Figures

Photos

Chapter 26. Drainage and Structure Maintenance

Maintenance of trail drainage features and associated structures ensures that water flows in a non-destructive manner across, under, and through the trail and trail structures.

26.1. Understanding Water Flow

Water can cause significant damage to a trail and its features and is a major factor to anticipate during trail layout and design. The potential for water-related damage is greatest when it is overlooked. Because rain and snow are normally seasonal and event-related, their destructive power is unnoticed during dry periods when most trail work takes place. Maintaining proper drainage must be considered throughout the year and during all trail maintenance and construction activities.

Water that reaches a trail comes from a variety of hydrological processes. (See Chapter 5, *Principles of Trail Layout and Design*, and Chapter 14, *Drainage Structures.*) Many drainage problems are due to poor layout, design, and construction. Problems occur when the trail interrupts or alters the natural drainage flow of a landform. Trail designs and structures intended to manage or control water have a high probability for failure and require regular and timely maintenance. These trails can collect and convey runoff from sheet, spring, ephemeral, and stream flows. Once water is captured by the trail, the tread becomes muddy, soil is eroded, and the trail becomes entrenched, taking on the characteristics of a stream channel. (See Photo 26.1.)

Photo 26.1 - Trails Capturing Water

26.2. Drainage Problems

Find drainage-related problems by performing a trail condition assessment during wet weather, preferably when the soil is wet, ephemeral watercourses are flowing, and sheet flow is occurring. These conditions enable staff to determine the source of water flowing on the trail, which is essential to correcting any problems. Failure to accurately identify the source of water on the trail can lead to unnecessary or unsuccessful (and costly) repairs, poor trail conditions, and increased trail maintenance workload.

26.3. Water Bars, Drain Dips, and Rolling Grade Dips

Many trails have drainage structures, such as water bars, drain dips (grade reversals), and rolling grade dips. These structures are usually installed to direct water off a trail. Installation may be part of the original design or as part of trail repair after the trail has captured surface drainage and become eroded. All of these drainage structures capture and accumulate water from the trail and redirect it onto the hillslope below the trail. These drainage points are often located between naturally occurring watercourses such as swales and streams. The concentrated discharge of water onto an unprotected slope can lead to hillside erosion in the form of rills or gullies. (See Photo 26.2.) Therefore, water bars, drain dips, and rolling grade dips require regular maintenance or else these structures and/or the trail tread above or below them will degrade. (See Photos 26.2, 26.3, and 26.4).

Photo 26.2 - Drain Dip (left) and Water Bar (right) Discharge Eroding Hillslope

Drain dips and rolling grade dips are drainage features that are constructed as part of the trail bed. Maintaining these features requires simply reshaping and compacting the trail bed back to its original design. (See Chapter 14, *Drainage Structures*.)

Photo 26.3 - Unmaintained Water Bar

Photo 26.4 - Unmaintained Drain Dip

Water bars are maintained by first determining if they have been properly placed. Water bars are often constructed without appropriate attention to the location. Evaluate whether the water bar is needed or if standard outsloping can rectify the drainage issue. Water bars may direct water onto highly erosive and unstable locations on the hillside below the trail. In most cases, existing water bars need to be removed or relocated to appropriate, erosion resistant locations. Some water bars

can be replaced with a drainage structure requiring less maintenance, such as a drain dip.

Water bars need to be maintained regularly during the wet season. Often times, water bars are cleaned only once in the spring and forgotten about until the next year. Water bars need to be cleaned and monitored throughout the wet season, especially during peak storm events. A plugged water bar can cause severe damage to a trail, as well as any watercourses bisected by the trail.

Maintenance of a water bar is the same, whether the bar is made of wood, rock, or other material. The area immediately above the water bar accumulates sediment and fills in the trail to the top of the water bar. Once full, water flows over the water bar and erodes soil below the water bar, creating a "headcut." The area below the water bar is also subject to mechanical wear from user traffic and is often eroded. To correct this problem, de-compact the soil on the downhill side of the water bar. The sediment from the uphill side of the water bar is excavated, placed on the downhill side, and compacted, preferably with a vibration plate compactor. (See Figure 26.1.) If there is a shortage of fill material for below the water bar, it can be imported from sections of the trail receiving slough and berm or back slope maintenance. Material excavated from above the water bar can be transported to another location or sidecast off the trail away from watercourses.

