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Programme: Harvesting

Task No: 1.1
Milestone Number: 6.1

Report No. H029

2016 Cable-Assist Workshop – Improving Operations

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Date: 1 July 2016

Leadership in forest and environmental management, innovation and research

Disclaimer

EXECUTIVE SUMMARY

Cable-assist harvesting systems increase the operating range of ground-based operations on steep slopes. The overall goal of this development is to provide not only safer, but also more cost effective, harvesting systems.

The objective of this project was to develop a set of training notes that can be used for an in-field workshop for machine operators, contractors as well as company planners and safety managers. It provides a combination of technical information, discussion points, and easy-to-use tools that can improve our understanding of cable-assist harvesting systems.

The early development and implementation of these workshops was supported by both Rayonier New Zealand Ltd. and Hancock Forest Management (NZ) Ltd. A series of nine workshops have been held to date (June 2016) and these provided the opportunity to continually update and improve the content of the workshop material.

While all of the workshops to date have been led by the University of Canterbury, School of Forestry, these workshop notes are being made available to the wider forest industry, through Future Forests Research Limited (FFR), so that other forestry companies can implement their own training programmes. FFR asks that forestry companies acknowledge the University of Canterbury, School of Forestry for preparing this workshop material.

INTRODUCTION TO 2016 CABLE-ASSIST WORKSHOP


Goal: To provide tools and techniques to practically assess the operational conditions and improve safety for steep terrain cable-assist systems.

Schedule: During this workshop the participants will carry out a series of tasks that are designed to support the teaching materials covered in the 2016 UC Cable-Assist workshop. It will take approximately 3 hours to complete.

Modules

1. Introductions and Overview of Operation (30 min)
2. Review of the Harvest Plan & Measuring Slope (30 min)
3. Soil Strength and Traction Efficiency (20 min)
4. Hazard Assessment Work Sheet (20 min)
5. Setting up the Anchor Machine (20 min)
6. Wire rope inspection (20 min)
7. End Connector inspection (20 min)
8. Operating experience/techniques - open discussion (20 min)

Materials

- Field visit handbook
- Map of harvest area & company guidelines
- Clinometer, calculator, ruler, measuring tape
- Gloves, wire brush, masking tape, cleaning cloth, digital calipers.

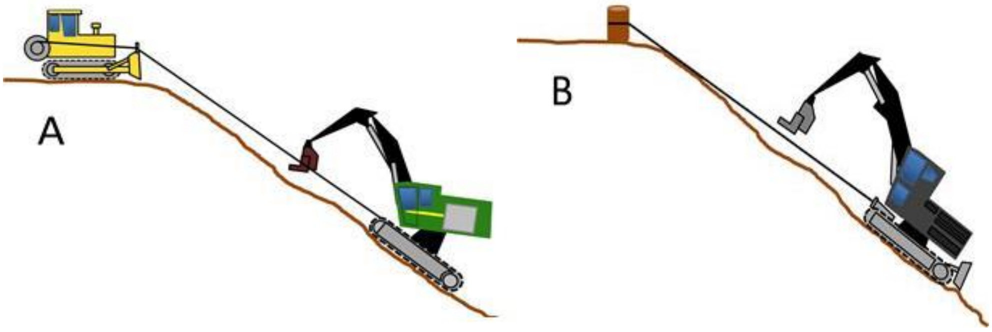
1. OVERVIEW OF OPERATION

Introductions – people in attendance:

Operator / contractor to describe system:

Carrier Base: Wheeled versus Tracked

Winch System: ‘Dynamic’ (A) versus ‘Passive’ (B) - Advantages and Disadvantages



Advantages	• Readily connected to, and disconnected from, any felling or bunching machine • Winch assist machine is mobile and can readily be moved • Power requirements for winching and working tasks are split between two machines	• Single machine ‘system’ • Less rope wear as it is not moving across the ground • Does not require access to back line/top of hill
Disadvantages	• System requires two machines, and a communication between them for effective winch operation • Requires access to the back line/top of hill for winch machine • Potential for more rope abrasion, but also for cutting in to the ground and or stumps used to re-direct the rope, as rope moves	• Higher capital cost felling machine • Winch is integrated so cannot be used with other felling machine • Requires suitable anchors such as stumps, deadmen or mobile tail hold machine

Anchoring System: Dozer versus Excavator versus Stump

		
Advantages	• Low centre of gravity • Sturdy base & large blade. • ? • ?	• Keep rope off ground. • Lift rope for line-shift • ? • ?

Single rope versus double rope systems

Double rope: ‘back-up’ rope adds additional security?

Single rope: reduces operating complexity and cost

Discussion - Company Position on Implementation

- Overall position on cable-assist systems in forest?

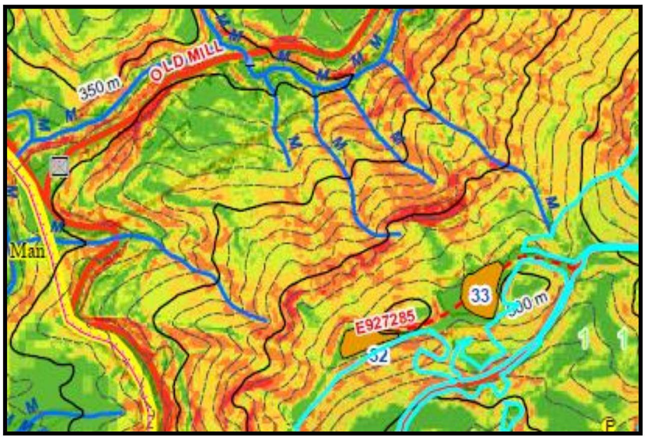
- Productivity and cost expectations for contractors operating cable-assist?

- Main concerns about current operations?

2. HARVEST PLAN & MEASURING SLOPE

Harvest Plan

In groups of 3 – discuss the Harvest Plan (Map):



Segment of a Map showing slope categories

Company –

- What decision making process helps decide if, and where, a contractor with cable-assist is either desired or required for a harvest area?

Contractor –

- What decision making process helps decide actual cable-assist operating areas (and or limits)?
- How do you decide anchor locations and operating corridors?
- Do you identify areas where manual falling is preferred / required over mechanised falling?

Discuss – what, if any, information is most useful on a harvest plan map to make informed decisions about where to operate / limits?

Task – In groups of 3, on the map identify the next anchor location and the extraction corridors.

Slope Refresher:

Degrees (deg or ^{o}): circle is 360 equal units, or 90 degree in right angle - continuous scalar variable preferred by schools (& harvest planners!).

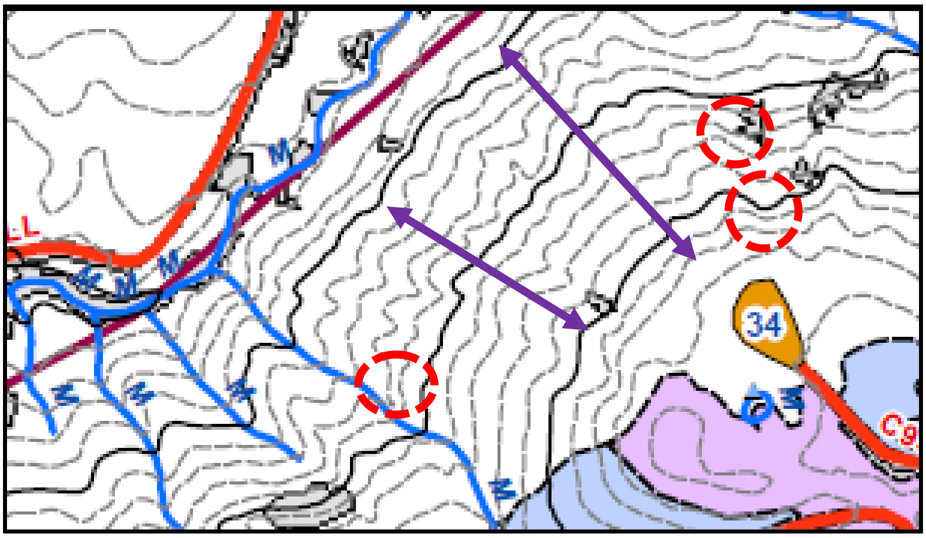
Percent (%): ratio of ‘rise’ over ‘run’ - preferred by engineers as easily implemented in map reading & surveying.

