Chapter 11: Lower/Raise (Mechanical Advantage) Systems

Scope: This chapter serves as an introduction to lower/raise (mechanical advantage) systems.
Terminal Learning Objective (TLO): At the end of this chapter, the student will be aware the considerations when selecting the type of mechanical advantage system (MA) to be used in a raising operation.
Enabling Learning Objectives (ELO):

1. Describe rope rescue lowering and raising systems
2. Demonstrate how to convert a lowering system to a raising system with a 3:1 inline - rpm
3. Demonstrate how to operate a lowering system
4. Demonstrate how to convert a lowering system to a raising system with a 5:1 inline – rpm and a 3:1 or 5:1 inline with directional pulley
5. Demonstrate how to construct a 3:1 and 5:1 mechanical advantage system
6. Demonstrate how to construct a 3:1 and 5:1 pig rig
7. Demonstrate how to convert a lowering system to a raising system with a 3:1 and 5:1 pig rig

Rescue operations in low angle rope rescue, in terms of victim extrication, are primarily a lower/raise function. The tools and staffing positions to complete the lowering operations can be completed off the main line component of an RPM system.

This may not be the case with raising operations. Equipment may be required from the mechanical advantage component and an additional line may be required as well.

Therefore, the rescuer has a few options to consider when selecting the type of mechanical advantage system (MA) to be used in a raising operation. This chapter will show the following considerations for MA systems:

- ❒ The inline MA system.
- ❒ The inline MA system with a change of direction.
- ❒ The piggyback system.
- ❒ Straight pull.
- ❒ Apparatus positioning.

Key Points Regarding Lower/Raise Operations

- ❒ Basic lowering operations and inline MAs can be accomplished off the main line component and be supervised by the Rope Group Supervisor (RGS). A more detailed explanation of job titles and functions is in Chapter 13.
- ❒ MA systems with a directional change require additional equipment and staffing. This includes both in-line and piggyback systems.
- ❒ A Haul Team Leader will direct the construction of the MA system, command and control the haul team, and report to the RGS. This is a key management position and requires a person with strong leadership skills and a high technical knowledge base of rope rescue operations.
- ❒ Apparatus positioning is also very important. Proper positioning of the apparatus will ensure a safe and adequate working area for personnel and maximize the effectiveness of the MA system used.
- ❒ As the name denotes, this is the primary line in any rope system. The main line will be loaded during rappel and lowering and/or raising operations. The main line may also have the additional duty of a haul line in some mechanical advantage systems.

Lowering Line Systems

- ❒ All or part may be prerigged and bagged.

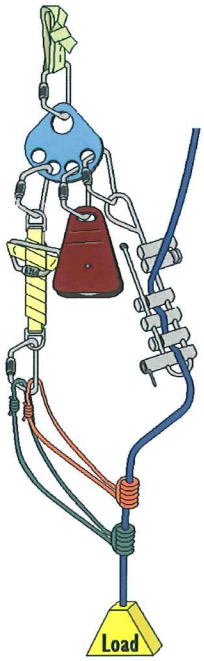


Figure 11-1: With Brake Bar Rack

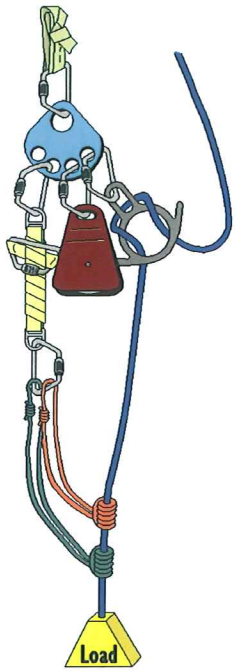


Figure 11-2: With Eight Plate

System Staffing

- ❒ Lowering line tender(s) ***required***.
  - Tends descent control device (figure eight plate or brake bar rack).
- ❒ Lowering line brake ***optional***.
  - If used, a brake tender is ***required*** to tend the tandem prusiks.

System Operation

- ❒ Brake bar rack – one- or two-person load.
  - One tender - adjusts bars as required.
- ❒ Figure eight plate – one-person load.
  - One tender – adjusts attachment as needed.
- ❒ Figure eight plate – two-person load.
  - Two tenders – adjust attachment as needed.
- ❒ Tandem prusik brake.
  - May be removed (staffing or operational considerations).
  - Staffed by main line brake tender when used.

Raising (MA) Systems

These systems are typically utilized after lowering operations are complete. They are either constructed at the scene as part of the main line with component pieces (inline system) or are prepackaged in a separate rope bag and attached to the main line (piggyback system). This chapter deals with the following variations of the haul/MA systems:

❶ 3:1 and 5:1 inline MA systems.

❷ 3:1 and 5:1 MA systems with a directional change pulley.

❸ 3:1 and 5:1 piggyback systems.

❹ Straight pull system.

System Staffing[1]

❒ Main Line Brake Tender.

❒ Haul Team.

Key Points Regarding Raising Operations[2]

Prusik Brake(s)

The prusik brake(s) shown in this chapter are not ratchet cams; they are not configured to self tend. The distance is too great between the pulley and the prusik. This distance creates an excessive amount of slack in the main line if released or set. The brake(s) ***must***, therefore, be tended.

Haul Team

The Haul Team will typically grasp the line and walk in a controlled manner to apply force to the system. In situations of limited hauling space, the team will haul using the hand-over-hand method.

Lower to Raise Conversion: 3:1 Inline – RPM

1) Tie off the DCD as shown in Chapter 10.
   - If prusiks were not attached to the main line during lowering operations.
   - Not needed if litter team/rescuers are on a safe level platform.
   - Not needed if the lowering line tender holds tension as prusiks are attached.
2) Attach prusik(s) to the line if not previously attached during the lowering operation.
   - One prusik is proven adequate as a brake to the main line.
   - It is not necessary to attach the second prusik to the main line, but it is acceptable to do so.

[1] Additional positions are described in Chapter 13: Scene Organization and Management.
[2] Additional key points are described in Chapter 13: Scene Organization and Management.

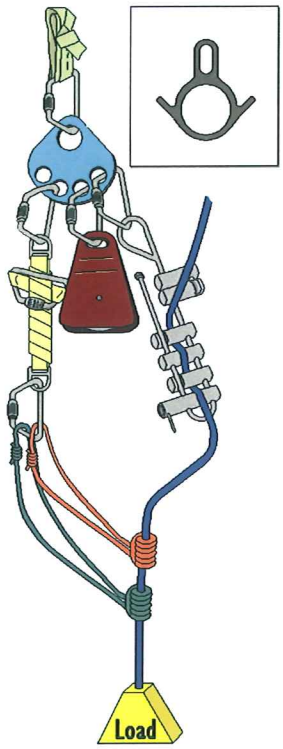


Figure 11-3

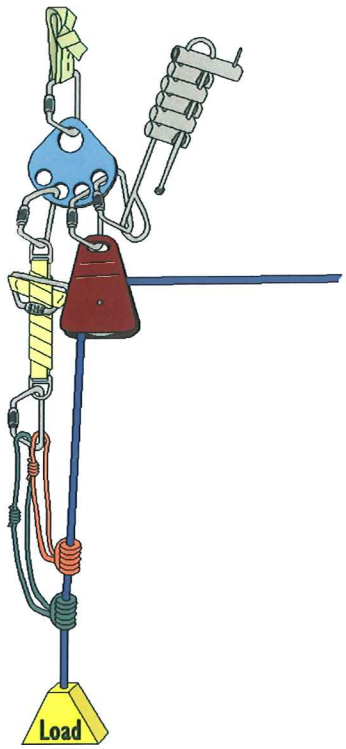


Figure 11-4

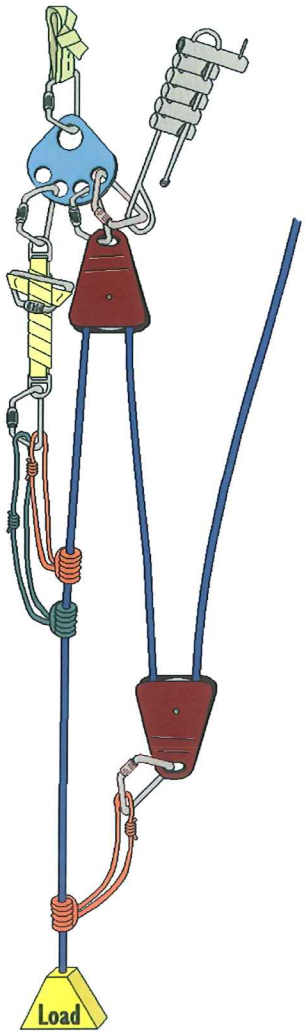


Figure 11-5

3) Set the prusik(s) brake.
4) Remove the line from the DCD.
5) Attach haul prusik (short) to line on load side of prusik(s).
6) Install haul line in mechanical advantage pulley.
7) Connect mechanical advantage pulley to haul prusik with carabiner.