26.4. Drainage Solutions

Maintenance of trail drainage depends on the condition and location of the trail. A properly laid out and constructed trail allows water to pass across, through, or under it where it bisects a flow. The objective is to ensure that the trail does not disrupt the natural drainage pattern of the landform, and that overland sheet flow and water courses are not disrupted or coupled (trail and watercourse merge together) by the trail alignment. Even with a properly designed trail, drainage maintenance is required to ensure visitor safety, and protect the trail, related structures, and surrounding resources. Most drainage problems occur during prolonged or peak rainfall events or when the snow pack melts off. The best time of year to perform maintenance is during these peak flows when the flowing water can be used to flush sediment and debris through structures. Unfortunately, peak flows usually occur during the time when trail programs have the least capability to perform maintenance, or the trails and drainage features and structures are the least accessible. If maintenance cannot occur during peak flows, every effort should be made to prepare for these hydrologic events in advance. Inspections and Work Log prescriptions can be developed during peak flows and then incorporated into scheduled trail projects at a future date.

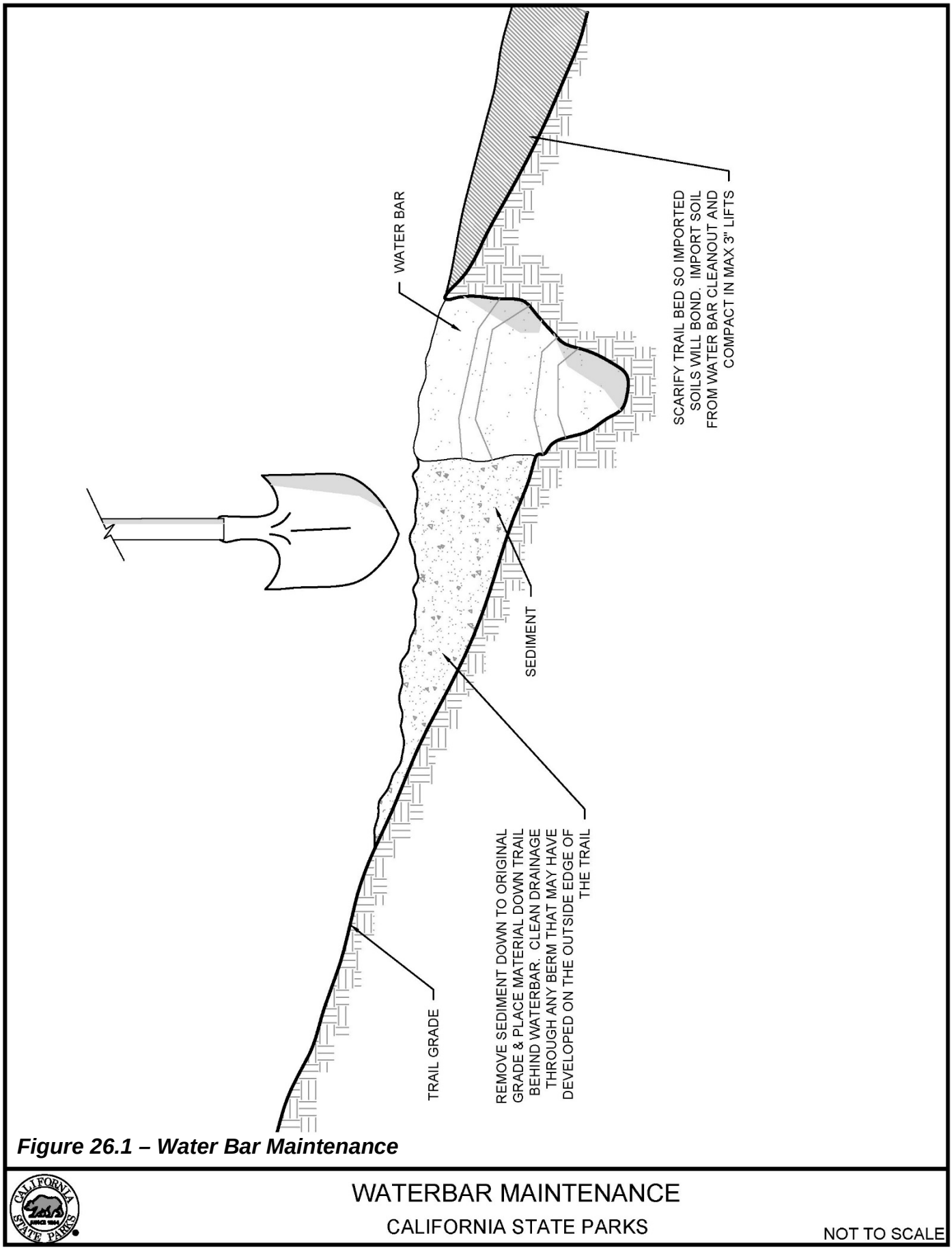

Figure 26.1 – Water Bar Maintenance

WATERBAR MAINTENANCE

CALIFORNIA STATE PARKS

NOT TO SCALE

Basic drainage maintenance activities are listed below.

- Maintain tread outslope and remove impediments to cross-drainage flow, such as heavy organic litter build up, woody debris, and soil deposition, to allow sheet flow to follow its natural course across the trail and down the slope. A good outsloped trail design is the most effective and immediate form of drainage control.
- Clear open watercourse channels of large, woody debris, rocks, and soil dislodged from bank failures. Debris can dam a channel, causing overflow or widening of the channel and allow water to flow down the trail. Where a puncheon or bridge has been constructed, clean the channels leading up to, under, and away from the structure to sustain unobstructed flow and protect abutments from erosion.
