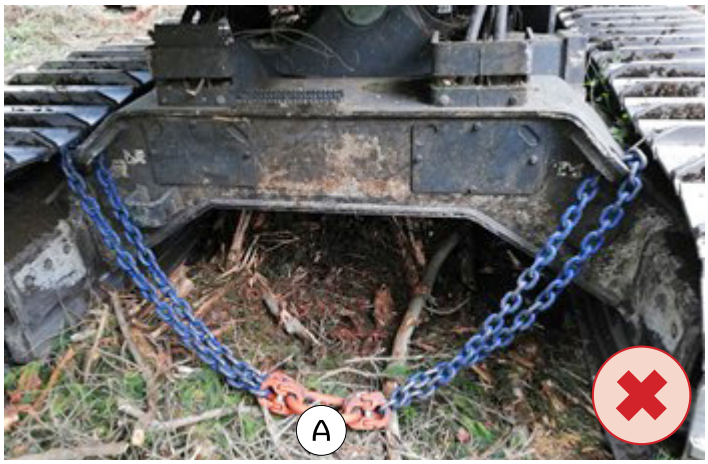
Machine attachment points

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

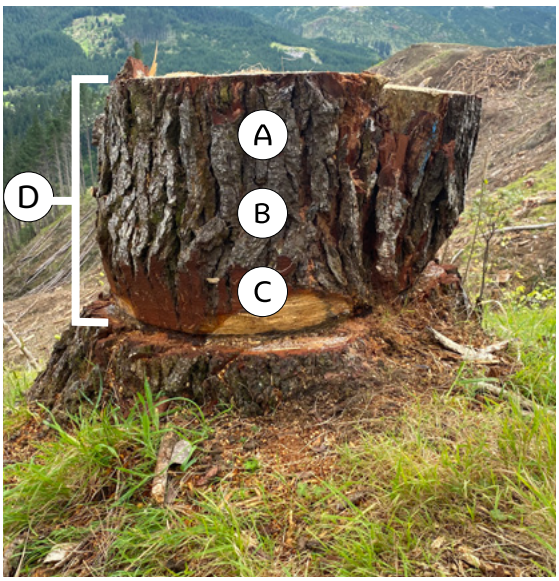
In this chapter you will find out:

- ✓ 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

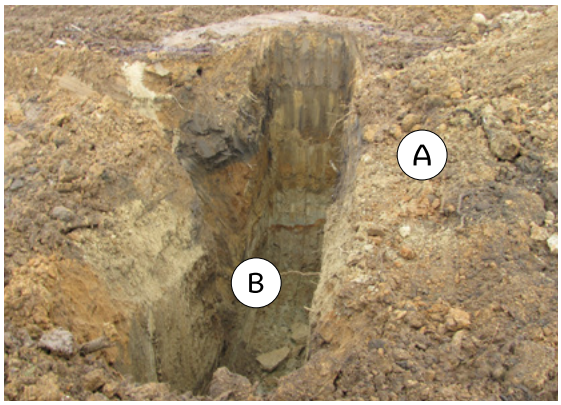
Also:

- A stump monitor alarm should be fitted.

Shock loading stumps can loosen or pull them out.

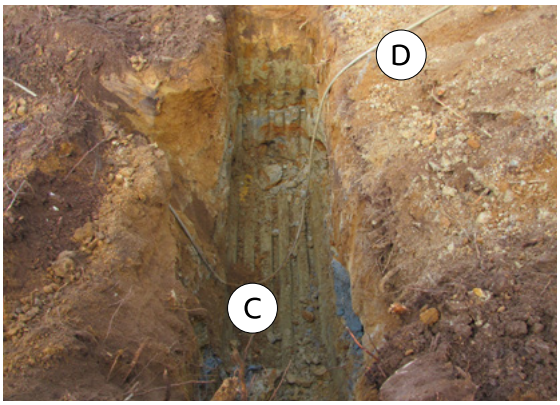
Deadmen

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.



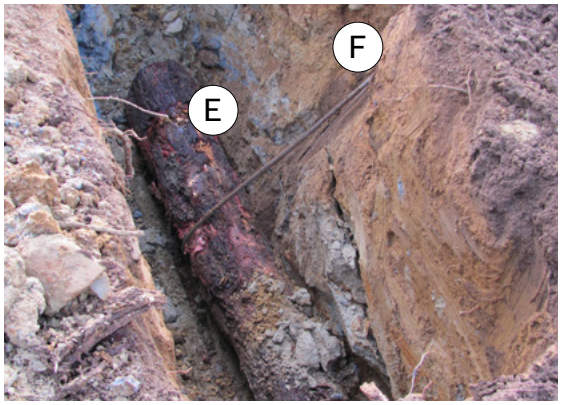
A Dig the trench at right angles to the pull

