Green Trails

Guidelines for environmentally friendly trails

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Acknowledgements

The efforts of numerous people during a span of many years inspired this project and brought it to the trailhead, so to speak. These people, from all walks of life and work, have supported the development of a regional trail network. They are community and business leaders, funding strategists, policy advisors, municipal staff to parks, members of Metro advisory committees, natural resource managers and technical specialists, municipal employees, teachers and citizens. They share a vision of a network of trails that wends like green ribbons through our communities and natural areas – trails that provide routes to a livable future for residents of the Portland metropolitan region.

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Green Trails: An Overview

What is the Purpose of the Green Trails Handbook?

Many of this region's most important fish and wildlife areas are in our publicly owned natural areas. As the region grows and the desire for trails increases, there is a need to develop guidelines to plan, design, construct and maintain trails so that impacts on natural resources are kept to a minimum. In some parts of the region, existing trails need rehabilitation and maintenance because of poor drainage capability. In other areas, trails near seasonal wetlands, streams and other sensitive habitat could be moved or improved to better protect aquatic and wildlife resources.

This publication is intended to provide guidelines for environmentally friendly (or green) trails that support the goals of Metro's Greenspaces Master Plan. Those goals seek to promote an interconnected system of parks, natural areas, trails and greenways for fish, wildlife and people throughout the Portland metropolitan region while maintaining biodiversity and protecting water quality. These guidelines are not standards; they are recommendations to complement existing standards and guidelines adopted by local cities, counties, park providers and watershed groups in the region.

There is no single source of information that comprehensively addresses planning, construction and maintenance of environmentally friendly or "green trails" – trails that avoid or minimize impacts to water resources and fish and wildlife habitat. This guidebook fills that gap. It is a resource for citizens, trail planners, designers, builders and maintenance staff. It focuses on trails in environmentally sensitive areas and recommends strategies for avoiding or limiting the impacts on wildlife, water quality and water quantity. It also provides an extensive bibliography of other sources that provide more specific guidelines for trail planning, design, construction and maintenance in a range of other settings. Readers of this book are encouraged to seek professional help in designing and implementing trail plans.

Table of Contents

Implementation

Chapter 8 Trail types, dimensions and materials

What resource-friendly trail materials are available?

Chapter 9 Managing trail construction to protect natural resources

What are some resource-friendly construction techniques?

Chapter 10 Trail maintenance

How should we take care of the trail?

References and Appendices

Chapter summary

Introduction

Chapter 1 Purpose of this guidebook and the benefits of having trails in a community. Importance of regional trails in the Portland metropolitan area.

Planning

Chapter 2 First steps in planning a trail, including identifying the purpose and intensity of use, involving the public, researching opportunities and challenges, costs and long-term management options.

Chapter 3 What information should be gathered to determine if there would be an impact on natural resources when planning a trail. Includes plans, contact information and web site addresses of agencies that deal with natural area management plans, zoning, vegetation and wildlife habitats, fish habitat, water resources and hydrology, geology, topography, cultural resources, viewpoints and interpretive opportunities. Offers a short checklist for assessing natural resource information.

Chapter 4 Principles of planning for "green trails" and rules of thumb for avoiding impacts to natural resources, including vegetation and wildlife habitat, fish habitat, water resources and hydrology.

Chapter 5 Ways to minimize impacts to natural resources. Identifies planning guidelines, setbacks and seasonal windows for working in fish and wildlife habitats, as well as strategies for planning and designing drainage ways to avoid concentrated flows and decrease erosion.

Implementation

Chapter 6 Environmental permits and permitting processes that may be needed if a trail has an impact on natural resources. Web addresses and phone numbers assist the reader in getting additional information from agencies.

Chapter 7 Ways to plan a route on site, including refining test alignments and identifying trail stewards.

Chapter 8 Construction techniques, surface material and width of trail that could be used in sensitive areas.

Chapter 9 Procurement of services to construct "green trails."

Chapter 10 Resource-friendly "green trail" maintenance program, including developing a schedule of activities, inspecting trails, maintaining drainage and vegetation and evaluating existing trails.

1.1 Trails and Quality of Life

Almost everyone enjoys the chance to explore a trail and get out into nature. In fact, area residents told the Oregon Parks and Recreation Department in a 2002 survey[1] that their favorite outdoor recreation activities – running and walking for pleasure – are trail-related. The same study found that people generally engage in these activities close to home and on a regular basis. These neighborhood trails encourage healthy lifestyles.

The Portland metropolitan region boasts a unique landscape of mountains, buttes and rivers that makes it a perfect setting for a variety of trails. People are fond of their trails – from the neighborhood pathways they take to their favorite natural areas to the multi-use trails shared with cyclists, walkers, skaters, equestrians, wheelchair users and joggers. Trails help residents of all ages and abilities get around in the community and explore the region, making it a highly desirable place to live.

By offering connections to and between places people want to go, trails reduce dependence on driving and promote healthy recreational opportunities close to where people live. They provide routes to work, to parks, to public transit, to the post office, to shopping and to schools. Trails offer people the chance to be immersed in the beauty of nature, alone or with family, friends or community. Trails contribute to the character of the natural settings they traverse by building bonds between people and the environment and by fostering environmental awareness and community pride. By connecting to other features, trails bring people and the landscape together in a way that encourages adventure, healthy lifestyles and a commitment to take care of our natural resources. When people of all cultures, ages, levels of income and ability enjoy the amenities trails provide, everyone benefits.

1.2 Where Will the Trails Go?

When conceived 100 years ago by landscape architect John Charles Olmsted, a 40-mile loop of parkways and boulevards was to encircle Portland. Since then, the metropolitan area has grown – and so has the vision of a regional trail system. In 1992, the Metro Council adopted the Greenspaces Master Plan, which included the Regional Trails and Greenways Plan, an updated vision for this network of regional trails connecting parks, natural areas and communities. The Greenspaces Master Plan assigned Metro the responsibility of building a regional trail system in coordination with local governments, the state, the 40-mile Loop Land Trust and other partners. Passage of a regional bond measure in the mid-1990s provided local governments and Metro with additional funds to bolster trail construction and right of way acquisition efforts. To date, 150 miles of the proposed 650 miles of regional trails have been completed.

Local governments and Metro have worked together to determine the general locations of proposed greenways and land and water trails. Refer to Appendix A for more information about the location of existing and proposed regional trails.

1.3 Partnerships for Regional Trails and Greenways

Residents of the region are so passionate about their trails, parks and natural areas that local park providers, the 24 cities and three counties in the Portland metropolitan region are working with Metro to implement the Regional Trails and Greenway Plan. This network extends to and includes cooperation and partnerships with Vancouver/Clark County, Wash. Trail connections also extend beyond the metro area to state and federal trail networks on the Pacific Coast, in the Cascade Range and in Central Oregon and Washington.

Cities and counties also are working to extend their local trail systems to connect with the Regional Trails and Greenways Plan. Ultimately, trails will connect large and small natural areas, neighborhoods and parks throughout the region.

Achieving this vision of a regional trail network will require planning and sustained effort by all levels of government, non profit groups, park providers and individuals. Many successes already have been realized. For example, several municipalities have developed integrated trail master plans and completed trail projects. On the east side of the region, the Springwater Corridor extends from downtown Portland to Clackamas County. On the west side, the Fanno Creek Greenway Trail is halfway complete and one day will provide a separate pathway connecting Portland to the Tualatin River. Other regional trail segments are in the planning and design phase or under construction. The Trolley Trail, a former rail line running from Milwaukie to Gladstone, has been acquired for conversion to a multi-use greenway trail. The first phase of construction has begun on the Gresham-to-Fairview Trail, another segment of the long-ago inspired 40-Mile Loop Trail.

The public will continue to play a key role in the success of these trail projects in many ways. Residents will help identify trail user groups and their needs and be involved in the details of route selection. Community members will contribute ideas to trail and trailhead design and to the development of interpretive programs. They will help identify local safety and landscaping needs and will assist in the development of funding strategies. Finally, communities and trail user groups will become important stewards who will assist in the long-term care of the trails they have helped foster.

1.4 Planning Trails With Natural Resource Protection in Mind

On a clear day, a person looking out over the region from Cooper Mountain, Skyline Ridge or Powell Butte sees a rolling urban landscape softened by green. Streams and lakes glint in the sunshine. About 1.3 million people live in the 24 cities located in this lush landscape between the forested mountains of the Coast and Cascade ranges. Still, bald eagles spiral over rivers where otter, mink and bobcat can be tracked on river margins. Salmon and steelhead spawn in local streams. Tundra swans and snow geese spend the winter with other migrating waterfowl in the vast wetlands of the Columbia River floodplain. In spring, the calls of thousands of small migrating birds echo in wooded hilltop parks throughout the region where they make short stopovers on their long journeys. Elk, brown bear and cougar occasionally wander in from the wild to the city's edge. The residents of the region are aware of and appreciate the unique wildlife resources that contribute to the character of the place they call home.

Many of the decisions trail planners will contemplate about trail location and design will be influenced by the desire to protect and manage greenspaces for fish and wildlife as well as for people. Environmental regulations concerning the protection of wetlands, endangered species and water quality plays an important role. With thoughtful planning during the early phases, trail planners can avoid many issues that could harm fish and wildlife, cause project delays or add expense due to natural resource regulatory processes.

Many of the trails will be constructed to the standards of the American with Disability Act (ADA). That means they will be wide, firm-surfaced trails that will be accessible to people of all ages and abilities. Many of these trails double as transportation corridors and may be eligible for federal, state or local transportation funding. Because many of these proposed trails may be built close to riparian corridors, there will be implications for water quality, quantity and fish and wildlife habitat. This guidebook discusses ways to plan and build trails that will avoid and minimize impacts to natural resources. The guidebook primarily considers two kinds of trails: those in urban corridors that will receive multiple uses at high levels, and those in natural areas that may receive a more limited variety and levels of use.

Reference materials. The following chapters touch on the key points of many complex topics, leaving readers to follow up by reviewing more technically detailed resource material. Sources that were particularly useful in preparing this guidebook are listed in Selected References at the end of the book. Readers can also refer to the glossary for definitions of technical terms used in the guidebook. Finally, as they embark on the exciting tasks of bringing new trails into existence, readers are encouraged to seek help from professionals with specialized trail knowledge.

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[1] Johnson, Rebecca L., *Oregon Outdoor Recreation Survey. 2002. Oregon Parks and Recreation in cooperation with Oregon State University.*

We have an idea for a trail. What do we do first?

2.1 Introduction

Building a regional trail system requires a shared vision and long-term commitment of many people. Long before a trail segment can be constructed, funding strategies need to be identified. The public should be engaged in a dialogue about the trail's location and amenities. Land or rights of way need to be acquired and specific challenges regarding access, safety, utilities and myriad other details need to be solved. In fact, many years of lead-in planning at the local, regional, state and federal levels are required to bring a trail from concept to an on-the-ground reality.

Ideally, planning starts at the landscape or the watershed level, depending on the scale of the project. A watershed is the area of the land that drains into a particular river or stream. Watersheds can be as large as all of the land draining to the Columbia River or as small as 20 acres draining to a pond. A landscape and watershed overview can help trails be more compatible with wildlife, fish and people. For example, it is helpful to understand the connectivity of wildlife habitats, as well as connections between neighborhoods, natural areas, urban nodes and transportation systems, including trails. This overview can help planners gain an understanding of a watershed's natural hydrologic dynamics and the effects of human activities on watershed conditions. Potentially important opportunities and constraints become evident at this scale of analysis. These include the need to avoid geologically unstable slopes or the habitats of threatened and endangered species, or the opportunity to restore a previously disturbed site. Once planners understand the landscape and watershed conditions, planning can take place at the site level.

Sites are local areas being considered for trails. A site may be a

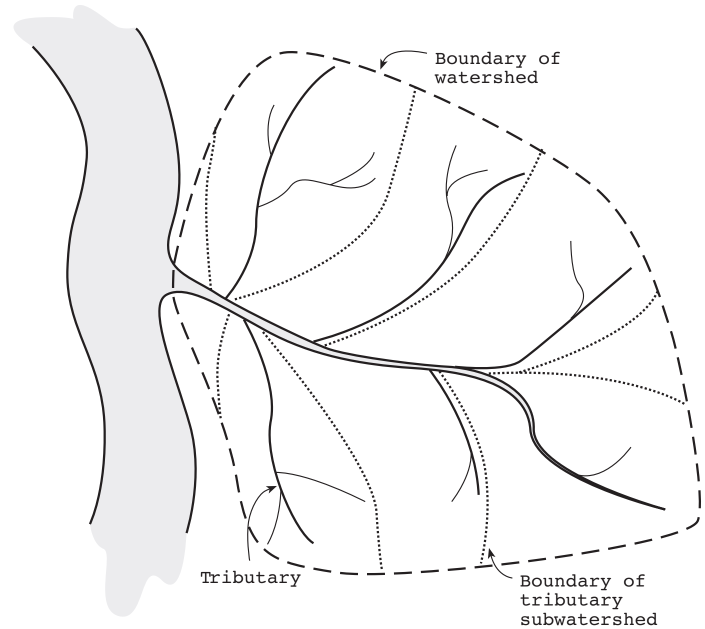


Figure 2-1 A watershed is an area of land that drains into a particular stream. It includes the stream's tributaries and associated subwatersheds.

large natural area that possesses many natural habitat features such as East Buttes and Forest Park. A site may be an urban greenway such as the Springwater Corridor, whose natural resources can lend relief to trail users, particularly in the context of the surrounding city.

2.2 Why Have Trails Here?

Proposed trail routes should provide users with an aesthetically pleasing outdoor experience. In natural areas, users also want to use trails to increase their fitness level or to commute from one place to another. If these needs are not met, “social trails” (also known as demand trails) tend to increase in natural areas and urban corridors. Social trails are unplanned trails users create to get to a scenic point or to a short cut through an area. Sometimes they also develop along long-established corridors such as fence lines, utility easements and existing right of ways.

The presence of social trails in an area can indicate the need to construct trails at that location. It is important that future trails enhance the area and augment users’ experience of it. The trail should be easy to maintain and should support both existing and future uses. The planning process must consider how the trail could provide these amenities while preserving and protecting natural and scenic resources.

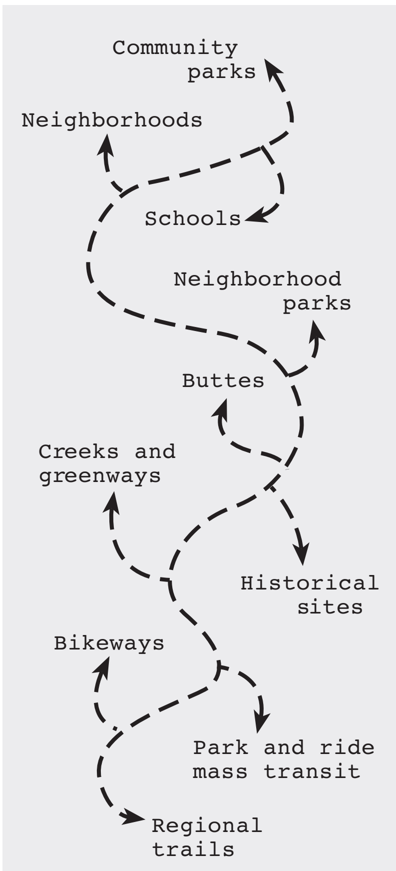


Figure 2-2 Trails connect people to places they want to go. (Gresham Trails Master Plan, 1997)

Trails and paths provide recreational opportunities as well as increased transportation choices.

2.3 What is the Purpose of the Trail?

Trails can be used for recreation, transportation or a combination of both. Some recreational trails double as commuter corridors. Others are barrier-free, multiple-use recreation routes. Still others function as narrow footpaths for hikers and walkers. While some trails are essential to link communities, arterial streets or regional greenspaces, others will serve very local uses. Trail planners need to identify users and levels of use in order to avoid or minimize user conflicts by means of trail location and design.

This guidebook considers two kinds of trails: those in urban corridors that will receive multiple uses at high levels, and those in natural areas that may receive a more limited variety and level of use. Within each broad group of trails it is possible to have a range of different dimensions and surface materials, depending on natural resource conditions, users and levels of use.

Trails in highly urbanized settings should provide safe, efficient, smooth travel opportunities while offering interesting experiences. Wherever possible, trails in urban corridors should take advantage of opportunities for users to experience unique or pleasant natural features such as tree groves, viewpoints, historic and cultural features, wildlife habitats, open spaces and interpretive opportunities. Corridor trails also should provide connections into neighborhoods, business centers, public transit connections, schools and neighborhoods. Wherever possible, they should create opportunities for trail loops and connections.

In contrast, trails in natural areas provide minor routes that give users an opportunity to enjoy and experience wildlife habitats, stream corridors and floodplains while protecting and preserving them.

2.4 Assess Zoning and the Review Process

Before starting, check with the local municipality and other entities (regional, state and federal) with jurisdiction in the vicinity to learn what standards and guidelines will apply. Having this information at the outset of the project will save time in the long run, and there is a likelihood that it will provide value to the project as well. Refer to Chapter 6 for more information on environmental permits.

2.5 Plan a Process to Involve the Interested and Affected Public

Before investigating potential trail alignments at the site scale, discuss the potential trail with trail advocates and other stakeholders who will be affected by trail-routing decisions. Fully engaged communities that have shared in the deliberations leading to decisions regarding trails often become the strongest advocates of the trail.

Public outreach can be managed in many ways, depending upon complexity, the scale of the project and resources involved. Planners can use existing neighborhood groups in the local area, or create new ones to discuss the need for the trail. If possible, make sure to involve people who can represent user groups of all ages and abilities, such as equestrians and bicyclists, who have particular needs for trail surfacing and trail networks.

Following are some techniques for involving the public in the trail planning process:

Identify stakeholders. Public outreach, regular meetings, citizens' advisory committees, community design workshops, integrated committees, news stories or features, and media coverage all help involve the community and build consensus about and support for the trail.

Involve community stakeholders. Consider establishing a citizen advisory committee at the outset of trail planning or use an existing committee to serve as an advisory board. As work progresses, the committee may expand to include people who live near areas that become designated as potential trail routes. Their concerns are likely to become the focus of trail design solutions.

Involve users of the trail. Potential users such as cyclists and equestrians can help identify what initial and future demand there will be for the trail. This information is essential to determine the locations and amenities of trailheads, the width of the trail and its surface materials, and the trail's gradient and design speed. This input will influence the selection of potential trail routes, so they need to be considered early on.

Distribute newsletters and surveys. Surveys can be used to make sure all community concerns are identified. Newsletters (electronic or printed) can be used to share information and to conduct surveys about the trail. Project web sites have become popular and effective ways to communicate information to and garner input from the public.

Develop a plan. Having a public information strategy from the inception of the project to the grand opening could help garner popular interest, involvement and support. The trail should be named early in the planning process. Planned public events also foster community "ownership" of the proposed project.

Integrate committees. It is important to integrate the work of staff planners and technical advisors with the citizen advisory group. Everyone gets a chance to understand the issues that influence technical recommendations, and this tends to result in favorable decisions for all on the committee.

Many regional trail projects will require multi-level inter-governmental participation to maintain the trail vision; initiate legislative and funding processes; assure access across railroads, highways, bridges, waterways and other barriers; and to develop consistent policies that will protect the trail in the future.

2.6 Identify Appropriate Uses and Intensity of Use

The needs of trail users for connections at both neighborhood and regional scales will affect decisions about the types of trails that will be built, how wide they will be and what kinds of surfaces they will need to have. The range of groups expected to use the trail – hikers, walkers, wheelchair users, naturalists, cyclists, runners, skaters, equestrians – and their desired destinations also will affect decisions about trail type. Trail planners also should be aware that trail widths and surfacing materials are specified by local code in some municipalities.

Very low	Less than 25
Low	25-100
Moderate	100-200
High	200-400
Very high	More than 400

Table 2-1 Number of users per busy day. (Table excerpted from Trails Design and Management Handbook, Open Space and Trails Program, Pitkin County, Colo., 1994)

Trails used by only a few people will require a different design approach and materials for construction than trails that will have a very high level of use. Table 2-1 provides a way to categorize the intensity of existing or expected trail use. This information is essential for selecting appropriate trail widths and curve radii, as well as surface materials.

Trails with very high uses that serve many different groups – such as bicyclists, families with strollers, in-line skaters and people in wheelchairs – are almost always constructed with very durable surfaces that can stand up well to heavy wear and last a long time. Multiple-use trails that are used less could be constructed with softer surfaces such as well-graded crushed rock or bark chips. These materials allow rain to soak into the ground and can be constructed in riparian areas where impacts should be as minimal as possible. Such trails tend to be narrow and serve very low numbers of people. Natural surface trails serve people on foot in various modes. Properly designed, they also could serve people in wheelchairs. Table 2.2 gives examples of trail surfaces for different groups and levels of use. Refer to Chapter 8 for more information on trail surfaces.

Multiple-Use Hard Surface	Crusher Fines or Other Unpaved Surface	Natural Surface
Baby carriages	Baby carriages +	
Bicyclists (mountain bikes)	Bicyclists (mountain bikes)*	Bicyclists (mountain bikes)*
Bicyclists (road bikes)	Bicyclists (road bikes)+	
Equestrians**	Equestrians *+	Equestrians*
Hikers**	Hikers	Hikers
In-line skaters		
Joggers**	Joggers	Joggers
Runners**	Runners	Runners
Walkers	Walkers	Walkers
Wheelchair users	Wheelchair users +#	Wheelchair users +#

* May or may not be permitted depending on the site, design, structure and surface of the specific trail.
** Best on adjacent soft-surface trail.
\+ Use may or may not be suitable depending on the site, design, structure and surface of the specific trail.
+# Indicates a possible but not optimized use. Site, structural and management elements of the specific trail determine, create or improve access.

Table 2-2 Trail types and users. (Table excerpted from Trails Design and Management Handbook, Open Space and Trails Program, Pitkin County, Colo., 1994)

2.7 Establish an Interdisciplinary Technical Team

It may be useful to use an existing interdisciplinary team or establish one to assist with natural resource planning. Smaller municipalities with limited funds could consider inviting other public-sector natural resource scientists and transportation, development and infrastructure planners to assist on a limited or as-needed basis.

Design professionals, planners, transportation engineers, infrastructure planners and park maintenance specialists should be included on the planning team. Their knowledge of costs, policies, regulations, performance, equipment, public safety, permitting and environmental regulations will help the planning team make informed decisions about trail location and design.

Fish and wildlife biologists could provide information about fish and wildlife that need to be protected in the project area and recommend methods to avoid or minimize impacts. Further, they could collaborate on the design of trail facilities to minimize impacts to habitats and provide early input that can help with permitting.

Hydrologists, soil scientists, geologists and geomorphologists could interpret hillslope, channel and floodplain dynamics for the planning group. They could identify and interpret phenomena at the landscape scale that give rise to springs, slope instability and other conditions that could affect public safety and the condition of future trails. These physical scientists also could interpret geologic mapping and other studies to recommend routes at least risk of failure due to earthquakes, landslides and other geologic hazards. Further, they could help minimize impacts to trails by recommending appropriate designs in challenging physical settings.

2.8 Identify Natural Resource Opportunities and Challenges

Options for trail alignments in urban areas often are dictated by narrow existing corridors and by long-established land ownership and uses. It is essential for the alignments of these high-use trails to take advantage of available scenic, aesthetic, cultural and interpretive opportunities.

In natural areas, alignment options may be less constrained by development patterns, but instead influenced by the locations of streams, wetlands, floodplains and other water resource areas and by the habitats of threatened, endangered and sensitive species. As a general principle, trails should avoid (or minimize) crossing streams and wetlands, floodplains, steep slopes, high groundwater sites and other conditions that can result in failure of or damage to the trail or the safety of trail users. Trails in natural areas should be aligned at habitat edges or in existing disturbance corridors such as utility line easements and old road and rail beds. Chapters 3 and 4 provide guidelines for assessing natural resource conditions to make decisions about trail locations.

Plants and water provide the basic elements of wildlife habitat.

2.9 Identify Access Needs and Constraints

The type of trail to be built depends on use, needs, source of funds and sensitivity of the environment. In some instances, there are great opportunities to build trails that will allow those of differing abilities, such as wheelchair users, the elderly or people with other disabilities, to get out into natural areas. Trails often are the only way people with disabilities can gain access to natural areas. Thus, trails can become critically important for these users. While many trails are not easily conducive to equal access (due to steep slopes or other geographic constraints), and compliance with the Americans with Disabilities Act (ADA) may not be possible, it is important to take advantage of the areas where conditions lend themselves to accessibility and to design trails accordingly. Further, some trails, while not ADA-compliant, may still provide barrier-free or accessible opportunities. Look for opportunities to provide barrier-free trails in high recreation opportunity areas as well as in more challenging terrain. Minor side trails may provide more challenging barrier-free opportunities.

In addition, trails that receive federal transportation funds – an important source of funding for bicycle and pedestrian routes everywhere – need to be accessible to all age groups and physical abilities. These trails should be able to serve people with a range of abilities, including limitations to sight, hearing, movement and ability to judge and respond to hazards.

There are well-established standards for accessible or barrier-free trails. New standards allow flexibility in this area. These standards concern surface materials, maximum trail gradi-

ADA design standards assure equal access to natural areas on Fanno Creek Greenway Trail.

ent and cross-slope, minimum width and accessibility of trail infrastructure such as signs, resting areas and stream-crossing structures. In the pre-planning phase, it is essential to establish the degree to which the trail will meet ADA standards. When designing trails to meet accessibility needs, involve people with disabilities in the planning process.

2.10 Identify Broad, Tentative Route Possibilities

At this stage in trail pre-planning, the interested and affected community and the technical team should review both goals for habitat and connectivity at the landscape scale to identify several potential trail routes that appear to meet these goals. It is important to remember that the lines on the map at this phase of planning are conceptual. They are not alignments, but broad swaths in which trails might be located, depending on the outcome of further analysis.

2.11 Identify Costs of Building and Maintaining Trails

Before making a final decision on trail location, size and materials, it is a good idea to review construction and maintenance activities and costs. The team should have a clear idea about the costs of preparing the site for construction and the equipment and materials needed to build the trail. At this point, it also is a good idea to determine the long-term cost of maintaining the trail, including labor, equipment and time. “Long-term” means measuring costs at five-, 10- and 15-year intervals for resurfacing, bridge repair, replacement and other such costs. Determining these costs will help the team choose a trail type that can be constructed and maintained within the proposed budget and with available personnel. If the desirable level of maintenance cannot be provided, it may be prudent to construct a more durable, lower-maintenance trail.

2.12 Long-term Management

Difficult management issues should be identified before trail routes are approved. Public use rules and enforcement measures also should be determined in the planning stage. Trail management responsibilities and partnerships should be identified at this time. Trail users should be invited to contribute their insights about trail management and should be encouraged to become partners in stewardship of the trail.

What should we consider when planning the trail?

3.1 Introduction: Site Assessment in Urban and Natural Areas

Trail planners think about two fundamentally different settings when determining the location and design of trails: natural areas and linear urban corridors. The two settings require different approaches so that realistic natural resource goals can be established, according to the degree of existing disturbance. The existing degree of disturbance refers to the quality of habitat for wildlife and fish (see Figure 3-1). Typically, urban landscapes are heavily disturbed and need to be restored. In more pristine settings, preserving what is there and minimizing impacts may be the major goals.

An early step in preliminary trail planning would be to evaluate the existing degree of disturbance in the setting in which a trail is being considered. Following are guidelines developed by Colorado State Parks for assessing the degree of habitat modification in natural area settings:

- determine the kind and condition of wildlife habitat present
- determine whether the plants and animals typically associated with the habitat are present, or whether the ecosystem has been simplified
- determine the nature of past and present human impacts to the habitat
- evaluate the surrounding land uses and their proximity to and impacts on the habitat
- identify roads that bound the habitat to determine whether they pose obstacles to wildlife movement
- determine how well the habitat is protected from external impacts
- determine what opportunities there are to improve habitat on the site.

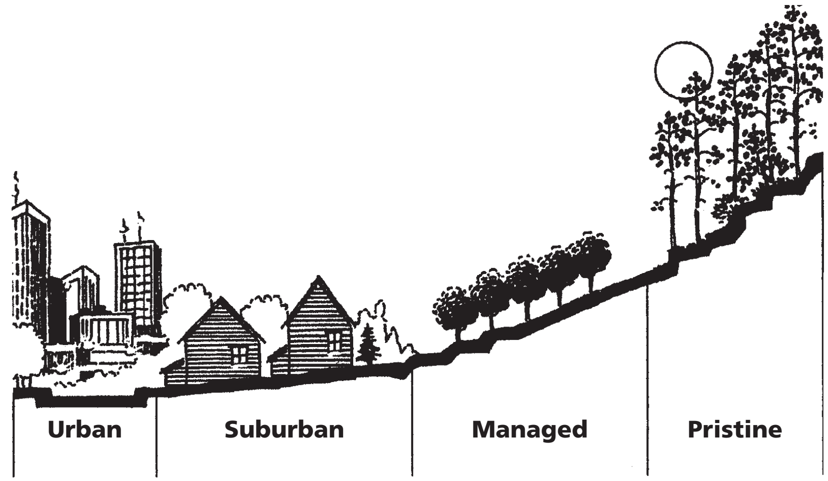


Figure 3-1 Natural resource protection goals for trails reflect trail setting and degree of disturbance. (Planning Trails with Wildlife in Mind: A Handbook for Trail Planners, 1998)

Following are some additional principles to keep in mind when assessing potential trail corridors in urbanized settings:

Best case: Look for long-established routes or boundaries that may already have become trail routes, such as fence lines, old trolley lines, railroad lines, social trails (also known as demand trails) and utility corridors.
Next best case: Use an alignment or a human imposed "edge" between two adjacent different land uses such as the boundary between a developed area and an adjacent natural area.
Last resort: Use a right of way along an established transportation corridor.

The remainder of this chapter provides information about how to find and evaluate a wide range of information during site analysis. The kind of trail, the setting in which it is proposed and the permits required will determine the extent of information to be gathered and analyzed.

3.2 Site Analysis

Site analysis involves research, inventory, field analysis and mapping to gain an overview of physical, biological and cultural conditions that present both opportunities and constraints to potential trail routes. Because trails will be incorporated into existing and future land uses, trail planners will need to review zoning, local and regional trail plans and municipal street and utility plans in addition to natural resource information. Many areas already have been studied for other purposes, so start by researching existing information. By reviewing available information, planners will be able to prioritize and expedite planning for potential trail routes.

Existing site uses. Whether considering a trail system for an urban corridor or a natural area, it is important to understand how pedestrian needs are met and identify ways to improve them. A study of existing uses helps clarify how they relate to the surrounding transportation system and existing roads, trails and utility corridors. It also can reveal what is needed to improve pedestrian routes. Examine overhead and underground utility corridors and other rights of way because these often serve as informal trail routes or connectors and can be important links in both local and regional trail systems.

Planners from different jurisdictions get together to look at improving pedestrian access by examining existing roads, proposed and existing trails and utility corridors.

Evaluate existing use information to identify opportunities and constraints. Another important step is to identify current and future uses. Both of these uses have their opportunities and constraints.

- identify existing uses and needs for student walking routes, walk-to-shop routes, bike routes, pleasure walking routes and crossings
- identify opportunities to enhance such routes
- identify conflicting needs and uses
- identify negative impacts of existing uses and potential negative impacts of increased uses (see Chapter 4 for ideas about how to avoid impacts, and chapters 5, 6 and 8 for information about how to minimize them).

For sources of information about existing site uses, refer to Appendix B.

Natural area management plans. Management plans exist for many natural areas such as Government Island, Forest Park, Smith and Bybee Lakes Wildlife Area and the Sandy River Delta. In all likelihood, natural resource inventories were undertaken to develop management plans for each natural area. The trail-planning team should review the plans for special management areas in which trails are being considered because careful planning and coordination may already have taken place to determine trail locations. Information about habitats for sensitive species may be included in the plans.

Evaluate natural area plans. Discuss the natural area plan with the area manager. Learn if trails are consistent with habitat goals. If trails are compatible with natural area goals, learn the appropriate level of use to determine the user group, width of trail, surface materials, signing and connections to other trails.

For sources of natural area plans, refer to Appendix B.

Regional and municipal trail maps. The 27 municipalities of the region have developed a coordinated, regional transportation plan, the 2000 Regional Transportation Plan. This plan includes both bicycle and pedestrian systems and a regional trail network. Analyze potential trail routes with the connections of neighborhoods to the regional trail network in mind.

Evaluate information about municipal and regional trails. Learn how the area in the vicinity of the new trail will be developed in both the short and long terms to determine the connections users will need to other trails and public transportation.

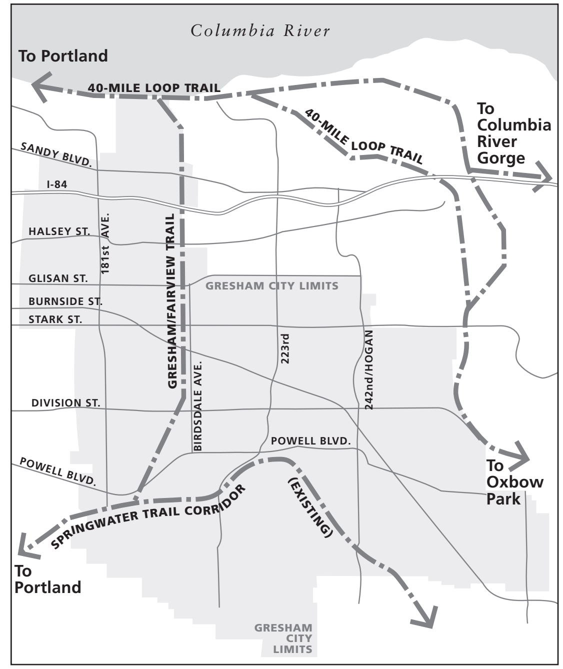


Figure 3-2
Potential new trails provide links and connections to local and regional trails and transportation routes. (Gresham Trails Master Plan, 1997)

Number and type of trail users. The type and number of users expected for the new trail segment will affect the design width, gradient and travel speed of the trail, its surfacing materials, the extent of vegetation clearing, management of the trail edges, and the location and level of development of trailheads and related facilities. User safety and the accessibility of the trail to emergency and maintenance vehicles will affect trail design and location. Potential impacts of trail users on water resources and wildlife habitats also will affect these decisions.

For sources of information about municipal and regional trails, refer to Appendix B.

Municipal zoning and comprehensive plans. City and county zoning ordinances regulate uses allowed in the areas that will be considered for trails. There may be requirements regarding trail location and width, limitations on what may be constructed, requirements for setbacks, and specifications for construction and plant materials. Many municipalities, for example, are requiring permeable trail surfacing for trails in riparian areas.

Sources of information about zoning, permits and requirements. Trail managers can learn precisely what will be required by requesting a pre-application meeting with the permitting agency. In addition to learning what the local municipality will require, the applicants also may learn what local, state and federal permits will be needed. See Chapter 6 for additional information on getting permits. Trail planners should expect to spend two to 12 months in the permit process.

Evaluate information about zoning, permits and requirements. By making a few changes to the preliminary trail route, it may be possible to meet local zoning code exemptions, avoid certain permit processes or design requirements, become eligible for grant funds and eliminate potential opposition or gain the support of important stakeholders in the trail.

Vegetation and wildlife habitats. Plants and water provide the basic elements of wildlife habitats. The amount and variety of native plants and the structural diversity of plant associations provide both food and cover, and reflect habitat types. Because plants also reflect elevation, aspect, weathering processes, soil depth, soil moisture conditions and disturbance regimes, a great deal about habitat type and quality can be interpreted from low-elevation aerial photos of vegetation. Even if the vegetation of the site under consideration has been photographed and/or mapped for various studies and master plans, it may still be necessary to check the information in the field.

Sensitive species. Trail planners should particularly seek information about the locations of habitats of sensitive species – those that are listed as threatened, endangered under the Endangered Species Act, or for which the need for concentrated conservation actions are noted. Forty-five vertebrate species that inhabit the metropolitan region are designated as sensitive, threatened or endangered by federal and state fish and wildlife organizations. These species are listed in Appendix C of this guidebook.

Water resource areas are especially rich in wildlife values. Special consideration is needed for trails in these areas.

When trails pass through sensitive areas, planners should consider trail location, design and materials.

Habitats in decline. Some sensitive species inhabit habitats that are declining. The Willamette Restoration Initiative (2001) and other regional initiatives have identified the following habitats in decline:

- riparian habitats and bottomland forests
- upland and wet prairie
- upland forests
- oak woodlands and savannas
- wetlands, springs and seeps
- off-channel or alcove habitats.

Other habitats. Other habitats in decline in the metro area may be key to the preservation of certain wildlife associations. For example, colonial nesting birds such as great blue herons depend on river islands and deltas, which are habitats in decline. Wildlife corridors take on added importance in urban areas where connections between natural areas are the only way for wildlife to travel from one place to another.

The presence of habitats for sensitive wildlife provides trail planners with interpretive opportunities. By contacting the Oregon Department of Fish and Wildlife, the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries), trail planners can learn what state and federally listed species may be present and how to protect them by means of trail alignments, design features and management measures.

For more information about wildlife habitat and trails, refer to Chapter 4 and Appendix B.

Fish habitat. Salmonids and other native fish species require cool, clean flowing water with a high level of dissolved oxygen clean gravel in streambeds for reproduction, a variety of instream cover, a sufficient food source and unimpeded access to and from spawning areas and the ocean. Four important factors influence streams as habitat for salmon: water quality, (temperature, dissolved oxygen level, turbidity) stream flow, physical structure of the stream and food supply.

For more information about fisheries and trails, see Chapter 4 and Appendix B.

Water resources and hydrology. Trail planners should review the hydrologic systems of watersheds traversed by potential trail routes by reviewing existing watershed/hydrologic maps. Trail planners who know about the locations of headwaters, seeps and springs, wetlands, streams, riparian areas and

Threatened and endangered salmonid populations have habitat in or migrate through rivers and streams in the Portland metropolitan region.

floodplains, and the hydrologic regimes that sustain them will be better able to frame constraints and opportunities for siting the trail with least impacts to water resource areas. They also will gain information about future runoff conditions that will result from development and can incorporate this information into decisions about trail design and location to improve management and longevity of the trail.