Lower to Raise Conversion: 5:1 Inline – RPM

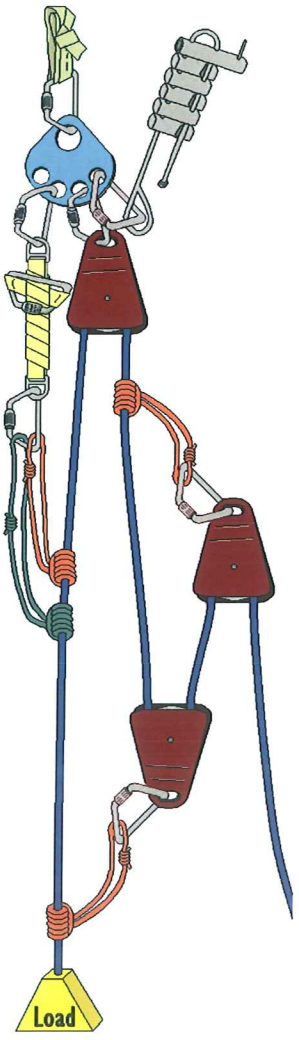


Figure 11-6

1) Attach haul prusik (short) to line on haul side of prusik minding pulley on RPM.
2) Install haul line in second mechanical advantage pulley.
3) Connect second mechanical advantage pulley to haul prusik with carabiner.

Lower to Raise Conversions

Once lowering operations are completed, the rescuer and victims most often must be pulled back up the incline to a safe area. This is accomplished by utilizing mechanical advantage or haul systems. In order to accomplish this, the rescuer must know how to convert a lowering system to a raising system. This initial conversion process will be the same for all mechanical advantage systems in this course.

3:1 or 5:1 Inline Mechanical Advantage System

If the distance between the main line anchor and edge is adequate, an inline mechanical advantage system will be used. Adequate distance will provide the hauling team a safe area to work inline toward the incident. This distance must also be long enough to minimize the number of resets necessary to complete raising operations. Keep in mind how much rope will be used to reach the victim(s); this will determine your maximum set back.

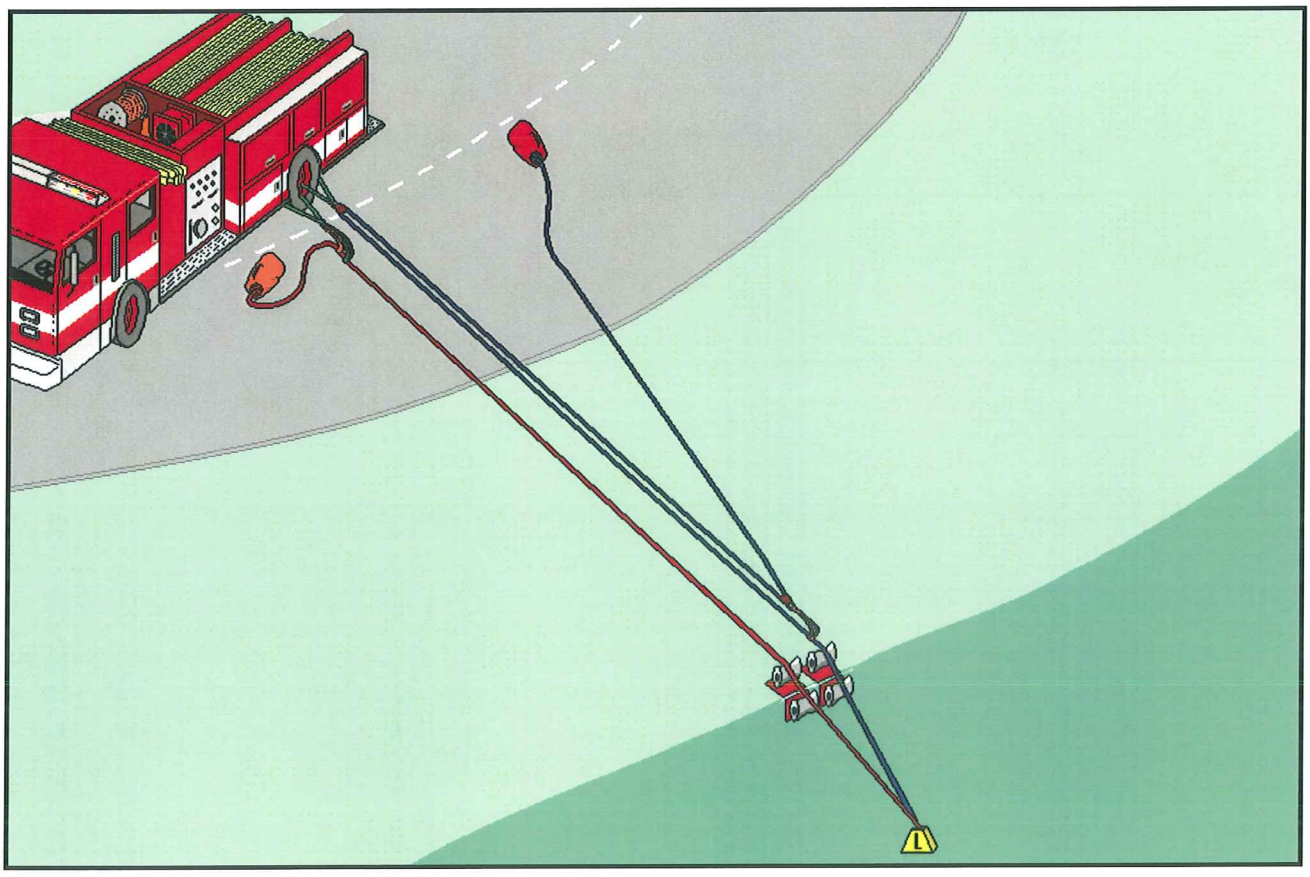


Figure 11-7: 3:1 or 5:1 Mechanical Advantage Inline System Layout

3:1 or 5:1 Inline with Directional Pulley

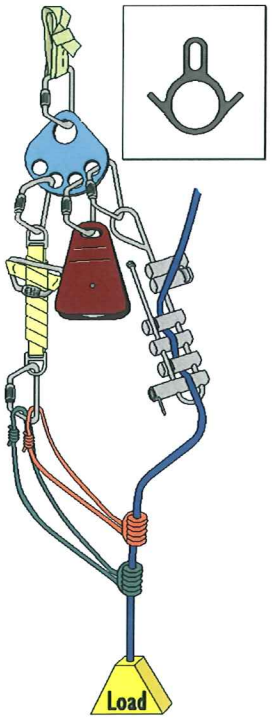


Figure 11-8: Lower with Load

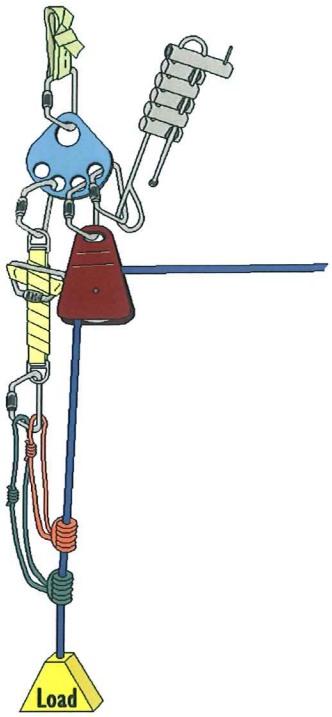
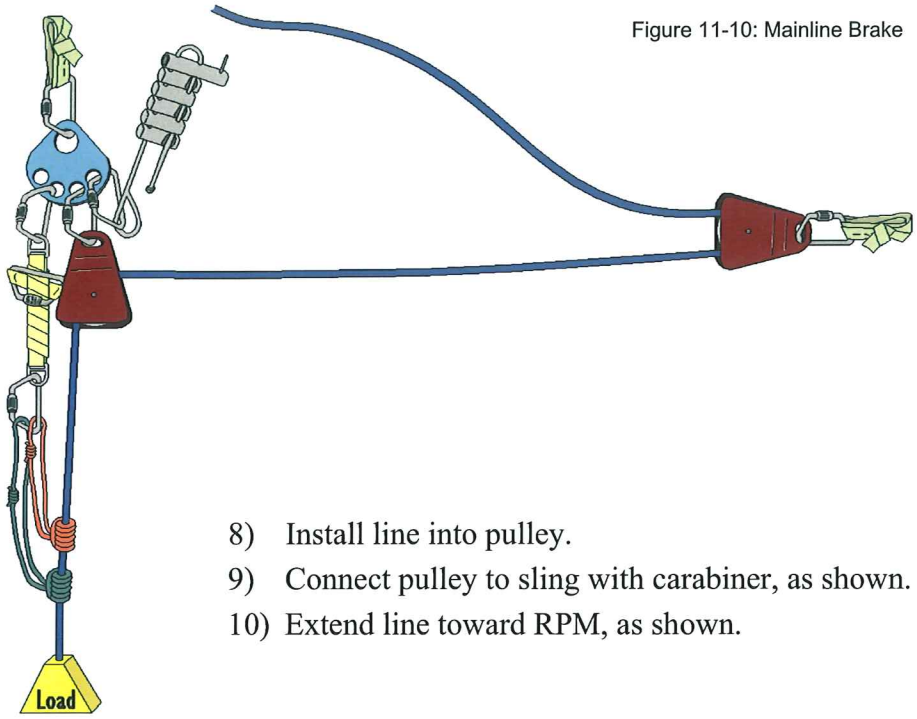


