Course 302. Drainage Crossings

The PCT and its feeder trails cross water courses of every conceivable size and type. Because bridges are time consuming and expensive, whenever possible it is better to build simpler structures that are more durable. Learn to build and maintain two to three of the following: fords, stepping stones, culverts, French drains, armored swales, and step down drains. If you enjoy working in water, this is the course for you! Pre-requisites: 201 through 205 and 300.

STUDENT SKILL OUTCOMES:

- Ability to evaluate watersheds for likely water flows
- Ability to choose the right structure for each drainage crossing.
- Practice quarrying, transporting, and installing rock safely.
- Construction experience with at least two of the following: ford, stepping stones, culvert, step-down drain, French drain, or armored swale.

KEY TERMS:

ford, stepping stones, culvert, step-down drain, armored swale, Wilderness, watershed, mineral soil, inside ditch, pressure-treated wood

TRAIL MAXIMS:

"Get the water across the trail or the trail across the water." "If you're gonna do it, do it right."

TOOLS NEEDED (PER 8 STUDENTS):

(depends on the projects selected) 2 fire shovels, 1 McLeod, 1 adze hoe, 1 Pulaskis, 2 pick mattocks, 2 small chisel-tipped rock bars, 4 five-gallon buckets or canvas dirt bags, 1 heavy sledge hammer, 1 light sledge, rock stretcher &/or rock sling (if available), a wheel barrow (if outside wilderness), crosscut or chain saw and related safety equipment, 2 log carriers or slings, rubber boots &/or waders, 2' level (for culvert installation).

MATERIALS NEEDED:

40 pin flags, 4-11" x 17" photocopies of detailed topographic maps showing the entire watershed. For log projects: 10" spikes, and brace and bit to pre-drill holes. For pipe culvert projects: plastic or aluminum culvert of diameter and length to fit the crossing.

WORK SITE REQUIREMENTS:

Section of trail needing a variety of drainage crossings, ideally with several already in place. Replacement of a bridge or pipe culvert in Wilderness with a ford or armored swale can make a fine project; if local managers agree (the bridge would need to be removed in advance or the ford in a different location). Ideally such work is near a trailhead, with nearby rocks and logs suitable for building the needed structures. If possible, the trail should allow horses, to emphasize the importance of building solid structures.

KEY CONCEPTS:

1) Safety Documents: Pre-trail work paperwork:
   - Personal Protective Equipment (PPE), Job Hazard Analysis (JHA), Tailgate Safety Session (TSS), Emergency Action Plan (EAP)
2) Principles of Drainage Crossings:
   - Consult local managers about their preferences
   - Assess carefully if a structure is needed
   - Analyze the watershed to choose the best crossing solution
   - Simpler solutions are generally better
   - Understand working in Wilderness: Keep it Wild!
   - Structures built with rock are usually better than wood
   - Understand use of pressure-treated wood: ground and water contact-rated
   - Work when conditions are dry, but know how wet it gets
3) Fords:
   - Best locations are in straight channel with shallow, slow water and solid even base; build only what is needed
   - Gradual non-eroding entrance designed to prevent high water from flowing down the

trail
   - Stepping stones needed?
   - Clear out debris washed in or placed by users
4) Step-down Drains:
   - Use big well-fitted rocks that can withstand horses and water flow
   - Bottom must be solid and not too deep
5) Armored Swales:
   - To harden natural or constructed drainage crossings of modest size
   - Sufficient rock to withstand amount of water and horse traffic
6) Culverts:
   - Made of pipe, rock, logs, or lumber (possibly pressure-treated)
   - Handle more water, but not floods, if sized correctly
   - Pipes faced with rock, all have 6” cap of compacted dirt
   - Wood culverts are best capped with pressure-treated to slow rot
7) Place large guide rocks at entrance to drainage crossings wherever needed to keep users (especially horses) in the middle of the trail.
8) An inside ditch can collect several seeps to one drainage crossing.

