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National
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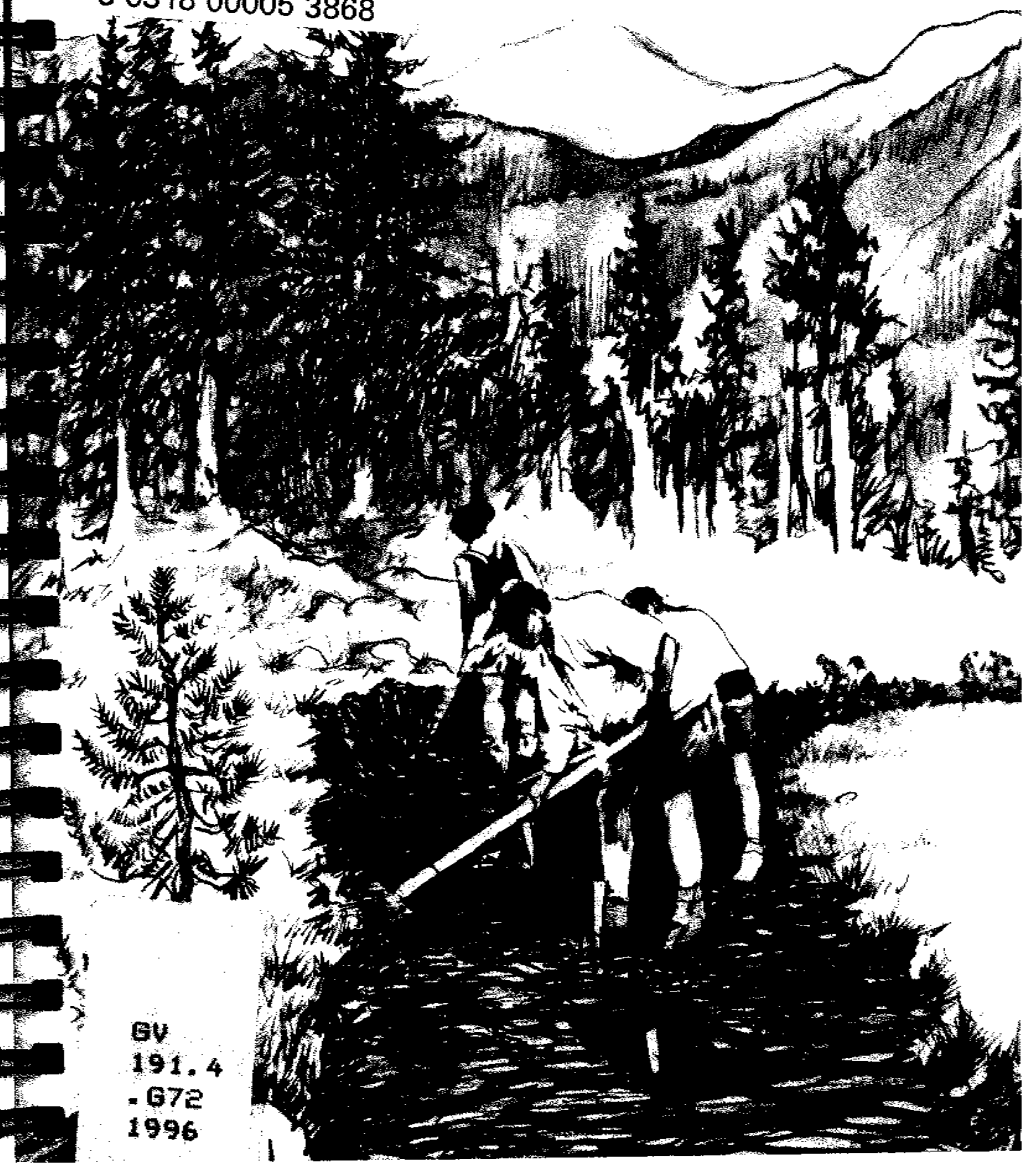
Service

A HANDBOOK ON TRAIL BUILDING and MAINTENANCE

For National, State and Local Natural Resource Managing Agencies



A HANDBOOK ON TRAIL BUILDING and MAINTENANCE

For National, State and Local Natural Resource Managing Agencies

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TABLE OF CONTENTS

INTRODUCTION

Although this trail handbook was prepared for use at Sequoia and Kings Canyon National Parks, the basic trail building and maintenance principals presented here are applicable almost anywhere. Whether one works for a national forest, state park or a local non-profit trail organization is immaterial. The handbook provides information that can be used in a variety of natural settings. We expect that you will find the handbook a practical guide for your trail building and maintenance needs.

The backcountry of Sequoia and Kings Canyon National Parks (SEKI) contains more than 90 percent of the total land area of the two parks, approximately 737,000 acres or 1,151 square miles. From the 14,000+ foot peaks of the Sierra crest to the canyon bottoms alongside the powerful rivers, there is a great diversity of land, vegetation, and wildlife. Most of the recreational use of the backcountry is concentrated on maintained trails within a network of trail corridors. This trail system has evolved since prehistoric times from, in many cases, game trails. Game trails became Indian trails which became the trails of early explorers and trappers; these in turn were followed into the mountains by ranchers herding their livestock to high meadows in the summer. These routes were consolidated into the National Park Service trail system. The Park Service has rerouted, reconstructed, and rehabilitated many of these trails and endeavors to maintain the entire trail system in a manner which promotes resource protection and a quality recreation experience. A great deal of trailwork remains to be done.

This *Trail Handbook* is meant to be used by the trailworker. Sections of the handbook may be read and discarded, and other sections may be removed and found useful in the backcountry as a reference for project work (and starting fires!) The handbook gives the trailworker a few suggestions for solving the kind of problems encountered on a high Sierra trail system and presents standards for sound, long lasting, and environmentally compatible trailwork.

The primary standard for trailwork in Sequoia and Kings Canyon is one of environmental integrity. All problems and projects are approached from an environmental perspective which allows natural processes to prevail. No work is undertaken or campsite used which unacceptably impacts the backcountry resource. We trailworkers, along with backcountry rangers, are the major "stewards" of the backcountry.

If we don't set the standard, who will?

This *Trail Handbook* is intended to be used in conjunction with other books and plans (some of which are listed in the Reference section) and in particular the SEKI *Backcountry Management Plan*, SEKI *Stock Use and Meadow Management Plan*, and the SEKI *Natural Resources Management Plan*, with which all trail leaders and trailworkers should be familiar.

TRAILS AND TRAILWORKERS

The trail system in Sequoia and Kings Canyon National Parks includes 695 miles of backcountry trails and 100 miles of frontcountry trails connecting all major regions of the parks and passing through all major environmental zones. The trail system consists of trailheads, bridges, campsites, signs, and trails within a network of trail corridors.

Annual visitation to SEKI is about 2 million persons and many of these visitors take time to hike and explore areas of the parks using components of the trail system. Backcountry overnight use by hikers and stock parties averages about 45,000 person/nights annually.

The diversity of the parks' environments and the amount and distribution of use present a wide variety of trail maintenance and reconstruction problems. All trails are affected by the movement of water from seasonal storms and spring runoff, and drainage system design and control is a major activity of the trail maintenance and reconstruction crews. Heavily used frontcountry trails and the most popular backcountry routes suffer from the impacts of use, including multiple ruts in high meadow areas and damaged retaining walls caused by visitors shortcutting switchbacks.

A trail, for the purpose of this handbook, consists of the trail tread and the trail corridor. The trail tread is the actual surface of the trail upon which hikers and stock step. The trail tread is typically the earthen surface upon which the trail has been established with use, but may also be hard bedrock granite, carefully laid riprap, or crushed rock with a soil tread which has been packed onto a constructed trail or causeway.

The trail corridor is an imaginary three dimensional zone which includes the trail and areas above and to the sides of the trail. The corridor is the area within which most all trail maintenance activities take place, with the exception of off-trail drainage work.

The trail corridor is the area which must be clear for the safe passage of hikers, riders, and packstock. This area is roughly 4 feet either side of the centerline of the trail and 10 feet high. Large rocks, trees, and other natural features along the corridor perimeter are obvious exceptions.

The trailworkers that perform the annual trail opening, maintenance, and reconstruction must be able to recognize and solve many kinds of trail problems caused by the interaction of environmental processes and use. They must develop appropriate skills using manual labor, traditional skills, minimum tools, and available native materials. They must learn to recognize the integrity of the trail corridor and maintain that corridor as an appropriate mix of environmental considerations and user needs.

Throughout this handbook are discussions of many expectations, requirements, and general tips for the trailworker. Below are presented the most important, followed by a brief discussion of each:

- Backcountry Cleanup
- Visitor Relations
- Think from an Environmental Perspective
- Think Safety
- Work Together
- Develop Your Trailwork Skills
- Develop an Eye for Trailwork Aesthetics
- Keep an Open Mind to Trailwork Solutions
- Your Daypack
- Your Daybook

Backcountry Cleanup

All trailworkers are responsible for general backcountry maintenance. This includes needed off-trail or campsite maintenance and *always* includes general backcountry trash cleanup. Small trail litter and trash can be picked up as you travel the backcountry and put in your pocket or a spare lunch sack.

Larger quantities should be put in burlap sacks for the packer to pack out. Be sure to tell the packer where they are.

Visitor Relations

All National Park Service employees in the backcountry are expected to maintain a cordial, friendly, helpful, and tolerant attitude toward the visitor. Remember that park visitors are frequently inexperienced and will sometimes ignorantly engage in poor backcountry practices. Give them the benefit of the doubt. It is the responsibility of all of us to attempt to educate the backcountry visitor in proper backcountry practices. Approach an observed backcountry violation with a patient and logical explanation of the proper backcountry practice *and* an explanation of the potentially harmful effects of the observed practice.

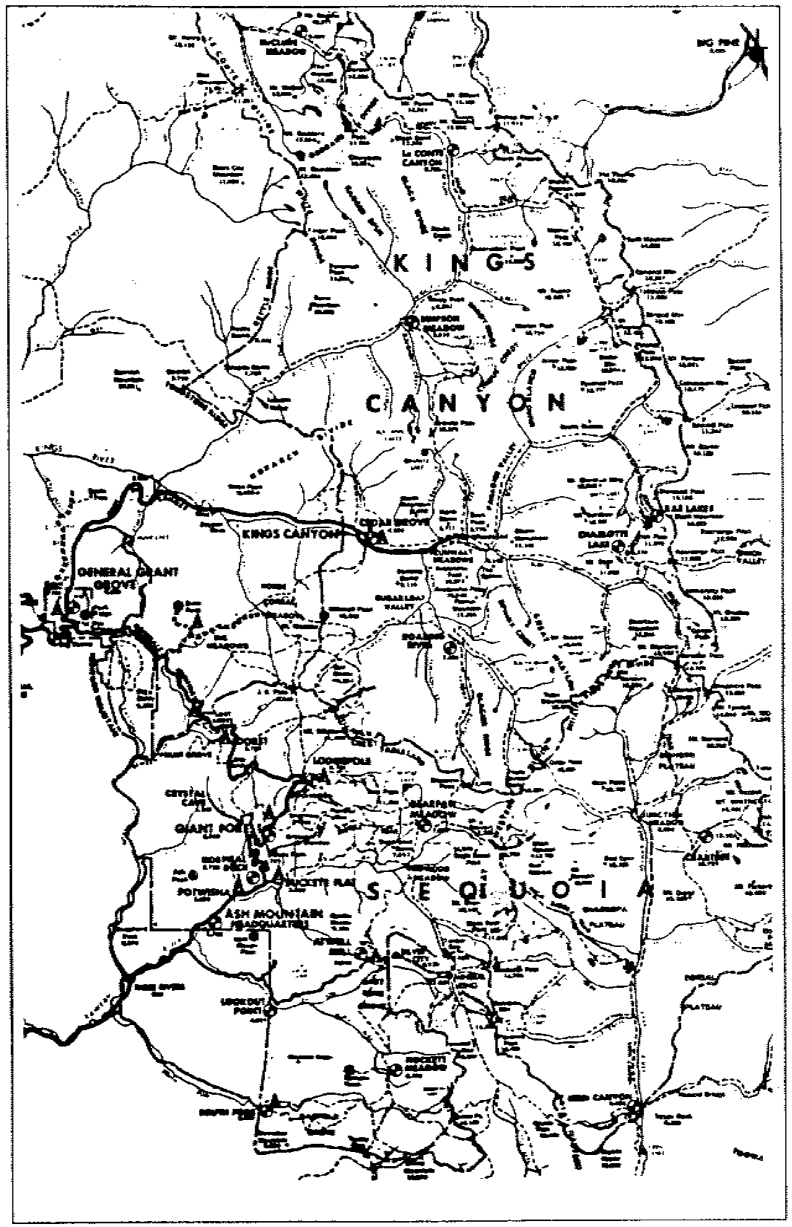
Work Together

Cooperation with your co-workers and the NPS backcountry rangers is mandatory. Remember, successful backcountry maintenance and management depends upon the performance of the "team" of NPS employees working in the backcountry. Work together for mutual benefit and support. Be familiar with and understand backcountry regulations *and practice them yourself.*

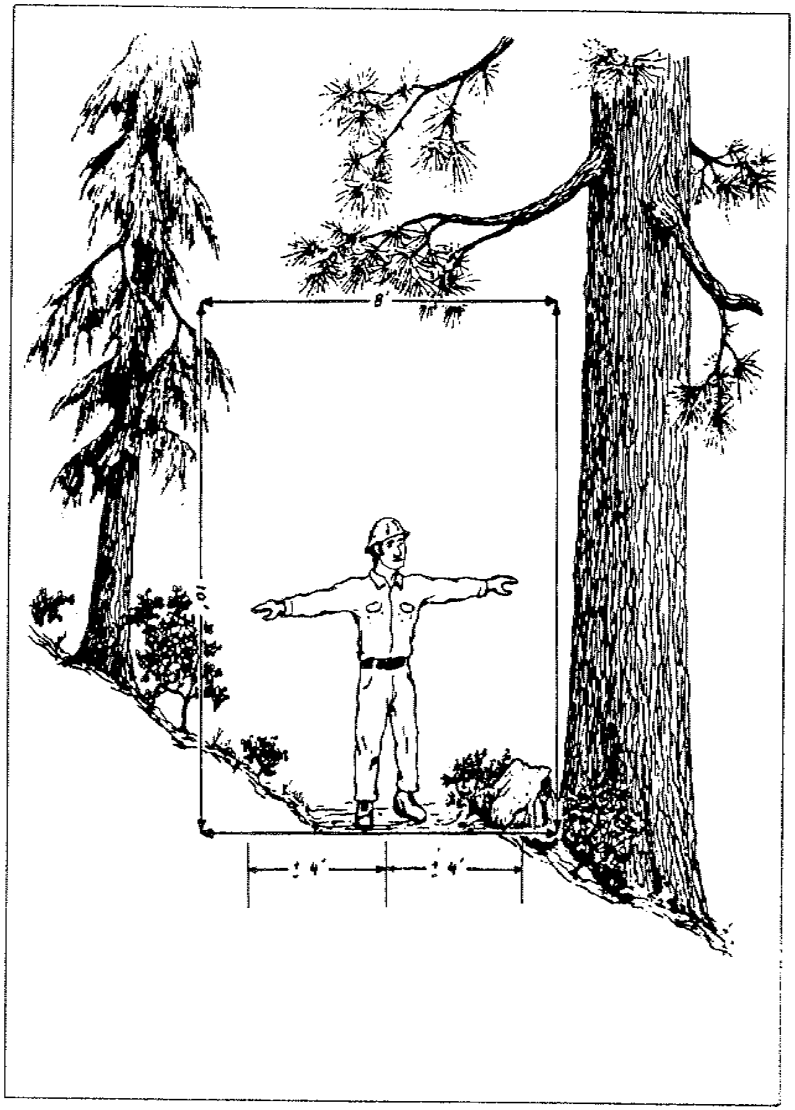
Think from an Environmental Perspective

Whenever decisions are made in the backcountry with regard to trail work, camp operation, or general backcountry living, your primary consideration must be for the environment. Be aware of the delicate balance of environmental factors in the backcountry and always act in a manner which will preserve those natural processes to the greatest extent possible. If an error is to be made, err on the side of environmental preservation. Remember, as employees of the National Park Service, we are charged with the stewardship of our nation's most valued resources.

Sequoia & Kings Canyon Trail System



The Trail Corridor



Use the natural environment as a model, and ask yourself, "How would 'Ma Nature' do it?"

Think Safety

Safe work practices are an important consideration in any job, especially in remote backcountry work sites where a minor injury could quickly develop serious consequences. For this reason, it is necessary for backcountry trailworkers to develop and maintain extra-safe work practices. Have safety meetings weekly or whenever a crew would benefit from a discussion of safe work practices or safety hazards, whether it be before starting a new assignment or when a safety problem is first observed. Each employee should take the time to think through a job with an eye toward safety and, most importantly, take the time to use safety gear whenever needed. Be aware of environmental hazards, such as how quickly hypothermia can set-in due to a sudden rainstorm near the end of a long and tiring day. Encourage safe practices on-the-job and in-camp by others and strive to develop them in yourself. *Never* relax when it comes to safety.

Develop Your Trailwork Skills

Trailwork skills develop with instruction and experience. Communication of many trailwork skills has been an oral tradition for many years, passed from worker to worker and crew to crew. Enthusiastically tackle any assignment and strive to be exposed to as many types of projects and operations as you can. Take advantage of the knowledge of your more experienced co-workers and encourage informal training and discussion of project work.

Develop an Eye for Trailwork Aesthetics

Develop an eye for the aesthetic of backcountry trailwork. Finished trailwork must be pleasing to the eye and above all unobtrusive to the natural setting. Whether it be a trail reroute, a causeway, or a large rock wall, the appearance of a project reflects its strength and integrity, as well as the professionalism of you the trailworker and your crew.

Keep an Open Mind to Trailwork Solutions

The backcountry environment is dynamic and ever-changing. No two situations are alike just as no two trail problems, or solutions to trail problems, are alike. Keep an open mind to the variety of acceptable, workable solutions and methods to solve trail problems. Adhere to the basic principles and logic of trail work, but also accept the wide range of solutions possible depending on the situation.

Your Daypack

When you hit the trail in the morning to put in a days' work, be ready for many unexpected situations. Each trailworker carries a daypack which should enable him or her and the crew to deal with most any routine backcountry development and most unexpected situations. Many of the items suggested below to be carried in a trailworkers' daypack need not be carried by each member of the crew, but should be carried by someone on the job site who is accessible much of the time:

The obvious: Lunch, litter bag, notebook and pencil, canteen or waterbottle, raingear, matches, first-aid kit, hardhat, safety glasses, and ear plugs.

Less obvious: Extra gloves, extra safety glasses and ear protection, small tool kit for in-the-field tool repairs, including small vice-grip pliers, needle nose pliers, small screwdriver, small crescent wrench, chain saw files, wrench or bar tool, 16' or 50' tape, torpedo level, wire, electrician's tape, rags, and a small spare parts kit for chainsaw or jackhammer, (spare filter, screws, nuts and bolts, etc.)

Have available: Flashlight or headlamp and spare batteries, flagging tape, park radio and spare battery, water filter.

Your Daybook

Crewleaders are required to keep a record of each day's trailwork activities. Trailworkers may also benefit from keeping their own daybook and are encouraged to do so. Suggested daybook topics are:

Daily activities - maintenance or reconstruction; a detailed description of the project; number of trees cut, rocks moved, etc.; and hours and number of persons involved. Also:

- Stock use - especially overnight grazing
- Employee attendance - sick or annual leave used
- Groceries and supplies ordered or received
- Meals served versus commissary expenses
- Safety meeting records or safety problems observed
- Employee injuries - even if insignificant at the time
- Campsite location and conditions
- Wildlife observations
- Archeological site observations
- Observed violations of backcountry regulations - note day, time, party, description of violation, and location. Let a backcountry ranger know.
- Any other backcountry problems

Updates or corrections to the trail structure and feature inventory - including trail condition and recommendations for future work.

The daily/weekly change in inventory is recorded in conjunction with the Maintenance Management System (MMS) for the end-of-season work summary. The maintenance and reconstruction statistics recorded, and units of measure, are:

- Maintenance and brushing - miles
- Waterbars - number, material
- Retainer bars - number, material
- Single and multi-tiered wall - square feet
- Causeway and causeway wall - linear feet
- Riprap - linear feet
- Other log structures:
  - Turnpike - linear feet
  - Cribbing - square feet
  - Puncheon and gadbury - linear feet
- Drift fences - length, condition, type of gate (pole, wire, swing)

BACKCOUNTRY LIVING

Living softly in the backcountry requires knowledge of low impact living techniques, an awareness of potential environmental problems, a recognition of park regulations, and experience. Backcountry trail crews have traditionally lived in camps located throughout the backcountry at established sites. These sites are used whenever crews are in the work area and are selected according to many factors, among them their proximity to feed and water for stock, proximity to the trail and work site, etc. Rarely is it necessary to establish a new camp; however with increased understanding of environmental problems and the effects of use on the backcountry, as well as overall increased use, established camps should be looked at with environmental criteria in mind.

Park backcountry camp regulations are discussed in detail in the SEKI *Backcountry Management Plan* (pp. 12 -14). When terrain permits, a 100 foot minimum distance between water and camp is required. Camps should be 100 feet from trails and meadows if possible, and in no case should they be less than 25 feet from water, trails, or meadows. Human waste and grey water must be buried not less than 100 feet from lakes and streams, in areas not subject to flooding or groundwater flow, with 500 feet recommended.

Campfires are permitted only below designated elevations in the backcountry. These elevations are below 10,000 feet in Kings Canyon and 11,200 feet in Sequoia. Other fire regulations apply to specific areas. Any exceptions to these regulations for backcountry crews and camps must be explicitly cleared through the trail foreman and the Environmental Management Committee.

Any new permanent campsites must be selected in conjunction with the trail foreman. Avoid the establishment of a new site unless there are serious problems with the traditional site, such as environmental damage caused by stock, presence of a sensitive plant species, too close to water, etc.

Many factors are considered when locating a backcountry camp. The following list includes most of these factors, some of which are discussed in more detail:

- Proximity to work
- Proximity to frontcountry and resupply
- Stock/helicopter access
- Stock pasture/feed and distance to drift fences
- Access to water - for stock and for camp
- Proximity to trail and visibility from trail
- Proximity to backcountry visitor's campsites
- General environment - bear country, sensitive plants, mosquitos, sun/shade, etc.
- Campfires - approved elevation?, firewood availability
- Fire danger
- Established site - good condition?
- Dry site for cook tent or fly
- Potential to hang food or other method to keep supplies from bears

Camp Construction

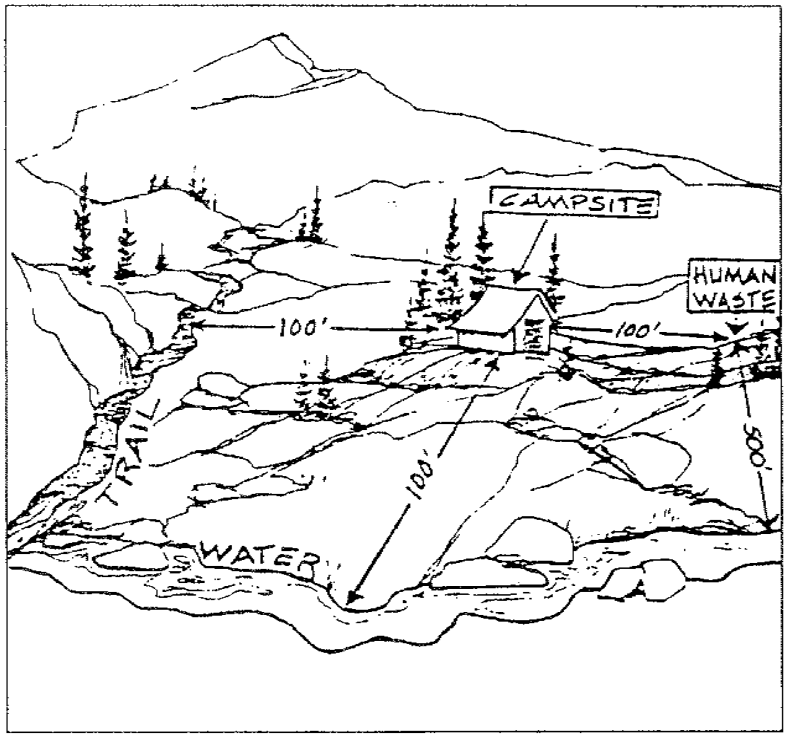
Depending upon the length of time a crew expects to be at a site, the number of persons on the crew, and other factors, camps are set up to be a comfortable backcountry home for the crew members. Generally, the more simple the camp the better. An elaborate camp takes more time to set up and break down and has more potential for impact on the environment. Set up an adequate camp to meet the crew's cooking and living needs, but try to keep it simple.

Camp set-up depends in large part upon the preference of each crew, as long as it is within basic environmental guidelines. Many established campsites have caches of poles, rounds, and cut slabs with which to construct tables, dishracks, etc. in the camp. This material should be used before other material is cut and should be carefully taken down when camp is broken and re-cached for the next crew. If more poles or materials are needed, a minimum

number of dead or down trees may be discreetly cut to build tables or racks, etc., but don't overdo it. Avoid the use of too many nails or spikes and never nail to standing trees, living or dead.

In an established camp, a well constructed fire pit may already exist or may be constructed and left if fires are permitted. One of the better firepit designs is a low, inconspicuous horseshoe shape with flat walls and top, roughly at ground level. The open end accommodates feeding wood and easy ash removal and the flat top will accommodate a small grill and a 5-gallon can (for hot water) or a coffee pot on the corner. Lay one tier of large rocks or 2 tiers if needed, using thin, deep rocks. Dimensions are

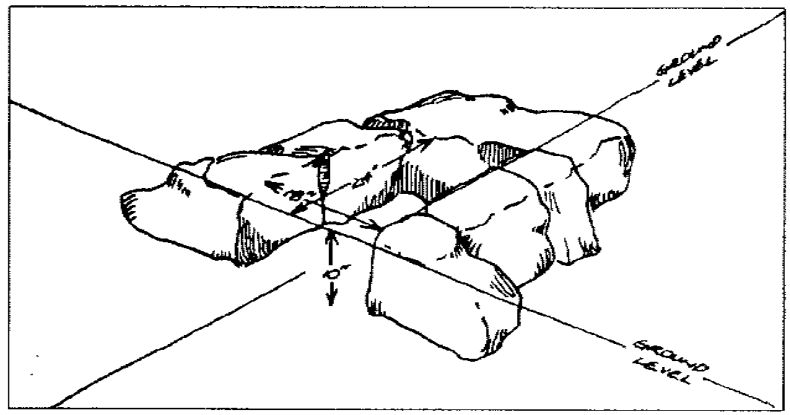
Backcountry Camp Regulations



approximately 18 inches wide (inside at the mouth), 24 inches deep (inside to back wall), and 8 to 10 inches high. This is enough to accommodate a small to average size crew.

Other structures such as hitch rails may be temporarily erected using rope to lash rails to trees and poles. Lightweight backpacker's crew tents are fast to erect and take down. The kitchen area is covered with a large heavy duty rainfly stretched across a long skinny pole or tight rope. Cooking is done over the campfire and on a white gas or propane fueled stove.

Firepit Design



Backcountry Health and Sanitation

Backcountry camps must be maintained in a sanitary, clean condition to promote the health and safety of the occupants and to not attract bears and other wildlife. Sanitary practices must be utilized in food storage, dishwashing, personal hygiene, and wastewater disposal. Due to the isolation and close living situations in backcountry camps, extra precaution to control the growth of bacteria and the spread of diseases must be taken seriously by all crewmembers. The following is a discussion of proven, healthful practices:

Drinking Water - Boil or filter any drinking water about which there is any doubt. Giardiasis is a proven threat to your health from backcountry water sources. The most effective and easiest method to treat backcountry water is to use water purifiation filters which can filter out contaminents of 0.5 microns or less. There are many types of filters available. See the trail foreman for the best system to use with your crew.

Personal Hygiene - For everyone's well being, pay attention to personal hygiene. Wash your hands and face every morning with hot water before doing anything in the kitchen or common areas. Always wash your hands with hot water after using the latrine. Keep your personal camp clean and sleeping bag aired out to prevent mice and other vermin from making a home in your gear. Wash your clothes as needed. Don't allow your socks to walk away without you. It is the crewleader's responsibility to set a good example for the crew in this regard.

