Steep Slope Rope Access Guidelines

Washington State Department of Transportation
Multimodal Development & Delivery
Construction Division
Geotechnical Office
1655 2nd Avenue SW
Tumwater, WA 98512-6951

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Exhibit 1. Engineering Geologist conducting slope assessment work on I-90, near North Bend, WA.

Exhibit 2. Ropes training, near Snoqualmie Pass, WA.

1 INTRODUCTION

1.1 GENERAL

Rope access is a form of work positioning, initially developed from techniques used in climbing and caving, which applies practical ropework to allow workers to access difficult-to-reach locations without the use of scaffolding or some type of work platform. Rope access is a system of techniques by which access is gained to structures, geologic features, or locations where ropes are the primary means of support, positioning and fall protection. The support of the rope (main line) is intended to eliminate the likelihood of a fall altogether, but a back-up fall arrest system is used in case of the unlikely failure of the primary means of support. This redundancy system can be achieved by using a second rope (back-up line), with a second anchor. The back-up line is compatible with the primary line and the equipment used on each is compatible with both ropes. The primary line supports the weight of a worker, and the back-up line catches the worker if the primary line fails.

Rope access techniques are successfully used around the world, and at the Washington State Department of Transportation (WSDOT), the use and needs are growing quickly.

Appropriate standards, documentation, training, equipment, and supervision are essential for maintaining a safe rope-access program.

1.2 PURPOSE

The purpose of these guidelines is to establish minimum acceptable standards for personnel, procedures, equipment, and conditions for conducting safe rope-access activities. These guidelines set out recommendations for all WSDOT Geotechnical Office employees who are involved in steep slope rope access. It outlines safe rope access techniques when working at height in a variety of situations and describes the best practice requirements for the design of anchors and other systems, along with their use and maintenance.

Describing best practice principles of rope access techniques and equipment will give WSDOT Geotechnical Office employees confidence in rope access methods as a safe and effective system for work.

WSDOT's Steep Slope Rope Access program is committed to ensuring that this type of work continues to maintain high health and safety standards. These best practice guidelines have been prepared to provide guidance and advice to WSDOT Geotechnical Office employees about the health and safety requirements for rope access work.

1.3 Introduction to Working at Height

In order to establish a safe and effective working-at-height program, especially one involving rope access, management must implement/procure the following:

1. Standards and Procedures
2. Thorough Training
3. Proper Equipment
4. Qualified Supervision

2 DEFINITIONS

Access work plan/Steep Slope Rope Access Assessment Form: This form helps assess the risks of a slope and what steps need to be taken before accessing the slope. The form is filled out by the climbing technician describing how a particular job should be undertaken to ensure any risks to health and safety of the workers, or others who may be affected, are minimized, or eliminated.

Access Zone: The area in which people are at risk of falling (i.e., while on rope or close to a vertical drop of more than 4 feet).

Anchor (main): A fixed attachment point, or series of points, on a structure, or a natural anchor (i.e., stable tree, boulder, etc.) which support the rope system and other connections to personnel. Main anchors are those that directly support the rope access system. (WAC 296-880-40020 requires that anchors will be capable of supporting at least 5,000 lbs. or designed, installed, and used, under the supervision of a qualified person, as part of a complete personal fall protection system that maintains a safety factor of at least two). WSDOT's Engineering Geology section's Qualified Person list is located in Appendix A.

Anchor System: A system of two or more interconnected anchor points, linked so as to provide a single secure anchor point. Rope access anchor systems are designed to support the weight of the climbing technician while they carry out tasks at height.

Anchor (deviation): Deviation anchors change the direction of the rope system. In common practice, the rope does not connect to a deviation anchor, but runs through a carabiner or connector. In general use, a deviation anchor should not pull the rope system more than 20 degrees off vertical.

Anchor (load sharing): A system consisting of two or more individual anchors which join together at a main anchor point to form an anchoring system that meets the strength required for rope access work. (Including load sharing anchors, WAC 296-880-40020 requires that anchors will be capable of supporting at least 5,000 lbs. or designed, installed, and used, under the supervision of a qualified person, as part of a complete personal fall protection system that maintains a safety factor of at least two).

Ascender: A type of rope grab that allows a climber to move up, or ascend, the rope. It is used primarily for climbing a rope by gripping the rope when loaded in one direction and sliding freely in the opposite direction.

Back-up line/system: A secondary line/system deployed in the event of a failure of the primary system.

Buddy Check: A process where each operator checks the rigging and equipment setup of another climber on the team prior to slope access work.

Carabiner: A type of connector, used to secure ropes or equipment, with one side that opens using a spring-loaded mechanism called a springlock.

Carabiner (Locking): A carabiner that can be locked in the closed position to provide extra protection against accidental gate openings. A locking carabiner may include the standard screw-gate or other style carabiner in which a positive action is required to lock the gate. (The Geotechnical Office does not screw-gate carabiners for fall protection due to the possibility of them unscrewing during use or of the user forgetting to screw them shut before use. WAC 296-880-40020 requires that fall protection carabiners must be auto-locking with a minimum tensile strength of at least 5,000 lbs.).

Carabiner (two-stage locking): A locking mechanism that requires at least two different consecutive manual actions to open the gate.

Carabiner (three-stage locking): A locking mechanism that requires at least three different consecutive manual actions to open the gate.

Carabiner (self-locking): A gate that locks automatically when it closes.

Climber: A term used generically to refer to a rope-access operative that may be climbing, descending, or traversing a rope or structure/slope.

Competent Person: An individual who can demonstrate they have the necessary knowledge, skills and experience to carry out a task. They will be able to spot hazards and mitigate them through their required training.

Descender: A device that acts as a brake on a rope. A descender is a mechanical device which provides a means of controlled lowering on a rope for rescue and/or rope access work. Generally, rope is fed through or around a descender to create friction which can be controlled by the operator to vary their descent speed and position. (The Geotechnical Office uses the Petzl I'D S, which is a descender with an anti-panic feature that controls the descent speed allowed. It also is equipped with an auto locking feature, which allows the workers to position themselves without having to manipulate the handle or tie off the device).

Dynamic Loading: A sudden load introduced into a system, as in the case of a fall.

Dynamic Rope: A rope that is specifically designed to absorb the energy of a fall by extending in length, thereby minimizing the shock load to the climber, rope system and anchors. Its dynamic characteristics allow the rope to absorb the energy of a sudden load more quickly than a static rope.

Energy Absorber: A device that reduces the energy exerted on an operator imposed by a suddenly arrested fall.

Fall Arrest: A form of fall protection which involves the safe stopping of a person already falling.

Full-body Harness: A form of protective equipment designed to safeguard the user from injury or death from falling. An assembly of interconnected shoulder and leg straps, with or without a body belt, designed for attachment to a lanyard, pole strap or fall arrest device, and used where there is a possibility of a free or limited free fall. Also called a safety harness.

Fall Factor: A method of working out the proportional seriousness of a fall. It is the length of the fall divided by the length of the secondary/back-up safety device. It is the main factor determining the violence of the forces acting on the climber and the equipment.

Fall Protection: The use of controls designed to protect personnel from falling or in the event they do fall, to stop them without causing severe injury.

Fall Restraint: A system that prevents a person from entering an area where a risk of falling exists. Prevents a person from falling any distance.

Fall Line: The route leading straight down any particular part of a slope.

Fixed Rope: A rope securely attached to an anchor point.

Free Fall: Any fall or part of a fall in excess of 2 feet either vertically or on a slope on which it is not possible to walk without the assistance of a handrail or line.

Hazard Zone: Any area where a person may be at risk as a result of the work being performed. The hazard zone is concerned with the risk that the public or other workers may be struck by a falling object. This includes the climbers on rope as well as anyone at ground level.

Helmets: Head protection designed to meet general industry standards as well as special requirements for working at height, such as chinstraps. (OSHA has adopted the ANSI Z89.1 standard for head protection. Some key features include deflecting blows to the head, resisting penetration, absorbing force of impacts, preventing top of the head impacts from traveling down the spine, insulation against electric shock (if needed), water and fire resistance, etc.).

Kernmantle Rope: A rope constructed with its load-bearing core protected by a braided sheath designed to optimize strength, durability and flexibility.

Lanyard: A line used to connect a fall arrest harness to a line or anchor. May be employed as part of a fall arrest lanyard assembly, which includes a personal energy absorber. (WAC 296-880-40020 requires a minimum tensile strength of at least 5,000 lbs.).

Main or Working Line: The primary rope used for descending, ascending or positioning during steep slope rope access work. (WAC 296-880-40020 requires a minimum tensile strength of at least 5,000 lbs.).

Minimum breaking strength: Manufacturer's rating used by the employer to calculate safe working loads. Minimum breaking strength is usually marked on the equipment by the manufacturer.

On-rope: The condition of being suspended from or attached to a rope.

Personal Protective Equipment (PPE): Protective equipment designed to protect the worker from hazards in the work environment (i.e. helmet, gloves, safety glasses, etc.).

Proof load: A test load applied to verify that an item of equipment will not exhibit permanent deformation under that load, at that particular time.

Pulleys: Friction-reducing wheeled devices used to change the direction of a rope or create mechanical advantage through proper rigging.

Rescue: The act of moving an injured or incapacitated worker(s) from the work zone.

Rescuer: A person performing a rescue, other than the subject of the rescue.

Rope Access: Techniques by which access is gained to structures (i.e. buildings, bridges, etc.) and geologic/geomorphic features (i.e. cliffs, steep slopes, etc.) where ropes are the primary means of support, positioning or safety protection.

Rope Access System: All equipment, including anchor system and technicians, used during rope access work.

Rope Grab (back-up type): A device which travels as a secondary point on the working/main line or secondary line that automatically engages and locks so as to arrest the free fall of a climber.

Rope Protector: Equipment that helps protect a rope from abrasion or cuts.

Safe Zone: Any area outside the hazard zone or the access zone.

Static/Low Stretch Rope: Low-elongation rope that is designed to stretch minimally when placed under load. Static rope has an elongation of 6% or less at 10% of minimum breaking strength.

Ultimate Strength: The highest engineering stress developed in a material before rupture.

Webbing Slings: Multi-purpose sewn synthetic slings commonly used for rigging in anchors.

Work Seat: A seat board that can be added to a work-positioning or rope-access system to make suspension while working more comfortable.

Working Load Limit: The maximum working load, determined by the manufacturer, that an item of equipment is designed to sustain. This load represents a force that is much less than that required to make the equipment fail.