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



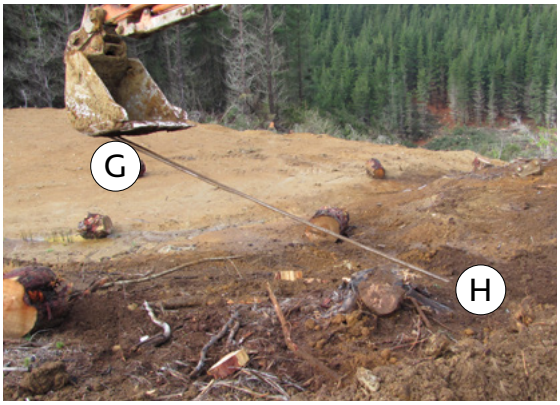
C Lay a strop in the trench

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:

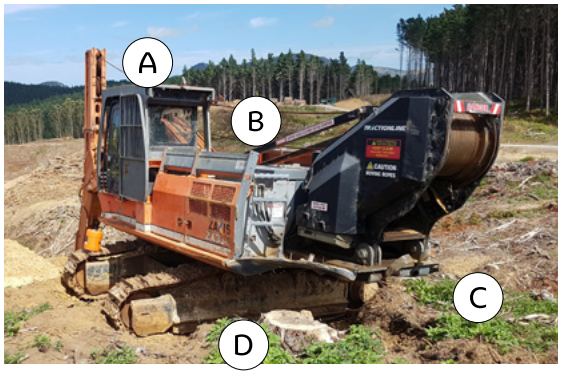
- Poor anchor positioning, including an anchor machine not on level ground and blade or bucket not dug in correctly.
- Weak soil strength.
- Overloading the anchor.
  - Anchors aren't strong enough.
  - SSH machine pulling from a too wide lead angle.
  - Shock loading from the steep slope harvesting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

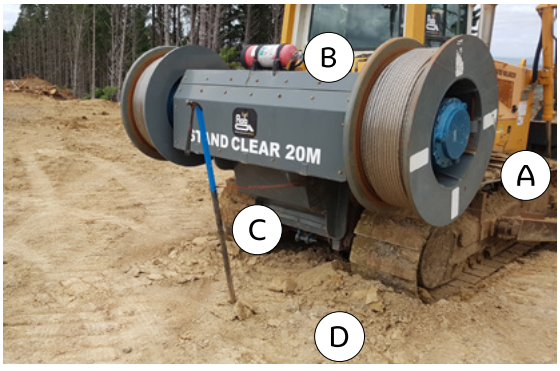
If the soil is weak, there are three common ways to strengthen the anchor:

- 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

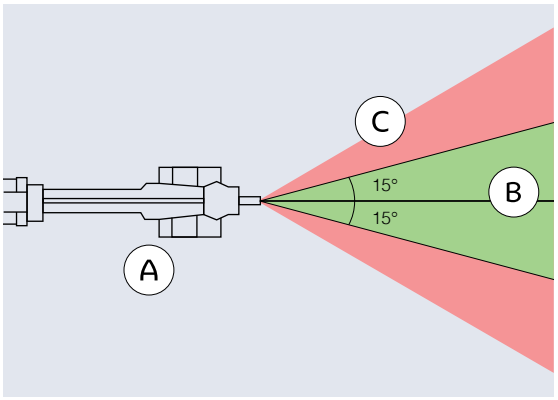
Machine anchors do move. Put the blade or bucket behind a stump. Check the anchor is holding each set up. Do a straight pull test.

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

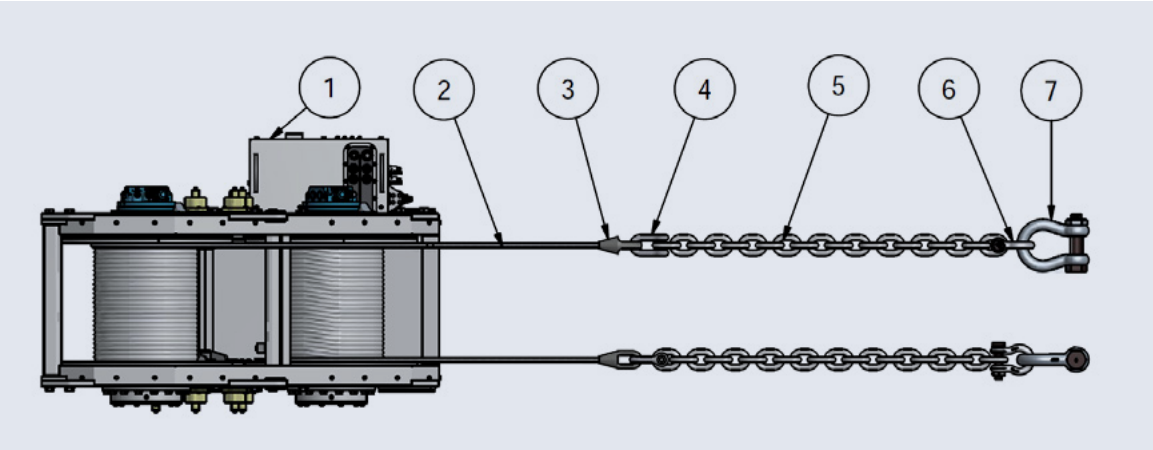
In this chapter you will find out:

- ✓ 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

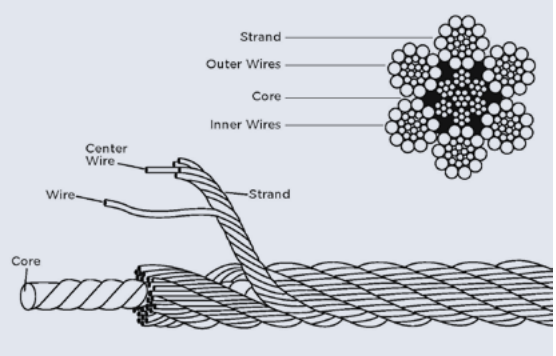
This section describes the basics around wire rope and guidance around its use. Chapter 11 covers wire rope inspections and maintenance.

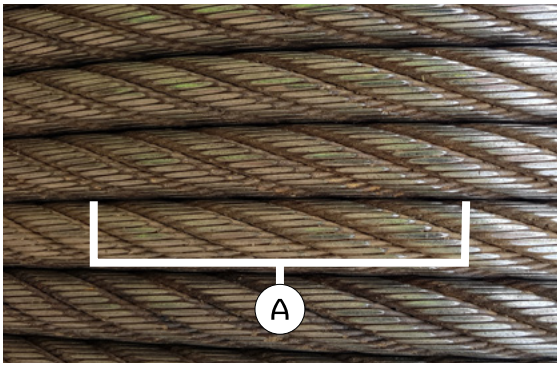
Nearly all 'wire rope failure' incidents are caused by failed end connectors, failure due to poor practice like overbending the rope, or equipment design problems.

Parts of a wire rope

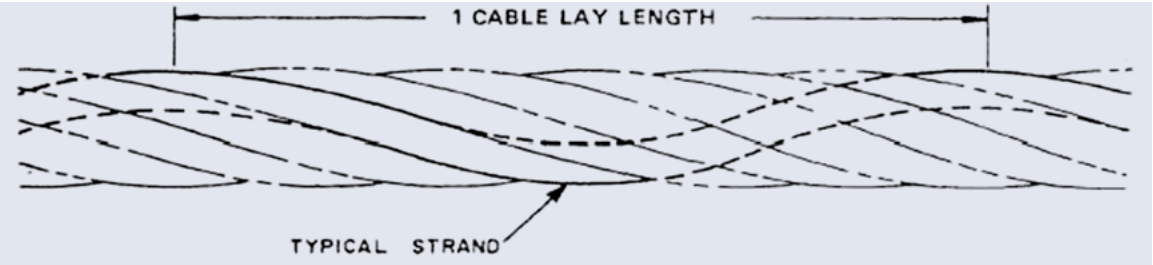
A rope consists of individual wires twisted into strands. These preformed strands are then twisted around the core to complete the rope.

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.

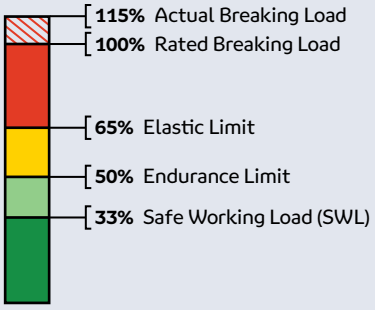
Use the manufacturer's specified rope.

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.



SWL = Breaking load / 3

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.

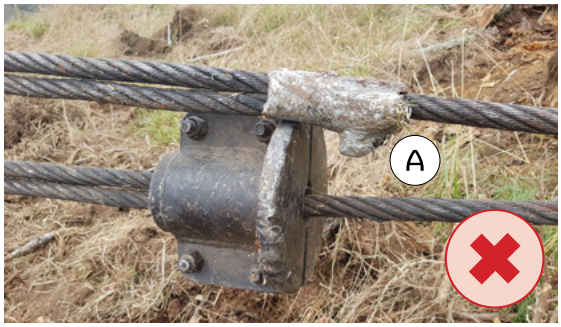
Beware of shock loading or dragging a cable over rock.

