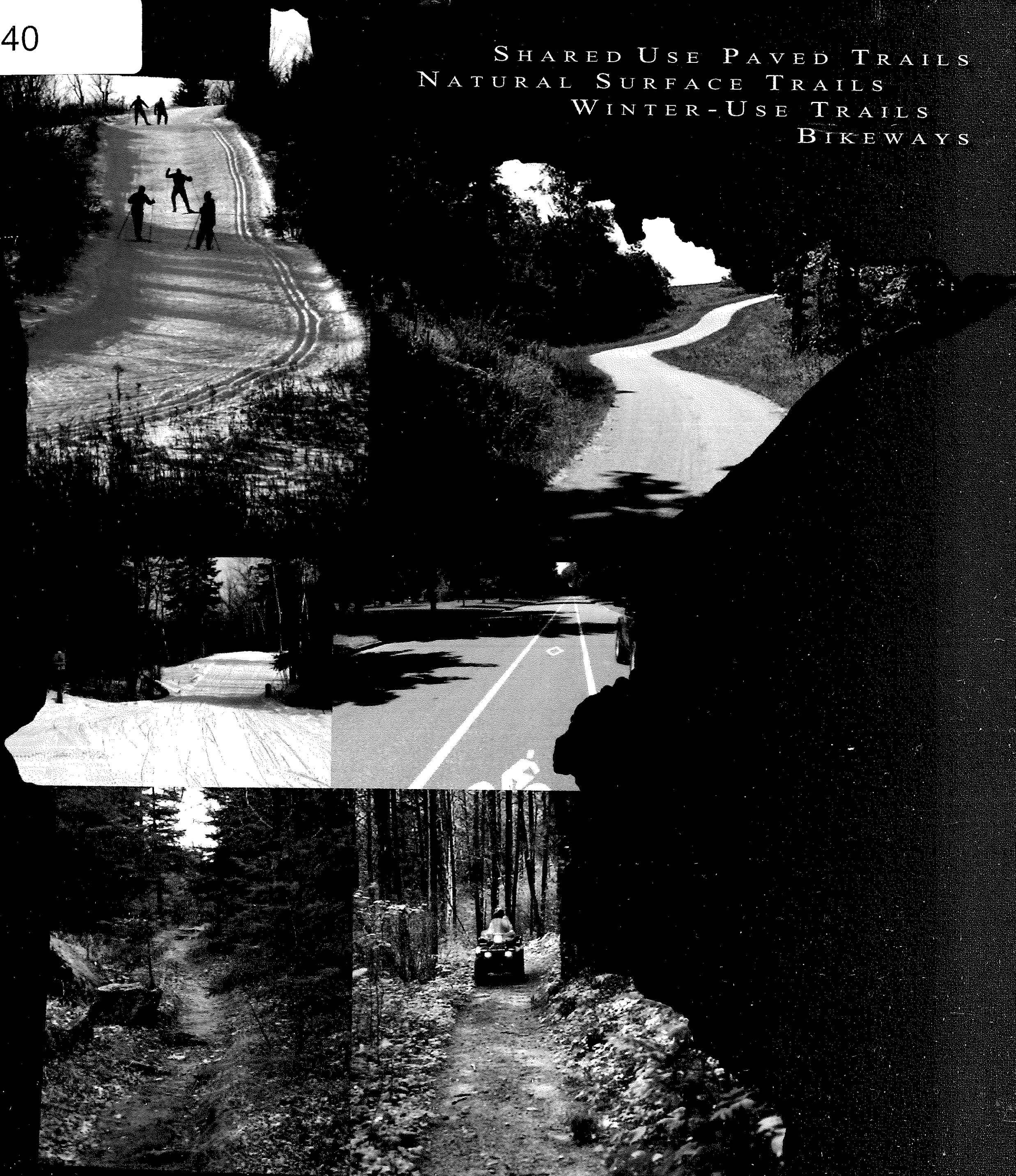
Trail Planning, Design, and Development Guidelines

Shared Use Paved Trails
Natural Surface Trails
Winter-Use Trails
Bikeways



Minnesota Department of Natural Resources
Trails and Waterways

Minnesota DEPARTMENT OF NATURAL RESOURCES

TRAIL PLANNING, DESIGN, AND DEVELOPMENT GUIDELINES

Minnesota Department of Natural Resources (DNR) – Trails & Waterways Division

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Introduction/ Acknowledgments

INTRODUCTION

The trail planning, design, and development guidelines presented in this manual are the result of multiyear effort by the Minnesota Department of Natural Resources (DNR). The goal of the project was to develop a consistent set of guidelines and common language for developing motorized and nonmotorized trails at the local, county, regional, and state level. The guidelines take into consideration and build upon past practices common to Minnesota.

The guidelines also attempt to fill in some of the gaps in best practices and techniques. For example, extensive attention is given to developing trails that are physically, ecologically, and economically sustainable. A comprehensive trail classification system was also developed to enhance consistency among agencies and trail advocates in how different types of trails are described and planned. The principles of trail design put increased emphasis on the art of design in order to make trails more visually appealing and enjoyable.

The technical guidelines for various types of trails have been extensively researched and, at times, significantly expanded to create a more complete reference for the detailed design of trails that will be physically, ecologically, and economically sustainable for decades to come. Collectively, the guidelines provide a comprehensive reference for agencies, trail advocates, and policy makers as they embark on various types of trail development projects.

The limitation of the guidelines lies in the fact that each trail situation is unique and requires site-specific evaluation to determine the most appropriate design approach. In some cases, refinements or adjustments to the guidelines will be warranted to ensure that the health, safety, and welfare of the public is not compromised. Whereas the manual is an important reference, it is not a substitute for the in-the-field expertise required to make informed decisions about the design and development of a specific trail.

ACKNOWLEDGMENTS

The preparation of a manual this comprehensive inherently involves extensive research on past practices and synthesizing the best working knowledge from practitioners. The importance of the many individual contributions to the manual cannot be overstated. In many ways, the project was as much about organizing information from many sources as it was about creating new approaches and practices. To the many individuals and agencies who contributed in large and small ways, a heartfelt thank you is extended.

A heartfelt thank you is also extended to the advisory team and professional staff at DNR for the many contributions they made to the manual. Their willingness to discuss trail development practices, provide information, and suggest sources greatly enhanced the end product. The peer review at various points in the process conducted by DNR staff and practitioners from across the U.S. and Canada also greatly added to and improved the end product.

A special thank you is extended to Brian McCann, DNR recreation planner and project coordinator, who spent years shepherding the project forward to its eventual conclusion. His working knowledge of trails and patience on all matters reassured the writing team that quality and completeness was as valuable as expedience, which is reflected in the quality of the end product.

The initial contributions of Troy Scott Parker to the manual also need to be acknowledged. His working experience and overall knowledge of natural-surfaced trail design proved to be of particular value, as were his photographic contributions and accompanying graphics. The indirect contributions of Mel Baughman are acknowledged as well, especially his past writings on recreational trail design and construction that was the industry standard for many years. Although not directly included in the manual, Angela Anderson's *Guidelines for Managing and Restoring Natural Plant Communities Along Trails and Waterways* was an important reference on numerous occasions and is an important complement to these guidelines.

In addition to those provided by the DNR and Brauer & Associates, Ltd., photographic contributions from Mel Baughman, Dale Gundberg, Troy Scott Parker, Tim Wegner, and Kathy Schoenbauer also greatly enhanced the manual.

The editing of Mary King Hoff was greatly appreciated and made the manual more concise, well organized, and consistent. Teresa A. Hudoba's work on indexing the manual also added much value by making it easier to find information on specific subjects.

On a personal note, Brauer & Associates, Ltd. extends a thank you to DNR for the opportunity to work on a project of this magnitude and prepare a manual that we hope will be a valued resource for years to come.

Sincerely,

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SECTION I

Framework for Planning Sustainable Trails

OVERVIEW

This section provides a foundation for trail planning and design. It considers:

- Common goals associated with trail development
- Key planning and design concepts
- Key factors in developing sustainable trails
- Regulatory framework and grant program considerations
- Publications that complement the guidelines
- Trail planning relative to broader comprehensive/ resource management plans
- Trail project planning guidelines

COMMON GOAL – A SUSTAINABLE TRAIL FUTURE


Minnesota's parks and public lands offer many miles of enjoyable trails serving many needs within the context of long-term sustainability.

At the core of all trail planning is satisfying a trail user's desires for a specific type of trail experience. Whether for recreation, fitness, commuting, or utilitarian purposes, most trail users seek a fulfilling outdoor experience that does not unduly harm the environment. Most trail users also appreciate that access to trails is a privilege and that each has a responsibility to preserve that access through proper use.

The primary goal of this publication is to provide a set of practical guidelines for planning and designing sustainable trails that will meet the needs of Minnesotans for generations to come. Other specific goals include:

- Promoting statewide consistency in how trails are classified, planned, and designed
- Promoting best practices to help ensure that all trail experiences are enjoyable, safe, and sustainable, with minimal impacts to Minnesota's natural resources
- Promoting a high level of access to trails serving the many needs and physical capabilities of trail visitors
- Reducing costs through the use of practical, time-tested methods for developing and maintaining trails

KEY TRAIL PLANNING AND DESIGN CONCEPTS

A number of key concepts underpin the trail planning and design guidelines.

USING A COMMON LANGUAGE

The guidelines establish a common language to foster consistency in classifying and developing trails across Minnesota.

SUSTAINABILITY FRAMEWORK

The guidelines emphasize the development of physically and ecologically sustainable trails that will serve the needs of users for generations to come while preserving the sense of place and protecting the surrounding environment.

TRAILS MUST BE PLANNED TO ENGENDER STEWARDSHIP

Instilling a sense of ownership and responsibility with the public for stewardship of trails is a key ingredient of creating sustainable trails.

ALL TRAILS HAVE AN IMPACT

The placement of any trail on the landscape has an ecological impact. The challenge is to keep those impacts to a minimum while providing the desired trail experience. All trails should be conceived as low-impact recreational experiences with a built footprint only as needed.

ALL TRAILS CHANGE OVER TIME

Trail use promotes change. Trails must be designed in anticipation of changes to ensure that they remain relatively stable with appropriate maintenance and management. This is especially the case with natural trails.

TRAILS SUPPORT A WIDE VARIETY OF VISITOR CONTEXTS

All trails must be developed and managed for a desired set of specific visitor values and experiences deemed suitable for the site. These guidelines support a wide variety of trail and visitor experiences.

SUCCESSFUL TRAILS ARE A SEQUENCE OF EVENTS

Trails offering a rich and continuous experience do not just happen. They are the result of thoughtful consideration of the site's physical and scenic qualities and conscientiously using them to create a sequence of events that add interest, offer challenges, and exhibit scenic values that contribute to the trail experience.

Successful trails are designed at a detailed, intimate scale offering moment-to-moment experiences that bring visitors back again and again. The more a trail responds to the nuances of the site, the higher its value to the user. Even in cases where existing roads and rights-of-way are used for trail corridors, creating a sense of place and trail context are essential design objectives.

GUIDELINES ARE SPECIFIC TO MINNESOTA

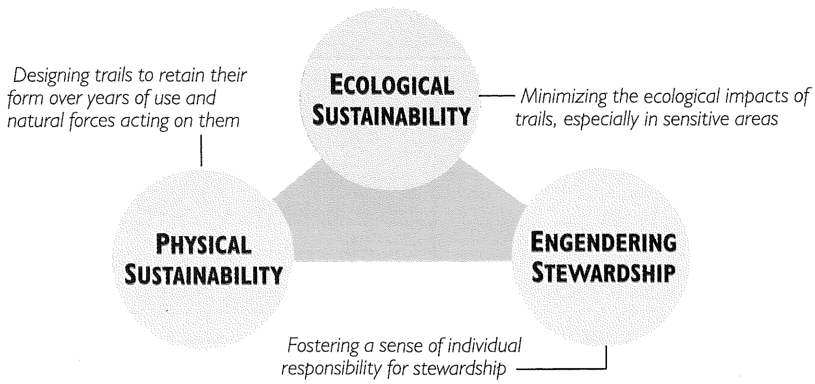
The guidelines are based on the unique circumstances of Minnesota and may or may not be appropriate elsewhere.

KEY FACTORS FOR DEVELOPING SUSTAINABLE TRAILS

Three key factors are common to all sustainable trails, as illustrated in the following diagram.

Economic Sustainability

An important consideration in developing trails is ensuring that the implementing agency or trail advocacy group has the capacity to economically support it over its life cycle. Lacking this commitment, the prospects of maintaining a sustainable trail become suspect and the validity of developing the trail in the first place becomes questionable. Developing a long-term maintenance strategy is a critical aspect of initial trail planning and fundamental to a successful trail program.



For a trail to be sustainable, each of these factors must be considered in its planning, design, and development. The factors are also complementary, whereby trails that are the most physically sustainable also tend to be the most ecologically sustainable and appealing to use. This, in turn, encourages trail users to use trails appropriately and take personal responsibility for stewardship to ensure continued access for generations to come. This basic concept is fundamental to all trail development projects. The following provides additional context to each of these factors.

PHYSICAL SUSTAINABILITY

Designing trails to retain their physical form over years of use and natural forces acting on them is a major theme of these guidelines. The specific guidelines defined in this manual related to a trail's classification, general and technical design, and stewardship are all focused on developing trails that are physically sustainable.

ECOLOGICAL SUSTAINABILITY

Minimizing the ecological impacts of trails, especially in sensitive areas, is also a major theme of these guidelines. Section 3 – Principles of Ecological Sustainability provides the essential underpinning for developing trails that are enjoyable to use without diminishing the environment and sense of place in the process.

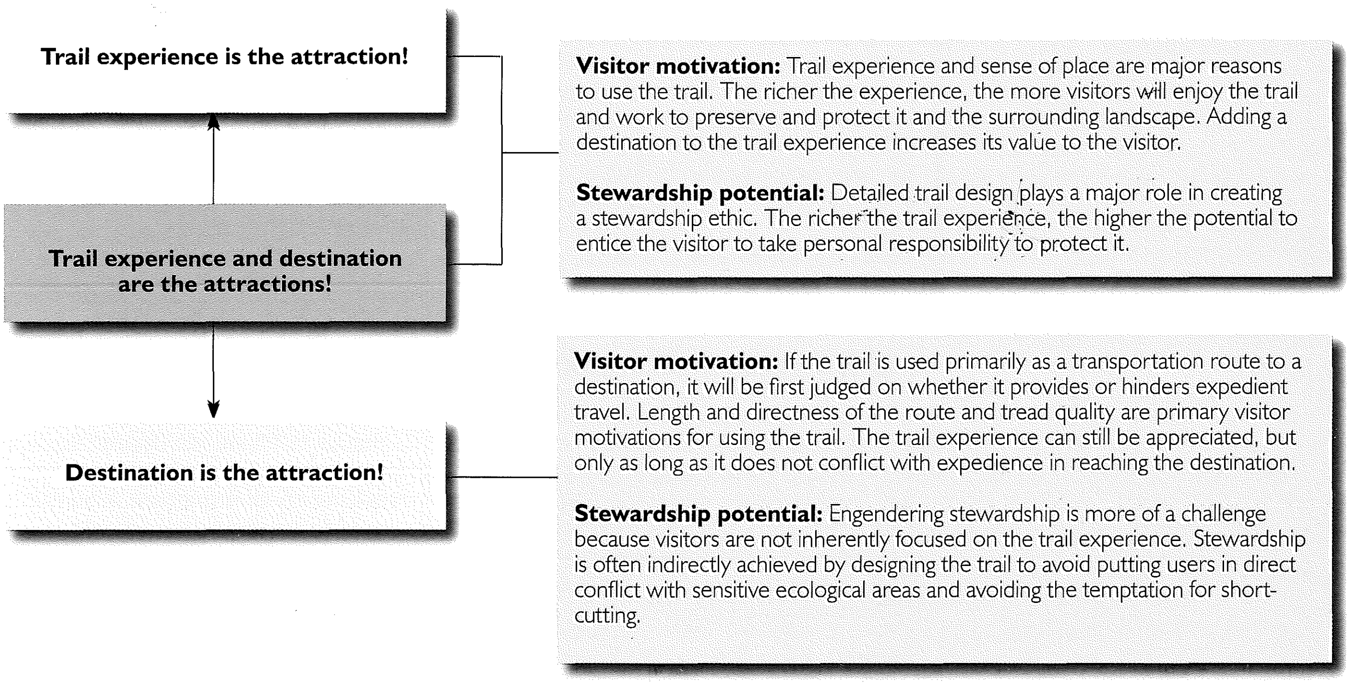
ENGENDERING STEWARDSHIP

A sense of individual responsibility for stewardship is fostered when trail users:

- Use trails in an appropriate manner
- Avoid impacts to surrounding ecological systems
- Educate others about sustainable ethics and practices

Since people protect what they value, stewardship can only be engendered when trails are designed with a full understanding of a visitor's motivations for using them, as the following diagram considers.

STEWARDSHIP POTENTIAL BASED ON VISITOR MOTIVATION



The essence of engendering trail stewardship is creating a rich experience without losing sight of the primary motivation for a visitor to use the trail. Even where getting to a destination is the primary reason to use a trail, the more it is designed to be a rewarding experience, the more likely the user will feel responsible to protect it.

Engendering stewardship also requires an inclusive public process where all stakeholders have the opportunity to participate in a meaningful way and where outcomes truly reflect the needs and concerns of those the trail is intended to serve.

Regulatory Framework – A Key Consideration

As with all forms of development in Minnesota, there are specific regulatory and permitting requirements associated with trails. Most of these relate to protecting Minnesota waters and wetlands. The following is a listing of the most common regulatory requirements that should be reviewed to determine their pertinence to the development of any given trail. The list is not, however, comprehensive.

DNR Division of Trails and Waterways

The DNR Division of Trails and Waterways (www.dnr.state.mn.us/trails_waterways) is the clearinghouse for information related to state trails throughout Minnesota. The division is an especially important source of information on off-highway vehicle (OHV) riding, as well as the latest information on managing and restoring natural communities along trails. The division also administers many trail grant programs. Specific requirements for those seeking trail grants can be found on the Division's website (www.dnr.state.mn.us/grants/index.html).

DNR Division of Waters

The DNR Division of Waters (www.dnr.state.mn.us/waters) is a key source of information related to permit requirements associated with development across or near public waters and wetlands, including trails. This includes information on how the Public Waters Work Permit programs relate to requirements associated with the Wetland Conservation Act and Section 404 of the Clean Water Act and related information and management recommendations/requirements. The link to "Do I Need a Permit?" is particularly useful to understanding specific permit requirements.

Particular attention should be given to the Public Waters Work Permit that is administered through this division and relates to state waters (lakes, wetlands, and streams) that are mapped out and identified on county-based Public Water Inventory maps. These waters are separate from the wetlands protected by the Wetland Conservation Act, and include lakes and wetlands of more than 10 acres in unincorporated areas, and of more than 2.5 acres in incorporated areas. Streams having a total drainage area of more than 2 square miles and designated trout streams of any drainage area are also subject to the provisions of this program. This program was initially enacted in 1937 with the goal of protecting surface waters while providing for reasonable riparian access and use. See the website for more information and access to Public Water Inventory maps and lists, application form information, and more.

Simplifying the regulatory process!

In Minnesota, a number of regulatory agencies created a common application form for water/wetland-related projects entitled *Minnesota Local/State/Federal Application Forms for Water/Wetland Projects*. This ensures a consistent approach to evaluating the need for specific permits associated with trail development in sensitive environments. This permit application covers local government units, MN DNR, U.S. Army Corps of Engineers and MPCA 401 Certification. However, this common application form is not used as the MPCA application for the NPDES Construction Stormwater Permit.

DNR Division of Ecological Services

The DNR Division of Ecological Services (www.dnr.state.mn.us/ecological_services) collects, analyzes, and delivers vital ecological information to Minnesota citizens, leaders, and decision makers. With respect to trail development, the division administers Minnesota's endangered species law, which imposes a variety of restrictions, a permit program, and several exemptions pertaining to species designated as endangered or threatened. Persons involved in trail development are advised to read the full text of the statute and rules in order to understand all regulations pertaining to species that are designated as endangered, threatened, or species of special concern.

Local Agencies and Units of Government

The local soil and water conservation district (www.bwsr.state.mn.us/directories/index.html) is a clearinghouse for information related to protecting Minnesota waters and wetlands. The soil and water conservation district is a key source of information relating to the requirements of the Wetland Conservation Act. Each of the listed governmental entities has specific roles and permit requirements related to protecting local land and water resources. The local unit of government should be the first agency contacted to determine specific permit requirements for a given trail development.

U.S. Army Corps of Engineers

Through Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers (www.mvp.usace.army.mil/regulatory) has oversight of navigable bodies of water. Understanding which bodies of water this encompasses is important in trail planning. Refer to corps mapping whenever trails are near these areas.

Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. The basic premise of the program is that no discharge of dredged or fill material can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if the nation's waters would be significantly degraded. When applying for a permit, the permittee must show that steps to avoid wetland impacts where practicable and compensation for any impacts was provided through restoration activities and/or creating new wetlands. Refer to the corps website for more information on permits.

Minnesota Pollution Control Agency (MPCA)

Minnesota's lakes, rivers, forests, and farms all depend on the replenishing waters of annual precipitation. Stormwater runoff can change both water quality and quantity affecting state water resources physically, chemically, and biologically. The Minnesota Pollution Control Agency's (MPCA's) Stormwater Program is designed to reduce the pollution and damage caused by stormwater runoff. Mandated by Congress under the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) Stormwater Program is a comprehensive national program for addressing polluted stormwater runoff. Minnesota regulates the disposal of stormwater through State Disposal System (SDS) permits. MPCA issues combined NPDES/SDS permits for construction sites, industrial facilities and municipal separate storm sewer systems (MS4s). Information on NPDES Stormwater Construction Permit requirements can be found on the MPCA website (www.pca.state.mn.us/publications/wq-strm2-51.doc)

Another standard to be aware of is MPCA Water Quality Standards in Minnesota Rules Chapter 7050 (www.revisor.leg.state.mn.us/bin/getpub.php?pubtype=RULE_CHAP &year=current&chapter=7050). Parts 7050.0130 to 7050.0227 apply to all waters of the state, both surface and underground, and include general provisions applicable to the maintenance of water quality and aquatic habitats; definitions of water use classes; standards for dischargers of sewage, industrial, and other wastes; and standards of quality and purity for specific water use classes. This chapter applies to point source and nonpoint source discharges and to physical alterations of wetlands. These water quality standards regarding the protection of all waters/wetlands and wetland alteration are applied to the MPCA determination of compliance with water quality standards in the issuance of the Construction Stormwater NPDES Permit and the issuance of the Clean Water Act Section 401 Certification as part of the U.S. Army Corps of Engineers Section 404 permitting. More information regarding the MPCA 401 Certification may be found at (www.pca.state.mn.us/water/401.html)

Environmental Quality Board (EQB)

The Environmental Quality Board (EQB) draws together the chair, five citizens, and the heads of nine state agencies that play a vital role in Minnesota's environment and development. The board develops policy, creates long-range plans, and reviews proposed projects that would significantly influence Minnesota's environment. Refer to the Minnesota Environmental Review Rules (Minnesota Rules Chapter 4410) at the EQB's website (www.eqb.state.mn.us) for regulatory requirements that may relate to trails.