3 EQUIPMENT

Members from the Geotechnical Office train with different equipment and select suitable items that they favor; however, all equipment kits are acceptable for steep slope rope access.

The equipment shown and described below is a common list of steep slope rope access equipment. Not all items discussed are required to be in each climber's equipment kits.

3.1 ROPE ACCESS KIT

Rope Access Harness – The harness provides the link between the operator and the rope access system. Sternal, ventral, hip and dorsal D-rings are required for steep slope rope access work. Many of our newer harnesses come with an integrated chest ascender (croll) which allows for ease of ascending without the need for two hand ascenders. All WSDOT employees must use a rope access harness during steep slope rope access activities.

(Wilderness Supply, 2018)

Fall Arrestor and Energy Absorber – This item is used during steep slope rope access and is connected to the back-up line in case the main line fails. It is used during both ascending and descending activities.

(The Treegear Store, 2017)

Descent Control Device – A descent control device is used to control the user’s rate of descent down the rope with the use of friction. Most descent control devices are compatible with all ropes used in the steep slope rope access system. Many of our descent control devices come equipped with automatic locks. (The Geotechnical Office uses the Petzl I’D S for their main descent control device. One of the other options (Figure 8, ATC, Petzl Stop) can be carried as a back-up if the main device malfunctions while on slope).


(Adventure Climb Rescue, 2021)   (Alibaba, 2019)   (Pinterest, 2018) (Nencini Sport, 2016)

Carabiners/Pulleys – A carabiner is a specialized type of shackle, a metal loop with a spring-loaded gate used to quickly connect components of the fall arrest system. Carabiners and pulleys are used as all-purpose connectors to create temporary tie-in points, redirect rope, hold equipment, and attach lanyards and accessories into the rope and harness. Carabiners used for the life support system must be self-closing and auto-locking. This includes double or triple auto-locking carabiners. Single action snap carabiners and screw gate carabiners must not be any part of the rope access system of the operator; however, they are commonly used to attach gear to the harness that is not being used as part of the rope access system.



(Wes Spur, 2013)   (Weigh My Rack, 2018)   (WRF Fire, 2020)

(Repetto Sport, 2018) (Life Gear, 2018)

Hand Ascender & Footloops – Hand ascenders and footloops are used during ascending, edge negotiation, rescue and other techniques. They work in tandem and relieve the climber of overexertion while ascending a slope.

Short-Haul/Rescue Pulley – A short-haul pulley is commonly used to lift short distances during rescue events. This type of equipment is typically used to lift (take weight off) the patient's equipment during a rescue. (During rescue, it is temporarily connected to the patient's sternal attachment point and to an ascender above on the patient's main line, then removed when the patient is transferred to the rescuer's gear. It can also be connected to the patient's dorsal attachment point and a separate anchor, descent device and rope, if a lanyard was used).

(Gravitech Systems Inc., 2020)

Lanyards – Fixed length and adjustable lanyards are used for travel restraint, fall arrest and positioning techniques.

Fixed length

Adjustable

(Tri-State Industrial Supply, 2018) (Taunton Leisure, 2021)

Personal Protective Equipment (PPE) – Helmet, leather gloves, protective eyewear, boots, etc., are part of our typical PPE. Nearly all items of steep slope rope access equipment are considered to be PPE. All PPE should fit correctly, and the helmet should be equipped with a chin strap to keep the helmet on the head at all times.

(Iglu Sport, 2020)

(Samba Top 10, 2018)

Foot Protection – Foot protection requirements are outlined in WSDOT's Safety Manual – Chapter 5 M75-01. In addition, safety-toe requirements are outlined in WAC 296-800-16060.

Protective footwear must comply with any of the following consensus standards established by the Occupational Safety and health Act (OSHA).

- American Society for Testing Materials (ASTM)
- Canadian Standards Association (CAN/CSA)

(Gear for Life, 2018)

WSDOT employees are to use approved safety-toe footwear protection if their job duties present a risk of foot injury. The Geotechnical Office works on unstable slopes and are required to wear safety-toe footwear when working on rope. Approved safety-toe footwear is a lace-up boot, made of leather or equally firm material, which extends above the ankle for support, has built in steel or composite toe protection and a sole and heel designed and constructed for slip resistance. A safety-toe boot must have a label attached, indicating it meets the specifications of ASTM F2413, or CSA.

Rope – A rope is a line that can have various jobs, i.e., safety line, working/main line, secondary line, hauling line, etc.

(Ebay, 2020)

3.1.1 Harness

A rope access harness is essentially a hybrid between a traditional mountaineer's harness and an industrial fall protection harness. The harness incorporates all necessary connections for fall protection, while giving the climber comfort and versatility. WSDOT employees must use harnesses that are equipped with the components described below.

Dorsal Area – To meet fall protection requirements, all harnesses must be equipped with a dorsal D-ring. Rope access harnesses have dorsal D-rings and can be integrated with fall protection systems. The dorsal D-ring is the main attachment point for lanyards, vertical lifelines and retractables.

(American Scaffolding Inc., 2019)

(American Scaffolding Inc., 2019)

Waist Area – Most harnesses have a wide, padded belt-like arrangement around the waist. This padded area provides support and increases comfort while “on rope”. The belt area usually includes hip-mounted D-rings for work positioning and “gear loops”, where extra carabiners, accessory cord, tools and equipment can be hung. The torso area usually includes two connection points (D-rings), one at the waist level (ventral) and another at the chest level (sternal). Both have several purposes, but the waist-level connection is mainly for use with descent control devices and the sternal connection is mainly for rope access secondary systems (back-up devices, etc.). Both can be used for ascending ropes.

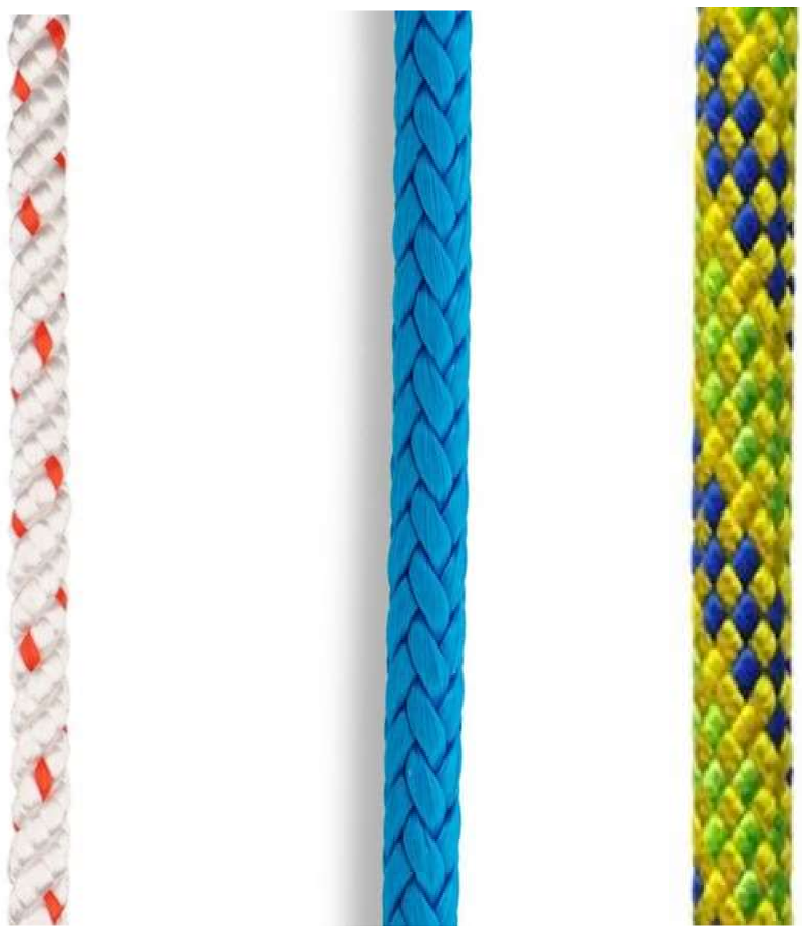
Sub-Pelvic Area – The sub-pelvic area on a rope access harness does not usually include a sub-pelvic strap. For rope access work, technicians need quite a bit of freedom to move and spread their legs, to climb and descend around structures/outcrops. A sub-pelvic strap limits this ability. The leg straps connect around the upper thigh, rather than through the groin area. This arrangement makes sitting (hanging from a rope) much more comfortable and allows technicians to sit in the harness for several hours.

(American Scaffolding Inc., 2019)

3.1.2 ROPE

Rope is widely specified for lifelines (main line). Not all ropes can be used for lifelines. Ropes are available at several locations, i.e. hardware stores, mountaineering stores, on-line stores, etc.; however, it is important to use ropes specified by the manufacturer, approved for life saving use. Ropes specified for lifelines have higher standards for the material of construction, connectors, breaking strengths, stretch and compatibility with the fall arrestor. They shall be designed, tested and labeled for fall protection purposes.

TWISTED BRAIDED KERNMANTLE



(BMI Supply, 2014) (Forestry Suppliers, 2020) (Rope, 2018)

Different types of ropes available for rope access work.

WSDOT's steep slope rope access team typically uses 11mm static rope for lifelines (main line and back-up line) and 7mm-8mm accessory cord (typically used for slings, anchors, prusiks and emergency tie-offs). Other size ropes are available for use, i.e. 10mm-12mm; however, the 11mm rope fits our gear (hand ascenders, decent control devices, etc.) best.

Strength – A fall protection lifeline rope, used correctly, can save lives while on the job. Rope used for lifelines must maintain a minimum strength rating to ensure the lifeline does not fail and has enough residual strength to withstand the rigors of an outdoor, on-slope setting. ANSI Z359.15 requires terminated lifelines (lifelines with a defined end, i.e. sewn, thimbled, shackled, knotted, etc.) have an ultimate strength of 5,000 lbs (22kN) and non-terminated lifelines (lifeline with no defined end) have a strength of 6,000 lbs (26.7 kN) to compensate for anchoring methods. Contact with surrounding structure(s) can damage the rope and reduce the breaking strength. When setting up systems, common practice is to protect the rope from sharp edges (edge of rock, guardrail, etc.) by using a rope protector/edge protector.

3.1.2.1 Rope Protectors/Edge Protection

Ropes and slings can be damaged by sharp or abrasive edges. Rope protection/edge protection can extend the lifespans of ropes and slings and prevent catastrophic failure during rope access work. Rope protection/edge protection can also assist in keeping ropes/slings clean from debris, potentially further extending the lifespan of the equipment. The Geotechnical Office typically uses rope protectors only when the rope will be weighted on sharp/abrasive edges.

