New Zealand Land Search and Rescue Incorporated

SAR

Rope Rescue Standard

Table of Contents

Chapter 1 Introduction

Purpose of this standard

The intention of this Rope Rescue Standard is to provide a foundation to initiate an increase in efficiency, performance and safety **through informed decision making** for rope rescue operations.

Scope of this standard

This standard applies to New Zealand Land Search and Rescue (NZLSAR) teams undertaking ground based technical rope rescues including cave rescue, alpine rescue and cliff rescue in remote locations.

History

There has been many and varied people who have looked at rope rescue standards for rescue over the years in New Zealand. Various documents and books that have become de-facto standards. Notably *Alpine Rescue Techniques* by Don Bogie has been the tried and trusted alpine standard since it was first published in 1984 and *Vertical* by Allan Warild has been the caving standard.

Technical rescue sub-committee

The technical rescue sub - committee for NZLSAR lead the process for putting this rope rescue standard together. The Backcountry Technical Rescue Standard is seen as a starting point to initiate a change in thinking for NZLSAR rescue teams.

Where possible research and best practice has been used from the international rescue scene. However, as additional sources of information are found and new research is undertaken, the information will be revised and updated.

This revision and updating will occur through the technical rescue sub committee which will meet once yearly. Input will be from relevant publications and research as well as individuals and teams in the technical rescue scene.

Chapter 2 System Standard

Section 1 Systems Analysis[1] (for Rope Rescue Systems)

Definitions

A **Rope Rescue System** can be described as a *system using fibre ropes, generally two or more, a main line(s), and a belay line, used to raise, lower or transport injured or stranded persons.*[2]

Systems analysis of a rope rescue system is the identification and examination of its components in order to understand their interrelated and interdependent nature as they perform a specified function. Systems analysis is broken into three parts:

- **Whiteboard analysis**
- **Comparative analysis**
- **Failure analysis**

Why would you want to undertake a systems analysis?

1. **Systematic:** To have a methodical way of assessing a rope rescue system.
2. **Facts not feelings:** To deal with facts without distortion by personal feelings or prejudices.
3. **Does it work? :** To make sure that the rope rescue system actually works the way it is intended or designed to.
4. **Improvements:** To have a method of comparing and contrasting new techniques, devices and procedures to make sure they not only work but are better than what is currently used.

Whiteboard Analysis

Sketch the entire system out in detail including angles(vectors), change of direction pulleys or other things that would affect the forces on the system. Check the system for the following:

Safety factor

What is a safety factor?
The ratio between the weakest link in the system compared to the maximum expected static load.

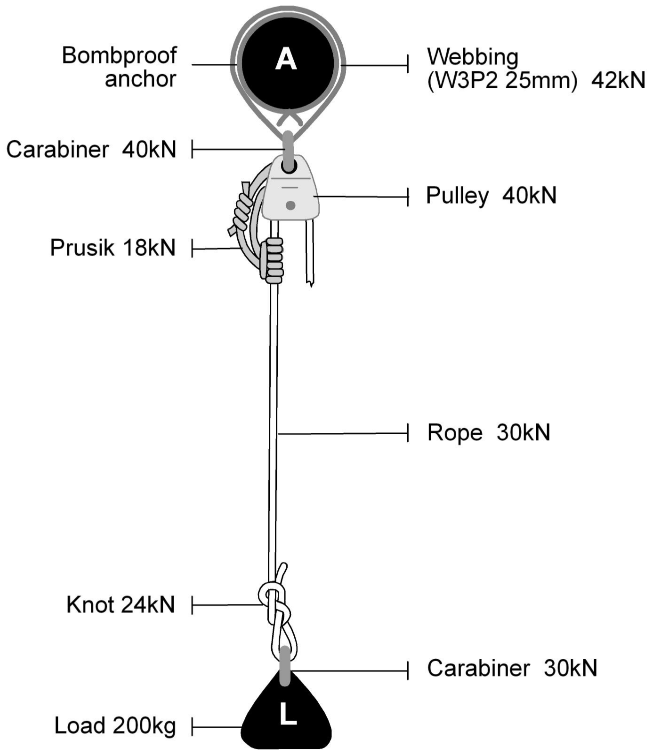
Why do we want a safety factor?
The static system safety factor accounts for complex and variable dynamic forces and unknowns such as rope ageing, abrasion, bending, rock/structure contact.[2]

[1] Original source of system analysis material: Kirk Mauthner. *Rigging for Rescue*, Invermere British Columbia, Canada.
[2] Arnor Larson. *Belay Competence Drop Test Method.* British Colombia Council of Technical Rescue.