Evaluate water resources and hydrology. Trail planners should consider rarity, quality and disturbance when considering potential trail routes. This can help focus decisions about whether a resource should be avoided completely, or whether minimal impact will be acceptable. Consider the following conditions:

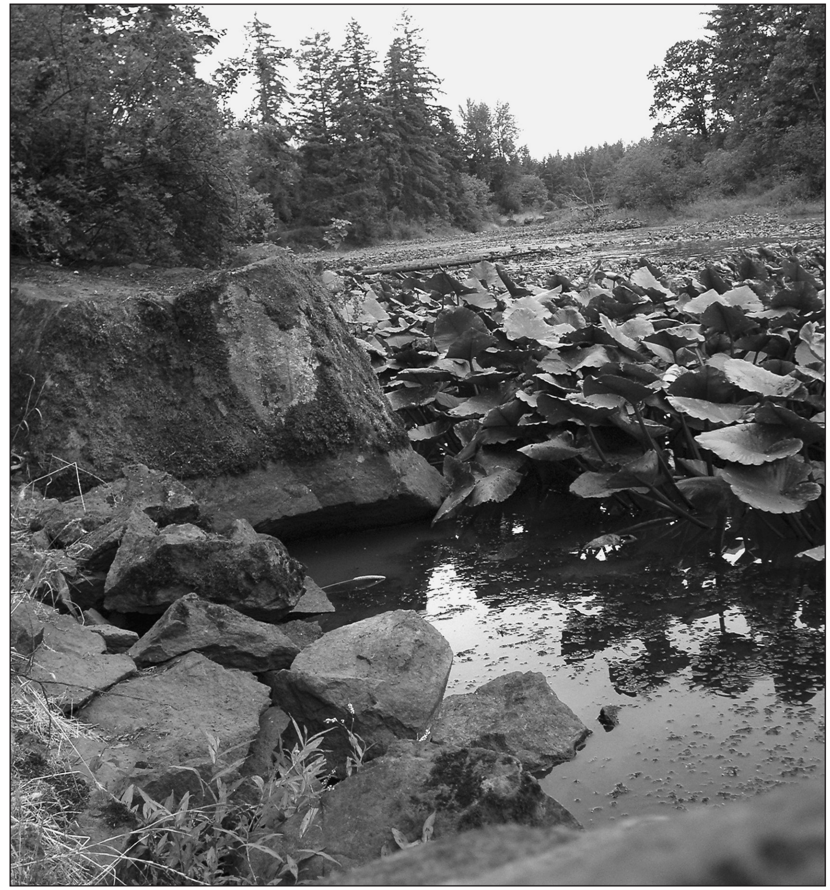
- existing and potential disturbance (by people, dogs, trampling, dumping, hunting, social trails, compaction and erosion, noise, littering, off-road-vehicle use, adjacent development) on hydrology, native vegetation and wildlife habitat

- the unconstrained function of floodplains, including over-bank flows and sediment deposition
- the function of riparian areas in providing shade, organic materials, nutrients, bank stabilization and sediment control, flood storage and microclimate
- changes, such as increased imperviousness and stormwater runoff from adjacent development that are affecting or are likely to affect the water resource.

Soils and geology. This region's geologic history has produced a variety of local conditions that can present challenges for construction and long-term stability of trails. For this reason, a geotechnical engineer should provide input to trail routes under consideration. Trail planners who are aware of these conditions can make informed decisions about trail locations, designs and construction budgets. Some of these conditions are summarized:

Loess soils. The region was blanketed with very fine rock powder at the end of the last ice age. This wind-deposited rock powder, or loess, is highly erodible and does not make an enduring earthen trail surface. The resulting soils absorb moisture very readily and dry out quickly. They tend to be dusty in summer and soft in winter. Earthen trails in these soils tend to require special attention to drainage, and, depending on intensity of use, surfacing.

Clay-rich soils. Floodplain dynamics and soil weathering processes have produced clay-rich soils in some areas of the region. In general, a little clay in soil helps to bind the materials of the trail surface. But high clay content can make a soil so moisture-sensitive that, like the loess soils, it can become too wet to support a firm trail surface in the winter. In summer, such a soil can become dusty. Structural support, drainage and surfacing are special concerns for these soils.



It is challenging to place a trail in natural areas dominated by boulders.

Bouldery and rocky conditions. Soils in low-lying areas of the region, particularly near the Columbia Gorge, contain large boulders that were deposited by large floods at the end of the Ice Ages. Excavation of the boulders is expensive. Rock frequently needs to be imported to fill the voids left by the boulders and to provide a cushion, or tread surface. In other locations, poorly cemented ancient river gravels (for example, the Troutdale Formation in Eastern Multnomah County) may make hillslope trails unstable and expensive to construct.

Perched groundwater. Many upland soils in the region have seasonally perched groundwater. This is a regional anomaly that is not common in other areas. In certain soils, weathering has created a shallow hardpan, usually within 20 inches of the soil surface, that concentrates groundwater during the wet months. When a slope is cut to create a "bench" for a trail, this groundwater can rush out to the surface and create cut slope instability, trail slumping and seasonal problems of erosion and wetness on the trail. The lower third of slopes, particularly on north aspects, and the contact zones between geologic units are also prone to chronic wetness and should be avoided.

Shallow debris slides. Shallow debris slides commonly occur in the region during very wet periods due to saturation of soils on disturbed or convex slopes, undercutting of slopes by roads, building pads or streams, and in the inner gorges of streams and rivers. Some geologic materials are prone to ravel, which can result in continual maintenance and safety problems for trails.

Liquefaction. Extensive areas close to the Columbia and Willamette rivers are subject to liquefaction, or sudden collapse and spreading during an earthquake due to the increase of soil pore water pressure during ground shaking. Many relatively flat areas close to these large rivers are coded as high hazard areas on regional earthquake hazards maps. Most are intensely developed, and, with their views of the river, are popular locations for trails. Trail planners should refer to municipal planning departments to learn what uses are allowed in these zones and what construction standards apply.

Evaluate soils and geologic data. When reviewing data about soils, floodplains and geology, trail planners should try to avoid locating trails in geologically dynamic or hazardous conditions. Some of the indicators of unstable settings include:

- A history of rockfall, landslides, slumps or low-angle earth flows in a particular area.
- Soil types rich in silt-to-clay-sized materials. Because of their capacity to absorb water, some clay-rich soils can become wet and soft during the wet season and will not provide support to the trail.
- The presence of loose rock materials. Loose or poorly cemented rock materials, particularly those that are rounded, may not provide adequate support to the trail. By avoiding these materials, trail planners may be able to save time, effort and money on design and engineering.
- Downslope-orientation of planes of weakness in bedrock where there is danger of earth slippage or rockfall.
- Slope undercutting from both natural and cultural causes. Undercut slopes may be subject to failure.
- The likelihood of intense rainfall on sensitive or exposed slopes.
- The presence of fill or spoils materials that exceed the angle of repose, or the presence of fill materials not properly keyed or compacted, on slopes.
- Fill material at risk of settlement or failure due to the decomposition of organic material in it.
- Steep slopes greater than 25 percent.
- Conditions in which altered or increased drainage affect slope stability or local drainage.
- The presence of saturation and drawdown conditions, for example, in reservoirs where water levels are manipulated or along rivers that experience tidal fluctuations.
- Flooding and/or dynamic bedload deposition.
- Presence of high erosion hazard, shrink-swell soils, soils with poor bearing strength and soils with hazard of freezing.

For sources of information about soils and geology, refer to Appendix B.

Figure 3-3 Topographic map of a section of the Clackamas River

Topography. Trails fare best in the long run if they are located on moderate cross slopes of 25 percent or less, where they can be easily drained, are not subject to flooding and the ground is likely to be relatively stable. Trails on flat ground may be subject to drainage problems. Conversely, trails in steep areas with switchbacks may invite short cutting. A review of topographic information about the trail routes under consideration can provide useful information about both favorable and unfavorable trail alignments.

Evaluate topographic information.

- Try to find routes that avoid ground flatter than 5 percent of gradient and steeper than 25 percent.
- Avoid or minimize impact to floodplains, wetlands and stream headwater zones and intact habitat.
- If stream crossings cannot be located with existing disturbances, choose stream crossing sites located at natural pinch points (naturally confined channel locations) located downstream of meadows and wetlands, where spans footings can be located outside the floodway and their footings constructed on native rock.

3.3 Natural Resource Restoration

Trail planners should seek information about potential restoration projects where trail routes are being considered. Bringing a new trail into an area can provide access and opportunity to restore a disturbed area. If the restoration opportunities are

Bringing a new trail into a disturbed area can open up opportunities to restore native habitat.

identified, it is possible that the projects can be undertaken as mitigation for unavoidable impacts elsewhere. Examples of restoration projects include:

- removing exotic plants and re-planting with native vegetation
- storm-proofing, decommissioning or retrofitting old farm and forest roads in urban greenspaces so that they do not discharge directly into streams
- rehabilitating wet meadow systems in urban greenspaces whose hydrology is affected by old roads
- removing stream crossing structures (culverts and fill) if they impede fish passage, and replacing them with bridges
- retrofitting stream crossing structures for better fish passage
- providing for wildlife passage structures on roads that fragment their habitat
- removing hazardous materials and contaminants from trail routes and rights of way.

3.4 Cultural Resources

Many developed and undeveloped landscapes contain historic districts, sites, structures, buildings and objects of significance to Native American history, American history, architecture, culture or archeology. Check the local library and contact history groups and the Oregon Historical Society. To learn whether any site in the vicinity is listed as an historic resource, check with the Oregon Historic Preservation Office at the Oregon Parks and Recreation Department in Salem. City and county offices also maintain records of some of this information. The city of Portland has specific cultural resource protection regulations that apply in certain areas along the Columbia Slough in Portland. If an historic resource is present, find out what measures must be taken to protect the resource, and what the cultural interpretation opportunities may be.

3.5 Viewpoints and Interpretive Opportunities

Just as trails enhance the character of a place, so does the character of a place enhance trails. As much as possible, trail routes should meet goals for users' aesthetic experience. A good trail location is a balance between where users want to go and where managers want them to be. If the trail does not satisfy users' desires, they will pioneer their own routes.

People are intrinsically interested in the landscapes trails traverse. They enjoy the contrast of a trail that moves from shade to sunlight, forest to meadow, wet to dry, hillslope to river, high to low. A trail that visits a grand viewpoint between points A and B will be a popular trail. A trail that curves can have the effect of slowing down the pace at which people use the trail and enhancing their experience.

People like the opportunity to interpret natural or cultural history along the way. As much as possible, potential trail routes should include landscape contrast, viewpoints, points of interest, interpretive opportunities and scenic overlooks.

How can the trail preserve sensitive natural resources?

4.1 Introduction: Avoiding Natural Resource Impacts

After learning about the natural resources of the study area, the technical team should discuss its findings with residents, the resource agencies and the trail-planning group so that everyone has the same information and criteria can be developed for selecting general trail routes.

Before field-locating the routes, review the guidelines in this chapter and in Chapter 5 that highlight best practices for siting and designing green trails. The guidelines will help the group evaluate alternative alignments and select the best location for the desired kind of trail. This chapter provides background information on the needs of wildlife and fish and discusses general principles for avoiding impacts to fish and wildlife.

4.2 Vegetation and Wildlife Habitat

Wildlife species function within a home range that varies according to the size and needs of the animal, the season and the quality of the habitat. Home range is where the animal lives a major part of its life – including feeding, breeding and wintering over. Human activities may impact some species more than others. Some species such as crows thrive in the presence of humans; others such as pileated woodpeckers prefer habitats away from humans. It has been shown that disturbance by humans can cause nest abandonment, decline in parental care, shortened feeding times and lowered reproductive success in some birds.

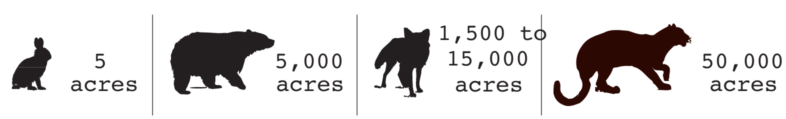


Figure 4-1 Habitat edges can accommodate trails with least disturbance to wildlife. (Adapted from Planning Trails With Wildlife in Mind: A Handbook for Trail Planners, 1998)

In particular, there seems to be an increase in conflict between humans and wildlife in riparian areas. Most humans like to recreate near streams. In response, planners have increasingly placed trails in riparian corridors. Most species of wildlife, including nearly half of all birds and 45 percent of all non-fish vertebrates in the Portland metropolitan area, use riparian areas for breeding, feeding, moving and dispersing. Ninety percent of all terrestrial species in North America depend on riparian corridors to travel from one end of their home range to another.

Following are general principles to consider when planning for trails in natural areas.

Keep trails to a minimum. If the area being considered for trails contains a sensitive natural resource, has high quality or restorable riparian or upland habitat and is home to many species, trails should be avoided in the area or there should be insurance that impacts are minimized. Studies have shown that initial human disturbances may have more impact on wildlife than continuing disturbance. This suggests that trails should avoid high-quality resources and be located where uses can be concentrated in areas that have habitats of lower quality.

Use existing disturbance corridors. Align trails along existing disturbance corridors when possible and, if appropriate, to reduce their long-term environmental impacts. Examples of disturbance corridors include:

- existing or abandoned rail lines
- corridors for overhead power lines
- old farm or forest roads
- social trails

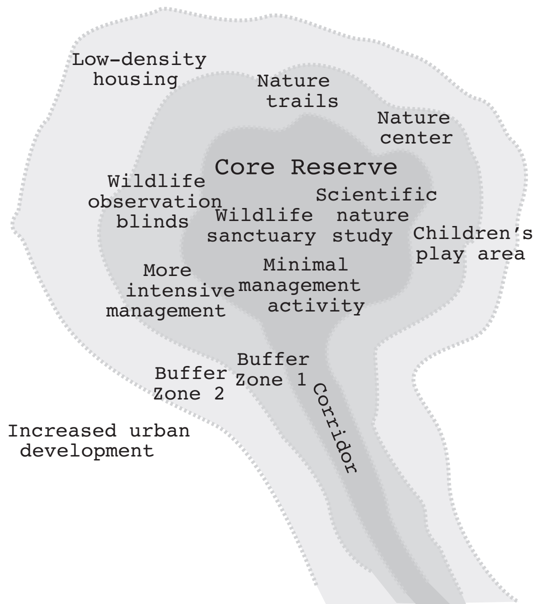


Figure 4-2 Low-impact trails in set-backs from core wildlife areas can provide users with opportunities to observe wildlife from overlooks and blinds. (Wildlife Reserves and Corridors in the Urban Environment, 1989)

- rights of way corridors
- swaths adjacent to roadways
- construction routes over buried sewer lines and other utilities
- utility maintenance access routes
- routes to quarries or borrow pits.

Trail stream crossings can be aligned to take advantage of sites where utilities cross streams. By carefully locating and aligning a trail, trail planners can subtly discourage off-trail uses and preserve sensitive resources from trampling.

It will be important to assess existing disturbance corridors, particularly those in wetlands, riparian areas or deep within habitat patches, to ascertain whether they should become trail alignments or be put to bed, abandoned or decommissioned (see Chapter 10: Trail Maintenance). The scale of the trail will play a large role in this decision. In some instances, the corridor may have become an important habitat for some species or it may retain relic habitats that have largely disappeared in the developed landscape. Restoration opportunities, such as improvement of fish and wildlife passage or removing invasive exotic vegetation, also should be identified during the corridor assessment.

Locate trails at habitat edges. Vegetation changes at habitat edges often are tension zones where opportunistic plant and animal species can thrive. Invasive exotic plants also may thrive here. Aligning trails in these locations provides an opportunity to remove the exotic plants from the corridor and replace them with natives that are better food sources for wildlife. The restored plant community also can serve as a transition zone between the trail and the intact habitat.

Keep trails out of core habitat areas and avoid fragmenting sensitive or significant habitats. In general, habitats occur in patches. Since the greatest species diversity and presence of sensitive areas is usually associated with the largest habitat patches, trails should avoid fragmenting large, intact habitats (see Figure 4-2). Because the greatest habitat impacts of trails occur with the first disturbance, the highest quality habitats should be avoided altogether and recreation uses should be concentrated where other disturbances already are present.

Maintain habitat connectivity. Access, seasonal availability and diversity of water resources are major factors contributing to the quality of wildlife habitats. Wetlands and streamside environments provide a variety of plant food and cover for wildlife, and wildlife use of these areas is disproportionate to other habitats in the landscape. Where a water resource is present, wildlife use of a corridor may be especially high. Trails should avoid stream and wetland crossings, if possible, and avoid posing a wildlife barrier between main channels and temporary wetlands.

Avoid small patches of high-quality connector habitat. Small habitat patches should be avoided, particularly if they contain unusual, sensitive or threatened and endangered species or rare habitats. Not all small habitat patches need to be connected in order to be significant. For example, many isolated hilltop forests of the region provide important stopovers for migrating neotropical birds. In other instances, physical connection of patch habitat to nearby habitats is essential. An example is the use of intermittent headwater streams by mainstem amphibians for reproduction and rearing.

Avoid habitat for threatened, endangered and sensitive species. Future trail routes should avoid the habitats of threatened, endangered and sensitive species. Each species responds to disturbance differently, so wildlife biologists should be consulted to help with preliminary planning and precise trail location.

4.3 Fish Habitat

Trails should be located outside the riparian corridor to protect stream banks from erosion, conserve riparian shade and allow recruitment of large woody debris to the stream. Only as a last resort should trails be placed in riparian areas.

Twelve threatened and endangered salmonid populations have habitats in or migrate through rivers and streams in the Portland metropolitan region. Salmon require cool, clean flowing water. Riparian habitat is very crucial for salmon and 70 other fresh water and estuarine fish species in the Pacific Northwest.

Riparian habitat provides shade, large woody debris and stabilizes stream bank and sediment. It shades streams and helps maintain cooler temperatures in the summer, which is critical to the survival of cool water fish such as salmon and trout. Elevated water temperature affects the metabolism and alters the feeding activity of fish. The roots of riparian vegetation such as trees and shrubs anchor soil and stabilize the banks. Major disruptions such as urbanization result in sediment delivery exceeding natural levels of suspended sediment. This increase in sediment lowers water quality and contaminates salmon gravel and spawning beds. If unchecked, stream bank erosion can increase sediment in the water, along with an increase in stream width, allowing more solar radiation and increasing water temperatures.

Social trails and improperly constructed trails and trail crossings placed close to streams and wetlands result in trail compaction, in some cases destroying the soil profile through loss of vegetation. This can result in an increase of erosion and delivery of sediment to nearby water bodies.

4.4 Water Resources

Avoid crossing streams, wetlands and floodplains. Trails can interfere with floodplain dynamics, groundwater movement, and stream transport of large wood and bedload. Care should be taken to avoid the impacts of trails on these resources by avoiding wet areas, springs, floodplains, stream corridors, wetlands and the lower portions of slopes, especially those that face north. The lower portions of north-facing slopes tend to be wet for two reasons. Groundwater moving downslope in the soil horizon tends to come to the surface at the toe of the slope. This condition is commonly expressed as springs or wet areas at the break in slope. The northerly aspect receives less direct sunlight than other slope exposures, and these areas generally remain wetter than south, east or west slopes.

4.5 Runoff and Erosion

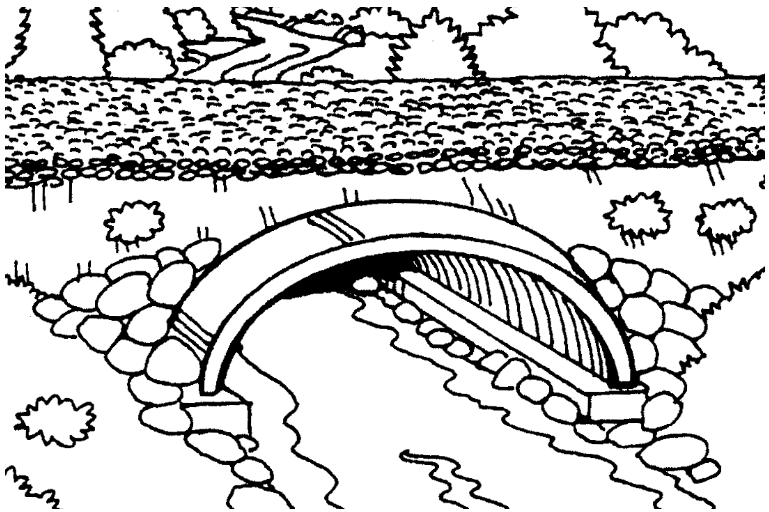


Figure 4-3 By crossing the stream on an existing structure (such as a road), new trails avoid creating new stream corridor disturbances. (Low-Volume Road Engineering Best Management Practices Field Guide, 2001)

Avoid steep trail pitches. Avoid creating even short segments of the trail that have a gradient steeper than 10 percent. It is very difficult to control drainage on steep trails, and erosion of steep earthen trails is expensive to repair. Also, runoff has a greater chance of becoming concentrated on steep trails. This can create erosion problems at the site where the water runs off the trail.

Encourage infiltration. Select trail designs and materials that facilitate infiltration rather than runoff of stormwater. Before selecting trail designs and materials, evaluate trail location and width, anticipate levels of use and the range of user groups expected so that drainage and infiltration can be fine-tuned. Also refer to Chapter 8 and Appendix E of this guidebook for more detailed discussions about trail drainage and infiltration-friendly materials.

Don't let watercourses run down the trail. Align trails perpendicular to the slope to prevent water from running down the trail surface. Trails should not be aligned "with" the slope. Trail routes should descend to water crossings from both sides of the channel so that high water does not result in the stream flowing down the trail. To avoid sediment from trail runoff entering the watercourse, it may be necessary to armor the trail with rock in the section that dips down to the crossing.

Avoid long sustained grades. Avoid long, sustained grades that can concentrate runoff on trails. Install rolling dips or grade breaks to get runoff off the trail and to allow users a rest.

Avoid flat ground and steep cross-slopes. In general, trails should be constructed on minimum cross-slopes of 5 percent and maximum cross-slopes of 25 percent. As a rule, trails on flat ground do not drain well. Trail widening is a common problem due to "walk-arounds" at wet areas on trails on flat ground. Trails on very steep slopes require larger excavations to create a level travel surface. There is an increased potential for sloughing, ravel, erosion and mass wastage of cut banks on steep cross-slopes. These dynamics can encourage the formation of bypass trails and can increase maintenance costs.

Avoid discharging trail runoff onto fill slopes and unprotected soils. Concentrated runoff from trails can cause damage to fill slopes and to unprotected soils adjacent to the trail. Discharge sites for trail runoff need to be carefully selected so that runoff velocity is slowed and sediments can settle out. Fill slopes should be armored where runoff is discharged onto them, or the runoff should be conveyed in a down drain such as a pipe to a location where sediments can be deposited and the flow infiltrated.

Avoid discharging trail runoff into streams and wetlands. Trails (and roads used as trails) have the capacity to change the timing, quantity and quality of the natural hydrologic system by delivering both sediments and runoff directly to streams, wetlands and riparian resources.

Avoid removing trees and shrubs at stream crossings.

Use existing roads and bridges wherever possible to refrain from removing trees and shrubs at crossings and to avoid new stream corridor disturbances.

Route selection and trail design should consider how trail drainage will be accomplished without affecting these water resources. Measures to avoid such impacts include:

- encouraging filtration on site as much as possible to avoid concentrating flows
- spreading crushed aggregate on earthen trails in locations where they can drain to streams or wetlands
- providing more frequent drainage relief for trails in these sensitive areas
- making trails as narrow as possible, and using existing disturbance corridors.

Avoid stacking switchbacks and climbing turns. Trail switchbacks and climbing turns need to be carefully sited so that their locations do not invite cut-throughs. When more than one switchback is necessary, they should not be inter-visible, particularly in winter, when many plants do not have leaves. Switchbacks should be offset from one another, and they should take advantage of natural benches, slope breaks and natural screening to prevent cut-throughs and short-cuts.

To further discourage cut-throughs, grades leading immediately into switchbacks and out of switchbacks can be increased, and brush or log barriers can be installed in the turn. Often it is necessary to field design an earth-retaining structure in the turn. For an informative video, “Constructing Trail Switchbacks,” contact the U.S. Forest Service Technology and Development Program and request 2300 Recreation video, 00-02-MTDC.

What are some practices for minimizing the natural resource impacts of trails?

5.1 Introduction: Minimizing Natural Resource Impacts

This chapter focuses on strategies for minimizing the environmental impacts of trails. By integrating the practices summarized in this chapter with knowledge about site natural resources, trail planners can develop specific, environmentally friendly low-impact trail routing and drainage alternatives at the site scale.

In addition, there is much published information available to help accomplish these goals, and there is an extensive list of additional resources in the topical bibliography section at the end of this guidebook.

5.2 Protecting Vegetation (Wildlife Habitat)

Try to determine where people want to go, and then give them an easy way to get there that avoids the sensitive resource.

Techniques for limited access areas. If sensitive habitat cannot be avoided, try to find a way to place the trail at the habitat edge. Use an elevated trail or trail construction type that allows for low-impact access that encourages trail users to stay on the trail. Create a spur to a point of interest such as a wildlife-viewing area or scenic overlook. If possible, establish vegetative screening.

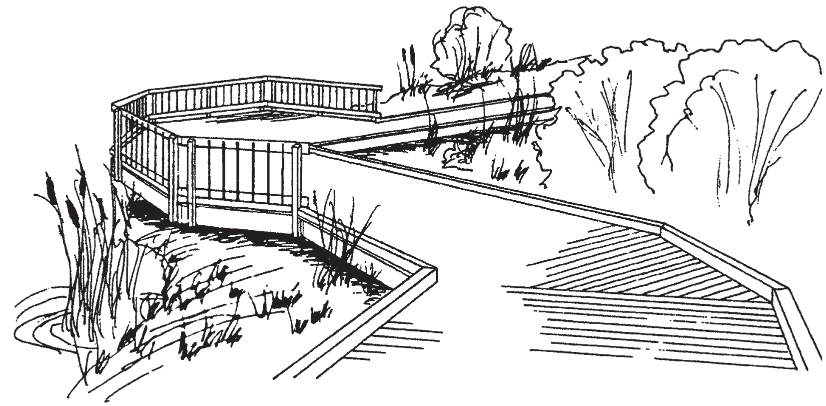


Figure 5-1 A boardwalk allows access to a wetland while encouraging users to stay on the trail. (Trails Design and Management Handbook, Open Space and Trails Program, Pitkin County, Colo., 1994)

If a trail is not designed to accommodate large numbers of users, its entry point might be made obscure and/or a proper trailhead may be omitted. The angles of trail intersections can be subtle ways of influencing the direction of travel on particular trail segments. A raised trail in a wet area – be it a bog bridge or a boardwalk – always keeps people on the trail.

Vegetative screening. To protect sensitive species from trail disturbances, establish native vegetation buffers of appropriate widths and densities to screen the trail.

Selected thorny native plants can be placed in some settings to discourage off-trail uses. However, more substantial barriers may need to be constructed to discourage off-trail uses. For example, to discourage cyclists from venturing onto wet or natural area trails, the first segment of a trail might be constructed as a stairway, perhaps flanked by thorny plants.

Trails in the Smith and Bybee Lakes Wildlife Area in Portland, Ore. are designed and sited to protect sensitive species such as the Western painted turtle.

Setbacks for threatened, endangered and sensitive species. Establish setbacks from habitats of threatened, endangered and sensitive species and water resources, including wetlands, streams, meadows, riparian corridors and ponds (see Appendix C). For example, don't encircle a pond with a trail, but identify low-impact opportunities for trail users to view the pond while leaving a majority of the area in its natural state. After an office and field inventory is completed to identify sensitive wildlife habitat in an area, an alternative analysis should be done to place the trail in an area where it will have the least impact on habitat.

If a threatened, endangered or sensitive species is using the site, follow appropriate measures after consultation with regulatory agencies. For example, if bald eagles are observed foraging or perching in the vicinity of a project site, keep activity and noise levels to a minimum to reduce the potential for disturbance. If nest sites are observed or known to occur within a quarter mile of a project site and work is proposed during the nesting season (Jan. 1 through Aug. 15), activities must be carried out at a distance greater than 800 meters (in line of sight) and 400 meters (out of line of sight) from eagle use areas to minimize the potential for disturbance. Construction work should be scheduled outside wintering period (Oct. 31 through March 31) and/or the nesting period (Jan. 1 through Aug. 15). Screening activities from view (i.e. through vegetation or topography) can also minimize disturbance.

Trail closure. The posting of signs let users know that a trail will be closed during breeding season for a sensitive species, either fish or wildlife. If trails will be closed to protect wildlife, the times and method of closure should be known at the time the trail is planned, and notification and enforcement strategies should be developed.

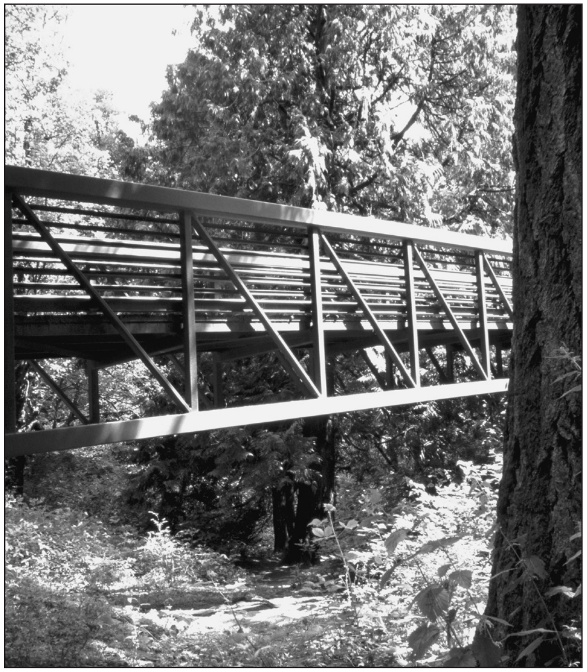
5.3 Minimizing Impacts to Fish Habitat

The following steps are recommended if an office or field inventory indicates that a trail will be near a native fish-bearing stream.

Use appropriate setbacks for trails near fish-bearing habitat. To protect fish and water quality, researchers have recommended riparian area setbacks from 50 feet to 200 feet from the top of bank, depending on the stream to protect fish and water quality (see Appendix C).

Trail closure. Closing a trail during key spawning times may help alleviate disturbance if users understand and agree with the rationale behind the restriction. Tools to educate the user could include signs, outreach activities and pamphlets.

Work windows for threatened, endangered and sensitive species. If a trail is constructed near a riparian corridor, associated in-stream work must be scheduled to occur within work periods established by the Oregon Department of Fish and Wildlife. Depending on location, the work window extends from as early as June 1 to as late as Oct. 10 (see www.dfw.state.or.us/ODFWhtml/infocntrhbt/0600inwtrguide.pdf).



This pedestrian bridge over Butler Creek in Gresham completely spans the 100-year floodplain.

Stream crossings. City and county zoning codes include specific regulations for setbacks from streams and other water bodies. If a trail must cross a stream, the trail-planning team's hydrologist, geomorphologist and fisheries and wildlife biologists can help determine whether a bridge or a culvert will provide the best solution for fish and wildlife passage. All culvert sizes for stream crossings should be prescribed by a fish passage engineer based on the size and conditions of the contributing watershed, the passage needs of fish and stream corridor wildlife, the dynamics of the stream and the best hydrologic data available. Some common prescriptions by ODFW and Washington Department of Geology include:

- In order of preference, use bridges, bottomless arches (see Figure 5.3), partially buried culverts or other similar structures
- Do not substantially alter water velocities and especially do not create excessive velocities. Keep culvert velocities to those navigable by fish.

Examples of fish-friendly designs

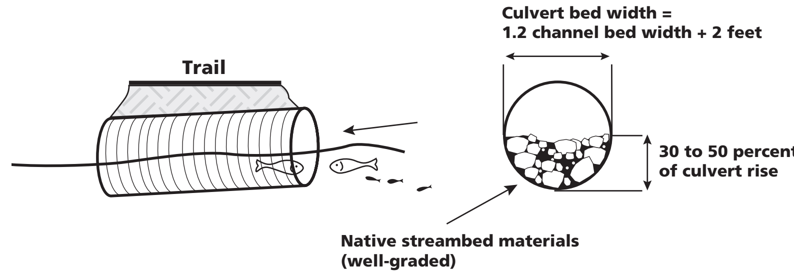


Figure 5-2 Easy passage. (Fish Passage Design at Road Culverts – Washington Department of Fish and Wildlife)

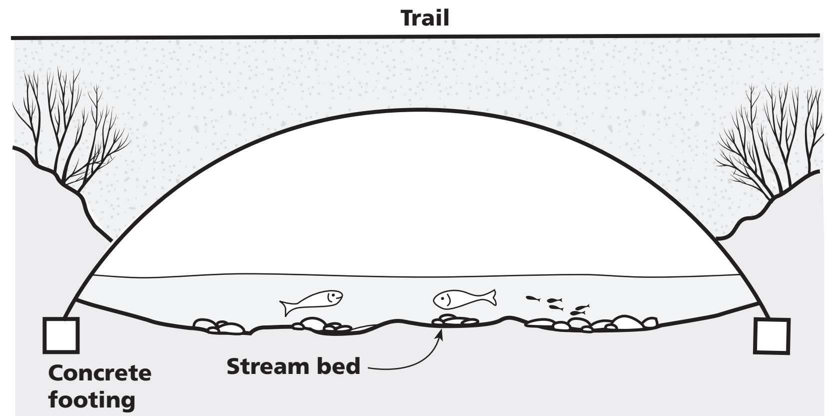


Figure 5-3 Bottomless arch culvert

- Do not create adverse water depths. Keep culvert flow depths comparable to the associated stream channel (see Figure 5-2).
- Provide resting pools at culvert inlet and outlet for culverts installed across streams with high channel gradients.
- At stream crossings, select a culvert size where there will be no abrupt change in gradient and the upstream and downstream channel alignments are as straight as possible for 50 feet in either direction.

- Fill slopes that drain to the stream should be trimmed to stable angles and vegetated or bioengineered or armored with rock.
- Pipes and culverts should be sized for the expected 100-year flow event in streams with habitat for sensitive species such as salmon. This design is intended to minimize channel erosion and deposition influenced by the crossing.

There are many excellent references to help with design of spans and culverts, and some are listed in the bibliography of this guidebook, under *Fish and Fish Passage*. For a thorough reference on designing culverts for fish passage, see www.wdfw.wa.gov.

5.4 Protecting Water Resources (Streams, Wetlands, Floodplains and Riparian Corridors)

Minimize stream corridor crossings. Trails should not cross streams more often than necessary and should not cross the same stream more than once if crossing cannot be avoided. Metro's Green Streets guidelines recommend stream crossings be no more frequent than about ¼ mile apart. Stream crossings should be as narrow as possible, and trails approaching bridges should become narrower where they cross in order to minimize the impacts of the crossing.

Trails should not be located in long stretches of riparian or streamside areas, but should cross them on short, direct routes. Crossings should take advantage of landscape settings where streams are naturally confined by hillsides, and ideally, crossings should be located downstream of floodplains. Trails in water resource areas should be surfaced with materials that allow infiltration of rainfall and that will not be washed by runoff into the water resource area.

One way to avoid constructing additional riparian corridor crossings is to use existing roads or utility crossings as crossing points for trails. Another is to use very long spans whose footings are outside the floodway (see Figure 5-4).

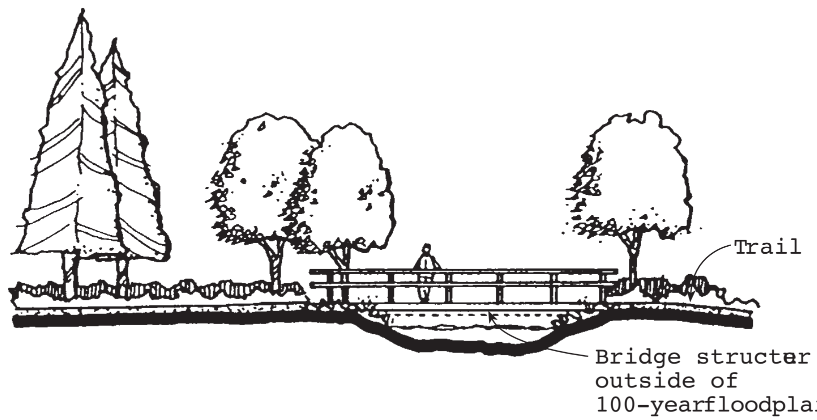


Figure 5-4 Locate footings outside of stream channel at top of bank (Trolley Trail Master Plan, Metro, 2003)

Fords, bog bridges, causeways and boardwalks. Each of these construction types enables trails to be constructed in wet ground:

Fords. Fords are installed where it is not feasible to construct a bridge or to install a pipe culvert, i.e., where streams have no, or low, banks (see Figure 5-5). Approaches to fords and low water crossing should be low gradient, armored with rock to prevent erosion and placed where bottom material is firm and erosion is minimal. Don't locate a ford in a spawning area, and make certain the ford does not become a passage problem for fish.

Bog bridges. Managers of natural areas, sensitive habitats and wetlands like to use bog bridges when low-use trails must pass through wet areas. There are many styles of construction, but all create a narrow pathway that spans between low supports that are laid on the ground. Traditionally, native wood puncheons and planks were used. Other materials such as plastic lumber might be used today. Typically, bog bridges do not have railings because they are low to the ground, but they may be constructed with low curbs. This kind of trail should not be used where flooding is expected.

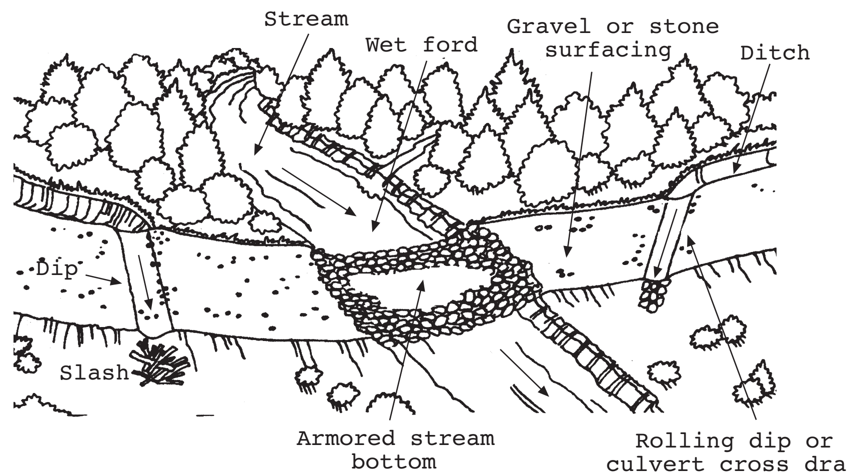


Figure 5-5 Simple ford design in an area with no fish spawning or fish passage problems. (Low-Volume Roads Engineering Best Management Practices Field Guide, 2001)

Log supports laid flat on the ground provide a foundation for a low-use bog bridge while limiting disturbance to a fragile wet area. (Wetland Trail Design and Construction, 2001)

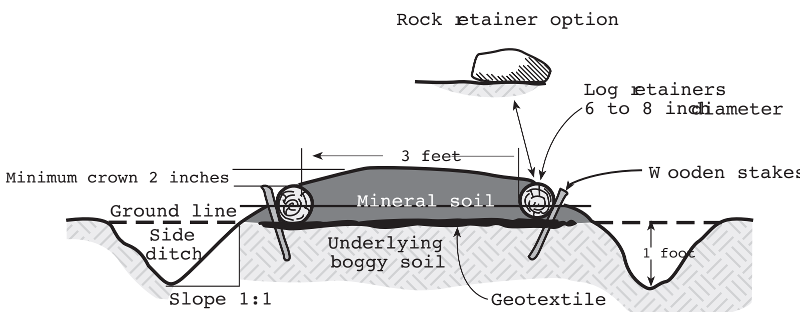


Figure 5-6 Cross-section of causeway construction. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook. United States Forest Service.)

Causeways. Causeways (see Figure 5-6) are a time-honored way to elevate a trail tread above a wet section of trail. They encourage trail users to stay on the elevated trail instead of walking around a wet spot. There are many different techniques for constructing causeways and they all provide a filled, elevated, drained surface and a means to let groundwater and surface water pass under the trail at grade. They no longer are commonly used in wetlands because of the potential effects of ditches on groundwater conditions. They can be an effective way of elevating a trail through a wet spot.

Another way to provide a dry trail through a wet section is to use a cellular confinement system, a duck board or a metal grate. A cellular confinement system is a rigid mat with honeycomb-like cells that can be laid over the geotextile and backfilled with gravel to provide tread support through the wet area (see Figure 5-7). A duck board elevates the tread surface above a wet area by means of boards.

A duckboard elevates the tread surface above a wet area.

Metal grates can provide a dry trail through a wet section.