BACKGROUND

Building durable drainage crossings can be very gratifying trail work. When done skillfully, with patience, care, and hard work, it is possible to build structures that will serve the trail for many years.

Drainage crossings must be matched to the ***watershed*** they traverse. Before beginning work on drainage crossings, it is essential to assess the source of the water that crosses the trail. A seep or spring-fed stream that fluctuates only slightly throughout the year can utilize a wide range of crossing solutions. A stream fed by a larger watershed that is prone to annual high water and occasional flooding requires a much more durable solution. Local managers usually have access to hydrologists and also have their preferred types of drainage crossing structures, appropriate for their area -- thus they should be consulted.

Most important of all, be sure that a drainage crossing structure is needed at all. If a stream runs only briefly when few trail users are present, and it is not eroding significantly, better to put efforts into higher priority crossings.

In general, the simplest drainage crossing structure that will be effective is the best choice. Complex solutions simply have more ways to fail and generally need more maintenance. For example, a well-built ***armored swale*** is likely to last longer and require less maintenance than a ***culvert*** or ***step-down drain***. Similarly, a bridge is much more likely to fail than ***stepping stones***, which in turn are more likely to fail than a simple ***ford*** without stepping stones.

Beyond a bias for simplicity, rock drainage crossings, if built skillfully with large rocks, generally are better than those built with logs, both for durability and reduced slipping hazards. Especially log culverts, when they inevitably begin to rot, can be extremely hazardous for horses punching a hoof through. Of course, if neither suitable rock nor skilled labor is available, then wood is the better choice, if a structure must be built. When a wood structure is built, judicious use of ***pressure-treated wood*** rated for ground contact can be a prudent decision, if local managers approve. Note: logs that stay wet year round can last a very long time, though become slippery. Logs that go back and forth from wet to dry, especially when in contact with dirt, will rot very quickly, unless from very special rot-resistant tree species. All wood is vulnerable to abrasion by horse hooves so high horse traffic warrants consideration.

The easiest time to work on drainage crossings is when they are at low water or dry. However, it is essential to have seen the project area when the water was high so the full scope of the problem and force of the water is clearly understood. It is generally impossible to work when the water is high, though with special effort and equipment it may be possible to work at moderate water levels. Waders, tall rubber boots, wet suits, and fly fishing boots are the sorts of extra items essential for working with higher water. Extreme water situations will require additional safety systems but are unlikely to be tackled by volunteers.

Drainage Crossings in Wilderness: ***Wilderness*** areas are to be managed constructing only the fewest structures necessary to protect wilderness resources from degradation, such as clean water, vegetation, and fish habitat. User convenience is of little relevance and, except for extreme danger; user safety is generally of lesser concern, as Wilderness areas are set aside to provide challenge and adventure for users.

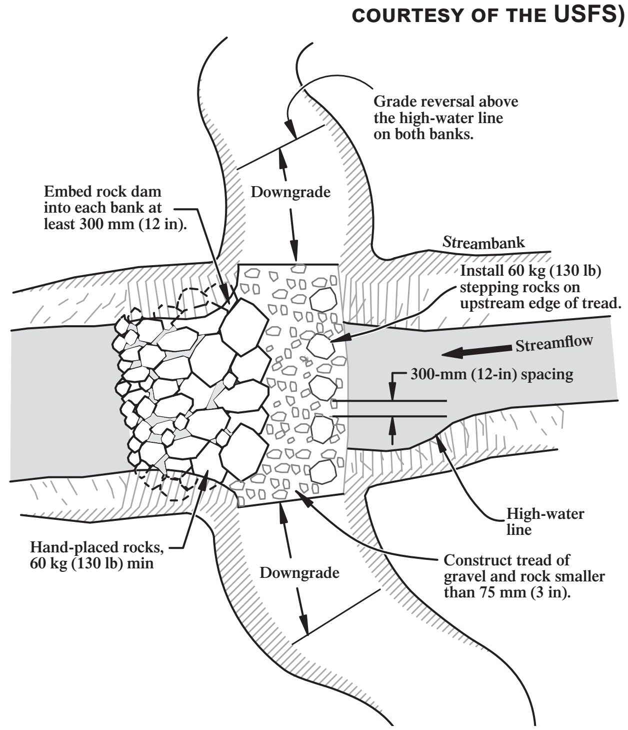
Thus, some Wilderness managers are eager to remove inappropriate bridges, replacing them with simpler drainage crossings such as fords and armored swales. Most Wilderness managers also prefer not to utilize metal or plastic pipe culverts, because of their unnatural appearance. Thus, some managers will request the removal of existing pipe culverts and replacement with more natural drainage crossings. If culverts are utilized in Wilderness they must be invisible to the trail user, well covered by large rocks and mineral soil. Alternatives include step-down drains and wood or rock culverts.