- Inspect the drainage systems of retaining walls to make sure they work properly. A retaining wall subjected to additional pore pressure associated with captured water has an increased risk for failure.

Other maintenance activities considered critical to trail longevity include:

- **Parallel and inboard drainage ditches**: Remove soil and organic matter build-up. In vegetated ditches, remove excessive growth that might be an impediment to drainage.
- **Culverts and other closed or underground drainage structures**: Remove woody debris and sediment at the inflow and outflow and inspect and repair headwalls and energy dissipaters.
- **Drain Lenses**: Inspect and ensure the permeability of the rock lens is sufficient to accommodate the incoming flow and replace drain rock as required.

There are many trails with drainage conditions that require maintenance beyond the items identified above. Trails that are severely entrenched or lying in low or flat areas often have drainage problems. A number of techniques can be applied to these trails that help stabilize soil and allow surrounding plant life to recover. Maintenance of entrenched trail tread is more than just redirecting water. Once the source of water is properly re-directed, the rebuilding of trail tread can be addressed. (See Chapter 14, *Drainage Structures*, and Chapter 25, *Trail Tread Maintenance.*)

26.5. Structure Maintenance

Preventative maintenance keeps trail structures at or near their design and construction standards. The goals of maintaining a structure are ensuring visitor safety and protecting resources, as well as maintaining public access and avoiding expensive reconstruction and/or replacement.

Maintenance needs are identified during the annual trail condition assessment. (See Chapter 2, *Trail System Management and Development.*) Usually the maintenance needs of a single trail structure are minimal, and dedicating a trail crew to the task is an inefficient use of resources. To maximize crew efficiency, structure maintenance is performed in conjunction with brushing and clearing, tread maintenance, and other annual or cyclical maintenance activities. However, repairs to correct issues that affect visitor safety must be performed immediately; they cannot wait to be scheduled with

other projects and are often assigned to small work groups that can work quickly and efficiently.