Kitchen Practices - Clean ice chests frequently. Discard rotting or inedible produce promptly by burning. Ice chests containing meat need to be rinsed out daily to keep meat fresh. If available, snow is a great help in keeping meat, produce, and dairy products fresh. Drain ice chests and add more snow frequently.

Ice chests may be partially buried in the ground to gain insulation from the warmer daytime temperatures. If it is cooling off at night, crack the lid of the ice chests during the night to cool off the contents, then reseal them during the day. During the hot periods of the day, minimize use of the ice chests. Some dairy products and produce may be kept cool by submerging them in a creek or river. Use a burlap sack or a milk crate which is tied securely to the riverbank. Use two lines if the current is swift.

All dirty dishes are to be washed following each meal. Use hot water right off the fire with plenty of soap in the wash and a minimum of one, preferably two, rinses, using a small amount of bleach to purify the final rinse.

Discard used dishwater and other greywater into shallow sumps on the edge of camp, always more than 100 feet from water. Dig the pit 12 to 18 inches deep and fill it partially with large crushed rock so that the water will not be standing exposed in the bottom of the pit for long periods. Use a similar sump for laundry water.

Latrine - Dig the latrine well away (100 feet or more) from camp and at least 500 feet from water. Dig the pit at least three feet deep and of a size to accommodate the number of crewmembers for the length of time anticipated so that the waste will be buried at least 12 inches under the surface when the camp is closed. Spread chlorinated lime or ashes from the fire daily in the latrine to control odor and insect activity.

In general, the camp is to be left neat and clean on a daily basis. Before going out on the trail each day, dishes are to be washed, garbage burned, food secured, and the camp area policed and left in an orderly manner. This is not only for general camp safety and sanitation, but also to present a positive image to the public, and to discourage marauding animals.

Bears

Take precautions to protect food, gear, tack and stock feed from bears. Bears can be a persistant nuisance and methods of anti-bear storage and protection are experimental and uncertain at best. The best practice is to camp in areas where bears are not, but with a large crew and/or with stock, this is frequently impossible. Methods to consider:

- Bear cables - permanent and temporary
- Bear boxes
- Electric fence
- 24 hour camp watch and intimidation
- Bear proof pack boxes or canisters

Break Camp

Break camp by dismantling all structures, such as tent frames, benches, and tables. Completely remove all nails. Do not burn or otherwise destroy poles and materials which could be used for future structures if they are in good shape. Stash them in an out-of-the-way place near camp which can be easily found by the next crew.

It is a dirty job, but the firepit must be picked through for all foreign material, no matter what it's origin. Before breaking camp, allow time for the fire to cool, so that you can, once again, be painstakingly meticulous in picking through the ashes for any burnt cans, bits of foil, melted glass, etc. Ashes from the fire may be buried in the latrine or grey water pit, but take extreme precautions that only throughly burned material is buried, and that no partially burned or other organic material that will attract curious animals is included. Do not ever bury any foreign material, and minimize the size and number of holes or pits that are dug in and around camp and always refill them.

Rehabilitate all areas where stock have been tied or picketed. Rake and disperse the "vegetable matter."

In the event of severe or inclement weather (usually snow) which may force a rapid breaking of camp, a satisfactory clean-up of the camp and firepit may not be possible. In this case, the inadequately cleaned camp location must be reported to the trail foreman and arrangements made to get back into the area to clean up after the weather improves or as soon as possible the following season.

There is no excuse for not leaving a *meticulously* cleaned camp. This is a primary responsibility of all trailworkers and cannot be overlooked in the rush of breaking camp. Always try to leave a campsite cleaner than you found it. Painstaking, meticulous policing of the campsite for *all* non-native material, such as bits of plastic or foil, is mandatory. The entire camp, including the campfire, should be left as a prime example to the public of minimum impact camping.

Garbage

Garbage is a major concern of backcountry maintenance. Whether it be small trailside litter, burned trash from campsite firepits, or garbage from the trail crew camps, all trash must be packed out. Garbage removal is the responsibility of both trail crews and packers, and backcountry rangers. Cooperation is essential to make arrangements to pack out trash.

Never bury anything in the backcountry with the possible exception of cleaned campfire ashes and human waste. Buried garbage won't stay buried for long as animals will dig it up and spread the garbage throughout the campsite. This is not a solution to the garbage problem.

Cigarette smokers must not litter the backcountry, including trails and campsites, with butts and matches. If you smoke, ground out the butt and put it in your pocket with other trash for disposal in the fire or to be packed out with the garbage. Clean up the backcountry whenever and wherever it is needed. Garbage, more than any other single thing, gives the public a direct positive or negative impression of the Park Service's management of the backcountry.

Radio Use

A portable radio and spare batteries are with each crew in the backcountry. Radio transmission and reception varies with location. Many of the traditional backcountry camps are located in deep canyons in order to be near grazing areas. Radio contact from many of these sites is at best not dependable. Sometimes it is necessary to change locations to hit a backcountry repeater, especially if in a canyon bottom or other area surrounded by high mountains. Radio transmission and reception generally improves with elevation. The more clear or unobstructed your line to a mountain top repeater, the more readable and clear your transmission will be.

Backcountry repeaters are located on remote ridges and high mountain tops. The repeaters operate using batteries which are charged by solar energy. Extensive use of the repeater, especially at night, depletes the batteries and they may fail to be available when needed in an emergency situation. For this reason, all radio transmission using the backcountry repeaters is to be kept to a *minimum*. Necessary daily business over the radio is fine but chatty conversations and recipe swapping at night is not only unacceptable but is potentially life-threatening in the event of an emergency. Do not depend on the radio for routine planning, grocery orders, etc. Make all plans in advance and stick to them whenever possible. Avoid unnecessary spur-of-the-moment plan changes, especially if the changes are dependent upon successful radio contact.

For further information regarding SEKI's backcountry radio system, see the SEKI *Radio Manual*, copies of which are available at the Packer's Dorm or from the trail foreman.

TRAILWORK

Trailwork involves many activities. As an introduction to the work standards which follow, this section presents the basics of trailwork: an introduction to the tools of the trade; basic on-the-job and personal safety considerations; a discussion of reroute policy and trail layout concepts, including basic principles for good trail design; and trail rehabilitation methods.

Tools

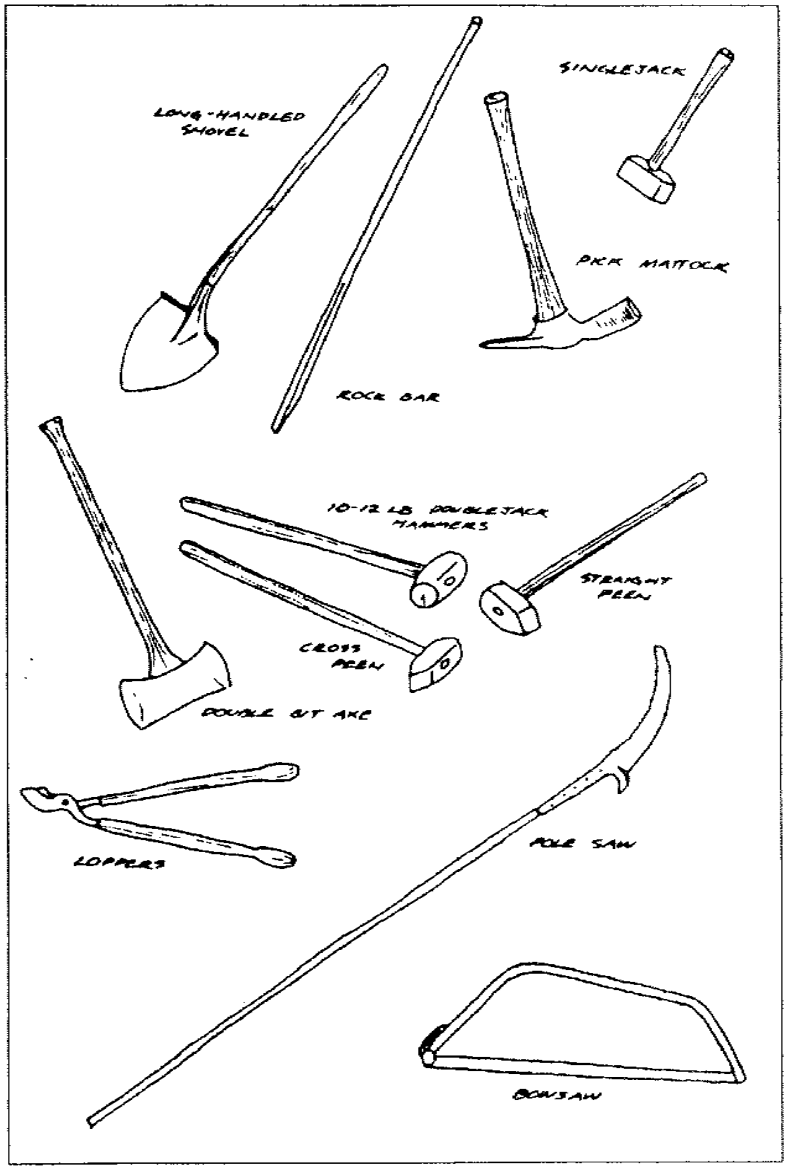
Basic trailwork tools fall into four overlapping categories: Camp Tools, Trail Maintenance and Rockwork Tools, Bridge Tools, and Explosives. The following list will serve to introduce the tools and tool terminology for the purpose of further discussion. This list is not meant to be all-inclusive; at times other tools may be needed and used to get the job accomplished. The proper care and use of these tools will be a subject of safety meetings and on-the-job training sessions.

Camp Tools

Axes, wedges, and splitting mauls

A basic tool kit: Tool box, claw hammer, screwdrivers, fence pliers, assorted nails (common 8 and 16 penny, horseshoe) and staples, crescent wrenches, large and small vice-grip pliers, needle nose pliers, torpedo level, string level, string, electrical tape, duct tape, fiber tape
Saw kit including: files, file handles, spare plugs and parts, and rags
Jackhammer kit including: cleaning and maintenance tools, spare parts and rags
Shoeing kit

Tools



Trail Maintenance and Rockwork Tools:

Shovels - spade blade, lady or fire shovel if preferred
Hammers - 3 or 4 lb. singlejack or chink hammer, 8, 10, and 12 lb. doublejacks or sledgehammer, with and without a peen head; straight-peen preferred, also cross-peen
Pick, pick-mattock
Rock bar - one of the most versatile, all-around tools
Safety equipment - hardhats, gloves, eye & ear protection
Specialized rock tools - wedges (or plugs) and feathers, bullset, rock chisels
Brushing tools - chainsaw, pole saw, folding saw, steel handled loppers

Bridge Tools: In addition to the basic hand tools already mentioned, bridge work may require the following specialized tools:

Brace and bits
Griphoist, comealong, chain hoists
Chainsaw winch - such as the Olini winch, capable of up to a 4000 pound straight pull
Various snatch blocks, pulleys, and tackle
Bridge spikes, 8 to 14 inches
Alaska chainsaw mill
Peavey, cant hook, timber carrier
Barking spud, peeling spud
Wire rope and related tools - eye vise, swedge tools, wire clamps, turnbuckles
Tree and pole climbers

Explosives - Explosives are a tool that can be very effective for backcountry trailwork. Explosives are used to break up or move boulders or rock slides, establish trail tread on bedrock, make fill rock from larger rocks, remove stumps or move down trees, and other tasks.

Recordkeeping

An example of a typical safety meeting report: Keep it concise and simple

RECORD OF SAFETY TRAINING

Date 7/10/9X Location Simpson Meadow Division Maint
Instructors Trailleader Smith, Crewleader Jones
Title An Introduction to Safety Gear
Discription of Content All kinds of safety gear were shown and was discussed. Gear on hand included chaps, hardhats, earplugs, safetyglasses, facemasks, etc.

PARTICIPANTS

	NAME	TITLE		NAME	TITLE
1	J. Smith	Trailleader	13		
2	L. Brown	Trail Maint. Wkr.	14		
3	L. Jones	CCC Crewleader	15		
4	B. Black	CCC Corpsmember	16		
5	K. Green	CCC Corpsmember	17		
6	W. Blue	CCC Corpsmember	18		
7		ETC.	19		
8			20		
9			21		
10			22		
11			23		
12			24		

Signature

1 _____ Supervisor
2 _____ Division Chief
3 _____ Safety Manager

The National Park Service has a program of Blasting Safety and Blaster Certification established in 1986. There are three levels of certification of individuals involved with explosives work: Blaster, Blaster-in-Training, and Explosives Handler. Blasters and Blasters-in-Training are required to take the week long Blaster's Safety and Certification course and be re-certified every three years. The Handler's course is covered in the first two days of the Certification course and also is required every three years. Only these persons are authorized to use and handle explosives within the National Parks. Refer to NPS 65, *Explosives Use Policy and Blasting Program Guidelines* for further information.

Discussion of the many different types of explosives and detonator systems is beyond the scope of this Handbook. Use of each is covered in the Certification course and those trained in their use will become proficient, safe, and effective backcountry blasters as they gain experience.

Trailwork Safety

On any backcountry project or activity safety is always a primary consideration. Basic safety equipment is expected to be worn whenever needed. It is the responsibility of the trail leader or person-in-charge to anticipate the safety requirements of the job and to make sure that safety gear is worn. Injuries can be reduced significantly if safety hazards are anticipated and safety gear is used. Basic safety gear for trailwork is:

Hardhats
Gloves
Safety glasses with side shields
Ear protection
Breathing protection

These items should be with every trail worker on the job each day. When safety gear is needed it should be available and used. Safety glasses do not protect eyes from flying rock when they are in your pack, or worse, "back at camp." It is each trailworker's responsibility to carry gloves, ear protection, dust

masks, and glasses (and extra sets if available) in your daypack every day. If any safety equipment is not available, let the trail foreman know so that the items can be ordered.

Specialized safety gear is available for specific jobs and should be used when required. Specialized gear includes sawyer's chaps, climbing ropes and climbing gear for anchoring a worker while drilling or doing bridge work, steel-toed boots especially for large rock wall projects, and breathing masks to protect from granite drill dust or other hazardous materials.

Safety is each employee's responsibility. As a part of the job, you are required to protect yourself and those around you. Always be alert for safety problems and do not hesitate to bring them to your co-workers attention at any time, at any place. Safety is the number one concern of all of us and we all should work together to achieve and maintain a safe working environment and safe work practices.

On the job, especially on rock projects, an orderly, organized work site contributes to a safe and satisfying job. Take the extra time to spread out, unstack, and look over your rock selection. This time will be more than made up in ease of construction and by the quality of the results. A jumbled rock stockpile is an invitation for smashed fingers, smashed toes, and other "surprises." Tools and materials should be placed far enough off of the trail tread to allow for the safe passage of hikers and stock through the worksite. Minimize obstacles which may create hazards or force traffic to impact an area other than the existing (or under construction) trail tread.

By taking the time to think the job through and plan beforehand, a safe work environment is promoted. Safety, orderliness, and cleanliness go hand in hand. A neat, clean camp or jobsite is also a safe camp or job; there are no stray tools to step on, and no unknown piles of gear to trip over. Keep your tool area clean and organized. You should be able to see what you have without digging through a mixed pile of sharp tools and equipment.

Above all, the basic elements of a safe work environment are your intelligence, your experience, and your awareness. You can prevent accidents by thinking ahead and anticipating potential problems before any hazard exists.

Tailgate Safety Meetings - "Tailgate" safety meetings are held at least weekly and are used to discuss any safety problems specific to the job and for general safety training. "Tailgate" meetings are short, to the point, serious discussions or presentations of safety related topics. These meetings are documented on the provided forms and in each trail leader's daybook. A list of possible topics for safety discussion follows. These may seem repetitive and increasingly boring as the season progresses, but it is the leaders' responsibility to keep the discussion pertinent, timely, and beneficial. Remember, one cannot be reminded of safety too often. Even the most experienced workers *need* periodic reminders of safe practices. The mere fact that we discuss safety once a week will make all personnel more safety conscious.

Do not hesitate to hold on-the-job informal, unscheduled safety discussions as the need arises. The best time to discuss safety problems is, of course, before they occur, but next best is to discuss problems immediately as they occur and take corrective action.

It is the leader's responsibility to orient all workers on a particular job to any safety hazards *before* beginning work. Discuss anticipated problems and potential hazards to watch out for before swinging the hammer or starting the chain saw.

Topics for Discussion at Safety Meetings

A Safe Attitude - take time for safety, safety equipment

The Day's Work - what safety problems did we see today or will we see today?

Hand Tool Orientation - safe use, maintenance, and transport

Chainsaw Safety - use, maintenance, bucking and falling, logjams, in-camp use, mill use & safety

Winch Safety - including rigging principles and safety

Pionjar and Jackhammer safety - daily maintenance and safe use, including use of plugs and feathers

In-camp Safety - including tool maintenance, rehandling, axe safety, overhead hazards, kitchen safety

Rock Work Safety - moving rock, lifting, communication and warning, construction hazards, slick rock hazards

Bridge Work Safety

Brushing - personal safety, crew safety

Safety around Stock - packing, unpacking

Lifting

Overhead Hazards - hardhats

Camp Sanitation - water, backcountry health

First Aid - emergency radio use

Blasting - shot rock hazards

High Elevation Weather - hypothermia

Recreation Hazards - hiking, climbing, swimming

Helicopter Safety - loading, unloading

Visitor Safety - passing through jobsites

Climbing Rope and Harness - tie-in safety

Trailwork and Tool Safety

Backcountry Tool Transport - Backcountry trail maintenance frequently involves traveling great distances carrying a variety of tools, many of which are heavy and cumbersome. The safest way to carry tools is in your hand, at your side. Sometimes for relief from the weight, tools are carried on a trailworker's shoulder. Be extra cautious of those around you when carrying tools on your shoulder, particularly long or heavy tools such as rock bars or shovels. If you turn to talk to someone near you, be certain you know where those tools on your shoulder are swinging. When hiking with a crew carrying tools, spread out and give each person ample room to allow for abrupt halts or swinging of the tools. If passing a person from behind, let them know well in advance. Talk to them and tell them on which side you intend to pass. Do not sneak up and startle your co-worker, you might end up with a rockbar or shovel to the side of your head. Whenever you are near a person with tools on their shoulder, take a defensive and cautious approach. In other words, be prepared to duck!

Chainsaw Use - The *Backcountry Management Plan* permits chainsaw use during normal working hours only. A one day Chainsaw Certification course is required by park safety policy for all chainsaw operators. This course is taught every spring for trail personnel. When using chainsaws, all the basic safety gear (hardhat, glasses, ear protection) is required plus chaps, gloves, and steel-toed boots when needed. When sharpening the chain, wear gloves to protect your hands from a slip of the file putting your hand onto the chain. Chaps are a good idea anytime the saw is being run for an extended period, such as bucking firewood or cutting a large log out of the trail. Chaps help prevent careless injuries resulting from an idling saw being thoughtlessly "rested" on the sawyer's thigh.

Perhaps the most frequently observed and potentially most damaging error in chain saw use is failure to use ear protection. Did you ever notice your ears ringing at the end of a day of saw

work? Suffice it to say that the ringing is a warning. Hearing damage is cumulative and frequently will not be noticeable until later in life. *Use* your ear protection.

Pionjar or Jackhammer Use - When using a jackhammer, use the basic safety gear plus breathing masks to protect the operator and assistants from the granite dust which floats in the air. Hardhats, gloves, safety glasses, dust masks, and ear protection are required for both the operator and any nearby employees. It is the operator's responsibility to not start the jackhammer without first warning those around that safety gear is required. When it is necessary for traffic to pass through the drill site, the operator will pause to allow for safe passage free of noise, dust, and other hazards. If stock is to pass through the site, obstacles, equipment, and personnel should be removed before passage to minimize "spooking" the animals.

Never strike wedges (or plugs) and feathers without safety glasses. Pieces of feathered plug steel can fly off when struck.

Rockwork - The main hazards from rockwork are back injuries from using an improper method of moving or lifting, eye injuries from striking rocks with a singlejack or busting fill with a doublejack without wearing safety glasses, and smashed fingers while laying walls or riprap.

Move rocks using the strongest muscles in your body, your thighs. Always keep your back straight and don't ever lift using the lower back.

Wear eye protection when swinging any hammer or when you are around anyone who is. If a rock chip flies into your eye, it doesn't matter who swung the hammer. When busting fill, take note of where people are around you at the work site and warn them to wear their safety glasses if there is any chance they are in the "danger zone."

Gloves help to minimize the extent of a finger injury, but preventing smashed fingers is mainly a function of experience and forethought. "You gotta be smarter than the rock."

An overhead hazard that is frequently overlooked when doing rockwork is from the rockbar. Whenever you bend lower than the rockbar to adjust the position of a rock, the rock bar is a potential hazard while held in the air. Wear a hardhat to avoid being hit in the head by a falling rock bar.

Brushing - The tasks of brushing are many and varied. Primary hazard is to the eyes. Hardhats and safety glasses with sideshields are mandatory and gloves are recommended. If chain saws lead the brushing crew, proper safety gear, including chaps, is to be used.

Overhead hazards exist from falling cut limbs, especially when using a pole saw. An assistant is helpful on the pole saw crew to aid in catching falling limbs. Always wear a hardhat and safety glasses.

Helicopter Safety - Helicopters may be used by the backcountry crews for resupply, emergency operations, and to assist with camp moves. It is important that every trailworker know and observe basic safety practices when working in the vicinity of a helicopter. The basic practices are as follows:

Always wear a hardhat *with the chinstrap in place.* Also recommended is eye protection from blowing debris and ear protection, particularly when exposed to engine noise for a long period of time. Always buckle your seat belt and shoulder harness (if available) when you are a passenger.

Communicate with the pilot and wait for his signal before approaching the helicopter. Visual hand signals are effective and satisfactory. On a large operation, designate someone with a radio to be in charge of safety.

Give an indication of wind direction and intensity to the pilot before the helicopter lands. This can be done via radio or visually by throwing pieces of grass into the air or standing with your back to the wind with arms outstretched indicating wind direction.

Approach the helicopter only from the front half to avoid ever being in the vicinity of the tail rotor. Never, even if the helicopter is shut down, walk around the tail section of the helicopter. This practice must become habit for all concerned with helicopter operations.

If the landing site is uneven, never approach a helicopter from uphill. Always approach cautiously from the downhill side. On level ground, always approach with caution as a rotating blade can dip with a sudden gust of wind.
Keep all carried objects low. Any cargo being loaded or offloaded, especially if it is long and tall (such as polesaws or skis), must be consciously kept low to the ground.

Load and unload all cargo cautiously. Avoid sudden weight shifts that may affect the helicopter's stability, especially in a power or hover landing situation (such as on snow or in confined, rocky areas).

With sling loads, be sure that the load has been grounded before grabbing it to allow for static discharge. This can be done by letting it first touch the ground or using a green stick to ground the load. As sling loads approach the landing zone, remove all non-essential persons from the area, including persons who may be working beneath the approaching flight path.

Stretching - Stretching is a good practice before and after any physical activity, especially strenuous work such as trail work. Muscles are limbered and loosened in anticipation of the day's work, instead of by the day's work. Many on-the-job injuries can be prevented by a simple daily stretching routine. Stretching makes the trailworker more aware of his or her body and muscles and of the proper positions for lifting, digging, and other physical tasks. It is recommended that all trailworkers undertake a program of routine morning stretching to develop full-body aware ness and a positive attitude toward work. A

good reference is Bob Anderson's *Stretching*, Shelter Publications, Inc., Bolinas, CA. USA, 1980, copies of which are available from the trail foreman.

Reroutes

Trail routes have evolved over hundreds of years of back country use. As recreation use has increased, the impact of such use has changed the way we look at trail design. Many of the established historic routes are no longer acceptable given the back-country management objectives of the National Park Service. Trails through meadows, steeply up and down passes, and along shores of lakes are good examples of trails which need to be considered for reroutes.

Minor reroutes of less than 50 yards can be undertaken routinely if all other options, such as reconstruction of the existing trail, have been thoroughly considered and the crew can accomplish the work in a reasonable amount of time. The project leader should consult with the trail foreman before beginning construction of most minor reroutes.

Major reroutes, such as moving the trail out of a meadow or rerouting a pass, need to be considered carefully before being undertaken. All such reroutes need to be planned thoroughly with the trail foreman, including a variety of feasible alternatives, who in turn will present the project to the SEKI Environmental Management Committee for their consideration.

Factors to Consider when Planning a Reroute - A full discussion of planning larger reroutes is beyond the scope of this Handbook, but a few factors are important for a basic understanding of trail design and will aid the trailworker in reconstructing any trail section. When laying out the rerouted trail, consider:

Grade - If the trail ascends or descends in elevation, the steepness or grade of the trail needs to be considered. If the reroute

is a long section, attempts should be made to equalize the grade over the entire section. The grade of the trail depends primarily upon the tread material and slope soil. Some loose, granitic soils cannot withstand use at more than 5% grade. For the ease of hikers and stock, grade should not exceed 15 percent, with 10 percent being the maximum for continuous climbs over many miles.

Switchbacks - If switchbacks are needed to pull the grade, they should be laid out as long as possible depending on topography. Short stacked switchbacks invite major slope failures to a much greater degree than long switchbacks. Long switchbacks are easier to construct because there are fewer switchback corners and the longer switchbacks will require less maintenance and wall repair. Shortcutting on short stacked switchbacks often results in damaged or knocked-down retaining walls. Long switchbacks discourage shortcutting since, ideally, one cannot be seen from the other.

Drainage - Plan the entire drainage of a rerouted section before beginning work. The drainage should be planned around the natural drainage pattern of the area. Anticipate the runoff and systematically plan a trail drainage system which moves the water through and out of the reroute area. Water turned off the trail by a waterbar above must lead to another waterbar on the switchback below, and so on down the trail section. You can't overdrain. Anticipate the infrequent deluge which historically has been the cause of trail washouts, not just routine drainage. Sketch a drainage plan of the section to aid in planning the waterbar system.

Environmentally Sensitive Areas - Before laying out a reroute, survey the locale for any environmentally sensitive sections or other areas which are poorly suited to supporting a trail. Areas to look for include archeological sites, areas of endangered plant or sensitive wildlife species habitat, meadows

and other wet or boggy areas, excessive bedrock, or sandy, unstable slopes. Plan to minimize tree removal.

Natural Features - To layout a rerouted trail through any area, survey the locale for any prominent natural features such as large trees or heavily forested areas, bedrock outcrops, or talus slopes. Plan the trail to avoid environmentally sensitive sections and to take advantage of these natural features. Contour the trail across the slope with rock outcrops at the switchback corners or used as outside walls. Route the trail above large trees to help stabilize the trail tread and prevent slope creep. Plan for full bench construction whenever possible with the entire width of the trail tread excavated into the slope. Less than full bench construction may require an outside wall and considerably more time in construction.

Trail Rehabilitation

Trail rehabilitation refers to any action taken to expedite the rate of recovery of abandoned or rerouted trails. Recovery is judged by the extent to which the treadway has refilled or returned to the height of the surrounding landscape and vegetation, by the extent to which vegetation and ground cover reestablished in the treadway approaches that of adjacent plant communities, and the overall appearance of the section.

Trails through sensitive meadow environments are slowly being rerouted leaving abandoned trails in need of rehabilitation. For more than a decade, experimental projects have been undertaken by NPS and volunteer crews to rehabilitate some of these sections. Many of the projects were at least in part successful and there is much to be learned from these experiments. Some documentation is available regarding past projects from the trail foreman. Documentation by the trail leaders of present rehabilitation efforts is essential to add to our knowledge of methods and techniques.

All reroute projects must include rehabilitation of the old or

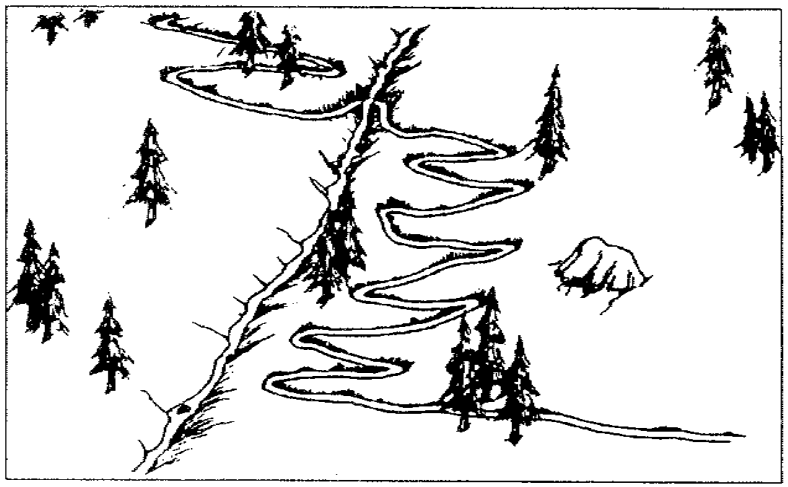
abandoned trail. In this section, a summary of accepted methods and techniques for successful trail rehabilitation is presented. These techniques apply to the difficult challenge of closing trails in meadows, and also in principle to rehabilitating all abandoned or rerouted trails.