Be sure to consult local managers about their preferences. More can be read about the topic of “Minimum Requirements Analysis” and “Minimum Tool Philosophy” in Wilderness at http://www.wilderness.net/MRDG/ and http://www.fhwa.dot.gov/environment/fspubs/07232806/page11.htm

Fords & Stepping Stones: Ideally, fords are located in straight and shallow sections of streams with a solid and even gravel bottom. A big plus is minimal need to cut a steep ramp through a high bank to the water’s edge, though there must be enough ramp up to keep high water from flowing down the trail. If it is an option, consider moving the trail to the best suitable location. More likely, a crew must simply make improvements at an existing trail crossing doing the best they can with the situation. Consult local managers about what options there are for ford relocation and stream disturbance. Local fishery and other ecological issues may preclude some choices.

Ideally, the ramp down to the creek is less than 15% grade and through durable substrate that can handle stock traffic with minimal sediment entering the stream. However, we often contend with sub-optimal conditions: grades need to be steeper, and the substrate can be muddy. If such is the case, log or rock steps may need to be built into the banks to reduce erosion of sediment into the stream. Mud may need to be removed and replaced with ***tread hardened*** with a fitted rock foundation and stream gravel on top. Any steps built must be sturdy enough to withstand yearly high water and occasional moderate floods.

Figure 1. Elaborate ford design for a steep gradient stream (fast flowing). Many fords require less manipulation, as long as the stream is not too fast and the bottom is relatively uniform and solid. (Image courtesy of the USFS)



There are many different techniques for building fords. (Consult local agency partners if there is a question as the preferred ford for your local soil conditions.) Some prefer to build a rock or log dam to slow fast moving deep water, as shown in the diagram below. That is a major undertaking and should only be done if absolutely necessary. At all fords, remove any logs that users might have tried to install across the streams. They dam the water causing it to widen the channel by eroding banks. This can be an on-going struggle. In Wilderness areas especially, users are expected to be willing to get their feet wet.

If local managers agree, large rocks are available, and the stream is shallow, setting stepping stones across a ford may be a reasonable choice. Obviously, such stones need to be large and stable enough to withstand high water flows. Spring-fed streams and those with small watersheds above the crossing are better choices for stepping stones. Steams that flood regularly are likely to wash away any stepping stones placed by a crew.

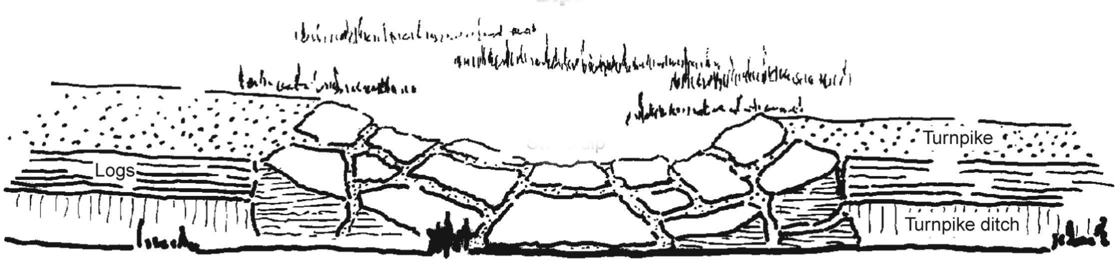
Figure 2. Fords should be established in a straight and shallow section of a stream. Approaches must climb above the high-water line to prevent water from running down the trail. Note the armored entrance/exit ramp into the ford, constructed of rock and gravel. (Image courtesy of the USFS)

