Part V

Safety Precautions
when using Hauling systems

A rope breaking or prusik slipping is a real danger to rescuers. Last year after the Gore Canyon race, race safeties were trying to free a pinned boat in Gore Rapid. ***The prusik slipped and the stored energy in the system sent a carabiner flying up the rope at bullet speed.*** The carabiner smashed one of the pullers fingers, breaking it in two places. He couldn't grip his paddle and had to be evacuated by the railroad truck.

Hanging something on the rope can prevent kickback by absorbing some of the energy or redirecting the whiplash. Consider where the system will fail and position the weight(s) to prevent the whiplash effect from injuring someone. The system will likely fail at the sharpest bend, which could be the connection to the boat, at a carabiner pulley or small pulley wheel. Also the weakest knot or the PCD are other potential failure points. Remember as you pull to keep moving the weight back past the halfway point. Be careful if you decide to use a lifejacket for this purpose. Anyone near the water should wear all his gear, especially his lifejacket and helmet. You can also reduce the risk of whiplash further by standing off-line, behind a tree or facing away. Watch for anchor system failure as well and take countermeasures to reduce the risk of injury from this too.

Boomer and the boyz using the hand pull method and multiple ropes. Note the pull angle and distance to a good anchor. Also note those not pulling are in the systems "danger zone." If the system failed they could be easily injured by the whiplash of the rope. They should be behind something or completely out of the picture.

Anchor Systems

The single most important aspect in setting up a successful hauling system is the pull angle. Anchor system requirements that allow an effective pull angle vary greatly depending on available anchor points. Carrying a variety of anchor pieces gives you the best chance at setting an anchor system quickly that will allow good pull angles. The following is a very complete kit for a 9:1 system from which you can pare down depending on the characteristics of the river and the number in the group: 3 climbing nuts (small, medium, & large), a medium sized hex, 6 carabiners (16kN), 2 - sewn 9/16-inch nylon super tape slings, a 6 foot "Ladder web" and a 1-inch tubular webbing sling (20 ft.). The Ladder web has loops sewn into the webbing itself about every 4 inches and can be used as a sling when joined with a carabiner (44kN) or like a climbing "runner" with a carabiner on each end (33kN). (This anchor kit is in addition to the equipment required for the mechanical system used.)

Wildwasser Rescue kit w/ Ladder web and Robot Friction

Some experts recommend that all carabiners used in a rescue should be locking. I agree that locking carabiners should be used in the haul rig, but regular carabiners are fine in multi point anchor systems. If you use non-locking carabiners in an anchor system make sure that they will not open. If you have any doubt, use two carabiners with opposing gates or a locking carabiner.

Generating Force to free a pinned boat

How much force is needed to free a pinned boat? There are far too many variables to tackle this physics question! It is much easier to just design the mechanical system to maximize rope strength based on the number pulling on the rope. There are still lots of variables in the force generated through mechanical advantage: the number and weight of the people pulling, the method of pull used, the vector angle of pull, the mechanical advantage used, the friction of pulleys, and rope stretch. Enough to make your head hurt or engineer geeks drool.

Table-2 shows the approximate force generated in pounds with the number of pullers shown in the first two columns, and the mechanical advantage across the top row. The two methods of pull are the shoulder jerk (SJ) and hand pull (H). The SJ method generates about 1.2 times the weight of the puller while the H method is about a 0.6 factor. (See "Swiftwater Rescue" p. 79 for detailed explanation of pull methods and factors.) These calculations assume a 3/8-inch Spectra® rope is used; a 10% friction factor for each rescue pulley; and the average puller's weight is 180 lbs.

Using Table-2 you can determine what kind of mechanical advantage is needed for the size rescue party you have to generate the max load for a 3/8-inch Spectra® rope [when using Butterfly knots instead of clamping devices (2650 lbs), when the kleinheist hitch is used to "pull" the rope, or the traveling pulleys are attached to the load (3150 lbs)]. Remember these are approximate forces based on the method of pull and an average puller's weight of 180 lbs.