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.

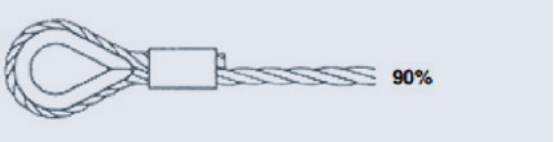
However, the spliced eye is not the strongest connector (~80% efficiency). Using a thimble adds strength and prevents eye deformation (up to 90% efficiency). Balancing strands is not as critical as thought. Eye splices failed at the last tuck at similar tensions, whether balanced or not.

Logger's eye with rollover shackle and hammerlock link.

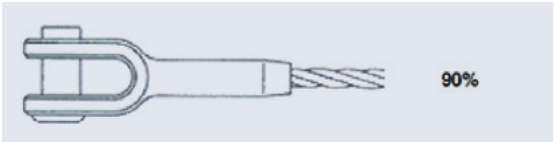
Tuck loggers eye splice three times on one side and two on the other (ACOP).

Ensure no eye-to-eye splices.

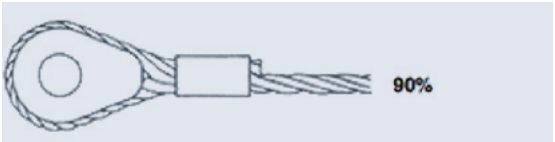
Different connector's strength compared to the wire rope



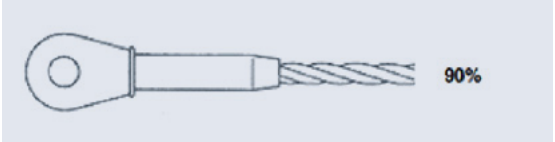
DIN 3093 Aluminum Splice with HD Thimble



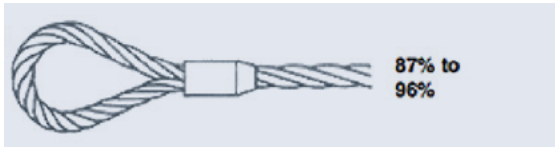
Open Swaged Socket



DIN 3093 Aluminum Splice with Solid Thimble

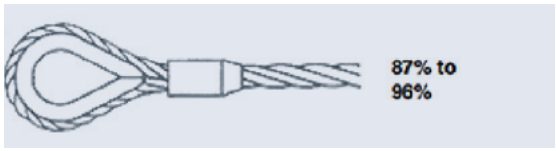


Closed Swaged Socket

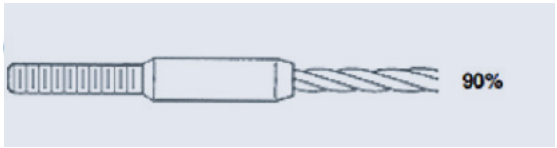


Flemish Eye with steel sleeve

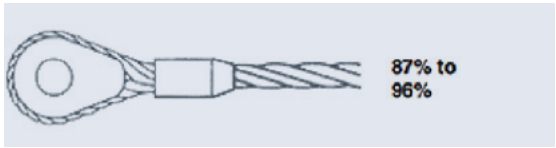
UNI-LOC™ Button



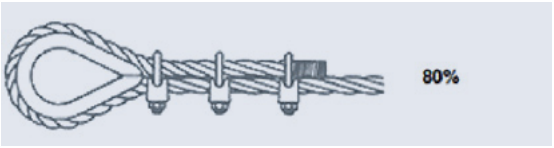
Flemish Eye with steel sleeve and HD Thimble



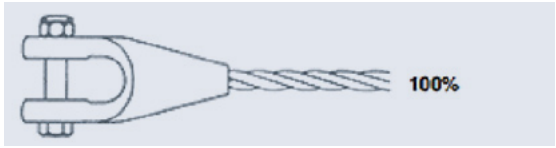
UNI-LOC™ Threaded Stud



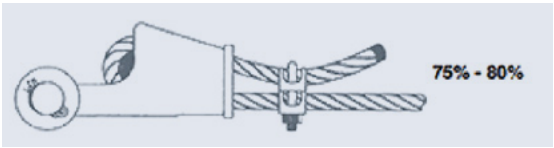
Flemish Eye with steel sleeve and Solid Thimble