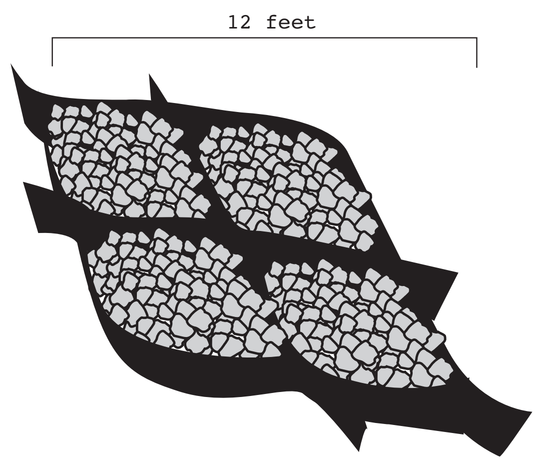


Figure 5-7 Cellular confinement system. Rigid cells filled with aggregate can provide support to a trail in a wet spot. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook. USDA Forest Service.)

Elevated trails and viewing platforms. Viewing platforms can provide exciting ways for people to see wildlife in natural areas without disturbing their habitat. When a well-used or multi-use trail must pass through a wetland, an elevated trail can minimize impacts by raising the tread and traffic above these sensitive resources (see Figure 5-8). The tread, preferably made of synthetic lumber or metal grating (not galvanized), is supported on steel foundation pilings sometimes called "screw piles." Screw piles have been noted to resist sinking in some conditions that cause boardwalks on wooden pilings to sag over time. Plastic lumber often is used for railings and non-structural elements of boardwalks. Some structurally reinforced plastic lumber is beginning to be available as well.

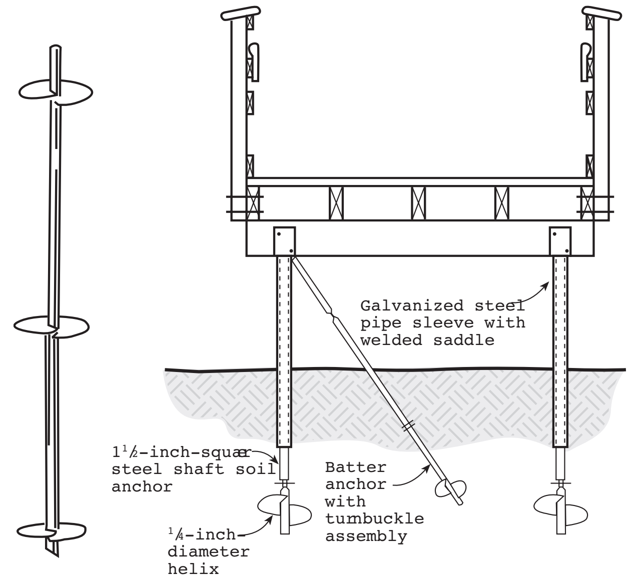


Figure 5-9 Metal screw piles can give reliable support to boardwalk structures in soft ground and do not need to be driven as deeply as traditional log pilings. (Wetland Trail Design and Construction, 2001)

Viewing platforms can be great destination points along trails, and they provide opportunities for interpretive education. For safety reasons, structures that are 30 inches or more above the ground must have railings. Biological conditions may require platforms be located so they don't shade sensitive resources and that trail treads allow light to penetrate to vegetation under the trail. Metal grating allows light penetration and provides a non-slip surface. Because smooth trail surfaces can become slippery during the wet season, roughened tread surfaces, open grating or grit-treated mats can be used to combat this safety problem.

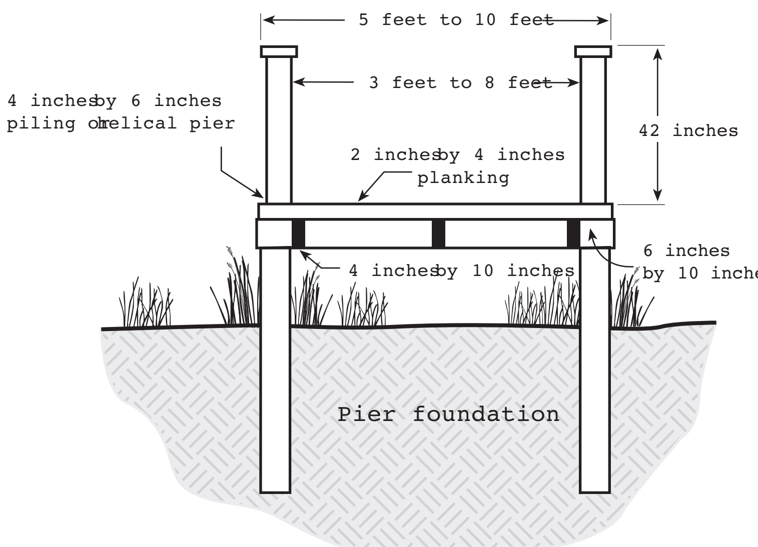


Figure 5-8 Elevated trails do not disrupt ground or surface water movements and they allow for wildlife passage. (Wetland Trail Design and Construction, 2001)

Geotechnical exploration is necessary to determine how deeply boardwalk and viewing platform supports must be driven into soft sediments (see Figure 5-9). Screw piles require special equipment to install, but in some cases, do not need to be driven as deeply as traditional pilings. Screw piles do not require the careful attention to environmental protection that is needed when working with treated wood products. For more discussion on this topic, see the section on treated wood products in Chapter 8 and Appendix F. Connecting hardware for elevated trails should be corrosion-resistant. Wood that has been treated with waterborne preservatives containing copper must use galvanized connecting hardware.

5.5 Preventing Erosion

Unsurfaced trails are subject to erosion, as are some trail surface materials. Both natural and constructed trail surfaces can generate concentrated runoff, which can increase erosion, affect water resources and damage trails. By being aware of the kinds of problems that can be created or invited by trails in and near water resource areas, trail planners can work to avoid them through alignment, design and surfacing decisions. Solutions that can be implemented in the planning phase include trail siting, alignment and the use of vegetated setbacks. Solutions that can be implemented in the design phase focus on drainage design approaches, drainage templates and surfacing.

Techniques for the planning phase

Identify water resources at risk of receiving trail runoff and sediments. It is important to know the locations of water resources within about 200 feet of each proposed trail alignment. The location of these potential "receiving" water resources relative to the trail will help planners make decisions about trail type and siting, placement of trail drainage structures, designs for interception and infiltration of trail runoff and design of the cleared right of way. The proximity of water resources also should influence the selection of trail maintenance equipment, the season when certain maintenance work will be done, and even the disposal of earth materials generated during construction and maintenance activities.

Vegetated setback for trails. Researchers have recommended riparian setbacks for development ranging in distance from 33 to 250 feet from top of bank to minimize the impacts to water quality and to protect the full array of riparian functions (see Appendix C). Local governments have adopted ordinances to protect water quality and setbacks range from 50 feet to 200 feet depending upon slope.

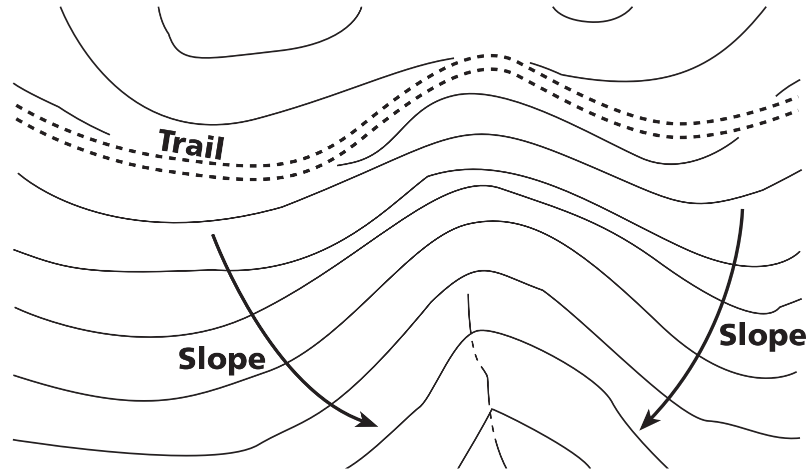


Figure 5-10 When trails traverse slopes instead of plunging directly up or down them, they are easier to maintain in good condition. (Low-Volume Roads Engineering Best Practices Field Guide, 2001)

Minimize trail width. Most municipalities in the region prescribe a vegetated setback between water resources and trails. Within these setbacks, trail width should be kept to a minimum and trail drainage should be managed for complete infiltration of runoff and immediate deposition or filtering of sediments in trail runoff. Runoff is less of a concern on trails in dense coniferous forests because the canopy intercepts much rainfall. For road-to-trail conversions, excess width can be ripped, sloped to drain and seeded to reduce the amount of bare earthen surface exposed to erosion.

Align the trail parallel to contours. This will discourage water from running down the trail surface (see Figure 5-10). Consider stairs where slopes are steep. Switchbacks can be another solution, but they require careful location, design and construction to remain stable and to discourage short cutting.

Plan ahead for construction in sensitive ares. Develop a plan for preventing erosion and controlling sediments in or near sensitive areas. Chapter 9 provides some guidelines on this topic. Cities have their own erosion control measures. For example, Portland's Erosion Control Manual includes best management practices for construction in sensitive areas.

Strategies for drainage design

Make sure to involve the appropriate specialists in decisions about types of trail surfaces, construction planning, trail drainage designs, drainage ditches, pipes and culverts. Some general design approaches for avoiding concentrated flows and erosion follow:

Trail surfaces for water resource areas. Use permeable surfaces and design stormwater infiltration to reduce the risk of trail runoff discharging directly into water resource areas.

Trail construction techniques. Adequate preparation of the sub-grade and base are necessary to support a stable, structurally sound trail, particularly in wet spots or wet conditions. Without this support, trails can become soft and muddy, which can encourage off-trail uses and erosion. Trails that will be used by maintenance vehicles need to be designed for this purpose to assure that rutting and erosion do not result.

Trail drainage templates. Trails should be sloped in cross section so that their surfaces shed water. Favorable drainage cross-gradients are achieved by in-sloping, out-sloping and crowning (see Figure 5-11). By controlling the nature of the trail cross slopes, trail designers control erosion of earthen trails and determine where runoff will be directed. Drainage designs also determine how much water will be present in trailside ditches and runoff discharge points. Hydrologic calculations are necessary to determine whether the ditch will need to be armored (protected with rock), how large and deep the rock should be and how frequently drainage relief will need to be provided. As a general principle, it is best to avoid inside ditches when possible to avoid ongoing maintenance needs.

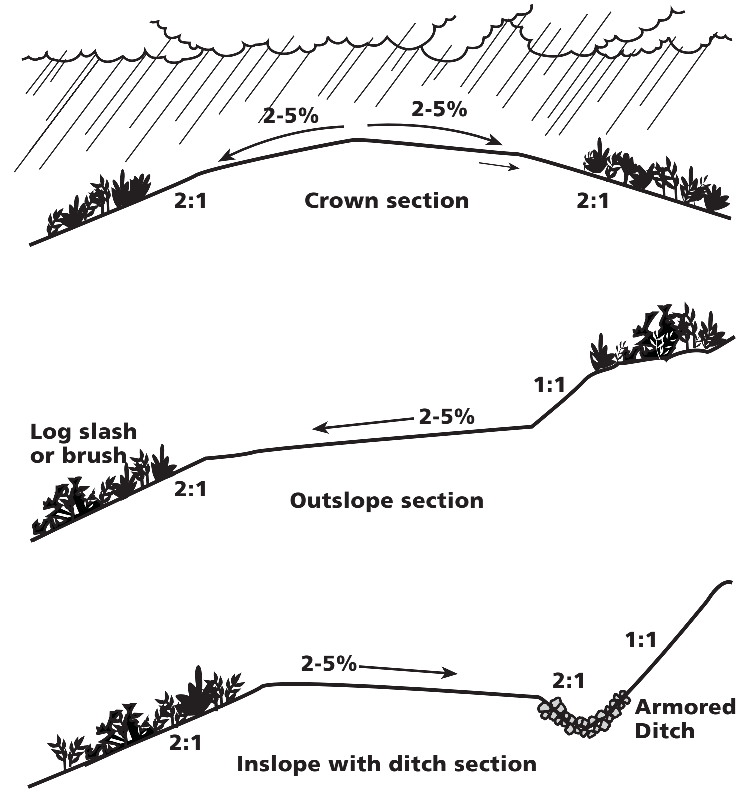


Figure 5-11 Typical trail drainage templates. (Low-Volume Roads Engineering Best Management Practices Field Guide, 2001)

Minimize runoff. Manage runoff in small quantities close to where it is generated so that risk of drainage system failure is low and runoff is concentrated as little as possible. Provide out-sloped drainage of at least 3 percent for earthen trails where possible so that runoff will sheet evenly off the outside edge of the trail. Out-sloping trails with constructed surfaces also can reduce the amount of concentrated runoff and minimize erosion that can be generated by discharge of concentrated runoff (see Figure 5-12). Out-sloping trails can eliminate or reduce the need for water quality facilities. Out-sloping also reduces the need for inside ditches and trail cross-drains (under-trail drain pipes), which frequently require greater maintenance to prevent erosion.

Planting trees and shrubs to create dense vegetative cover near the trail also can minimize runoff. The leaves of the overhanging plants will intercept much of the rainfall so that less of it falls directly on the trail. Leaf litter on the ground near the trail will absorb much of the rainfall, and the roots of plants in the vicinity of the trail will aid in both infiltration and uptake of water in the soil.

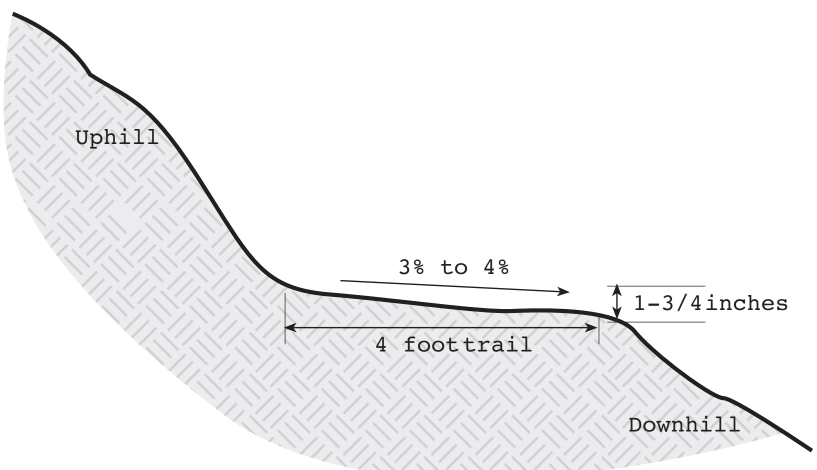


Figure 5-12 Outslope cross section. (Adapted from California State Parks and Recreation)

Figure 5-13 Bio-filtering swale. (Green Streets: Innovative Solutions for Stormwater and Stream Crossings, 2002). Vegetation in trailside ditches and swales can slow and filter trail runoff, providing important water resource protection.

Vegetative filtering. Trails can be designed to slope to adjacent vegetated areas so that diffuse runoff can be immediately filtered, level spread and infiltrated (see Figure 5-13). Locations selected for this purpose require sufficient light to support a dense growth of ground cover. Where concentrated flows cannot be avoided, treatment can be provided in created grassed swales, created ponds or other passive trailside facilities.

Drainage from trails should be treated before release to water resource areas. In settings where trail runoff must be concentrated and conveyed to a suitable discharge area, look for opportunities to combine this water with other runoff to create a treatment wetland or pond that offers a seasonal or perennial source of water for wildlife. It is important that trail drainage discharged from such created facilities does not change the hydrology of natural wetlands in the vicinity.

Metro's Green Streets: Innovative Solutions for Stormwater and Stream Crossings has many ideas for dispersing runoff and integrating it into the adjacent landscape. Many techniques explained in the publication such as filter strips and swales, permeable pavements and level spreading are applicable to multiple-use trails and should be considered. The city of Portland's Stormwater Management Manual also provides useful suggestions about appropriate vegetation for managing stormwater.

Limit sustained grades. Limit sustained grades to less than 10 percent to control erosion of the trail surface and to provide the majority of users with a trail gradient that they will find pleasant. A 10 percent sustained gradient is the steepest gradient commonly acceptable for moderate-to-challenging trail use by hikers, equestrians and long-distance mountain bikers.

Prevent erosion at outlets of rolling dips and culverts. Drainage outlets from trails should be protected to prevent erosion of the runoff discharge area. Often, a small armored earthen basin is constructed beside the trail to dissipate flows at runoff discharge points and to facilitate the deposition of sediments (see Figure 5-14). Such basins usually have sufficient volume to hold runoff for a time and encourage infiltration. For a minor outlet, brush or native organic debris can be spread to slow the velocity of the runoff. Major outlets should be armored with rock. Adequate armoring generally consists of two layers of angular rock sized to withstand movement by "worst-case" flows. To design an armored outlet that will last, a hydrologist can calculate the runoff expected in a 50-year storm or greater and select the rock size to resist this flow. Sometimes it is necessary to place brush at outlet of such basins where they overflow to break up concentrated flow and prevent erosion.

Use of drain pipes. When drainage from a trail interrupts surface or groundwater, a drain pipe or culvert should be used. Pipe-sizing calculations often must take into account the contributing watershed, its size, the nature of vegetation or disturbance, and how future development in the contributing watershed may affect groundwater or surface runoff that drain to the ditch. Rainfall and soil characteristics also are to be considered.

Finally, a decision must be made about the "design storm" each culvert must be capable of passing. In some jurisdictions, the design storm may be a storm with a 15-year recurrence frequency. Many jurisdictions are upgrading the design storm for which pipes are sized, recognizing that in urbanizing areas, runoff amounts can subject pipes to failure if they are not adequately sized. The selection of a larger pipe may contribute to a more stable trail drainage system that requires less maintenance in the long run.

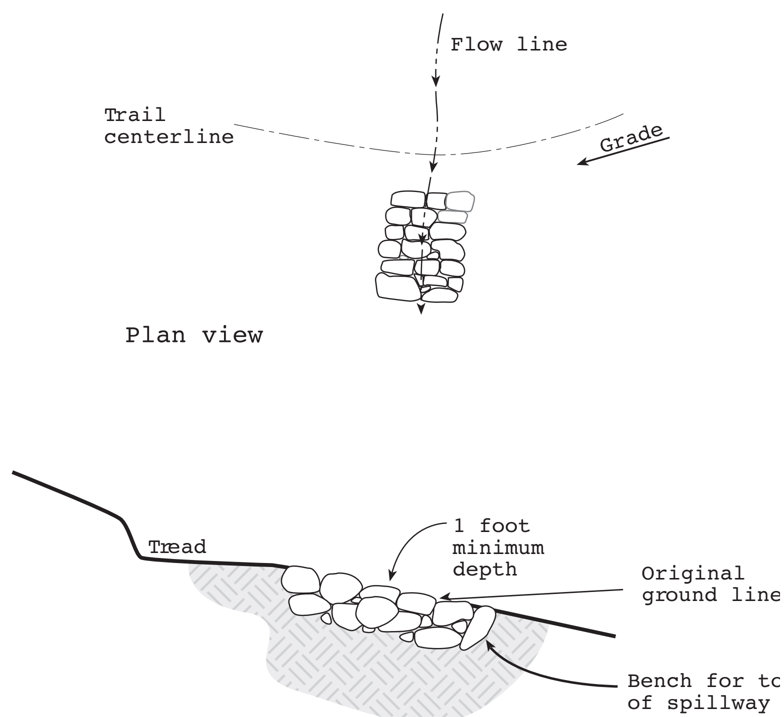


Figure 5-14 Rock-armored outlet, also known as drainage dissipation apron. (U.S. Department of Transportation. 2001. Gravel Roads Maintenance and Design Manual.)

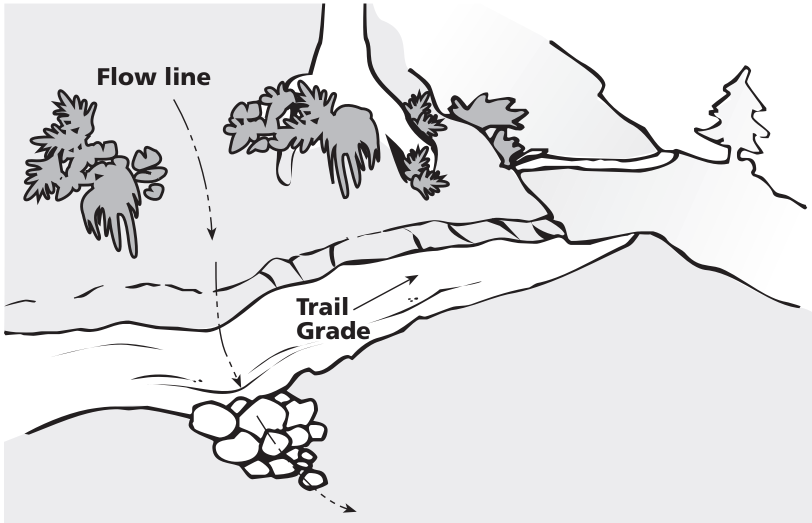


Figure 5-15 Runoff is directed from the trail to a rocked discharge area that protects the slope below from erosion.

Provide frequent drainage relief. Trail designers need to determine how every segment of each trail will be drained (see Figure 5-15). Frequent drainage relief is essential to minimize runoff and related erosion. Greater frequency of drainage relief is needed when trails are steep, constructed in erodible materials or near water resources, so that runoff discharge volumes and velocities remain low. To create rolling dips, the trail is designed so that the longitudinal profile is undulated frequently (this also is called rolling or breaking the grade) to disperse water from the tread (see Figure 5-16). The dips route runoff off the trail before rilling (erosion deeper than 1 inch) can occur. Spacing depends on gradient and the erodibility of the native earth materials. Some managers recommend more closely spaced drainage relief for urban-area trails, due to other factors that contribute to increased runoff.

The spacing of drainage features is related to both trail grade and materials. Steeper trails require more frequent drainage relief. Sandy, rocky and gravelly soils require less frequent drainage relief because runoff drains quickly into the soil and because these large, heavy materials are not easily moved by runoff. Silts, which are characteristic upland soils in much of this region, easily erode. Silty trail surfaces require more frequent drainage relief to resist erosion. The spacing suggested in Table 5-1 is a starting point for minimum drainage frequency. Aspect, position on slope and gradient of the cross-slope also influence the spacing between drainage features. The trail-planning team's soil scientist and geotechnical engineer can help with this.

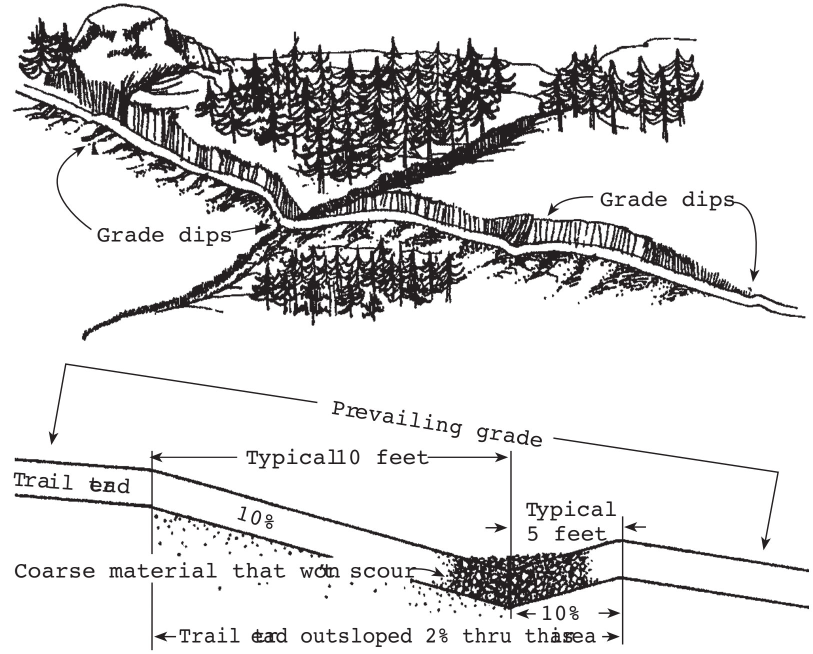


Figure 5-16 Subtle drainage features such as these rolling dips are incorporated into the trail so that runoff does not concentrate and is quickly routed off the trail. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook. USDA Forest Service.)

Trail grade	Coarse, rocky gravelly materials (in feet)	Gravelly sands, silty sandy gravels, coarse clay, extrusive volcanics (in feet)	Silty clays, clays, fine sandy silty weathered volcanics (in feet)	Friable silts, fine silts and sands, fine decomposed granitic soils (in feet)
2 %	300	160	136	100
4 %	280	145	121	85
6 %	250	140	113	75
8 %	230	135	106	70
10 %	200	125	97	60
12 %	175	115	80	50

Table 5-1 Recommended frequency or spacing of rolling dips and water bars to prevent rill erosion by runoff on earthen trails. (Adapted from Geotechnical/ Materials Engineering Training Session, USDA Forest Service, 1982, 2002)

Table 5-2 shows recommendations about culvert spacing. Some managers prefer to space cross-drains closer on trails in urban settings due to a number of factors that can increase expected runoff. In Portland's West Hills, for example, or in the East Buttes (Boring Lava Domes in East Multnomah County), it is important to plan for drainage of perched groundwater that trail excavation captures. Increased use of earthen trails can also generate more runoff.

It is not always easy to determine how erodible a soil is by looking at it. For this reason, the soil scientist on the trail-planning team should evaluate soil erosion hazards along the trail route and provide recommendations about drainage features and spacing.

A note about drainage features and bicyclists. Rolling dips must be "transparent" to a bike wheel – that is, elongated so that riders roll smoothly through them – and the dips must be angled at 45 degrees or so to the travel direction. They must fall at about 20 percent of slope so that they are self-cleaning, meaning that sediments moving in runoff from the trail will be transported off the trail in runoff from the dip. For longevity, particularly to withstand wear by mountain bikes, both the mound and dip should be armored with gravel or rock.

Trail or road grade	Soils with low to moderate erosion hazard (in feet)	Soils with high erosion hazard (in feet)
0-3 %	500	325
4-6 %	400	230
7-9 %	325	160
10-12 %	280	130
12+ %	245	100

Table 5-2 Recommended distance between culvert cross-drains. (Adapted from Low-Volume Road Engineering Best Management Practices Field Guide, USDA Forest Service, 2001)

5.6 Working With Steep Slopes

Steep cross slopes (greater than 25 percent slope) present special challenges for trails, trail designers and trail users. A steep earthen trail that descends "with" the slope can develop severe erosion problems that are difficult to fix and may affect water resources. Small rock fragments on steep, hard, earthen or bedrock trails can be very treacherous for users. The danger of slipping on small rolling rocks or a slick section of trail often results in the development of numerous side trails where people can get a foothold on vegetation. If a steep trail is too demanding, users may choose another route. Steep trails may invite unwanted uses (such as cross-country bicycling) that are not conducive to natural resource protection goals. The need to protect public safety as well as water resources and wildlife habitats requires special approaches to the design of trails if steep terrain cannot be avoided.

Climbing turns. On moderate slopes (less than about 15 percent), it may be possible for a trail to gain elevation by means of a broad climbing turn (see Figure 5-17). The steepest part of the turn may be steeper by a few percentage points for a short "pitch" than the steepest sustained grade on the trail.

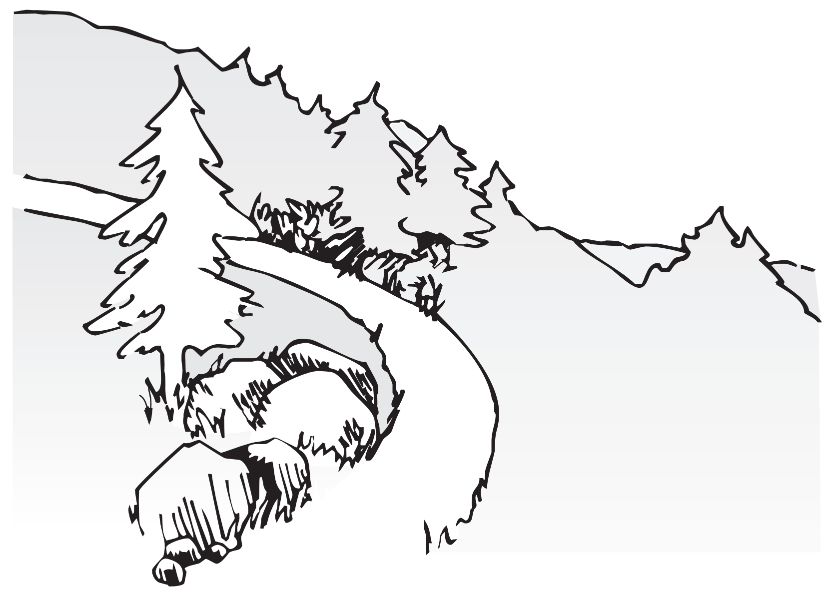


Figure 5-17 Climbing turns sweep gently upslope, minimizing the portion of the trail that runs "with" the slope and keeping gradient low. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook. USDA Forest Service.)

Switchbacks. Switchbacks provide a way to gain or lose elevation on steep slopes greater than about 15 percent by means of slope traverses with periodic reversals in trail direction (see Figure 5-18). A person with trail engineering skills should design the switchback's "hairpin" turn because earth cut and fill are necessary. The area where earth materials will be placed as fill needs to be properly prepared before the fill is placed in compacted layers. This means that vegetation and organic debris should be stripped from the "fill" site and all roots grubbed out to a depth of about 1 foot. The fill layers should be "keyed" into one another. These details are essential for the fill section of the trail to have structural integrity.

A person with field engineering skills should oversee the construction. The turn often requires an earth retaining structure with large rock or wood material placed on it to keep it from being short cut. In wildland settings, the materials for the retaining structure and its protective "armoring" are frequently scavenged from the surrounding woods, but in urban natural areas, may need to be brought in. Native vegetation can often be installed in the retaining structure to visually screen the switchback and prevent users from developing switchback short cuts.

Switchbacks can be problematic where there is shallow soil over bedrock and where they are likely to capture groundwater. Natural "benches" or flattish spots in the landscape are ideal places to construct switchbacks. Avoid inter-visible switchbacks as they may be used as short cuts by users.

The trail segment going into the switchback from above should have a drainage feature that protects the turn from erosion and does not discharge onto the trail segment below it. The outside edge of the switchback also should have a drainage feature. Some designers increase the gradient of the trail segments leading into and out of the switchback to prevent short-cutting.

Stairs. Stairs have a number of advantages in steep terrain.

Switchback with retaining wall

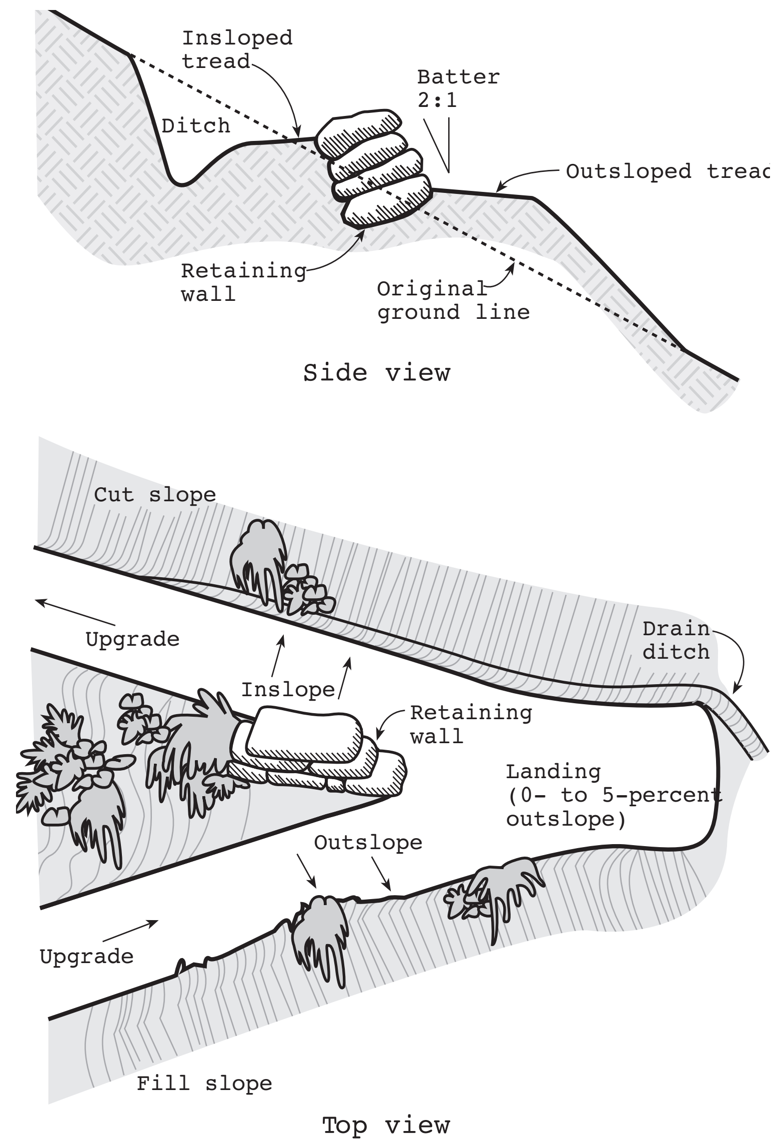


Figure 5-18 Switchbacks allow the trail to ascend a steep slope by traversing and changing directions while maintaining a reasonable gradient. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook. USDA Forest Service.)

They can go directly up or downslope in locations difficult to fit with traverses and switchbacks. They can encourage people to stay on the trail in steep terrain and they can discourage non-pedestrian uses. Make sure to design stairs that do not create a blockage for wildlife movement. Stairs can be elevated above the ground to minimize ground disturbance and to allow passage of wildlife. In urban settings, planners often specify dense or thorny vegetation at stair edges to discourage bicyclists from going down beside the stairway. Stairs may be made of stone, concrete, wood or aggregate-filled wooden cribs. Specifications should be used to assure that proper anchoring and pinning provide stability to the stair and safety for the user. An important design detail for safe and usable steps concerns the ratio of riser to tread. See Glossary for information about determining this ratio.

A word about groundwater. Where a slope cut will be

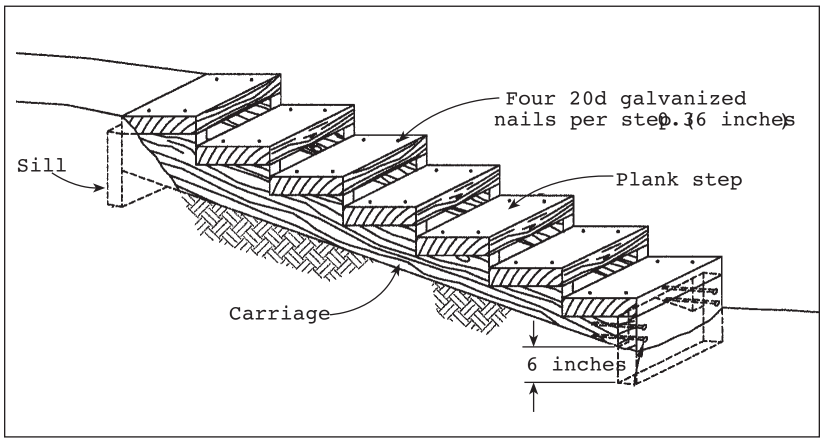


Figure 5-19 Plank stairway. (Jackson, B. 1993. Recreation Site Design)

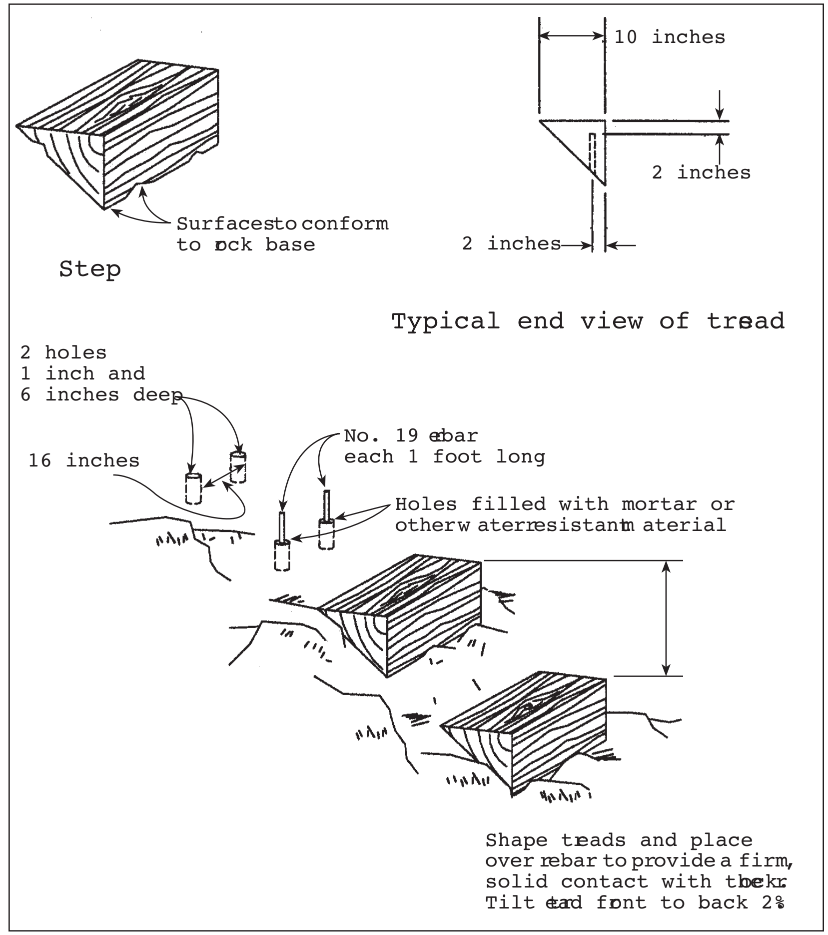


Figure 5-20 Pinned stairway. (Jackson, B. 1993. Recreation Site Design)

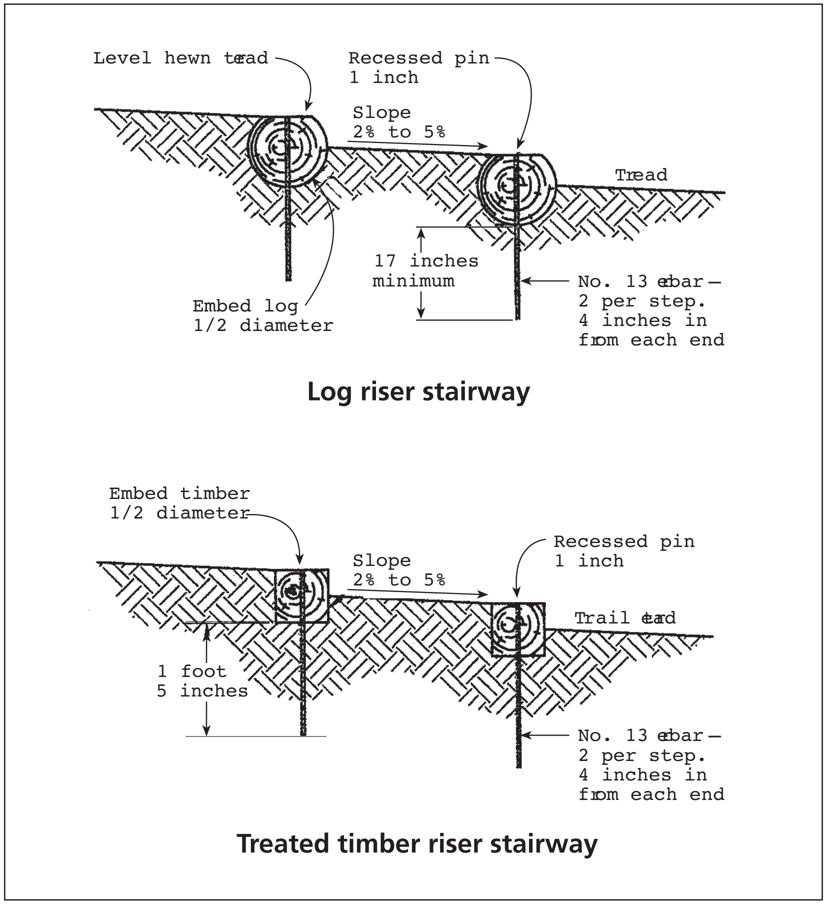


Figure 5-21 Log and treated riser stairways. (Jackson, B. 1993. Recreation Site Design)

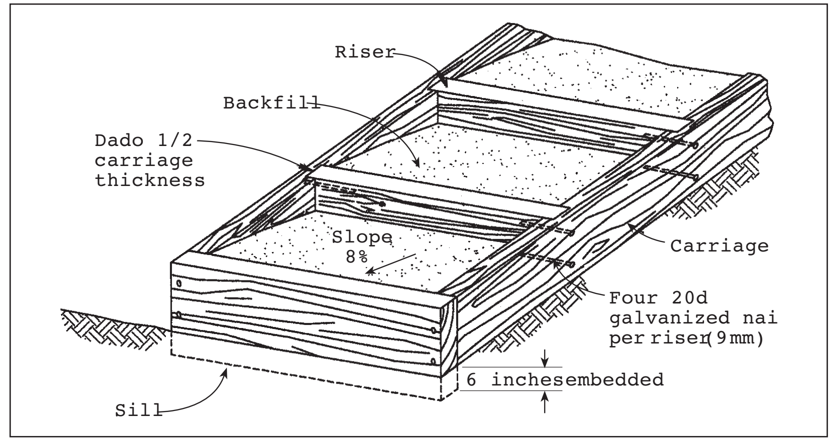


Figure 5-22 Crib ladder stairway. (Jackson, B. 1993. Recreation Site Design)

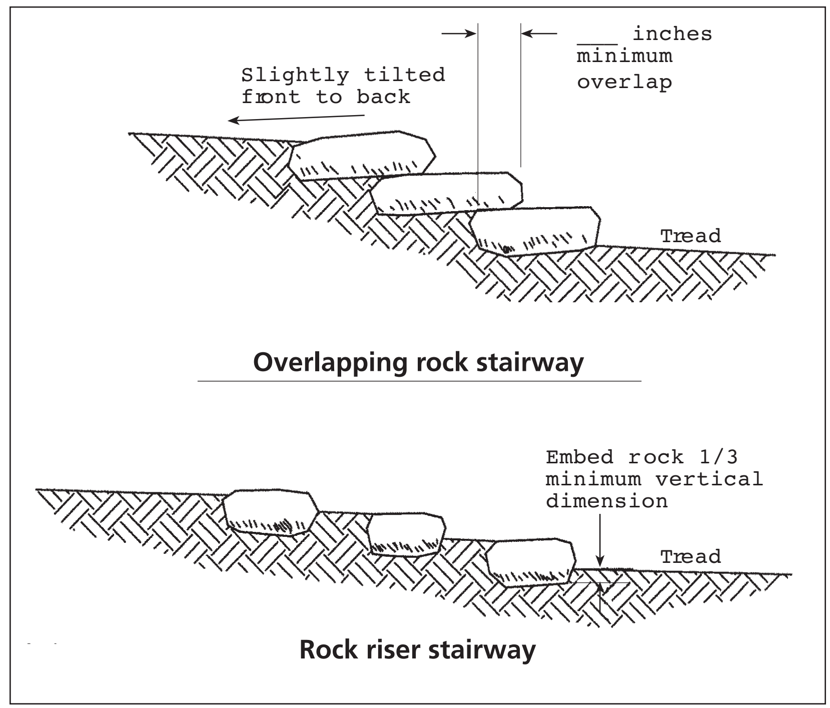


Figure 5-23 Rock stairways. (Jackson, B. 1993. Recreation Site Design)

made for stairs, a switchback or a climbing turn, it is important to plan for groundwater that may be intercepted by the cut. One technique is to construct a drainage ditch at the uphill edge of the trail. This is lined with geotextile fabric, backfilled with crushed rock in which a perforated pipe has been placed and covered (see Figure 5-24). Groundwater that is intercepted by the cut flows into this system and is discharged by the pipe to passive water quality facilities in the vicinity of ephemeral streams near the trail. Periodic risers provide access for pipe clean-out.