26.6. Bridges

Trail bridges require minimal superstructure maintenance. Abutments and stringers either function properly or need to be replaced. Common bridge maintenance includes replacement of a single section of decking, post sills, post braces, posts, and railings. See Chapter 16, *Trail Bridges,* for how to install post sills, post braces, posts, decking, and railings.

Annual maintenance is focused on the surrounding soil and vegetation, as these items can affect the bridge's lifespan. The tread adjacent to the soil dams on the ends of the bridge must not project beyond the dam elevation, nor should it make contact with other bridge components. Any soil that is above the top of the dam may come into contact with the decking, posts, or stringers, and accelerate their failure. Check the condition of the soil dam, which separates the stringers from the soil and will naturally deteriorate over time. Properly sized and installed soil dams should present no problems over the lifetime of the structure, but should be monitored annually. (See Figure 26.2.)

Inspect the mudsills to ensure the tops, including the space between the stringers, are clean and clear of any soil or vegetative matter. Both ends and the face of each mudsill should be above the surrounding ground to allow water to drain off the top of the sill, instead of standing next to and under the stringers. See Photo 26.5 for an example of a stringer with a good air gap and a mudsill with minor organic build up; and Photo 26.6 for an example of a stringer that contacts the soil and has no air gap. Keeping the mudsills free of soil and organic build up and maintaining an air gap between the stringers and the ground is normally the only maintenance task that is done annually. (See Figure 26.2.)

Walk across the bridge, inspecting it for wear or broken parts. Check railing and posts to ensure they are tight. Keep in mind that rails are leaned on by users and if the rail fails the user may fall off the bridge. Make note of and repair any loose or damaged rails and posts. Check the decking for pieces that are worn or damaged, and remove and replace as needed. Clear the top of post sills of any soil or vegetative matter that may have accumulated.