Forged Wire Rope Clips



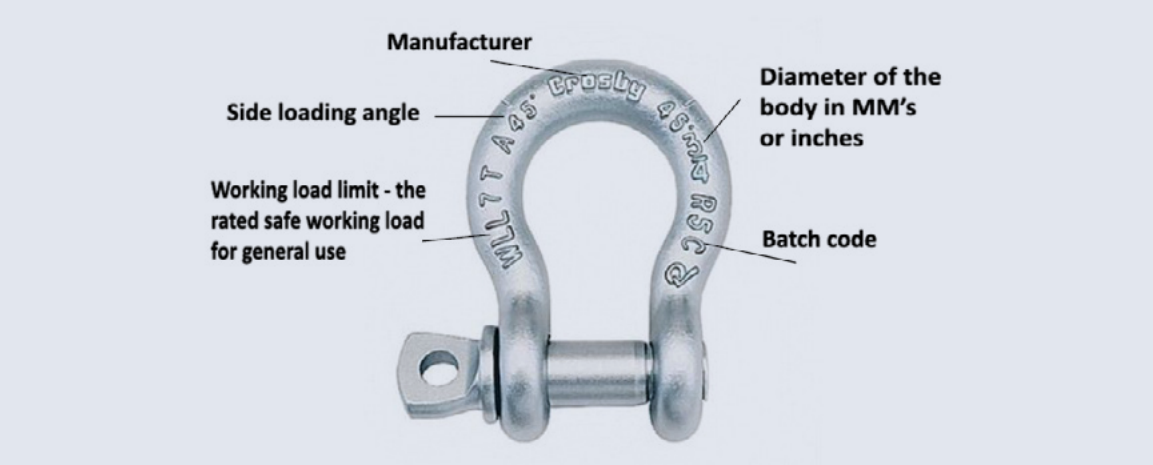
Open Spelter Socket (Closed not shown)



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

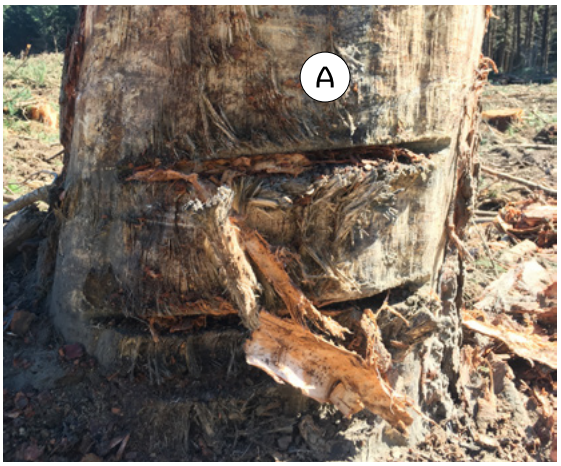
In this chapter you will find out how to:

- ✓ 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.