Trail planners who understand the natural resources of the area and who are familiar with techniques for siting and designing environmentally friendly trails can embark on the exciting work of locating test alignments. Some techniques for locating and evaluating potential trail alignments are discussed in the next chapter.

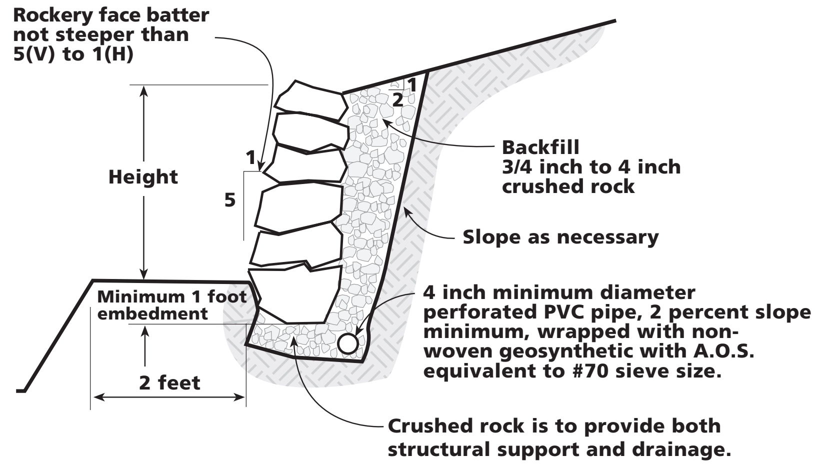


Figure 5-24 Perched groundwater that "daylights" in the trail cut drains to a gravel-bedded pipe behind this dry wall. It is then conveyed to a discharge area. (Gresham Saddle Trail, David Evans and Associates)

What environmental permits will we need?

6.1 Introduction

Permits ensure that projects will comply with federal, state and local environmental standards. Environmental permits are required for actions that will disturb vegetation, move soil, enter environmental or natural resource zones or have the potential to cause impacts to wetlands, water bodies or endangered species. Because regulatory programs change, it is always wise to check with local government and state and federal permitting agencies in the early phases of project planning.

6.2 Municipal Natural Resource Codes and Standards

As required by Statewide Planning Goals 5, 6 and 7, and other local zoning and code requirements, cities and counties implement protections for natural resources such as fish, wildlife, wetlands, steep slopes, streams and floodplains by means of local policies, codes and standards. One permit application may result in the need for another. For example, in Portland, if a trail will be in a zone designated "P" for protection or "C" for conservation, the project will require a land-use review. The land-use review triggers the need for a site-development permit, which is likely to require detailed drawings of grading, drainage, erosion control and construction management activities. A pre-proposal conference with the municipal planning and development office will provide project planners with information about the codes and standards the project must meet. This knowledge can expedite the issuance of permits, saving projects time and money.

Alternatives analysis. If a proposed trail will pass through a regulated natural resource (as delineated on a local map), an analysis of alternatives may be required. This analysis will determine if there are other routes that could result in lesser impacts to the resource. If no alternatives are available, steps may need to be taken to minimize (Chapter 5) and mitigate impacts of the trail. Each local government oversees codes and requirements that vary from one jurisdiction to another, so trail planners should be aware of these nuances.

6.3 State and Federal Environmental Permitting

Following are federal and state agencies with regulatory responsibility for a range of activities likely to be associated with trail projects. A majority of these permits reflect federal regulations outlined in the Clean Water Act (1972), the River and Harbor Act and the Endangered Species Act (1973). Refer to Appendix D for a checklist of permits required to construct a trail.

Federal agencies and acts

US Army Corps of Engineers (COE). This agency administers permits for activities regulated through Section 404 of the Clean Water Act and Section 10 of the River and Harbor Act. The goal of the act is to maintain and restore the physical, chemical and biological integrity of waters of the United States. Under the Clean Water Act, Section 404 regulations apply to discharges of dredged or fill material into the waters of the United States. Section 404 permits trigger Section 401 of the act, administered by the Oregon Department of Environmental Quality. Section 401 of the act includes regulations to protect and enforce water quality standards.

Because many activities require certification, and many others are permitted under 40 different nationwide and general permits, trail planners should always check with the COE to learn what permits will be required for particular conditions and circumstances. Trail planners working on projects along waterways will be especially interested in the provisions of the Nationwide Permit 42 for recreational facilities. For more information, call the Corps' Portland district office at (541) 465-6877 or visit www.nwp.usace.army.mil/.

Section 10 of the River and Harbor Act (1899) requires that any work in or over navigable waters of the United States or that affects the course, location, condition or capacity of such waters receive approval from the COE.

Following is a partial list of activities that can trigger the need to apply for COE permits:

- dredge and fill activities in the waters of the United States, regardless of the amount of area affected by the activity and the amount of fill used (waters of the United States include designated wetlands, lakes, rivers, streams and tributaries)
- removal or alteration of material in wetlands, streams, lakes and other waterways
- discharge of a pollutant in violation of state water quality standards
- obstruction or alteration of navigable waters of the United States, including structures below the mean high-water mark
- restoration or enhancement of wetlands, or fish habitat enhancement.

U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Aeronautic Association (NOAA Fisheries) administer the Endangered Species Act. When there's a federal nexus such as a regulatory trigger, federal funds or federal lands involved in a project, this triggers Section 7 of the Endangered Species Act requiring consultations if protected species may be affected, the National Environmental Policy Act, the National Historic Preservation Act, and possibly other requirements such as Level 1 contaminant surveys. However, the lead federal agency for the project is responsible for compliance in those cases.

When there is not a federal nexus, Endangered Species Act regulations still apply and the non-federal entities are required to get "take" coverage if listed species may be affected. If additional information is needed on wildlife, including federal status and other relevant information such as obtaining a species list for an area, refer to the U.S. Fish and Wildlife Service Oregon web site at oregonfwo.fws.gov/EndSpp/EndSpp_home.html.

NOAA Fisheries has jurisdiction over listed threatened and endangered fish species. The agency has delineated their evolutionary significant units in the Portland metropolitan area and also will be designating critical habitats in the region. All of these species migrate as adults and juveniles through the metropolitan area in the Columbia River and its tributaries. Others also spawn and/or rear in metropolitan area streams. If additional information is needed on the status of fish species and ESA regulations and habitat sensitivity, refer to the NOAA Fisheries web site at www.nwr.noaa.gov/1salmon/salmesa/index.htm.

NOAA Fisheries also is responsible for implementing the Magnuson-Stevens Act "essential fish habitat" provisions. Essential fish habitat is broadly defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." Portions of essential fish habitat are present in the Portland metropolitan region and provide important habitat for salmon and other species; visit www.nmfs.noaa.gov/sfa/magact/ or talk to a NOAA Fisheries staff person for more information about this regulation.

State agencies

Oregon Division of State Lands (DSL). This agency reviews Section 401 and 404 permits jointly with the COE and is the lead state agency responsible for managing wetlands, submerged lands in the state's navigable water ways, and wetland fill and removal. The division implements erosion control and fill and removal permits. Oregon's Removal-Fill Law requires the DSL to oversee a removal-fill permit program to conserve, restore and maintain the health of Oregon's waters. The division's jurisdiction extends to the ordinary high water or high tide line, or to the line of non-aquatic vegetation- whichever is higher. If the activity involves filling or removing less than 50 cubic yards and is not in an area determined to be Essential Salmonid Habitat or a State Scenic Waterway, a state permit is not required. The division also oversees permitted fish habitat enhancement projects and wetland restoration and enhancement projects. Call (503) 378-3805 or visit http://statelands.dsl.state.or.us/todolist.htm if the project includes any of the following:

- building a pond
- constructing a marina or a dock
- removing gravel or rock from uplands, wetlands or water ways
- controlling streambank erosion
- building in a wetland
- construction of a large or small dam
- any work that will affect the bed or banks of a water way
- enhancing or restoring wetlands or fish habitat.

Oregon Department of Fish and Wildlife (ODFW). This agency comments on project activities and operations, and reviews structures such as bridges, wharves and culverts in and over water. The ODFW does not issue permits but provides input to assist project designs and construction activities to comply with in-water work requirements and to recommend measures to protect fish and wildlife. These protections concern salmon, steelhead, trout, warm water game fish, state and federally listed threatened and endangered species, and other native species. The ODFW also maintains a list of Oregon waters, their fish species and the recommended time periods for in-water work that are most compatible with fish and wildlife needs. If trail planners seek input early in project planning, the department can provide valuable input on the "permit-ability" of project components, including mitigation. Call (503) 872-5255 or visit www.dfw.state.or.us/ for assistance and information on in-water work windows and permit requirements under any of the following conditions:

- work is proposed in or over a water way
- dams, in-stream culverts, or spans or bridges over water are proposed
- the project will take place in or near a wildlife conservation area, floodplain or stream
- to learn whether federal or state-protected species are present in the project area.

Oregon Water Resources Department. Projects that will use, divert or store water generally require a water right certificate or permit from the department. For example, if water from a stream will be pumped to provide temporary irrigation for trailside plants, a permit will be needed. The department provides technical assistance on water-related projects, and can advise applicants on the likelihood that a permit can be obtained. For more information, contact the Water Rights Division in Salem at (503) 378-3741 ext. 499. The department administers the following permits:

- instream water rights certificate
- limited water use license (e.g., for temporary irrigation)
- permit to appropriate surface water
- permit to construct a reservoir
- permit to store water (e.g., in a pond)

- water diversion structure permit (e.g., to facilitate in-stream work).

Oregon Department of Environmental Quality (DEQ). This agency implements protections for land, air, groundwater and surface water in Oregon. DEQ reviews permit applications submitted to the U.S. Army Corps of Engineers under Section 401 Clean Water Act. Section 401 requires DEQ to certify that the proposed activity does not endanger Oregon's streams and wetlands and to confirm that the plan meets water quality laws and standards. Once this is confirmed, the DEQ issues a water quality certification.

Contact the Northwest Office of DEQ at (503) 229-5263 or 1-800-349-7677, or visit www.deq.state.or.us/wq/permitcorner/ for information about permits, particularly if any of the following actions are planned:
- land disturbance, grading or clearing vegetation on one acre or greater, including all project phases
- generation of waste water, for example, a drain field for a restroom or a drinking fountain at a trailhead
- dewatering of pits or trenches under certain circumstances
- construction activities near a water quality limited stream
- disposal of stormwater in an underground injection system
- wetland fill/removal.

6.4 Application Fees and Turnaround Times

Application fees generally must accompany local permit applications when they are submitted. Depending on the scope and scale of the project, the fees can be considerable. Make sure to research the costs of permit applications and build these into the project budget.

Planners should be prepared for permitting on long trail alignments in sensitive habitats to take at least 12 months. The range of permits and their applicability in specialized planning, engineering and environmental fields underscores the need for trail planning by an interdisciplinary team.

6.5 Useful Contacts

Municipal planning departments

Counties

Clackamas County	(503) 655-8581
Multnomah County	(503) 823-4000
Washington County	(503) 846-8611

Cities

Beaverton	(503) 526-2222
Durham	(503) 639-6851
Cornelius	(503) 357-9112
Fairview	(503) 665-7929
Forest Grove	(503) 992-3200
Gladstone	(503) 656-5225
Gresham	(503) 618-3000
Happy Valley	(503) 760-3325
Johnson City	(503) 655-9710
Hillsboro	(503) 681-6100
King City	(503) 639-4082
Lake Oswego	(503) 635-0270
Milwaukie	(503) 786-7555
Oregon City	(503) 657-0891
Portland	(503) 823-7526
Sherwood	(503) 625-5522
Tigard	(503) 639-4171
Troutdale	(503) 665-5175
Tualatin	(503) 692-2000
West Linn	(503) 657-0331
Wilsonville	(503) 682-1011
Wood Village	(503) 667-6211

More information

Topic	Agency or Department	Contact
Wetland maps	Oregon Division of State Lands Municipal planning departments (see page 65) Oregon Department of Fish and Wildlife US Fish and Wildlife Service Metro's Data Resource Center	(503) 378-3805 (503) 872-5255 (503) 231-6179 (503) 797-1742
Wetland permits (Section 404)	US Army Corps of Engineers Oregon Division of State Lands USDA Natural Resources Conservation Service (for information about wetlands on agricultural lands) Municipal planning departments (see page 62)	(503) 326-6995 (503) 378-3805 (503) 222-7645
Water quality permit (Section 401)	Oregon Department of Environmental Quality Municipal planning and permit offices (see page 62)	(503) 229-5279
Water rights and certificates	Oregon Division of State Lands	(503) 378-3741 or (503) 378-3741 ext. 499 or 1-800-624-3199
Trail construction along levees	Multnomah County Drainage District	(503) 281-5675
Comments on proposed projects	Oregon Department of Fish and Wildlife US Environmental Protection Agency	(503) 872-5255 (503) 326-3250
Erosion and sediment control	Oregon Department of Environmental Quality, Water Quality Division Portland Bureau of Environmental Services Clean Water Services, Inspection Services Clackamas County Surface Water Management Natural Resources Conservation Service	(503) 229-5279 (503) 823-7740 (503) 846-8621 (503) 353-4567 (503) 222-7645
Fish and wildlife conservation areas and information about threatened, endangered and sensitive species	Municipal planning departments (see page 65) Oregon Department of Fish and Wildlife Oregon Natural Heritage Program Bonneville Power Administration (GIS data base on resident and anadromous fish) US Fish and Wildlife Service NOAA Fisheries	 (503) 872-5255 oregonstate.edu/ornhic/ORNHP.html nppc.bpa.gov (503) 231-6179 (503) 230-5425

How do you site a potential trail route?

7.1 Evaluate Trail Routes in Natural Areas and Restricted Urban Corridors

In natural area settings, it is of primary interest for trail routes to avoid negative impacts to wildlife habitats and water resources. This is achieved by routing the trail around these resources. If this cannot be done, a route and trail materials should be selected that will minimize the impacts. But in densely developed urban areas, there often are not trail routing alternatives, and trail routes may be restricted to urban corridors (for example, utility easements, street rights of way, abandoned trolley and rail lines, vacated streets and along streams). In these locations, limitations such as gradient or soil conditions often can be compensated through design.

The following techniques for route selection may not be applicable to all trail types or to all areas. Nonetheless, they can be useful tools for decision-making, provided that trail planners recognize that many limitations, particularly for multiple-use trails in restricted urban corridors, can be overcome through design.

7.2 Set Control Points and Plot Test Alignments

Before going to the field to flag test alignments, set control points for each potential trail route on maps and aerial photographs. Control points are critical locations the trail should connect, avoid or pass through. For example, the trail may need to be set back from a heron rookery, pass above or below a rock outcrop, avoid a property, cross a stream at a particular spot or switch back at a break in slope on a steep hill. The trail needs to begin and end at points that are complementary to the network of trails and transportation system with which it is connected. Zoning, municipal transportation plans, permitting requirements, rights of way in vehicular travel corridors and potential funding sources are among the many additional factors that will influence preliminary trail routes. Each known condition that can affect major trail alignment decisions should be plotted.

Plot test grades for potential routes. The next step is to connect the dots by plotting test grades and alignments on a topographic map. If the trail will serve multiple uses, try to keep the test grade less than 5 percent. If an earthen trail is planned, the gradient may be steeper, but as a general rule, should not exceed 10 percent.

Grades of 10 percent and 5 percent are relatively easy to plot with a pair of dividers. Here's how: Find the scale and contour interval (the number of vertical feet between contour lines) on the map. Let's say the contour interval is 40 feet. To test a 10 percent gradient, set the dividers for 10 times the contour interval, or 400 feet. Start at the first control point and step the dividers from one contour line to the next all the way to the second control point. To test a 5 percent gradient, step the dividers two times between each contour line. If the potential route on grade cannot span between the two control points without exceeding the test gradient, the route can be dropped from consideration, or an alternative route can be tried. The workable routes should be plotted on the map using dashed lines.

To keep the test alignment from exceeding the gradient being tested, the trail may have to swing out and double back on itself to reach the next control point. The precise location for the turn will have to be worked out later on the ground, when a preliminary flag line is tied. Field conditions often result in the actual alignment being as much as 5 percent to 10 percent longer per mile than the dashed line on the map. In some cases, stairs may be an appropriate way to solve a gradient problem.

7.3 Identify Existing and Planned Infrastructure

In urban areas, it is essential to investigate how a future trail alignment will work with existing and/or future infrastructure. Property boundaries, easements and rights of way must be known and the locations of public utilities must be determined. This information can disclose opportunities and constraints for future trail alignments.

By Oregon law, all local governments are required to have long-range transportation and growth management plans. These plans designate the type, density and location of future development, and the future locations of sewer lines, wastewater treatment plants and stormwater management facilities. Municipal engineers, infrastructure planners and land use planners on the trail-planning team can help find and interpret this information. They also can plot relevant items on maps and aerial photos in relation to test alignments and help determine if permissions must be granted for the trail to cross or use particular easements and rights of way. It is essential to learn whether these permissions will be granted before putting much additional effort into aligning the trail and making pre-design decisions.

7.4 Field-locate Alternative Alignments

Once all alternative alignments are plotted, gather tools for a field check. These include:

- topographic map
- aerial photo
- field notebook (to record observations and data)
- flagging (to mark points in the field)
- altimeter (to check elevations)
- clinometer (to check slope percentages)
- Global positioning system (to set points in the field)
- compass (for orientation to the site, the map and the aerial photos).

Clinometer. (Trail Building and Maintenance – Building Better Trails, IMBA Resources)

Begin by ground-truthing the start and end points for the trail to make sure they will accommodate the uses stated in the goals for the trail. If start and end points must be relocated, find more suitable locations, make sure to plot them on the aerials and map, and make a note regarding the reason for the change. Finalizing start and end points for trails often requires complex coordination with state highway departments, railroads, local transportation planners, infrastructure planners, safety and security personnel and engineers. Many issues concerning public safety, travel and stopping speeds, signage and security need to be resolved.

The next step is to test the grades by walking a rough route between control points, observing and recording conditions on the way. Shoot spot grades with the clinometer and try to stay roughly on or slightly less steep than the test gradient. Don't flag this route, but do flag and number the control points and record them in the field notebook If the test grade between control points is successful, note this. If the test route would need to be longer or the gradient steeper in order to connect the two control points, make a note of this but don't correct the grade line at this time. Continue walking a rough route to the next control point, staying at or slightly less steep than the test gradient, observing and recording conditions.

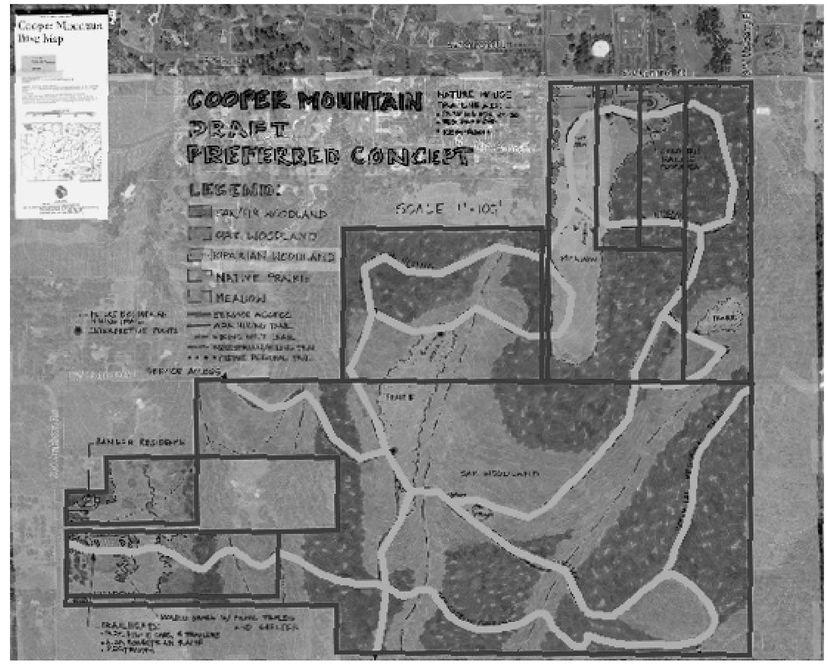
There almost always are conditions on the ground that cannot be anticipated by studying an aerial photo and a topographic map. The test alignment may encounter small seasonal drainages, rock outcrops, wildlife travel corridors, seeps and springs or special habitats that the trail should avoid. It may have to lose or gain grade in order to bypass such conditions or to create a setback for sensitive species. It may be necessary to drop back and lift a long section of trail up and around an area to be avoided, or to increase the gradient to drop below it. Some control points, such as suitable stream crossing points, may need to be scouted out on the ground. Make detailed notes about the locations of the control points and the needed grade adjustments, but do not fine-tune the precise alignment during this phase of fieldwork. This phase is primarily to find out if a route is feasible. Before determining this, re-evaluate each potential trail segment with respect to seasonal wildlife habitats and groundwater conditions.

If the test alignment between beginning and ending points hits the control points and stays reasonably within grade limits, and meets all the criteria for route selection, this route may be a candidate for more precise route location.

7.5 Identify Areas Where There Are No Alternatives (Restricted Urban Rights of Way)

Some potential trail routes are so defined or constrained that there are no reasonable alternative alignments for a future trail in the vicinity. In these cases, trail planners should identify the restricted rights of way in the planning zone and highlight them as potential routes or linkages in the future trail system. For example, old railroad beds and trolley line rights of way provide trail routes and important connections to neighborhoods and significant transportation corridors. The cleared easements for overhead and underground utilities (power lines and sewer lines) can make useful trail routes. In urban settings, trails often can be accommodated in the spacious rights of way beside county and state roads. Former streets that have been abandoned by municipalities, and platted but unbuilt streets also can become valuable trail linkages.

These opportunities are especially significant in fully developed areas where land uses are long established, and little, if any, opportunity for new trail alignments exist. Another advantage of using such routes is that municipalities may be able to avoid the costly and time-consuming process of acquiring land, parcel by parcel, along a favored trail route.



Trail planners used topographic maps, sensitive habitat information and interpretive and scenic vistas to draw this conceptual trail map for Cooper Mountain, Ore. (Metro, 2004)

7.6 Identify Areas Where Users Want to Go

Trail users enjoy the opportunity to experience the unique features of distinctly different landscapes. Planners should identify the significant scenic, interpretive and cultural opportunities associated with potential trail routes. A new trail is all the more attractive when it can take people to view spots, allow them to get close to wildlife, give them an opportunity to see historic features or stop at a local park. Trail planners should look for ways to provide these experiences along the trail and incorporate them whenever possible. If striking opportunities are not available, planners can look for ways to make the route interesting by taking advantage of different vegetation, moisture and light conditions along the way. If there is contrast along the trail – steep and not-so-steep, light and dark, wet and dry, remote or close to civilization – and an opportunity to experience the contrasts will make the trail pleasurable.

7.7 Identify Current and Future Public Uses at the Site

Trail planners must also estimate trail use. They need to understand how people currently use the site, how the trail will affect site uses and what off-site uses may occur because of the trail. Each of these scenarios has the potential to influence both trail alignment and design. Neighborhood residents and the citizens committee could review potential trail routes on the maps and in the field to help determine the final trail alignment. If they have been involved in this process, they are likely to understand the solution and support the ultimate alignment.

Some trail alignments have management consequences that can be solved through trail design landscaping, design of the trailhead or entryway, or by signage. The trick is to anticipate what human behaviors the trail will elicit. Seasoned trail managers can provide important input to decisions about trail alignments, designs and facilities. Their experience and ability to predict trail users can be used to good advantage as the planning committee begins to focus on particular alignments and design concepts.

7.8 Refine Each Test Alignment

To evaluate the remaining routes, tie a test flag line at grade between each control point. If it is to be an earthen trail, tie the line at 1 or 2 percentage points less than the desired maximum gradient of the trail. This will create slack in the gradient so designers can adjust the grade as needed to design drainage. Drainage will be designed later, if the route is selected. It will be important for field and office trail personnel to have expertise in trail drainage and know how to manipulate trail gradient to facilitate drainage. Typically, a corridor along the selected route is surveyed. Designers use topographic information in this corridor to fine-tune the micro-site location and gradient of the trail.

Before selecting a final route, it is important to note that if federal funds or federally managed properties are involved, the potential route will need to be assessed in compliance with the National Environmental Protection Act and the National Historic Preservation Act. If threatened and endangered species or their habitat could be affected, then compliance with the Endangered Species Act is essential. Many municipalities contract this work to consulting firms, whose inventory protocols and knowledge of environmental permitting processes can provide valuable, repeatable and defensible results on which to base future planning, permitting and design.

Consider the impacts of the favored alignment, based on disturbance levels for sensitive fish and wildlife species and their habitats. Based on these findings, adjust the flag line to avoid or minimize these impacts and to incorporate the municipality's setback and buffer standards for habitats of sensitive species.

7.9 Select the Best Route That Avoids or Minimizes Impacts

If trail gradients are still favorable, select the route with least environmental impacts. If impacts are unavoidable and no other route is feasible, the best route can be the one that also offers opportunities for restoration, and for which measures to minimize impacts can be funded and are likely to succeed.

7.10 Re-evaluate Goals for the Trail Use, Scale, Materials, Connections or Location

If irreversible impacts cannot be avoided, trail goals should be re-evaluated. The intended users of the trail, its width and surfacing can be adjusted. Instead of the route serving multiple users, having direct connections to regional multi-use trails and a high level of amenities, perhaps the route can accommodate a more modest, local trail. Or perhaps a multi-use route can stay out of the resource area but offer a scenic view of it or have a narrow, pedestrian spur into a part of it. Such a trail might have a specially engineered segment such as a boardwalk, or a section built on cantilevers to minimize resource impacts. Solutions such as these might enable the route to avoid or minimize impacts to sensitive natural resources.

7.11 Identify Potential Stewardship and Maintenance Partners for the Alignment

Trails that have been "adopted" by local residents and user groups tend to fare well. When people support a trail, they turn out for work parties and help with outreach education. Volunteer stewardship groups often provide a friendly presence to the public and an essential liaison to the municipality. Neighborhood and "friends" groups should be identified early in the trail planning process and encouraged to participate in every aspect of trail planning. Their involvement will create powerful stewardship bonds and lasting community support for the trail. They also are the first line of defense in preventing vandalism.

Trails, like rivers, cross many political boundaries. For example, a trail may traverse the right of way of a state transportation corridor, be located in an easement across private land, follow a utility corridor, or be part of a local or state park. It may traverse a busy public street, a river levee or descend deep into an undeveloped natural area. As a future trail alignment is resolved, a trail management team also begins to emerge, composed of many public and private land and resource managers.

What resource-friendly trail materials are available?

8.1 Introduction: Fitting the Trail and Materials to the Setting

As the trail route takes shape, planners will narrow the options for trail dimensions and materials based on the user types expected, the level of use anticipated, the environmental settings and degree of disturbance to natural resources already present along the route.

Trail width may range from 18 inches for little-used earthen walking paths to 10 feet or more for paved multi-use trails. In general, trails should be narrower and permeable to rainfall in water resource areas, which include streams, wetlands, riparian areas and floodplains. One important consideration in deciding about trail surface is that trails need to be pervious to stormwater. In some cases, earthen trails, if heavily used, may compact over time and may not retain their permeability to stormwater. Trail design is site specific and will depend on environmental conditions, level of use and stormwater drainage capability. This chapter explains the basic materials used to construct trails and provides guidance on how to select them for site conditions and uses.

8.2 The Anatomy of Trails

Whether they are large or small, most multiple-use trails have three basic parts: the sub-grade, the base and the surface. The sub-grade consists of the native earth materials under the trail. The base consists of materials placed over the sub-grade to make a stable foundation for the trail surface and support the weight of trail uses. In general, earthen trails do not have a base, unless needed for support through wet areas. The surface is the tread, or the part of the trail contacted by feet, wheels and hooves. The shoulder (or verge) is part of the constructed and cleared trail corridor that begins at the edge of the tread and extends a few feet outward (see Figure 8-1).

Most people think of the trail surface when they think of a trail. But in trail design, a lot of attention is paid to the ground underneath the trail surface. It must be properly prepared so that the tread surface will remain stable. In fact, among the most important decisions affecting the longevity of trails are the geo-technical and engineering decisions that bear on sub-grade and base treatments. A summary of some considerations regarding these treatments follows, with the caveat that trail planners should always rely on engineering input to prescribe these treatments.

A stable, well-built trail – be it a narrow earthen trail or a wide, paved multiple-use trail – is likely to be an environmentally friendly trail. A stable, properly drained trail keeps people on the trail, particularly through wet areas where poor drainage might cause go-around trails that damage vegetation and create wide mucky areas with little vegetation. Most likely, a stable trail also uses good drainage designs, which frequently route small amounts of water off the trail into trailside environments (see Chapter 5 for more details on drainage). Those good designs minimize trail failures and maintenance needs.

Constructed trails. For trails that will have sub-grade and base treatments, the sub-grade is cleared of organic materials. After vegetation and leaf litter have been cleared, roots and fibers are grubbed from the soil so that their decay will not cause later deterioration of the trail. Clearing and grubbing usually extend for at least several feet beyond the tread to include the shoulder and the hillslope under the future fill, where feasible (see Figure 8-1). The sub-grade needs to be well drained so that it will support the base materials (rock) that transfer weight to the sub-grade.

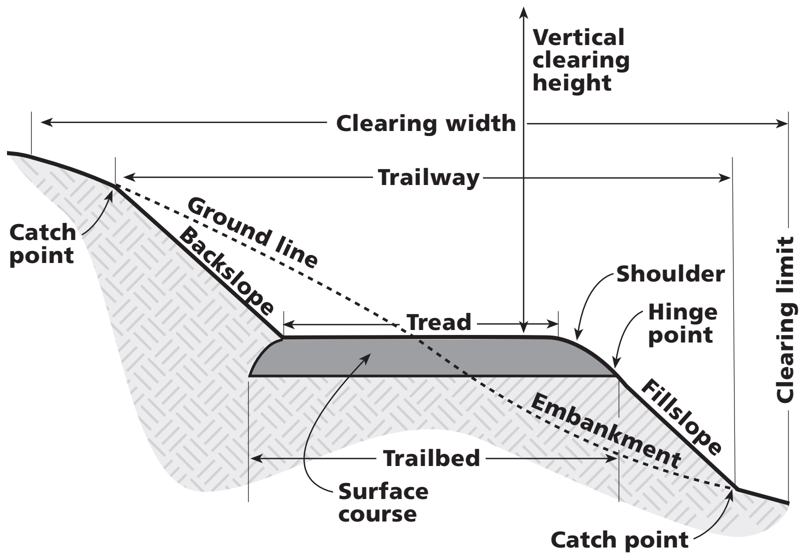


Figure 8-1 Trail structure terminology. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook. United States Forest Service.)

Before the base rock is placed, the prepared sub-grade is usually compacted. If the sub-grade is wet or moist for even part of the year, drainage needs to be provided and/or a moisture barrier of some sort placed between the sub-grade and the base materials. Typically, a geotextile fabric can provide this barrier, although additional drainage measures may need to be designed. When a layer of large angular rock is placed on top of the fabric, the fabric keeps the rock from sinking into the yielding, wet soils.

However, sometimes the wet soils must be removed and replaced with angular rock. It is important to first know for certain whether a wetland fill/removal permit will be needed to remove wet soils or to place base rock in wet settings (see Chapter 6 for information about environmental permits). It also is important for an engineer to prescribe how to prepare the ground on which fill material will be placed and the thickness and compaction necessary for each layer of fill (see Figure 8-2). An engineer can determine whether it will be necessary to

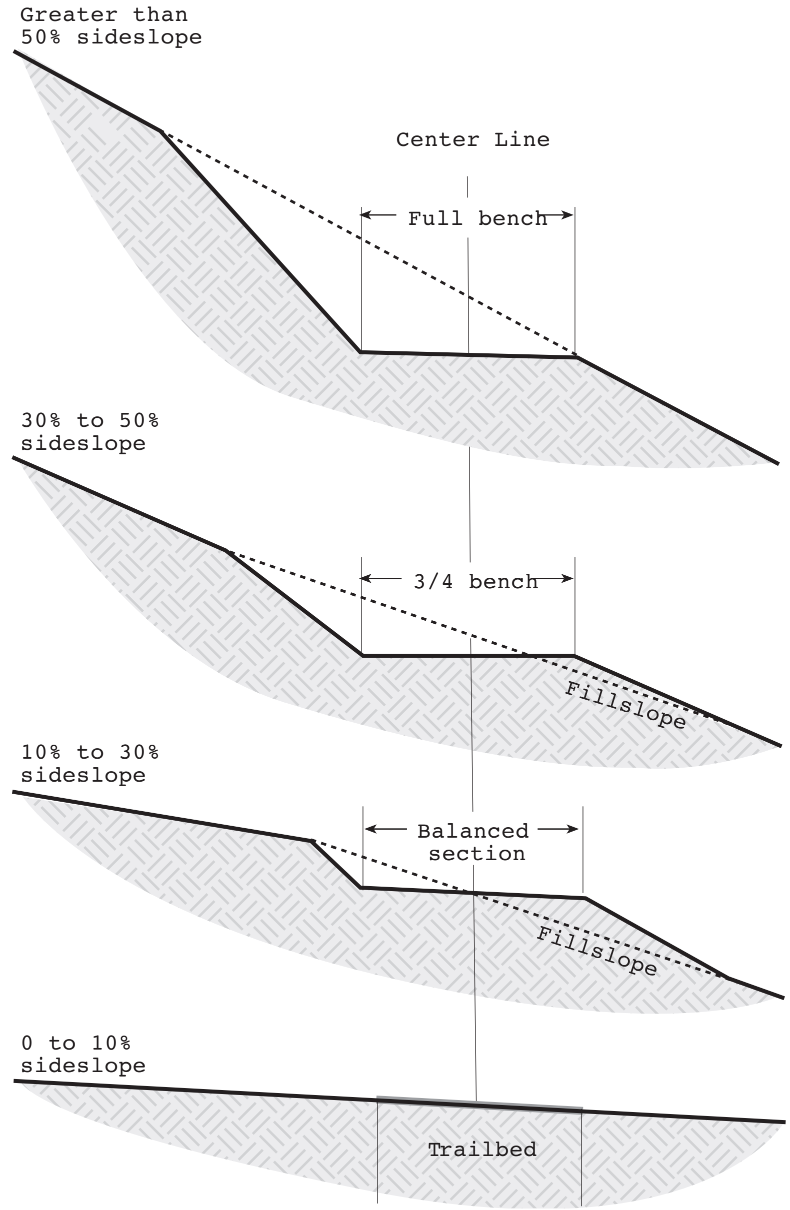


Figure 8-2 Typical trail cross sections. (Trail Construction and Maintenance Notebook, 2000)

excavate wet soils and what kind of geotextile fabric to use. An engineer also can determine compaction standards and the size and thickness of base materials (rock). These decisions are based on sub-grade conditions as well as the highest expected loads expected for the trail. For many trails, these loads will be maintenance and emergency vehicles.