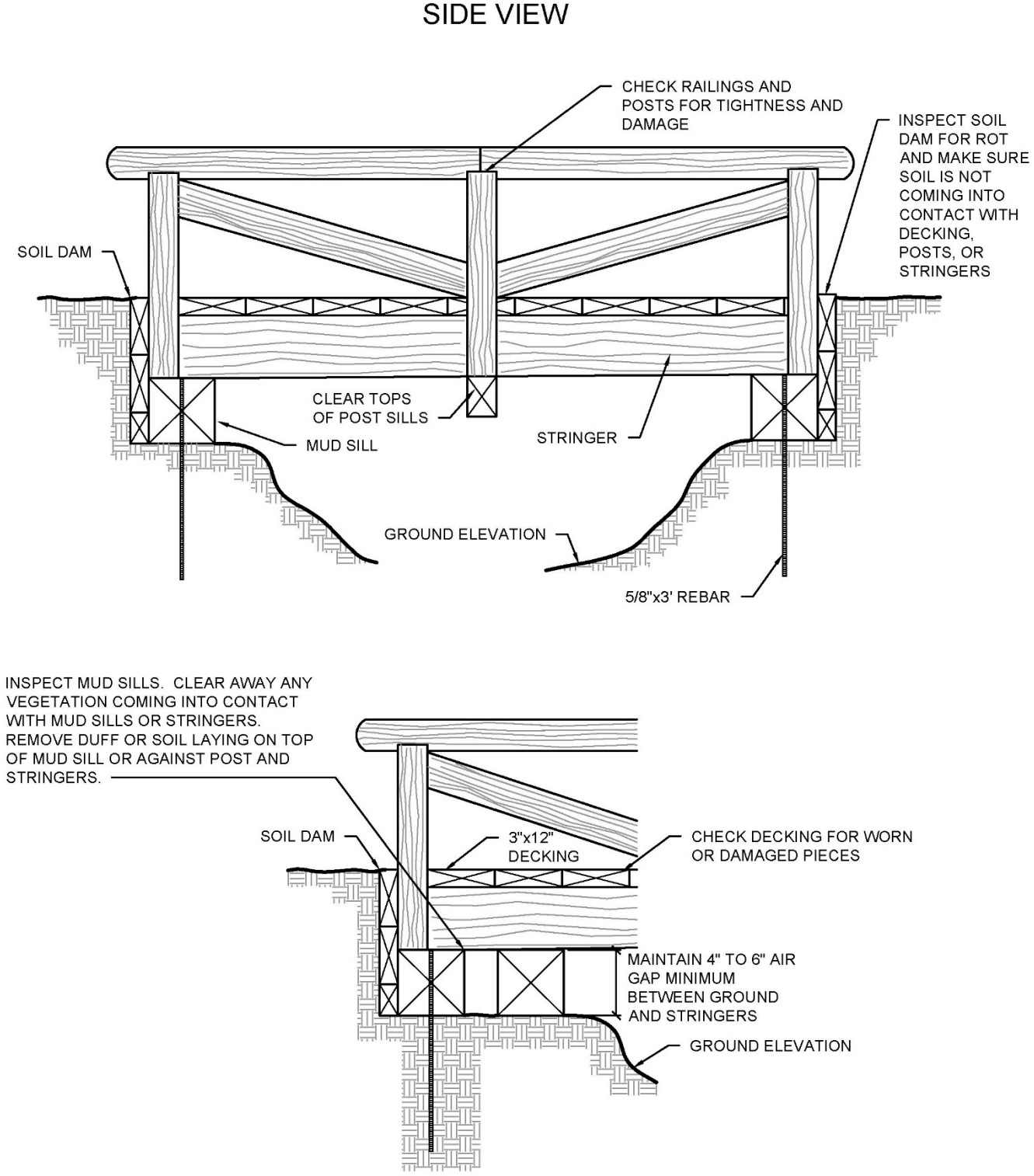

Figure 26.2 - Bridge Maintenance

BRIDGE MAINTENANCE

CALIFORNIA STATE PARKS

NOT TO SCALE

Photo 26.5 - Bridge Stringer (good air gap) and Mudsill (organic buildup)

Photo 26.6 - Bridge Stringer with No Air gap

Check under the bridge to ensure a good air gap remains around all the stringers. Clear away any vegetation that has encroached on the stringers. Stringers are usually the first part of a bridge to fail, and anything done to increase their longevity is time well spent. While under the bridge, inspect the diaphragms or bridging as applicable. Check the condition of the sway braces and make certain they are tight. You should be able to pull the braces apart by about an inch where they cross. Braces that are loose and rattling need to be tightened. If the braces cannot be pulled apart where they cross, they need to be loosened. Inspect adjacent streambanks for lateral scour and

undercutting. Also, check for trees being undermined or failing within close proximity of the bridge.

Bridge approaches require cyclical maintenance. Make certain they are at the original design standards. Level approaches are best for accessibility. Other cyclical maintenance items include replacement of wear boards on equestrian bridges and replacement of any other item likely to require maintenance on a shorter cycle than the lifespan of the bridge.

Because bridge failures have the potential to significantly impact public safety and park resources, a bridge inspection checklist has been developed to assist trail workers in performing inspections. (See Appendix U.) In addition, with the increased use in all-weather steel bridges and the sensitivity of all-weather steel to certain climatic conditions, it is important to provide information on how to determine the condition of the all-weather steel during annual inspections. See Chapter 16, *Trail Bridges,* and Appendix U, *Bridge Inspection Checklist,* for further information on inspecting all weather steel bridges.

Bridge replacement can occur with prorated maintenance funds. (See Chapter 21, *Trail Maintenance Principles.*) Prior to replacing a bridge, thoroughly evaluate the trail alignment and bridge site to determine if (1) a bridge is still required, (2) it is located at the best site, and (3) it still has the most appropriate design. Incident-related or one-time repairs to bridges are mostly limited to railings and decking that has been vandalized or damaged by a fallen tree or limb.