Table-2 (Force in lbs)
Assumes 3/8" Spectra and rescue pulleys are used

SJ	H	3:1	4:1	6:1	9:1
1	0	518	691	907	1166
1	1	778	1037	1361	1750
0	4	1037	1382	1814	***2333***
1	2	1037	1382	1814	***2333***
2	0	1037	1382	1814	***2333***
0	5	1296	1728	***2268***	**2916**
1	3	1296	1728	***2268***	**2916**
2	1	1296	1728	***2268***	**2916**
0	6	1555	2074	***2722***	3499
1	4	1555	2074	***2722***	3499
2	2	1555	2074	***2722***	3499
3	0	1555	2074	***2722***	3499
0	7	1814	2419	**3175**	4082
1	5	1814	***2419***	**3175**	4082
2	3	1814	***2419***	**3175**	4082
3	1	1814	***2419***	**3175**	4082
1	6	2074	***2765***	3629	4666
2	4	2074	***2765***	3629	4666
3	2	2074	***2765***	3629	4666
4	0	2074	***2765***	3629	4666
1	7	2333	**3110**	4082	5249
2	5	2333	**3110**	4082	5249
3	3	2333	**3110**	4082	5249
4	1	2333	**3110**	4082	5249
2	6	***2592***	3456	4536	5832
3	4	***2592***	3456	4536	5832
4	2	***2592***	3456	4536	5832
5	0	***2592***	3456	4536	5832
4	4	**3110**	4147	5443	6998
5	2	**3110**	4147	5443	6998
6	0	**3110**	4147	5443	6998

(Multiply by .0044 to convert lbs to kN, by .455 to convert lbs to kG

If these combinations don't work you should try to make sure friction loss is reduced as much as possible and rethink pull vector angles. Adding more people will likely fail the system if friction has been reduced. (See Table-3 for equipment to support these kinds of systems.)

The number of "pullers" listed in Table-2 does not include the belay person in a 4:1 or a system that uses a belay rope instead of a PCD. These systems can be complicated, difficult to set up, and very dangerous if something fails under these max loads. They should only be used if no other options are available. The required load rating for rigging components under these kinds of loads is very high.

The combination of the equipment carried by the number pulling should total two 3/8-inch Spectra® ropes, one 1/4-inch Spectra® rope, enough "rigging" to make the required haul system, and sufficient anchor rigging to support the load.

Haul Rig Components

The next thing to consider is what load rating the haul system components need for the rope to reach max load. The system should never have hardware as a weak link. A carabiner or pulley that fails can kill someone. A rope that breaks or clamping device that slips can also cause injury like in the Gore Canyon incident, but nothing like the lethality of flying metal pieces from exploding hardware. The weak link should never be metal. The component ratings in Table-3 make the weak link the rope, which should only fail if the guidelines

1" TUBULAR WEBBING ~ 4000#
1/8" THICK x 4 => 1/2" MIN BEND. KNOTTED, SAFE = 3500#

Table-3
Load rating and Qty using a 3/8-inch Spectra® rope

	3:1	4:1	6:1	9:1
32kN Pulley -1.5" Tread dia.	1	0	1	2
32kn Locking Carabiner	1	0	1	2
16kn Pulley-1.5" Tread dia.	1	2	2	2
16kN Locking Carabiner	4	6	6	5
Klemheist Hitch (1" sewn sling)	1	1	1	2
Progress Capturing Device (PCD)	1	1	1	2
32kN Anchor System	1	0	1	2
16kN Anchor System	1	3	2	1
Release System	1	1	1	2

in Table-2 are not followed.

Table-3 provides the quantity and load rating for each component in the specified system to maximize a 3/8-inch Spectra® rope that has a Figure-8 loop and an estimated load rating of 3150 lbs. The ratings allow for a 10% safety factor with the possible exception of the kleinheist hitch.

Change of direction pulleys, their supporting locking carabiners and anchor systems may need to hold a max pulling load up to two times the actual load, depending on the change of direction angle. A 10% safety factor has been added to get a rating of 32kN. Be sure all anchor components can hold this load during pulls. A 1-inch tubular webbing sling, that is double or triple looped and secured with a water knot will support this load if a single anchor point will hold. Sewn slings should also be double looped if used to support the pulling load. The safest and simplest system uses the Ladder web sold by Wildwasser.

Traveling pulleys and locking carabiners must carry the max load of the rope. A 16kN rating includes a 10% safety factor. Friction loss from carabiners used as pulleys is very significant as mentioned before. Some sources think carabiner pulleys reduce a 3:1 mechanical advantage to a 2:1 ("River Rescue" Bechdel & Ray p. 129.) This means a carabiner pulley has a friction factor of about 20% while a good rescue pulley has a friction factor of less than 10%. Using high quality rescue pulleys with sealed bushings will reduce this friction even more to realize a greater force. Remember that carabiner pulleys and pulleys with a tread diameter less than 1.5 inches will also reduce rope strength because of the bending effect. I cannot emphasize enough how important good rescue pulleys are to maximizing the force generated by the system.