Figure 11-9: Mainline Brake with Load

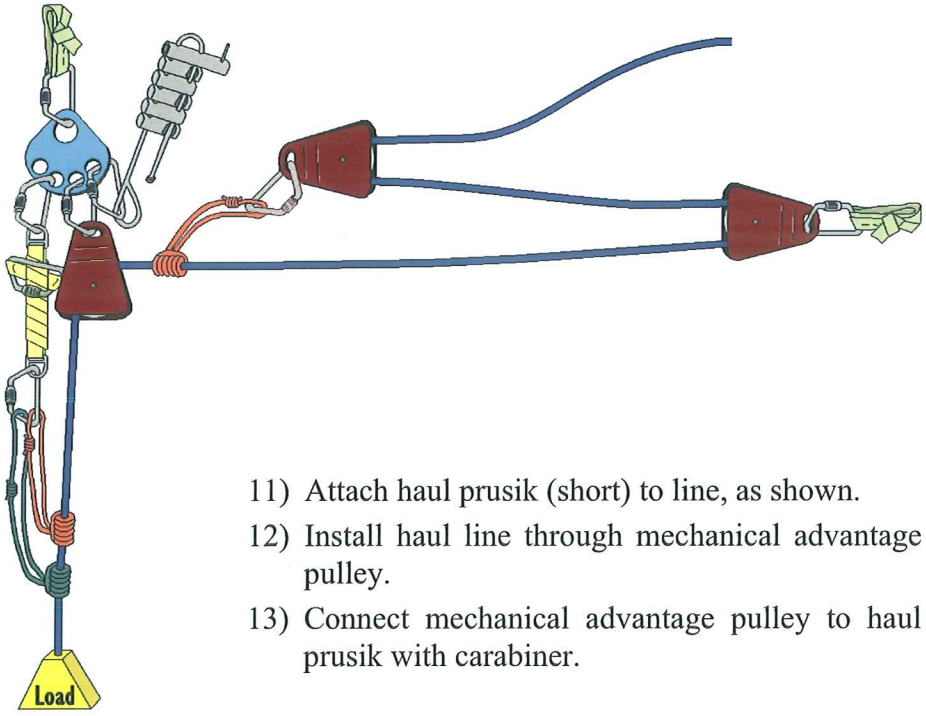
1) Tie off the DCD as shown in Chapter 10.
   - If prusiks were not attached to the main line during lowering operations.
   - Not needed if litter team/rescuers are on a safe level platform.
   - Not needed if the lowering line tender holds tension as prusiks are attached.
2) Attach prusik(s) to the line if not previously attached during the lowering operation.
   - One prusik is proven adequate as a brake to the main line.
   - It is not necessary to attach the second prusik to the main line, but acceptable to do so.
3) Set the prusik(s) brake.
4) Remove the line from the DCD.
5) Install the line through the prusik minding pulley.
6) Place the line toward the secondary anchor (second apparatus).
7) Attach sling to secondary anchor. The secondary anchor is often a vehicle or picket system positioned along the road or trailhead at an angle to the mainline RPM as shown. Always maximize the distance between these two anchors in order to reduce the number of resets during hauling [raising] operations. In a **3:1** system, that distance will be one-half the length of the remaining rescue line. In a **5:1** operation, that distance will be one-third.

Figure 11-10: Mainline Brake



8) Install line into pulley.
9) Connect pulley to sling with carabiner, as shown.
10) Extend line toward RPM, as shown.

Figure 11-11: 3:1 Mechanical Advantage



11) Attach haul prusik (short) to line, as shown.
12) Install haul line through mechanical advantage pulley.
13) Connect mechanical advantage pulley to haul prusik with carabiner.

Often at low angle rope rescue incidents, there is inadequate working area for an inline mechanical advantage system. In these situations, a directional change pulley is used at the main line RPM to change the direction of the main line to a secondary anchor (often a second engine). This apparatus is located a good working distance (approximately one-half the length of the unused rope in the bag for a 3:1 mechanical advantage system or one-third the length of unused rope in the bag for a 5:1 mechanical advantage system) from the main anchor and placed parallel to the roadway or trail. When an apparatus is staged in this position, it can also provide a safe working area for the haul team.