Rehabilitation Objectives - Four basic objectives must be accomplished in order for rehabilitative efforts to result in naturalization of the site within a reasonable period of time. First, drainage must be restored to a natural, pre-trail condition. Second, rutted trail tread must be filled to a level comparable to that of the adjacent landscape surfaces and the linear pattern of the rut must be broken. The fill must be stabilzed, or retained, in the tread using rock or wooden structures. Third, vegetation similar to that of the surrounding landscape must be reestablished and finally, visitor use of the rehabilitated trail tread must be eliminated.

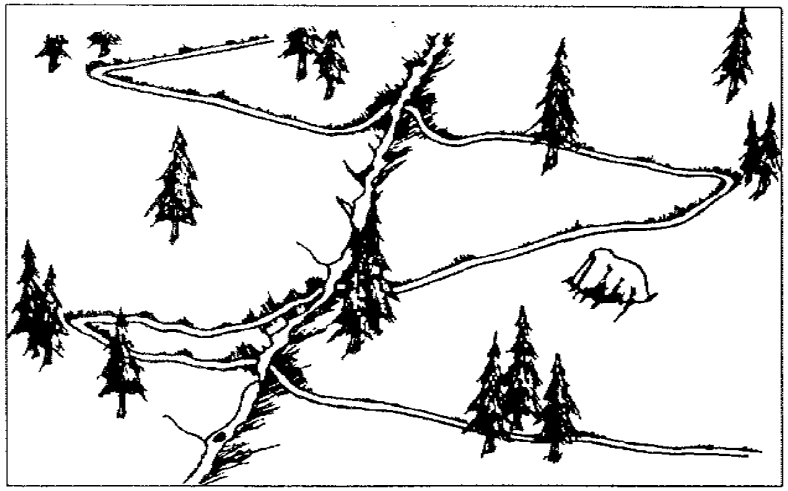
Develop a Plan - To achieve these objectives, a plan for the area to be rehabilitated must be determined. The natural drainage pattern is discerned and a means planned to reestablish that pattern through the rehabilitation area. Different revegetation methods are considered and an approach to the project is determined based on availablility of materials, amount of labor available, and other variables. The pattern of the impacted area to be rehabilitated is considered; are the walls between ruts going to be eliminated to aid in breaking the linear pattern? Should established vegetation within the ruts be disturbed and transplanted to ground level? Is there a good, nearby source of compatible fill? Is there established vegetation in the vicinity similar in physical type which can be successfully transplanted onto the rehabilitation site? What erosion control structures will be required, will they be of rock or wood?

Drainage - A natural drainage pattern must be reestablished to stabilize the rehabilitated area. Abandoned trail tread,

Switchbacks



Short Switchbacks



Long Switchbacks

particularly if rutted, can become an eroding torrent of water during thundershowers and spring runoff. "Read" the landscape and plan to reestablish the natural drainage pattern across the trail as best observed *above* the impacted zone.

Low, subtle waterbars of rock or wood may be required to restore the natural drainage pattern of the rehabilitation zone. Wooden structures are preferable because they will deteriorate over time, to theoretically complete the re-naturalization. Do not worry that too little water is penetrating to the revegetated zone, initially too dry is preferable to too wet.

Fill - Abandoned trails have frequently been eroded to depths of 1 foot or greater, and may have formed rows of multiply rutted parallel trails. Soil at the bottom of the former trail tread has been compacted by many seasons of use, and topsoil has been swept away by the eroding effect of altered drainage patterns.

To rehabilitate the ruts begin by scarifying, or aerating, the soil to disrupt the compaction using shovel, pick, rake, or a special revegetation tool, called an aeration fork, to a depth of 4 to 6 inches. First, break the compacted soil and dead root systems using picks and follow with shovels turning the soil over taking bites of about 2 inches.

For areas of multiple ruts, experience has shown that the best approach is to remove the vegetated islands between rows, saving them for later replanting, and treat the entire section as one large plot. This breaks the linear pattern of the former trail created by the tread walls and creates a more natural appearance. The soil of the entire plot is then decompacted or scarified as described above. Before adding soil to the section, rock or wooden retainer bars (or checks) must be constructed in the rut or aerated section to stabilize and hold the fill. Soil fill is an extremely valuable resource, especially at higher elevations, and should not be used in a situation that will be vulnerable to further runoff. Along with reestablishing a natural drainage system, using checks to

stabilize the soil fill will vastly improve the potential for a successful and natural rehabilitation project.

Rock retainer bars are constructed as described in section 5 under Rockwork Standards, across the trail tread, or perpendicular to the direction of potential water and soil movement. It is important that the bars are laid entirely below the final surface level of the rehabilitated section, so that they will not be noticeable when the section is completed. A large above-ground rock can be used in single ruts if set so that it will retain soil and appear natural. Wooden retainers are laid in the same way with similar caution taken as to their height above the surface of the surrounding landscape. Wooden retainers have an advantage in this application in that they will eventually deteriorate as the section becomes established and the vegetation matures, leaving a naturally rehablitated landscape.

In ruts more than 6 to 8 inches deep, crushed rock fill may be used deep in the ruts to reduce the amount of soil required and allow for sub-surface drainage. The rock is broken using sledge hammers, and graded with the larger sized fill (up to 3 inches in diameter) deepest in the rut and the progressively smaller rock (to about 1 inch) above. This rock is a good base upon which to lay retainer bars and waterbars. If available, organic litter (branches, leaves, needles, or unuseable grubbed vegetation) can be used with soil in deep ruts when soil is sparse.

Match the soil with the surrounding soil type. If practical, borrow soil from a site similar in physical character. Generally a mixture of sand and organic soil similar to the surrounding mix will succeed in growing like vegetation. Sand tends to erode, while organic soil is more cohesive and will compact with moderate water impact.

Soil can be effectively moved using hand labor. Wheelbarrows, large buckets, burlap sacks, and human chains are used to move large quantities of soil moderate distances. Pack animals with dirt boxes can be used to transport soil long distances, but extreme care must be taken to minimize and control the impact of the stock. Do not establish unwanted trails, particularly in

sensitive meadow environments, and always thoroughly naturalize the borrow pit.

Reestablishment of Vegetation - Several methods to revegetate and reestablish the original plant communities can be used. All are experimental and must be undertaken with care, and during the seasons following revegetation, the section's progress must be observed to determine the most advantageous techniques. Among these techniques are seeding, and the most utilized, plugging.

Seeding - Seeds can be obtained from special nurseries or on site. Gathering seeds from the surrounding meadow is a delicate process which should be done only in conjunction with knowledgeable personel. Seeds are gathered in paper bags by placing the bag over the plant, then gently shaking the plant to loose the seeds. The seeds are then sown onto the carefully prepared revegetation plot.

Plugging - Plugs of vegetation similar to that of the surrounding area are transplanted into the prepared soil fill in the fall to minimize moisture stress. Once established, the plugs expand, stabilize the soil, provide mulch and organic matter, and introduce seed to uncolonized portions of the plot. Plugs should not be less than 4 inches in diameter and 3 inches of soil should be retained beneath the plug to protect the root system. The plug is buried to a level slightly below the prepared bed to compensate for surrounding compaction and frost heaving. Some settlement of the soil in the bed is expected and the soil should be crowned or more soil added later to accomodate this. Possible sources of plugs are from the rows of vegetation between the eroded trail ruts, sluffed-off vegetation from collapsed stream banks, vegetation growing in the bottom of the ruts, and isolated clumps of vegetation at the edges of meadows or other visually and environmentally acceptable sources. The typing or matching of vegetation is

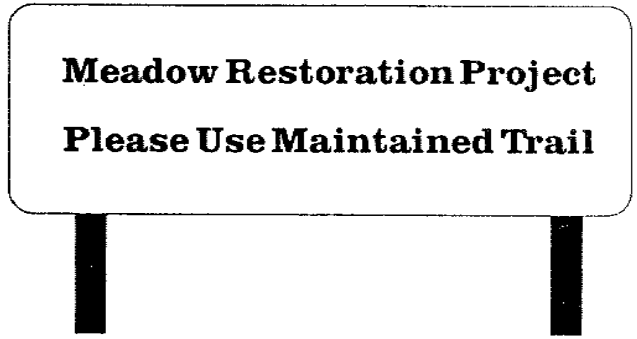
taken from a dry site and planted on a wet site is less likely to survive than plugs taken from a similar site.

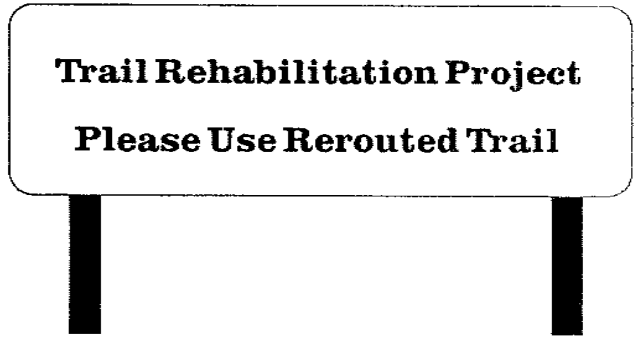
Other techniques to aid in the successful reestablishment of vegetation in the scarified tread include mulching, irrigation, fertilization, and the addition of soil amendments. Mulching and irrigation are done in conjunction with the transplanting of the plug. Mulch is organic matter lightly spread over the plantings to preserve and hold moisture. Dried grasses raked from the surrounding meadow work well for this. Irrigation refers to the careful and systematic watering of the newly transplanted vegetation to aid in maintaining a properly moist environment during the critical initial weeks and months of the project. The addition of fertilizer and/or soil amendments is aimed at increasing the nitrogen content and increasing the moisture holding potential of the soil. Fertilization can range from the addition of manure gathered from pack and saddle stock to the addition of chemicals. Peat moss and vermiculite are other possible soil amendments. Use of any of these compounds must be carefully documented and the results monitored to aid in determining the most appropriate procedure.

Reestablishment of vegetation is a tedious and laborious process. At high elevations the growing season is short and under the most ideal of conditions (moist, stable, organic soil), restored vegetative cover may approach that of undisturbed sites in 10 or 12 years. More realistically, 50 or even 100 years may be required. Once reestablished however, the site is stabilized for all future generations to enjoy unnoticed.

Eliminate Visitor Use - Visitor use must be eliminated to prevent additional trampling and compaction of the revegetated plots. Signs explaining to the visitor the nature of the project can be successfully used as most visitors are in favor of such restoration projects. Temporary barricades of down trees may be placed to discourage the use of a former route. Former trail junctions must be completely disguised to discourage continued use.

Two examples of signs read:





TRAIL MAINTENANCE STANDARDS

Backcountry trail crews are assigned backcountry trail maintenance each season. What is actually accomplished varies according to trail priority, time and personnel available, and overall workload and work required.

Trail maintenance is typically done in conjunction with trail opening which is theoretically performed annually on all maintained trails. Trail maintenance refers to clearing drains, digging waterbars, and other basic drainage functions such as off-trail drainage work. Maintenance may include the reconstruction of non-functioning waterbars and drains as time and personnel available allows. Maintenance also includes basic hazardous rock removal from the trail tread. These rocks are generally of greater than softball size, 3 inches or more in diameter. Large boulders which have rolled onto the trail and obstruct stock travel, should also be removed at the time trail opening and initial trail maintenance occurs. These boulders can frequently be removed by several persons with rock bars, but upon occasion explosives are necessary to clear the trail. In these instances, a minimum of three persons is required to safely set-up the shot and lookouts. All blasting regulations must be strictly observed. It is recommended that a small amount of powder (12 pounds of Kinepak, for example) and a blasting kit be carried if a certified blaster is a member of the maintenance crew.

Trail maintenance also includes brushing of the most overgrown portions of the trail corridor, limbing of overhead hazards, drift fence and gate repair, and any other overall backcountry maintenance as time and crew size allow. If a waterbar is not functioning and can be easily repaired, as is the case when one rock is out, fix it if possible.

In summary, trail maintenance is involved with trail opening; performing whatever tasks are required to open the trail to hikers and stock for the season and basically to attempt to

maintain the environmental status quo, with all drainages functioning as well as possible short of full reconstruction, and environmental damage, both potential and actualized, held to a minimum.

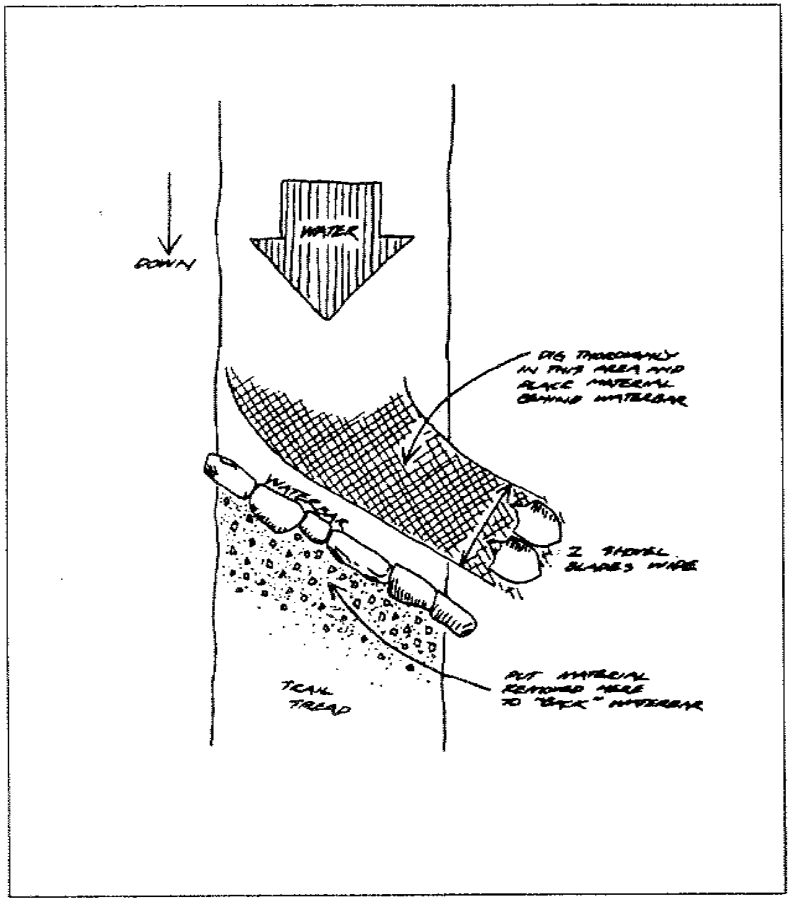
Cleaning Waterbars

"Digging drains" is the most basic of trail activities, yet it is not uncommon to see the job done inadequately. Proper waterbar maintenance is essential to the long term function of the drainage system. The drain should be cleaned thoroughly to allow for an entire season of trail traffic (which moves and kicks debris and soil into the drainage), as well as "flash flood" thunderstorm conditions frequently encountered during a typical Sierra summer.

Drainage maintenance allows for the "natural" flow of water on and off the trail. The natural drainage pattern, that is the pattern which would occur most naturally without the presence of the trail, is reinforced by the presence of waterbars, dip drains, and other structures. When any decision need be made with regard to a trail drainage system, think in terms of natural processes and the natural (pre-trail or without trail) drainage pattern. An experienced trail employee learns to "read" the drainage, including off-trail drainage above and below the trail. Time should be taken to "think through" the drainage pattern, "read" the landscape, and work the trail to accommodate the anticipated runoff.

The most common problem observed with maintenance of drainage systems is that the job is not done in a thorough enough manner. There is a strong tendency, especially with new and less experienced employees, to move too rapidly through a section of trail and not pay adequate attention to thoroughly anticipating the runoff and thoroughly digging out the drainage. When digging a drain, do not think that the water must run down the trail and actually hit the waterbar and then be turned off the trail. Rather think of the waterbar as the ultimate back up to turn water off the trail in the extreme "flash flood" runoff situation. Dig the drain to naturally turn the water off the trail before it

Cleaning a Waterbar



Proper method for thoroughly digging a drain

ever reaches the waterbar. Dig the drain wide, thoroughly, and take it well off the trail. Do not allow debris to dam up off the trail. Clear off-trail drainages of all logs, rocks, and other debris, and even consider cutting logs out of the off-trail drainage if needed to preserve the most direct natural flow of runoff.

The width of the drain leading off-trail should be at least two shovel blades wide, approximately 12 to 18 inches if possible, within the limitations of rocks or other obstacles.

The material dug out from in front of a waterbar when "digging drains" should be placed in the trail tread behind the waterbar (downslope) and used as backing for the waterbar and as tread material. Any object larger than 2 to 3 inches in diameter should not be returned to the trail tread.

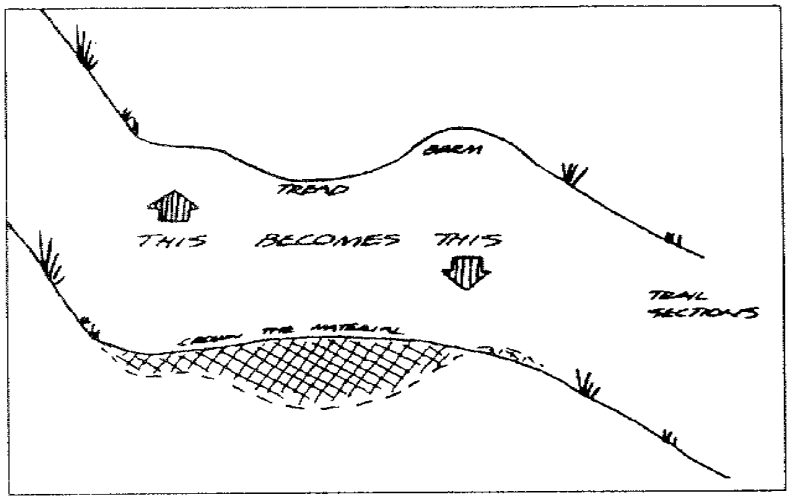
Berm Removal

Heavily used trails, especially those used by stock, will develop a shallow, narrow trench in the center of the trail. This is a routine development on trails in forested areas with a soft, loose, sandy, or mineral soil tread. Along with the trench, the trail will develop an outside berm of displaced soil. This berm can grow to be to six inches high or more if the trail is not maintained. This berm has the potential to alter the natural drainage and runoff patterns across and off the trail and lead to severe erosion.

The solution is simple. Periodically the berm must be removed and shoveled back into the center of the trail. This, on some high use trails, needs to be done annually as a part of routine trail opening and tread maintenance. On other trails, berm removal is part of maintenance as needed, usually in conjunction with "digging drains."

If the berm is large and enough material is available, "crown" the material in the center of the trail to allow for compaction. Fill the trail so that it has a gentle outward slope to facilitate drainage off-trail at any point along its edge.

Berm Removal



Trail Opening

Trail opening occurs as soon as weather and runoff conditions permit. Logistical access to more remote areas may have to wait until closer-in areas have been opened, but generally trail opening begins as soon as feasible. In general, lower elevation trails are opened earliest, followed by higher elevation trails as the snow begins to clear. In addition to drainage maintenance, trail opening consists of several activities:

Trail Clearing - Rocks greater than three inches in diameter, limbs, small trees, and minor slides in the trail tread will be removed as the trail is opened. Much of this material can be removed as the crew hikes down the trail by safely throwing, kicking, or moving with a shovel any undesirable object. This should be done at all times when hiking the trail. Take care not to plug any drainages, on or off-trail, and not to shower debris onto a trail below.

Logging All trails in the trail system are logged annually as the trails are opened. Logging may be done by a trail leader or maintenance person with a packer for support. Logging crews may carry two chainsaws, one with a large bar 32 inches or more in length, along with a saw kit, fuel, oil, and other tools.

All trees which interfere with the trail corridor should be considered for logging. Initial trail opening is primarily concerned with down trees across the trail corridor, but leaning trees (or leaners) and projecting limbs which interfere with the safe passage of stock and rider should be cut if time permits. If a leaner or tree will interfere with the trail corridor within the next 10 years, cut it when you have the opportunity. Don't pass it by because it is unknown when a crew able to cut it will be back in the same area.

The minimum trail width for cutting down trees from the trail corridor is allow enough space for the most heavily ladened large pack animal to pass easily and safely through; the wider the better. Whenever possible, cut logs as wide as the location permits, up to five feet on each side of the trail centerline, even if an additional cut or two is required.

Cut-rounds from logs are rolled off the trail on the down-hill side. If necessary, roll the logs down the trail to an appropriate point to put them over the bank. *Never* put cut logs (or any debris) in the off-trail drainage. Special attention must be taken to recognize off-trail drainage and no logs should ever be allowed to roll into or otherwise block a drainage. Portions of trees remaining on the up-trail side of the corridor must be cut back sufficiently clear of the trail and should be securely bedded to prevent movement.

Whenever possible, cut-ends of logs or stumps which are visible in the trail corridor should be buried, rubbed with soil, or otherwise "weathered" to minimize the visual disturbance caused by the chain saw cut. Flush all stumps to ground level by digging out around the stump, cutting it flush, then burying it with soil and debris.

Brushing

Brushing refers to the removal of limbs, bushes, and small trees, living or dead, from the trail corridor. The trail corridor is 4 to 6 feet from the center line of the trail and approximately 10 feet high. Large trees, boulders, etc., within this corridor are obvious exceptions and will remain. The critical dimension is the safe and unhindered passage of hikers and stock, both fully packed and with a rider. Brushing can be one of the most satisfying of all trail jobs because the results are swift as a brush choked trail is "transformed" to a safe and easily traveled route. When you are brushing or limbing, ask the critical question, "Is this small tree or limb going to be a problem 10 years from now?" If it is, cut it now while you have the opportunity. If in doubt, generally it needs to be cut. Avoid unsightly stumps or other scars on the landscape.

Basic brushing tools are steel handled loppers, a pole saw, bowsaw, or folding packsaw, and a small chainsaw if needed. When a crew is available, run a chain saw crew ahead, followed by a lopper and pole saw crew. The lopper crew stashes all cuttings off the trail and the pole saw crew follows, stashing their own.

Limbing - When removing limbs from a tree, cut the limbs off flush with the tree trunk whenever possible. This promotes the good health of the tree. Unsightly cut-off branches (or staubs) may be a route for disease to enter the tree. Take the extra time and effort to get your loppers or pole saw close to the tree before cutting. When cutting with a saw, make a shallow undercut first, then follow with the top cut. This allows for a clean cut and prevents the limb from peeling bark off the tree as it falls. If a limb is too high or too large to cut at its base, try to cut it at a "fork" of the branch as close as possible to the trunk.

Lopping limbs from horseback is discouraged because it is difficult to get close to the tree and do a good job. But in many

cases it is the only way that the job will get done and can be considered as a first time through, preceding a regular brushing crew.

Stashing of Cuttings - With brushing, like any other trail work, there are aesthetic considerations. The trail must be more than safely passable, it must also look good. Whenever possible, branches, limbs, and especially small trees, should be stashed out-of-sight of the hiker or rider on the trail. Often a small clearing behind a tree or shrub will suffice to stash several armloads of cut limbs. Young trees that have been cut should be dragged into the surrounding forest and/or hidden behind rock outcroppings, out-of-sight from the trail. Take special care that the cut, butt-end of a tree is not visible from the trail.

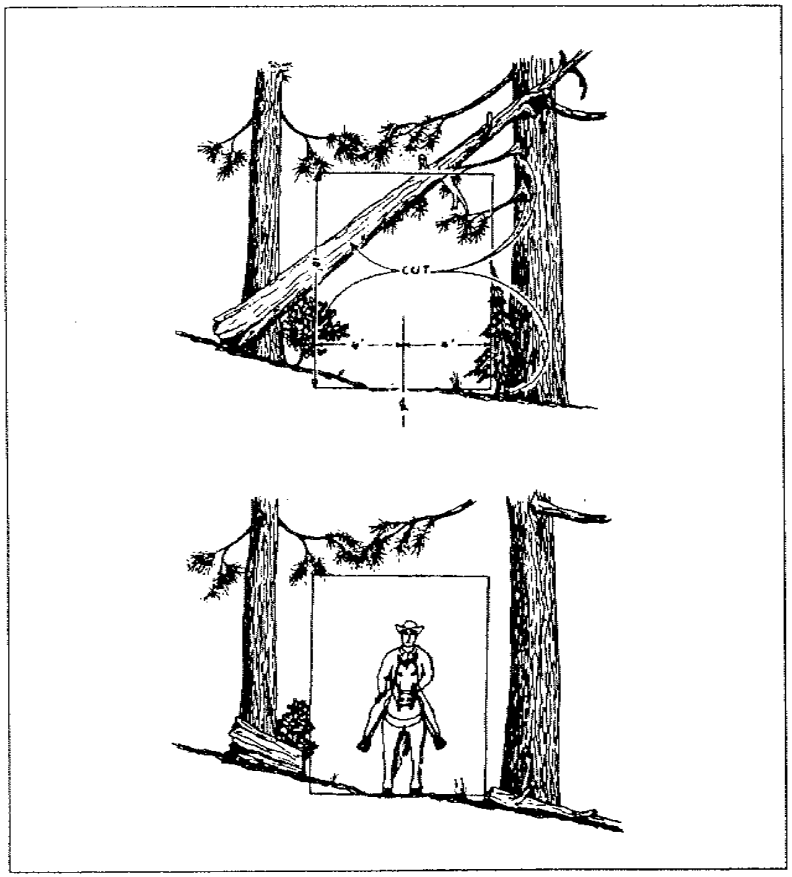
Young Tree Removal - In many forested areas, young trees up to 4 feet tall become very thick along the sides of the trail and begin to invade the trail corridor. While small, these trees are easily thinned with loppers or a small chain saw. It is best to get them early, thereby preserving the integrity of the trail corridor. All stumps should be flushed and buried, and larger stumps or limb scars should be rubbed with soil and/or forest debris to minimize the fresh appearance of the new cut.

Before cutting many limbs off a small tree next to the trail, consider removal of the entire tree if a chain saw or axe is available. The small tree will not be missed, as opposed to the denuded half of a tree which is unnatural and unsightly in appearance, and is unhealthy for the tree.

Leaners - When clearing the trail corridor with chain saw or axe, be sure and take a step back and view the corridor from a distance. You will notice trees both large and small leaning toward the corridor. These "leaners", if they are not already interfering with the safe passage of stock and rider, may be on their way toward interfering with the trail corridor and may soon present a hazard.

Leaners which encroach on the trail corridor and show evidence of impending failure should be cut whenever possible. Considering that a crew may not get into a given area frequently, especially with a chain saw or axe in hand, inspect any leaner in question to determine its condition and remove it if it poses a threat. It is all part of doing a thorough job of brushing and clearing the trail corridor.

The Brushed Trail Corridor



Cut the leaners flush with ground level and bury the stump. It may be easier and safer to make two cuts, the first at a comfortable height several feet above the ground which will serve to fall a majority of the leaner's weight, and the second cut at ground level to flush the stump. Drag the cut trees into the forest so that they are not visible from the trail and turn the freshly cut ends of the logs away from the trail.

Signs

The *Backcountry Management Plan* outlines a general policy for a sign system in the backcountry. In general, mileage signs are located at all major trail junctions and trailheads. Regulatory signs are located as required, mainly at park entrances and trailheads. It is the responsibility of both backcountry maintenance crews and backcountry rangers to maintain the sign system.

Trail leaders and rangers should report any down, inappropriate, or dilapidated signs to their supervisors. In most cases, old wooden signs are being replaced as they deteriorate by routed grey aluminum signs. Whenever a sign can be re-erected or a post replaced to put the sign back in use, it should be done. There are too many signs that are left leaning against trees, lacking a post or someone to install them. Signs should be placed so that they are visible to the trail user, but not so close as to interfere with the safe passage of packed livestock.