- *See conversion table in Appendix 1*

'Dominant' hill slope **–** average slope over the full length of the main slope (i.e. exclude the hill top and valley). This has traditionally been used to provide a good overview of what type of system might be appropriate.

- < 30% (17 deg) = readily traversed by wheeled machines
- < 40% (22 deg) = readily traversed by tracked machines
- < 50% (27 deg) = able to be traversed by suitable machines with an experienced operator on good soil conditions
- < 70% (35 deg) = able to be traversed by purposed built steep terrain machines with an experienced operator on strong stable soils with no obstacles.

Machine 'Micro' slope **–** identifies the slope over a shorter segment. A suggested useful length is 8 to 10m – being double the length of a machine. While it is possible to measure slope over this distance in the field using a clinometer, on the map realistically you are limited to approx. to 25 to 50m (depending on contour intervals and map scale).



The purple lines would be good estimate for the dominant slope (approx. 60%, 30 deg), whereas the red circles are the micro-slope areas with the steepest terrain (130%, 55 deg!).

Task – what is the slope of the terrain at the current setting? Compare Map slope to actual terrain slope.

Dominant Slope – using slope categories

If the map uses colour to designated slope categories, what is the slope of the terrain at the current setting? Note that the category gives you a slope range (min and max).

Slope (from Map, using slope category) = [   ] to [   ] deg (= [   ] to [   ] %)

'Dominant' Slope – using map contours

(1) draw two lines from the top to the bottom of the 'main' slope – start and end at a contour line

(2) count the number of contours along the line and multiply this by the contour interval (likely to be either 5m or 10m, but check!) - this equals the rise.

(3) Use your ruler to measure the length of the line (in mm). Multiply this by the map scale to get actual length.

(4) Divide this value by 1000 to convert to metres – this equals the run.

(5) Divide rise by run and multiply by 100 to get slope in percent (%) and look up the conversion chart to also record the degree slope.

= rise [   ] / run [   ] x 100% = [%] (= [deg])

= rise [   ] / run [   ] x 100% = [%] (= [deg])

Dominant Slope – using a clinometer

(1) from the edge of the landing / road identify the end of the dominant slope - find a shrub / tree that is approximately your height.

(2) Using the clinometer, measure the slope to that point.

(3) repeat the measure approx. 30 degrees either side.

(Note: over 100m, 1m height = 1% or 0.6 deg – i.e. not that much!)

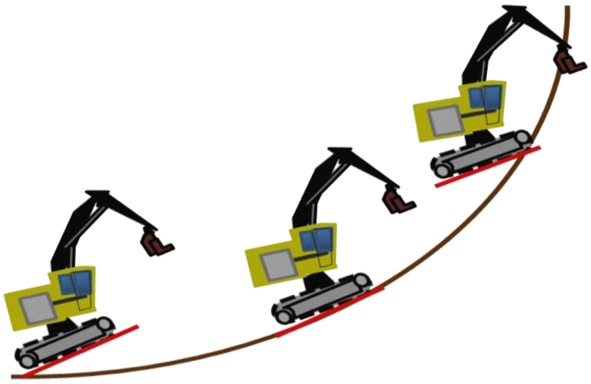
Dominant Slope 1 = [%] = [deg]

Dominant Slope 2 = [%] = [deg]

Discuss –

- How well do the three measures of dominant slope match up? What are likely sources of 'error'?
- Should operating slope limits relate to 'dominant' or 'micro' scope measurements?
- At this site, based on these slope measures, how do you perceive the roll-over risk for the machine?

Managing Machine Slopes



Study[1] showed that machine slope is not terrain slope – on lower slopes it is often higher.

However, the study also showed that operators can influence machine slope especially on steep segments of the slope.

Question to operators, what can you do to maintain safe machine slope when on small steep segments of the terrain?

[1] Visser R. and Berkett H. (2012).

3. SOIL STRENGTH & TRACTION EFFICIENCY

Approve Code of Practice (ACOP) 2012

6.1.7 Mobile plant shall be equipped with a braking mechanism capable of holding itself and its load on any slope on which it is operated.

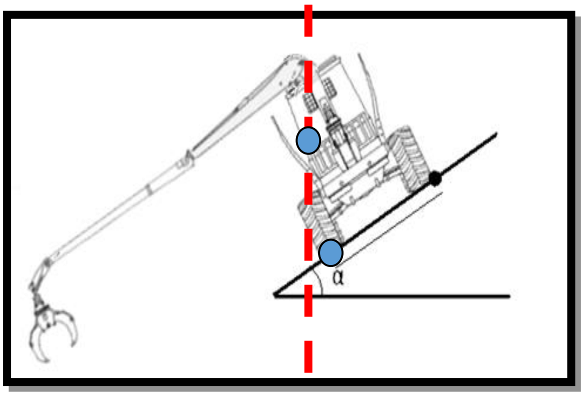
6.2.2 Where the stability of mobile plant is compromised by slope, weather or ground conditions then a specific hazard management plan shall be developed, implemented, and monitored.

6.2.3 Mobile plant shall not be operated on slopes that exceed the maximums in accordance with the manufacturer's specifications (or their agent).

How can machines be compromised?

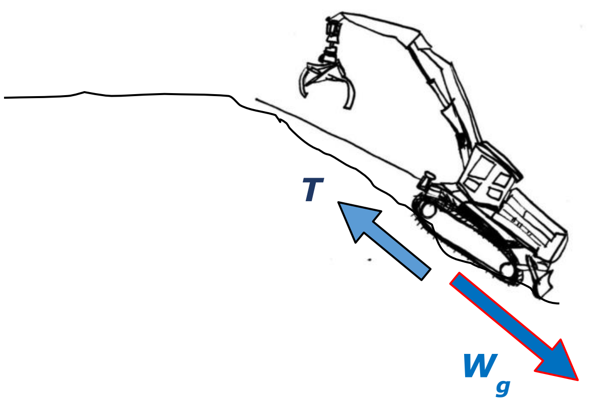
Reminder – Machine Limits – machine can be compromised by either rollover or loss of traction

Machine rollover: When the centre of gravity of the machine is below the lowest machine contact point with the ground →



Note: a machine travelling directly uphill with the boom out the front will not rollover on slope >55 deg, HOWEVER, a machine on a side-slope with the boom out at full length with load can tip over <10 deg.