This is relatively new!

Be aware of the EQB rule changes as of October 2005.

Pursuant to these rules, some trail development projects may undergo an Environmental Assessment Worksheet (EAW). The EQB adopted rules establishing new mandatory EAW and exemption categories for certain types of recreational trails in October 2005. The rules can be accessed through the Statutes and Rules link on the EQB's website. The specific citations for the recreational trail sections are: mandatory EAW category – part 4410.4300, subpart 37; exemptions category – part 4410.4600, subpart 27.

If the responsible government unit (RGU) decides that a project has the potential for significant environmental impacts, a more detailed Environmental Impact Statement (EIS) may be required. Environmental review must be completed before a trail project is implemented.

Minnesota State Historical Society (MHS)

The Minnesota Historical Society (MHS) (www.mnhs.org/index.htm) and the State Historic Preservation Office (SHPO) can help determine if the development of a trail impacts any cultural or historical elements that may require documentation and protection. Refer to the MHS website for any specific requirements regarding preserving these resources across the state.

Stay abreast of grant opportunities!

All providers of trails are encouraged to submit applications to the various grant programs to take advantage of funding opportunities that can leverage local matching funds.

Grant Program Considerations

The DNR and other public agencies offer a number of grant programs for trails, each of which has specific requirements. The following references are listed to encourage trail planners to become familiar with these programs and to underscore that a variety of funding programs are available for trail development across the state.

DNR Trail Grant Programs

The DNR Division of Trails and Waterways administers a number of trail-related grant programs for a variety of trail types, including (but not necessarily limited to):

- OHVs), including all-terrain vehicles (ATVs), four-wheel drive vehicles (ORVs), and off-highway motorcycles (OHMs)
- Cross-country skiing and snowmobiles
- Local trail connections
- Regional trails

The division also administers the federal recreational trail grant programs. Refer to the website (www.dnr.state.mn.us/grants/recreation/index.html) for the most up-to-date information on program offerings and submittal requirements.

Legislative Citizen's-Commission on Minnesota Resources (LCCMR)

The Legislative Citizen's-Commission on Minnesota Resources (LCCMR) is a bipartisan commission that makes funding recommendations to the Legislature for special environmental and natural resource projects. Matching grants are provided under this commission for local and regional trails (administered by DNR Division of Trails and Waterways) and Metropolitan Regional Parks and Trails (administered by the Metropolitan Council). Proposals for each of these are submitted directly to the administrating agency. Additional information can be found on the two agencies' websites. (LCMR at www.commissions.leg.state.mn.us/lcmr and DNR at www.dnr.state.mn.us/grants/recreation/index.html)

Minnesota Department of Transportation (Mn/DOT) Programs

The Minnesota Department of Transportation (Mn/DOT) administers a variety of trail-related state and federal grant programs. Refer to the website (www.dot.state.mn.us/library/bike_peds.html) for the most up-to-date information on program offerings and submittal requirements.

Publications That Complement the Guidelines

There are a number of trail-related publications that complement these guidelines, some of which are referenced in other sections. Many of the publications have relevance to specific trail issues, such as accessibility, that require greater detail than can practically be provided here. Note that this list is limited to publications that seem to have the greatest value in complementing what is provided in this manual. Trail planners and designers are encouraged to retain a copy of the relevant publications to become familiar with their content and application to specific types of trail projects.

Mn/DOT Bikeway Facility Design Manual

This Mn/DOT manual complements these guidelines, with the most recent update completed in 2006. The manual has particular relevance to on-road bikeways, where it is the de facto standard referenced for bike lanes and bike routes as described in these guidelines. The manual can be found at website www.dot.state.mn.us/transit/bike/bikedesign.html. The Mn/DOT Manual and these guidelines also reference the *1999 AASHTO Guide for the Development of Bicycle Facilities*, a common technical design standard for shared-use paved trails.

Accessibility-Related Publications and Websites

The United States Access Board is a commonly referenced resource for up-to-date information on accessibility, including trails. The ADA Accessibility Guidelines for Buildings and Facilities (ADAAG) can be found at www.access-board.gov/adaag/html/adaag.htm. Several other publications also provide valuable information on accessibility guidelines, including the following.

A good reference to have on hand!

This brochure is a quick guide for designing accessible sidewalks and trails and is worth having for reference.

DESIGNING SIDEWALKS AND TRAILS FOR ACCESS

This is an exhaustive two-part publication that covers virtually every aspect of accessible sidewalks and trails and complements the guidelines provided in this manual. The publication has particular application to the detailed aspects of curb ramps, pedestrian crossings, and sidewalks. This and other related information can be found on the FHWA general safety website (safety.fhwa.dot.gov/index.htm).

A more handy accessibility guideline is a foldout brochure entitled *Accessible Sidewalks and Street Crossings – On the Safe Side* published by the U.S. Department of Transportation Federal Highway Administration (FHWA). The publication number is FHWA -SA-03-017; it can be found at safety.fhwa.dot.gov/ped_bike.htm. This brochure covers day-to-day accessibility issues associated with trails and sidewalks and is a worthwhile tool to have for quick reference.

UNIVERSAL ACCESS TO OUTDOOR RECREATION (PUBLISHED BY PLAE, INC.)

This publication focuses on accessibility to outdoor recreation, including trails, based on different needs and expectations of potential users. While the publication focuses on providing access to all, it also recognizes that the level of accessibility is relative to the setting. It is a worthwhile reference book to have on hand.

VOLUNTARY SITE-LEVEL FOREST MANAGEMENT GUIDELINES

Published by the Minnesota Forest Resources Council, *Voluntary Site-Level Forest Management Guidelines* covers virtually all aspects of forest management by homeowners, loggers, and resource managers. Although it has particular relevance to trail planning in the northern part of the state, it is a worthwhile publication that trail planners should have available for reference. The guidelines are available at www.frc.state.mn.us/FMgdline/Guidebook.html.

GUIDELINES FOR MANAGING NATURAL PLANT COMMUNITIES

DNR Guidelines For Managing And Restoring Natural Plant Communities Along Trails And Waterways provides an easy-to-understand approach to restoring and managing natural areas associated with trails and are a worthwhile reference to have on hand as a resource. The guidelines are at www.dnr.state.mn.us/trails_waterways/naturalcommunities/index.html.

GUIDELINES FOR OHVS

The publication *Park Guidelines for OHVs* (published by the National Off-Highway Vehicle Conservation Council (NOHVCC) and George Fogg, FASLA) provides a broad-based discussion on OHV trail planning and complements the guidelines presented in this manual. It is a general reference that may be of value in the detailed design of OHV trails. It is available through the NOHVCC website (www.nohvcc.org).

GUIDELINES FOR MOUNTAIN BIKE TRAILS

The publication *Trail Solutions – IMBA's Guide to Building Sweet Singletrack* (published by the International Mountain Biking Association (IMBA)) provides user-friendly guidelines on planning and developing high-quality mountain bike trails.

DNR SIGN MANUAL

This manual covers all of the signs used by the DNR for trails and other purposes. The manual is available on the DNR's website (www.dnr.state.mn.us).

MN/DOT SIGN MANUAL

The *Minnesota Manual on Uniform Traffic Control Devices* (MN MUTCD) is the primary reference for general traffic control and safety sign standards. *Part 9 – Traffic Control Devices for Bicycle Facilities* and *Appendix C – Sign Listing* are particularly useful.

FOREST ACCESS – SIGNING AND PLACEMENT OF GUIDELINES

The DNR Division of Trails and Waterways has developed a sign manual for forest access roads and trails as related to OHV uses. Refer to www.dnr.state.mn.us/trails_waterways/index.html for the most up-to-date information on this manual.

Methods for Defining Natural Areas/Sensitive Ecological Systems

The latter part of *Section 3 – Principles of Ecological Sustainability* provides an extensive overview of methods for defining natural areas and sensitive ecological systems, including rare and endangered species. Refer to this section for specific resources and publications available through various agencies, especially the DNR.

Trail Planning Relative to Broader Resource Management and Comprehensive Plans

The development of trails and trail systems should be consistent with broader resource management and comprehensive plans prepared by local, regional, state, and federal agencies with various types of land use authority. The following provides an overview of the most common of these plans as related to trails.

Local Comprehensive Plans

All local city, township, and county jurisdictions develop comprehensive plans that cover all aspects of community development and land use. Typically, this includes a parks, open space, and trail system component, albeit with varying degrees of detail. These plans should be reviewed as part of any local trail development. Contact the parks and recreation, planning, or natural resources departments of the local governing unit (LGU) for more information on local trail systems plans and development standards.

Regional Parks and Trails Plan

The Twin Cities area's nationally renowned system of regional parks and trails contributes significantly to Minnesota's high quality of life. Preserving green space for wildlife habitat and recreation enhances the region's livability and thus its economic strength. Parks and trails within the system are operated by several partnering cities and counties. These local agencies work with the Metropolitan Council on acquisition and development, protecting natural resources, and providing outdoor recreation for public enjoyment. The council also works with these partners to develop policies that protect the region's water quality, promote best management practices, and help integrate the park and trail systems with housing, transportation, and other regional priorities. More information is available at www.metrocouncil.org/parks/parks.htm.

State Parks and Trail Plans

DNR Division of Trails and Waterways is responsible for planning, operating, and managing state trails, public water access sites, piers and shore-fishing sites, and canoe and boating routes. Through grants-in-aid funding with local units of government, the division administers snowmobile, OHV, and cross-country ski trails. It also provides financial and technical assistance to local units of government and organized interest groups. More information about the division's oversight of state trails and related programs can be found at www.dnr.state.mn.us/trails_waterways/index.html.

There are also numerous other divisions within DNR that may need to be contacted for specific trail-related projects, including Ecological Services, Enforcement, Fish and Wildlife, Forestry, Lands and Minerals, Parks and Recreation, and Waters. More information is available at www.dnr.state.mn.us/sitemap/index.html.

Forest/Public Lands Resource Management Plans

Local counties, the DNR, and the U.S. Forest Service (USFS) have responsibility to develop and implement resource management plans for county, state, and federal lands, respectively. These plans typically focus on managing timber harvests, forest health, scenic qualities, and public access and enjoyment. The latter typically includes policies related to the use of roads and trails for recreational purposes, especially OHV uses. Notably, these policies may vary, sometimes considerably, from agency to agency. Always contact local offices of these agencies prior to any trail planning or development that may directly or indirectly affect the lands under their jurisdiction. Minnesota is in the Eastern Region (R9) of the USFS system; more information is available at www.fs.fed.us/r9.

Trail Project Planning Guidelines

Planning guidelines note!

The guidelines presented in this section are general. Projects seeking grants or requiring regulatory approval should adhere to the specific requirements of the administering agency or agencies.

Sustainable trails are a result of a well-thought-out process that brings stakeholders together to find the best solution within the context of site opportunities and constraints. The process must also accommodate regulatory and permitting requirements to ensure that trails will be physically and ecologically sustainable.

Project planning is typically a multiple-step process from initial inception through development, management, and maintenance. The guidelines provide a checklist of essential elements to consider when planning and developing a sustainable trail. Typical steps in the process include:

- Step 1 – Project proposal and stakeholder involvement
- Step 2 – Public notification and comment
- Step 3 – Environmental review
- Step 4 – Trail design and construction documents
- Step 5 – Project permitting
- Step 6 – Management, monitoring, and stewardship (maintenance)

These steps consider the typical requirements of common grant applications. If grant funding is being sought follow the specific requirements the program.

The following considers each of these steps in greater detail.

Step 1 – Project Proposal and Stakeholder Involvement

The proposal defines the trail project in sufficient detail to ensure that interested and affected parties and regulatory agencies can understand the type and scope of the trail being proposed. Common components of a project proposal include:

Vision Statement

The vision consists of a straightforward description of the type of trail envisioned, user group(s) to be served, benefits, and the desired visitor experience. The statement should clearly define the project's intent.

Program Statement

The program statement is a collection of thoughts, ideas, and factors that will influence the planning and design of a trail. It is essentially a shopping list that is used throughout the planning process to ensure that the final plan addresses all pertinent issues. The program statement is dynamic, meaning it can change and evolve as new information or perspectives are considered.

Items typically included in the program statement include the following:

Project Expectations

An expectations statement should be prepared for each stakeholder defining the group's or individual's vision of success (within the context of the larger vision). These statements can be valuable in tailoring the planning process to emphasize the issues of most importance to stakeholders.

Past Plans Affecting the Trail

All previously prepared plans identified by stakeholders should be reviewed for relevance. The final trail plan should include reference to any existing plans that affect planning outcomes.

Restricted or Permitted Uses

Any restrictions associated with the type of trail allowed within a specific area should be thoroughly investigated early in the process. An initial listing of all required permits should also be included.

Regulatory framework!

Refer to the regulatory framework provided in this section as an initial starting point for defining permitting requirements.

Base Mapping

Accurate base mapping significantly affects the completeness and quality of the planning and design documents. The box on the next page highlights the essential aspects of a site survey.

A PLANNING ESSENTIAL: AN ACCURATE SITE SURVEY

An accurate site survey and analysis are important to the planning process and as much detailed information as reasonably available should be gathered. This consists of a variety of maps, including general base mapping (preferably in GIS format) where multiple overlays of information can be illustrated. Aerial photography (black and white, color, and other forms as available) is also a valuable planning tool. Photos should also be taken from the ground at various vantage points to record site conditions. The following provides an overview of the information that should be included in the site survey and analysis graphic. The level of detail needed depends on the circumstances and the size and scale of the project.

Topography: Relates to grades, elevations, and drainage patterns across the site. Topographic maps typically provide contours on a 2-foot basis. The character and extent of undulation should be graphically illustrated on the site analysis graphic.

Surface Water and Hydrology: Understanding surface water patterns and hydrological flows is critical to designing sustainable trails. The base mapping and site analysis graphic should illustrate:

- Lakes and ponds
- Wetlands
- Ephemeral wetlands
- Rivers, streams, and ephemeral streams
- Floodplains
- Wet meadows and wet slopes
- Springs and seeps
- Drainages and drainage channels

All drainage channels should be identified given their influence on erosion issues, especially for natural surface treads. The size and minimum/maximum normal flow rates and/or water levels should be estimated for each of the items listed above.

Ecologically Sensitive Areas/Vegetative Inventory: Defining ecologically sensitive areas through a vegetative inventory and land classification is one of the most important aspects of designing trails that are sustainable. (The common methods for doing this are defined in Section 3 – Principles of Ecological Sustainability.) In all cases, sensitive ecological systems should be defined to a level necessary to understand the system and protect its integrity during the planning process. Specific items to identify and avoid impacts to include:

- Critical habitat of endangered, threatened, and special concern species
- Rare, unique, contiguous, or high-value natural areas
- Patches of high-quality and unique habitat
- Riparian areas
- Migratory routes or seasonal use areas for wildlife

Soils: An understanding of soil types where the trail will traverse is important to creating a sustainable trail. This is especially the case with natural surfaced trails, where erosion can be a particular problem. The soil analysis should include:

- Soil types using standard practices; broad characterization (loam, sandy loam, silty loam, sandy clay, etc.) is sufficient for initial planning
- Identification of areas of particular instability or erosion potential as related to the intended use

A more detailed soil study is often needed for load-bearing paved trails and natural surface trail treads where erosion is a major concern.

Property Boundaries and Adjacent Land Uses: Property boundaries and any public or private easements should be recorded on the survey. Identification of current or anticipated adjacent land uses is also important, including how those uses complement or conflict with the trail. All covenants that may exist for the property or adjacent properties should also be recorded.

Administrative Boundaries and Jurisdictions: All special management areas or other jurisdictional boundaries should be recorded as part of the site analysis. This is especially important with respect to resource and wildlife management areas and areas set aside as wilderness or other protective designation.

Distinct Site Edges: On the site analysis, distinct edges of ecologically sensitive areas, water features, or landforms should be identified. These areas tend to be interesting features that could serve as highlights along the trail (within a sustainable context).

Existing Site Features and Anchors: These are physical features of the landscape that would add interest to the trail experience. The site analysis should identify all anchors that could be integrated into the trail design to make for a richer trail experience. Known or potential points of interest, scenic views, recreational use areas, destinations, and so on should all be identified as part of the site analysis.

Cultural Sites: The entire site should be assessed for cultural or historic features that may influence the location of a trail and/or provide a point of interest. This includes European and Native American/tribal cultural site reviews.

Existing Developed/Disturbed Areas: The site analysis graphic should identify all developments on the site and other areas that have been previously disturbed, including:

- Trails, including closed, abandoned, and decommissioned with current use, condition, and estimated level of sustainability defined
- Trailheads and trail access points
- Roads of any type or usage, including abandoned roads (the potential to reuse abandoned roads as part of the trail corridor should be identified)
- Railroads and abandoned railroad grades
- Utility corridors
- Facilities, agricultural operations, buildings, structures, parking areas, campsites, and other human works
- Environmentally disturbed areas (mine sites, dump sites, transportation corridors, etc.)
- Any known locations where existing development or disturbance is causing:
  - Erosion
  - Sedimentation into waterways
  - Wildlife habitat disruption
  - Fish habitat disruption
  - Nonnative plants or noxious weeds

Hazardous Situations: Areas prone to flooding should be identified, including ordinary high water (OHW) level. Unstable or steep slopes should be identified. Any potentially hazardous adjacent land uses should also be recorded, as should hazards posed by operations such as mining, agriculture, railroads, and highways on adjacent land.

Construction/Maintenance Access: All points of access for trail construction and maintenance should be identified on the site analysis.

Planning and Design Issues

The following box highlights the essential planning and design issues to be considered in establishing a clear basis and rationale for a trail.

TRAIL-RELATED PLANNING AND DESIGN ISSUES

A well-written program statement defining the planning and design issues associated with the development of a trail for a specific purpose is essential to establishing the base-line rationale for the project. It also provides an opportunity to define project constraints that are best addressed early in the process, when they can be proactively considered and acted upon.

Trail Type Being Proposed: The type of trail being proposed should be clearly defined, including its specific trail classification.

Basic Set of Justifications: A basic set of justifications should be established for the trail. Questions to be answered include:
- Why have this type of trail in this location?
- Who are the primary user groups and where will they be coming from?
- Will the trail be single use or multiuse?
- What purposes does the trail serve (recreation, transportation to a destination, etc.)?
- Who benefits from the trail, and who or what will be adversely affected by it?
- How can sensitive ecological areas be avoided, minimized, and/or interpreted?
- What kinds of recreational experience will the trail and site offer?
- What types and amount of trail use can be expected and sustained?
- If this trail were not formally designed and constructed, would visitors eventually form a new and potentially damaging trail anyway?
- Where does the trail go? Is the destination significant? Does it link existing or planned recreation facilities?
- Is this a reroute, reconstruction, or entirely new trail?
- What noteworthy or developed features can be found on or near this trail?
- What type of trail surfacing options need to be considered, given site conditions?
- Is all or part of the trail to be accessible?

Basic Site Characteristics: Highlighting the site attributes that will be used to create a rich and varied trail experience is an important initial planning step. This is most often accomplished in both written and graphic form. Site attributes to be identified include:
- Landscape features offering scenic values, places of interest, local landmarks, trail challenges, etc.
- Control points such as unique landscape features, viewing points, and site constraints that might limit access
- Ecologically sensitive areas
- Less sensitive areas where trail impacts are less
- Basic topography
- Soils and vegetation
- Site drainage characteristics
- Nearby roads, trails, and adjacent land ownership patterns
- Legal and administrative boundaries, right-of-way width
- Current uses of the site and adjacent areas
- Trails or destinations to which proposed trail(s) may connect
- Areas to screen or feature associated with adjacent sites
- Other site features as applicable

Intrinsic Qualities: This relates to how the various site elements collectively create a compelling and enjoyable experience for the trail visitor. Asking the following questions helps define these qualities:
- What is the sense of place being exhibited and preserved?
- How "rich" is this site in terms of varied or dramatic landforms and spatial diversity? Where are the richest areas and what makes them rich?
- What kind of trail experience is desired? What kind of experience can the site reasonably sustain?

Engendering Stewardship: Eliciting individual responsibility for stewardship of the trail is vital to its long-term sustainability. At the program level, ways in which stewardship can be encouraged should be defined. Examples include establishing a:
- Formal volunteer trail group for promoting and maintaining the trail
- Communication plan to promote the trail and sustainable use practices
- Trail signage program that includes a stewardship component

Potential Conflicts and Limitations: All potential conflicts and limitations should be clearly stated in the program statement, including anticipated action to resolve them. No conflict should ever be ignored since it will likely come back around when the trail is to be developed. An inclusive planning process helps in overcoming apparent constraints and obstacles.

Accessibility: The level of accessibility envisioned should be clearly defined relative to the type of trail being proposed and site constraints that might affect grades and other accessibility issues. Interconnectiveness with other trails and facilities should also be defined.

Time Zoning and Seasonal Use/Restrictions: The seasons of use should be clearly defined. This is especially important when a trail corridor may be used for a variety of uses over the course of a year. Also, some trails may have access restrictions imposed on them, such as limiting ATV use to coincide with hunting season on some lands. Time zoning can also be used on a more limiting basis, such as allowing dog sledding on a snowmobile or ski trail at certain prescribed times during the season.

Project Budget Parameters: If available, the budget for developing the trail should be defined to avoid conflicts at the point of implementation. Knowing the budget parameters for the project will ensure that the plan that emerges out of the public process is one that can actually be implemented.

> ***Important consideration!***
>
> Note that overall time frame for planning and designing a trail is typically at least six months and often longer depending on local site conditions, public involvement, and regulatory considerations.

Time Frames and Schedules

Prepare an overall project time frame at the outset of the project. Typically, the schedule is initially broadly defined and then refined as the project progresses past established milestones.

Integrate schedules associated with agency review and permitting into the overall project schedule. This is especially the case where permitting timelines are longer.

Project Communications

Prepare a communication strategy at the outset of the project to maintain consistency in public notices and information sharing. Use communication outlets such as local news media, websites, Internet mailings, and correspondence with stakeholders in a coordinated manner.

STAKEHOLDER INVOLVEMENT

> ***Grant reminder!***
>
> Keep in mind that grant proposals often require a formal public notification and public comment process to ensure that all interested parties have an opportunity to participate and that all legal requirements are met. (See Step 2 – Public Notification and Comment.)