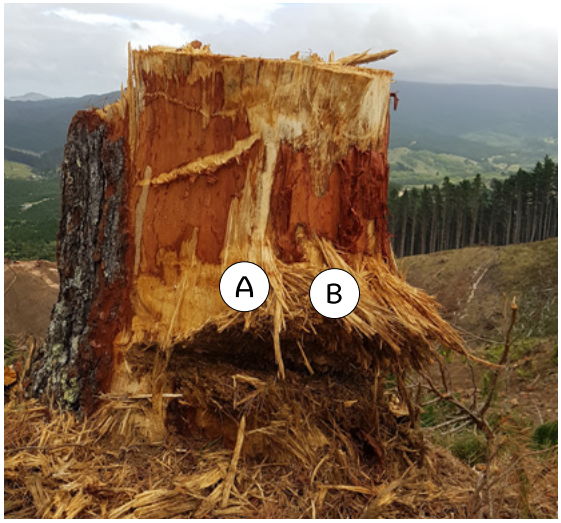
A Redirect stumps and trees

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

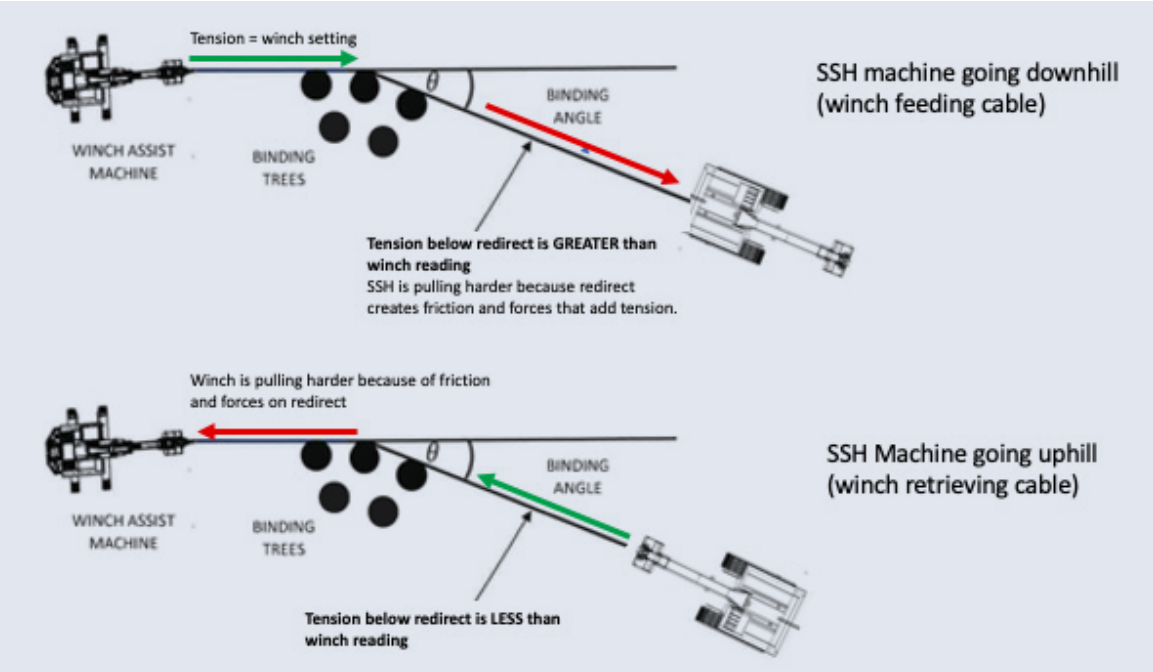
Redirects add friction and result in the rope tension being different above and below the redirect. For example, if a winch applies a rope tension, the pulling power of the rope reduces after going around a redirect. The greater the redirect angle, the less tension goes to the SSH when being pulled uphill.

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.

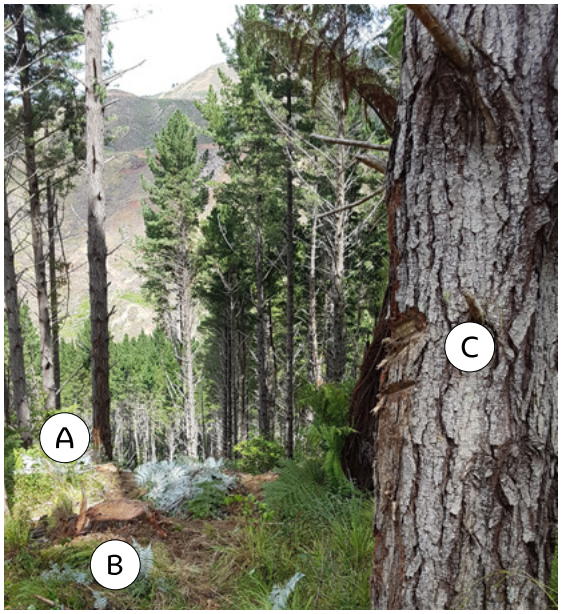
BINDING ANGLE (DEGREES Θ)	TENSION (TONNES) When machine is tracking downhill				
	5	10	15	20	TENSION MONITOR READOUT
10	5.4	10.8	16.1	21.5	ACTUAL TENSION VALUES
20	5.8	11.6	17.4	23.1	
30	6.2	12.4	18.7	24.9	

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!

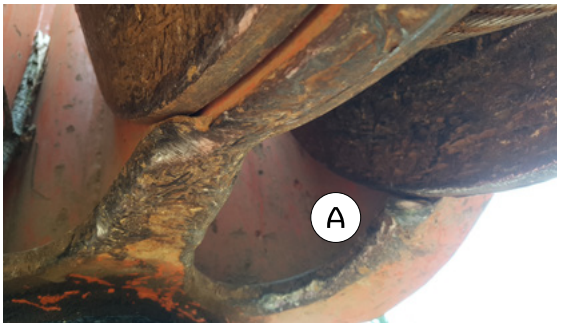
Moving up, then getting the rope over a redirect no longer needed

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.

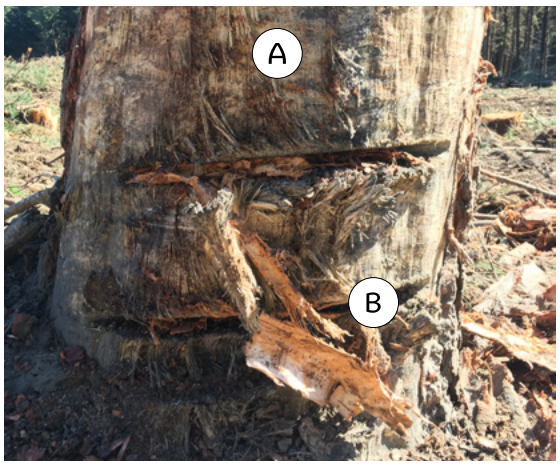
If the block is attached to a looped chain, then the SSH can carry it and put over a stump. It can then also be lifted back over the stump when the SSH returns uphill.

