RESCUE TECHNIQUES FOR EMERGENCY RESPONSE

An introductory manual for

European Volunteer Rescuers

EUROPEAN VOLUNTEER RESCUE TEAMS – SYNERGISING

edited by Trevor Calafato

Basic Rescue

Collapsed Structure Rescue

Rope Rescue

Water & Flood Rescue

Wildfire Response

RESCUE TECHNIQUES

FOR

EMERGENCY RESPONSE

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The European Association of Civil Protection Volunteer Teams

First published in 2017

Editor

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Design and typesetting

IdeaSoft – www.ideasoftmalta.com

ISBN: 978-99957-1-117-7

Printed at Progress Press, Mrieħel, Malta

Funded by the Erasmus+ Programme of the European Union

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"The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein."

Disclaimer:
This manual is meant to provide a brief overview of the various strategies and tactics used in various rescue scenarios. It is not meant to be a complete set of instructions by itself. It is mandatory that competent, knowledgeable and qualified instructors provide the necessary hands-on rescue training supplementing this manual. None of the techniques presented in this book are to be considered as stand-alone tuition.

The standards quoted in this manual were either standard at the time of writing or the acceptable practices adopted by the authors through experience. It is widely acknowledged that various skills and techniques may be adopted but the teams are presenting here what they believe is most appropriate in the fields they are usually working in.

All authors and organisations involved in the compilation of this book accept no liability or responsibility for personnel injury or death from the use or misuse of the information contained therein.

To all those committed rescue volunteers
who strive to help and save others when the need arises.

Contents

List of abbreviations

AED	Automatic Emergency Defibrillator
ANPC	National Authority for Civil Protection (Portugal)
ASR	Assessment, Search and Rescue
BCCTR	British Columbia Council for Technical Rescue
BoO	Base of Operations
BVM	Bag Mask Valve
CE	European Conformity
CEN	European Committee for Standardisation
CIC	Commander in Chief
CO2	Carbon Dioxide
CPR	Cardiopulmonary Resuscitation
DEFRA	Department for Environment, Food and Rural Affairs (UK)
DRA	Dynamic Risk Assessment
EN	European Standards
EVOLSAR	European Association of Civil Protection Volunteer Teams
GP	General Practitioner
GPS	Global Positioning System
HMPE	High Modulus Polyethylene
HUSAR	Heavy USAR
IC	Incident Commander
ICAO	International Civil Aviation Organisation
ID	Identification
INSARAG	International Search and Rescue Advisory Group
IRATA	Industrial Rope Access Trade Association
K-9	Canine
KED	Kendrick Extrication Device
LACES	Lookout, Awareness, Communications, Escape Routes, Safety Zones.
LAST	Locate, Access, Stabilise, Transport
LEMA	Local Emergency Management Authority
LUSAR	Light USAR
MA	Mechanical Advantage
MBL	Minimum Breaking Load
MBS	Minimum Breaking Strength
MMS	Moment Magnitude Scale
MUSAR	Medium USAR
NFPA	National Fire Protection Association
NGRO	Non-Governmental Rescue Organisation
OSL	Operational Section Leaders
OSOCC	On-site Operations Coordination Centre
OT	Operational Team
OTL	Operational Team Leader
OU	Operational Unit
PFD	Personal Flotation Device
PMA	Personnel Mechanical Advantage
PPE	Personal Protective Equipment
PTT	Push-to-Talk
QUAD	Quadrant
RDC	Reception and Departure Centre
RO	Rescue Operator
RT	Rescue Technician
SAR	Search and Rescue
SO	Safety Officer
SWL	Safe Working Load
TFA	Team First Aider
TPB	Tandem Prusik Belay
UHF	Ultra High Frequency
UIAA	International Climbing and Mountaineering Federation
UKFRS	United Kingdom Fire Rescue Service
USAR	Urban Search and Rescue
UV	Ultra-violet
VHF	Very High Frequency
VO	Virtual OSOCC
WLL	Working Load Limit

Acknowledgements

The authors, the editor and the persons who have supplied photographic or illustrative material are naturally the first that come to mind when acknowledging this work. However, being part of a multinational project, this book is the result of extensive work by several other people working behind the scenes. The project itself started with developing the idea and writing a proposal for the funding application, a task which involved the EFRU committee members. Later, following the approval of the funds, coordination and planning work involved members of the project partners, led by the EFRU project coordinator. Several committed members from the partner organisations were further involved in the background preparations for transnational meetings and rescue simulations.

Over and above the teams working on the project, a number of other volunteer rescue organisations contributed through their participation in the five-day training activity and in some occasions, also in transnational meetings discussing the topics covered in this book. These organisations include Associação Humanitária dos Bombeiros Voluntários de Peniche (Portugal), Unidad Canina Rescate y Salvamento Madrid (UCRS, Spain), Central Buda Volunteer Civil Protection Association (ÖPVE, Hungary) and Rescue GR (Greece).

The project is all about bringing together volunteers working in rescue scenarios and this book is a testimony to the great team work developed by all persons involved, all dedicating their time voluntarily to achieve the best outcome for the project. To all this, we are truly grateful and we hope to inspire more people to join this growing community of rescue volunteers.

Maria Vassallo Micallef
(Project Coordinator)

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(Project Manager)

On behalf of the EFRU,
lead team for this project.

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A significant amount of sketches and illustrations have been prepared by **Elina Nikolaou** (CCPVC) and **Josef Mizzi** (EFRU) respectively. Josef also worked extensively on vRigger illustrations used in Chapter 3: Rope Rescue, as well as substantial photo editing throughout the book. Some illustrations were supplied by **Kyriakos Kyriakides** (CCPVC) and **Angeliki Apostolaki** (ETSM). **Keith Borg** (EFRU) produced artwork and design ideas for the cover page and chapter title pages, while typesetting and book design was taken care of by **Stephen Said** (www.ideasoftmalta.com).

Proofreading and Indexing

The following contributed greatly to the quality of the book through proofreading as well as in developing the book index:

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Muscat, Iona (EFRU) – Proofreading, indexing.

Zammit, MariaElena (EFRU) – Proofreading, indexing.

Synergising European Volunteer Rescue Teams

Lead Team:

Emergency Fire & Rescue Unit

Partner Organisations:

Cyprus Civil Protection Volunteer Corps

Edelweiss

Elite Team Special Missions of Greece

Escola Portuguesa de Salvamento

Serve On

6 Volunteer Rescue Organisations

Rescue Manual Development

Transnational Meetings

November 2015 .... **Portugal**
April 2016 .... **Italy**
July 2016 .... **Malta**
September 2016 .... **United Kingdom**
January 2017 .... **Greece**

Rescue Manual Chapters

- Basic Rescue
- Collapsed Structure Rescue
- Rope Rescue
- Water & Flood Rescue
- Wildfire Response

42 foreign participants

30 local participants

5 Day Training Activity

Malta, February 2016

≈ 70 foreign participants

≈ 50 foreign observers

≈ 30 local participants

Rescue Simulation

Malta, 12th May 2017

Preface

More than 15 years ago, I remember today's EFRU director and myself dreaming about developing a guidebook for rescuers, something that we felt was lacking while we were both involved in rescue volunteering. Of course, there were already various books dealing with rescue disciplines requiring a high level of skill out there and today, even more so. However, a basic manual that could guide a team in developing its human resources in the elementary aspects of the most important disciplines was not available. When the director and myself conceived the idea of such a book and discussed the objective of such a project, we had no means, time and resources. Today, I find myself writing the preface as the editor of a rescue manual, a book which resulted from the effort of multi-European teams led by the Emergency Fire & Rescue Unit.

Time passed and I had to give up rescue volunteering due to my academic engagements but in summer 2015 the EFRU director contacted me. After a chat, he informed me of the possibility that our dream of developing a rescue manual could become true. The EFRU had applied for EU funds to implement a project that would see the development of a rescue manual together with five other European voluntary rescue teams. The director explained that resources had become available and he offered me the possibility to edit the book. It was the first time that I was taking this role. However, since I had finished my PhD about a year and a half before, I thought that this would be the perfect time for me to do this. The next step was to meet the people directly involved in this project, within the EFRU. A number of decisions had to be taken and it was not an easy task, particularly because of very strict deadlines. On the whole, however, I have to admit that it was a great team to work with. Finally, with great effort and after innumerable sleepless nights we, as a team, managed to coordinate this project together with the other voluntary rescue organisations. It was quite an arduous task to overcome language and cultural barriers. Additionally, it was quite strenuous on all the organisations involved to create a baseline, to decide what should be included and what information should be left out, what style of writing to adopt and most of all to ensure that what is written is clear, understandable, informative and edifying for the new recruits. Though being a daunting exercise, one must say that all the groups on board the project appreciated each other's effort and finally agreed that skills and techniques listed in this book should set the basic standards of the European Association of Civil Protection Volunteer Teams (EVOLSAR – www.evolsar.eu).

The EFRU had, along with another four voluntary rescue organisations, founded EVOLSAR back in May of 2014. Being at the helm of the association, the EFRU was incessantly on the lookout for funds to start developing and harmonising rescue skills among the various teams. The opportunity was identified within the Erasmus+ KA2 Strategic Partnerships funding strand and therefore, back in the first months of 2015, the EFRU approached all the founder members of EVOLSAR (CCPVC, Edelweiss, EPS, ETSM and the then candidate team member Serve On). The aim was to develop a harmonised approach through sharing of ideas, networking, training together and long hours of discussions during and beyond transnational meetings.

At the time of publication, EVOLSAR boasts nine voluntary rescue organisations as member teams and intends to have more teams on board within this year. It is an ever-growing community of volunteer rescuers who wish to come together to be able to deploy as a multinational team in the aftermath of a catastrophe. In a country where member team/s already exist, EVOLSAR could deploy personnel in support of the member organisation of the home country, thus reinforcing the team of the country under emergency. The networked teams train regularly together, at least twice yearly in their various countries.

Thus, after having stopped ten years ago being a rescue volunteer, I am happy to be editing *Rescue Techniques for Emergency Response: An introductory manual for European volunteer rescuers*. This book is a dream coming true because it brings together a series of techniques that are used in various emergencies. More than that, this book is going to serve a much bigger purpose than one could ever dream of as it will be used by numerous volunteers across Europe. These rescue techniques are brought together in five distinct chapters. The first chapter is called *Basic Rescue* and is aimed at bringing together basic principles that are common to the rescue disciplines dealt with in this book. These principles provide a thorough look at the skills, techniques and equipment that equip the volunteer to intervene in real rescue operations, which might vary. The subsequent four chapters focus on specific rescue disciplines and the management of various scenarios. Every chapter sets the context and background of incidents, which determine a particular rescue discipline and the related safety measures and equipment to be applied and used as well as related rescue techniques. Rescue from collapsed structures – which is the subject of Chapter 2 - often occurs after an earthquake takes place. This chapter therefore briefly outlines different systems that measure the effect of earthquakes, followed by the process of managing and conducting Urban Search and Rescue (USAR) in such situations. Chapter 3 delves into rope rescue and includes detailed graphics illustrating different equipment used, as well as the concepts involved in setting up for the rescue task at hand. This includes anchoring, pulley systems and the related mechanical advantage, applied to low angle, steep angle and high angle rescue techniques.

Water and flood rescue, the theme of Chapter 4, digs into rescue from fast flowing water and flooding. Topics discussed include different hazards relevant to each scenario, the decision-making process and rescue priorities, managing the incident scene, safety, signalling methods and victim care considerations in water-related incidents. Finally, Chapter 5 reviews the role of the rescuer in *Wildfire Response*. Fire extinguishing strategies vary with the different wildfire behaviours. Therefore, the reader is first taught to understand the behaviour of fire through its various indicative features. Apart from helping to choose the strategy, this is also critical for the rescuer to be one step ahead of the fire and plan safe escape routes. Still, it may sometimes be necessary to use emergency procedures should a worst case scenario occur.

These five chapters might not cover all the scenarios that a rescuer might encounter, but in my opinion this is a testimony of tough work, the situations that rescuers face and, most of all, the great dedication and investment of voluntary rescue groups. Thus, while I cannot stress enough that this manual should not be used by rookies to test and experiment any of the techniques unless under the instruction of properly qualified and experienced tutors, I hope that you enjoy this work and make the best use of it to help others!

Trevor Calafato

1 BASIC RESCUE

The Emergency Fire & Rescue Unit (Malta)

Supported by:

Serve On (UK)

Cyprus Civil Protection Volunteer Corps

Introduction

The aim of this chapter is to introduce the volunteer to the principles of basic rescue. It groups together concepts, skills and equipment that are common to a number of rescue disciplines covered in the following chapters of this book. All techniques being presented here are meant to accompany proper training by a qualified instructor. Organisations which are members of EVOLSAR[i] plan to use this material to prepare their volunteers for deployment under the EVOLSAR umbrella.

This chapter is split into two sections, with the first section dealing with the principles, presenting an overview of the role of the rescue volunteer, the characteristics of a non-governmental rescue organisation and an understanding of risk management. The second section deals with skills, techniques and equipment common to most rescue scenarios, covering an element of first aid in a rescue team, information about ropes and knots, ladders, casualty and stretcher handling as well as communications during rescue operations.

The Principles

The rescue volunteer

A rescue volunteer can be any person (over the age of 18) who is physically and mentally fit to perform the various rigorous tasks pertaining to rescue and civil protection and who has a genuine interest in helping others in need.

Volunteers need to show dedication and a serious commitment towards the rescue organisation and its cause. The volunteers should refrain from enrolling if they are already involved in other activities that might interfere with their duties in the organisation. The strength of the team depends greatly on the work of its members. The commitment required should therefore be made clear to potential recruits during an interview prior to enrolment. Subsequently, the selection committee must take an informed decision as to whether the potential recruit is to be accepted or not, in the interest of the organisation.

The selection committee should encourage the potential recruit to portray one's skills. Such skills may vary from an administrative nature to more hands on such as mechanical skills, or qualifications to operate certain equipment or vehicles.

A volunteer should not enrol within an organisation solely for personal gain, such as the intention to acquire a better position in the work place or to find a better career. The enrolled volunteers should present a good image of themselves and the organisation through their behaviour in public, in order to maintain the confidence of civilians in the rescue volunteers and the organisation.

Figure 1: A rescue volunteer sorting equipment in the staging area.

[i] EVOLSAR stands for the European Association of Civil Protection Volunteer Teams. More information may be found in the preface of this book.

The volunteers are to address their superiors and each other in a respectful manner. Any type of harassment should not be tolerated and should be professionally dealt with through the correct channels within the organisation and beyond, as necessary.

Personal appearance, self-discipline and physical condition

Personal hygiene is of utmost importance especially when working within a team. The personal appearance of a volunteer determines the outlook of an organisation. A clean, smart uniform, clean boots, complemented by well-groomed hair and beard (where applicable) will yield a positive impression of the organisation and helps to maintain a good reputation, especially with respect to good order and dependability. It is expected that every volunteer is committed and self-disciplined when it comes to wearing the organisation's uniform. Jewellery, especially face piercings, may pose a safety risk and should therefore be avoided. In the case of earrings, for instance, only the small stud-type are to be worn.

A volunteer is expected to keep in a good physical condition and take part in any set physical programmes that the organisation offers. Rescue operations may be arduous and all volunteers have to ensure to keep themselves physically capable so as to serve the team as an asset and not become a liability. Smoking should be forbidden at all times during training and operations and should be allowed only when away from the training or operation zone and only during rest periods.

Attention to training

It is very important that volunteers participate in the training sessions with utmost attention and should endeavour to understand well what is required of them, under the guidance of a mentor or instructor. Through its leaders, the organisation is to note the volunteer's strengths and weaknesses and strive to maximise the ability of each volunteer.

The leaders have a good knowledge of the requirements of the different rescue disciplines that the organisation practices. Therefore they should periodically evaluate the aptitude and skills of the volunteers, in order to recommend the best volunteers to start training in a specific discipline (thus maximising efficiency and likelihood of success in training). Volunteers should make every effort to attend such training and abide by newly established procedures.

Involvement in exercises and operations

It is expected that after being trained and assessed, the successful recruit will get involved in the activities that the organisation partakes in. For this reason, the administration should periodically evaluate each volunteer and the involvement within the organisation. Training provides the ideal setting for the volunteers to query about new procedures and techniques. Meanwhile, during simulation exercises and actual rescue operations, a volunteer is not expected to question and should refrain from disobeying specific instructions given by the leaders (unless the safety of anyone involved is in jeopardy).

Before the rescue organisation entrusts assignments, it is essential that any limitations that might hinder the completion of the task given are pointed out by the respective volunteers. Thus, although the officer in charge is expected to be well aware of the capabilities of the volunteers, it is the responsibility of each and every member to see that their limitations are not jeopardizing the rescue operation. These limitations may include physical, medical and/or mental issues and should be listed in the enrolment form if already present at the time of enrolment.

While exercising various potential scenarios a volunteer also needs to be prepared for the realities of a disaster scene. The role of the rescue volunteer in case of a major disaster may include dealing with injuries and death, which leaves an impression on those involved in the situation. Thus, the team leaders are to approach volunteers involved in an incident, particularly those struggling with the traumatic stress caused by the incident and encourage the member to seek help and consult a counsellor or a psychologist.

The importance of psychological support is also valid for the casualties themselves. While tending to the casualty, the volunteer needs to provide emotional and psychological support. This is an essential part of all rescue operations where the casualty should be kept calm as much as possible so as to avoid further injuries to themselves or even to the rescuers. Therefore, it is vital that the volunteer keeps the casualty aware of what is happening, including any procedures and actions that will follow until the casualty is in transport to hospital.

Working as a team member

Volunteers work in teams which may include a mix of genders, ethnicities and nationalities. Hence the volunteer should adopt a sense of integrity and respect for persons with different backgrounds and cultures.

All team members must be competent in the techniques involved in the respective rescue discipline and must be aware of the various dangers and risks inherent in rescue. All members are responsible for the safety of their colleagues and third parties, including the casualties themselves, as well as their own.

The rescue organisation

An organisation is '*a social unit of people that is structured and managed to meet a need or to pursue collective goals*'.[1] In any rescue organisation the most important and collective goal is to preserve life and mitigate the deterioration of the casualty's condition. Adequate basic training to the volunteers in preparedness for operations and deployment is fundamental. This manual is primarily meant to guide volunteers and Non-Governmental Rescue Organisation (NGRO).[ii]

All organisations need to have a management structure that defines the relationships between the members and their assigned roles, responsibilities, and authority to carry out different tasks as required by the organisation. This structure has to promote interoperability, not only amongst the individual team members but also between rescue organisations that frequently train and work together. Interoperability is, in fact, one of the attributes that EVOLSAR actively promotes among its member organisations.

NGROs greatly rely on the commitment and sacrifices done by its volunteer members to reach its objectives. More often than not, the volunteers dedicate long hours and sometimes even money out of their pocket for the benefit of the organisation. For this reason, the organisation (through its administration and management) is morally obliged to function as efficiently as possible and to be focused on achieving its goals and mission. In order to achieve this, members need to be selected diligently, trained adequately and led by competent leaders. A team of instructors and a documented system to evaluate learning outcomes are key to this. The organisation also needs to seek and make available training and simulation activities with other similar organisations to achieve a network that can provide peer learning opportunities.

Figure 2: A team may be composed of several rescuers from different organisations.

[ii] For the purposes of this manual, a Non-Governmental Rescue Organisation (NGRO) is considered to be an organisation which exists for a particular cause, with educational/charitable objectives, and from which its volunteers and the management, including Directors, do not benefit financially or in any other way. Any funds earned by a non-profit organisation must be retained by the organisation and used for expenses relating directly to the work it does, such as setting up training operations, purchasing of equipment etc.

Rescue organisations should set as their main objective the preservation of life and the rescue of live casualties, irrespective of any differences in beliefs (such as, politics, religion, culture, race and gender) between the members. This is especially true when a team is composed of individuals coming from various countries, possibly having conflicting cultural influences. These influences could, in turn, affect the priorities of a rescue operation. A rescue team could face a similar situation when deploying to countries having religious or cultural differences. An example of such situation is where the dead need to be buried before sunset, so the relatives would pressure a rescue team to retrieve dead bodies first. Priority should be to rescue live casualties first, but a compromise may sometimes be needed where a separate team is assigned objective of recovering dead casualties as soon as it is practically possible.

Team fitness

Being involved in rescue operations may be mentally and physically demanding. Consequently, every rescue organisation should not only ensure that its members are knowledgeable of the various rescue techniques that are used, but also the volunteers should have an adequate standard level of fitness for the task. The aim is not to expect professional athletes, but to have a team of people who can endure and perform efficiently and on whom the team leader can rely during rescue operations.

Fitness in itself should not be a criterion for the selection of potential recruits. However, the organisation needs to assess the physical activities involved in its various operations. In order to verify that the individual members meet the required fitness level, every volunteer should be periodically assessed to ensure an adequate level of fitness is maintained, ready for deployment. Rescue organisations should set fitness guidelines for their members to reach and maintain the required level of fitness. Some typical physical exercises that may be used to gauge fitness levels are push-ups, sit-ups, jumps, half pull-up hangs, sit-and-reach and 12-minute runs.[iii]

The rescue team

In order for a rescue team to operate with synergy and efficiency, it requires a hierarchy of roles, normally referred to as the command structure. While this may be pre-established in the case of a standalone rescue team, there are cases where multiple teams join forces to work together. In such cases, the command structure needs to be established ad-hoc. The principal objectives are to have one person in charge (incident command) taking the overall decisions and a supporting structure to which tasks and responsibilities may be delegated. The number of people that the incident command communicates with should be limited to manageable levels to enable good communication and to maintain situational awareness. Whenever teams include members from various nationalities, it is important to have multi-lingual team members to facilitate communication.

The command structure that is ultimately established depends on several factors such as the size and type of the incident and the teams responding to the incident. The following is one possible structure based on the EVOLSAR concept of multinational deployment. On top of this hierarchy there is the Commander in Chief (CIC). The CIC is in charge of managing a number of rescue teams, so the CIC needs to be able to prioritise, be a good strategist and to be fully aware of the capabilities of the teams and available resources, while not necessarily being directly knowledgeable of the individual volunteers' capabilities within each team. The CIC communicates with Operational Section Leaders (OSLs) who are in charge of Operational Units (OU).

OSLs are usually field officers who are responsible for the various operations. OSLs are technical people who are knowledgeable of the volunteers' capabilities, strengths and weaknesses, as well as the equipment and resources available. An OU will have a number of Operational Teams (OT) composed of volunteers having various roles, knowledge and expertise. Every team is led by an Operational Team Leader

[iii] 2-minute runs are frequently used to test the cardio-vascular fitness of a person. Dr. K.H. Cooper determined norms for the distance covered in 12 minutes, based on age, against which one can compare their result. Cooper, K.H. (1968), "A means of assessing maximal oxygen uptake," Journal of the American Medical Association, 203:201–204.

(OTL) who communicates with the OSL and normally the operational team is tasked with a specific rescue technique, for example rope rescue. The OTL will normally have reached this rank through experience and technical expertise and should be extensively skilled in various disciplines with particular capabilities including people management. The person holding this role should have a good understanding of the strengths and weaknesses of the individual members of the team and be well acquainted with the available equipment and its limitations.

An OT will also have a Team First Aider (TFA), a Safety Officer (SO), Rescue Technicians (RT) and Rescue Operators (RO). The person acting as TFA should have an advanced knowledge of first aid and can administer at least the initial medical aid to a casualty at the rescue site. The TFA should also be able to reach the rescue site without requiring additional assistance from the other rescuers. An experienced member of the team will act as a Safety Officer (SO) and will have the responsibility to assess the work site and inform the team members of any hazards. The SO is also assigned the task to check on all the operations and call out on any unsafe situation when and as it is noticed. Ideally, the SO should be a person dedicated only for this role but may assist in the actual operation as an assistant in hauling or to support edge transitions.

The more technical persons, the RT, will assume responsibility for the technical aspects of the operation. Depending on the size of the team and the nature of the rescue, each team may have a number of technicians. The RT may be responsible for the rigging and hauling systems, tools and equipment, mechanised tools such as spreaders and demolition hammers and shoring construction, just to mention a few technical aspects. Finally, there are the RO. These are usually the runners, the hauling and lowering line attendants, the tool users and those who are assigned to do any other task synonymous with the rescue scenario.

Risk management in rescue operations

Volunteers need to be prepared to work with official organisations at a national or international level according to the arrangements for civil protection. Good management of potential risks and coordinated efforts aim at providing the best response to the needs of casualties while ensuring the safety of rescuers. In a multi-agency context one requires to understand that different organisations adopt different methodologies.

Nonetheless, health and safety matters remain of utmost importance because they safeguard legal, economic and moral parameters. Organisations and individuals are to abide by health and safety laws and regulations. The provision of adequate equipment and training reduces the risk of persons getting injured besides the eventual legal repercussions. Everyone in the team has health and safety responsibilities but the leaders and commanders are ultimately responsible for the overall management of the risks involved. In a multi-national context, the perception of risk might vary, as do the respective mitigating methods. Thus the key to success is to maintain dialogue with all teams and operate within a clearly-defined command structure.

To adequately manage safety at any incident, continuous risk assessment becomes a requirement. Anyone working at the incident site needs to be made

Figure 3: Hazards in an emergency scenario.

aware of any hazards identified as well as protection put in place to safeguard against these hazards. The organisation needs to have procedures in place, while the individual needs to follow these procedures and be proactive in noticing potential risks and communicating them to others. Thus, it is crucial for the volunteer to understand the importance of health and safety procedures and guidelines to reduce operational risks to the minimum.

The following is a basic overview of risk management, including how risk can be assessed and how mitigation measures can be identified. While there are various sources of information on risk management, guidelines from the Irish Health and Safety Authority were consulted in the compilation of this section.[2]

Managing risk involves identifying hazards and providing adequate controlling measures when possible. It is therefore important for the rescue volunteer to understand the following:

- The principles of dynamic and analytical risk assessment,
- The method used to carry out risk assessments,
- The importance of recording risk assessments, and
- The significance of sharing the risk assessment with all the other team members and rescue agencies.

There are various types of risk assessment but this work takes in consideration only the analytical and dynamic assessments, being the most suitable for the scene of the incident and the close proximity. The analytical assessment is most

Figure 4: Pointing out risks during a handover.

likely to be done by or on behalf of the incident commander or sector commander and should be recorded. Meanwhile, the dynamic assessment should be ongoing by all operatives to continuously manage their own working environment. The risk assessment process is the same for both types of assessments as both follow a guide of five main steps:

1. Identify the hazard (What could potentially cause harm to you and others?)
2. Consider the risks associated with the hazards (Risk is defined by the severity and the likelihood of the harm occurring due to the abovementioned hazards).
3. Identify who is at risk.
4. Consider what control measures are already in place and add further control measures required to mitigate the risk.
5. Review the situation after implementing the new measures and restart the process.

When considering who is at risk, one should include all stakeholders, be they members of the organisation, bystanders or any other third parties. It is important that everyone who may be affected in any way is informed about the outcomes and control measures of the assessment. When deciding on any control measures needed, one may consider the following hierarchy based on reducing the effectiveness of the control measures but also decreasing effort to implement the control measures:

- Eliminate the risk
- Reduce the level of risk
- Isolate the risk
- Control access to the risk
- PPE (ensure correct PPE is worn)
- Discipline (Impose and maintain discipline and ensure the competence of people exposed to the risk)

When conducting a risk assessment exercise, there could be a number of pitfalls which could jeopardise the assessment. Some of these pitfalls include:

Example: The risk of further building collapse due to aftershocks following a major earthquake.

The **hazard** is the potential for aftershocks, which may cause further building collapse.

The **risk** is rescuers being trapped in further collapse due to aftershocks.

It is possible to **ELIMINATE** the risk if no one goes inside. However, this means that rescuers would never enter collapsed buildings to rescue survivors, so this is not always practicable.

Risk can be **REDUCED** though, by only allowing the minimum numbers of rescuers to enter the building.

Risk can also be **ISOLATED** putting cordons in place so other rescuers/bystanders do not go in. One can also **CONTROL** who goes in and comes out by putting in place entry and exit points and then making sure all who go in are wearing the correct **PPE** and using guidelines. This will ensure that one can quickly follow the guideline through the rubble to reach trapped rescuers if a further collapse takes place while rescuers are inside.

Finally, only **DISCIPLINED** (trained) operatives enter the building.

To understand the nature of the different hazards and to help during their identification, it may be useful to break them down into categories. Table 1 (below) shows some examples of hazards and how they can be broken down into different categories.

Physical	Chemical	Biological	Psychological
Electrical	Chemical storage	Blood	Violence
Trips and falls	Flammable substances	Bodily fluids	Working alone
Vibration	Corrosive substances	Human waste	Poor leadership
Poor lighting	Mutagenic substances	Bacteria/viruses	No procedures
Temperature	Drugs	Animal waste	Bullying
Humidity		Insect and animal bites	Fatigue
Exposure to UV rays			
Work at heights			
Overhead hazards			
Smoke			

Table 1: Categorising the types of hazards.

- The rescuers becoming over excited or too keen to help, which may result in lack of safety focus. This is called the 'hero syndrome'.
- The demands of the incident putting pressure on the risk assessor to act before thinking clearly and considering all possibilities.
- Conflicting priorities among rescue organisations.
- Lack of understanding of the needs of the rescue response.
- Confusion over who has ultimate responsibility during a multi-agency operation.
- The casualties or relatives crying out for help or assistance, disturbing and hindering the assessor from obtaining a clear and objective judgement of the risks present.

Ideally all risk assessments are written down and recorded. However, in critical situations there will be no time to write down the dynamic risk assessments. Yet, for team leaders and safety officers responsible for the safety of the team, the process of recording risk assessments is necessary to ensure that all hazards and risks are identified and appropriate control measures are put in place.

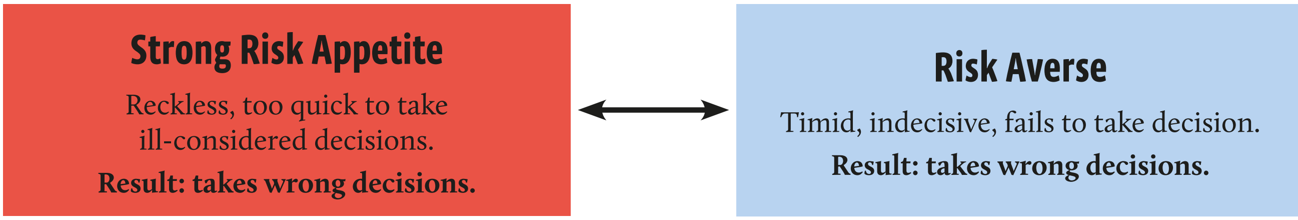

Figure 5: Extremes of Risk Appetite.

Writing down risk assessments provides a record that can be used to brief other personnel entering the scene as well as for reviewing further assessments. There is no standard format for recording assessment but it is important that the volunteer should be familiar with the systems used in the organisation.

A sample risk assessment recording form, in Appendix 1, provides an example of how risks may be recorded. The form requires the assessor to determine the level of a particular risk by scaling the severity of the risk and also the likelihood that it happens. This can be subjective, depending on the assessor's experience. Thus, the incident commander (who is ultimately responsible for the overall safety of the rescue operation) has to ensure that whoever is doing the risk assessment has the necessary background of knowledge and experience, as these factors determine the accuracy in identifying and scoring potential risks. Based on the level of the risk, the assessor will take a decision if the risk is acceptable or if any actions (generally referred to as control measures or mitigating measures) are needed to reduce the risk to an acceptable level.

When existing control measures are adequate enough to allow one to accept the risk, then the operation may proceed. Otherwise, it may be necessary to increase the control measures, if possible, in order to further lower the level of risk. The scoring process is repeated taking into consideration the additional control measures which determine a new rating of the potential risk. This remaining risk rating is called residual risk. At this point, one needs to take a decision if the residual risk is acceptable or at least tolerable, which would permit the continuation of the operation. On the contrary, if the residual risk is perceived to be still too high the operation shall be stopped.

There could be instances where, despite the residual risk still being higher than normally accepted, the benefits of conducting the operation outweigh the residual risk. In such instances the risk may be tolerated. This is referred to as a 'risk/benefit analysis'. The attitude of a person towards risk, also referred to as 'risk appetite', that is how much risk a person is ready to tolerate, determines how one would react to high risk situations (Figure 5).[3]

The Safe Person Concept and situational awareness

Risk management continues throughout any operation and exercise and follows the 'Safe Person Concept'.[4] The safe person concept is a way to ensure safety at an incident site where it is not possible to control the working environment to make it safe, so instead, the persons working onsite will use safe equipment and PPE, follow safe working practices and are trained to look for and avoid risks (thus the term 'safe person'). As both organisations and individuals have health and safety responsibilities, training to develop the understanding of risk awareness and risk attitude is of utmost importance. Improving best practices will eliminate poor attitudes and malpractices. Some personal qualities that training aims at improving are the following:

- Competence
- Self-awareness
- Observation
- Decisiveness about hazard and risk
- Ability to communicate effectively
- Situational awareness

These attributes are essential for when the volunteer is to face serious and large-scale incidents.

Volunteers need to be prepared to react appropriately when faced with tasks that will be outside their comfort-zone and to be more aware of the surrounding context and situation. This is easier said than done, however, since rescue volunteers have very limited direct exposure to such big incidents.

Situational awareness is the perception of and responsiveness to what is going on in the surrounding context as it could affect oneself, the team or the operation. This would include anything that can happen in the near future, that could suddenly require a change of plan or action, especially in relation to risk mitigation. An incident site can be very dynamic and if rescuers, especially team leaders, focus on a specific task without taking into account any changes in the working environment, then they will be taken by surprise. Consequently, they will find themselves unprepared for any new risks that crop up. A complete and continuous situational awareness and understanding of the information at hand ensures a more adequate management of the perceived risks, helping to plan ahead of events and avoid potentially critical situations.

Skills, Techniques and Equipment

First aid

An inherent part of rescue is the retrieval of casualties from a variety of dangerous situations. In many cases, the persons being rescued require some form of medical attention. Since the rescue team is normally the first contact with the casualty, it needs to provide first aid as initial care on the scene before transporting the casualty to a safer location and eventually convey the casualty to the paramedics or hospital teams. Thus, all team members must be competent in basic first aid and preferably have some knowledge of advanced care. Ideally, at least one team member should be qualified in advanced first aid, because the incidents that rescuers are deployed on, very often involve seriously-injured casualties. The assignment of the advanced first aider is to monitor the casualty and provide care during transport until handed over to the paramedics or hospital teams. First aiders need to keep up to date with the latest guidelines laid out by local and European entities such as the European Resuscitation Council, among others.

The basic first aid skills required by every volunteer, derived from guidelines published by the European Resuscitation Council and based on the expected nature of injuries or conditions of casualties, include the following:[6]

- Assessing the scene of the incident, identifying any dangers and applying measures required to prevent further injury to the casualty or to the rescuers;
- Performing primary and secondary assessments of the casualty (identifying any injuries and conditions, including constant monitoring of the casualty for any signs of deterioration);
- Performing cardiopulmonary resuscitation (CPR) and using an Automated External Defibrillator (AED);
- Identifying and treating conditions affecting the uptake of oxygen by the casualty such as hypoxia, airway obstruction, drowning, asthma and penetrating chest wounds;
- Identifying symptoms indicative of blood circulation problems, including internal and external bleeding and shock, as well as controlling such injuries or conditions;
- Treating severe injuries such as impalement and amputation, crush injury, head wounds, and foreign objects embedded in wounds;
- Treating and managing different types of fractures and also treating strains and sprains, applying bandages, splints and slings;
- Identifying head injuries, spinal injuries and stroke;
- Treating burns, dehydration, heat exhaustion, heat stroke, hypothermia and frostbite;
- Identifying and treating other conditions such as allergies and anaphylactic shock, hypoglycaemia and

hyperglycaemia, poisoning, bites and stings;

- Providing basic psychological support to the casualty by offering reassurance and keeping the casualty informed of what is about to happen; and
- Advising the other rescuers on the best casualty handling techniques to use, after taking into consideration the injuries sustained.

Once a first aider identifies the casualty's injuries or conditions, treatment will require certain equipment and medical supplies. These are normally carried to the scene in a first aid bag. The contents (see inset box) of the first aid bag should reflect the capabilities of the users and all team members should be familiar with the correct use of at least the basic components of the kit. More equipment may be included in first aid bag, depending on the skills, knowledge and qualifications of the person administering the first aid. However, the use of particular equipment may be restricted to adequately qualified personnel. National regulations (of the country where the incident occurred) may also prohibit the use of certain equipment or medication. Thus, it is necessary to keep constantly updated on first aid guidelines and national rules, which determine the use of specific equipment and techniques.

Figure 6: First Aid Kit Bag (Contents shown are just an example).

Suggested contents of a typical first aid kit

The basic components of a first aid kit bag include:

- Rigid cervical collar – adult and paediatric. Preferably adjustable to fit different neck heights
- Roller bandages (various sizes)
- Triangular bandages
- Foil blanket
- Swabs
- Sterile dressings
- Adhesive dressings
- Sterile saline solution (for irrigation of wounds)
- Tape (for closing off a bandage end)
- Gloves
- Splints
- CPR mask
- Oral rehydration salts
- Glucose syrup
- Burn gels (specially formulated burn covers)
- Cling film (for covering of burns)
- Kidney tray (for collection of fluids and waste items)
- Waste bag
- Clean plastic bags (for collection of amputated body parts)
- Instant cold packs
- Freeze/cold spray

The following items must be used only by qualified personnel and kept under their direct supervision. The qualified person is completely responsible of first aid kits, which may include the following items:

- Tourniquet
- Sphygmomanometer (manual and/or automatic)
- Blood glucose meter
- Pulse oximeter
- Oropharyngeal airways
- Bag valve mask (BVM)
- Oxygen masks (adult and paediatric)
- Portable oxygen cylinder (ensure cylinder is full and functioning)
- Butterfly stitches
- Topical skin adhesive
- Needles (for lung decompression)
- Stethoscope (preferably with built-in amplification)
- Topical anaesthetic spray (Ethylene chloride)
- Manual suction pumps

Ropes

In rescue and emergency response, ropes[iv] are a vital piece of equipment, used in a variety of ways and for different functions. A rope is essentially a length of fibres, plies, yarns or strands that are twisted or braided together to improve the tensile strength and length. Ropes are flexible and are used for pulling, lifting or connecting, but they do not have any compressive strength (so they cannot be used for pushing). Ropes can be made of various materials, can have a different thickness and length and can be made in different ways (rope construction style). Different applications may require the use of different rope types.

The following is a short overview of some materials used in ropes.

Natural fibre rope (Figure 7a): Natural fibres include manila hemp, linen, cotton, coir, jute, straw or sisal. A negative aspect of this material is easily affected by mildew, suffers from deterioration of the fibres and is very difficult to dry properly. Natural fibre rope is used for utility tasks and should never be used for life safety applications.

Synthetic fibre rope (Figure 7b): The most common material used includes nylon, polyester, polypropylene and high performance fibres such as high modulus polyethylene (HMPE) and aramid. The fibres run through the entire length of the rope. Synthetic fibres are stronger than natural fibres and are more resistant to rotting, mildew and burns. This kind of rope can be washed and dried easily. Damage to the material can occur through exposure to ultraviolet light, strong acids and alkalis and is highly susceptible to abrasions and cuts. These ropes are often used for life safety applications (except for polypropylene fibres) such as rope rescue applications. This is because the ropes can be reliably tested, so that they can be certified to conform to the specifications required for the task.

Steel wire rope (Figure 7c): Galvanised steel or stainless steel are the main materials used for wire ropes, having a very high tensile strength (can withstand large pulling forces). Damages are very difficult to identify because internal breakages in the strands are not visible. This is extremely dangerous as the rope may fail without notice. Steel wire ropes corrode many times faster than a steel bar of the same diameter. This kind of rope is used for permanent rigging, such as zip lines, but is also commonly used in cranes, hoists and in winches.

The following is a short overview of various ropes construction techniques:

Laid or twisted rope: These are typically made up of either three separate strands (plain-laid) or four strands (shroud-laid) wound around each other. This rope is built up in three stages: fibres are spun into yarns, yarns are twisted into strands and strands then are twisted to lay the rope. The fibre material used in this rope can be

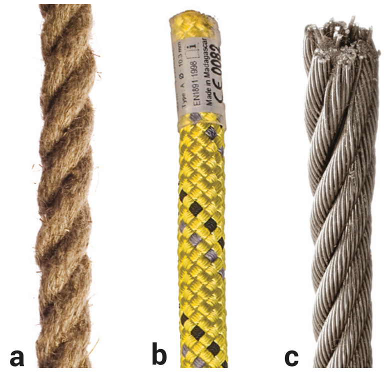

Figure 7: Rope materials: a) Natural fibre; b) Synthetic fibre; c) Steel wire

either natural or synthetic. In laid ropes, all fibres are exposed to abrasion, they stretch significantly and are prone to un-twisting during use. Stretching of the rope is not always a bad thing, but it depends on the application (for example ropes used in rock climbing need to stretch to absorb some of the energy in case of a fall).

Braided rope: These are typically made of synthetic strands that are braided together. The number of strands used in the weave determines the stretching properties of the rope. Single (or hollow) braided ropes tend to flatten under load, causing malfunction when using friction devices or damage when running through pulleys.

Other construction variations include the solid braid and the double braid. Solid braid ropes have strands that travel in the same direction, clockwise or anticlockwise, and alternate between forming the exterior and interior of the rope. Double braid ropes consists of a tubular braided

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[iv] Ropes are sometimes referred to as 'lines' as in 'safety line' and 'backup line'. Therefore, the terms 'line' and 'rope' may at times be used interchangeably in this text.

jacket over strands of fibre (which may also be braided). The inner braid fibre is chosen for strength while the outer braid fibre is chosen for abrasion resistance.

Plaited rope: Plaited ropes are made up from braiding twisted strands (also called square braid). This rope is less prone to kinking than twisted rope and, depending on the material used, can be very flexible and therefore easy to handle and knot. The typical use of this rope is for anchoring due to its energy absorbing characteristics. However, all fibres are exposed and are prone to picking (snagging and pulling out of fibre bundles). This rope should never be used for life safety applications.

Kernmantle rope: This rope is constructed with its interior core (the kern) protected by a woven exterior sheath (mantle) designed to optimize strength, durability, and flexibility. The core fibres provide the tensile strength of the rope (70% of the rope's strength), while the sheath protects the core from abrasion and dirt. Each fibre in the kern extends the entire length of the rope. Both the kern and the mantle are synthetic but can be made out of different material. This is a very strong, flexible, thin and lightweight rope that is generally used for rescue and climbing ropes.

Rope properties

Low-stretch ropes, also referred to as static ropes, are used for the safety of persons working at heights, for rescue work and for other similar activities.[7] These ropes are designed for minimal elongation and maximum strength, as all fibres are constructed parallel to each other. Typical static elongation is less than 5%.

In rescue work, rope may typically be used for life safety applications or for general utility. Life safety means that the rope will carry the weight of a person (or persons) during the rescue operation. Life safety rope should be dedicated solely for this purpose and needs to be compliant to the EN 1891:1998 European standard. This standard specifies the requirements for two types of low-stretch (static) ropes, Type A and Type B. Type A, being superior to Type B, is typically used in rescue.[8] Another rope property defined in this standard is the minimum breaking strength greater than 22kN (meaning that the rope must be able to withstand a minimum of 22kN before breaking). Life safety rope requires careful regular inspection to determine if the rope is still fit for this use. Meanwhile, utility rope is used for hoisting and lowering tools or securing items and equipment, but never to carry the weight of a person (not to be used for life safety applications). Utility rope requires less stringent inspections, yet still requires to be free from damage before use.

On the other hand, dynamic ropes are designed to break a climber's fall, so a certain degree of elongation is crucial to absorb the resultant energy generated during a fall. These properties result from overlapping (woven) fibres in the core, making the rope elastic. Climbing and mountaineering are main uses for dynamic ropes and the dynamic elongation of this rope does not normally exceed 40%.

Care and inspection

All ropes require proper care and inspection, particularly life safety ropes. Apart from ensuring a longer lifetime of the ropes, proper care, maintenance and inspection reduces the potential for accidents during use.

Care: Ropes should be protected from damage which may be caused by dirt, sharp and abrasive surfaces, chemicals, sources of heat or ignition, friction (against other ropes), prolonged exposure to UV rays. Ropes should never be treaded upon, as grains and stone chips may become embedded underneath the sheath and damage the core.

Cleaning: Ropes may be washed by hand or a gentle machine wash using mild soap and cold water. After washing, or whenever ropes get wet, they should be spread out or hung to dry away from direct sunlight and should never be dried using a mechanical dryer or other heat sources. Also, ropes should never be stored when still wet or damp.

Storage: Ropes should be stored at room temperature, away from direct sunlight, in dry locations and neatly coiled (kink and twist free) inside rope bags for protection. No heavy object should be placed on the ropes. The storage location should away from fumes of fuel, oil and hydraulic fluids. Precautions need to be taken to prevent rodents from gaining access to the ropes.

Inspection: Due to the importance of the purpose they are used for, life safety ropes should be inspected after each use as well as on a regular schedule even when unused. Things to look for are cuts, fraying and other visible damage to the rope sheath. The use and inspection of ropes should be logged and recorded. Life safety ropes are normally replaced after 4 years when used occasionally, or after 2 years when used frequently. After this, they are normally used as utility ropes. If a major fall is sustained by the rope (shock loading), it must be replaced immediately. If a rope's condition and history is not known, then it should never be used in life safety applications.

Basic knots

Ropes will not be useful unless they are attached to something. For this reason, it is important that rescuers are proficient at tying knots, most often in difficult situations. In rescue, knots are selected for their simplicity, strength, efficiency, multiple functions and uses as well as for their ease of recognition. When selecting a knot for a particular application, it is important to keep in mind that knots significantly reduce the rope's load-carrying capability, as much as 50% reduction in strength. The results of tests[9] performed to assess the efficiency of a selection of knots have shown that the efficiency of knots does not only depend on the knot itself but also on the rope used.

In order to facilitate communication when referring to knots, it is quite helpful to be aware of the following terms, illustrated in Figure 8:

Bight – A 180° change in direction of the rope without crossing itself.

Overhand loop – The rope crossing over itself, with the running end on top (when the loop faces the rescuer).

Round turn – The rope forms a complete turn around an object, completely encircling it.

Running end – This is the end of the rope that 'runs' through the knot while tying it. Also referred to as 'working end'.

Standing part – This is the remaining part of the rope after the knot has been tied.

Underhand loop – The rope crossing over itself, with the standing part on top (when the loop faces the rescuer).

Some other terms (not shown in Figure 8):

Bend – A category of knots that are used to join two ropes together.

Dressing a knot – Adjusting all the parts of a knot to take away all the slack in the rope and ensuring there are no kinks or unnecessary crossovers in the knot. It is important that a knot is properly dressed to maximize strength and efficiency.

Hitch – A category of knots that are used to attach a rope around an object. Hitches, unlike knots, come undone when they are not tensioned around a solid object.

Tail – The remaining length of rope between the knot and the running end. It is good practice to always leave around 15 cm of tail when tying a knot. This provides a safety buffer in case a knot slips (the exception is the double fisherman's knot where the tail left is between 5 and 7 cm).

The following is a list of common knots, hitches and bends that are utilised in rescue operations. Some knots include an efficiency figure (derived from tests by CMC Rescue,[9] based on their CMC Static-Pro Lifeline Polyester rope). These are only intended to acquaint the reader with the different efficiencies and provide a quick comparison between knots. The method of tying the following knots is well illustrated on the website *Animated Knots by Grog*.[10]

Figure-eight knot (Figure 9a): This is a quick and convenient stopper knot, used to prevent a rope from sliding through an eyelet or to alert an operator that the rope is about to end. It can be easily undone.

Figure-eight loop or **figure-eight follow through** (Figure 9b): This knot secures the end of a rope to a fixed object. It creates a loop at the working end of rope. It is also possible to tie this knot directly to an anchor without additional carabiners using a follow through method. This knot is easy to tie but may be difficult to untie after heavy loading. This knot generally has an efficiency of 70%.

Directional figure-eight loop (Figure 9c): This knot provides a loop in the middle of the rope that is in line with the tension. It is useful when tensioning a rope (e.g. trucker's hitch) while using the loop as a mechanical advantage. The loop can take load only in one direction and can be difficult to untie after heavy loading. The average efficiency is 68%.

Double figure-eight loop (Figure 9d): This knot secures the end of rope to a fixed object using two loops. It has various applications including equalizing load on two anchors. This is a very stable knot because once correctly dressed there is very minimal movement of

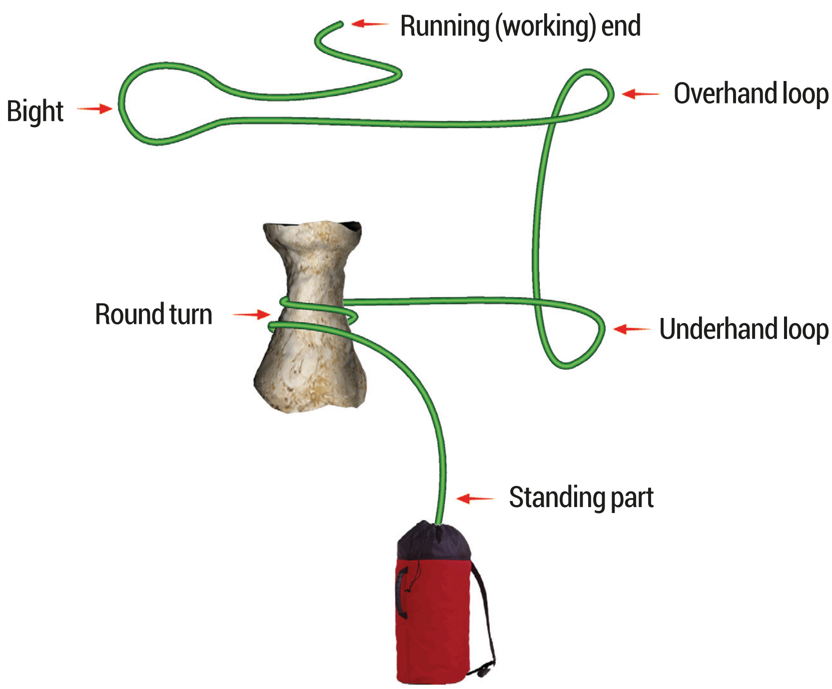


Figure 8: Terms used with ropes

the rope upon loading. The average efficiency is 66%.

Bowline (Figure 9e): This knot creates a reasonably secure loop at the end of a rope, which does not slip or bind. The bowline can be used to tie rescuers or casualties directly into a system and can be easily undone once tension is removed. The average efficiency is 58%.

Bowline on a bight (Figure 9f): This knot forms two secure loops in a rope. It does not slip or bind and has various applications including quickly lifting a person in an emergency by passing the legs through the loops. This knot is easily untied even after being loaded.

Alpine butterfly knot (Figure 9g): This knot forms a loop in the middle of a rope. It is a very stable knot and it is easy to undo even after heavy loading. This knot may be used as a rescue load attachment point. Its average efficiency is 61%.

Munter hitch, also known as **Italian hitch** (Figure 9h): This hitch is used to add friction to a rope to control the rate of movement, generally when belaying. It provides greater friction when the brake rope is held beside the loaded rope (as shown in the picture). The Munter hitch is used in the Radium Release System (refer to Chapter 3 - Rope Rescue).

Double sheet bend (Figure 9i): This knot is used to join two ropes together in a secure way. The two ropes may be of unequal diameter. In such cases, the bight is formed on the thicker rope, while the thin rope passes through and turns twice round the other rope.

Double fisherman's bend (Figure 9j): This is a reliable and compact knot that is used to join two ropes together. Once loaded, the knot will be very difficult to untie. In rescue it is frequently used to make Prusik loops (see Prusik hitch below). The average efficiency is 80%.

Autoblock, also known as **French Prusik** (Figure 9k): This is a variation of the 3-wrap Prusik, where the carabiner is used to make it easier to pull on the Prusik loop by providing a 'handle'.