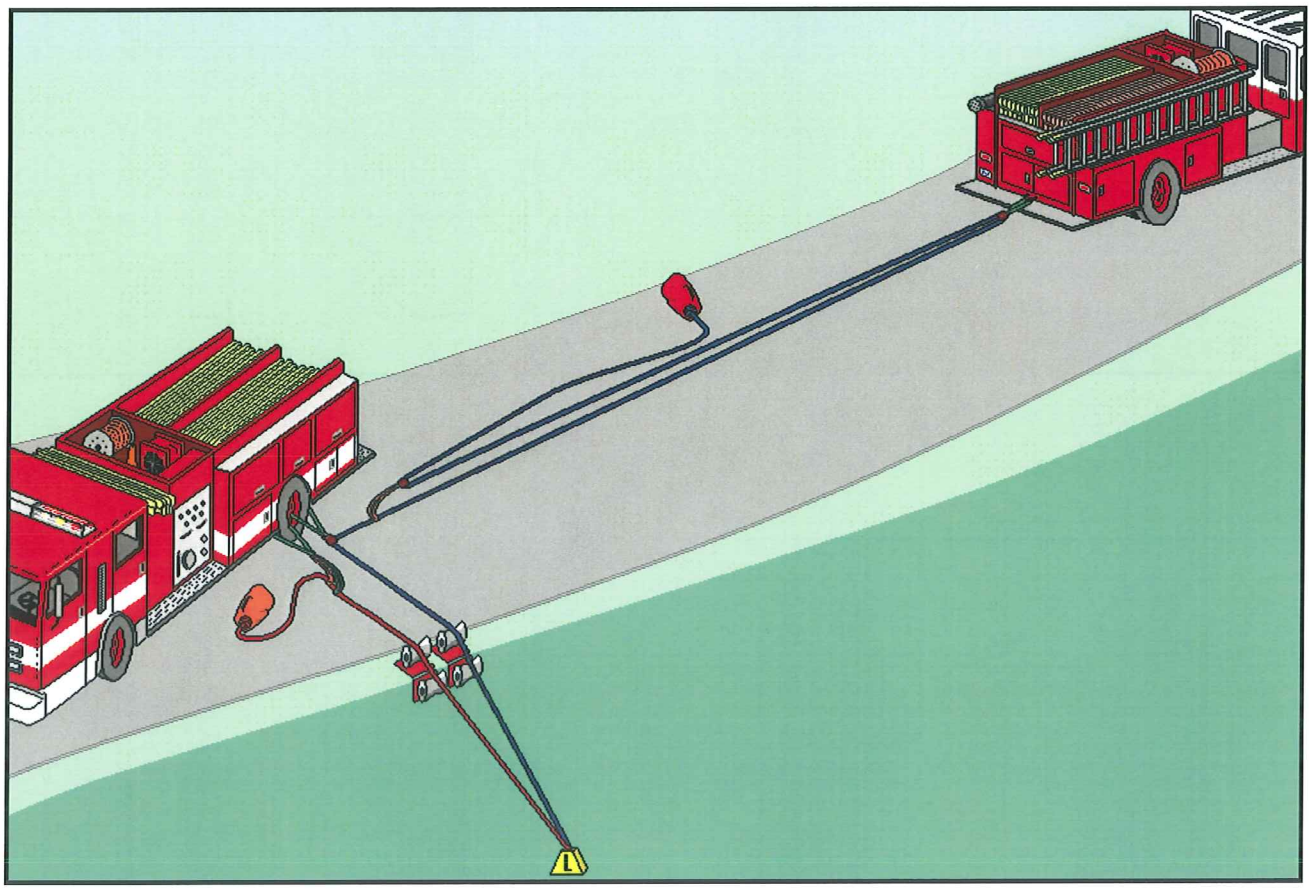


Figure 11-12: 3:1 Mechanical Advantage Directional Change System Layout

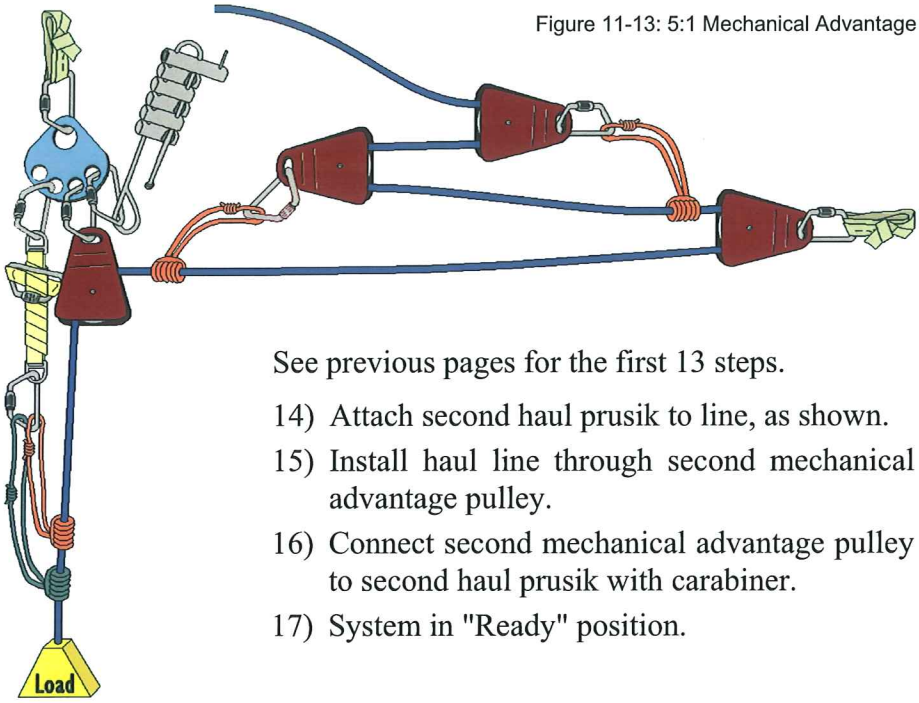


Figure 11-13: 5:1 Mechanical Advantage

See previous pages for the first 13 steps.

14) Attach second haul prusik to line, as shown.
15) Install haul line through second mechanical advantage pulley.
16) Connect second mechanical advantage pulley to second haul prusik with carabiner.
17) System in "Ready" position.

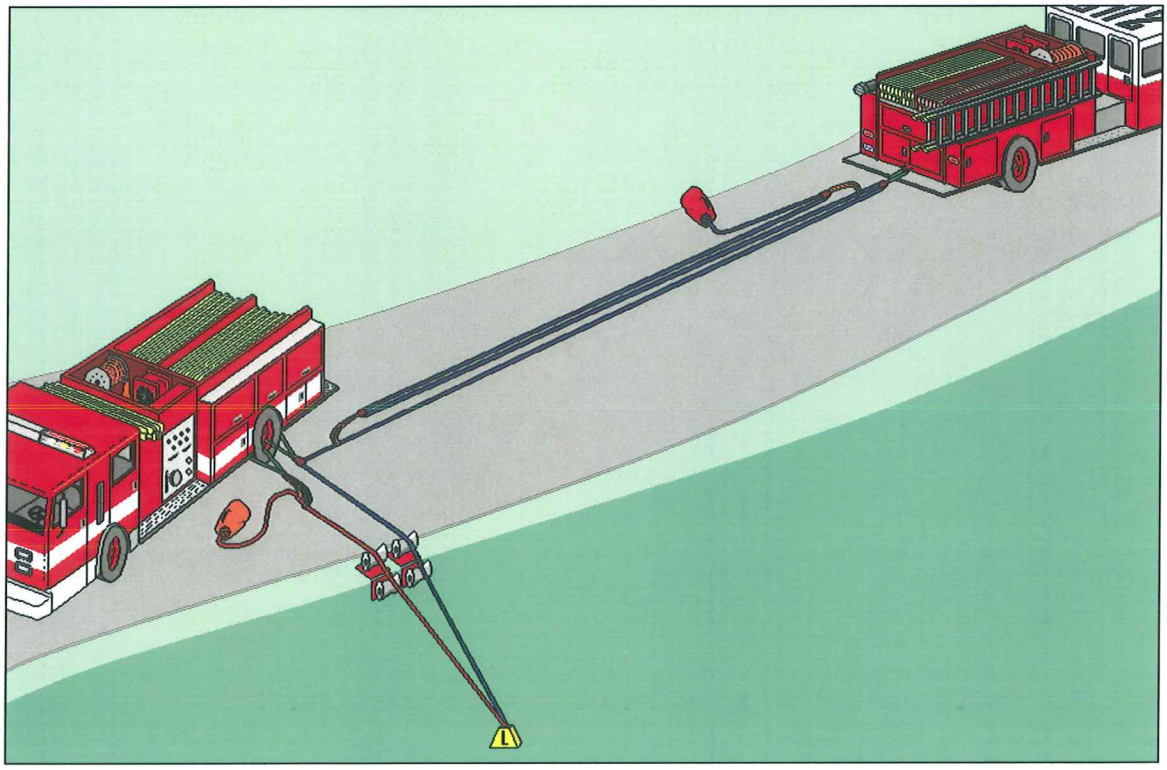


Figure 11-14: 5:1 Mechanical Advantage Directional Change System Layout

Key Points for Apparatus Placement

- ❒ The set back of the apparatus and/or anchor will be determined by your working area, type of mechanical advantage used, and the amount of line used.
  - Consider the condition of the edge. Will it support the apparatus?
  - Consider your minimum working space. Is it enough room for the litter, RPM, and their operation?
  - Consider your maximum working space. It is dependent on the rope length and available area.
- ❒ The angle that the apparatus is positioned will determine how raising operations are set up.
  - Position the apparatus with enough angle to provide clear access to the secondary anchor/apparatus.
  - The angle is determined by the location and lay out of the apparatus.

Piggyback Systems

Introduction

In long lowering operations, most of the main line can be used in the primary lower. This will not leave enough line to construct an inline mechanical advantage system. In these situations, a "piggyback" or "pig rig" mechanical advantage system is used. In this course, two options will be presented: a 3:1 and a 5:1 piggyback system. As with inline systems, the 5:1 will build off the 3:1 rigging.

Key Points

- ❒ A piggyback system adds another line to the main (lowering) line, much as a block and tackle does. This added line will provide the mechanical advantage needed for raising operations and is often referred to as the haul line, MA line, or pig line.
- ❒ The pig rig concept allows the first-in companies to fully extend the first two lines (belay/safety and main) to the incident.
  - It also allows a second-in company to construct, extend, anchor, attach, and operate the mechanical advantage system.
- ❒ Many teams carry a preassembled pig rig in a third rope bag. This can be quickly extended and attached to the main line, reducing set-up time for the raising system.

Pig Rig Construction: 3:1

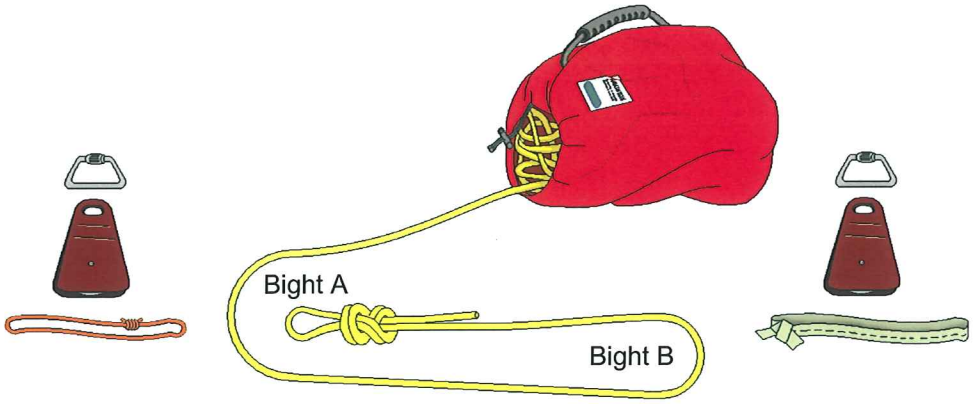


Figure 11-15: How to Construct a 3:1 Pig Rig

1) Tie a figure eight on a bight with a 4" loop in the end of the pig rig line.
2) Place rope on the ground, forming two bights as shown above.
3) Place bight "B" into pulley and connect a carabiner to this pulley.
4) Connect an anchor sling (5'–20') to this carabiner.
5) Place bight "A" into pulley and connect a carabiner to this pulley.
6) Secure figure eight on a bight into this carabiner on top of the pulley.
7) Connect the short prusik to this carabiner