Identify stakeholders – all individuals, groups, agencies, and other entities that will be involved in or have influence on the planning process. Typically, this includes:

- **Public agencies** – including local, county, regional, and state jurisdictional authorities and all regulatory agencies. Specific information should include:
  - Agency name, specific authority, permit processes, and approvals protocol
  - Contact person (name, address, telephone, e-mail, and fax)
  - Specific involvement in the process
- **Citizen advocacy groups** – include name of group, contact information, organizational structure (user group, ad hoc committee, local board or commission, civic group, etc.). Also include a statement about the group's interest in the project and specific role in the planning process.
- **Individuals and affected landowners** – include names of all individuals and landowners who have a vested interest in the project. Include the same information as for citizen advocacy groups. Individual stakeholders could include residents from local communities, trail visitors, knowledgeable citizens, and local elected officials.

Prepare a specific strategy for stakeholder involvement. A variety of techniques can be used to involve individuals and groups in the process, as the following box highlights.

Stakeholder Involvement Techniques

Technique	Overview
Brainstorming Session	Undertaken with select stakeholders early in the process to uncover ideas and key planning issues.
Individual Interviews	Undertaken with select individual stakeholders to gain firsthand information and perceptions.
Focus Groups and Workshops	Undertaken with identified user or advocacy groups to gain broad understanding of related concerns and perceptions. Also used for planning and design charettes to explore possible trail options.
Public Meetings/ Open Houses	Open to the public to address concepts or specific issues. Format ranges from a formal presentation to general open house, depending on the context.
Surveys	Used to solicit information from a targeted area or group. A statistically valid survey can add broader legitimacy to the planning process.
Peer Roundtable	Brings noted peers together to discuss planning issues and design approaches. Often used to uncover new insights or construction techniques that might have been overlooked.

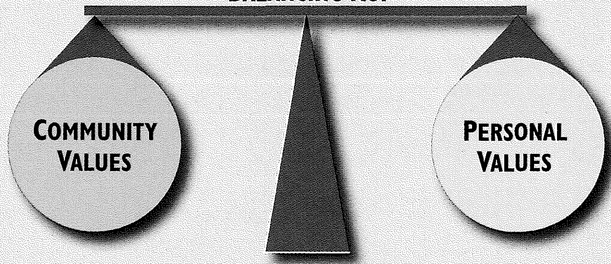
Respecting the Values Stakeholders Bring to the Project

Stakeholder involvement in developing the master plan is critical to the success of most trail projects. It should be expected that stakeholders will bring both community and personal values to the public process, as illustrated in the following box.

BALANCING STAKEHOLDER VALUES

Balancing community and personal values is one of the most important aspects of trail planning. *Community values* relate to broader public interests that are substantiated through research, user-group input on needs, and input from the public process. *Personal values* are also substantiated through public process, but focus more on individual concerns and firsthand accounts. The former tend to emphasize the reasons for a trail, while the latter tend to emphasize personal issues and concerns that are either in support of or against the development of a trail.

BALANCING ACT



As illustrated, planning for the common good and serving the interests of the broader community must occur within the context of respecting the concerns of individual stakeholders and searching for reasonable, workable solutions. To do this, stakeholder involvement needs to be carefully managed to ensure that outcomes reflect due consideration of the values that each stakeholder brings to the process.

TRAIL MASTER PLAN

The trail master plan translates the vision and program statement into a physical form. This step also includes a more detailed evaluation of the program items. The following considers each aspect of developing a master plan.

Create the Master Plan

Creating a master plan typically involves several levels of refinement, starting with broad concepts and ending with a single refined plan. Using the site base map and analysis graphic(s) and program statement as the starting point, the initial concepts should include all reasonable trail alignments. Note that each alignment being considered should be consistent with the vision and program statement.

For more insight!

Refer to Section 2 – Principles of Designing Quality Recreational Trails for more techniques to maximize the value of trails and the key elements of good trail design.

The master plan should align the trail to take advantage of each amenity feature in a sustainable fashion. Control points that are considered site opportunities and constraints should also be factored into the alignments. A variety of specific design principles should be applied to the master plan as defined in forthcoming sections, including:

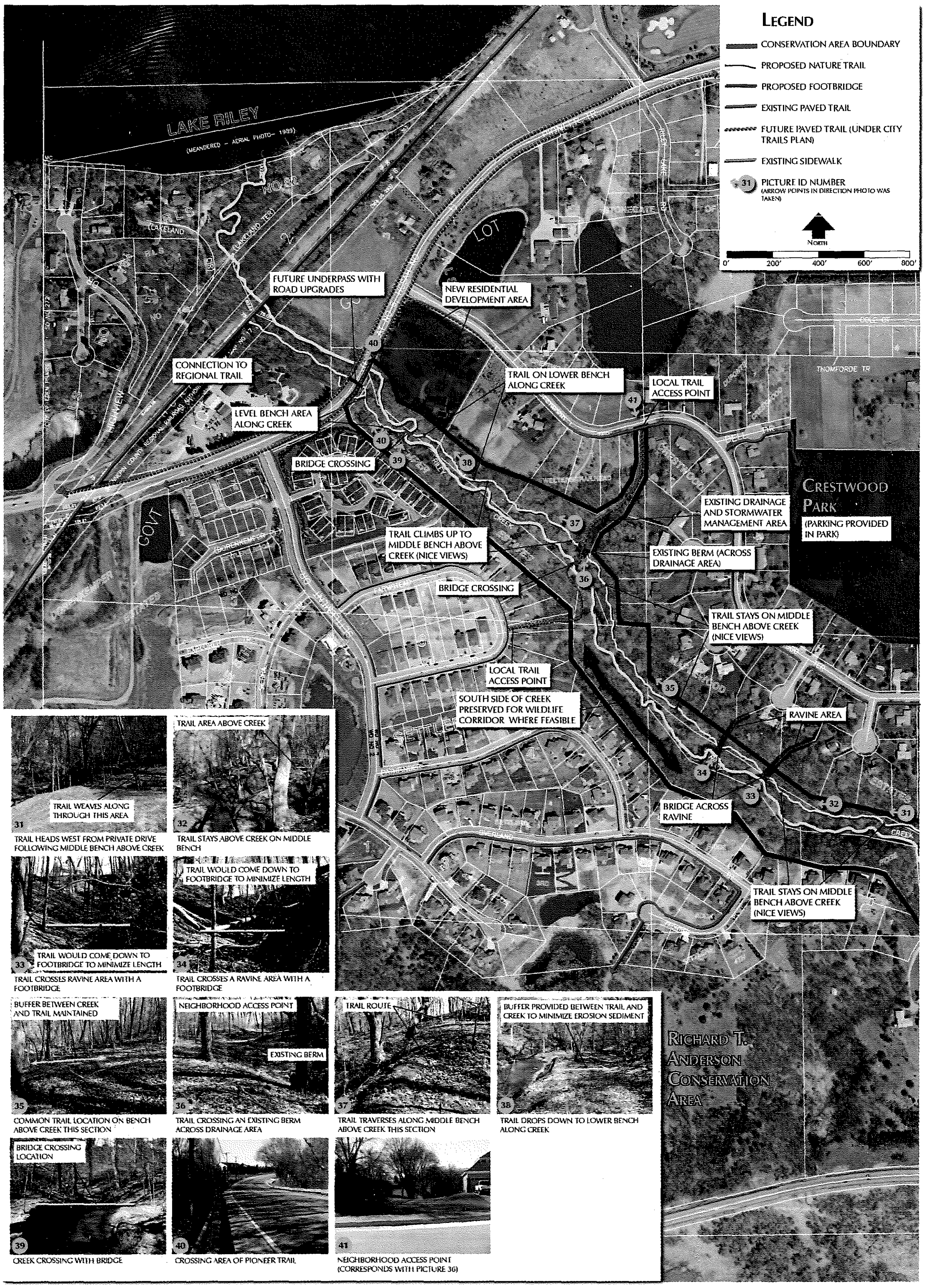
- Form corridors that provide a variety of trail experiences while working with control points and around sensitive areas that must be avoided
- Establish desirable trail movement and flow patterns, with each alternative creating different sequences of events
- Ensure that trail grades remain sustainable and suitable for the desired use
- Use landscape and vegetation patterns to add interest to the trail experience

Depending on the type of trail being proposed, alignments will range from broad sweeping layouts that traverse a large space to tightly woven trails that respond to the nuances of landforms and vegetative patterns. Maximizing the trail experience by taking advantage of what the site has to offer is the essence of all trail designs. The graphic on the next page illustrates a master plan for a trail.

Master Plan Example

In graphic form, the master plan should illustrate the trail's alignment and all physical nuances that affect its location. Photos and other supportive graphics can enhance stakeholders' understanding of the proposed plan. This particular image is one section of a linear trail following a creek corridor in a conservation area in a suburban setting. A natural hiking trail is proposed in keeping with the setting. Buffers are also provided along the creek to minimize the likelihood of sediment migrating from the trail to the creek.

Western Section (Part I of 3 parts)



Detailed Considerations at the Master Plan Level

There are numerous detailed considerations that start at the master plan level and are refined through subsequent steps. It is especially important to identify and consider issues that directly impact the decision on the appropriateness of the trail for the intended uses and environmental review and permitting.

Listing of regulatory agencies!

A listing of regulatory agencies and their area of jurisdiction is listed under Regulatory Framework earlier in this section.

Permit Requirements

A detailed listing of all permits required for the trail project should be assembled based on the master plan. For local, county, and regional trails, local regulatory agencies should be contacted to determine permit requirements.

Ecological Sustainability

Once the preferred trail alignment is laid out, a critical review of site-specific ecological impacts should be undertaken. This typically includes review of the six principles of ecological sustainability as defined in Section 3 – Principles of Ecological Sustainability.

Physical Sustainability

For more specific design and development information!

Refer to Section 5 – Shared-Use Paved Trails and Section 6 – Sustainable Natural Surfaced Trails for guidelines on designing physically sustainable trails.

A physically sustainable trail is one that can stand the test of time through years of use. The heavier the use and more susceptible the landscape, the more diligence is needed on the physical development of the trail. At the master plan level, factors affecting the physical sustainability of the trail should be identified. This includes identifying potential:

- Trail alignments that balance desired experience with physical sustainability
- Tread surfacing materials for each segment of the trail, taking into consideration soils, slopes, drainage, vegetation patterns, and other influences
- Locations for structures, including:
  - Bridges
  - Boardwalks or other forms of traversing wetlands or sensitive areas
  - Underpasses, overpasses, and grade crossings
  - Stream crossings
  - Culverts
  - Retaining structures and railings or fencing
- Areas requiring extensive earthwork or engineering to establish the trail

Construction impacts should also be considered as part of evaluating the physical sustainability of the trail. This includes the impacts of heavy machinery on the site, the potential erosion during construction, temporary accesses, and noise. The collateral impacts of construction should also be considered, including impacts to:

- Sensitive areas
- Wildlife (nesting, breeding, migration, etc.)
- Exotic species and noxious weeds
- Adjacent landowners (noise, dust, access)
- Existing trails and roads used to access the trail during construction

Engendering Stewardship

Engendering stewardship is a hard-to-define but important aspect of creating sustainable trails. Trails that are ecologically and physically sustainable are more likely than unsustainable trails to elicit a sense of stewardship in users because less effort is required of them.

Stewardship is also influenced by how well the trail meets users' expectations. The higher the personal value the trail holds, the greater the likelihood the visitor will take responsibility for taking care of it.

Step 2 – Public Notification and Comment

For more information!

Refer to Grant Program Considerations earlier in this section to determine the specific public notification and comment requirements related to particular grant program.

Public notification and comment is part of a formal process often legally required by administering and regulatory agencies to ensure that all interested parties have ample opportunity to respond to a trail proposal. This is part of the overall stakeholder input strategy defined under Step 1. For DNR projects, a 30-day comment period is a common requirement.

The public typically is notified by e-mail, U.S. mail, press releases, paid advertisements, and/or website postings. Public meetings may also be scheduled as necessary.

Listing of regulatory agencies!

A listing of regulatory agencies and their area of jurisdiction can be found under Regulatory Framework earlier in this section.

Sound ecological planning is the essence of sustainable trails!

Section 3 – Principles of Ecological Sustainability provides sound advice on planning trails in natural areas. If these principles are applied, the design of a trail is likely to be very consistent with standard regulatory requirements.

For more specific design and development information!

Refer to Section 5 – Shared-Use Paved Trails, Section 6 – Sustainable Natural Surfaced Trails, and Section 7 – Winter Use Trails for guidelines on design and construction of various types of trails.

STEP 3 – ENVIRONMENTAL REVIEW

Environmental review is fundamental to sustainable trail planning to minimize impacts to sensitive ecological systems. For some projects, a formal environmental review may also be required. Refer to the Minnesota Environmental Review Rules (Minnesota Rules Chapter 4410) at the EQB's website (www.eqb.state.mn.us) for regulatory requirements that may relate to trails. Note that trail projects requiring a formal environmental review cannot be implemented until the review is complete.

Determining the level of environmental review that is necessary for a given trail project is typically the responsibility of the RGU. For DNR Division of Trails and Waterways projects, the Environmental Policy and Review Unit in the Division of Ecological Services would perform the RGU responsibilities. If the review process identifies potential significant environmental effects, modifications to the project or mitigation of impacts will likely be required.

STEP 4 – TRAIL DESIGN AND CONSTRUCTION DOCUMENTS

Once the major planning and environmental review is completed, detailed design and construction document preparation is undertaken. This includes the application of specific design standards that will ensure the health, safety, and wellness of the public. It also includes the application of best practices to ensure long-term sustainability and protect the surrounding environment.

The guidelines presented in this manual provide the basis for trail design for most types of trails. These guidelines should be complemented with other established standards to ensure the highest quality design and engineering. For state and federal funded projects, very specific design and engineering requirements are mandated. Adhering to these requirements for a given trail project is typically the responsibility of the RGU, in cooperation with state or federal agencies responsible for administering state or federal grants.

STEP 5 – PROJECT PERMITTING

Virtually all trail projects will require permits as part of the approval process. Most of these relate to protecting Minnesota waters and wetlands. Submittal and approval of all permit applications is required prior to any construction. Typically, the RGU provides assistance in determining permit requirements. However, proposers of trail projects should be familiar with the various permitting agencies and jurisdictions to ensure that all requirements are met prior to any trail development.

In addition to regulatory permits, land-use approvals from landowners or land managers (public and private) should be obtained. Road right-of-way use and site access approvals from appropriate state, county, or local highway authority may also be necessary.

STEP 6 – MANAGEMENT, MONITORING, AND STEWARDSHIP

Once a trail is developed, appropriate management, monitoring, and stewardship (maintenance) are all necessary to ensure its long-term sustainability. Trail management defines operational procedures, marketing approaches, rules, and enforcement levels to ensure the trail serves the targeted user group(s) and is properly used. More intensive and/or specialized uses require higher levels of management.

Trail stewardship relates to the routine preventive maintenance of the trail and stewardship of adjoining natural areas. The higher the classification and more intensive the use, the more maintenance required to ensure sustainability.

A specific management, monitoring, and stewardship plan should be prepared and implemented as part of a trail's development. Other sections of this manual provide guidelines on each of these issues as related to specific types of trails.

SECTION 2

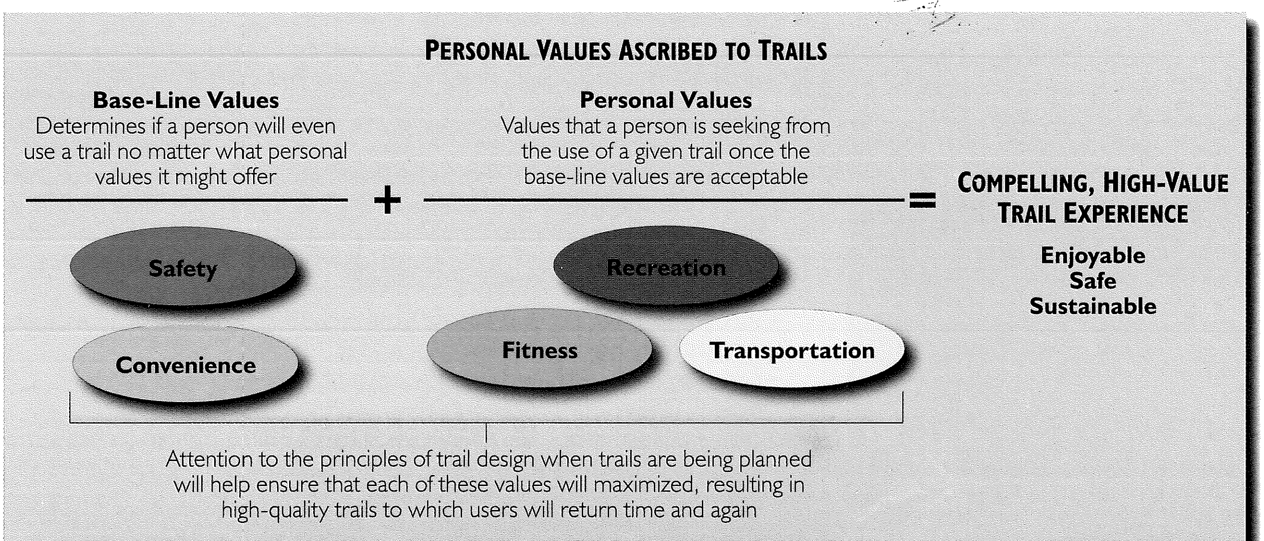
Principles of Designing Quality Recreational Trails

Overview of the Principles

This section describes a set of design principles that, if thoughtfully applied, will result in rich, high quality, and rewarding trail experiences. The principles take into consideration the values trail users ascribe to trails, the key elements of design, and other factors that influence the quality of the trail experience. The use of sound design techniques have merit and can be applied to all trails, whether motorized and nonmotorized.

Values Ascribed To Trails

The values ascribed to trails are considered in this section because they are at the core of why a person would use a particular trail. Preference studies clearly indicate that trail users make a distinction between certain trails based on their perception of value. In broad categories, trail values include safety, convenience, recreation, fitness, and transportation/commuting, as the following graphic illustrates.



As the graphic illustrates, safety and convenience are base-line determinants for whether a person will even use a trail irrespective of its quality. If a trail is perceived as being unsafe, it is unlikely a person will consider using it. If it is not convenient enough, a person will be less likely to put forth the effort to use it even if the recreational experience might be better than a more convenient trail. Once these two values are perceived as being acceptable, then the personal values will be given more consideration. The following considers each of these values in greater detail.

SAFETY

A sense of physical and personal safety is the most important trail value in that without it people are disinclined to use a trail irrespective of how many other values it might provide. Physical safety can be relatively assured through good trail design relative to its intended use. By adhering to and applying the principles of this manual and other best practices, physical safety can be relatively assured for the responsible trail user, albeit there is always an inherent risk with any activity. Notably, physical safety is viewed differently by different trail users relative to the experience they are seeking. The key to providing a safe trail environment is matching the level of difficulty with the skill level of the intended user, then making sure that is well communicated to trail users.

Personal safety, which relates to a sense of well-being while using a trail, is a less tangible yet still important factor that cannot be taken lightly. The guidelines in this manual can help reduce personal risk and enhance the perception of safety.

CONVENIENCE

The convenience of a trail is listed second largely because of its importance to day-to-day use of a trail. This is most pertinent to local, county, and regional level trails, where reasonable convenience is an expectation. It is less applicable to state trails, where users are more willing to travel to get the desired trail experience.

The convenience factor is perhaps most important with respect to shared-use paved trails, which receive the highest levels of use of all trail types due to their universal appeal and an expectation that this type of trail is readily available near one's place of residence. Studies have shown that the vast majority of shared-trail users live within a few miles of the trail they use most frequently. For example, research reported in 2005 by the Metropolitan Council suggests:

- 50 percent of all trail users live within 3/4 mile of the trail
- 75 percent of all trail users live within 3 miles of the trail
- 25 percent of all trail users come from elsewhere within the region, usually during the day on the weekend.

Although convenience is important, its influence is still tempered by recreational value. No matter how convenient, a poorly designed trail in an uninteresting setting will have limited recreational value. Alternatively, a well-designed trail in an interesting setting might draw users from some distance. The point is that trails should be located where they are both convenient and offer the amenities that users are seeking.

RECREATION

Of all the values ascribed to a trail, its recreational value is perhaps the most important in terms of predicting its level of use, assuming that safety and convenience are not issues. In general, trails offering a high-quality recreational experience are those that:

- Are scenic and located in a pleasant parklike setting, natural open space, or linear corridor away from traffic and the built environment
- Provide a continuous and varying experience that takes visitors to a variety of destinations and is a destination unto itself
- Offer continuity with limited interruptions and impediments to travel


A recreational experience can be as simple as a fall walk down a nature trail to enjoy the colors and change of seasons.

This underscores that trail planning must be based on criteria that go beyond simply providing miles of trail – with considerable emphasis on the quality of the trail experience as well as quantity.

At the local level, creating trails with high recreational value inherently affects community planning and development. Planning for trails that follow greenways that seamlessly traverse public open spaces and private developments alike is considerably different than planning for trails that follow road rights-of-way. Whereas greenway-based trails often pose more challenges to plan and implement, the value of these trails to the community has proven to be very high and seemingly worth the investment. Communities that have been successful at integrating these types of trails into their comprehensive plan often highlight them as key aspects of the city's quality of life.

Note that interpretive trails fall under recreation. Here too, the quality of the interpretive experience is at least as important as the quantity of trail miles.

FITNESS

Fitness is a growing value that cannot be overlooked. Fortunately, this value is generally achieved if safety, convenience, recreational, and transportation values are met. Most critical to encompassing this value is developing an interlinking trail system that provides numerous route options and the trail lengths necessary for the types of uses envisioned.

TRANSPORTATION (COMMUTING)

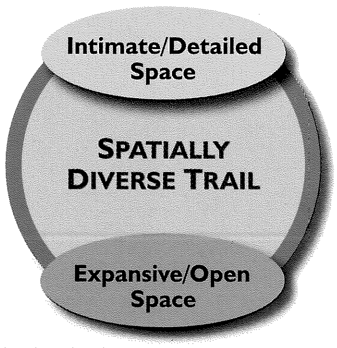
The transportation (commuting) aspect of trails is valuable to a growing subset of the user population. This is especially the case with shared-use paved trails, where bicycling, in-line skating, and walking are viable means of transportation, especially for people in urban and suburban settings.

In the larger multimodal context, the value of trails for transportation is an important funding consideration, especially at the federal level. From the user side, the more trails are planned as integrated systems across municipal boundaries, the more value they will have to the commuting public.