(Amazon, 2019)

(Rescue Tech 1, 2018)

Examples of rope protectors.

3.1.2.2 Rope Materials

Nylon – This type of rope is very strong and is known for its elasticity and ability to absorb tremendous shock loads. Although nylon tends to lose some of its strength when it is wet, it remains shock absorbent. Nylon rope is the most common and preferred material used in rescue ropes, vertical caving, industrial descents and tactical operations due to its high strength and low stretch properties.

Polyester – Polyester rope and cord will provide similar strength to Nylon rope with less stretch and better abrasion resistance. It works well for applications that call for UV resistance, abrasion resistance, high strength and low stretch. Good dielectric properties make it an excellent rope for use in many electrical/utility applications.

Polyolefins (including polypropylene) – Often referred to as the plastic rope, this rope is not usually found in a climber's gear bag due to its poor performance all-around. They won't conduct electricity and can be safely used with and around open electrical sources. Polypropylene rope should not be used as a component of a fall protection system.

Technora – This rope is primarily designed and reserved for those who work in a high heat environment, much like firemen or welders. Well-suited for climbing and rigging applications, Technora is known for its high strength and low stretch. Technora rope will not fail if the cover is burned.

3.1.2.3 Rope Construction

Rope may be constructed of any long, stringy, fibrous material but generally is constructed of certain natural or synthetic fibers. The most common type of rope construction used for lifelines is three strand twisted, because it is inexpensive and readily available; however, many other construction methods are acceptable.

Laid Ropes – Also known as twisted ropes, this is the most common form of rope. Common twisted rope generally consists of three strands and is normally right-laid (right-handed twist). The strands are twisted several times to make the finished rope. Laid ropes are often used as lifelines or in shorter lengths as lanyards.

Plaited/Braided Ropes – These ropes are not twisted. They consist of a braided, tubular jacket/sleeve that covers the braided/woven strands inside. Plaited ropes are not as prone to spinning or kinking under load like twisted ropes, are considered higher quality and have a longer lasting method of construction.

Kernmantle Ropes – Kernmantle ropes are constructed with its interior core protected by a woven exterior sheath designed to optimize strength, durability and flexibility. The core fibers provide the tensile strength of the rope, while the sheath protects the core from abrasion during use. Kernmantle ropes have the advantage of being non-rotational. Kernmantle ropes are commonly used in pulley systems, evacuation and rescue systems, and rope access applications.

Life Safety Rope – Life safety rope is dedicated solely for the purpose of supporting human loads during rescue, fire-fighting and other emergency operations. Quality of materials and construction is high, and many fall protection lifelines are made from ropes classified as life safety rope. Life safety rope is generally put into three categories, depending on how much it stretches: static, low stretch, and dynamic.

Static rope is a low-elongation rope that is designed to stretch minimally when placed under load. Static rope is defined as rope that stretches at a maximum elongation of less than 6% at a load of 10% of the rope's minimum breaking strength. Under load, the fibers inside the static rope do not stretch very much.

Low stretch rope stretches between 6% and 10% at a load of 10% of the rope's minimum breaking strength. Low stretch rope is probably the most widely used rope in rope access, work positioning and restraint, as it is pliable enough to easily work with and stiff enough to still maintain system efficiency when used for descent control and rescues. Static and low stretch ropes are typically made with several kern fibers (twisted/parallel fibers) braided or placed parallel to each other inside the mantle (tightly braided sheath). The kern fibers provide the majority (~70%) of the rope's strength. The mantle is tightly braided, providing higher abrasion resistance.

Dynamic rope is rope that is constructed to be somewhat elastic. This type of rope stretches over 10% at a load of 10% of the rope's minimum breaking strength. It is used primarily in rock climbing, ice climbing and mountaineering. Its dynamic characteristics allow the rope to absorb the energy of a sudden load more quickly than a static line. The high stretch capacity works well to distribute fall forces over time and distance, but the rope elongation requires a tremendous amount of clearance during a fall. This elongation also reduces the system efficiency when used in a hauling system. Dynamic rope has little or no application in the rope access industry.

The Geotechnical Office uses a static kernmantle rope that features a polyester sheath over a nylon strand core with an ultimate strength of 7,935 lbs (35.3 kN), which exceeds the OSHA requirements discussed above.

3.1.2.4 Rope Terminations

All fall protection ropes should have some type of termination on one or both ends. When terminating a rope, the climber must be careful not to decrease its strength below the minimum requirements discussed above. ANSI allows knots tied in the end of the lifeline to create anchorage systems, providing the ultimate strength of the rope is still within acceptable standards. Lifelines terminated from the manufacturer with an ANSI Z359.12 compliant connector ensures this strength requirement is met. (The Geotechnical Office typically uses ropes with knot terminations).

Sewn Termination

Knot Termination

(Power Tool Outfitters, 2018) (British Mountaineering Council, 2017)

Examples of terminations on lifelines.

3.1.2.5 Care/Storage of Lifelines

Consistent with other fall protection equipment, ropes are retired by condition, not age. By following basic care and handling steps, the life expectancy of a rope can be maximized. Store ropes out of direct sunlight. Avoid stepping on a rope that is on the ground to minimize dirt grinding in the mantle. Wash ropes that have excessive dirt/mud on the mantle. If a rope becomes wet, hang it to air dry.

Ropes dedicated for rope access work should not be used for any other type of work and should be stored in a separate location. Ropes are inspected before and after each use. Ropes that show damage should be discarded. We retire damaged ropes and replace them with new ropes. Ropes are retired if deemed unsafe for lifeline use.

When rope is not in use, it is important to store it properly. The most efficient and safe way to do this is to store the rope in a bag. A bag is not only for storage and transportation but also for deploying the rope by throwing the bag down slope. Some of our employees prefer to wear the rope bag (backpack style) during their on-slope work, to better manage their rope, instead of throwing the entire length of rope (and bag) down slope. The entire length of rope is often not needed on many of our projects. Others prefer to throw their rope (and bag) down slope for comfort and ease of descent.

Examples of rope bags. Rope bags extend the life of a rope and is a practical way for storage and transportation.

(Columbus Supply, 2021)

3.1.3 CONNECTORS

When assembling rope access systems, it is essential to use a dependable method of attaching components together. Typically, such systems are connected to anchorage connectors, then into full body harnesses. Regardless of the number and type of connections used, components must remain securely fastened once they are assembled.

Every type of connector has compatible and incompatible partners. A compatible connection can be defined as a connection that is capable of orderly, efficient integration and operation with other elements or components in a system, without the need for special modification or conversion, such that the connection will not fail when used in the manner intended. The Geotechnical Office typically uses carabiners for rope connectors.

3.1.3.1 Carabiners

Carabiners are widely used in rope-intensive activities such as climbing, fall arrest systems, etc. They are predominantly made from either steel or aluminum. Both steel and aluminum carabiners have their advantages and disadvantages. Steel is stronger than aluminum, but aluminum is lighter and is also more corrosion (rust) resistant than steel. The Geotechnical Office typically utilizes aluminum carabiners; however, steel carabiners are still used, depending on the climber. Both aluminum and steel carabiners meet the minimum strength requirements established by ANSI, as described below. Carabiners come in four characteristic shapes:

1. **Oval (C-shaped):** Smooth regular curves are gentle on equipment and allow easy repositioning of loads. Their greatest disadvantage is that a load is shared equally on both the strong solid spine and the weaker gated axis.

2. **D-shaped:** Asymmetric shape transfers the majority of the load onto the spine, the carabiner's strongest axis.

3. **Offset-D:** Variant of a D-shape with a greater asymmetry, allowing for a wider gate opening.

4. **Pear:** Wider and rounder shape at the top than offset-D's, and typically larger. Typically used for belaying. These are usually the heaviest carabiners.

Oval (C-shaped)

(Weigh My Rack, 2018)

D-shaped

(Canterbury, 2015)

Offset D-shaped

(Facewest, 2017)

Pear-shaped

(AliExpress, 2017)

It has been shown that the C-shaped carabiners are susceptible to cross-gate loading, and their non-locking gates could easily open. These two characteristics make them unsuitable for use as fall protection equipment. The Geotechnical Office uses C-shaped carabiners for non-fall protection uses, i.e., hanging equipment from the harness, etc.

The Geotechnical Office typically uses offset-D carabiners for fall protection; however, the D-shaped type are included in our fall protection equipment bag. The offset-D carabiners are shaped specifically so that the spine and the gate are no longer parallel. This reduces the likelihood of cross-gate loading by encouraging the attached components to roll toward the long axis of the carabiner. Offset-D carabiners are also stronger because the spine is longer than the gate. The standard design requirement (ANSI Z352.12) states that carabiners must maintain, at a minimum, 5000 lbs. (22.2 kN) tensile strength along the major axis; in addition, it requires that the gate strength (minor axis) be able to withstand a minimum load of 3,600 lbs (16 kN).

The Geotechnical Office uses the following four basic gates that are commonly used for carabiners:

1. **Non-Locking Carabiners** – These types of carabiners have spring-loaded gates that open when you push them. They allow the user to quickly and easily push open a spring-loaded gate to accept a rope, webbing, or other hardware. This non-locking gate often opens unintentionally under load because its spring is too weak to offer much resistance. Non-locking carabiners are a cheap option for attaching equipment not in use to your harness; however, they shall not be used for fall protection.

Non-Locking Carabiner

(Weigh My Rack, 2018)

2. **Twist, Screw, or Barrel-Lock** – These carabiners use a security sleeve over the gate which must be engaged and disengaged manually. They have fewer moving parts than spring-loaded mechanisms, are less prone to malfunctioning and are easier to employ one-handed. Because the gate must be manually locked, it is likely to cause problems for several reasons. The main reason is that the climber might forget to screw/lock the gate before applying a load. When left unscrewed, it is equivalent to the non-locking carabiner. For this reason, the Geotechnical Office is no longer using this type of carabiner for fall protection and is solely using the auto-locking type of carabiners.

Screw-Gate Carabiner

(Facewest, 2017)

3. **Auto-Locking Carabiners (Double-Action)** – The prominent feature of this carabiner is its auto-locking capability. It takes only two motions to release the auto-lock gate, which are typically rotating the sleeve manually and drawing the lock inward. When the gate is released, a spring causes it to snap back into place, whereupon another spring causes the sleeve to rotate and lock into place. These carabiners are considered much more reliable than the screw-gate type. Auto-locking carabiners are similar in appearance to the double-locking carabiners described below.