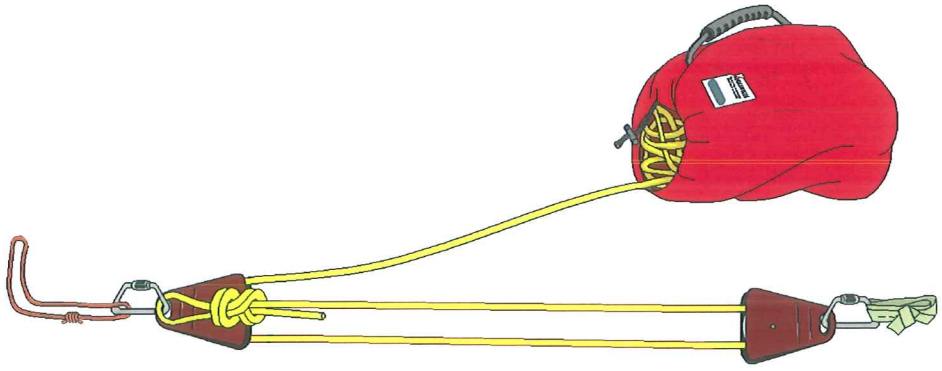


Figure 11-16: Assembled 3:1 Pig Rig

Pig Rig Construction: 5:1

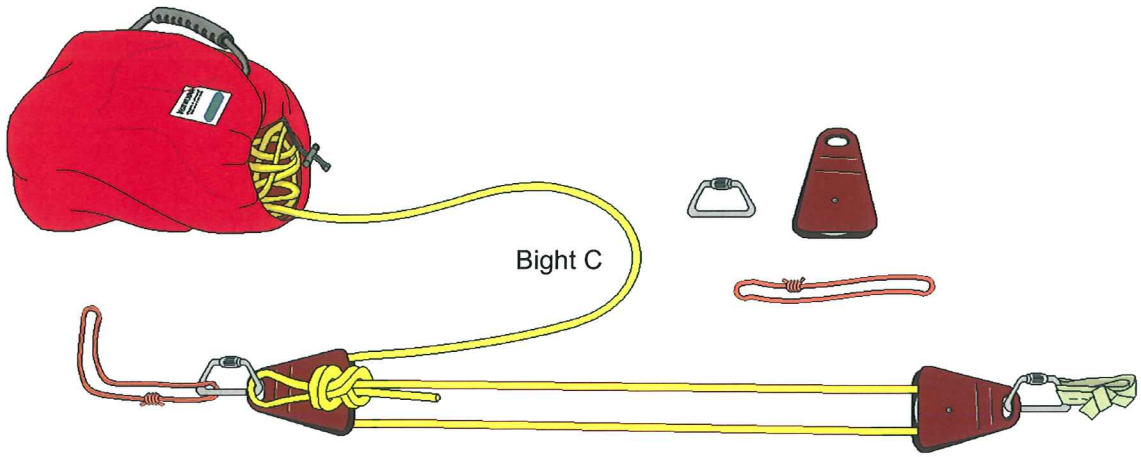


Figure 11-17: How to Construct a 5:1 Pig Rig Starting from a 3:1 Pig Rig

1) Place the rope on the ground to form bight "C."
2) Place bight "C" inside the pulley and connect a carabiner to this pulley.
3) Attach a short prusik to the line at the pulley on bight "B" using a three-wrap prusik hitch.
4) Connect the prusik loop to the bight "C" pulley with the carabiner.

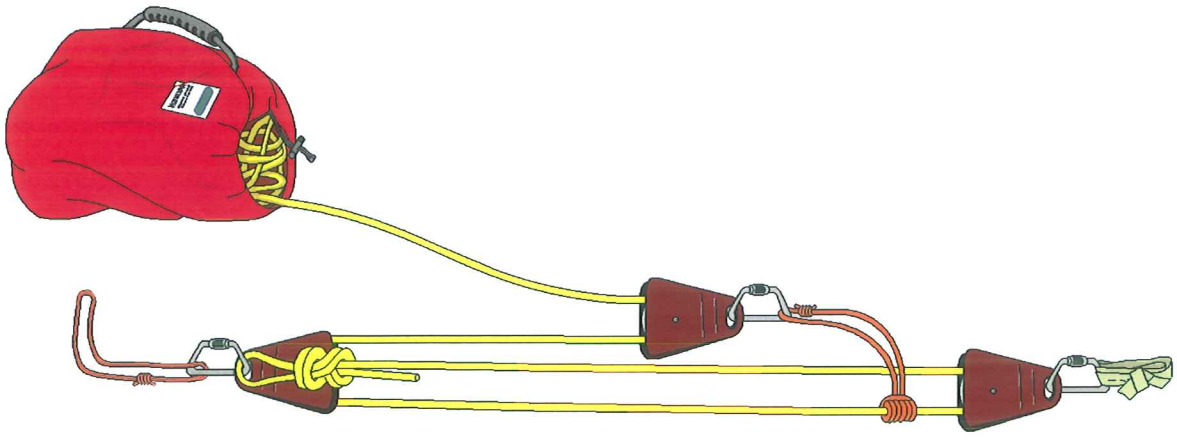


Figure 11-18: Assembled 5:1 Pig Rig

Lower to Raise Conversion: 3:1 Pig Rig

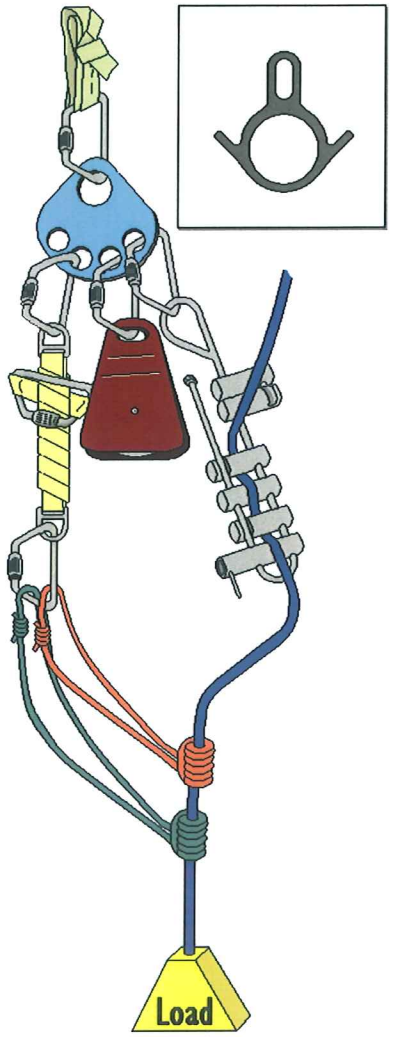


Figure 11-19: Lower with Load

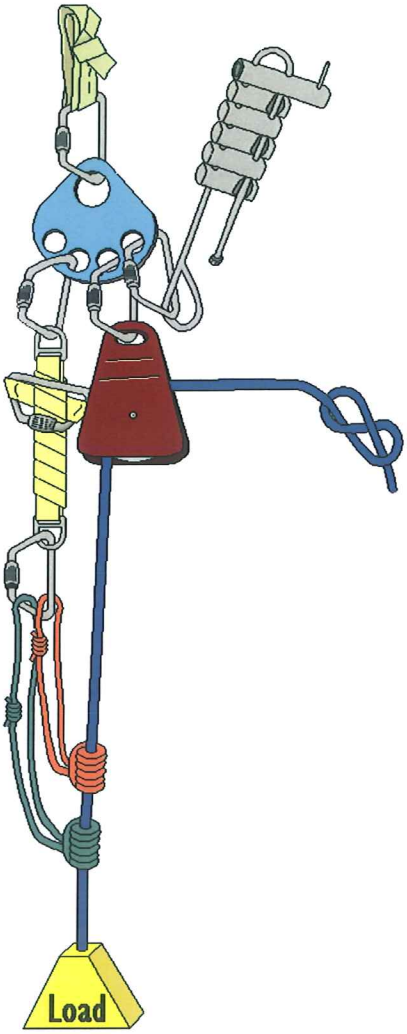


Figure 11-20: Mainline Brake with Load

1) Tie off the DCD as shown in Chapter 10.
   - If prusiks were not attached to the main line during lowering operations.
   - Not needed if litter team/rescuers are on a safe level platform.
   - Not needed if the lowering line tender holds tension as prusiks are attached.
2) Attach prusik(s) to the line if not previously attached during the lowering operation.
   - One prusik is proven adequate as a brake to the main line.
   - It is not necessary to attach the second prusik to the main line, but acceptable to do so.
3) Set the prusik(s) brake.

4) Remove the line from the DCD.
5) Install line through prusik minding pulley.
6) Place line toward secondary anchor (second apparatus).
7) Construct the 3:1 pig rig or lay out preassembled pig rig.