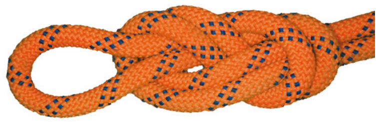
Chair knot, also known as **Fireman's chair** (Figure 9l): This knot forms an efficient and quickly made sling in which a person may be raised or lowered. The loops formed give support to the chest and legs of the person being rescued, maintaining a horizontal position. The chair knot can also be used for stretcher support.

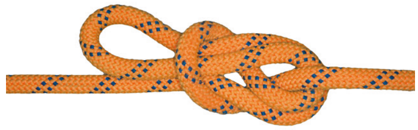
Clove hitch (Figure 9m): This hitch is useful where the length of the running end needs to be adjusted and tightened to a new position. It can be used to start and finish off all lashings. This hitch can be formed anywhere in a rope and can be easily undone when the tension is removed.

Round turn and two half hitches (Figure 9n): This hitch secures the end of a rope to a fixed object. It is useful to secure a rope while maintaining tension (e.g. securing a tensioned guy rope for a tripod).

Water knot, also known as **Tape knot** (Figure 9o): This is used to join two ends of webbing instead of rope. Care must be taken to leave the tails long enough as sometimes the knot starts to slip after repeated tensioning and un-tensioning.


a – Figure-eight knot


b – Figure-eight loop


c – Directional figure-eight loop

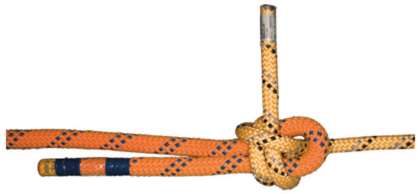

d – Double figure-eight loop


e – Bowline


f – Bowline on a bight


g – Alpine butterfly knot

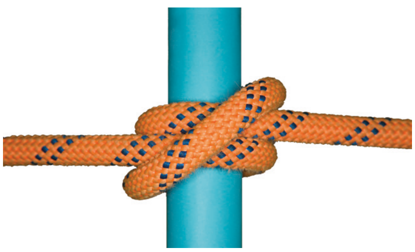

h – Munter hitch

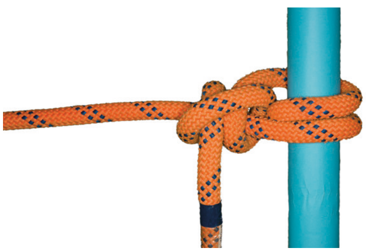

i – Double sheet bend

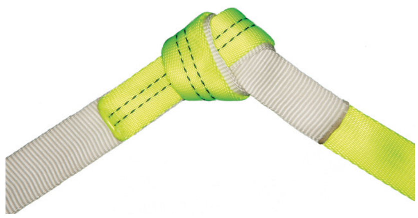

j – Double fisherman's bend

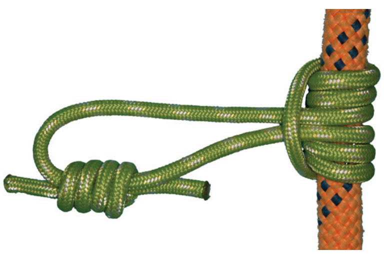

k – Autoblock


l – Chair knot

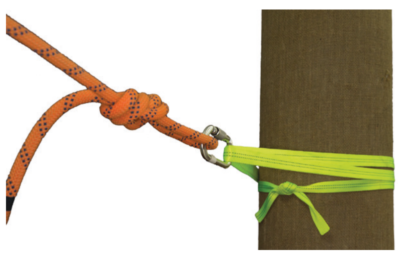

m - Clove hitch


n – Round turn and two half hitches


o – Water knot


p – Prusik hitch


q – Tensionless hitch


r – Wrap-3-pull-2

Figures 9a-r: Common knots used in rescue

Prusik hitch, also known as **'3-wrap English Prusik'** (Figure 9p): This hitch is used as a rope grab, mostly for progress capture. It does not damage the rope like some mechanical rope grabs do. It can grab the rope in both directions and can grab more than one rope at the same time. When overloaded, the Prusik hitch slips, thus absorbing some of the energy and preventing damage to other parts of the system.

Tensionless hitch, also known as **'No Knot'** (Figure 9q): This hitch is quick to tie and untie. It can be tied while the rope is already under tension. Since no knot is used in the rope, this retains all the efficiency of the rope. Ideally the anchor object is round and smooth to prevent damage to the rope. The efficiency is 100%.

Wrap-3-Pull-2 (Figure 9r): This is normally used as an attachment point when trees, poles or similar are used as anchors. The load pulls on two of the wraps (excluding the wrap having the knot in it), so the knot is generally not loaded as much, making it safer and easier to untie.

Stretcher and casualty handling

The rescue of injured persons, as a primary objective in the aftermath of an accident or disaster, requires fundamental knowledge of handling and transporting casualties away from danger to a triage area or to a waiting ambulance. This includes casualty carrying methods ranging from single-rescuer techniques without the use of any particular equipment, to the transportation of a casualty using stretchers. The book *Disaster Rescue* has been consulted during the compilation of the following sections in addition to the authors' knowledge and experience.[11]

Casualty carrying methods

Proper casualty handling is required to get the casualties to medical assistance as quickly as possible, with minimal deterioration to injuries already sustained. This involves selecting appropriate carrying methods depending on the situation. The following are some considerations to take into account when selecting the carrying method to use:

1. Rescuer safety – the carrying method chosen should not cause any injuries to the rescuer(s).
2. Casualty injuries – the choice of carrying method should be based on the type and severity of the injury as well as the response level of the casualty.
3. Availability of rescuers and/or bystanders – the number of rescuers available determines which carrying methods are possible. Bystanders may also help, provided that they are guided as necessary.
4. The weight of the casualty – an increase in weight and stature of the casualty may reduce the possible choices of carrying methods.
5. Distance and route – the distance, route and terrain over which the casualty needs to be carried will play a part in determining the choice of carrying method.
6. Urgency of the situation – if a casualty needs to be transported very urgently due to the injuries sustained, the carrying method chosen should be one that takes minimal time for the rescuers. This is also the case when there is a pending danger for the rescuers so the casualty needs to be taken out as rapidly as possible, such as when there is a fire or risk of building collapse.

Single-rescuer carrying methods may only be used when the casualty does not have a spinal injury. Another restriction to the use of these methods is casualty weight, which is normally limited to around the same weight as the rescuer or only slightly heavier, except for the human crutch method.

Human crutch (Figure 10a): The casualty needs to be conscious and able to walk with assistance, supporting most of the weight. The rescuer simply supports the casualty and is ideally of a similar height to the casualty.

Piggyback (Figure 10b): The casualty needs to be conscious in order to hold on to the rescuer and should not be too heavy, to prevent injury to the rescuer. This is useful when the casualty is too weak to be able to walk even with support. This method is relatively comfortable for both the casualty and the rescuer.

Fireman's lift (Figure 10c): This method enables the rescuer to stay in a more natural upright position while carrying a casualty who may be conscious or unconscious. This facilitates movement over uneven terrain or on stairs, but all the

a – Human crutch b – Piggyback c – Fireman's lift d – Fireman's crawl

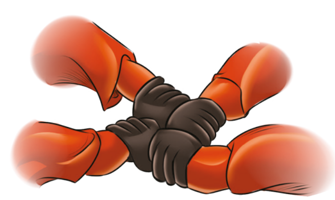
Figures 10a-d: Single-rescuer carrying methods

weight of the casualty will be on the rescuer's spine. So the casualty weight plays an important part in choosing this method. An improper initial manoeuvre to raise the casualty onto the shoulders may cause injury, so proper training is required before performing this method. This carrying method may also be fairly uncomfortable for the casualty if conscious.

Fireman's crawl (Figure 10d): The rescuer may use this method to move both a conscious or unconscious casualty. The condition of the floor over which the casualty is dragged will determine if this method can be used since the rescuer needs a good grip to be able to crawl and drag the casualty. Yet if the terrain is too rough, this may cause further injuries to the casualty. Stairs should be avoided. This method is particularly useful in confined spaces and when smoke is present.

Two-rescuer carrying methods offer the possibility of transporting slightly heavier casualties and in general they facilitate movement over difficult terrain, when compared to single-rescuer carrying methods. Still, these methods should not be used if a spinal injury is suspected.

Fore-and-aft (Figure 11a): This method may be used for both conscious or unconscious casualties. The rescuer at the back carries the bulk of the weight, while the rescuer in front guides the other along the route and carries the rest of the weight. The latter rescuer



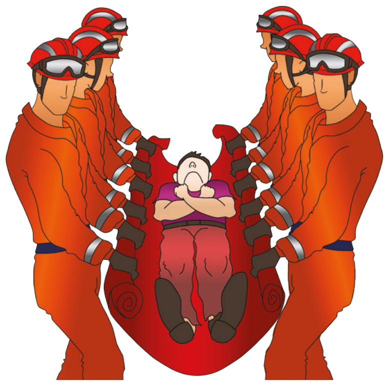
a – Fore and aft b – Two-handed seat c – Four-handed seat

Figures 11a-c: Two-rescuer carrying methods may take more of the weight by lifting at the casualty's knees rather than at the ankles. This method provides a good solution even when the two rescuers are not of equal strength.

Two-handed seat (Figure 11b): This carrying method is better suited for rescuers of similar height and strength. The two rescuers would be able to carry a heavier casualty than with the fore-and-aft method but also tire out faster as they each have to carry a lateral load. The casualty may be unconscious as the rescuers support the casualty's upper body.

Four-handed seat (Figure 11c): This technique is similar to the two-handed seat method except that the rescuers interlock their hands as shown in Figure 11c to be able to carry a heavier casualty. The rescuers should be of similar height and strength. The casualty needs to be conscious to be able to hold on to the rescuers' shoulders.

When the casualty has suspected spinal injuries, or when the casualty is too heavy for two rescuers, it is necessary to get further assistance. In case there are not enough rescuers available, it is possible to ask bystanders to help, as long as they are guided in every action they need to perform. Having more resources also facilitates movement over uneven terrain. The casualty may either be conscious or unconscious. When multiple rescuers are involved, it is necessary to us a blanket or a stretcher to carry the casualty on. Figure 12 shows how a casualty is lifted using a blanket. This method may be used to transfer the casualty onto a proper stretcher or to be carried over a short distance, if the terrain is relatively smooth and level and the casualty does not have spinal injuries. For longer distances and uneven terrain, it is important to use a stretcher. A stretcher also provides the possibility of suspending it to raise or lower it or to cross over a gap.



Figures 12: Blanket carry method

Spinal injury and casualty immobilisation

Whenever a neck or back injury is suspected, the casualty should be immobilised to prevent damaging the spinal cord further, which could lead to partial or full paralyses.[12] In such cases more than two rescuers are required to handle the casualty, taking extra care while doing so. A rescuer must support the head at all times, also leading the rest of the time in every action. Appropriate techniques to turn, move or lift casualty need to be used in order to keep the spine of the casualty as straight as possible. The log roll, shown in Figure 13, should be used to turn the casualty and the six-person lifting method, shown in Figure 14, may be used to lift the casualty onto a stretcher.

The casualty should be immobilised using a cervical collar (Figure 15) to keep the head in line with the shoulder blades, together with a KED[v] (Figure 16) or a spinal board (Figure 17) to keep the spine from being twisted. Spider straps (Figure 18) are used to secure the casualty on the spine board and prevent movement. Ideally a blanket should be wrapped around the casualty for warmth, as well as to reduce pressure from any lashing ropes. The blanket also facilitates the transfer of the casualty from the spinal board to the ambulance stretcher. However, when possible, a scoop stretcher (Figure 19a) should be

Figure 13: Log roll technique

Figure 14: Six-person lifting method

[v] KED (Kendrick Extrication Device): This is frequently used where space is limited and a whole spinal board does not fit, especiaĺly when the casualty is in a sitting position. Handles at the back of the KED are useful when the casualty needs to be lifted.

Figure 15: Cervical collar

Figure 16: Kendrick Extrication Device (KED)

Figure 17: Spinal board

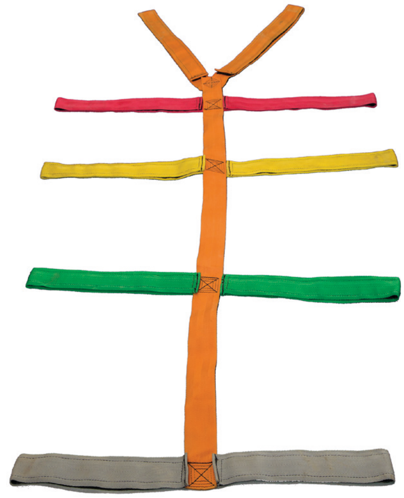


Figure 18: Spider straps

used instead of manually lifting the casualty using the six-person lifting method.

Stretchers

Stretchers are intended to carry injured persons who are not able to walk, or whose injuries may be made worse by alternative carrying methods. In a rescue operation, stretchers may be required during the extrication and/or evacuation phases. There is a variety of stretchers available on the market, some of which are designed or adapted for specialised conditions. Rescuers should therefore have a basic knowledge of different stretchers and their features to be able to select the best stretcher that suits the situation at hand. Some of the variables that need to be considered are:

- the weight of the casualty;
- the need to protect the casualty from protruding rocks or other sharp objects, especially for the casualty's back;
- the prevention of further deterioration of existing injuries;
- the manageability, handiness and portability of the stretcher;
- the ability to properly secure the casualty according to the rescue scenario;
- the capability of a stretcher to be lifted vertically; and
- the adaptability to the size, stature or particular conditions of the casualty (e.g. when the casualty is a child).

Since it is quite difficult to include all the various stretchers available, this manual gives an overview of seven models. The models chosen (below) represent a wide range of applications.

Scoop stretcher (Figure 19a): This stretcher splits in half to be able to 'scoop' a casualty from the ground without the need of lifting the casualty. This is a useful feature when the casualty is suspected to have a spinal injury. Nonetheless, the rescuers must be careful not to pinch the casualty's back while closing the two halves of the stretcher together. Also, rescuers must make sure that the stretcher is properly locked before lifting it. This stretcher is not recommended where the terrain is rough or uneven.

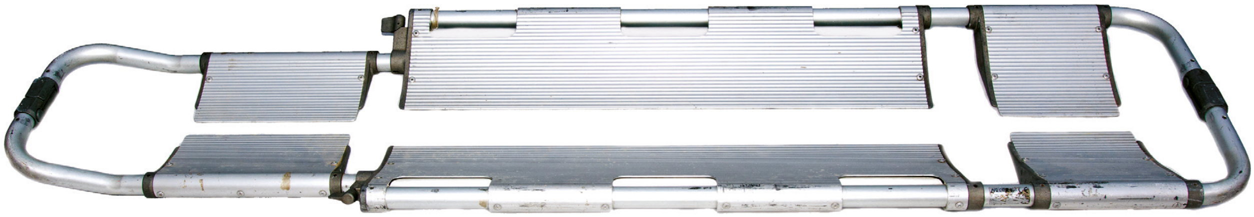


Figure 19a: Scoop stretcher

Figure 19b: 'D' stretcher

Figure 19c: Basket stretcher

Figure 19d: SKED stretcher

'D' stretcher[vi] (Figure 19b): This type of stretcher was originally developed by the military. It is used for general casualty evacuation (transporting the casualty from relatively accessible places to the triage area or to an ambulance). It is collapsible and relatively easy to transport, being made of canvas and lightweight aluminium. The 'D' stretcher is easily handled by 2 rescuers (depending on the weight of the casualty), but the casualty should ideally be secured with lashing ropes if the stretcher is to be handled for long distances.

Basket stretcher, also known as a **Bucket stretcher** (Figure 19c): The rugged plastic construction of this stretcher offers good protection for the casualty on the sides and bottom. It offers good support for the back of the casualty, especially on rough terrain and may be dragged over a surface if necessary. This stretcher normally requires four rescuers to carry a casualty in it. It has several attachment points, which facilitate horizontal or vertical suspension. The versatility

vi The name of the 'D' stretcher arises from the shape of the legs of the stretcher, resembling the letter D.

Figure 19e: Kong Lecco stretcher

Figure 19f: Alpine stretcher

Figure 19g: Neil Robertson stretcher

of this stretcher makes it useful over a wide range of rescue scenarios, hence its popularity.

SKED[vii] (Figure 19d): This is a flexible yet durable stretcher that may be rolled up and carried in a backpack. It is very light and easy to carry. Once the casualty is placed inside, the SKED becomes rigid. It is very useful in confined spaces as it wraps tightly around the casualty, making it possible to pass through small breaches in walls and ceilings and it can be dragged if necessary. This stretcher can also be suspended horizontally or vertically.

Kong Lecco stretcher[viii] (Figure 19e): This stretcher is designed primarily for rope rescue, especially for mountain-related incidents and when helicopter transportation is required. The stretcher is very light and sturdy, as well as collapsible, such that it can be packed into a backpack. This stretcher also has built-in lashing straps for the casualty and has an outer layer of canvas that protects the casualty from wind and rain. It also has a number of optional attachments (e.g. wheels and over-shoulder handles) to facilitate movement of different types of terrain.

Alpine stretcher (Figure 19f): This is another light and sturdy stretcher developed for mountain rescue. It folds in two such that it may be carried on the back. The foldable legs provide clearance from the ground to protect the casualty's back, while the built-in lashing straps are used to secure the casualty. It is relatively easy to load a casualty on this stretcher even in cases of spinal injuries, particularly when compared to the Basket stretcher.

Neil Robertson stretcher (Figure 19g): This stretcher wraps around the casualty making it very useful in confined spaces. It is generally made from bamboo and fabric, so it is relatively cheap and rugged. It may also be used for vertical lifting.

Whenever casualties are carried on stretchers, they should be properly secured. The method of securing the casualty, referred to as 'lashing the casualty', depends on

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[vii] The SKED stretcher is not to be confused with the KED (Kendrick Extrication Device). SKED is a registered trade name for the stretcher produced by the company SKEDCO.

[viii] Lecco is a trade name for the stretcher produced by the company Kong.

the selected stretcher, the distance and the terrain to be covered, as well as any vertical displacement needed. The lashing aims at preventing the casualty from sliding on the stretcher itself or from falling off. There are two kinds of lashing, internal and external lashing.

The aim of internal lashing is to prevent the casualty from sliding on the stretcher. If a spinal board is used, the casualty is secured to it using spider straps. However, the spinal board itself may slide on the stretcher, so it has to be lashed to the stretcher using rope or webbing. If no spinal board is used, the casualty would be secured directly to the stretcher, either using the harness (if the casualty is already wearing one), by improvising a harness with rope or webbing, or by using the straps of the stretcher *per se,* as found on the Kong Lecco (Figure 19e) and Alpine stretcher (Figure 19f). Securing the casualty firmly to the stretcher is particularly important if the stretcher is to be raised vertically because it prevents the casualty from sliding down and risk suffocation by the straps or ropes pushing against the throat.

The external lashing complements the internal lashing, preventing the casualty from falling off the stretcher when being raised vertically. Generally, internal lashing is enough when simply carrying the stretcher over relatively flat terrain. However, external lashing is required whenever the stretcher will need to be raised vertically or suspended even though the stretcher is expected to remain horizontal. When using a Basket stretcher, the external lashing is generally done using rope. Lashing with a rope starts with a clove hitch around an attachment point close to the casualty's shoulder. The rope then crosses to another attachment point on the opposite side, over the casualty, while keeping the rope taut all the way, forming a sort of web over the casualty. The lashing is finished off with another clove hitch on the opposing side, again at shoulder height. The rope crosses over the casualty at least four times. Stretchers like the Kong Lecco and Alpine stretchers also include the external lashing in their design.

In very rare and exceptional circumstances, a rapid evacuation may need to be carried out without the casualty being secured or immobilised in a stretcher before evacuation. This may only be done when the situation is unsafe, the casualty is not medically stable or if the casualty is blocking the way for other casualties who may be in danger if not evacuated immediately.[12]

Stretcher handling

Once the casualty is on the stretcher and properly lashed, the team of rescuers may start carrying the stretcher to a triage area or to the ambulance. An adequate distribution of the rescuers around the stretcher will make transportation more comfortable for the casualty and less tiring for the rescuers. The team distribution should take into account the height of the rescuers, where the shorter ones should be in front, that is by the feet of the casualty. Meanwhile the taller rescuers should position themselves at the back, near the head of the casualty. This ensures that the head of the casualty will remain slightly higher than the. The casualty should be moved feet first unless going up an incline. It is important to note also that the rescuers near the head will be carrying the bulk of the weight.

The team carrying the stretcher is normally formed by four to six persons. The rescuer on the right hand side of the casualty's head will be designated as the team leader, as this person will have a good view of all the team members and the casualty. The leader will give clear and direct orders that provide proper guidance to all his colleagues. Precautionary words of command are used to alert all rescuers what the next action will be. This is then followed by the actual command that initiates the action. These words of command include: lift, lower, move, left wheel, right wheel, well, rest and still. When moving with the stretcher, the rescuers should coordinate their pace, avoiding unnecessary abrupt motions and should start moving the leg closest to the stretcher first. This will minimise the wobbling of the stretcher will make the transportation more comfortable for the casualty and for the rescuers themselves.

There may be instances where the stretcher would need to be raised or lowered over a short height using ropes (usually not higher than 6m).[11] Such circumstances arise due to the various obstacles that rescuers encounter in their path while carrying the stretcher. Thus, it would be more efficient and less time consuming to lower or raise the stretcher using ropes.

The two techniques used to overcome such difficulties are the Two-point suspension (Figure 20a) and the Four-point suspension (Figure 20b). Both techniques provide a fast and efficient way to raise or lower the casualty without setting up any fixed rope rescue system. Before using either of these techniques, it is important that the casualty is properly secured to the stretcher. Two knots are used in these suspension techniques, such that one knot backs up the other for safety. Usually the knots used are the bowline and the clove hitch. The rope is tied near the extremities of the stretcher to improve the stability of the stretcher and prevent it from overturning during the suspension technique.

Two-point suspension (Figure 20a): In the Two-point suspension method one rescue team will support all the weight from above, while the other team simply pulls the stretcher away from the wall, as the stretcher is being raised or lowered. In this technique, the stretcher is almost in a complete vertical position.

Four-point suspension (Figure 20b): In the Four-point suspension the rescuers will position themselves at each corner of the stretcher, sharing the weight among them as they raise or lower the stretcher. Also, this technique permits the stretcher to be kept horizontal throughout the application of this method.

When employing these techniques, it is important that rescuers do not to let the rope slide over their hands, as this would cause rope-burn, which would cause the rescuers to let go of the rope. Instead, a hand-over-hand technique should be used to maintain control of the descent rate.

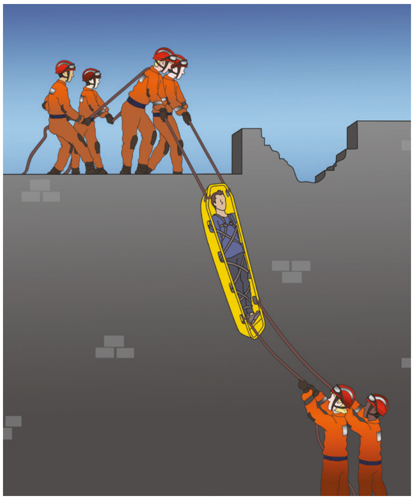


Figure 20a: Two-point suspension

Figure 20b: Four-point suspension

Ladders

The ladder is a basic and versatile tool in rescuer's toolbox. However, misuse of the ladder may easily lead to serious injury, so it is important that rescuers are familiar with the various types of ladder available, as well as their appropriate use and associated techniques. Ladders are designed primarily for climbing up and down, but in rescue operations they may also be used to lower stretchers, to provide a high anchor point for a pulley, to serve as bridges and even to serve as rudimentary stretchers, among other alternative uses. Figures 28–33 show some alternative uses of ladders.

Ladders are made in various styles and lengths and can be made of different materials. They are constructed to support the maximum load in a particular position, called 'load bearing position'. Ladders should always be used according to the specifications of the manufacturer. It is imperative that rescue service ladders conform with EN-1147 or NFPA 1931 standards, unless other country-specific standards apply. Ladders are referred to by their length when fully-extended and by the type, for example a 10.5m extension ladder. The following sections are based on guidelines provided in the book *General and Disaster Rescue*.[11]

Terminology

Before being involved in ladder operations, rescuers need to be familiar with the basic ladder terminology (Figure 21). These terms are:

Head: the top part of the ladder.

Strings: the vertical elements of the ladder to which the rungs are attached.

Guide: in extension ladders, the guides are C-shaped metal plates that keep the sections of the ladder together and guide the top part as it is being extended or lowered.

Pulley: the pulley is used in extension ladders for the hauling rope to pass over it such that a pull

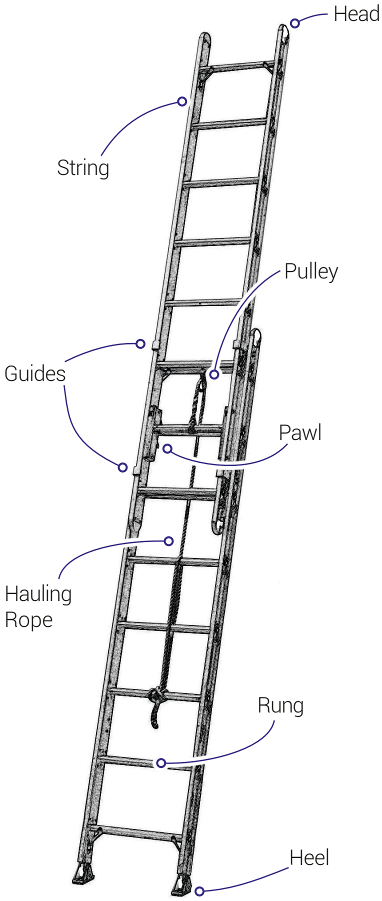


Figure 21: Ladder terminology

on the hauling rope will raise the top section of the ladder.

Pawls: the metal hooks fitted on extension ladders to lock the top part from sliding back down when extended.

Rungs: the cross-members between strings, which also serve as steps to climb up and down.

Hauling Rope: the pulling line used to raise the top part in extension ladders.

Heel: the bottom or ground end of the ladder.

Principle types of ladders

The principle types of ladders that are typically used in rescue are the single ladder, the folding ladder and the extension ladder.

The single ladder (Figure 22) consists of a single section having a fixed length, typically between 3 and 8 metres. Its construction is simple, which reduces the need for maintenance and the possibility of malfunction. It is lightweight and easy enough to be handled by one rescuer and provides a quick access to one or two storey buildings. It is also easy to use in tight spaces.

Folding ladders (Figure 23) have hinges incorporated in the strings, making the ladder collapsible to a more manageable length. This ladder may either be opened up similar to a single ladder, or else it may be left folded in two. When folded in two, it becomes self-supporting and does not need to lean against a wall. In their fully open position, folding ladders generally do not exceed 3 metres in length. Folding ladders are ideal to be carried through confined spaces.

Extension ladders (Figure 24) consist of two or more sections of ladder, with the uppermost sections sliding over the section below them. The ladder is extended using a hauling rope and locked in placed using the pawls once the desired length has been reached. The most

Figure 22: Single ladder

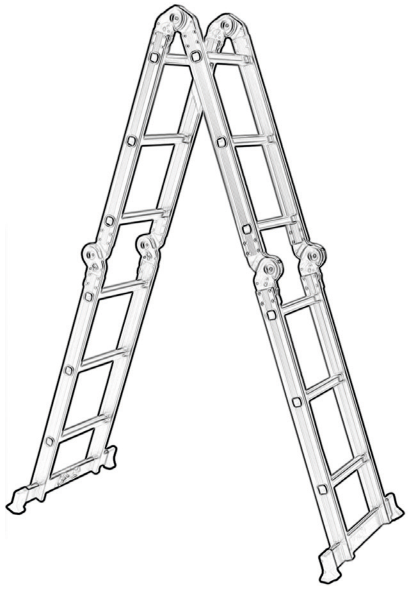


Figure 23: Folding ladder

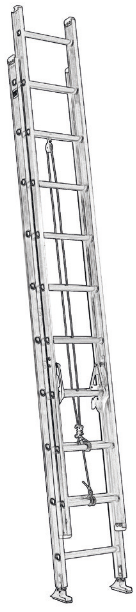


Figure 24: Extension ladder

commonly used ladders in the fire service are the 10.5 metre and 13 metre extension ladders, reaching between three and four storeys respectively. These are heavier and bulkier than other types of ladders and require multiple rescuers to carry, raise and lower them. At least two rescuers should handle a 10.5m ladder. However, it is ideal to have four rescuers.

Inspection and maintenance

Ladders are exposed to various conditions that in the long term cause deterioration of the materials and components of the ladder. Thus, inspection and maintenance of ladders should take place regularly, following the recommendations of the manufacturer and any applicable standards. Periodical inspection frequency may vary depending on how often a ladder is used as well as the conditions it is operated in. Inspections should take place after every use and on a monthly basis. Every year, the ladder also needs to be tested to prove that it is still safe for use. A ladder inspection logbook, containing the details of the ladder and the records of all maintenance and inspections must be kept.

Ladder maintenance consists of cleaning it and applying dry silicon lubricant spray on the moving parts. The monthly inspection involves extending the ladder and visually checking it for signs of damage, corrosion, defective or missing fittings and excessive wear in any of the ladder components. The annual test involves fully extending the ladder horizontally and applying weights (equivalent to three average persons), while measuring both the deflection on load as well as the deflection without load. The British Standard EN 1147:2010 covers the maintenance and inspection requirements for portable ladders in the fire service.

Carrying and using ladders

As the size of the ladder increases, it gets more challenging to carry, raise and lower. The larger ladders require multiple rescuers to work together to raise and lower them, making it even more important that all rescuers know their tasks well. There are various methods of carrying a ladder from the transportation vehicle to the placement site and this depends on the size of the ladder as well as on the number of available rescuers. Ladders are always carried heel first, such that once the ladder arrives on site it does not need to be turned around. Typical carrying methods include high-shoulder, low-shoulder and arms' length carrying methods. When multiple rescuers are carrying the ladder, each rescuer needs to hold the ladder in a way that the hand or arm does not get caught in between the rungs in the event that a member in the team trips or falls.

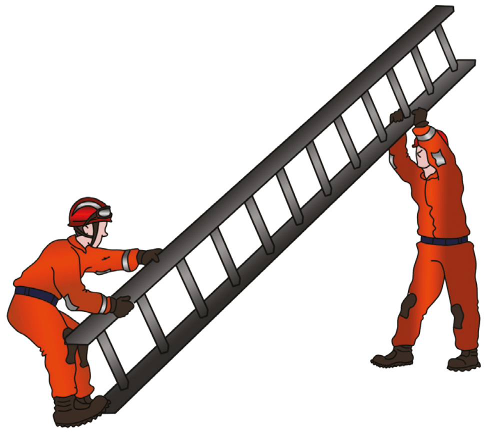
Before raising a ladder, it is very important to check for any overhead obstructions such as electrical wires, trees and overhangs. Other elements such as strong winds should also be taken in consideration. As soon as the best place for the ladder has been identified, the team carrying the ladder will stop and lower the heel of the ladder. A rescuer will 'foot the ladder' (block the heel from moving) while other rescuers 'under-run the ladder' (walk from the head towards the heel pushing the ladder up as they go along) until the ladder is upright. These steps are shown in Figures 25b and 25c. If the ladder needs to be extended, a rescuer will raise the top section using the hauling rope while other rescuers keep the ladder upright. This procedure will need to be adapted, depending on the type of ladder and the number of rescuers available. For example, one rescuer with a single ladder can raise the ladder placing the heel against the wall, then under-running the ladder as normal and finally pulling the heel away from the building as necessary (Figure 25a). This technique is limited to 8.5m ladders for one rescuer or 11m ladders for 2 rescuers. Another alternative way for raising the ladder is the beam raise, shown in Figure 25d. This method is useful when there is not enough space in front of the building to lay the ladder straight. Instead, the ladder is carried on its side alongside the building, one of the heels is lowered to the ground while the ladder is under-run while still on its side.

Finally, the head of the ladder is lowered towards the building. When leaning a ladder against a building, the head should not be knocked against the wall. If the ladder needs to be moved sideways, it should not be dragged along the wall as it may damage the ladder or cause debris to fall onto the rescuers below. In this case, the head should be pulled away from the building, the ladder is lifted and moved sideways and finally the head is lowered gently towards the building again. Similarly, when

a – Flat raise, 1 or 2 rescuers

b – Flat raise, 2 rescuers

c – Flat raise, 3 or 4 rescuers



d – Beam raise

Figures 25a-d: Ladder raise methods

lowering the ladder into a window, rescuers need to be careful of any falling glass. Once the ladder has been placed in position, leaning against the wall, the ideal angle should be around 75° to the ground (as shown in Figure 26), such that the ladder is neither too steep nor too shallow. In practice, this is done by ensuring that the height which the ladder reaches is four times the distance of the heel from the base of the wall (4:1 ratio). For example, if the ladder needs to reach a window 12m high, then the heel needs to be 3m away from the base of the wall.

Once the ladder is in place, rescuers wearing adequate personal protective equipment (PPE) can proceed to climb up the ladder. Whenever any person is on the ladder, there should be someone footing the heel of the ladder preventing it from sliding. While climbing the ladder, rescuers should climb at a steady pace, keeping the body erect and the head upright, with the arms straight but not tense. The hands should be kept at shoulder height and grasp the rungs in line with the shoulders. At any point in time, the individual should have three points of contact with the ladder, for example 2 feet and 1 hand touching the ladder, as shown in Figure 27.

In addition to providing a vertical path for people, ladders are used in alternative ways to move casualties quickly, safely and efficiently with minimum additional equipment. It is important to be familiar with

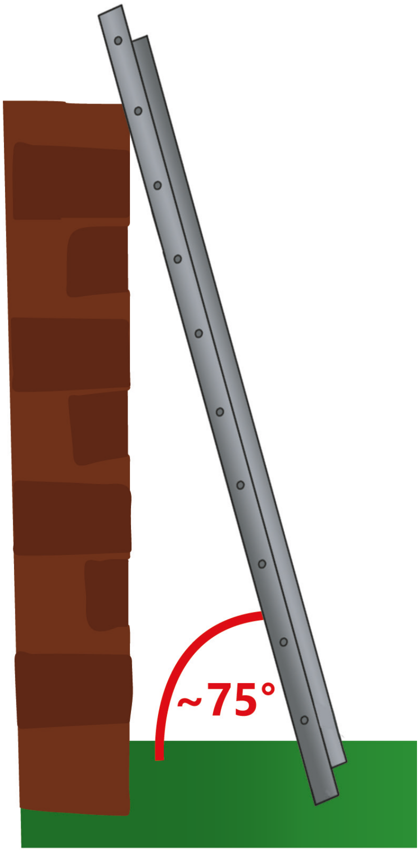


Figure 26: Safe ladder angle

Figure 27: Climbing the ladder

these different methods to make the best use of this tool, but also to ensure this is done safely. Common ladder techniques are summarised below.

Ladder slide (Figure 28): A ladder may be used to slide a stretcher on it down from a window or a low roof. The angle of the ladder should not exceed 70 degrees and the stretcher should be able to skid smoothly along the ladder, with guide ropes controlling its descent. Basket-type stretchers are normally used for this technique. This is an efficient technique when several casualties need to be evacuated.

Figure 28: Ladder slide

Ladder hinge (Figure 29): The stretcher may be tied at one side to an upright ladder, while ropes tied to the other side are controlled by rescuers from a window or a roof. As the ladder is slowly lowered with its heel against the wall, the stretcher is gently lowered down with it. This technique can be used when the casualty needs to be kept horizontally. It is also useful to lower heavy casualties since the ladder takes most of the weight. The same technique may also be used to raise a casualty.

Figure 29: Ladder hinge

Ladder bridge (Figure 30): A ladder may be used to bridge an open space to allow rescuers or a stretcher to cross over a void space and it may be lowered in place from one side using a rope. The ladder should be extended to have at least three rungs on either side of the bridged gap. It is recommended that only one rescuer at a time crosses the gap, unless accompanying a stretcher being pulled across. Rescuers should sit on the ladder and pull themselves along the ladder.

Ladder gin (Figure 31): The ladder is placed at a 70° angle, supported by guy lines to the anchor points, while the heels are anchored to

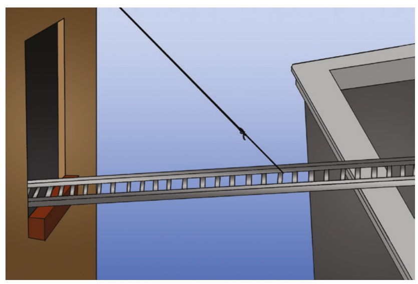


Figure 30: Ladder bridge

the ground (against a vehicle tyre, wall, curb or large boulder). A pulley system is then attached between the ladder's strings such that rescuers or a stretcher may be raised or lowered directly underneath the pulley system. It is used to access vertical shafts, wells, pits, vaults or other similar confined spaces.

Figure 31: Ladder gin

Leaning ladder (Figure 32): This technique may be used to create a high anchor point for a pulley system to be able to lower a stretcher from a window. The ladder should be raised above the window, placed at a 75° angle and properly anchored. A pulley system, similar to the ladder gin, is attached to the anchor point at the head of the ladder. Lowering the casualty is controlled using the friction created from the reeving the rope through the bottom rungs.

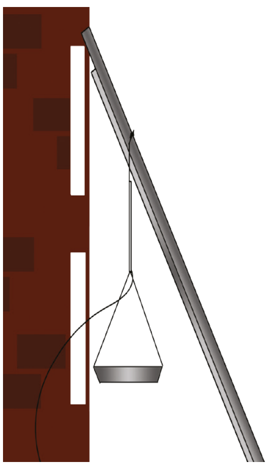


Figure 32: Leaning ladder

Ladder derrick (Figure 33): This method is very similar to the leaning ladder, except that the ladder is self-supporting (using guy ropes) and does not put pressure on the building. As the ladder does not need to be supported by a wall, its use is more versatile than the leaning ladder and may be used to lift casualties from manholes, trenches and so on. It is also useful when evacuating casualties from damaged buildings with unstable walls.

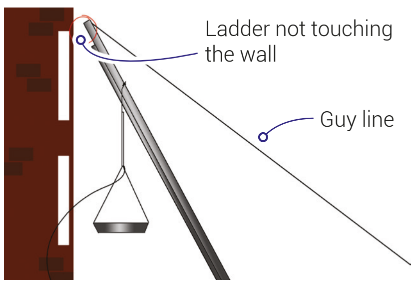


Figure 33: Ladder derrick

During ladder operations, it is recommended to extend the ladder three rungs above the window or ledge where rescuers intend to get on or off the ladder. Similarly, when using the ladder as a bridge, there should be at least three rungs on either side, in case the ladder inadvertently moves.

Communications

The final important skill mentioned in this chapter is communication. Rescue operations require good and efficient teamwork, which in turn is highly dependent on effective communication within the team as well as with other entities. Among the different means of communication available, VHF / UHF radios[ix] are perhaps the first that come to mind. However, other methods may need to be used to make up for the limitations of radios. These may include mobile phones or satellite phones for voice communication, messaging applications for text or image-based communication or whistles and hand signals in specific circumstances. This chapter will not go into detail with regards to mobile or satellite phones or messaging applications as most people are already familiar with their use. Furthermore, the use of whistles and hand signals follow standard protocols that may vary from one rescue discipline to another. Where applicable, these signals will be covered in Chapter 2 – Collapsed Structure Rescue, Chapter 3 – Rope Rescue and Chapter 4 – Water and Flood Rescue. The rest of this section therefore focuses on radio communications, from basic terminology to the procedures used during field operations.

Radios, normally operating in the VHF or UHF bands, enable voice communication over significant distances between several personnel. The messages

[ix] VHF (Very High Frequency) and UHF (Ultra High Frequency) radios are sometimes referred to as two-way radios and permit wireless communication between radio units tuned on a pre-agreed frequency (or channel).

Figures 34: A typical hand-held radio unit

communicated may be elaborate and the user is not limited to a small set of pre-determined pieces of information (such as whistle or hand signal protocols). However, the volunteer needs to keep in mind that radio communication suffers from a number of limitations, such as interference from surrounding noise, other radio transmissions and from other users on the same channel. Radio reception may be lacking in certain places, especially in confined spaces. Radio waves travel predominantly in straight lines (line of sight), reflecting off any objects they find in their path so the distance reached by the radio signal depends on terrain features and other obstructions. Furthermore, a radio may be difficult to use when the rescuer is suspended or handling a stretcher or a casualty unless voice activation accessories are used. Finally, radios do not permit simultaneous communication. If two users try to talk at the same time, the signals will be garbled and impossible to understand.

When using a radio, the volunteer shall be aware that it is unethical and unlawful to use foul or obscene language, to purposely interfere with other radio users, to use any frequency for which no valid licence is held and to transmit unrelated information during that particular operation. As with other aspects of a rescue operations, radio communications need to be coordinated by one entity, which is the command and control centre (referred to as control centre from here onwards). The control centre assigns a frequency (or radio channel) to be used as the main operational channel and also assigns a unique call sign for each search and rescue team. These call signs use the ICAO phonetic alphabet[x] (Table 2) such as Sierra for a Search and Rescue team, Bravo for the Base of Operations, etc. It is

A	Alpha	J	Juliet	S	Sierra
B	Bravo	K	Kilo	T	Tango
C	Charlie	L	Lima	U	Uniform
D	Delta	M	Mike	V	Victor
E	Echo	N	November	W	Whiskey
F	Foxtrot	O	Oscar	X	X-ray
G	Golf	P	Papa	Y	Yankee
H	Hotel	Q	Quebec	Z	Zulu
I	India	R	Romeo		

Table 2: ICAO phonetic alphabet[13]

[x] The ICAO phonetic alphabet is the common name for the International Radiotelephony Spelling Alphabet (ICAO stands for International Civil Aviation Organisation). Each letter in the English alphabet is assigned a code word to avoid misunderstandings when the quality of communication is low.

Strength		Readability	
LOUD	Strong signal	CLEAR	Excellent quality
GOOD	Acceptable volume	READABLE	No difficulty in hearing the message
WEAK	Can be heard with difficulty	DISTORTED	Readable with difficulty due to distortion or interference
FADING	The signal occasionally fades preventing continuous reception	INTERMITTENT	Inconsistent readability due to intermittent signal
NOTHING HEARD	No useful signal received	UNREADABLE	Very bad quality, impossible to understand

Table 3: Radio signal strength and readability

important that the control centre retains a list of mobile numbers for emergency communications in case the radio systems fail.

Before commencing operations, those volunteers assigned the role of radio communications officers should check that the radio set does not have any broken parts, that all basic accessories are included in the radio pack and that the battery has been charged. A radio check should be performed with the control centre to confirm that the radio is operating properly and that the correct frequency has been set. Similarly, radio checks are also done with other radio units to ensure that all communication channels are functional.[14]

In the event of a radio communication failure, radio operators should exercise their best judgment and expertise to maintain critical communication with the control centre. Personal mobile phones may be used to send brief messages to the control centre, providing the minimum indispensable information to keep the operation ongoing. Nonetheless, one should keep in mind that during a major event such as an accident or disaster, mobile networks will quickly be overloaded by civilians attempting to make calls or send messages, potentially saturating the network or causing it to collapse.

The main channel should be used only for urgent communication or to establish contact before shifting to an alternative channel. Main channels should remain free and any calls answered promptly. Whenever a radio channel is being used for the first time, or when there is doubt of adequate radio signal reception, a radio check should be carried out periodically. The aim is to check if two-way contact can be established as well as checking the signal strength and clarity (also referred to as Readability). The quality of the signal can be described using the scales shown in Table 3.

Four key communication qualities to be followed when using the radio are rhythm, speed, volume and pitch. The rhythm of speech should make use of short sentences with slight pauses after each word. The speed should be slightly slower than for normal conversation. The volume should be as for normal conversation. The microphone should be held to the side of the mouth. Voice emotions are to be kept as minimal as possible, regardless of the situation. The Push-To-Talk (PTT) button should be pressed about a second before starting to talk, to prevent part of the first word being clipped. Similarly, the PTT is kept pressed for a second after the message is complete.

Radio traffic at an incident site can be substantial, especially when the area involved is large and several teams are operating at the same time. Therefore, rescuers speaking on the radio should follow basic radio protocol as suggested below to reduce confusion.

- Listen carefully before transmitting to ensure not to interrupt another message

AFFIRMATIVE	Yes / Correct
NEGATIVE	No / Incorrect
CORRECTION	Correcting a part of the last message
DISREGARD	Last message cancelled
ROGER	Last transmission satisfactorily received
OVER	Message transmitted, waiting for a reply
OUT	Transmission has ended and no reply is required or expected
SEND	Go ahead with your transmission
BREAK – BREAK	Transmission to a different call sign is going to follow immediately
SAY AGAIN	Repeat your last message as it was not received successfully
SILENCE	Cease all transmission immediately and maintain until lifted
SILENCE LIFTED	Silence is lifted – channel is free for traffic
READ BACK	Read back the message to make sure it was received successfully
RELAY	Repeat the message to be received by a station that is out of range of the first sender

Table 4: Standard radio phraseology

being transmitted on the same channel.

- Prioritise the communication by the most urgent information that needs to be transmitted.
- Initiate radio contact by identifying the call sign of the person you need to contact, followed by own call sign (e.g. Sierra 5, Bravo 1).
- Wait for the recipient to acknowledge by communicating the caller's call sign followed by own call sign.
- Repeat call sign immediately followed by the intended.
- One should use call signs and recognizable abbreviations or codes when referring to personnel or locations, not actual names.

The message to be communicated should ideally be prepared beforehand. Written notes may reduce incoherent communications and messages are to be kept clear, orderly, and concise. The following simple example illustrates some of the above points. The Base of Operations (call sign Bravo1) is calling Search Team 5 (call sign Sierra 5), asking for a situational report (sitrep):

Bravo1: '*Sierra 5, Bravo 1*'.

Sierra5: '*Bravo 1, Sierra 5. Send*'.

Bravo1: '*Sierra 5, provide a sitrep when possible*'.

Sierra5: '*Bravo 1, Sierra 5 has finished the search in zone Alpha 1. No casualties found. Starting search in zone Alpha 2. Over*'.

Bravo1: 'Sierra 5, copied. We have civilian reports of two adults and one child missing in zone Alpha 2. Over'.

Sierra5: 'Bravo 1, two adults and one child missing in Alpha 2. Copied. Out'.

At times, some words or abbreviations might be difficult to be understood over the radio. In such cases, it might be necessary spell these words using the phonetic alphabet. The pro-word, '*I SPELL*' is used to advise the listener that a word is going to be spelt out. Similarly, numbers may be spoken digit-by-digit if there is a risk of misunderstandings. In this case, the pro-word '*FIGURES*' will precede the number. '*I SPELL*' and '*FIGURES*' are part of the standard radio phraseology practiced by many radio users, from radio amateurs to pilots and air traffic controllers. These phrases facilitate communication due to their widespread recognition and specific meaning. Other standard phrases are listed in Table 4.

Conclusion

The material presented in this chapter is meant to give an initial foundation in topics that are common to most rescue disciplines that will be covered in the next chapters. It is therefore advisable that the reader is familiar with this content before proceeding to the next chapters.

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2 COLLAPSED STRUCTURE RESCUE

Cyprus Civil Protection Volunteer Corps
Edelweiss (Italy)
Elite Team Special Missions of Greece

Supported by:
Serve On (UK)
Escola Portuguesa de Salvamento (Portugal)

Introduction

Structural collapse may have a number of causes, perhaps the most common being natural disasters such as earthquakes. Earthquakes, in fact, cause simultaneous damage to structures in a widespread area, which further increases the challenge to emergency responders. This chapter, therefore, starts off with some background information about earthquakes, their cause and effects. This is followed by an introduction to Urban Search and Rescue (USAR) and description of different rescue teams that normally respond to collapsed structure incidents. Response to incidents follows the logical methodology of assessing damage, determining priorities, and assigning the tasks to cover the affected area, searching for the casualties and finally extricating them from the collapsed structure to provide them with medical care. The chapter also goes through the different types of collapse, stabilisation techniques to ensure safety for the rescuers and casualty, the personal protective equipment as well as the equipment required during USAR operations.

What is an earthquake?

An earthquake is a sudden violent shaking and movement of the ground, caused by the release of built-up stress accumulated deep within the earth's crust, where the geological faults lie. The geological faults form at the boundaries of tectonic plates. There are eight major tectonic plates around the world (Figure 1).

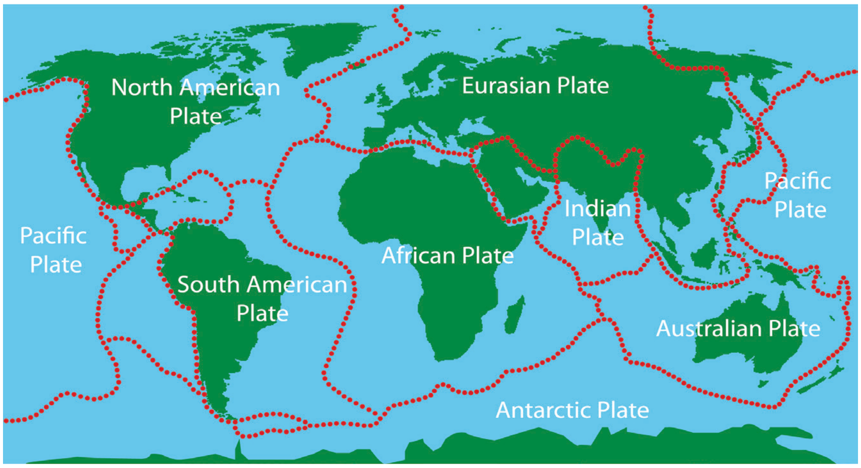

Figure 1: The Earth's main tectonic plates

Earthquakes occur primarily at the boundaries between the major tectonic plates and at many smaller fault lines that accompany the boundary fault lines. There are different types of boundaries, some of which are described below.[1]

A constructive boundary or divergent plate boundary occurs where two plates move apart from each other to form a new crust when molten magma cools and solidifies at the earth's surface within the formed gap (Figure 2). Examples of this boundary type are the Mid-Atlantic ridge and the East Pacific rise.

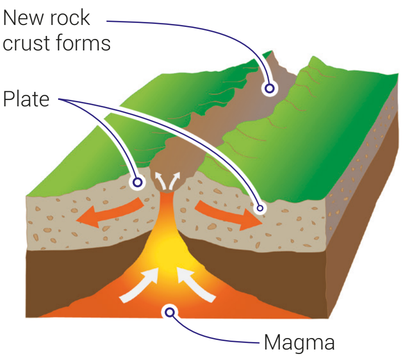

Figure 2: A constructive plate boundary on land.

A destructive boundary or convergent boundary is where two plates move against each other forcing one of the plates to sink below the other (Figure 3). The sunken plate travels underneath the other plate in a process known as subduction and the friction between the plates causes the earthquake. When two continental plates collide together they are usually pushed upwards, thus forming mountain ranges, such as the Alps.

A conservative boundary or transformation plate boundary occurs where two continental plates move sideways past each other and land is neither destroyed nor created (Figure 4). A well-known example of this is the San Andreas Fault line in California, which is strongly associated with intense earthquake activity.

Conservative boundaries often create some of the worst and most violent earthquakes because the plates glide past each other at a rate of around 5 to 6 centimetres per year. This movement builds considerable pressure due to

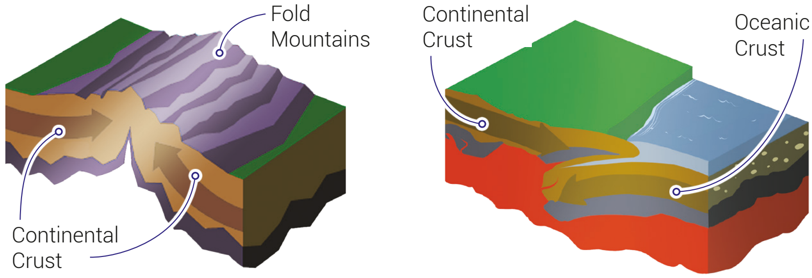

Figure 3: An example of a destructive plate boundary between two continental plates (left) and oceanic-continental plates (right).