ELEMENTS OF TRAIL DESIGN

The most successful trails are a reflection of the setting and landscape they traverse. People purposefully choose specific settings for the experience they seek, and the trail should reflect those expectations. The more natural the setting, the more the trail needs to be shaped by nature. The more urban the setting, the more the trail needs to highlight local landmarks and points of interest and provide a social atmosphere.

CREATING TRAIL SEQUENCES AND EXPERIENCES



The thoughtful juxtaposition of the spatial qualities of a site is one of the keys to creating compelling trails with enduring value.

The human eye tends to shape visual cues into a conscious thought that triggers an emotional response – ranging from positive and inspiring to disappointing and troubling, depending on the situation. Well-designed trails play upon these tendencies by using the natural or built forms and spatial diversity of a site to create sequences of visual, physical, and emotional responses that are pleasing to the trail user. This concept is fundamental to good trail design and should always be kept at the forefront of the design process. Even though the trail itself is artificial, thoughtful design ensures it will be reflective of and in harmony with its particular setting.

Creating trail sequences refers to consciously connecting landscape features to create a unified trail experience that is appealing to the visitor. All aspects of a site – its topography, viewsheds, water features, ecological communities, cultural sites, developed areas, roads, and trails – should be perceived as part of the sequence of events that give the trail its character. To be successful, the collective sequence of events must also meet the expectations of the visitor in terms of desired mode of travel, setting, level of difficulty, and length of trail.

MANAGING VIEWSHEDS

Managing the views as one progresses along trail is an important consideration in designing trails. Taking advantage of compelling views and downplaying those that detract from the trail experience is all part of controlling the sequence of events that enhances the trail's recreational value. Importantly, managing viewsheds is an ongoing maintenance issue and may, at times, conflict with vegetative management. In these instances, it is important to define which viewsheds are important to the trail experience and how those will be preserved over time as part of the vegetative management program for the trail.

SHAPING TRAILS TO BE CONSISTENT WITH VISITOR EXPECTATIONS

The connecting link between individual events is the trail itself, which is laid out in response to the spacial features of the site. The "shape" of the trail is a very important aspect of creating a trail that offers high recreational value relative to its setting. Understanding the emotional response that various shapes induce is critical to designing trails that successfully mesh with the larger landscape experience.

Trail design is centered around taking advantage of landscape features that add interest to the trail experience without diminishing that experience in the process. The primary design elements include landscape anchors, edges, gateways, and terminus points/destinations, as the box on the next page illustrates.

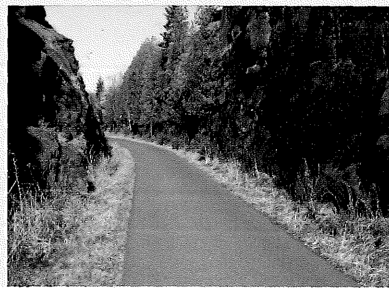
ELEMENTS OF DESIGN USED TO CREATE TRAIL SEQUENCES

Defining and linking together the key elements of design creates compelling experiences that will keep trail users interested in a trail and encourage personal stewardship.

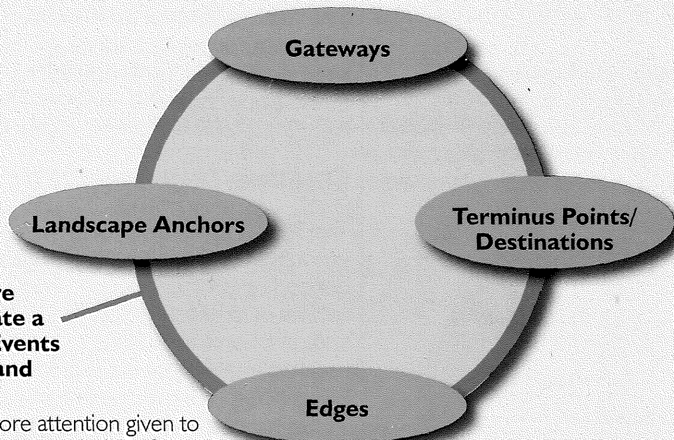
LANDSCAPE ANCHORS

Landscape anchors can be as simple as trees and rocks that provide contrast and a visually interesting experience in keeping with the setting.

GATEWAYS



Gateways can be created by natural forms and materials (left) or artificial structures that create a sense of entrance (right).



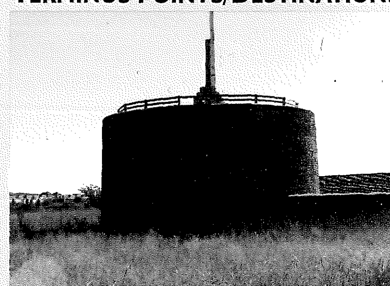
Elements of Design are Woven Together to Create a Compelling Sequence of Events With Spatial Diversity and Managed Viewsheds

The best trail designs leave no detail to chance. The more attention given to understanding and incorporating the nuances of a site into the design of a trail, the more compelling and enjoyable the experience will be for the trail user!

EDGES

The character of this ATV trail (left) comes from its natural shape and association with a vegetative edge. With this shared-use paved trail (right), the gentle curves play upon the edge effect in subtle way that is much more interesting than a straight line.

TERMINUS POINTS/DESTINATIONS

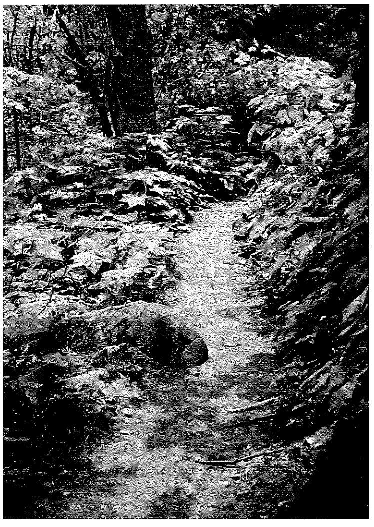


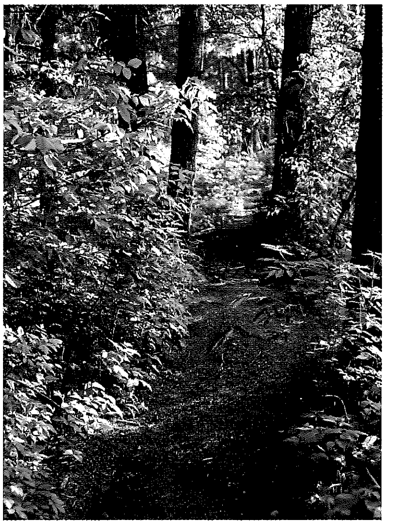
Terminus points and destinations can be historic or cultural (top) or a compelling natural scene (bottom) that entices a trail user to continue on.

The following provides a broader overview of each of the design elements shown in the graphic.

Landscape Anchors

Landscape anchors are any vertical site feature that visually help tie the landscape scene together in three-dimensional space to give it interest and balance. Anchors also serve as standalone points of interest that independently draw attention and provide continuity from one visual sequence to the next. Trees, rocks, signs, structures, hills, ridges, valleys, and other vertical features all serve as landscape anchors that can help integrate a trail into its site. Anchors coupled with other landscape forms give the trail its sense of flow and purpose, as the following photos illustrate.





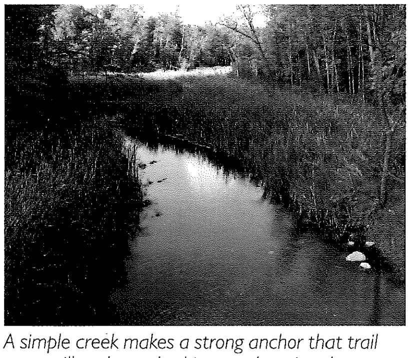
Anchors and the natural form work together. *These trails—for hiking, multiple use, and ATV use are well anchored by the trees and rocks around them. Note how the trails take their shape from their anchors. Trails that respond to and respect the site inherently appeal to the visitor's sense of balance and appropriateness. In the left photo, the rock is an anchor because it is incorporated into the trail tread. Also note the strong naturalizing and softening presence of natural shapes—even the paved trail gently curves as it tops the rise, guided by the naturally shaped edge of trees.*

Wrapping Trails Around Anchors

Wrapping a trail around landscape anchors refers to routing it to take direct advantage of site attributes. These attributes are used in three ways:

- **Visual cues** – the trail location is justified because the anchors gives the visitor something to focus on. Anchors give the trail a clear reason to be "here" instead of "over there," thus supporting the natural order that people find comfortable and to which they are naturally drawn.
- **Points of interest** – each tree, rock, slope, or other anchor is highlighted because the trail responded to it. Strategically placing anchors where they will be noticed enhances the user experience.
- **Engendering stewardship** – the more attention given to even subtle anchors, the more likely the trail will provide a compelling experience that visitors will cherish and ultimately want to protect.

Well-designed trails integrate landscape anchors into the design as a sequence of events, rather than a series of independent objects. Each feature should purposefully position the trail user for the next anchor. This is accomplished by controlling sightlines, changing the direction of the trail, and changing the sense of openness and enclosure to draw attention to different objects and views. The photos on the next page highlight this concept.



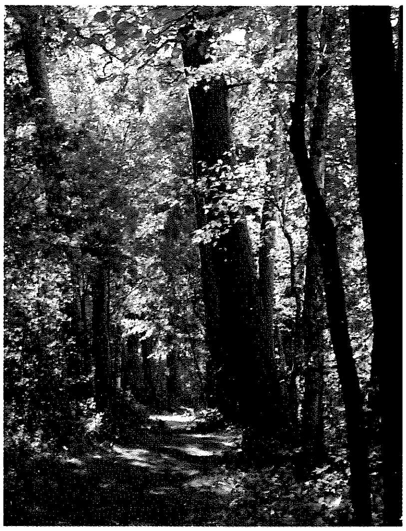
A simple creek makes a strong anchor that trail users will seek out. In this case, locating the trail crossing to take advantage of open views provides a pleasant juxtaposition with the forested character of the trail leading up to it.

Wrapping around anchors. *The trail clearly wraps around the trees, which anchor the trail and gives it a reason to be where it is. Also note that the first tree anchor sets up the sequence for the next one, and so on down the trail. A straight trail through this same area would not feel as anchored, and consequently not be nearly as inviting.*

Topography as anchor. *Cutting a trail into a sideslope firmly anchors the trail in three-dimensional space. The sideslope also provides the visual connection to the next anchor, which is the tree that forces a change in direction. As the cutslope and fillslope revegetate, the trail will seem like it has always been here.*

Anchors at Varying Scales and Spacial Contexts

Incorporating anchors of varying scales and spacial contexts adds interest and reduces repetitiveness of a trail segment. A simple tree anchors the trail right next to it. A major bridge anchors the trail in the vicinity and provides a visual cue in the distance. A small lake anchors the area around it and provides a destination. A large lake, river, or hill anchors the region around it. To register in our perception, though, an anchor must be visible. The design of the trail has to provide the visual cues to keep the visitor moving forward with a sense of anticipation – which can range from the very subtle to the dramatic. With anchors, size does matter, with larger anchors having much more effect.



(Left) Individually, the larger trees provide strong site anchors that draw the attention of the trail user. Combined, the trees also form a strong gateway. The lead-up to a site anchor is also important to creating a compelling experience. In this case, the large trees were slowly revealed as the trail user crested a hill.

(Above) A high-contrast anchor, such as this viewpoint, is very compelling and attractive to visitors. The deck helps anchor the trail and also uses natural shapes (segmented curves in lumber) to wrap around the large tree at right, which in turn ties the two together into a natural form. The raised, extended deck provides a vista through the trees, while at the same time discouraging visitors from leaving the trail.

Bridges, especially major ones, can anchor entire trail segments. Original railroad trestles provide enough natural shapes to be suitable anchors. The water is also an anchor on a landscape scale.

This dry-laid stone retaining wall anchors a trail segment and adds rustic natural shapes and new colors and textures to this asphalt trail. Vegetation overlapping the stones ties the wall into the site.

Contrasting Forms of Anchors

Anchors add drama and excitement by rising from the ground plane. They make the vertical dimension of three-dimensional space more tangible, enriching the experience. Using anchors with varying heights and dimensions provides contrast and keeps the trail more exciting.

The contrast between the boardwalk and surrounding wetland anchors the trail. Even the little tree is used as a vertical anchor that gives a reason for the trail's location.

Artificial forms can be effectively used as anchors to provide contrast and excitement.

A rock outcrop where a trail emerges from the forest provides contrast and drama, especially if it overlooks the surrounding landscape.

Anchored Trail Structures

All trail structures should be used to anchor the trail. The placement of any structure should be purposeful and add to, rather than detract from, the trail experience. Materials, size, scale, and visual relationship to the landscape are all factors in siting trail structures.

Anchors as Measurements of Progress

From the short distance to a tree to the main destination for the day, anchors serve as intermediate goals and measurements of progress. Even a place where the trail curves out of sight can provide enough contrast to serve as a distant anchor and a goal. Exceptionally strong anchors can be goals for an entire trip.

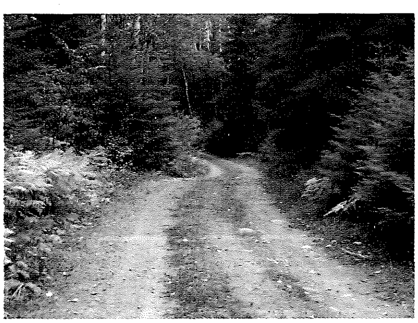
The curves, trees, and topography combine along this trail to draw the visitor along, wondering what is around the next corner.

In the foreground, each segment of a curvilinear trail provides a sense of progress, as does gaining on the distant city in the background. If the path were straight it would harder to judge progress.

The prospect of something at the end of this quarter mile boardwalk compels a visitor to continue on.

Strength in Combination

Multiple anchors create a stronger sense of place and a more grounded feeling than do single anchors. Also, a single anchor with many natural shapes or internal contrasts of color, texture, material, and size tends to be a stronger anchor than a single smooth one with few natural shapes.



Various vegetative forms to "push" this ATV trail in a new direction and to anchor it, providing a much more compelling experience than a straight ride through the woods.

This old trestle provides a strong, contrasting anchor that adds interest to the trail experience.

Artificial and natural anchors can be combined to create exciting experiences that leave an impression on the visitor, often providing the reason to return time and again to the same trail.

Strength of Natural Form

Anchors that have a natural form are the strongest and most harmonious. For example, gracefully aged structures and trees arching over the edge of a trail can provide an anchoring effect.

Where trails are necessarily straight, anchors are psychologically important. The tree in the foreground, the tall tree in the middle ground, and the woodland in the background are anchors by which progress is measured. The trees also anchor the trail to the ground plane and give it a reason to be here instead of somewhere else.

Edges

Edges are borders between landscape features or transitions between ecological systems. The trail itself creates edges within the site, one along each side.
Edges come in many forms and at a variety of scales. Examples include:

- **Land and water** – riparian edges, shorelines, and wetlands
- **Topographic** – edge between slope and more level ground, valleys, ridges, rock outcrops
- **Vegetation** – woodlands to grasslands and natural systems to ornamental landscapes
- **Wildlife** – transitions between one habitat and another (often with no visual indication) and migration corridors
- **Human-influenced** – borders between land uses, established fence lines, roadside edges, and highway rights-of-way

Edges often offer rich recreational opportunities for trails. Following or crossing edges enables the visitor to experience different aspects of the site in unison, making them very important design elements.

Edges Are Often Ecologically Rich and Sensitive

Many natural edges are ecologically rich and support birds, wildlife, and diverse plant communities associated with ecotonal areas. Riparian areas are especially ecologically sensitive. Even the unmowed right-of-way or property line along an agricultural field or developed area can exhibit rare or threatened native plant communities.

Because edges often have unique attributes, integrating them into a trail's design has to be undertaken with care and forethought so the trail experience can be realized within the bounds of acceptable impacts to the systems upon which it is imposed.

In sensitive ecological areas, the first course of action remains avoidance. If this is not achievable, the trail should be placed where the trade-offs between ecological protection and trail construction are acceptable. This can only be assured if an adequate assessment by trained professionals is completed and best practices protocols applied (as defined in this and other related guidelines) to protect the environment.

The following photos illustrate how trails have successfully taken advantage of edge situations.

Following edges. *Being near or adjacent to edges often enriches the trail experience. When the trail is on an edge, the contrast between the different realms on either side creates drama and interest.*

Importantly, the trail location must respect the ecotone (transition area between plant communities that is often very diverse) associated with edges, which can vary considerably in width as the photos illustrate. In the two top photos, the trail stayed close to the edge since the impacts to the existing ecotone was limited.

(Left) The trail stays on a rock outcrop to limit impact to adjoining natural areas.

(Right) An adequate buffer between the trail and riparian area protects the ecotonal area while still providing a rewarding experience.

Crossing edges. *Although being on the edge is dramatic, crossing edges – especially sharply delineated ones (left) – is often more dramatic. All bridges cross edges. Rocks in a tread can also be edges (right) – in fact, well-placed edge crossings are a mainstay of interesting and challenging trails. Many edges are more subtle, such as vegetative or topographic edges. In designing trails, finding ways to incorporate edge crossings can optimize their recreational benefit.*

Edges Can be Viewed as Long Anchors

Since edges typically have a vertical dimension, they also serve as landscape anchors. Larger edges, including hills, bluff lines, and large rivers or lakes, can anchor entire sites or even regions. Edges, like anchors, are most successful when they emulate the natural shape of the surrounding landscape.

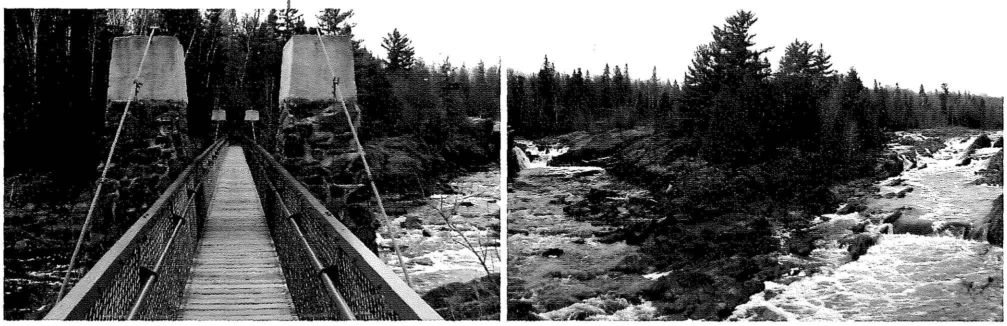
Creating Different Trail Experiences With Edges

As with anchors, a sequence of distinct areas and edges makes a trail more interesting and offer contrasting experiences, or at least noticeable changes. The more variety in the types of areas the trail traverses through – along with the more and varied ways in which the trail follows, approaches and crosses edges – the more interesting the trail.

Using Edges as Standalone Experiences

Use strong landscape edges, such as viewpoints, major lakes or rivers, and other lineal anchors, as stand-alone experiences along trails wherever possible. In some cases, changing the shape of the trail as it approaches these features can make a stronger statement and therefore make it more interesting to the visitor. For example, a winding trail through the woods up to a bluff line might abruptly change to a linear exposed edge that distinctly changes the character of the trail. The following photos illustrate some dramatic, stand-alone edges in the form of a viewpoint or vista.

Edges as viewpoints. *Views and viewpoints are highly attractive recreational amenities on any trail. Not only is the viewpoint a trail edge, but the view itself contains many more edges.*



Edges and gateways in combination. *This panoramic view leverages gateways and edges into a very compelling, standalone trail experience that visitors will return to many times.*

The trail experience can also be impacted by the relationship between an edge and a trail. The following photos illustrate this contrast both positively and negatively.

A weak edge experience. *The full beauty of this trail-side edge feature is diminished when the shape of the trail does not respond to the feature. Although ecologically sensitive areas such as this often force a choice between using an existing utilitarian roadbed or having no trail, it is still important to recognize that the natural shape of the trail—or lack of it—significantly affects the visitor experience.*

A strong edge experience. *This trail fully explores the character of this slope by becoming part of it. The trail is a naturally shaped edge anchored in the slope by its own earthwork and by the trees and vegetation. The trail takes the shape of the hillside as it curves around and, in so doing, (1) respects the slope, (2) echoes the slope, (3) gains natural shape derived from the slope, and (4) makes the visitor more aware of the landscape form.*

GATEWAYS

Gateways are created when horizontal or vertical clearances are suddenly constrained and noticeable. In the landscape, gateways are places where the trail is temporarily constrained on two or three sides—left, right, and above. A passage between two trees close to the trail can be a gateway, as can be a tunnel-like situation such as arching trees or an underpass. Gateways are often very distinct landscape features that, if taken advantage of, can add significantly to the trail experience.

GATEWAYS CREATE A SENSE OF PASSAGE

In longer or more significant gateways, sightlines may be constrained, the trail may significantly narrow horizontally or vertically, or the visitor may have to do something unusual (such as proceed with caution). The best gateways create an inviting, memorable, and unique sense of passage because of their shape, their size, and/or the anticipation of an upcoming new view. The trail design should take full advantage of these opportunities without compromising the safety of the user.

Natural shape + anchors + edges + gateway. *Arching trees shape a subtle but pleasant gateway on these diverse trails. In both cases, the trail emerges from shade to sun. The curves in the trails respond to the trees, the gateway view, and the many surrounding natural shapes nicely combine anchors, edges, and a gateway in a single spot. While most visitors would not find these places compelling enough to stop, they would nonetheless be positively affected by this type of peaceful, well-anchored experience.*

Gateways Are Anchors, and Sometimes Occur at Edges

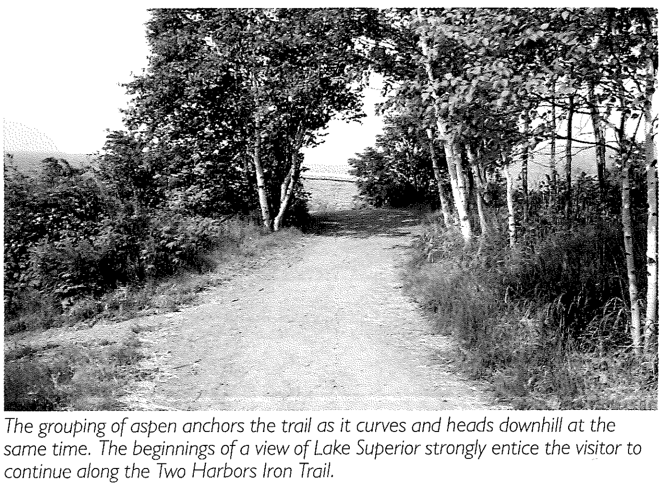
Since gateways confine the trail on two or three sides, they are routinely used as primary trail anchors. Gateways that are along an edge, such as a bluff line, can also make compelling anchors. Artificial and natural bridges are also common edges and gateways. The larger or higher the bridge, the more of a gateway it will be perceived to be to the trail user. Gateways that are formed by natural elements are especially appealing to trail visitors.