Earthen trails. Earthen trails typically do not have constructed base layers and surfaces. However, these treatments are often necessary where earthen trails traverse moist ground. In urban settings where many earthen trails receive high use, are used by horses and/or bikes or are used during the wet season, sections of earthen trails often require improved drainage and sub-grade, base and surface treatments. Make sure to check on wetlands regulations when considering upgrades to trails in wet conditions. It may be more effective to re-route the trail away from problem sections.

Drainage considerations. An environmentally friendly trail is stable in the context of the water present in the trail environment and prevents impacts to natural resources due to runoff or off-trail uses. Drainage considerations play a large part in the selection of trail surfacing materials. Keeping water away from the sub-grade, the base, the surface and the edges of the trail is important to the longevity of both earthen and constructed trails. Water can cause problems for trails in many ways:

- Moisture from a wet sub-grade can migrate into the trail base and weaken its ability to support trail uses.
- Trailside drainage ditches can allow water to stand next to the trail and saturate it, deteriorating the trail surface and the base materials.
- Runoff from the trail surface can erode the trail and embankment.
- Stormwater from neighboring streets, parking lots, roof-drain pipes and other sources can affect the trail and trailside environments.
- Water that freezes in the base or sub-grade can cause gradual weakening of the subsurface layers that support the trail. Freezing in some semi-permeable trail surfaces can degrade these materials to the point that they will not support the uses the trail is designed for. Freezing in the base or sub-grade may cause the hard surface of the trail to crack.
- Perched groundwater that is "day-lighted" by an excavation can result in water pouring onto the trail and eroding it.
- Groundwater that is "captured" by storm drain or utility pipe trenches near the trail can saturate or undermine trails. Water leaking from underground water or sewer lines under or near a trail also can affect the structural integrity of the trail.

Geotextile fabrics. There are many kinds of geotextile fabric, each made to perform a particular role in a particular setting. Geotextiles function to separate materials, reinforce and provide drainage. Also known as filter cloth, geotextiles let water pass through them, promoting the movement of groundwater but keeping the soil in place. They are particularly useful in fine-grained soil such as loess, found in much of the region's uplands. Some geotextiles are woven, some are welded and some are made of millions of tiny strands pressed together to form a felt-like material.

Geotextiles are distinct from geo-nettings, which are constructed like a sandwich, having an internal layer that collects water and allows it to drain out to the edges. Each kind of geotextile comes in several grades. Many geotextiles will degrade with exposure to sunlight and require careful storage. It is important to select the right kind of fabric for the job. An engineer or manufacturer's representative can provide excellent information about the kinds and grades of geotextiles appropriate for particular projects. Many manufacturers like to partner with local governments on demonstration and research projects and can provide discounted materials for this purpose.

8.3 Preparing the Ground

Trail designers need to be aware of conditions that will require sub-grade and sub-base preparation. If trails must traverse loess soils, clay-rich soils, rocky, bouldery soils, wet soils or areas prone to debris slides, extra effort may be necessary to create a stable trail. A stable trail in difficult soils or terrain is less likely to be the source of unacceptable impacts to natural resources. Some soils or geologic problems can be ameliorated by removing native materials and replacing them with rock, coarse-grained or granular materials, by providing better drainage, by elevating the trail surface above the ground or by providing an engineered structure. Each of these alternatives generally involves greater construction expenses, and sometimes can require greater maintenance. Civil engineers, geotechnical engineers and geologists can evaluate relative costs for routes that will require engineered solutions versus routes that don't.

8.4 Resource-Friendly Materials

Preferences for and application of different trail surfaces vary among cities, counties, park districts, trail designers, engineers, permit reviewers and trail settings. The remainder of this chapter addresses a range of environmentally friendly trail surface types, from natural to highly constructed. Additional comments on material durability, maintenance, susceptibility to vandalism, functionality, adaptability to ADA standards and cost are provided in Appendix E.

Natural and native trail surfaces. Natural trail surfaces include in-situ rock, grass, sand and packed soil. A survey by Oregon State Parks found that trail users vastly prefer earthen and natural-surface trails. Many such natural-surface trails may start out as narrow stringer trails that become wider with increasing use. In forested locations, annual leaf and needle fall may provide natural mulch that protects the trail surface from excessive wear and erosion. If trails begin to erode, widen, bog down or ravel, they require a surface treatment that can withstand the increased traffic. Often, a change in surface type will require changes to the trail base and/or subgrade. Some options for soft-surface trails constructed with native materials are discussed below.

Trail surface of wood chips.

Native trails surfaces include those constructed of various shredded wood products and gravel or crushed rock. Trails with these surfaces retain a great deal of the "soft" feel of natural trail surfaces, and for this reason are second to earthen trails in popularity among trail users.

Shredded bark, wood chips or hog fuel. Many trail managers and trail friends' groups top-dress trails with a 3-inch-to-4-inch layer of shredded bark, wood bark chips or hog fuel. These materials are aesthetically pleasing and make nice walking surfaces. The job of spreading is usually labor intensive. In general, these materials need to be replaced every year because they are trodden into the trail surface, get flicked off the trail by trail traffic and decompose due to wetting and drying. Bicycles and horses can wear these materials down very quickly.
Although these woody materials can absorb a lot of moisture and allow for infiltration, they also are susceptible to being

washed off the trail by cross drainage and at rolling grade dips. Larger diameter bark chips are more subject to washouts than finer chips, and are not as likely to be stable at steeper grades.

These materials should not be used in the floodway, in stream approaches or on portions of the trail with surface cross-drainage. They should not be used in any location where over-bank flows or trail drainage would transport them to channels or wetlands. This is because their decomposition in water can lower dissolved oxygen levels, contribute harmful tannins and perhaps cause or exacerbate other water quality problems.

Most trail designers prefer to provide base and sub-grade treatments to enhance the longevity of bark chip trails. These typically include installation of geotextile fabric over a properly prepared subgrade, followed with a layer of angular base rock. This treatment provides both support and drainage and retards the ability of vegetation to grow up in the trail.

Hog fuel consists of bark and wood or wood wastes that have been mechanically processed and sometimes mixed with sawdust, shavings, sludge and/or other materials. It is often used as fuel but sometimes is used as a trail or playground surfacing material. Because inorganic contaminants may be present, it is important to know the source and composition of the material, particularly if it is to be used in playground or habitat areas or near water resources. It should not be placed directly on the ground but be separated from the subgrade by geotextile fabric and base rock. Many trail managers prefer shredded long and stringy cedar because it resists weathering longer than other materials.

Pea gravel. Pea gravel, a by-product of aggregate crushing, is tiny quasi-rounded rock material that can be treacherous on trails with any gradient. Most designers and trail managers do not recommend its use anywhere on trails. However, the availability and low cost of pea gravel can make it tempting to use. Some managers have found that pea gravel may drain well if fines and organic materials can be kept out of it. Others say it has useful applications in level areas, particularly if adequate base support is present, subgrade separation is provided with geotextile fabric, and the material can be contained with curbs. Maintenance of the curbs can be problematic. Proper sub-grade preparation is necessary to keep vegetation from growing up in the trail.

Crushed aggregate. Well-graded, compacted 1-inch minus crushed rock can provide a durable surface for hiking and biking trails. "Crushed" means that the rock has angular surfaces. "Well-graded" means that the rock contains a gradation of material sizes, from very small to very large. Rock that is not well graded generally does not compact well and thus has limited viability and durability as a trail surface.

When the crushed rock is spread at a thickness of 4 inches or so, and compacted to 95 percent at the right moisture content, the fine materials will form a tight matrix around the coarser ones to create a durable surface. The angular shapes of the coarser materials cause them to lock together when compacted. The surface is crowned or sloped to drain at 3 percent to 5 percent. This surface may both shed water and allow some infiltration. A "cushion" layer of well-graded 3/8-inch rock can be applied and compacted as a top dressing. Equestrians and pedestrians alike may favor this somewhat-softer surface.

Proper sub-grade preparation is necessary to keep vegetation from growing up in aggregate-covered trails and to prevent the aggregate from sinking into the subgrade. Crushed aggregate should be graded, placed and compacted per engineering specifications. Clean aggregate (not well-graded) and aggregate merely placed on trails, particularly trails having any cross-slope or gradient, is likely to migrate quickly into trail-side areas unless it can be contained.

A containment strategy for aggregate is to place it in over-excavated trail segments, separating it from the properly prepared and compacted sub-grade by means of geotextile fabric. The excavated area is typically 4 inches to 5 inches deep, and is designed so that it does not trap water. The aggregate is raked in to a depth an inch or so greater than the desired final surface elevation. Compaction of the subgrade and the aggregate can be achieved with a mini-roller. The surface should be crowned or outsloped so that water will flow off the trail. Cross-drainage must be provided in order to maintain a suitable percentage of fines in the aggregate. Drainage should be designed and installed prior to placing the aggregate.

Crusher fines. Various mixtures of very fine material and small angular or sub-angular crushed rock can be moistened and compacted to very durable surfaces. The mixture is placed about 7 inches to 8 inches thick in an excavated trench of 5 inches to 6 inches over a properly prepared and drained sub-grade. If the sub-grade is wet or moist, a geotextile fabric should first be installed. After placement, the crusher fines are compacted. Sometimes, a "cushion" of crusher fines is placed over crushed aggregate to make a more hospitable surface for horse hooves, bike tires and bare feet. This surface may both shed water and allow some infiltration. The color of the mixture depends on the color of the source rock. To avoid a bright trail surface or one that does not blend in with the surroundings, managers can specify the source rock.

Limit the gradient on which crusher fines trails are constructed. Make sure to provide for cross drainage (under trail). Material should be angular and well graded. Expect to do spot repairs. Depending on use, climate and drainage conditions, the surface will need to be re-graded periodically, additional stones and fines added, and the surface sloped or crowned and re-compacted. Turn radii must not be too sharp or bicycles may skid.

Hardeners for natural and native trail surfaces. In some conditions, trails with natural and native surfaces can be hardened by the addition of various binders to make them more durable.

Soil binders. Soil binders can be useful means for hardening trail surfaces in difficult-to-access locations, sensitive sites where a light touch or inert materials are required or in circumstances where rock is not available or its use is not practical.

Resin-based binders. Various organic resins can be combined to bind soil, well-graded aggregate or small stones to create an enduring hard surface in locations where site or environmental conditions dictate. Care must be taken to prepare the subgrade properly. After application, the mixture is rolled and compacted. Trail sections subject to freezing may be damaged by frost heave if moisture is present, so it is very important to properly prepare the sub-grade and install a moisture barrier (geotextile fabric) and adequate drainage (angular base rock).

Soil cement. If rock is not available, pulverized native soil can be mixed with Portland cement to make a hard trail surface. A thickness of about 4 inches is poured, rolled and compacted on prepared sub-grade. The surface and the sub-grade must be sloped to drain. The trail cross-slope should not exceed 4 percent and sheetflow should not occur on slope segments steeper than 4 percent. The trail gradient should not exceed 8 percent. Vegetation may grow through or in the trail surface. The surface will show wear with use by bicycles or horses.

Permeable surfaces. When both durability and permeability of the trail surface are desired, permeable pavers or confined cellular systems may be appropriate.

Permeable pavers. These are manufactured porous, concrete-like paving units set in sand over properly drained and prepared sub-grade. This pavement system allows rainwater to infiltrate into the sand layer, then into the sub-grade. The

Sand set permeable pavers.

paving units are held in place by countersinking them into the trail bed so that their surfaces are flush with the surface of the surrounding undisturbed soil. Grade and curves are limitations. Some sources recommend that permeable pavers be restricted to slopes no greater than 5 percent. Some types of permeable pavers are favored for trails in water resource protection areas because of their ability to infiltrate precipitation.

Confined cellular systems. These honeycomb-like systems can be anchored in place and back-filled with aggregate or a soil mixture to create enduring, porous and plantable retaining walls, armored slopes or reinforced trail surfaces. Anchoring can be tricky, particularly on slopes. These systems come in many materials and dimensions. Installations must comply with manufacturers' requirements.

Porous concrete. When the finest portion of rock ingredients is reduced or eliminated from a concrete mixture, the resulting material has many small voids through which water can pass. Some managers note that porous concrete resists plant growth better than porous asphalt and is more water permeable.

Recycled materials. Trail designers can choose other permeable surfaces in addition to gravel and crushed rock. Many recycled materials are available for use as trail surfacing, including shredded car tires, crushed pottery and glass, plastic, Styrofoam and recycled asphalt. Climate, site conditions, use, preparation and application methods, and other factors may influence how these materials perform. Many trail managers recommend testing materials before using them on an entire project. Others warn that recycled materials should not be used where they can be washed into streams or wetlands.

Railroad ballast. The coarse angular rock of in-situ railroad grades may make excellent, well-drained support for a trail. A geotechnical engineer should evaluate foundation soils and base materials to determine their behavior under different moisture conditions and loads. Sometimes base materials need to be removed and replaced because they will not provide adequate structural support, or due to soil moisture conditions. This material should be checked for environmental contaminants. "Tie memory," a condition in which the rock retains the impression of the railroad ties, will need to be remedied by removing, replacing and compacting the upper layer of rock.

Re-screening or re-processing base material can be done on site with a portable rock crusher. Before replacing the rock, improved sub-drainage or cross-drainage may need to be provided so that the sub-grade and base will support the trail and the trail surface will wear well. Sometimes a moisture barrier will need to be installed. This may reduce the necessary thickness of the base layer. A geotextile also can prevent vegetation from growing up in the trail.

An engineer should calculate the maximum load and speed of the largest emergency or maintenance vehicle expected on the road to determine whether a geotextile should be used to promote the structural stability of the trail.

A serviceable temporary surface cushion of crushed aggregate can be placed on the reconditioned railroad grade. But for maximum utility for a wide range of users, a final hard surface of asphalt or concrete will provide the best and most enduring surface.

On rail-to-trail conversions, equestrians prefer a soft-surface trail beside the hard one. The horse trail can be earthen, or it can be constructed of well-graded, compacted 3/4-inch minus angular crusher fines. The placement of horse paths on former railroad grades is very sensitive to the structural integrity of the materials comprising the grade. A horse path at the edge may be less desirable from a structural standpoint than one set back from the edge or in the center.

Hard surfaces. Both asphalt and concrete are used when durable surfaces are desired. These materials differ in their costs, longevity and maintenance needs, so each is used in different settings for different performance. (See Table 8-1).

Asphalt (macadam, tarmac). Asphalt, or "asphaltic concrete," is a somewhat plastic medium that can create a very smooth surface attractive to in-line skaters, wheelchair users, stroller pushers, skateboarders and bicyclists. It is composed of graded aggregate mixed with a binder of bituminous oil. If made with coarse aggregate, it is more porous than asphalt composed of smaller rock fragments. The coarser grades are somewhat permeable, if the base and subgrade are designed to drain. The expected life span of asphalt is seven to 10 years.

Asphalt conforms to the ground surface and is stable on both steep grades and horizontal surfaces if properly mixed and applied, and the sub-grade is properly prepared. It is generally installed in a 2-inch layer, then smoothed and compacted by the asphalt machine and rollers (see Figure 8-3). Favorable drainage cross-slopes may be as little as 2 percent. Sometimes a fresh asphalt surface will be dusted with sand or a porous fine material to stabilize excess oils. However, this treatment can diminish permeability. This, and other considerations of pavement design, are the province of civil and geotechnical engineers.

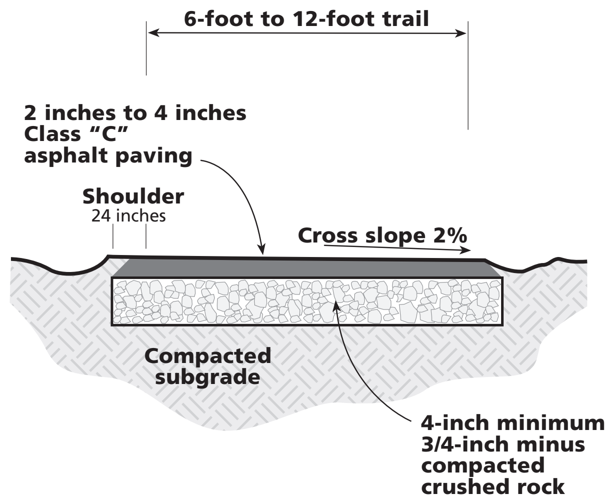


Figure 8-3 Typical cross section of an asphaltic concrete surface. (Trail Master Plan, Tualatin Hills Park and Recreation District, 1998)

Asphalt is not a favored trail surfacing material in settings where the base or subgrade are susceptible to moisture or where the trail surface is subject to freezing. These conditions, particularly in the absence of a "live" traffic load, can contribute to heaving and cracking of asphalt-surfaced trails. Additionally, asphalt is easily distorted by tree roots. For these reasons, asphalt is not appropriate for wet areas. However, asphalt has its place as a trail-surfacing material on dry, well-drained, rocky, south-facing hillslopes with little clay or plastic material in the soil.

Table 8-1 A comparison of asphalt and concrete for trail surfacing. (Adapted from Trails Design and Management Handbook, Open Space and Trails Program, Pitkin County, Colo.)

	Asphalt	**Concrete**
Material qualities	• Plastic, malleable	• Very strong, brittle, durable
Initial cost	• Subgrade preparation costs can be high • Site prep costs can be high • Installation costs generally less than for concrete	• Marginally higher installation cost than asphalt, but maintenance costs are lower • Subgrade preparation costs are lower
Life span	• 15 to 30 years • Sealing in the second year greatly prolongs the life span of asphalt	• High: 30 to 50 years, particularly with proper preparation of subgrade and base, proper mix, application, finishing and curing
Installation	• Can be applied on uneven surfaces • Can be applied at steeper gradients than concrete • Sensitive to soil type (coarse and well-drained subgrade is optimum)	• Can be installed in wet areas, on curves, and with precision • Requires forms and internal structural support • Requires skilled contractors • Proper design for crack control is critical
Resurfacing needs	• Edges tend to crumble over time • Prone to cracking, doming, heaving and settling • Life span can be greatly prolonged if sealed in the second year • Must be sealed or chip-sealed every 5 to 10 years	• No resurfacing needed for decades; surface grinding may refresh traction surface after decades of wear
Suitability in natural resource protection areas	• Not suitable for wet areas • Will deform to accommodate tree roots • Porous grades can be used to facilitate infiltration	• Holds up well in wet areas • Not as prone to buckling from tree roots as asphalt • Bridges imperfections that may develop in the subgrade
Susceptibility to moisture and temperature extremes	• Prone to drawing moisture to the subgrade and base, and subsequent freezing and deterioration • Dark surface warms quickly, facilitating snowmelt • High temperatures can facilitate deformation	• Performs well at high and low temperatures
Construction season or limitations	• Cannot lay asphalt below 35 degrees farenheit.	• Newly poured concrete must not freeze during initial hydrating period • Care must be taken in wetland and aquatic environments
Preference by users	• Preferred by runners for its greater resiliency than concrete	• Consistent, smooth surface for all users • Broom finish makes skid resistant
Ease and expense of spot repairs	• Easier to remove and replace deteriorated sections than concrete	• Spot repairs can be made flush with surface

Chip seal. An asphalt surface can be refreshed by application of a surface emulsion of tar or oil. Sand or rock chips are added to the oil and rolled to provide a fresh wearing surface. Researchers have found that hydrocarbons in runoff affect aquatic invertebrates making asphalt near water resources cause for concern. To be safe, it is best not to apply chip seal near water resources due to the potential for excess oil to be washed off the trail surface. However, proper proportions of sand or rock chips and proper application and rolling will prevent excess oil. Managers can reduce the chance of poor chip seal workmanship by pre-qualifying bidders and equipment. Some users report that chip sealed surfaces are rougher and slower. Others warn that in some settings and applications, chip seal may not withstand concentrated flows of water and can erode.

Concrete. Concrete, or Portland cement, is tough but brittle. It is the material of choice in settings with severe climate changes and the heaviest uses. In addition to requiring proper structural support from base and sub-grade, it must be reinforced with wire or fabric mesh and jointed to control cracking. It is commonly placed 4 to 6 inches thick and can be colored to blend with surrounding materials. It can be scored or rough-finished to reduce slipperiness. The use of concrete can be limited by site access.

The pH of water may increase when it comes in contact with fresh concrete, causing problems for salmon and trout. For this reason, the state of Oregon regulates how concrete work is managed in streams and lakes. Trail planners should explore options for trail materials and trail construction methods when planning multi-use trails in and near water resources.

See Appendix E for more information about trail surfaces for high and low use.

8.5 A Note About Equestrian Trails

For durable, all-season urban equestrian trails, plan a 2-foot to 4-foot-wide tread surface[1] to accommodate single-file use. One way of constructing an equestrian trail includes:

- moisture-barrier geotextile, as specified by an engineer for the site
- base rock
- additional geotextile layer, if needed
- 3/4-inch minus, well-graded, compacted aggregate
- compacted cushion layer (should be angular rock, 1/4-inch minus, not larger).

Horses tend to favor the outside edges of narrow trail treads. An engineer or geotechnical engineer can recommend proper placement and compaction of fill material at trail edges required for equestrian safety. This is of special concern at the edges of trails constructed on pre-existing fill whose materials and construction methods are not known.

8.6 Trail Materials for Wet Areas and Wetlands

Native local wood. Traditionally, trail managers have felled trees near trails to build needed trail structures. This has been a cost-effective way to get construction materials to the sites where they are needed, particularly on remote, narrow earthen trail systems. But today, many managers are balancing the decision to use local native materials against the need to maintain

[1] Seasoned horses and riders can negotiate the narrower trail treads of more primitive settings, provided there is adequate overhead clearing (10 feet) and that the width of the cleared trail corridor is sufficient to accommodate horse, rider and packs. However, there can be safety hazards for riders and horses that are not experienced in pivot turning on narrow trails, particularly on steep cross-slopes.

park landscapes that support long-term ecosystem needs. Managers should weigh the need to use standing trees, hazard trees or wind-thrown trees for trail structures against the long term ecosystem needs for these logs as snags, downed wood or as future woody debris for streams and important wildlife habitat features. A hazard tree that must be felled is a logical choice for creating lumber or puncheons for trail structures. But if the species is not resistant to rot, it may be better to top the hazard tree and leave it as a wildlife snag, or fell it and let it decompose on the forest floor for other wildlife species.

Locally, the most rot-resistant wood comes from the heartwood of cedars. Douglas fir logs do not contain the rot-resistant tannins that are present in Western red cedar heartwood, but the density of the wood does repel some fungus and insects. These two local species are good local candidates for making lumber and puncheons for on-site construction of wooden trail structures. If non-treated rot-resistant lumber is desired, consider obtaining boards from cedar.

Treated wood products. See Appendix F for best management practices for the use of treated wood products.

Plastic lumber. Plastic lumber looks like wood and can be worked in much the same ways as wood. Its smooth wood-like surface does not get slippery during the wet season, and it does not catch fire. It can be colored or painted to blend into natural environments and does not raise the concerns of environmental contamination that come with treated wood products. But it is heavy, expensive, low in strength and resilience, and is weathered by sunlight. Strength limitations mean that it may be more appropriate for decking than joists, beams or posts. However, new technologies are continuing to improve the looks, strength and performance of plastic lumber and it is certainly well worth considering for use in sensitive areas.

Plastic lumber can be used in much the same way as wood.

Selection of trail materials in water resource areas. Permit applicants for trails near essential habitat for salmonid species listed under the Endangered Species Act should be aware that if there is federal review, trail materials are likely to be restricted within 100 or more feet of these habitats. Guidelines for trail materials for the most sensitive water resource areas follow.

- If trails have hard surfaces, keep them away from streams.
- If trails must get closer than 100 feet to streams, construct them with permeable surfaces (see Figure 8-4). Bark should not be placed in locations where it can wash into streams.
- Consider rock-filled geocells or gabions to avoid placing fill in wetlands.
- Avoid using galvanized metal where runoff from galvanized materials can be delivered to water resources.

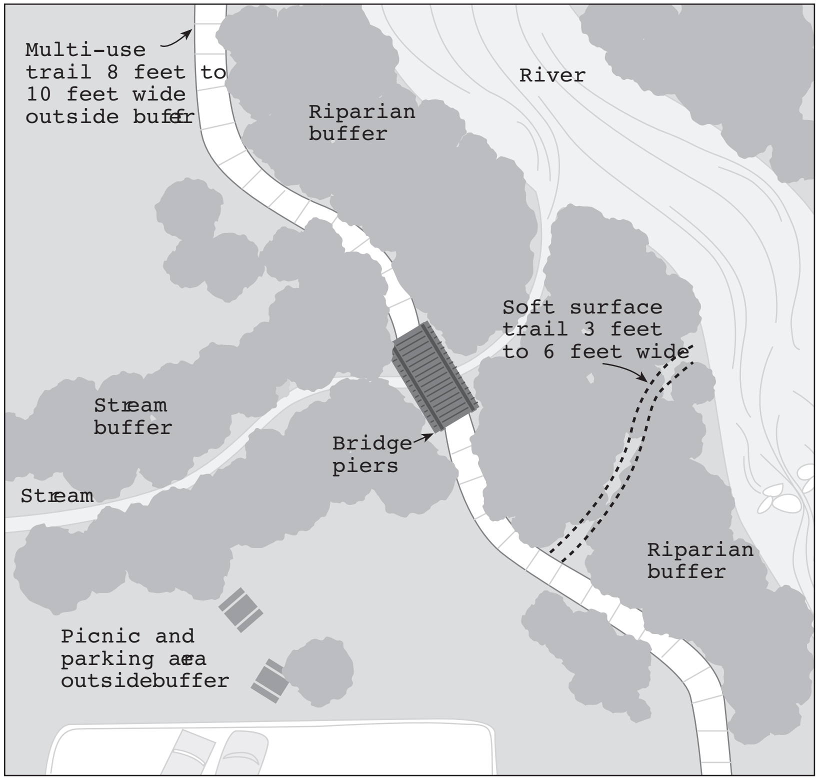


Figure 8-4 The riparian corridor should remain free of impervious surfaces, structures and recreational amenities, including multi-use trails.

8.7 Summary: Choosing Trail Materials, Widths and Surface Types

Trail surface materials reflect the kind and intensity of use expected and the environmental sensitivity of the site.

Choices for width and materials of the trail should reflect users' needs and their expected level of use. Safety and environmental impacts are serious concerns for trails that are too narrow, particularly if crowding forces users onto trail shoulders and verges. Refer to Table 8-2 to match users, level of use and trail types.

The surface materials of trails passing from uplands into riparian areas or floodplains need to be permeable to rainfall. This design detail minimizes runoff in water resource areas and protects them from trail impacts. Surface materials for trails in natural areas and urban corridors are given in the Table 8-3.

Table 8-2 Selecting trail width and surface material based on level of use. (Adapted from Trails Design and Management Handbook, Open Space and Trails Program, Pitkin County, Colo.)

Trail type	Very low (<25)	Low (25-100)	Moderate (100-200)	High (200-400)	Very high (>400)
Multiple use hard surface	8 feet	8 feet	8 feet	10 feet***	10 feet***
Crusher fines surface, bikes	4-5 feet	6 feet	8 feet	8-10 feet	7-10 feet
Natural surface	18 inches-2 feet*	2-3 feet*	3-5 feet*	4-6 feet**	5-7 feet**

* Construction and maintenance can be expensive (and the natural appearance of the trail compromised) if the cross slope of the hillside is less than 10 percent (15 percent if the trail width is more than 2 feet). Consider using crusher fines on at least the parts of the trail with a hillside cross slope of less than 15 percent.

** Often requires high and expensive maintenance. Maintenance can be minimized in well-drained, cohesive (i.e., not sandy) mineral soil where hillside cross-slopes are less than 20 percent. If these conditions cannot be met, a crusher fines surface is recommended.

*** Or up to 12 feet or more, where practicable, as used in the Portland metropolitan area.

Table 8-3 Trail Surface Types in Relation to Environmental Settings

Setting	Uplands			Riparian areas			Floodplains		
	Natural	Permeable	Hardened	Natural	Permeable	Hardened	Natural	Permeable	Hardened
Natural area	◆	◆		◆	◆		◆	◆	
Urban linear corridor			◆		◆**	◆	◆**	◆*	

* If soft/permeable trails are in the path of floodwaters, they may be a source of scour erosion. This can damage both the trail and floodplain and increase sediment loading to the stream. Instead, hard and soft surface can be combined and short soft surface spurs can be created to floodplains to provide trail users a satisfying experience of the river or stream. Good places for location of trail are (1) downstream end of the floodplain, (2) perpendicular to the stream, (3) upslope edge of the floodplain, (4) edge of existing disturbance corridor.

** If use of trail is very low to low (see Table 8.2). If use of trail is high, other surfaces may need to be considered.

What are some resource-friendly construction techniques?

9.1 Introduction

Like other construction projects, trail projects can be organized and managed in ways that encourage sustainable practices and minimize environmental impacts. This chapter describes strategies for setting up a trail construction project so that the contractor or project team is encouraged or required to use environmentally friendly construction practices.

Virtually all of the strategies discussed here are based on natural resource protection requirements already in place in the regulatory permits and contract documents issued for typical trail construction projects. The strategies highlight these natural resource requirements for typical trail construction projects.

This chapter discusses strategies for procurement, communications, construction staging and site management, quality assurance and quality control, schedule, and post-construction monitoring and maintenance. These topics reflect issues trail managers encounter in managing trail construction to protect natural resources.

9.2 Procurement

A procurement strategy determines how environmentally friendly services, materials and equipment for a trail project will be purchased. Part of the strategy is to ensure that natural resource protection requirements are defined as separate bid items that can be enforced.

Identify natural resource protection measures as separate bid items. Even if natural resource protection measures such as tree protection, replanting, erosion and sediment control and hazardous material management are incidental to another bid item such as earthwork, they should be clearly and fully described on the bid form. In some cases, trail designers and project managers may decide to list them as separate items on the bid form. These measures can be broken down further, so that individual activities and materials are listed as separate bid items. Again, using erosion and sediment control as the example, this would mean listing separate bid items for installation, inspection and record keeping and maintenance.

It is important to create a balanced approach so that an excessive number of separate bid items does not result in unreasonably high bids and unreasonably increased costs for construction and maintenance. A properly balanced procurement strategy will require the contractor to take natural resource protection measures seriously in order to be paid for them. It also will give the trail project manager leverage to ensure that complete and adequate protections are carried out for the duration of construction.

Provide descriptions of bid items for natural resource protection. Trail designers and project managers should include explicit descriptors in bid items. If biodegradable erosion control materials are desired, insert the term "biodegradable" in the item description rather than depending on the contractor, subcontractors and suppliers to notice that key word in the specifications. If a certified weed-free seed mix is desired, insert those key words in the bid item description. If a certain brand of product is needed, specify it by name in the bid contract.

Identify pre-qualified designers and contractors. Standard practice is to accept design proposals and construction bids from all who meet minimum requirements for registration, licensing, bonding and insurance. However, it is increasingly common for project managers to require bidders to demonstrate their specific qualifications and experience. Trail project managers can use this approach to identify designers and contractors who have trail experience and are knowledgeable about environmentally friendly construction practices. There are many approaches to pre-qualifying bidders but all require the same basic information:

Firm profile. Information provided for pre-qualification should include staff size and resources, organizational structure, equipment and relevant experience with environmentally friendly construction practices.

Qualifications and experience of key team members. Information about the role and availability of key team members also should be provided.

References. At least two to three references should be listed to check on past work products.

Project approach. Pre-qualification applications should include a description of how the bidder intends to execute the trail project and provide the natural resource protection measures.

Establishing a pre-qualified pool of proposers/bidders can be done in conjunction with an individual project or an ongoing program. For example, a trail project manager can pre-qualify contractors before accepting their bids on a specific trail project. Alternatively, a land management entity, such as a park district, may wish to establish a pre-qualification list from which project managers can invite individual firms to submit proposals or bids as new projects are implemented. Pre-qualification lists also can be borrowed from other agencies. As always, project managers must take care not to create such restrictive requirements that the pool of providers is unnecessarily limited.

Consider alternatives to the traditional design-bid-build process. The traditional process of designing a trail project and then seeking the lowest bid may not result in environmentally friendly construction. Alternative project delivery methods can help trail project managers achieve the desired results and still stay within the budget. Alternatives include:

Guaranteed-maximum-price agreements, under which a contractor agrees to deliver a completed project for a lump-sum price that will not be exceeded.

Design/build, which typically involves the general contractor retaining the design team.

Construction manager/general contractor, under which a contractor may negotiate an agreement with the project owner to deliver a finished project and then solicit bids from subcontractors.

Sustainable purchasing. More and more jurisdictions, including Metro, the city of Portland and Multnomah County, are now implementing sustainable purchasing requirements. Examples are purchasing and using recycled materials and certified wood products.

In practice, elements from each of these approaches usually are combined to create a project delivery method that is uniquely suited to the requirements of the project and owner. For example, guaranteed-maximum-price and construction manager/general contractor provisions almost always are combined when they are used in public agency contracts. Many organizations that own trail systems have procurement departments and procedures that can be valuable resources for project managers who need to purchase design and construction services.

The use of guaranteed-maximum-price, design/build and construction manager/general contractor contracts is allowed by state law but the local agency's contract review board must approve these types of contracts.

Use a qualification-based selection process. Public agencies in Washington and, increasingly, in Oregon may select designers and contractors based on their qualifications and value of the services they offer. This allows agencies to select contractors on the basis of highest quality work at the most reasonable price. Depending on the circumstances, quality of work may be more important than price. In other cases for some agencies, the lowest bid may be taken into consideration.

Requests for proposals and negotiated bids are sometimes used by federal agencies, but state and local agencies are not always allowed to use these procurement methods. Agency procurement departments and procedures should be consulted before using a quality-based selection process. Professional organizations such as Associated General Contractors and the American Council of Engineering Consultants have well-developed positions on legal and ethical considerations associated with quality-based selection and alternative project delivery.

Require pre-qualified construction equipment. A contractor's choice of trail construction equipment can have profound effects on natural resources. For example, oversized excavating equipment can damage a swath of vegetation that is wider than the trail construction corridor. It also can permanently compact the soil in areas outside the intended limits of disturbance, yet many contractors do not own equipment suitable for low-impact trail construction.

Pre-qualifying construction equipment requires the trail designer or project manager to take a balanced approach. In some cases, the trail project manager will be able to specify a type or model of equipment known to be environmentally friendly. The key is to insert the words "or approved equal" after the requirement. This will avoid claims of bias.

In other cases, it will be more appropriate to define the desired performance criteria and ask the contractor to submit a list of proposed equipment for approval prior to awarding the contract or proceeding with construction. This approach will avoid requirements that bidders perceive as unduly restrictive.

Public works agencies have used these approaches for many years and can provide valuable advice and information. Equipment providers can provide performance and production statistics. Some can provide sample specifications that define how their equipment can get the job done with minimum impact on natural resources.

Provide contingency rock and material quantities for the contractor to bill against. The trail designer cannot always know in advance whether a certain construction item will be needed or how much of it will be needed. For example, it is not always possible to predict the need to drain and stabilize areas of wet soil.

One way to address these uncertainties is to include an allowance in the bid form for a certain quantity of an item that may be needed, making it clear that only the amount that is actually used will be paid for. As an example, if wet or unstable soil is suspected but cannot be verified or quantified until construction has begun, the designer can include an allowance for a specific amount of stabilization rock of a specific size. That way, the trail project manager can be assured of receiving the rock at a pre-determined price without making a commitment to actually purchase a specific amount.

9.3 Communications

A communication strategy can determine how the trail project team will be informed about resource-protecting construction practices. Many instances of construction-related environmental damage are the result of uninformed workers. Other difficulties with natural resource protection during trail construction are the result of conflicting expectations between the contractor and the project manager. Requirements for natural resource protection are usually in place in the regulatory permits or the contract documents but must be highlighted for the construction team.

Construction drawings and specifications. Requirements for natural resource protections, such as coffering, filtering and preservation of vegetation, should be integrated into the construction drawings and specifications, rather than stated only in a separate document. Site-specific instructions are most appropriately placed on the construction drawings. Most workers, suppliers and subcontractors will see the construction drawings; few will see the regulatory permits or environmental reports.

Training for contract managers. Staff who will be managing trail construction contracts should receive training in all aspects of contract management. Project managers with appropriate experience and contract management skills should be selected.

Worker education. It is not always enough to require natural resource protections in the plans and specifications. The trail project manager may decide to conduct a training session to inform the project team about specific natural resource protection requirements. Alternatively, the contractor can be required to do this. The pre-construction conference, weekly project meetings and daily "tailgate" meetings can provide good opportunities for worker education.

9.4 Construction Staging and Site Management

Trail construction plans and specifications focus on how specific trail elements will be built. However, it is also necessary to consider how work will be staged and how the project site will be managed. These requirements are set forth in regulatory permits or environmental reports, and relate to keeping construction materials and staging areas away from sensitive environmental areas including riparian zones, floodplains and wetlands.

To implement a unified natural resource protection plan, information on construction staging and site management must be made easily accessible for the entire project team. This can be done in several ways:

On the construction drawings. For example, construction limits should be shown adjacent to the trail alignment.

On a separate plan. This approach can be used to show activities that occur away from the trail alignment, such as material storage.

On a plan developed by the contractor. This approach can be used when the contract document sets forth general requirements for natural resource protection, such as protection of vegetation in material storage areas. The contractor's plan shows specific "means and methods" for protecting vegetation.

On the ground. Construction limits, vehicle maneuvering areas and staging areas should be indicated with flagging, markers or, in critical areas, orange construction fencing. Silt fences double nicely for erosion control and setting disturbance limits.

The following discussions provide examples of staging and site management issues that warrant special attention. Which issues are given priority and how they will be handled will depend on the site conditions and the specifics of construction.

Construction boundaries. The boundaries of construction areas, resource protection areas, construction access and vehicle maneuvering areas and staging areas for material and equipment must be marked and, in some cases, fenced. Construction workers often are focused on convenience and efficiency. Their awareness of natural resource impacts cannot be assumed. Project managers can work with construction managers to designate project boundaries in order to ensure compliance.

Protection of trees and other plants in the construction zone during project activities must be made very clear, both in the plans and construction drawings, and on the ground. If it is not an option for contractors to remove plants that are in the way, even if they intend to replace them, this information needs to be clearly communicated.

Erosion control and water resource protection. Good erosion and sediment control begins with good planning. Erosion and water resource requirements are usually set forth in the regulatory permits. Protection measures are set forth in the contract documents. Contractors can be asked to contribute information about the following:

Prevention. Identify strategies for sequencing and managing construction activities to minimize exposure of disturbed earth during the wet season and near sensitive water resources. Identify strategies for inspecting and maintaining construction site erosion control during inclement weather especially at night, on weekends and during holidays.

Contractors also can be asked to identify typical erosion conditions that can develop under construction conditions, and list typical mechanisms that they might use to control them. For example, covering an earthen stockpile with plastic will probably prevent the pile from eroding during heavy rainfall conditions. However, water shed from the plastic covering may become an erosion agent and contractors can be asked to further identify how they would prevent erosion in this situation.

By considering potential erosion scenarios and their solutions, contractors can arrive at realistic costs for project erosion and sediment control activities. By considering worst-case potentials, they can evaluate the costs of applying costly measures and heroic efforts versus making changes in project schedules.

The trail project manager must ensure that the contractor applies erosion and sediment control measures effectively in the field. To accomplish this, it is usually necessary to modify or refine the measures shown on the construction drawings.

The trail project manager must reach an agreement with the contractor on how refinements or modifications to the natural resource protection plan can be implemented within the existing budget. Finally, the project manager must have documentation showing that resource protections are being monitored, maintained and modified to meet changing conditions.

Potential worst case runoff scenarios. Contractors should be asked to identify where construction site runoff will flow and the resources at risk in the event of unexpected or unusually intense rainfall.