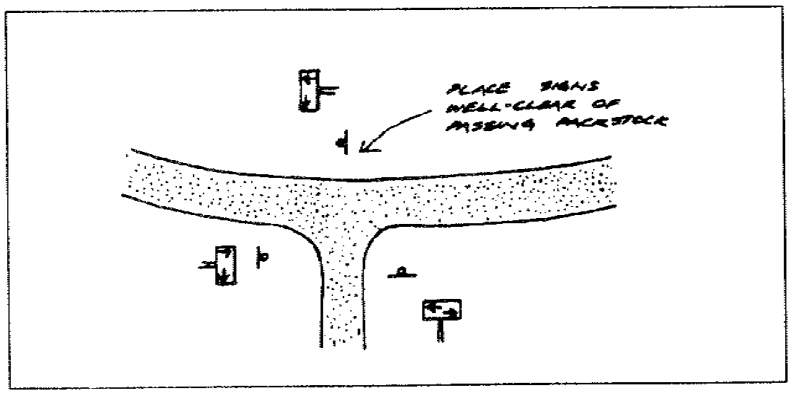
To install a sign post, whether it be wooden or metal, first make sure your post is long enough to be anchored deeply and solidly into the ground; a minimum of 20 inches, if possible. New backcountry signs have short posts of less than 5 feet and are meant to be set 2 to 3 feet above ground level. Select a spot near the junction or trailhead on the right side of the trail facing the sign. Select the spot with easy digging in mind, away from bedrock and trees with large roots, and in soil with as few rocks as possible. Dig a shovel width or better diameter hole on that spot about 20 to 24 inches deep using a rock bar to dislodge any

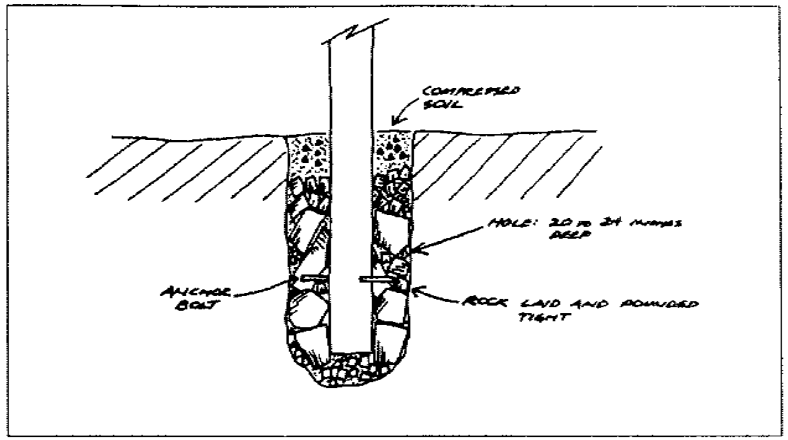
rocks that can be removed. Sometimes this may take awhile, but be persistent, a well secured sign will stand for a long time while a weakly anchored one will soon be pushed over by the heavy backpacks that are leaned against it.

Square metal posts come with holes drilled through the post about a foot up from the bottom in which a large bolt is inserted. Do not remove this bolt, it is a very effective anchor for the sign post and will help to make the post very difficult to pull out of the hole. On a wooden post, 6 to 8 inch spikes or even 16 penny nails can be driven into the post to have a similar anchoring effect.

Drop the post into the hole and hold it vertical while you drop a few rocks into the hole to initially secure it. Tamp these rocks with a rock bar, a tamping bar, or shovel handle to jam them into place. Do not fill the hole with soil or merely kick a rock into the hole, but carefully fit and place the rocks in the hole, always tamping as you go. Avoid too much soil because disturbed soil cannot be made as solid as rocks. Tamp, pound, and crush the rocks around the post until the hole is nearly full, then top it off with soil, tamp or step on it, and the post should be solidly in place.

Signs





ROCKWORK RECONSTRUCTION STANDARDS

This section of the *Trail Handbook* describes the standards for rockwork reconstruction. The section begins with a presentation of the terms used in the various trail reconstruction tasks, and follows with an introduction to the principles of drywall rockwork and a discussion of how to construct the most common type of rock structures to standard.

Rockwork Terms

Common terms used in Sierra rockwork:

Drywall Rockwork - Rock laid without the use of wet mortar is called drywall. This method of laying rock uses the weight and shape of the rock combined with the skill and technique with which they are laid to give the structure strength, longevity, beauty, and overall integrity.

Structure - A structure is any constructed feature in the trail corridor. Waterbars, walls, causeways, riprap, etc. are structures.

Waterbars and Waterbreaks - Waterbars or waterbreaks are rock or wooden structures laid across the trail tread at an angle which turns water running down the trail off the trail to the downhill side. Waterbars are one of the basic elements of a trail drainage system.

Retainer Bars - Retainer bars are rock or wooden structures laid perpendicular to, or across, the trail tread. Retainer bars hold, or retain, the fill in the trail tread. An evenly graded trail may be a series of near equally spaced retainer bar steps, each holding a terrace of tread material, or fill.

Riprap - In trailwork, riprap refers to carefully laid, interlocking rocks in the trail tread, usually used to climb steep grades or to provide a solid trail tread in wet areas where drainage is a problem. Riprap, laid in an eroded gully, for example, resembles tiers of climbing rock steps.

Causeway - A causeway is an elevated section of trail which is laid over a wet or eroded section, usually having rock or log outer walls (see Turnpike) holding crushed rock fill and covered with soil or other tread material.

Terrace - A terrace is a flat near-level area where the trail from above meets the trail from below, as in a switchback corner (or landing), or the near-level area behind a retainer bar on a climbing or graded piece of trail.

Wall Rock - Wall rocks are usually large rocks (one cubic foot or more) which are selected because their shape is good for building wall or other rock projects. The ideal wall rock is a nearly cube-like shape, which allows for good contact on 3 or 4 sides with the rock surrounding it, can be easily laid with its weight back into the project, etc.

Shapes - Rocks can be found in all sizes and many shapes. Shapes is a term in rockwork which refers to rocks with specific characteristics best suited to the particular rock structure being constructed or problem being solved; as in "get good shapes," or "Find a shape which..." etc.

Faces - Faces are the surfaces of a rock which are identified when planning how to lay the rock, such as outside face, inside face, right or left face.

Keystone - A keystone is the rock which anchors a project and gives the project its strength - the "key" rock. Keystones are usually large, very well anchored, and provide an ideal surface

to construct the rest of the project. They are always at the lowest point of the project or project section.

Header - A header is generally a wall rock which is laid with its weight well back into the wall, to the point where a long rectangular rock is laid with its greatest dimension back into, or perpendicular to the face of, the wall. The typical header rock is said to have "good depth." The use of headers gives the wall greater strength and stability.

Contact - In a structure, the points of rock which touch are said to make contact. When one point of a rock touches another, it is said to have single contact; two points, double contact; etc. "Make good contact" is one of the three basics tenets of dry wall rock work.

Joints - A joint is the area at which one rock meets another, specifically, the space between them. The basic tenet of rock work, "Break your joints" refers to the rocks on one tier of wall straddling, or breaking, the joints of the rocks below.

Tiers - Tiers refers to the rows or levels of rock laid in a wall or riprap, for example, bottom tier, or second tier, etc.

Chink Rock - Chink rocks are small rocks which are hammered into the joints between laid rocks in any rock structure after the rocks have been laid. Chink rocks are also used to prop a rock up when adjusting its final position. Chink rocks tighten up and solidify a rock structure and usually "chinking" is the final construction step. If chinking is done before an entire tier is laid, it may drive the rocks apart and contact will be lost. Care must be taken to avoid this and projects must not be chinked too early in the construction process.

Stuffing - Similar to chinking, stuffing refers to solidly filling any void in or around a rock structure. Inside joints of a wall are stuffed with small rocks to strengthen and solidify the wall and hold in fill. This is called stuffing because frequently

it is hard to hammer the rock into the cracks due to the tightness of the situation, and it must be stuffed by hand and pounded tight with a rock bar. In riprap, stuffing refers to packing the spaces between riprap rocks with small rock and fill material.

Fill or Fill Rock - Small rock or crushed rock is used to fill in the trail tread, to fill behind rock walls, or to be stuffed beneath individual rocks to adjust height, angle, contact, etc. Crushed fill is the main component of a trail tread which theoretically allows water to move through it and through the trail, such as in a causeway.

Junk Wall - In some non-critical situations, a fast single tier or multi-tier wall is "thrown" together rapidly without the ordinary care for broken joints, good contact, etc, called junk wall. This is only done when it is *not* necessary to have a wall with the full strength and structural integrity of a normal wall.

Inside Wall - Wall laid on the *uphill* side of the trail, i.e. the inside of the trail.

Outside Wall - Wall laid on the *downhill* side of the trail, i.e. the outside of the trail.

Tray - A tray is a small section of laid rock, similar to riprap, which is placed immediately uphill from a waterbar, in most cases, to serve two functions: first to support and strengthen the waterbar and secondly to allow for the smooth and swift passage of water off of the trail.

Trail Grade - In common usage and used throughout this Handbook is a method of referring to trail grade as a percent. Trail grade is based on a triangle. The rise or grade of the trail corresponds to the vertical rise of the triangle over a linear distance. In most cases, the dimension used for this reference is feet, but any unit of dimension may be used as long as both base

and rise are measured using the same unit of dimension.

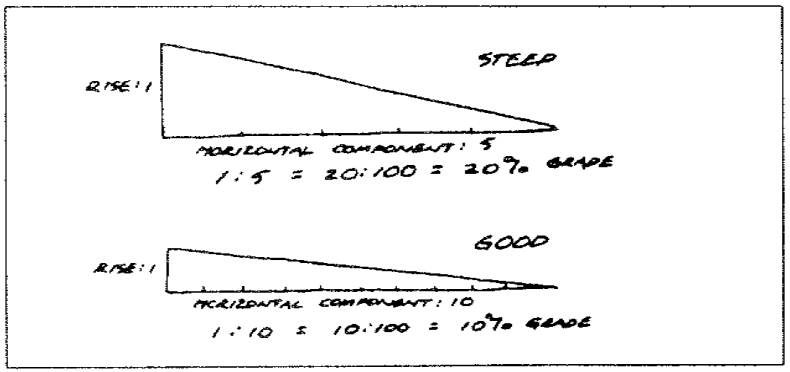
A percent represents a certain portion of 100. For example, a 10% trail grade refers to a 10 foot vertical rise over 100 feet of horizontal trail; a 25% grade means 25 feet over 100, etc. For trail purposes, rarely do we find 100 feet of consistent grade, therefore it may be more useful to reduce the base unit to 10 feet. The 10% grade then indicates a 1 foot rise over 10 horizontal feet of trail. This can be more easily estimated on the ground.

Soil and slope stability are the primary factors in determining the limits of a trail's grade. In stable soils and slopes, a 10% grade is considered comfortable for hiking over a long haul. A grade in excess of about 20% is considered steep and is tough on the backpack laden hiker. Occasional steep sections are found on any trail, but a key to good trail design is to minimize the number of these sections and to keep them short.

Drywall Rockwork

Rock is the material of choice to solve most problems encountered on the trail. The longevity of a drywall rockwork

Grade



solution properly constructed according to basic principles is unequaled. High quality drywall is aesthetically pleasing and will withstand the rigors of many a high Sierra winter, as well as heavy use by Pacific Crest Trail hikers, stock, and Mt. Whitney climbers. Drywall rockwork, that is, rock laid without the use of wet mortar, takes time. It is labor intensive, but with practice and experience a trailworker's skill will improve, and better quality rockwork solutions to trail problems can be expected in less time.

Aesthetics are an important consideration in rockwork, however it will be argued that strength is what is important, not aesthetics. The two are inseparable: as rockwork techniques are mastered, a strong solution to a trail problem will equal an aesthetic solution. Examples of this are presented throughout the following discussion of rockwork methods. For example, outside faces that are leaning back without overhang are strongest, and strong appearing, as well as being pleasing to the eye. Tight joints with good contact are also strongest, strong appearing, and aesthetic.

Rockwork Steps - Drywall rockwork consists of a series of logical steps which lead to a strong, aesthetic, and appropriate final product. The omission or shortcutting of any of the steps may impair the integrity of the entire project. The most important steps in any rockwork project are:

Think the project through and get a good mental image of the final desired result.

Get a good selection of rocks at the jobsite.

Move rocks safely, and don't gather more than you can safely work with and around.

Dig a good footing for your foundation tier of rock.

Begin laying rock at the lowest point of the project.

Lay a solid foundation tier, digging out carefully for each rock.

Break all joints and make good contact underneath and to the sides.

Pay attention to faces and lay the weight of the rock back into the project. Use headers.

Stuff inside and around each tier as it is completed and fill solidly behind each tier before beginning the next.

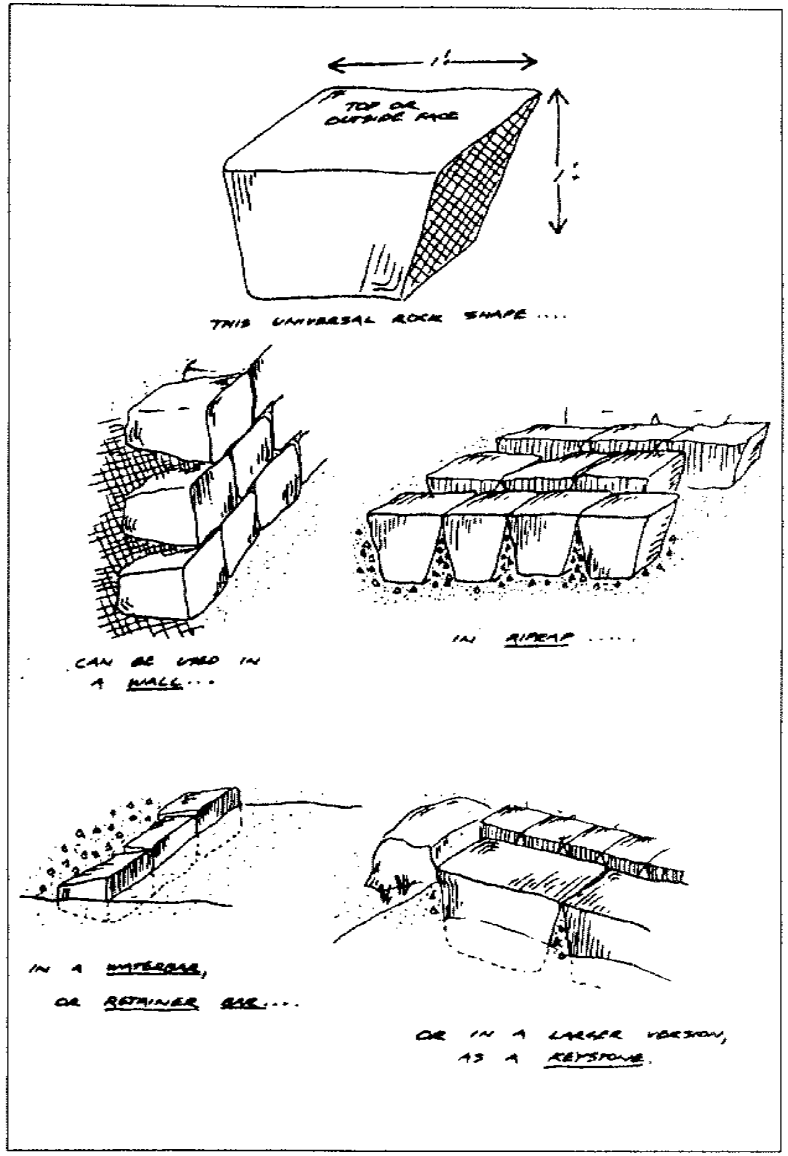
Chink the outside joints to tighten the rocks against each other.

Rehabilitate the work area, including quarry sites, and revegetate where possible.

Application of basic drywall rockwork methods will assure strength and longevity in rockwork solutions. These are discussed in the following sections and apply equally to both new construction and repair or reconstruction of existing projects.

Project Planning First, think the project through, taking into account natural features of the landscape which may help or hinder the project. Survey the site and material available. Rocks and bedrock already in place make excellent anchors or keystones, while others may inhibit grade or safe footing and will have to be removed. If the final project solution can be pictured in the trailworker's mind or even roughly sketched, the solution will be arrived at more easily. There are always unforeseen obstacles and unpredictable rock shapes that may alter the final vision, but this is part of the excitement and challenge of a rockwork solution. No two trail problems are exactly alike, just as no two solutions are the same. We are dealing with a dynamic, evolving environment and an infinite variety of material shapes with which to solve a

An Ideal Rock Shape



problem. The challenge is to use available materials, tools, and traditional skills to solve a trailwork problem with a strong, aesthetic solution constructed in a reasonable length of time.

Rock Selection - Estimate the number of rocks needed and look for rocks uphill of the jobsite. Get a good rock selection, but don't get more than the site can safely handle or you can safely work around at the project site. If the project is large and the number of rocks needed is so many that they will unsafely jam up the work area and block the trail to hikers and stock, then get rocks more than once. A rock stockpile which is crowded with one rock on top of another is nothing more than potential smashed fingers and toes, dangerous to work with, and ultimately will slow up production. Gather only the number of rocks that your stockpile area will comfortably hold, yet still provide an adequate selection.

Look for rocks of reasonable size with a good shape. A rock so large that it is almost impossible to move, even with 2 or 3 persons and bars and rollers and other tricks, will not be worth the time and energy required. The same result can be achieved with 2 or more smaller rocks, carefully selected and well placed. Use as big a rock as can be moved into place and laid according to sound dry-wall principles, but don't sacrifice the ability to lay the rock to size alone. The size of the rock, especially foundation rock, does contribute to the overall strength of a project, but it can be more than made up for by skillful placement of smaller rocks. The best shaped rocks are those with at least one or more good planar surface, one of which can be used as an outside face, and a shape that can be laid with the weight of the rock set slightly back into the wall. An ideal, universal rock shape would be something like shown in the illustration.

Always rehabilitate all holes and scars made in removing and moving rock to the site. Fill the holes with sand, soil, or decaying wood discretely removed from an adjacent area and replant any sod removed, if possible.

Moving Rocks - Rocks are moved only one way: safely. It is important to be careful when lifting or rolling heavy objects. Use the thighs and bend the knees. Never use the lower back to

lift or push. In the backcountry, rocks are moved using solely manual labor. Rocks are dislodged using shovel and bar, and moved either by rolling and flopping the large ones or carrying them upright. A rock is never moved downhill by "letting loose." Get off to one side of the lower edges of a downhill bound rock and slowly "shimmy" it down using gloves, a rock bar, and brawn to hold it back and keep it under control. When bringing a rock down, never permit anyone to be below in the potential path of the rock. Always know where your other crewmembers are and be aware of switchbacks below and close the trail using trailguards if necessary.

The Footing - Take the time to dig a good, solid footing. Often this step may take as much time as laying the rock, but it is well worth it. A good footing is the key to a strong, long-lasting solution and along with actually laying the foundation tier of rock may be the most difficult work of the entire project. The footing should be dug down to the point where a platform has been made upon which the large foundation rocks can be laid without any overhang and leaned back solidly into the slope of the project site.

Laying Rock - Begin laying rock at the lowest point of the project. Whether it be waterbar or wall, use gravity to assist you in laying a good, solid structure. By beginning at the lowest point, the rocks will "fall" into place more easily and a difficult "balancing act" can be avoided when attempting to insert one rock downhill from another. Joints will be tighter and contact will be better if you have gravity on your side.

Move the rocks slowly and carefully. Think ahead to save yourself work. Think about how your rock should roll into the hole, ask yourself; "Which side up? Which face out?" Dig out to depth carefully, using your shovel handle to measure depth in relation to the rock faces, and roll the rock into the hole once, slowly, taking time to be certain it falls into place as planned. Chink and stuff beneath the rock solidly with small rock fill.

There is nothing more difficult in rockwork than rolling a rock perfectly into a hole, except having to take it out again. If you originally find a rock uphill from your worksite, nature has provided most of the energy needed to move the rock downhill to your project - use and control it carefully.

Select a rock to be laid by searching the rock selection for the shape required. Visualize the shape by measuring the space where the rock will be laid and thinking about the contact points and faces needed. Granite rock can be broken into precise shapes for drywall using basic rockwork tools. Granite develops a "memory" when struck repeatedly along a desired break line. No need to strike hard, repeated light stikes along the line with a singlejack will implant a "memory" into the rock. Finally strike the line forcefully with the straight peen of a doublejack and the rock will crack along the line. Always wear safety glasses when working around rock, especially when any tool, such as a bar or hammer, is striking a rock.

Lay the rocks in tiers of roughly equal height. This makes for fewer problems in laying the next tier. Think ahead, don't lay yourself into a "corner" by creating a situation in which it will be difficult to break joints or make good contact with the next tier. This will save time and lead to a more professional result.

The three basic principles in laying drywall rock are:

- Make good contact.
- Break your joints.
- Pay attention to faces and set the rock's weight back into the project.

Adherence to these basic principles are the key to a strong and aesthetic rockwork solution.

Make good contact with all adjacent rocks below and to the side. Single point contact is adequate, double point contact is better. Trim the rock, if practical, using the peen end of the

single jack to make double contact. "Slam" the rocks together using a rockbar to a get a good, tight, fit.

Break the joints of the rocks below by laying the rocks as you would bricks. Plan ahead on each tier so that each rock is allowed adequate space to strongly break the joint of the rocks below. Again, don't lay yourself into a difficult situation.

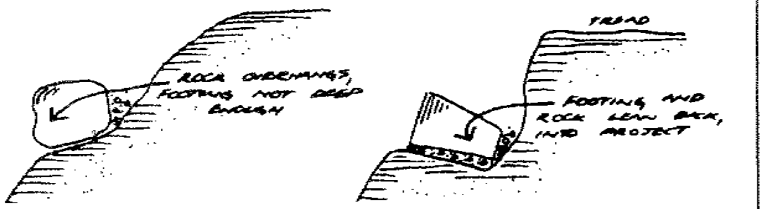
Pay attention to the rock's faces. Lay the rock so that the outer face is not overhanging, but rather is leaned back into the project. You should never be able to push or stand on the forward top portion of a laid rock and cause it to roll forward and out of position. It should be laid so that the weight is transferred down through the rock into the project. On rounded rocks, use an "average" of the rounded portion as your face. See illustration.

Once the rocks are laid in position, stuff small rock and fill inside and around each rock in the tier to strengthen its placement and secure it in position. Be sure that no voids remain for the rock and fill to shift into. Your objective is to make the tier of laid rocks into one solid mass of rock and fill. After the rocks are stuffed and chinked on the inside, backfill behind the tier to achieve a solid, level footing for the next tier. Keep in mind when filling, however, that good rock to rock contact must be made between the upper and lower tiers. Don't overfill.

The final step in drywall rock construction is to chink the outside of your structure. Drive small chink rocks into all voids, joints, or cracks between the laid rocks. Take time to chink well and the entire structure will be solid, tight, and will last many years.

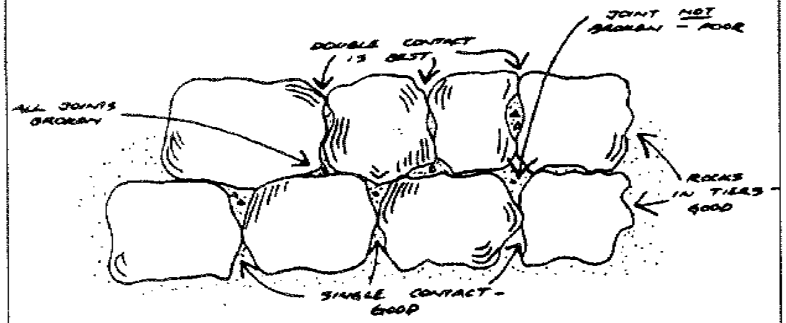
Site Rehabilitation - Once the construction phase of the project is completed, a thorough clean-up of the work site is required, including any area from which rocks were taken. Rehabilitate any scars remaining from the construction activities by filling holes with soil, replanting sod, raking the area, and spreading needles as appropriate. Restore the area to as natural an appearance as possible.

Drywall Fundamentals



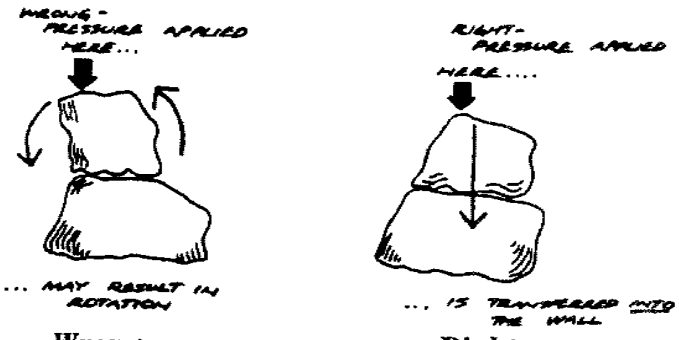
Wrong ***Right***

Dig a good, solid footing, and lean the rock back, into the project



Make good contact and break all joints

Laying Rock



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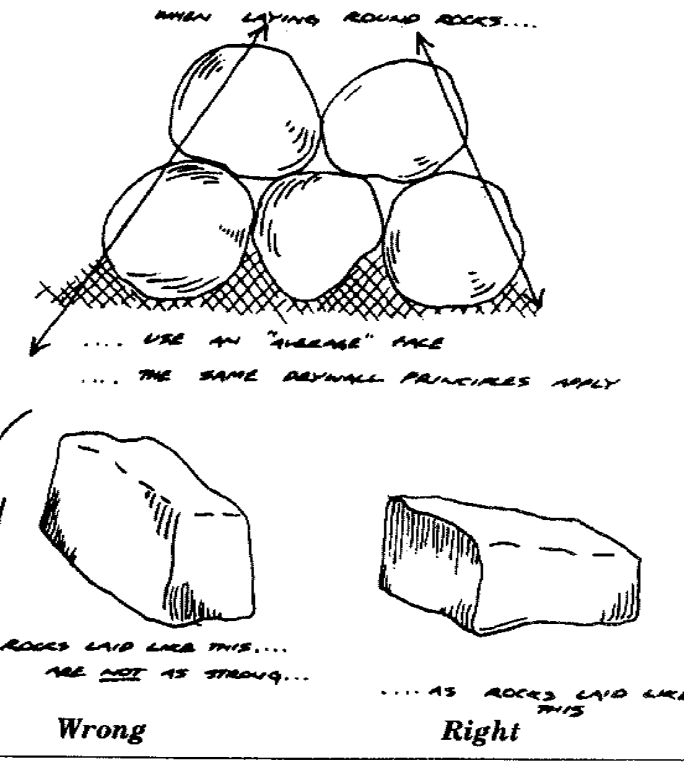


Wrong ***Right***

Borrow Pits and Quarries

In trail reconstruction projects, it may be necessary to establish borrow pits or quarries to obtain needed material. For example, to re-establish trail tread, material from an off-trail area may be moved to the existing eroded trail or causeway. Selecting the sources of materials and the location of borrow pits or quarries is done with careful consideration of many factors by the crew and project leader.

First, be certain the existing trail or causeway section is ready for tread material. Retainer bars or checks need to be constructed to hold the fill or soil in place, and the section must be protected by a functioning drainage system.

A borrow pit should be as close to the work site as possible, constrained by the following considerations: Will the site be seen from the trail or camp areas? Will it be seen at a distance from above? Can it be easily naturalized? Will a trail be developed to and from the site that cannot be easily rehabilitated and that may become an unsightly "detour?"

Attempt to locate the borrow pit in an area that has the potential for natural replenishment. Sand and gravel can be gotten from both large and small drainages which are replenished by storms and seasonal water flow. Other sources may be at the base of bedrock domes or cliffs where heavy runoff occurs to deposit sand and gravel.

When soil is needed for trail tread material and stock is available to transport it, one large deep pit is more advantageous than many small or shallow ones. Deep mineral soil is best for a "dirt pit" and for tread material. Look for an area away from trees and roots with good access and exit for stock.

Save all plugs of grass removed when digging the pit for replanting. Keep them in the shade and try to keep them moist by covering them with wet burlap, dampened daily.

All pits, whether from the removal of one rock or tons of soil, must be rehabilitated by minimizing the visual impact of the pit. Fill in all pits as much as possible with rock, down trees, and soil

from collapsing the sides of the pit. Minimize the depression formed by a large pit and resod with the grass that was removed and saved. Finally, naturalize the area and adjacent trails with boulders and deadwood.

Consider your quarry site or rock source carefully. For big projects consider quarrying the rock from one large source, especially if a rock drill is available. Getting rock from one large boulder will have far less impact than leaving many smaller source scars. Plan to use the entire source rock. Do not leave a partially quarried rock, especially one that is visible from the trail. Plan to use it all or don't begin to cut it.