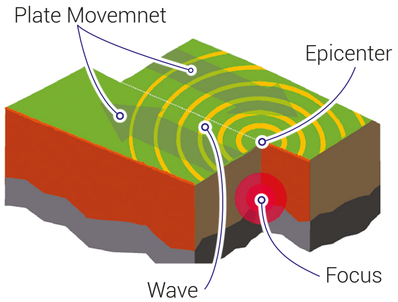

Figure 4: An example of a conservative boundary where adjacent plates move in parallel to each other.

friction between the plates. When the pressure overcomes this friction and a slip occurs there is a sudden release of significant energy that results in a series of shocks and tremors. Aftershocks are primarily powered by further slow, and generally less powerful, pressure releases.

Different plate movements give rise to various earthquake phenomena with various degrees of impact. Some of the effects of earthquakes include:

- Shaking of the earth's surface
- Soil liquefaction, landslides and mudslides
- Submarine avalanches
- Snow and ice avalanches
- Tsunamis

The serious consequences of earthquakes may result in the need for search and rescue operations, like in the case of collapsed buildings.

Measuring earthquake magnitude

Seismographs are used to measure the magnitude of an earthquake, or the energy released at the epicentre. The Moment Magnitude Scale (MMS) is a logarithmic scale[i] used by seismologists to describe the earthquake intensity, which is more accurate than the Richter Scale. Smaller earthquakes may go completely unnoticed. Nevertheless, as earthquakes increase in strength, the likelihood of damage to buildings and structures increases. Table 1 shows possible effects of an earthquake on people close to the epicentre, depending on the magnitude.

Magnitude	Possible effects on people close to the epicentre
1.0–3.0	Unlikely to be noticed.
3.0–3.9	May be noticed by people indoors. Ceiling lights sway and plates rattle. May not be recognized as an earthquake.
4.0–4.9	Felt by most people indoors and outdoors. May cause some objects to move.
5.0–5.9	Felt by all. Considerable damage is possible to poorly built buildings and structures.
6.0–6.9	Some damage to well-built structures. Severe damage to poorly-built buildings and structures.
> 7.0	Considerable damage to most structures. Potential total damage to whole areas.

Table 1: Earthquake magnitude and the effects on people near the epicentre[2]

[i] A logarithmic scale is used to represent a very wide range of values and is not linear. This means that when the logarithmic scale increases by 1, the real value is actually multiplied by a particular factor. In the case of the Moment Magnitude Scale (MMS), this factor is around 32, meaning that the real value of the energy released in an earthquake is multiplied by 32 every time the MMS increases by 1.

Modified Mercalli Intensity Scale	Damage and observed effects
I	Normally not felt by people but detected by seismographs.
II	Felt and noticed only by very sensitive people.
III	Felt by many indoors but not recognised as an earthquake. Often mistaken for a passing truck.
IV	Felt noticeably indoors and may awaken people at night. Dishes, windows and doors may move.
V	People are awakened at night. Some dishes and windows may get broken, cracks appear on plastered walls, trees or other tall objects move visibly.
VI	Many people are frightened and run outdoors. Heavy furniture moves, some plaster falls from the walls and minor damage to buildings occurs.
VII	Everyone leaves the buildings. Poorly designed buildings suffer considerable damages, while ordinary buildings may suffer slight to moderate damage. Also felt by people in moving vehicles.
VIII	Specially built structures suffer slight damage. Considerable damage and partial collapses occur in ordinary buildings. Heavy furniture is overturned. Poorly built structures suffer widespread damage.
IX	Considerable damage even in specially designed buildings. Widespread damage will be observed in all other buildings and structures, while some will be shifted off their foundations. The ground cracks and underground pipes break.
X	Severe and widespread destruction of buildings. The ground is badly cracked landslides occur on steep slopes. Rivers will splash over the riverbanks. Railway lines will be bent.
XI	Very few, if any, buildings and structures remaining standing. Bridges are destroyed and deep fissures form in the ground. Earth sinks and slides on medium slopes. Railway lines will be severely bent.
XII	Practically all buildings and structures suffer catastrophic damage. Waves are formed on the ground surface.

Table 2: Modified Mercalli intensity scale and the observed effects.[2]

Different scales are used to quantify the intensity of an earthquake. The most commonly used is the Modified Mercalli Intensity Scale, simply referred to as 'Mercalli scale'. The intensity of an earthquake is not measured by instruments but rather by the observed effects of the earthquake on people and structures close to the epicentre and by the ranking of these effects.[3] An earthquake occurrence has one measured magnitude, but it may have different effects depending on factors like location and distance from the epicentre. The destruction caused by different magnitudes will also vary depending on the state of the structures involved.

In the Mercalli scale, the intensity of the earthquake is normally defined using Roman numerals to highlight different levels of damage, as listed in Table 2. Irrespective of the level at which the earthquake has been recorded on the MMS, it is the damage sustained by the collapsed buildings that determines the intensity of the Mercalli Scale. The extent of the structural damage will consequently affect the level of harm and loss of life.

Urban Search and Rescue (USAR)

The first rescue effort, in the immediate aftermath of an earthquake, comes from the local community. However, when casualties are trapped within or underneath collapsed structures, such as heavily-reinforced concrete buildings, the situation requires highly skilled rescuers with specialized equipment to locate, access and rescue the casualties. The rescue teams deployed in such circumstances are called USAR teams.

USAR teams generally follow guidelines to internationally accepted common standards developed by the International Search and Rescue Advisory Group (INSARAG[4]). INSARAG is an international organisation composed of a network of disaster managers, government officials, non-governmental organisations (NGOs) and Urban Search and Rescue (USAR) practitioners. INSARAG operates under the umbrella of the United Nations (UN) and its principal aims are to establish minimum standards for USAR teams and international coordination during disaster response. INSARAG also provides a number of ethical considerations that rescuers deployed in international USAR operations should follow.[5] It is important to remember that whilst engaged in USAR work, all team members are ambassadors for their team and their country. When operating on a disaster site, everyone should behave ethically, according to country-specific rules and avoid unnecessary problems among rescuers, local authorities and the local population. Rescuers should keep in mind that their behaviour will have an effect on the perception and the level of trust earned from the local community by the rescue teams.

USAR teams have different operational capabilities, qualifications and resources. INSARAG classified the levels of USAR teams into three levels, based on these operational capabilities. These are Light USAR (LUSAR), Medium USAR (MUSAR) and Heavy USAR (HUSAR). Teams that follow these guidelines will be able to integrate effectively together, having the same structure and methodologies.

The number of casualties that survive in the hours after an incident will vary depending on their injuries, access to water and air and other crucial factors. Thus, it is important to have a prompt intervention by the local response teams and the community to rescue those that are only lightly trapped. This will maximize life-saving opportunities prior to the arrival

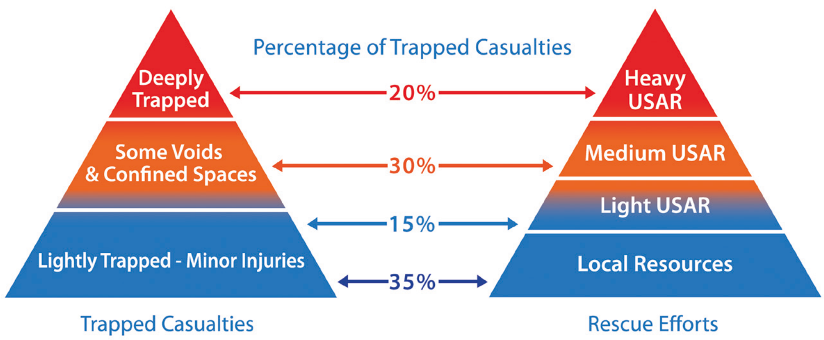

Figure 5: The relationship between the percentage of trapped casualties, the degree of entrapment and the rescue efforts required.[6]

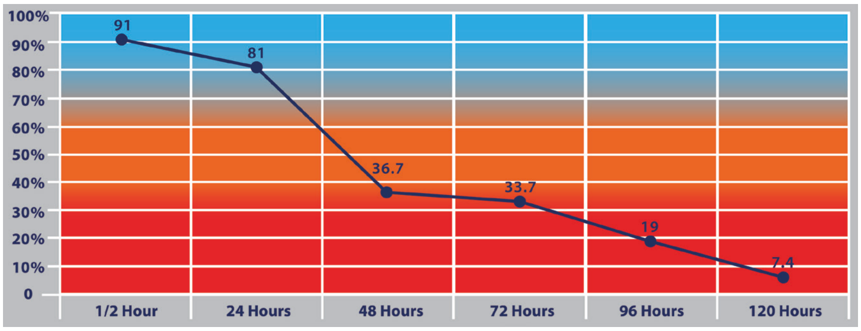

Figure 6: The relationship between casualty survivability (vertical axis) and the time after a disaster occurs (horizontal axis).[7]

of international or local specialised USAR teams. These USAR teams are normally better equipped to tackle the casualties trapped in voids and confined spaces, especially when access to these casualties requires breaking through building material. The relationship between the percentage of trapped casualties, the degree of entrapment and the corresponding rescue effort required is shown in Figure 5.

Figure 6 shows the decrease in survival rate as time goes by after a disaster has occurred, because of untreated injuries as well as due to lack of basic necessities such as food, water and even fresh air (when the casualty is entrapped in enclosed spaces). One may notice a significant decline in the survival rate between 24 and 48 hours after the occurrence of the disaster.[7] However, it is important to note that there are a lot of factors that may affect survivability such as temperature, age, nature of injuries, type of construction and materials used, etc. Therefore survival rates should be interpreted accordingly.

Due to the nature of earthquake response, USAR teams may be requested to deploy to foreign countries at short notice. The host countries might not be able to support the rescuers with basic necessities, so enough provisions need to be carried in order to be self-sufficient. This is further highlighted in the INSARAG guidelines Volume II Manual B, and each country may have further guidelines in place.[8]

Light USAR team (LUSAR)

LUSAR teams have very basic equipment capabilities. Due to their limitations, these teams are the first responders in the event of a local disaster but do not normally deploy internationally.

The tasks of a LUSAR team include assessing and surveying an incident site, gathering information on hazards and reducing them when possible.[9] These teams also perform a surface search for casualties, initiate the extrication of such casualties and tend to their medical needs. LUSAR teams may also establish a medical triage area where the casualties are taken to before further transportation to hospital. Upon the arrival of international teams, LUSAR teams give assistance by facilitating the integration with local emergency response.

LUSAR teams are expected to operate in light-construction material such as wood, light metal, non-reinforced masonry, mud brick or raw mud and bamboo structures. LUSAR teams work on one incident site at a time. To carry out these tasks, rescuers make use of basic cutting and breaking tools, ropes and accessories, levers, cribbing supplies. Other tools include communications equipment, basic life-support, personal protective

Figure 7: The recommended structure for a Light USAR team, with 18 personnel. Adapted from INSARAG Guidelines.[9]

equipment (PPE), whistles, marking supplies, fire extinguishers as well as equipment to set up a Base of Operations (BoO) including shelter, sanitation, tool maintenance, food and hygiene areas. Rescuers in LUSAR teams also require training in hazardous materials, first aid, incident command, basic USAR as well as general INSARAG guidelines and concepts.

Figure 7 shows an example of the structure of a LUSAR team made up of 18 persons. Additional personnel may be engaged as required. For example, an operations officer (SAR Team Leader) may lead a single rescue team or might be engaged to lead two teams simultaneously. A planning or information officer may also form part of a LUSAR team. The recommended number of persons forming the team may vary depending on country regulations, organizational differences and task distribution amongst members of the team.

Medium USAR team (MUSAR)

MUSAR teams can deploy both within their own country as well as internationally. The team is equipped to work at a single work site without requiring the support of other teams. MUSAR teams have the capability to conduct searches using dogs or technical equipment such as listening equipment or cameras, as well as breaking through collapsed buildings and structures made of heavy wood, reinforced masonry and lightweight steel.[9] MUSAR teams should be able to work for up to seven days without stopping (with personnel operating on a rotational basis). Medical treatment

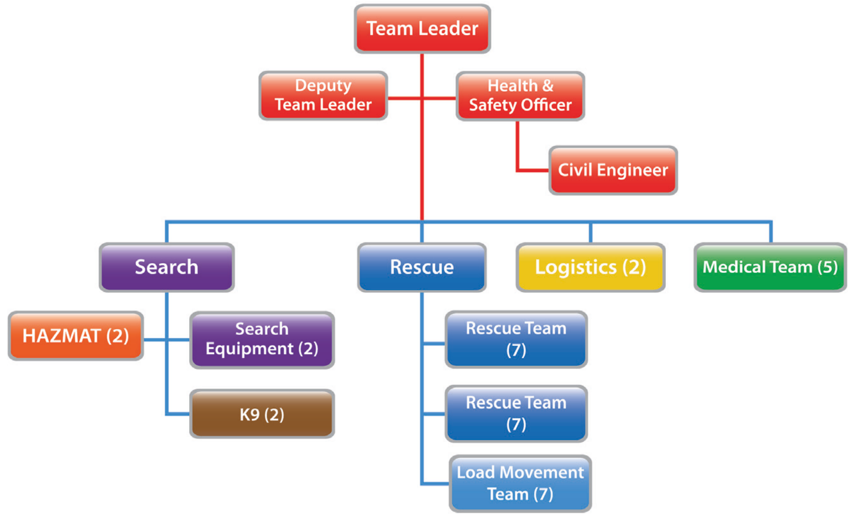

Figure 8: The recommended structure for a Medium USAR team with 40 personnel in the team. Adapted from INSARAG Guidelines.9

(for casualties or team members) should be available within the team itself. Some required technical abilities of MUSAR teams are to:

- manually lift loads up to one metric ton;
- mechanically lift up to 12 metric tons;
- use accessories for anchoring, securing, moving and dragging loads up to 12 metric tons;
- break, breach, lift and remove building components;
- assemble vertical, window or door shoring systems;
- cut and penetrate concrete up to 300mm thick and timber up to 450mm.

To meet these requirements, MUSAR team members need to be knowledgeable of the INSARAG guidelines and the duties associated with their role in the team, health and safety, first aid and working at heights, as well as being skilled in the use of tools and equipment used in USAR. Furthermore, it is ideal for them to be trained in rope rescue, confined space rescue and trench rescue.

The equipment used by the MUSAR team include communications equipment, equipment to set up a Base of Operations (BoO) with sleeping quarters, sanitation, food and hygiene areas and tool maintenance repair. Tools may consist of ropes, rope accessories, stretchers, mechanical, hydraulic, pneumatic and electrical tools, fire extinguishers, lifting, shoring and cribbing material as well as medical primary care and life support tools for the casualties, the team and search dogs.

The hierarchical structure of a MUSAR team, as shown in Figure 8, was adapted from INSARAG guidelines based on the experience of the authors of this chapter. Although the size of the team is recommended to be 40 persons, it is not excluded that additional personnel would be included.

Heavy USAR Team (HUSAR)

HUSAR teams may respond to incidents in their own country but, due to the severity of the incidents they are capable to respond to, it is more common for them to be involved in major international disasters. HUSAR teams are also more difficult to set up, maintain and equip, which further limits their availability. HUSAR teams perform technical searches and rescue operations in collapsed structures that are deemed too complex for MUSAR teams. Team operations normally include cutting, breaking and breaching steel reinforced concrete, as well as lifting and moving heavy structural materials to enable access to deep voids where survivors may be found. HUSAR teams are required to have enough equipment and personnel to enable the team to work at two different work sites simultaneously round the clock for ten consecutive days, with personnel working on a rotational basis.[9] The team is also capable of conducting searches using both dogs and technical equipment such as search cameras and sound-detecting equipment.

Some technical abilities required of HUSAR teams include being able to:

- manually lift loads up to 2.5 metric tons;
- mechanically lift up to 20 metric tons;
- use accessories for anchoring, securing, moving and dragging loads up to 20 metric tons;
- break, breach, lift and remove building components;
- assemble complex shoring systems;
- cut and penetrate concrete up to 450mm thick;
- cut and penetrate timber up to 600mm thick;
- cut and penetrate metal, structural steel or steel bar up to 20mm thick.

To meet these capabilities, HUSAR teams use equipment for communications and to set up a BoO (which would include shelter, sanitation, tool maintenance, feeding and hygiene areas). These teams also use mechanical tools, ropes accessories, hydraulic tools, pneumatic tools, fire extinguishers, lifting equipment, shoring and cribbing material, electrical tools, internal combustion tools, medical primary care and life support equipment. The training requirements for HUSAR team members are similar to those of MUSAR teams, except that they need to be skilled at using a wider variety of equipment. Additionally, safely lifting and moving heavier loads requires deeper knowledge of the techniques involved.

Similarly to the MUSAR structure, the hierarchy shown in Figure 9 was adapted from INSARAG guidelines based on the experience and views of the authors of this chapter. Thus, the exact number of personnel may vary.

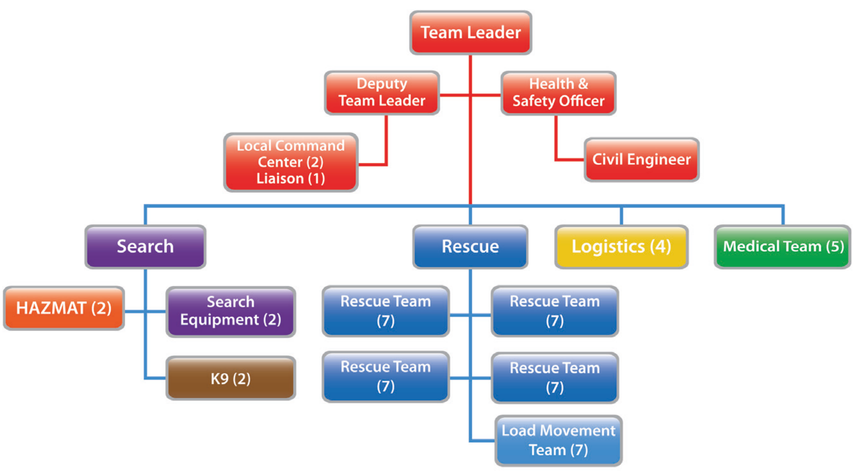

Figure 9: The recommended structure for a Heavy USAR team with 59 personnel. Adapted from the INSARAG Guidelines.[9]

Assessment, Search and Rescue Levels (ASR Levels)

One important element of the INSARAG coordination methodology is a system which clearly identifies and defines every level of work needed in response to a major incident involving structural collapse. This can range from initial assessment to deconstructing a building to recover the last deceased victim. The extent of USAR work to be carried out is broken down into five ASR levels.[10] There are also a number of forms that are used to gather and disseminate information and coordinate the work of the USAR teams. These forms are mentioned in Table 3 below and may be found in the

INSARAG Operational Field Guide Annexes.[11]

ASR Level 1 – Wide Area Assessment: This is a fast visual check of the area to establish the extent of the incident, identify hazards, potential BoO locations, infrastructure issues, urgent resource requirements and the development of a sectorisation plan. No actual rescue takes place during this level of assessment.

ASR Level 2 – Sector Assessment: This assessment is to identify possible rescue sites within each sector, carried out by part of a USAR team. The assessment needs to be fast but methodical and may involve search dogs or technical search equipment. Information from the locals and other response teams can be helpful. Sketch maps, worksite triage forms and worksite identification should be

<table>
<tr><th rowspan="2">Forms</th><th colspan="5">ASR level</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>USAR Team Fact Sheet Form</td><td colspan="5">Uploaded to VO[*] by USAR teams before departure and handed to RDC[†] on arrival into the country.</td></tr>
<tr><td>Worksite Triage Form</td><td colspan="2">Completed by LEMA[‡] and assessment teams to identify possible rescue opportunities.</td><td></td><td></td><td></td></tr>
<tr><td>Worksite Report Form</td><td></td><td></td><td colspan="3">Compiled by USAR teams to report activity carried out at a worksite for OSOCC or for the next team taking over.</td></tr>
<tr><td>Victim Extrication Form</td><td></td><td></td><td colspan="3">Completed by USAR teams to collect basic information of all victims extricated for LEMA.</td></tr>
<tr><td>Incident/ Sector Situation Report Form</td><td></td><td colspan="4">Compiled by the USAR Coordination team within OSOCC to summarise sector operations conducted or situational reports of an incident using worksite triage and worksite report forms submitted.</td></tr>
<tr><td>Demobilization Form</td><td colspan="5">Filled in by USAR teams once they cease operations, with information about the intended departure for OSOCC.</td></tr>
<tr><td>Post-Mission Report</td><td colspan="5">Compiled by USAR teams to provide feedback about the mission to the INSARAG secretariat.</td></tr>
</table>

Table 3: INSARAG forms to be filled at different ASR levels.[10]

* VO (Virtual OSOCC) – This is an online portal under the Global Alert and Disaster System (GDACS) where affected countries can request international resources and USAR teams may offer their help.

† RDC (Reception and Departure Centre) – This is an information and registration point for USAR teams on arrival into the country, where the USAR teams can register their details and get the latest information.

‡ LEMA (Local Emergency Management Authority) – This is the local authority assuming responsibility to conduct emergency response coordination.

carried out such that the On-Site Operations Coordination Centre (OSOCC) can plan and assign tasks to USAR teams. Rescues are not usually carried out during ASR level 2, but if the team encounters a rescue opportunity, the decision to carry out the rescue depends on the situation and on instructions from OSOCC. Documentation of this sector assessment should be done using the INSARAG Worksite Triage Form.

ASR Level 3 – Rapid Search and Rescue: This task is usually carried out by MUSAR or HUSAR teams, who rapidly perform rescues beyond the capabilities of local response teams. These rescues should take no more than a few hours and should be carried out by employing canine and technical searches, removal of debris, limited shoring, breaking and breaching and limited penetration into building material. These teams may also identify and report structures where ASR level 4 effort may be needed. Although it is possible for a MUSAR or HUSAR team to switch to ASR Level 4 with permission, this must be done after finishing assigned Level 3 work first. Once ASR Level 3 work is completed, the INSARAG Worksite Report Form should be filled in, worksites marked and the INSARAG Victim Extrication Form completed if any casualties are extricated.

ASR Level 4 – Full Search and Rescue: This levels involves the search and rescue of heavily trapped survivors by MUSAR or HUSAR teams and involves penetration into survivable voids using a wide range of techniques. This may include heavy breaking and breaching work, extensive shoring and confined-space rescue deep inside these structures. There may be more than one team working at the same site. Similar to level 3, the INSARAG Worksite Report Form, the Victim Extrication Form together with the marking of buildings should be completed once work is finished.

ASR Level 5 – Total Coverage Search and Recovery: The final level usually involves the recovery of deceased victims once the rescue phase is complete. It is normally carried out by local resources and the Local Emergency Management Authority (LEMA) using heavy machinery such as cranes and

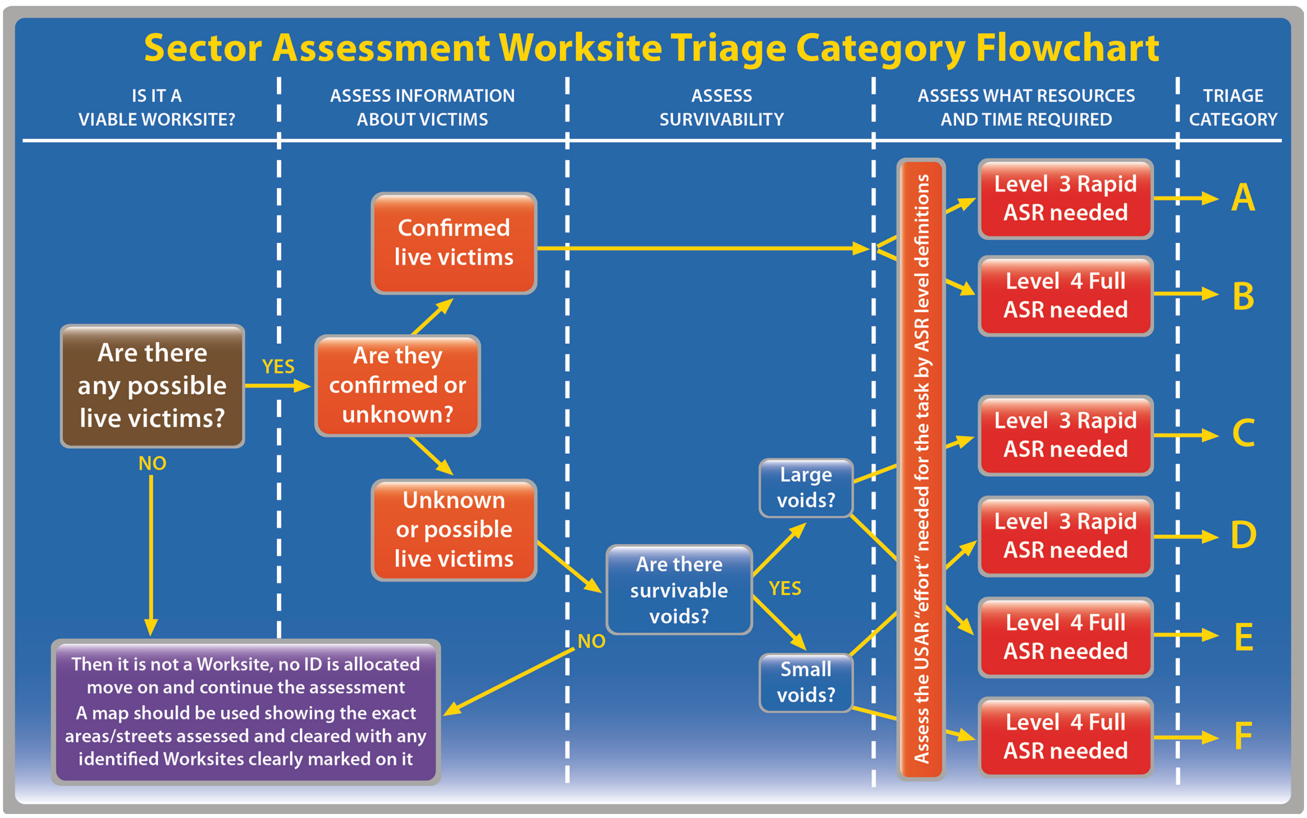

Figure 10: Sector assessment – Worksite triage category flowchart (adapted from INSARAG guidelines).[12]

demolition equipment in order to gain access to all parts of the collapsed structures and rubble piles. International USAR teams may be asked to help with this task, where body recovery is a high priority, but the decision is at the discretion of the individual team. On completion of this stage, reports and building markings similar to those used in level 3 and 4 are completed. Sometimes USAR teams may be asked to carry out an Area Clearance to ASR level 5, intended to assess structures which would require USAR techniques to gain access and ensure clearance. This should enable relatively large areas to be cleared quickly. The information reports and resulting maps of the cleared area are passed on to OSOCC/LEMA.

Worksite triage

The objective of a triage process is to determine the priority for rescue work. The key to triage is consistency in the comparison of triage factors and a good understanding of what the triage factors mean.[12] The following terms are used during the triage process:

Confirmed live victims, refers to the presence of live people within the collapsed structure.

Unknown victims or possible victims refers to information about known missing people, which the assessment team cannot confirm whether these people are alive or if they are within the collapsed structure at all.

Voids within collapsed structures are empty spaces where casualties may be found. These spaces depend on the nature of the collapse. Voids provide higher probabilities of survival and may be defined as big or small. Big voids are large enough to allow a person to crawl within, while in small voids a person can hardly move at all. In small voids, the chances of injury are higher as people trapped inside have less space to move to avoid falling or shifting objects.

In order to determine the priority for each worksite, the assessment team takes into account any information about the victims (confirmed or unknown victims), the potential survivable conditions where the victims may be, as well as the rescue effort required to reach the victims (defined by ASR Level). The assessment team determines the priority of the worksite according to the triage category. The flowchart (Figure 10) developed by INSARAG facilitates this process. Triage category A defines the highest priority as it has the highest chance of successfully and rapidly saving a victim.

Sectorisation and worksite identification

Disasters normally affect a large area of a country, making it necessary for the local emergency authorities to break the area down into sectors. This is done in order to facilitate planning, coordination and assignment of work to responding teams. The size and shape of sectors depend on a combination of factors such as geographical features, the resources available as well as the degree of intervention required. The sectorisation plan is usually performed by local authorities (LEMA) or by OSOCC. This process follows the INSARAG guidelines and may be seen as a two-stage process.[13]

Stage 1 – Sector identification: The affected area is divided into sectors in which the so-called sector assessment teams can work to identify potential worksites. Sector boundaries tend to follow large and

Figure 11: Sector identification

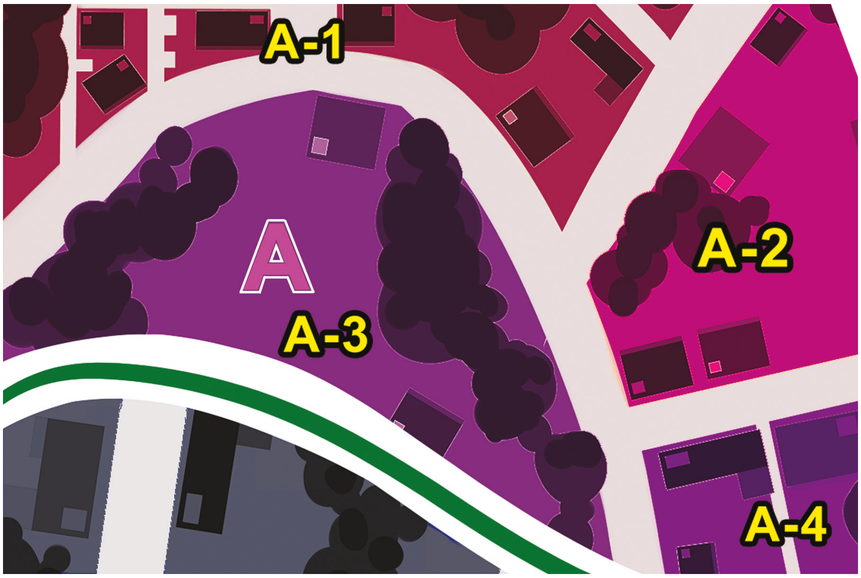

Figure 12: Worksite identification

recognisable features such as roads, rivers and railways. The INSARAG guidelines recommend sectors to be identified by sequential capital letters, starting from the letter 'A'. Figure 11 shows an example of an area divided into sectors using major roads.

Stage 2 – Worksite identification: Once the affected area has been broken down into sectors, sector assessment teams within each sector can work to identify individual worksites that require significant USAR operations, which in turn determines the deployment of USAR teams. These worksites can be single dwellings or a collection of buildings within a boundary, such as a school or hospital complex. Worksites are assigned a 'worksite ID'. The worksite ID is composed of a sector letter followed by a sequential number, as shown in Figure 12. The worksite ID is in addition to a geographical reference such as the street address, if available.

When a worksite is very large, such as a school or hospital, it could be divided into further worksites. These worksites are identified by adding a small letter for each 'sub-site'. Figure 13 shows worksite A-4 divided into three smaller worksites, namely A-4a, A-4b and A-4c.

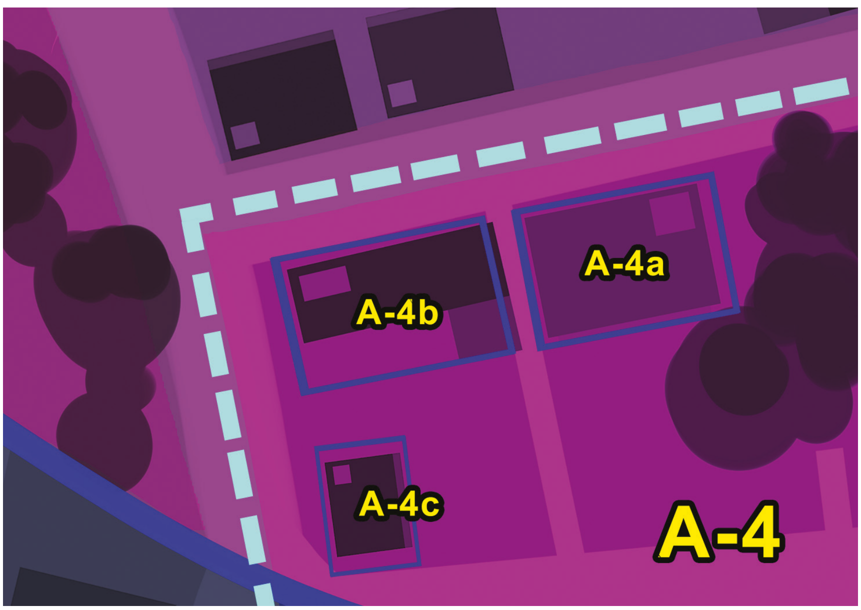

Figure 13: Dividing a worksite into smaller ones.

The INSARAG marking system

During the response to a major disaster, several different USAR teams will be working in the affected area. This makes it very important to have an agreed system of marking and signalling to convey critical information for situational awareness and planning purposes. INSARAG has developed recommended marking systems as described below.[14]

General area marking: This may be required to assist with navigation and coordination especially since collapsed buildings make it more difficult to identify locations. These markings should be highly visible and contrast with the background, making a reference to the existing street name and building numbers as much as possible. If no maps are

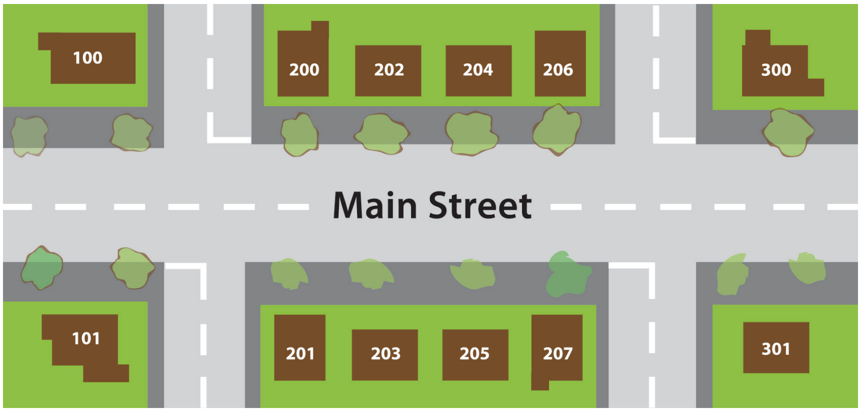

Figure 14: General area markings based on street address and building numbers.

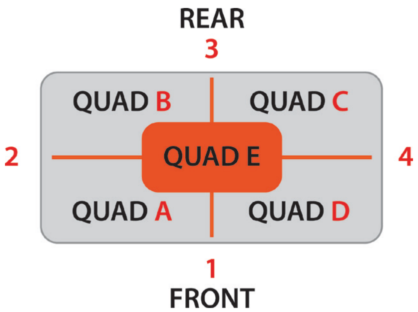

Figure 15: Interior and exterior identification shown on a plan view of a structure.

available, then a sketch map should be drawn and handed to OSOCC. Any landmarks should also be shown on the sketch. Figure 14 shows a sketch based on the street name and building numbers.

Structure Orientation: Whenever referring to areas inside a structure, it is important to avoid any confusion by following a common exterior and interior identification. The exterior identification starts from the front of the structure (street address side) marking it as side '1'. The other sides are marked in sequence (2, 3 and 4) turning clockwise around the building, as shown in the plan view of a building in Figure 15. The interior identification of the building consists of quadrants (in short QUAD), starting from QUAD A in the corner where sides '1' and '2' meet, continuing clockwise around the building. An extra quadrant (QUAD E) is added for lift shafts or staircases in multi-storey buildings as shown in Figure 15. Floors are labelled as seen from the exterior, starting with Ground Floor. The first floor is labelled 'Floor 1' and so on. Levels below the ground floor are labelled 'Basement 1' and so on, as shown in Figure 16.

Cordon marking: This type of marking is done to restrict access to an area as well as to mark hazards. Restricting access may be necessary both due to the inherent danger present during a rescue operation as well as to prevent the rescue team from being disturbed by bystanders. Cordon marking the operational zone is also useful to set specific entry and exit points for the rescuers, which facilitates entry control. Furthermore, certain areas may be hazardous and need to be cordoned off even when there are no operations taking place. Cordon marking is done using plastic tape which is either red and white or red and yellow. The two types of marking are shown in Figure 17a

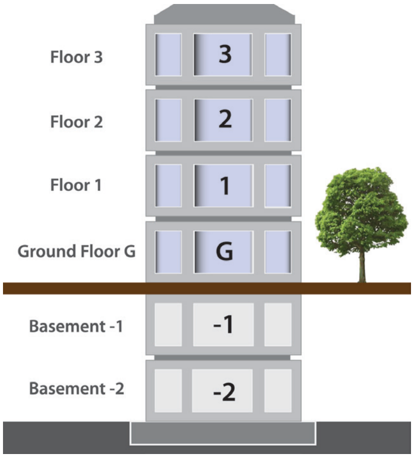

Figure 16: Floor identification for multi-storey buildings

Figure 17a: Operational zone cordon

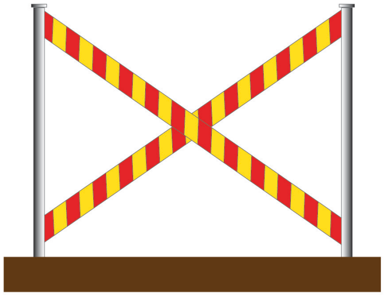

Figure 17b: Hazard zone cordon

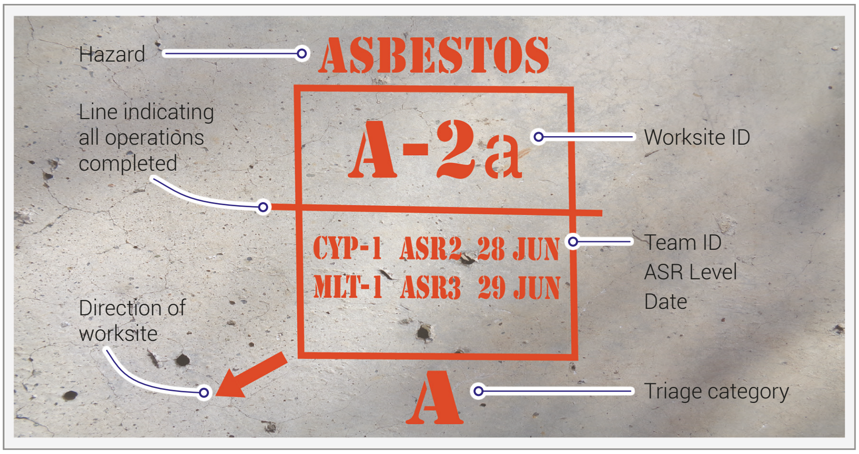

Figure 18: An example of worksite marking.

(Operational Zone) and Figure 17b (Hazard Zone).

Worksite marking: This marking is applied close to the main entrance of a potential worksite believed to contain live casualties. The markings identify the worksite and also convey important information such as hazards, the triage category, the USAR teams that have worked at the site and corresponding ASR Level completed. Figure 18 shows an example of such markings, which are recommended to be approximately 1m wide by 1.2m high using a highly visible colour contrasting with the background. The worksite ID should be large enough to be easily recognized, normally around 40cm high. An arrow may be placed to point to the worksite entry point. A line crossing the middle of the box indicates that no further operations are required at the worksite.

The example shown in Figure 18 includes:

1. The type of hazard present (Asbestos).
2. The location of the worksite indicated by an arrow.
3. The worksite ID (A-2a – Sector A, worksite 2, sub-site a).
4. A horizontal line that cuts in half the length of the box, indicating the completion of all operations.
5. The team ID, showing the teams that deployed to the worksite, the ASR Level completed and the date.
6. The triage category assigned to the worksite by the assessment team during ASR Level 2.

The team ID normally consists of the three-letter Olympic country code,[ii] followed by numbers (e.g. MLT-1). The numbers are allocated according to the classification and registration of the team in the INSARAG USAR directory. Unclassified teams are assigned a number starting from 10 onwards by the Reception and Departure Centre (RDC) upon arrival in the affected country. USAR teams that do not have the national support of a country may be assigned the Search and Rescue (SAR) code instead of the Olympic code (e.g. SAR-1). Also, a USAR team may use its team name or acronym if agreed with the national focal point. Table 4 lists some Olympic codes as an example.

Victim marking: This marking is used to indicate the potential or identified locations of victims to the rescue teams if the search team does not remain on site. This is also used when there are multiple casualties, or when it is necessary to avoid misunderstandings about the exact location and number of

CYP	Cyprus	GBR	Great Britain	MLT	Malta
ESP	Spain	HUN	Hungary	SRB	Serbia
GRE	Greece	ITA	Italy	PRT	Portugal

Table 4: Examples of three-letter Olympic country codes.

[ii] The Olympic code is a three-letter unique code for every country assigned by the Olympic committee.

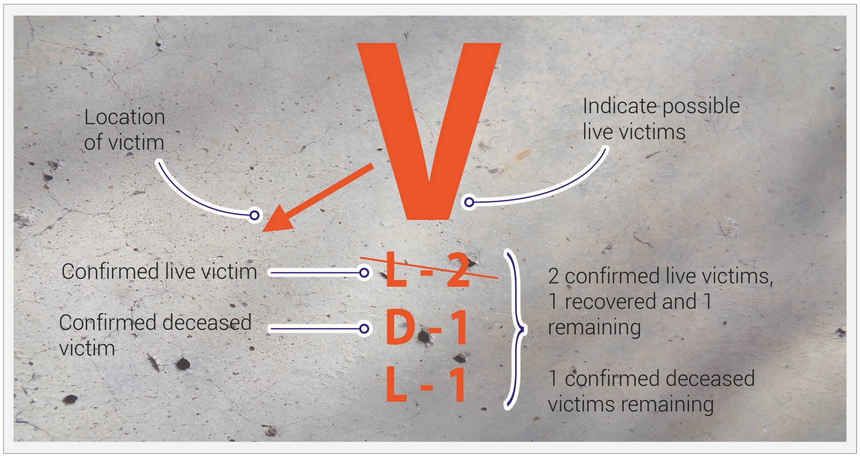

Figure 19: Victim location marking.

Figure 20a: 'All clear' rapid clearance marking.

Figure 20b: 'Deceased only' rapid clearance marking.

casualties. Victim markings should be placed as close as possible to the actual location of the victim, which is not normally at the entrance to the worksite. Both potential live and dead victim locations are marked. The size of the marking would be around 50cm high and consist of a large 'V' indicating potential victims, an arrow indicating the direction to the location of the victims, followed by the letter 'L' in the case of live victims or 'D' in the case of dead ones. A number next to 'L' or 'D' indicates the number of victims. Once one or more victims are extricated, the corresponding marking is crossed out and a new updated marking is done if necessary. Figure 19 shows an example of such markings, where initially two live victims and one dead victim were located. One live victim was extricated so the 'L-2' was crossed out and a new 'L-1' was marked to indicate that one live victim remains, together with the dead victim. When all known victims have been extricated, all markings will be crossed out.

Rapid clearance marking: This marking is used to indicate sites which have been confirmed to

Evacuate (3 short blasts, 1 second each – repeated until site is cleared)	— — — repeated
Cease Operations – Quiet (1 long blast, 3 seconds long)	———
Resume Operations (1 long blast + 1 short blast)	——— —

Table 5: Emergency whistle signals used in USAR, as defined by INSARAG.[15]

contain no victims, or deceased victims only. This is done to prevent duplication of work and unnecessary use of resources since normally only sites with potential live casualties are marked using victim marking. Rapid clearance marking is only used at locations that can be searched quickly and when there is strong evidence that no live casualties are present. These markings indicate that a search equivalent to ASR Level 5 has been conducted, with only deceased victims remaining, if any. The decision to apply these markings can be made by the OSOCC, LEMA, or by the USAR team.

Rapid clearance marks consist of a diamond shape with a ‘C’ inside to indicate that there are no victims (all clear) as shown in Figure 20a. A ‘D’ is used to indicate that only deceased victims are present (Figure 20b). The team ID and the date are written underneath.

Emergency signalling

Whistle signals provide an efficient means of communication in emergency situations where voice alone is not enough or may lead to misunderstandings, especially between USAR teams of different nationalities. The signals are universally known by USAR team members, who are briefed about emergency signalling at the beginning of the operation. An alternative to using whistles is to use air horns. In USAR operations the three main signals are evacuate, cease operations and resume operations, as shown in Table 5. It is imperative that all rescuers know these signals.

Types of partial building collapse

The nature of a building’s collapse can provide assessment teams with important information about where casualties may be located as well as the most efficient way to reach them. This requires a good understanding of the different types of collapse.[16]

Pancake collapse (Figure 21): A number of floors collapse relatively flat onto each other. Some small voids may be created, depending on the strength of furniture or objects inside the building, but generally this type of collapse does not leave any survivable voids.

Lean-to-floor collapse (Figure 22): This occurs when a ceiling loses support from three sides and falls intact to the floor below it, while still leaning against the remaining wall. The void created between the wall and the leaning structure will be large and provides a better chance of survival for casualties.

V-shape collapse (Figure 23): Two opposite sides of a ceiling remain supported by walls while the ceiling itself splits into two and falling down to the floor below such that each part of the ceiling is leaning against one of the supporting walls. This creates survivable voids whose size depends on the dimensions of the leaning ceiling above them.

Cantilever collapse (Figure 24): Cantilever collapse occurs when one or more of the outer walls supporting the ceiling collapse. However, the weight of the remaining supporting wall on the ceiling stops it from collapsing down. This creates big voids where

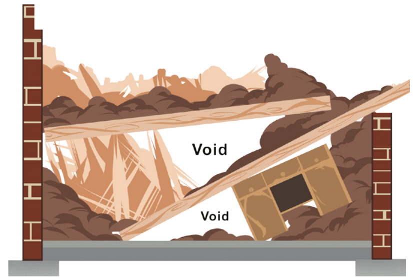

Figure 21: Pancake collapse

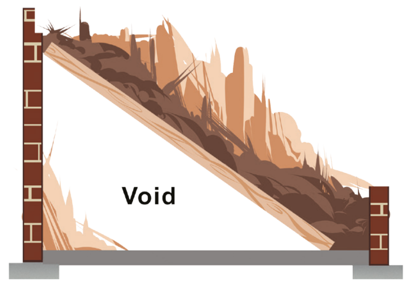

Figure 22: Lean-to-floor collapse

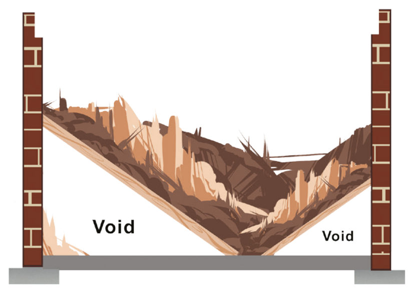

Figure 23: V-shape collapse

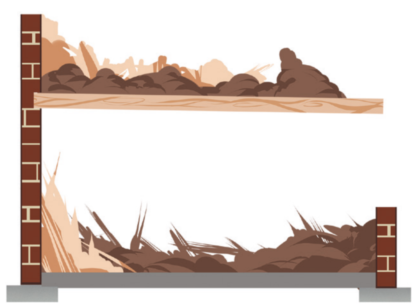

Figure 24: Cantilever collapse

casualties may be found. However, this type of collapse could be quite dangerous as a secondary collapse might cause the supporting wall to topple, causing the ceiling to fall onto rescuers working on site. USAR operations at this type of site generally involve supporting the wall and ceiling with shoring to ensure safety for the rescuers and casualties.

A-frame collapse (Figure 25): This type of collapse happens when a supporting wall along the middle of a ceiling continues to support it while the sides fall to the floor such that two ceiling slabs are leaning against the same middle wall forming an A-shape. Sometimes this is also called a tent-collapse. Similar to the lean-to-floor collapse, this type of collapse creates large survivable voids, but the middle supporting wall should be monitored and if possible supported by shoring to prevent secondary collapse.

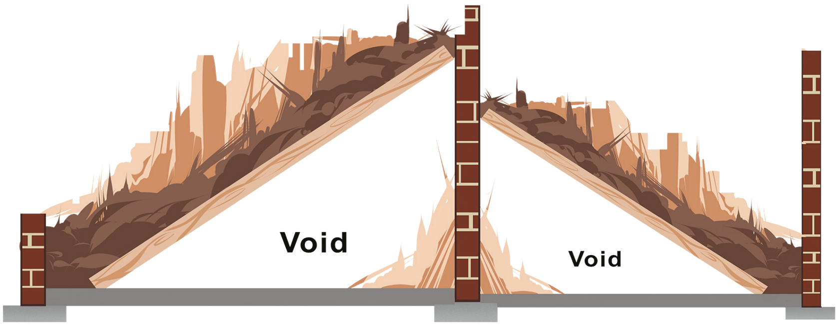

Figure 25: A-frame collapse

Worksite search

The size of the worksite, type of building collapse, information about possible trapped victims, as well as the worksite triage category may determine the type of search procedures that will be used to locate them. There are several types of searches used in collapsed structure incidents. Figure 26 shows some of these search methods, such as open area search, canine search and technical search. The search team may talk to local people to get more information about possible casualties and their location. A drone may also be used to get a general overview of the area and the degree of damage sustained by buildings.

An open area search may involve a simple line search over a pile of rubble. This is sometimes called a surface search. The rescuers would be calling and listening for a response from anybody trapped

Figure 26: Examples of different searches at a worksite.

who can hear the call. This search entails rescuers occasionally shouting '*Rescue team. Can anybody hear me?*' It is important that rescuers listen attentively for any potential replies and get close to the rubble while listening. Replies are likely to be very faint and may easily be missed. The exact wording of the call does not really matter as those trapped may not speak the same language. It is also important to look for recent signs of life, such as clothing, food, food wrappers, etc. The open area search may be extended to search in voids that are easy to access, which is called a void search.

Figure 27a: K-9 search team ready to be lowered with ropes.

Canine[iii] searches are conducted under the guidance of an appropriately trained dog handler. Dogs are able to search an area of a collapsed structure much faster than humans due to their ability to detect scent. Thus, a canine search team can be a valuable asset in detecting human life as dogs indicate the presence of live casualties trapped within collapsed structures. Since dogs use their sense of smell to detect casualties, it is important that rescuers or bystanders do not walk all over the site beforehand as this makes it harder for the dogs to single out the scent emitted by the buried casualties. The scent of a person will move with the wind before it disperses in the air. Therefore, the wind direction and the position of rescuers and bystanders around the search area will affect the dog's search, as the wind blowing the rescuers' scent onto the search area will make it more difficult for the dog. Figure 27a shows a dog and handler ready to be lowered with ropes to the area to be searched. Figure 27b shows a dog searching for a hidden casualty during a training exercise.

Figure 27b: K-9 search team during a training exercise.

Technical search involves the use of technical equipment to look for signs of life and identify the location of casualties that are not immediately visible to the rescuers. The equipment used can range from a simple mirror attached to a stick that enables a rescuer to see around a corner or in voids, to the use of more sophisticated

[iii] Dogs are sometimes referred to as canines or K-9. In the field of rescue, it is more common to find the term canine search rather than dog search, but essentially it refers to the use of trained dogs to search for missing people.

Figure 28: Drone used in search and rescue.

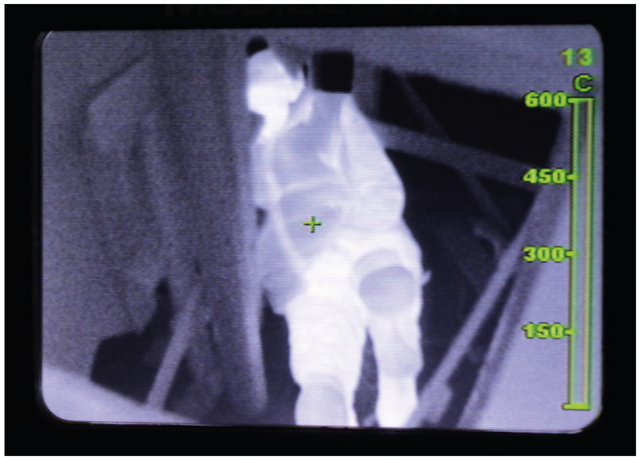

Figure 29: Thermal image of a casualty.