Gateways Can Be Attractive Places to Linger

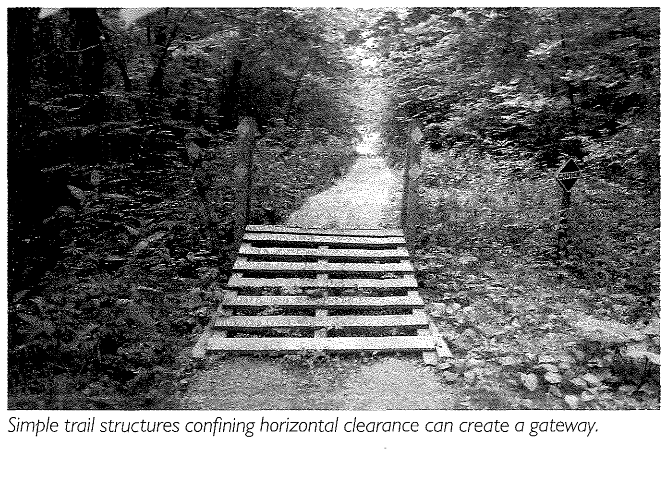
Well-anchored gateways at the juncture of multiple or spectacular edges, such as a bridge, can become destinations or places to linger. Since bridges are also edges and anchors, they are one of the few trail structures that can be an anchor, edge, and gateway all at the same time. The most popular bridges will also be designed with natural shapes and be supported by the natural shapes in their immediate surroundings.

Use Every Opportunity to Form a Gateway

It is rare to have too many gateways, and trails should be designed to take full advantage of them. Through good anchoring techniques and control of sightlines, gateways can add considerably to the trail experience. This also includes controlling the gateway effect of trail structures by using them to confine horizontal or vertical clearance. This is especially the case with constructed bridges, gates, and other forms of entryway.



The grouping of aspen anchors the trail as it curves and heads downhill at the same time. The beginnings of a view of Lake Superior strongly entice the visitor to continue along the Two Harbors Iron Trail.



Simple trail structures confining horizontal clearance can create a gateway.

A series of "tree tunnels" adds interest (and shade) to this straight section of rail trail, creating a more intimate experience. Although constrained on the sides, sightlines along the trail remain open.

A natural arch of trees frames a gateway between thick, shady forest and open, sunny fields, making for an inviting trail experience.

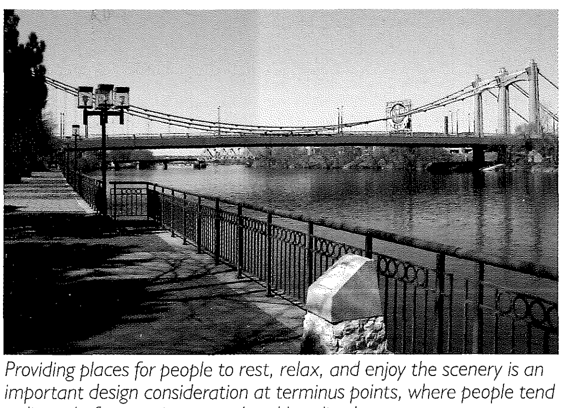
Simple anchors such as boulders and trees can form a gateway. As the crest of a small rise, the gateway is also a topographic edge.

Regardless of size, all bridges form a gateway—as well as anchors and edges. Bridges and boardwalks create a variety of visual and physical relationships, they are popular amenities on trails.

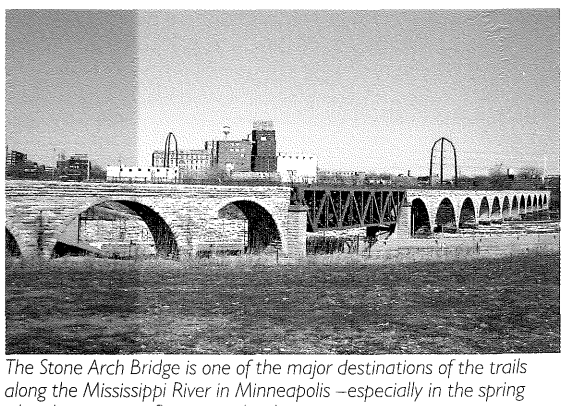
Overpasses and other low clearance situations create strong gateways. This gateway intentionally has an unobstructed view and an open, airy feel.

TERMINUS POINTS, DESTINATIONS, AND PLACES TO LINGER

Terminus points and destinations are distinct landscape features that have their own appeal and provide an endpoint or place to linger for those traveling down a trail. They can range from the dramatic, such as an overlook of Lake Superior or a major river, to the more subtle, such as a small pond in a regional park known for its wildlife. In any case, destinations and terminus points can have a profound effect on how often a person uses a trail. Wherever possible these points of interest should be integrated into trail routing plans.



Providing places for people to rest, relax, and enjoy the scenery is an important design consideration at terminus points, where people tend to linger before turning around and heading home.



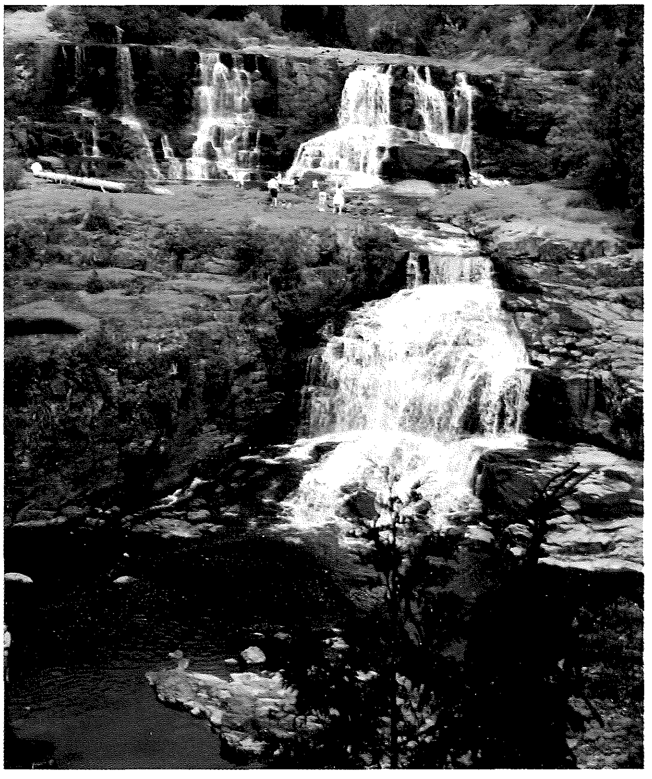
The Stone Arch Bridge is one of the major destinations of the trails along the Mississippi River in Minneapolis –especially in the spring when heavy water flows over the dam.

Dramatic natural scenes are common points of destination that entice trail users to go the extra mile. Taking advantage of these opportunities is always a top priority in trail planning. Notably, the scene can range from the subtle, such as a wetland, to the dramatic, such as a river view from a bluff.

Historic destinations, such as Forth Snelling, can be successful destinations for trail users, as long as there are provisions for securing bikes for tours.

Visitor centers, such as at the Mississippi headwaters in Itasca State Park, provide services that support the trails within the park, including concessions, restrooms, and gift shop.

Destinations can have a seasonal appeal as well, ranging from the fall color along a river valley to the drama of a waterfall during the springtime. These features have a universal appeal and should be integrated into the trail experience with a sense of intrigue.

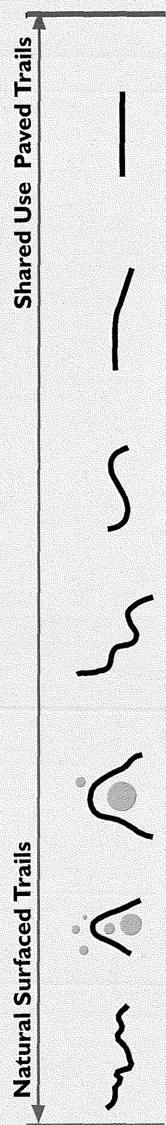


Tying Design Elements Into a Sequence of Events

The connecting link between individual design elements is the trail itself. Its form is very important to creating a trail that offers high recreational value relative to its setting and type of use. Understanding the emotional response that various shapes induce is important to designing trails that successfully make the trail part of the larger landscape experience. The following box illuminates the emotions induced by various trail shapes.

Emotional Responses To Trail Shapes

In general, the following shapes induce predictable emotional responses:



Straight:
- Ordered and obvious
- Practicality of point-to-point travel is the main concern
- Straightness overrides nature forms
- Utilitarian character, entices limited emotional response
- Encourages fast travel
- Predictable, with heavy reliance on adjacent scenery for visual appeal

Rather straight, or straight in segments:
- Direct and practical, but with some acknowledgment of natural features where it curves for an obvious reason
- Feels arbitrary if it alternates between curves and straight sections for no apparent reason (consistency of form is an important design principle)

Constant radius curves:
- Urban over natural character
- Geometric and less tied to natural forms
- Pattern associated with long-distance travel

Gentle, flowing curves (but not constant or all similar):
- Relaxed, supportive, passive
- Allows travel at many speeds
- Flowing curves exist for apparent reasons in response to the landscape
- Settled, harmonious feel, especially if well anchored in the site

Sharper anchored curves:
- Balance is tipped toward yielding to nature
- Site is dominant over trail, although if curves are not anchored it feels like a manipulation

Very abrupt curves, anchored:
- Forceful, must yield to site
- Entices visitor to look for shortcuts, including cutting switchbacks

Natural shape:
- Nature based, wild, uncontrived, self-anchoring—the essence of nature itself
- Often considered the master shape because it entices a variety of emotional responses

Common Associations Between Trail Shape and Type:

Trail users have predictable expectations regarding the most appropriate trail shape for a certain type of trail.

In general, geometric forms are most often associated with shared-use paved trails, with natural forms most associated with natural trails.

The more consistently a trail adheres to these expectations, the more highly regarded it will tend to be to the user seeking a particular experience.

Selecting one trail shape over another is a conscious design decision that purposefully entices a particular response from the trail visitor. In an urban setting, where the trail often responds to the built environment, a straight or constant radius curve shape may be appropriate. In a regional or state park, a natural trail shape would have the highest merit to be in sync with the natural landscape. For any trail to be successful, its shape must be consistent with visitor expectations and be laid out in response to and in harmony with the surrounding landscape.

Weaving a Trail Into the Site

The concept of "lying lightly on the land" is applicable to trails. The more a trail seems to fit into the landscape, the better it will be received by the visitor.

The most successful trails are "woven" into sites with topographic shapes, anchors, edges, and gateways are all seamlessly integrated to create a rich trail experience. The art of trail design is reacting to the site rather than simply running a trail across it. This requires attention to detail, especially as it relates to the placement of anchors in relation to the trail tread.

Placing Anchors for Effect

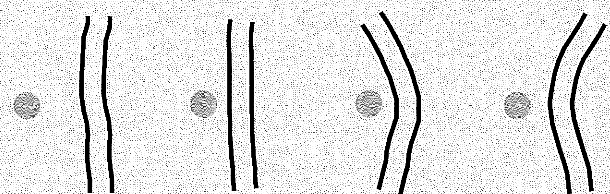
The more obviously the trail wraps around a feature, the more the feature is highlighted. Trees, rocks, hillsides, water features, vegetative edges, and other elements are highlighted by consciously using them as design features and purposefully controlling how the visitor interacts with them. For example, using a tree to anchor a curve focuses attention on the tree, however briefly, making the tree an integral part of the trail experience. The extent to which it is highlighted is directly relative to its placement, as the following box illustrates.

Itasca State park, Dr. Roberts Trail

The tree becomes part of the trail experience by being used as an anchor.

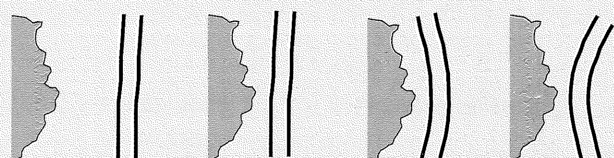
Effects of Anchor Placement

Anchors have different effects in different layouts......



Weak anchor due to its distance and lack of response by the trail	Stronger anchor by proximity, but trail does not respond to the anchor	Strong anchor because trail wraps around it	Strong anchor because the trail approaches it – with the anchor in the sightline

The same affects holds true with edges......



Weak from distance	Stronger by proximity	Strong by wrapping	Strong by approach

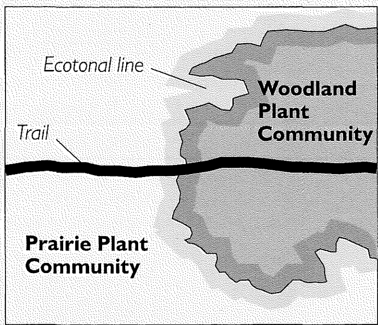
This naturally shaped segment of the Harmony–Preston Valley State Trail is enlivened by the way it follows and crosses varied prairie, woodland, and agricultural edges. In the foreground, the trail is cut into the slope at left. Note the richness of the varied tree edges and anchors.

Using Edges to Create Varied Trail Experiences

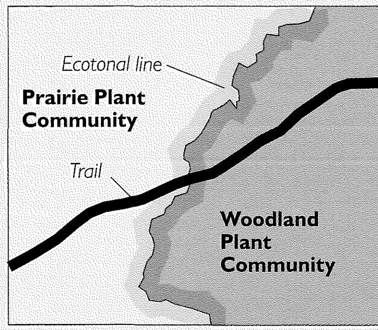
Following, approaching, and crossing edges in different ways create different trail experiences, as illustrated in the following box.

Following, Approaching, and Crossing Edges

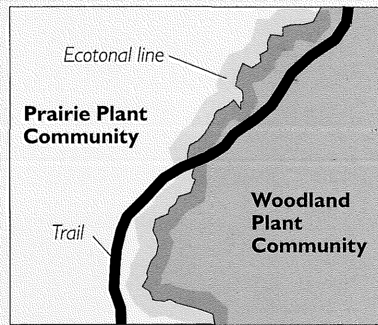
These examples show various ways a trail can interact with a woodland/grassland edge. Note that ecological impacts need to be considered anytime an ecotonal area is impacted by a trail, either running along it or crossing through it.



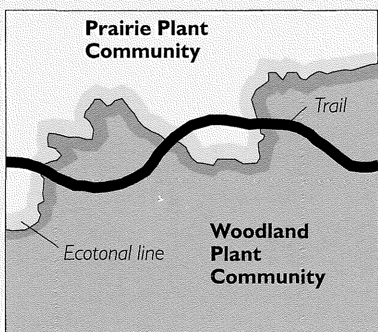
Head-On Crossing: Abrupt maximizes the feeling of sharp contrast or efficiency



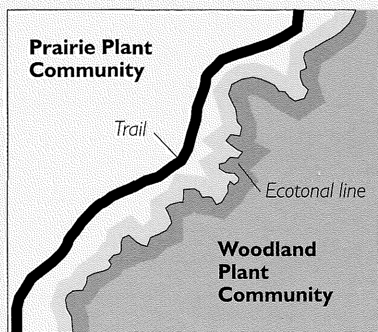
Approach and Cross at an Angle: Softer than a head-on crossing, feels more relaxed and gentle



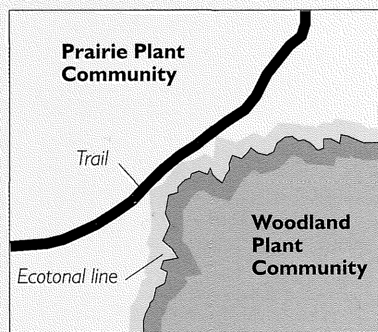
Follow Edge on Both Sides of Crossing: Creates pleasant and anchored sense of anticipation that is satisfied at the actual crossing



Cross the Same Edge Repeatedly: Creates dynamic excitement and feeling of rapid change, feels well integrated into the site



Follow Without Crossing: Respects the edge and is anchored by it



Skirt in One Place: Commonly used where a sensitive area is on the no-trail side of the edge

In general, avoid bisecting open areas, such as grasslands, where possible because this is generally not as interesting as other alignments. (Exceptions are when the area is large enough that the visitor cannot define a particular edge, or when there is a defined purpose to do so.) Working with edges will keep the trail flow more in sync with natural land patterns. Staying near an edge, and perhaps crossing it occasionally, will also create a much more compelling visitor experience. An important qualifier to trails along edges is the need to avoid unnecessary impacts to sensitive ecotonal areas. Careful placement of the trail is vital to providing a compelling trail experience while still protecting the landscape.

Using Spur Trails to Sensitive Areas

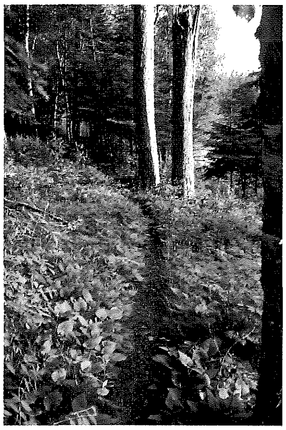
In highly sensitive ecological areas, using spur trails can reduce impacts to ecotonal areas by reducing visitor traffic. Whereas the main trail carries all trail visitors, spur trails only carry those interested in a particular site feature. In many cases, the trail can be narrower, slower, and have more varying natural shapes than the main trail. The type of uses allowed on it can also be limited.

A short spur off the Superior Hiking Trail at Alfred's Pond, this narrow boardwalk crosses a rare floating bog. The boardwalk is built in hinged sections like a boat dock to fluctuate up and down with the floating bog. Although a spur trail per se, several miles of the Superior Hiking Trail were purposefully aligned to access this pond and provide this experience to visitors. Its remote location several miles from a trailhead keeps usage relatively low.

Seeking Out the "Places Beyond the Ordinary"

Nature occasionally combines shapes, anchors, vegetation, color, texture, and other aspects in particularly pleasing ways. These "places beyond the ordinary" stand out as being more interesting or visually appealing than the majority of the site. For example, in a forest, a few large trees or a rare rock outcrop may create places beyond the ordinary for that site. Even in a spectacular setting, some places are more interesting than others.

Places beyond the ordinary tend to be well anchored to the site and contain strong natural shapes. They can range in size, from the single unique plant to a grand vista. On many sites, capturing diminutive features that make a trail interesting is the most challenging aspect of trail design. But, paying attention to the details does matter.



Places beyond the ordinary can range from the intimate details of vegetation and rocks along a trail to the grander views at a well-placed overlook.

Influencing Visitors Through Design

In trail design, the best way to influence visitors' actions is to make sure the trail is well anchored and interesting. People inherently gravitate toward visually appealing trails offering a physical challenge consistent with their expectations. If the trail does not meet expectations, people will often simply create their own "social" (informal, non-designated) trails that give them the experience they want. The following provides an overview of some useful techniques to influence visitors' trail use.

Develop Longer Trails Within the Same Site

If a trail is primarily for recreation, the efficiency of getting from one point to another is not the primary concern. Winding the trail more tightly within the site and taking the time to find and use site anchors and edges can increase trail length and hence the amount of time it takes to travel.

In an urban setting, hardscape can be used to reinforce where trail users should be. Texture changes, bollards, and retaining walls are some of the features that can be used to control flow while actually enhancing the experience.

Use Visual Anchors to Reduce Temptation

Where visitors may be tempted to go off trail, topography, vegetative screening, hardscape, and trail alignment can be used to prevent undesired sightlines and access. If the tempting area cannot be hidden from the trail, anchors can be used to screen the view and make it seem unnatural to enter.

Control Travel Speed Through the Use of Curves, Clearance, and Sightlines

Shaped curves and limited clearance and sightlines will tend to reduce travel speed. Sightlines should be long enough for safe travel at design speed but no longer. In particular, long, straight segments with wide clearances, long sightlines, and smooth treads tend to encourage faster travel for wheeled uses – which is fine if the trail is intended for that purpose.

A thin strip of trees and brush screens a small wetland from a motorized trail. Although the wetland is visible from the trail, entry feels barred by the well-anchored vegetation. The stronger the anchors, the more entry feels unnatural and the more effective the barrier.

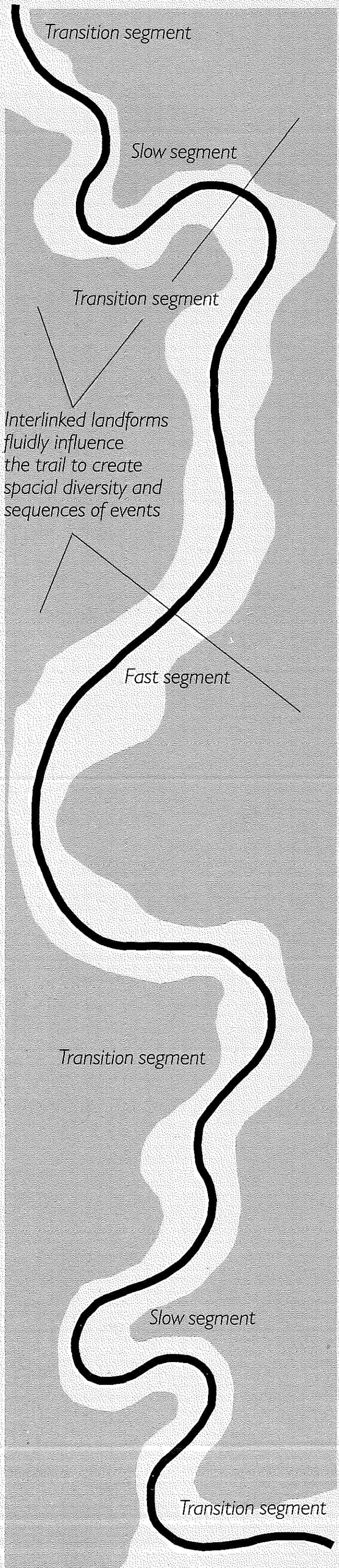
With natural trails, surface roughness and frequent changes in direction through natural shape – preferably in all three dimensions – also helps control speeds. A high tread texture is formed by:

- Rough and irregular tread surface
- Frequent tread dips and crests
- Native or imported rocks

Any combination of these tread textures tends to improve sustainability of natural surface trails and encourage slower speeds for most types of uses.

Trail Flow

Trail flow is a function of thoughtful design and should not be left to chance. The most successful designs are those that respond to the landforms and create a sequence of events using anchors, edges, gateways, and terminus points/destinations.



Shaping Trail Flow to Be Engaging And Fun

Like well-orchastrated music, a well-designed trail is perceived by the user as a sequence of experiences across time layered with feelings created and changed along the way. The order of experiences along the trail defines the sequence. The timing between experiences determines the rhythm. Feelings come and go with the shape of the trail and how well anchored it is. Together, sequence, rhythm, and spacial diversity create a flow to the trail – the overall sense of appeal from one segment to the next. The more intimate the trail experiences, the more the trail feels anchored to the site. The more engaging the trail feels, the more pleasing its flow. *Flow is predictable,* and – like music – can be designed to appeal to different tastes and moods.