To break the drilled source rock use plugs and feathers or, rarely, explosives. Strike the plugs evenly with a singlejack and be sure to use all appropriate safety equipment, especially eye protection.

Stoneboats are a good method of moving quarried rock to the project site, depending on the availability of stock and harness. When quarrying the rock form one source, a regular stone boat route can be established with care taken to minimize impact and not over-use the route.

Drill Marks - Rock drills are used on larger construction or trail opening projects to quarry rock, install pins, and for blasting. When a rock is quarried and split with plugs and feathers, each part of the divided rock will retain a share of the drill hole. These marks should be camouflaged or disguised as much as possible in backcountry projects.

As a general policy, do not lay rocks with the drill marks visible from the trail. Attempt to lay the faces of the rocks with drill marks down to minimize the aesthetic intrusion of drill marks upon the backcountry landscape. This, of course, limits the options for which a quarried or scarred rock may be used, but it is part of the challenge of drywall rockwork and adds to the professional quality of any project.

Occasionally, it may be necessary to violate this policy and lay a rock in a situation where its drill marks are visible, but this

is only a final recourse. In this situation, use a singlejack to break off the edges of the drill holes and obliterate the marks as much as possible.

Rockwork Standards

Waterbars - A waterbar turns and directs water to the downhill side of the trail. Waterbars are made of rock or wood, with rock preferable because of greater longevity and strength.

The angle of a waterbar across the trail depends on the gradient of the trail, the amount of water expected or drainage area of the waterbar, and the off-trail terrain. Typically the angle is 15 to 40 degrees from a perpendicular line across the trail. Waterbars at less than 15 degrees may dam up and require frequent maintenance, and waterbars of more than 40 degrees may promote erosion and undercut the waterbar rocks or log. The ideal drainage works somewhere in between, at a point where the flow of the water off the trail keeps the waterbar clear of sand, soil, and debris. This self-maintaining type of waterbar is the objective for any waterbar construction, but may not always be possible.

An approximate rule-of-thumb to determine the angle of a waterbar across the trail is to begin with 15 degrees and add a degree for each percent of grade of the trail section. In other words, a trail of 15% grade would require a waterbar at an angle of approximately 30 degrees.

Waterbar Placement - Look at the natural drainage of the area; if the water now crosses the trail naturally, the waterbar will reinforce this pattern, but if the trail has altered the natural drainage pattern of the area and the water runs down the trail, determine the natural, most direct, drainage pattern and build the waterbar to enforce that pattern. Try to observe the trail with water on it during spring runoff or during a cloudburst and the drainage requirements of the trail will be more evident.

To determine the final location of a waterbar, look for

natural anchor points, especially large rocks embedded alongside the trail. These make excellent keystones for waterbars. Trees may occasionally be used when well located. Final placement of waterbars should be done in consultation with your trail leader.

Waterbar Construction - Once the site of the waterbar has been determined, dig out a trench in which the rocks will be laid. Dig the trench deep enough and large enough for the rocks to be laid strong and low. After getting sufficient materials (either rocks or a log), measure the depth required for the waterbar using your shovel handle or other tool.

A waterbar should be constructed to a minimum height across the trail tread which will accommodate the amount of water it will receive in a cloudburst-type storm, yet not high enough to interfere with the ease of travel by hikers and stock. Usually a waterbar can be lower than you are inclined to make it. The best waterbars are subtle, low structures, barely noticeable as the hiker steps over them.

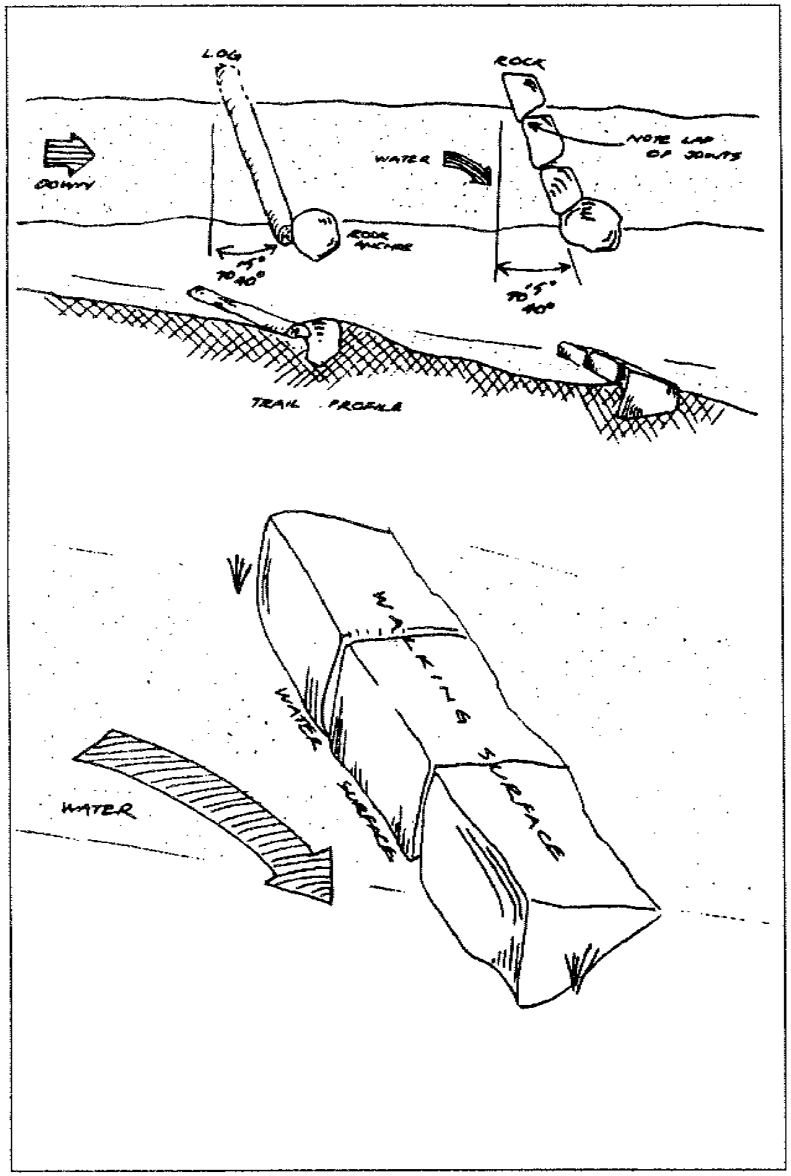
Begin laying the waterbar from the downhill or outside edge of the trail. Make sure that the waterbar begins far enough off the trail to sufficiently cross the trail tread area, and preclude the trail "naturally" moving over with use to below the waterbar (with the drainage following). Build the waterbar low and long.

In laying each rock in the waterbar, think about a good water surface and a good top or walking surface. The water surface is the line of rock faces down which the water passes. The walking surface is the top of the waterbar upon which both hikers and stock may step. Select your shapes with the angle between these two surfaces in mind.

Lay the rocks with as high contact between rocks as possible. The lower portion of the rocks will be buried by the waterbar tray and can be chinked tight so that low contact is not as important as good high contact.

Take care that the points of contact overlap with the flow of water, rather than provide an entry for the water to erode

Waterbars



between the rocks. Lay the rocks in their most stable position with the main portion of the weight down and in the trench. It is better to lay a rock with the weight low rather than upright where it may be kicked out.

Stuff and fill behind the waterbar and chink it tight. Lay a rock tray if required in front of the waterbar to provide a non-eroding surface over which the water will pass. The final construction step is to clean up the work site and bury the waterbar on the downtrail side and dig out in front as if maintaining the trail.

Backed Waterbars - On steeper trail sections of more than 10% grade, heavily used trails, or trail sections that take a heavy amount of runoff, it may be advantageous to construct a "backed" waterbar. A backed waterbar is essentially a retainer bar which is installed across, or perpendicular, to the trail, several feet below, or down trail, from the waterbar. Between the waterbar and the backing retainer bar are crushed rock, fill, and trail tread material to the level of both waterbar and backing retainer.

Backing a waterbar provides a more solid "dam" to effectively turn water off the trail and it minimizes the "hurdle" or large step-over that a waterbar on a high-use trail can become. Be cautious to minimize the height of the step-up of the backed waterbar; a large step-up is not necessary. A comfortable step-up similar to a retainer bar of 4 to 6 inches or less is all that is needed. Crown the trail tread material to allow for compaction by weather and use.

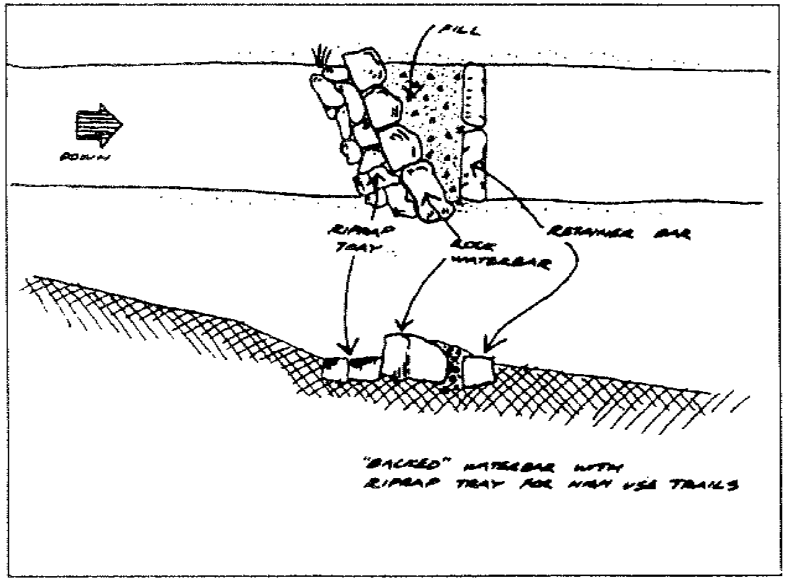
Retainer Bars - Retainer bars are laid across the trail, especially in a rutted section, and are used to hold trail tread material in place. Retainer bars sometimes appear similar to steps. A retainer bar is expected to hold dirt and fill material in place in the trail, usually restoring the trail tread to its pre-erosion level.

Retainer bars are of wood or rock. Peeled log retainer bars are fast and effective, but do not provide the project life that rock does. For permanence and longevity, which is especially important when revegetation is anticipated along the trail and around the retainer bar, rock is best.

For rock retainer bars, look for keystone-like rock shapes. These are ideally large, long rectangles with a flat top or walking surface which also present a good non-overhanging face down-trail. One or more of these retainer bar rocks are laid across the trail in a manner similar to waterbars and are dug well into the banks.

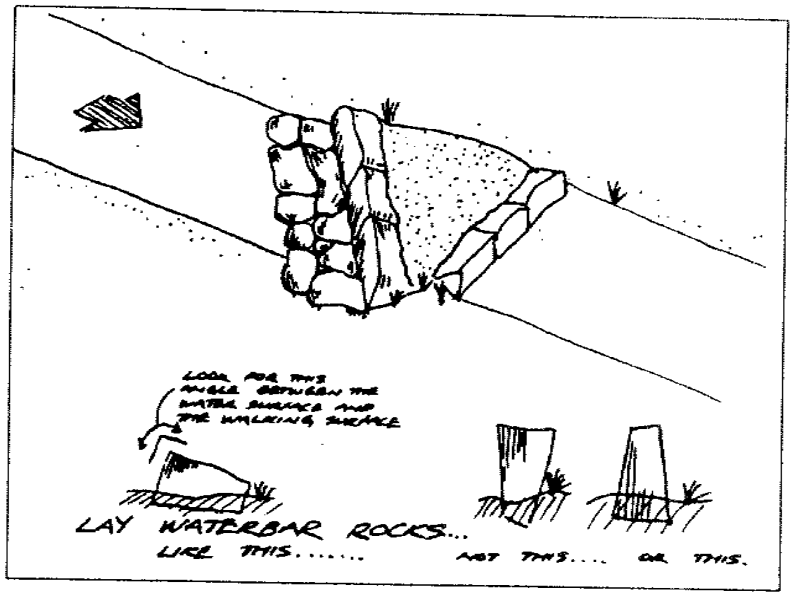
The height of retainer bars is determined by the required trail tread level. When a series of retainer bars is going to be installed over a section of graded trail, it is useful to use a string to establish a steady gradient by stretching the string from the first to the last

Backed Waterbar With Riprap Tray

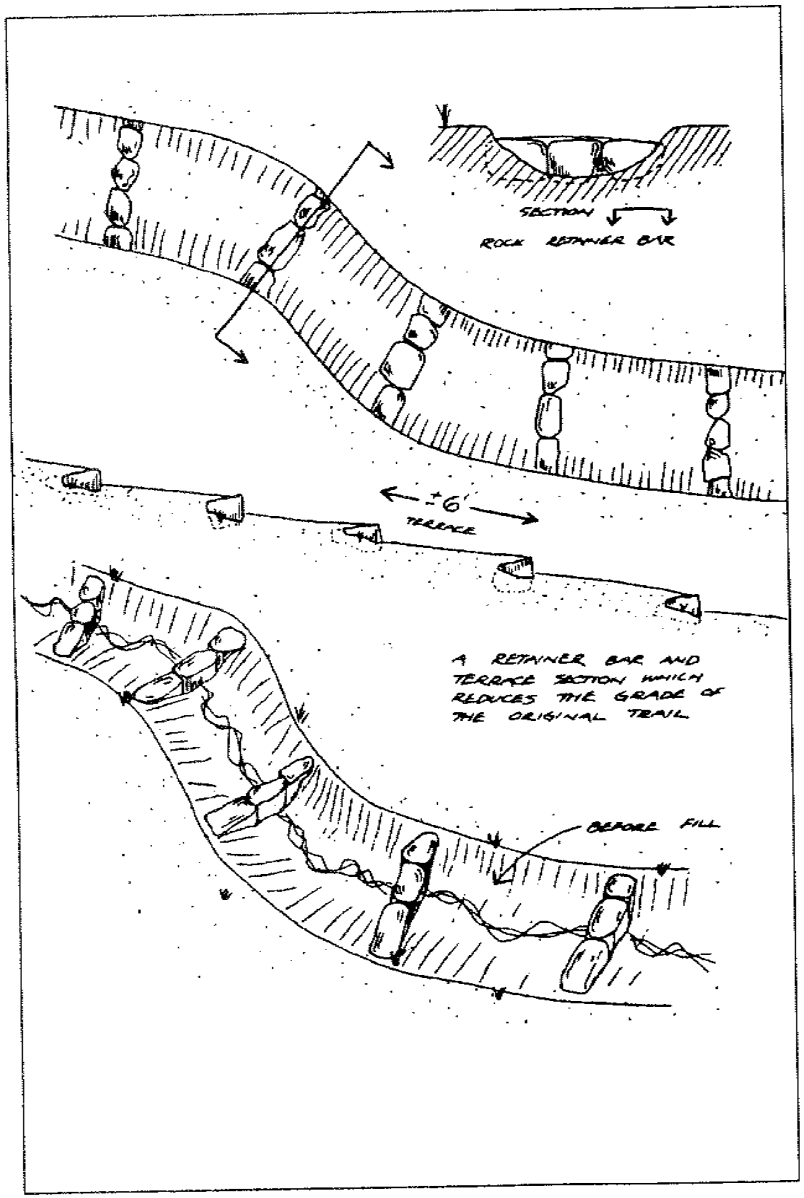


retainer bar. The height of all retainer bars within the section is determined by the height of the string. Attempt to place the retainers equidistant from each other, that is, the terraces behind each retainer are of roughly equal length. This makes for easy walking, especially for stock, as the grade is pulled steadily and easily. Experience has shown that the best length for a retainer bar/terrace section is roughly equal to the length of a horse (about 6 feet), or multiples thereof. This makes for easy walking with a string of stock.

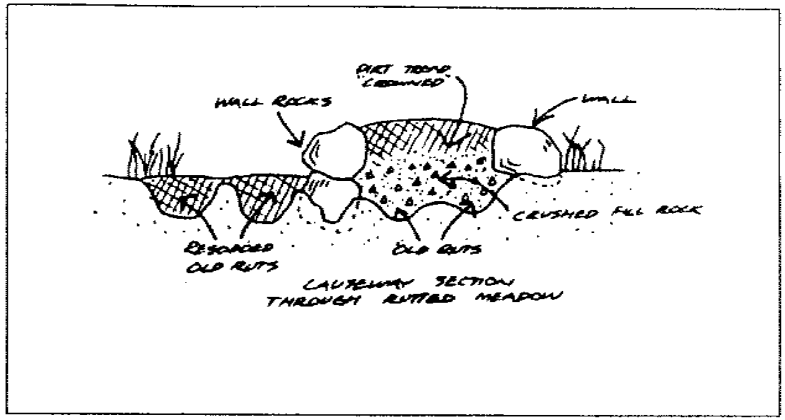
Backed Waterbar



Retainer Bars



Causeway

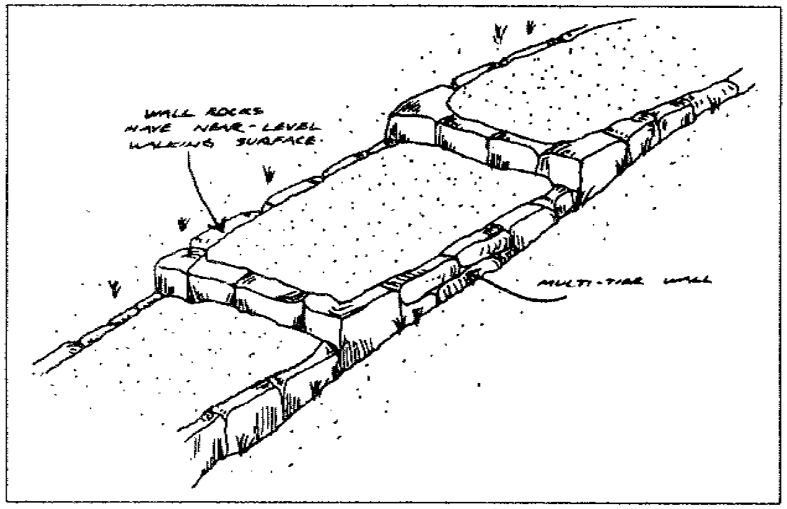


Retainer bars do not always step-up like steps. Their function is to hold fill, not necessarily to provide a step-up. Sometimes the retainers are entirely buried by the trail tread material at grade. In this case, the height of the retainers is 4 to 6 inches below the desired trail tread level. In theory, deteriorated wooden retainer bars may not have to be replaced once new drainage patterns and revegetated sections have been established and they are no longer required to hold established trail tread.

All retainer bar sections must be protected from water by re-establishing original drainage patterns using waterbars and other drainage structures.

Causeway - A causeway is an elevated section of trail, usually through permanently or seasonally wet areas. Causeways can also be used to consolidate areas of multiple ruts into one trail and allow revegetation to take hold in the extraneous ruts. Generally, the outer walls of the causeway are of rock, but

A Terraced Causeway



logs are also used (called turnpikes) depending for the most part on the situation, material availability, and the time and crew available for the project.

A causeway is built to be as inconspicuous as possible. That is, the causeway must be built close to the minimum height and width needed to bridge the problem area. Anticipate high water in the area and build the causeway to at least be visible through shallow water in the extreme case. Do not depend on this in a routine situation however, because water will quickly become muddied and stock especially can lose their way and step off.

Causeway walls are laid into the ground to whatever depth allows the wall rock to present a near level surface which could be walked upon. Lay the rock with a good outside face to present an aesthetic appearance and allow water to easily flow along the outer face of the wall. The inside face is not as important because it will be buried with crushed rock and a soil tread. The walls are stuffed and chinked from the inside before any rock is crushed or tread constructed. Ramp the approaches to the causeway section if necessary to avoid an unacceptable jumpup.

Once the walls are laid and chinked, begin to build up the tread by bringing in rock and breaking it up to fill size (maximum diameter 3 to 4 inches) with 10 or 12 pound hammers. Pick through the fill with a singlejack to be sure that you've broken all the big ones. Fill the causeway with rock to within no more than 4 inches of the top of the walls. If the causeway is filled too full with rock, the rock may work its way up through the soil tread to the surface with use.

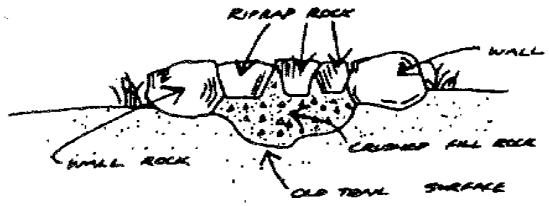
Fill the remainder with plenty of mineral soil, being sure to "crown" the soil to allow for compaction, especially in the center. Soil is most easily moved with stock and dirt boxes, but can also be moved with buckets, burlap sacks, wheelbarrows, and other labor intensive methods.

Riprap - In trail work, the term riprap is more specific than is found in common landscape construction use. In high Sierra trailwork riprap refers to a trail tread consisting of carefully placed rock used to climb steep grades. Many people think of "cobblestones" when they see riprap, but it is very different from the cobbled streets of Europe.

In many ways, riprap is the culmination of the trailworker's art. Riprap can be described and illustrated, but only after painstaking hours of application will the craft be learned. Riprap takes time and for that reason is only used where most needed, but it is a craft that all trailworkers strive to master.

Riprap provides good footing for stock (although they don't like to walk on it) and hikers. Riprap is used anywhere steepness of trail and/or water running down the trail tread is a problem. It is most appropriate for short, steep sections, including "jump-ups." Riprap can ascend steep grades as a series of small steps and still allow water to run down and over it. This is not meant to imply that riprap should be used as a substitute for good drainage control and design, but simply to admit that there are those areas where both water and use must be accommodated. The erosion caused by water and travel can be controlled and eliminated in these areas by laying a non-erodable rock tread, or riprap.

Riprap



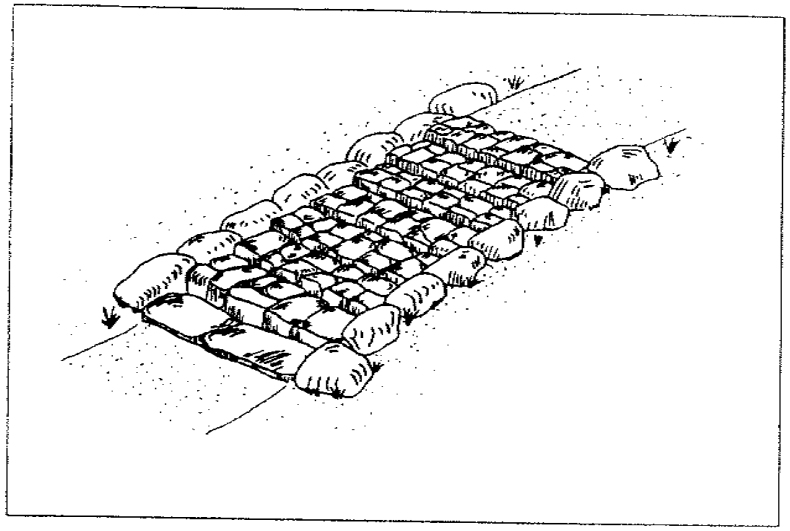
Riprap Section

Riprap Construction - First, assess the site. Make sure that riprap is the appropriate solution to the problem. Riprap will work to ascend nearly any grade, but first ask yourself if there are other more appropriate solutions such as retainer bars with terraces, or even a short reroute to solve the problem.

Once decided, plan ahead and visualize the final solution. Use a string to determine a good average grade or series of grades. Plan walls and keystones. Gather rock for walls and keystones, and stockpile riprap rock. Camouflage all areas where rocks have been gathered.

The Keystone - For riprap, the keystone is large and flat and intended to be walked upon. It is buried deep and is anchored to other rocks or bedrock if possible. Its strength is derived from its size, the depth to which it is buried, and the

Riprap



strength of its anchors. Keystones do not have to provide a large step-up, rather they provide a firm anchor from which the riprap rocks and wall rocks will ascend. Care should be taken to place the walking surface of the keystone nearly level. Dig out carefully to match the bottom contour of the rock. Take the time to dig the hole right, measuring depth with your shovel handle. If your keystone is a large trail width size rock, you don't want to be pulling it out of the hole to re-dig. Once the keystone is placed, take the time to raise the low corners or low side with a bar and throw a chink rock beneath the corner to hold it up. When "adjustments" are finished, be sure to stuff underneath the keystone solidly with crushed rock. Take the time needed to do a thorough job to lay a near-level keystone.

Riprap Rock - The ideal riprap rock is the one that is

easiest to lay, and best in function and appearance. This rock would have a flat, near rectangular top or walking surface, with gently sloping sides that would make tight, high contact with the rocks around it. Occasionally such rocks are found, or they can be quarried, but the real craft or art of riprap comes in learning to lay almost any rock, any shape, in any situation. Even rounded river rocks can be used with good results. Just remember the principle of "averaging the faces" of the rocks to envision how the rock will function in your wall or riprap.

Riprap Walls - Outside walls for riprap are similar to those for a causeway. The basic purpose of the wall is to lock the rock or fill which comprises the trail tread in place. Other factors are also taken into consideration for a well-laid wall for riprap.

When laying a wall, strive to make the wall as low and unobtrusive as possible. Your ultimate objective is to make the wall part of the trail tread so that it can be used as a walking surface if needed. This means that the wall is laid low and flat, depending on its shape.

Riprap can also be tied directly into solid soil, particularly clay-like moist grassy soil, eliminating the need for wall in some sections. Meadow soil is a good example. Save all vegetation, especially grass, for later replanting.

Laying Riprap - Once the walls are in place and a good selection of riprap rocks has been stockpiled, it is time to lay the riprap. Begin to lay riprap from the keystone up by thinking of tiers of rock that present a surface of easily broken joints to the next tier of rock. Try to anticipate potential problems laying the following tiers and work to avoid them. Make contact with the adjacent rocks in each tier as high and tight as possible. Make minor and careful adjustments to each rock to improve contact, height, and general placement using a rockbar or singlejack.

The amount of rise of each tier of riprap is best obtained by using a string stretched from the lower edge of a keystone or step to a point on the wall uptrail. If the forward edge of each rock

laid touches this string then the grade will be even and steady, easy to walk, and pleasing to the eye. Each step-up should not exceed 6 to 8 inches (less is better) and the depth of the tread is that size which a boot (size 12) can easily step on and stand, about 8 to 14 inches. This near-level "tread" can be more than one rock deep.

The riprap should be laid into a bed of fill which supports the rocks. The riprap should be tight and each tier nearly level. Fill rock should be stuffed beneath and around each tier as much as practical before laying the next tier.

The most difficult rocks to lay are the last rock in each tier and the final rocks of a section when the upper anchor is already in place. These are rocks which must be laid into tight, confined situations and need to be specific shapes and sizes.
Think ahead when laying each tier of riprap to that last rock. You want the last rock in the easiest location, not under the edge of an overhanging wall rock. Try to lay the outer rocks next to the walls first and work in to the last rock somewhere in the center. This will minimize "problems", as well as smashed fingers and frustrated trailworkers.

The upper tiers of riprap either tie into an upper keystone or step (which begins the next section) or into a natural feature such as bedrock or large boulder. Occasionally a root, tree, or clay soil may be used to tie-in the upper end of a riprap section. When tieing-in to bedrock or an existing natural feature think ahead to that final tier so that there is plenty of room to lay a tier of full depth. If the string method has been successfully used, the rise of the last tier will be right on the string. You can carefully shape the rocks to fit, but what it usually boils down to is finding the right shape.

When tieing into an upper keystone or step, try to allow yourself some latitude of movement in order to slam (with a rock bar) the upper key rock down onto the final tier to tighten everything up.

Finish Work - The entire riprap section and walls must be carefully stuffed and chinked. As much stuffing as possible isdone as the tiers of riprap are laid but hard chinking can only be effectively accomplished when all the rocks are locked

into place. First, crushed rock, gravel, and other small rock are stuffed into all cracks between the riprap rock. The idea is to turn the section of individual riprap rocks into as-one-solid-a-mass of rock as possible. Stuff small rock into the cracks and compact them tightly using a shovel handle, hammer handle, and rock bar. Use the handle or narrowest end of the rock bar to compact coarse sand into the smaller holes. Finally chink the entire project tight by hammering rocks into all possible cracks between rocks. Be sure to chink the outside of the walls.

Finally, clean up the area. Fill with soil any holes outside of the walls and revegetate with plugs of grass if appropriate. Rehabilitate all holes and other scars left from construction. If necessary, temporarily move objects such as dead and down wood to the riprap or causeway edge to "encourage" use of the trail by making stepping-off inconvenient. Revegetate any ruts or holes as appropriate with grass that has been saved from the construction.

