OBJECTIVE PAGE

Ropes
Lesson One
High Line Systems

DOMAIN: COGNITIVE / PSYCHOMOTOR

LEVEL OF LEARNING: COMPREHENSION
APPLICATION

MATERIALS

International Manual of Basic Rescue Methods, 2004 edition; High Angle Rescue Techniques 3rd edition, by Tom Vines and Steve Hudson, available through Mosby / Jems publishing or Firehouse.com; CMC Technical Rope Rescue, and Rigging for Rescue Inc. Technical Reports. Laptop computer and multimedia projector, white board, marking pens; a suitable number of 1” or 2” flat or tubular design web slings in untied lengths of 6’ and 12’ or anchor straps of same lengths, several various lengths of 8mm low stretch kernmantle accessory cord including 53" and 65" ; 1 - 33’ section of 8 or 9mm accessory cord for rigging a load release hitch; 20 steel locking carabiners, 2 – 25’ and 50’ sections of lifeline for tie-back use. Various sizes of single and double sheave pulleys (minimum diameter should be 4 x the diameter of the rope being used); 2 Kootenay pulley (or equivalent); 2 prussik minded pulleys; 2 small rigging plates or one large one; for a single track line system: 1 - 1/2" diameter low stretch kernmantle rope, for a 2 track line system 2 - 1/2" diameter low stretch kernmantle rope, 2 - 1/2" diameter low stretch kernmantle ropes for use as belay tag lines (length is determined by the span to be crossed), multiple tag line hangers, 1 – 12' - 15' length of lifeline for litter tender (pigtail); slings for the tender (non-litter operation), 2 spider rigs made with a minimum of 7/16" diameter lifeline or 2 commercial type spider rigs for use at the head and foot end of the litter; 1 length of one inch untied webbing to be used as a spreader between the two attachment points on the litter; several rope grab devices rated for general use; 25 - 20 small diameter accessory cord (4-mm) tied as prusik sling to be used as tag line hangers and15 - 20 large key type snap links or equivalent, 12 brake

bar racks; 1 Rescue 8 descenders; 1 litter rated for horizontal use, and 1 Class III rescue harness.

NFPA 1006, 2008 edition JPRs

6.2.5 Direct a team in the construction of a high-line system
6.2.6 Direct a team in the operation of a high-line system

Junior Member Statement:

Junior Member training activities should be supervised by qualified instructors to assure that the cognitive and psychomotor skills are completed in a safe and non-evasive manner. While it is critical that instructors be constantly aware of the capabilities of all students both mentally and physically to complete certain tasks safely and successfully, the instructor should take every opportunity to discuss with departmental leaders and students the maturity and job awareness each participant has for the hazards associated with fire and rescue training.

TERMINAL OBJECTIVE

The Technical Rescuer shall correctly identify, describe, and demonstrate the setup, operation, and function of highline systems for use at a rescue incident. Distinction should be drawn between horizontal, sloping and steep high lines.

ENABLING OBJECTIVES

1. The Technical Rescuer shall correctly identify in writing the minimum specifications and requirements for setting up a highline system.

2. The Technical Rescuer, given the appropriate equipment and working as a member of a team, shall correctly demonstrate setting up a horizontal highline system and executing a rescue operation.

3. The Technical Rescuer, given the appropriate equipment and working as a member of a team, shall correctly demonstrate setting up a sloped or steep highline system and executing a rescue operation.

Ropes
Lesson One
High Line Systems

MOTIVATION

There are situations in rope rescue operations that require horizontal rather than vertical movement. Highline systems can provide a solution to this problem and is designed to horizontally span the distance between two elevated points, or from an elevated point to the ground. This system allows for safe, effective, and efficient patient retrieval and transport between the various elevations. This system requires specialized equipment and extensive training, since it places a tremendous amount of stress on lifelines and hardware. The load limitations of the system's components must be well known and understood by the Technical Rescuer in order to design and operate the system correctly and safely. One mistake could result in a catastrophic failure of the system causing it to collapse.

PRESENTATION

ENABLING OBJECTIVE #1

The Technical Rescuer shall correctly identify in writing the minimum specifications and requirements for setting up a highline system.