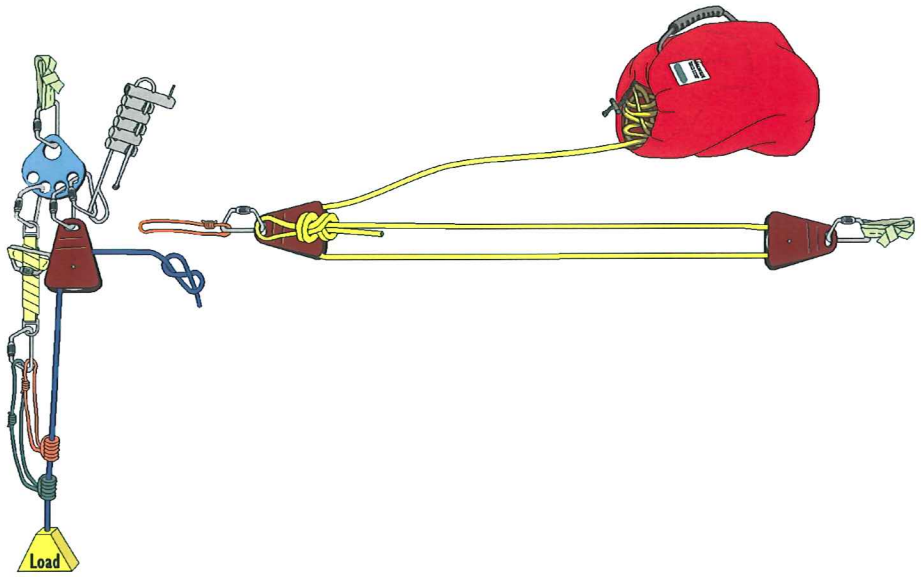


Figure 11-21: Construct 3:1 Pig Rig

8) Extend the 3:1 pig rig from the secondary anchor to the main line anchor.

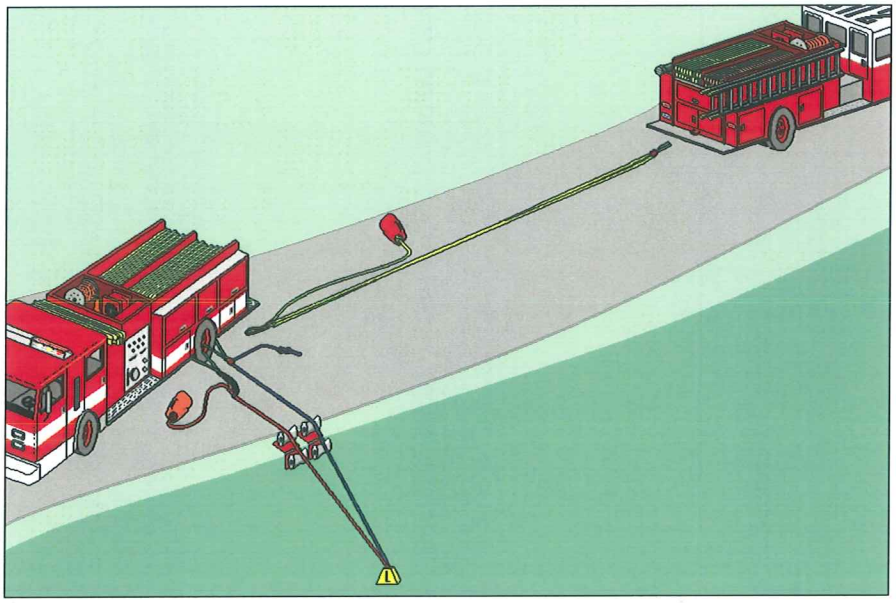


Figure 11-22: Extend 3:1 Pig Rig

9) Anchor the 3:1 pig rig using an anchor sling to attach to the secondary anchor.

The secondary anchor is often a vehicle or picket system positioned along the road or trailhead. Always maximize the distance between these two anchors in order to reduce the number of resets during hauling [raising] operations. In a 3:1 system, that distance will be just under one-half the length of the haul line.

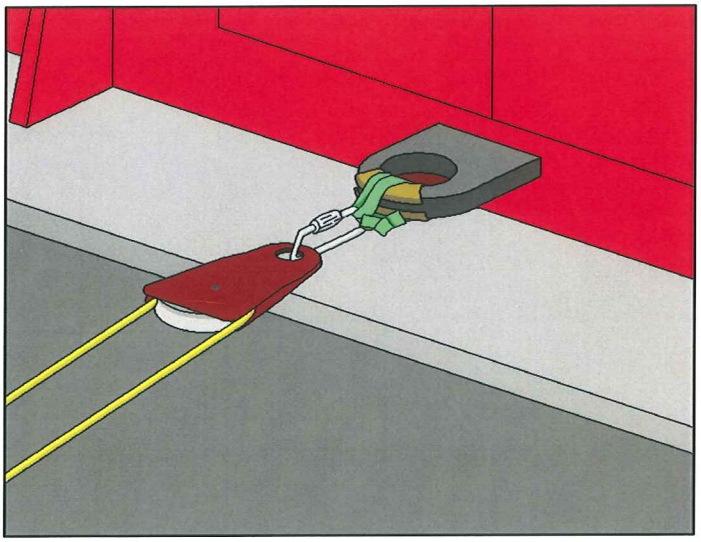


Figure 11-23: Anchor 3:1 Pig Rig

10) Attach the 3:1 pig rig to the main line using the short prusik already attached to the pig rig.

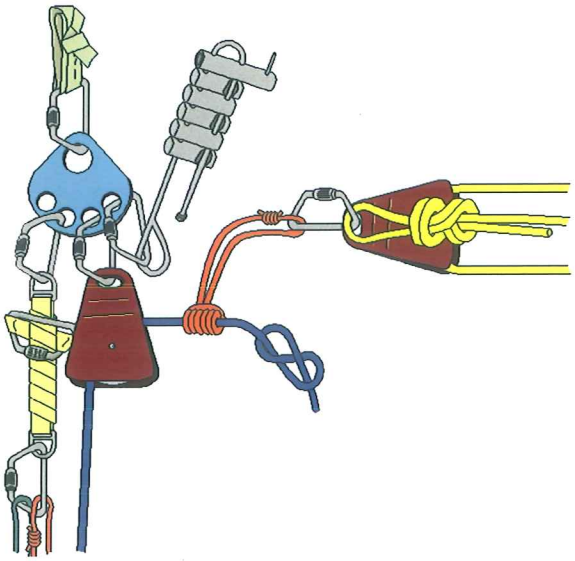


Figure 11-24: Attach 3:1 Pig Rig

11) System in "Ready" position.

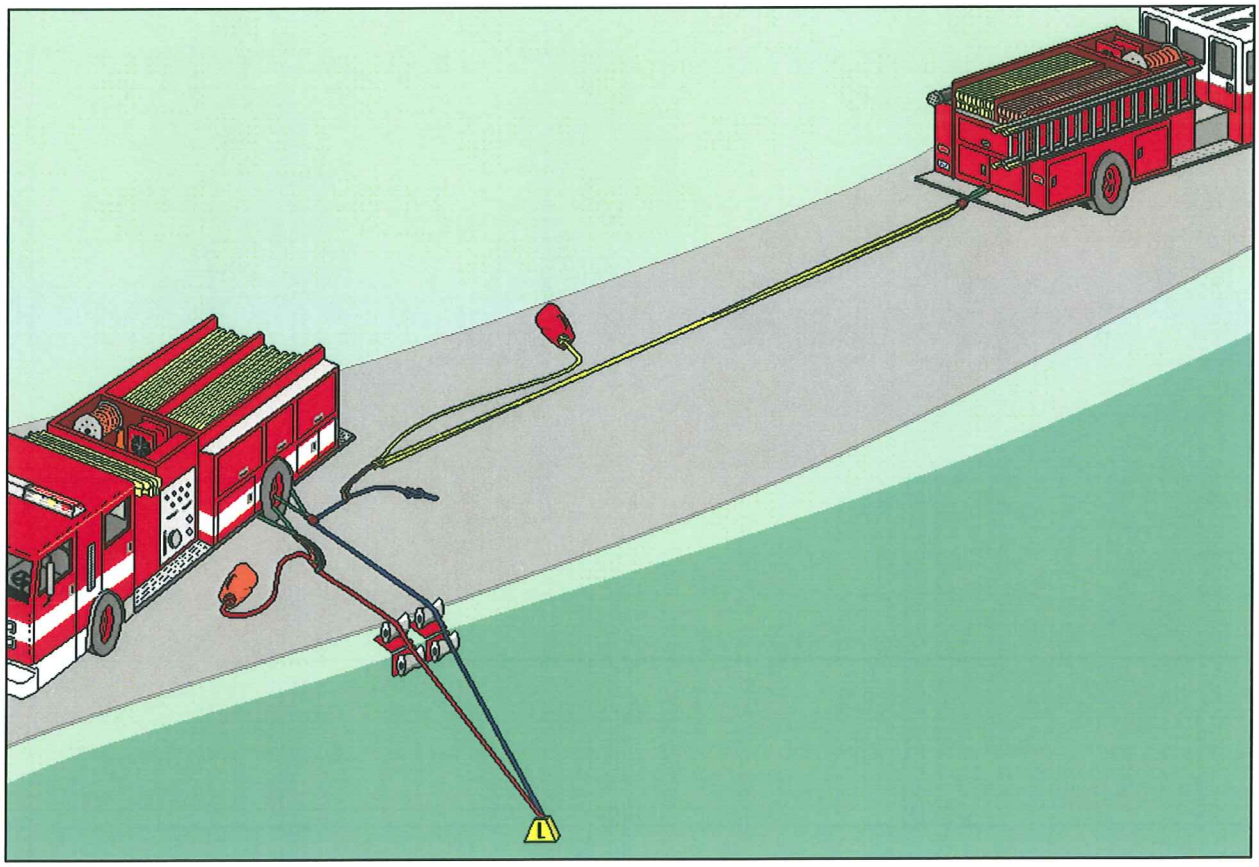


Figure 11-25: 3:1 Pig Rig with Directional Change System Layout

Key Points for Apparatus Placement

- ❒ The set back of the apparatus and/or anchor will be determined by your working area, the type of mechanical advantage used, and the amount of line used.
  - Consider the condition of the edge. Will it support the apparatus?
  - Consider your minimum working space. Is it enough room for the litter, RPM, and their operation?
  - Consider your maximum working space. It is dependent on the rope length and available area.
- ❒ The angle that the apparatus is positioned will determine how raising operations are set up.
  - Position the apparatus with enough angle to provide clear access to the secondary anchor/apparatus.
  - The angle is determined by the location and lay out of the apparatus.