How to work it out?

- On your sketch of your system identify the strength of each component part. Remember to take into account strength losses due to such things as knots in ropes and doubling of forces on change of direction pulleys.
- Decide on a maximum load that you would commonly put on your rescue system. This may be 100kg for a cave rescue or 200kg for a cliff or alpine rescue.
- Now identify the component with the least strength in the system and divide by the maximum load that will be put on it.

For Example



The diagram above shows a typical ratchet Prusik with a Prusik minding pulley set up with the mainline. The load is hanging on the ratchet Prusik.

- System weak point is the 18kN Ratchet Prusik.
- The 200kg load is creating approximately 2kN force on the system.
- 18 divided by 2 equals 9
- The safety factor for this system is 9:1

What is the goal safety factor?
A commonly used safety factor in rescue for a static system is 10:1.

What is a kilo Newton (kN)?

- The Newton [N] is the derived SI unit of force. One Newton is the force required to give a mass of 1 kilogram an acceleration of 1 metre per second per second. *It is named after the English mathematician and physicist Sir Isaac Newton (1642-1727).*
- With a prefix of kilo gives Newtons a multiplication factor of 1000 (or 10^3) hence a kN is a 1000 Newtons.
- To work out force you multiply mass and acceleration (f=ma).
- For example imagine a 100kg person hanging free on the end of a rope being acted on (accelerated) by the force of gravity.

  Force (N) = Mass (kg) x Acceleration (m/s^2)
  = 100kg x 10 m/s^2
  = 1000kg. $m/s^{2(}$
  = 1000N
  = 1kN

Critical Point Test

What is a critical point?
The critical point test examines whether or not a failure of any one component would result in a total system failure with ensuing catastrophic outcome.[3] *If critical points are found, they should be analysed to see if they need to be eliminated by a redundant component, backed up or accepted.*[4]

Why do we want to minimise critical points?
So the system is not dependent on one component. For example, if there were a main line failure due to an anchor pulling out the load would be caught by the belay line.

Hands off Test

What is it?
The hand off test determines what the rope rescue system will do if all the operators let go of it at the same time. If all the operators let go at once, the load should not end up the bottom of the slope or drop.[4] For example, consider a lowering system where both ropes pass through the same brakebar (twin rope). This would not pass the hands off test.

Why do we need a hands off test?
Firstly if everyone let go of the system at the same time there is a way of stopping the load from hitting the deck and secondly for dynamic events where human grip strength is unlikely to be able to hold the high forces involved in the fall.

Operating guidelines for safety

What is operating guideline for safety?
Consider how the system changes when performing operations and what procedures are used to keep its integrity.

When using a rescue system rescuers need to be aware of the safety factor, critical points and hands off capability of what they are doing. Meeting all three of these criteria will give the safest technical system.

If operating outside of these criteria rescuers need to be aware of the limitations of what they are doing and the possible consequences.

[3] Definition from Mauthner & Mauthner, *Release-Devices: A Comparative Analysis* Rigging for Rescue,1999.
[4] Frank, James A:*CMC Rope Rescue Manual.* 3rd ed. CMC Rescue, 1998.

Comparative Analysis

What is comparative analysis?
Comparative analysis is the examination of one or more alternative techniques, to what you currently do, to establish similarities and dissimilarities and to compare and assess these results to predetermined criteria. This requires one to practice the alternatives to fluency before an "informed" judgement can be made.
Criteria for comparison.

- Pro/con to what you currently do.
- Field trials – what did you find while practising the new technique.
- Practicality/efficiency/gear intensity

For example.
Release-Devices: A Comparative Analysis (Mauthner & Mauthner, 1999) developed the following tying complexity definitions:
Simple – Only a few simple instructions to tie it. Very few options to tie incorrectly. No difficult manoeuvres required. Would likely be able to remember how to tie even if not used very often.
Medium – Between simple and complex. Still reasonably straightforward but more time consuming and/or more likely to be forgotten over time.
Complex – Multiple steps involved, fiddly and/or easy to tie incorrectly. Would likely have to refer to the instructions if not used very often.

Failure Analysis

What is failure analysis?
Failure analysis is used to find out if the system configuration proves to be adequate or capable of carrying out the expected function to predetermined test criteria.
Testing.
This includes both dynamic and static type tests:

- Destructive tests
- Do the back ups work as intended under worst case conditions? (minimum and what additional margin?)
- It is important that the testing is representative of the typical field use situation.