Emergency response. They also can identify typical personnel, equipment, materials and communication strategies for quick response to emergency runoff situations.

Management of excavated and stockpiled soil and rock. Often the project documentation will not provide comprehensive guidelines for handling excavated or stockpiled soil and rock. However, the trail project manager must have a clear agreement with the contractor on how these materials will be handled in an environmentally friendly manner.

Typical issues include:

Disposal of organic materials generated in clearing and grubbing. In many cases it is acceptable, economical and even environmentally beneficial to "lose" or scatter these materials in the project area rather than disposing of them off-site. However, this activity must be planned and executed carefully.

Disposal of construction waste. Construction waste should be recycled or disposed of at an approved site.

Storage and re-use of excavated soil. This may include material that will be used as fill or topsoil that will be used for re-vegetation. In either case, stockpiles should be protected against erosion. Topsoil stockpiles should be limited in height in order to retain air content and avoid creation of anaerobic conditions.

Delivery, storage and transport of gravel, crushed rock and other construction materials. The trail-project manager should have a clear agreement with the contractor on how and where each of these operations is staged so that natural resources will be protected.

Management of fuels and toxic materials. Depending on materials, topography and proximity to water resources, it may be necessary to provide spill protection or containment facilities. These range from berms and pumps to diapering of equipment. If a spill occurs, a contingency plan must be in place for dealing with it. Equipment fueling and washout should occur off-site or in designated, properly protected areas away from drainages and streams. As noted, it is often best for the trail designer or project manager to set forth performance and protection criteria and then require the contractor to develop and execute a protection plan. Project managers should always specify that the contractor have spill response supplies on the job site.

Management of treated-wood construction materials. Many trail facilities and structures, such as bridges and retaining walls, are constructed with wood products that have been chemically treated to resist rot. Treated wood construction debris can be a source of pollution if not managed properly. Examples of management considerations include:

Training employees. Personnel who will work with these products need to be taught proper methods for storage and handing of treated wood products.

Documentation. The contractor may be required to show receipts for delivery of hazardous materials, such as sawdust, shavings, trimmings and used absorbent pads, to garbage transfer stations.

Off-site fabrication. The contractor may be required to provide facilities for off-site fabrication.

Management of concrete in streams and lakes. The pH of water may increase when it comes into contact with fresh concrete. This can be a problem for cold-water species such as salmon and trout, which are sensitive to pH and to dissolved solids. The state of Oregon regulates how concrete work is managed in streams and lakes. Contractors will be required to provide temporary cofferdams around concrete work areas in bodies of water. They must be able to show records that these have remained in place until the concrete has dried and they may be required to show evidence that their concrete trucks were rinsed at appropriate off-site facilities.

9.5 Quality Assurance and Quality Control

A quality assurance plan sets goals for protection of specific vegetation, habitats and water resources. A quality control plan identifies specific checks and procedures to ensure that quality assurance goals are being met. Specific quality control procedures should be set for each project and should identify specific methods for ensuring that natural resource protection goals are being met. These methods include observation, monitoring, inspection, testing, maintenance and documentation.

As a general approach, quality assurance/quality control procedures that have been developed by public transportation agencies for road projects can be used to manage construction of wide hard-surfaced multi-use trails. The construction processes are the same for roads and trail projects of this nature. Trail managers should take maximum advantage of the extensive body of knowledge available about road construction and should spend time in the field on quality control and quality assurance during trail construction unless there are other inspectors available.

Construction observation and inspection. The trail owner and/or designer must observe the construction enough to know that the trail is being built in accordance with the plans and specifications, and that natural resource protections are in place and operational. Construction inspection entails more in-depth investigation, measurement and testing of the contractor's work to ensure conformance to the contract documents. The trail designer or project manager must determine what level of observation and inspection will be needed and assign responsibilities accordingly.

Observation and inspection records. All construction observations and inspections should be recorded in a daily report. This responsibility can be shared among the owner, designer and contractor. However, specific roles and responsibilities should be assigned to each party. Records should conform to a standard format and should include a section for natural resource protection. Additional documentation may include:

Contractor requests for information from the owner or designer.

Material submittals from the contractor, including test reports or brochure information to demonstrate that construction materials conform to the contract documents and are environmentally friendly. Contractors also may provide shop drawings, showing how they propose to construct specific details.

Contractor's point person for natural resource protection. The trail contractor should designate a single point of contact for natural resource protection, including erosion control. Usually this contact will be the same person responsible for other quality assurance/quality control compliance.

9.6 Schedule

Schedule and time management are essential to any construction project. Typically the emphasis is on efficiency, convenience and following the shortest path to completion. Trail projects are the same except that the construction schedule often must revolve around the timing of events in the natural world.

Seasonal work windows. Seasonal work "windows" specify when certain types of construction may or may not be done. Work windows may be imposed to avoid disruption of wildlife migrations, fish runs, periods for nesting or rearing young, or to avoid erosion and stream sedimentation due to heavy rains.

In-water work windows may affect the construction of bridges and stream crossings. In-water work windows typically occur in late summer and early fall, when stream flows are at their lowest level. This means that construction in or near the water must be deferred to low-flow periods. However, current regulatory policy is such that any work in or near fish-bearing streams is unlikely to be permitted unless it can be shown that there is no other reasonable alternative and an overriding public benefit will be provided. The best strategy for trail designers or project managers is to contact regulatory agency representatives during the planning process and integrate their requirements into the project from the earliest stages.

Work windows also may be imposed when the rainy season leaves soils too wet to be worked. Different soils have different "liquid limits" for the amount of moisture they can absorb and still remain workable. Typically, soils with high silt or clay content have lower liquid limits. Granular or rocky soils are less sensitive. Many trail construction activities must be carefully planned so they can be completed before the onset of the rainy season. If work is stopped because of weather, measures such as seeding or installation of barriers should be taken to stabilize and protect sites until the project starts up again.

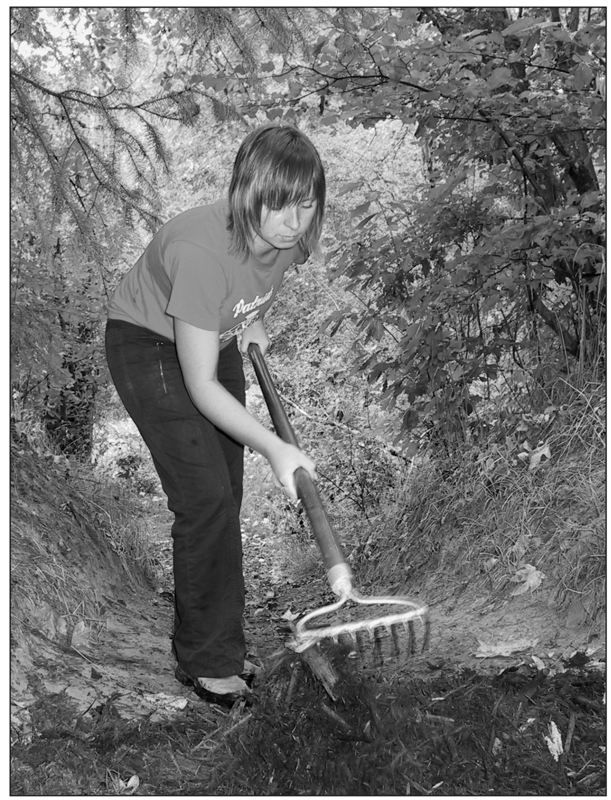
However, trail work does not necessarily have to stop when soil moisture is high. In some situations, a layer of crushed rock may be used to protect moisture-sensitive soils. While grading or earthwork may not be possible when soil moisture is high, other operations such as brush clearing may still be practical. General information on soil capabilities can be obtained from county soil surveys. Geotechnical engineers should be consulted for specific recommendations on large or sensitive projects.

Duration, sequence and phasing. The length of time needed for each construction activity should be indicated in the schedule. Among other things, this will assure the project manager that preparatory work will be completed in advance of seasonal work windows. The construction sequence also should be indicated so the project manager knows that the contractor has thought through the construction process and will avoid repeated disruption of natural resources.

It may be necessary to identify project phases that are based on natural resource issues. For example, pruning or felling of certain trees must be delayed until birds that nest in them have hatched and fledged their young. Tree removal should be scheduled outside the wildlife nesting season (April 15 to July 15).

9.7 Post-Construction Monitoring and Maintenance

Trail-project managers should consider strategies for ensuring that environmental protection measures remain effective after trail construction has been completed. Public agency construc-



Contractors need to maintain and monitor the site after construction is completed.

tion contracts typically obligate the contractor to a one-year maintenance and warranty period. During this time, the contractor must keep the project in a condition that conforms to the contract requirements. On trail projects, vegetation monitoring and maintenance typically are problematic. The contractor should hand over "as built" drawings and specifications to the owner. The drawings will specify the actual construction of the trail. The project specifications should include detailed requirements for watering, removal of unwanted vegetation and desired plant survival rates. If these rates are not achieved, additional plants must be installed. Monitoring of new trails' drainage features during the first year after construction is covered in the Chapter 10.

After a year (or as agreed by the contractor and owner), ongoing trail maintenance and operation typically become the responsibility of the owner. Ongoing natural resource protection typically is focused on habitat and water resources. Periodic monitoring and maintenance are necessary to ensure proper drainage, prevention of erosion and re-establishment of native vegetation or non-invasive cover plantings. The transfer of maintenance responsibility from contractor to owner should include a transfer of information on what the contractor has learned about maintaining the project. This will give the trail owner's staff a head start as they assume responsibility.

How should we take care of the trail?

10.1 The Goals of Resource-Friendly Trail Maintenance

Most park managers agree that there is a lot more to trail maintenance than meets the eye. A trail that looks inviting on a sunny afternoon also must be safe during wet and cold conditions. The pungent gold cottonwood leaves that light up trails in fall need to be raked out of bio-swales. Plants next to the trail must be pruned so that people can pass safely. Hazard trees must be pruned or removed, signs replaced, litter picked up and glass swept. Workers and volunteers need to be trained, equipment maintained and the trail surface repaired.

A resource-friendly green trail maintenance program provides care to the trail surface and its drainage system before normal wear and weather can create problems that affect water resources and fish and wildlife habitats. The maintenance schedule is sensitive to the seasonal needs of fish and wildlife. It enhances and preserves wildlife habitats in the trailside environment, creating opportunities for trail users to enjoy nature at its best.

Environmentally friendly trail maintenance begins in the trail-planning phase by anticipating trails' future maintenance needs and influencing decisions about trail location and design. This chapter highlights maintenance actions that support environmentally friendly trails. These actions begin in administration of the maintenance program and extend to inspection and record-keeping, routine upkeep and repairs, retrofitting and upgrades.

10.2 Administering a Trail Maintenance Program

Administrative practices establish a maintenance program for trails. They assure that maintenance activities are scheduled, budgeted, tracked and properly executed before resource degradation can occur. Some of the items to take into consideration are listed below.

Develop an overview of maintenance activities

Annual, seasonal, occasional and emergency inspections are important to maintaining trail systems in good condition. A typical schedule of maintenance includes the following:

Annual/seasonal activities.

Readiness for winter. Trail drainage systems should be inspected and maintained before the onset of the wet season.

Storm response. Trails should be inspected and necessary maintenance provided after high winds, freezing rain, unusually intense rainfall or flooding.

Mid-winter. A good time to check on the functioning of trail drainage systems is after soils are saturated.

Winter's end. Inspection and maintenance should be provided to make sure the trail and its drainage features are in top shape before the beginning of the high-use season.

High-use season. Wear and tear on the trail can affect both natural resources and public safety. Inspections and maintenance throughout the high-use season can prevent degradation of the trail and wildlife habitats in the trailside environment. Also check for presence of social trails.

New trails. For additional information about maintenance schedules for new trails, refer to the inspection section of this chapter.

Light seasonal maintenance. Inspectors should carry hand tools that enable them to take care of light tasks such as cleaning plugged drainpipes and trimming vegetation. This work should be noted on the inspection forms to support the forecasting of maintenance requirements for each trail segment. More time-consuming maintenance work that can be accomplished by hand crews should be prioritized and completed as soon as possible after seasonal inspection.

Medium-duty seasonal maintenance. Activities that may need to be scheduled include:

- spot-improvements to drainage features
- clearing wind-throws
- repairing informal detour and cut-off trails
- assessing and removing of hazard trees, particularly at trailheads and gathering points
- cleaning major drainage system and making repairs that are important to prevent water resource or habitat impacts, and/or trail damage
- cleaning boardwalks and bridges
- placing seasonal "hop-across" materials in small pedestrian water crossings, if they will keep the trail passable for users and help prevent further damage by detour trails.

Occasional inspection. Trails and their surfaces, furnishings and drainage facilities need occasional upgrading to maintain functionality, public safety and appearance. For example, a failing trail segment in a wet area may need to be reconstructed or a trail surface and base treatments may need to be upgraded to accommodate increased trail use. To address these and other occasional needs, trail managers need to have a broad view of trail lifespans, future trail upgrades and typical reconstruction scenarios.

Emergency inspection. Drainage problems that result in impacts to receiving water resources or fish and wildlife habitats should be taken care of as soon as they are discovered. Other repairs may need to wait until soils are firm enough to support repair vehicles, if needed. It may be necessary to install temporary stabilization until environmental windows are favorable for sensitive species or in-water work.

Develop a multi-year budget

It is essential to budget for both regular (seasonal and annual), occasional (repairs and reconditioning) and long-term maintenance needs (projected for five, 10, 15 and 20-year horizons). Because not all of these activities will be necessary on each trail segment in each year, the budget should reflect varying activity levels across time and should include line items for big jobs: storm damage response, major reconditioning, realignment or replacement of structures or jobs that require large equipment.

Develop tracking methods

Maintenance activities such as inspection, repair and emergency response should be tracked with inventory forms, field notes and other records. Written inspection records for each trail segment should be logged. These records will become the basis for budget and labor forecasts, equipment purchases and schedules for improvements all vital to the health of the maintenance program.

Provide training for staff

Maintenance crews tend to change with the changing seasons and shifting assignments. Therefore, education in environmentally friendly maintenance practices is an on-going need in most maintenance departments.

Develop a program of environmental improvements

Many trail managers must maintain trail systems that were constructed in ways or settings that do not reflect current thinking about natural resource protection. By identifying trail segments that result in chronic functional problems and unacceptable impacts to fish or wildlife, or to water resource areas or their functions, managers can develop programs of environmental improvements and budgets and schedules to accomplish them. Inspection and assessment of existing trails may reveal opportunities to minimize or eliminate these impacts.

Potential remedial actions include:
- retrofitting bridges and culverts for fish and wildlife passage
- replacing culverts with spans
- upgrading trails to reduce impacts in or restore functions to wetlands and floodplains
- realigning or reconstructing trail segments where erosion has been a long-standing problem
- abandoning or decommissioning trails in sensitive species habitats
- upgrading drainage on roads and trails to stop chronic delivery of trail runoff and sediments to streams, wetlands or riparian areas
- removing exotic vegetation from trailside environments and replacing it with native plants
- providing improved wildlife passage
- dealing with long-standing social trails.

Note that these remedial actions likely will require city, county and state permitting if located in environmentally sensitive areas. More information about assessing existing trails is provided further on in this chapter.

Develop resource-friendly contracting practices

When maintenance activities will be accomplished under contract, natural resource protection practices need to be specified in the contracts and approved in the field.

Following are examples of practices to include:
- Contractors should attend a pre-work site meeting and provide input into maintenance contracts.
- Contractors should participate in identifying places where and how excess earth materials can be disposed in the field (not in wetlands, near streams or in other sensitive locations).
- Contractors should be experienced in particular techniques such as herbicide application and have certified workers.
- Maintenance plans should contain special directions for contractors to follow under worst-case conditions. For example, contractors might be required to stockpile bio-filter bags to install in ditches in the event there is a rainstorm during reconditioning of a trailside drainage ditch.
- Earth-disturbing activities such as blading and shaping dirt roads and cleaning ditches with equipment should be paid by clearly marked segments, not by lineal feet (a practice that encourages over-maintenance and unnecessary exposure of disturbed earth to erosion and transport to water resources).
- As with construction, erosion prevention and sediment control practices are part of all maintenance practices that disturb ground. Erosion control practices are inspected and maintained daily while maintenance work is being completed. Measures such as seeding or mulching for erosion control are inspected by the contractor during the rainy season until the project manager finds that the disturbed earth has been stabilized.
- Controls for sensitive area protection are installed before maintenance activities begin. These can include erosion and sediment controls, designation of areas for equipment maneuvering and parking, areas for storage of equipment and materials including soils stockpiles, and limits on removal of organic matter.
- Ground-disturbing work is delayed in wet weather.
- Contractors provide project schedules showing how they will accommodate working windows for sensitive species.
- There is daily inspection of work that can affect water or other sensitive resources, and a written record of inspections and follow-up actions.

10.3 Inspecting Trails

Inspection and maintenance are important elements in resource-friendly sustainable trails. A regular trail inspection program is an insurance policy for taking care of conditions before they result in impacts to water resources or fish and wildlife habitats. For example, a clogged culvert inlet might be spotted during routine inspection. The few minutes the inspector takes to remove the debris could prevent the trail from washing out and sending sediment to downslope water resources. Timely inspection and follow-up also protect the trail itself from damage by wear and weather.

First-year inspection for new trails.[1] New trails need to be closely monitored in the first year after construction so problems can be corrected before they cause damage and become more costly to fix. A typical inspection schedule for the first and successive years is provided in Table 10-1.

Long-term inspection. After the first few years of rigorous inspection and maintenance, any trail problems should have been identified and solutions implemented. Inspection and maintenance of drainage systems should continue as before. As drainage swales age, they may require additional maintenance such as reshaping, cleaning out or reestablishing of vegetation. The trail structures also will begin to require more attention as they weather, settle and wear. Vandalism may take its toll on signs and structures, and solutions will need to be found to control off-trail uses.

Inspecting asphalt and concrete. Asphalt surfaces will need to be re-sealed (see Chapter 8). "Alligatoring," or a pattern of small cracks in asphalt, can indicate moisture in the base or sub-grade. This condition may require reconstruction of a section of the trail.

Type of trail	Item	Suggested frequency
New hard and soft trails	Note drainage design including ponding, gullying and wash outs	After the first heavy rains
	Drainage should be repaired, trail structure inspected and check for presence of social trails	Two months or after several moderate rains
	Joint inspection with contractor to inspect trails including structure, surface, drainage and vegetation	Four to six months after the trail is completed. Soft surface trails require greater attention than hard surface trails
	Spot improvements of trails for handling wet weather or worst case runoff	End of the first year prior to rain
Existing trails and newly built trails (ongoing maintenance)	Weed control	Seasonal
	Water plants (newly established trails) and remove exotics	As needed
	Mow the edges where applicable	Biannual – fall and spring
	Prune trees/shrubs	Five months to one year
	Clear drainages including smaller pipe inlets, outlets for sediment, leaves and blockages	Annually, especially after a large water event (late spring) or fall after leaves are down and before rains
	Clear vegetation along ditches	Every two years
	Trail sweeping	Regular schedule
	Trash disposal	As needed

Table 10-1 Maintenance recommendations for green trails.

When concrete surfaces have been properly constructed, they should require virtually no maintenance. Cracking of concrete surfaces can indicate that scoring patterns were not properly spaced. Cracks should be filled to prevent moisture damage to the base and sub-grade.

A word about earthen and soft-surface trails

The same general schedule of inspection and maintenance applies to soft-surface trails. Newly constructed earthen and soft-surface trails should also be monitored closely in the first year. The tread surfaces of earthen trails generally require greater attention than constructed trail surfaces, particularly if use is high. Because elements of trail drainage are present in the tread surface of earthen and soft-surface trails, special attention is given to them in the following maintenance practices.

10.4 Maintaining Trails

Drainage features

Many of the drainage features discussed are common to earthen and constructed trails. However, one of these features, the rolling dip, is almost exclusive to earthen trails.

Rolling dips and sediment traps. Water running down the surface of an earthen trail almost always pulls a little sediment with it, no matter how perfectly spaced drainage features may be. The function of rolling dips is to catch the runoff and sediment and route them off the trail in a leadoff ditch (see Figure 10-1). But this does not always occur as neatly as planned, and someone has to come along with a shovel and clear out the collected sediment – both in the dip and in the leadoff ditch. This operation needs to be done every one to three years, depending on soils, vegetation, use and other conditions (rolling dips on earthen trails under full conifer canopy may require less frequent maintenance). Depending on the scale of the project, large equipment may be needed to rebuild and reshape the dips, or to reshape the leadoff ditch and dissipation apron and sediment deposition area.

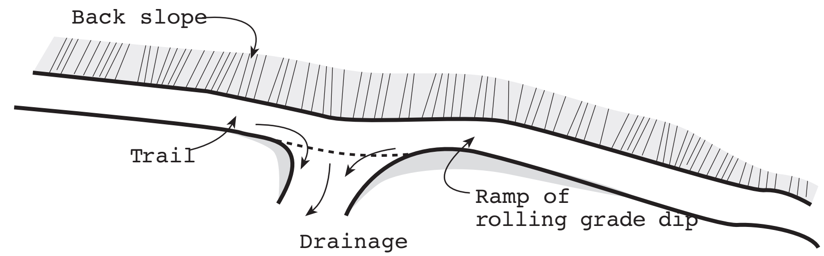


Figure 10-1 Schematic of a rolling grade dip. (Trail Building and Maintenance: Rolling Grade Dips – Erosion Control, IMBA Resources)

Dissipation aprons ("catch basins"). When concentrated stormwater is discharged over the side of a trail, the energy of the falling water may rapidly erode the discharge area. This may be particularly true where the trail incorporates a drainage system to capture groundwater and route it under the trail. To avoid erosion at the discharge point, the site typically is armored with cobbles and boulders, which slow the water and sometimes, level-spread it into the surroundings. Despite this, discharge sites frequently sustain erosion anyway, and the discharge apron needs to be maintained every few years. This entails bringing in more rock or coarse woody material, perhaps from the immediate area, and placing it where it will help to dissipate the energy of the runoff and allow settling of sediments. An engineer or qualified designer typically selects the rock type, shape, size, weight and armor thickness.

Culverts. Culverts are pipes that route water under the trail for discharge on the downhill side of the trail. They typically have an inlet basin and an outlet, or dissipation basin. Woody debris and buildup of sediments can clog culverts. Inspectors can clear them with shovels and handsaws during inspection. Both inlets and outlets should be cleaned. Work with power saws in natural areas should be deferred until a favorable work window that reflects fish and wildlife needs.

Ditches. Ditches route water alongside or away from trails until it can be discharged. Whether they are maintained by hand or by machine, ditches require regular maintenance. Their neglect can cause serious consequences – when, for example, runoff that should have been contained in the ditch overflows on the trail and gullies it or washes it out, then flows to the nearest receiving water. Sediments can clog ditches and should be removed if they interfere with conveyance of runoff. However, maintenance can result in bare ditches, which are vulnerable to erosion. It may be necessary to add roughness elements (such as rock) to prevent ditch erosion. Major work on ditches should be done during the dry season, and erosion and sediment control should be provided on bare ditches. Many managers use bio-filter bags – net bags filled with chipped bark. These can be staked to the ground and are removable. Some are biodegradable.

Trail-side vegetation

Brushing and pruning. Low-intensity and narrow pedestrian trails should be hand-pruned annually to keep them open (Figure 10-2 and 10-3). Due to declining budgets for trail maintenance, many trail managers schedule trails for vegetation maintenance every two to five years. Because of this, trail friends' groups have become vital components of many trail maintenance programs.

The vegetation should not pose a hazard to trail users or restrict their movement (see Figure 10-4). It is critical to maintain sight distance at trail intersections with streets, roads and railroads so that trail users have unobstructed views at pedestrian crossings and intersections.

Both city and county zoning codes regulate cutting and spraying of native vegetation. Trailside pruning should take place after the nesting season. Consideration should be given to avoiding or minimizing pesticides (see the last section of this chapter, Integrated Pest Management). The potential impact of chainsaw noise on sensitive wildlife species also should be considered. Pruned material can be lopped and scattered near the trail but not in or adjacent to the trail's clearing limits.

Mowing. Increasingly, trail managers are mowing less frequently and deferring mowing until late spring to avoid disturbing wildlife. Others are converting to slow-growing, heterogeneous lawn mixes or "eco-lawns" as no-mow alternatives to turf.

Clearing vegetation from ditches. Vegetation growing in trailside ditches can impede water flow and cause sediment build-up. If vegetation causes water to stand in the ditch and saturate the trail foundation, the trail can be damaged. On the other hand, ditch vegetation can be effective in the uptake of nonpoint pollutants associated with runoff. Therefore, its removal should be carefully considered.

On wide high-use trails, ditches are usually "cleaned" or "pulled" every two years or so. This operation is done with a backhoe bucket that scoops out the sediment and the vegetation in the ditch (i.e., typically weeds, willows, alder and other wet-loving plants). Ironically, this often leaves the ditch bare and susceptible to erosion by the runoff that flows into it. Therefore, ditch cleaning should occur after the spring rainy season so that annual vegetation can re-establish before the onset of fall rains. Biofilter bags or straw wattles are usually staked at intervals in the ditch to filter sediments if the ditch should flow.

If the ditch discharges directly to a stream or wetland, erosion of the bare ditch can be a problem and the ditch may need to be maintained by hand. In this case, plants should be cut and sediments removed with a shovel.

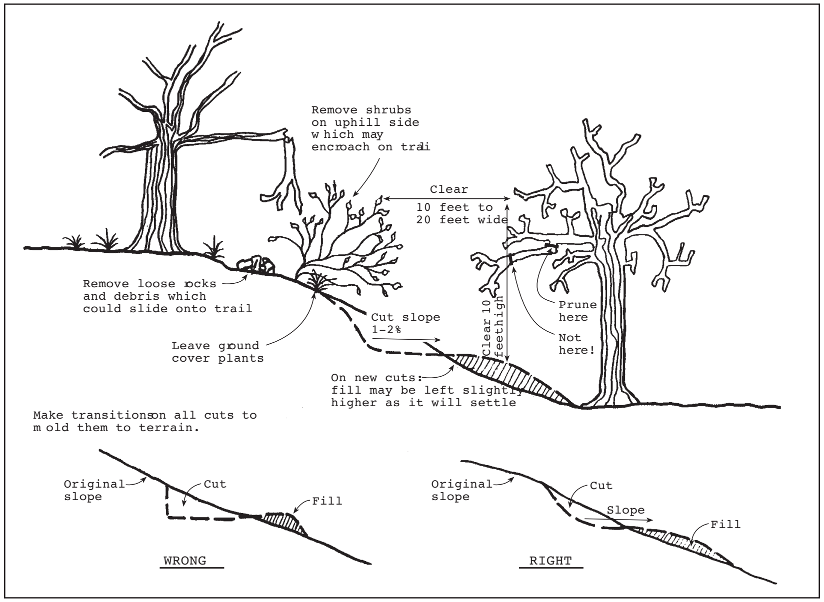


Figure 10-2 Make transitions on all cuts to mold them to terrain. (Trails Manual, 1995)

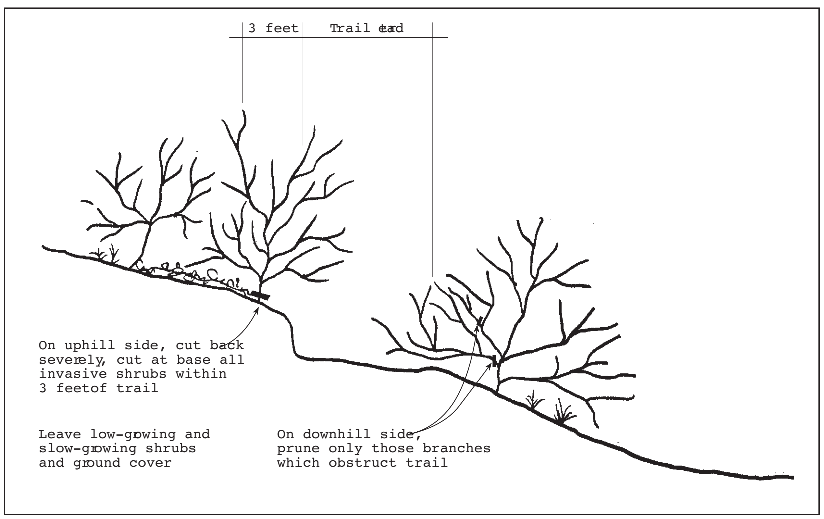


Figure 10-3 Typical vegetation clearing from slide slopes. (Trails Manual, 1995)

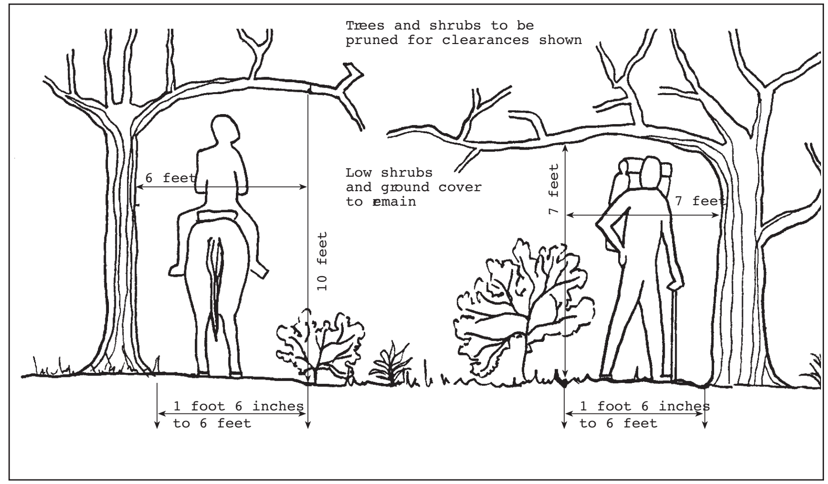


Figure 10-4 Typical vegetation clearing for hikers and horses only trails. (Trails Manual, 1995)

Bio-swales. The drainages that flow to swales should be inspected regularly to make sure that erosion from upstream stream or drainage facilities are not loading the swales with sediments. If eroding up-line ditches are found to be a source of sediments, roughness elements such as rock and coarse wood may need to be added to the ditches to slow the flow and reduce erosion. If flow volumes are too high and ditch erosion cannot be controlled, the flow may need to be split so that it is received by two swales, instead of one. Annual leaf-fall should be removed from swales when possible, to improve their efficiency. Sediments that accumulate in swales should be removed periodically, so that the swale is capable of holding runoff from larger storms. This may necessitate removal and re-establishment of vegetation.

Seasonally closed trails

Inspect closed trails to make sure drainage is in good order, closure signs are up and/or gates are locked.

Unsurfaced gravel park roads

Unsurfaced park roads are often used as trails. Vehicular traffic on unsurfaced park roads during the wet season can degrade the road surface and generate sediments in runoff. If water stands on the roadway and/or the surface becomes soft and muddy, pedestrians, equestrians and bicyclists may create detour trails. Routine inspection and maintenance can prevent detour trails.

The following steps could be taken to maintain unsurfaced gravel park roads:

- Use seasonal closures if needed but allow access for seasonal drainage inspection.
- Before winter, install seasonal waterbars, check or install trash racks, clean culvert inlets and outlets, gate and close to non-essential traffic.
- Reduce or minimize hauling and grading during wet weather conditions.
- Grade only when and where needed and only when moist, not wet, after rainy season.
- Don’t disturb sections of the roadway that don’t need maintenance while repairing, blading or grading sections that do.
- Don’t blade, grade or drag in rain or freezing temperatures.
- Avoid work near streams during the rainy season.
- Don’t blade surface materials when they are dry (contributes to loss of fines and subsequent washboarding.)
- Don’t blade ditch spoils back onto the road surface, but dispose of them in a pre-determined area.
- Control dust in summer to conserve fines in the road surface. Place a layer of well-graded aggregate on the road and compact it at the proper moisture content. If the road has already been rocked, sometimes ripping and re-compacting will be sufficient to reduce dust problems. Sometimes, it is necessary to adjust the percentage of coarse to fine materials. If aggregates are not desired, organic lignins can be applied by spray to reduce dirt.

10.5 Evaluating Existing Trails

Existing trails can be evaluated to ascertain what impacts they may be having on water resources and wildlife habitats. Trails that affect the hydrology of water resources or chronically discharge stormwater or sediments to them are cause for concern. Following are several indicators to keep in mind when assessing the impacts of trails on wetlands, wet meadows and streams.

Trails that do not function properly may show some of the following characteristics:

- Deep trenching – trail is sunken because of poor drainage and berming of the outslope and sediment build up.
- Short cuts – many users take short cuts because they are the shortest distance between two points. These short cuts are referred to as social trails and can damage vegetation, habitat and water bodies. Often shortcuts are developed by users to avoid wet, muddy segments of trails.
- Impacts to natural resources such as trail runoff to meadows and wetlands and issues with culvert crossings.

Other characteristics of poorly functioning trails include widening of the trail, increase in tripping hazards because of exposed tree roots and steep trails or people avoiding these trails because of their danger. The main cause of poorly functioning trails is the movement of water, which can cause erosion and deep entrenchment. Other causes are poor initial trail design and placement, and inadequate maintenance.

A social trail leading to the stream is obliterated by placing big boulders at the end of the steep trail.

Social trails

Social trails can be obliterated by following the following steps:

- Cover the trail with duff, topsoil, plants, woody debris, grasses or small trees, where feasible.
- As a long-term strategy, thorny native shrubs should be planted because they are hard to navigate.
- Large boulders or large woody debris can be placed on the trail in areas that are steep or hard to revegetate.

Trails in wet meadow and wetlands

- A culvert that is set below grade in a meadow can cause incision of the meadow, increasing erosion and disturbing native plant and wildlife habitats there. Incision can dewater the wet area as groundwater levels adjust to the lowered drainage point at the culvert. This can lead to a change in species in the wet meadow or wetland. If culverts are set below grade, they should have stable drop inlets to prevent incision.
- When concentrated runoff from a trail is directed and into a meadow or wetland it can cause channelization, increase erosion and disturb hydrologic regimes needed to support native vegetation. Trail runoff should be diffused and trail ditches should have frequent turnouts and plugs to prevent channelization of trail run-off.
- Presence of trails can facilitate invasion of exotic species and upland plants into meadows, causing rapid ecosystem changes. Mowing, removal or spot treatment by appropriate chemicals may be needed to reduce invasions by exotic species especially along trail edges.

Signs of erosion caused by runoff from trails

- Erosion and raveling of cut and fill slopes
- High use of earthen trails results in sediments being delivered to water resource areas.

In the Western Cascades, research shows that trail drainage will not impact the water area if there is at least a 200-foot set back from a watercourse.

Refer to Chapter 5 for additional cautionary notes on culvert crossings of streams.

If chronic problems are identified, the trail system may be a candidate for reshaping, upgrading, storm proofing or decommissioning.

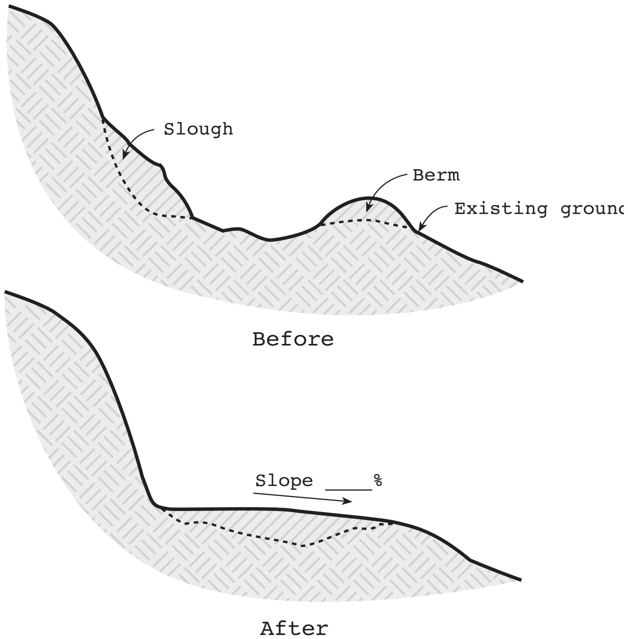


Figure 10-5 Restoring existing trails.

Reshaping the trail template

Earthen trails may begin to develop low spots in the center where use is concentrated, and the trail template may need to be re-shaped (see Figure 10-5). This may entail knocking down the outside edge of the trail with hand tools, spreading this soil across the trail and compacting it, or using equipment to re-grade and compact the trail. In problem situations, a more durable surface may need to be installed or more frequent drainage relief constructed. Sometimes a degrading trail segment may need to be retrofitted with stairs.

Upgrading. In this approach, engineered changes are made to the trail base, drainage template, or drainage features to reduce sediment generated from the trail. For example, a crushed aggregate surface may be applied to reduce erosion from runoff on the tread surface. Alternately, additional drainage features may be constructed on the trail.

Storm-proofing. Stream-crossing fills and pipes are removed and the exposed edges of the trail are laid back to a stable angle and vegetated or armored with rock. This treatment lowers the risk of the trail “blowing out” at the pipe. Storm-proofed trails should be inspected after major storms to make certain that conditions are still stable.

Decommissioning. Options range from blocking the problem trail or obliterating it and re-establishing the pre-trail topography and vegetation.

Conversion. An earthen trail that is too wide may become a chronic source of sediments, which can be problematic if the trail drains to a water resource. Such a trail may be made more stable by outsloping it, narrowing the tread surface and planting vegetation in the area that will not be used for the tread.

In this road to trail conversion a former forest road was ripped, reshaped and seeded. (Heavy Equipment Operator's Guide to Road Rehabilitation, Casaday and California Department of Parks)

10.6 Planning for Trail Upgrades

Successful upgrades of earthen trails start with understanding how sub-grade and base conditions can affect the trail. Problems often arise when concrete or asphalt are placed over earthen trails without proper sub-grade and base preparation. The surface may begin to deteriorate and cracks may appear because foundation support and a moisture barrier are missing. Similar problems can occur when gravel is placed directly on the surface of a boggy trail without the benefits of improved drainage or a moisture barrier. The gravel shortly migrates down into the muck and will need to be applied again.

If an upgrade from an earthen trail to a constructed surface trail is planned for the future, it will be necessary to make the appropriate upgrades to both the trail sub-grade and the base (see Figure 10-6). These actions are vital to assure a solid foundation for the trail and to preserve the trail surface from degradation due to settling or moisture. Upgrading a railroad bed to a gravel, asphalt or concrete trail also may require sub-grade and base treatments, particularly if there are poorly graded materials in the railroad grade and/or moisture conditions affecting the sub-grade or sub-base. As with many other things in life, investment of initial effort can save future labor and maintenance costs.

10.7 Using New Trail Alignments to Accomplish Natural Area Restoration

An exciting opportunity is presented when a new trail traverses an area that has a high potential for restoration. Such areas might have been tiled for agriculture, have infestations of non-native plants, contain hazardous materials or abandoned roads that affect wildlife habitat use, fish passage or ground- or surface-water hydrology. There might be an opportunity to convert an old road into a trail, re-establish a wetland or create a special habitat. Plan to take advantage of restoration opportunities that can be accomplished in conjunction with new trail

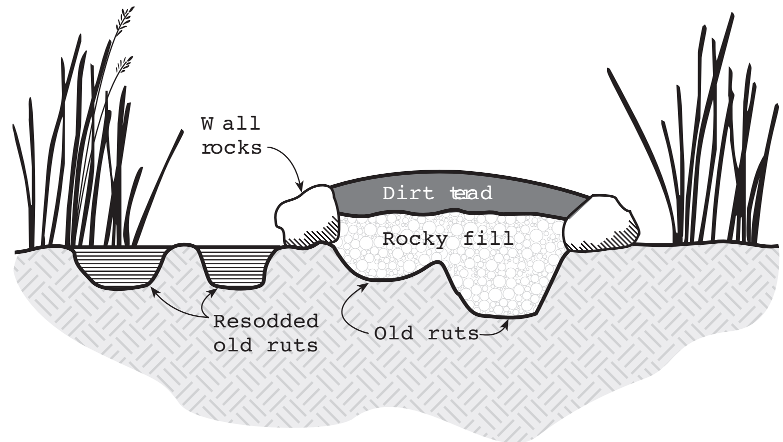


Figure 10-6 An old decomissioned roadway was converted to provide dry trail passage through a wet spot. (Hesselbarth, W. 2000. Trail Construction and Maintenance Notebook, USDA Forest Service)

development.