Auto-Locking Carabiner
(Double-Action)

(Ebay, 2019)

4. **Double-Locking Carabiners (Auto-Locking/Triple-Action)** – These devices require three separate actions to open their gates. The gate assembly contains three movements, one on the shaft and two in the sleeve. Upon release, one movement closes the gate, a second rotates the gate sleeve and a third pulls the sleeve over the carabiner shaft. To unlock the carabiner, the sleeve must first be lifted free of the carabiner shaft and rotated 90° before the gate can be pulled open. Double-locking carabiners are similar in appearance to the auto-locking carabiners described above.

Auto-Locking Carabiner
(Triple-Action)

(Wes Spur, 2013)

The Geotechnical Office only uses auto-locking (double and triple action) carabiners described above for fall arrest. The screw-gate carabiners are no longer being used for fall arrest due to the potential of forgetting to screw/lock the gate. The screw-type and non-locking carabiners will only be used for non-fall arrest scenarios, i.e., attaching equipment to the harness, etc.

3.1.4 BACK-UP DEVICES

The term “back-up device” is a generic term that refers to the secondary device used during rope access, typically during descent. The back-up device is the fall arrestor that travels along the lifeline, above the climber. The climber is attached to the device, typically on the sternal D-ring of the harness, and it travels along the length of the rope as the climber moves. If a fall should occur, the device locks onto the rope. It is desirable to reduce the free fall distance during rope access work. Climbers should be conscious of where the back-up device is located on the rope and always position it as high as possible. For example, if the climber moves up the rope, the climber must also move the back-up device up the rope as far as possible to limit the free fall distance. (The Geotechnical Office typically uses the Petzl ASAP Lock (lower left) for its main backup device; however, we carry prusiks (lower right) in our gear packs in case a secondary backup device is needed or the main backup device malfunctions).

(Conterra, 2020) (Amazon, 2020) (Dreamstime, 2019)

Examples of some available back-up devices.

3.1.5 LANYARDS

A lanyard is a flexible line of webbing, synthetic rope or wire rope that is used to secure a safety belt or full body harness to a lifeline or anchor. For fall arrest applications, energy-absorbing lanyards are connected to the dorsal D-ring of the full body harness. If the worker falls, the lanyard holds fast, and the energy absorber deploys to reduce the arresting force. The Geotechnical Office uses fall arrest lanyards while on a man-lift, high-lift, bucket truck, etc.

(Honeywell, 2021)

An example showing a fall arrest lanyard attached to the dorsal D-ring.

Although sharing a similar name, rope access lanyards are a little different and serve a broader purpose. They are much shorter than fall arrest lanyards and connect to the front D-ring of the harness, since they are often removed and replaced during descending/ascending maneuvers and connection to the dorsal D-ring would be too difficult.

(Gravitech Systems Inc., 2020) (Eyolf, 2019) (Taunton Leisure, 2021)

Examples of rope access lanyards used by the Geotechnical Office.

3.1.6 ASCENDERS

Ascenders are mechanical devices whose principal function is to hold onto the rope and assist the climber with ascending the rope. Ascenders are characterized by a toothed cam which clamps onto the rope when the ascender is weighted, creating a solid point for a climber to move upward on the rope. When the pressure on the cam is released, it can travel up the rope or be slightly opened to move down the rope. If a climber has to descend for any great distance, a changeover to a descent control device is advised.

Ascenders can be broken down into three categories:

- Personal use ascender
- Hand ascender
- General use ascender

Croll (Personal use ascender)
(Elite Mountain Supplies, 2019)

Hand ascender
(Repetto Sport, 2018)

General use ascender
(Mid Atlantic Rescue Systems, 2021)

The Geotechnical Office uses all three types of these ascending devices but more often the personal and hand ascenders.

3.1.7 DESCENDERS

A descender is a friction device or friction hitch that allows climbers to descend the rope in a controlled fashion, with minimal effort by the user controlling it. Descenders, friction devices, rappelling devices, descent control devices are all terms that describe the same type of device. The Geotechnical Office utilizes a descent control device and/or a friction device.

Descenders employ friction to create an advantage. This friction advantage allows a climber to hold several hundred pounds with the grip of one hand. The device is attached to the rope and then connected into the ventral D-ring of a full body harness. Climbers can control the amount of friction the device produces, thus allowing them to slide down the rope at variable speeds. All descending devices require a secondary/back-up device in case the descender fails, i.e., ASAP, prusik, etc. (discussed above). (The Geotechnical Office uses the Petzl I'D S for their main descent control device. We carry one of the other options (Figure 8, ATC, Petzl Stop) as a back-up).

(Adventure Climb Rescue, 2021)

Petzl I'D S – Manually operated device (mechanical variable friction with auto lock feature) – This type of device is designed for suspended work. It has mechanically variable friction and a safety feature: auto-lock. If the user lets go of the unit, it will lock automatically. If the user isn't operating the device correctly and pulls down on the handle too far, the unit will also lock. It is a rappel device that can be used on either the harness for self-descent control or it can be attached to the anchor to lower equipment. The Petzl I'D S is compatible with 10 to 11.5 mm ropes only.

Petzl Stop – Manually operated device (mechanical variable friction with auto-lock) – This type of device is very similar to the Petzl I'D S, but does not have self-braking or anti-panic functions. It can build up speed if the operator opens the device too far or does not control the descent. The Petzl Stop is compatible with 8.5 to 11 mm ropes only. (The Geotechnical Office no longer uses the Petzl Stop as a main descender).

(Nencini Sport, 2016)

Rescue Figure 8 – This type of device does not have auto-locks or panic features and the amount of control (friction) is not mechanically variable. Friction is only variable by the type and diameter of rope used and the strength of the user's brake hand. Unlike the manually operated devices described above, the Rescue Figure 8 can utilize many different sizes of rope thickness, depending on the user's ability and experience. (The Geotechnical Office has discontinued these for general use, but they are sometimes carried as a back-up, or for rescue).

(Alibaba, 2019)

3.1.8 LIGHTS

Artificial light may be needed during slope assessment work. Whether we are looking into crevices or cavities that might be shadowed or due to the loss of daylight, safe work practices must continue. We carry headlamps and hand-held flashlights in our climbing kits when additional light is needed.

Headlamp

(Backcountry, 2018)

Flashlight

(LED plantgrowlife, 2015)

3.1.9 Climbing Knife

Knives are included in our climbing kits. Some common uses include cutting old webbing from existing rappel stations, cutting new webbing for new rappel stations, first aid, cutting a stuck or damaged section of rope, etc.

Climbing Knife

(The Climbing Guy, 2020)

3.1.10 Webbing

Webbing is a strong nylon fabric woven as a flat strip or tube of varying width and fibers, often used in place of rope. Webbing is both light and strong, with breaking strengths readily available in excess of 10,000 pounds-force (44 kN). The most popular webbing is 1 inch wide; however, the Geotechnical Office uses webbing between 1 and 3 inches wide. 3-inch webbing is stronger and heavier than 1 inch webbing, but both are acceptable for steep slope access work, and it is generally left to a climber's personal preference. For rope access, webbing is used to make slings, runners, harnesses, and anchor systems. The Geotechnical Office typically uses them for slings and assistance with anchor systems.

Tubular 1-inch webbing

(omni progear, 2001) (Strapworks, 2019)

3.1.11 WALKIE TALKIES/2-WAY RADIOS

The use of walkie talkies and/or 2-way radios are mandatory when rope access team members are out of site or hearing range of each other. They are also used to communicate with WSDOT personnel that may be on the ground, out of hearing range. Communication is paramount for safety during slope access work, to not work immediately above your partner, calling for assistance, or for an emergency/rescue. Communication with personnel below the working area is also important to let them know if loose material is knocked off the slope or assistance is needed for emergency purposes and/or rescue. The Geotechnical Office utilizes Tait 9400 series radios which are approved by WSDOT.

Walkie talkies/2-way radios

(Don't Waste Your Money, 2019)

At a minimum, each personal steep rope access kit will have the following:

- Rope access harness,
- ~150’ of static rope (rope lengths vary depending on the job),
- Two ascenders (hand ascender/personal use ascender, etc.),
- Decent control device (Petzl IDs/Figure 8, etc.) with back-up,
- ~30’ of accessory cord (7mm-8mm),
- ~30’ of webbing (1”-3”),
- 8 Locking carabiners,
- 8 non-locking carabiners,

- Lanyard(s),
- Climbing knife, and
- Personal protective equipment (gloves, helmet, eye protection, boots, etc.).

4 KNOTS

Knots are widely used in rope access. Proper training and knowledge are key to ensuring that the climber selects the correct knot for the application, knows how to tie it correctly and can identify a properly dressed knot. Knots can be tied that facilitate remote rope retrieval without getting stuck, create load-sharing anchors, and isolate damaged sections of rope.

Knots knowledge and tying is an essential skill for any climber for use in steep slope access. Knots are used for tying anchors, securing your harness to the rope, joining ropes together, rescue situations, etc. Knot-tying should be practiced, and efforts should be made to learn the application of each knot. Knots should be tied and dressed properly for maximum strength of each knot.

The Geotechnical Office conducts monthly knot-tying practice that is led by one of our steep slope rope access trained employees. WSDOT steep slope rope access employees practice tying knots that are utilized during on slope work, i.e. anchoring knots (figure 8 knot, figure 8 follow-through knot, overhand knot, etc.), securing to safety lines (girth hitch knot, prusik knot, etc.), isolating damaged sections of rope (butterfly knot), and securing rope ends with stopper knots (EStar knot, stevedore knot, double overhand knot, etc.). We often use Animated Knots by Grog during our monthly knot-tying practice. Videos of how to tie each knot are available during our monthly knot-tying practice. An example of Animated Knots by Grog is included in Appendix B. The monthly knot tying practice is recorded on our Steep Slope Rope Access experience log (Appendix C).

4.1 Knot Terminology

The following terms are used to describe sections of the rope or techniques used when knot tying.

Standing End – The end of the rope not active in knot tying.

Working End – The end of the rope actively involved in knot tying.

Loop – A bend in the rope that crosses over itself.

Bight – A u-shaped section of the rope with parallel sides where the working end does not cross over itself.

Bend – a knot used to join two ends of rope(s) together.

Follow Through – The re-weaving of a knot used to tie into, or around, an existing object.

In-Line – A knot or hitch tied to match the direction of load on the rope.

Double – Repeating a step in the tying of a knot, usually used to increase the size or strength of the knot.