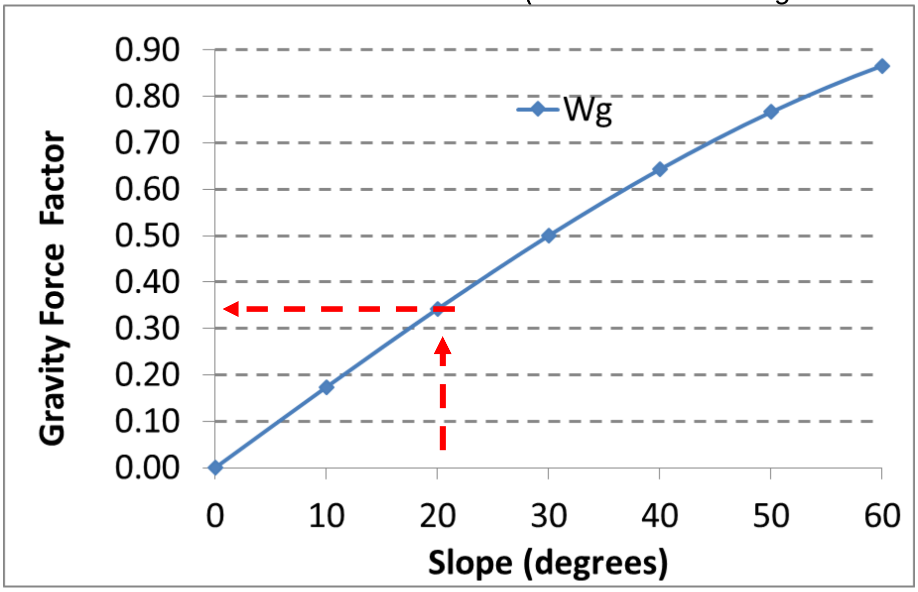
Loss of Traction: When gravity force (Wg) on machine is greater than traction force (T) …



Calculating gravity force:

= Machine Weight [______t_] x Gravity Force Factor [__________] = __________tonnes

(Note: Machine weight x sine of slope angle)



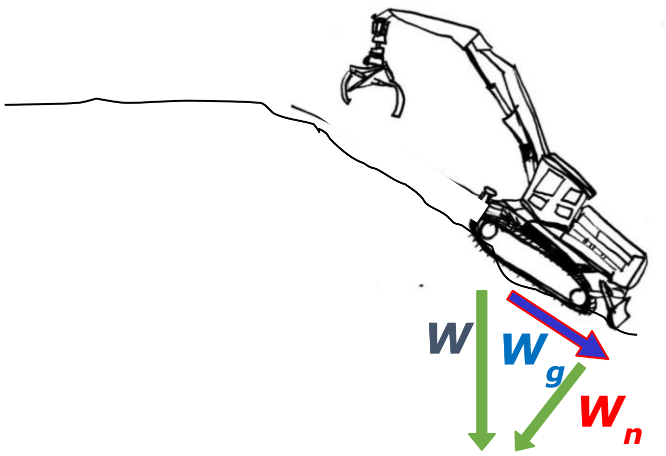
Using the slope chart – locate your slope (deg) on the bottom axis, move straight up until you hit the line, then go straight across to read off the gravity factor. For the red line shown, for a machine on a 20 deg slope, the gravity force will be 0.35 x machine weight.

Calculating traction force: *(use calculators)*

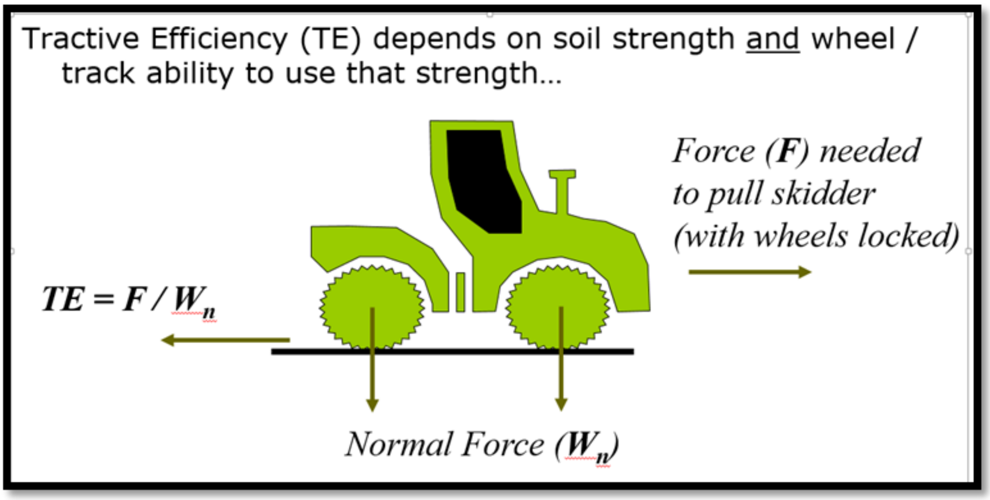
Traction Force = ***Normal Force*** (=Machine weight x Cos Slope Angle) x ***Traction Efficiency***

Normal Force = Machine weight [______t_] x Cos (Slope Angle) [______] = [______t_]

Normal Force – the amount of weight actually acting 'into' the ground – this will get smaller as you increase the slope angle.



What is Tractive Efficiency?



So tractive efficiency is the ratio of the force it takes to pull a machine with the normal force.

Tractive efficiency – four ways of measuring / estimating:

1. We can use a load cell and pull a machine with the wheels locked and we will get TE *for that machine at that site*.

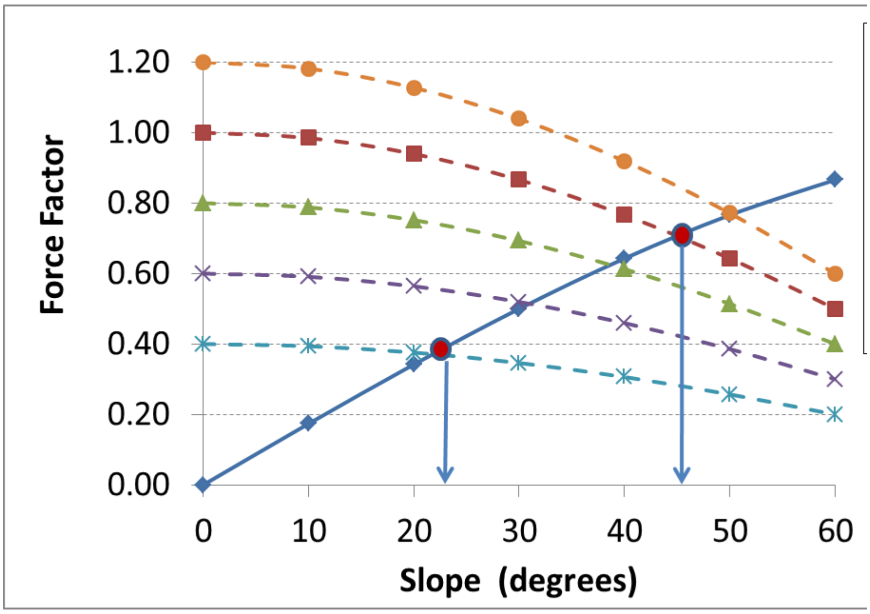
2. We can use old text book tables:

Tractive Efficiency	Soft Ground	Strong Ground
Tires	20%	50%
Tires with Chains	30%	60%
Tracked machines	40%	80%

3. We can use operators manuals such as that published by EMS Ltd:

As a guide, ground condition affects the Tractive Effort as follows:
% 100 – 90 TE: Dry, load bearing ground.
% 90 – 70 TE: Brown earth under moderate climatic conditions.
% 70 – 50 TE: Soil with high clay content under wet conditions.
% 50 – 0 TE: Wet soft / boggy ground.

4. We can ask the operator to keep a record of the slope where the machine loses traction and use the chart below to indicate the Traction Efficiency - and provide a brief description of that soil for future reference.