On trails open to stock, stepping stones must be placed upstream of the main crossing to allow a clear path for the stock animals. The bottom of the stream should be manipulated to set the stones well, but may not be allowed by some managers in critical habitat. Stepping stones should be set as far apart as possible to allow water to flow easily between them -- 12- 24” gaps. A dam is NOT the goal, as it will back up the water and force it around the edges, thus eroding the banks. Users are likely to add more rocks and logs, which will need to be cleared out regularly.

Step-Down Drains: Where suitable rocks are available, step down drains can be a good choice for seeps, small springs and intermittent streams that cross the trail. Rocks must be large enough and deeply set to withstand horse traffic. While step-down drains can be built from logs or dimensional lumber, it is not recommended because they become slippery and horse hooves and rot will make quick work of them. The drop down into the bottom of the drain should be no more than 10”.

One style is to make the drain’s width less than 2’ so that it can be stepped over easily by both hikers and horses, without stepping down into the drain. However, others prefer to make the drain 4’ or more across the bottom, so that a string of horses can step down into it and walk through it easily. It is important not to build something that a horse must jump over, potentially throwing a rider or causing a pack string “wreck”. Such a wider drain must have a solid bottom, either large stable rocks or firm gravel, to support horses stepping into the bottom.

Figure 3. Excavated armoured swales can serve as drainage crossings for turnpikes and inside ditches (Image courtesy of FHWA)



Armored Swales: ***Swales*** are a type of ***grade reversal*** designed into a trail to shed water by contouring down through a small natural drainage. In some cases they are excavated to pass water through a ***turnpike*** or across a trail from an ***inside ditch***. In all cases, if erosion or mud is a problem, the swale should be ***armored*** (hardened) with large deeply-set fitted rocks. The greater the horse traffic or higher the water flow, the sturdier the armoring must be. Fast water requires inclusion of a downstream rock apron to prevent back cutting.

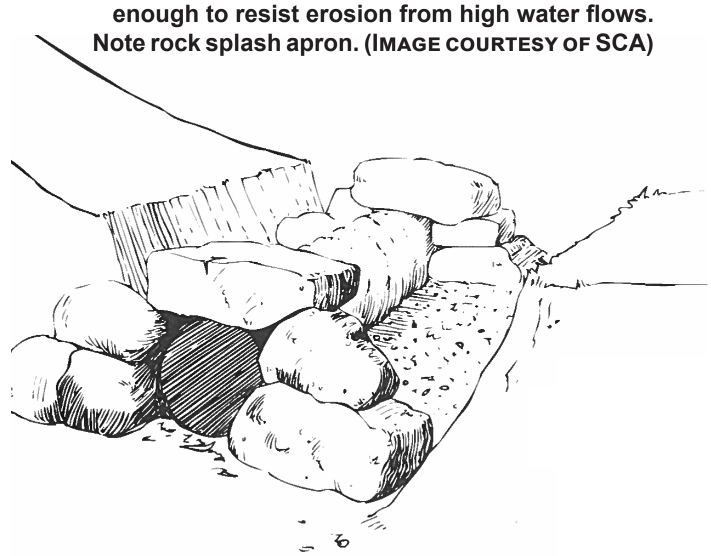
French Drains: Named for Henry French, a 19th century American who introduced them from Europe, ***French drains*** are elaborate structures today used in building and landscape construction to carry away excess surface and ground water. They are adapted to trail work in areas with seeps and other ground water issues that cause muddy areas. In their simplest form French drains are simply an excavated trench sloping across a muddy section of trail that is completely filled with rocks (gravel to fist sized) to wick away water. The bottom of the trench can be underlain with flat rocks, drain tile, or perforated drain pipe. In some cases the complete contents of the trench are wrapped in ***geotextile*** to prevent silt penetrating (which would reduce the ability of the rock to carry away water). For details see Wetland Trail Design and Construction, 2007, http://www.fhwa.dot.gov/environment/fspubs/07232804/page05a.htm or search "French drains, trail work."