Lower to Raise Conversion: 5:1 Pig Rig

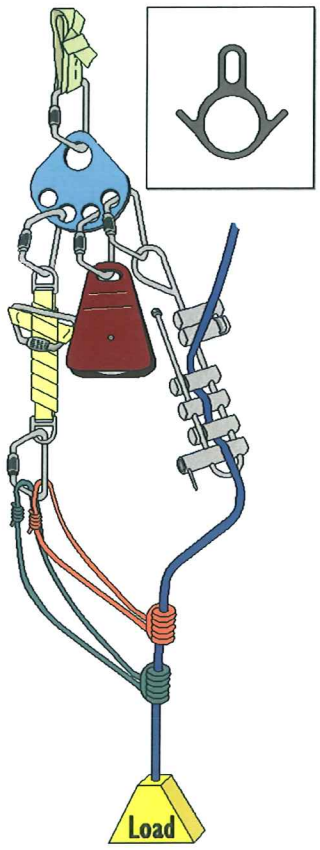


Figure 11-26: Lower with Load

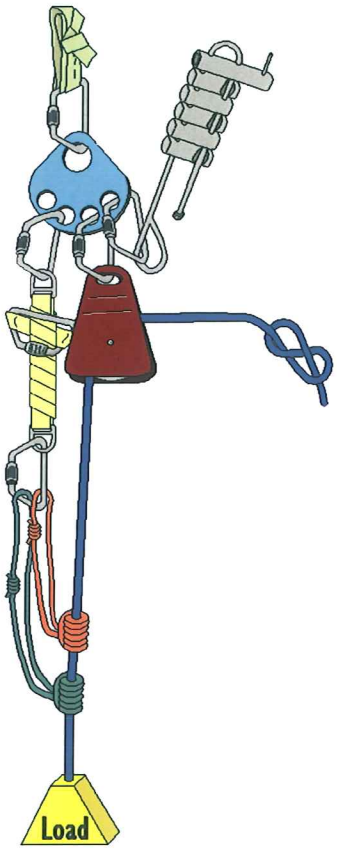


Figure 11-27: Mainline Brake with Load

1) Tie off the DCD as shown in Chapter 10.
   - If prusiks were not attached to the main line during lowering operations.
   - Not needed if litter team/rescuers are on a safe level platform.
   - Not needed if the lowering line tender holds tension as prusiks are attached.
2) Attach prusik(s) to the line if not previously attached during the lowering operation.
   - One prusik is proven adequate as a brake to the main line.
   - It is not necessary to attach the second prusik to the main line, but is acceptable to do so.
3) Set the prusik(s) brake.
4) Remove the line from the DCD.
5) Install line through prusik minding pulley.
6) Place line toward secondary anchor (second apparatus).

7) Construct the 5:1 pig rig or lay out preassembled pig rig.

Figure 11-28: Construct 5:1 Pig Rig

8) Extend the 5:1 pig rig from the secondary anchor to the main line anchor.

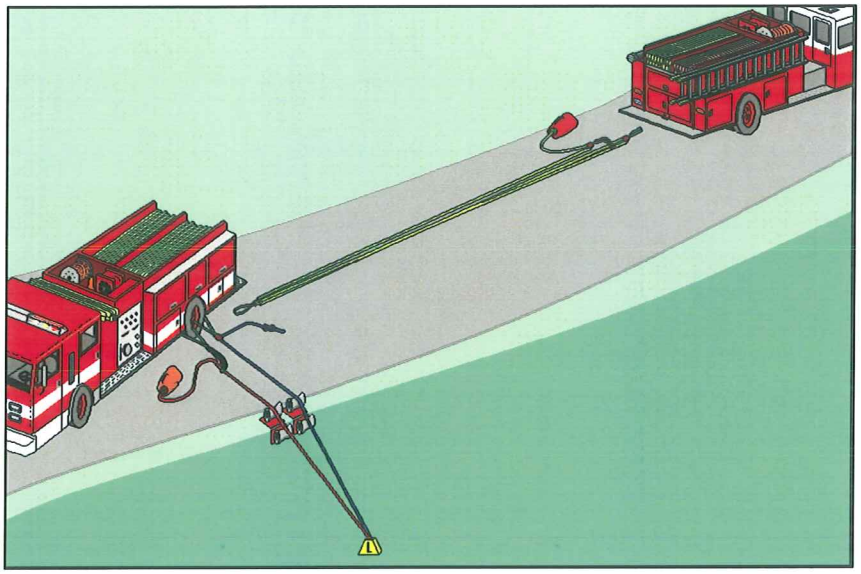


Figure 11-29: Extend 5:1 Pig Rig

The secondary anchor is often a vehicle or picket system positioned along the road or trailhead. Always maximize the distance between these two anchors in order to reduce the number of resets during hauling [raising] operations. In a 5:1 system, that distance will be approximately one-third the length of the haul line.

9) Anchor the 5:1 pig rig using an anchor sling to attach to the secondary anchor.

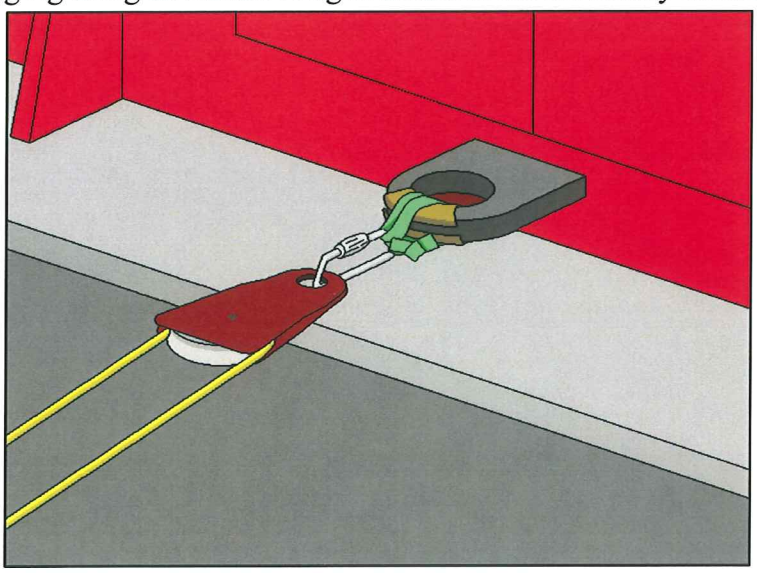


Figure 11-30: Anchor 5:1 Pig Rig

10) Attach the 5:1 pig rig to the main line using the short prusik already attached to the pig rig.

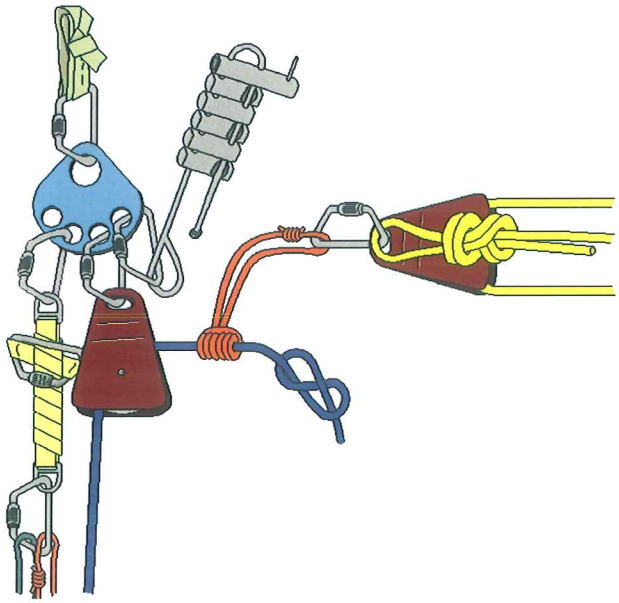


Figure 11-31: Attach 5:1 Pig Rig

11) System in "Ready" position.