Measure the slope when the machine slips, go straight up until you hit the blue (Gravity Force) line, then follow the curved line back to get Traction Efficiency (note: x 100 to get %)

Task: Assess soil condition

For the top 30 or 40cm characterise the strength of the soil?

- dry/moist/wet
- clay/silt/sand/gravel
- bedrock
- weak, strong?

Notes:

- Clay content – clay at a low moisture is like glue to hold everything together, but a lot of clay makes it susceptible to either very dry or wet conditions.
- Gravel – tends to make a soil much stronger, but large gravel might cause the tracks to not get a good grip on the soil along their full length.
- Bedrock – strong, but machines tend to slip on bedrock so there is a real risk
- Sand – a sandy soil, or even a gravel, without clay will be very friable and have low TE
- 'Ideal' – an ideal soil for strength has a good mixture of gravel, sand and clay.
- ?
- ?
- ?

Discuss - What can add to the tractive efficiency to help keep a machine on the slope?

- Putting tracks on stumps / strong root systems.
- Using the boom to either pull or push the machine up the slope.
- Using the tracks to 'dig down' into a stronger soil layer.
- What do the operators do when they start to slip?

Putting it together… Will this machine stay on this slope?

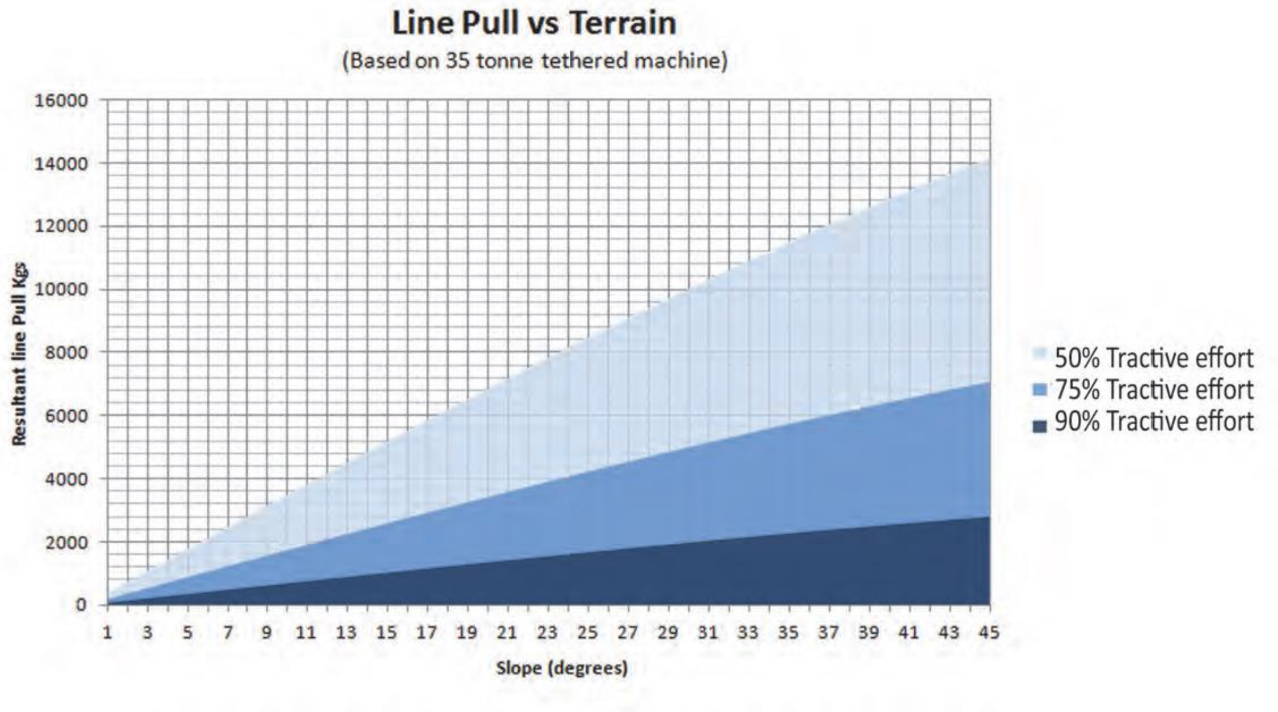
What is the Traction Force? Normal force [ ] x Traction Efficiency [ ] = [ ]

What was the gravity force? [ ] *(from page 9)*

If gravity force greater than, or close to the traction force – we need the cable-assist!

The force in the cable is added to the Traction Force. These two forces summed together need to be greater than the Gravity force for the machine to be stable!

The EMS provide the chart below – the chart below is intended to give an indication of the cable line pull required for a given slope and Traction Efficiency…



4. HAZARD ASSESSMENT WORK SHEET

ACOP 6.4.5 All winch-assisted mobile plant operations shall have a documented safe working best practice, including as a minimum":

- Hazard management
- Machine and wire rope inspection and maintenance routines
- Operator fatigue plans
- Work alone procedures
- An emergency plan

Further to 6.4.5 it is suggested that the document should include:

- An operating plan including a map indicating slope & terrain features
- Slope/soil condition operating guidance
- Safe operating procedures
- Training requirements
- Daily prestart checks

Task

Your task is to complete a steep terrain hazard assessment form. Review the harvest plan map and identify and mark a higher risk area (noted as 'sub-area' on the form). If time permits, walk around that area.

Remember some of the key factors that need to be considered when performing a hazard assessment for operating on "steep terrain" whether cable-assisted or not:

- Slope & Length
- Terrain Stability / Classification
- Ground Roughness
- Soils
- Soil Depth
- Pre-Existing & Post-Harvest Debris
- Duration of Exposure
- Worker Isolation
- Hazardous Environmental Factors

STEEP SLOPE HAZARD ASSESSMENT TOOL
HAZARD IDENTIFICATION AND ASSESSMENT

PAGE 1

DATE		LICENSEE / OWNER	
LICENSE / CP		SITE SUPERVISOR OR CONTRACTOR	
BLOCK		SITE OR SUB-AREA	

MACHINE STABILITY FACTOR	RISK LEVEL 1	RISK LEVEL 2	RISK LEVEL 3	COMMENTS
SLOPE & SLOPE LENGTH, TRACKED MACHINES	40 to 50% and Slope Length <50 metres	40 to 50% and Slope Length >50 metres	>50% and Slope Length >10 metres	
SLOPE & SLOPE LENGTH, WHEELED MACHINES	35 to 45% and Slope Length <50m	35 to 45% and Slope Length >50m	> 45% and Slope Length >10m	
TERRAIN STABILITY / CLASSIFICATION	No Instability Indicators and slopes <50%	Instability Indicators and slopes <50%	Slopes >50%	
GROUND ROUGHNESS: BOULDERS, OUTCROPS, HUMMOCKS, DEPRESSIONS	<30% of steep slope area covered by roughness features	30 to 50% of area covered by roughness features	>50% of steep slope area covered by roughness features	
SOILS	Well-drained (e.g. gravel, coarse sand)	Mod. well-drained (fine sand, silt); indicators of sub-surface flows	Poorly-drained or saturated (silt, clay), high water table	
SOIL DEPTH	>30 cm to bedrock	15 to 30 cm to bedrock	Thin soils (less than 15 cm), or bedrock exposures	
PRE-EXISTING AND POST-HARVEST DEBRIS	Open understory, no windthrow	Moderate downed timber, understory, stumps <30 cm	Heavy downed timber, 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 site? Also consider shift length, # of scheduled breaks, # of consecutive shift days, etc.*			
RISK RANKING				
WORKER ISOLATION - TIME FOR ASSISTANCE TO REACH OPERATOR	< 15 minutes	15 to 30 minutes	> 30 minutes	
ENVIRONMENTAL FACTORS (WIND, HEAVY SNOW, ETC.)				