Culverts: Culverts are used commonly to carry water across trails, offering the advantage of keeping the tread on fairly level ground (not dropping down to the level of the stream). They can be built in various sizes, though to avoid being blown out by high water; they are best used for seeps, springs, and very small or intermittent streams.

The opening diameter/width of culverts, whether built with pipe, rock, log, or lumber must be large enough to accommodate the usual high flows of the drainage. Culverts are NOT a good choice for creeks that flood, as they will be washed out. It is essential to understand the hydrology of a watercourse before deciding whether it is sensible to build a culvert.

The base of a culvert, if possible, should have a grade slightly greater than the stream bed, so that water accelerates passing through it. This reduces sediment build up inside the culvert. Some builders create a basin just before the opening as catchment for debris and sediment, in hopes of discouraging clogging of the culvert itself. Regardless, culverts need to be cleaned periodically to keep them open, especially after high water events that often clog culverts with debris and sediment.

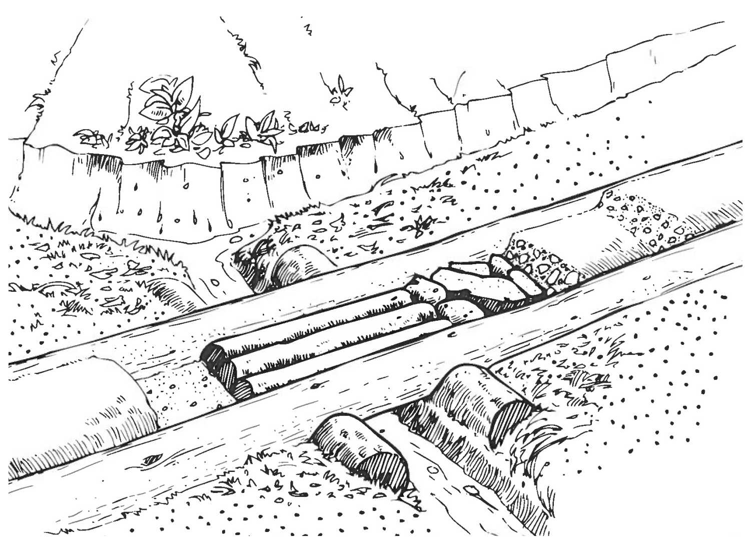
Figure 4. The exposed end of a pipe culvert is shielded from view with rock facing that is stout enough to resist erosion from high water flows. Note rock splash apron. (Image courtesy of SCA)



Pipe culverts must be at least 2' wider than the tread so that the ends can be obscured with rock facing. A rock apron should be built at the downstream end of the culvert if the pipe drops into a place that will be eroded by high water. Culverts must be sized and set low enough to allow a 6" cap of crushed rock and compacted ***mineral soil*** for the tread surface. In some cases multiple smaller pipes are required instead of one large pipe.

Wood culverts can be built of either native logs or pressure-treated poles (or pressure-treated lumber). Pressure-treated is a good choice for beneath the tread to extend its life and reduce the likelihood of a horse hoof breaking through a rotted wood culvert top. Any pressure-treated in contact with the water should be of a type least toxic to aquatic life -- such standards are regularly revised, so check with agency staff. There are numerous designs for lumber culverts; several can be seen at http://www.fhwa.dot.gov/environment/fspubs/07232804/page05a.htm

Figure 5. A log culvert is covered with six inches of compacted mineral soil or gravel. If allowed by managers, under the soil cap utilize ground contact-rated pressure-treated poles or lumber, to reduce rot. Notice at left an inside ditch. (Image courtesy of SCA)



Final Notes: When a trail has been cut into a hillside that reveals numerous seeps close together, rather than build a drainage crossing for each seep, it can make sense to excavate an inside ditch. Dug on the uphill side of the trail, it collects water from several seeps and directs it to a single drainage crossing.