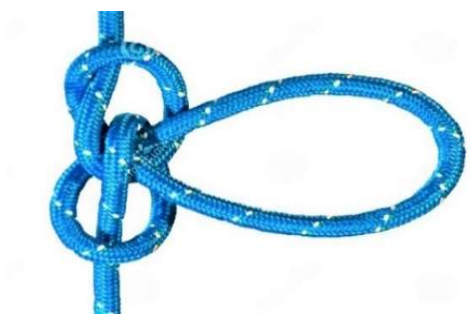
Hitch – Type of knot that attaches a rope to some object or rope. A useful friction hitch is easily moved up and down the main rope while slack and holds on to the rope with friction when loaded (i.e., prusik).

The following are examples of knots that are typically used in steep slope rope access:

- **Bowline** – The bowline creates a fixed loop at the end of a line of rope. It is easy to tie and, after use with heavy loads, is easy to untie.

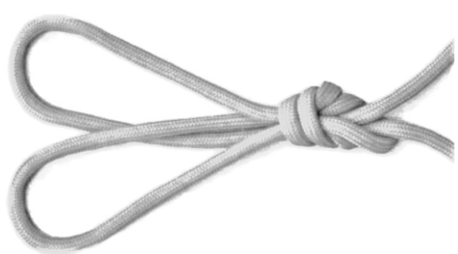
(Andrew D. Pope Training & Coaching, 2020)

- **Butterfly** – A butterfly knot (alpine knot) is used to form a bight in the rope. This knot is often used to isolate a damaged section of rope so that no further load is placed on it.



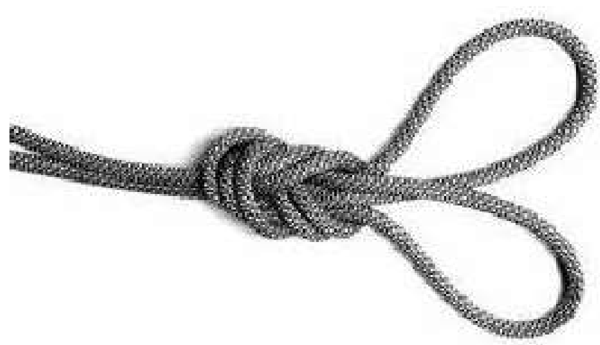
(Dreamstime, 2017)

- **Double Butterfly** – The double butterfly knot creates two, non-collapsing clip-in points in the middle of a rope. No load is placed on either loop; similar to the butterfly knot.



(Animated Knots, 2013)

- **Double Figure 8 Loop (Bunny Ears)** – This knot is based on the figure 8 knot. It forms two loops, which distinguishes it from the similar figure 8 on a bight and figure 8 follow through that form single loops.



(Climbing, 2017)

- **Double Fisherman** – This knot securely ties two ropes together or can be used to fasten the ends of a rope or cord to make a closed loop or sling. It is also an example of a bend knot.

(Shutterstock, 2017)

- **Double Overhand Knot** – This knot is an extension of the overhand knot, made with one additional pass. The result is a slightly larger and more difficult knot to untie. It is sometimes used as a stopper knot.

(Comtrain USA, 2020)

- **EStar Stopper Knot** – Another variation of a stopper knot used in steep slope rope access work.

(Animated Knots, 2014)

- **Figure 8 Bend** – A figure 8 bend is effectively an end-to-end rethreaded figure 8 tied with two different ropes. This is a useful bend for joining ropes of similar condition and diameter. This knot can also tie two pieces of similar sized webbing together.

(Gravitech Systems Inc., 2019)

- **Figure 8** – A single figure 8 knot is used as the first portion in the formation of many knots in the figure-eight family. It can be used as a stopper knot at the end of a rope.

(Everest Gear, 2018)

- **Figure 8 On-A-Bight** – A figure 8 on-a-bight is used to secure a bight in the end of the rope. It is a strong mid loop, where the two ends come out of the knot parallel.

(Gravitech Systems Inc., 2019)

- **Girth Hitch** – This knot is commonly tied with a sling of webbing or rope and is commonly used to attach webbing to a harness or to rope to create an anchor point.

(The Survival Channel, 2017)

- **Half Hitch –** This knot is basically an overhand knot with the working end brought over and under the standing part. Although it is insecure by itself, it forms the basis of many other reliable knots.

(Animated Knots, 2019)

- **In-Line Figure 8** – This variation of the figure 8 is tied mid-line and used when hauling or lifting weights in one direction.

(Gravitech Systems Inc., 2019)

- **Klemheist Knot** – This knot is used as a friction hitch that grips the rope when weight is applied and is free to move when the weight is released. It is similar to the Prusik knot.

(Trek Bible, 2018)

- **Munter Mule** – This knot is a useful combination knot that allows the user to stop passage of the rope past a carabiner (in its tied-off state using the "mule" – see Appendix A), but that can be easily released with the pull of a rope to allow a smooth, controlled lower. This knot is often used when belaying a climber.

(Australian Geographic, 2016)

- **Overhand Knot** – The overhand knot is primarily used as a stopper knot. It is often used to prevent the end of a rope from unraveling. It significantly reduces the rope strength and should not be used in a load-bearing system.

(Gravitech Systems Inc., 2019)

- **Prusik** – A friction hitch used to grip a rope in climbing. When the hitch is tied into a length of rope, the prusik grabs and holds the rope very effectively when loaded.

(Dreamstime, 2019)

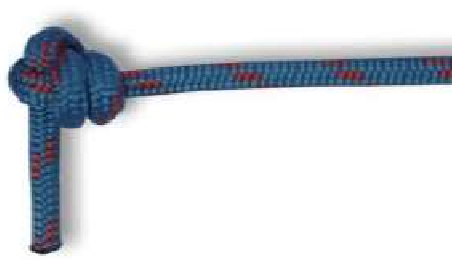
- **Sheet Bend –** This bend is also known as a becket bend, weaver's knot and a weaver's hitch. It is practical for joining lines of different diameters or rigidity.

(Fine Art America, 2018)

- **Square Knot** – A type of double knot that is made symmetrically to hold securely and is easily untied.

(iStock, 2018)

- **Stevedore Knot** – This knot is commonly used as a stopper knot. It is more bulky and less prone to jamming than the related figure 8 knot.



(Handy Mariner, 2020)

- **Water Knot** – This knot is frequently used for joining two ends of webbing together, for instance when making a sling or an anchor.

(Pinterest, 2018)

Table 1. Examples of knots reducing the minimum breaking strength (MBS) of a rope

Knot	% Reduction of (MBS)	Main Purpose
Overhand	45%	Stopper Knot
Figure 8	35%	Stopper Knot
Figure 8 (Bight)	20%	Terminate Rope End
Figure 8 (Bend)	20%	Connect Two Ropes
Figure 8 (In-line)	40%	Mid-Rope Knot
Double Fisherman	21%	Connect Two Ropes
Butterfly	31%	Mid-Rope Knot
Bowline	35%	Terminate Rope End

4.1.1 THREE RULES OF KNOTS

1. **Dressing the knot** is a practice designed to ensure that the knot is tied properly. A dressed knot optimizes the security and strength of the rope system. Knots that have twists, unparallel lines, kinks, loose bights, or overlapping sections are not dressed and may reduce rope strength and possibly unravel during use.

2. **Setting the knot** is the process of tightening the knot. Improper setting can cause certain knots to underperform. The setting application will ensure that the knot maintains its shape until a load is imposed upon it.

3. **Stopping the knot (stopper knot)** is a term that has two main uses in ropes access. The first is a practice that secures/locks the tail end of the rope against the base of a knot (also called a backup knot). Primarily for security, it is a secondary knot intended to prevent the primary knot from coming untied. When a knot is tied, there will typically be a tail of rope coming out of the knot. When the rope is loaded, this end, or tail of the rope will tend to slide back into the knot, possibly causing the knot to unravel. Common practice is to have 8” to 12” of rope extending from the end of the knot in which a stopper knot can be tied. Common knots for this purpose include the overhand and double overhand knots.

   The second use of the term stopper knot is in the creation of a well-defined area of thickness in an otherwise uniform rope to prevent it from slipping through a narrow passage (other knots, descenders, etc.). Typically, this type of stopper knot is tied at the bottom end of the rope to prevent climbers from descending off the bottom of the rope. Typical stopper knots include the double overhand knot, figure 8 knot, and the stevedore stopper.

5 SAFE WORK PRINCIPLES

Rope access can provide safe methods to access slopes and to carry out tasks at height or in other difficult-to-access situations.

The principles for a safe rope access system include:

- Planning and management
    - Before work begins, all rope access projects are discussed internally (with management and all on-slope personnel) with all safety issues highlighted during the meeting, including access to the top of the slope, types of anchors to be used, type of on slope work being conducted, etc. This information is covered when filling out our Steep Slope Rope Access Assessment (SSRAA) form (discussed in detailed below) and during the hazard identification and management process (discussed in detail below).
- Selection, training and supervision of competent personnel
    - All steep slope rope access personnel are considered competent for on-slope work through successful completion of mandatory training and annual experience requirements (discussed in detail below).
- Selection, use and maintenance of appropriate equipment
    - This knowledge is obtained through mandatory training and experience.
- Suitable working methods
    - This knowledge is obtained through mandatory training and experience.
- Provision for emergency situations
    - This knowledge is obtained through mandatory training and experience.

WSDOT's Geotechnical Office has received the annual Rope Access Safety Recognition award from The Association of Geohazard Professionals since its inception in 2016.

5.1 Principles for Permanent and Temporary Anchor Systems

Anchor systems need to be designed and fit for purpose. They must provide assurance that the minimum strength requirements are met or exceeded.

Safe permanent anchors require:

- An appropriately engineered design and/or manufacture
- Correct installation
- Testing, certification and documentation

The Geotechnical Office rarely uses permanent anchors simply because they are not available very often. We might use a permanent anchor that was installed by a contractor or during our annual training, where permanent anchors have been installed.

Typically, however, we rely on safe temporary anchors, installed by ourselves. If we do use previously installed anchors, they are to be inspected for safe use, i.e., inspected for damage, putting weight on them before you hang from them, etc.