SITE FEATURES / CONSTRAINTS (DANGER TREES, BENCHES, RETENTION STRATEGY, ETC.) ____________________

RISK RANKING :

TIMBER HEIGHT (AVG.): __________ TIMBER SPECIES: __________

AVERAGE STEM DIAMETER: __________ MAXIMUM STEM DIAMETER: __________

OVERALL MACHINE STABILITY RISK RATING: __________

3 OR MORE "RISK LEVEL 3" RATINGS RESULTS IN "NO GO" UNLESS ADDITIONAL MEASURES ARE TAKEN (SEE PAGE 2).

QUALIFIED ASSESSOR : SIGNATURE :

Steep Slope Hazard Assessment Tool
Practices and Controls to Eliminate or Mitigate Hazards

Cutting Permit: ____________ Block: ____________ Site or Sub-Area: ____________

Type of Machine: ☐ Feller-Buncher ☐ Skidder ☐ Hoe-Chuck ☐ Processor ☐ Other:

Designated NO GO for Mechanical Operations

Identify Designated Machines / Name Designated Operators:

Indicate those Mechanical Features Prescribed to Ensure Machine Stability

☐ Non-Tilting Cab ☐ Tilting Cab ☐ Zero Tail Swing Design ☐ Extended Tracks ☐ Telescoping Boom

Picks / Grousers (describe height & spacing):

☐ Non-swivel Head ☐ Rotating Head ☐ Intermittent Saw ☐ Hot Saw ☐ Shave Stumps, As Required

Head Cutting Capacity (Diameter): ____________ **Tree / Weight Handling Capacity:** ____________

Allowable Stump Height: ____________ **Target Bunch / Turn Size:** ____________

☐ Chains on 4 Wheels ☐ Flotation Tires ☐ Swing Grapple ☐ Other Devices:

Mechanical Features to Ensure Stability

☐ Approach Steep Slopes From Below ☐ Operations During Daylight Hours Only ☐ Utilize Existing Benches

☐ Up trail, safe turn-around, Direct down-slope Skid ☐ Construct & Use Machine Trails (identify on map)

☐ All-season Operations ☐ Summer Only ☐ Winter Only Maximum Snow Depth:

Communications Process (e.g. 2-way radio, cell, etc.)	**Man-check Frequency (who, how often)**
Poor Weather Shut-down Conditions (describe)	**Available Assistance (machine, operator)**

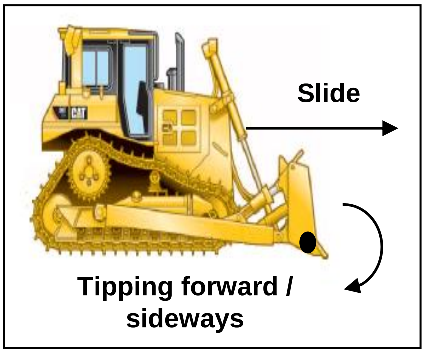
Site-Specific Requirements & Notes

Date:	Signature:	Date:	Signature:
Date:	Signature:	Date:	Signature:

Qualified Person Building Plan:	***I have reviewed the associated Steep Slope Hazard Assessment and verify its accuracy.***	Signature:

5. SETTING UP THE ANCHOR MACHINE

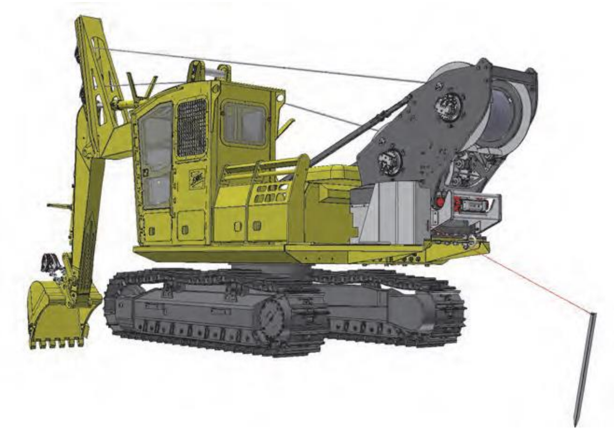
An anchor machine can fail by either sliding forward or tipping over. Of course a mechanical failure of the winch itself or the connecting components can also cause a sudden failure.

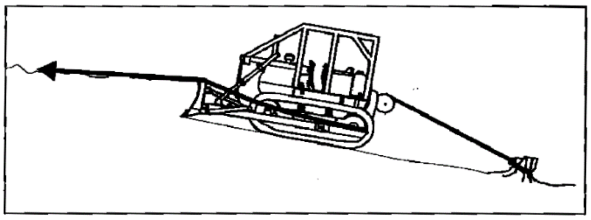


Anchor machine Holding Strength:

If no bucket, blade or tie-back is used, then the anchoring strength of the machine is the same as calculated previously for Traction Force, that is the Normal Force x Traction Efficiency.

- *Note, for most of our anchor machine sizes (30 tonne x 70% TE = 21 tonne) and cable forces (peak loads over 20 tonnes), the anchor machine alone is <u>not</u> sufficient and will <u>move</u> during operations.*
- *Note, putting the anchor on a slope. If the anchor machine is on a slope, then gravity will either add to the strength if uphill, or add to the overall force if downhill.*





Attaching the winch rope to a stump anchor

By putting the blade or bucket in the ground, or by tying off to a stump, we increase the Holding Strength (– typically by the weight and shear strength of the soil 'enclosed')

Discuss –

1. What are the procedures and techniques for stabilising the anchor machine (i.e. placement of bucket or blade & techniques for side slopes)
2. What is the horizontal range of angle of departure from anchor machine?
3. Does the system have an emergency stop, how is it activated?
4. Check and discuss with the operator (and or contractor) the calibration of the winch settings / tension monitor and their typical operational settings.
5. Does the system have an anchor movement / displacement safety mechanism and is it set up correctly?

6. WIRE ROPE INSPECTION

Inspection Criteria

Wire ropes are a critical component in cable-assisted systems, and care should be taken to inspect the rope(s) for wear and damage against a formal rejection criteria. For example, the NZ Best Practice Guidelines for Cable Logging suggest the following criteria to indicate when a rope should be immediately discarded:

- Severe surface wear and inter-strand nicking
- Drum crushing
- Bird caging
- Kinking
- Broken wires near fittings
- Broken wires, when over a length of 8 diameters the total number of visible broken wires exceeds 10% of the total number of wires.

For example:
26 mm diameter rope, 6X19 construction, total wires = 6 X 19 = 114
8 diameters = 8 X 26 = 208, 10% of 114 = 11.4
If in a length of 208 mm, there are more than 11 visible broken wires, then discard.

In the absence of mechanical damage and excessive broken wires listed above, it is still necessary to frequently inspect and document the severity of the rate of wear of the rope. Normal wear can be categorised into three main modes of deterioration: Wire breaks (due to bending), Decrease in diameter (due to abrasion and/or high tension) and Corrosion (due to exposure). Even if the severity of individual modes of deterioration are relatively low they can combine with other modes to create an unsafe combined rating of severity (see table below)

Example	Severity rating of individual modes of deterioration %			Combined severity rating %	Comment
	Wire breaks	Decrease in diameter[a]	External corrosion		
1	0	20	20	40	Safe to continue
2	20	20	0	40	Safe to continue
3	20	20	20	60	Safe to continue
4	40	20	20	80	Inspect more frequently
5	40	40	0	80	Inspect more frequently
6	0	80	0	80	Consider discard if reduction in diameter is mainly attributed to external wear
7	60	0	0	60	Inspect (particularly for broken wires) more frequently
8	60	20	0	80	Inspect more frequently (particularly for broken wires) and prepare for replacement

[a] Only taken into account when rope travels through steel sheave and/or spools on to single-layer drum.