Anchored design is the toolbox for creating trail experiences. All anchors, edges, gateways, and terminus points form trail experiences and are part of trail flow, as are tread patterns and trail grades, curves, drainage crossings, structures, signs, fences, and anything else of note.

Actively Designing a Sense of Flow into a Trail

Trail flow can be formed by happenstance or through purposeful design. Trails designed by chance (i.e., drawing a line on a map and building the trail accordingly) often show little regard for sequence, rhythm, or visitor feelings. Whatever occurs happens by default. Too often, many trail experience opportunities are missed. Trail scale and the impact of repeated use are often not seriously considered. The result is that the sustainability of the trail is questionable from the start and engendered stewardship is often very low. The trail experience falls short of its potential.

Actively designing flow into a trail takes advantage of the opportunities for creating interesting and varied sequences and engaging rhythms to the fullest extent. A variety of emotional responses are evoked by the site, how the trail responds to the site, and how the visitor responds to the trail. In establishing trail flow, the type of use is a major factor since what works and feels right for one use may be entirely inappropriate for another.

Within the realm of sustainability, trail flow is created by:

- Optimizing individual anchors, edges, and gateways to be strong, weak, or neutral as part of overall flow
- Aligning the trail to travel through and explore different aspects of the site
- Intentionally using landscape forms as the basic shape of the trail
- Considering flow in forming grades, curves, sightlines, clearance, drainage crossings, and trail structures
- Constantly querying what type of emotional response is desired as the trail is being designed:
  - Is this alignment awkward? Does it flow?
  - Is something needed here to create a statement?
  - Does this fit better here or over there?
  - Has it been too soon or too long since this was last done?
  - Has this been done or seen before?
  - Is the sightline leading visitors along the trail, or is it leading them somewhere else?
  - Does the site support this feature, or does the feature fight the site?
  - Does this feel too contrived?
  - Would a visitor shortcut or bypass this feature?
  - Is this too sudden or too difficult?
  - What could be done instead?
  - Is this going to cause excess uncertainty, braking, or acceleration in one spot?
  - Could this be done more simply?

The many nuances of trail flow can be used to build a predictable emotional response into the trail experience. Trails can be shaped to be fast, slow, challenging, easy, graceful, jerky, peaceful, contemplative, direct, utilitarian, elegant, inspiring, and much more. Thoughtful trail design helps ensure that the type and intensity of the emotional response will be in sync with the trail setting and the expectations of the user. The photos on the next page highlight trails with good flow.



With natural trails, rolling grade design is the primary tool used to create trail flow and sequencing. As each of these trails illustrates, the simple act of walking or riding down a trail can be greatly enhanced when forethought is put into creating an experience versus simply placing a path on the ground.



Although different design techniques are used with paved trails, a sense of flow and connection to the setting is as important as with a natural trail – whether the trail is located in a large natural park area or in an urban core. Intentional design does matter if the value of the trail is to be maximized.

INTEGRATING STRUCTURES INTO TRAIL DESIGN

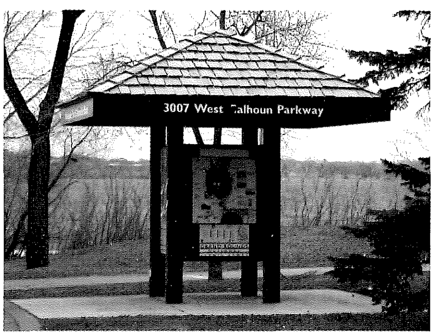
Structures can add to or destract from the trail experience. To be harmonious, structures must be designed to fulfill the intended purpose *and* add to the character of the trail. The design quality, construction materials, and maintenance of structures are statements to visitors about the trail's value as a public amenity. The more a structure adds to the quality of the trail experience, the more a visitor will appreciate its value and see it as an amentity for which to care.

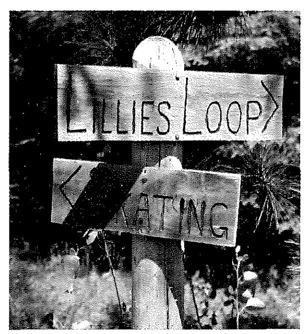
The most important guideline for a harmonious structure is making sure that it is needed in the first place. Each structure should serve a well-defined purpose and contribute to the trail experience. Ill-conceived, poorly designed, and incongruent trail structures take away from the sense of place and trail context.

HARMONIOUS STRUCTURES ARE CUSTOMIZED, SIMPLE, AND CHANGE WITH THE SITE

To be harmonious, every trail structure must be customized to fit the site and setting. Whether a sign, bench, trailhead kiosk, or visitor center, the type of materials, design character, and visual prominence all must be consistent with the desired trail experience. As an example, the type of materials and design character of signage and benches along an urban trail will be distinctly different from those found along a nature trail in a state park. Although standardization of materials and design has its merits, structures have to be in harmony with the trail context for them to add to the visitor experience.

Signage is one of the most visible built forms associated with trails. Being in harmony with the setting is important to the maintaining the sense of place. As the photos illustrate, an urban setting requires a more refined approach, with incrementally more natural settings requiring an increasingly more rustic approach.



As with natural landscape features, structures should be purposefully used as anchors to elicit a specific response from the trail user. A deck overlooking a pond, a bench aside a small creek, a trail sign at the end of a long loop all should be designed and placed with a specific intent in mind. Incongruent structure design and placement is a detraction from the trail experience and should be avoided.

Simple designs for trail structures tend to be the most harmonious with the landscape. This is especially the case with trails in natural settings, where visitors are seeking escape from the built environment and are most interested in viewing natural landscapes. In these instances, the success of a structure lies in how well it serves its purpose without detracting from the visual context and immediate sense of place.

Changes that are likely to occur to a trail structure should be anticipated and planned for. The effects of general use, weathering, and vegetation all warrant consideration during the design stage to ensure that the structure will last. In natural settings, this favors natural materials such as wood and stone that gracefully show their age.

Structure designs should be in keeping with the setting and used as anchors. Ranging from the bold (left) to the simple (right), structures can be visual cues that add interest to a trail experience.

Harmonious Structures Are Sturdy and at a Human Scale

To be harmonious, structures need to look and feel strong enough to be sustainable. Making sturdiness visually evident often requires using thicker materials than may be structurally necessary. Even though some materials, such as wood, need to be replaced in time, they are still often favored where they are most in keeping with the trail context.

Human scale refers to using materials that visitors can comfortably see and touch. Individual components that are too large or too small work against harmony, as do components with large surfaces without visual variety. Large surfaces, such as concrete foundations, retaining walls and bridge decks, feel more harmonious when color, texture, or lines visually break them into components at a more human scale.

The structures used at this trailhead for the headwaters of the Mississippi River in Itasca State Park provide a visitor context and sense of entrance in keeping with the sense of place and uniqueness of the experience. The right materials, size, and scale can enhance the visitor experience.

Design Character and Styles for Trail Structures

The design character or style of trail structures is directly influenced by the sense of place exhibited by the site. Structures should be consistent with the context to avoid creating a visual distraction for the visitor. The following considers several different styles for trail structures.

Rustic Style for Remote Areas and Wilderness Settings

In remote or wilderness areas, a rustic style with simple design features that emulate the natural setting is common practice. In these settings, the key principle is to preserve the sense of place and avoid creating a distraction from the innate trail experience.

The use of natural materials for structures prevails in these settings. For example, rough-hewn logs and thick, rough-sawn timber are common materials, as is indigenous stone. The use of waney-edge timber (with bark left on some corners) is also common. Hardware is often heavy-duty steel. Construction techniques are often unrefined, with nothing being absolutely straight, square, or regular. Most components of a structure are not larger or heavier than could conceivably be moved without heavy equipment.

The use of irregularly shaped logs, rough-edged (not square) cut ends on timber, and irregular lengths promotes a more rustic character than mitered joints. On bridges and boardwalks, the deck itself can have variations in level. The use of uneven ends provides a visual break along long straight sections. Using an asymmetric or natural shape for the entire structure is also common, especially if it wraps around an existing anchor such as a series of boulders or trees. Below-ground or ground-contact structures are typically dry-laid or mortared fieldstone. The more anchored the structure is to the site, the more harmonious it feels to the visitor.

This timber boardwalk is simultaneously an anchor, edge, and gateway.

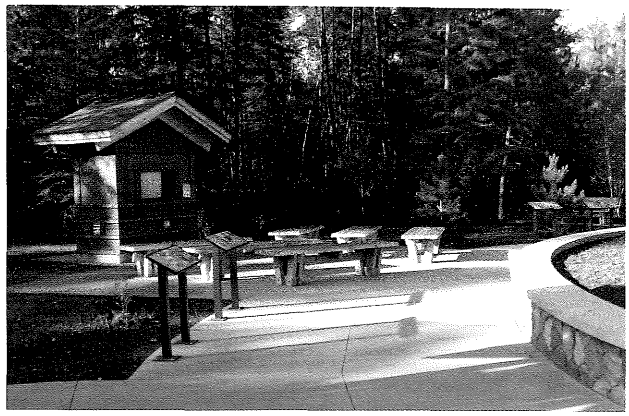
Slightly irregular ends soften the bridge rectangle and vegetation anchors the ends.

Thick timber posts, thinner rails, nonsquare ends of posts and rails, and overlapping joints are rustic elements of this pedestrian bridge. The objective of rustic structures is to create a relaxed, natural character by avoiding straight or curvilinear lines, allowing rough materials to shape the details of how parts fit together.

Natural Style for Rural, Natural, or Agricultural Settings

Natural style contains many of the same design elements and materials as rustic style, only in a more refined application. In natural-style structures, thick, rough-sawn timber and lumber is often combined with steel, stone, concrete, or masonry to create an appealing form that is consistent with the setting. The character of the structures comes from the texture of materials, overlapping ends and visual breaks in long lengths, irregular edges, and occasional curves or dogleg segments. Salvaged or reused materials are also often used, especially those that are weathered or otherwise have a harmonious natural character.

Since materials may be less natural than in rustic construction, designing natural shapes into the structure and anchoring it in the site are very important for harmony. Topography, rocks, large trees, vegetation, or combination often anchor natural-style structures to the site. Planted vegetation is often used to anchor the points where the structure touches the ground. Allowing unpainted materials to weather is also common.



The natural style still relies on natural materials, but uses them in a more refined fashion in keeping with the setting. Adding simple design details provides trail users with additional visual cues that add enjoyment and sense of comfort with the surroundings. Maintaining a human scale is important to avoid overpowering the setting.

The sturdy, rough-around-the-edges character of converted railroad bridges and trestles are typical examples of rural style.

Refined Style for Suburban or Urban Settings

A more refined architectural style is appropriate for structures in suburban and urban settings. Although still at a human scale, a higher level of detail design is often used to create visual appeal beyond its utilitarian function. Well-designed structures in these settings become key site anchors that add to the trail experience.

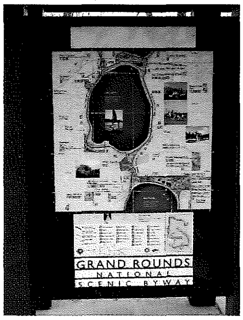
A wide variety of materials are appropriate for structures in suburban and urban setting. Almost any material can be used if it is in keeping with the surroundings. Tastefully combining multiple materials, textures, and colors can create harmony and appeal. For example, a trail bridge may have a concrete foundation with a facing or inset of native or cultured stone. Painted metal railings may have a wood handrail to soften the feel. A concrete deck may have insets of pavers to add visual and tactile texture. Native stone retaining walls may be used to help anchor the abutments.

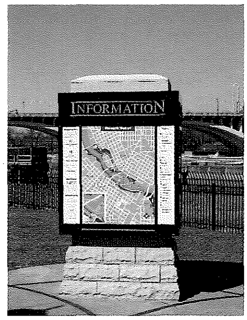
Structures such as bridges can draw attention to themselves as community features or amenities. Their visual contrast can be increased through use of color and strong or unusual forms, textures, and shapes that complement the setting.

Larger structures in nondramatic support roles, such as retaining walls, should not draw excess attention to themselves. Breaking longer lines and adding visual and/or tactile texture to larger masses can soften the visual impact of larger structures. The use of natural shapes and anchoring techniques to blend and ground the structure into the site is also common.

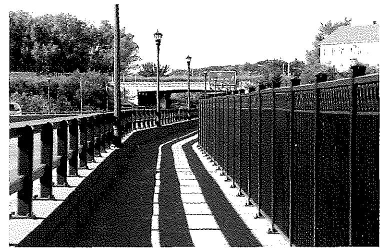
Paints and stains can help integrate the trail into its surroundings. Even touches of bright color can be quite festive and effective, adding to the recreational spirit of the trail. Touches of decoration may also be appropriate, especially if they add human scale to an urbanized setting. In industrial areas, trail structures can use bright colors to stand out from the more subdued surroundings.


Suburban and urban style should complement or improve the character of their surroundings. Representing the higher end of development, this pedestrian-bicycle underpass (left photo) with glacial granite facings, seating wall, and landscaping carries the trail under the main street of a resort town. With well-placed design features, the underpass is anchored to the site and becomes an amenity rather than a distraction. A simpler, yet appropriately detailed, underpass in a suburban setting (right photo) provides a much more appealing site feature than a basic concrete box culvert.





A more ornate and detailed approach to signage and monumentation is also common in urban settings, especially when it plays upon a historical theme.

Suburban and urban style is often reflected in the details of bridges, fences, and barriers. This bridge (left) purposefully juxtapositions itself against the natural character of the stormwater retention pond it crosses to better anchor the trail in its urban context. Ornamental railings (right) add visual appeal to this otherwise heavily trafficed thoroughfare. The apparent material strength is used to convey to the user that the corridor is safe even though traffic is but a few feet away.



The urban context can take many forms, ranging from a riverfront walk with a concrete-bordered trail (left), to a comfortable relationship between a trail and an apartment complex where the corridor is limited (middle), to a pleasant walk along the shores of Lake Superior. When naturally compelling scenes are not available to anchor the design, visual cues have to be created through design.

Design Elements for Trail Structures

With trail structures, design details matter. This is true of rustic style, natural style, and refined style. Even though a structure may be simple, the design should still be purposefully considered to elicit a positive response from the trail user. The following pages provide some additional examples of design elements that illustrate how the character of structures can add value to the trail experience.

Design Elements: Integrating Structure Shape and Site

Site anchor or incorporated anchor. Where feasible, the structure should connect to, wrap around, or incorporate anchors. The more anchored the structure, the more in harmony it will be with the site.

Example: A boardwalk bends around a tree.

Alignment on curve. This allows a trail user to visualize the structure from different angles on approach. As the sightline changes, so does the sense of anticipation, making the structure more of an interesting experience.

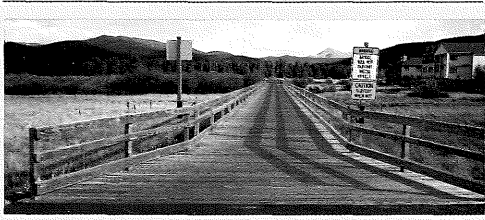
Curved, articulated, or natural-shaped structures. These shapes add intrigue because the sightline keeps changing, making the experience much richer. Each curve or joint also anchors the structure to the site at that point, especially if the site provides a good reason for the articulation to exist.

Examples: A curved or articulated bridge with handrails (top), boardwalk with wooden curbs that reinforce the edge (near right), and rustic boardwalk in a more remote location (far right) incorporate intrigue into design.

Itasca State Park, bike/snowmobile path

Flared or angled end. Abutments or approaches to bridges and boardwalks can flare out to welcome and guide visitors onto the structure.

Example: The flared ends on this bridge at an intersection with a path invites users and accommodates natural walking patterns.



Varying width, height, and/or thickness. Transitions in the size and shape of a structure can add considerably to its design character.

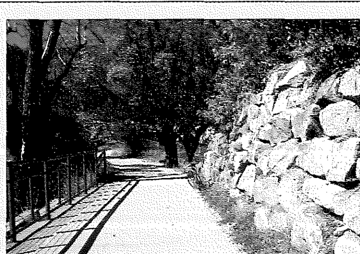
Example: Part of a boardwalk can be widened to encourage visitors to linger, or railings can be different heights to create a more natural character to a bridge or boardwalk.

Overlapping ends. Structures often better integrate with the site when some parts overlap onto the area adjacent to it.

Example: Railings extending beyond the bridge anchor the structure more directly to the site.

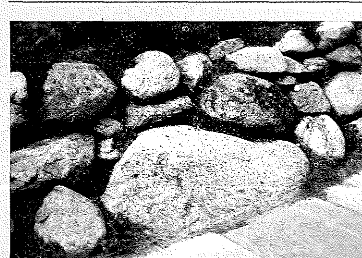
Flared base. Walls, piers, abutments, and vertical elements often feel more anchored when they flare outward at the base. A natural example of this is a large tree that flares as it approaches its base. A flared base is an essential design element for trail structures.

Examples: The visitor center at Itasca State Park (above) uses a subtle flared base, with the bottom below the diagonal log brace flaring more than the upper section. This helps create the feel of strength and stability. The retaining wall (right) leans into the hillside, which anchors it and keeps it from being too imposing.



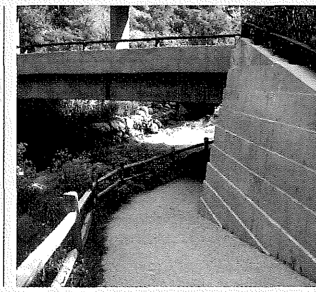
Stone on or below grade. Stone makes for a very strong and permanent connection to the ground. Stone is preferred in rustic locations, although concrete and like products are common in less rustic and urban settings.

Example: This stone retaining wall performs well and suits the rustic setting.

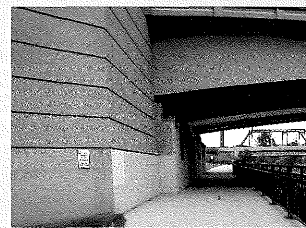


DESIGN ELEMENTS: COMBINING STYLE AND FUNCTION

Differentiated large surfaces. Large blank surfaces (bridge abutments, underpass walls, concrete retaining walls, etc.) are blank canvases that tend to attract vandals. To create more visual interest, preserve a human scale, and reduce vandalism, these surfaces can be broken or differentiated by bands of color, inlaid bands of stone or brick, stone facing, staggered levels, painted murals, or other similar means.



Examples: (Top left) Concrete wall with flared base formed by molding narrow ziggurat-like steps is attractive and anchored. The concrete is also painted. (Top right) Vertical fluting is form-molded into this retaining wall. Note the shadow line created by the horizontal inset band below the top of the wall. (Bottom left) On the Sakatah Singing Hills State Trail, concrete with thickened edges and molded imprints is painted in two colors. The partial facing is cultured stone made to look like regionally native limestone. (Bottom right) Horizontal lines molded into highway bridge abutments breaks up the visual mass. This abutment also has a slight flared base.



Natural shaped edges. To accentuate natural shape, edges can be left rough or irregular. The more rustic the setting, the more appropriate rough edges are on structures.

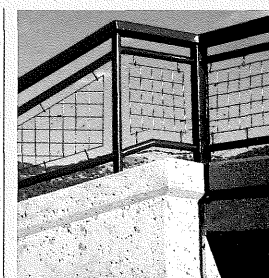
Example: The edges of this rustic boardwalk are irregular, with boards cut at slightly different angles and slightly different lengths. The unrefined look emulates the character of this trail.

Shadow lines are desirable design details on most structures. Typically horizontal, shadow lines are created when a horizontal surface cantilevers over a vertical face.

Example: Sunlight casts a moving shadow on the vertical face of the stringer. This creates an interesting articulation in the structure and a source of added depth.

Thickened edges. The edges of walls and decks have a stronger and more anchored feel when they are thicker than the rest of the structure. Thickened edges also often create interesting shadow lines.

Examples: (Left) A thickened edge caps this concrete wing wall and bridge deck. (Right) Edge bumpers on the boardwalk accentuate the trail.



DESIGN ELEMENTS: USING THE CHARACTER OF MATERIALS

Multiple materials, textures, and colors. A variety of materials can be used in combination to enhance the character of a structure. For example, stone-faced concrete abutments, glulam timber stringers, a rough-sawn wood deck, a steel or smooth wood railing, and an asphalt or stone-hardened trail on the approaches add a compelling structural and visual appearance to a bridge.

Examples: (Top right) Concrete (painted two colors with molded texture), black painted steel railing, cultured stone facing, and shiny metal letters add to the appeal of this bridge. (Bottom right) Stones anchor the simple wooded bridge both physically and visually. (Bottom left) Wood, stone, steel, water, earth, and vegetation create a compelling anchored design for this bridge.

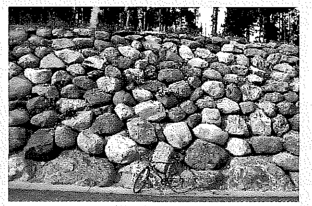
Heavy-duty hardware. Used as an integral part of structures, hardware also can add strength and character.

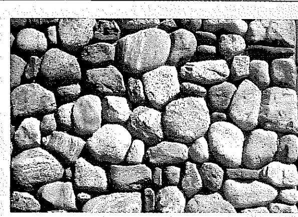
Example: Heavy-duty hardware used to join heavy materials gives a sturdy feeling to this bridge railing.

Design Elements: Using the Character of Materials (continued)

Stone structure or facing. Stone is very appealing and the most durable material available for trail structures. Field, quarried, or cut limestone or granite is commonly used and very appropriate where the stone types are found. In central and northern Minnesota, loose glacial or river-rounded granite is common. Round stone is commonly mortared into structures or used unmortared for retaining walls. Round stones also make an excellent facing for structures such as bridge abutments. Stone can also be used as a decorative inset or as pilasters. Cultured stone (cast from molds) can also be used to create a compelling architectural statement.

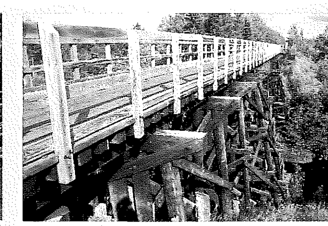
Examples: (Left) This mortared stone abutment uses rounded fieldstone. (Middle) Dry-laid rounded fieldstones form a retaining wall. (Right) Rounded cultured stones provide a stone facing on a retaining wall.





Thick lumber and timber. The scale of an outdoor setting calls for heavier lumber to give the appropriate weight and character. Full-dimension lumber and timber for decks and posts lasts much longer and feels much more appropriate than standard finished stock.