1. Identify the potential uses of a highline system.
   a) To cross a canyon or gorge.
   b) To avoid hazardous terrain.
   c) To bridge swift moving water.
   d) For emergency evacuation for a high rise-structure.

2. Identify and discuss the components of a highline system.
   a) Track-line - Primary load bearing rope in the highline system used as a track line to support the major portion of the weight of the load on the

highline. One half inch diameter is typically the most common diameter of choice for track lines, as it is most commonly the choice for most other rope rescue operations.

b) High Strength Tie-off - a tie off which maintains 100% rope strength. Example: no knot tensionless hitch, the minimum diameter of the anchor must be 8 x the diameter of the rope.
c) Control Side - the side on which the tensioning system is attached.
d) Far Side Anchor - the side on which the high strength tie-off is secured.
e) Load - the mass, including personnel and equipment that will be attached to the highline.
f) Pulleys - they are used for creating tension systems and moving personnel and equipment across the highline.
g) Tag Lines - attaches to the load carriage and serves as a controlled belay system while loads are being moved across a span.
h) Rescue size load - total force applied to the highline system.

3. Identify and discuss problems associated with highline operations.
   a) The potential stress and failure of the system.
   b) There is a lengthy setup.
   c) There can be difficulty getting initial personnel and equipment across to other side.

Reference: High Angle Rescue Techniques, 3rd edition, pages 304 through 307.

4. Discuss the guidelines for selecting the appropriate diameter of lifeline to use for a highline.
   a) Based on extensive testing of highline systems, the rope type and diameter of choice for a track line is 1/2" low stretch kernmantle.
   b) There has been extensive testing and written documentation to confirm the safety of using tandem 8mm prussik cords on 7/16" (11mm) and 1/2" (12.7mm) low stretch kernmantle rope.
   c) The basic reason for using a prusik system on a highline is to act as a slip clutch alerting the rescue team to a possible overload of the system.

d) Many rope rescue teams in various parts of the country use 7/16" diameter rope as a track line.
e) Selection of the diameter of the rope and the number of track lines needed is dependent upon the rescue size load, the span and the maximum allowable sag.
f) Some AHJs mandate the use of 5/8" rope for single line highline rope.
g) The issue for steering away from 5/8" rope for use as a track line is not the strength of the rope, but whether or not 8 or 9mm prussik cord will actually act as a slip clutch when the rope is excessively overloaded.
h) Currently there is not enough written documentation of testing to confirm the safety of using 8 or 9mm prussik cord on 5/8" rope.
i) Other consideration for not using 5/8" diameter rope for a track line includes stiffness, bulkiness, and weight.
j) Ultimately the AHJ should make the determination based on the breaking strength of the rope and other components in the system and competent system information.

5. Discuss the elements of a safety check.
   a. Make sure all software is undamaged.
   b. Check all hardware for serviceability and correct set up.
   c. Make sure all rope contact points are protected.
   d. Lock all carabineers.
   e. Make sure all back-up systems are in place and functional.
   f. Execute a whistle test.

PRESENTATION

ENABLING OBJECTIVE #2

The Technical Rescuer, given the appropriate equipment and working as a member of a team, shall correctly demonstrate setting up a horizontal highline system and executing a rescue operation.

1. Discuss the 10% rule for determining the amount of pre-tension sag needed in a highline system to prevent overloading.

a) Ideally a dynamometer is the most effective way to determine the amount of actual stress that is being exerted upon a highline system.
b) The 10% rule is a conservative method for tensioning a highline system.
c) Accordingly the center of the unloaded highline should sag vertically about 10% of the span for every 200 pounds of expected load and every 100' of span.
d) Calculating rope sag according to the 10% rule should be based on the total weight of the load. For a 200 pound load (1X Load or 1L) to be carried on a 100 foot span, the formula would be 1L x 100' x 0.1= 10'. For a 400 pound load (2L) to be carried on a 200' span, the formula would be 2L x 200’ x 0.1= 40'.
e) A simpler option would be to pre-tension the track rope with a 2:1 or 3:1 MA using one rescuer.
f) The rescuer shall make one pull on the system to a point where pulling becomes difficult.
g) The rescuer shall not make any additional pulls on the track line.
h) When multiple tracks are used, a 2:1 MA pulley system in series should be rigged to apply equal tension on all track lines.
i) It’s important to understand the difference between pre-tension and maximum tension.