Stock does not like to walk on riprap or any rock in general, including bedrock. Covering the riprap with 4 to 6 inches of soil will help to give stock confidence in their footing, and placing objects alongside the trail will discourage them from stepping off.

Walls - Walls are constructed for specific purposes, depending on the requirements of the project. The basic principles of drywall rockwork apply in all cases. The following sections discuss types of walls and specialized situations in which walls are used. The types of walls discussed are Single and Multi-tier Walls, Pinned Wall, Switchback Corners, and Riprap and Causeway Walls.

Single and Multi-tier Walls - Rock wall construction in the backcountry is predominantly single tier. Single tier walls are most frequently used to hold trail tread to a sloping sidehill by constructing an outside wall. Single tier walls require a good footing, solid foundation, a good and sometimes specialized rock selection, and good high contact. The rocks should be laid with the weight of the rock leaned back into the trail. A hiker or stock

animal walking on the wall itself should not be able to dislodge any of the rocks, even stepping on the very outer edge of the wall. Their weight should be transferred through the rock into the wall, and not translated into a rotational force which will dislodge the rock. Applying downward force to the outer edge of a rock as it is laid is a good test for wall rock.

The higher the contact in the top tier of a wall the better it will hold fill and trail tread material. Poor low contact in the joint can be easily stuffed and chinked if there is good contact above, but large gaps in the upper portion of joints can present problems when trying to hold fill. Remember, the purpose of the wall is to hold or retain trail tread material. This is best accomplished by laying rocks with high contact.

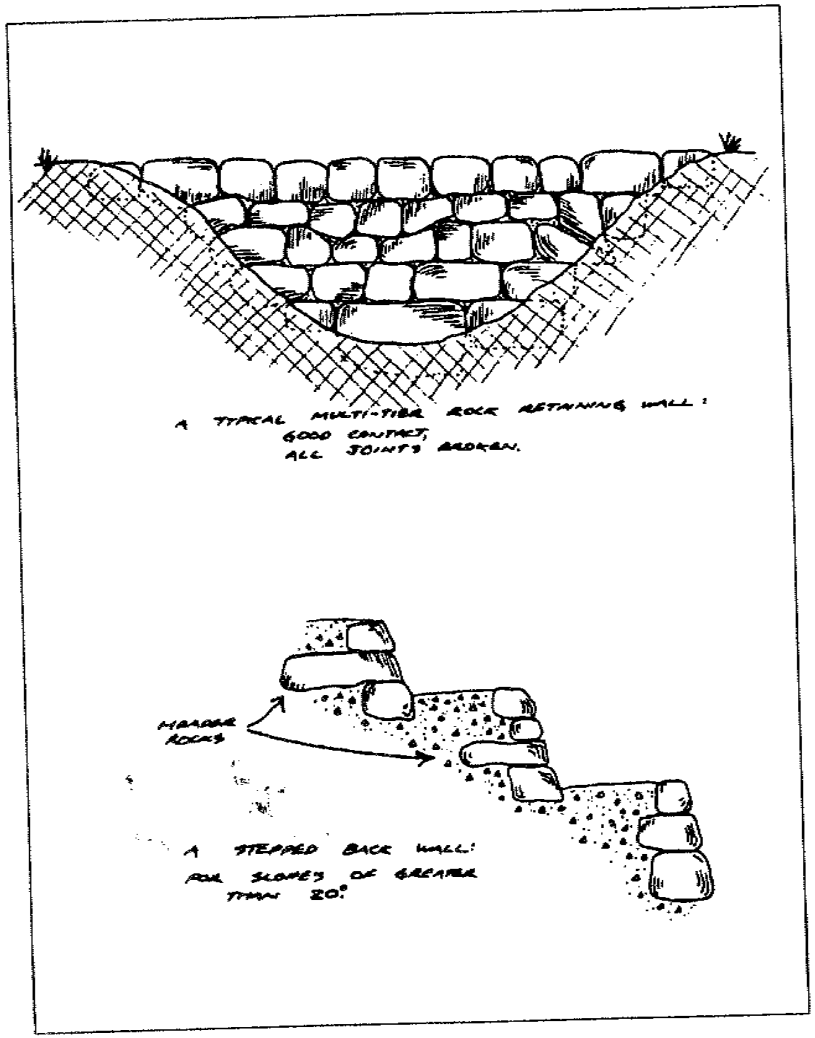
A multi-tier wall is used like a single tier wall, except in steeper areas and in more extreme situations. Multi-tier walls are used as outside walls holding trail tread, inside walls protecting the trail from slough-off, inside switchback corner walls, and in other situations, including fords, culverts, and causeways.

The basic procedure for laying multi-tier walls is like that of any wall; good footing, good foundation, solid bottom tier of as-large-as-possible foundation rocks, with upper tiers of good wall rocks with strong contact, all joints broken, then solidly chinked and filled. The use of frequent header rocks will add strength to the wall by adding depth to the project and anchoring the wall to the adjacent landscape.

In steep, difficult construction situations, as many as 1 in every 4 rocks laid may be a header.

A multi-tier wall may be nearly vertical if the situation requires or may have up to a 20 degree backslope. The greater the backslope, however, the more care must be taken to be certain that the joints of each tier are broken solidly by the tier above and that the weight of the upper tier is not back upon the fill behind the lower tier. If greater than 20 degree backslope is required, it is recommended that the wall be stepped back at roughly equal intervals; i.e. that several tiers of rock be laid at a comfortable backslope in the vicinity of 10 degrees, and then another section of

Multi-tier Wall



several tiers be laid from a footing stepped back several feet or more. This is a strong, solid method to gain elevation in a multi-tier situation when verticality is not a consideration, but hauling of fill is.

Pinned Wall-At times it is necessary to build wall, especially outside wall, over a slick bedrock section which has few, if any, anchor points. Wall rocks can be secured to small anchor points on a bedrock surface in the right situation. The shape of these wall rocks must be carefully selected to cling to small edges or knobs on the bedrock. Usually the optimum shape is triangular, with the base of the triangle being the outside face of the wall. Lay the rock with the face leaning back in toward the trail for stability.

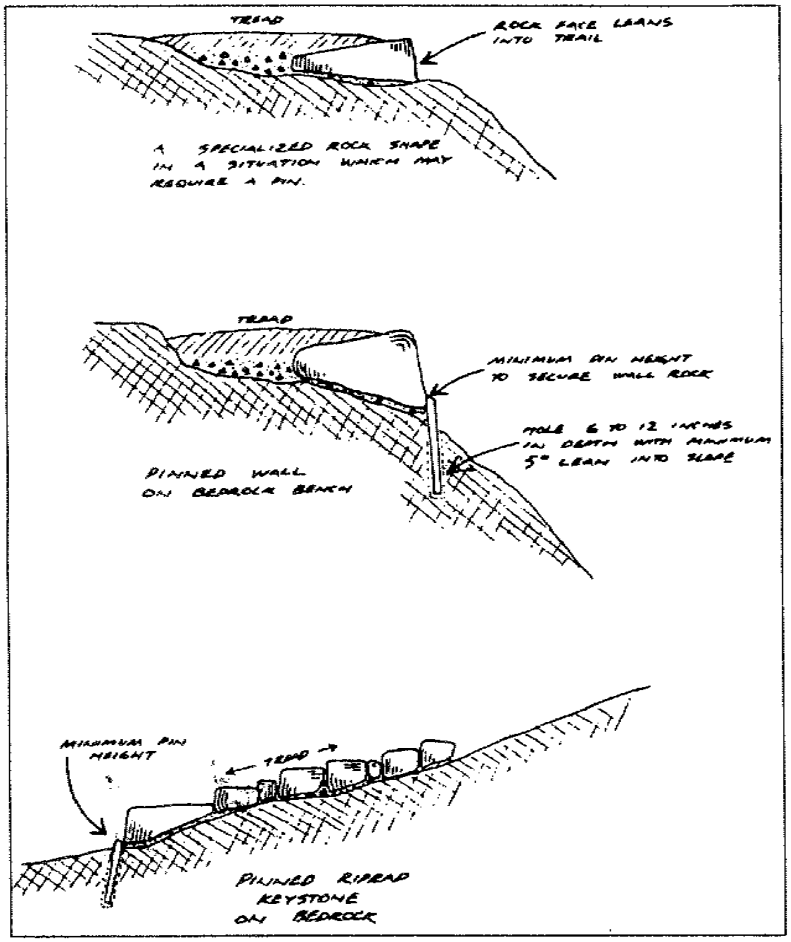
If this method proves infeasible or will not provide enough strength or stability, the project leader may decide to pin the wall or pin key rocks that will support the wall. The first option in pinned wall is to lay the wall as described above, placing a tier of outer wall rocks on the bedrock in the position required for trail construction. Once these rocks are in place, then the wall is pinned in a few strategic locations which will "lock" the wall in place.

Another approach to pinning a wall, is to set pins first, then lay the wall against the pins. This is a less desireable approach because there is a tendency to rely on the pins for wall strength, rather than the skillful placement and laying of the wall rocks. Pins should be thought of as a final source of reinforcement for a wall, not as the only source of strength. Skillful laying of rocks is still the primary means of solving the bedrock-outside-wall anchor problem, with pins thought of as a backup source of strength; "in the event of..."

Pins are most commonly used to anchor the foundation rocks of a wall. Pins are also used to anchor retainer bars, keystones, or even waterbars to bedrock. Holes are drilled with a jackhammer to a depth of 6 to 12 inches depending on load, length of pins, base material, etc. Drill the holes with an angle of 5 to 15 degrees toward the trail or so that the pin leans uphill. Pins are usually cut in pre-measured lengths of 12, 18, and 24 inches (for example) and are placed in the drilled holes to minimize height.

Minimize height of the pins to about one inch above the contact point between the pin and the wall rock. Pins that stick up high above the wall rock or trail are unacceptable and constitute an aesthetic, as well as a safety, problem. If possible, shorten

Pinned Wall



pins already in place in the backcountry to meet this standard. Pin material is 1 to 1-1/4 inch diameter steel rod, depending on the size of the hole drilled in the bedrock. Steel rod has proven to be capable of withstanding the pressure of the rock wall, trail tread, and snowloads. Re-bar is unacceptable and will not be used. Re-bar will weaken and bend with age and load.

Place the pin in the hole, shift the rock weight onto the pin and tighten it in the hole. Then fill the void around the pin in the hole, carefully packing the hole with sand or drill powder so that the pin will not rattle loosely in the hole. A small wire tool is helpful for packing the fine sand. This prevents water from filling the hole and expanding when frozen, potentially cracking or exfoliating the bedrock.

Pins are an aesthetic intrusion in the natural backcountry environment and their use must be minimized both in number and in height. In addition, holes drilled in bedrock are a permanent scar to one of the prominent features of the backcountry and for this reason must not be undertaken without careful deliberation with the project leader and the trail foreman whenever possible. Remember, minimum number and minimum height.

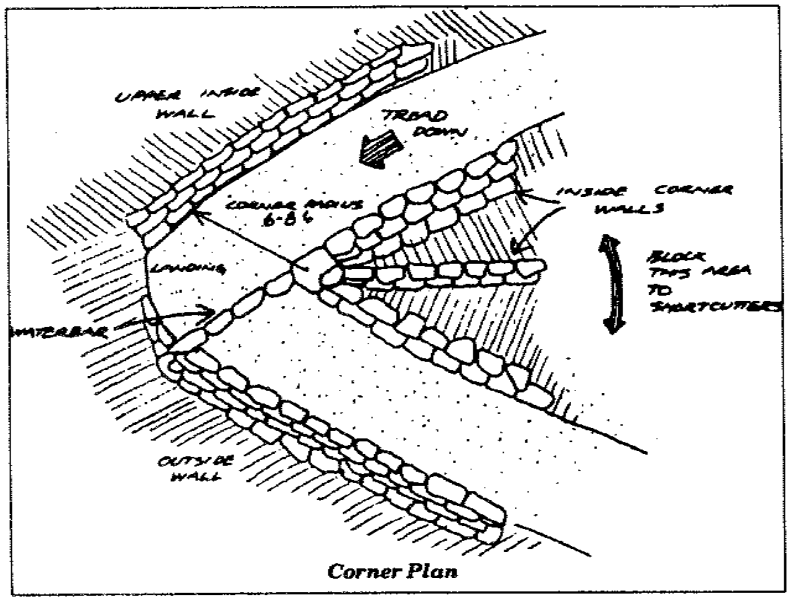
An Alternative to Pins - In the appropriate situation, an option for building on bedrock exists, especially if pins and jackhammer are not available. Keyrocks can be anchored below trail level on a bedrock ledge or bench or anchored into soil at the base of the bedrock. The trail wall rocks are tied into those keyrocks by laying intermediate headers and other larger rocks, each carefully tied into the tier or keyrock below, and triangulating upward to support several or more wall rocks.

Advantages of this method are that few or no pins are required, the high outer wall is less unsightly, and many wall rocks can be laid triangularly off of a few keystones.

Switchback Corners - Switchback corners can be among the most complex dry wall rock projects undertaken by backcountry trail crews. At its most complex, in steep rocky terrain, a switchback corner project involves an outside wall on the lower switchback, a nearly level landing with a waterbar or other drainage structure, an inside-outside wall between the two switchbacks, and an inside wall above the upper trail.

When the project is broken into its component walls, landing, drainage, and trail tread it becomes more easily understood

Switchback Corner



Corner Plan

and construction can begin one step at a time. Always begin work at the lowest point and excavate thoroughly for a good footing.

If required, construct a multi-tier outside wall to trail level on the lower switchback. Chink and fill behind as you lay tiers. Use large rocks, with frequent headers.

Lay out the switchback landing with no more than 10% grade. Allow a broad, nearly level area to turn. Measure the radius of the landing from the inside corner to include a semi-circle of trail width or greater, about 6 feet minimum to 8 feet or more. Include in the landing a waterbar which directs any water running down the upper switchback off the trail at the corner.

Construct a multi-tier switchback corner wall inside the two trail sections. Be sure the wall is steep enough to inhibit shortcutting down the wall and long enough to discourage shortcutting uptrail. Excavate below lower trail level or below

the level of the interior slope for a solid footing. Use large rocks, get good contact, and break all joints. Build the wall to upper switchback level, stepping back if necessary.

Finally, establish an upper trail tread and construct an upper inside wall if needed.

In most cases, reconstruction of a switchback corner is not as complex as the project described above. Most commonly, switchback corner reconstruction involves rebuilding or repairing the inner wall. Collapse or erosion of the inner wall is most commonly caused by switchback cutting so care must be taken to reconstruct the wall in such a manner as to prohibit, or at least discourage, switchback cutting. Methods of doing this are making the wall more steep, laying a top tier of rough, jagged rock, and last in preference, placing dead logs or brush on the former cut route. Revegetation should be undertaken when the cut has stabilized.

Maintain the trail width and minimum grade throughout the corner. Avoid the common corner situation where either the landing itself or the first piece of trail up from the landing is too steep. In this case the trail, and the corner and inner wall, need to be extended and the switchback lengthened to reduce the required grade.

Riprap and Causeway Walls - Outside walls for both riprap and causeways are similar. Typically, they are single-tier walls which are laid to contain the trail tread material, either fill or riprap rock.

Begin by digging out for the wall rocks using pick, rock bar, and shovel. Use existing rocks and features of the landscape as much as possible. Existing well-anchored rocks are ideal for tieing in sections of wall. Walls are laid from the keystone or lowest point up, each rock making good contact with the rock below and presenting a good face to the top and to the outside. For riprap, the face of the wall on the inside must be free of radical variations in the faces at the height where the riprap will tie in. For example, a severely undercut rock presents a problem

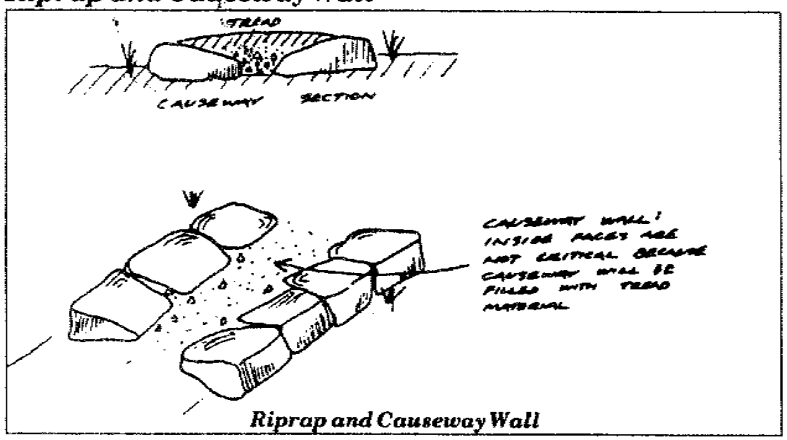
when the riprap rock is laid. Optimally, riprap wall rocks meet evenly so that the joint may be easily broken by a riprap rock. For causeway walls, the wall rocks are laid in large terraces to pull grade. Elevation is gained within each terrace and by the placement of periodic steps across the trail tread, similar to retainer bars. The wall rocks correspondingly gain in elevation with each terrace and step-up.

These terraces may be from 6 to 30 feet or more in length through gently climbing formerly rutted sections of trail. A minimum length is that which a horse can comfortably stand on and walk up the step to the next terrace, about 6 feet.
The maximum height of the terrace step-ups depends largely on the grade and terrain, but is never more than 10 to 12 inches, and 6 to 8 inches (or less) is best.

After the walls are laid, they must be stuffed and chinked from the inside. Small chink rocks are stuffed into the larger gaps between the rocks and driven into the cracks to tighten up the entire wall.

The causeway must be roughly uniform in width. Select an easily measured width using a shovel or other tool as a measuring stick. A good rule of thumb is that a shovel handle is a good width for a normally traveled trail, and the shovel handle plus blade is a good width for a heavily used trail.

Riprap and Causeway Wall



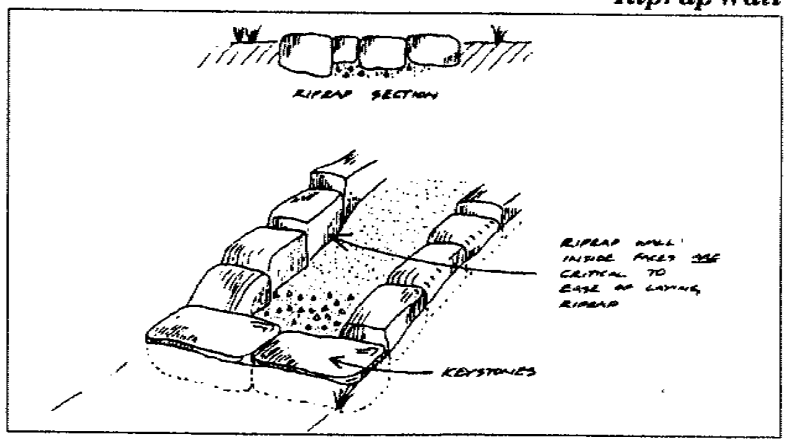
Riprap and Causeway Wall

Fords - Fords can vary in size from a small seasonal creek, several feet wide at the trail crossing to large river crossings requiring approach trails cut down through the river banks, riverbed rock "adjustment" annually, signs, and even riprap approaches. This section concerns the smaller cross-trail variety of ford.

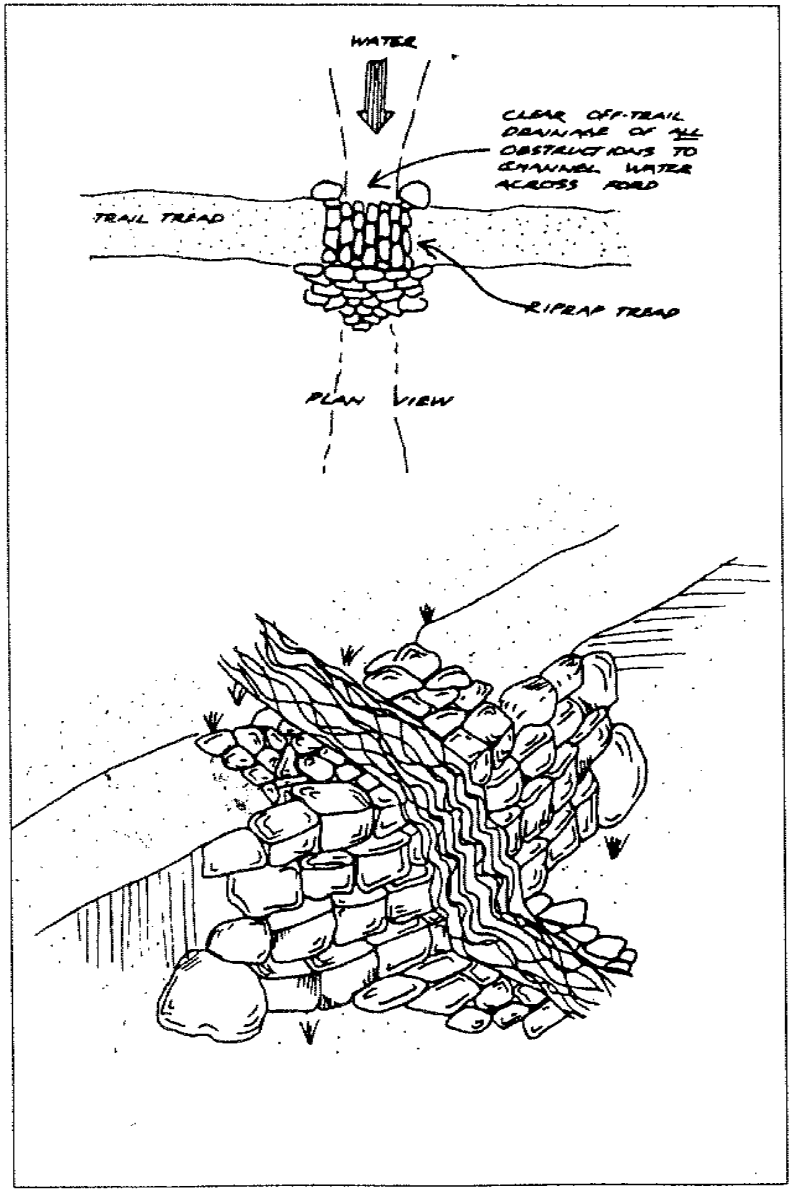
A constructed trail ford is basically a section of trail which allows the water to flow swiftly across and off the trail while still providing a solid, firm footing. The key is to make the trail tread portion of the ford as level as possible with only a slight outward grade and to make the drainage area slightly lower in the center to concentrate the flow of the water across and off the trail.

Begin construction of the ford with the outside wall, if required, at its lowest point. Dig a firm footing and plan to accommodate the water flow on and over the wall. If the drop from the trail tread portion of the ford to the off-trail drainage is greater than 4 or 5 feet, a catchment structure may be required to prevent the outfall from eroding below the trail and outside the wall. This depends on the drop and anticipated flow. The effect of the drop can be mitigated somewhat by constructing a wall which has a backslope of 10 degrees or more so that water will run down the wall, and not spill freely like a waterfall.

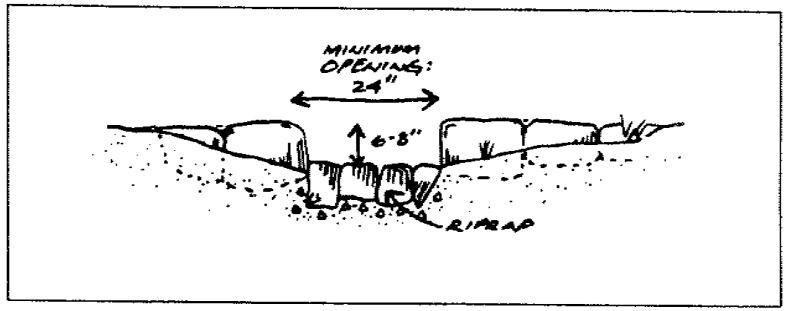
Riprap Wall



Fords



Rock Culverts



The outside wall is constructed using standard drywall procedures and the upper tier is laid with rock as large as possible to present as few joints as possible to the flowing water. Construct the center of the upper tier lower than the sides to consolidate the water flow.

The trail tread portion of the ford can be sand or gravel held behind an outside wall if the anticipated flow is not too great. The best ford design, especially if the flow is seasonally large, is a riprap tread.

A riprap ford must be constructed at low water. The center of the section is lowest and is the starting point for the riprap which will climb in both directions to trail height. Dig out below trail level at least 10 to 18 inches and lay a center row of rocks across the trail at this level on a bed of crushed fill. Lay the tiers of side rocks against the center row, breaking all joints, and filling all voids beneath the rock with crushed fill. Chink the structure tight.

Clear off-trail drainages on both the upper and lower sides of the trail to assure a swift, direct flow of water across the ford. Be especially aware of down logs or debris above the trail directing water to another trail area. These blockages should be removed to assure that all water goes over the ford.

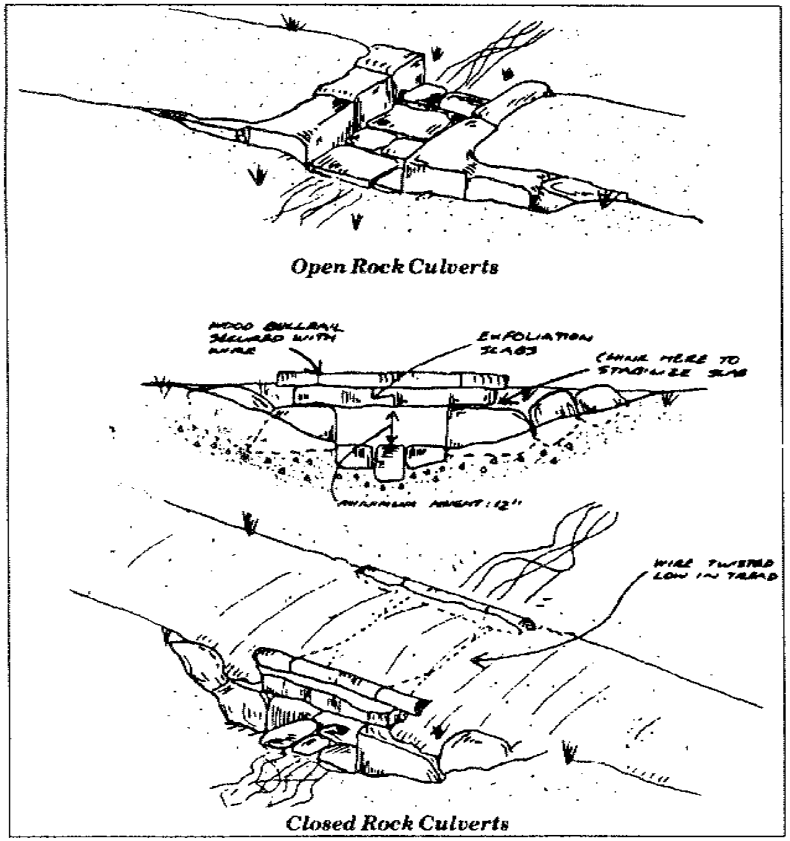
Culverts - Backcountry culverts are constructed from either rock or wood, and they are either *open* or *closed*. An open

culvert is one which has no small bridge-like tread spanning the opening. A closed culvert has a tread which allows traffic to pass over it while water flows underneath.

Manufactured round corrugated metal culverts will be installed only with the trail foreman's consent. The use of metal culverts is inappropriate in the backcountry.

Wooden culverts are made from slabbed or milled wood and pose the problem of rapid deterioration caused by rot and are a potential hazard on the trail. Their use is also discouraged.

Rock Culverts



Open Rock Culverts

Closed Rock Culverts

Rock is the preferred material for both open and closed backcountry culverts. Closed culverts have rock slabs bridging the gap with tread material over the slabs.

In an open culvert, the gap in the trail, or channel width, must not be too small. The gap must be at least 2 feet, as anything less will present a hazard to stock stepping down into it. The idea is to plan for stock to step into the open culvert, and not over it. The depth of the open culvert depends on anticipated waterflow but is generally from 4 to 10 inches. Riprap the channel for solid footing.