Safe temporary anchors (typically used by the Geotechnical Office) require:

- Experience and knowledge in selecting suitable objects, structures and substrates to attach to
- An understanding of how forces are generated and distributed by systems (Appendix D)
- Suitably rated attachment equipment

The Geotechnical Office typically uses safe temporary anchors during our steep slope rope access work, since permanent anchors are not always available. Generally, these are trees, bushes, boulders, guardrails, etc. We rely on our training and experience to determine whether a temporary anchor is safe to use. At times, suitable temporary anchors are not present. If this is the case, then we will not conduct rope access work. We may use a drone (UAV) to conduct some of the work that would be conducted from ropes (video/photos of drape systems, anchors, rock outcrops, etc.). Drones can also be used to differentiate between areas that should be inspected from ropes (and identify safe approaches) from other areas that do not require on-slope rope work.

5.1.1 ANCHORING

Anchor points can either be engineered or non-engineered. Engineered anchor points can either be permanent or portable to suit the needs of different situations. Engineered anchors are designed and certified by a professional that meets specific standards. Non-engineered anchors are anchors of undetermined strength. The Geotechnical Office typically uses non-engineered anchors during slope access. Training, experience, and judgement are required to determine which non-engineered anchors are suitable. The climber must determine what anchors have the necessary strength and location for the required job. Typical anchors used in the field are:

- Suitable tree(s)
- Guardrail post(s) (dual or multi-anchors advised, provided the posts are not compromised by the instability under investigation)
- Large boulder(s)
- A series of bushes (a last resort, only if a suitably strong multi-anchor system can be devised)

If none of the above are strong enough or limited, then we design load-sharing anchors. A load-sharing anchor is an anchorage system consisting of two or more individual anchors intended to share the load between them and to assist in moving the rope to a more desirable location.

5.2 HEALTH AND SAFETY PRINCIPLES FOR ROPE ACCESS WORK

Before commencing any work, a site assessment should be carried out to confirm if rope access is the safest and most suitable method for the job.

Identify the hazards associated with the upcoming on-slope work. Implement controls to eliminate, isolate or minimize these hazards. This will help to ensure that rigorous safety procedures are effectively followed.

The hazard identification and management process involves:

- Identifying hazards that could cause or create falls, i.e., poor anchors, loose debris, slippery slope, etc.

- Assessing the significance of these hazards to determine if they are capable of causing serious harm.

- Controlling the hazards by implementing the most effective hazard controls using the following:

  1. Control the hazard by using a passive fall prevention system, i.e., netting, handrails and/or guardrails, etc.

  2. If a passive fall prevention system is not practicable, control the hazard by using a work positioning system (personal harness secured to a permanent/temporary anchor with a lanyard).

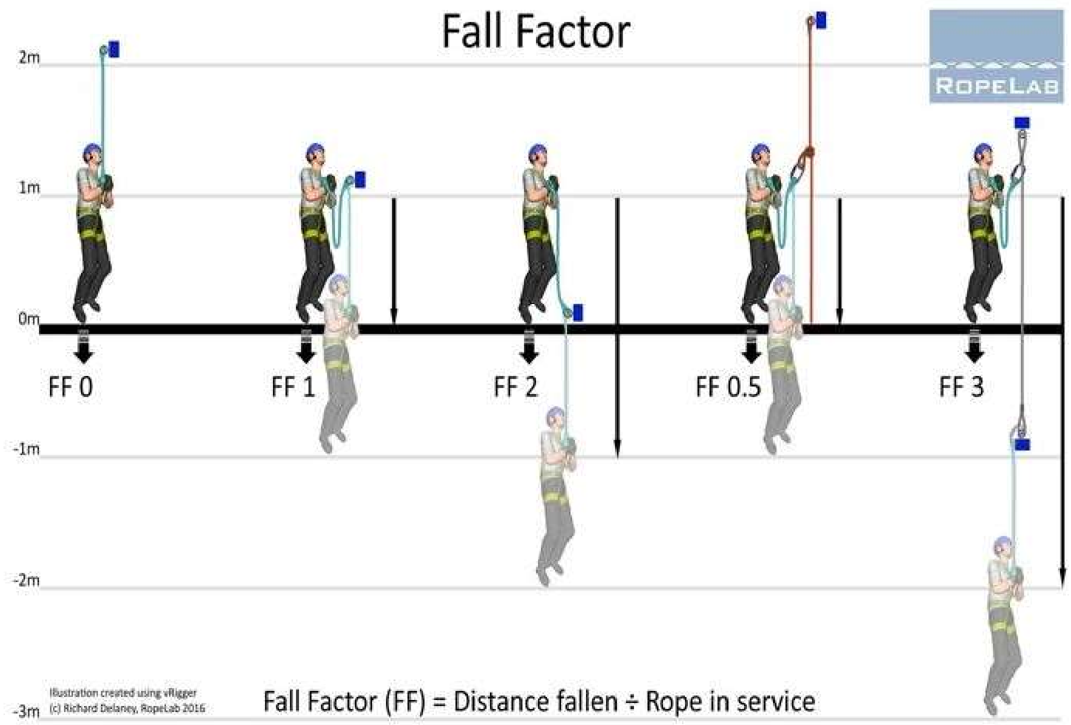
  3. If neither of the above are practicable, control the hazard by using a fall arrest system (equipment that protects workers from falling at dangerous heights), while considering the Fall Factor (described below).

  4. If none of the above is practicable, control the hazard by using all other practicable hazard control measures.

There are instances where the job is too hazardous, at the time, and on-rope work will not be conducted, i.e., slope is too unstable, poor weather/visibility, cannot access the top of the slope safely, traffic control is not available (if needed), etc. The slope will be reevaluated on a different day and rope access work will begin once the site is deemed safe.

Double protection is a fundamental safety principle for rope access. This generally means that a worker uses a minimum of two points of contact i.e., descending device (main line) and a backup (e.g., ASAP with a lanyard – back-up line), two hand ascenders or one hand ascender and a CROLL when ascending (main line) with an ASAP and lanyard (back-up line).

Fall factor is the ratio of fall length to rope length (lanyard). The fall factor can be a useful way to describe the proportional seriousness of a fall. The Geotechnical Office trains to position the back-up device (ASAP with lanyard/prusik, etc.) as high as possible on the rope to limit the fall factor.



(RopeLab, 2019)

All personnel must be adequately trained to carry out any rope access project, and must work in teams of at least two people, i.e., one person on rope and one on the ground or two people on ropes.

6 PERSONNEL

6.1 QUALIFIED PERSONNEL/TRAINING

Everyone working at height should have some formal knowledge of fall protection principles and methods (annual training, experience, etc). Everyone selected for rope access work should have an adequate level of fitness and be able to work on rope safely. They should be comfortable working at heights without compromising their own or others' safety.

The Geotechnical Office's training is contracted every other year from an outside organization for a two-to-three-day course and the Geotechnical Office conducts in-house training during opposite years. The outside organization has been approved for steep slope rope access work by OSHA, Bureau of Reclamation, United States Army Corps of Engineers, etc. They also have SPRAT-trained (Society of Professional Rope

Access Technicians) instructors on staff. The Geotechnical Office conducts in-house-led training annually (up to several times a year to monthly) to remain comfortable and confident while on steep slopes that require rope access. This training includes, but is not limited to, knot-tying practice, safe anchor evaluation and set-up, passing the knot (ascending/descending), rescue techniques, etc.

An individual from the Geotechnical Office is responsible for scheduling annual training, ordering gear and ensuring that each Geotechnical Office employee that works on steep slopes is in compliance with the minimum standards set forth in this document.

6.1.1 Physical requirements

All Geotechnical Office employees that conduct rope access work must be in good physical health. At a minimum, all rope access employees must be able to ascend/descend on a vertical lifeline, must be able to "pass the knot" while ascending/descending vertically, must be able to transfer from rope system to rope system, and must be able to perform a rescue with an injured/unconscious climber (see Section 6.2.1 for more detail on these maneuvers).

It is the employee's responsibility to notify their supervisor of any ailments that may affect their ability to perform rope access work or pose a risk to themselves or their team, i.e., sickness, injury, etc.

6.2 Competency

Competence is attained through a combination of training, knowledge and experience. WSDOT's Geotechnical Office employees receive a Certificate of Competence every other year from the accredited organization that conducts the two-to-three-day course. The Geotechnical Office conducts in-house training several times a year, especially during the years not trained by an outside source. Each person must have at least 20 hours of WSDOT approved rope-access training/experience annually to be allowed to participate on a steep slope team. Our employees keep a log of training/skill hours for proof of experience. This information should include the type of work/training, hours worked and dates the work is performed. An example of this log is in Appendix C. This experience log is reviewed by one of our qualified personnel annually to ensure all steep slope rope access employees are obtaining their mandatory experience and training.

6.2.1 Basic

Basic competence will require a full set of skills relating to personal safety on ropes, including:

- Ascending – moving up rope while conducting steep slope rope access work.
- Descending – moving down rope while conducting steep slope rope access work.
- Knot bypass techniques – ascending/descending past a knot where a damaged section of rope is localized, where no weight should be applied to that area.

- Rigging for simple systems – competency to safely create a rope access work site, i.e., setting up full body harness, setting up anchor(s), attaching harness to anchor(s), having correct gear for ascending/descending, etc.

- Rope to Rope Transfer – transferring from one main line to another while maintaining a minimum of two points of contact.

- Rescue – competency to rescue another hurt/unconscious climber from their rope system to your rope system and descend to the bottom of the slope safely while the Emergency Management System (EMS) is en route to the job site.

Additionally, all personnel should hold a first aid/cpr certificate (recertification every two years) along with some formal fall arrest (and fall protection) qualifications and training for the inspection of equipment. Fall arrest (system developed to stop a fall and absorb the energy from the fall) and fall protection (equipment device or system that is used to prevent or reduce the risk of falls from height) qualifications, along with inspection of equipment are all taught and emphasized during our mandatory annual training and our monthly knot-tying training. The Geotechnical Office emphasizes the inspection of equipment (ropes, carabiners, harnesses, etc.) before and after each use to identify if and when equipment should be retired. Below is a list of typical retirement guidelines:

- Ropes – Ropes should be retired immediately after a fall with extreme loads or if it shows damage, i.e., cuts, abrasions, etc. Regularly used ropes (few times per month) should be retired approximately every 1-3 years; rarely used ropes (1-2 times per year) should be retired approximately every 7 years; and rope that is never used should be retired approximately every 10 years.

- Harness – A harness should be retired if it is more than seven years old, even if it has been properly stored and shows no visible damage. Harnesses should be retired if webbing is cut or significantly worn or frayed, show signs of discolored or melted fibers, if the stitching shows signs of pulled threads, abrasion or breaks, if hardware shows signs of damage, sharp edges, etc. The harness should not be used if the original labels are no longer attached or are illegible.