Reference: High Angle Rescue techniques, 3rd edition, pages 310 through 312.

2. Discuss the Rule of 12 and Rule of 18 for preventing overloading a highline system.
   a) For 7/16" diameter rope, the rule of twelve applies. Example: for a 3:1 MA, a maximum of 4 rescuer may tension the line; 3 x 4 = 12.
   b) For 1/2" diameter rope, the rule of 18 applies. Example: for a 3:1 MA, a maximum of 6 rescuers may tension the line. 3 x 6 = 18.
   c) The maximum tension (using the rule 12 or 18) should only be applied when the rescue load is at center span.

3. Demonstrate setting up a horizontal highline system across an urban wilderness environment.

a) Select as narrow a span as possible for the training exercise.
b) Get a second team across to the far side.
c) Brief the second team beforehand on steps to be carried out.
d) Establish a communication link between both sides via radios.
e) Get the ropes going to the far side across the span.
f) Use a line gun or other approved launching device. If a water setting, rafts or kayaks are beneficial.
g) For a long span, like a gorge, the highline components may have to be lowered then carried across to the far side where a rope is lowered and the highline is raised to the needed point.
h) Once the line is across, the rigging technique is basically the same as outlined in the procedures for setting up a sloped highline system.
i) Secure one of the track lines to a solid anchor using a high strength tie-off.
j) Set up the pre-tension system using a 2:1 or 3:1 MA system to the opposite side. (Do not be real aggressive pulling the 3:1 system).
k) Set up the tag line systems.
l) Connect the load to the track line and tag lines.

4. Demonstrate attaching a litter to the highline using a single point and a two point system.
   a) Make sure that the connection device attached to the track line is capable of absorbing the energy created by multi-directional force.
   b) Distinctions between advantages and disadvantages between using a single point carriage connection versus a two-point carriage connection to the track rope should be discussed especially when using a litter.
   c) Using two 8' sections of 7/16" or 1/2" lifeline, tie a figure-eight-on-a-bight in the middle of each. This length can be adjusted as needed. This creates two spider slings. Attach the spider slings to the litter, one near the head end of the litter and the other near the foot end of the litter.
   d) Clip a locking carabiner into each knot.

e) Attach two pulleys to the highline and attach a rigging plate or rescue ring to each and clip then into each pulley of the highline.
f) Clip the locking carabiners from the spider rigs to the rigging plate or rescue ring.
g) Using a section of webbing, attach a spacer line between each rigging plate or rescue ring.
h) The spacer line allows both pulleys to travel across the highline in a smooth motion.
i) Thread the tag lines through the two track line pulleys in an “X” fashion (left side tag line goes to right side track line pulley and vice-versa).
j) Attach a triple wrap prusik onto the tag lines on the inside of each track line pulley and connect them to the pulleys the prusik attached to the left tagline is connected to the right pulley and vice versa (leaving a little slack in the track line on each side).
k) When using a single-track line pulley, connect the left tag line to the left side of the track line pulley and vice versa.
l) Attach prussik to the tag lines on the each side of the pulley and connect into the side holes on each side of the pulley.
m) When using a single tag line that crosses the entire span thread the single tagline through the pulley or pulleys and attach the prusiks from the tag line to the pulley on the inside of a two pulley track line system and on the out side of a single track line pulley system leaving a little slack in the tag line.
n) To create a single point hook up to a single-track line pulley, bring the two single spider slings to the center point and attach them to the track line pulley.
o) Tag lines shall always be attached the track line pulleys instead of the litter or attendants. Attaching the tag line to the track line pulleys reduces the shock load to the tag line in the event of a main line failure.
p) For spans greater than 100', attach tag line hangers between the track line and tag lines, doing this keep the tag lines from sagging severely, this manages rope slack which reduces the shock load to the tags in the event of a track line failure.

q) Spacing between the hangers can between 15' - 30'. Tag line hangers are not a critical load-bearing component, therefore various materials can be used.

NOTE: A commercial litter harness can be used as an alternate rigging system.

NOTE: There are many variations to setting up the components of any highline system. The above systems have a history of being safe and efficient. The instructor is encouraged to show any variation as long as it is safe and efficient.