Seasonal pipe bridges are installed and removed annually. (See Chapter 16, *Bridge Structures.*) The components are inspected and repaired during annual installation and removal. Generally, individual bridge sections will last for many years. Inspect the ends of the stringers where they attach to the brackets for cracks or breakage; the decking for wear or broken pieces; brackets and especially the welds for cracks or signs of breakage; and plastic-coated wire rope railings to ensure they are sound and free of cuts and frays that might cause injury. Have a supply of replacement brackets, nuts, and bolts available during installation. Because a pipe bridge is installed below the high water level, maintenance of the tread approaches must be performed annually during installation of the bridge.

Seasonal pipe bridges can be maintained on a prorated system. Plan on replacing about one fifteenth of the pipe bridge parts each year. In addition to the wooden components and metal brackets that comprise the bulk of the bridge parts, the pipes (stanchions) driven into the creek or riverbed get flared at the top from pounding and must be trimmed back annually prior to assembling the bridge. Therefore, these pipes get shorter every year and must be replaced when they no longer have the required length.

Incident-related maintenance on a seasonal pipe bridge typically involves a bridge washed out by high water. In this case, salvage what you can for re-use but use caution as brackets are most often bent, broken, or lost during high water wash outs.

Photo 26.7 – Washed out Pipe Bridge

26.7. Puncheons and Boardwalks

Puncheons and boardwalks are used to cross small ephemeral streams, swales, or bogs. With an elevated tread surface, they permit dry passage for trail users while allowing ephemeral or poorly defined watercourses to function. Puncheons and boardwalks require cyclical maintenance to ensure that any associated drainage structures (parallel ditches, cross drains) remain functional and do not accumulate vegetation or soil. One-time or incident-related maintenance may also be required due to fallen trees or debris blocking parallel or cross drains.

Annual inspection and maintenance of puncheons and boardwalks are essentially the same as for bridges, with emphasis on maintaining air gaps. It is common to find vegetation and soil encroaching on the joists of these low lying structures, which must be cleared to maintain the same air gap as for bridge stringers. Soil dams are inspected and mudsills cleaned to provide an air gap and ensure proper drainage. (See Photo 26.8.) The importance of cleaning mudsills cannot be over-emphasized. Vegetation and soil on top of a mudsill are the leading cause of early puncheon and boardwalk failure. Inspect the tread pieces for wear, breakage, or loose fasteners. Repair or replace as needed.

Cyclical maintenance includes maintenance of the approaches to the puncheon or boardwalk. Make certain that soil is not overflowing the top of the soil dams and that

the trail tread has not eroded and created a step at the edge of the puncheon or boardwalk. See Photo 26.9 for an example of a puncheon where the decking is in contact with the soil on one end and the approaching tread too low at the other end.

Prorated maintenance of puncheons and boardwalks includes scheduled replacement. If multiple sections are linked together, replace all sections at once rather than disturbing the site over several years by replacing only a few sections at a time. See Photo 26.10 for an example of a boardwalk with a structural failure needing replacement.

Incident-related or one-time maintenance includes repair of deck boards and bull rails, or replacement of a single section of a multi-sectional puncheon in the event of damage.

Photo 26.8 - Maintained Puncheon

26.8. Steps

When steps are installed according to recommendations in this handbook, they will require little maintenance. As with other structures, they must be inspected annually. Wooden, interlocking, and cribbed steps are inspected to ensure stability. Any steps that have come loose need to be reset and secured. If some steps are rotten or damaged, they need to be replaced. If more than a couple of steps require replacement, the step section is probably at or near the end of its lifespan and needs to be replaced entirely. (See Photo 26.11.) As with any other structure, consider whether steps are the best option before replacement. A short reroute or re-grading of the trail might allow you to eliminate the steps. Steps are an obstacle to trail users with a

mobility impairment, and should be removed and replaced with an alternate design whenever possible.

Photo 26.9 - Puncheon in Need of Maintenance

Photo 26.10 - Boardwalk in Need of Replacement

Cyclical maintenance includes refilling the backfill of wooden steps as necessary. (See Photo 26.12.) Clear or fill the back part of the step to re-establish the designed height between the backfill and the top of the step. Make certain all steps have cross slope drainage into a drainage structure and clear the structure as necessary. Sediment

removed from ditches can be used to backfill eroded steps. If the drainage ditch has eroded, it may be necessary to install an energy dissipater.