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

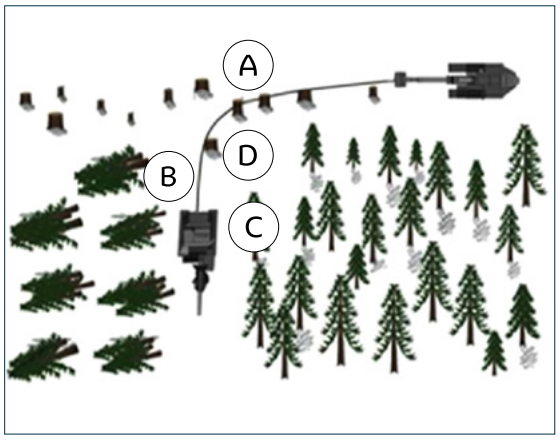


A Use stumps that are large and strong so they won't move and create rope bending fatigue.

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.



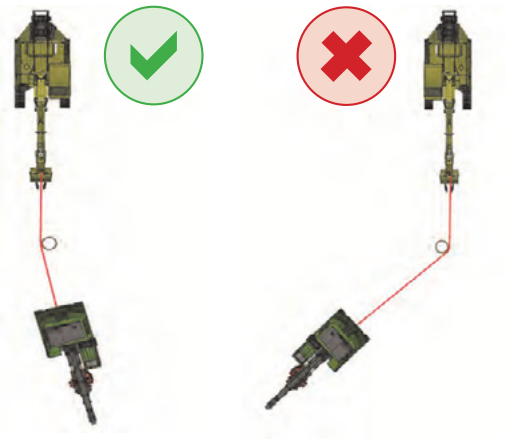
A Use multiple stumps or stems. A single stump failure could result in shock-loading. Even though multiple redirects will cause rope wear and reduce anchor winch power, it is safer than a single stump.

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.

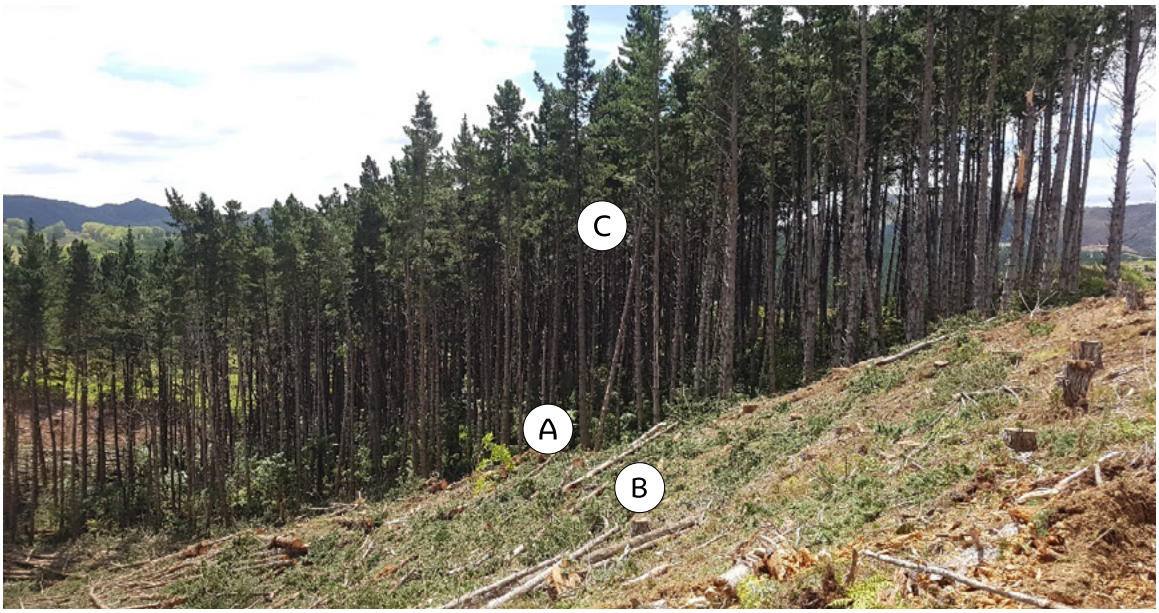
Ideally, the hand fallers fell before the winch-assisted operation starts in the setting. However, often it isn't until the winch-assisted machine is on the slope that the operator can work out the hand felling boundary, leaving the hand felling until later. Otherwise, if hand felling occurred first,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