Figure 30a: A geophone in use at a collapsed building after an earthquake.

Figure 30b: A geo-radar being used during a training exercise.

equipment like drones with infrared cameras. Drones may also be used to assess the scale of damage over a large area using aerial photographs or video (Figure 28). This may help with the wide area assessment (ASR Level 1) and sector assessment (ASR Level 2) as well as in assigning priority to worksites.

A simple, yet effective search method involves the use of a mobile phone to take photographs inside otherwise inaccessible voids. More specialised search cameras, purpose-built for search and rescue, may be used to access deeper voids. These cameras are attached to flexible rods and normally include a microphone and speaker beside the camera. The microphone is used to listen for any noises or for the casualty to talk to the rescuers. The speaker enables the rescuer to speak to the casualty. Thermal cameras may also be used to detect the presence of trapped persons by the heat that they radiate, as shown in Figure 29.

Technical listening equipment include geophones. Geophones give rescuers the ability to detect faint acoustic signals under the rubble, such as scraping, tapping or the noise of a moaning casualty from under the rubble. Figure 30a shows a geophone being used in the aftermath of a real earthquake in Amatrice, Italy, in 2016.

Another technical search equipment that may be used to locate trapped casualties is the geo-radar. Using high frequency signals, this equipment detects very small movements of a casualty's chest while breathing and gives an indication of the location and depth of the victim. Normally, geo-radars are able to detect a breathing casualty at a depth of up to 5m. Figure 30b shows a geo-radar in use during a training session.

Another method to detect possible live casualties is by detecting high concentrations of carbon dioxide (CO_2) gas. When a person exhales air in an enclosed space, the CO_2 level increases and this may be detected by CO_2 probes inserted into voids within the rubble. However, it is also possible that higher concentrations of CO_2 may be the result of bacterial reactions, such as rotting food. Therefore, it is advisable to use a combination of different techniques to verify the presence and location of casualties.

Reaching and extricating trapped casualties

The extrication of trapped casualties may range from simply assisting someone uninjured but physically trapped in a void, to rescuing a badly injured casualty located deep within a collapsed structure. Lightly trapped casualties may be freed by moving rubble by hand, using levering methods and cribbing structures to facilitate the access to the casualty. On the other hand, more complex methods may be required to reach victims that are heavily trapped. The methods used depend on the following factors:

- The stability of the building and immediate environment.
- The construction material.
- The number of rescuers available.
- The time available.
- The available tools and equipment.
- The training and capabilities of the rescue team.
- The condition of the casualty.

After taking these factors into consideration, a team with different equipment and capabilities may need to be called to carry out the extrication. If it is possible to penetrate into the structure, then the work is likely to involve an element of confined space and tunnelling work. This requires extra safety precautions for the rescue team, particularly from toxic gases. Gas monitoring equipment should be used to check for such gases. Breathing equipment may need to be used in such cases. Some of these gases, their characteristics and effects are found in Table 6.

Table 6 shows how critical it is to check properly for any gases present in confined spaces before attempting a rescue, due to the serious risks involved. Even after confirming that hazardous gases are not present, rescuers must keep in mind that rescue tools powered by an internal combustion engine generate carbon monoxide. If such equipment is used in confined space, the gas concentration can be lethal both for the rescuers and the casualties. In such cases, electrical, hydraulic or pneumatic tools should be used. Additionally, if flammable or explosive gas leaks may be possible, the tools selected should not cause sparks. Finally, cutting building material in confined space may generate a high concentration of dust that makes breathing very difficult. In such cases, appropriate dust masks or breathing apparatus should be used.

The methods of entry into the collapsed structure depend largely on the equipment available, the estimated location of the casualty and the time needed to carry out the rescue. In rescue from collapsed structures it is important that rescue teams rotate regularly to avoid fatigue. The number of rescuers committed to enter the structure at any time should be kept to a minimum due to the danger of further collapse. Rescuers should wear the appropriate PPE and carry the minimum equipment required to avoid clothing and equipment getting snagged or caught on debris.

If the structure is badly damaged, it is critical to use cribbing and apply shoring at entry points and passage ways, making them safe before entering. Rescuers should always work in pairs and use a guideline (rope) to facilitate finding the route back to the entry point. This practice should be done even if the route out appears obvious because further collapse may drastically change the appearance of the area. A guideline could also help other rescuers standing by outside the structure to reach their colleagues inside should the latter need assistance. As rescuers move through a building, evacuation will take longer, so it is worthwhile for the rescuers to take note of potential safe areas, such as stairwells, in case of aftershocks.

Gas type	Characteristics	Effects
Carbon Dioxide[17]	Colourless Odourless Heavier than air	Shortness of breath Reduced vision Fatigue Drowsiness Confusion
Carbon Monoxide[18]	Colourless Odourless Poisonous Slightly lighter than air Caused by internal combustion equipment in enclosed space	Light-headedness Nausea Headache Confusion Shortness of breath Tiredness Dizziness Unconsciousness Death
Natural Gas[19]	Colourless Lighter than air Highly flammable An artificial smell is normally added to make it recognisable. May be caused by a leak from broken gas pipes.	Reduced oxygen Dizziness Fatigue Nausea Headache Irregular breathing Explosion and fire
Butane Liquid Petroleum Gas (LPG)[20]	Colourless Heavier than air Toxic Highly flammable An artificial smell is normally added to make it recognisable. May be caused by a leak from broken gas pipes.	Shallow breathing Confusion Loss of consciousness Cardiac arrest Death Explosion and fire
Hydrogen sulphide[21]	Colourless Foul ‘rotten egg’ smell Heavier than air Highly toxic Highly flammable and explosive	Nausea Eyes irritation Headaches Airway problems Fatigue Dizziness Altered breathing Unconsciousness Death Explosion and fire

Table 6: Some gases that may be found in confined spaces, their associated characteristics and effects.

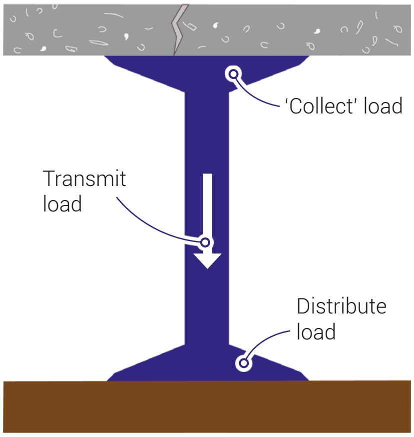

Figure 31: The concept of shoring – collecting, transmitting and distributing the load.[22]

Basic shoring techniques

Shoring is the temporary support of part of a damaged structure where it is necessary to conduct search and rescue operations. Shoring techniques are used to reduce the risk to rescuers and victims from further collapse. In simple terms, shoring 'collects' the load from the damaged or unstable parts and transmits this load to distribute it onto the remaining undamaged building element or to the ground.[22] This concept (Figure 31) is known as the double funnel principle. An important characteristic of shoring is that it should give warning of overload. If the weight being supported by the shoring is too large, the shoring should not fail suddenly. The creaking and cracking of the material should serve as a warning to the rescuers to evacuate to the nearest safe place.

Different methods of shoring may be employed, depending on the part of the building to be stabilized. Shoring may be built using timber, pneumatic rams, or a combination of both. Pneumatic rams are more expensive and the amount available to a rescue team will be somewhat limited. Timber is more widely available and it may also be possible to procure timber from the vicinity of the worksite. The material used has to be graded first, to ensure that it is suitable for the task. To reduce the rescuers' exposure time to the unsupported structure, timber should be cut to size outside of the building, then moved inside and used to shore the unstable building elements. Once in position, all parts of the shoring should be monitored closely for any movement, which may indicate that the load is not being adequately supported.

When selecting timber for shoring operations it is important to choose construction grade timber, preferably pine wood, with minimum dimensions 10cm x 10cm. When this is not available, locally sourced timber may be graded for its suitability for shoring by a competent person. The timber should be dry, free from rot, have a minimum of 8 rings per 25mm when viewed from the end and should be as free from knots[iv] as possible. Quick reference guidebooks such as the *Technical Rescue Field Operations Guide* by CMC Rescue provide detailed specifications for types and sizes of timber needed for different types of shoring, accompanying diagrams of the different types of shoring.

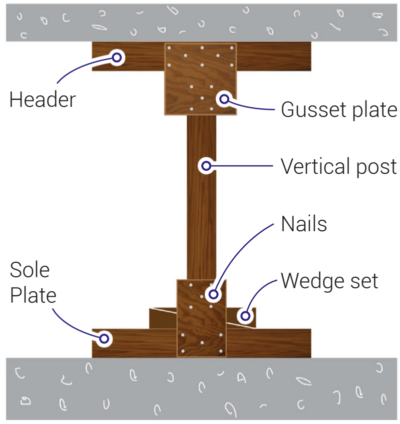

Figure 32: Basic shoring terms, shown on a single vertical T-spot shore.

Figure 32 shows some basic terms used with shoring, based on a vertical T-spot shore.[22] The header is the upper element of a shore, which 'collects' the load. The load is then transferred through the vertical post. The vertical post rests on a set of wedges, which are used to apply pressure between the vertical post and the sole plate underneath them. The wedges allow the height to be adjusted, to a certain degree. The load is transferred from the vertical post through the wedges and onto the sole plate, which in turn distributes the load on the floor beneath it. Gusset plates are used to connect the vertical post to the header and to the sole plate using nails. Gussets may be rectangular or triangular in shape and the nails are applied in patterns as shown in Figure 32. These patterns ensure the strongest possible joint and also are least likely to split the wood.

[iv] Knot, in this context, refers to the location where a branch is attached to the tree trunk. When wood is cut from a tree trunk, the knot is characterised by a circular shape with a darker colour than the surrounding wood. The knot weakens the wood.

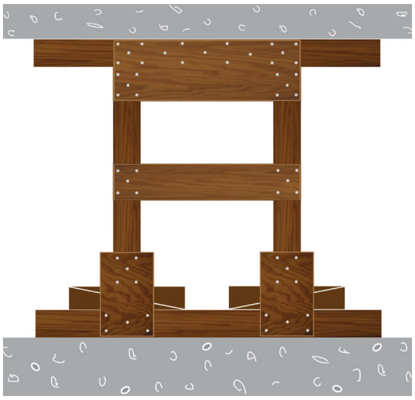

Figure 33: Vertical double T-spot shore.

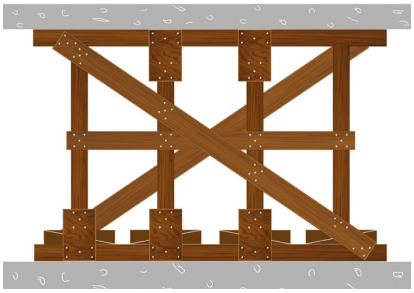

Figure 34: Vertical multi-post shore.

Cleats (not shown in Figure 32) are used to prevent shoring members from sliding out. For example, in the T-spot shore, cleats may be used to prevent the wedges from sliding out due to vibration. Depending on the type of shoring, the vertical post may be called differently, for example horizontal strut or raker (diagonal). Diagonal braces are sometimes used to prevent the vertical post from buckling.

The single T-spot shore shown in Figure 32 is categorised as a Vertical class 1 (1-dimensional) shore. This means that it can only support load directly on top of it. If the load shifts to one side of the post, the shore will become unstable. This is fairly quick to construct and is used for initial stabilization. A variation of this the double T-spot shore, shown in Figure 33. This shore has two vertical posts sharing the load. This type of shore is more forgiving with a small shift in load, hence it is considered a vertical class 2 (2-dimensional) shore. It is still used as a temporary shore and is also quick to construct.

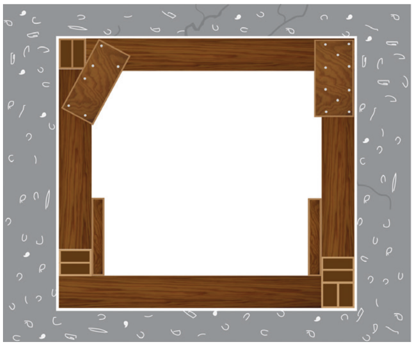

Figure 36: Door or window shoring.

More vertical posts may be added to further distribute the load among them, enabling both a heavier load to be supported, as well as enhancing the stability of the shore. This is called a multi-post vertical class 2 shore (Figure 34). This type of shore takes longer to construct, so it may be necessary to construct temporary spot shoring first to reduce the risk for the rescuers while they work on the multi-post shoring.

Figure 35: Vertical class 3 shoring with integrated working platform.

Stability and load bearing capability can be improved further by joining Double-T or Multi-post shoring to form vertical class 3 (3-dimensional) shoring. This type of shoring looks very similar to a scaffolding and is useful to support large ceilings. A platform may also be added in the middle of the shoring to enable rescuers to stand on it while cutting an opening in the ceiling to access the floor above through it, as shown in Figure 35.

Doors and windows which have incurred damage to their structure need to be shored as shown in Figure 36. This type of shoring provides the necessary support and stability while still allowing access through the door or window.

The above examples are just a few of the different types of shoring possible. These are meant to provide an understanding of what shoring consists of and to give an appreciation of the considerations involved. There are several other types of shoring, which are not covered in this chapter. Constructing effective and safe shoring requires practical training delivered by competent instructors.

Breaking and breaching

At times, there may not be a safe or practical point of entry into a partially collapsed building, or extensive and time-consuming shoring may be required before a safe entry can be made. Such cases make it necessary to create new openings to gain access, as these alternative entries would take less time and energy, thus increasing the efficiency of the rescue operation. Nonetheless, breaching through walls and ceilings may still necessitate the use of additional supporting equipment to prevent the structure from collapsing further, exposing the rescuers to serious risks. Rescue teams need to have the appropriate tools, material and capabilities for shoring and cribbing to be able to perform breaking and breaching, which are vital when working within collapsed structures.

During the breaking and breaching operation, it is important not to compromise the stability of the remaining structure. The location and type (square, triangle or circle) of breaching should be decided based on the advice of a structural engineer, while also taking into account any available information on the location of the casualty. The size should also be large enough for a stretcher and casualty to pass through.

During the operation to break building material, rescuers need to be very careful in case the casualty is very close to the breach. Debris falling onto the casualty may cause further injuries. To avoid debris falling onto the casualty, rescuers need to perform a clean breach, cutting the material in a way that keeps the debris on the rescuers' side. However, a clean breach is more time consuming when compared to a dirty breach. When there is no risk that the debris will fall on the casualty, rescuers may perform a dirty breach, where the debris is allowed to fall into the void or on the other side of the wall.

Penetration through a vertical element of a structure, such as a wall, is called a vertical surface breach. When breaching a wall, especially when the material is brick or masonry, a triangular shape will retain most of the strength and integrity of the wall, compared to other shapes. A circular breach in a wall is not practical. When breaching a ceiling, the easiest shapes to cut are the square and the circle, depending on the tools used. This is called a horizontal surface breach. Rescuers may perform a horizontal surface breach to gain access to a floor below them, or to reach a floor above them..

Before breaching a surface it is advisable to drill a hole large enough to fit an inspection camera through. This gives the rescuer an idea as to whether there is a casualty or an obstruction behind the wall, the kind of material that the surface is made of, its thickness, and also the space available in the void to make the breach worthwhile. Another consideration is to check if any plumbing or electrical wires are embedded in the surface that is to be breached. Once the rescue team decides to proceed with the breach, one has to decide which type of cut is most suitable for the situation.

When the structure is built using bricks or masonry, the rescuers may create an opening in the wall

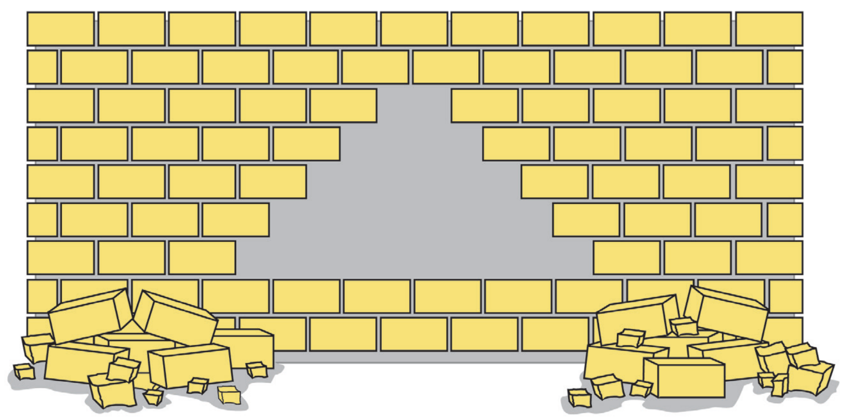

Figure 37: Mortar cut and block removal.

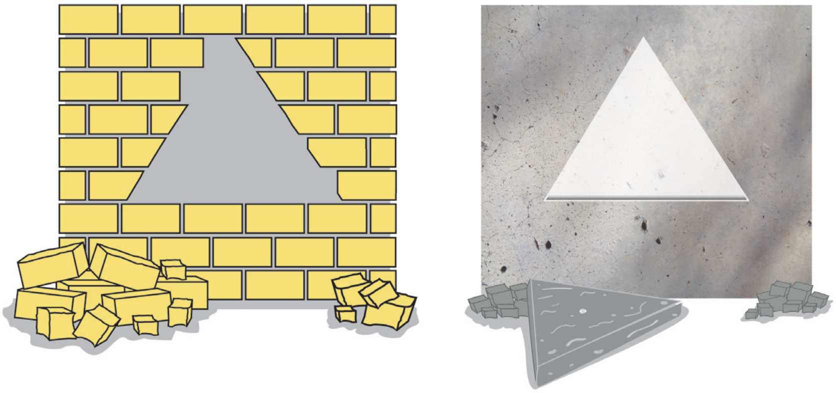

Figure 38: Triangular breaching in masonry and in pre-cast concrete.

by removing individual blocks in the shape of a triangle without significantly compromising the structural integrity of the wall. This is called mortar cut and block removal (Figure 37). Alternatively, the shape of the triangle can be cut directly using a circular saw, particularly when the surface is made of wood, concrete or steel, although it can still be used with masonry and brick walls (Figure 38). If a circular saw is not available, it is possible to drill several holes along the line of the triangle, close enough to each other. A rotary hammer may then be used to break away the remaining material between the holes.

When cutting through concrete as described above, the triangular block of concrete will be fairly large and heavy. It stands to reason that if a casualty is close by, this block needs to be prevented from falling on the side of the casualty, so a clean breach needs to be

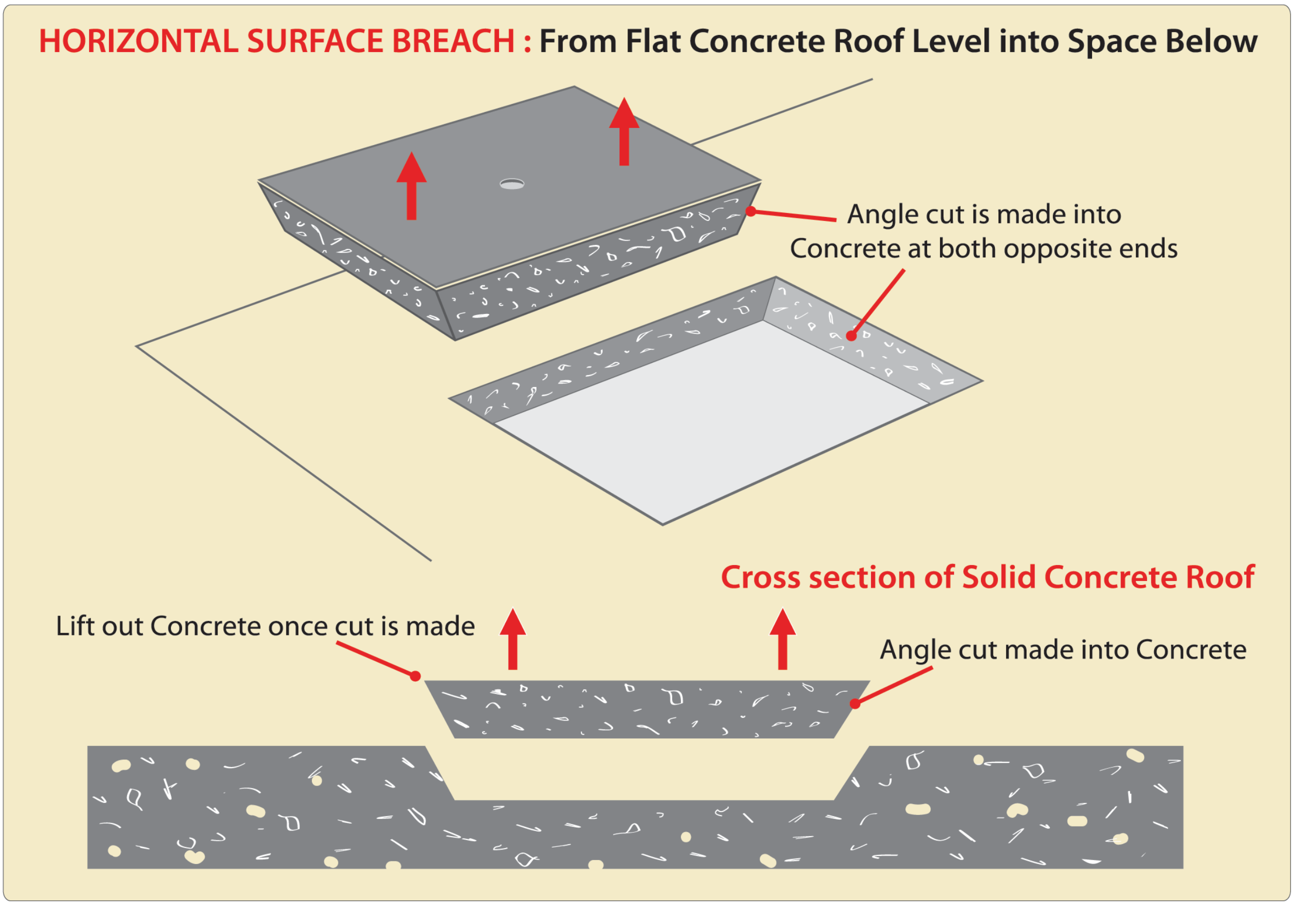

Figure 39: Horizontal surface breach with bevel cut.

Figure 40: (a) Triangular clean breach being prepared. (b) Final result of the clean breach. (c) Spinal board being passed through the breaching.

Figure 41: Final result of a step cut in a concrete wall.

performed in this case. This is done by cutting two sides of the triangle at an angle. This is called a bevel cut, where the angle of the cut prevents the block from falling down towards the casualty, having an effect similar to that of a sink plug. When breaching a horizontal surface such as a ceiling, the same method may need to be adopted to prevent the block from falling down into the void. In this case the shape of the cut would normally be a square and two opposite sides are cut at an angle to create the bevel as shown in Figure 39. A rope is passed through a hole in the middle of the block and tied above such that once the block is cut, it can be lifted up and moved aside. Figure 40a shows a triangular clean breach being prepared, with the rope passing through the inspection hole. The final result of the clean breach is shown in Figure 40b, while Figure 40c shows a spinal board being passed through the resulting breach to extricate the casualty.

The thickness of a wall or a ceiling may be significant such that the size of the blade of cutting tools does not reach through to the other side. One method to solve this is to use a step cut. A step cut consists of cutting the outline of two triangles, with the blade going as deep as it can reach into the material. The size of inner triangle should be

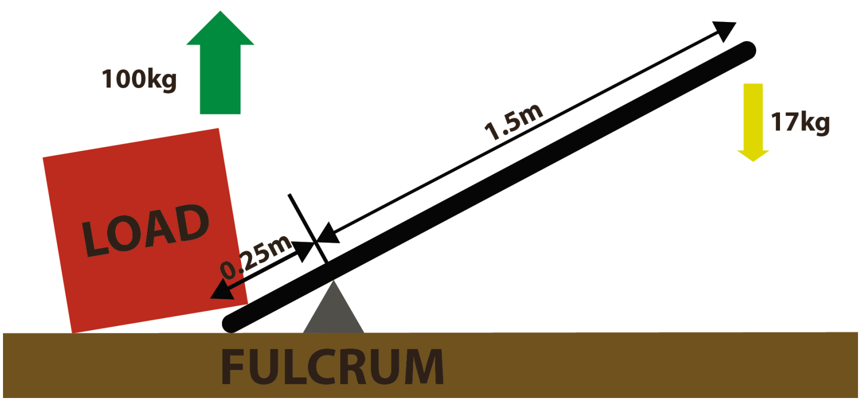

Figure 42: Principle of levers (illustration is not to scale).

large enough to pass through a stretcher and casualty. The size of the outer triangle should be large enough for the cutting tool to fit in the space between the two triangles. Once this has been done, the material in between the two triangles is broken away using a rotary hammer to form a channel around the inner triangle. The cutting tool may now fit inside the channel to perform the remaining cut to isolate the inner triangular block such that it may be removed. Figure 41 shows the final result of a step cut.

Lifting and cribbing

Large objects, such as large pieces of rubble, concrete or metal beams, may need to be moved or lifted to create access to a void or to enlarge an existing one. This may be done without the use of heavy machinery by using levers and cribbing. A lever enables rescuers to apply a large force by taking advantage of the distance from a fulcrum between the load and rescuers, as shown in Figure 42. The illustration shows a 100kg load, 25cm away from a fulcrum, being lifted by applying just 17kg at the end of the lever, 1.5m away from the fulcrum. USAR rescue teams generally have purpose-made levers available in their equipment cache. However, levers may also be improvised from metal bars or poles or even timber used for shoring. It is important to select an object that is strong enough for the load to be lifted.

Generally, levers can be used to simply slide the large object or rotate it over itself. However, when the object needs to be lifted, support will be needed from underneath. Anyone working in the fire service is familiar with the saying ‘Lift an inch, crib an inch’. This, adding layers of cribbing as the object is lifted higher, is important so that if the object falls off the lifting mechanism, the height of the fall will be minimal. Cribbing consists of blocks of timber (or plastic in case of manufactured cribbing) and each layer is placed perpendicular to the one below it, as shown in Figure 43. The name cribbing is derived from the shape of the structure formed, which resembles a crib. Wood used for cribbing should be carefully selected and inspected regularly for any damage or rot.

When the surface to be supported or lifted is slanting, wedges (also called shims) may be placed to alter the angle of the cribbing as shown in Figures 44a and 44b.

The size of the cribbing is defined by the number of blocks, also called ‘members’, in each layer. Starting from 2x2, more members can be added (e.g. 3x3, 4x4, etc). The size does not depend only on the weight of the load to be supported, but also on the type of floor that will need to support the cribbing. In fact, when soil or asphalt are present, the bottom layer would need to be a solid layer, i.e. the blocks are placed next to each other without any gap, to prevent the bottom layer from sinking into the soft floor. When cribbing is used correctly, the load is evenly spread as it is distributed over several surfaces. The lateral stability depends on the crib’s width to height ratio. The height should never be more than three times the shortest width (footprint) of the crib.[23] For example, if the footprint is 50cm, then the cribbing should be no higher than 1.5m. Also, it is important that each wood block ‘overlaps’ the layer below it by at

Figure 43: 2x2 box cribbing.

Figure 44: (a) Example of wedges on top of box cribbing. (b) Supporting a slanting load with box cribbing and wedges.

The following is an outline of the procedure for lifting and cribbing:

1. Evaluate the situation properly.
2. Develop a plan that ensures the safety of rescuers and casualty.
3. Stabilize the object to be lifted such that it doesn't move during the operation.
4. Prepare the cribbing blocks and remove any debris underneath or around the object.
5. Initiate the lift using a lever and fulcrum for mechanical advantage.
6. Keep hands and feet clear of the load.
7. Have someone ready to assist the casualty as necessary.
8. As the object is lifted, add cribbing as needed.
9. Always crib from a safe and stable surface.
10. Use the correct size of cribbing according to the load and do not exceed the height limit.
11. When the object is adequately supported, the casualty may be removed.

least 10cm as shown in Figure 43, because wood fails at cut ends first.

Making contact with a casualty

If contact is made with a trapped casualty during a search, it may be possible to get information about any other casualties that may be present at the same site. This information can be valuable to speed up the search of the worksite and increases the potential to save live casualties. Furthermore, information about any injuries sustained by the casualty will help determine the urgency and will enable the extrication team to prepare necessary medical equipment in advance.

Due to the persistent danger at an incident site, rescue teams should aim to make a swift recovery of the casualty to reduce exposure time to the danger. The team leader therefore assigns different tasks to the rescuers. The team first aider or medic is tasked with making contact with the casualty, monitoring medical parameters and applying initial care on site, while the other rescuers prepare for the extrication. The first aider should also reassure the casualty by providing information on what will happen during the extrication. Even if the casualty does not understand the language, speaking in a calm voice will still reduce the casualty's fear and tension. When a rescue team is deployed to a foreign country, it may help to prepare some basic words and questions in the local language, as this helps to establish a rapport between the rescuers and casualties. The first aider should not leave the casualty alone. When this is not possible, another rescuer should take the first aider's place so that the casualty does not feel abandoned.

Crush syndrome

Among the various injuries that are commonly associated with major incidents such as structural collapse, crush injury is one of the most important for rescuers and first aiders to be aware of. A crush injury occurs when a significant weight exerts force on a part of the body, causing damage to the muscle tissues.[24] This may potentially lead to the life-threatening conditions of crush syndrome. This syndrome depends on the weight of the object, the size of the muscle mass affected and the elapsed time since the muscle has been crushed.

When the crushing object has been in place for more than fifteen minutes, muscle tissue starts breaking down and creating toxins. The crushing object also greatly reduces the blood flow to the limb that has been crushed. Once the object is removed, the toxins are released into the bloodstream and circulate around the body. If untreated, these toxins quickly cause failure of the kidneys and ultimately death. If a rescuer suspects that a casualty may develop crush syndrome once the object is removed, a medic should be called before releasing the weight. A secondary complication of crush injury is compartment syndrome, when the trauma suffered from the crushing injury causes very high pressure in the area, further reducing blood flow to the muscles and nerves, leading to paralysis of the limb. In such circumstances it is important to monitor the 5 Ps:[24]

- Pain – severe pain due to the pressure formed in the area;
- Paraesthesia – the feeling of 'pins and needles' in the affected limb;

- Pain with passive movement – pain felt when the first aider moves the extremity of the limb;
- Pallor – pale skin colour at the extremity of the limb; and
- Pulseless – no pulse in the extremity of the limb.

The rescuer's equipment

In the eventuality that rescuers are deployed to an area affected by a disaster, they need to carry with them essential personal items and the necessary equipment. Often, it will not be possible to acquire these items in such places, where all resources will be in short supply. It is advisable to pack items in two bags, a small rucksack containing items needed at worksites, and another bag containing other items and equipment that may be left at the base of operations.

Table 7 lists some common items that may be required by rescuers on deployment. The suggested list is not exhaustive and may vary depending on the rescue team's standard operating procedures, weather conditions in the affected area and country in general. Figure 45 shows a rescuer wearing typical personal protective equipment (PPE) necessary when working in collapsed structures. Certain items shown may need to be replaced with more appropriate equipment depending on the conditions. For example, the dust mask shown may need to be replaced by one that has better filters and a tighter seal around the face if the rescuer needs to work with cutting tools in a confined space.

A rescue team is usually expected to conduct 24-hour operations at a worksite. Therefore, rescuers should pack enough food to be self-sufficient for at least 24 hours as sometimes the worksite may be far from the base of operations. Teams would then have food and water ration packs to replenish the individual rescuers once back at the base of operations. In order to prevent the spread of any potential illnesses, personal bottled water should not be shared. Frequently used items such as PPE, water and food should be easily accessible. It is also recommended to carry replacements for consumable or disposable items such as torch batteries or latex gloves.

USAR tools and equipment

The general equipment needed during USAR operations includes paraphernalia related to casualty handling and rope access. The former includes stretchers and casualty immobilisation equipment (described in *Chapter 1: Basic Rescue*). Stretchers used in this environment need to be rugged, so the basket stretcher and the SKED (Chapter 1, Figures 19c and 19d respectively) are the perhaps the best choice. Cervical collars, spinal boards and spider straps (Chapter 1, Figures 15, 17 and 18 respectively) are used for casualty immobilisation. Gaining access to particular areas of a building may sometimes require vertical access using ropes. Rope access techniques and associated equipment are discussed in *Chapter 3: Rope Rescue*. The minimum basic equipment includes ropes and straps (for anchoring), harnesses, carabiners, descenders, ascenders and safety backups.

Rescue operations from collapsed structures, particularly those where casualties are trapped in voids, require the use of specific tools and equipment for cutting, breaking and breaching building surfaces as well as lifting, moving and stabilising heavy objects. These tools may have different methods of operation namely electric (including battery operated), mechanical, hydraulic, pneumatic as well as internal combustion engine powered equipment. Tables 9–14 provide a quick overview of such equipment, including some advantages, disadvantages and safety considerations where applicable. Figures 46–50 show some of the actual equipment. Certain tools may be available in different methods of operation. The selection of equipment depends on factors such as the task at hand, the location where the equipment will be used (e.g. confined space), the space available to manoeuvre with the tools as well as availability of the source of power (e.g. electricity). The use of these tools requires the user to be appropriately trained and well aware of the associated safety considerations.

Figure 45: Typical PPE used by USAR rescuers responding to collapsed structure incidents.

General equipment	Phone charger GPS Sunglasses Mosquito repellent Money Camera Multi-tool Whistle Sunscreen Lighter / matches ID / passport Extra Batteries Electrical socket adapters	Personal hygiene	Towel Tooth paste Tooth brush Soap Toilet paper Toiletries Wet wipes Shaving kit Personal first aid kit Personal medication
Clothing	Underwear Socks Sleeping bag Sleeping mat T-shirts Waterproof jacket and trousers Reflective jacket	Food	Vacuum flask Plastic plate Cutlery Cup Small stove Dried / tinned food Fresh water and canister
PPE	Safety helmet Head torch Ear defenders Safety goggles Dust mask Whistle Uniform (boiler suit)		Harness Elbow pads Safety (working) gloves Latex gloves Handheld torch Knee pads Safety shoes

Table 7: Suggested list of items to be packed for deployment.

Electric (corded) tools		
	Electric tools require a source of electrical power to function.	
	Tools • Cutters (disc, blade and chain) • Breakers • Drilling tools	**Safety** • Operation in wet environment creates risk of electrocution. • A safety device should be present to avoid electrocution. • The proper diameter for extension cables should be used. • Earthing is necessary, especially when a generator is used.
	Advantages • Compact and lightweight. • Minimum maintenance required. • Do not emit fumes (useful in confined space). • Do not require fuel.	**Disadvantages** • Require an electrical source nearby. • Require a cable to be connected continuously to the source. • Cable may be damaged by debris. • Generators (when used as a source) generate noise. • Cannot be used in wet environments. • Form dust during operation.

Table 9: USAR equipment characteristics – electric (corded) equipment.

Figure 46: Electric (corded) equipment – (a) disc cutter (b) chain saw (c) rock driller.

Electric (battery-operated) tools	
These are powered by a battery and are standalone tools.	
Tools • Disc cutters • Drills • Breakers • Saws	**Safety** • Operation in wet environment creates risk of electrocution. • Charging should take place using the charger supplied by the manufacturer. • Should not be left near a heat source.
Advantages • Portable, as no power cord is necessary. • Generally lightweight. • Do not emit fumes (useful in confined space). • Battery may be interchangeable with that of other tools (by the same manufacturer). • Advancements in battery technology offer longer times between charging. • Not dependable on distance from an electricity source.	**Disadvantages** • Less powerful than corded electric tools. • Requires charged spare batteries to avoid interruption in use. • Charging requires availability of electricity source and takes time. • Higher cost than corded tools. • Batteries discharge even when not in use. • As the quality of the battery deteriorates, so does the power or torque generated.

Table 10: USAR equipment characteristics – battery-operated equipment.

Mechanical tools	
These tools are hand-operated with a mechanical advantage provided by the tool to facilitate operation.	
Tools • Jacks / Hi-Lift • Steel cable winch • Manual chain hoist	**Safety and Maintenance** • Keep the tools properly lubricated. • Ensure that jacks are properly stabilised before taking any load. • Place a blanket or similar item on the tensioned steel cable when operating cable winches to minimise recoil in case it snaps.
Advantages • Easy to operate. • No electricity or fuel required. • Low cost. • Multi-purpose and highly versatile.	**Disadvantages** • Relatively light loads can be lifted or moved. • Cable winches need a good anchor point in line with the direction that the load needs to be moved. • Operation of mechanical tools is usually slow and requires frequent stopping and resetting of the system.

Table 11: USAR equipment characteristics – mechanical equipment.

Hydraulic tools	Hydraulic tools operate by highly pressurised oil.	
	Tools • Cutters • Spreaders • Lifting jacks • Shoring rams	**Safety and Maintenance** • Gloves and eye protection should always be worn during operation. • Pressure should be released at the end of operations. • An operator should control the hydraulic pump at all times. • Damage to the hydraulic hoses should be avoided. • Fittings and hoses should be inspected prior to any operation. • Oil leakages are not acceptable.
	Advantages • Relatively compact and light. • Minimum maintenance is required. • Do not emit fumes (useful in confined spaces).	**Disadvantages** • A power source is required for the hydraulic pump. • The reach of the hoses is normally limited. • If the hydraulic pump is driven by an internal combustion engine, it cannot be used in confined spaces. • An additional person is required constantly by the hydraulic pump.

Table 12: USAR equipment characteristics – hydraulic equipment.

Figure 47: Battery-operated equipment – breaker hammer drill.

<table>
<tr><td rowspan="3">Pneumatic tools</td><td colspan="2">Pneumatic tools use compressed air to function. Compressed air may be obtained from a compressor on site or from compressed air cylinders.</td></tr>
<tr><td>Tools
• Breakers
• Drills
• Disc cutters
• Water pumps
• Airbags</td><td>Safety and Maintenance
• Avoid releasing compressed air from loose hose ends.
• A rescuer should always be at the compressor to control the air flow.
• When uncoiling the hoses avoid any sharp edges and hose kinking.
• Smaller air bags should be always placed on top.
• For stacked air bags, the maximum load is that of the smallest airbag.
• During lifting all personnel should be at a safe distance.
• Cribbing should be placed after every lifting step.
• The compressed air should not contain humidity.</td></tr>
<tr><td>Advantages
• Easy to use.
• More powerful than electric and self-powered tools.
• May be used in all weather conditions.
• Low maintenance.
• Portable (when used with a compressed air cylinder).
• The compressed air cylinder used is the same as that used in self-contained breathing apparatus.
• Do not emit fumes (useful in confined space).</td><td>Disadvantages
• Require a dedicated source of compressed air.
• The compressor generates a lot of noise.
• Limited range of distance for operations due to hoses.
• A dedicated person is required at the compressed air source.
• Spare compressed air cylinders required.
• Longer set up time required compared to electrical and self-powered tools.</td></tr>
</table>

Table 13: USAR equipment characteristics – pneumatic equipment.

Internal combustion engine	These are self-powered tools that are equipped with an internal combustion engine that powers the tool.	
	Tools • Chain saw • Disc cutters • Breakers • Water pumps	**Safety and Maintenance** • Powerful chain saws and disc cutters may 'kick back' so the operator needs to be aware and ready all the time. • Proper protection from high speed flying particles needs to be worn. • Fuel may create a fire hazard in the working environment. • Exhaust fumes are produced, therefore adequate ventilation is necessary.
	Advantages • Portable • Not limited by hoses or cables. • Considerable power to weight ratio. • Fast set up time.	**Disadvantages** • High noise levels. • Produce fumes that preclude the tools from being used in confined spaces. • Flammables present at the operations area. • Require substantial maintenance. • Require availability of fuel.

Table 14: USAR equipment characteristics – internal combustion engine equipment.

Figure 48: Hydraulic equipment – (a) hydraulic pump with hoses and cutters (b) hydraulic hand pump and rams.

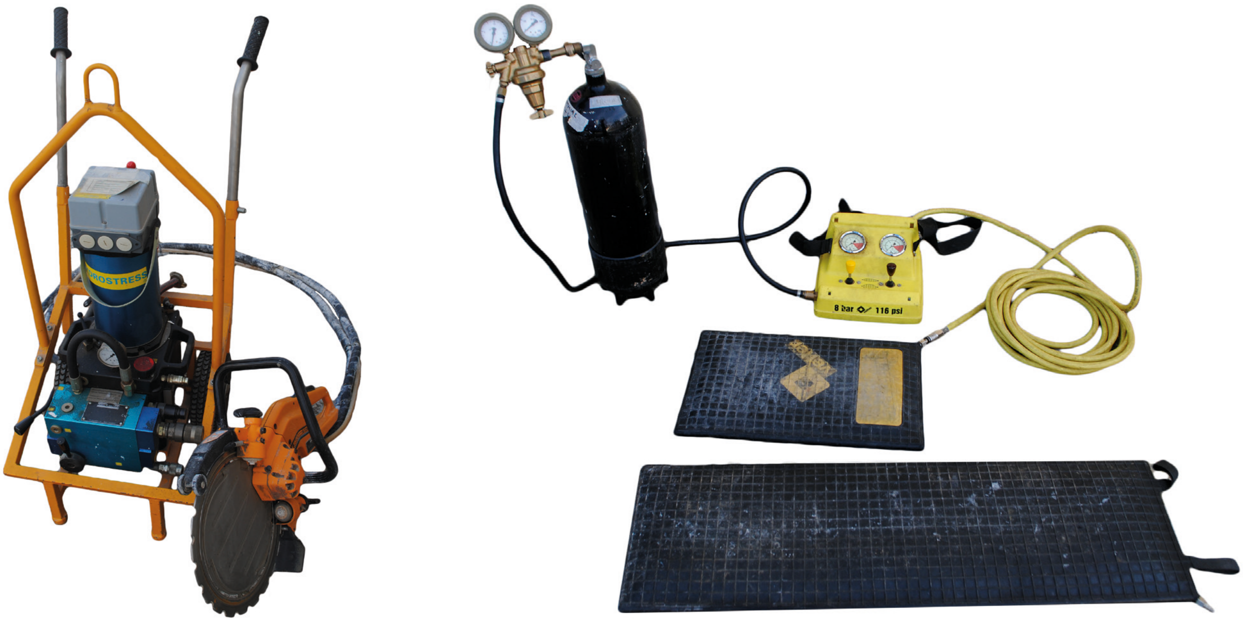

Figure 49: Pneumatic equipment – (a) air compressor and disc cutter (b) compressed air cylinder with controller and air bags.

Figure 50: Internal combustion engine – disc cutter.

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3 ROPE RESCUE

The Emergency Fire & Rescue Unit (Malta)

Introduction

Rope rescue is considered technical rescue. The ropes used in rope rescue may be made of steel or synthetic rope. The more commonly used synthetic materials in ropes are nylon, polyester and other materials in kernmantle 'style' rope. The kernmantle rope is often classified as dynamic (as it stretches to absorb the shock of a falling load) or static (a very low stretch rope to enhance positioning) which is normally used in rope rescue scenarios and industrial rope work.

Rope rescue techniques are re-classified into various disciplines, which include high angle rescue, low angle rescue, urban/structural/mine rescue, wilderness/river/mountain rescue, and cave rescue. For the purpose of this manual, the authors will not focus on the various classifications but will refer to the basic principles applicable to high and low angle rescue scenarios, which can then be adapted to various other scenarios.

Before embarking on any rope rescue, it is important to identify and understand the principles that are involved in various scenarios as well as inherent risks. Once these principles are identified, appropriate techniques or methods should then be determined and set by the team leaders to minimise risk and carry out the rescue successfully and efficiently.

Individuals who are not formally trained in rope rescue should not attempt to carry out such work. Rope rescue is a very mentally and physically demanding discipline and all volunteers need adequate theoretical and practical training.

Standards

The rescuer must be aware of the various standards that are used by several manufacturers for different equipment. In evaluating the certification status of a piece of equipment, the rescue team-leader must understand the widely accepted principal standards and the recognized standard of equipment, which must be sought for the intended use. Most standards are manufacturing standards and not necessarily user standards. Hence it is critical to recognise the significance of certain widely used standards.

Rope access and rope rescue equipment design varies widely on the basis of application and therefore, equipment standards are expected to differ according to:

- the purpose of application,
- the manufacturer's country requirements,
- the manufacturer's quality standards, and
- the nature of the third party entity that tests the respective equipment.

Different countries may adopt their own specific standards, or may base their requirements on widely accepted standards as certified by dedicated entities. For instance, the European Committee for Standardisation allows the marking of any standardised equipment (duly checked by accredited laboratories) with 'EN' & 'CE'. Although there are various standardising entities, of which some are mentioned below, their requirements are quite in concordance. Rope rescue leaders and instructors, should provide guidance to volunteers as to what these standards are and which ones to follow in their region. Below is a brief description of three of these standardising agencies:

- Union International des Associations d'Alpinisme (UIAA – International Climbing and Mountaineering Federation)[1]: The UIAA works actively in determining appropriate technical standards for equipment and has been a pioneer in the field of mountaineering equipment standardization. It regularly evaluates reported near misses and accidents. This federation also issues advice on equipment usage and care on the basis of technical standards. It is the longest standing standards agency.

Figure 1: Pulley showing UIAA mark indicating that this equipment has been tested and certified against relevant UIAA standards.

- Industrial Rope Access Trade Association (IRATA): This association normally targets and promotes the safety of rope access work practices. It also provides informed guidance to both operators and employers. IRATA focuses on high quality standards and promotes the development of improved training and working methods.

- The European Committee for Standardisation (CEN): This association is recognised at EU level for the development of standards and the standardisation of activities. The CEN, in relation to rope access, bases its standards on UIAA standards but also derives some from national standards such as the British Standard (BS) and the German Standards (DIN) among others. The latter two standards are generally similar to each other, but not entirely the same. The equipment compliant to CEN standards is marked with CE (Figure 2). The CE mark certifies that the equipment complies with the current European standards. However, a CE mark without accompanying specific EN references or the UIAA mark does not define the category of intended use of the equipment.

Figure 2: The spine of a carabiner showing CE mark. This implies that this piece of equipment abides by the European Norms applicable to its use.

Figure 3: The image on the left shows the front side of a Petzl I'D L descender while the image on the right shows the back part of the same I'D version with its magnified central part. The NFPA markings (being the 'L' version), show a notation 'G' indicative of general use, hence able to withstand larger forces than the equivalent 'T' equipment.

- National Fire Protection Association (NFPA): The NFPA has developed standards relevant to various specific products and processes and sets standards for specific use equipment, including technical rescue equipment, using widely recognized standardized methods. The NFPA is not authoritative, and does not certify equipment or processes itself. However, various manufacturers, nowadays international, often manufacture their equipment to NFPA standards. Certification to NFPA standards is clearly marked on the respective equipment. Notations of E, T and G refer to 'escape', 'technical' and 'general' equipment, respectively. Strength ratings of 'E', 'T' and 'G' marked equipment increases respectively (Figure 3).

Equipment rating

Equipment used for rope rescue is governed by various standards. These standards pose various limitations and restrictions on the methods used. These restrictions aim at preventing abuse and ultimately reduce risks and prevent accidents in an otherwise dangerous environment. The equipment used in rope rescue comes with a variety of markings on it, which often include the MBS (Minimum Breaking Strength) or MBL (Minimum Breaking Load) (Figure 4). Other markings include the SWL (Safe Working Load) and the WLL (Working Load Limit) (Figure 5). These terms are explained in more depth hereunder:

- The MBS or MBL is the minimum force that a piece of equipment can withstand for it to start failing. This marking refers to the weakest points of the equipment. The value in itself is derived from a statistical evaluation of a sample of units per batch that are subjected to destructive testing using static loads.

- The SWL is a term that was used often in the past. This marking defines the minimum breaking force divided by a safety factor, determined by the manufacturer on the basis of the intended use of the equipment that is aimed at lifting, suspending, or lowering a load safely without fear of breaking.[2] Because of legal implications, this is no longer being used or declared by manufacturers and standard setters, both in the US and the EU. Therefore, if the SWL term is used, the onus remains on the person who shall competently calculate the actual conditions of usage and application of the equipment, while keeping in consideration the WLL or MBS as specified by the manufacturer, then establish the safety factor to be applied to a system and hence the applicable SWL.

Figure 4: Carabiner spine with embossed Minimum Breaking Strength (MBS) rating.

Figure 5: WLL of 500 kg.

- The WLL term replaced the SWL term upon legal considerations. The WLL outlines the maximum working load that should be applied to a piece of equipment when operating in ideal conditions, with a margin of safety. The WLL is issued by the manufacturer to avoid irreparable fatigue on the equipment.[3] The declared WLL value would be applying a factor of safety over the MBS (usually a factor of four),[3] though this depends on the type of equipment. The WLL is still equivalent to an amount of force that is much less than that required to make the equipment fail, which is the load equivalent to the MBS.

The rope rescue team

A rope rescue team is constituted of a group of highly trained personnel with adequate skills pertaining to rope rescue. The only safe way to conduct rope rescue is to have a good team leader, good team players and a good level of knowledge amongst all team members.

The competencies of the team may vary depending on the type of operation, terrains, scope and objectives of the rescue, and the number of casualties. However, **All** team members must be competent in rope work and must be aware of the various dangers and risks inherent to this discipline. **All** team members are responsible for their own safety, that of their colleagues, as well as any third parties including the casualties that could be affected by the actions or omissions of the rescue team.

A typical set up for the rope rescue team involves various individuals and every role purports specific responsibilities and obligations. The main actors of a rope rescue team and their responsibilities are namely the following:

The team leader shall:

- Take the overall command and control of the operations;
- Have a good knowledge of all team members, their capabilities and limitations;
- Have a good technical knowledge of the systems needed to carry out a safe and efficient rope rescue operation; and
- Have good communication skills to be able to delegate responsibility to the various team members according to

their skills and to brief them on his/her plan of action.

The safety attendant shall be:

- Capable of carrying out risk assessments;
- Competent in all aspects of rope rescue to be able to monitor all that is happening;
- Able to liaise continuously with the team leader to carry out a safe operation;
- Continuously looking out for potential hazards especially in a changing and dynamic environment; and
- Checking on the system and instigating caution and safety checks prior to any operation.

The first aid responder shall be:

- Able to take responsibility for the care and well-being of the casualty, mitigating harm and distress during operations until the casualty is handed over to the ambulance service;
- Responsible for the administration of emergency aid and assists in the loading and packaging (securing) of the casualty onto the selected stretcher;
- Continuously monitoring and observing the state of the casualty, and regularly recording vital signs; and
- Able to assume the role of rescue responder/rescuer to complement the rest of the team if necessary.

The responders/rescuers shall be:

- Responsible for the wellbeing of casualties during their lowering or lifting;
- Responsible for the safe packaging of the casualty in the stretcher;
- Responsible for the safe connection of the stretcher to the main hauling line and backup as well as for the main logistics for the actual lift; and
- Trained and qualified in emergency first aid.

The riggers and line operators/technicians shall:

- Follow the leader's plan to build the system in the area of operations;
- Choose anchors and distribute the system accordingly;
- Calculate the safety factor in the system;
- Ensure that the system is operational;
- Support the edge transition[i] for the rescuer and the casualty;
- Operate the main line to haul or lower the load (first responder/s and/or casualty) accordingly;
- Control and assist on the main line i.e. to set Prusiks, to pull on lines etc.;
- Operate the belay line and ensure its safety all the time;
- Lock off line as necessary to establish a secure position; and
- Assist in other work when necessary.

The person responsible for logistical support shall:

- Issue all the team with equipment;
- Ensure the return of all team equipment and the appropriate make-up of equipment by all team members; and
- Manage equipment provision and needs, as necessary.

The edge transition management rescuer shall:

- Lead, with the assistance of the responder/rescuer, in the edge transition phases;
- Be responsible of any handling at the top to facilitate such transition;
- Attend the tripod and any other rescue frame that is being used; and
- Act as a pivot point where no high point anchors are available by securing oneself at the edge and use a pulley on own harness to redirect the main line away from the edge.