A closed culvert first depends on the availability of good slab rock. Exfoliated bedrock is a good source. Slabs can sometimes be found at the base of, or peeled off of, an exfoliated dome or exposed piece of bedrock. Once the slabs have been located, the side support rocks for the culvert can be laid. Dig out the drain to more than 10 inches below trail tread level, and wide enoughto lay the 2 sides of support rocks and still have a minimum 2 foot wide culvert channel. If the channel is too narrow, it will be prone to clogging up with rock, branches, and floating debris. Lay the side rocks as you would a single tier outside wall, with special attention to the top surfaces where contact must be made with the rock slabs. Choose large rocks for the side support walls. These rocks should be as deep or deeper than they are tall, rather than slabs stood on edge. The trail width at this point is about 4 feet. Dig the rocks into the ground several inches, make good contact with the adjacent rocks, and present good, smooth faces to the inside of the channel to avoid snagging debris.

After both sides of the culvert are laid, riprap the channel at drainage level. Dig down approximately 10 inches between the side walls and lay a solid pattern of smooth riprap on a bed of crushed rock. Allow for the inside of the culvert to be at least 12 inches high.

Move the slabs into place once the walls and riprap are laid. Shape the slabs with a singlejack or rock chisel to achieve a good fit between slabs, particularly at those joints in the tread area. Break off any overhang of the slab beyond the side walls to prevent the rock from being loosened by a step on the outer

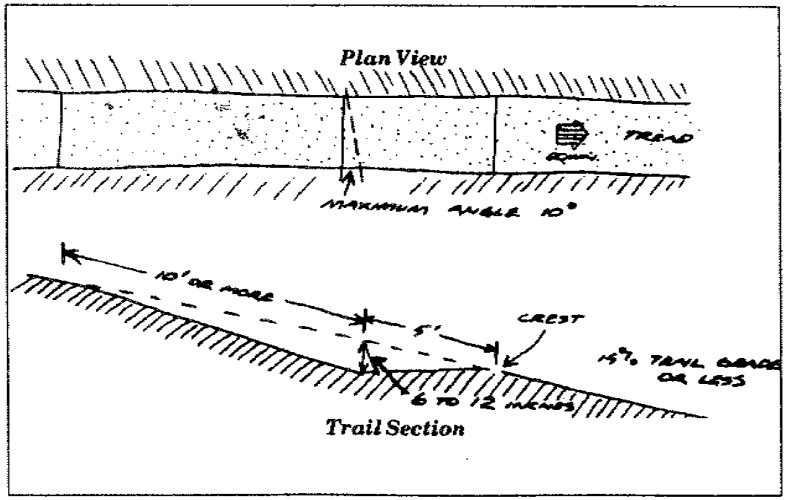
edges. Chink beneath the slabs to stabilize the walking surface.

To hold tread material on the slabs, use higher outer rocks or secure a 6 inch diameter wooden bull rail to the outer edges of the slabs using wire or rocks on either end. Wire the two bullrails together by making a loop of wire and twisting it, keeping the wire low on the slab so it can be buried with tread material. The tread remaining should be at least 30 inches wide, and crowned with tread material.

Dip Drains - A dip drain is any maintained and/or natural depression on the outer edge of the trail which allows water to flow off the trail freely, theoretically without eroding the trailhead or gullying the off-trail drainage.

Maintained dip drains usually reinforce natural drainage points where waterbars have not been installed, but drainage does occur. These may be, but are not limited to, drains at the lowest points of a trail. Dip drains can be installed on most trails with a grade of up to 15% if the graded approaches to the drain are dug out far enough up-trail. The drain itself will dip down

Dip Drain



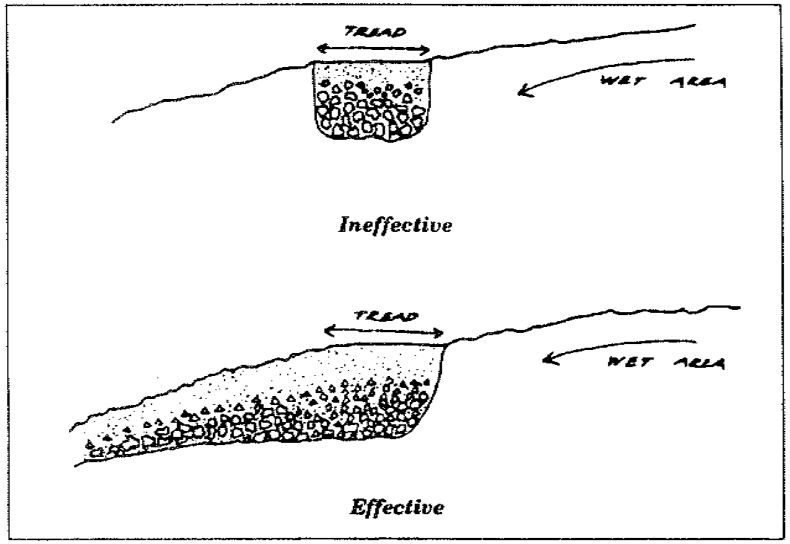
up to 12 inches below trail level across the entire width of the trail. The up-trail approach to the drain will begin a minimum of 10 feet above the drain (up to 20 feet for steeper trails) and approach the drain at an even and steady grade several degrees steeper than the trail grade. Down trail, the approach will extend about 5 feet below the drain and will also be a steady and consistent grade extending across the entire width of the trail.

Dip drains can be used in many situations where waterbar construction is not possible. A dip drain can be just as effective as a waterbar if maintained properly, and in conjunction with other drainage structures it is a basic component of an effective backcountry drainage system.

French Drains - A french drain, or rock drain, is used to provide drainage across the trail at wet or boggy sections. The drain is installed by digging out the section to up to 2 feet in depth, then filling the section with crushed rock. Larger rock is placed on the bottom of the drain, with progressively smaller rock used toward the surface. The purpose of the drain is to allow water to flow through the rock and out of the trail area, while still providing a firm footing for trail users.

The problem with french drains is that they soon become clogged with soil, mud, and debris, and water will cease to flow through them. To slow this process, extend the constructed crushed rock drainage 2 to 6 feet below the trail tread, giving the water more area to drain to. The installation of french drains is discouraged and the construction of alternatives such as fords, culverts, causeways, turnpikes with culverts, or puncheon and gadbury-type bridges is recommended.

French Drain



LOG STRUCTURE STANDARDS

In some areas of Sequoia and Kings Canyon logs must be used to build trail structures due to the lack of available rock. Rock, of course, is the preferred material for trail structures, but in forested areas may be difficult to find. Log structures are also used when a quick temporary solution is required because neither time nor manpower is available to get involved in a rock construction project.

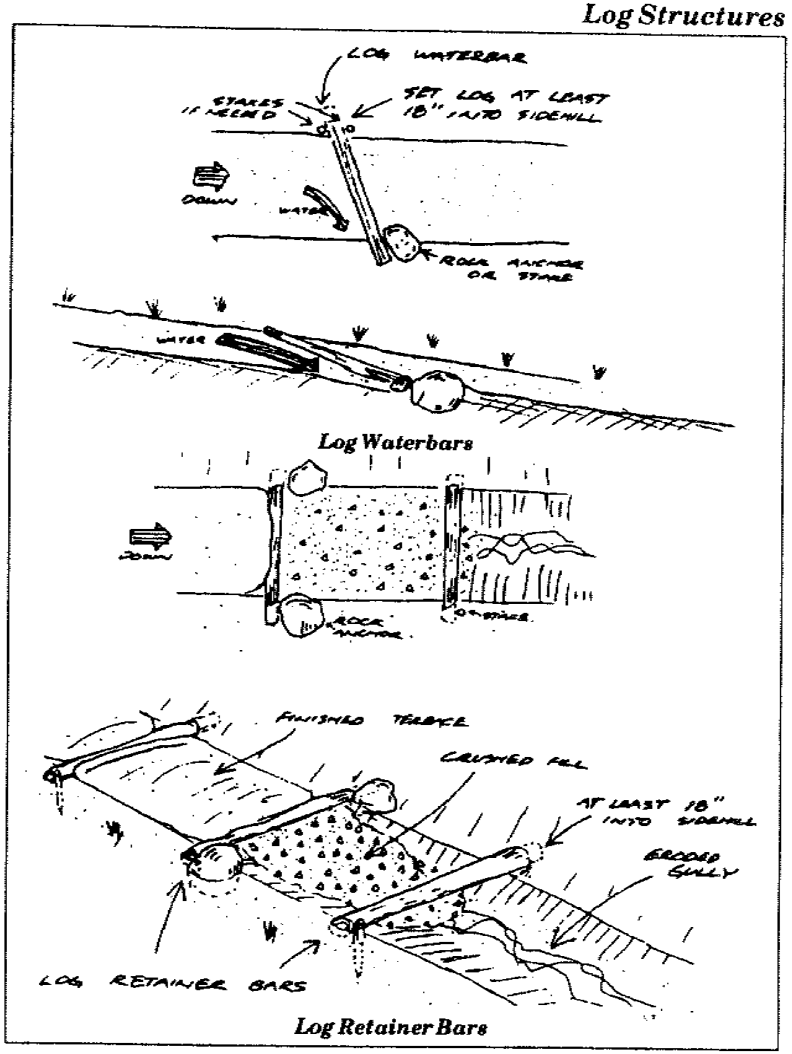
Whenever logs are used they should be peeled to inhibit rot and lengthen the project life. Preferred tree species for log structures is cedar, followed by fir, lodgepole pine, other types of pine, and oak. In general, the kinds of wood available in the backcountry of these parks, except for cedar, can be expected to have a short life-span when used for trail structures. Keep this in mind before expending a large amount of time and effort on a project.

The most typical log structures constructed in these parks other than log bridges are waterbars, retainer bars, turnpike, and simple crib walls. Other log structures, such as gadbury and puncheon are rarely constructed due to the typical availability of rock to construct more permanent solutions. This does not mean that log structures cannot be considered for use in appropriate areas, but careful consideration of the time required for construction versus the permanence of an alternative solution must be taken into account.

Corduroy is a non-specific term used to refer to a variety of wooden structures used to "bridge" wet or boggy sections of trail. Logs are generally laid either perpendicular or parallel to the trail and are placed directly on the surface, or "in the mud", after which some kind of trail tread or soil fill is used to bury the project. Corduroy has proven to be short-lived due to rot and deterioration and is hazardous, in particular to stock, when in an unknown condition of decay. Corduroy is not recommended for use in these parks and alternative solutions will be used.

Waterbars and Retainer Bars - The most common use of logs in the backcountry is for waterbars and retainer bars. These are laid in a very similar manner to rock waterbars and retainer bars as described in the previous section on drywall rock structures.

Log Structures



Be certain the log selected is at least 18 inches longer than the trail tread is wide, allowing for overlap on the sides of the trail. Minimum diameter for a log waterbar or retainer bar is 6 inches. Anchor the log at the crest of the drainage by setting it into the trail about one-half to two-thirds of the log's diameter and anchoring the ends into the trailside if possible. The outside end of the log can be secured in position with large rocks or log stakes at least 18 inches long and 2 inches in diameter driven deep into the ground. If rocks are used, they must be set in the ground, not merely "leaned" against the log.

Consider "backing" the waterbar with a log of minimum height perpendicular to the trail which will hold fill material behind the waterbar on the downhill side and insure that water will be turned at the drain. Clean the drain thoroughly as described in the maintenance section.

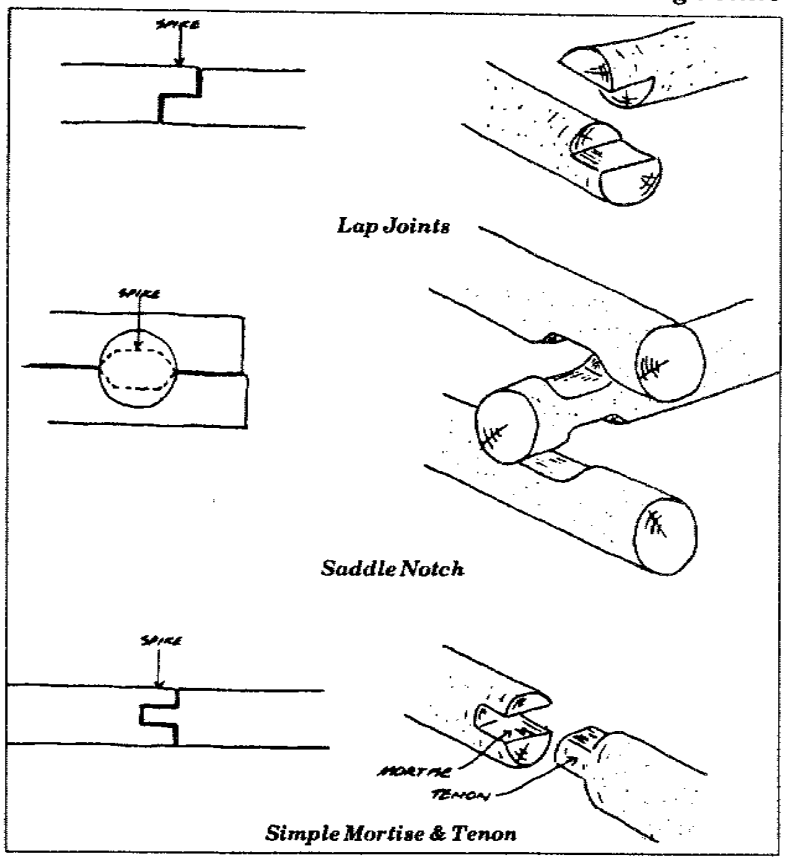
Log retainer bars are used in forested areas to hold fill or trail tread material in place. When the section is subjected to water and erosion problems, a log or rock waterbar must be installed to protect the section before the retainer bar can be expected to successfully hold fill.

Turnpike - A turnpike is a log version of a rock walled causeway. Essentially, logs are used as outside walls to hold fill and trail tread material to establish an elevated, firm trail through wet, boggy, and/or meadow areas. Larger diameter logs (up to 14 inches) are peeled and set in place parallel to the trail tread about 4 feet, or one shovel length, apart. Use lap joints to join more than one log on each side. The logs are secured in position with large stakes on the outside and/or wire ties holding the two logs in position. Wiring the logs is the most effective and fastest technique. Use no. 9 telephone wire or double strand fence wire wrapped around the outer logs and twisted together low in the trail tread. If wooden stakes are used they should be sharpened limbs or small peeled logs 2 to 4 inches in diameter and 18 to 24 inches in length. These are driven into the ground at an inward angle to the turnpike. In other words, with the increased outward pressure onthe outer logs

exerted by the rock fill and tread material, the pressure on the stakes would tend to stand them straight up, rather than lay them down and allow the logs to separate. As a final step, the stakes are trimmed to turnpike height with an axe or saw.

In wet or boggy areas, culverts may be installed beneath the turnpike logs to facilitate drainage. Unlike rock walled causeways, logs tend to work like a dam and drainage must be carefully considered. The logs may be notched to fit over the culvert, depending on the heights required. Open culverts, at

Log Joints

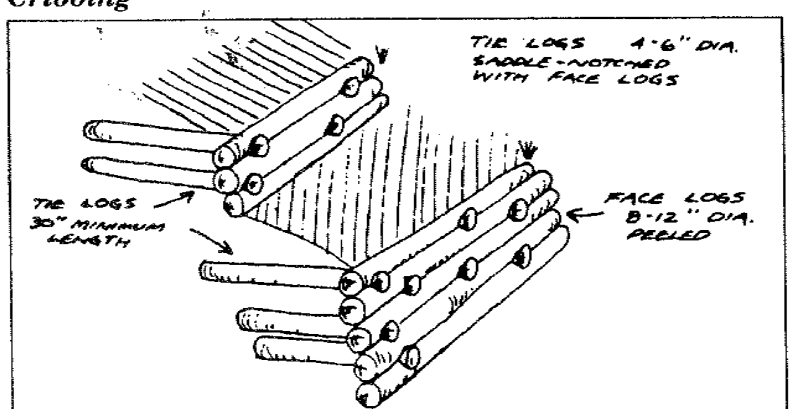


least 18 inches wide with a riprap tray, may also be installed to facilitate water flow across the trail corridor.

Cribbing - Simple cribbing is used as a substitute for multi-tiered rock walls, particularly if rock is not closely available and time is a factor. Cribbing can be used for inside or outside walls, switchback corners, and bridge approaches, abutments, and piers. The basic method of constructing a crib wall is to lay peeled rail or face logs (8 to 12 inch minimum diameter) one on top of another and lock them into place with notched, smaller diameter, tie logs. The tie logs and rail logs are locked in place using saddle notches as shown in the illustration. The tie logs extend into the project at least 30 inches and are about 6 inches in diameter. The face of the crib wall can be nearly vertical or backsloped up to 20 degrees. It is important that the top rail log be at least 12 feet long (or as long as possible) to anchor the project below it in place. The tie logs are fastened to the rail logs using 10 inch spikes. The project is backfilled as it is constructed, tier by tier, like in multi-tier rock wall construction.

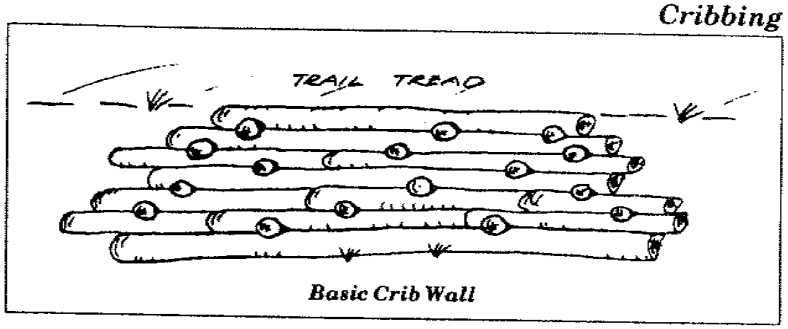
Puncheon - Puncheon is an elevated boardwalk used to cross boggy or marshy ground where uneven terrain or a lack of

Cribbing



Stepped-back Crib Wall

Cribbing



Basic Crib Wall

trail tread material makes turnpike or causeway impractical. Puncheon resembles a short version of the familiar log foot-bridge. Its main components are; sill logs laid perpendicular to the trail, 3 stringers laid on the sill logs parallel to the trail, decking laid across the stringers, and outer bull rails on the decking to pin the deck to the stringers and provide a degree of safety for stock and other users of the puncheon.

Sill logs of 12 to 16 inches in diameter, 4 to 6 feet long, are laid in dug-out trenches at both ends of the area to be bridged, and at intervals of 8 to 12 feet in the interior of the section if needed. The sill logs are buried in firm ground with about 2/3 of their diameter below ground. If firm footing is not available, use crushed rock and fill to solidify the bottom of the trench and/or increase the length of the sill log to give it better "flotation."

The three stringers must be at least 10 inches in diameter, depending on span, and are carefully placed on the sill logs and adjusted for height and level by notching. It is important that all deep notches be cut into the sill rather than the bottom of the stringer to preserve the strength of the stringer and reduce the possibility of splitting. The stringers are spiked to the sill logs using large spikes.

The decking is either milled on site, split on site, or packed in. It should be 3 to 4 inches thick and at least 4 feet long and is spiked to the stringers using 8 inch spikes. Do not spike to the center stringer because center spikes may work themselves up with time and become obstacles in the deck. The bull rails are

made from smaller logs about 6 inches in diameter and are either ripped or split to create a flat surface which is secured to the deck. The bull rails are positioned over the outer stringers and spiked through the deck using 10 inch spikes. The resulting clear deck tread between stringers is about 30 inches.

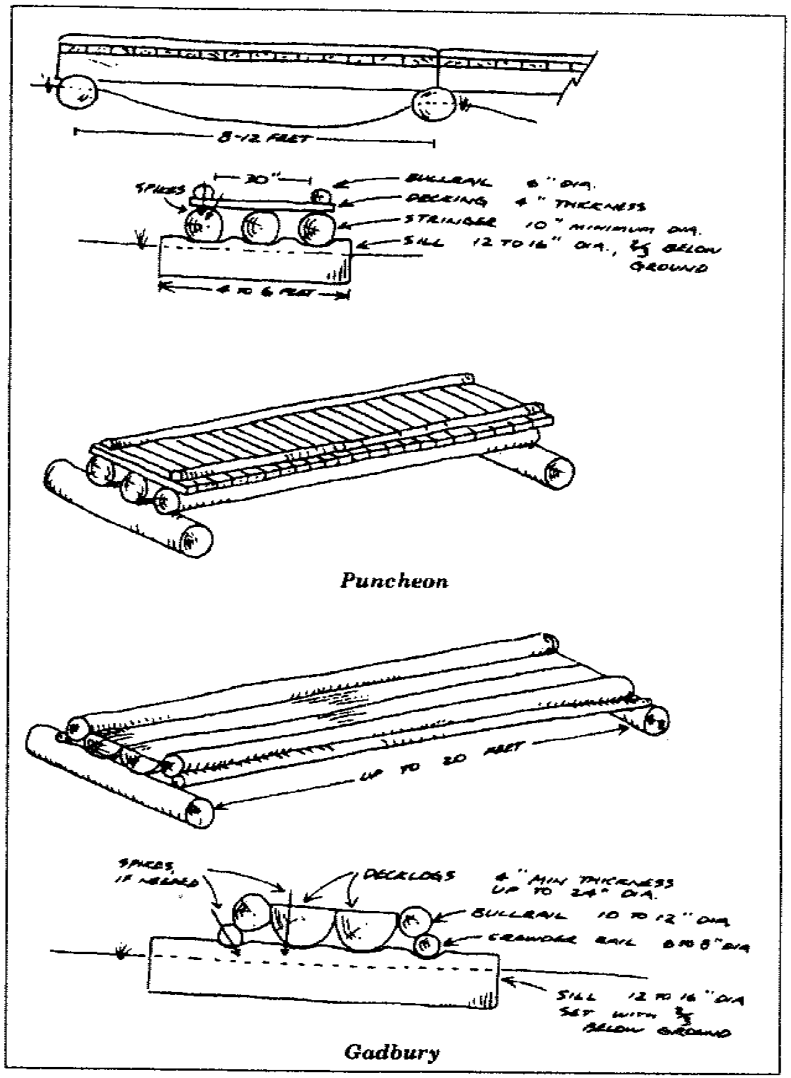
Finish the puncheon by trimming the outer edges of the decking with a chain saw if necessary and constructing trail approaches which meet the puncheon at deck level. Clear all brush or debris from under the puncheon to allow for unimpeded drainage.

Gadbury - Gadbury is used like puncheon to span muddy or boggy sections and allow for a clear drainage underneath the section. Gadbury can be quicker and easier to build than puncheon because it does not involve as many components and requires fewer trees. In gadbury, the components are sill logs, large deck logs, bull rails and crowder rails. The main drawback of gadbury from a construction viewpoint is the weight of the deck logs and bull rails.

The sill logs are placed in a manner similar to those used for puncheon, except that the span for gadbury can be up to 20 feet or more depending on the dimensions of the material available. For a 20 foot span the deck logs need to be nearly 24 inches in diameter. One 2 foot diameter tree can be ripped down the middle to provide the 2 decking logs required for a 20 foot gadbury. The deck logs are positioned on the sills and shaped to meet at center with a minimum of 4 inches of deck thickness and a tight fit over their entire length. Any major notching required to adjust the height and level of the deck logs must be done to the sill logs, with a minimum of "trimming" done to the deck logs in order to maintain their strength.

The bull rails are a minimum of 10 to 12 inches in diameter and are wedged into place outside of the deck logs using smaller diameter crowder logs (about 6 to 8 inches.) The bull rails must not touch the sill logs or the wedging effect will be lost. Spikes may not be necessary, but are a good idea, especially for shorter

Puncheon and Gadbury



Puncheon

Gadbury

spans. Wire may also be used to secure the components. Trimthe deck so that it is level and clear of protrusions and clear all debris from beneath the span.

Backcountry Bridges

Through the years, several types of bridges have been constructed in the Sequoia and Kings Canyon backcountry. In addition to the standard wooden stringer bridge, there are Bailey-type metal bridges, metal stringer bridges, a cable suspension footbridge, and several types of truss bridges. Methods of construction of these specialized bridges are beyond the scope of this *Trail Handbook*. Typically, these specialized designs are accompanied by plans and specifications for each installation. Construction of bridges is generally limited to replacement of existing bridges. Construction of any new bridges must be proposed by the trail foreman and approved by the SEKI Environmental Management Committee.

Bridge Construction - This section addresses construction of basic backcountry wooden stringer bridges of less than 50 feet in length. The components of a simple stringer bridge are the sill, 3 stringers, decking, bullrails, and handrails. The accompanying table gives dimensions required for given spans. Due to many variables, bridges in excess of 30 feet will be designed by the trail foreman for the specific site.

Timber for the construction of wooden stringer bridges is found near the bridge site. Solid standing trees are felled for stringers, sill logs, and other critical components. For bullrails and handrails, solid down trees may be located that are in satisfactory condition. Generally, for lack of a better choice, a variety of pine or cedar will be used. Lodgepole pine is the only material available at many higher elevation bridge sites. All trees will be peeled to prevent rot and moved to the site using the Olini chainsaw winch, grip hoist, timber carriers, and/or stock. Decking is either packed in or milled on site.

Wooden stringer bridges typically last from 10 to 30 years, depending on location and high-water conditions. Care must be taken in selection of trees at a bridge site so as to minimize thedeforestation of the site. It is tempting to select and to use

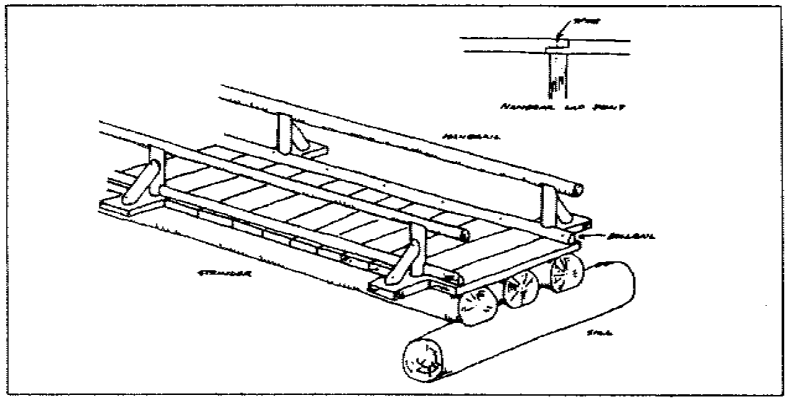
the timber nearest the site, but this may, over time, result in a denuded site which may possibly lead to increased erosion, and even a change in the river's alignment, not to mention the aesthetic impact. Select trees farther from the site if the haul to the site is practical and not too choked with obstacles. This problem of deforestation near bridge sites is one of the strongest arguments for use of non-native materials in bridge construction, such as aluminum or steel I-beam stringers and even bailey-type bridges. In many cases, they can be constructed to better avoid high water problems than wooden stringer designs and the materials are less susceptible to deterioration.

If a bridge has been washed out, carefully examine the site to determine why it was washed out and what, if any, improvements in site and location can be made to lengthen the lifespan of the replacement bridge. In particular, inspect the abutments, the river bank, and the sill logs for signs of slumping caused by scour eddies which may have undercut the bridge's support and alter the hydrology of the river. If evidence of scour eddies is found, a redesign or relocation of the abutments may be necessary. This should be done in consultation with the trail foreman.

If abutments are damaged, begin by repairing and reconstructing the abutments using solid drywall reconstruction techniques. Pay particular attention to joints so as to not provide points of purchase for the moving water to exert a destructive pressure on the rock. Stuff and pack the interior of the abutments with crushed rock. Less reliance on exterior chinking is necessary due to the action of the water, so joints must be tight and contact especially good. Take the time to shape the rocks with a single jack to achieve a tight fit.