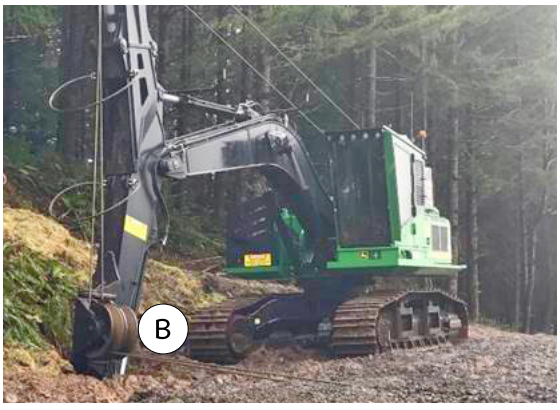
A solution is to sit the excavator perpendicular (90 degrees) to the lead angle and use the bucket to redirect the load from the SSH. Unlike the standard winch-anchor machine anchoring where the anchoring is through machine, boom and bucket, most of the rope's force goes on the bucket:

- 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.

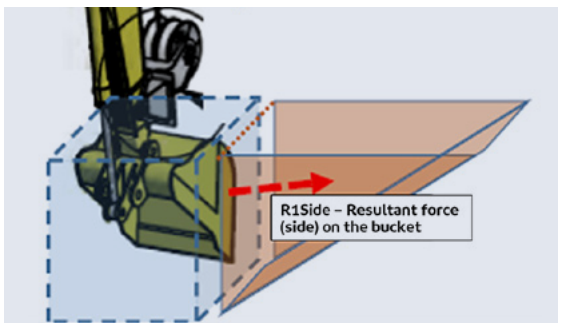
Increasing sideways forces could generate forces large enough for failure on the bucket/boom/sheave unless manufacturers have modified their equipment design to accommodate such large angles.

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.

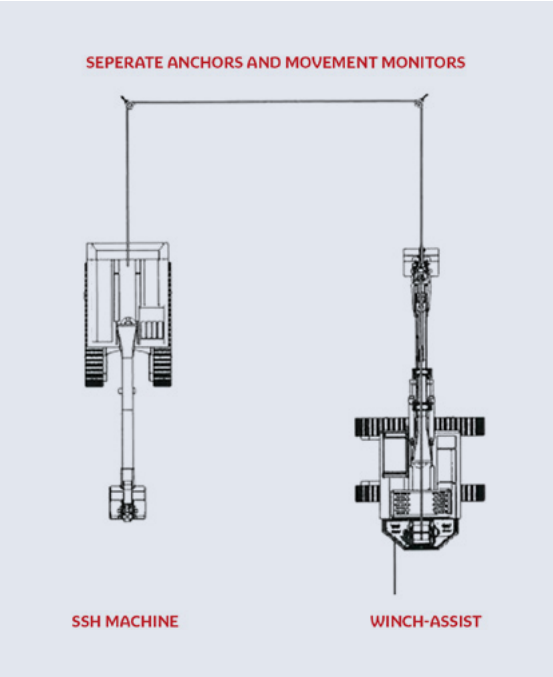
Winch anchor machines (WAM)

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

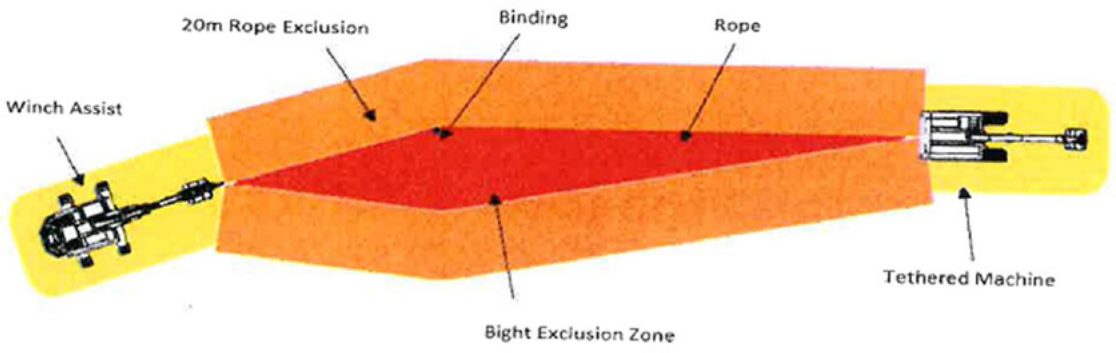
Operational work exclusion zones differ depending on the harvest site. These should be determined as part of the site safely plan. The following are indicative work area exclusion zones.

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.