Wire Breaks

Wire breaks are measured by counting the number of visible breaks over a lay length or specified diameter. Severity is determined by the % of broken wires until discard. For example, if the criterial for rejection for a 6X25fi + IWRC ordinary lay rope is 10 broken wires over a length of 6 diameters and the inspection finds two broken wires than the severity rating is (2/10) X 100 = 20%.

Rope category number RCN (see Annex G)	Total number of load-bearing wires in the outer layer of strands in the rope[a] n	Number of visible broken outer wires[b]					
		Sections of rope working in steel sheaves and/or spooling on a single-layer drum (wire breaks randomly distributed)				Sections of rope spooling on a multi-layer drum[c]	
		Classes M1 to M4 or class unknown[d]				All classes	
		Ordinary lay		Lang lay		Ordinary and Lang lay	
		Over a length of $6d$[e]	Over a length of $30d$[e]	Over a length of $6d$[e]	Over a length of $30d$[e]	Over a length of $6d$[e]	Over a length of $30d$[e]
01	$n \leqslant 50$	2	4	1	2	4	8
02	$51 \leqslant n \leqslant 75$	3	6	2	3	6	12
03	$76 \leqslant n \leqslant 100$	4	8	2	4	8	16
04	$101 \leqslant n \leqslant 120$	5	10	2	5	10	20
05	$121 \leqslant n \leqslant 140$	6	11	3	6	12	22
06	$141 \leqslant n \leqslant 160$	6	13	3	6	12	26
07	$161 \leqslant n \leqslant 180$	7	14	4	7	14	28
08	$181 \leqslant n \leqslant 200$	8	16	4	8	16	32
09	$201 \leqslant n \leqslant 220$	9	18	4	9	18	36
10	$221 \leqslant n \leqslant 240$	10	19	5	10	20	38
11	$24 \leqslant n \leqslant 260$	10	21	5	10	20	42
12	$261 \leqslant n \leqslant 280$	11	22	6	11	22	44
13	$281 \leqslant n \leqslant 300$	12	24	6	12	24	48
	$n > 300$	$0{,}04 \times n$	$0{,}08 \times n$	$0{,}02 \times n$	$0{,}04 \times n$	$0{,}08 \times n$	$0{,}16 \times n$

NOTE Ropes having outer strands of Seale construction where the number of wires in each strand is 19 or less (e.g. 6 × 19 Seale) are placed in this table two rows above that row in which the construction would normally be placed based on the number of load bearing wires in the outer layer of strands.

[a] For the purposes of this International Standard, filler wires are not regarded as load-bearing wires and are not included in the values of n.

[b] A broken wire has two ends (counted as one wire).

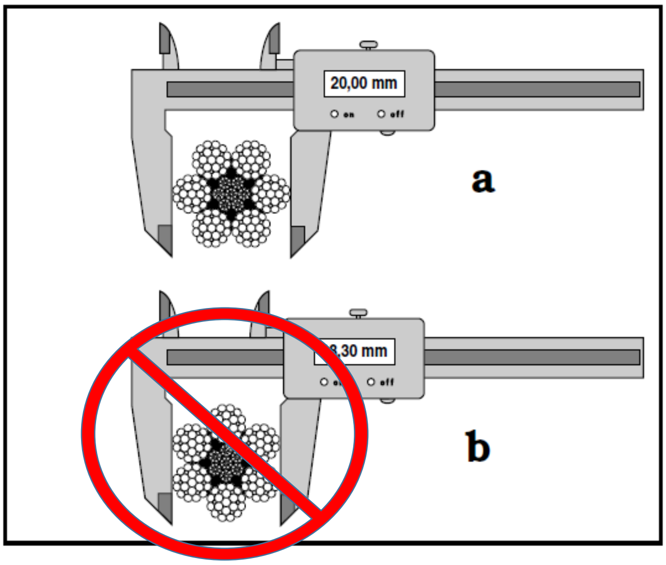
[c] The values apply to deterioration that occurs at the cross-over zones and interference between wraps due to fleet angle effects (and not to those sections of rope which only work in sheaves and do not spool on the drum).

[d] Twice the number of broken wires listed may be applied to ropes on mechanisms whose classification is known to be M5 to M8.

[e] d = nominal diameter of rope.

Decrease in diameter

Decrease in diameter is calculated from four measurements at each inspection point. Using callipers two measurements are taken at right angles and then two more measurements are repeated but at least one lay length apart from the first two measurements. It is important that the diameter is measured correctly from strand crown to crown (A) and not from valley to valley of strands (B).



All four measurements are averaged to come up with a single diameter value for the point inspected. Severity is determined by the reduction in diameter as a percentage of reduction required for discard.

Rope type	Uniform decrease in diameter (expressed as % of nominal diameter)	Severity rating	
		Description	%
Single-layer rope with fibre core	Less than 6 %	—	0
	6 % and over but less than 7 %	Slight	20
	7 % and over but less than 8 %	Medium	40
	8 % and over but less than 9 %	High	60
	9 % and over but less than 10 %	Very high	80
	10 % and over	**Discard**	**100**
Single-layer rope with steel core or parallel-closed rope	Less than 3,5 %	—	0
	3,5 % and over but less than 4,5 %	Slight	20
	4,5 % and over but less than 5,5 %	Medium	40
	5,5 % and over but less than 6,5 %	High	60
	6,5 % and over but less than 7,5 %	Very high	80
	7,5 % and over	**Discard**	**100**
Rotation-resistant rope	Less than 1 %	—	0
	1 % and over but less than 2 %	Slight	20
	2 % and over but less than 3 %	Medium	40
	3 % and over but less than 4 %	High	60
	4 % and over but less than 5 %	Very high	80
	5 % and over	**Discard**	**100**

Corrosion

Corrosion is assessed visually after cleaning the surface of the wire rope. Severity is determined by the following guidelines (ISO 4309):

Figure H.1 — Beginning of surface oxidation, can be wiped clean, superficial — Rating: 0 % towards discard

Figure H.2 — Wires rough to touch, general surface oxidation — Rating: 20 % towards discard

Figure H.3 — Surface of wire now greatly affected by oxidation — Rating: 60 % towards discard

Figure H.4 — Surface heavily pitted and wires quite slack, gaps between wires — Discard immediately

Task

For the section of rope that is readily accessible, inspect for any mechanical damage. Also, pick several spots along the rope including where it comes on and off the drum as inspection points for broken wires, diameter reduction and corrosion. Complete the provided wire rope inspection form (ISO 4309).

Steps:

1. Pick a spot along the wire rope for inspection.
2. Note the position in the rope (e.g. distance from terminal connection)
3. Measure and tape off a section of rope equal to 6 and 30 times the diameter of the rope.
4. Count the visible broken wires along both of these distances
5. Measure the diameter (twice at right angles) and again at least one lay apart from first two measurements
6. Record the average of the four diameter measurements in the inspection form
7. Inspect for corrosion along the length of 30 times the diameter
8. Note the severity level of each broken wires, diameter reduction and corrosion to establish a combined severity rating.
9. Find a new spot along the wire rope and repeat steps 2-8.

Discuss – actual / realistic 'strategy' for rope inspection and replacement?

Crane reference	Rope application
....	....

Rope details..