NOTE: Manufacturers advise that aluminum figure of eight plates are not designed for use in systems that have the potential for loading the plate in three directions. Tests done by manufacturers suggest this application reduces the strength of figure of eight plates a maximum of fifty percent (50%). When tri-loading, a suggested alternative is the use of a steel "O" ring or rigging plate rated for tri-loading or a pulley with multiple attachment points like the Kootenay pulley or an equivalent.

5. Demonstrate attaching a rescuer to a highline system for horizontal crossing.
   a) Secure a pulley to the highline and clip a locking carabiner with rigging plate into it.
   b) Clip a 3' - 5' web sling into the rigging plate.
   c) The rescuer should wear a Class III harness.
   d) Run the web sling from the rigging plate down through a locking carabiner attached to the chest harness and secure it to the seat harness.
   e) At this point the rescuer may cross the highline by hand or tag lines can be attached to the rigging plate in a pattern and the rescuer can be controlled by the near and far side rescue teams.

Reference: High Angle Rescue Techniques, 3rd edition, page 309.

6. Demonstrate rigging a rescuer for a vertical descent from a highline.
7. Secure a pulley to the highline and clip a Kootenay type pulley to it.

a) Attach both tag lines to the lower pulley.
b) Using a separate lifeline, thread it through the lower pulley, through the carabiner on the rescuer's chest harness and secure it to the seat harness.
c) The rescuer then attaches a short sling, within arm's length of the highline, from the carabiner connecting the two pulleys on the highline to the seat harness, and a foot sling can be added to assist with disconnecting the short sling, prior to being lowered.
d) Once the rescuer reaches the lowering point, before unclipping from the track line system the rescuer can attach a triple-wrap prussik onto the track line and connect it to the track line pulley on the opposite side of the lowering system, this acts as a clutch brake during the raising phase of the operation.
e) Once the rescuer is in position, the short sling is disconnected and the rescuer is lowered on the highline.
f) When the rescuer is pulled up to the highline, the short sling is reconnected and the rescuer is pulled to the near or far side.
g) An English Reeve can be used for this purpose also.

8. Demonstrate rigging an English Reeve system to a highline.
   a) Attach a Kootenay or equivalent type pulley to the highline.
   b) Attach locking carabineers to each side of the highline pulley.
   c) Attach tag lines to each side of the highline pulley.
   d) Attach a short triple wrap prusik hitch to each tag line and clip them into the lateral carabiners on the highline pulley.
   e) Create a little slack in each tagline between the prussik and the lateral carabiners.
   f) Using a single lifeline, or reeving line, that will span from near side to far side, attach two 2" pulleys to the reeving line, and clip both into the bottom anchor point on the highline pulley.
   g) Pull slack between the two small pulleys and attach a prussik-minded pulley with the flat edge

pointing up and clip a locking carabiner into the bottom of the prusik minded pulley.

h) Attach two prussik hitches to the reeving line on each side and above the prusik minded pulley.

i) Attach the prussik hitches to the carabiner that is clipped into the bottom of the prusik minded pulley.

j) Point out the English Reeve system allows rescuers to lower and raise personnel and equipment from either the near or far side anchor positions to the near or far side.

Reference: High Angle Rescue Techniques, 3rd edition, page 315.

9. Demonstrate attaching a litter tender to the highline system.
   a) Using a 12’ piece of lifeline, minimum 7/16" diameter, tie a figure-eight-on-a-bight in one end and clip it into the rigging plate or rescue ring.
   b) The litter tender is attached to the lifeline line, also called a pigtail, using two ascenders.
   c) The bottom end of the pigtail is clipped into the litter tender’s seat harness or can be crossed under the litter and clipped to the rail on the opposite of the litter.
   d) The litter tender will also need to able to descend on the safety line.

10. Point out that this system gives the litter tender the freedom to maneuver as needed up and down and side to side.

11. Demonstrate rigging a drooping highline.
   a) Follow all the same set up procedure for establishing a horizontal highline system.
   b) Secure a high strength tie-off to a solid anchor on one side of the span.
   c) On the opposite secure a web sling anchor system to a solid anchor.
   d) Hook a lowering device into the main track line and secure it to the anchor, then rig a piggy-back hauling system.
   e) Secure the tag lines to the load in the appropriate manner for single or double tag line system.

f) The lowering and hauling system can be controlled from the same side or the functions can be split.
g) Attach a load release hitch to one side tag of the line system.
h) Complete a safety check of all systems, and perform a whistle test.
i) Assign a spotter to coordinate the lowering and raising of the system.