It will be worthwhile to explore several grant programs to help with restoration costs. These include Greenspace Program restoration grants from the U.S. Fish and Wildlife Service and Metro, funds from the Oregon Watershed Enhancement Board, and others. In Portland, trail proponents may be able to share costs with the Bureau of Environmental Services Watershed revegetation program.

10.8 Integrated Pest Management

In the mild, wet Pacific Northwest where plants seem to thrive unbidden, invasive vegetation control is a fact of life for trail managers. The amount of vegetation control that must take place along trails may not be evident to the young family taking a half-mile nature hike or to a cyclist riding the entire length of the Springwater Corridor. Yet mowing, weeding, hoeing, pruning, clearing and spraying vegetation along trail corridors can be major maintenance tasks in manicured parks as well as in primitive settings. These tasks keep tree branches from overhanging trails, blackberries and other vegetation from taking over trail rights of way, trees from becoming established where they shouldn't and exotic plants from spreading. Vegetation maintenance keeps bio-swales operating properly, provides sight distance at intersections and curves, allows for maneuvering of maintenance and emergency vehicles, and provides a measure of safety and security along trails.

Most natural area managers recognize that careful consideration should precede the selection of chemical methods, or herbicides, to control vegetation. This is because some herbicides have the potential to affect people and wildlife that come into contact with them in the trail corridor. Runoff carrying herbicides to streams and water resource areas can affect wetland and aquatic life as well. For these reasons, most herbicides are restricted for general use and can only be applied by trained and certified applicators. Any herbicide use near a stream that may affect listed fish may directly or indirectly trigger ESA regulations.

Park districts regularly provide their maintenance people with up-do-date education about handling herbicides. Yet, having a reliable method to determine when to use herbicides judiciously can be a bit of a challenge. This section summarizes the components of an integrated pest management program and strategies for developing such programs for trail systems.

Integrated Pest Management Defined (IPM). Integrated pest management is a sustainable approach to managing pests that combines biological, cultural, physical and chemical controls in ways that minimize economic, health and environmental risks. IPM is a least-risk approach that relies on information-gathering and informed decision-making to control pests. The U.S. Environmental Protection Agency promotes a graduated scale for making IPM decisions.[2]

Set action thresholds. Before taking any pest control action, set an action threshold, a point at which pest populations or environmental conditions indicate that pest control action must be taken. An understanding of the level at which pests will either become an economic or environmental threat is critical to set action thresholds.

Identify and monitor. Not all insects, weeds and other living organisms require control. Many organisms are innocuous; some are even beneficial. Pests should be identified so that appropriate control decisions can be made in conjunction with action thresholds. Monitoring can remove the possibility that pesticides will be used when they are not really needed.

Prevent. As a first line of pest control, find ways to manage an area to prevent pests from becoming a threat. This may mean using cultural methods, such as selecting pest-resistant varieties, and planting pest-free rootstock. These methods can be effective, cost-efficient and present little or no risk to people or the environment.

Control. Evaluate control methods for both effectiveness and risk. Choose effective, less risky pest controls first. These might include the use of highly targeted chemicals, such as pheromones to disrupt pest mating, or mechanical control, such as trapping or weeding. If further monitoring, identifications and action thresholds indicate that less risky controls are not working, then additional pest control methods can be used, such as targeted spraying of pesticides. Broadcast spraying of non-specific pesticides is a last resort.

Strategies for avoiding risky pest controls. The following strategies are used to avoid the need for chemical pest management:

Planning. A least-risk approach should be used during conceptual trail design when a new planting is being considered. Evaluate site conditions, site uses, vegetation management capabilities and goals, and the sensitivity of adjacent resources when selecting plants. The goal is to avoid disturbing intact habitats so non-native nuisance species are not favored, and to select vegetation that will thrive in the environment with the least care, and require little or no herbicides, pesticides or fertilizers. By the time design documents are being prepared, the future management program for the vegetation should already be known.

Use of native plants. Make sure to select plants that will do well in site-specific conditions of aspect, light, moisture, soil type and other conditions.

Improving soil conditions. Chances are that native plants will naturally re-establish themselves along narrow, new trails that traverse relatively undisturbed native habitats. This is because the soil seed bank is likely to be intact if the original topsoil is present and the soil microorganisms are relatively undisturbed. These conditions favor the reestablishment of the native flora.

However, when large-scale excavation has taken place and the resulting planting medium consists of low-organic, compacted sub-soil, more ruderal or "weedy" species are likely to flourish. These conditions also can favor exotic plants. Whenever possible, save and stockpile topsoil from earthwork and reapply over final grade. Improving soil conditions can enhance survival of native plants in trailside environments. This may involve ripping or tilling to loosen and aerate the soil, and addition of mulch to add organic materials, retain soil moisture and discourage weeds.

Occasionally, other soil amendments are needed. Landscape architects or horticulturists who specialize in native plants can have soils tested, interpret test results and specify soil treatments and amendments. Plants should not be selected that require regular amendments, particularly fertilizers.

Avoidance of actions that degrade soils. Trail alignments, dimensions and construction plans should be carefully selected and designed to avoid degrading trailside soils.

Use of existing disturbance corridors to site trails. This approach avoids attracting pests and unwanted plants to undisturbed sites by siting trails in pre-existing linear routes as discussed in Chapter 4 and other sections of this guidebook.

10.9 Strategies for Minimizing Risky Pest Controls

Restore native plants. Exotic plants or plantings that require regular applications of pesticides should not be considered for replacement, particularly if there are concerns about human exposure, sensitive habitats, or water resources. Care should be taken to select native species that will be able to shade out, or otherwise out-compete, invasive or exotic plants.

Rethink turf and turf mixes. Vegetation for corridors along multiple-use trails does not always need to be a dense, non-native grass. Heterogeneous, low-growing ground covers may provide many of the same benefits as turf in these settings. For example, a substitute seed mix for pure turf might include a native herbs and grasses and forbs that can do well in the site's soil and light conditions.

Consider alternatives to aggressive non-natives in stormwater swale and erosion control plantings. Exotic grasses can provide quick cover for erosion control plantings as well as dense stems and root masses for passive runoff treatment swales. However, some non-native grasses used for such purposes can spread quickly into wildlife habitats and become nuisances that require aggressive controls.

Many seed supply companies specializing in grasses can help formulate seed mixes that will be effective for erosion control treatments but not spread aggressively. It can be worthwhile to make a few calls and give the sales representatives a summary of site conditions and the desired performance of the future planting. Many companies specialize in native and local seed. There also is a sterile grass "regreen" that could be used as an interim erosion control measure.

Use a zoned approach to pest control. Some municipalities classify their park and greenspace landscapes according to the level of use and management they receive. For example, the Portland Parks uses the following classifications:[3]

- highly managed area
- intermediate managed area
- impacted natural area
- intact natural area.

Within these zones, the following conditions are distinguished:

- buffer zone for wetland, pond, lake or waterway
- wetland, pond, lake or waterway.

The city has developed pest management objectives and specific actions for each type of area in each of its parks and greenspaces. In addition, site-specific guidelines are provided for the use of pesticides and fertilizers in the buffer zones of waterways. These guidelines are based on levels of management and/or maintenance, and restoration goals or activities. Management practices within bodies of water, biofilters and wetlands also are specified. Finally, special exception areas (such as golf course streams and park turf behind seawalls) and their pest management needs and practices are identified.

Portland applies several integrated pest management practices to all areas. These include:

- use of low-pressure, low-volume, hand-held spraying, injection, daubing, painting and wiping equipment and drop-spreaders
- management of drift by means of nozzle size, pressure regulation, height of spray wand and restrictions to spray application in buffer areas when wind speed is greater than 5 mph or when wind direction would carry spray toward open water
- listing of all post-emergent and pre-emergent pesticides allowed in buffer zones, and all pesticides allowed in certain circumstances in aquatic sites
- formal review of policies each two years
- provision for collaboration with the National Marine Fisheries Service in the event of need for emergency application of actions not already approved
- strict adherence to state and federal record-keeping requirements and mixing, handling and disposal protocols
- rigorous training and licensing of grounds maintenance personnel who will apply pesticides.

Endnotes

[1] Adapted from Pitkin County, Colorado Open Space and Trails Program, Trails Design and Management Handbook. 2000, by Troy Scott Parker.

[2] Items in italics are summarized from the U.S. Environmental Protection Agency's web site, www.epa.gov/pesticides/citizens/ipm.htm, accessed on July 21, 2002.

[3] Summarized from www.portlandparks.org (accessed on April 26, 2002). NOAA Fisheries Division has approved the Integrated Pest Management Program developed by Portland Parks and Recreation. However, other jurisdictions are not covered by this program. A summary of the program is provided here.

Glossary

Angle of repose: The maximum angle of slope (measured from a horizontal plane) at which loose, cohesionless material will come to rest on a pile of similar material.

Armor: Rock placed in a ditch, catch basin or dissipation apron to protect it from erosion by concentrated flows of water. Typically, rock for armoring is sized to resist the greatest flows expected and is placed at a depth corresponding to twice the diameter of the average stone. Rock sizes typically are determined by an engineer or qualified designer. Also see "riprap."

Base course (base): This is the main load-spreading layer of the constructed trail and is normally constructed of crushed stone.

Bedload: Sediment that slides, rolls or bounces along the bottom of the streambed due to flowing water.

Best management practices (BMPs): Practical guidelines that can be used to reduce the environmental impacts of land uses or operations by means of careful planning, location, design, construction, management and maintenance.

Bog bridge: A pathway elevated above wet soils by means of planks or puncheons laid across wooden supports, such as logs, that are laid on the ground.

Catch basin, sediment catch basin: The excavated or constructed basin at the inlet of a culvert cross-drain pipe used to collect water and direct it into the culvert pipe. Catch basins or "sumps" also may serve to slow the velocity of moving water, thereby encouraging sediments to drop our of the flow before entering the pipe. Also see "drop inlet."

Causeway: A pathway elevated above wet soils by means of earthen fill placed between retainers, such as logs or large rocks that are countersunk or pinned to the ground. Crushed stone is frequently used as a top dressing to "cushion" the tread. The earthen fill is separated from the wet ground beneath it, either by over-excavating the wet soil and replacing it with base rock, and/or by means of geotextile fabric. Causeways typically include design details that provide ways for groundwater and surface water to pass at grade beneath or through the structure.

Concrete: A mixture of crushed stone or gravel, sand, cement and water that hardens as it dries.

Cross-drain: Installed or constructed structures such as culverts and tolling dips that move water from one side of the trail to the other.

Cross-section: A drawing depicting a section of the trail sliced across the width.

Cross-slope: The gradient of the hillslope as measured directly down the fall line.

Cut-and-fill: A method of trail construction in which the trail is built by cutting into the hillside and spreading and compacting the spoil materials in nearby low areas.

Ditch: A low point adjacent to the trail intended to collect runoff from the trail and adjacent land for transport to a suitable point of disposal.

Dividers: A simple drafting tool, somewhat like a compass, for marking off distance on a map or aerial photo.

Down-drain: An enclosed pipe that leads concentrated stormwater away from a slope before discharge to the ground. Down-drains protect slopes from erosion.

Drainage dissipation apron ("catch basin"): A catch basin is an area designed to receive and dissipate concentrated storm-water discharges. Typically, the basin is armored with rock and sized to encourage energy dissipation and sediment settling before discharge of stormwater to the ground.

Drain rock: This term usually refers to the class of rock used in leach fields. Typically, it is angular clean 2-inch to 4-inch rock. If alluvium (rounded rock, also known as wash rock) is used for drainage, some sources recommend that it be slightly larger and well graded. Problems may ensue if rounded rock is used in the trail base or subgrade or if trail retaining structures are constructed on top of rounded drain rock. A civil engineer or qualified design professional should specify rock, whether it is needed for drainage or support.

Drop inlet: A masonry or concrete basin, or a vertical riser on a metal culvert inlet, usually of the same diameter as the culvert, and often slotted, to allow water to flow into the culvert as water rises around the outside. Drop inlets are often used on ditch relief culverts where sediment or debris would plug the pipe. A drop inlet also helps control the elevation of the ditch.

Floodplain: A level low-lying area adjacent to streams that is periodically flooded by stream water. It includes lands at the same elevation as areas with evidence of moving water, such as active or inactive flood channels, recent fluvial soils, sediment on the ground surface or in tree bark, rafted debris and tree scarring.

Floodway: Narrowly interpreted, the floodway is the area near waterways where the Federal Emergency Management Agency has prepared detailed engineering studies to designate where the water is likely to be deepest and fastest. It is the area of the floodplain that should be reserved (kept free of obstructions) to allow floodwaters to move downstream. Placing fill or structures in a floodway may block the flow of water and increase flood heights. Depending on many variables, the floodway is typically the portion of the floodplain within a stream or river's present-day meander belt.

Focal species: A species whose habitat needs represent the range of needs for an entire group of wildlife that uses a specific habitat type. Focal species are numerous enough to be monitored and are at least moderately well studied.

Ford: An unimproved route across a stream usually selected for its wide, shallow character, and, usually, a cobble or firm rock bottom. Also see "low-water crossing."

Geotextile or filter fabric: Textile made from synthetic fibers, usually non-biodegradable, to form a blanket-like product. Geotextiles can be woven or non-woven and have varying degrees of porosity and strength. In trail construction, they are used as moisture barriers, for separation or reinforcement of soils, filtration and for drainage.

Grade, gradient: The slope of the trail along its alignment. The slope is expressed in a percent ratio, or the ratio of elevation change compared to the distance traveled (rise over run). Also see "sustained grade" and "pitch."

Inlet: The opening in a drainage structure of pipe where the water first enters the structure.

Inslope, insloped, insloping: A trail cross-section that is sloped 3 percent or more into the hillside. In-sloped trails drain to parallel ditches that collect water, which is periodically conveyed, sometimes in culvert pipes under the trail, to suitable discharge areas.

Inside/outside: Refers to the inside of the trail (typically the cutslope or back slope), or the outside of the trail (typically on the fill slope or down-slope side.

Lead-off ditches (turnouts): Excavations designed to divert water away from a trail or trail-side ditch in order to reduce the volume and velocity of trailside ditch water.

Level-spread, level-spreading, level-spreader: Level-spreading is a way of preventing concentrated flows and erosion by maintaining runoff as sheet flow and dispersing it, usually in dense groundcover, for filtration and infiltration.

Liquefaction: The sudden collapse and lateral spread of sediments due to loss of cohesion because of increased pressure of soil water during ground shaking during an earthquake.

Loess: In the Portland metropolitan area, loess soils consist predominately of silt, and were deposited by wind. They are common in uplands. Loess soils are generally highly erodible because they lack binding colloids.

Low-angle earth flow: Slow-motion ground movement that can occur in areas with little to no slope due to a combination of factors.

Low-water crossing: A low-water crossing is a constructed feature that creates a temporary stream crossing that is expected to wash out during high water. Also see "ford."

Mass wastage: The various means by which earth material moves downslope under the influence of gravity.

Outlet protection: Devices or material, such as a headwall or riprap, placed at the outlet of pipes or drainage structures to dissipate the energy of flowing water, reduce its flow velocity and prevent channel or bank scour.

Outslope: A slight cross-ways tilt of the trail tread (typically 3 to 5 percent) in the direction hillslope's fall line to facilitate efficient movement of runoff across the trail and off it.

Pitch: A short section of trail that is steeper than the maximum design grade.

Porous concrete: A concrete mix that is lean in fines, resulting in many small voids, through which water can pass.

Puncheon: A short, heavy piece of roughly dressed timber. Puncheon also refers to a level tread surface for a bridge or trail created by smoothing one face of a log.

Ravel: Constant surficial movement of loose or coarse material on a slope in poorly cemented material. Also, a process where the coarse material on a trail surface comes loose and separated from the trailbed because of lack of binder or poor gradation of material.

Retaining structure: A structure designed to resist the lateral displacement of soil.

Rill, rills, rilling: Rills indicate that sheetwash has begun to concentrate. When rilling is observed, significant erosion has already taken place. Erosion up to 1 inch deep is considered rilling. Gullies are considered to have developed when rills coalesce and erosion is deeper than 1 inch.

Right of way: Legally, it is an easement that grants the right to pass over the land of another. Also see "trail corridor."

Riprap: Well-graded, durable, large rock, ideally with fractured surfaces, sized to resist scour or movement by water and installed to prevent erosion of native soil material.

Rolled trail grade: On a climbing trail, a rolled trail grade is one that levels off periodically (depending on trail gradient, width and soils) to allow runoff to be routed off the trail, usually by means of a rolling dip (see next definition).

Rolling dip: Water running down the surface of an earthen trail almost always pulls a little sediment with it, no matter how perfectly spaced the trail's drainage features may be. The function of rolling dips is to catch the runoff and sediment and route them off the trail. The dip is a subtle "hump," usually in an outsloped earthen trail, that serves as a velocity stop for trail runoff and routes it off the trail. The frequency of rolling dips is based on trail width, gradient, surface type, soil erodibility and the proximity and sensitivity of trailside areas that will receive the runoff. A qualified professional should specify the frequency of rolling dips and the angle at which they are placed relative to the tread. Some general guidelines follow:

Rolling dips on earthen trails should be "transparent" to a bike wheel – that is, elongated so that riders roll smoothly through them – and the dips must be angled 45 degrees or so to the travel direction. They must fall at about 20 percent of slope so that they are self-cleaning, meaning that sediments moving in runoff from the trail will be transported off the trail in runoff from the dip. For longevity, particularly to withstand wear by mountain bikes, both the mound and the dip can be internally reinforced with rock and/or armored. General guidelines for spacing of rolling dips are given in the adjacent table.

Scale: Scale is the proportion that a map or aerial photograph bears to the ground it represents. This is usually stated as a ratio. The scale of 7.5-minute topographic map, for example, is 1:24,000, or one map inch represents 24,000 inches on the ground. To be more meaningful, ground inches can be converted to feet or miles. One inch on a 7.5-minute topographic map represents about 2,000 feet on the ground.

Trail grade	Coarse, rocky, gravelly materials	Gravelly sands, silty sandy gravels, coarse extrusive volcanics	Silty clays, clays, fine sandy silty clay, weathered volcanics	Friable silts, fine silts and sands, fine decomposed granitic soils
2%	300 feet	160 feet	136 feet	100 feet
4%	280 feet	145 feet	121 feet	85 feet
6%	250 feet	140 feet	113 feet	75 feet
8%	230 feet	135 feet	106 feet	70 feet
10%	200 feet	125 feet	97 feet	60 feet
12%	175 feet	115 feet	80 feet	50 feet

Recommended spacing of rolling dips or water bars on earthen trails in different materials. (Adapted with permission from the author from Geotechnical/Materials engineering Training Session, by Keller and Vandhurst, USDA Forest Service, Region V., 1982, 2002).

Sediment catch basin: A constructed basin designed to slow water velocity and trap sediment as it settles out of the water. Also see "catch basin."

Sensitive species: A species that is listed under the Endangered Species Act as threatened or endangered, candidate or proposed by the Oregon Department of Fish and Wildlife or is a species of concern for listing.

Shoulder: The surfaced or unsurfaced width of a trail next to the tread, or traveled way.

Stairs: A series of risers and treads used to ascend a slope where a trail on grade would be too steep. A common formula to determine ratios for outdoor stairways is 2R + T = 26 inches to 27 inches, where R = riser and T = tread. This ratio should be held constant for the entire stairway or set of stairs. Rounded stair edges and beveled risers are important for trip avoidance.

Subgrade: The surface of trailbed upon which the base course is constructed.

Sustained grade: A trail grade that is more or less consistent between two points.

Test gradient: A trial gradient that can be plotted between two points by referring to map scale and using dividers.

Trail corridor: The strip of land in which trails and other facilities such as roads and utility lines are built. This includes the tread itself, the shoulder or verge, and the cleared areas beside the trail.

Tread: The portion of the trail that is contacted by feet, wheels and hooves.

Turnpike: A structure that elevates the trail above wet ground on earth fill. Turnpikes can be distinguished from causeways in that ditches are constructed on one or both sides of the trail to provide localized drainage of groundwater. Because such drainage features have the potential to change the groundwater conditions in wetlands, they are no longer favored. Also see "causeway."

Underdrain: A buried trench, filled with coarse aggregate, coarse sand or gravel and typically placed in a ditch line along a trail, which acts to drain subsurface water from a wet area and discharge it in a safe and stable location. Underdrains may use a uniform size or rock, be wrapped in geotextile and have a perforated drain pipe in the bottom of the trench.

Waterbar: A feature placed in earthen trails, typically using mounded earth or countersunk stone or wood, whose purpose is to intercept runoff and route it off the trail. Care must be taken that such features do not pose barriers or safety hazards to users. Typically, waterbar materials are countersunk in the earth, sometimes with a geotextile to prevent undercutting, seepage or piping from undermining the waterbar's stability. Also see "rolling dip."

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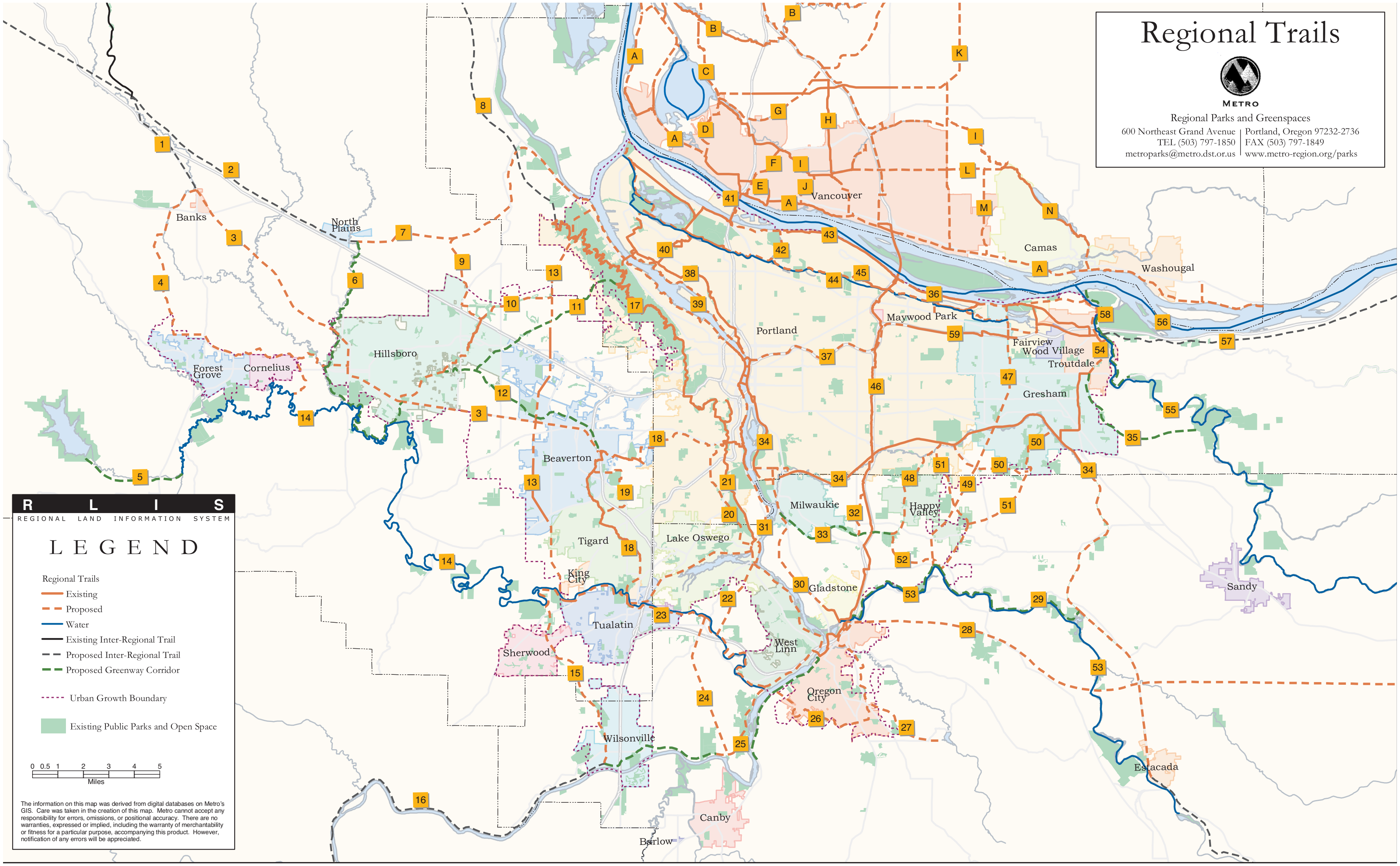
Appendix A – Regional Trails



Existing trails

Offering a glimpse of things to come, these regional trails are at least partially completed and open to the public (as of July 2003). They connect neighborhoods, schools, parks and jobs and provide access to nature and opportunities to hike, bike, walk, run and roll. For more information about these trails, visit the Metro web site at www.metro-region.org/parks and click on "regional trails and greenways."

10. ***Rock Creek Trail.*** From the Tualatin River, this trail parallels Rock Creek and heads northeast through Hillsboro, eventually connecting to the Beaverton Powerline Trail. Several segments are complete.

13. ***Beaverton Powerline Trail.*** An electric powerline corridor owned by PGE and BPA, this trail route runs from the Tualatin River near the Tualatin Wildlife Refuge north to Forest Park. Currently, some portions of the trail are complete, totaling more than 2 miles of the 16-mile trail.

17. ***Wildwood Trail.*** This soft-surface pedestrian trail runs the length of Forest Park south to Hoyt Arboretum and Washington Park. From the Vietnam Veterans Memorial near the Oregon Zoo, it continues south as the Marquam Trail to Council Crest Park, Marquam Nature Park and Terwilliger Boulevard. Forest Park's Leif Erikson Drive offers 11 miles of rugged all-weather bicycling.

18. ***Fanno Creek Greenway Trail.*** This trail begins at Willamette Park on the Willamette River Greenway, just south of downtown Portland. It stretches 15 miles to the west and south through Beaverton, Tigard and Durham, and ends at the Tualatin River in Tualatin. Approximately half of the trail is complete; additional sections are under construction.

21. ***Terwilliger Trail and Parkway.*** Running along Terwilliger Boulevard in Portland's southwest hills from Duniway Park to Oregon Health and Sciences University campus and George Himes Park, this trail heads south to Lake Oswego and ends at Highway 43 near the Willamette River Greenway.

34. ***Springwater Corridor.*** The metro area's premier multi-use regional trail. Currently, the improved portion of the Springwater is 17 miles long starting near OMSI and extending along the Willamette River and Oaks Bottom to the Sellwood Bridge. Most of the rest of the route parallels Johnson Creek east to the Clackamas County line in Boring.

38. ***Willamette Boulevard Bikeway.*** From the Peninsula Crossing Trail in North Portland, this bike trail heads south and east to North Killingsworth Street. The bike lanes are on the bluff above Mocks Bottom and the Willamette River.

40. ***Peninsula Crossing Trail.*** This 4-mile trail, completed in 2002, crosses the North Portland Peninsula between the Willamette and Columbia rivers. The pedestrian and bike path connects urban neighborhoods to schools, workplaces and natural areas such as Smith and Bybee Lakes Wildlife Area.

41. ***I-5 Bridge Trail Crossing.*** This trail across the Columbia River connects the regional trail system with Vancouver and Clark County trails.

43. ***Lewis and Clark Discovery Greenway Trail.*** Marking the historical path of Lewis and Clark along the Columbia River, a vision for the Lewis and Clark Discovery Greenway Trail originated in 1965. Current plans encompass several existing and proposed trail segments on both sides of the Columbia River. On the south side, this includes the Marine Drive and Columbia River levee sections of the 40-Mile Loop. (For more information about this trail, see the "Vancouver/Clark County" section.)

46. ***I-205 Corridor Trail.*** Adjacent to I-205, this multi-use trail is a major north-south connection between Clackamas, Multnomah and Clark counties. The trail links Oregon City, Gladstone, Portland and Vancouver.

54. ***Beaver Creek Canyon Trail.*** Located on the east side of Troutdale in Beaver Creek Canyon, this trail traverses Mt. Hood Community College. Some sections of the trail are incomplete. A greenway connecting from the trail to Oxbow Regional Park is envisioned.

59. ***I-84 Bikeway.*** This bikeway runs along I-84 from I-205 to Fairview.

Proposed trails

Trail planners and community advocates have proposed several future trail projects that are a conceptual part of the regional trails and greenways system. Before decisions are made about trail alignment and appropriate use, there will be a master planning process and many opportunities for public involvement. For more information about the status of these projects, visit the Metro web site at www.metro-region.org/parks and click on "regional trails and greenways."

3. ***Turf to Surf Rail with Trail.*** This trail will run from downtown Lake Oswego to the Oregon coast. Connections to the coast could be made via the Fanno Creek Greenway Trail, the Banks-Vernonia Trail and/or other railroad corridors and river valleys.

4. ***Council Creek Trail.*** This trail is planned from the end of the westside MAX light-rail line in Hillsboro west to Banks via Cornelius and Forest Grove, with an additional short trail extension south connecting to the Tualatin River.

7. ***Burlington Northern Rail to Trail.*** This corridor was originally envisioned to provide public access from Sauvie Island just north of the island bridge, over the Tualatin Mountains to the Tualatin Valley. At this time, a trail option is not likely, since freight train service is currently offered in the corridor.

9. ***Oregon Electric Trail.*** A southern spur of the Burlington Northern Rail with Trail, this trail will head south to Hillsboro just north of US 26.

15. ***Tonquin Trail.*** This trail will run south from the Tualatin River National Wildlife Refuge through Sherwood and Wilsonville to the Willamette River Greenway.

19. ***Washington Square Regional Center Trail.*** This trail will provide a loop around Washington Square on the east side of Highway 217 with connections to the Fanno Creek Greenway Trail.

20. ***Hillsdale to Lake Oswego Trail.*** A pedestrian-only trail will run from the Hillsdale town center in South-west Portland to downtown Lake Oswego traversing Tryon Creek State Park along the way. It also will provide a connection to the Willamette River Greenway Trail.

22. ***River to River Trail.*** This trail will connect the Willamette and Tualatin rivers via Wilson Creek and/or Pecan Creek. The trail will begin in Lake Oswego and end in Tualatin.

23. ***Lower Tualatin River Greenway Trail.*** This trail will run along the Tualatin River from its confluence with the Willamette River west to the Tualatin River National Wildlife Refuge.

24. ***Stafford Trail.*** This trail will cut though the Stafford Basin from the Tualatin River (near Stafford Road) south to the Willamette River.

25. ***Willamette Narrows Greenway Trail.*** Part of the Willamette River Greenway vision. This trail will run along the west side of the Willamette River from the mouth of the Tualatin (south of Willamette Park in West Linn) to land purchased by Metro near the Canby Ferry.

26. ***Oregon City Loop Trail.*** This trail will create a loop around the perimeter of Oregon City. It will cut through Newell Creek Canyon, connect to the Beaver Lake Trail and skirt the southern edge of the city on its way back to the Willamette River across from its confluence with the Tualatin River.

27. ***Beaver Lake Trail.*** Beginning at the End of the Oregon Trail Center in Oregon City, this trail will head south on the east side of Newell Creek Canyon and east to Beaver Lake.

28. ***Oregon Trail-Barlow Road.*** This trail will follow the pioneer wagon train route from the Cascades west to the End of the Oregon Trail Center in Oregon City.

30. ***Trolley Trail.*** This trail corridor follows a former streetcar line extending south from Milwaukie through Gladstone. Metro and North Clackamas Parks and Recreation District acquired the 6-mile trail corridor and are currently planning trail construction.

31. ***Willamette Shoreline Trolley Rail with Trail.*** Part of the Willamette River Greenway vision. This trail will run along a former streetcar line corridor from Willamette Park in Portland to downtown Lake Oswego between Highway 43 and the Willamette River. The planned use for this right of way is a future rail transit project. Where there is room for both, the trail is proposed as a "rails-with-trail" project.

Water trails

Trails in rivers and other waterways offer a unique view of the nature of the region. Developing water trails means providing access points for canoes, kayaks, boats and rafts. To find out more about the status of these efforts, visit the Metro web site at www.metro-region.org/parks and click on "regional trails and greenways."

14. ***Tualatin River Water Trail.*** This water trail has become very popular during the past several years thanks, in part, to the efforts of the Tualatin Riverkeepers. Several excellent launch sites are operated by local jurisdictions: Rood Bridge Park in Hillsboro, Cook Park in Tigard and Brown's Ferry Park in Tualatin. Open space properties acquired by Metro along the Tualatin River will serve as additional future access points. This water trail runs from the Tualatin's confluence with the Willamette River west toward Hagg Lake.

44. ***Columbia Slough Water Trail.*** A water trail running from the confluence with the Willamette River east to Fairview Lake. Points of interest along the water trail include Kelley Point Park, Smith and Bybee lakes and Whitaker Ponds. Addi-tional launch sites will be developed.

53. ***Clackamas River Trail.*** A water trail running from Estacada west to the confluence of the Clackamas and Willamette rivers.

55. ***Sandy River Gorge Water Trail.*** This will be a trail on the water connecting Oxbow Regional Park and Dabney State Park with the Sandy River delta on the Columbia River at Lewis and Clark State Park.

56. ***Lower Columbia River Water Trail.*** The Lower Columbia River Water Trail encompasses the 146 free-flowing river miles of the Columbia River from Bonneville Dam to the ocean.

Greenways

Greenways generally follow rivers and streams and may or may not provide for public access. In some cases, greenways may be a swath of protected habitat along a stream with no public access.
In other cases, greenways may allow for an environmentally compatible trail, viewpoint or canoe launch site. For more information about these greenways, visit the Metro web site at www.metro-region.org/parks and click on "regional trails and greenways."

5. *Hagg Lake Greenway.* Beginning in the foothills of the Coast Range at Hagg Lake, this greenway will head east along Scoggins Creek connecting to the Tualatin River.
6. *McKay Creek Greenway.* From the confluence with the Tualatin River, this greenway runs north through Hillsboro to the confluence with Dairy Creek and continues to North Plains.
11. *Bronson Creek Greenway.* From the confluence with Beaverton Creek, this greenway heads east and crosses the ridge of the Tualatin Mountains linking with the trail system in Forest Park.
12. *Beaverton Creek Greenway.* From the confluence of Beaverton and Bronson Creek, the Beaverton Creek Greenway connects with the Fanno Creek Greenway Trail at Highway 217 near Southwest Allen Boulevard.
29. *Clackamas River Greenway.* This greenway will provide limited public access on the north side of the Clackamas River from the Willamette River east to Barton Park.
33. *North Clackamas Greenway.* Beginning at the Milwaukie waterfront, this greenway will generally follow Kellogg Creek and Mt. Scott Creek east to the I-205 Trail and end at the Mt. Scott Trail.
35. *Beaver Creek Canyon Greenway.* This greenway will follow Beaver Creek Canyon east from where the trail ends in Troutdale, toward Oxbow Regional Park.
58. *Sandy River Gorge Greenway.* This greenway will follow the Sandy River from Dabney State Park to its confluence with the Columbia.

Vancouver/Clark County regional trails

A growing network of regional trails is taking shape on the north side of the Columbia River in Vancouver and Clark County, Wash.
For more information about the Vancouver/Clark County trail system, visit www.ci.vancouver.wa.us/parks-recreation.

A. *Lewis and Clark Discovery Greenway Trail.* A multi-use trail stretching 38 miles along the Columbia River from Ridgefield National Wildlife Refuge to Steigerwald National Wildlife Refuge. Approximately 12 miles of trails are complete on the Washington side, including trails from Ester Short Park to Wintler Community Park and between the Columbia Springs Environmental Education Center and the I-205 Bridge. (For information about trails on the south side of the Columbia, see the "Existing Trails" section.)

B. *Salmon Creek Greenway and Trail.* This trail runs along the south side of Salmon Creek and the Salmon Creek Greenway to Klineline Pond and Salmon Creek Park and will continue east along the creek toward Battle Ground. The western portion of the trail is complete.

C. *Lakeshore Trail.* Lakeshore Trail parallels the northeast side of Vancouver Lake on Lakeshore Drive connecting Burnt Bridge Creek Greenway Trail and Fruit Valley Trail to Salmon Creek Greenway and Trail.

D. *Fruit Valley Trail.* This trail will make up part of the Vancouver Lake Loop. Located in the east Vancouver Lake Lowlands, this trail will connect Burnt Bridge Creek to the Lewis and Clark Greenway Discovery Trail.

E. *Discovery Historic Loop Trail.* This well-traveled urban loop trail connects Fort Vancouver National Historic Reserve, Officers Row National Historic District, Columbia River Waterfront, old downtown Vancouver and the I-5 Bridge.

F. *St. John's Trail.* This bike path or trail will connect Burnt Bridge Creek Trail to Central Park.

G. *Lewis and Clark Rail with Trail.* Envisioned as a rail-with-trail project, this trail will begin on the east side of Vancouver Lake at Burnt Bridge Creek north and east across the county to Chelatchie Prairie.

H. *Lieser/Andresen Trail.* This trail makes up a major north/south connection through Vancouver. Beginning at 88th Street, the northern portion follows along Andresen Road to David Douglas Park where it jogs east to follow Lieser Road to Lieser Point and the Columbia River. Major sections along Andresen Road are complete.

I. ***Burnt Bridge Creek Greenway and Discovery Trail.*** Starting on the east side of Vancouver Lake and running east along Burnt Bridge Creek. The western portions of the greenway trail are completed.

J. ***Blanford Canyon Trail.*** This trail will connect Burnt Bridge Creek Greenway to Evergreen Boulevard.

K. ***164th Avenue Trail.*** A major north/south connection, this trail runs along 164th Avenue from the northern side of Vancouver to the Columbia River. Major portions of the trail are complete.

L. ***Bonneville Reach Discovery Trail.*** This trail will connect Burnt Bridge Creek to Lacamas Heritage Trail by way of the 18th Street powerline corridor.

M. ***Fisher Basin Trail.*** This trail will run from the Bonneville Reach Discovery Trail to the Columbia River.

N. ***Lacamas Heritage Trail.*** This mostly completed trail runs adjacent to Goodwin Road from Lacamas Creek to the Washougal Greenway.

Inter-regional trails

The proposed inter-regional trails will connect the Portland metropolitan region to other areas, such as the Columbia River Gorge, Mt. Hood National Forest, Pacific Coast and Willamette Valley.

1. ***Banks to Vernonia Trail.*** This multi-use trail connects Banks and Vernonia. Managed by the state of Oregon, the trail is open to all non-motorized uses – horse-back riding, biking, walking, etc.

2. ***Portland to the Coast Trail.*** A long-range vision for a trail connecting the Portland metropolitan area to the Pacific coast.

8. ***Pacific Greenway.*** A long-range vision for a greenway connecting the Portland metropolitan area to the ocean at Astoria.

16. ***Willamette River Greenway.*** Part of the Willamette River Greenway vision. This segment of the trail extends well beyond the Portland metro area south to Eugene.