Brand name (if known) ....

Nominal diameter...................................mm

Construction..

Core[a]: IWRC FC WSC

Wire finish[a]: Uncoated Zinc/Gal.

Direction and type of lay[a]: (Right) sZ zZ Z (Left) zS sS S

Permissible number of visible broken outer wires .... in 6*d* and......................... in 30*d*

Reference diameter.................................mm

Permissible decrease in diameter from reference diameter.......................... mm

Date installed (yy/mm/dd).................................... Date discarded (yy/mm/dd) ....

Visible broken outer wires				Diameter			Corrosion	Damage and/or deformation		Position in rope	Overall assessment i.e. combined severity rating[b] at position indicated
Number in length of		Severity rating[b]		Measured diameter	Actual decrease from reference	Severity rating[b]	Severity rating[b]	Severity rating[b]	Nature		
6*d*	30*d*	6*d*	30*d*	mm	mm						

Other observations/comments

Performance to date (cycles/hours/days/months/etc.) ....

Date of inspection (yy/mm/dd)............................

Name (print) of competent person.................... ....Name (signature) ....

[a] Tick as applicable.

[b] Describe degree of deterioration as: slight, medium, high, very high, or discard.

7. END CONNECTOR INSPECTION

Some common types of end connectors:


Hand Spliced Eye


Pressed Thimble Eye


Pressed Solid Thimble Eye


Pressed Soft Eye


Wire Rope Clips


Spelter Socket


Split Wedge Ferrules


Flemish Eye

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:

Split wedge ferrules

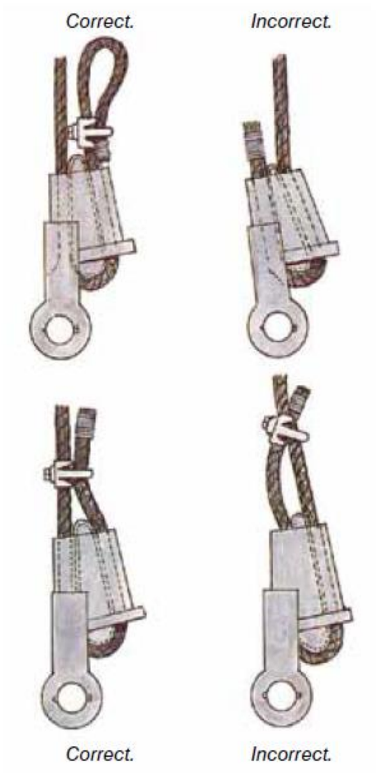
The strands of wire rope should protrude roughly 1/4" past thetop of the wedge button. Once the first load is applied, the wedge will seat firmly into the wedge button.

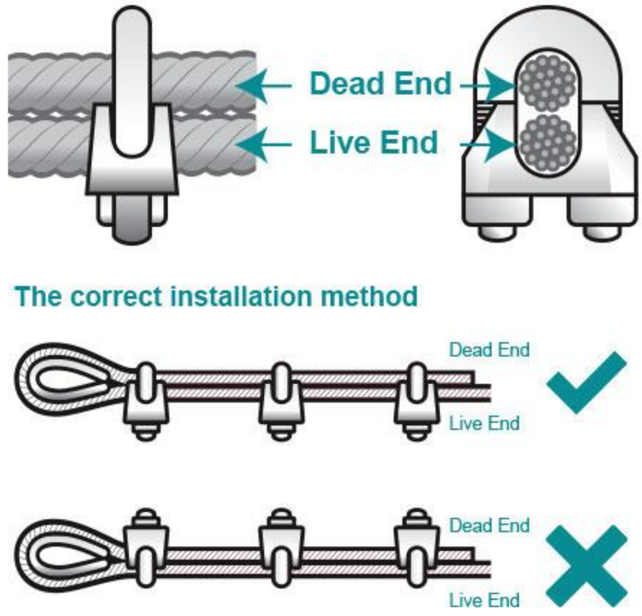
Loggers' eye splice

In accordance with NZACOP 2012, should be tucked three times on one side and two on the other.

Wedged sockets and **Cable Clips**

Remember the saying "Never saddle a dead horse!"





Task

Your task is to identify and make a list of all the end connectors in the rigging system. Inspect them for wear and note their condition. Using the tables below what is the expected strength efficiency of each connector type and consider the strength reduction to the wire rope due to both end connectors and the diameter of sheave size.

End Connector Type	Condition	Correctly Installed	Efficiency (%)
Smallest sheave	**Rope diameter ratio**		**Efficiency (%)**
New SWL based on Efficiency %			

Wire Rope Strength Efficiency:

There is surprisingly little known about the actual strength of most of the connections / attachments / splices that are commonly used. The table below pulls together Strength Efficiency values (effectively strength of the connection relative to the cable breaking load) from various publications. These values are not from standardised tests and are provided as a starting reference. Most manuals will identify the need to ensure the end-connection and or splice is carried out to a high standard. Poor installation will lead to a large reduction in Strength Efficiency.

Attachment or Splice	Efficiency (% of rope strength)
Long splice	80
Sockets; Zinc, pressed or resin	100
Sockets; Wedged	70-90
Cable clips	80
Flemish/Farmer's eye w/pressed ferrule	92-95
Other eyes w/pressed ferrule	90-95
Spliced eye and thimble 9mm 13mm 16mm 19mm 22-35mm	88 86 84 82 80
Spliced eye without thimble	<80?
Swaged/pressed ferrule	80-90

Sheave/Rope Diameter Ratio	Efficiency (% of rope strength)
10 times	79%
12 times	83%
14 times	86%
16 times	88%
18 times	90%
20 times	91%
24 times	93%
30 times	95%

Factors of Safety:
In Forestry we typically use a Factor of Safety of 3 for all wire rope applications – often higher factors are used for shackles and blocks. Factors of Safety are used to account for unknown forces, unintentional overloading and some level of wear and tear over time.
There is no clear guidance in any of our safety manuals as to how to incorporate these. Given that eye splices and pressed ferrules are approved in the ACOP, and they are typically rated at 90% of rope strength, it would be reasonable to assume that this is accounted for in the Factor of Safety. As such, our focus and or concern should be on connectors, sheave diameters, wear and tear that is likely to reduce the strength below 90%. We can then take it into account by adjusting our Safe Working Load (SWL).

Strength reductions

By way of example, if you have identified any component and or operating practice that warrants an adjustment of the SWL – then you can use the table below.

Efficiency	SWL (Shaw's 6X25 Fi swaged)		
	28 mm	25 mm	22 mm
100%	21.1	18.4	14.1
90%	19.0	16.6	12.7
80%	16.9	14.7	11.3
70%	14.8	12.9	9.8
60%	12.7	11.0	8.4
50%	10.6	9.2	7.0

Discuss – How do we account for the weak link in our systems?