Examples: (Left) Full-dimension lumber looks and feels solid underfoot and lasts long. (Middle) Heavy lumber can also be used for trail stabilization in select locations, as is the case with this ATV trail. (Right) Heavy timber railroad bridges make excellent trail bridges.



Materials for Trail Structures

Wood

Favored for its intrinsic natural shape, feel, versatility, workability and relatively low cost. Types of wood include:

- **Log.** Rough-hewn or peeled
- **Timber.** Usually rough-sawn
- **Full dimension lumber.** Rough sawn
- **Standard dimension lumber.** Typically S4S (surfaced four sides)
- **Glulam (glued and laminated) wood.** Girders, lumber, and panels, custom made in a wide variety of sizes and lengths
- **Salvaged or reused wood.** Bridge or trestle timbers, utility poles, wood from other structures
- **White oak.** Rot-resistant; used rough-sawn for a rustic, naturally weathered look

Most woods need preservatives for longevity. Use nontoxic or less-toxic preservatives where feasible. Some wood preservatives use oils and other agents to impregnate wood with brownish colors for a more natural look. Creosote is not recommended for new construction.

Wood finishes

- **Stains and paints.** Rarely used except in developed areas
- **Boiled linseed oil.** A thick, all-natural sealer for above-ground use; requires periodic reapplication; initially orange, it turns matte dark brownish-gray in humid conditions or on the shady side of structures

Steel

Used where high strength is needed. Handsome and rugged when combined with wood.

- **Wide variety of cross sections.** I-beam, angle iron, tube, square tube, etc.
- **Salvaged or reused steel.** Road bridge trusses, parts, and girders should be repainted before reusing

Steel finishes

- **Weathering.** Rust patina protects against further rusting, requires no maintenance
- **Primer and paint.** Requires occasional repainting
- **Plating.** Zinc-plated or galvanized for rust prevention.

Poured Concrete

Used for structures such as foundations, piers, abutments, retaining walls, drainage structures, and tread. Finishes include:

- **Transverse broom finish.** Standard, nonslip texture for concrete
- **Saw-cut joints.** Used for contraction joints in continuous tread pours; creates a smoother tread than troweled joints
- **Form liners.** Concrete molds lined with patterns to cast a relief in poured forms; an attractive way to add texture
- **Concrete stamping.** Flexible mats with a pattern are pressed into the floated faces of slabs while still wet
- **Leaf embossing.** Live leaves pressed into wet floated concrete to create a subtle pattern
- **Exposed aggregate.** Floated surface of partially cured concrete blasted by high-pressure water to expose aggregate
- **Tinting.** Tint mixed into wet concrete; difficult to match color later for repairs
- **Staining.** Can closely match weathered stone
- **Paint.** For non-horizontal faces.
- **Texture paint.** For nonhorizontal faces, provides texture as well as color
- **Facings.** Natural or cultured stone or brick on all or part of the concrete; multiple facing materials can be used on the same structure
- **Inlays.** Natural stone, cultured stone, or brick inlays mortared into specially molded areas

Stone and Other Masonry

- **Fieldstone.** Mortared or unmortared
- **Cut stone.** Usually mortared
- **Cultured stone.** Used as a facing or inlay with concrete
- **Brick and salvaged brick.** Most appropriate in urban/historic settings
- **Split-face concrete block retaining walls.** Can be used in developed areas, although native fieldstone or cultured stone are preferred
- **Concrete pavers.** Decorative tread or inlays in concrete
- **Interlocking concrete paving blocks.** Interlocking pavers for tread hardening available in many patterns
- **Boat ramp planks.** Used for tread hardening in well-drained soils

Other Materials

- **Plastic or composite lumber.** A substitute for wood
- **Fiberglass.** Used primarily for high-strength bridge and boardwalk superstructures

DESIGN ELEMENTS: USING THE CHARACTER OF MATERIALS (CONTINUED)

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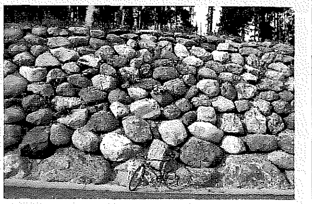

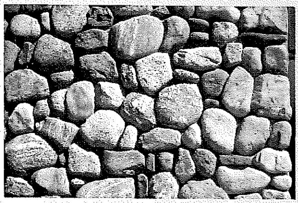

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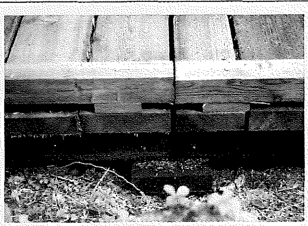

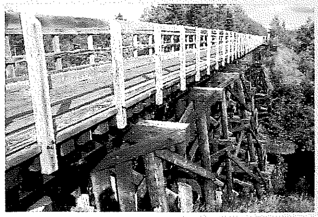

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SECTION 3 - PRINCIPLES OF
ECOLOGICAL SUSTAINABILITY

SECTION 3

Principles of Ecological Sustainability

OVERVIEW

This section considers ecological sustainability as related to trails in Minnesota. The section covers:

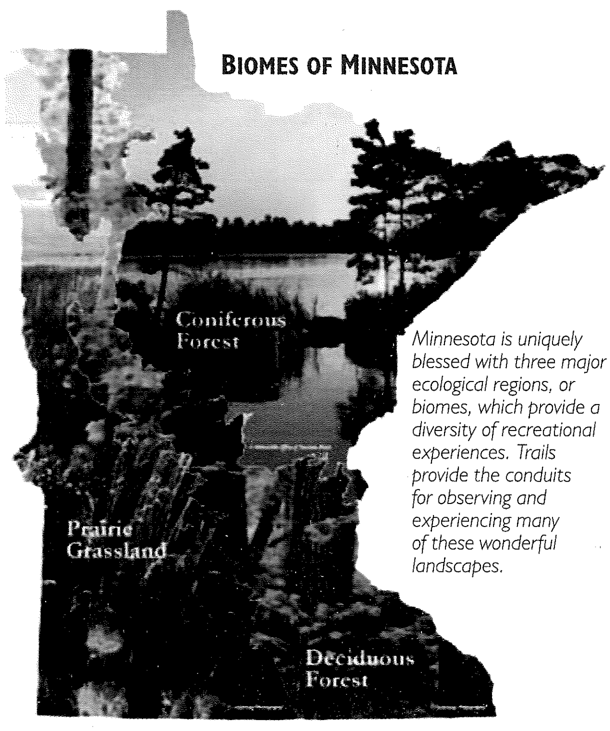
- A vision of ecologically sustainable trails
- Guiding principles for sustainable trails
- Common methods for defining natural areas and sensitive ecological systems

A VISION OF ECOLOGICALLY SUSTAINABLE TRAILS

Trails at the local, county, regional, and state level all across Minnesota provide recreational opportunities for residents and visitors throughout the seasons. An ever-growing network of trails links urban and suburban places to the rural countryside, natural open spaces, and parks of many shapes and sizes. Individually and collectively, recreational trails enable visitors to experience Minnesota's natural and cultural landscapes.

Trails must be responsibly developed to avoid diminishing the natural environment or the experience of being in a natural setting. The objective of this manual is not to limit or preclude trail opportunities, but to embrace and promote them in a sustainable manner, striking a reasonable balance between resource protection and human access and enjoyment.

The blufflands of Minnesota are among the many natural features that add to the quality of life in the state. Providing access to these areas via trails in a sustainable manner is a major emphasis of this manual.



Minnesota is uniquely blessed with three major ecological regions, or biomes, which provide a diversity of recreational experiences. Trails provide the conduits for observing and experiencing many of these wonderful landscapes.

GUIDING PRINCIPLES FOR SUSTAINABLE TRAILS

Guiding principles for ecologically sustainable trails provide the underlining rationale for actions related to protecting, restoring, and managing natural environments associated with trail development. There are seven core principles, as the following graphic illustrates.

Regulatory Reminder!

Refer to Section I - Framework for Planning Sustainable Trails for typical regulatory requirements whenever planning a new trail.

ADHERENCE TO THESE PRINCIPLES WILL ENSURE ECOLOGICAL SUSTAINABILITY

Guiding Principle #1
Avoid Sensitive Ecological Areas and Critical Habitats

Guiding Principle #2
Develop Trails in Areas Already Influenced by Human Activity

Guiding Principle #3
Provide Buffers to Avoid/Protect Sensitive Ecological and Hydrologic Systems

Guiding Principle #4
Use Natural Infiltration and Best Practices for Stormwater Management

Guiding Principle #5
Provide Ongoing Stewardship of the Trails and Adjoining Natural Systems

Guiding Principle #6
Ensure that Trails Remain Sustainable

Guiding Principle #7
Formally Decommission and Restore Unsustainable Trail Corridors

Minnesotan's have long appreciated the simple pleasure of accessing a natural setting via trail. The challenge is to maintain this access in the context of increasing use pressures and increasingly sophisticated means of getting around – enjoying the experience without diminishing it in the process.

Application of these principles will minimize the impact of trails on natural resources and sensitive ecological systems. *Importantly, the strict application of these guiding principles has to be balanced against the need to locate trails where they will be of high recreational value to the targeted users,* who often want to be close to nature, enjoy beautiful scenes, and observe wildlife. This is an important consideration and underscores the need for resource managers and trail designers to work together to determine which values are most important for any given situation.

For example, under the guiding principles, it is reasonable and desirable to buffer a given trail from sensitive ecological systems, such as a rare fen. However, once a trail alignment is agreed upon, the design of the trail should be consistent with the parameters set for that type of trail to avoid compromising its safety or value to targeted trail users. In other words, the width or clearance zone for a trail should not be modified to reduce its ecological impact if doing so would appreciably diminish its value and defeat the purpose of providing the trail in the first place.

The following considers each of the guiding principles for sustainable trails in greater detail.

Guiding Principle #1 – Avoid Sensitive Ecological Areas and Critical Habitats

Even when the most stringent safeguards are put into place, all development, including trail development, has an impact on natural systems. This includes direct (i.e., the trail itself) and indirect (e.g., changes to surrounding hydrological patterns, erosion, invasive plant migration, habitat fragmentation) impacts.

Additional perspective on avoiding sensitive ecological systems!

The publications entitled *Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife* and *Natural Areas: Protecting a Vital Community Asset* are important resources in support of this principle and underscore the importance of avoiding sensitive areas. The most poignant point is the fact that relatively little natural habitat remains in Minnesota, and once disturbed, natural systems are both difficult and expensive to restore. These publications can be found at www.dnr.state.mn.us/cwcs/index.html.

Although trail development is often justifiable, avoiding sensitive ecological systems is always the best protection strategy and should be the first considered when planning a trail. Ecologically sensitive systems include:

- Native plant communities and critical habitat for endangered, threatened, and special concern species as identified by the Natural Heritage Program, County Biological Survey, National Wetland Inventory, and by other means
- Significant geologic features, such as eskers
- Wetlands, lakes, rivers, and streams
- Steep slopes and soils that are easily eroded or rutted
- Habitat for animals that are sensitive to habitat fragmentation
- Larger remaining open spaces exhibiting high-quality natural systems, and smaller patches of isolated remnant landscapes that are vulnerable to development

The benefit of extensively mapping ecological systems is that sensitive areas are more clearly defined and more readily protected as trail alignments are considered and established.

Public Perception of Naturalness

The general public's perception of "naturalness" is often less discriminating than that of a trained professional ecologist or naturalist. This enables many trail users to have an enjoyable and satisfying experience even though a trail is routed through areas that are not very ecological sensitive and pristine.

However, allowing controlled access to sensitive ecological areas is an integral part of educating the public about the value of protecting them. Most often, this takes the form of routing a corridor trail on the periphery of a sensitive area (with adequate buffers) and allowing more direct access to specific settings only in very select locations for closer observation. This approach provides reasonable access while limiting the potential for environmental impact.

This sensitive wetland ecosystem is best viewed from a single or a series of strategic vantage points, rather than traversed directly with a trail. Insightful planning and design can make the visitor experience very compelling without unduly impacting the ecological system that is being observed.

A view such as this across a small lake in the northern forest can be a compelling trail terminus point that is accessed with a spur trail from a main trail that is a sustainable distance away from the ecologically sensitive shoreline zone. Although the temptation is to provide a trail around the lake, that is not always the most compelling or ecologically sustainable approach.

This simple nature trail alongside a prairie pothole is ecologically sustainable due to light levels of use, a reasonable natural buffer between it and the pond, and restored and managed natural vegetation surrounding it to prevent erosion. Close monitoring, maintenance, and general stewardship by park staff and trail users will be necessary to maintain this balance.

Guiding Principle #2 – Develop Trails in Areas Already Influenced by Human Activity

Consistent with the first principle, new trail development should occur primarily in environments already influenced by human activity. Depending on the circumstances, this can take a variety of forms, as the following considers.

Park Settings

In park settings, ecological and cultural inventories and analysis are typically used to define the most sensitive areas and, subsequently, areas most suited for various forms of recreation-based development. In most cases, development of trails is best suited in previously disturbed or degraded natural areas. Trail alignments should also be consistent with ecological stewardship plans related to restoring disturbed sites to higher quality natural areas.

The type of trail also affects its alignment relative to sensitive ecological systems. The more a trail focuses on interpretation, the more appropriate it is for it to approach sensitive ecological areas, as the following graphic illustrates.

Trail Alignments Relative to Sensitive Ecological Systems in a Park Setting

There is a direct relationship between the trail type and its proximity to sensitive ecological areas, as the following illustrates.

Proximity to Sensitive Areas* Becomes More Acceptable as the Focus Shifts From General Recreation to Nature Interpretation

Recreational Shared Use Trail → **General Hiking Trail** → **Interpretive Trail (Paved or Natural Surface)**

This paved trail traverses a greenway that was once a rail yard. In this case, the alignment of the trail was based more on recreational value than needing to respond to existing sensitive ecological systems. (Notably, the restored native landscape adds value to the trail, but it did not greatly influence its actual alignment.)

This natural hiking trail places value on the natural experience and so proximity to sensitive ecological areas is important. But the trail does not need to traverse any sensitive systems as long as the trail user is able to obtain a similar experience.

When natural interpretation is a desired value of a trail, direct encroachment can be acceptable as long as it is done sustainably with manageable ecological impacts. This boardwalk is more sustainable than building a footpath or paved trails through the sensitive wetland system.

* Sensitive ecological areas refers to natural values, not scenery. With respect to the latter, all trails should take advantage of scenic opportunities and follow the principles of good design as defined in Section 2 to ensure that a trail is of high recreational value.

Forests and Other Public Lands

Nonpark public lands most often consist of county, state, and federal forests throughout the state. These lands are often managed for multiple uses such as timber harvesting, hunting, maintaining biodiversity, and recreation.

In many of these settings, an extensive network of forest access routes and roads already exists for resource management and timber harvesting, and subsequently for hunting and general public access to forests. Whenever designated trails are established, these existing routes should be used when feasible to avoid creating a larger ecological footprint and further encroachment into ecologically sensitive areas.

The one limiting factor in using existing roads and trails is that they are often too straight or not challenging enough for some uses, especially OHV riders and mountain bikers. As defined in Section 4 – Trail Classifications and General Characteristics, a mix of dedicated trails, trail conversions, and on-road trails is typically used for designated OHV trails to provide an interesting trail experience, as the following photos illustrate.

An important consideration!

Creating a high-quality recreational experience must be taken seriously during route selection if the trail is to be of value to the targeted users. At times, this will require creating a new trail through an area that does not conveniently follow existing routes. Under these circumstances, environmental impacts must be balanced against the benefit of the trail to intended users. This will require close coordination between trail designers and resource managers to ensure that an acceptable balance is reached.

On-road trail *takes advantage of the existing road infrastructure and provides its own diversity of experience. (Typically, these are lower-level roadways within a forest setting.)*

Trail conversion *takes advantage of an old road by letting it "grow in" to create a narrower, more intimate trail experience within the same developed footprint.*

Dedicated trail *is shaped specifically for OHV use and designed to add challenge and excitement. Careful assessment of ecological impacts is a key aspect of selecting new trail routes.*

An important consideration!

In instances where new dedicated trails are developed to augment existing ones, decommissioning an equal number of forest roads and trails (that are not needed for other resource management purposes) should be considered. In doing so, the quality of the trail experience is enhanced without expanding the overall road and trail footprint associated with a given parcel of land.

Guiding Principle #3 – Provide Buffers to Avoid/Protect Sensitive Ecological and Hydrologic Systems

Maintaining buffers between trails and adjacent sensitive natural areas is essential to ensuring their long-term ecological quality, diversity, and habitat value. Irrespective of how well they are aligned and designed, trails have an impact on the resource, including habitat fragmentation, soil compaction, increased runoff and erosion, and introduction of nonnative plant species. For these reasons, the use of buffers is an essential part of trail planning and design.

Limitations of Buffer Guidelines

All sensitive ecological systems exhibit intrinsic natural values that require individual attention and various site-specific protection strategies. Scientifically, the optimal width of a buffer is variable due to the uniqueness and complexity of living environments that often require different types of protection. In addition, different types of trail development have more or less impact on ecological systems, which in turn affects the desirable width of an ecological buffer. Understandably, a specific buffer "standard" is inherently elusive to define.

At the same time, natural resource managers and trail planners need some clarity about buffer requirements in order for trail planning to occur. For this reason, general guidelines are provided in this manual to provide a basis for determining the optimal buffer width under a variety of situations. Notably, these guidelines should not be construed as being a substitute for site-specific evaluation of ecological systems to determine the protection strategy best suited for any given circumstance.

Buffer Definitions

"Buffer" refers to the area between a sensitive ecological system and the edge of a trail or construction related to the trail. It is an area in which no development is meant to occur, with the exception of restoration, management, and stewardship of natural resources. Stormwater may be managed in this zone through the use of natural infiltration techniques if it is done in harmony with the natural systems on the site.

The term "sensitive ecological system" refers to lands where ecological systems exhibit qualities that would be degraded (e.g., health, function, diversity) due to development if a buffer were not provided. It includes all ecological systems that hold the promise of being stable, functioning, and productive systems if managed and cared for through a routine stewardship program.

Wetlands, riparian areas, and water bodies are always considered sensitive ecological systems irrespective of their location and condition – whether that is in a northern Minnesota forest, a suburban regional park, or along an urban creek corridor. This also holds true for steep slopes and other landscape or geological features that if disturbed would significantly impact other ecological systems. In each case, adequate buffering is essential to protecting these systems.

Regulatory Reminder!

Minnesota has specific regulatory and permitting requirements associated with buffers that may have application to trails. These include, but are not necessarily limited to:

- MPCA's NPDES Stormwater Construction Permit www.pca.state.mn.us/publications/wq-strm2-51.doc
- MPCA Water Quality Standards in Minn. Rule 7050 www.revisor.leg.state.mn.us/bin/getpub.php?pubtype=RULE_CHAP&year=current&chapter=7050
- Minnesota Environmental Review Rules (Minnesota Rules Chapter 4410) at the EQB's website www.mnplan.state.mn.us/eqb
- Section 404 of the federal Clean Water Act
- MPCA Clean Water Act Section 401 Certification is required prior to the issuance if any Corps of Engineers Section 404 authorization.
- DNR Protected Waters Program
- Wetlands Conservation Act

These requirements should be reviewed to determine their application to any specific trail project.

Buffer Width Guidelines

Buffer widths vary in response to a number of conditions, including:

- Sensitivity of the ecological systems being impacted
- Extent of the natural open space or greenway corridor being traversed
- Type of trail being proposed and its potential for creating ecological impacts
- Desired trail experience

The type of trail and desired trail experience are important considerations when establishing buffer requirements for a trail. For example, a natural trail is more likely to cause erosion and migration of soils downstream than is a paved trail, while a paved trail can produce concentrated runoff that has to be infiltrated. Depending on the circumstances, each of these situations will affect the optimal width of a buffer.

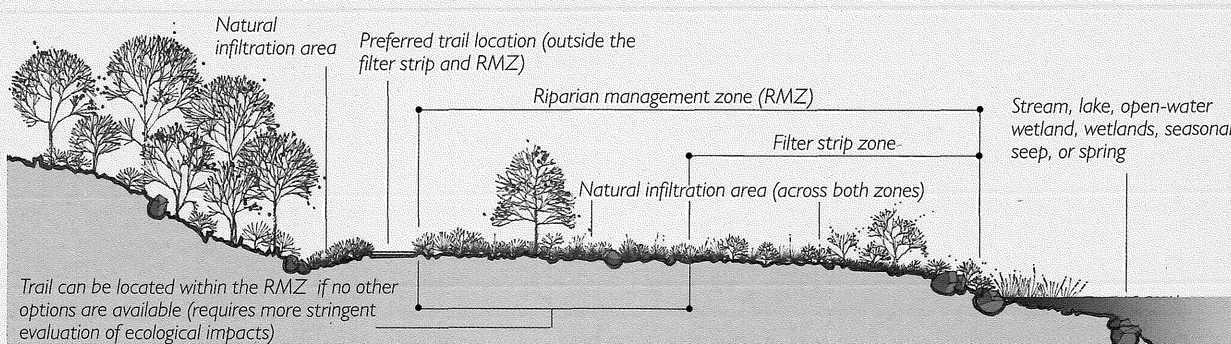
Certain trail experiences can conflict with buffer guidelines – for example, a nature trail may purposefully be routed through a highly sensitive area for its interpretive value. Guidelines should be tempered with site-specific evaluations when making a final determination on the type of buffer needed. The following defines general guidelines for buffers under various circumstances.

General Buffer Guidelines for Riparian Areas

Sustaining Minnesota Forest Resources (Minnesota Forest Resources Council, 1999) provides guidelines for buffers ("filter strips") for managing nonpoint pollution near surface water and wetlands associated with timber harvesting, prescribed burning, and road construction. These guidelines also have application to trail development adjacent to perennial and intermittent streams, lakes, open water wetlands, wetland inclusions, seasonal seeps, and springs.

The guidelines distinguish between filter strips and riparian management zones (RMZs). Filter strips help minimize the runoff of sediment, debris, nutrients, and pesticides into water bodies and wetlands. RMZs encompass the area of land and water forming the transition from aquatic to terrestrial ecosystems along streams, lakes, and open-water wetlands. Within this zone, a higher level of protection is recommended, including greater scrutiny of trail alignments. The following graphic defines the width guidelines for filter strips and RMZs.

Buffer Width Guidelines Associated With Filter Strips and Riparian Management Zones



Filter Strip Zone Width Guidelines

Slope of Land	*Recommended Width*
0%–10%	50'
11%–20%	51'–70'
21%–40%	71'–110'
41%–70%	111'–150'

Non-Trout Stream RMZ Width Guidelines

Water Body Type	*Recommended Widths*
Stream > 10' wide	100' minimum/200' preferred
Stream 3'–10' wide	50' minimum/100' preferred
Perennial Stream < 3' wide	50' minimum and preferred
Open water > 10 acres	100' minimum/200' preferred
Open water < 10 acres	50' minimum/100' preferred

Trout Stream RMZ Width Guidelines

200' preferred (150' minimum) for all designated trout streams, lakes, and tributaries

Regulatory Reminder!