Photo 26.11 - Step Carriage in Need of Replacement

Cable steps are typically removed and installed annually, depending on the location, and can be maintained on a prorated basis. In saltwater environments, the wire ropes and wire rope clips may require frequent replacement. For cable steps in a stable location and not subject to annual removal, the maintenance is the same as for other types of steps. Otherwise, cable steps can be evaluated during annual installation and removal. If the steps are not removed but are subject to flooding or wave wash, expect to have to re-install them. (See Photo 26.13.)

Inspect the step pieces, wire ropes, and wire rope clips. During re-installation, it may be necessary to repeat the step calculation to account for variations that may have occurred to the slope. If an individual step needs replacement, cut the wire rope above or below the step, install a new step, and splice the wire rope back together. Incident-related or one time repairs to cable steps are a repeat of the annual installation and removal process. (See Chapter 17, *Trail Steps.*)

Photo 26.12 - Steps in Need of Tread Maintenance

Photo 26.13 - Cable Steps in Need of Reset

26.9. Railings

Safety railings generally require only minimal maintenance. Cyclical maintenance includes sanding any roughness from weathering of the top rail and re-setting nails that have worked loose. Inspect railings and posts, and make certain they are secure. Any deficiencies must be corrected immediately. Check for loose, rotten, or damaged posts, mid-rails, and top rails. Lightly damaged or vandalized rails may still be serviceable. Drawknife or sand any rough surfaces that could result in splinters.

As with other structures, prorated maintenance will likely involve replacing the entire railing section. If there is a long stretch of railing, it may be possible to replace only certain portions at a time, and stretch out replacement costs over several years. (See Photo 26.14.)

Photo 26.14 - Railing in Need of Replacement

Incident-related or one-time repairs commonly involve removing carved graffiti or repairing a railing struck by a falling tree or limb. (See Photo 26.15) The need to remove graffiti is balanced against structural damage that removal may cause. If a drawknife is used every time someone puts initials on a railing, the railing may need to be replaced earlier than if the graffiti was left in place.

26.10. Retaining Walls

Retaining walls require minimal annual maintenance beyond inspections. Check that gaps between wall sections are not clogged with debris that prevents drainage from the backfill material, and clear as needed.

Cyclical maintenance includes maintaining the trail tread material behind and approaching the retaining wall at an elevation above the top of the retaining wall to direct drainage off the trail. (See Photo 26.16.) Maintenance of the trail tread behind a retaining wall should also prevent water from ponding behind the wall.

Photo 26.15 - Railing Damaged by Falling Limbs

Prorated maintenance may include scheduled replacement of the wall. Isolated repairs may involve the replacement of individual wooden components (facers, wings, or anchor post) or resetting stones that have come loose and are making poor contact with adjacent stones. Once a wall loses its structural integrity, it must be replaced. (See Photo 26.17.)

A well-built, dry stack masonry rock retaining wall could have a prorated life span of hundreds of years and, therefore, is a good investment. When replacing a retaining wall, always consider the opportunity to replace it with a different design and materials that will increase the longevity of the retaining wall.

26.11. Accessibility

When performing maintenance on any of these structures, look for opportunities to improve the level of accessibility. Bridge, puncheon, and boardwalk decking can be widened to 36 inches or more; abrupt elevation changes on the approaches and decking can be eliminated or smoothed out; and bull rails to provide edge protection can be installed. Hand railings can be added to step sections to aid users in ascending and descending stairs. Remember to keep the individual rise and run of each step and landing consistent. Elevated edge protection can be provided along retaining walls, where there is a precipitous drop-off, steeper linear grade or cross slope, or bend or turn in the trail.

Photo 26.16 - Retaining Wall Higher than Trail Tread

Photo 26.17 - Retaining Wall Needing Replacement