Section 2 Lowering System

Definitions

Lowering System (n) A lowering system consists of a mainline package and belay package. The mainline package includes a brake, anchor, brake operator and rope. The belay package includes a belay, anchor, belayer and rope [5] (see Section 4 of this chapter for more details on the belay system)

Lowering(v) For the purpose of this standard lowering is defined as the process of lowering of a rescue sized load[6] down sloping or vertical terrain using a fixed brake lower[7] with the stretcher being attached at a single point either vertically or horizontally orientated. This technique allows the stretcher attendant(s) to concentrate on patient care and managing the stretcher with the rest of the operation being controlled from above.

Brake device consideration

Enough friction? - Make sure the brake device that your team uses can provide enough friction to safely lower a rescue sized load:

1. In a range of expected environmental conditions (e.g. wet, muddy or frozen ropes).
2. You have tested in the environment you intend to undertake the rescue (e.g. caves, mountains or cliffs)
3. With the equipment you intend to use (e.g. rope type)
4. With the rescuers to make sure they have enough gripping ability with the above variables.

Variable friction device – Can the friction on your brake device be increased or decreased when the tension is on the mainline? Consider changes in terrain angle, friction (or lack of it) from the slope or edge and weather (e.g. snow and rain). The brake will need to be able to account for these factors to keep a steady pace for the attendant(s) and allow the brake person to safely control the load.

Rope twisting – It is suggested that you choose a brake device that allows the rope to travel straight through rather than twist the rope.

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[5] Lipke, Rick. *Technical Rescue Riggers Guide. 1997.*

[6] There are three accepted rescue sized loads (test block mass) used: 100kg for a patient with no attached attendant e.g. cave rescue, 200kg for a patient and one attendant e.g. cliff and alpine rescue, 280kg for a patient and one or two attendants e.g. industrial and fire rescue.

[7] As opposed to a travelling brake lower where the rate of descent of the rescue load is controlled by a brake on the stretcher by the attendant as well as the belay line, patient care and managing the stretcher.

Section 3 Raising System

Definitions

Raising system(n) A raising system consists of a mainline package and belay package. The mainline package may include a pulley system, anchor, pullers and rope. The belay package includes a belay, anchor, belayer and rope (see Section 4 of this chapter for more details on the belay system)[8]
Raising(v) For the purpose of this standard raising is defined as the process of lifting a rescue sized load, on sloping or vertical terrain, with a direct haul, winch or a pulley system to create a mechanical advantage.

Pulley systems

Pulley Systems (Rigging for Rescue - Notes, 1997) describes pulley systems in terms of: *The ability to raise loads with a rope is increased when the rope is used in conjunction with a pulley or pulleys. Combinations of fixed and moving pulleys create systems that multiply the force that rescuers are able to apply – making use of mechanical advantage to reduce required strength, at a trade-off of increased endurance. Said another way, mechanical advantage enables a rescuer to lift a load applying less force than the load itself, but over a longer distance.*

Attaching a haul system to the main line

When deciding what to use as the link between the main line and the pulley system you need to consider:
- What will happen to the rope and device if the force applied gets too high?
- What safety factor are you now applying to your raising system?

Rope grab[9] test results are provided for your information in the "Guidelines" section of this standard to enable you to make an informed decision on which attachment method to use.

[8] Lipke, Rick. *Technical Rescue Riggers Guide. 1997.*
[9] A rope grab is any device that is used to hold onto a rope. This includes prusik (and similar knots) and mechanical devices.

Capturing the load as it is hauled

A method of holding the mainline is recommended between resets of a haul system. A manual or automatic ratchet device can be used.

As there is a chance for dynamic forces, careful consideration needs to be given to the choice of methods or devices. It is advisable that teams test their configuration to make sure it works under worst-case conditions.

Considerations for ratchet devices:

1. What is the result of a dynamic fall in position of function? i.e. if the haul team all let go of the raising system at the same time! What additional margins you have? What forces are involved?
2. What is the efficiency of the setup? i.e. what losses through friction in pulling power would you get with the ratchet.
3. What is the strength of the ratchet? This would affect the safety factor for the raising system.