Team management

To ensure the safe and effective outcome of rope rescue operations, each member of the team shall undergo ample training. Team leaders must ensure that all team members are adequately trained, have sufficient experience, are competent in their roles and in different scenarios, are able to perform effectively as a group and are prepared to face real-life situations.

During training the team members will experience and become competent in various rope rescue techniques. In real situations, the actual rescue operation may require the application of more than one technique, whether concurrently

[i] The edge transition is the process of transiting from a horizontal plane to a vertical plane or slope during lowering or vice versa during raising.

or consecutively. Thus, the team members need to be conversant with the various systems possible which may enable the team to reach its ultimate objectives. Team members should also be versatile and able to improvise, so that various techniques can be amalgamated for effective recovery.

Planning is crucial before executing a rope rescue. Thus, one needs to consider:

- The objectives of the rescue operation;
- The loads and resistance on the equipment being used; and
- That the equipment standards are respected.

To execute a rescue operation in the safest way possible, it is necessary that:

- each team member abides by the safety requirements; and
- the safety officer has a proper overview of all aspects of the operation to ensure that everybody is safely kitted before approaching the hot zone.

Communications

In rope rescue, operations communication is vital. Apart from the use of VHF/UHF radios, as well as gestures and signs, an important and effective tool is the whistle. Following the *Standard Guide for Using Whistle Signals During Rope Rescue Operations,* (ASTM F1768 – 97) this manual is providing some of the different signals (Figure 6) that are used to signal danger or an evacuation of the disaster location. Reactions to whistle communication are generally faster than those to radio communications.

Equipment

In any rope rescue intervention, the equipment is a critical part of the system. Availability of the right equipment determines whether an operation is a straightforward one or a strenuous one for the rescuers and also to the injured. Furthermore, considering that there is the safety of people involved, the equipment selected should have the correct ratings and certifications, as well as be properly maintained, cared for and inspected using correct documentation practices.

It is also important that equipment is categorized between personal equipment and team equipment. Each rope rescue team must have its own equipment. The team equipment may vary according to the specialisation of the team such as mountain rescue, USAR (Urban Search and Rescue)

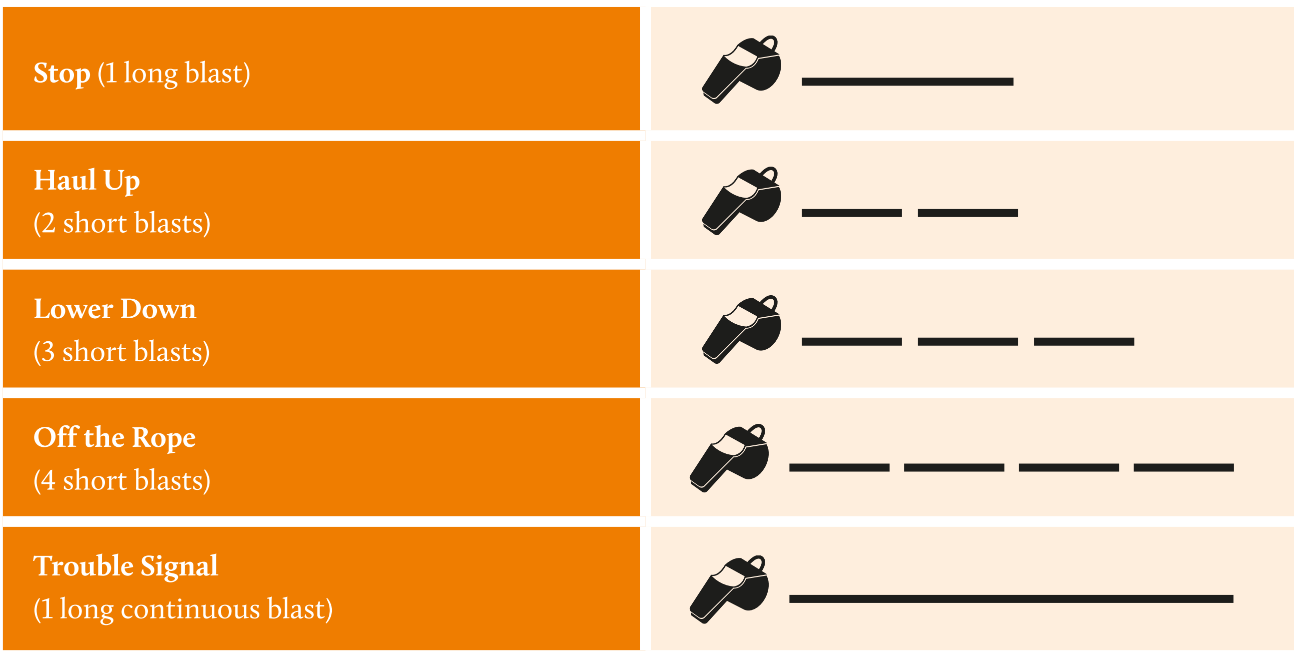


Figure 6: Standard whistle signals used in rope rescue, following the acronym SUDOT, in line with ASTM standard F1768.[4]

or others. However, irrespective of this, the team's kit should include equipment to enable anchor set-up, as well as hauling and lowering systems, rescue frames and stretchers. The kit of a rope rescue team should include a wide spectrum of equipment (the diagrams and methods of utilisation are found below) some of which are the following:

- Descenders with progress capture capabilities such as the I'D from Petzl;
- Pulleys – single, double, Kootenay type pulley from Petzl and Prusik minding pulleys;
- Prusiks, ideally colour-coded according to size and use;
- Carabiners, which may include steel type for anchorage and rough use;
- Straps of various sizes;
- Anchor Plates;
- Tripod, quadpod or other rescue frames;
- Stretchers specialized for use in rope rescue;
- A rescue harness and a rescue sling;
- Various lengths of ropes such as 50 m and 100 m, as well as other lengths to use for various scenarios.

Personal equipment is to be used by the individual rescuer and must be available for use at all times. Team equipment should be used for major set-ups, which include rigging, lowering and hauling lines, and mechanical advantages, among other activities.

When it comes to personal equipment the variety of types of equipment available is endless. For any operation, the rescuer should kit up diligently. Having too much equipment could be a burden to the rescuer as the weight of the equipment could lead to unnecessary difficulties when going through confined spaces, besides the physical exhaustion of the person carrying it. On the contrary, having too little equipment may inhibit the proper execution of a rescue. Therefore, the personal kit should be chosen following consideration of all factors surrounding the rescue scenario to be dealt with. Nevertheless, there is always a baseline from where to start off. Figure 7 illustrates basic equipment including Personal Protective Equipment (PPE).

Harnesses

A harness is one of the rescuer's main pieces of equipment. Harnesses come in various shapes and sizes. Particular attention must be taken when sourcing one. The choice of harness depends on the nature of the work that it is required for as this would determine the kind of padding on the main contact points, the attachment points and also adjustment possibilities.

An appropriate harness allows the rescuer to operate on the edge, to suspend oneself on a rope system in a safe way and to access the casualty as needed. The requirements of the rescuer's harness are well defined in the NFPA 1983.[5] This text refers to the NFPA classification of harnesses – Class II and III. The European Standards do not apply directly to rescuer harnesses but rather to harnesses that enable work safety at heights. Nonetheless, to operate in rope rescue in Europe, both NFPA and CE standards should be considered. It is to be noted that some differences in nomenclature are encountered in the different standards. For example, the EN standards refer to the 'sit' harness while NFPA refers to the same harness as 'seat' harnesses. For the purpose of this section, the 'sit' nomenclature will be utilized. Table 1 summarises the standard requirements of the sit and full

Safety note on equipment

Equipment should be regularly checked before and after each rope rescue operation! One's life is literally hanging on the equipment used. Each and every use of any rope rescue equipment, especially the ropes, should be logged and documented.

All hardware is to be visually inspected during the making up process for any visible damage. Ropes are to be checked and properly stored, away from sunlight and humid areas.

Wet ropes and equipment are to be left to dry, away from direct sunlight, before being stowed away. Any hardware that is subjected to rough use should be examined and decommissioned, where necessary.

Head torch

- Should be mounted on the helmet, preferably on the front part or to the side;
- Different light intensities should be used to avoid blinding other rescuers, while saving the battery from being drained too quickly;
- The torch should be intrinsically safe for use in hazardous areas.

Ear defenders (ear plugs or ear muffs – ideally helmet-mounted)

- Intended to attenuate any noise that may hinder concentration;
- Ear defenders may be able to discriminate between noise and speech to allow hearing of speech, and may have a built-in radio communication system.

Rescue harness (preferably Class III)

- Provides padding and comfort for prolonged use;
- The harness shall prevent the weight of the body from creating pressure on nerves and arteries;
- The harness must be easy to inspect for damage and abrasion;
- Must have various connection points and equipment loops.

Overalls

- Provide protection against abrasion;
- Protect from cold and manage perspiration;
- Sizing should allow for unhindered movement especially when extending arms above the head or when crouching.

Helmet

- Necessary to protect against falling objects as well as lateral blows, such as from bumping the head against walls or rock;
- The chinstrap is needed, to prevent the helmet falling off the rescuer's head;
- The helmet needs to have a 3-point suspension that absorbs some of the energy of a hit and prevents it from being transmitted directly to the skull;
- The helmet should be EN12492 certified for use in work at heights and to give suitable protection against mechanical impact.

Eye protection

- It could be a visor attached to the helmet or separate safety glasses. The glasses should be clear;
- This equipment is important to protect the eyes from any falling debris, dust and shrubbery.

Gloves

- Should be suitable to protect against rope burn and abrasion;
- Provide a good grip;
- Flexible enough to allow feeling of the rope and proper manipulation of ropes;
- Half finger gloves give more dexterity when tying knots, but at the same time expose the fingers to possible abrasion or cuts.

Safety boots

- Should provide comfort, protection and a good grip;
- Should allow flexibility of movement of the foot and ankle;
- Leather trekking shoes are probably the most versatile and recommended for rope rescue, but careful consideration of the environment is required for each situation.

Figure 7: The rescuer with PPE appropriate to rope rescue operations. Key and recommended features of the different PPE parts are defined.

Full body harness	Sit Harness
› NFPA 1983 Class III › EN 361:2002 – PPE against falls from height – full body harnesses › EN 813: 2008 – Personal fall protection equipment: sit harnesses	› NFPA 1983 Class II › EN 813:2008 – Personal fall protection equipment – sit harnesses
› Provides additional safety when the rescuer risks turning upside down while suspended. › Provides more attachment options (attachment points are found at waist), front and sides, ventrally and dorsally. › Compatible with chest ascenders such as the Croll, unless the ascender is already incorporated in the harness. Refer to Figure 8.	› Quicker to put on. › Less restricting than a full body harness. › Lighter and more compact. › Will require body strength to keep upright especially when suspended for long periods. › User has to be careful not to accidentally turn upside down while suspended. › May be more applicable to confined space, USAR, cave rescue and mountain rescue. Refer to Figure 9.

Table 1: A comparison between the sit and full body harnesses.

body harnesses and gives an outline of the key advantages of the two types of harnesses.

Points for consideration:

- When carrying heavy items on the back (for e.g. a backpack) one may opt to use a Class III type harness to be able to use a higher attachment point to keep upright.
- A sit & chest harness combination allows more flexibility. One may choose to use only the sit harness or both depending on the situation. Generally, the chest harness has less padding so the combination of sit and chest harness is less bulky, lighter than a full body harness but less comfortable. When worn together, a sit & chest harness can be considered as a Class III harness only if the sit harness is of the Class II type.

Figure 8: An example of a full body harness (Petzl AVAO BOD European Version).

Warning

A chest harness must never be used by itself in rescue training and/or operations!

Figure 9: An example of a sit harness (Petzl AVAO SIT Harness).

Carabiners

One of the most common hardware equipment found in both personal and team kits is the carabiner. Carabiners come in various configurations and are essential to connect most of the rope set-up into one system. The use of carabiners is to connect all the rigging, lines, mechanical advantages and progress capture systems. Figure 10 shows the principal features of a carabiner. The load bearing capability of the carabiner depends on the axis of loading. Therefore, all carabiners are marked with three force values, in kilonewtons[ii] (kN; Figure 11). However, it is to be noted that loading should be done only on the major axis as detailed below.

Carabiners come either in steel or in alloy. Both materials have their own strengths and weaknesses as indicated hereunder:

- Steel carabiners are more durable and resistant to wear, especially from friction against other hardware or steel cables. However, these carabiners are heavier than alloy ones;
- Alloy carabiners are light, but still strong enough. However, these may be more susceptible to damage and deterioration.

The shape of the carabiners and their gate locking mechanisms also vary according to need (Figures 13–16).

Common locking mechanisms in rescue carabiners include a screw gate locking mechanism (Figure 16A), a twist-lock mechanism (Figure 16B) or a triple-action-lock mechanism (Figure 16C) for additional safety.

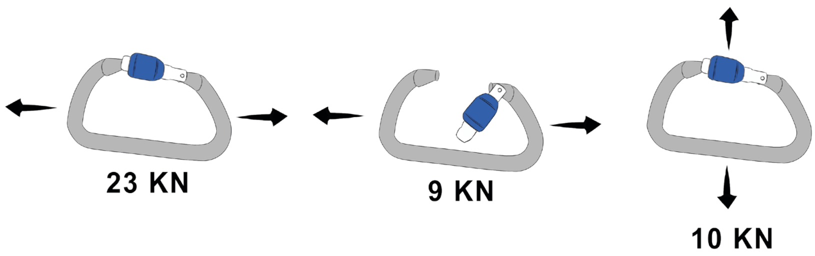


Figure 11: An example of carabiner strength dependent on the load-bearing axis. Only the major axis loading conformation should be used in operations. The other loading conformation strengths are only indicating the carabiner strength if it had to be subjected to such directional forces.

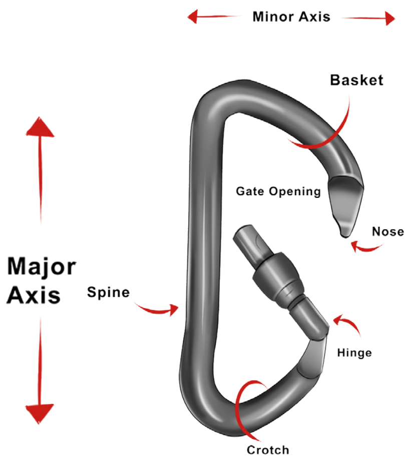


Figure 10: Carabiner parts nomenclature.

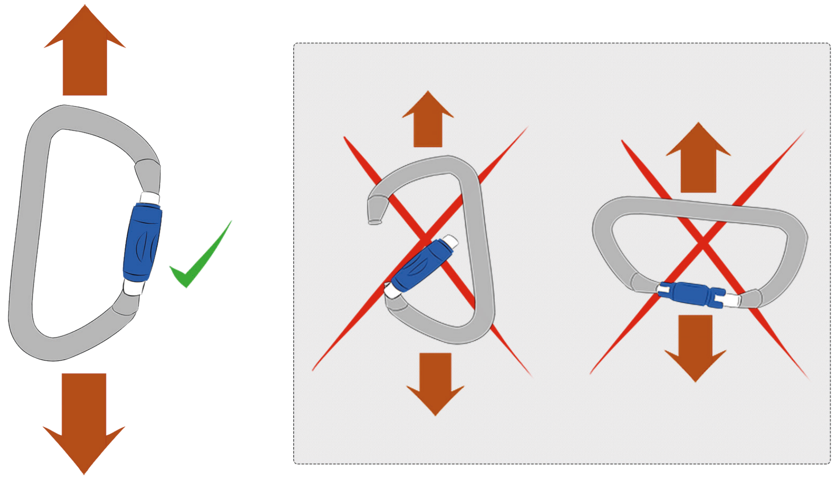


Figure 12: Loading of carabiners should always be done in such a way that the spine (and the parallel axis, where applicable) takes the principal load. Loading of carabiners with an open gate or on the minor axis should not be done.

[ii] 1 kN is the weight (force) generated by a 100kg load.

Oval Shape

- Equal loading on the spine and gate.
- Difficult to open gate when loaded.
- Ideal for pulley mounting.

Figure 13

D-Shape

- The shape of this carabiner enables the rope or other attached hardware to be placed closer to the spine. Thus, the majority of the load will be directly on the spine rather than the gate.
- Most suitable for a single attachment when the weight is distributed symmetrically over the carabiner.
- More points of attachment may be accommodated on the asymmetric D-shape.

Figure 14

Pear Shape

- This carabiner has a wide round basket that accommodates multiple attachments.
- This model is more susceptible to rotation, with the risk that the load shifts onto the gate unless one pays attention until loading.

Figure 15

Figures 13–15: Types of carabiners

Notes for consideration

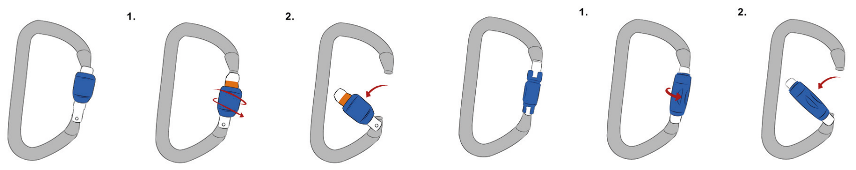
It is important to load and position carabiners correctly (Figure 12). Thus, one should consider the following:

The loading should be on the major axis;

The gate should be closed and locked;

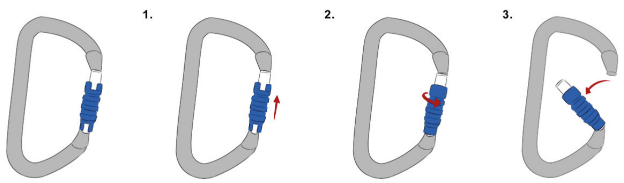
The carabiner needs to be positioned in such a way that the gate does not rub against other objects or sustain pressure on it; and

The carabiners should not have multi-directional loading.



A: Conventional screw gate locking mechanism – requires the user to lock the gate manually, may unlock accidentally with vibrations (e.g. during hauling).

B: Twist-lock mechanism – auto locking and quick to unlock, but may be susceptible to accidental unlocking if the gate rubs against a moving rope.



C: Triple-action-lock mechanism – auto locking and triple action to unlock (lift, twist and push), making it safer against accidental unlocking.

Figure 16: Types of locking mechanisms.

Pulleys

Pulleys are important instruments in a rope rescue team's kit bag, but also as a personal must-have for the rescuer. One pulley can facilitate the reach of the rescuer towards the victim or halve one's load in a simple 2:1 mechanical advantage configuration. The main purpose of a pulley is to let a rope ride over it with minimal friction. The pulley itself will bear some friction in its bearings and this affects the efficiency of the pulley. Figures 17–21 illustrate a number of pulleys used in rope rescue operations.

The diameter of the pulley should be large enough for the size of rope being used (normally at least 4 times the thickness of the rope). Ideally, the pulley should have a side that opens or slides to pass a rope over the it without having to feed the end of the rope through. However, other pulleys usually used for zip lines or tyro lines[iii] may not have this option as these are meant to ride over a taut rope or cable. Other fixed pulleys that need the rope to be passed through the aperture also exist.

Pulleys may range from relatively low efficiency to high efficiency. A review of commonly marketed rescue pulleys indicates a range of 70% to 95% efficiency. The efficiency of a pulley depends on:

- The size of the pulley compared to the size of the rope;
- The proper upkeep of the pulley;
- The angle of the rope passing through the pulley;
- The type of rope used (e.g. elasticity of the rope reduces efficiency); and
- The type of shaft system that the pulley has. This can vary from a sealed bearing mounted pulley with maximum efficiency, to a bushing pulley with medium efficiency, to a steel shaft on nylon bearing with the lowest possible efficiency.

Descenders

Descenders are pieces of hardware equipment that facilitate a controlled descent along a line. Descenders are generally part of a personal kit, although they are also an integral part of the team's kit as they can be used in various situations, such as in progress capture[iv] on a hauling system and to offer a controlled descent of the stretcher in a rescue. Figures 22–24 show some examples of descenders used in rope rescue.

Ascenders

Ascenders are essential in rescue as they allow the user to efficiently ascend a rope to reach the work areas (Figures 25 and 26). Essentially, these are rope grabs which when engaged have only a one-way movement on the rope. For this reason, they can also be used in rescue set-ups where a quick and effective rope grab is needed. However, the blocking mechanism of most ascenders is based on a spiked camshaft, which in excessive loads, may jeopardize the integrity of the rope itself.

Safety back up system

The safety systems of any set-up or fall arresting systems ensure that the rescuer is constantly working in the safest conditions possible. Fall arresters are purposely designed and built to slide up or down the rope in controlled conditions. However, the same device is designed to grab on the rope immediately in the event of any abrupt movement downwards. Hence, the fall arrester engages as a grab on the rope in the case of a fall on the system. Figures 27 and 28 show two examples of such safety back-up systems.

When using any kind of fall arrest system, a shock-absorbing lanyard must be used in combination with it. Consequently, when the fall arrester grabs on to the safety line in a fall, the shock-absorbing lanyard is released depending on the force of the fall. This lanyard release absorbs part of the energy of the falling person, to minimize the peak force of the fall arrest and hence minimise potential injury.

Two typical examples of fall arresters are the ASAP (Figure 27) and the Rocker (Figure 28). The

[iii] A tyrolean line or traverse, also known as a 'tyro line', is a traverse of rope between two high points, usually between mountains or hills. This would enable the passage of persons from one end to another, rigged to the line using a pulley and progress capture devices. A zip line is a similar traverse but at a slope which would enable the user to move from the higher point to the lower point by gravity, again with the use of a pulley but with no need for progress capture as travel is enabled under gravity.

[iv] 'Progress capture' is a term often used in rope rescue to explain the notion of retaining any progress made (for e.g. during hauling by blocking the rope in the position reached by a mechanical advantage system) that is the action that enables the avoidance of loss of progress already made, before resuming with further raising.

Figure 17: Single Pulley

Commonly forms part of a personal kit;

Facilitates the movement or lift of the rescuer;

Can be used as part of a mechanical advantage system.

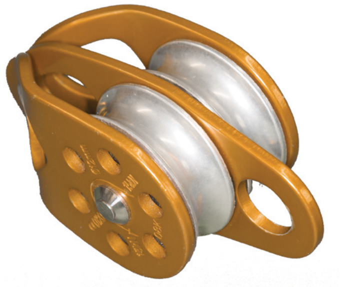


Figure 18: Double Pulley

Often found as part of the team's kit;

Has two separate wheels;

Often used in mechanical advantage systems or to manage a twin line system.

Figure 19: Tandem Pulley

Often found as part of the team's kit;

It has two attachment points, one at the top and one underneath, facilitating second line back up;

Normally used for zip lines.

Figure 20: Kootenay Pulley

Normally forms part of the team's kit;

Essentially a large knot-passing pulley;

Can also be used for zip lines, to mount the pulley over multiple, parallel mounted ropes at the same time.

Figure 21: Prusik-minding Pulley

May form part of both the team's kit and personal kit;

Designed to block a Prusik hitch from moving with the rope into the pulley;

When the tension is released, the Prusik grabs on the rope and stops it from moving back (progress capture);

The size of both the Prusik-minding pulley and the Prusik loop needs to be matched to the size of rope being used. The pulley size should be such that the Prusik hitch "catches" the side of the pulley. The length of the Prusik loop should be such that when tension is released on the hauling side, the load does not move back significantly.

Figure 22: Figure 8

May form part of both the team or personal kit;

Simple and inexpensive;

May twist the rope when this passes through it;

Difficult to keep control of the descent with particularly heavy loads;

May be used as a multi-point connector.

Figure 23: I'D

May form part of both the team or personal kit;

Self-breaking descender;

Anti-panic safety function;

Easy to control;

Possible to install the rope without detaching the I'D;

Blocks movement of rope if installed in the wrong way;

A specific carabiner may be used to have better control on the running end.

Figure 24: RIG

Generally forms part of the personal kit;

Similar to I'D but more compact;

Does not have anti-panic feature;

A specific carabiner may be used to have better control on the running end.

Figure 25: Chest Ascender

› Strictly part of the personal kit of a rescuer;

› Normally attached from two points at chest level on a full body harness;

› Allows for hands-free operation of the ascender when combined with foot ascenders and the proper technique.

Figure 26: Handle Ascender

› Usually part of the personal kit;

› Used for ascending and can be connected via a strap to a harness or a leg strap;

› Can be used as a rope grab to help pull a rope, for progress capture or in a mechanical advantage system although not recommended for reasons mentioned in text.

Figure 27: ASAP

ASAP is a versatile fall arrester that can slide easily both up and down a rope. The Rocker is designed to break a fall by grabbing onto the rope with a smooth cam. It may need to be dragged along by the user unless it is being used in high angle descent.

Personal restraints are other pieces of equipment that enhance safety of rescuers when working close to an edge. Personal restraints have a different functioning mechanism from fall arresters, in that they prevent the fall from happening rather than protecting the user in a fall. One type of personal restraint is the cow's tail (Figure 29). This provides at least two points of attachment so that the user is always attached at one point while positioning the second attachment. Another personal restraint, the Purcell Prusik (Figure 30), provides the possibility to quickly adjust its size. It also has the ability to absorb some energy in the event of a slip or minor fall. A set of 2 Purcell Prusiks can be used as a personal restraint system, having 1 Purcell Prusik always attached to a point while positioning the other Purcell Prusik.

Prusik loops

Prusik loops or cords are pieces of specialized cord, generally between 6mm and 8mm (for rope rescue), tied into a loop using a double fisherman's knot to secure the loop. These cords are very light when compared to other hardware but are used extensively in rope rescue. Most notably, rescuers use Prusik loops as rope grabs and they can

Figure 28: Rocker

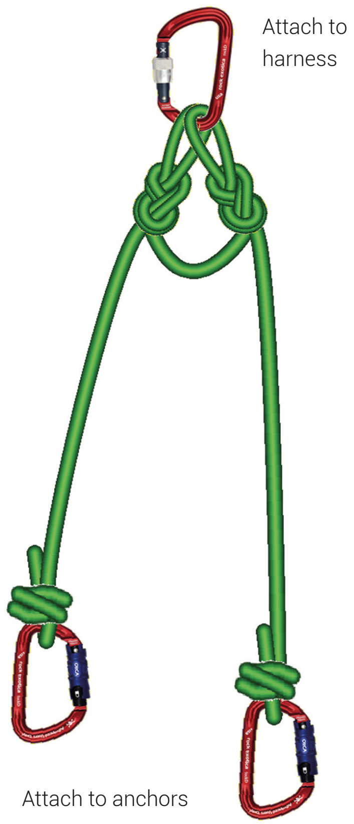


Figure 29: Cow's Tail

also be safely and efficiently used in mechanical systems and progress capture.

The use of Prusiks results in several advantages. When a Prusik loop is hitched on a line (Figure 31) it is important to note that it will not damage the main rope (as a spiked cam ascender would) and if overloaded, it will simply slip. Therefore, Prusik loops can be used to prevent system failures in case of overload by virtue of such slippage. Other rope grab devices equipped with spiked camshafts would tear the rope if seriously overloaded. Prusik loops can be used to take the load from a knot hence relieving the rope from load deficiency stresses at main anchor points. Additionally, Prusik loops are relatively cheap and can easily be made using available but suitable cordage in an emergency.

The type of rope used for Prusik loops needs to be adequately flexible. The rope should provide a balance between cordage

Figure 30: Purcell Prusik

Figure 31: The Prusik hitch on a rope acts as a rope grab.

suppleness and stiffness to avoid line breakage or slippage, respectively.[6] The pinch test (Figure 32) is helpful in assessing the flexibility, or otherwise, of the rope. The diameter of the Prusik loop rope needs to be at least 2 mm less than that of the main rope. It is recommended, through experience, that the cordage length for the pair of Prusik loops (length of rope before the double fisherman's knot is applied) is:

- 110 cm for a short Prusik
- 130 cm for a long Prusik

When setting up a Prusik hitch, it is important to slide it on the rope and to listen to its sound to verify that there is adequate friction and that the Prusik will grab the rope as intended.

Figure 32: The pinch test is done to evaluate rope potential for use as Prusik rope. The inner diameter of the loop formed in the pinch test should be approximately equal to the outer diameter of the same cordage.[6] This ensures that the cordage is balanced in suppleness and stiffness to grab the rope sufficiently.

Edge protection

Ropes are literally the rescuer's lifeline and should be protected at all cost. The edge protection is necessary to protect ropes from sharp and abrasive edges that expose ropes to substantial wear and tear. When ropes are statically rigged the edge protection can be achieved by placing a blanket, or perhaps an empty rope bag under the ropes to act as cushions and shields from any material that can damage the rope. Rope protectors (Figure 33) wrapped around the rope can be used for the same function. Alternatively, when ropes are dynamically rigged, such as when they are being lowered or hauled, the edge protection should be in the form of edge rollers (mechanical means of protection; Figure 34). This equipment is designed to settle on edges or uneven terrain and to assist the rope to slide over fixed or revolving rollers. The advantage of mechanical protection for dynamically set systems is the minimization of frictional forces on the rope at the edge besides safeguarding the integrity of the rope.

Figure 33: Edge protection ideal for static rigging whereby a sheath of durable material protects the rope.

Figure 34: Edge protection in the form of mechanical protection whereby friction against abrasive terrain is avoided by rollers.

Tripods and rescue frames

The surrounding environment does not always facilitate the use of rope rescue. In such cases, tripods or rescue frames become essential equipment to proceed with the rescue operation. Such systems redirect the anchored line while bringing the point of redirection as close to the edge as possible. It is imperative to back up the tripod or rescue frame prior to loading the system as it may tip over once loaded.

The load resultant force on the tripod should lie within the footprint area created by the tripod or rescue frame feet and it should be balanced between the two frontal feet of the system (Figure 35). Therefore, when using the tripod, it is critical that the rigging supporting the tripod or

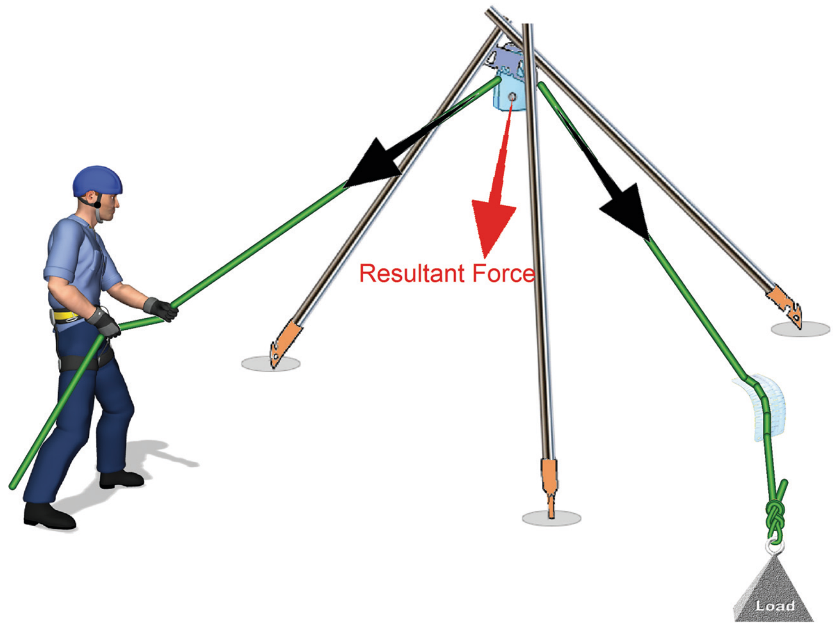


Figure 35: The main line is being redirected by the tripod. The resultant force direction lies within the triangular footprint of the tripod.

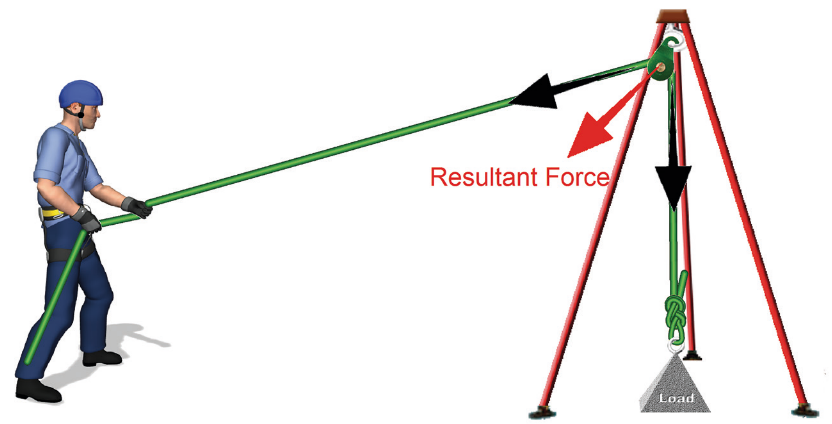


Figure 36: The main line is being redirected by the tripod. The resultant force direction lies outside the tripod footprint.

rescue frame as back up, balances the forces on the tripod when the system is bearing the load. The rear tripod foot, when used, should only support the frontal feet and assist in getting the anchor point as far out towards or beyond the edge as possible. Whenever the downward resultant force on a tripod or rescue frame does not fall within the footprint formed by the feet (e.g. Figure 36), additional supporting forces (e.g. weights at the back part of a rescue frame) would be necessary to counterbalance the loading forces through moments.

Equipment compatibility

When setting up a rope rescue system it is very rare that rescuers use only equipment that has been specifically tested together. The technician should be aware of potential equipment incompatibilities. Incompatibilities decrease the safety level and increase the risk. Obvious incompatibilities are often observed between certain Prusik cords, rope diameters and pulleys.

The technician should also take note of the equipment ratings when setting up a system. The overall capacity of the system will depend on the weakest link i.e. the lowest rated equipment. Therefore, certain appropriate doubling of elements (such as in anchorage) is to be considered to minimize system weakening.

The use of steel and/or alloy components is to be done diligently. To minimize equipment damage and not jeopardize safety, technicians and operators should be aware of any recommendations provided by the manufacturer and should be conversant with the use of equipment before using it. For example, steel carabiners may damage the alloy equipment as the latter material is more malleable when compared to steel. The ratings of steel and alloy elements are nowadays very similar and the preferential choice of steel for enhanced strength is no longer significant. Nonetheless, the choice of steel carabiners may still be a requirement in harsh environments.

Taking care of equipment is of utmost importance. For instance, cleaning and oiling of carabiners and other moving parts is indispensable and should be done regularly. Methodical and routine visual checks of system components before and after use are essential to pre-empt potential failures and minimise risks. Additionally, equipment should be used specifically for what it was designed for. To put equipment to its appropriate use, the rope rescue team should be:

- Aware of the capabilities of the equipment;
- Conversant with the versatility of certain equipment devices;
- Knowledgeable about the application of the equipment through regular hands-on training and in real-case scenarios.

Knots and anchors

The discipline of rope rescue necessitates the knowledge of various basic and more complex knots. A list of knots and their uses is included in the section of knots in Chapter 1. Knots that are of particular importance to rope rescue operations include the following:

- Bowline on a bight;
- Double figure-eight loop;
- Figure-eight loop;
- Alpine butterfly knot;
- Prusik related knots (Double Fisherman's knot and the Triple-wrap);
- Wrap-3-Pull-2.

A critical consideration when tying a knot on a rope is the implication of rope strength reduction. While knot efficiency varies from knot to knot (see Chapter 1), when calculating safety factors the rescuer shall assume that the tensile strength of a rope is reduced by 75% to 50% when tying knots. Thus, knots are often bypassed using the Prusik bypass system to restore the rope's strength by avoiding tension applied on knots. In the Prusik bypass, the Prusik hitch clutches the rope from beneath the knot, which effectively bypasses the strength-reducing knot.

Adequate anchoring is a must in rope rescue. Anchors vary according to scenario as they differ in type and strength that they offer. In some critical places, extra anchoring might be necessary due to the nature of the rescue. When employing a rope rescue system one should take note that:

- Any anchor should be considered in relation to the load it will be subjected to. For instance, the load could be of one person, two persons or two persons with the litter.[v] Thus, appropriate backup shall be factored in. Ideally, an anchor point which is not engineered should be 'bombproof'. The term 'bombproof' signifies that the anchor can withstand the potential load it may be subjected to and is immovable. This definition is one of a number of applicable definitions that are implied by the term itself.[7] When it is not possible to find a bombproof anchor, multiple anchor points may be necessary. These are known as 'marginal anchor points';
- The final anchor point should be directly above and close to the casualty; and
- There is constant use of padding and rope protection where there are sharp edges.

Anchor points found *in situ* could be natural or could also be manmade. This section will go through a number of natural and manmade anchors and what are the factors to look for when choosing an anchor. Some of the most common anchors are the following:

Trees

Particularly in the wilderness trees can be ideal anchors. However, when selecting a tree as an anchor the rescuer should consider its diameter and how well-rooted it is. The tree should appear to be healthy and strong without any visible signs of decay. However, the anchor strength of trees should never be assumed. Figure 37 shows how a tree may be rigged as an anchor. In this case the tree forms

Figure 37: Tree anchor.

[v] The term 'litter' refers to the stretcher, generally a basket stretcher often used in search and rescue activities.

part of a multipoint anchor system. The tree shown in Figure 37 would not suffice as a 'bombproof' anchor due to its diameter.

Boulders and Rock Outcrops

When using boulders or rock outcrops as an anchor point one should ensure their stability. The material used for anchorage around boulders or rock outcrops should be adjusted to avoid any slips. Figure 38 illustrates an example of rigging on a boulder. Before using such anchors, the riggers should check for cracks and erosion which could lead to potential breakage upon loading.

Figure 38: Boulder rigged anchorage.

Structural anchors

There may be various anchor possibilities in buildings or parts of structures, such as beams and columns or openings such as doors and windows (Figure 39). It is important to check if metal parts in the structure are corroded or if there are signs of erosion in the stonework, as this may cause the anchor to fail. It is also important to understand that erosion and corrosion not only weaken the anchor but also produce jagged surfaces, which may damage straps and lashings.

Figure 39: Anchor mounted on a built structure.

Vehicles

Vehicles can also be used as anchors. There are various points in a vehicle which can be used as an anchor such as axles, cross members, towing points and wheels. Once a vehicle is identified as a potential anchor it is immobilized in any way possible, from chocking up the wheels to avoid any movement, to removing the keys from the ignition of the vehicle. It is also important to have a visual sign over the steering wheel stating 'DO NOT MOVE THE VEHICLE'. Any straps or lashing used in such anchors should be protected from any soiling with grease, fuel and hydraulic fluids.

Chocks and hexes

In rocky environments, chocks (including hexes; Figure 40 and 41) are inserted in cracks and crevices found in the rock to create anchor points. Chocks are easy to install but one should be careful of the direction of the pull as this might displace the chock or hex.

Rock Bolts & Pitons

When no other anchor points are available, rock bolts can be set up on any solid surface while pitons may be set in semi-soft substrata. To employ rock bolts and pitons in the rescue system, the rescue team needs to be equipped with the necessary drilling or hammering equipment. Some examples of rock bolts and pitons are shown in Figure 40, while a piton embedded in compact soil, ready for use, is shown in Figure 42.

Figure 40: Some examples of chocks (top left), pitons (middle), hexes (right) and bolts (bottom left) used in anchorage systems.

Figure 41: An anchor set on a rock outcrop using the hex system.

Figure 42: Piton embedded in compact soil with carabiner in eyelet for sling or rope attachment.

Picket anchor

Where there is soft ground (e.g. soil or clay) and no anchors are available one may resort to the use of picket stakes as anchors. Each picket in the picket stake system should be at least 2.5 cm in diameter and 120 cm long.[8] A single picket may hold approximately 300 kg while a system e.g. the 3-2-1 system, which includes 3 pickets at the front, 2 in the middle and 1 picket at the back may hold between 900 and 1800 kg.[9] The strength of a picket anchor system depends on the ground substratum and on the linearity of the system with respect to the load that it is holding. Non-linearity might imply uneven load distributions where the first part of the system bears the entire load.

The system, as shown in Figure 43, is construed of picket stakes that are inserted in the ground. The pickets should be at least two-thirds of their length in the ground.[9] The angle of the pickets should be 15° to the ground, in the direction away from the load.[9] The distance between each picket in the system should be approximately equivalent to the length of the pickets used (L=1).

Webbing (e.g. a sling) is used to secure a clove hitch at the top of the front picket and the other end of the webbing is secured at the bottom of the second picket. Similar webbing is set between the second and third picket assembly. A rod is then inserted between the two strands of parallel webbing and the rod is turned 360° several times to tension and combine the system.

Anchoring concepts

This section presents two principal notions of anchoring, namely the single point anchor where a 'bombproof' anchor is available for use and the multipoint anchor system. Depending on the particular location of anchors relative to the position of the load, different systems of multipoint anchor systems may be applicable as described below.

Single point anchoring is used only when the anchor is 'bombproof'. When a bombproof anchor, as the major anchor, is available but it is far away from the load, a marginal anchor may be used. The latter would be used only if it occurs close to the load; it needs to be backed up with a back-tie system[10] and this system

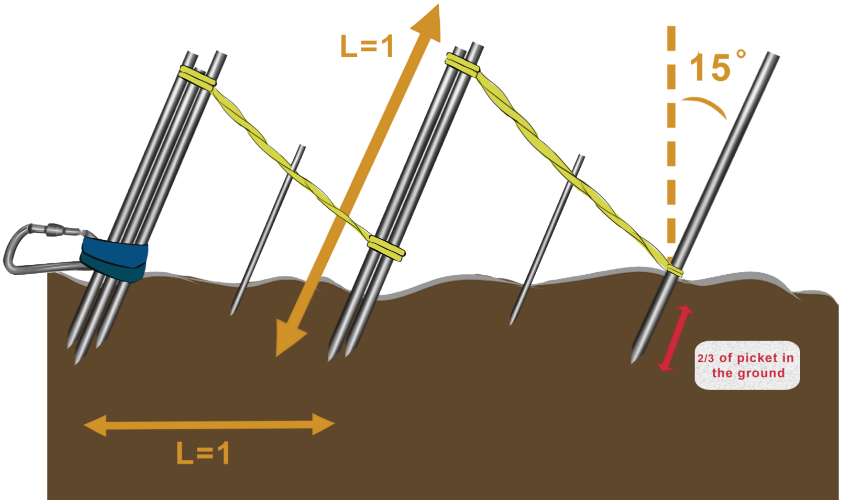


Figure 43: Picket system.

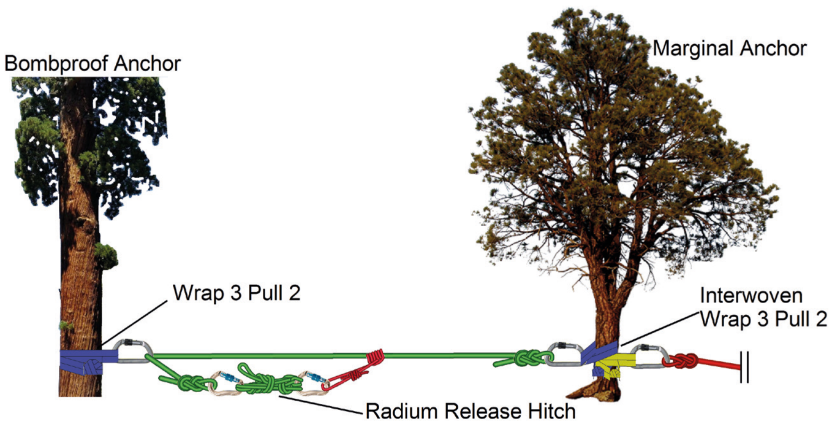


Figure 44: A 'bombproof' anchor (tree on the left) is supporting the marginal anchor (tree on the right) using a back-tie system.

would effectively include a 3:1 MA[vi] system thanks to a radium release hitch (Figure 44). This method effectively supports the marginal anchor under tension. The interwoven wrap-3-pull-2 set-ups on the marginal anchor provide a fail-safe scenario. Should the marginal anchor fail and become obsolete, the back-tie system holding the load shall remain supported by the 'bombproof' anchor.

The concept of multipoint anchors refers to the combination of a number of anchors to create an appropriate load bearing system in the absence of a single 'bombproof' anchor. This section will go through two types of multi-point anchors using different equipment and applied to different contexts.

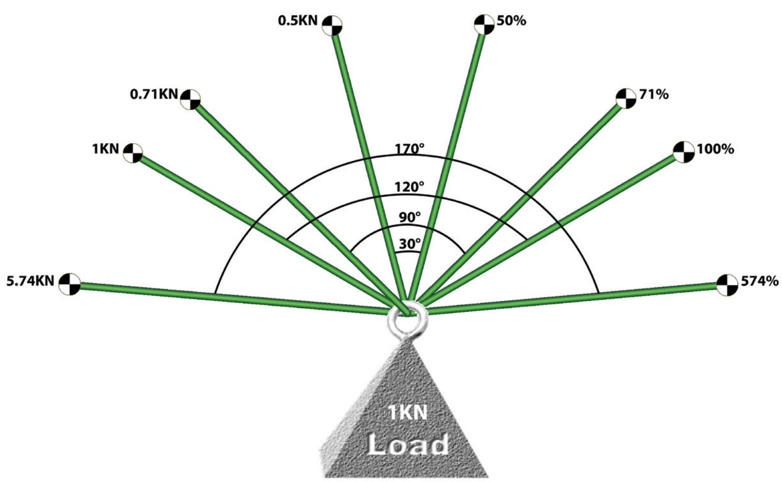


Figure 45: Load sharing depends on the angle between the vicinal anchors, at the load. (Adapted[10])

Method 1: Load sharing anchors

A system involving multiple anchoring points should always be set up in the direction of the load, otherwise one of the anchors may bear the principal load and the whole system might fail. Thus, all the lines from the various anchors should be independent and pointing toward the load. In this manner, if an anchor or line should fail the other anchors are not compromised and will keep on sharing the load. The internal angles between two or more anchor points are of utmost importance. As the angle increases, the force on each anchor point also increases (Figure 45). For example, with an internal angle of 30°, each anchor point will bear 50% of the load. If the internal angle is of 90° each anchor point will bear 70% of the load. If the angle between two points is beyond 120° (referred to as the critical angle) each anchor point will bear more than 100% of the load weight.[11] Since the purpose of using multiple points is to reduce the load on each anchor, it is important that the internal angle should be kept as low as possible, not exceeding 90°.

Method 2: Directional anchors

Directional anchors are anchors that are used to deviate the rigging line coming from the main anchor towards the load. These kinds of anchors are not used as main anchors. It is not always possible to find an anchor pointing directly towards the load, but if there is

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vi Mechanically Advantaged system. This is explained in detail in the next section.

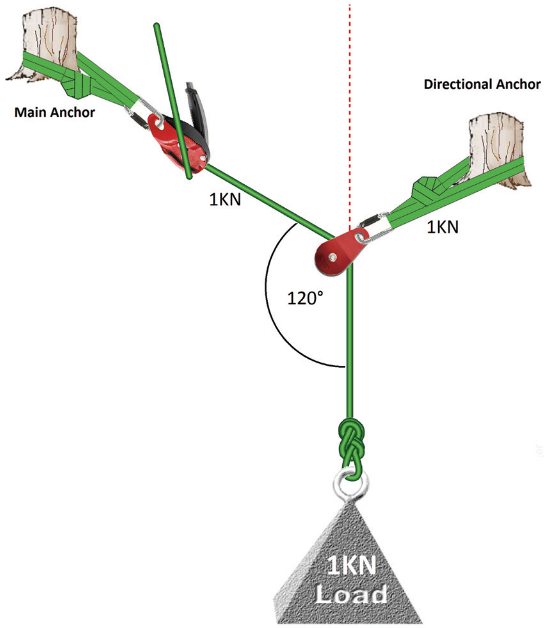

Figure 46: The main line is redirected with a pulley rigged to a directional anchor with an internal angle of 120°. (Adapted[13])

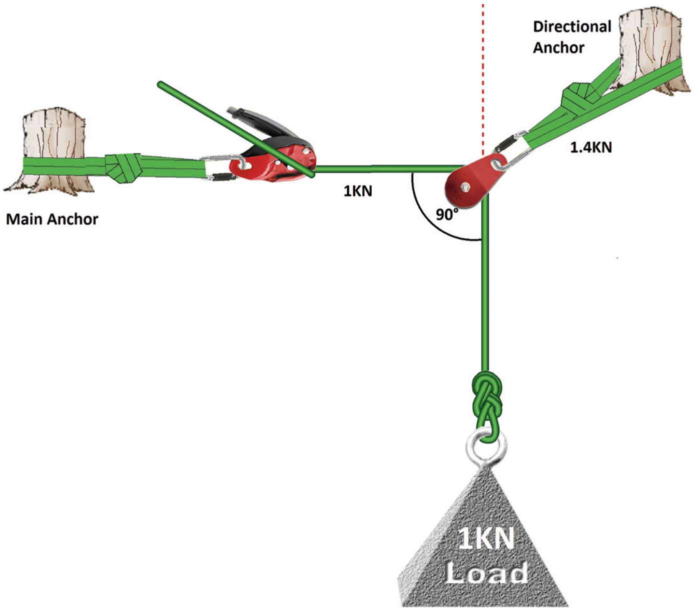

Figure 47: The main line is redirected with a pulley rigged to a directional anchor with an internal angle of 90°. (Adapted[13])

a marginal anchor point close by, it may be used to redirect the line coming from the main anchor through an appropriately positioned pulley. This marginal anchor would hence act as a directional anchor. Such anchors are also used to elevate the lines away from edges, when using tripods or beams in a structural environment.

The internal angle created by the directional anchor on the main line, determines the load that is imposed on the main anchor and the directional anchor itself (Figures 46 and 47).[10] If the formed angle is 120° (the critical angle), the directional anchor will bear as much as the main anchor, i.e. 100% of the load weight. If the formed angle decreases to 90°, the directional anchor will bear 140% of the load while the main anchor would bear the equivalent of 100% of the load weight.[12] Therefore, the choice of the anchor points should be studied considering the contextual and situational requirements. The wider the angle of redirection the lower the load on the directional anchor. Figure 46 shows an angle of 120° where the load on the directional anchor is of 1 kN, the same weight as that of the load. The smaller the angle between the main anchor line and the line that is redirected (Figure 47) where the line is given a 90° redirection, the load on the directional anchor is of 1.4 kN, which is more than the load *per se*.

Knots and hitches for anchoring systems

Apart from the standard knots mentioned in the first part of this section, there are specific techniques to tie a rope to an anchor. One of the methods used is the 'full strength tie-off', also known as the 'tensionless hitch' (refer to Figure 9q in Chapter 1) where a rope is tied to an anchor without any loss of rope strength. This remains one of the simplest and most efficient ways to tie a rope. This method entails wrapping the rope several times around a tree or a post (with a diameter at least 8 times the rope diameter). This method enables the rope to withstand the load. Usually four to six wraps are tied around the object tightly to secure the rope,

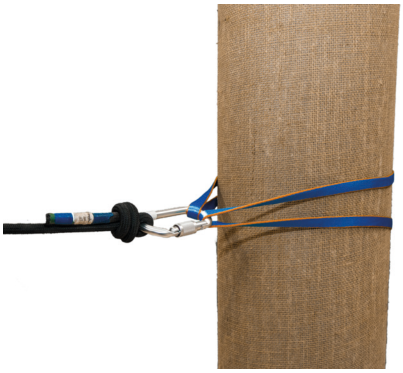

Figure 48: Basket hitch.

but a smooth surface anchor may require more wraps to increase friction. For additional security, the rope end is clipped to the loaded part with a carabiner. Any edges on the anchor point will reduce the rope's tensile strength.

Another method is the 'basket hitch' (Figure 48). The basket hitch is a closed loop of webbing that is wrapped around an object where both loops are hooked to a carabiner leading to the load. Another wrap may be added around the object to increase friction and to avoid the hitch sliding down. Both sewn webbing or knotted webbing may be used but sewn webbing is preferred as the knot may be difficult to untie after it has taken the load or if loaded inappropriately.