- Carabiners – Carabiners should be retired when they have been dropped a significant distance (>25 feet), exposed to heat sufficient enough to alter the surface appearance, if cracks develop, if distortion or deep gouges are evident, if gates don’t line up, if sharp edges are present that could cause damage to your rope, etc. Carabiners will also be retired if the function and condition have been compromised.

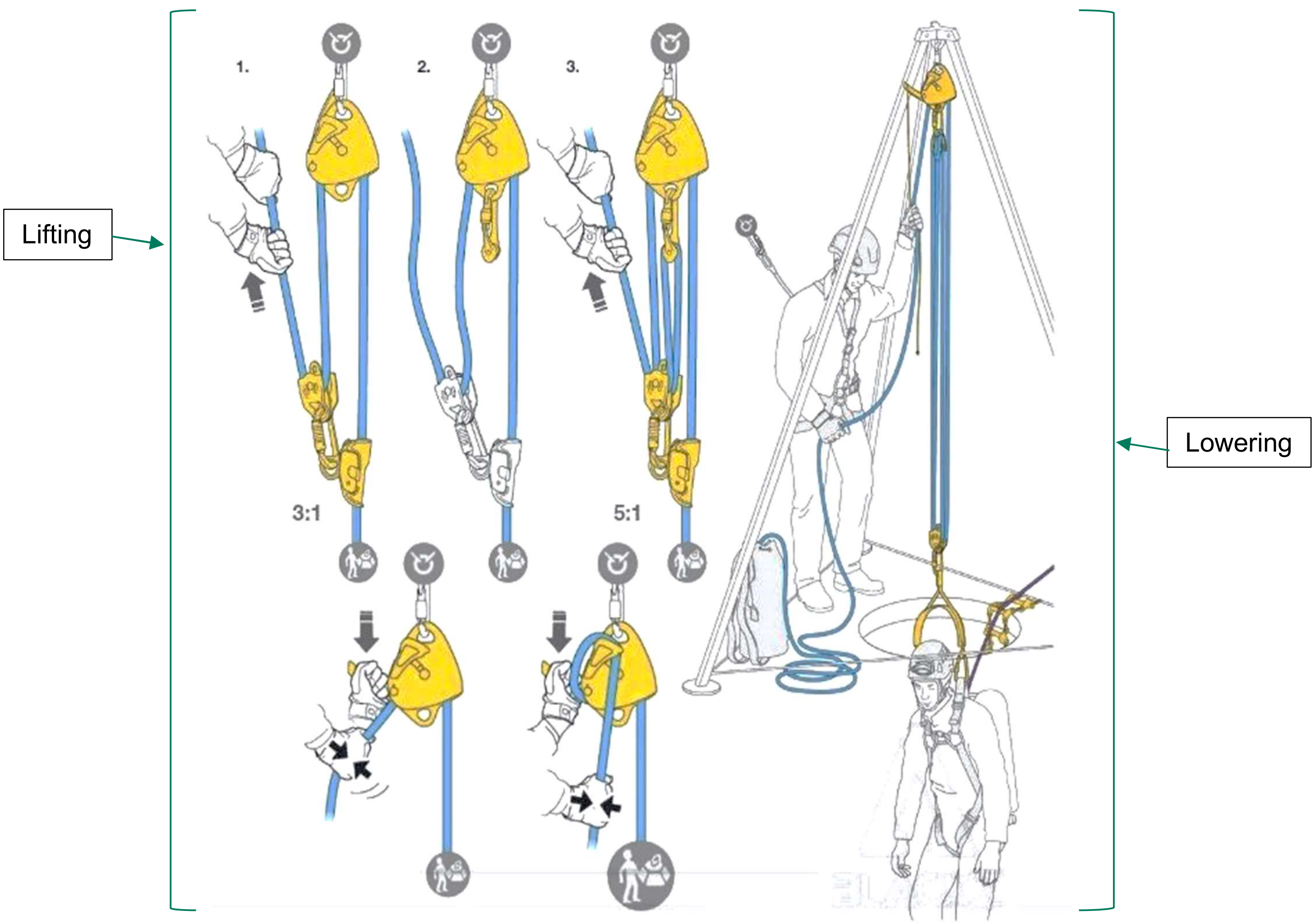
6.3 TEAM SIZE

Rope access teams must be supervised and self-supporting so that the team is capable of handling all rescue and emergencies with the resources on hand. If an emergency arises, EMS will be contacted, if possible, and rescue of the injured/unconscious team member will commence. The rescuer receives mandatory annual training on how to safely move the injured/unconscious climber from their rope to yours and descend to the bottom of the slope while EMS is en route. Teams must have a minimum of two members. Any team must have a designated team supervisor in control of all decisions relating to safety.

7 LOAD MANAGEMENT/HAULING WITH PULLEYS

At times, we need to haul gear up/down to our work area or possibly pull up/lower a rescue patient. These loads can be heavy. In order to lift/lower these heavy loads, we must create a mechanical advantage. We can create a mechanical advantage with the gear we have in our climbing kit (rope and pulleys). We use pulleys in our hauling (rope) system, since forces are multiplied at each pulley location, creating a mechanical advantage to haul heavy loads.

Examples of Mechanical Advantage Using Pulleys



(Rigging Werx, 2020)

8 JOB PLANNING

Before rope access work is conducted, pre-planning must take place to determine the safest and most efficient way to conduct the work. Pre-planning determines how to access the slope, mitigate/reduce risks from the work, how to evacuate or rescue from the area, and maintain the safety of personnel and the public around the work area. Before any work is conducted, a Steep Slope Rope Access Assessment (SSRAA) form must be completed. The SSRAA form was developed by senior members of the Geotechnical Office's rope access group. The SSRAA form assists the climbing team to identify what hazards might be present in the work zone, how to minimize or eliminate the hazard(s), the best access route to the top of the slope, what climbing equipment the team should have, the nearest hospital with contact information, etc. An example of a SSRAA form is included in Appendix E. The rope access team also fills out a Pre-Activity Safety Plan (PASP), specifically for steep slope rope access work. This PASP is an additional checklist to review before on slope work initiates. The PASP was also developed by senior members of the Geotechnical Office's rope access group and can be found in Appendix F. The PASP, similar to the SSRAA form, assists the climbing team to identify what hazards might be present in the work zone (loose rock, uneven terrain, etc.), what type of PPE the team should have, etc.

Once the SSRAA form and PASPs are filled out, they are texted to our supervisors and filed in our project folder for documentation.

8.1 WORK ZONES

- **Fall Zone:** The area in which people are at risk of falling such as rope access climbers on-rope or near a working edge. This area requires protective measures such as verbal warnings, signs, barriers, safety lines, or other devices designed to prevent or arrest a fall.

- **Hazard Zone:** Any area where a person may be at risk as a result of the work being performed. This includes the rope access climbers on-rope as well as anyone at a lower level that may be struck by a falling object.

- **Safety Zone:** Any area outside the hazard zone or the fall zone.

All work zones need to be identified while filling out the SSRAA form.

In addition to the type of work that will be performed at the project site, job planning requires identifying any and all hazards, mitigating these hazards (or avoiding them) and outlining an emergency plan, should it be needed.

The team should be knowledgeable of the work site and the hazards that are present and be familiar with emergency services (phone numbers, locations, etc.) before on slope work is performed. This information is included on the SSRAA form, which should be filled out by the team leader. All members of the team should go over the SSRAA and PASP forms and comment and sign before any slope access work is performed. Typical items listed on the SSRAA form are:

- Names of personnel on the team
- Last training date of each member of the team
- Weather
- Emergency plan (contact information and rescue plan)
- How to safety access the work area
- Type of slope (rock, soil, both)
- Dimensions of slope (height, length, slope angle, etc.)
- Condition of the slope (unstable, marginally stable, localized instability, etc.)
- Hazards that may be encountered (failures, tripping, slipping, environment, etc.)
- Mitigation of these hazards (remove loose rock/soil, avoidance, etc.)
- Identify work zones
- Sketch front and cross-section views of the slope for familiarization
- Identification of anchorages used
- Fall protection and rope access system used (including PPE)

9 EMERGENCIES AND RESCUE

All rope access operators must receive training in dealing with emergency situations and maintain their competence through regular practice. Rescue typically consists of the following:

1. Assess the situation. This includes the cause of injury to the patient and/or the unstable/environmental conditions that caused the injury. Make sure the area is safe to enter. The hazards (rockfall, landslide) may still be present. Do not become another patient.

2. Stabilize the patient. Administer first aid, if needed, and stabilize the patient if there is a possible spinal injury.

3. Transfer patient onto your rope access system. Typically, this involves removing the patient from their equipment and transferring them to your equipment. You

may have to create a mechanical advantage to raise them and release them from their equipment.

4. Transfer the patient to an area where Emergency Medical Services can take over the rescue.

All of the above steps should be discussed while filling out the SSRAA form every time we are conducting steep slope rope access work. Someone specific should be identified to call EMS; however, everyone should be capable and ready to contact EMS in case the designated person becomes the patient.

All personnel should be aware of Suspension Trauma. Suspension Trauma, or Harness-induced Pathology (HIP), is a condition that can present itself when a motionless or unconscious patient is left suspended upright in a seat or body harness.

In a motionless patient, blood pools in the legs and will eventually cause circulatory distress and dangerously low blood pressure, depriving blood to vital organs, including the brain. The pressure of the harness on the femoral arteries and veins contributes to the problem. These symptoms can occur in as little as 20-30 minutes of motionless suspension. Rapid rescue is critical. During rescue, loosening the leg straps and moving the legs should be done as soon as possible. All patients suffering from HIP should be transported to a hospital as soon as practicable.

Prior to the start of on-slope work, a rescue plan must be developed that takes into account the potential hazards present, the necessary equipment, competent personnel present, and first aid equipment available. This information is included on the SSRAA form.

In rescue situations, rope access systems will often be subjected to higher-than-normal loads (operator and patient) on one main line. This needs to be recognized and discussed while filling out the SSRAA form.

Rescues should occur promptly and proper emergency authorities should be contacted as soon as is practical (e.g., via cell phone, radio, etc.).

Every worksite should have:

- Specific rescue equipment to carry out a rescue in commonly encountered climbing situations
- A first aid kit
- All operators should be certified in first aid

10 CLOSURE

These guidelines were developed for updating and standardizing the techniques, safety practices, and the equipment used by the Washington State Department of Transportation's Geotechnical Office Steep Slope Rope Access Group.