Lastly, all drainage crossings may require installation of ***guide rocks*** to insure the trail users pass through the middle of, and do not avoid, any structures built.

Be sure to review Course 300 Intro to Rock Work if you need a brush up on rock skills and safety concerns.

TEACHING TIPS & TECHNIQUES

Most course locations will present only a few options for construction of various types of drainage crossings. At any rate, choose work sites that present the most typical kinds of water crossings that students need to learn about for working on their stretch of the PCT.

Review the concept of watersheds and demonstrate how to outline one on a topographic map. Have teams of two examine the topographic map copies for the day’s work area and draw a line around the watershed for a stream. Then have them do the same thing for a small side stream.

Walk a section of trail with a variety of existing drainage crossing structures, discussing each (be sure to point out any swales, whether armored or not.) Discuss whether structures are: functioning well; sturdy enough for their watershed and traffic; and how they might be improved.

Next, have each team of two examine a drainage crossing that might need a structure. Have them evaluate and then report to the group about: 1) the size and nature of the watershed; 2) why or why not the crossing warrants a structure; 3) and describe what type of structure might be most appropriate. Have them use pin flags to outline the scope of the project. Have them also describe the type and source of materials, how to transport them, and steps in the construction.

Then have them begin work, either teams working on their respective projects, or working in larger teams the most relevant drainage crossings.
Have students work in teams of two to four to build at least one successful drainage crossing. If a major stream ford is tackled, divide the crew into teams to work on either side and in the water.

Supervise closely to be sure that materials are large enough and of an appropriate type. Encourage students to find and flag a few candidate rocks and have an instructor evaluate them before they are transported to the trail. Use a similar approach to construction of the crossing. It is essential that students do good work, or they will be wasting their own and future crews’ time. A poorly built drainage crossing may only take an hour or two to build, but it might not last even a few years. A well built crossing may take a day or more to build, but should last a lifetime. Surely an extra few hours is worth that extended life.

Ask students to redo their work if it is unsatisfactory; though try to catch it early to minimize frustration. Remember the test for every rock placement: dance a jig on it and be sure it does not move AT ALL.

Trail Eyes: The ability to see where to locate and decide what type of drainage crossing is needed is an acquired and essential art. The last thing we want is to spend several hours or days of hard labor finding, transporting and placing the perfect rocks, only to realize they are in the wrong location or for an inappropriate kind of drainage crossing.

Quality Work: We use rock because it can last “forever”, but ONLY IF we build it right. Poor quality rock work will fail faster than wood rots, especially with horses on the PCT. “If you’re gonna do it, do it right.”

Safety Awareness: Working with rock is potentially dangerous. Careless workers regularly crush fingers, hands and toes. Strained or severely injured knees and backs are much too common. STRESS the importance of doing everything slowly and carefully with rock, to avoid injuries.

TRAIL FUN

For a fun wrap-up do a fast-paced “Jeopardy”-style quiz based on the KEY CONCEPTS.

REFERENCES

Lightly on the Land: The SCA Trail Building and Maintenance Manual. 2005. Robert Birkby. The Student Conservation Association and Mountaineers Books. Chapter 11, “Trail Drainage”, pp. 165-168 covers drainage crossing structures. See sections of this book at http://books.google.com/books?id=xD6ThtJNgLkC&printsec=frontcover&dq=Lightly+on+the+Land#

OSI Trail Skill Series. Outdoor Stewardship Institute, a program of Volunteers for Outdoor Colorado. 2009. Based in Colorado, VOC has developed some excellent materials on drainage crossings. www.voc.org

Trail Construction and Maintenance Notebook. 2007. Woody Hesselbarth. USDA Forest Service. See especially section on “Crossing Streams” pp. 89-95 at http://www.fhwa.dot.gov/environment/fspubs/07232806/page11.htm . A free copy can be ordered at: http://www.fhwa.dot.gov/environment/rectrails/trailpub.htm

Trail Solutions: IMBA’s Guide to Building Sweet Singletrack. 2004. An excellent book with section on rock armoring. While the PCT is not open to bikes, many of the rock techniques needed to stand up to horses are the similar.