The third hitch that rescuers resort to when tying a rope to an anchor is the 'radium release hitch'. This hitch has various uses and may be used as part of a back-tie system (Figure 46) or as part of the safety line. This hitch is usually pre-rigged. When the radium release hitch is used on the safety line, it allows for system release should the fall arrester on the same line become engaged (for e.g. if the main line is being lowered too quickly). The radium release hitch is released slightly to allow the load to be shifted back to the main line. The 'untied' radium release hitch and the 'tied-off' radium release hitch are shown in Figure 49. This figure illustrates how a figure of eight knot is set on the load bearing side. The running end is then passed through the anchor carabiner and again through the load carabiner, followed by a Munter hitch on the anchor side. The radium release hitch becomes a load-releasing hitch. The hitch is secured by tying two half hitches around the releasing hitch itself. An overhand knot may be applied to the remaining bight as a stopper knot.

Figure 49: Radium release hitch.

Mechanical advantage

A pulley system is set up on the main line, while progress is captured using a Prusik minding pulley that is equipped with a Prusik loop or uses appropriate specific equipment. The safety line should also capture the equivalent progress taking place on the main line. The main line with the MA

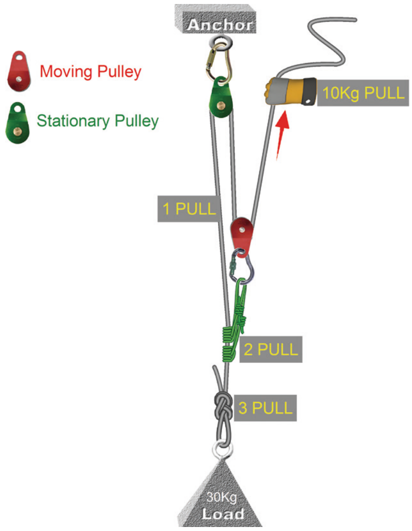

Figure 50: A simple 3:1 MA system showing the transfer of mechanical advantage onto the load.

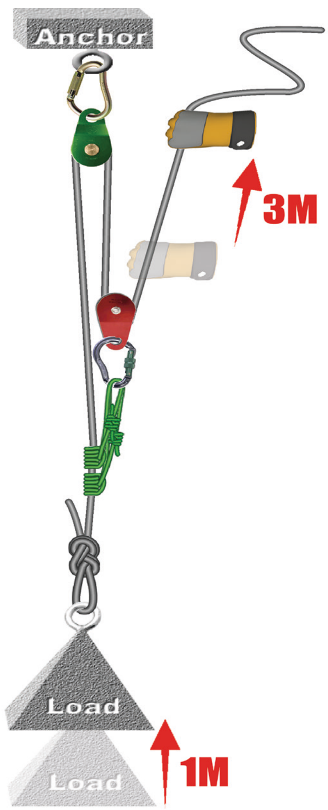

Figure 51: A simple 3:1 MA system showing the length of rope on the running end that needs to be pulled for a 1 m load movement.

system and the safety line should be manned at all times so that the progress is captured on both the main and safety lines in real time leaving no room for significant falls.

The concept of mechanical advantage (MA) refers to the use of pulleys for the multiplication or amplification of forces through a designed mechanical system. For instance, when using a 5:1 pulley system, the 4 kN pulling force exercised by the rescuers would result in a hauling force of 20 kN (4 kN multiplied by 5). However, this is not taking into consideration the frictional losses. The effective force of the pull is explored in more detail below. The MA is achieved when the hauling rope is redirected on a free-moving bearing, such as a pulley bearing as indicated in section on pulleys above.

Figure 50 shows a simple MA system with the basic key elements. This diagram portrays a stationary pulley at the anchor point for efficient redirection of the hauling

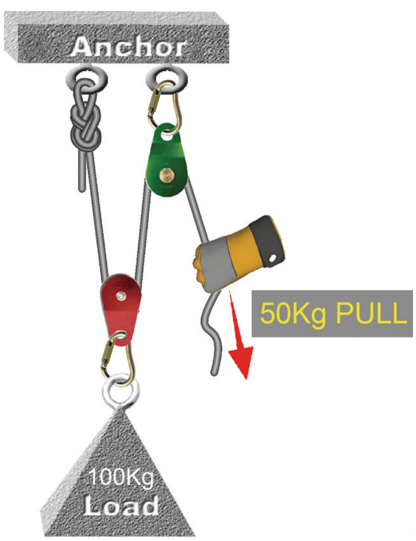

Figure 52: A simple 2:1 MA system for a 100 kg load.

line. The moving pulley creates a mechanical advantage that clutches the main line using a Prusik hitch while the anchor functions to support the hauling line. In principle, '1 pull' on the running end of the hauling line multiplies by two on the moving pulley. These two pulls are transmitted to the main load bearing line where the Prusik grabs the rope. The '1 pull' haul combines with the '2 pull' resulting from the pulley, for an effective resultant haul of '3 pull'. Therefore, in theory, a pull of 10 kg may carry the load of a 30 kg.

The application of MA on a hauling system requires a balance of speed, length of the hauling rope and force. On the same 3:1 MA system, (Figure 51) when the running end of the rope is hauled by 3 m, the load is raised only by 1 m, with the same ratio of the MA strength. Therefore, the higher the MA the longer the distance that the hauling rope needs to be pulled through, to elevate the load through the same distance.

The hauling force is multiplied in the MA system according to the MA rating. Figures 52, 53 and 54 show how three different simple MA systems with factors of 2:1, 5:1 and 10:1, necessitate a different hauling force to hold the same load weight of 100 kg. In a 2:1 system, the hauling force needed is 50 kg (i.e. 100 kg divided by 2). In a 5:1 system, the hauling force needed is 20 kg (i.e. 100 kg divided by 5), and so on.

When implementing MA systems the following points should be taken into consideration:

- When a system uses the same line as the main line, the length

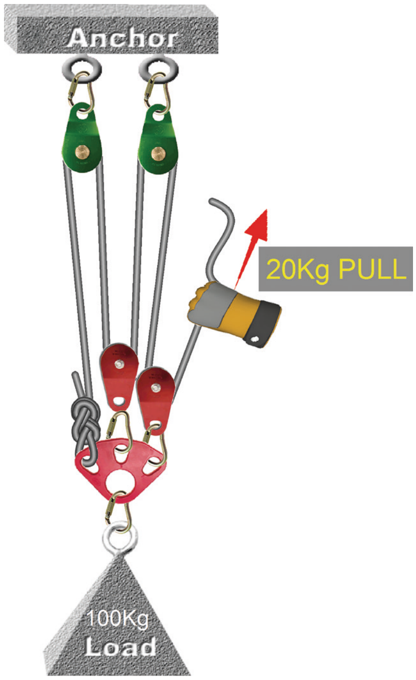

Figure 53: A simple 5:1 MA system on a 100 kg load.

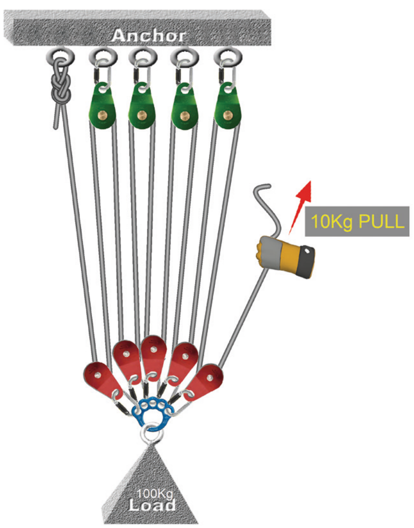

Figure 54: A simple 10:1 MA system working on a 100 kg load.

of the available rope is a key issue;

- The ground area available for movement of the hauling party; and
- The number of available rescuers or bystanders able to form part of the hauling party.

Any MA must be complemented with a number of persons in the hauling party to successfully haul the load, which would minimally include a rescuer and/or a casualty. A whole rescue operation might be jeopardised by excessively rated MA system set-ups or excessively large hauling parties. Thus, it is essential to follow the rule of 12 when calculating the personnel mechanical advantage (PMA). The PMA is essentially the multiplication of the number of people in the hauling party together with the mechanical advantage of the system. This multiplication generates a gauge of the operational strength of the MA.

The PMA = People x Mechanical Advantage for a 3:1 system is as follows:

- If 2 rescuers are hauling on the MA system → 2 (No. of persons) x 3 (MA factor) = PMA of 6.
- If 3 rescuers are hauling on the MA system → 3 (No. of persons) x 3 (MA factor) = PMA of 9.

Calculating the PMA is important to avoid overloading the hauling systems with excessive force. The PMA should not exceed a factor of 12, hence the 'Rule of 12'. Thus, on a 6:1 MA system there should not be more than two persons hauling. Overloading hauling systems may result in catastrophic outcomes because excessive forces affect the anchor points and stress the equipment beyond the indicated safety margins.

Safety Note

A high-factor mechanically advantaged system may downplay system issues. For example, if a stretcher and rescuer system gets stuck against a ledge, persisting in pulling may create an overload of forces on the system that triggers the failure of the weakest link. In the case where the mechanically advantaged system is suddenly generating a lot of resistance, the system must be holistically checked rather than simply increasing manpower. The PMA rule of 12 should be respected at all times and should never be exceeded.

Forces

When calculating the pulling force of a pulley system it is assumed that there are no losses in the MA system. In reality, the rescuer shall take in consideration those losses that occur due to inefficiencies in the system. Pulley systems are subject to the efficiencies or inefficiencies of the pulleys used in the system. Figures 55, 56 and 57 show how different equipment with differing inherent efficiencies would affect the actual hauling force needed for the same load, with the most effective piece of equipment being the actual pulley. The carabiner is not designed for dynamic rope movement which consequently presents substantial frictional losses. Also, the I'D is not free running because it is a camshaft-bearing device, thus presenting a scenario of high

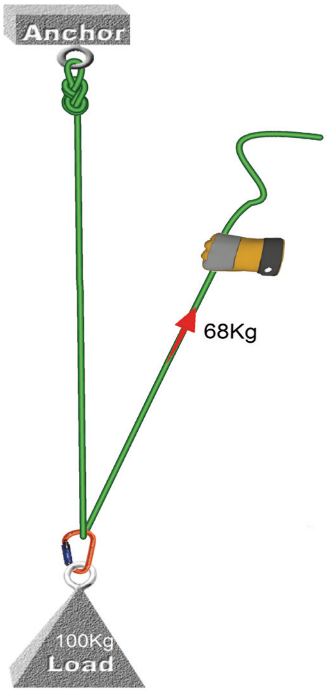

Figure 55: Illustration showing the hauling force necessary when using the carabiner as a pulley function. (Adapted [14])

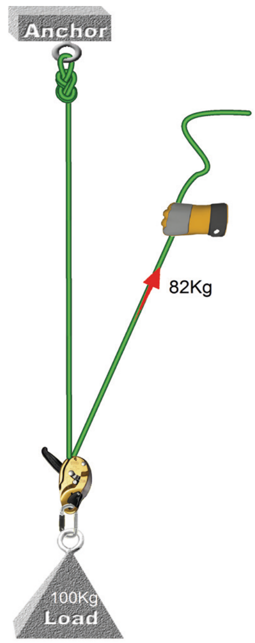

Figure 56: Illustration showing the hauling force necessary when using an I'D as a pulley function in a simple 2:1 MA system.

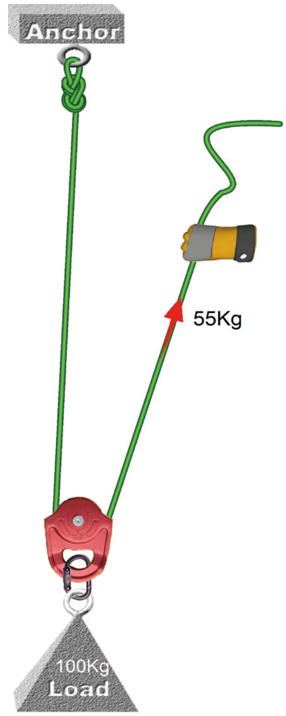

Figure 57: Illustration showing the hauling force necessary when using a high efficiency pulley for a simple 2:1 MA system.

frictional losses. Conversely, the high efficiency pulley enables a highly effective 2:1 MA system because only minor frictional losses are incurred.

The efficiency of a MA system varies with the equipment. For example, the roller/ball bearing type of pulley is generally more efficient than its equivalent as a bush-bearing type. The latter pulley may be 5–15% units less efficient than the roller bearing type. The roller bearing type pulleys are highly efficient, often in the region of 90 to 95% efficiency. On the other hand, camshaft devices (e.g. I'D or Rig) do not perform well as pulleys since they are construed of a cam that is not free-moving with the rope.

Since the efficiency of pulleys is never at 100%, the actual MA factor is always lower than the theoretical estimated one (Figures 58 and 59). A drop in the efficiency of the MA system occurs with the implementation of every pulley irrespective of whether it is static or moving. Consequently, the pull that the hauling team needs to apply to the system is more than the estimated (theoretical) pull value. Without frictional losses a 100 kg load could be lifted by a haul equivalent to 25 kg, using a simple 4:1 MA system. However, when frictional losses are applied and the efficiency of the pulley is considered, the actual MA factor is reduced. For example, if the efficiency of the pulley is reduced to 80%, '1 pull' becomes '0.8 pull' when it is subjected to the first pulley. The 0.8 pull becomes 0.64 pull when subjected to another pulley, and so on. The total MA factor is the sum of all 'pulls', i.e. $1 + 0.8 + 0.64 + 0.512 \approx 3$. Therefore, assuming there are no other frictional losses apart from those related to pulleys, a theoretical 4:1 MA system may effectively provide results as a 3:1 MA system would.

The camshaft-bearing device may be relatively inefficient because of its lack of a free-moving bearing (Figure 56). When used at the head of a MA system to capture the progress, it compromises the efficiency of the MA system (Figure 60). When the progress capture device is incorporated within the MA system, it would not require a

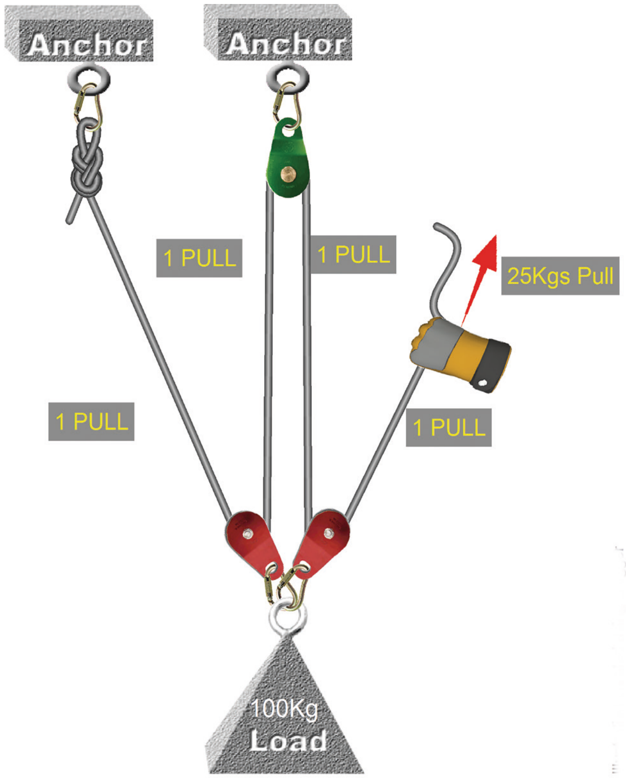

Figure 58: A simple 4:1 MA system assuming no frictional losses.

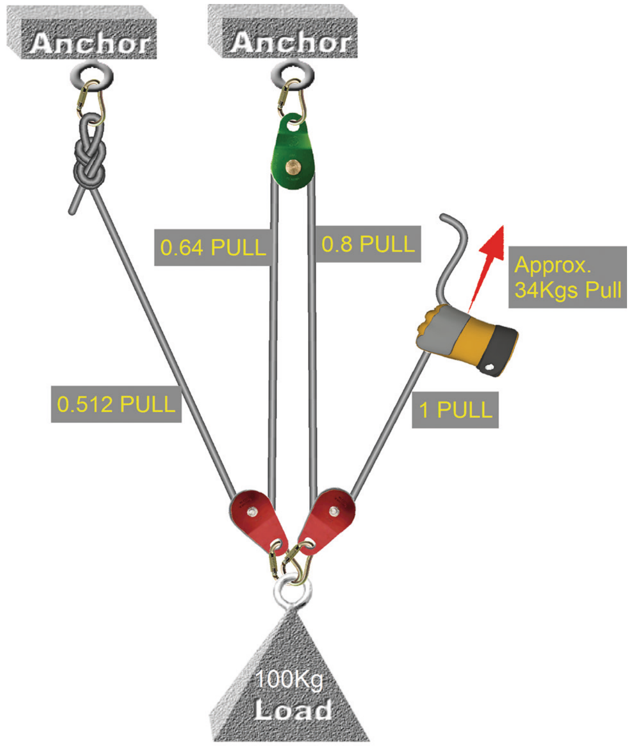

Figure 59: A simple 4:1 MA system showing the actual hauling force when taking in consideration the frictional losses related to pulley efficiency.

dedicated operator but functions as a progress capture device automatically. However, the low efficiency of such a progress capture device (being a camshaft-bearing device) lowers the efficiency of the MA system.

A camshaft device hinders the efficiency of a MA and consequently should only be used to facilitate the progress capture of the line being hauled. Therefore, the MA system could be built separately using efficient pulleys only. The progress capture device is set directly on the main line and consequently, the low efficiency of the camshaft-bearing device as a pulley does not effect the MA system. This system, however, necessitates an additional operator on the progress capture system feeding the camshaft-bearing device to ensure immediate progress capture (Figure 61).

An alternative progress capture system to the camshaft-bearing device is the use of a Prusik minding pulley with the advantage of high efficiency and automated progress capture (as part of the MA system). The disadvantage of such a system is that it needs to be altered to achieve a lowering function (reversal of the system). Thus, a camshaft-bearing device is more versatile.

When calculating the MA factor it is important to take note whether a pulley is stationary or moving (Figure 62). Stationary pulleys do not affect the MA system but simply change the direction of the hauling rope to facilitate the hauling team's operations. Moving pulleys may be set up either directly on the load for an immediate 2:1 MA system per installed pulley or along the hauling rope through a rope grab, such as a Prusik. A moving pulley will effectively multiply the force being applied on the load. The multiplying factor depends on the type of MA system.

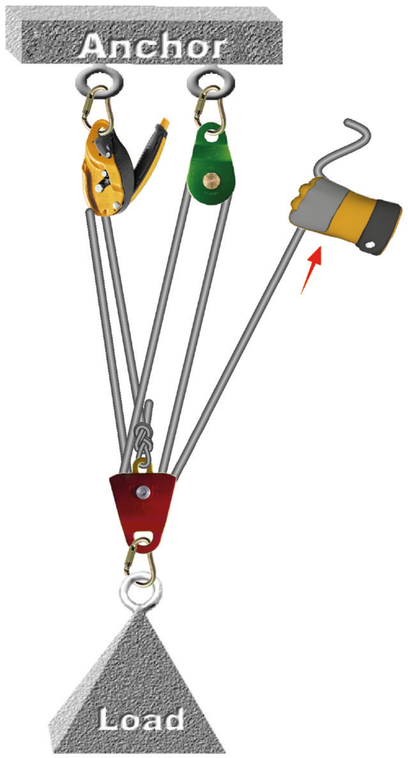

Figure 60: The use of an I'D (a camshaft-bearing device) at the head of a MA system.

Categories of mechanical advantage systems

A mechanical advantage system can range from a simple system to a compound or a complex system. Each one has a different formation and involves specific pieces of equipment. A simple MA system employs pulleys at the anchor (for change of direction) and others directly on the load for the simple addition of MA at each moving pulley.

Simple MA System

Figure 62 depicts a simple 3:1 MA system. As a convention, '1 pull' starts off at the end of the hauling line. The pull that enters

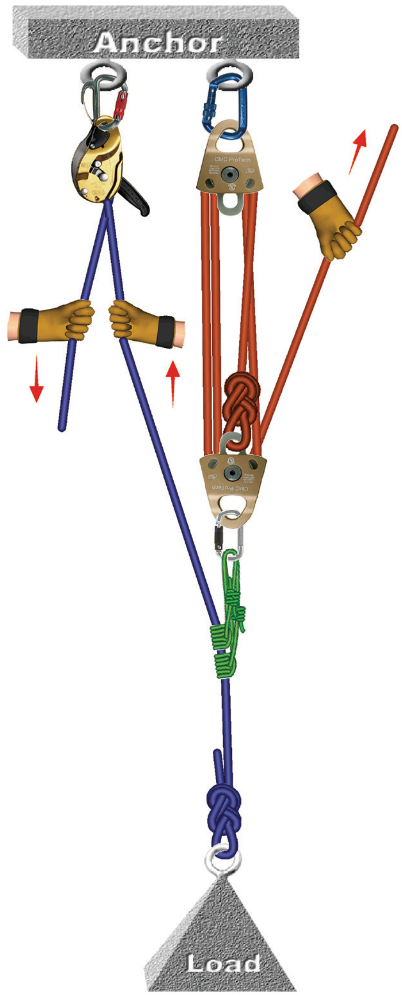

Figure 61: A simple 4:1 MA system showing a camshaft-bearing progress capture that is acting on the main line and is independent to the MA system.

the moving pulley is doubled because of the multiplier effect of the moving pulley, resulting in an effective pull of two on the load, but the hauling line moving out of the pulley remains with a pull force of one. This '1 pull' enters the static pulley without any multiplier effect and ends up on the load, effectively resulting in another pull on the load. The outcome of this system is that the total pull on the load is of '1 pull' together with '2 pulls' (total

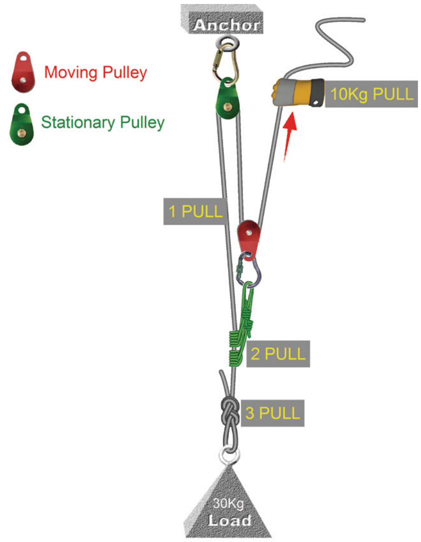

Figure 62: A simple 3:1 MA system.

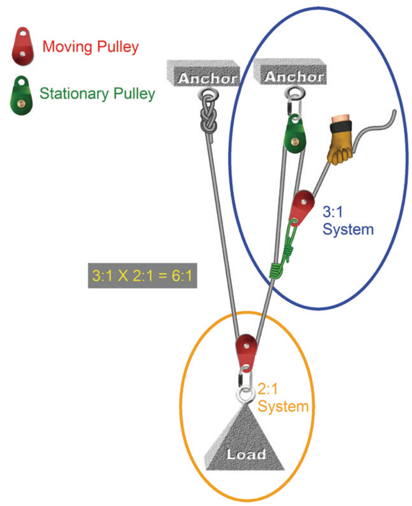

Figure 63: A compound 6:1 MA system construed out of two simple systems i.e. a 3:1 MA system working on a 2:1 MA system.

of '3 pulls'). Therefore, assuming no frictional losses, a pull equivalent to 10 kg would hold a 30 kg load.

Compound MA Systems

In compound systems, the MA is achieved by two or more simple MA systems pulling on each other

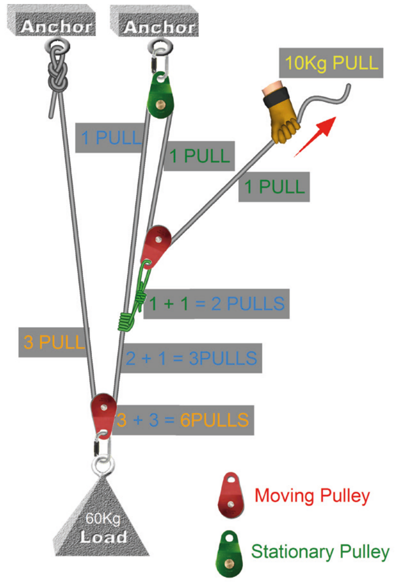

Figure 64: The same compound 6:1 MA system illustration as in Figure 63 showing the build-up of 'pulls' along the hauling line.

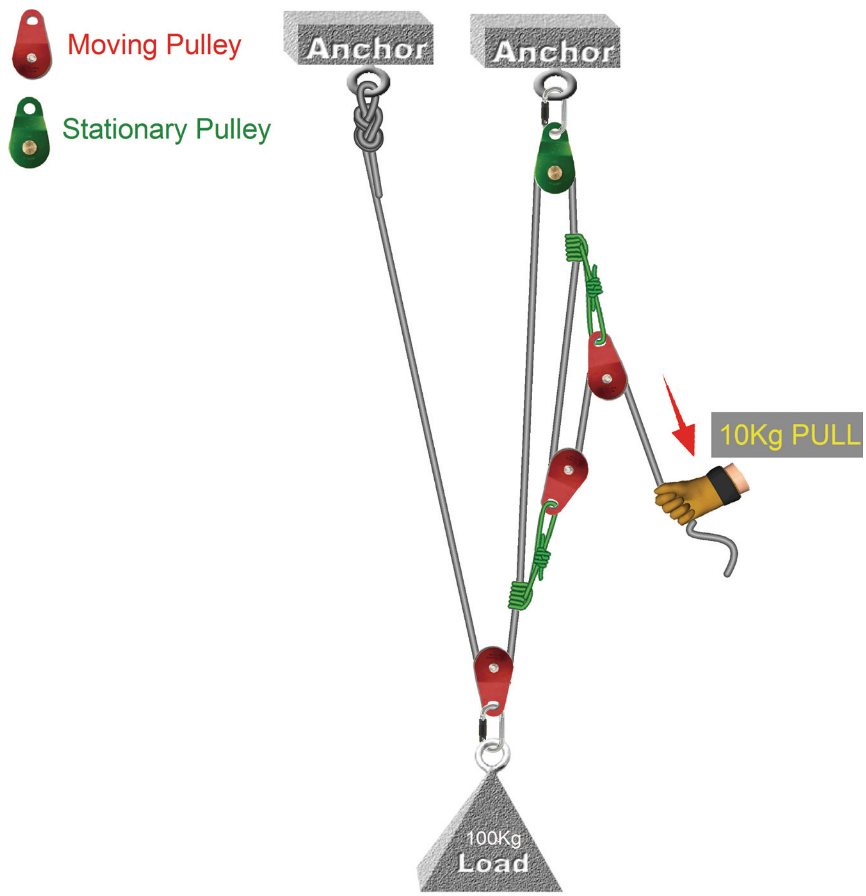

Figure 65: An example of a complex 10:1 MA system which inherently includes pulleys that move towards the load during hauling.

via Prusik connections. At Prusik connections, effective 'pulls' are added to the basic MA system. For instance, Figures 63 and 64 show a compound MA system. The system is constructed by two simple MA systems, as shown in Figure 63. To calculate the MA, following Figure 64, one starts at the hauling line with '1 pull'. Going through the first moving pulley will result in '2 pull' on the Prusik point of connection, but the hauling line will retain its '1 pull'. Going through the static pulley on the anchor leaves this pull unchanged until the point of Prusik connection is reached. The '1 pull' on the hauling line is added to the '2 pulls', resulting in a total of '3 pulls' where the Prusik joins this MA to the basic 2:1 system. '3 pull' will enter the second moving pulley and the multiplier effect of the pulley would place a total of '6 pull' on the load. Hence the MA is of 6:1 where a load of 30 kg requires only a haul of 5 kg (assuming no frictional losses).

Complex MA System

The third MA system type is the complex system which integrates simple MA systems built in a way that at least one pulley, upon hauling, moves towards the load (Figure 65). This system is used when requiring a higher mechanical advantage or when the hauling space is limited. The build-up of 'pulls' on the hauling line leading towards the load follows the same principles as for the simple MA systems, that is, additional 'pulls' at Prusik connections and doubling of 'pulls' at moving pulleys. Though this chapter will not delve into further detail on these MA systems, the rescuer needs to be aware of the possibility of such systems.

Pulley-on-load systems: A concept

Figure 63 depicts a typical example of a MA system to be used on a load. The key to this system lies with the pulley that is installed on the load, effectively creating a MA of 2:1. The second system (MA = 3:1) is then working on the 2:1

system. Therefore, both systems together create a MA factor of 6:1. Figure 66 shows the same typical application of a compound MA system on a tripod set-up. Such a MA system is convenient because a 100–150 kg load may be hauled by only 2 persons. The simple 2:1 MA achieved by virtue of a pulley employed on the load is key to such a compound system.

The limitation of this set-up is the length of the rope. The rope must be at least double the distance between the hauling party and the load because the pulley-on-load requires double rope length. Consequently, where such rope length is not available, the mirrored systems of safety and main lines may be set up with separate simple MA hauling lines (e.g. 5:1 only on each line) with a hauling party working on each line (see section on mirrored-systems, below).

Techniques

Rope rescue techniques vary according to the variables found in a rescue scenario. These can be anything from terrain and weather to the standards and equipment used. The following are few techniques recommended for use whilst employing EU and/or NFPA standard equipment. Although there are various techniques, this section will provide a baseline for safe rope rescue operations.

In principle, rope rescue can either be low angle rescue or high angle rescue. This is determined by the angle of terrain and the required method of rescue (Figure 67). The technical rescue industry classifies the angle of terrain in four categories,[15] namely:

- Flat terrain – a 0–15°slope
- Low angle terrain – a 15–30° slope
- Steep angle – a 30–50° slope
- High angle – above 50°

Figure 67 provides a guideline of rope usage according to the various possible slopes and inherent risks. Nevertheless, it is difficult to adhere to these figures because circumstantial factors such as, loose rocks, wet or dry terrain and even the nature of the rescue *per se* may compel the rescuers to adopt different approaches to the presented scenarios. The number of ropes shown as applicable to rescue scenarios in different terrain angles is only indicative because, again, this depends on the nature of the terrain and other conditions such as weather.

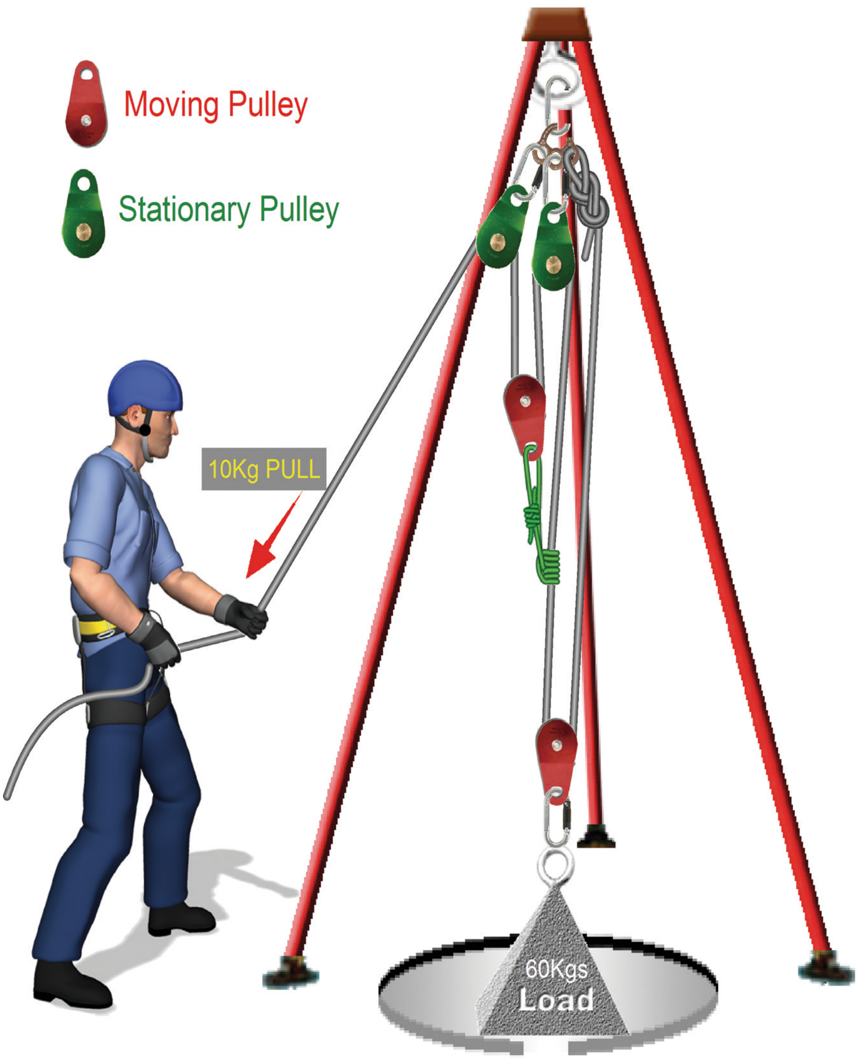

Figure 66: A compound 6:1 MA, construed of two simple 2:1 and 3:1 simple MA systems, set on a tripod, showing a pulley on the load to achieve the simple 2:1 MA.

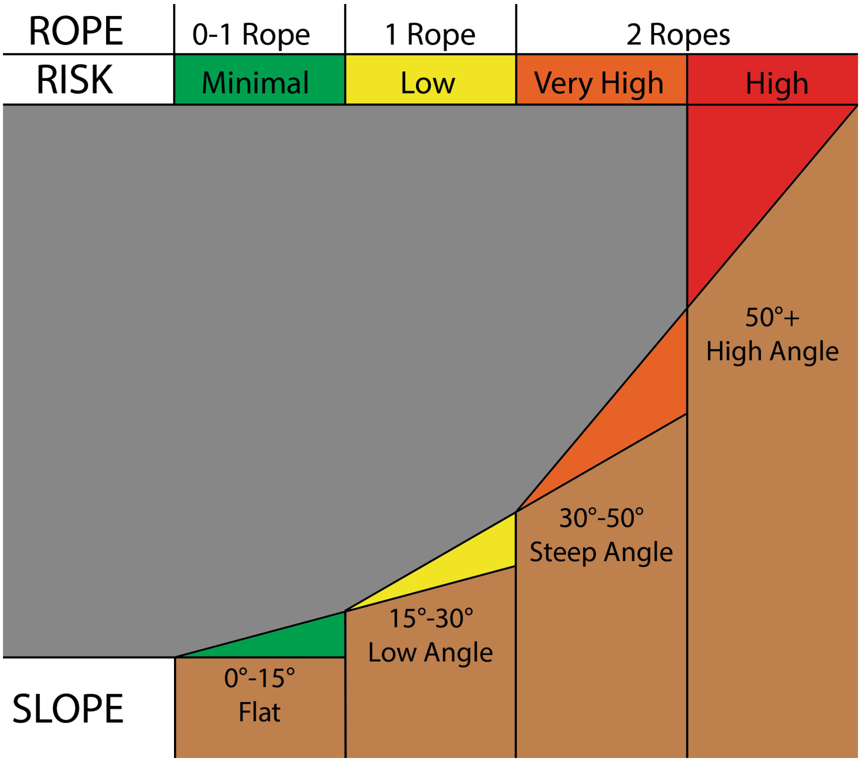

Figure 67: The relationship between the slope angle, risk and rope usage, as a general guide (Adapted[16]).

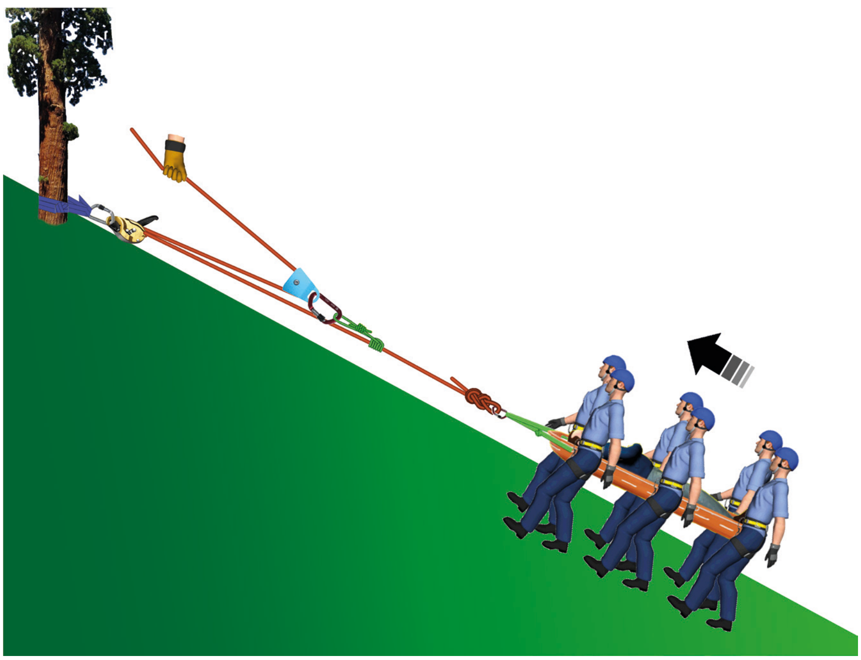

Figure 68: Low angle rescue scenario showing six rescuers handling the stretcher using a single rope equipped with a simple 3:1 MA system.

Low angle rescue

A low angle permits an able-bodied person to walk down or up this slope. However, when recovering a casualty, assistance is to be provided to the rescuers in support of the recovery operation. Although it is a low angle rescue both the casualty and the rescuers need to be secured.

In view of the low angle, the team leader must revise the risk assessment and decide on the method and work sequence to be adopted. A low angle recovery may be done using a single rope to create the mechanical advantage needed to recover the casualty and assist the stretcher-bearers up the slope. Usually, this will be a simple 3:1 MA system with an I'D or a Prusik minding pulley, equipped with a Prusik loop as progress capture while providing better efficiency (Figure 68). An operator at the head of the system will manoeuvre the MA and progress capture systems.

This main line also serves as a back up to the rescue team. The stretcher bearers can connect to the main line via a Prusik. Ideally, the rescuers use a Purcell Prusik (Figure 30) or alternatively a rope grab to ensure that they are safe should they lose their footing (Figure 69). The number of rescuers handling the stretcher usually ranges from four to six, depending on the manpower needed for the stretcher and the type of terrain.

Steep angle rescue

Steep angle rescue takes place when the terrain has a slope angle of approximately 30° to 50° (Figure 67). Again, the condition of the

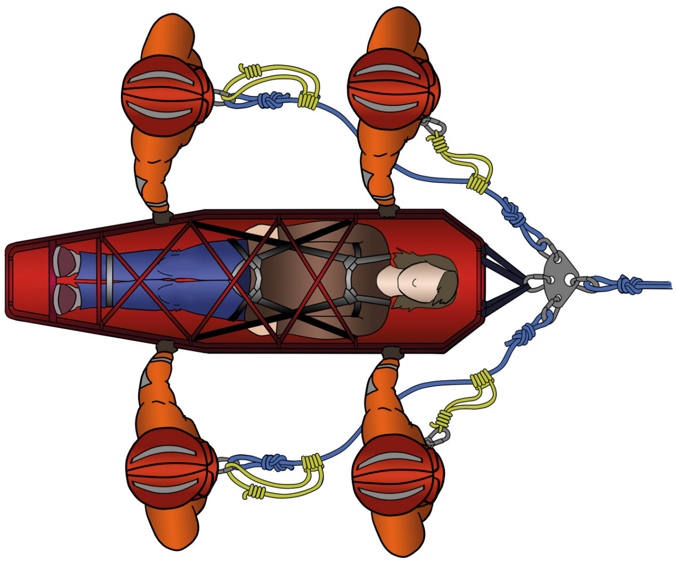

Figure 69: Low angle rescue scenario demonstrating how rescuers may be secured to the main line.

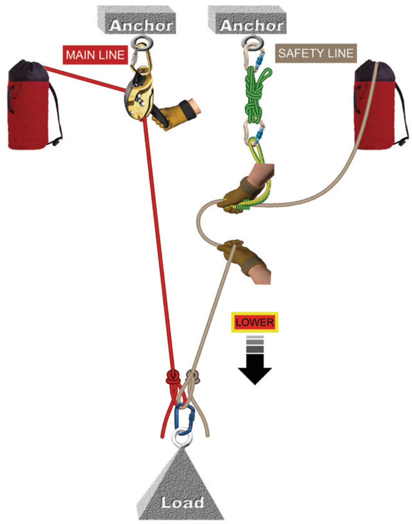

Figure 70: Non-mirrored system set for lowering with an I'D as a belay device for lowering and a Tandem Prusik Belay for the belay of the safety line.

terrain will determine the technical level and expertise required to perform the rescue safely and efficiently.

Steep angle operations present a high risk due to various hazards such as rock fall, loose shrubbery and the fact that the rope system may often be overloaded with several rescuers on it. Rescuers are also generally fully dependent on the ropes for upward travel in such situations. It is important that the team leader conducts a thorough on-site risk assessment before determining the best method of rescue to adopt. Thus, the rescue method varies according to this risk evaluation. This may well be an area where high angle methods are adopted and it is a scenario that often necessitates the use of two ropes.

High angle rescue

High angle rescue is applied in extremely elevated angles where the weight of the casualty and the rescuers are entirely on the rope system. In high angle rescue one must employ a double rope system with a main line and a safety line. In this case, the rescue team requires more specialised skills, necessitating more dedicated training and commitment, as failure may result in one or more fatalities.

In steep and high angle rescue, the role of the safety officer/s should be exclusively dedicated to the continuous evaluation of the operation and to ensuring the safety of all the team and the operation. In such cases, the safety officer cannot undertake other roles in the team.

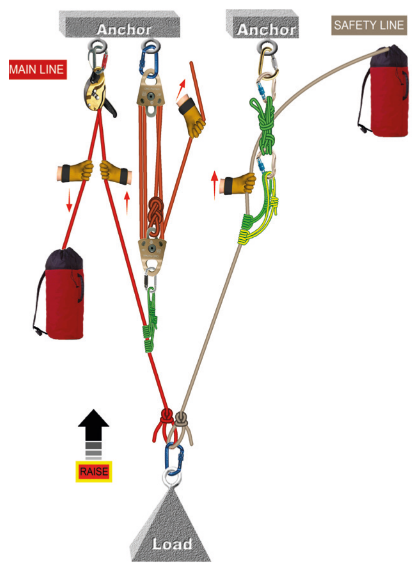

Figure 71: Non-mirrored system set for raising.

Rescue lines

Any high angle rope rescue operation requires a reliable and safe lowering or hauling system. The simplest of the rescue systems requires a main line and a safety or backup line. These lines can be configured individually or in a mirrored set-up where the main and safety line reflect each other and are therefore, equivalent. A safety line is often not necessary in a low angle situation.

The main line is usually the rope that will take the principal tension of the load. This is usually used to lower the rescuer to a casualty. This line should be configured in a way that uses a controlled descent apparatus such as an I'D or similar equipment (Figure 70). Once the rescuer reaches the targeted location, the line is then configured using a MA system on the main line (Figure 71). This will facilitate the recovery of the casualty and the rescuer depending on the MA that the rope technicians set up. The I'D may be left at the same point on the main line to act as the first pulley in the hauling system and also to provide progress capture. To improve efficiency on the main line and retain progress capture, the I'D may be exchanged with a high efficiency pulley on a MA system and retain the I'D for progress capture only, aside from the MA system.

The safety line is the rope that will be usually kept taut by regularly taking in loose slack, using the Tandem Prusik Belay (TPB) in line with the progress done on the main line. An operator whose role is to take away any slack mans this line while the casualty and/or rescuer is/are belayed or hauled up. The safety line can be rigged using:

- a Petzl I'D
- a Tandem Prusik Belay system.

In both set-ups, the safety line operator must ensure that no slack is left on the line. In the event of a failure on the main line, if there is extra slack on the safety line the sustained shock may damage or cause a complete failure of the safety line system.

The mirrored set-up

The mirrored set-up implies that the main line and the safety line reflect each other (Figure 72). This arrangement is applied when the cumulative load of the casualty together with the rescuer, the additional load of the stretcher and any other equipment is substantial. Additionally, there may be space restrictions for sufficient manpower in the hauling team to haul on the main line or there may not be enough rope to build up a higher factor MA system. The advantage of having both lines already pre-tensioned is that if one fails, the stretch and load difference on the second rope will not be as stressful as to when the rope is not yet tensioned. The risk of a line failing and the other line not being able to brake the load over a short distance is significantly reduced in this set-up.[17]

Once the load is over the edge, the two lines are pre-tensioned and therefore a mirrored system is employed.[18] Once the system is engaged for raising, the safety line is also rigged up with a MA system using pulleys. In this case, rescue operators are also active on the safety line. Thus, the safety line will act as a hauling line as well. In this case, the safety line must be still equipped with a progress capture system and both hauling teams must coordinate together to get equivalent load sharing and synchronized hauling, targeting 50% load on each line.

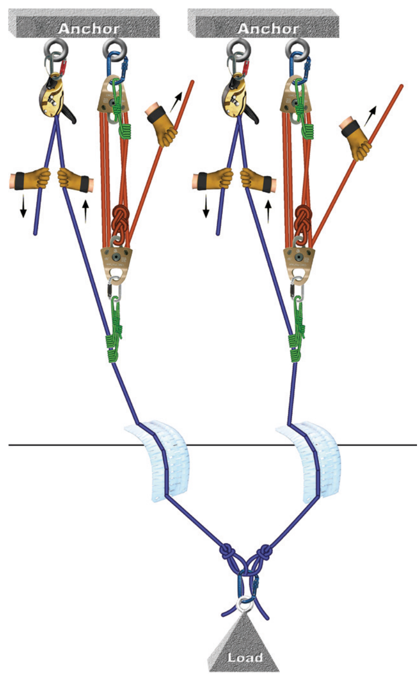

Figure 72: A mirrored system where the safety line and main line are equipped with separate but equivalent hauling systems (simple 5:1 MA).

The Tandem Prusik Belay (TPB) system

The Tandem Prusik Belay (TPB) system has two Prusik loops of different length that are hitched on the rope, circa 10 cm apart between hitches, while hooked onto the same carabiner (Figure 73). This doubles the efficiency of

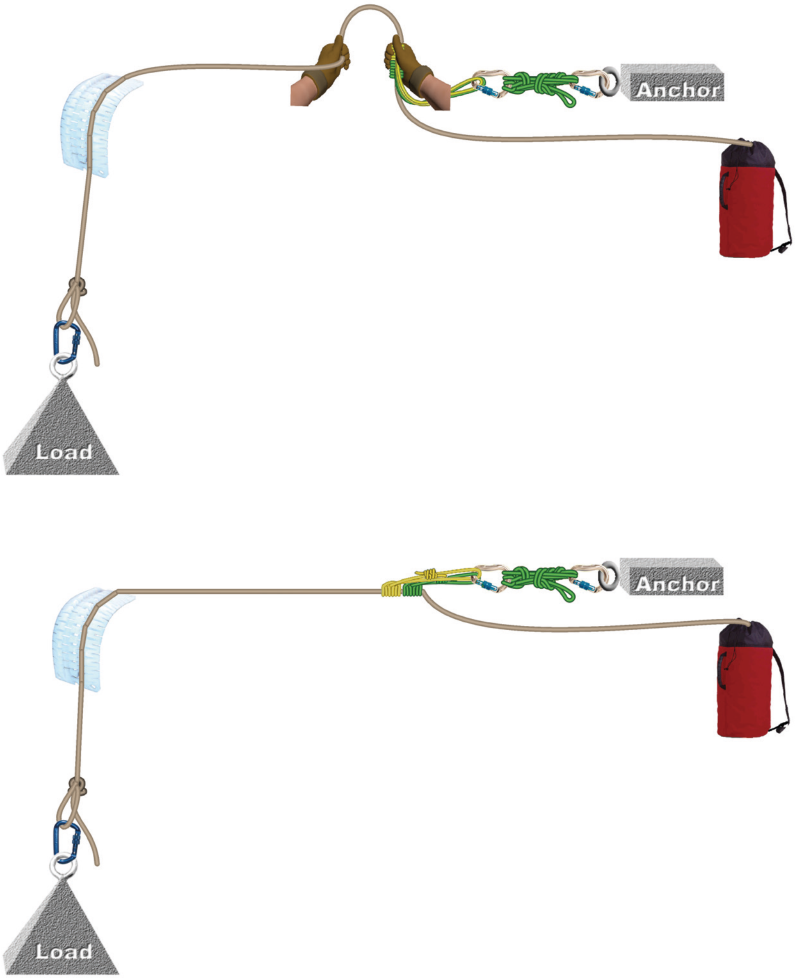

Figure 73: The Tandem Prusik Belay system on the safety line, showing belaying (above) and the grab potential of the two Prusiks if the line is actuated.

the normal Prusik hitch when used as a rope grab.

The British Columbia Council for Technical Rescue (BCCTR) classified the TPB as a safe system of belaying in technical rope rescue. This system successfully complied to the BCCTR's Belay Competence Drop Test where for a 200 kg load tied to 3 m of rope, the belay line withstands a load fall of one metre. The load is stopped within an additional one metre distance with less than 15 kN of force.[19]

Rescue pickup

The rescue pickup is a system used to shift a casualty from a supported or unsupported predicament onto the system of the rescue team such that the casualty may be hoisted up or lowered down to safety. It is a relatively simple technique because it involves a single rescuer (with the support of the team) effecting a pick-up of a casualty who is stranded on a vertical face of terrain. When rescue pickups are employed, all precautions should still be taken, including the use of two separate lines to reach the casualty and effect the rescue.

A rescue pickup can be done on casualties who are already supported by a harness. For instance, this is where the casualty was using a fall arrest system, including a harness, in rope access work and in climbing. The rescue pick-up can also be applied on casualties who have sustained an accidental fall over cliffs or other high structures, where the casualties are not aware of the dangers and do not have any training or PPE. In these cases, the rescuer or first responder will control the descent using an I'D or similar device. Being in control, the rescuer will aim at gaining the best positioning possible to implement the pickup.

When a rescue pickup must be effected on a casualty that is not supported by a harness the priorities of the first responder vary according to the situation of the casualty. When the rescuer lowers himself to the casualty, the first responder shall position himself slightly above the casualty to be in a position to reach the casualty with his hands. Subsequently, the rescuer shall:

1. Assess the situation and any injuries sustained by the casualty;
2. Decide on how best to secure the casualty to prevent any further slips down. This could be a short-term solution using a sling underneath the arms to secure the casualty onto the safety line while the rescue harness is being put on, or immediately putting on a rescue

harness in preparedness for the evacuation;

3. Connect to the safety line at a level slightly above the casualty, a 4:1 MA rope system using a rope grab or a Prusik and extend the lower end of this 4:1 system to the main loop of the rescue harness (on the casualty);
4. Raise the casualty enough to be able to connect the harness of the casualty to the main carabiner or connection on the first responder's descender;
5. Shift the load gently onto the rescuer's harness by extending the 4:1 system;
6. Secure a second line onto the safety line's fall arrest device and remove the 4:1 rope system; and
7. Indicate to the hauling team that the recovery procedure can commence.

When a rescue pickup is to be effected on a casualty supported on a harness, the rescuer shall:

1. Lower and position himself slightly above the casualty, just enough to be able to reach the casualty with his hands;
2. Assess the casualty and his harness, and decide on whether to use this equipment or if the harness needs to be bypassed utilizing a rescue harness; and
3. Follow steps 3 to 6, described earlier, for the unsupported casualty.
4. Remove or cut off any tangled or knotted ropes which may hinder the rescue operation; and
5. Indicate to the hauling team that the recovery procedure can commence.

Stretchers

There are various stretchers that can be used in rope rescue operations. These include: the bucket/basket shell stretcher; the KONG Lecco; the SKED; and the SAR Alpine MR. All these kinds of stretchers can be used in various configurations and scenarios. However, attention must be paid to ensure that operations are always conducted safely by taking into account the differences between such stretchers. For this purpose, below is a brief note on each stretcher.

The 'Bucket' or 'Basket shell' (Figure 74) is one of the most versatile stretchers. However, when used in rope rescue, particular care must be taken when harnessing the casualty because the stretcher may need to be shifted from a horizontal to a vertical position. This stretcher is usually equipped with three or four straps to secure the casualty. However, this does not secure the casualty well enough to allow for any stretcher movement, which may be necessitated during the edge transition or for vertical positioning. Therefore, the casualty

Figure 74: Casualty secured in a bucket stretcher, rigged horizontally and showing both the main and safety lines.