PRESENTATION

ENABLING OBJECTIVE #3

The Technical Rescuer, given the appropriate equipment and working as a member of a team, shall correctly demonstrate setting up a sloped or steep highline system and executing a rescue operation.

1. Point out that the difference between a sloped and steep highline system is the angle of the highline.
   a) The angle for a sloped highline system is between 10 - 45 degrees.
   b) The angle for a steep highline system is greater than 45 degrees.
   c) The set-up procedure is the same.

2. Point out that the steeper the angle of the highline the greater the applied force is to the belay system.

3. Make note that the setup procedures are basically the same as rigging for a horizontal system.
   a) Locate a strong anchor at the elevated site and the ground site.
   b) Ensure rescuers at both locations have a sufficient amount of safe work area.
   c) For urban settings, a large fire service or rescue vehicle with sufficient anchor points may be used for the ground anchor. Be sure the wheels are chocked, the emergency brake is set, and the keys have been removed from the ignition.
   d) Tie a tensionless hitch to the elevated or ground anchor point.
   e) From the elevated anchor, tie the mainline into the primary anchor using a tensionless hitch.

f) Drop the mainline to the ground crew and have them establish the estimated amount of sag needed for the system, and tie off the mainline to a strong anchor point using a tensionless hitch.
g) For a short span, the tension for the highline should be pulled manually whenever possible.
h) For a long span, the use of a mechanical advantage system may be needed to pull the highline into the correct position. Remember to use the Rule of 12 when doing so.
i) If the ground anchor is established first, have the rescuers at the elevated point drop a retrieval line so the mainline can be raised and secured.
j) Get the tag line to the low side.
k) Establish anchor points for the tag line on both ends.
l) Attach a piggy-back hauling system, a minimum 3:1, to the mainline in the event tensioning is needed to clear an obstacle during the crossing.
m) Attach a hauling system onto one side and lowering system, it can be a prusik belay system or brake bar rack, onto the other side of the tag line.
n) If deemed necessary, attach a tie-back system to one or both primary anchors, tie backs should be pre-tensioned prior to pre-tensioning the track line.
o) Provide edge protection for all contact points that might cause damage to the components of the system.

4. Demonstrate rigging the tensioning system on the ground using a vehicle.
   a) Follow the same pre-tension procedures as established for horizontal highline systems.
   b) An engine company or heavy-duty rescue vehicle can be used.
   c) Make sure the attachment point on the vehicle is immovable.
   d) Chock the wheels set the brake and take the keys out of the ignition.
   e) A load sharing or load distributing anchor system may be appropriate.
   f) Make sure all contact points of the slings are padded.

Reference: High Angle Rescue Techniques, 3rd edition, pages 307, 312 through 314.

APPLICATION

Assemble the Technical Rescuer candidates at the training site. Locate on the ground, several sites that will allow the candidates to practice rigging the three types of highline systems. Divide them into three groups. Have each group perform all the tasks listed in the Enabling Objectives to successfully complete a highline line lower and raise.

Station 1
Have the candidates correctly construct a horizontal highline system with a two-point litter system.

Station 2
Have the candidates correctly construct a horizontal highline system to lower a rescuer on an English Reeve system.

Station3
Have the candidates construct a sloped or steep angle highline system for a litter lower.

NOTE: A minimum of two instructors must be present, one to oversee elevated operations, and one to oversee ground operations or operations at the other elevated location. The lead instructor may deem it necessary to have additional instructors on site to maintain a safe working environment. Make sure all equipment has been inspected to ensure that all equipment is safe and operating properly. Make sure all candidates are using appropriate PPE for each evolution.

SUMMARY

Highline systems are an advanced form of rope rescue operations. They tend to be more complex and require a more exacting knowledge and execution from the Technical Rescuer than other areas of rope rescue. Review the importance of knowing the load capabilities and limitations of the system components. Re-emphasize the need for the Technical Rescuer to thoroughly understand the design and configuration of the highline system. Finally, review the rigging of the highline system while conducting the field application.