A way to release the rope under tension should be built into the haul rig. One option is the Mariners Hitch: 2 - locking carabiners (16kN) and 1- 9/16-inch or 11/16-inch sewn sling. The Robot Friction Device as mentioned before is another option for a release mechanism.

What's in your pin kit?

Now you have all the facts I could find and the assumptions I've made. Table-4 is a complete list of what I want as the sum of the group's equipment. I call it the "9er-kit." It's two 3:1 kits with a robust assortment of anchor pieces. I've broken the kit into two bags each less than 2 lbs dry.

I've been asked how to trim this kit down and make it lighter for self supported trips. I leave that decision up to the group. I have no problem putting two pounds of gear in my boat plus a throw bag. I choose to leave the camera behind if room or weight is a real concern. Also packing the kit and the rope in a small dry bag saves on water weight. If you do decide to cut back, a 4:1 is the most efficient mechanical system for the equipment needed (See Table-2 for required components). A 4:1 or 6:1 system is very flexible and maximizes vector pulls and pull angles. Be sure to practice whatever system you decide to carry.

Prevention is always preferred to a rescue, but accidents can happen to the best. As Dunbar Hardy mentioned in his article, start low tech and low risk first. A simple rope rescue or boat rescue normally does the trick, but staying proficient with the more complicated and technical skills and always being prepared may someday save a life. Don't let the low probability of need for these skills and equipment result in not having equipment that provides the greatest chance for a successful rescue. Practice the skills necessary to make setting up taglines and mechanical advantages a reflex instead of something you have to think about. Practice with all the equipment options and learn what works best for you. Plus you never know what kind of "group" equipment you might end up having to use. Keep in mind system strength, quick set up, the number of people available to assist, and overall simplicity when selecting your rescue kit.

Equipment is only as good as the one using it, so taking a swiftwater rescue course and practicing rescue skills is far more important than what components you use. In addition to courses, there are several excellent books on the subject that refresh and add to what we can learn in a two or three day course. I highly recommend "Swiftwater Rescue" by Slim Ray and "Whitewater Rescue Manual" by Charlie Walbridge to augment and improve your rescue skills. (These two books were the main references for this article.) The video "Whitewater Self Defense" is another excellent reference source by Ford, Walbridge, & DeCuir. You can order these and other safety books and videos through AW's web site with AW getting a kickback. **http://americanwhitewater.org/library/**

I hope you've found a few golden nuggets to put in your kit bag that may help on your journey…In Search of Eldorado. Also watch out for a guy named Edgar Allen Poe, he welched on the six pack he owes me for saving his butt in Harmon Falls. (The near miss on Harmon Falls is a true story. "Edgar's" real name …I'll never tell.)

Table-4 "9er-Kit"
(9:1 w/ 3 "pullers")

List below is the sum total of what a group should have. In a group of 4, the combination of any three paddlers' rescue kits should combine to make this list complete.

Component	Rating	Qty
Ropes		**3**
- 3/8" Spectra® rope (75'-80')	4500lbs	2
- 1/4" Spectra® waist throw bag (50-60ft.)	2500lbs	1
Pulleys-1.5" Tread diameter		**4**
- Change of Direction (COD)	32kN	2
- Traveling	16kN	2
Carabiners (haul system)		**7**
- Locking (COD)	32kN	2
- Locking	16kN	5
Progress Capturing Device (pick any two and carry two 6mm prusik cords to backup the PCDs) - Acsender - Tibloc - Robot Friction Device		**2**
Traveling Kleinheist Hitch		**2**
- 1" nylon tubular webbing sewn sling		2
Anchor Systems		**3**
- Change of Direction anchor	32kN	**2**
- Backup anchor	16kN	**1**
- 3 - climbing stopper (4, 8 & 11)		3
- 1 - hex (med size #6)		1
- 6 - Carabiners (locking optional)	16kN	6
- 2 - 9/16" sewn Super Tape slings	4500lbs	2
- 1 -1" tubular nylon webbing slings (20')	4000lbs	1
- 1 - Ladder web	7500lbs	1
Release System	16kN	**2**
Mariners Hitch (1)		
2 - locking carabiners	16kN	
1 - 9/16" sewn Super Tape sling	4500lbs	