Figure 75: Kong Lecco stretcher rigged horizontally.

Figure 76: The SAR Alpine stretcher rigged horizontally.

Figure 77: SKED stretcher rigged vertically.

must be secured further using rope or straps. This can be done using both internal and external lashing.

The Lecco stretcher (Figure 75) by KONG is a specialized stretcher intended for technical rescue. It is stored dismantled in a back-pack for ease of carrying and needs about five minutes to assemble and check properly. The Lecco package includes a variety of set-ups and straps that enable the stretcher to be used in both horizontal and vertical positions. For the latter situation the Lecco has both an external and an internal restraint system.

The internal system is made of strategically placed straps forming a harness type lashing. The external lashing secures the complete package inside the external shell of the stretcher, which protects the casualty against the elements. All connection points in the lashings system are construed of plastic buckles. Therefore, these buckles need to be checked regularly before and after every use to ensure that each buckle is able to function securely.

The Alpine stretcher (Figure 76) by SAR Products is another versatile stretcher intended for all types of rope rescue. This stretcher is hinged from the middle to facilitate carrying on the rescuer's back, when closed. The stretcher may also be divided into two for ease of carrying. The Alpine comes with an integrated casualty restraint system, however, it is best to secure the casualty further with a harness to prevent slippage during vertical operation.

The SKED (Figure 77) is a very useful stretcher to find among the equipment of the rescue team. It is a very compact and practical stretcher and can be used in a variety of situations. The SKED does not have a built-in casualty restraining system and this has to be done using rope and a spinal board. For a secure restraint in a SKED it is important that the rescuers adhere to the instructions of the manufacturer.

Rigging a stretcher

The first responder should always accompany a stretcher carrying a live casualty during a rescue operation. The first responder shall monitor the casualty during the transition onto the rope and assist in complicated recoveries on rough terrain and overhangs to awkward edge transitions. It is important that the stretcher and the first responder are connected to the system independently from each other so that at any one point the first responder may get himself released from the system. It is also important for the first responder to have a dynamic system rigged up with a simple mechanical

Figure 78: Two-point horizontal rigging shown on a basket stretcher.

advantage of 3:1 or 4:1. This could support the rescuer to adjust his/her relative position below or above the stretcher as necessary.

The horizontal or vertical position of the stretcher dictates the length of the dynamic rope system necessary to the rescuer. When the stretcher is in a horizontal position the first responder has to move from underneath the stretcher to above the stretcher which should require a maximum of one metre. However, if the stretcher is in the vertical position, the first responder has to be able to travel the whole length of the stretcher, from below the stretcher to completely above it, which could require a maximum distance of 2.5 m. In view that a stretcher's position may change depending on the exigencies of the situation, the responder shall always carry enough rope length for this dynamic system. It is essential that the safety line for the rescuer remains active at all times during travel and is not by-passed in any way.

The type of rigging applied to any of these stretchers depends substantially on the nature of the terrain and the state of the casualty rather than the stretcher itself. It is true that all stretchers are supplied with different straps and systems of attachments, but the team leader needs to be conversant with improvised methods that apply to all stretchers available to the team through continuous team training. Irrespective of the type of rigging, the principles remain the same for the various rigging types on the different stretchers, as long as all safety precautions are considered.

A single point rigging in the horizontal position is usually done with the head slightly tilted upwards. In this case, both the main line and the safety line may be attached to the centre point utilizing a small rigging plate (Figures 74–76). Whilst both the main line and the safety line are connected to the topside of the rigging plate via separate carabiners, the stretcher is connected using a separate carabiner to the lower side of the rigging plate. The first responder is then connected via another separate carabiner to another connection point on the lower side of the rigging plate. This ensures that the first responder and the stretcher are separately connected to the hauling system and therefore can be detached from it independently and easily.

The double point horizontal rigging (Figure 78) system requires that the hauling lines are connected to both ends of the stretcher while keeping the position of the stretcher with the head slightly tilted upwards. Both lines are to be backed up by safety lines. This system can also accommodate two first responders assisting on the stretcher. This is ideal when the rescue is in a high angle scenario over rough terrain and various obstacles are in the way. If only one responder is needed, then the responder should be positioned at the head of the casualty. The rigging of each system should be similar as for the horizontal rigging.

When using two hauling lines the rope technicians can vary the angle of the stretcher as needed. When a horizontal lift with two separate points is opted for, the two main lines can still be rigged up into a single complex mechanical advantage system. This depends not only on the requirements dictated by the terrain and the state of the casualty, but also by the number of rescue personnel available and their competencies.

In vertical rigging, stretchers are hauled through a single point attachment (Figure 77) unless otherwise specified due to limitations of the system or weight constraint reasons such as heavy loads. However, where a single point attachment is used, then a mirrored system approach is highly recommended, utilizing both the main line and the safety line to haul. In a vertical set-up, it is important that the first responder is able to change his position from the bottommost part of the stretcher to the topmost part. This is essential especially during edge transition and or confined space recovery.

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4 WATER & FLOOD RESCUE

Serve On (UK)

Introduction

Incidents involving water, most notably flooding and swift water, are on the increase.[1] Buildings in locations that are more prone to be affected by flooding, combined with extreme weather events, make it highly likely that rescue teams will be called upon to respond to these challenging and often highly dangerous events.

The aim of this chapter is to provide an awareness of water and flood rescue, starting with terminology and hazards associated with both flowing water and flooding, before moving on to highlight training requirements for the rescuers, working zones in an incident site and required personal protective equipment (PPE). Rescue priorities are covered briefly before introducing the stages of a rescue operation, casualty status and the rescue formula (an algorithm to help select the safest rescue option that will lead to a successful rescue operation). Basic knowledge on lines and knots, self-rescue techniques and communications are then followed by injuries, illnesses and medical conditions, a method for judging the likelihood of survival of the casualties, command and control and finally looking at other considerations related to water rescue.

Flowing water: terminology and associated hazards

Flowing water is powerful, predictable and relentless making water operations potentially very hazardous. It is commonly understood that fast flowing water can sweep people and vehicles away and the risk of this increases with increasing speed and depth of water. However, with training and experience, the predictable movement of water will allow rescuers to 'read' the water, identifying hazards and features. Flowing water will continuously apply force, unlike seawater, which breaks into waves.

Identifying hazards and understanding hydrology (the study of water behaviour) are two key assets that the volunteer needs to be able to take the most appropriate actions when conducting water and flood rescue. Thus, the rescuer needs to have knowledge of how flowing water behaves, as well as recognising the potential hazards. Knowing the terminology enables the volunteer to communicate effectively and efficiently during rescue operations. For the purpose of this manual, considering that it is principally intended for new rescue volunteers, the focus will be on terminology rather than going in depth into the study of water behaviour. The following is a list of basic terminology as well as associated hazards which would generally be explained further during actual rescue training by a competent instructor.

Upstream: Looking toward the source of the river (water flowing towards you – Figure 1).

Downstream: Looking toward the sea (water flowing away from you) (Figure 1).

River Left: The left hand side of the river when looking downstream (Figure 1).

River Right: The right hand side of the river when looking downstream (Figure 1).

Laminar flow: Water does not travel at a uniform speed. Different levels of friction cause water to move at different rates within the whole body of water. The

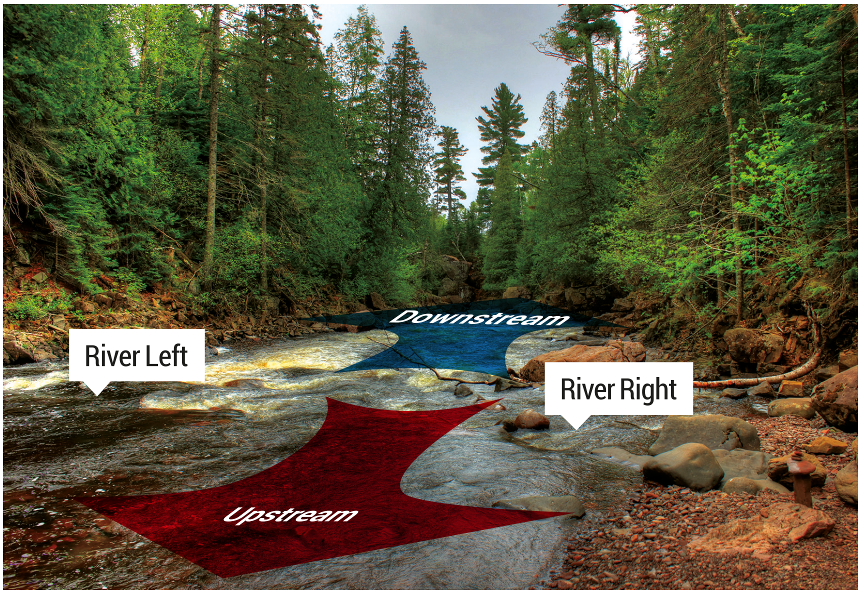

Figure 1: River terminology

water flow is slower when close to riverbanks and the riverbed, which cause the greatest friction.

Helical flow: The circular motion of water along banks, especially steep sided or man-made banks, caused by pronounced differences in the laminar flow. The helical flow may push debris and people back into the main laminar flow.

Current vector: Water does not curve with the actual line of the riverbank, rain or water course. Instead water travels in straight lines until an object such as the riverbank or boulder obstruction causes it to change course. Therefore water travels in a series of zigzags rather than moving in smooth 'S' shapes.

Siphons: When water is squeezed between the gaps formed by solid objects obstructing the flow (such as boulders or a vehicle), a powerful local flow of water is formed. This is called a siphon, and may pull a person underneath the water due to the force of the water. If the gap is not large enough, the person will be trapped there.

Strainers and sieves: Strainers and sieves are obstructions in the water, either natural or man-made, through which water can pass but larger objects (e.g. humans) do not. Similar to siphons, water passes through with a greater force, pulling a person or other objects. However due to the size of the gaps, persons or objects will not pass through and are entrapped there. These obstructions can include tree branches or roots, fences and street furniture. The difference between strainers and sieves is effectively in the size of the gaps, and therefore

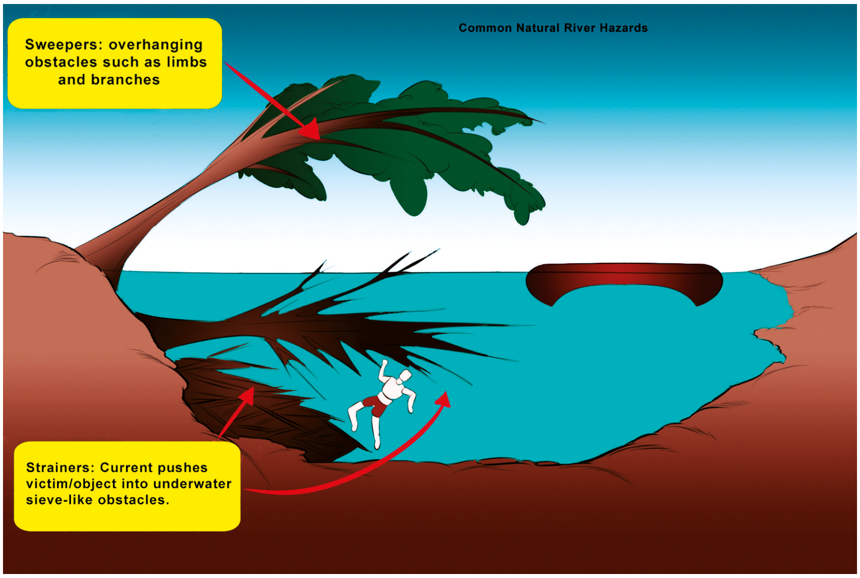

Figure 2: Strainers and Sweepers

the size of objects that can pass through (Figure 2).

Sweepers: Sweepers are objects which may cause obstructions at the surface of the water. An example of this is a tree branch, hanging low over the water. This may block a person floating in the water, who may be held there by the force of the water and may even be pulled underneath the surface (Figure 2).

Unstable vehicles: When small vehicles such as cars are caught in deep or fast-moving water, they may become unstable and could be swept away creating hazardous conditions. Meanwhile larger vehicles such as trucks and tractors may remain in place due to their mass. Heavy vehicles create barriers to the water flow, thus forming siphons, sieves or weir effects, all of which are potential hazards to rescuers.

Weirs and recirculating hydraulics: Changes in the level of the water (weir) cause the water to recirculate beneath the surface, because once the water falling down from a higher level hits the bottom some of it is forced upwards and backwards (upstream), forming a spiral current. Here water starts flowing upstream before starting to sink again. In this area, any floating person cannot continue moving downstream (stopper effect), but will be forced under water and into the recirculating current, leading to drowning (Figure 3).

Boil line: As explained in the weir and associated recirculating hydraulic above, after falling down from the weir and hitting the bottom, some of the water will be forced upwards and backwards, while the rest will continue flowing downstream (Figure 3). This delineation point is called the boil line because water at the surface will look like it is 'boiling' (Figure 4). If a person or a boat cross a boil

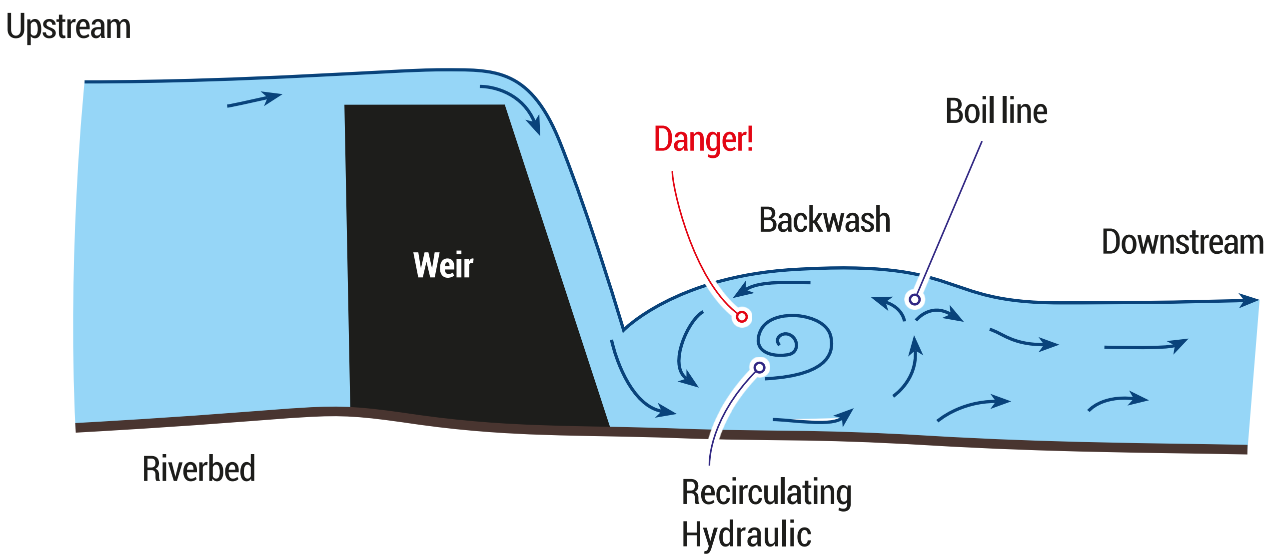

Figure 3: Weir, recirculating hydraulic and boil line

line, they will be pulled down into the recirculating hydraulic.

Cushion wave: A cushion wave is created when water hits a solid obstruction and is initially forced upward before passing around the sides. This may serve an indication that an obstruction such as a rock or boulder is present in the water.

Standing wave: A standing wave occurs when an object beneath the surface creates a disturbance/wave as water passes over it. To a person outside of the water, this looks like a wave permanently fixed in one place (hence the term standing wave) and indicates the presence of obstacles below the surface level.

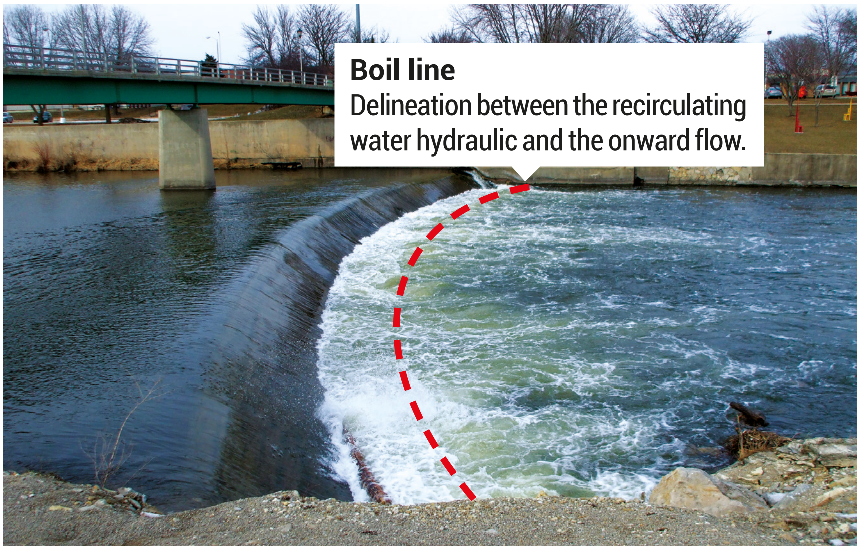

Figure 4: Boil line

Undercuts: Undercuts are hollowed out sections of the riverbank, caused by water erosion. Since water flows in a relatively straight line and changes direction on hitting an object (such as the riverbank), the force of the water will erode soil or rock at the area where it hits, forming a cave-like shape. These undercuts are often hidden from view by the water itself and may collapse without warning. Persons standing on the edge of a riverbank need to pay particular attention to these.

Eddies: An eddy is an area of low pressure behind an object surrounded by flowing water. In the immediate area behind the object the water flows upstream, slowing down. Consequently the water will be relatively calmer compared to the rest of the water flowing downstream. Thus, eddies may offer safe areas where a casualty or even rescuers may swim to, in order to rest and wait for help.

Eddy fence/line: This is a separation line between the main flow of water and the low-pressure eddy.

Upstream V: This is a disturbance in water caused by a single object, creating a 'V' shape in the water, with the convergence point being upstream (at the object). This can give an indication of the location of the object which may be beneath the surface.

Downstream V: This is a disturbance in the water caused by two objects spaced apart from each other. The respective objects will each form one side of the 'V' shape that converges downstream. This gives an indication of the location of objects which may be beneath the surface.

Fishing lure effect: Once an object is anchored or pinned by the force of the water flowing around or over it, that object will be driven beneath the surface by the flow of the water. If a casualty is being pulled through the water on a rescue line, the casualty will be pulled beneath the surface similar to a fishing lure or a float that sinks as it is reeled in.

Flooding: terminology, stages and associated hazards

Flooding is treated somewhat differently to flowing water primarily due to the area affected as well as due to the rate of movement of water to be expected. Flowing water is normally confined to a river path, where the rate of flow is significant such that it may sweep away persons or objects. Flood water normally affects a much larger area, while the flow rate is generally low (although certain urban features such as concrete slopes may cause rapid localised water flow). Vehicles and objects may still become unstable if they start to float, depending on how deep the flood water becomes. The following briefly introduce terms used to describe different types and causes of floods.[2]

Fluvial flooding: This occurs when a river overtops its banks and spills into surrounding areas. This may happen some distance from the area of original rainfall, and may be aggravated by high tides or storm surges, as rivers will be unable to flow freely into the sea.

Pluvial flooding: When the volume of rain over a period of time exceeds the drainage capacity of an area, pluvial flooding will occur. Previous levels of ground saturation and the porosity of the soil can worsen the effects. Sewers will often flood at this time due to the high levels of water trying to enter and flow through them, coupled with the lack of areas available for them to drain into.

Inundation: Coastal flooding with high tides combined with a low atmospheric pressure and wind direction will significantly raise sea levels, overtopping defences and flooding land.

Ground water flooding: Where the local water table level rises above ground level due to the effects of prolonged periods of heavy or persistent rainfall, water finds its way to the surface and floods the area.

Reservoir failure: This may be as a result of excess water levels, poor construction or malicious intent, where some of the water normally held up in the reservoir flows out and floods areas downstream. If the failure is sudden and catastrophic, the sudden flow of a big quantity of water will further add to the damage and danger caused by flooding.

Tsunamis: These are gigantic waves caused by underwater seismic events (earthquakes) which put a lot of energy into the water. These waves can travel great distances, increasing in height as they approach shallower waters near the coasts. Low-lying coastal areas and estuaries will be at great risk of destruction, flooding and loss of life. Tsunami waves may reach shores very far from the location of the original earthquake, so any coastal area could be at a threat, even if it is not in an area normally affected by earthquakes. Depending on the coastal topography, the water may travel quite a long way inland.

In addition to the terminology above, describing the different types of flooding, it is opportune to mention stages of a flooding incident, as defined in the DEFRA Concept of Operations.[3] This is being presented to give an appreciation of the different resource requirements during a flooding incident.

1. **Pre-flooding:** This is the stage where significant rain is being forecasted, particularly in flood-prone areas. Consequently, the authorities start to prepare for any eventual assistance that will be needed in these areas. The responsible emergency agency will start planning and assigning available resources where they will be needed

most. In the pre-flooding phase, volunteers are put on standby and are instructed to prepare their equipment for possible deployment.

2. **Flash flood:** At this stage, there is a rapid rise of fast flowing waters due to sudden heavy rain, presenting a high risk environment for casualties and rescuers. In urban environments, flash floods may sweep away vehicles with persons entrapped inside them. Due to the fast flowing water, this stage may require the most urgent rescue interventions, especially if persons are entrapped in vehicles.
3. **Wide area/lateral expansion:** Where rivers burst their banks or the sea overtops sea defences, there will be wide area flooding, possibly leading to the lower levels of houses being submerged under water. Work may last several days and many evacuations take place. This phase is resource intensive due to the large number of people affected. At this stage, authorities are most likely to involve and request the assistance of volunteers as the full time resources start to be overwhelmed.
4. **Recovery:** This follows the end of the rescue phase, marked by the return of population to the area. Although the water levels start to recede, hazardous material may still be present, deposited by flood waters. Repair to damaged buildings and infrastructure starts, aiming at the restoration of normal services as soon as possible.

A rescuer should consider a series of hazards associated with flooding that could influence themselves as well as the victims. One of the most common hazards is immersion into water, which may lead to drowning if a person is not able to reach the surface. Weather conditions may lead to heat exhaustion due to prolonged operations while working in full PPE, or hypothermia in case of prolonged exposure to cold weather or water. Bad weather may restrict visibility hiding other potential hazards, while also increasing the possibility of a rapid, unnoticed rise in water level caused by rainfall in a remote area reaching an incident site where rescuers are already operating.

Another characteristic of a flooding incident is that the effect is prolonged, leading to lengthy operations, frequently going on through the night. Night time operations increase hazards significantly due to lack of visibility. Scene lighting may be used, but careful placement is necessary as otherwise new hazards are caused due to blinding. Personal lighting for the rescuers needs to be helmet mounted, freeing the hands. Keeping track of other rescuers and equipment position can be tricky, but glow sticks may be used effectively. Different colours may also help to distinguish between different roles of rescuers, following UK standard colours for water rescue as defined in the DEFRA concept of operations:[4]

- Red – Water Rescue Technician or Rescue Boat Operator
- Yellow – Water Rescue First Responder
- Green – Rescue Throw Ropes (Equipment).

During flooding it is possible for hazardous material to find its way into the water. This could be biological or chemical and requires proper protective clothing to be worn to avoid contamination, as well as proper procedures for decontamination of clothes and equipment once out of the water. Other hazards present in the water include debris in the water as well as dangerous animals or insects, especially when rescuers are assisting in a foreign country that may be prone to such animals or insects. However one must keep in mind that even domestic animals may become aggressive if scared or panicked.

Flood water easily hides unstable, uneven or slippery surfaces that may cause trips and falls. In urban settings, drain covers may be lifted by the force of water, and once covered by water, it is possible for someone to become entrapped in the uncovered manhole. Open storm water drains and sluice gates (a sliding gate used to control the flow of water) may create powerful local water flows (siphons, described further above) which may pull a person through or entrap them under water. Power lines, gas leaks and chemical containers all add further hazards.

Other hazards associated with the rescue operation itself include panicking casualties, who may behave irrationally putting the rescuers and themselves in further danger and hazards associated with lifting and carrying people and heavy equipment. If helicopter operations are employed in the rescue, downdrafts could blow rescuers or casualties into the water. The rotors can be lethal if they strike a person, not to mention catastrophic for the helicopter itself if an object is hit, putting in danger the crew and other people in close proximity. Static charge from the helicopter can also injure a person. It is imperative that correct procedures by properly trained personnel are employed and the instructions of the crew need to be strictly followed.

Training requirements, working zones and PPE

The Department of Environment, Food and Rural Affairs (DEFRA) of the United Kingdom has published a document '*Flood Rescue Concept of Operations*' in which there are defined six distinct and established training modules in water rescue.[5] For the purposes of this manual and the level at which new rescuers are expected to operate, only levels one to three are explained in some detail. The other modules are mentioned for the sake of completeness. These six modules are the following:

Level 1: Personnel trained at this level are meant to achieve 'Water Awareness'. Training includes General Water Safety awareness and basic land based rescue techniques, covering water related hazard and risks, safe working and how to conduct land based operations in support of rescue teams.

Level 2: Rescuers trained at this level achieve the 'Water First Responder' qualification. Training covers (assuming Level 1 having already been achieved) working safely in and near water using land based and wading techniques. The Level 2 rescuer will also be capable of self-rescue in flowing water.

Level 3: This level of training leads to the 'Water Rescue Technician' qualification. The training includes specialist rescue operations involving dynamic entry into swift flowing water and the use of specialist water equipment and rescue lines to effect rescues from hazardous water environments.

Level 4: This training prepares the 'Water Rescue Boat Operator' to safely perform rescue boat operations in swift and flood water.

Level 5: This level involves training relevant to a 'Water Incident Manager'.

Level 6: The highest level is that of 'Subject Matter Advisor'. Personnel trained to this level are able to provide tactical advice during a flood or water rescue incident.

Rescuers that are involved in water rescue activities should have demonstrated competence in the corresponding water response levels defined above. All water rescuers must be able to swim, be confident in water, be disciplined and have a level of fitness appropriate for the rigour of the task they will accomplish. General rescuer fitness is mentioned in Chapter 1 – Basic Rescue.

The DEFRA '*Flood Rescue Concept of Operations*' and the Fire Rescue Service (UKFRS) '*National Operational Guidance Programme – Water rescue and Flooding*' both provide useful guidelines for anyone providing water and flood rescue service.[6] Among these guidelines, a method of separating the incident site into zones is proposed. This is done to enable effective command and control as well as enhance safety during water incidents. The operational area is divided into 3 different zones, namely the Cold Zone, the Warm Zone and the Hot Zone (Figure 5). As one moves closer to the water line,

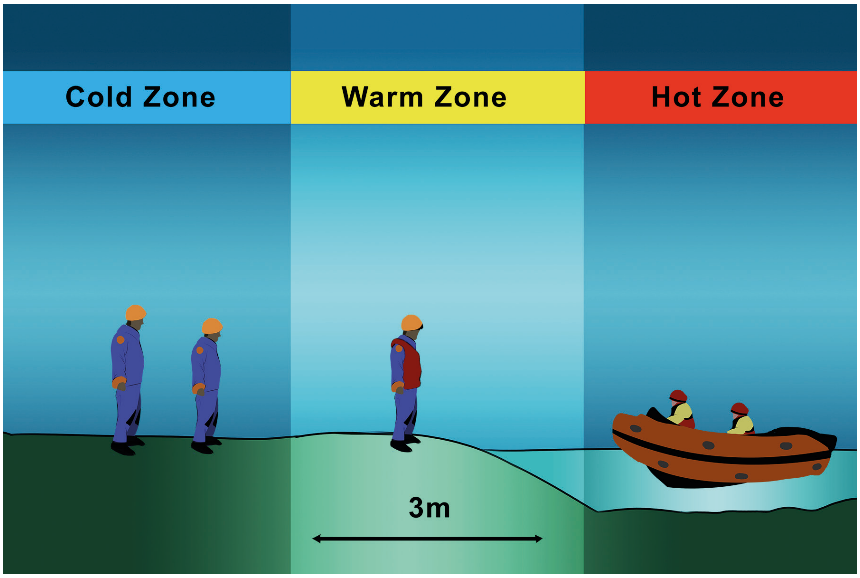

Figure 5: Working zones

Helmet: Must be specific for water rescue, colour depending on the training level i.e.: yellow = 1st responder, red = technician, black = instructor

Personal flotation device: Must conform to ISO 12402-6:2006 or equivalent, fit properly as not to ride up when in the water, should have a rear attachment for the quick release cows-tail system, provide some insulation and impact protection and should not limit arm movement. Equipment such as knives and whistles can be attached to the exterior. Pockets can contain useful items like carabiners and slings.

Lifejacket light: C-Strobe ™ H2O or light stick according to team preference.

Dry suit: Should keep the wearer dry and warm, provide wind protection, ease of movement and protection from water contaminants. Regular maintenance is required. Collars and cuffs can either be latex or neoprene.

Throw bag and belt: Come in various lengths. Quick release belt makes deploying easier.

Gloves: Full neoprene gloves provide best protection from cold and sharp objects. Wearing lightweight plastic gloves underneath provides best hygiene protection.

Boots: Need to be canyoning or scrambling type shoes to provide good grip on wet surfaces. Thick-soled wetsuit boots are also preferable. Boots with laces may cause an entrapment risk, so care should be taken.

Other considerations:

Base layers: Thermal one or two piece, lightweight or neoprene depending on environmental conditions.

Skull cap: Neoprene gives extra thermal protection.

Shin pads: Normal sports shin pads worn under socks can provide added impact protection.

Impact protection shorts: help protect coccyx against impact injuries.

Figure 6: Full water rescue PPE is required to enter the water. A thermal layer may be worn underneath in cold conditions as required.

the risk level increases. Therefore by defining and controlling who may enter these zones, what level of training they require and what protective equipment they need to use, the safety at the incident site may be adequately managed. A more thorough description of these zones is the following:

The **Cold Zone** is the furthest from the water line and is an area about 3 metres away from the beginning of the warm zone area. In the cold zone the rescuers are required to wear the regular PPE and uniform. Activities here will normally be associated with support work such as providing equipment. Bystanders should not be allowed to proceed beyond the cold zone.

The **Warm Zone** is normally 3m from the edge of the hot zone. However, there may be cases when the warm zone is more than 3m from the water's edge, depending on the terrain and on risks present in the hot zone. For example a steep slippery bank may result in a slip or fall into the water so, following a Dynamic Risk Assessment (DRA), the start of the warm zone may need to be extended beyond 3m from the waterline, as necessary. This zone requires that the volunteers wear at least a Personal Flotation Device (PFD) and a helmet. Also, operatives need to be trained to at least DEFRA level 1 (Water Awareness Operative) to safely enter this area. Operations here will be in direct support of rescuers and/or providing upstream and downstream safety cover. No bystanders should be allowed in this zone.

The **Hot Zone** is the highest risk area due to the close proximity to the water line, as well as due to potential rescue work in the water itself. The role of the rescuers in this area is to effect the rescues, sometimes requiring to enter the water to do so. The volunteers are required to be adequately trained before entering this area, at least to DEFRA level 2 (Water Rescue First Responder). Water Rescue First Responders may undertake only wading rescues in the water. Any operative needing to perform technical water rescue or searches will require a higher level of training as appropriate. Additionally all the volunteers should be wearing full water rescue PPE (Figure 6).

The Personal Protective Equipment (PPE) specific to water rescue is required for all personnel working in or near water. As mentioned before, specific PPE needed depends on the zone in which someone is working. Persons working in the Cold Zone only need regular PPE and their normal work wear for attending the incident, as they will be outside the hazard area (normally only a helmet and gloves are used). Those working in the Warm Zone need a minimum of a Personal Flotation Device (PFD) and a helmet in case they accidentally fall into the water. Any person working in the Hot Zone **MUST** be fully protected as shown in Figure 6.

Rescue priorities

In any water rescue situation it is important to ensure safety of all people involved as far as possible. A rescue team can only be effective if it is able to work without being adversely affected by the incident. Therefore the priorities should be:

1. Ensure one's own safety first.
2. Then the safety of other team members.
3. Next make sure any equipment to be used is secure and in working order.
4. Make sure bystanders are not at risk.
5. At this stage, the rescuers are finally ready to attend to the casualty.

Water incidents will often create a huge pressure to act. Urgency and emotion can push rescuers to act without properly assessing risk and drive the rescue, with potentially disastrous consequences. Failing to enforce these priorities will only increase the number of casualties. It is also important to emphasise the importance of the boat. If the craft's integrity is compromised, then the rescuers will be put in greater risk and the rescue operation will be compromised.

The stages of a rescue operation (LAST)

Water rescue, as with other rescue operations, can be summarised in four main stages. These stages include the following actions: Locate, Access, Stabilise and Transport, easily remembered as LAST. These actions are described in detail below:

Locate: find the casualties by carrying out interrogations of persons who may have witnessed the original event and use disciplined planned searches. These need to take into account the last known location of the victim, as well as the direction and force of flow of water, in order to identify potential areas where the victim could be found and the extent of the search area.

Access: find the best access route to reach the casualties and best locations of getting in and out of the water for the rescuers, while maintaining safe operations.

Stabilise: ensure that the casualty's condition is stabilised by providing first aid as required and briefing them on the rescue methods to be used to help recover them.

Transport: provide a safe and secure method of transportation for the casualty through the water, aiming to be as efficient and rapid as possible but at the same time avoiding to cause further injuries due to rough handling.

Casualty status

The status of the casualty needs to be taken into account while planning the rescue, as this may determine the available options for rescue. The context, the personality and also the surrounding circumstances all have an effect on the status of the casualty. For the purpose of this handbook the status of the casualty is defined into three broad groups:

1. **Normal:** The casualty is capable of rational thought, is able to make purposeful movement and able to follow simple instructions.
2. **Panic:** The casualty loses the capacity for rational thought, does not take appropriate actions for survival, makes non-purposeful movements (i.e. thrashing about) and may act aggressively.
3. **Counter Panic:** The casualty becomes withdrawn from the situation, may be totally unresponsive and just float, unable to help in any rescue attempt. This casualty has to be treated as unconscious, but may suddenly revert to 'panic'.

Rescue formula

Before a water rescue operation gets underway, the situation needs to be assessed to understand what options are available to carry out the rescue. A Dynamic Risk Assessment (DRA) will identify the risks and any control measures that need to be put in place to reduce the risk level to an acceptable one to keep the rescue operation. The outcome of the DRA may also influence what options are available for the rescuers because certain actions might be too risky and may have to be discarded. When considering the available options, it helps to list them in a sequence, starting with the safest action first. Going through each option one by one, the rescuer would then select the safest action that will lead to a successful rescue. The prioritised approach, as referenced in the DEFRA Concept of Operations, includes:[7]

Talking/shouting to the casualty: Is the casualty conscious? Are they capable of following instruction? Can they be encouraged to self-rescue or to help stabilise the situation (for example by giving them directions towards a safer location)? Note that this contact with the casualty should be ongoing, not just a first step.

Reaching out to the casualty: A wading pole, tree branch or inflated fire hose may be used to reach to the casualty without the rescuers needing to get into the water. One must ensure a safe footing first and whether there is a risk of being pulled into the water. Also one must consider how the casualty will be brought onto dry land.

Throwing a line: A rope, a lifebuoy or similar object may be thrown to the casualty so that, once they have a secure hold of it, they can be guided towards the shore and helped out of the water. The rescuer must also consider the area where the casualty will be guided to, as well as to decide the best technique to throw the line. The throwing techniques are over arm, under arm or side-arm and the technique chosen depends on the situation, with the over arm throw being the most accurate but having the shortest reach, while the under arm provides the longest reach but requires most space around the rescuer. It is important that the volunteer keeps talking to casualty and provide clear instructions during the whole operation.

Using wading techniques: This involves rescuers to enter the water and use wading techniques to move safely through the flowing water to reach the casualty. Since it involves entry into the water, it may potentially be a high-risk activity. Only trained rescuers that are properly equipped should be engaged in wading, and only after careful consideration of the rate of flow of the water. Different wading techniques can be pursued depending on the available number of rescuers, the strength and depth of the water (needs to be below knee level) as well as on the condition of the casualty. It is not intended to go into these techniques in this manual, as they require proper instruction and practice. When using wading techniques, a wading pole should be used to identify potential hazards underneath the water as well as to provide more stability.

Rowing: A boat (either crewed or un-crewed) can be guided to the casualty in the water. If the boat is crewed, the rescuers may row towards the casualty. Another option would be to tether and guide the boat by rescuers on land. An un-crewed boat is used only when the casualty is capable to get into the boat without any help. A boat is normally used when water is too deep for rescuers to wade through. If rescuers are on the boat during the rescue, this action is considered high risk as the boat may capsize and the rescuers find themselves in the water.

Towing: When the previous actions cannot be employed, a rescuer will be required to swim to the casualty who will then be towed back to safety. This involves a high level of risk and such action must only be undertaken by rescuers who are properly trained and equipped. The rescuer needs to employ 'aggressive' swimming techniques to reach the casualty, and may be tethered or untethered. The rescuer would then tow the casualty back to safety. Ideally the casualty is provided with a personal flotation device before being towed through the water, but this decision depends on the urgency and practicality of the situation.

Helicopter: The use of a helicopter is another alternative that could be used in water rescue. However, the deployment of a helicopter requires careful consideration due to the travel time needed, as well as other environmental factors that could impact the safety of the helicopter crew, other rescuers and the casualty. Proper communications with the crew and a good approach are key to the success of a helicopter rescue operation.

DO NOT GO: The decision of not pursuing an operation must always remain an option! The possible actions described above should be taken into account in the prescribed sequence and always

Do's	Do deploy upstream and downstream spotters (rescuers on the lookout for dangers and also to keep track of a casualty being carried by the flowing water). Do have multiple back up plans. Do apply the clean line principle and manage lines at all times. Do stay upstream of rope systems. Do enforce the priorities of rescue (self, team, equipment, bystander, casualty). Do a DRA and apply the rescue formula. Do avoid lone working.
Don'ts	Do not let urgency and emotion drive the rescue. Do not ever tie a rope around a rescuer who will enter the water (the rope is normally tied to the PFD in such a way that it may be released by the rescuer in an emergency). Do not tension a line at 90 degrees to the current vector. Do not go within 3m of the risk area without suitable training and full PPE. Do not put your feet down if swept away by the water – feet may get stuck under boulders or other obstructions, causing serious injury. Do not stand in the bights of lines.

Table 1: Desirable and undesirable actions during water rescue

plan a couple of steps ahead in order to foresee any dangers that may not be immediately evident. Assessing the situation and determining the priorities influences the level of risk that can be tolerated, depending if the situation is a rescue or a recovery (dead casualty) operation.

When engaging in a rescue operation there are a number of actions that a rescuer should or should not do. Table 1 indicates a series of recommendations that highlight desirable and undesirable actions.

Lines and knots

The use of lines[i] is essential in many aspects of water rescue. Although in DEFRA modules one and two these are less likely to be used, knowledge of relevant knots is advantageous in case rescuers may be supporting level three teams.[ii]

Figure 7: Clean line principle. The rescuer is braced to absorb the shock load, and a clean line has been adopted.

Before tying any knot the rescuer must understand the 'clean line principle'. This principle refers to the effort by rescuers to keep lines ready to be released easily and quickly. This means that as much as possible, a line should not have knots in it as otherwise, in an emergency, it will take too much time to undo the knot, or will even require the rope to be cut. The line needs to be easily released even while under tension. Furthermore, any unused part of the line should not be coiled or left lying carelessly on the ground as otherwise a person or object can easily be entangled. This is to ensure that rescuers are not put at risk of being trapped by a line resulting them being dragged into water, trapped within water or suffering injury through lines under tension cutting into them, for example strangling them if the line is caught around the neck. Figure 7 illustrates this principle.

One of the knots used in water rescue that demonstrates the clean line principle, is the 'No Knot' (Figure 8), also known as the tensionless hitch. This knot is used to secure a line, by wrapping it several times around an immobile object. The friction between the line and the object maintains the tension in the line without the rope slipping around the object. However, if the line needs to be removed quickly, no knots need to be untied. A line tied in this way could be still undone even while under tension. Tension can also be released slowly and in a controlled manner.

Figure 8: No Knot

Sometimes a line needs to be tensioned across a flow of water. In such cases, the line is set up at an angle to the flow of the water, not perpendicular. This is called a tension diagonal and is done such that the flow of water will naturally pull a person or equipment along the tensioned line downstream towards the intended destination point on the other side of the river. If the line had to be tensioned perpendicular to the flow of water, the person or equipment being pulled by the flowing water would exert a much greater force and the line could actually snap.

This skill is explained in detail in DEFRA module 3 training, however an awareness of the principle is still important to the new rescuer. A tension diagonal has two main uses, which are transportation and safety. A tension diagonal can be used to transport people and equipment from one river bank to another by providing a fixed line that can

i Line is another word for rope. It is more commonly used in maritime and water-related situations. However, the words rope and line may be used interchangeably throughout this manual.

ii Basic knots are covered in Chapter 1 – Basic Rescue.

support the movement of people and equipment passing through the body of water. Additionally a tension diagonal can be set up and used as downstream safety in case either the casualty slips past the intended rescue point, or rescuers themselves get swept away by the water. The tensioned line further downstream gives the possibility to the casualty or rescuer to hang on to it and even pull oneself towards the riverbank.

Self-rescue techniques

If a rescuer falls in to the water inadvertently, simple techniques can help keep them get back safely to the riverbank. First it is important that one does not panic and not attempt to stand up in the flowing water. Adopting the defensive swimming position (Figure 9) helps the rescuer to control better the situation. The aim of this position is that the rescuer is able to rest while at the same time is able to look towards the direction of travel, searching for the best place to exit the water. As shown in Figure 9, the defensive position involves that the rescuer stays on the back with the feet facing downstream and the head pointing in the direction of intended travel. Keeping the knees close to the surface and slightly bent will help the rescuer to fend off obstacles. Buttocks should be raised in order to avoid submerged objects, which may cause injury. Manoeuvring in the water involves positioning the body in a way that utilises the flow of the water to move in the intended direction. With feet still facing downstream the body is angled so that the head is pointing in the direction of intended travel. This is referred to as a ferry angle.

Figure 9: Defensive swimming position

On occasion the strength of the flow will not allow the rescuer to get back to the bank and an aggressive swimming technique may need to be used. Once a safe place from which to exit the water is identified, one must roll on to the front and employ an aggressive front crawl stroke to get to the bank. The head needs to be kept out of the water and maintain sight of the target. A ferry angle can also be used in an aggressive swimming position.

Communication signals

Water rescue operations are often conducted in noisy environments where it is difficult to communicate verbally so other signalling methods are used by the rescuers. These alternative communication protocols are defined in the DEFRA concept of operations.[8]

To quickly gain attention, rescuers use whistle signals. Whistle blasts often pierce prevalent ambient noise levels and having a series of particular signals that are understood by all may quickly convey safety critical information. These signals may be used by rescuers both in and out of the water and are summarised in table 2.

Similar to whistle signals, hand signals can be used to convey instructions or information to personnel in the water. When using these signals, one must always point to safety not towards the hazard, as otherwise a person in the water might erroneously move towards danger rather than safety. The following illustrations (Figures 10 to 14) show the hand signals used.

Figure 10: OK Signal. Used to confirm that the person is OK.

Figure 11: Stop

Figure 12: Move towards indicated direction

Figure 13: Distress Signal. Used to show that the person needs help/assistance.

Figure 14: Need medical assistance. This may also be used to request medical assistance for someone else, by using this signal and then pointing towards the casualty.

Injuries, illnesses and medical conditions

Persons requiring rescue from water, and in some cases even the rescuers, may need medical treatment for injuries or conditions caused by being immersed in water. Casualties of water incidents may also be affected by injuries from falling into the water or from being struck by objects whilst in the water by hypothermia, waterborne illnesses and in the worst cases drowning.

When a casualty is struck by an object while in the water, this may cause a number of injuries ranging from simple bruising to fractures, lacerations, concussion and possibly cervical spine injuries. Depending on the severity of the injuries sustained, care and proper casualty handling needs to be employed to prevent further injury. Furthermore, injuries such as fractures, concussions or cervical spine injuries may prevent a casualty from swimming to keep afloat, leading to drowning. Such cases require urgent rescue. A number of rescue techniques allow the rescuer to handle the casualty with cervical spine injuries while ensuring that the airway is not blocked. Some of these techniques include the vice grip, extended arms grip or the body hug techniques.[9] These techniques require a qualified instructor to teach them properly, followed by regular practice.

Another condition that frequently affects casualties in cold water is hypothermia. When the core body temperature drops below 35°C hypothermia sets in.[10] Hypothermia can be further classified as mild (core body temperature 32–35°C), moderate (core body temperature 28–32°C) or severe (core body temperature

Stop or attention towards signaller (1 blast)	
Attention to upstream or move upstream (2 blasts – may be followed by pointing or verbal instructions)	
Attention to downstream or move downstream (3 blasts – may be followed by pointing or verbal instructions)	
Emergency (3 blasts repeated)	(Repeated)

Table 2: Whistle signals used in water and flood rescue

below 28°C). Table 3 lists symptoms based on the core body temperature.

Water-related incidents are time critical as body heat may be lost 25 times more quickly in water than in air. Hypothermic casualties are at a great risk of going into ventricular fibrillation where the heart stops pumping blood causing a cardiac arrest. Consequently the rescuer would be required to resuscitate the victim. In order to minimise this, the casualty needs to be handled as carefully as possible. Defibrillation is less effective if the body temperature is less than 30°C. When facing a casualty exhibiting hypothermia symptoms, the rescuer must immediately call for help, should attempt to warm the casualty and most importantly should not stop the resuscitation process.

Another hazard linked with working in and around water is the exposure to harmful microorganisms including bacteria and viruses that cause waterborne illnesses particularly in flooding situations. These illnesses could cause gastro-intestinal disturbances while others may have more serious

Mild (32–35°C)	Moderate (28–32°C)	Severe (< 28°C)
Feeling Cold	Confusion	Shivering stops
Shivering	Loss of motor control	Completely altered mental state
Apathy	Slurred speech worsens	Unconsciousness
Amnesia	Decreased level of consciousness	Death
Slurred Speech	Shivering starts becoming less obvious	
Some loss of fine motor control		

Table 3: Hypothermia symptoms

consequences and could even be fatal. For instance, leptospirosis is a bacterial infection caused by the infected urine of animals getting into the water.[12] The bacteria enter the body through the mucous membranes of the nose, mouth or eyes and also from minor abrasions and cuts if they are not covered up. Initial symptoms usually appear after 3–4 days and are flu-like, including fever, shivering, headache, vomiting, muscle aches and loss of appetite. This can develop into organ failure, particularly the liver, which is termed 'Weil's disease'. Casualties can develop jaundice and in rare occasions death.

One should seek medical attention to treat leptospirosis with antibiotics. Anyone developing the early symptoms within 3–5 days from participation in water rescue needs to be seen by their GP and inform the doctor that they have recently been in the water. It is important to note that whenever rescuers have entered or been exposed to water proper decontamination must take place. The team leader must ensure that a decontamination plan is in place. Before entering the water all cuts and abrasions should be covered. Subsequently when leaving the water the rescuers should clean their hands and face with alcohol gel. This practice should take place before eating, drinking or smoking. Cleaning of PPE and other equipment should take place according to local guidelines and following the recommendations provided by the manufacturer for that particular equipment or clothing.

In the most unfortunate cases the casualties in water-related incidents may drown. In its publication 'Global Report on Drowning: Preventing a Leading Killer', the World Health Organisation defined 'drowning' as 'a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium'.[13] Drowning by submersion occurs when the entire body including the airway is under the liquid medium. Drowning by immersion refers to the body being under the liquid medium but not the head. Drowning occurs through a sequential chain of events that is shown in Figure 15.

The key thing to take from this is that cardiac arrest in drowning is caused by hypoxia, a lack of oxygen in the tissues. Unlike normal medical cardiac arrests, the guidelines for resuscitation of someone in cardiac arrest from drowning recommend to administer 5 rescue breaths. This can be done in the water by the rescuer using either mouth-to-mouth or mouth-to-nose techniques. Replacing the lack of oxygen is key in the successful resuscitation of the drowned casualty, so an early call to emergency services is vital, such that the casualty's airway can be secured as soon as possible, meaning that the casualty can be oxygenated properly.

Rescue vs Recovery

An incident manager will need to take a number of decisions including whether an operation will be a rescue or a body recovery. This decision will, in turn, influence

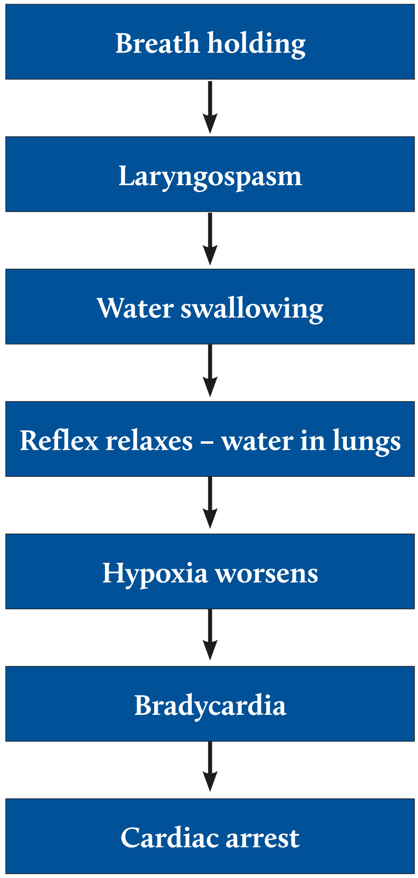

Figure 15: Drowning: The chain of events leading to cardiac arrest if the casualty is not rescued in time.

the strategy adopted, the urgency required and also the level of risk that will be tolerated during the operation. To help with such a decision in water-related incidents, a decision making model has been developed, based on the water temperature and the time elapsed since the casualty entered the water (Figure 16, adapted from Tipton and Golden).[14] This model, together with risk assessments, guides the commanding managers to determine the level of commitment they want their team to make. For instance the level of risk that may be tolerated depends on whether there is a chance of saving the casualty or if there is a high chance

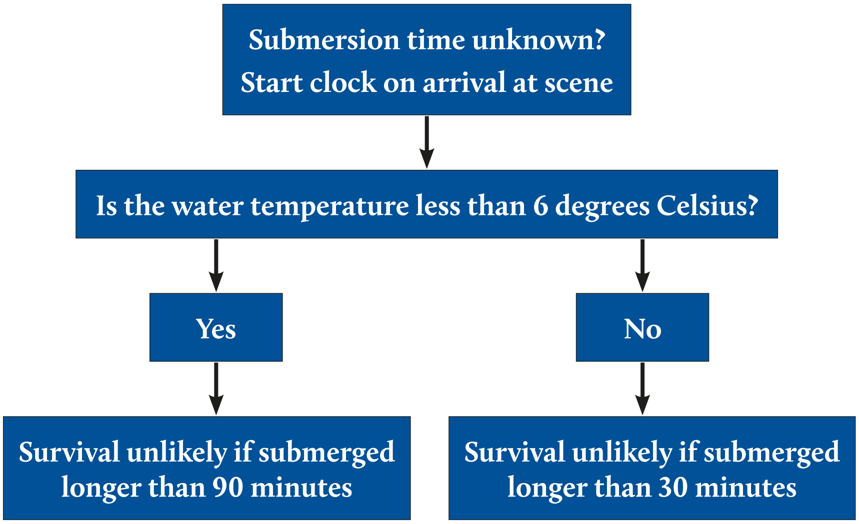

Figure 16: Rescue or Recovery? Tipton and Golden (2011) decision making model

that the casualty will not survive despite the rescue attempt.

Command and control in water incidents

Effective command and control needs to be exercised through established lines of communication and reporting structures.[iii] This requires a hierarchy of command based around the concept of a single Incident Commander (IC). The IC should limit the spans of control (the number of people they need to talk to) to manageable levels to maintain their situational awareness and concentrate on the key command tasks. It is common practice for team leaders and commanders for water-related events to wear white helmets while team members for first response wear yellow helmets.