Wetland Trail Design and Construction. 2007. Federal Highway Administration. http://www.fhwa.dot.gov/environment/fspubs/07232804/page05a.htm

PCTA Trail Skills College Curriculum

Field Reference

Course 302. Drainage Crossings

STUDENT SKILL OUTCOMES:

- Ability to evaluate watersheds for likely water flows
- Ability to choose the right structure for each drainage crossing.
- Practice quarrying, transporting, and installing rock safely.
- Construction experience with at least two of the following: ford, stepping stones, culvert, step-down drain, French drain, or armored swale.

KEY TERMS:

Ford: a wet crossing of a flowing water, ideally at a wide shallow place with a firm base. May be only for horses, with stepping stones or a small bridge for hikers, or in Wilderness for hikers and horses.

Stepping Stone: carefully selected and places large stones that allow hikers to safely cross a stream by stepping from one stable surface to the next. Usually in conjunction with a horse ford.

Culvert: a closed passage under a trail (or road) for water. Can be made using metal or plastic pipe, or constructed of rock, lumber, or logs.

Step-Down Drain: (aka curbed stone channel or open drain) an open drainage structure made of log or rock that allows trail users to either step down into a small stream crossing or simply step over it if small enough.

Armored Swale: (aka armored grade dip, armored dip, stone dip) a natural channel or excavated depression in a trail that has been hardened with rock or (rarely) wood. See also swale and rock armoring.

Wilderness: with a capital W refers to named Federal lands designated by the U.S. Congress under the Wilderness Act of 1964. They may be designated within any category of Federal public land, such as Forest Service, BLM, or Park Service, though management regulations may vary slightly among them. Much of the PCT passes through such Wilderness areas. Most important to trail workers, motorized tools and mechanized transport such as chainsaws, wheel barrows, and bicycles are prohibited, unless a waiver is obtained from land managers (generally not easily granted). Signs in Wilderness intentionally provide less information, to require more skill of their visitors. Group sizes, including volunteer trail crews, are usually limited to no more than 12 people. Heavily used areas such as alpine lakes may have additional regulations such as no campfires. More can be read about the topic of "Minimum Requirements" and "Minimum Tool Analysis" in Wilderness at http://www.wilderness.net/MRDG/. Small w wilderness generally refers to any remote area largely undisturbed by motorized vehicles. If not designated by Congress, such areas usually do not limit group sizes or use of mechanized equipment, though may have some interim management restrictions to protect the potential for future designation as Wilderness.

Watershed: (aka hydrological system) the ridge-top to valley bottom landscape from which all the water of a stream originates. Such water originates as rain and melting snow, both running over the land and as ground water. Climate, geology, soils, and vegetation of a given watershed all influence running water including seeps, springs, and streams. Trail workers must understand the particular watershed that leads to a drainage crossing for which a structure is contemplated. Any structure must be designed to accommodate fluctuations in water levels, especially high water.

Mineral Soil: dirt than includes little or no organic material, ideal for trail tread and fill. Ideally it is a mix of grain sizes including sand and small gravel so that it drains well. 100% clay is not a good choice.

Inside Ditch: (aka wing ditch) a ditch running along the inside edge of an insloped section of trail tread. It carries water from seeps in the back slope to a drainage structure (such as a culvert) to carry it across and off the trail.

Pressure-treated Wood (posts & lumber): (aka PT) round logs and dimensional lumber that has been through an industrial process to penetrate the wood with chemicals to prevent rot and thereby extend the useful life of the post. For trail work material rated for "ground contact" must be used. Industry standards claim such materials will last 50 years, whereas most untreated wood lasts only 5-10 years in contact with dirt. Some native materials, such as juniper or locust, can last considerably longer because of naturally occurring chemicals in their fibers. Native wood can also be hand-treated (usually only the portion in the ground) with a preservative such as Copper Napthenate.