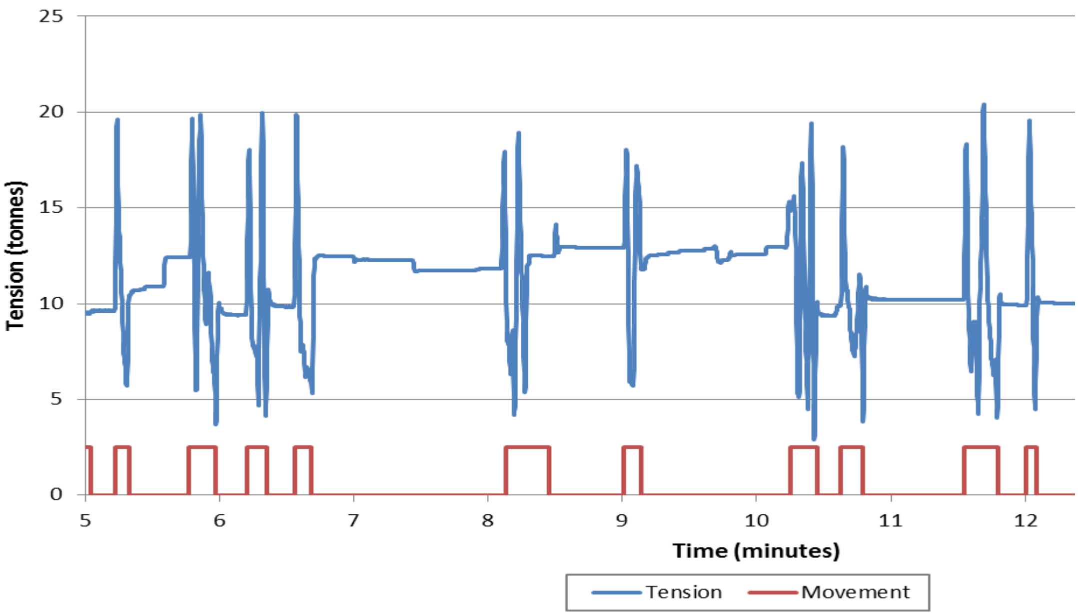
8. OPERATING EXPERIENCE/TECHNIQUES

Managing Tensions

ACOP *6.4.2*

The tension on the wire rope shall be restricted to 33 percent of its breaking load at all times.

From studies to date, we know that the largest shock loads during normal operations occur when the machine starts to move. The average tension, but also then the maximum tension occurring during the shock loads depends on the setting.

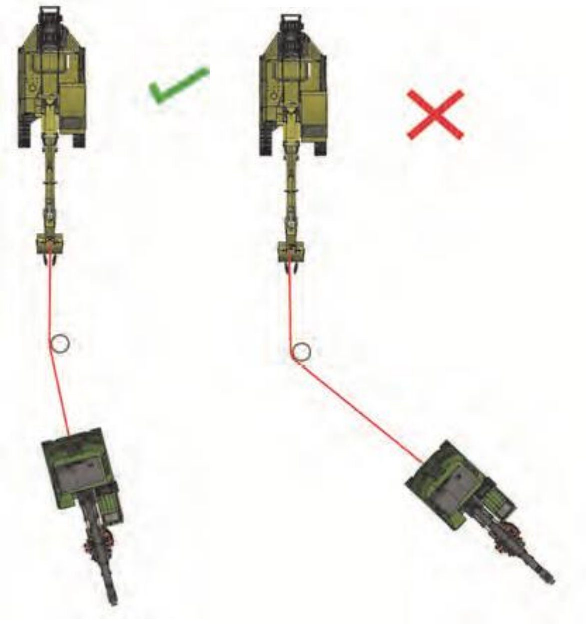


Discuss –

1. What tension monitoring system does the cable-assist machine have?

2. To what extent should the operator be aware of his cable tension?

Using trees to change cable angle

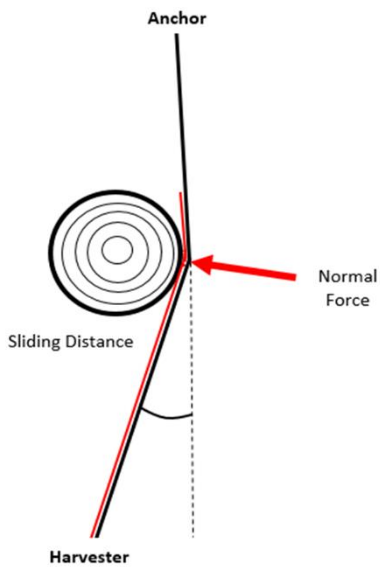


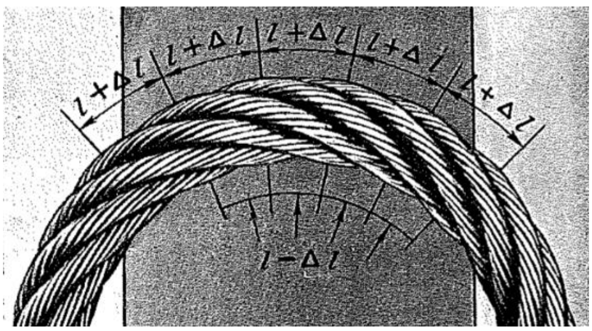
Using trees of stumps to redirect the direction of the cable is a common practice for NZ operators using cable-assist. It provides for the opportunity to harvest multiple corridors on the slope without needing to change anchor location. In many cases it also allows for the anchor to be on a flatter and more accessible location.
However, in neither the ACOP, nor in any company guidelines is it considered an approved practice. Some operating manuals, such as the EMS manual, indicate that it is an accepted practice but only if we limit the change in angle.

What do we know about wrapping a rope around a stump?

- Can put a significant horizontal force into the stump as the angle increases (easy to calculate), which can increase the risk of sudden failure (pull over tree/ pull out stump).

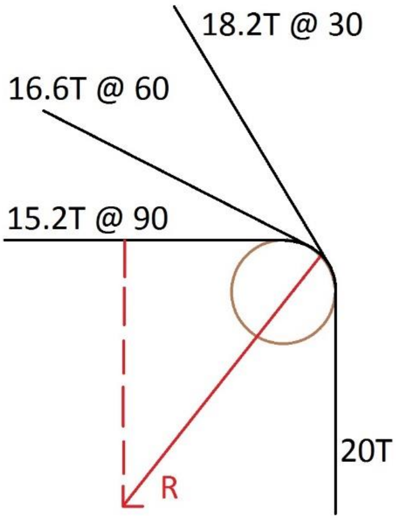
Note: a 45 deg angle will put 7t of force on the stump when operating at 10t of line tension, or 14t for a 90 deg angle





- Using a curved, but flat surface (tree / stump) to redirect a rope will cause the rope to deform under loading (flatten out) which both increases local tension and accelerates wear.

As the angle increases, so does the friction on the cable. This can cause the rope to experience quite different tensions between the upper and lower segments.



Estimated force difference for a cable being pull around a stump or tree (J Palmer 2016).

Operating Practices

- Getting on & off steep landings/approaching the anchor?
- Entering gullies & traversing side slopes?
- Felling & handling large trees on steep slopes?
- Other?

APPENDIX 1 – SLOPE CONVERSION CHART

Degrees	Percent (%)	Comment
0	**0**	Flat - level surface
7	12	Upper limit for forest haul roads - loaded
9	16	Upper limit for forest haul roads - unloaded
15	**27**	
16	29	
17	31	Old NZ ACOP limit for wheeled machines
18	32	
19	34	
20	**36**	
21	38	
22	40	Old NZ ACOP limit for tracked machines
23	42	
24	45	
25	**47**	
26	49	50% is now common limit for equipment designed to operate on
27	51	steep slope – i.e. WorkSafe BC
28	53	
29	55	
30	**58**	Angle of repose for loose soil / gravel (i.e. fill slope)
31	60	Old ILO limit for tracked machines
32	62	
33	65	Californian upper limit for ground-based machines
34	67	
35	**70**	Approx. limit for European steep terrain harvesters
36	73	
37	75	
38	78	
39	81	
40	**84**	
41	87	
42	90	Austrian Forest Service upper limit for cable-assist machines
43	93	
44	97	
45	**100**	Rayonier Guide upper limit for cable assist machines
46	104	
47	107	
48	111	
49	115	
50	**119**	