Section 4 Belay System

Introduction

It is important to consider what belay technique you have employed in your rope rescue system. If the mainline system fails can your belay hold the load? Often teams will make assumptions about their systems without having tested it under worst case conditions. Make sure you know what you have or haven't got!
(see "Guidelines - Rescue Belays")

Standards

The Belay Competence Test Method *for rope rescue systems* developed by the British Columbia Council of Technical Rescue is an established standard for belay systems. The Belay Competence Test Method is recognised in the rescue community as a stringent test of a belay system to simulate a worst case dynamic event For example, an attendant and a patient in a stretcher are being lowered over an edge when the mainline fails and drops the load onto the belay system.

The test method

The test method considers a belay system in the sense of a previously unloaded rope, managed by another person, that is able to arrest falling objects by its connection to an anchor through various belay devices.[10]

*The test method includes taking a testblock of 200 kg mass, free-falling it (drop test) 1m on 3m of nylon low stretch rope with the test block being arrested by the subject test article connected to the components in position of function.***Error! Bookmark not defined.**

Other testblocks of 100 kg and 280 kg mass are used to represent different rescue sized loads used in caving and industrial/fire rescue respectively.

The fall arrest system demonstrates belay competence, based on the following criterion (summarised):

1. *It must perform consistently without impairing the integrity of the belay rope. Any of the following are unsatisfactory:*
   a *Stripping the sheath off the rope.*
   b *Severe damage to the rope or belay unit.*
   c *Reduction of the breaking strength of the belay rope to less than 80% of the rope's minimum breaking strength.*
2. *The maximum arrest force must be less than 15kN*
3. *The stopping distance must be less than 1m (pre-rebound).*
4. *The belay unit extension must be less than 40cm.*
5. *The maximum arrest force must be less than 15kN*
6. *The stopping distance must be less than 1m (pre-rebound).*
7. *The belay unit extension must be less than 40cm.*

[10] Arnor Larson. *Belay competence Drop Test Method.* British Columbia Council of Technical Rescue.

For a more detailed explanation of the testing methodology see the Belay Competence Test Method document (see page 22 References)

Which type of rope?

Low stretch ropes are recommended for belaying of a rescue sized load as a high stretch climbing rope will cause the load to fall a greater distance with a greatly increased risk of hitting something on the way down or taking a ground fall.

Which belay device?

Many belaying devices on the market have been designed for single person loads in climbing situations i.e. using a high stretch rope to absorb much of the impact force. Your choice of belay device will depend on the size of your rescue load.
(see "Guidelines – Rescue Belays)

Chapter 3 Team Performance[11]

Section 1 Introduction

Exclusions

This Chapter is intended to define the minimum competency for rescuers performing low angle to highline rope rescue in a backcountry environment. Those NZLSAR teams using rope rescue techniques in the course of a rescue will need to meet these requirements. These standards are meant only for performance of rope rescue skills. Teams performing specialised rescue in various environments such as alpine and cave will also need additional skills not covered in this document.

Overview

Type Rescuer capability
Description: Examples of terrain and situations where teams of this nature would be deployed.
Minimum equipment: A list of equipment that each rescuer of that Type must have access to, in order to undertake the procedures.
Procedures: The minimum skill set that each rescuer within a given Type must be able to perform safely and proficiently. Assessment of competency in a given type accepts competence in all lower type designation skill sets.

[11] This chapter has extensively used the New Mexico Committee on Technical Rescue Accreditation, *Technical Rope Rescue Unit Guidelines*, Tim Manning, April 19, 2000, version 4.0.

Section 2 Rescuer skill levels

Level I
Low Angle

Level I rescuers must demonstrate knowledge of and proficiency in the following areas:

- Rope and webbing care, construction and properties.
- Knots, bends and hitches to be used in rope rescue procedures.
- Two point philosophy
- Protecting self at an edge
- Construction of single point bombproof anchors.
- Construction and use of appropriate rescue belay.
- Construction of and use of a simple pulley system.
- Appropriate techniques for packaging a subject in a stretcher.
- Communication and command structure
- Procedures for assuring safety during low angle rescue operations.

Level II
Steep Angle

In addition to the procedures listed for Level I rescuers, Level II rescuers must be able to demonstrate knowledge of, and proficiency in, the following areas:

- Personal skills of abseiling, ascending, change over abseil to ascend and back, rescuer based pickoff.
- Construction and use of compound pulley systems.
- Perform hot changeover lower to raise and raise to lower.
- Construction and use of and lowering system.
- Use of edge protection and directional pulleys.
- Construction of a focused multi-point and linear marginal rescue anchor system.
- Use of stretcher attendants.
- Knowledge and understanding of the loads generated by a steep angle system and the resulting static and dynamic stresses on equipment and anchors.
- Procedures for assuring safety during steep angle rescue operations.