KEY CONCEPTS:

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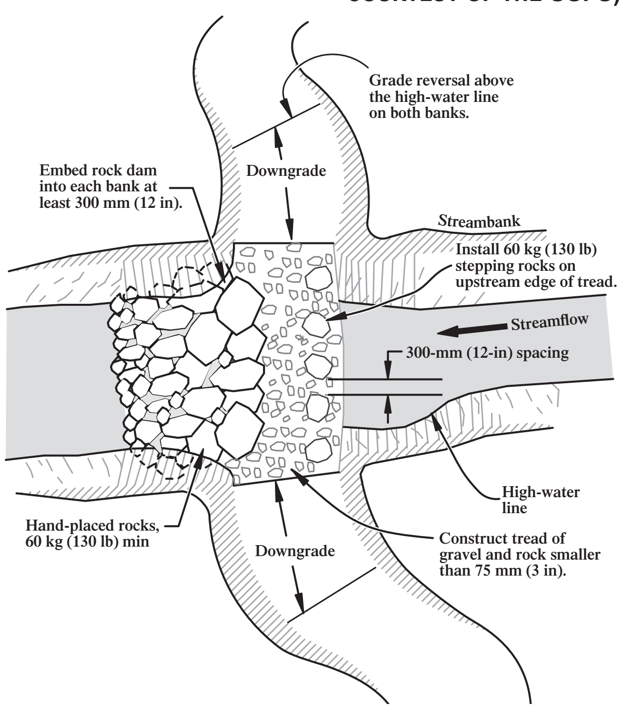

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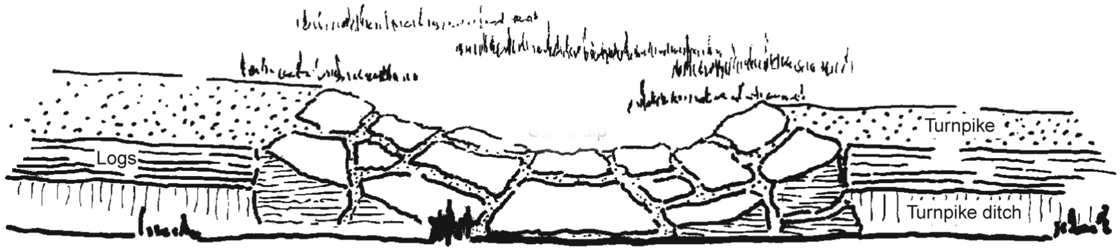

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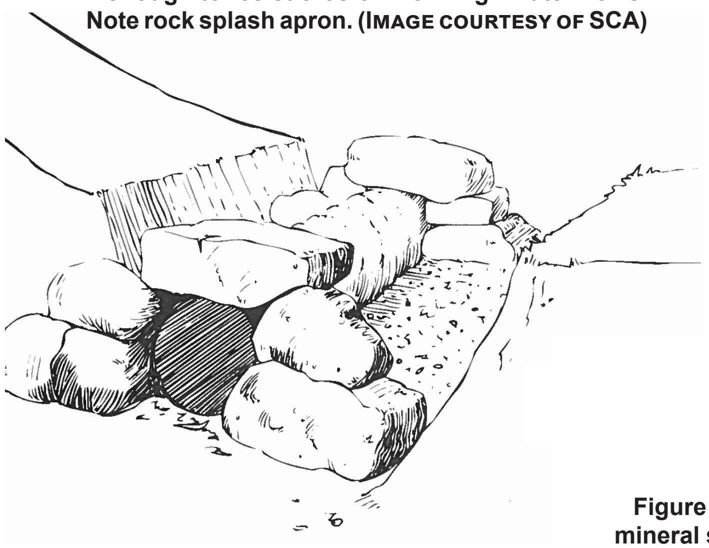

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