If no abutments are required, the sill logs are set in the ground similar to those for puncheon, except that because of the greater weight of the structure and potential snowload, the sills must be far enough back from the streambank to be certain of solid, firm support and no possibility of bank collapse. Generally, the sill logs are buried with 2/3 of their diameter in the

Log Stringer Bridge



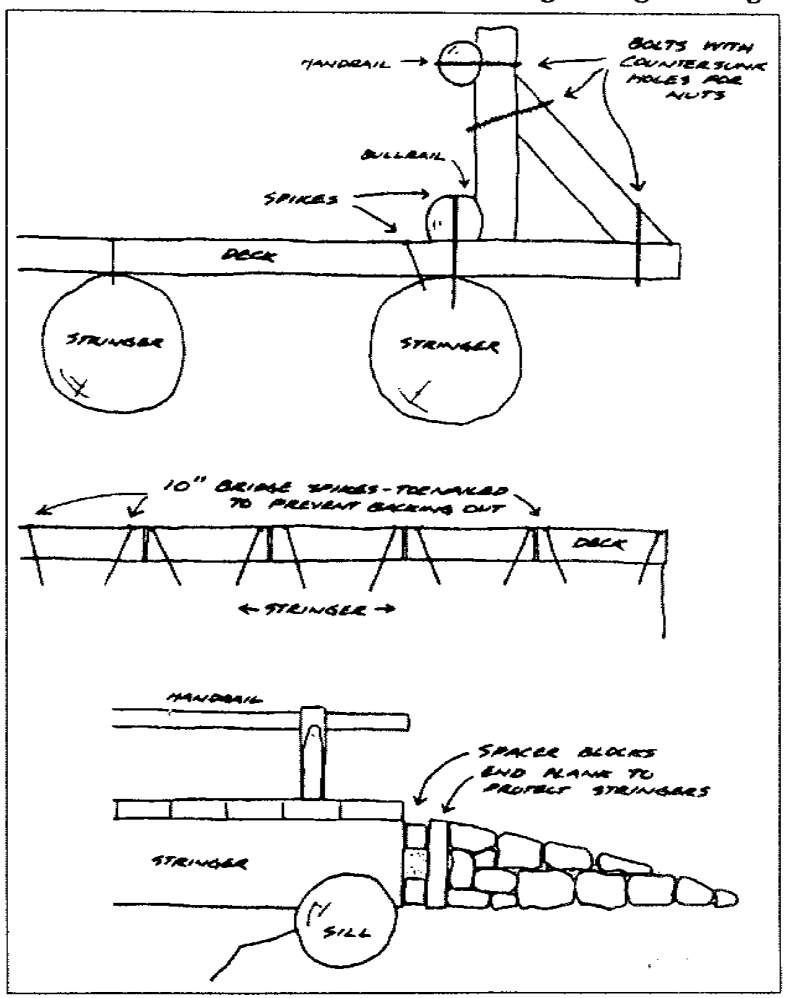
ground. Their length is from 8 to 10 feet depending on the length of the span or weight supported. Set them firmly into the bank on a bed of solid fill. If the sills are on solid rock or rock abutments, utilize pre-drilled holes to pin the sill logs with steel pins at least 1/2 inch in diameter.

The three stringers are selected according to the diameter specified in the accompanying table. Backcountry bridges need to be able to support a snowload of 150 to 300 pounds per cubic foot. Both the sill logs and stringers are saddle notched to assure a firm and solid fit. Notch the stringer only a minimum amount to gain a flat surface and cut any deep notches needed to level out the stringers in the sill logs only. If the stringer notches are deeper than 2 or 3 inches, the strength of the stringer will be adversely affected. Level the stringers and hew them of knots and swells to level their surface for placement of the deck. Spike the stringers to the sills using large bridge spikes 12 to 16 inches in length. Spike end planks and spacer blocks to the stringers to keep soil from the stringer ends and prevent rot.

The decking can be split or sawn planks at least 3 inches thick. The planks are either split or milled on site or commercially available pressure treated decking may be packed in. The decking is spiked to the outer stringers only using 8 to 14 inch

bridge spikes. Do not spike to the center stringer because the spikes may work themselves up and become obstacles on the deck. At points approximately every 10 feet along the deck where handrail posts will be set, a piece of decking 4 feet longer than the regular planks is centered to accommodate the handrail brace.

Log Stringer Bridge



Log Bridge Dimensions

Span	Sill		Stringer	Stringer Notch	
	Diameter	Length	Diameter*	Lodgepole, Ponderosa, Sugar Pines at 7000'	
				Depth	Strength Loss
10'	12"	8'	12"	2"	15%
20'	14"	8'	18"	2"	12%
30'	18"	9'	24"	2"	8%
40'	24"	10'	28"	3"	10%
50'	24"	10'	38"	3"	10%

*Dead load accounted for

Stringer Diameter = $\frac{\text{small end} \times 2 + \text{large end}}{3}$

**Dimensions are applicable for snow-loads up to 300 lbs/sq ft. at 50 ft

The bullrail is made from a log or logs with a minimum diameter of 6 inches. The bullrail logs are split or canted to provide a flat surface which will lay on the deck. If more than one log per side is used, they are joined with a lap joint. Spike or bolt the bullrails face down over the outer stringers using rebar spikes or bolts every 24 inches. Take care to maintain at least 5 feet of tread width if the bridge is for stock use.

Handrails are constructed from 6 inch diameter posts which are notched to fit the bullrail and bolted into both the bullrail and deck at points no greater than 10 feet apart along the bridge. The handrails must be at least 42 inches above deck level, and no more than 48 inches. A knee brace is installed to support the posts from the outside, being bolted to the wings of the longer planks of decking and notched and bolted to the post. The brace should meet the post at a point not lower than 24 inches above deck level. The handrails are made from one or more 6 to 8 inch diameter logs which are notched to sit firmly on top of the posts.

Use 8 to 10 inch spikes or bolts to attach the handrails to the posts. If more than one log per side is used for the handrail, join the rails with a lap joint over a post.

Countersink all bolted connections and use all-thread for bolted lengths greater than approximately 16 inches.

Abutments - If the riverbank is unstable and a firm footing for the sill logs cannot be found without increasing the length of the bridge to an unacceptable dimension, abutments will need to be constructed. Abutments will provide a stable footing where the bridge could potentially be threatened by the scouring action of the river on the unprotected bank.

Locate the best abutment sites in the area taking into account the potential effect of the abutments on the river's flow, the streambed composition and stability, the composition of the riverbank, trail access, and material availability. Abutments may protrude into the stream to some degree, however this may alter the flow of the river and the bank contour both upstream and downstream. Bedrock outcrops on the riverbank make an excellent footing for abutments. A small vertical wall constructed off of the bedrock may be all the major construction that is needed to complete the abutment.

An abutment is generally a three walled wood or rock crib filled with crushed rock and/or firmly packed coarse mineral soil. Construction is most feasible at low water. The footing for the abutments should be set at least 12 inches into the riverbed. Remove loose fill and excavate down to solid rock to lay either the bottom log of each crib wall or the foundation tier of rock. The face wall is laid parallel with the stream at a distance out from the bank appropriate for the bridge required. The upstream wall is laid at an angle of not more than 35 degrees from the line of the river's current flow. The downstream wall is laid at an angle of not more than 45 degrees from the line of the current flow. The walls are excavated and laid into the riverbank at least 36 inches to prevent washout.

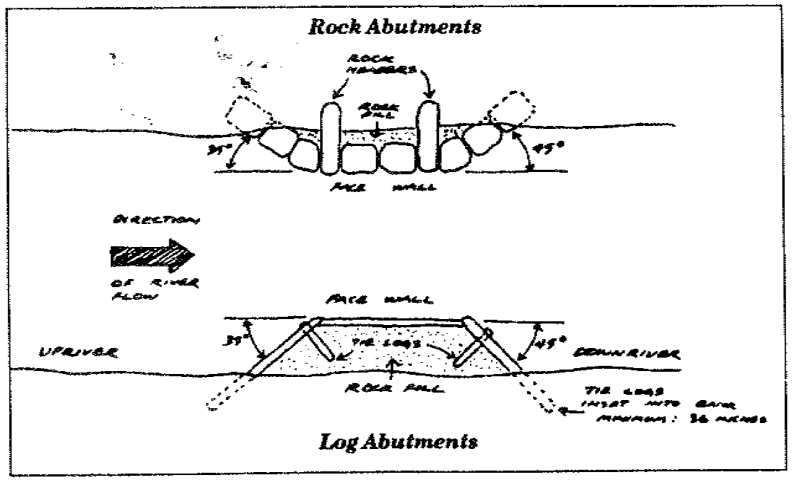
Once the bottom logs or foundation tier of rock is laid, construct the abutments so the bridge is at least 4 feet above the high water level of the river.

For log abutments, face logs are 8 to 14 inches in diameter and tie logs are 6 to 10 inches in diameter. Tie logs are staggered throughout the structure at a spacing of no greater than 6 feet apart. The tie logs and abutment corners are saddle notched and all notched joints are spiked, using 8 to 12 inch spikes.

For rock abutments, lay the rock in tiers with frequent headers, at least every 4 feet. Take extra time to select good shapes and further shape the rocks with singlejack and chisel to get as close contact between rocks as possible. Fill as you go and be certain that all voids within the abutment are solidly packed. Lay the top tier of cap rocks with large and heavy rock which cannot be washed out and have a good top face where needed to accommodate the sill log.

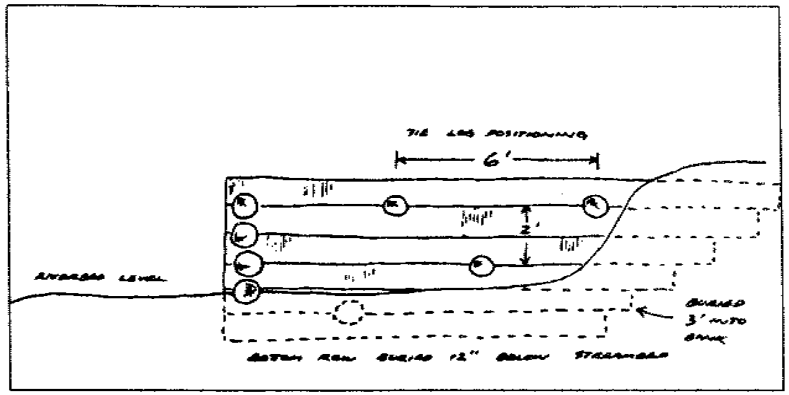
In some situations, mortar may be necessary to insure the strength and longevity of the rockwork due to extreme high seasonal runoff and the type of rock material available. Mortar will only be used with the approval of the trail foreman.

Bridge Abutments



Log Abutments

Log Abutment Profile



Approaches - If the trail does not meet the bridge at deck level, an approach will need to be constructed of logs or rock. Approaches are to be between 10 and 20% in grade. The tread can be compacted soil with step-ups or retainer bars, or riprap, with a minimum width equal to the width of the bridge deck.

Rock approaches are laid using basic drywall rock construction techniques with the forward portion of each tier of rock "locking" onto the tier below as the approach ramps up to the bridge deck.

Begin by digging out the footing for the walls at least 4 inches below surface level and laying the bottom tier of rock. Each tier above will be shorter than the tier below as the approach ramps up to the height of the bridge deck. Plan ahead for each ramped tier by laying a rock in the tier below which will "lock" the forward portion of each ramped tier in place. The lower rock needs to have some height above tier level in order that the outer edge rock of the tier above will set against it. Break your joints and use some headers in each tier, especially if rock retainer bars, step-ups, or riprap, are not going to be installed. Stuff and fill the section and chink the wall tight.

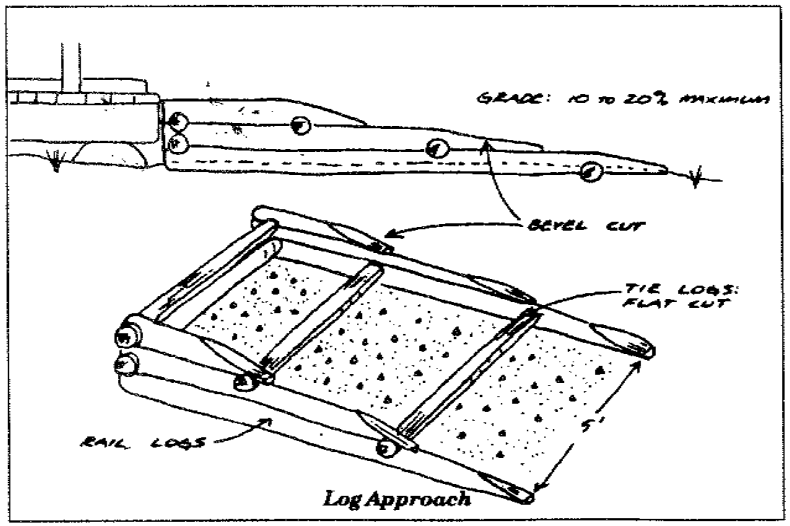
Lay the retainer bars or riprap in the approach tread using a string at average grade to determine their height. Begin

laying rock at the lowest point of the approach, stuffing and filling beneath the rock as you go. Lock the final tier of rock against the sill log or bridge deck at decking height and chink or backfill the entire section.

A log approach ramp consists of rail logs 8 or more inches in diameter and tie logs of 6 to 8 inches in diameter. The tie logs and rails are saddle notched together and spiked with 8 to 10 inch spikes. The upper side of any tie log within 6 inches of the finished tread surface should be hewn or sawn to produce a flat surface about 4 inches wide. Wire can also be used to tie the rail logs together similar to turnpike construction. Be certain the wire is only used in the lower sections of the approach wall and that it will be buried by at least 1 foot of fill. The ends of each tier of logs are bevel cut to conform to the slope of the ramped approach.

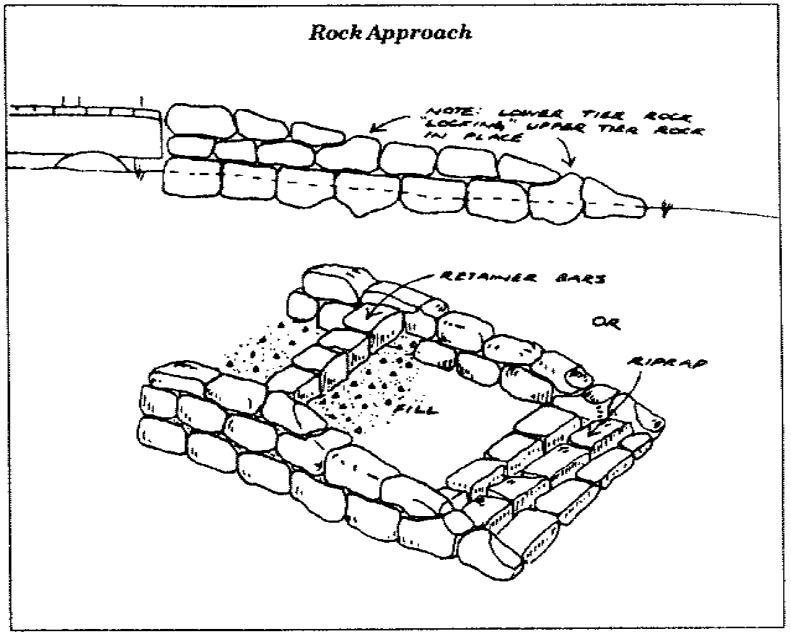
Piers - Piers are used to support a bridge structure in midspan. They can be either rock or wood and are constructed at lowest water by rechanneling the river around the pier site

Approach Ramps



Log Approach

Rock Approach



Approach Ramp Dimensions

Face Height	Length at Grade		
	10%	15%	20%
1'	10'	6.5'	5'
2'	20	13'	10'
3'	30'	20'	15'
4'	40'	26.5'	20'

Generally, piers are rarely constructed in the SEKI backcountry and any pier construction will only be undertaken with the approval of the Environmental Management Committee and under the direction of the trail foreman.

Drift Fences

Throughout the backcountry of Sequoia and Kings Canyon National Parks are drift fences used to control movement of stock. These wire fences with pole gates are located at the sites designated in the *Backcountry Management Plan.* The backcountry trail crews are presently responsible for maintenance and construction of the drift fences.

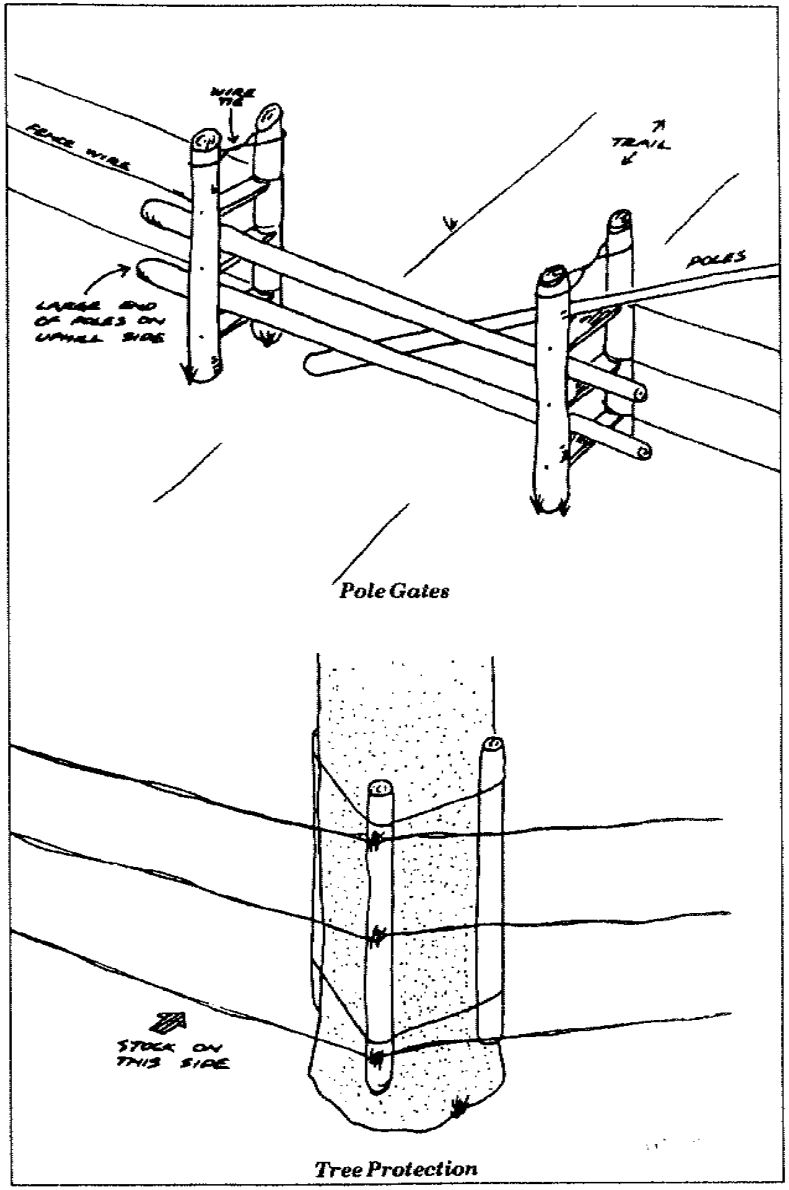
Fences are to be constructed using native materials for posts, 3 or 4 strands of "humane wire", fence staples, and pole gates. Occasional use of trees for corners or posts is acceptable. In addition to the basic backcountry crew's tool kit, specialized tools that may be needed for fence work are:

Additional fence pliers
Chain saw
Shovels
Rock bar, tamping bar
Fence puller, come-along
Humane wire, barbless, 1 roll equals 640 feet.
Barking spud

Old posts, if not of native materials (such as snow guides), are to be replaced and packed out as the fence is reconstructed. The posts were packed in, and they can be readily packed out. All snow guides and other non-native posts are to be removed from the backcountry.

Fences are to be located only as approved by the *Backcountry Management Plan,* but actual on-site location of each post and anchor is left to the careful consideration and best judgement of

Drift Fences



Pole Gates

Tree Protection

the crew. Be logical, minimize the use of trees, and protect the trees you do use. The shortest fence alignment is not always the best fence alignment, but the minimizing of both materials required and the impact of construction is a strong justification for a shorter fence. Use natural barriers in a fence whenever possible; large rocks, bedrock, talus or boulder fields, thick stands of trees, down trees, water, rivers, and swampy areas all can be used as barriers, making the constructed fence shorter, easier to build, and less obtrusive.

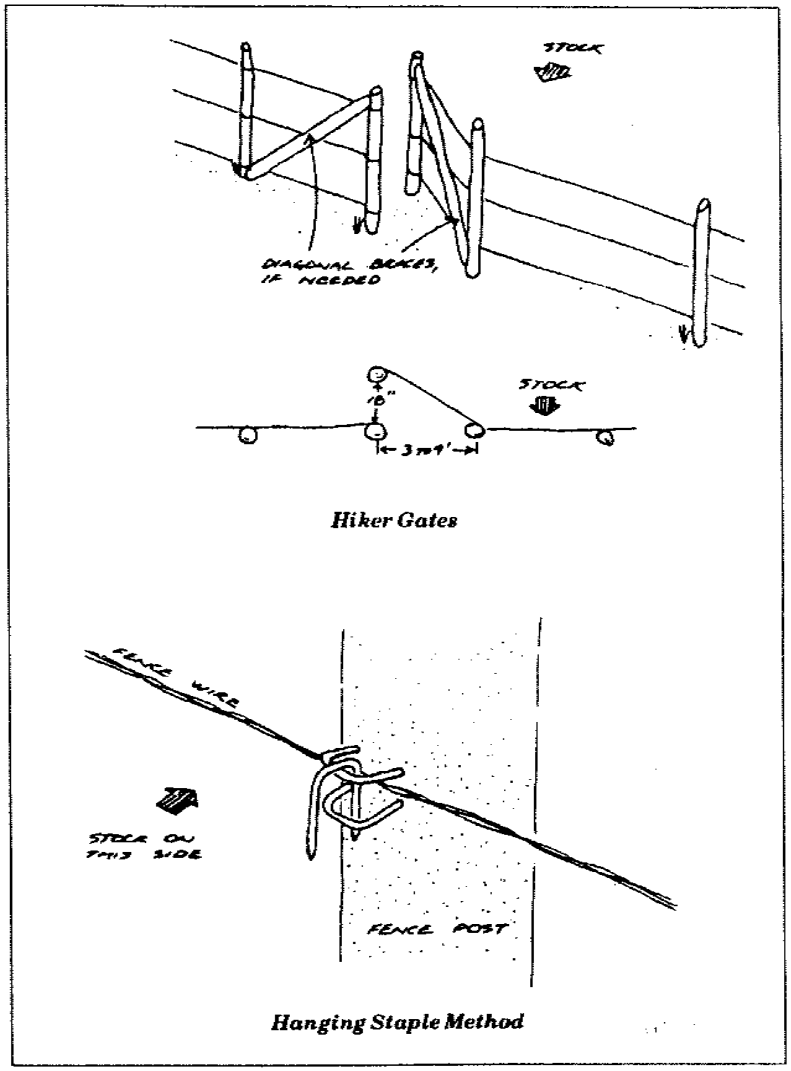
Fences should extend over water and into boulder fields to the point where you are sure stock cannot get around the fence. Do not stretch the fence wire too tight because the wire needs to be easily lowered in the fall and rehung in the spring with a minimum of tools.

The wire is always hung on the side of the fence that is to hold stock, so that it cannot be pushed off. The hanging staple method is the preferred method to attach wire to a backcountry fence because it allows the wire to be easily removed. Drive two staples into the post on either side of the wire and hang a staple through the two to lock the wire against the post. The wire can be easily dropped by removing the hanging staple. This practice adds considerably to the life of the fence. The removable staple is hung in its place on the fence post for the winter for use during the following season.

Replacement fence posts are to be of native trees or limbs found in the vicinity of the fence. Posts should be 4 to 8 inches in diameter and bark should be removed whenever possible. Posts should be buried at least 18 inches into the ground. Deeper is preferable. The posts are placed in the hole and dirt is solidly tamped around it using a tamping bar and a minimum of rock. Too much rock in the hole will make the post difficult to replace. If material for posts is sparse in the area of the fence, packing-in split cedar or other types of posts may be considered, but most likely the alignment chosen for the fence is too high in elevation and/or too conspicuous aesthetically if there is little timber available. Consider relocating the fence with the approval of the trail foreman.

Occasional use of a tree in the fenceline as a fencepost, especially a corner post, is often unavoidable and may add considerable strength to the fence. As long as the tree is protected, live trees may occasionally be used as fence posts.

Drift Fences



Hiker Gates

Hanging Staple Method

First, the number of trees used must not be excessive, never exceeding 1 in 4, averaged over the length of the fence. The use of trees must especially be limited in areas close to and seen from the trail.

Most importantly, the tree must be protected from damage from the wires and staples. The most simple and effective way to do this is to use a minimum of 3 fencepost diameter poles or limbs and 2 or 3 hoops of fence wire secured loosely around the tree. Space the poles around the tree and tighten the wire just enough to hold the poles in place, allowing room to adjust the poles and for the tree to grow. Take care to adjust the poles so that the wire never touches the tree. If after adjustment, the wire still touches the tree, add more poles. Pound the hanging staples into the poles, never the tree.

Pole Gates - Several different styles of gates have been used in the backcountry in the past, including swing gates, wire gates, and pole gates. As the fences and gates are reconstructed, all gates are to be replaced by pole gates as approved by the *Backcountry Management Plan.*

A pole gates consists of 2 pairs of posts set stoutly into the ground on either side of the trail. Between the posts are a series of 2 or 3 blocks spiked and wired to the posts. These blocks are used to support the poles of the gate. To open the gate, the poles are slid individually through the downhill pair of posts.

To construct a pole gate, select four posts about 6 to 8 inches in diameter, about 6 or 7 feet long. Peel the bark with a barking spud. Sink the posts at least 18 inches into the ground on both sides of the trail, at least 6 feet apart. Set two posts on each side of the trail, about 10 to 12 inches apart, in line with the trail as illustrated.

Pack and tamp rock around the posts to solidify the structure, as you would for any fence post. Cut the posts off at about 4 or 5 feet above ground level. Next cut notches in the posts on the inside with a chain saw where the blocks are to be inserted. These blocks are located at the level of the strands of wire in the fence. Cut the blocks from split or halved post scraps or smaller diameter limbs. Insert these blocks between the posts and drive

spikes, if available, through the posts into the blocks. Add loops of fence wire and pull the entire structure together by twisting the wire.

Select poles for the gate from straight, young trees, preferably dead and dry. Cut the trees about 3 or 4 feet longer than the gate opening and peel the bark. Place the poles in the gate by resting them on the blocks between the posts. Always put the larger end of the pole uphill to minimize the chance of it sliding downhill and out when the gate is opened.

Cut a shallow notch in one end of each pole if desired. This notch will catch the pole at the best position when the gate is closed.

Hiker Gates - In areas where the number of hikers passing through a drift fence gate is large or where there has been a problem with the stock gate being left open, installation of a hiker gate may be considered. A hiker gate is really not a gate at all, it is an opening in the drift fence which allows a hiker to pass through, but it is too tight for stock. The gate location is typically adjacent to the pole stock gate along the alignment of the drift fence. The installation of both a pole gate and a hiker gate at the same location requires at least 18 feet of open, nearly flat space along the fence line. The best locations for both gates are usually in open forested areas; many rocky drift fence locations simply do not have the space.

The hiker gate consists of three 4 to 6 inch diameter posts placed stoutly into the ground so that they are at least 42 and not more than 48 inches in height. Each post should be set in the ground at least 18 inches, preferably more, and be packed with rock around its base. The configuration of the three posts is basically a right triangle, with the hiker opening being perpendicular to the fence alignment, as shown in the illustration. This opening is no more than 18 inches, which is a tight fit for a hiker with backpack, but will not allow for the passage of drifting stock. The base of the triangle, or the portion in alignment with the fence, is 3 to 4 feet in width. The two posts on either side of

the hiker opening are essentially end posts for the fence and may need extra support in the form of diagonal braces from the top of the gate posts back along the fence alignment to the base of the next fence posts. These diagonals should also be 4 to 6 inches in diameter and are spiked to the shallowly notched fence posts using 6 inch spikes.

The opening portion of the gate perpendicular to the fence is always constructed into the area which is to hold stock, usually the up-canyon side of a drift fence. If the gate were to be built the other way, with the opening on the down-canyon side, the gate would function like a squeeze chute and could permit stock to pass through.

IN CONCLUSION

The problems encountered on the backcountry trail system are many and varied. No two problems are exactly alike and no two trailwork solutions are exactly alike. Presented in this *Trail Handbook* are methods and techniques for solving the basic kinds of problems encountered on the backcountry trails of Sequoia and Kings Canyon National Parks. Trailworkers are encouraged to study and implement these methods, then discuss them, refine them, and improve upon them. These methods and techniques are not the final word on trailwork, but rather a set of guidelines with which to begin to construct, and reconstruct, the backcountry trail system. These guidelines are not constraints, limiting what can be done, but rather basic, proven steps with which to begin the solution of trail problems. There remains plenty of room for creativity and self-fulfillment in trailwork.

Comments, suggestions, and criticism are encouraged, preferably written. Many topics may need elaboration and further discussion or illustration, and other subjects may be eliminated or added. All who use this handbook are encouraged to use it critically and then are challenged to improve upon what is presented here, in order that all may benefit.

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Good luck finding the perfect rock. I think I've found about three so far.

Steve

Stephen Griswold