Proper control of an incident can only be exercised through efficient communications that are established among all parties and follow pre-established protocols. The information passed must be strictly the amount necessary and relevant for effective working.

Other rescue considerations

Rescue from flooded areas involving vehicles in the water are normally tackled by trained rescuers (at least to DEFRA module 2 or higher) particularly if water is flowing. Other rescuers assisting from the riverbank should still be knowledgeable of the potential hazards to ensure valuable support to the rescue operations or as first responders.

Among the hazards associated with vehicles in the water, vehicles are likely to become unstable and get carried away by the flow, taking rescuers or casualties with them, or to become floating debris. In all cases, one should approach

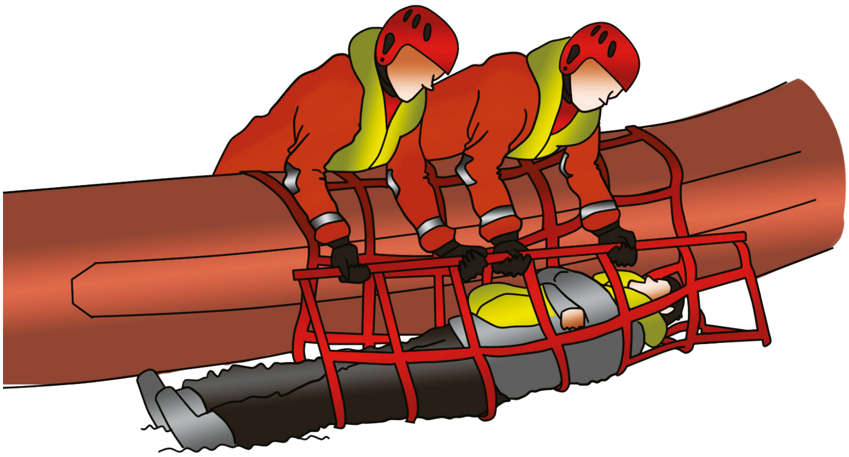

Figure 17: Jacob's cradle lift into a rescue boat

[iii] Further information may be found in Chapter 1 – Basic Rescue

with extreme caution, avoiding to approach from downstream and upstream and to be aware that vehicle buoyancy will increase as casualties are removed, making the vehicle more unstable. Casualties should be encouraged to get on top of the vehicle if possible. Once on top of the vehicle, a line can be thrown from the bank in order to secure them in case the vehicle suddenly floats away before it can be secured.

Another important consideration is the method of removing a casualty from cold water into a watercraft. The rescuers need to be aware of the effects of hydrostatic squeeze on the body of the casualty. Hydrostatic squeeze occurs when a casualty has been in the water for a long time.[15] The cold causes the peripheral veins to close down in order to channel blood to the body's core, attempting to keep the vital organs warm. As the water pressure squeezes the leg muscles, a seemingly normal blood pressure will be apparent due to the fact that all the blood is now in the core of the body. If the casualty is removed from the water vertically, the squeezing of the muscles is suddenly released, blood flows down to the legs aided by gravity and the blood pressure will drop rapidly, causing a possible loss of consciousness or, in worst-case scenarios, cardiac arrest and consequently can lead to death.

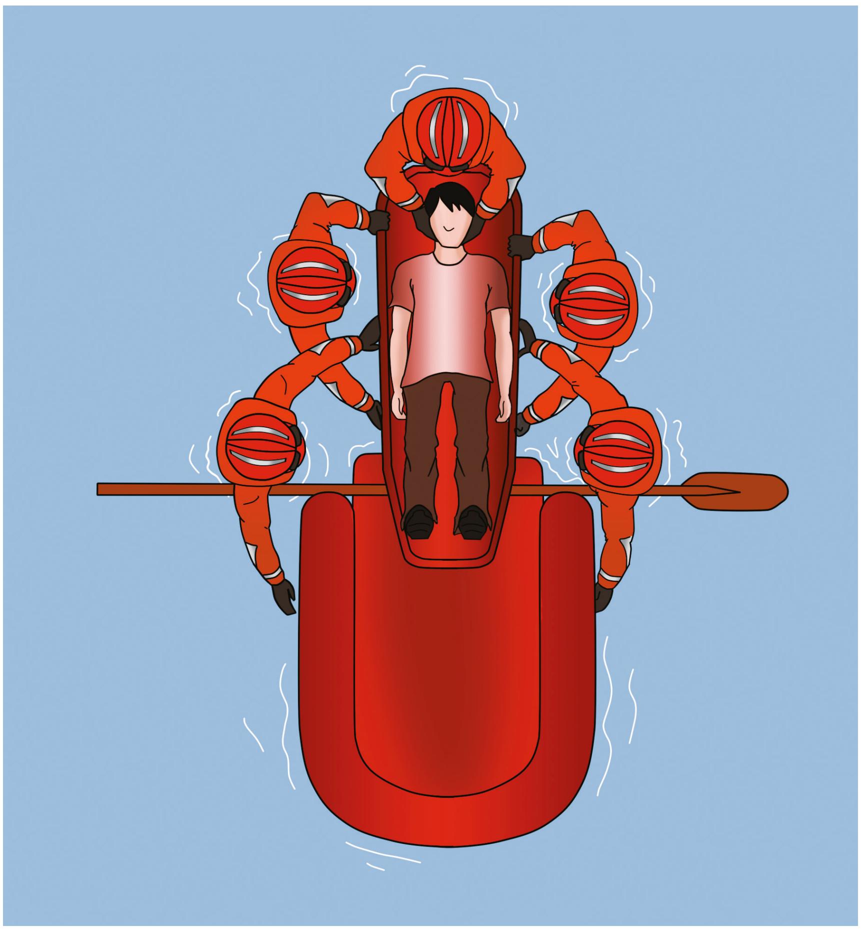

Figure 18: Egyptian roller

Ideally removal from cold water should be done with the casualty horizontal. There are a number of ways of achieving this. Figure 17 illustrates the use of the Jacob's Cradle style rescue. This technique entails that the rescuers roll the casualty onto the boat in a horizontal position. This can also be improvised by using two slings placed under the casualty's armpits and knees. Rolling the casualty into the boat necessitates two rescuers. Only appropriately trained and qualified rescuers can use this technique.

Another method of getting a casualty into a watercraft in a horizontal position is the Egyptian roller (Figure 18). When employing this technique the rescuers will use open-backed watercrafts such as rescue sleds. This method can be difficult to use in deep water. Thus, it is advisable to tow the casualty to shallower water before attempting this technique. The Egyptian roller entails that the casualty is first placed on a board. A paddle is then placed over the back of the craft and is used to reduce friction with the watercraft. After they control and stabilise the paddle, the rescuers nearer to the rear of the craft will place the paddle under their arms. In this way the weight of the casualty will lower the stern and the row will ease placing the casualty into the watercraft.

Another phenomenon that requires careful consideration is circum-rescue collapse.[16] When a casualty is involved in an incident, the stress of the situation causes the body to release hormones such as adrenalin, which in turn causes the heart to beat faster, thus increasing blood pressure. When help arrives, the casualty relaxes, such that adrenalin stops being released by the body, reducing the heart rate and causing a sudden drop in blood pressure, leading to collapse.

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5 WILDFIRE RESPONSE

Escola Portuguesa de Salvamento (Portugal)

Introduction

The aim of this chapter is to provide guidance to new rescue volunteers when responding to wildfires. This chapter starts by detailing the ways in which fires develop, the hazards associated with wildfires and provides an overview of firefighting equipment and tactics. Unless particular circumstances dictate alternative approaches, the advice and guidelines found in this chapter must be rigorously followed. Any deviation from the advice provided in this chapter must only be done following the completion of a suitable risk assessment completed by a person that has the knowledge and competence to weigh the potential risks of deviating from these guidelines. Firefighting teams must otherwise follow all procedures and work as directed by the operational team leaders and incident commanders. It is essential that all team members carrying out firefighting work are knowledgeable and familiar with the content of this chapter. Literature issued by the National Authority for Civil Protection (ANPC, Portugal) served as a general reference throughout this chapter.[1]

Wildfire

Fire has been part of nature since the world was created. It is one of the four fundamental elements and is essential for all life on earth. However, uncontrolled fires cause damages and may also put lives (both human and animal) at risk. Wildfires are normally associated with large scale fires affecting forests or countryside. 'A forest fire is, in essence, a reflection of fire behaviour. The development of a fire, the effects on soil and vegetation caused by the fire, and the difficulty to control it, all depend on the fire behaviour'.[2]

As shown in Figure 1, fire depend on the fundamental elements of fuel, oxygen and heat. In wildfires, the fuel charge may consist of grass, trees, dead leaves, branches and other foliage.

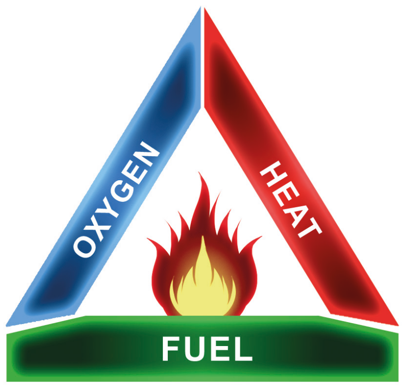

Figure 1: The Fire Triangle

Terminology

The following terms should be known by all firefighters to avoid confusion in the orders given by the team leaders and to facilitate communication during firefighting operations. These terms are also important so that firefighters and rescuers use common terminologies. The following are some terms used in relation to wildfire, and are illustrated in Figure 2:

Head: This is the area where the fire spreads with greatest intensity and is normally situated at the front of the fire.

Rear: This is the zone opposite the head. In this area the fire is at its least intensity but it can still progress in this direction.

Flank: This is the side between the head and the rear, taking into account the direction of fire progression.

Finger: This is part of a flank where the fire spreads with greater speed, causing that part of the flank to protrude out in the shape of a finger.

Pocket: This is an area of unburnt vegetation between the main flank and a finger. The finger may eventually turn back towards the flank, enclosing the pocket and leaving no escape to whoever might be inside the pocket.

Island: This is an area of vegetation that has not been burnt by the fire, which would already have passed.

Spot fire: This fire starts outside of the main wildfire perimeter due to sparks or embers carried by the wind.

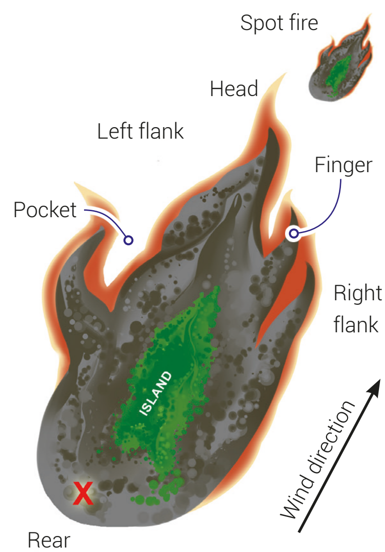

Figure 2: Wildfire terminology

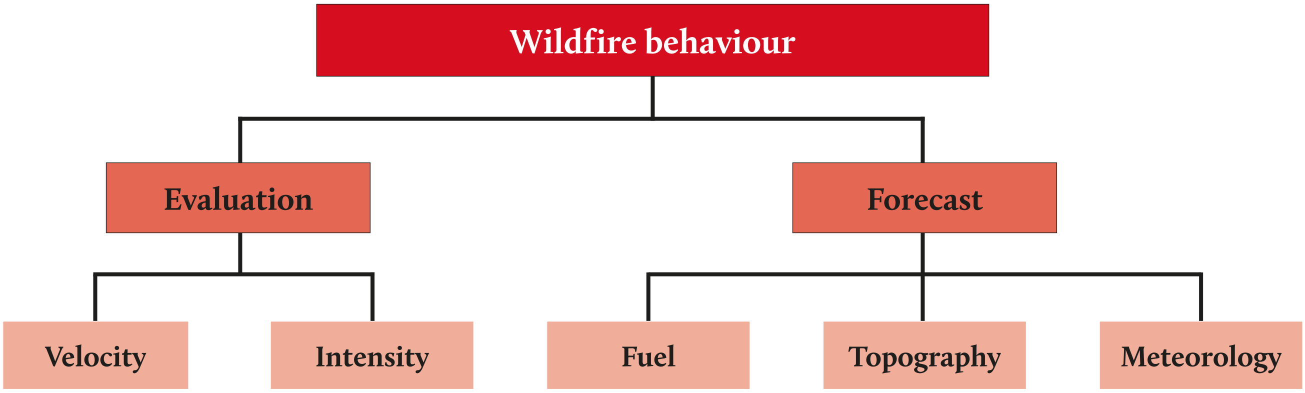

Figure 3: Fire behaviour analysis

Other terms used throughout this chapter (not shown in Figure 2) are defined below:

Anchor point: This is a part of the terrain without any combustible material, so that fire cannot sustain itself. Anchor points can be natural (for example mountains, rock outcrops or rivers), or can also be man-made (such as roads or paths).

Defence line: This refers to a path or strip of terrain where the firefighters remove anything combustible, reducing this path to bare soil. The defence line is also referred to as a 'discontinuity' in the fuel, and is intended to extinguish a fire once it reaches this defence line by starving it of fuel.

Fire line: This refers to the actual length of burning fuel, which forms a line of fire. The fire line can extend for several kilometres. This term may also be used in relation to firefighters working directly on the fire, who are said to be 'on the fire line'.

Tactical Fire: This is a firefighting technique where specially trained firefighters deliberately burn a part of the vegetation. The fire created by the firefighters is kept under control at all times. When the actual wildfire reaches these burnt areas, it will not have any more fuel to sustain itself and will be extinguished.

Wildfire behaviour

'By definition wildfire behaviour is how the fuel ignites, how the flames develop, how the fire grows and shows other features, determined by the interaction between the fuel, the weather conditions and the topography'.[2]

A good evaluation and a proper overall forecast of the fire behaviour is important in the planning of firefighting operations (Figure 3). The goal is to evaluate how the fire is likely to evolve, especially in terms of direction and speed. Understanding wildfire dynamics is a complex exercise because it involves the analysis of rapidly changing data but such evaluation determines the choice of tactics and manoeuvres.

The behaviour and intensity of wildfire depends on three critical factors: the fuel that feeds the fire, the meteorological conditions affecting the area and the topography of the terrain affected by the fire. Each of these three elements is further defined by three other criteria as explained in the triangle of wildfire depicted in Figure 4.

The **topography** is defined by the aspect, the slope and the size of the affected area. Aspect refers to characteristics like direction and shape with respect to the landscape. The direction that the slope faces determines the degree of exposure to the sun while shape refers to the relief of the terrain (for example valleys and gorges), which determines the flow of air currents within these terrain features. Size refers to the physical dimensions of the affected site, increasing the firefighting effort required as the size increases. The slope promotes the angle of approach of the flame to the fuel, increasing exposure to heat radiation. This increases the preheating speed, the ignition and consequently the intensity of the wildfire. If the fire spreads in the opposite direction to the slope, the effect is the opposite.

The inclination of a slope can be expressed either as a percentage or as an angle in degrees. The velocity of the fire increases almost exponentially with the increasing inclination of the slope, with the

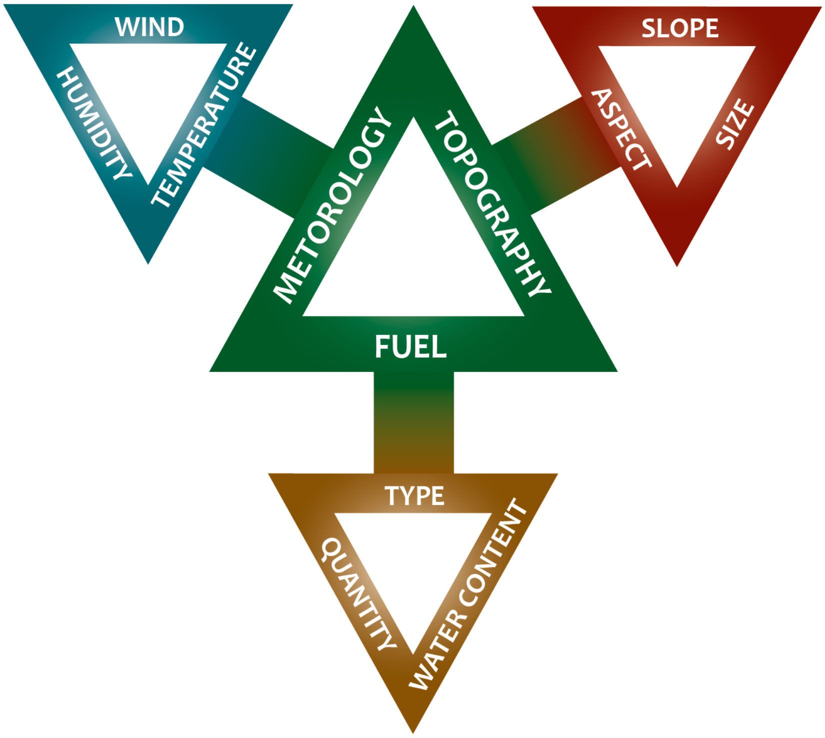

Figure 4: Factors affecting wildfire behaviour

speed doubling with every 10° increase in angle (Figure 5). Thus, firefighters should pay particular attention to steep slopes. Canyons and gorges can cause fires to accelerate rapidly from the foothills to the top creating very challenging scenarios due to their very steep slopes. In such circumstances, fires can reach very high speeds. This is referred to as an 'eruptive fire event'.

The **fuel** varies according to the type, quantity and amount of water content found in it. The type of fuel depends on the vegetation, because some species of trees burn with a higher intensity, as well as the presence of dead fuel (dead twigs, timber, etc.). The fuel charge (or fuel quantity, measured in tonne/hectare or kg/m^2) affects the burning time as well as the intensity. A lower water content will make the fuel more flammable and will sustain the fire for a longer time. The amount of fine dead fuel and its moisture content are two key aspects of wildfire behaviour. Dead fine fuel exists essentially on top of bushes, in foliage and tree cut waste, and makes up the surface fuels. Moisture can be affected by wind as well as the orientation of the terrain towards sunlight.

Meteorology, defined by humidity, wind and temperature, is undoubtedly the most important parameter in the assessment of fire hazard. When the humidity is low, materials are more susceptible to burning, increasing the likelihood of the fire spreading. The moisture content is directly related to the wind intensity and speed and is reflected in the weather risk index. This index reflects the probability of fire occurrence and spread potential. The wind provides oxygen to the fire and also 'pushes' the fire forward, increasing its velocity. Wind may also carry burning material to areas away from the main fire, starting spot fires. If the wind speed is greater than 30 km/h, the fire intensifies and spreads quickly. As the temperature increases, the fuel will ignite faster. In addition,

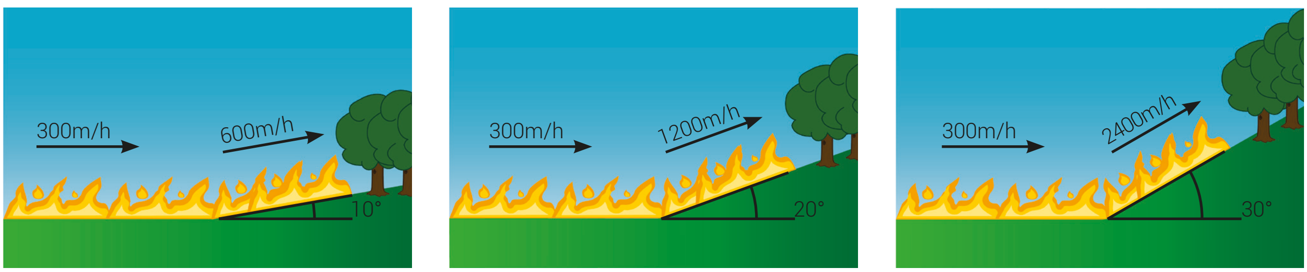

Figure 5: The effect of slope angle on fire velocity (Wind speed 10 km/h)

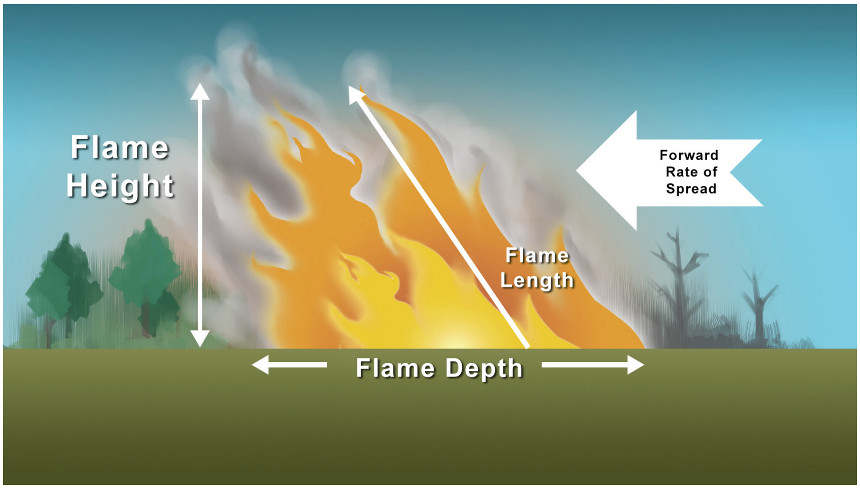

Figure 6: Elements of flame dynamics, looking at a cross-section view of the flame front

temperatures exceeding 30°C make the firefighting task more difficult.

Air movements have a close relationship with the topography and can vary widely due to their interaction with the surface. When observing how air movements affect wildfires, firefighters should consider the overall winds in the area, the changes in direction and intensity of the wind due to the effect of the topography, the thermal variations caused by the wildfire itself, the air movements related to valley breezes, mountains, land and sea, as well as the air movements produced by passing aircrafts. The overall wind and the topography remain the most important factors in the spread of fire, while smoke is a good indicator of the direction of air movements.

The effects of changes in air masses are harder to predict. Nevertheless, combining the wind forecast with good field observation helps to anticipate the development of wildfire. This allows commanders to change and adapt firefighting manoeuvres, avoiding dangers that would put the team in critical situations. Besides safeguarding the safety of the team, forecasting fire behaviour also helps to identify fire-extinguishing opportunities.

The height of the flames makes it possible for team leaders to estimate the intensity of the fire and to decide the firefighting strategy that should be adopted by the team, after considering the flame analysis and interpretation guidance (Table 1).

When analysing the above-mentioned factors, the firefighter

Flame height, m	Fire features
< 1.0	These fires can usually be attacked, using hand tools. The limitation to control them can be the smoke and the speed of progress (if it is too high). A line of defence made by hand may stop the fire.
1 < 2.5	Most times, these fires are too intense for a direct attack with hand tools at the fire front. For successful direct firefighting, the support of water, fire retardants and bulldozers (with endless tracks system) is essential.
2.5 < 3.5	These fires can present serious control problems at the front, and firefighting will probably not be effective. Firefighting with the aid of aircraft might have some success.
> 3.5	High probability of fire on treetops and secondary outbreaks in which the efforts of controlling the flame front are not successful.

Table 1: Flame analysis and interpretation, in terms of flame height and typical fire features.[3]

DANGER!			
Humidity	**Wind**	**Temperature**	**Slope**
< 30 %	> 30 km/h	> 30°C	> 30°

Table 2: The 'Rule of 30'

can predict better how a wildfire will behave. This knowledge helps incident commanders to plan better their operations, ensuring efficiency and safety. The 'rule of 30' (Table 2) helps firefighters remember that the danger of wildfire increases greatly whenever the humidity is less than 30%, the wind speed is more than 30km/h, the temperature is more than 30°C and/or the slope is more than 30°.

Fire extinguishing strategies

All firefighting actions must take into account the plans of other teams involved in the firefighting operation in order to strive for the same overall goal, controlling and extinguishing the wildfires. Wildfires may present various levels of complexity. Thus, sharing knowledge on the situation such as the size, position and behaviour of the fire is essential for the analysis and implementation of the firefighting strategy. Without knowledge and understanding of these factors, it is very difficult to create an effective plan. To extinguish a fire, one should act upon one or more of the basic elements forming the 'fire triangle' that together cause the fire (Figure 7). The following sections describe the three extinguishing strategies.

No intervention

This strategy consists of letting the wildfire burn until it reaches an existing barrier that is enough to contain the fire. As the fire reaches this barrier, it will eventually extinguish on its own once it consumes the available fuel. Firefighters do not actively combat the fire but monitor its progress. Taking a defensive approach towards firefighting (by not fighting the fire) helps to keep the fire teams safe because some fires present behaviours that exceed the abilities of active firefighting tactics. Fighting wildfire presents high risks that cannot be completely prevented or controlled.

Direct fire attack

This approach (also known as direct firefighting) describes the progressive extinguishing of the line of fire, usually with the use of water, which is spread over the fuel that is sustaining the fire (Figure 8). This strategy is used in the majority of initial attacks and is highly effective when fire lines are less extensive. This strategy requires that teams go 'into' the wildfire and the resources required depend on the intensity of the fire. The benefits are a reduction of the burnt area and the speed of intervention. The

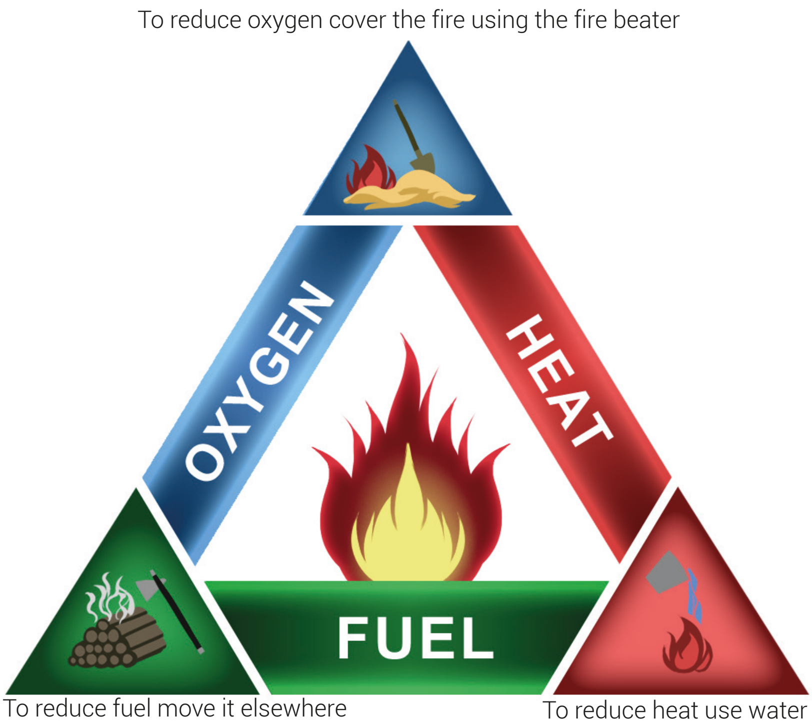

Figure 7: Extinguishing means

flame height (Figure 6 and Table 1) is a good indication that helps to evaluate what kind of resources are needed and if direct firefighting is feasible. The equipment for direct firefighting should only be used in very specific situations, where there is no possibility of using other means due to the intensity of the fire.

Water under pressure (from vehicles) loses much of its efficiency in high intensity fires. It is necessary to use considerable amounts of water to extinguish every metre of fire front without it re-igniting almost immediately. Thus, the progress in firefighting is rather slow. The heat makes it difficult for firefighters to stay near the fire front, even in the burnt area. Water released by aircraft usually aims to reduce the intensity of the fire to facilitate or enable intervention by firefighters on the ground. Direct firefighting may also serve to delay the fire front from progressing. Aircraft firefighting efficiency depends directly on good coordination and communication with ground firefighting teams.

Figure 8: Direct firefighting method – firefighters use water and hand tools to fight the fire directly.

Figure 9: Aerial and ground combined direct firefighting – aircraft drop water onto the fire while firefighters use hand tools to put out the fire.

Direct firefighting can be beneficial in stopping the fire from advancing. However, this firefighting technique should be done only after a very careful assessment of the risks, as this action exposes the firefighting teams to great risk, especially if there is no air support available for fire suppression or evacuation. Before using a direct firefighting technique, the firefighters should always consider the possibility of:

- Starting the firefighting by the flanks/sides.
- Waiting until the fire head changes behaviour due to the change of the slope, exposure to wind, fuel or land variation, avoiding the extension of the flanks.
- Fighting the fire from the rear of the flame, as it reduces firefighter exposure and makes it easier to accomplish the goal.

Note: This technique can be initiated by teams transported by helicopter into areas that are difficult to reach by vehicles. The firefighters would use hand tools while the helicopter would proceed to drop water onto the flames (Figure 9).

Indirect intervention

This strategy (also known as indirect firefighting) entails the establishment of firefighting defence lines using areas where there are natural discontinuities in the fuel or by creating the defence lines by removing the fuel (for example cutting grass and scraping the terrain to the soil – Figure 10). Even without interruption in the fuel, these defence lines can be created by using fire retardants or by using controlled fires set by experienced teams to burn some of the fuel in advance, thus creating a gap. These lines may also be, for example, a transition from a forest to a residential area, roads or forest tracks. In these situations, teams will strategically create the defence lines and wait for the wildfire to extinguish itself. This technique may be the best option in terms of safety as well as to minimise water use. This strategy also minimizes the risk that the fire reignites. Paths and roads are often used as defence lines.

When fuel is present on both sides of the firefighting teams, this manoeuvre may be risky as the fire may work its way around firefighters creating a pocket (Figure 2 as well as the definition of 'pocket' in the Terminology section above). If the line of fire is parallel to the line of defence, there is a higher probability that the fire encircles the firefighters creating a very dangerous condition. Preferably, this technique is performed in areas where the wildfire will have some anchor points ahead of the fire front. Anchor points are often used by firefighters as the starting point of a defence line as this reduces the chance of the fire encircling the firefighters (Figure 10). It is not recommended to perform indirect firefighting in the middle of a slope where the fire is downhill and is rising towards the firefighting teams because this can lead to serious accidents due to the speed at which fire advances up a slope. In addition, the smoke will hide the flames until it is too late to escape.

While planning defence lines for indirect firefighting, one should take into account the following considerations:

- The time required to build or improve the line of defence needs to be estimated, while taking into account the fire behaviour. This will help to determine if the action is viable or not;
- The width of any defence line required (discontinuities in the fuel) depends on the height of the flames. Experience suggests that the width should be at least twice the height of the flame. However, the existence of projections, such as trees or buildings, may reduce the effectiveness of the defence line; and
- The possibility of attacking the fire from the defence line increases the probability of its success.

In this strategy firefighters use hand tools to clear an area from fuel such as grass and foliage to create lines of defence. However, in the case of other fuels such as shrubs and trees, it is not feasible to use just hand tools due to the effort and time required. The use of chainsaws and mechanical grass cutters can make a significant difference, allowing the removal of tall grass, shrubs and bushes in a more efficient way. Heavy machinery (such as tractors) are also very effective in opening new discontinuities in the fuel as well as to improve existing ones. The use of machines, however, is conditioned by the terrain due to the accessibility required by the machinery.

Firefighting in the discontinuity may entail the use of either water or foam. Water will reduce the intensity of the fire when it reaches the line of defence, reducing the possibility that the flames jump across to the other side of the defence line. Foam also reduces the intensity of the fire or even stops it through its cooling effect as well as by smothering the fuel. Combining the use of water or foam, together with an interruption in the fuel, can be a very efficient way of stopping the fire (Figure 10). Foam can be applied prior to the arrival of the wildfire as the moisture will remain longer, giving more time for teams to retire from the discontinuity before the fire reaches it.

Tactical fire

Tactical fire is a technique that consists of intentionally burning an area ahead of the fire in a controlled way and is frequently used as a method of indirect firefighting. This method of fighting wildfires may have great advantages because once the wildfire reaches the burnt area, it will have no more fuel to sustain it so it will extinguish itself. This is normally done next to an existing discontinuity in the fuel, so that the burnt area will effectively increase the width of the discontinuity (Figures 10 and 11).

This requires a very good understanding of fire behaviour analysis, knowledge of the application mode, appropriate equipment, and should be used by experienced supervisors. Using the tactical fire technique without these requirements increases the probability of not achieving the intended objectives and decreases safety conditions. This technique should be considered only in very specific situations or where it is not possible to use other methods. A detailed risk/benefit analysis is critical before employing this firefighting strategy.

Although this method may have great advantages, firefighters still need to be very careful when dealing with particular fuels. For instance, if there are eucalyptus trees, the fire may become unpredictable due to sudden changes in direction. In addition, burning material may easily be carried by the wind, giving rise to new fires. This technique is not advisable where the fire becomes misaligned (does not followed the path intended by the firefighter), is against a slope, against the wind, or where the use of fire may cause greater damage, especially in the case of wooded areas.

For this technique to be successful, it is essential to identify from where to start the controlled fire and how to execute the manoeuvre. A detailed analysis of the air currents and slope is required in order to understand the direction of the greatest alignment of the fire and the area where the wildfire will arrive first. The manoeuvre must be anchored to a discontinuity and in a place where the slope and air movement will not cause the fire to grow in intensity. This reduces the possibility of fire spreading in an uncontrolled manner and the possibility of the fire jumping over the fuel discontinuity.

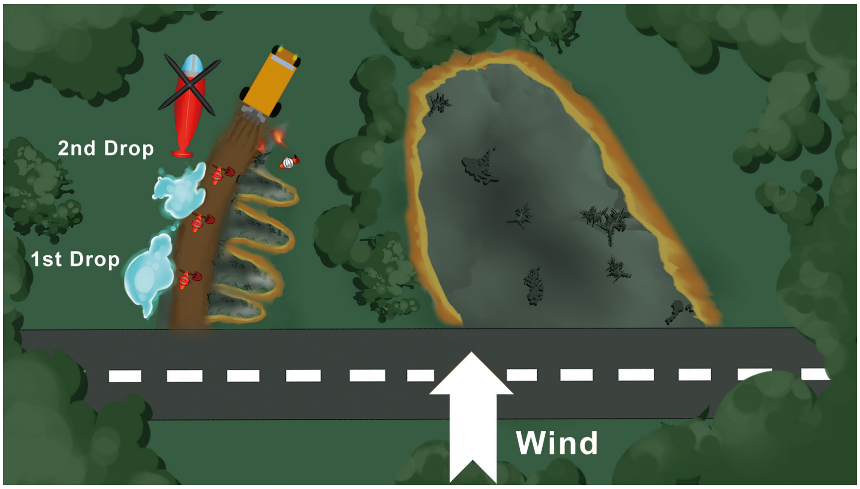

Figure 10: Combined tactics in indirect firefighting – a tractor creates a discontinuity, tactical fire is used to widen the discontinuity and aircraft drop water on unburnt fuel to prevent it from burning.

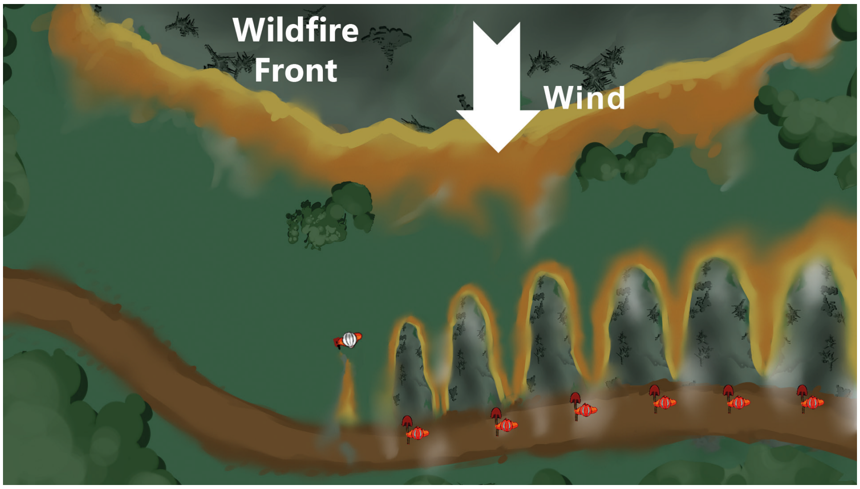

Figure 11: The use of tactical fire, with a specially trained firefighter (white helmet) creating the controlled fire, while other firefighters monitor and control it.

Personal protective equipment

Personal protective equipment (PPE) is mandatory for all firefighters working in wildfire zones. This equipment must be properly designed and tested for this purpose. Figure 12 shows the necessary equipment.

The tactical backpack is an integral part of the personal protective equipment and it shall include the following items:

- A personal first aid kit (including bandages, saline, compresses, burn dressings, etc.).
- Survival energy food for 24 hours, for own use.
- Water reserve for 24 hours, for own use (between 1 and 2 litres).
- A back-up light, snap light or light stick.
- A thermal blanket.
- Additional underwear.
- A fire shelter (carried on the belt for easy access).

The fire shelter is a mandatory item for all firefighters and must be carried by everyone on the fire line. The fire shelter is a cover made of reflective material that protects the firefighter from the fire and traps air to be able to breathe. The fire shelter should be used as a last resort, if the planned escape routes or safety zones cannot be used and entrapment is imminent. As this is a critical item to be used in a life threatening situation, every firefighter needs to be trained in the proper use of the fire shelter.

Firefighting equipment

Whether applying a direct or an indirect firefighting strategy, firefighters make use of a wide variety of equipment. The equipment consists mostly of hand tools, but may also include mechanical equipment. These tools can be divided as shown in Table 3 according to the firefighting technique used. The tools are depicted in Figures 13–26.

Figure 12: Typical PPE used by firefighters in wildfire response and applicable standards

	Hand Tool	Technique	Uses
Manual Operation	Extinguishing water back pack (Fig. 13)	Direct	Used for direct firefighting as shown in Figures 8 and 9, in conjunction with fire beaters or spades, in places inaccessible to vehicles.
	Fire beater (Fig. 14)	Direct	Used for direct firefighting as shown in Figures 8 and 9, in conjunction with water extinguishing backpack, in places inaccessible to vehicles.
	Spade (Fig. 18)	Direct Indirect	Used for direct firefighting (Figures 8 and 9) and indirect firefighting (Figure 10), in conjunction with water extinguishing backpack, in places inaccessible to vehicles. Can also be used in indirect firefighting, as a cutter.
	McLeod tool (Fig. 15) Pulaski tool (Fig. 16) Rake (Fig. 17) Spade (Fig. 18) Gorgui (Fig. 19) Scythe (Fig. 20) Machete (Fig. 21)	Indirect Tactical	Used for indirect firefighting and tactical fire as shown in Figures 10 and 11, to create a zone without vegetation (break / discontinuity).
	Torch (Fig. 24)	Tactical	Used for tactical as shown in Figures 10 and 11 to create a new fire to starve the main fire of its fuel.
Mechanical Operation	Chainsaw (Fig. 22) Mechanical Grass cutter (Fig. 23)	Indirect Tactical	Used for indirect firefighting and tactical as shown in Figures 10 and 11 to create the zone without vegetation (break / discontinuity).
	Leaf blower (Fig. 25)	Tactical	Used for tactical fire as shown in Figures 10 and 11 to help direct the new fire toward the main fire.
	Water atomiser (Fig. 26)	Direct Tactical	Used for direct and tactical fire because it has the capacity to be used with water for direct firefighting or without water as a blower.

Table 3: Firefighter-carried equipment categorised by type of operation and firefighting technique

Hand tools for direct firefighting

Figure 13: Extinguishing water back pack

Figure 14: Fire beater

Hand tools for indirect firefighting

Figure 15: McLeod tool

Figure 16: Pulaski tool

Figure 17: Rake

Figure 18: Spade

Figure 19: Gorgui

Figure 20: Scythe

Figure 21: Machete

Figure 22: Chainsaw

Figure 23: Mechanical Grass Cutter

Equipment for tactical fire (Using fire)

Figure 24: Drip Torch

Figure 25: Leaf blower to direct intended fires

Equipment for direct firefighting with water

Figure 26: Water atomiser for wildfire applications

Figure 27: Coupled water pump (vehicle mounted)

Figure 28: Motor water pump (as part of the primary intervention equipment)

The firefighting team

The firefighting team tackling wildfires is typically composed of five members, who take on the following roles:[3]

- The team leader: the leader receives the mission, delegates the tasks among the team members and will be in charge of the allocated resources. The leader supervises the operation and should also motivate the team to comply with the safety rules.
- The vehicle driver: the driver will be responsible for the vehicle, safe driving and also responsible for the equipment. When operations are conducted away from the vehicle, the driver assumes the normal role of firefighter.
- The firefighters: the other three members of the team are firefighters and their responsibility is to execute the tasks assigned by the team leader, managing fire hoses and other firefighting equipment.

Safety

Fighting wildfires brings with it various dangers that the firefighting team should be well aware of, some of which are listed below:[4]

- There is a lack of a proper assessment of the wildfire.
- The fire burns during the night in an unfamiliar location for the firefighters.
- No safety zones and escape routes have been identified.
- There is no knowledge of the weather and local factors influencing fire behaviour.
- There is no knowledge of the strategies, tactics and dangers.
- There are no clear instructions and tasks.
- There is a lack of communication between the teams and the operational command.
- Building defence lines without safe points of anchorage.
- Building a defence line in the slope where the fire is rising.
- Frontally attacking an intense fire.
- There is unburnt fuel between the team and the fire.
- There is no direct visual link with the main fire (or communication with someone who can see the fire).
- Fighting fire on a hillside where material rolling downhill can cause secondary outbreaks.
- The weather conditions suddenly become warmer and drier.
- Wind increases in speed or changes direction.
- There are frequent projections of incandescent particles.
- Access to safety zones is difficult due to the terrain or the fuel itself.
- Teams stop to rest ahead of the fire front.

Considering the dangers mentioned above, the firefighting team needs to follow a number of essential safety rules. The firefighters should:[3]

1. Keep themselves informed about the weather conditions, the forecast and foreseeable developments.
2. Always keep themselves informed about the current behaviour of the fire.
3. Base all actions on the current and expected behaviour of the fire.
4. Identify escape routes and keep all team members informed.
5. Place observers when there are foreseeable dangers.
6. Stay alert, calm and act decisively.
7. Maintain communication with operations on the ground and direct command elements and players from other organizations.
8. Give clear instructions and ensure that they are understood.
9. Keep all team members under control at all times.
10. After enforcing the rules above, one must fight the fire steadily, always ensuring safety first.

The safety rules for operations may be easily remembered through the acronym LACES.[3] LACES stands for Lookouts, Anchor Points/Awareness, Communications, Escape Routes and Safety Zones. LACES should be used before, during and after combat operation by all team members.

Lookouts

These are firefighters who are responsible to observe the fire and communicate the information to the team performing the firefighting operation.

- Lookouts need to be experienced and know what information is critical.

- There must be a sufficient number of lookouts to keep the fire in sight.
- They need to know the location of firefighting teams and escape routes.
- They need to have the required means of communication.

Anchor points / Awareness

- Defence lines should be initiated in safe locations.

Communications

- A communications plan needs to be prepared and disseminated.
- Everyone needs to be aware of the radio frequencies being used.
- If a potentially dangerous situation is noticed, this needs to be communicated as early as possible. Delays can be fatal.

Escape routes

- Potential escape routes need to be identified.
- The escape routes need to be set before starting the firefighting operation.
- There should be more than one escape route and everyone needs to know about them.

Safety Zones

- Natural safety zones: rocky areas, water and meadows.
- Man-made safety zones: built-up areas, roads, heliports and other areas without vegetation.

Note: The escape time and the size of the safety zone may change, depending on the fire behaviour.

Emergency procedures

Despite all the precautions taken, it is still possible that firefighters find themselves in serious and immediate danger by being encircled by the fire. This situation is considered an emergency and requires the firefighters to act quickly in order to save themselves. As soon as a firefighter notices the possibility of being encircled by fire, the following actions need to be followed:

- Communicate the exact location on the fire ground on the pre-established radio frequency to the command post.
- Protect the airway from smoke resulting from the combustion of fire.
- Keep a line of sight with the rest of the team.
- Consider the options and act immediately because the fire is fast and dynamic. Not taking action is the worst decision.

If the situation deteriorates further and the fire traps the firefighters, the following protocol needs to be followed:

- Drop unnecessary equipment.
- Keep tools used for fire suppression and the radio.
- Consider the possibility of requesting help from vehicles and helicopters near the area via radio. Vehicles need to have a water spray system for protection.
- Go to the burnt area.
- Find a survival area:
  - Start a fire to open an escape route (see Tactical Firefighting technique above).
  - Ask for support/help.
- Choose an opening for the fire shelter:
  - Maximize the distance of the fire shelter from unburnt fuels.
  - Gather the team and keep verbal communication.
- Be prepared for:
  - Overheated air currents.
  - Heavy fall of sparks and ashes.
  - Long development of the wildfire.

Helicopter operations safety

During firefighting operations, there may be occasions where firefighters need to interact with helicopters. Sometimes firefighters are transported by helicopter to remote areas, while in emergency situations, firefighters may need to be picked up by a helicopter to take them to safety.

Due to the danger presented by the rotors of the helicopter, firefighters need to be very careful how to approach a helicopter. Figure 29 shows the danger zones associated with a helicopter. The following are some other points to consider when approaching or leaving a helicopter:

- Always approach or leave from the front of the aircraft, such that the pilot has visual contact. When in proximity of a helicopter the body should be slightly tilted forward to prevent being hit by the main rotor blades. The movement should be rapid so that the area

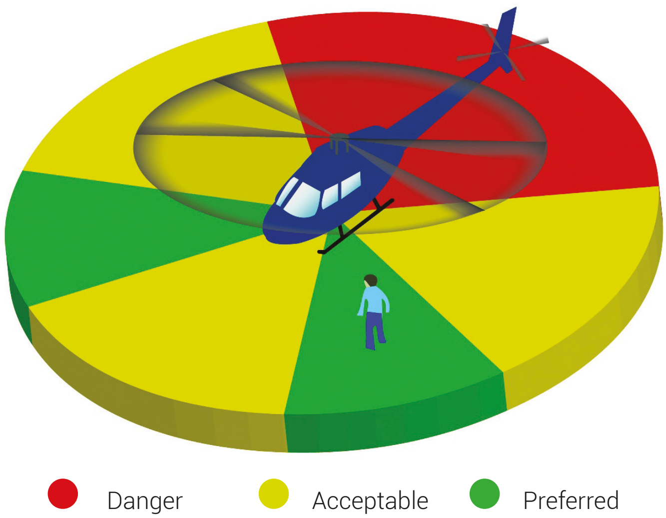

Figure 29: Helicopter approach safety considerations

of operations is cleared rapidly, but without running.

- When carrying objects always keep them horizontal at waist level. All objects (like hammock, tools, etc.) should be well packed. Never wear unsecured clothing (for example hats).
- When the rotors are turning, wait for authorization from the aircrew before approaching the aircraft. Pay close attention to the guidelines given by the crew during the briefing before each flight.
- Do not attempt to catch any object blown by the wind of the rotors.
- In case of momentary blindness near the aircraft, stop, sit and wait for help from the crew. Use goggles and ear protection whenever possible.
- Keep the landing area free from any material that could be blown away such as plastic bags, canvas, etc.
- Upon boarding, put on the seat belt and the headset.
- It is forbidden to touch the controls of the aircraft or to throw any object out.
- Never open the door during a flight.
- Avoid talking during take-off and landing.
- Only remove the headphones after the aircraft has landed.

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Appendix – Risk Assessment Form

The example risk assessment form presented overleaf shows an assessment considering the risk of a building collapsing during an earthquake aftershock, trapping people inside. The persons considered to be at risk include the rescue team (including rescuers standing by or performing auxiliary tasks outside the building) and bystanders. The **likelihood** of secondary collapse of a damaged building during an aftershock can be considered as probable (4) and the **severity**, in case this happens, is considered catastrophic (5) because there is the potential for people to be fatally injured by falling debris. The **risk level** therefore equates to 20, which is unacceptable (red), based on the **risk matrix** below.

Since the risk level is unacceptable, control measures to reduce the risk level are proposed. For example, limiting the access to properly trained rescuers wearing adequate protective equipment, having established access points, a known safe escape route and shoring of the access route to provide stability to the building will reduce both the severity as well as the likelihood that persons get trapped inside in the event of an aftershock. After a new evaluation of the risk (with the control measures in place), the severity is now considered minor (2) because the injuries expected would be leg sprains, scrapes and bruises. The likelihood is now considered to be occasional. This equates to a **residual risk** level of 6, which is tolerable. Although the risk situation is not ideal, the organisation chooses to tolerate this level of risk for the benefit of rescuing casualties. In this case, the rescue operation may proceed.

Note that the likelihood and severity scales are defined by the organisation and the definition may vary depending on the risks being assessed. In general, severity is judged by the potential final effect of the injuries. Likelihood is judged by the perceived or known probability of the risk occurring. The risk matrix is also defined by the organisation and is closely related to their 'risk appetite', i.e. the level of risk that the organisation is prepared to tolerate.

		Severity				
		5	4	3	2	1
Likelihood	5	25	20	15	10	5
	4	20	16	12	8	4
	3	15	12	9	6	3
	2	10	8	6	4	2
	1	5	4	3	2	1

Unacceptable Tolerable Acceptable

Risk matrix.

Ver. 1	Date:	Location:

RISK	PEOPLE EFFECTED				RISK RATING			CONTROL MEASURES REQUIRED	RESIDUAL RISK			PERSON IN CHARGE - TIME FRAME
	PUBLIC	RESCUERS	STANBY RESCUERS	BYSTANDERS	LIKELIHOOD	SEVERITY	LEVEL		LIKELIHOOD	SEVERITY	LEVEL	
Building collapse during aftershocks trapping people inside.		✓	✓	✓	4	5	20	• All rescuers working on scene should be USAR trained. • No lone working. • Use proper PPE (helmet, gloves, harness, shoes). • Identified access points. • Establish and control cordons, preventing bystanders from entering beyond the cordon. • Only allow minimum numbers to enter working areas. • Crews entering risk to take guidelines. • Communications with rescuers to be agreed and tested prior to entry. • Shoring of access routes.	3	2	6	

Likelihood: Improbable (1) - Remote (2) - Occasional (3) - Probable (4) - Frequent (5)

Severity: Negligible (1) - Minor (2) - Serious (3) - Critical (4) - Catastrophic (5)

Risk assessment form

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Note: Several photos were edited by Josef Mizzi, in preparation for the book design.

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This rescue manual is the end product of the project *Synergising European Volunteer Rescue Teams*, funded under Erasmus+ Key Action 2 – Cooperation for innovation and the exchange of good practices, Strategic Partnerships.

The project started in 2015 and included a five-day training activity consisting of emergency simulations held in Malta, as well as a series of five transnational meetings held in Portugal, Italy, Malta, UK and Greece. The meetings served to develop a structure and discuss the main topics for each chapter, as well as to evaluate and fine-tune the contents developed by the project participants.

The project was concluded with a half-day emergency simulation for multinational rescue teams, followed by a conference on the 13th of May 2017 in Malta, where this rescue manual was presented.

Rescue Techniques for Emergency Response is the result of an EU-funded project by six volunteer rescue teams, led by EFRU (Malta) in partnership with Edelweiss (Italy), EPS (Portugal), EPOMEA (Greece), Serve On (UK) and CCPVC (Cyprus). These organisations form part of the network of a European Association called EVOLSAR, having the harmonisation of rescue training and operations as one of its principal aims.

This book, *An Introductory Manual for European Volunteer Rescuers*, is therefore focused towards setting the foundations for new recruits, providing them with initial rescue skills and techniques. This will eventually lead them to become volunteer emergency responders able to integrate seamlessly in multinational teams working efficiently to save the lives of those affected by major disasters.

The rescue disciplines covered in this book are *Collapsed Structure Rescue*, *Rope Rescue*, *Water & Flood Rescue*, and *Wildfire Response*. These disciplines were chosen as they are among the most common areas covered by volunteer rescue teams and also because they are the strong points of the individual partners in this project. An additional chapter, *Basic Rescue*, was also added to cover the principles of rescue volunteering as well as common skills, techniques and equipment.

Project Leader

Project Partners

ISBN: 978-99957-1-117-7

Funded by the Erasmus+ Programme of the European Union