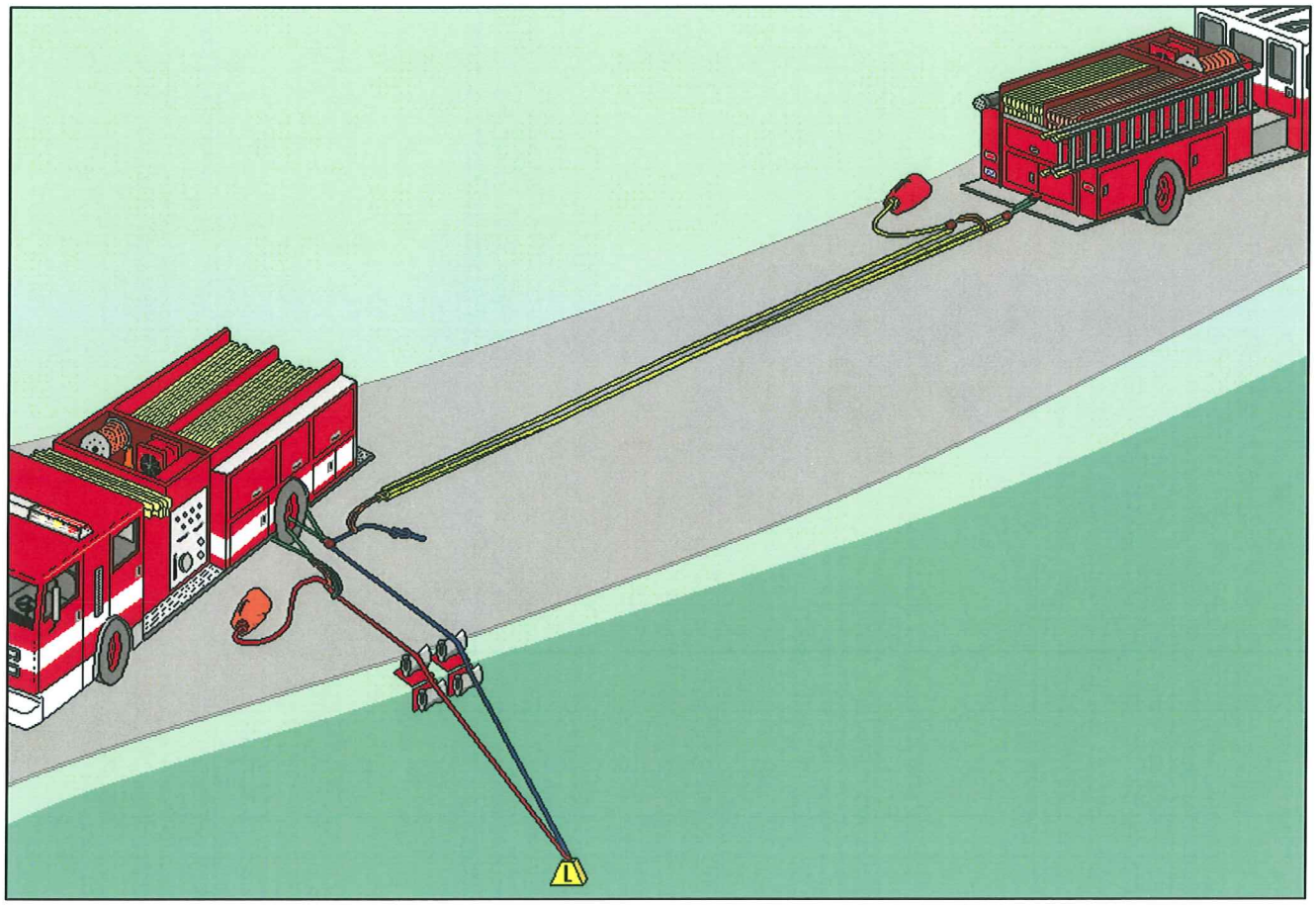


Figure 11-32: 5:1 Pig Rig with Directional Change System Layout

Straight Pull

Occasionally, the situation may arise where responders have adequate staffing but limited equipment with which to construct a mechanical advantage system. In these cases, an option to consider is the straight pull.

The formula to calculate a straight pull or 1:1 mechanical advantage system is that each rescuer hauling on the line can pull approximately 100 pounds of load.

Environmental conditions such as terrain and weather may affect the rescuers grip and footing. Thus, a 400-pound load to be lifted would require a minimum of 4 rescuers on the haul line. In a low angle haul situation, the amount of load may be increased or reduced by the following factors: 1) the angle of slope and 2) the amount weight being transferred from the litter tenders to the ground.

In low angle applications of the straight pull, two lines are used. The safety line uses a brake system, such as tandem prusiks, connected to a suitable anchor. The main line typically runs through a change

of direction pulley or simply a carabiner, which is also connected to a suitable anchor. The pulley is preferable due to the reduction in friction on the rope, but in the absence of a pulley, a carabiner may be used. A steel carabiner would be preferable to an aluminum carabiner because steel is stronger and produces less friction than aluminum. No other equipment is necessary on the main line.

Key Points for Apparatus Placement

- ❒ The set back of the apparatus and/or anchor will be determined by your working area, type of mechanical advantage used, and the amount of line used.
  - Consider the condition of the edge. Will it support the apparatus?
  - Consider your minimum working space. Is it enough room for the litter, RPM, and their operation?
  - Consider your maximum working space. It is dependent on the rope length and available area.
- ❒ The angle at which the apparatus is positioned will determine how raising operations are set up.

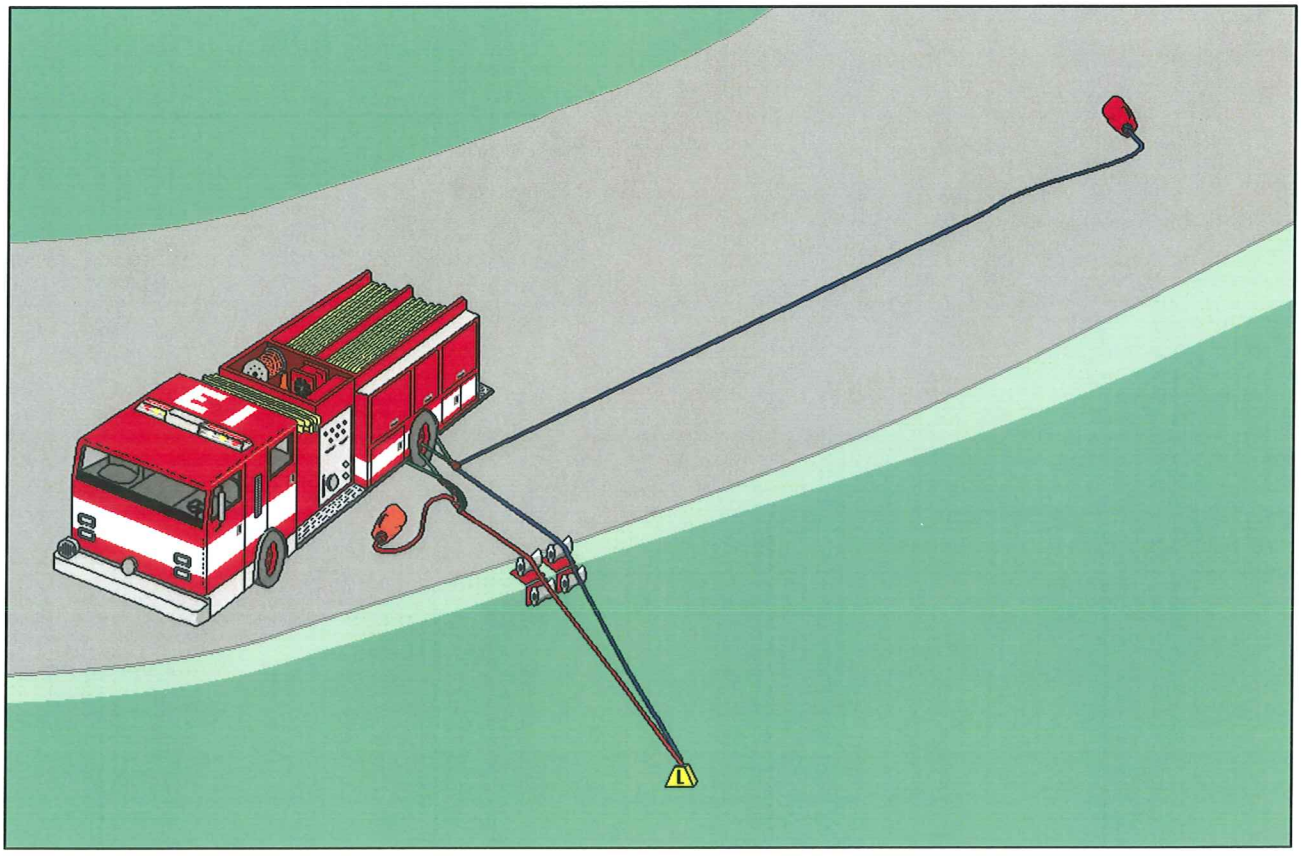


Figure 11-33 Straight Pull