57. ***Lower Columbia Gorge Trail.*** A trail through the Columbia River Gorge from the Sandy River will connect to other trails and recreation opportunities at state and national parks in the gorge.

Appendix B – Sources of Information for Trail Planning

Existing site uses

Sources of information

Neighborhood associations, schools, homeowner associations, youth groups and local walking groups often can provide information about:

- school bus stops and student walking routes
- walk-to-shop routes
- local bike routes
- local walking loops and destinations
- needs for connections and safe crossing sites.

Natural area management entities such as The Nature Conservancy, Port of Portland, municipal parks departments, U.S. Fish and Wildlife Service, Metro's Regional Parks and Greenspaces Department, watershed and friends-of-streams groups and others can provide information about:

- type and season of use
- popular trailheads (and trailhead problems)
- the needs and problems of existing trails.

Municipal public works departments, utility providers and departments of transportation can provide information about utility corridors and rights of way and easements. In some instances, the local community, including watershed groups, could provide information on right of way and local trail access needs.

Natural area plans

Sources of information

Many entities have special natural resource management areas, including:

- U.S. Forest Service
- Bureau of Land Management
- Oregon Parks and Recreation Department
- city, county and regional planning and park departments
- The Nature Conservancy preserves (for example, Camassia Preserve, the Diack Tract in the Sandy River Gorge, etc.)
- Columbia Gorge National Scenic Area
- Port of Portland
- U.S. Army Corps of Engineers
- universities and colleges (for example Reed College's old-growth study site on the Sandy River)
- corporate campuses (for example, Dawson Creek Parkway)

Regional and municipal trails

Sources of information

- Metro's Regional Parks and Greenspaces Department (see especially Metro's 2002 regional trail map)
- Metro's Planning Department and Data Resource Center
- city and county departments of parks, recreation, planning, and transportation
- chambers of commerce and visitor information centers
- Portland Office of Transportation
- Oregon Parks and Recreation Department
- Mt. Hood National Forest
- Bureau of Land Management
- Mazamas, SW Trails (explorepdx.com/swtrails.html), SW Neighborhood, Inc.
- outdoor recreation stores, including REI and Oregon Mountain Community
- map supply stores, including Powell's Travel Store, Oregon Blueprint and The Nature of Oregon.

Vegetation and wildlife habitat

Sources of data

- The Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service and NOAA Fisheries maintain information about state and federally listed species.
- The Bonneville Power Administration maintains a web site (nppc.bpa.gov) that has a searchable database on habitat for resident and anadromous fish species where users may generate maps.
- Federal land management agencies such as the U.S. Forest Service, Bureau of Land Management, USDA Natural Resources Conservation Service and others such as the Port of Portland maintain aerial photo archives for their lands.
- Many watershed councils maintain aerial photo files.
- The US Army Corps of Engineers maintains photo archives of the region's major waterways and adjacent lands.
- If the site includes privately owned forestland, aerial photos and/or habitat maps might be available through the Oregon Department of Forestry.
- Metro's Data Resource Center has maps, aerial photos and GIS data such as a high-resolution set of aerial photos for Multnomah, Clackamas and Washington counties.
- Metro's Planning Department has mapped the location of sensitive wildlife habitat in the region.
- Metro's Regional Parks and Greenspaces Department maintains a library of management plans for selected regional greenspaces, for which habitat mapping may have been done.
- Clean Water Services has a database of vegetation and wildlife habitat information as part of the agency's Watersheds 2000 program.
- The city of Portland has inventoried natural resource areas and published this information in detailed reports that describe the functional values of the resource sites.
- Aerial photos and habitat maps for special studies and natural area management plans may available through the planning departments of counties and cities.
- Colleges and universities may have databases of vegetation and/or habitat information associated with long-term or special studies in particular areas.
- The Student Watershed Research Project through the Oregon Graduate Institute's Saturday Academy program has developed vegetation and habitat maps for a number of sites throughout the region.
- Bergman's, Northern Light, Spencer Gross and WAC are private sources of aerial photography.
- The Oregon Natural Heritage Program maintains information about the locations of threatened, endangered or sensitive plants at oregonstate.edu/ornhic/ORNHP.html.
- Willamette Basin Habitat Conservation Priorities maintains information about declining habitat in the Willamette Basin at www.oregonwri.org.

Fish habitat

Sources of data

Many factors influence fish and their habitats. The following organizations maintain data bases on habitat elements for fish:

- NOAA Fisheries maintains information on fish listings, maps of critical habitats and other updates on fish issues. Go to www.nwr.noaa.gov for this information.
- The ODFW maintains a regional fisheries database in GIS that can be accessed at oregonstate.edu/dept/nrimp/information/index.htm.
- The Oregon Natural Heritage Program also maintains data bases on sensitive species. Visit oregonstate.edu/ornhic/ORNHP.html.
- ODFW undertakes fisheries surveys of various kinds for many of the cities and counties in the region, so data on fish presence, spawning, habitat and macroinvertebrates is often available through local municipalities.
- The Bonneville Power Administration maintains a searchable, scalable database on the presence of anadromous fish in the region, which is accurate down the sixth-field hy-

drologic unit code. Go to nppc.bpa.gov to review this data (further explanation under sources of data on hydrology and water resources).

- Clean Water Services has collected data on all the streams in its jurisdiction. Visit www.cleanwaterservices.org and follow links to the Healthy Streams Plan.
- Contact Metro's Planning Department for a list of culverts that are barriers to fish passage.
- Federal, state and some local departments of transportation have information about blockages to fish passage in their jurisdictions.
- The Student Watershed Research Project at Saturday Academy, Portland State University, has a network of member schools with sampling sites and years of data. Visit www.ogi.edu/satacad/. Also, the Northwest Region office of the Oregon Department of Environmental Quality may have prior years' data.
- Students in Mt. Hood Community College's Fisheries and Integrated Natural Resources Technology programs inventory various attributes of streams as part of the Watershed Research and Assessment Program. Visit summit-ecampus.org/watershed.
- Many watershed councils and friends of streams groups have commissioned studies of fish, instream habitats and stressors to them.
- The city of Portland and ODFW are cooperating in an ongoing study on how fish use the Willamette River in Portland. Data are available through the city of Portland's Endangered Species Program.
- Oregon Department of Environmental Quality (DEQ) maintains databases on macroinvertebrates in selected streams. The DEQ also has detailed information about selected stream segments that do not meet federal water quality standards. Also refer to the section in this chapter on hydrology and water resources.

Hydrology and water resources

Sources of data

- The U.S. Army Corps of Engineers maintains detailed mapped information about the location of the 100-year flood elevation for all major rivers and many major streams of the region. Floodplain maps also can be obtained from the Federal Emergency Management Agency at www.fema.gov.
- The U.S. Geologic Survey maintains watershed maps down to fifth-field hydrologic units, which are named using a hydrologic unit code, or HUC. The HUC identifies the basin, sub-basin, watershed and sub-watershed in which the drainage is located. Acreage for each hydrologic unit also is given, together with flow data, if available, and information about the presence of cold-water fish habitat in the system. This information is available online at the USGS web site at www.usgs.gov.
- The Oregon Department of Water Resources produces watershed maps down to the fifth-field hydrologic unit. For information about ordering, go to www.wrd.state.or.us.
- Metro has mapped watersheds (down to sixth field unit) and streams, wetlands and their associated riparian zones for the entire region. These can be accessed at www.metro-region.org/pssp.cfm?ProgServID=7.
- Clean Water Services has done extensive hydrologic and hydraulic modeling within its jurisdiction, and this data is available at www.cleanwaterservices.org.
- The Multnomah County Drainage District has hydrologic data for the Columbia Slough.
- Every few years, Bergman Photographic Services flies the Portland metropolitan region to produce a set of color infrared photos. These are especially helpful in distinguishing wetter areas from those that are better drained. Contact Bergman at www.mapps.org/capabilities/or.htm.
- The Port of Portland maintains extensive files on the type and location of wetlands at its holdings for air and sea terminals in the region.

- The U.S. Fish and Wildlife Service maintains mapped information about the presence and type of wetlands developed from high-altitude aerial photographs. This information is plotted on 7.5-minute U.S. Geologic Survey topographic maps. The maps can be ordered online through the Oregon Division of State Lands at statelands.dsl.state.or.us.
- More detailed information about wetlands is usually available at local planning departments, due to local studies undertaken to meet state requirements for local wetland planning.
- Stormwater system maps and specialized hydrologic studies also are available at city and county offices.
- The Oregon Department of Environmental Quality maintains a database of stream quality known as the 303(d) list. It is available at www.deq.state.or.us/wq.
- Stream gauge data is available from the Portland district office of the U.S. Geological Survey, and can be ordered at oregon.usgs.gov/pubs_dir/rptsinfo.html. Hard copies of Statistical Summaries of Streamflow in Oregon and Oregon Water Resources Data for the current water year can be picked up at the district's East Portland office at 10615 SE Cherry Blossom Drive.

Soils and geology

Sources of information

- The U.S. Geological Survey is a rich source of geologic studies and mapped geological information. Many documents can be downloaded at www.usgs.gov.
- The USDA Natural Resources Conservation Service has put its entire library of county soils surveys online at soils.usda.gov. Hard copies of county soils surveys can be obtained at the county offices of Soil and Water Conservation Districts.
- The USDA Forest Service has mapped the soils and geology of many watersheds and prepared special studies of selected sites.
- The Oregon Department of Geology and Mineral Industries has published earthquake and landslide hazard maps and other relevant geologic information of all types for the region. They can be purchased at the Nature of Oregon store in the Oregon State Building on Northeast Oregon Street, Portland.
- The Oregon Department of Transportation undertakes geologic studies for particular projects.
- The city of Portland has mapped potential landslide areas. This information is available on Portland's web site at www.portlandmaps.com.
- The Portland State University geology department maintains a library of geologic studies by students and professors.
- Maps designating natural hazard zones, steep slopes and floodplains are available in hard copy or electronically through county planning departments and Metro.
- Watershed councils are becoming repositories for this kind of data.
- Important information about soils and geology also can be interpreted from aerial photos and topographic maps.

Topography

Sources of information

- City and county planning departments have electronic databases of topographic information. The quarter-section maps maintained by many municipalities commonly show ground surface elevations at contour intervals of 1 to 10 feet.
- The U.S. Geological Service has 15-minute topographic maps at a scale of 2.6 inches to the mile. These can be ordered online at www.usgs.gov/.
- Metro's Data Resource Center also has topographic information for the region, which can be obtained as electronic files or printed maps.
- The Portland District of the U.S. Army Corps of Engineers

maintains flood hazard maps for the region.

- Municipal and state departments of transportation sometimes have topographic information for the surveyed rights of way of streets and highways.

Restoration

Sources of data

To identify restoration opportunities other than re-vegetation projects at the landscape scale requires data of the sort that many resource agencies may only be beginning to collect. However, some agencies have identified and prioritized restoration projects and they may administer federal, state or local laws specific to natural resource restoration.

Watershed councils increasingly are developing watershed plans and initiating studies to develop lists of potential restoration projects.

Metro has region-wide data about culverts that pose barriers to fish passage and wildlife crossing.

Clean Water Services' Watersheds 2000 stream inventory identifies sources that degrade streams.

Cities and counties with stormwater system licenses are required to identify non-point and point sources that degrade streams.

Oregon Department of Fish and Wildlife may have data about culverts that limit fish passage and about road segments with high mortality records for wildlife.

City, county and special recreation districts, parks and greenspaces managers may have identified restoration opportunities particularly in natural resource management plans.

Neighborhood, watershed and advocacy groups may have information about restoration opportunities in their areas.

U.S. Fish and Wildlife Service. The service manages several restoration grant programs, including the greenspaces program administered in partnership with Metro, and can provide technical assistance for restoration projects.

Oregon Watershed Enhancement Board has sponsored watershed improvement projects for many years and has developed a series of guidelines available in "The Watershed Toolbox."

Appendix C – Sensitive species list and riparian area widths

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]								
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
A	Cope's Giant Salamander	*Dicamptodon copei*	R	None	SU	G3/S2	2	XX	X		XX					
A	Columbia Torrent Salamander	*Rhyacotriton kezeri*	R	None	SC	G3/S3	2	XX			XX	X				
A	Cascade Torrent Salamander	*Rhyacotriton cascadae*	R	None	SV	G3/S3	2	XX			XX	X				
A	Clouded Salamander	*Aneides ferreus*	R	None	SU	G3/S3	3					X	X		X	X
A	Oregon Slender Salamander	*Batrachoseps wrighti*	R	SoC	SU	G4/S3	1	X			X	X				
A	Western Toad	*Bufo boreas*	R	None	SV	G4/S4	4	XX	XX	XX	XX	X	X	X	X	X
A	Tailed Frog	*Ascaphus truei*	R	SoC	SV	G4/S3	2	XX			XX	X				
A	Northern Red-legged Frog	*Rana aurora aurora*	R	SoC	SV/SU	G4T4/S3	2	XX	XX	XX	XX	XX	X	X	X	X
(A)	(Oregon Spotted Frog - extirpated)	*Rana pretiosa*	R	C	SC	G2G3/S2	1	(XX)	(XX)	(XX)	(XX)	(X)	(X)	(X)	(X)	
R	Painted Turtle	*Chrysemys picta*	R	None	SC	G5/S2	2	XX	XX	XX	X		X		X	X
R	Northwestern Pond Turtle	*Clemmys marmorata marmorata*	R	SoC	SC	G3T3/S2	1	XX	XX	XX	XX	X	X	X	X	X
R	Sharptail Snake	*Contia tenuis*	R	None	SV	G5/S3	4	X			X	X	X	X	X	X
B	Horned Grebe	*Podiceps auritus*	W / M	None	SP	G5/S2B, S5N	2	XX	XX	XX						
(B)	(California Condor - extirpated)	*(Gymnogyps californianus)*	R	LE	None	G1SX	1-ex	(X)			(X)			(X)		
B	Dusky Canada Goose	*Branta canadensis occidentalis*	W / M	None	None	G5T2T3/ S2N	4	XX	XX	XX	X				XX	
B	Aleutian Canada Goose (wintering)	*Branta canadensis leucopareia*	W / M	LT	LE	G5T3/S2N	1	XX	XX	XX	X				XX	
B	Harlequin Duck	*Histrionicus histrionicus*	W / M	SoC	SU	G4/S2B, S3N	2	XX	XX		XX					
B	Bufflehead	*Bucephala albeola*	W / M	None	SU	G5/S2B,S5N	4	XX	XX	XX	X					
B	Barrow's Goldeneye	*Bucephala islandica*	W / M	None	SU	G5/S3B,S3N	4	XX	XX	X						
B	White-tailed Kite (appears to be undergoing range expansion)	*Elanus leucurus*	W / M	None	None	G5/S1B, S3N	2	X			X	X		X	XX	
B	Bald Eagle[a]	*Haliaeetus leucocephalus*	S	LT[a]	LT	G4/S3B, S4N	2	XX	XX	X	X	X	X	X	X	X
B	Northern Goshawk	*Accipiter gentilis*	W / M	SoC	SC	G5/S3	2	X		X	X	X	X			
B	Merlin	*Falco columbarius*	W / M	None	None	G5/S1B	2	X	X	X	X	X		X	X	X
B	American Peregrine Falcon	*Falco peregrinus anatum*	N	None	LE	G4T3/S1B	2	X	X	X	X	X	X	X	X	X
(B)	(Mountain Quail - extirpated)	*Oreortyx pictus*	R / S	SoC	SU	G5/S4?	4	(X)			(X)	(X)	(X)		(X)	(X)
B	Band-tailed Pigeon	*Columba fasciata*	S	SoC	None	G5/S4	4	XX			XX	XX	XX		X	X
B	Northern Pygmy-owl	*Glaucidium gnoma*	R	None	SC	G5/S4?	4	X		X	X	XX	X		X	X
(B)	(Northern Spotted Owl - extirpated from Metro region)	*(Strix occidentalis caurina)*	(S)	LT	LT	G3T3S3	1					(XX)	(X)			
B	Common Nighthawk (nearly extirpated)	*Chordeiles minor*	N	None	SC	G5/S5	4	X	X	X	X	X	X	X	X	X
B	Lewis's Woodpecker (extirpated as breeding species)	*Melanerpes lewis*	W / M	SoC	SC	G5/S3B, S3N	4	X			X		XX	X	X	X
B	Acorn Woodpecker	*Melanerpes formicivorus*	R	SoC	None	G5/S3?	4						XX	X		X
B	Pileated Woodpecker	*Dryocopus pileatus*	R	None	SV	G5/S4?	4	X			X	X	X		X	X
(B)	(Yellow-billed Cuckoo; extirpated)	*Coccyzus americanus*	N	SoC	SC	G5/S1B	2	(XX)			(XX)					
B	Olive-sided Flycatcher	*Contopus cooperi (= borealis)*	N	SoC	SV	G5/S4	4	X			X	XX				
B	Willow Flycatcher (western OR race)	*Empidonax traillii brewsteri*	N	None	SV	G5TU/S1B	4	XX			XX	X	X		X	X
B	Streaked Horned Lark	*Eremophila alpestris strigata*	S	SoC	SC	G5T2/S2?	2							XX	X	X
B	Purple Martin	*Progne subis*	N	SoC	SC	G5/S3B	2	XX	XX	X	X	X	X	X		X
B	Western Bluebird	*Sialia mexicana*	S	None	SV	G5/S4B, S4N	4					X	XX	X	X	X
B	Yellow-breasted Chat	*Icteria virens*	N	SoC	SC	G5/S4?	4	XX			XX	X	X		X	
B	Oregon Vesper Sparrow	*Pooecetes gramineus affinis*	S / N	SoC	SC	G5T3/S2B, S2N	2							XX	XX	
B	Tricolored Blackbird	*Agelaius tricolor*	S	SoC	SP	G3/S2B	2	XX		XX		–	-		X	
B	Western Meadowlark (extirpated as breeding species)	*Sturnella neglecta*	W / M	None	SC	G5/S5	4	X		X				XX	XX	
M	Yuma Myotis	*Myotis yumanensis*	R / S	SoC	None	G5/S3	4	X	X	X	X	X	X	X	X	X
M	Long-legged Myotis	*Myotis volans*	R / S	SoC	SU	G5/S3	4	X	X	X	X	XX	X	X	X	X
M	Fringed Myotis	*Myotis thysanodes*	R / S	SoC	SV	G4G5/S2?	2	X	X	X	X	X	X		X	X
M	Long-eared Myotis	*Myotis evotis*	R / S	SoC	SU	G5/S3	4	X	X	X	X	X	X	X	X	X
M	Silver-haired Bat	*Lasionycteris noctivagans*	L	SoC	SU	G5/S4?	4	X	X	X	X	XX	X	X	X	X
M	Hoary Bat	*Lasiuris cinereus*	L	None	None	G5/S4?	4	X	X	X	X	X	X	X	X	X
M	Pacific Western Big-eared Bat	*Corynorhinus townsendii townsendii*	R / S	SoC	SC	G4T3T4/S2?	2	XX	XX	X	X	X	X	X	X	X
M	Western Gray Squirrel	*Sciurus griseus*	R	None	SU	G5/S4?	3					X	XX		X	X
M	Camas Pocket Gopher	*Thomomys bulbivorus*	R	SoC	None	G3G4/S3 S4	3							X	XX	X
M	White-footed Vole	*Arborimus (= Phemacomys) albipes*	R	SoC	SU	G3G4/S3	4	X			X	X				
M	Red Tree Vole	*Arborimus (= Phenacomys) longicaudus*	R	SoC	None	G3G4/S3S4	3	X			X	XX	XX			
(M)	(Grizzly Bear)	*(Ursus arctos)*	(R)	LT	None	G4/SX	2-ex	(X)			(X)	(X)		(X)		
(M)	(Columbian White-tailed Deer)	*(Odocoileus virginiana leucurus)*	(R)	LE	SV	G5T2QS2	1	(X)		(X)	(X)	(X)	(XX)	(X)	(X)	(X)

Sensitive Species List Key

*	Indicates species that are non-native (also known as alien or introduced) to the Metro region.
( )	Parentheses indicate a species that was historically present but was extirpated from the Metro region within approximately the last century.
1	Code (type of animal) **A** = Amphibians **B** = Birds **F** = Fish **M** = Mammals **R** = Reptiles
2	Migratory status (indicates trend for the majority of a given species in the Metro region) **A** = Anadromous (fish; lives in the ocean, spawns in fresh water) **C** = Catadromous (fish; lives in fresh water, spawns in the ocean) **M** = Migrates through area without stopping for long time periods **N** = Neotropical migratory species (birds; majority of individuals breeding in the Metro region migrate south of U.S./Mexico border for winter) **R** = Permanent resident (lives in the area year-round) **S** = Short-distance migrant (from elevational to regional migration, e.g., across several states) **W** = Winters in the Metro region
3	Federal status (based on current Endangered Species Act listings) **E** = Endangered. Endangered taxa are those that are in danger of becoming extinct within the foreseeable future throughout all or a significant portion of their range. **T** = Threatened. Threatened taxa are those likely to become endangered within the foreseeable future. **LE** = Listed endangered. Taxa listed by the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS) as Endangered under the Endangered Species Act (ESA), or by the Departments of Agriculture (ODA) and Fish and Wildlife (ODFW) of the state of Oregon under the Endangered Species Act of 1987 (OESA). **LT** = Listed threatened. Taxa listed by the USFWS, NMFS, ODA, or ODFW as Threatened. **PE** = Proposed endangered. Taxa proposed by the USFWS or NMFS to be listed as Endangered under the ESA or by ODFW or ODA under the OESA. **PT** = Proposed threatened. Taxa proposed by the USFWS or NMFS to be listed as Threatened under the ESA or by ODFW or ODA under the OESA. **C** = Candidate taxa for which NMFS or USFWS have sufficient information to support a proposal to list under the ESA, or that is a candidate for listing by the ODA under the OESA. **SoC** = Species of concern. Former C2 candidates that need additional information in order to propose as Threatened or Endangered under the ESA. These are species that USFWS is reviewing for consideration as Candidates for listing under the ESA.
4	State status (based on current Oregon Department of Fish and Wildlife "Oregon Sensitive Species List," 2001) **SC** (critical) = Species for which listing as threatened or endangered is pending; or those for which listing as threatened or endangered may be appropriate if immediate conservation actions are not taken. Also considered critical are some peripheral species that are at risk throughout their range, and some disjunct populations. **SV** (vulnerable) = Species for which listing as threatened or endangered is not believed to be imminent and can be avoided through continued or expanded use of adequate protective measures and monitoring. In some cases the population is sustainable, and protective measures are being implemented; in others, the population may be declining and improved protective measures are needed to maintain sustainable populations over time. **SP** (peripheral or naturally rare) = Peripheral species refer to those whose Oregon populations are on the edge of their range. Naturally rare species are those that had low population numbers historically in Oregon because of naturally limiting factors. Maintaining the status quo for the habitats and populations of these species is a minimum requirement. Disjunct populations of several species that occur in Oregon should not be confused with peripheral. **SU** (undetermined status): Animals in this category are species for which status is unclear. They may be susceptible to population decline of sufficient magnitude that they could qualify for endangered, threatened, critical or vulnerable status, but scientific study will be required before a judgement can be made.

5	ORNHP Rank (ABI – Natural Heritage Network Ranks): ORNHP participates in an international system for ranking rare, threatened and endangered species throughout the world. The system was developed by The Nature Conservancy and is maintained by The Association for Biodiversity Information (ABI) in cooperation with Heritage Programs or Conservation Data Centers (CDCs) in all 50 states, in four Canadian provinces, and in 13 Latin American countries. The ranking is a 1-5 scale, primarily based on the number of known occurrences, but also including threats, sensitivity, area occupied, and other biological factors. On Metro's species list the first ranking (rank/rank) is the Global Rank and begins with a "G". If the taxon has a trinomial (a subspecies, variety or recognized race), this is followed by a "T" rank indicator. A "Q" at the end of this ranking indicates the taxon has taxonomic questions. The second ranking (rank/rank) is the State Rank and begins with the letter "S". The ranks are summarized below. **1** = Critically imperiled because of extreme rarity or because it is somehow especially vulnerable to extinction or extirpation, typically with five or fewer occurrences. **2** = Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction (extirpation), typically with 6-20 occurrences. **3** = Rare, uncommon or threatened, but not immediately imperiled, typically with 21-100 occurrences. **4** = Not rare and apparently secure, but with cause for long-term concern, usually more than 100 occurrences. **5** = Demonstrably widespread, abundant and secure. **H** = Historical occurrence, formerly part of the native biota with the implied expectation that it may be rediscovered. **X** = Presumed extirpated or extinct. **U** = Unknown rank. **?** = Not yet ranked, or assigned rank is uncertain.
6	ORNHP List is based on Oregon Natural Heritage Program data. **List 1** contains taxa that are threatened with extinction or presumed to be extinct throughout their entire range. **List 2** contains taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon. These are often peripheral or disjunct species that are of concern when considering species diversity within Oregon's borders. They can be very significant when protecting the genetic diversity of a taxon. ORNHP regards extreme rarity as a significant threat and has included species that are very rare in Oregon on this list. **List 3** contains species for which more information is needed before status can be determined, but which may be threatened or endangered in Oregon or throughout their range. **List 4** contains taxa which are of conservation concern but are not currently threatened or endangered. This includes taxa that are very rare but are currently secure, as well as taxa that are declining in numbers or habitat but are still too common to be proposed as threatened or endangered. While these taxa currently may not need the same active management attention as threatened or endangered taxa, they do require continued monitoring.
7	Riparian association indicates use of any of the four water-based habitats. Single "X" in any habitat type (upland or water-associated) indicates general association; "XX" indicates close association, as per Johnson and O'Neil 2001.
8	Habitat types based on Johnson and O'Neil (2001). These habitats are described more fully within the text of the upland and riparian chapters. **WLCH** = Westside Lowlands Conifer-Hardwood Forest **WODF** = Westside Oak and Dry Douglas-fir Forest and Woodlands **WEGR** = Westside Grasslands **AGPA** = Agriculture, Pasture and Mixed Environs **URBN** = Urban and Mixed Environs **WATR** = Open Water - Lakes, Rivers, Streams **HWET** = Herbaceous Wetlands **RWET** = Westside Riparian-Wetlands

Range of functional riparian area widths for wildlife habitat

Terrestrial habitat			
	Function	**Reference**	**Recommended width *(each side of stream)***
Wildlife needs	Willow flycatcher nesting	Knutson and Naef 1997	123 feet
	Full complement of herpetofauna	Rudolph and Dickson 1990	>100 feet
	Belted kingfisher roosts	USFWS HEP Model	100-200 feet
	Smaller mammals	Allen 1983	214-297 feet
	Birds	Jones et al. 1988	246-656 feet
	Minimum distance needed to support area-sensitive neotropical migratory birds	Hodges and Krementz 1996	328 feet
	Western pond turtle nests	Knutson and Naef 1997	330 feet
	Pileated woodecker	Castelle et al. 1992	450 feet
	Bald eagle nest, roost, perch Nesting ducks, heron rookery and sandhill cranes	Castelle et al. 1992	600 feet
	Pileated woodpecker nesting	Small 1982	328 feet
	Mule deer fawning	Knutson and Naef 1997	600 feet
	Rufous-sided towhee breeding populations	Knutson and Naef 1997	656 feet
	General wildlife habitat	FEMAT 1993	100-300 feet
	General wildlife habitat	Todd 2000	100-325 feet
	General wildlife habitat	May 2000	328 feet

Acronyms

USFWS: U.S. Fish and Wildlife Service

FEMAT: Forest Ecosystem Management Assessment Team

Range of functional riparian area widths for fish habitat and water quality

Aquatic habitat			
Function		Reference	Functional width *(each side of stream)*
Temperature regulation and shade	Shade	FEMAT 1993	100 feet
	Shade	Castelle et al. 1994	50-100 feet
	Shade	Spence et al. 1996	98 feet
	Shade	May 2000	98 feet
	Shade	Osborne and Kovacic 1993	33-98 feet
	Shade/reduce solar radiation	Brosofske et al. 1997	250 feet
	Control temperature by shading	Johnson Ryba 1992	39-141 feet
Bank stabilization and sediment control	Bank stabilization	Spence et al. 1996	170 feet
	Sediment removal and erosion control	May 2000	98 feet
	Ephemeral streams	Clinnick et al. 1985	66 feet
	Bank stabilization	FEMAT 1993	1 SPTH
	Sediment control	Erman et al. 1977	100 feet
	Sediment control	Moring 1982	98 feet
	Sediment removal	Johnson and Ryba 1992	10 feet sand-400 feet clay
	High mass wasting area	Cederholm 1994	125 feet
Pollutant removal	Nitrogen	Wnger 1999	50-100 feet
	General pollutant removal	May 2000	98 feet
	Filter metals and nutrients	Castelle et al. 1994	100 feet
	Pesticides	Wenger 1999	>49 feet
	Nutrient removal	Johnson and Ryba 1992	33-141 feet
Large woody debris and organic litter	Large woody debris	Spence et al. 1996	1 SPTH
	Large woody debris	Wegner 1999	1 SPTH
	Large woody debris	May 2000	262 feet
	Large woody debris	McDade et al. 1990	150 feet
	Small woody debris	Pollock and Kennard 1998	100 feet
	Organic litterfall	FEMAT 1993	1 SPTH
	Organic litterfall	Erman et al. 1977	100 feet
	Organic litterfall	Spence et al. 1996	170 feet

Acronyms

USFWS: U.S. Fish and Wildlife Service

FEMAT: Forest Ecosystem Management Assessment Team

HEP: Habitat Evaluation Procedures

Appendix E – Trail Surface Materials Matrix*

Key		
Functionality	**Availability**	**Vandalism Susceptible**
B=Bicycle W=Wheelchair P=Pedestrian V=Emergency Vehicle S=In-line skate	H=High M=Moderate L=Low	G=Graffiti M=Moved C=Cutting D = Deformation A=Arson

Product	Description/ Installation Method	Durability	Maintenance Description	Permeable	Functionality	ADA	MTIP Fundable	Availability	Vandalism Susceptible	Cost Per SF	2'-12'-2' section cost*
High-use multi-use trails											
Nike Grind – Atlas Tracks (Familian Product)	Prepare subbase, place geotextile, 6" aggregate base, apply Nike grind atlas track rubberized surface over base.	8-10 years	Reapply binding agent every 5-6 years. Keep surface clean, dirt and sand wear surface down, Full replacement needed after 10 years	Yes	Pedestrian only. Avoid heavy loads including equestrians, bicyclists, and vehicles	Yes	No	L – locally based but few installers	C, A, G	$12.50	$3,198,000
Nike Grind – Field Turf	Prepare subbase, place geotextile, 6" aggregate base, apply field turf surface over base, similar to laying a carpet.	8-10 years	Sweep regularly; keep free of organic materials as they will rot the surface. Replace surface after 10 years	Yes	Pedestrians only, too soft for bikes and wheels	No	No	L	C, A, G	$11.75	$3,006,120
Nike Grind – Rebound Ace	Prepare subbase, place geotextile, 6" aggregate base, pour concrete or asphalt base, apply rebound Ace surface directly over hard surface.	8-12 years	Replace topcoat after 10 years	No	B, P, W, S, but not tested, intended application is sport surfaces	Yes	Yes	L	C, A, G	$10.50	$2,686,320
Permeable Concrete	Prepared subbase, place geotextile, 12" depth aggregate base, Portland cement, coarse aggregate, water, 5" depth section	15 years	Vacuum sweep and pressure wash 4 times a year	Yes	B, P, W, V	Yes	Yes	M	G	$6.00	$1,535,040

** From the Trolley Trail Master Plan, Metro, 2004*

Product	Description/ Installation Method	Durability	Maintenance Description	Permeable	Functionality	ADA	MTIP Fundable	Availability	Vandalism Susceptible	Cost Per SF	2'-12'-2' section cost*
Concrete	Prepared subbase, place geotextile, 6" agg. base, Portland cement, aggregate, sand, water 4" depth section	25 years	Periodic inspection for uplift and settlement, repair as needed	No	B, P, S, W, V	Yes	Yes	H	G	$4.75	$1,215,240
Permeable Asphalt	Prepared subbase, place geotextile, 12" depth aggregate base, emulsion and coarse aggregate 2" depth section	8 years	Vacuum sweep and pressure wash 4 times a year, patch any pot holes as needed	Yes	B, P, S, W, V	Yes	Yes	M	G	$3.50	$895,440
Glassphalt	Prepared subbase, place geotextile, 6" agg. base, asphalt with aggregate/glass, 2" depth section	7-10 years	Pothole patching	No	B, P, S, W, V	Yes	Yes	M	G	$2.75	$703,560
Reground Asphalt	Prepared subbase, place geotextile 6" aggregate base, emulsion recycled asphalt chips 2" depth section	7-10 years	Pothole patching	No	B, P, S, W, V	Yes	Yes	M	G	$2.75	$703,560
Asphalt	Prepared subbase, place geotextile, 6" aggregate base, emulsion, aggregate	10 years	Pothole patching	No	B, P, S, W, V	Yes	Yes	H	G	$2.75	**$703,560**
Poly Pave	Prepared subbase, place geotextile, 6" aggregate base, grade and shape, mix poly pave in top 2" of base, spray on two top coats of poly pave 2" depth section	5-10 years	Reapply Poly pave solidifier every 1-2 years depending on level of use. Make spot repairs as needed.	No	B, P, W, S, V	Yes	Unknown	L	G	$2.50	$639,600

Product	Description/ Installation Method	Durability	Maintenance Description	Permeable	Functionality	ADA	MTIP Fundable	Availability	Vandalism Susceptible	Cost Per SF	2'-12'-2' section cost*
Chip Seal	Prepared subbase, place geotextile, 6" aggregate base, emulsion, ½" – ¼" aggregate, two coat process	7-10 years	Pothole patching	No	B, P, W, V	Yes	Yes	M	G	$2.00	$511,680
Low-use trails											
Nike Grind – tlas Tracks (Familian Product)	Prepare subbase, place geotextile, 6" aggregate base, apply Nike grind atlas track rubberized surface over base.	8-10 years	Reapply binding agent every 5-6 years. Keep surface clean, dirt and sand wear surface down. Full replacement needed after 10 years	Yes	Pedestrian only. Avoid heavy loads including equestrians, bicyclists, and vehicles	Yes	Not as primary trail, ok as shoulder	L – locally based but few installers	C, A, G	$12.50	$1,200,600
Nike Grind – Field Turf	Prepare subbase, place geotextile, 6" aggregate base, apply field turf surface over base, similar to laying a carpet.	8-10 years	Sweep regularly; keep free of organic materials as they will rot the surface. Replace surface after 10 years	Yes	Pedestrians only, too soft for bikes and wheels	No	Not as primary trail, ok as shoulder	L	C, A, G	$11.75	$1,128,564
Nike Grind – Rebound Ace	Prepare subbase, place geotextile, 6" aggregate base, pour concrete or asphalt base, apply rebound Ace surface directly over hard surface.	8-12 years	Replace topcoat after 10 years	No	B, P, W, S, but not tested, intended application is sport surfaces	Yes	Yes	L	C, A, G	$10.50	$1,008,504
Pavers with Fines	Prepare subbase, place geotextile, 6" aggregate base, place plastic pavers over base, fill cells with 3/16" minus crushed rock.	15 years	Keep weeded, refill cells with gravel as needed	Yes	B, P, W, S, E, V	Yes	Yes	M	M	$4.50	$432,216
Wood Planner Shavings	Prepare subbase, place geotextile, 4" aggregate base, place 3" layer of wood planners shavings, add additional 3" layer after initial compaction	2-3 years	Add 2"-3" of new material annually	Yes	P, E	No	Not as primary trail, ok as shoulder	H	M, D, A	$2.60	$249,725

Product	Description/ Installation Method	Durability	Maintenance Description	Permeable	Functionality	ADA	MTIP Fundable	Availability	Vandalism Susceptible	Cost Per SF	2'-12'-2' section cost*
Crusher Fines/Gravel	Prepare subbase, place geotextile, 6" aggregate base, place 2" depth ½" minus over base, roll and compact	2-5 years, depending on maintenance	Sweep to fill voids from dislodged fines	Yes	P, B, V	No	Not as primary trail, ok as shoulder	H	M, D	$2.50	$240,120
Filbert Shells	Prepare subbase, place geotextile fabric, 4" aggregate base, then 3" layer of filbert shells	7-10 years	Keep shells in place by regular raking. Re-top every 5 years	Yes	P, E	No	Not as primary trail, ok as shoulder	M	M	$2.25	$216,108
Wood Mulch	Prepare subbase, place geotextile, 4" aggregate base, place 3" layer of wood mulch, rake and shape, apply second 3" layer after initial compaction and settlement	1-3 years	Top dress annually	Yes	P, E	No	Not as primary trail, ok as shoulder	H	M, D, A	$2.10	$201,700

*The cost for all hard surface options includes using 2' wide shoulders of ¾" minus gravel for a 6 mile trail..
* 6' width is used as an example and cost estimating purposes only. Other widths can be considered.

Appendix F – Notes and best practices for the use of treated wood products

Wood that will be used outdoors is frequently treated to withstand rot. Treated wood should not be used anywhere near aquatic environments. Two distinct wood treatment types are distinguished: oil-based and water-based. Each has many different processing methods. For the various combinations of treatment type and processing method, different environmental safety measures are used. These measures, or best management practices (BMPs), are intended to minimize leaching of treatment chemicals into the environment and to protect the health of the people who handle the treated products.

The treated wood products industry identifies sets of BMPs for each stage of manufacture of treated wood products and for ordering, receiving, storing and handling these materials. It is up to trail planners to specify the product and for trail construction managers to receive, inspect or reject, properly store the products and educate workers about safe ways to handle the products and construction waste. Some municipalities have discontinued the use of treated wood and are replacing it where it already exists. Some general BMPs for treated wood follow:

Design. Treated or untreated wood will last longer if it is not exposed to the ground and is allowed to dry out as the weather changes. Wood structures should be designed with this in mind.

Ordering. Before ordering, complete a site specific risk assessment to determine if and how well the water body flushes.

When ordering:

- Note whether the water flushes all the time, or with the tides, seasons or not at all.
- Specify the performance needed and note whether the product will be used in a wetland, in the water, over the water or in a splash zone.
- Note whether children will play on or around the treated wood.
- Don't ask for a rush order, as proper time for curing is essential for some processes and treatment types.
- Don't ask for over-treatment or re-treatment by the factory.
- Specify that no surface residues should be present.
- Ask for written documentation that treatments have been applied in accordance with the current standards of the Western Wood Processing Institute and Canadian Institute of Treated Wood.

Receiving. When the material arrives, the documentation should include a list of the best management practices used in manufacture and curing and a quality assurance identification mark that indicates third-party inspection. No surface residues should be visible and the lumber should not have an oily sheen.

Storage. Products should be stored on pallets or widely spaced 2 by 4s above ground in dry areas and covered. Some products need to be stacked so that there is ventilation under and between each piece.

Construction. Many managers rely on off-site construction of trail facilities made of treated wood products to lessen risks of worker and environmental exposure. Workers need to be trained in methods for handling specific products, including construction post-treatment and conditioning of sawn surfaces, bolt holes and the like. Working facilities need to be kept clean and wood dust and shavings collected and properly disposed.

Materials should be staged in small quantities for installation in the field. Fabrication that must be done in the field should take place over tarps so that sawdust and shavings can be collected. Outdoor work should cease in windy or wet weather. Field treatment of cuts and bore holes should be minimized. Field-applied chemical treatments should not be done over water. Disposable absorbent materials should be used to catch drips and to wipe excess chemicals from treated surfaces. These should be removed from the site and properly disposed. Field application of water repellants and stains is not recommended.