Level III High Angle

In addition to the procedures listed for Level I-II rescuers, Level III rescuers must be able to demonstrate knowledge of and proficiency in the following areas:

- Personal skills of lead climbing and, ascending / descending over a bend.
- Perform efficient knot pass procedures
- Construction of and use of a complex pulley system.
- Knowledge and understanding of fall factors and ideal and practical mechanical advantage.
- Perform team based pickoff with and without the stretcher.
- Perform rigging for multiple offsets including two line, deflection, tracking line, guiding line and tag line.
- Perform rigging for artificial high directionals including monopods, bipods and tripods and understand vector forces involved.
- Construction of multi point artificial rescue anchor system and focused floating anchors.
- Develop a rigging plan and undertake a whiteboard analysis.
- Procedures for assuring safety during high angle rescue operations.

Level IV Highline

In addition to the procedures listed for level I-III rescuers, Level IV rescuers are be able to demonstrate knowledge of and proficiency in the following areas:

- Procedures for rigging one, two and four rope highlines.
- Procedures for rigging the Norwegian and English reeve
- Procedures for rigging horizontal, sloping and steep highlines.
- Knowledge and understanding of the loads generated by a highline system and the resulting static and dynamic stresses on equipment and anchors.

Section 3 Team Type Descriptions

Type I Low Angle

Description:

- Evacuations on terrain up to 30 degrees.
- Typically low risk and low exposure to rescuers and subjects considering objective hazards and run out.
- A single rope belay may be needed.
- A 30-degree slope is similar to a moderate to steep ski run or a typical highway embankment.
- Rescuers may not be tied to system.
- Majority of weight on the ground
- Able to assist with more technical evacuation.

Minimum team equipment:

- Stretcher.
- One 50m 11mm low stretch rope.
- Belay device for rescue sized loads.
- Pulleys, Ratchets.
- Carabiners.
- Anchor ropes, 25mm tubular webbing.

Type II Steep Angle

Description:

- Capable of evacuations on terrain between 30 degrees and vertical.
- Rescues on this type of terrain would result in harm to rescuers or subjects if the team looses control of the stretcher load and will require a separate belay.
- A slope of 30 degrees to vertical requires the use of hands and feet to ascend.
- The environment would be accessible and not require lead climbing or multiple abseils to access the patient.

Minimum Equipment:

- Stretcher
- Two 50-60m 11mm low stretch ropes.
- Belay device for rescue sized loads.
- Lowering device for rescue sized loads.
- Pulleys, Ratchets.
- Carabiners.
- Anchor ropes, 25mm tubular webbing.
- Helmets, harnesses, and headlamps.

Type III
High Angle

Description:

- Capable of evacuations on steep to vertical terrain with multiple pitches and multiple changes in fall line possible.
- Lead climbing with a dynamic rope is likely to be required to reach the patient.

Minimum Equipment:

- Stretcher
- Four 60-80m 11mm low stretch ropes.
- Artificial High Directional, edge protection
- Pulleys, Carriages, Ratchets
- Belay device for rescue loads
- Anchor ropes, 25mm tubular webbing.
- Carabiners.
- Lead climbing equipment.
- Helmets; harnesses; headlamps
- Abseil and rope ascension equipment.

Type IV
Highline

Description for CIMS manual: Team capable of any evacuations involving complex highline operations. This a composite team

Minimum Equipment:

- Stretcher
- Eight 80-150m+ 11-13mm low stretch ropes.
- Artificial High Directional, Edge protection.
- Pulleys, Carriages, Ratchets
- Belay device for rescue loads
- Anchor ropes, 25mm tubular webbing.
- Carabiners.
- Lead climbing equipment.
- Helmets, Harnesses, Headlamps.
- Abseil and rope ascension equipment.
- Line delivery system, Pilot line, Messenger line.

Section 4 Minimum Response Team Makeup

Team Type	Team Leader (#1)	Team Members (#3)
Type I	Level I	Level I, X, X
Type II	Level II	Level II, Level I, Level I
Type III	Level III	Level III, Level II, Level II
Type IV	Level IV	Level IV, Level III, Level III

References

Frank, James (editor), *CMC Rope Rescue Manual,* CMC Rescue INC, 1998 (3rd ed).

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