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APPENDIX A: QUALIFIED PERSON LIST

WSDOT Engineering Geology Section

- Michael Mulhern
- Marc Fish
- Eric Smith
- Gabriel Taylor
- Samuel Johnston
- Stephen Newman
- Rebecca Garriss
- Jennifer Diguilio
- Cody Chaussee
- Katelyn Card

APPENDIX B: ANIMATED KNOTS BY GROG

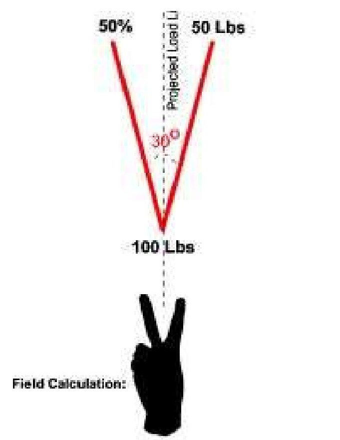
https://www.animatedknots.com/


Grog's Index of Climbing Knots
Alpine Butterfly Bend
Alpine Butterfly
Blake's Hitch
Bowline
Chain Sinnet
Clove Hitch
Directional Figure 8
The Distel Hitch
Double Fisherman's
Double Overhand
Figure 8 Bend
Figure 8 Double Loop
Fig 8 Follow Through
Flat Overhand Bend
Girth Hitch
Klemheist
Munter Mule
One Handed Bowline
Prusik Knot
Water Knot
Zeppelin Bend

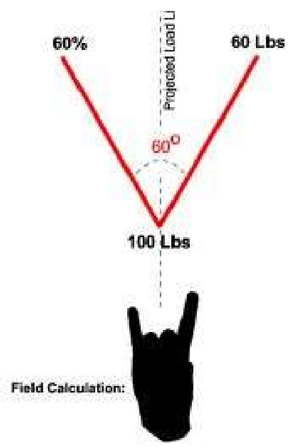
APPENDIX C: STEEP SLOPE ROPE ACCESS EXPERIENCE LOG

Steep Slope Rope Access Experience Log					
Date	Type of Project (Rockfall/Landslide, etc.)	Rope Access Details (ascending/descending/rescue, etc.)	Hours worked (nearest half hour)		
		Total:	0		

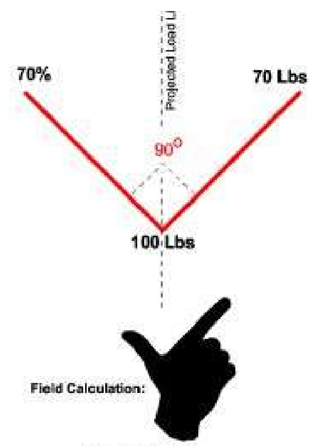
APPENDIX D: RIGGING – DUAL ANCHOR ANGLES FOR BALANCED LOADS



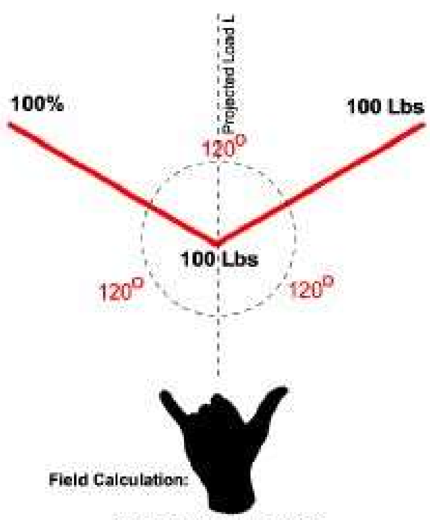
Ideal Angle (I)
30° or less
Note: Be Mindful not to let the load shift Left or Right. Extremely small variations will add additional stress to one of the anchors



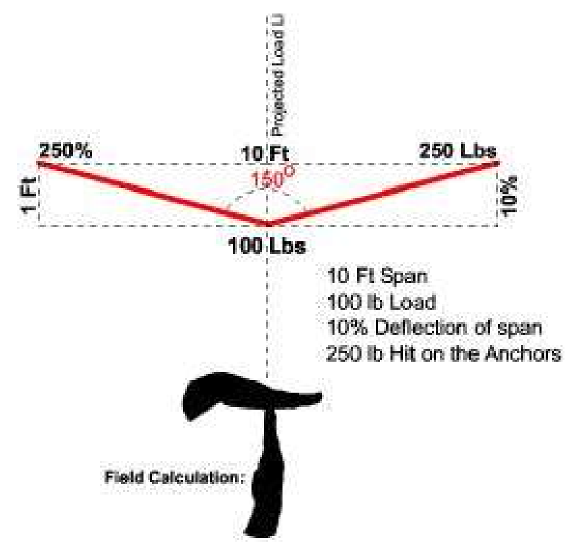
Yes Angle (Y)
60°
Note: Although there is 10% additional stress on each anchor compaired to an Ideal Angle, the stabalization of the load Left or Right is far less critical.



Yes Angle (Y)
90°
Note: The 60° difference between 30° and 90° angle increases anchor stress by only 20%



Cautionary Angle (C)
120°
Note: If you disect the circle by both the anchors and by the load line, you see that all 3 sections are equal. If all angles are equal then all loads must be equal. Any angle > 120° is classified as a (T) for Terrible angle.
TRY NOT TO EXCEED THIS ANGLE WHEN RIGGING!



TIME OUT - Terrible Angle (T)
150°
Note: The following rigging calculation must be applied. Try to achieve 10% Deflection based on span. (10% of Span)

$$\frac{\text{Span x Load}}{\text{(4) x Deflection}} = \text{Anchor Lbs} \quad \frac{\text{10ft x 100lbs}}{\text{(4) x 1ft}} \quad \frac{1{,}000}{4} = 250 \text{ lbs}$$

APPENDIX E: STEEP SLOPE ROPE ACCESS ASSESSMENT FORM

Steep Slope Rope Access Assessment Form

Slope Location (SR, MP, side of road): ______________________________________
Date:________________ Weather:________________
Preparer:____________Last Training Date:______________
Partner: ____________Last Training Date: ______________
Support Person (if available): ____________________ Planned On-Slope Activities: ____________________

Slope Description

Cut Slope ○ Natural Slope ○ Recent/Old Slide ○

Slope Materials

Soil ○ Soil and Rock ○ Rock ○

Slope Condition

Numerous detached blocks ○ Some detached blocks ○ Few detached blocks ○ NA ○

Slope Height

<50' ○ <100' ○ <150' ○ <200' ○ >200' ○

Slope Width W =___________ ○ ○

Slope Angle

35° to 45° ○ >45° to 70° ○ >70° to 90° ○ Overhanging ○ If yes, <5' ○ >5' ○

Rock block Size S (<1') ○ M (1'–3') ○ L (3'-6') ○ XL (>6') ○ NA ○

Average ________ Maximum ______

Equipment Check List

- Helmet ○
- Gloves ○
- Prussic ○
- Ascenders ○
- Rappel Device ○
- Rope ○
- Harness ○
- Safety Carabiners ○
- Daisy Chains ○
- Assorted Slings ○
- Boots ○
- Safety Glasses ○
- Ear Plugs ○

Access Route Safety and Upslope Hazards:____

____

Anchor/Access to Anchor:____

____

Brow Conditions/Stability and Mitigation:____

____

Apparent Stability of On-Slope Features:____

____

Downslope Risk Exposure (traffic/personnel/infrastructure) and Mitigation:______________________________

____

____ **Review Pre-Activity Safety Plan** ____**Inspect Ropes/Hardware** ____**Inspect PPE** ____**Test Radios**

____**Verify Adequate Rope Length/Tie Knot at the End**

(see other side for sketch)

Steep Slope Rope Access Assessment Form

Slope Location (SR, MP, side of road): ____________________________________
Date: ________________ Weather: _________________
Preparer: ____________ Last Training Date: _______________
Partner: ____________ Last Training Date: _______________
Support Person (if available): ____________________ Planned On-Slope Activities: ____________________

SLOPE DIAGRAMS

Cross Section Sketch	Front View Sketch (enter, exit, & emergency access locations)

Comments: ____

____

APPENDIX F: PRE-ACTIVITY SAFETY PLAN

ROCK SLOPE INSPECTION

PRE-ACTIVITY SAFETY PLAN

Safety Information for WSDOT

Rock Slope Inspection

☐ Discussion of work activity to be performed____

☐ Identification of potential hazards associated with performing the work and the steps that will be taken to mitigate each hazard

TASK	HAZARDS	CONTROLS
1. Traffic Control (if required)	Automobiles & Trucks	Wear reflective vests. Use cones, and signs.
2. Walk along bottom to inspect lower rock slope area	Cuts, abrasions, etc.	Wear long pants, sleeved shirts, steel toe boots, and hard hat.
	Traffic, construction equipment	Wear reflective vest and hard hat.
	Falling rocks and debris	Wear hard hat/climbing helmet & steel toe boots. Never work on a rockslope/rockfall site during night time hours or when it is actively moving.
	Animals & reptiles	Wear steel toe boots & stay alert.
3. Take notes, measurements & photographs	Traffic, construction equipment	Wear reflective vest & hard hat/climbing helmet.
	Falling rocks and debris	Wear hard hat/climbing helmet & steel toe boots
	Animals & reptiles	Wear steel toe boots & stay alert.
4. Walk or climb to top of rock slope to inspect upper slope area and then back down	Cuts, abrasions, uneven terrain, slipping/falling, falling rock or debris, muscle strain, animals & reptiles	Wear long pants, sleeved shirts, steel toe boots, hard hat/climbing helmet, gloves, & eye protection. Use ropes & safety harness if properly trained. If using ropes, a minimum of two people need to be on site. Exercise regularly to prevent muscle strain. Use the Geotechnical Division's Fall Protection Plan.

Tools used	Hazard	Control
Field Equipment	Weather, visibility,	Use common sense and expect the unexpected.
Geotechnical Division Vehicles	Roadside hazards,	
	Tripping, overhead hazards, other drivers.	

☐ **Required Personal Protective Equipment (PPE)**

1. **Hard hat/climbing helmet**
2. **Reflective vest**
3. **Steel-toed boots**
4. **Long pants**
5. **Gloves**
6. **Eye Protection**

☐ **Required Training:**

☐ Emergency medical provider:

☐ Emergency Contact phone Number:

☐ Emergency Evacuation Plan

Related PASP's

Other Information: General PASP's,
Fall Protection Plan (Geotechnical Division)

Contributors:

Created:

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