Pay special attention to MPCA's NPDES Stormwater Construction Permit for special waters and calcareous fen requirements

www.pca.state.mn.us/publications/wq-strm2-51.doc

Buffers Within Greenways and Trail Corridors

In settings where parcel size does not limit buffer width, the filter strip and RMZ widths previously defined are recommended for trail development adjacent to any ecologically sensitive area. In most situations, these widths will be adequate to manage stormwater using natural infiltration, ensure ecological diversity and provide a corridor for wildlife travel.

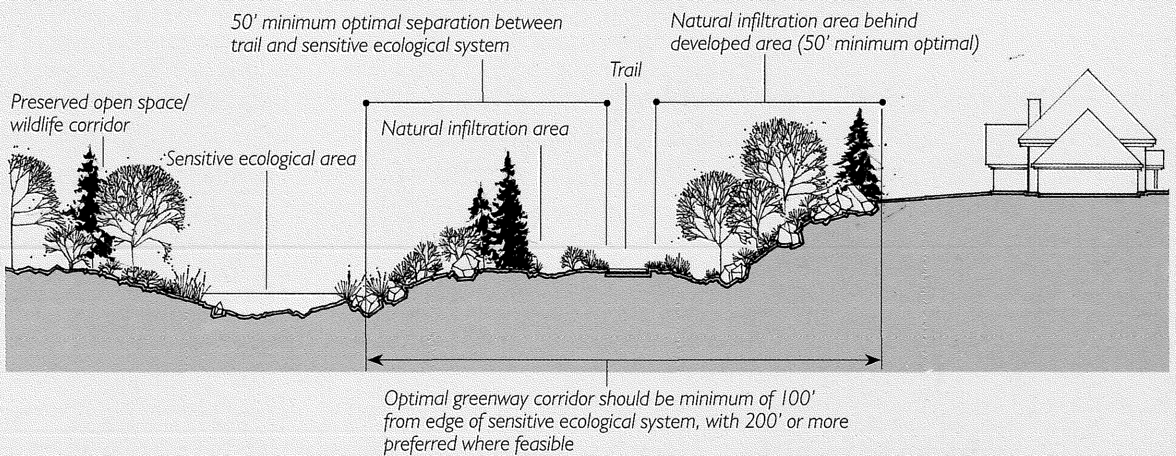
In highly sensitive settings, such as near rare fens and "special water", the buffer zone may need to be wider. It is not uncommon for these to be 200 feet or more. Also, the buffer width for trails should not be confused with buffers set up for wildlife migration, which vary depending on the setting and type of wildlife being accommodated.

Buffers Within More Constricted Greenways and Trail Corridors

In many urban and suburban settings, where greenways and trail corridors are often constricted, the recommended filter strip from the edge of a sensitive ecological system to the edge of a trail should still be maintained. In most cases, 50 feet is adequate for natural systems to infiltrate stormwater runoff and provide some space for wildlife.

Although not all of the values associated with RMZs can be met with a narrower buffer, providing adequate natural infiltration in areas that adjoin sensitive ecological systems remains important to maintain water quality and natural hydrologic flows, each of which has dramatic effects on native plant communities and the overall health of ecological systems. In some cases 50 feet will be adequate to ensure this protection, while in others a wider buffer would be more appropriate. The following graphic illustrates this situation.

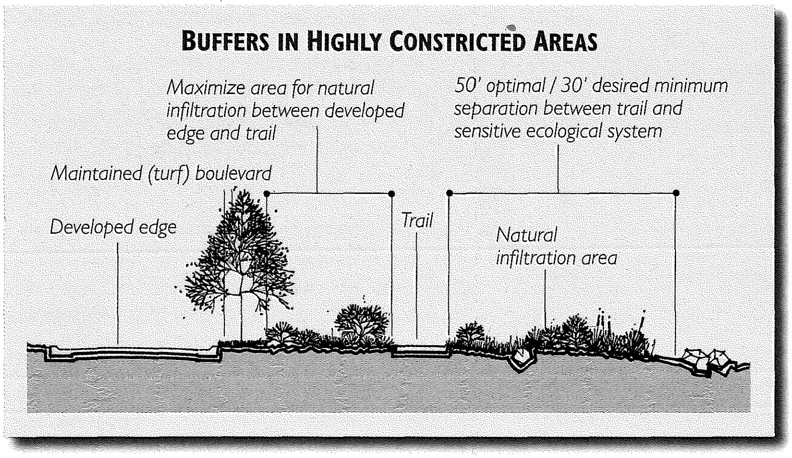
BUFFERS IN CONSTRICTED GREENWAY OR TRAIL CORRIDOR



Buffers Within Highly Constricted Areas

In highly constricted areas or where a trail is being retrofitted into a developed area with a narrow corridor, there may be no alternative but to limit the width of the buffer. In these cases, the buffer can be reduced to a recommended minimum of 30 feet, assuming that any ecological impacts from trail development can be mitigated.

If the buffer is less than 50 feet, additional attention needs to be given to ongoing stewardship of the impacted ecological systems to avoid increased potential for further degradation. The following graphic illustrates this situation.



ADDITIONAL GUIDELINES FOR DETERMINING BUFFERS

The following considers a number of additional guidelines for ecological buffers.

Trails Around Lakes

In natural settings, avoid closely paralleling or encircling lakes with trails, especially where wildlife is abundant. Instead, provide access for observation at select points to minimize impacts to surrounding ecological systems and wildlife corridors.

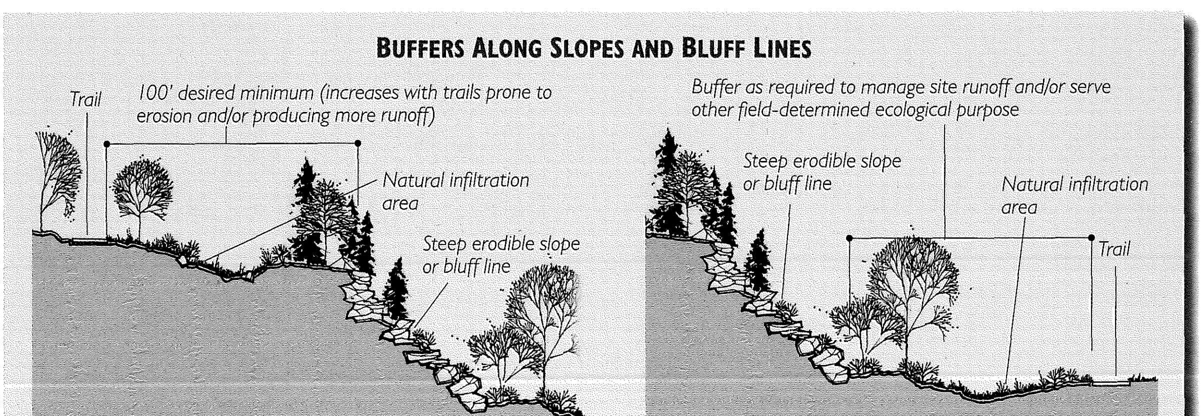
In urban and suburban settings where much of the area surrounding a lake is maintained parkland, trails are often among the most important recreational features. In these cases, buffers should be maintained between the lake and trail primarily for infiltrating stormwater and using natural processes to remove contaminants before they enter the lake system. Typically, a 50-foot buffer is optimal, with 30 feet being the minimum typically needed to be effective. Anything less requires careful site-specific evaluation.

Trails Adjacent to Streams

In a natural setting, trails should not parallel a stream for an extended distance. Rather, the trail should move toward and away from it at select intervals to provide a buffer for wildlife, protect natural systems in ecotonal zones, and make the trail more interesting. The buffer width should follow the guidelines previously described. Stream crossings should also be kept to a minimum to avoid unnecessary disruption to the riparian area.

Trails Adjacent to Steep Slopes (in Nonriparian Areas)

Steep slopes are inherently more susceptible than level ground to erosion, which can quickly undermine native plant species and send sediment downstream. A 100-foot minimum buffer is desirable above a steep slope. If stormwater can effectively be routed away from the slope line and the area is otherwise stable and not prone to erosion, 50 feet could be adequate. Anything less requires careful site-specific evaluation. The following graphic illustrates this situation.



Sometimes a trail must traverses a steep slope. In such cases, it is important to align the trail where site impacts related to stormwater management and erosion can be managed. (Section 6 – Sustainable Natural Trails extensively covers this issue.)

Buffers Associated With Ecotonal Areas

Ecotonal areas are the transition zones between ecological systems where native plant diversity is often greatest. These areas are also notable corridors for wildlife where animals travel from one type of habitat to another. Poorly placed trails can significantly impede travel for some species, even creating "sinks" that trap animals in an isolated area.

Understandably, ecotonal areas also appeal to humans, and it is very tempting to run trails continuously right along or through the edges of these diverse landscapes. As defined in Section 2 – Principles of Designing Quality Recreational Trails, the "edge effect" is a key element of design and plays a major role in making a trail interesting and exciting.

Finding a balance between providing the experience of traveling along an ecotonal edge and protecting the ecotone is a major consideration. A robust understanding of these systems is critical to aligning the trail in the least disruptive manner. Even locating a trail a few feet one direction or another can substantially improve the protection of ecotonal areas without diminishing the visitor experience.

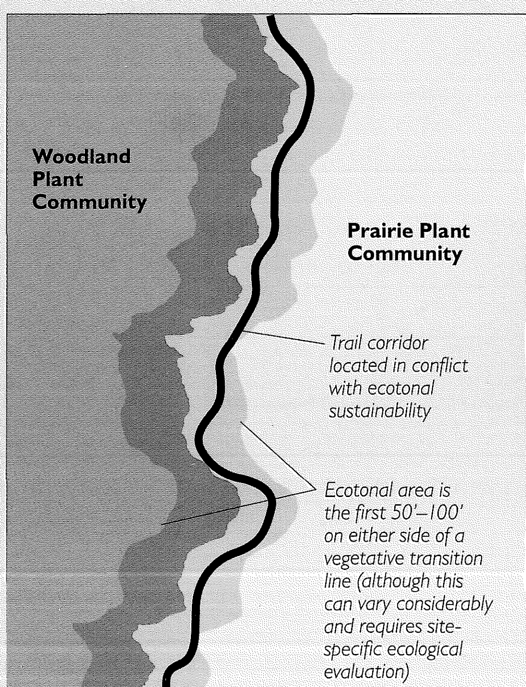
The ecotonal edge typically is the first 50 to 100 feet on either side of a vegetation transition line, although this can vary considerably. Generally, locating a trail right along the ecotonal edge should be the exception, not the rule. If trails are located within this zone, careful consideration should be given to minimizing the impact on diverse natural systems. This typically requires technical evaluation by a trained ecologicist or naturalist.

When trails must cross vegetation transition lines, it should be at select locations where impacts can be minimized. The following graphic provides examples of trails on the edge of ecotonal areas.

Buffers Associated With Ecotonal Areas

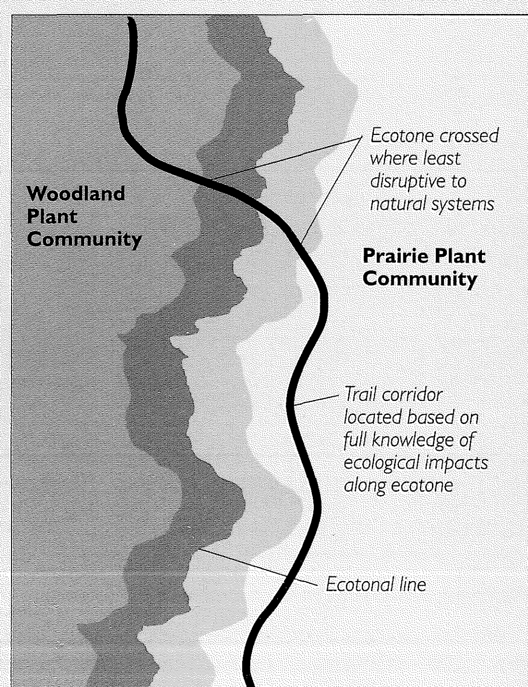
Trail in Conflict With an Ecotone

A trail located right along the edge of the ecotone impacts the most diverse area of native plants and disrupts the primary wildlife corridor. It also makes it more challenging to manage the ecotone with prescribed burning, since the trail creates an unnatural fire break.



Trail in Harmony With an Ecotone

A carefully located trail on the periphery of an ecotone but still close enough to enjoy the "edge effect" makes for a pleasant trail that is sustainable. Although all trails impact the site, through thoughtful design they can be much more sensitive to native plant communities and wildlife.



Using Buffers to Reduce Habitat Fragmentation

Mapping ecological systems, setting aside land for greenways, and providing buffers adjacent to development collectively reduce habitat fragmentation. In spite of these efforts, fragmentation can still occur if wildlife needs are not specifically considered as trail alignments are planned.

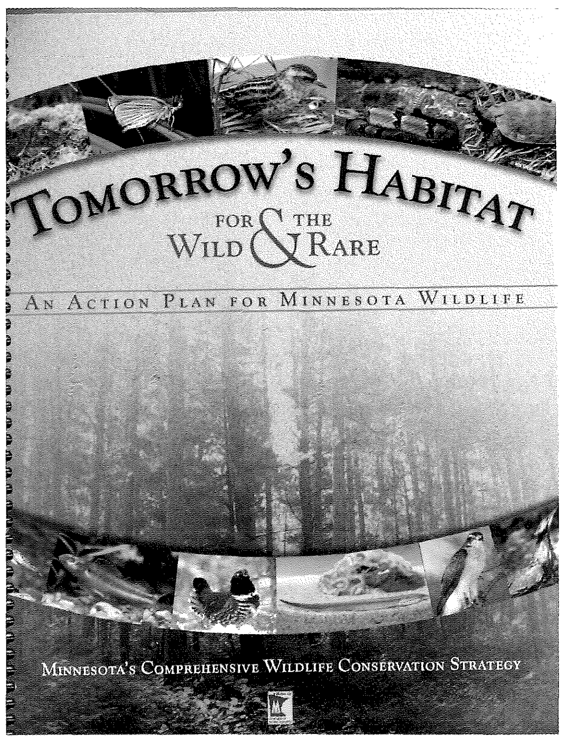
Reducing Habitat Fragmentation

Wildlife concentrate along ecological edges. This is especially true of riparian areas, the edge between forests and meadows, and areas adjacent to cliffs and major rock outcrops. The less a trail encroaches into these areas, the less fragmentation will occur.

To reduce habitat fragmentation, the physical design and management of a trail should incorporate the needs of wildlife and protect the ecological values that are most important to species of greatest conservation need. *Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife* is an important resource in this regard and should be referenced whenever a trail traverses a natural area, especially one that is known to harbor wildlife species that may be threatened.

This narrow ATV trail poses fewer impacts to wildlife than wider, unmanaged trails. The large trees on either side of the trail help keep it that way – as does responsible use by visitors. In some cases, a narrow trail will actually be used by wildlife.

The buffer between this ATV trail and a small pond and wetland is inadequate to prevent soil sediments from migrating into this sensitive ecological system, much less provide for the needs of wildlife. The trail needs to be realigned and the vegetation restored to make this more acceptable.



This publication can be found at www.dnr.state.mn.us/cwcs/index.html.

Design considerations include the use of vegetative screening, trail alignment away from key wildlife corridors, topographic screening, and seasonal closures. The photos illustrate a variety of these situations.

The topography along this trail was used to provide vertical separation between the trail user and a major wildlife corridor several hundred feet above the trail.

The enclosed character of this trail is less intimidating to wildlife than if there were no sense of protection. One limitation, however, is that wildlife will not be able to recognize an approaching user as quickly, especially if the user is not making much noise.

The impact of this walking trail on wildlife movement is limited. In many cases, natural visual screening of a trail in a wooded area frequently makes most wildlife tolerate human disturbance more than they would in open terrain.

The edge effect caused by trails can alter wildlife migration patterns. The wider the trail corridor, the more accentuated the break in natural systems. In forests, fragmentation can be caused when the canopy is excessively broken, which increases sunlight reaching the forest floor. Removing as few large trees as possible and weaving the trail through the forest using trees as anchors can markedly reduce fragmentation.

With natural trails, fragmentation can also be reduced by using native soil for the trail tread. Imported trail tread material, such as aggregates and soil stabilizers, increase the potential for fragmentation and introducing nonnative plants.

To limit disturbance to fish habitat, the most critical consideration is managing stormwater to avoid sedimentation of water bodies. Stream crossings need to consider fish migration needs and what effects winter ice dams could have on fish movements.

GUIDING PRINCIPLE # 4 – USE NATURAL INFILTRATION AND BEST PRACTICES FOR STORMWATER MANAGEMENT

Whether a trail is paved or natural, managing stormwater runoff is one of the most important trail development considerations. Passive, overland routing of runoff offers distinct advantages over conventional stormwater systems (i.e., storm sewers, engineered ponds, and other built structures), including:

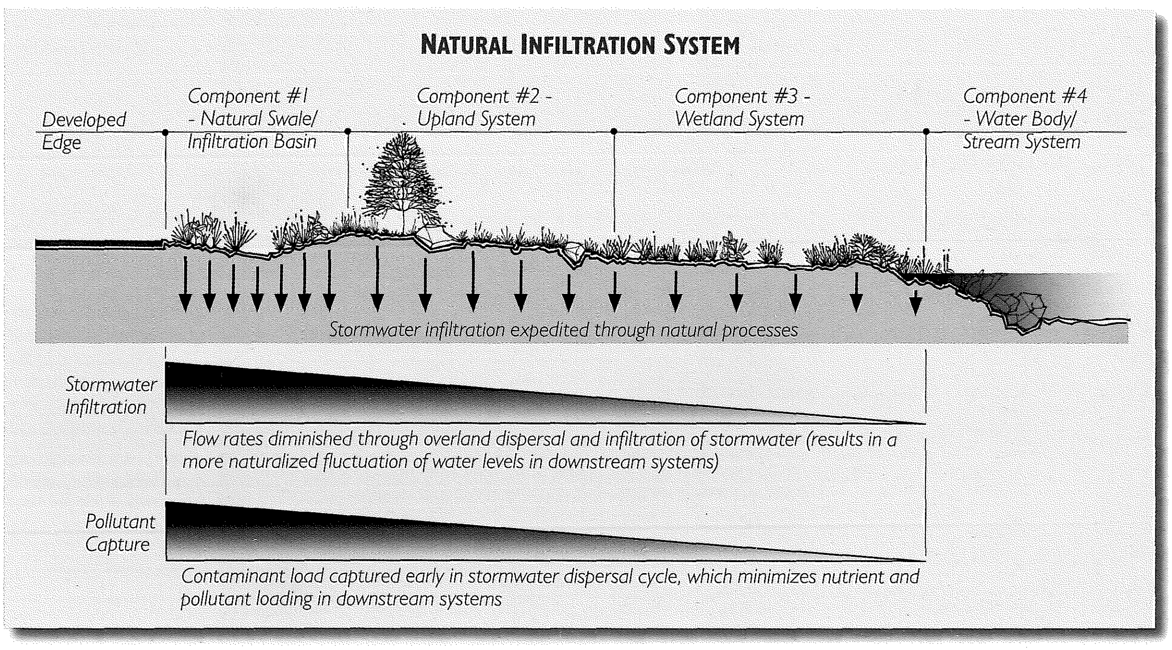
- Contaminants picked up by runoff are removed at the initial stages of water flowage, rather than being transported to downstream locations and accumulating in wetland, lake, and river systems. This greatly reduces degradation of water quality and vegetative health in downstream systems.
- Stormwater flow rates and volumes more closely emulate natural conditions. This greatly reduces unnatural fluctuations in water levels in downstream systems (wetlands and lakes) and therefore reduces impacts to the natural condition of water systems and vegetation.

It is essential that large and small hydrologic features be treated with the utmost sensitivity to avoid disruption to natural processes while still providing a unique trail experience.

For these reasons, the use of natural infiltration for managing stormwater is fundamental to creating sustainable trails where impacts to adjacent ecological systems are to be kept to a minimum.

COMPONENTS OF NATURAL INFILTRATION SYSTEMS

Natural infiltration systems typically consist of four primary components, as illustrated in the following graphic.



Each component of the system functions in sequence to treat the water before it enters wetlands, lakes, and rivers.

Shallow Natural Infiltration Swales and Basins Systems

Initially, stormwater runoff from the trail is routed into natural or artificial shallow swales or into natural infiltration basins (raingardens) planted with native plants with deep roots. These swales and basins provide initial infiltration and removal of pollutants, convey runoff from developed areas, and disperse runoff across upland and prairie systems.

(Left) The "ribbon infiltration area" between these trails is a depression (about 5 feet deep) to promote natural infiltration of runoff. With native grasses, absorption rates are increased and standing water only occurs after long or heavy periods of rain.

(Right) This natural infiltration approach is ecologically sound and also visually appealing to trail users.

Upland Systems

Upland systems (e.g., prairies, oak savannas, upland forests) are the second component, functioning to convey stormwater as diffused overland flow to the wetland systems that often link directly or indirectly to bordering lakes and rivers. These systems infiltrate a substantial portion of the annual surface runoff due to their very deep root system. They also provide additional solids settling capacity and biological treatment.

(Left) Deep-rooted prairies are well suited for natural infiltration. They slow down the flow of stormwater from hard surfaces, including trails.

(Right) Diverse forested systems also capture stormwater runoff in a natural way. Systems that are degraded (due to buckthorn infestations, lack of management, etc.) are much more susceptible to erosion than more diverse systems. This needs to be taken into account when planning a trail.

Wetland, Lake, and River Systems

Wetlands, the third component of the natural infiltration system, provide stormwater retention and biological treatment. The fourth component is the lake or river, which provides additional stormwater retention, solids settling, and biological treatment.

(Left) By the time water gets to a wetland, most of the impurities should be taken out by the previous parts of the infiltration system. Still, wetlands serve an important cleansing function and are critical to ensuring surface- and ground-water quality.

(Right) Natural infiltration systems help keep water fluctuations in lakes and rivers natural and stable. Limiting unnatural water fluctuations helps native plants compete with nonnative species that thrive when natural systems are compromised.

Other Factors Associated With Natural Infiltration Systems

The following considers a number of other factors associated with natural infiltration systems.

Soil Characteristics

The character and texture of soils significantly influences infiltration. In general, the tighter the soil, the slower the percolation rates (i.e., rates of absorption) and the more area needed to infiltrate stormwater. The following graphic illustrates the general characteristics of major soil types.

Soil Characteristics

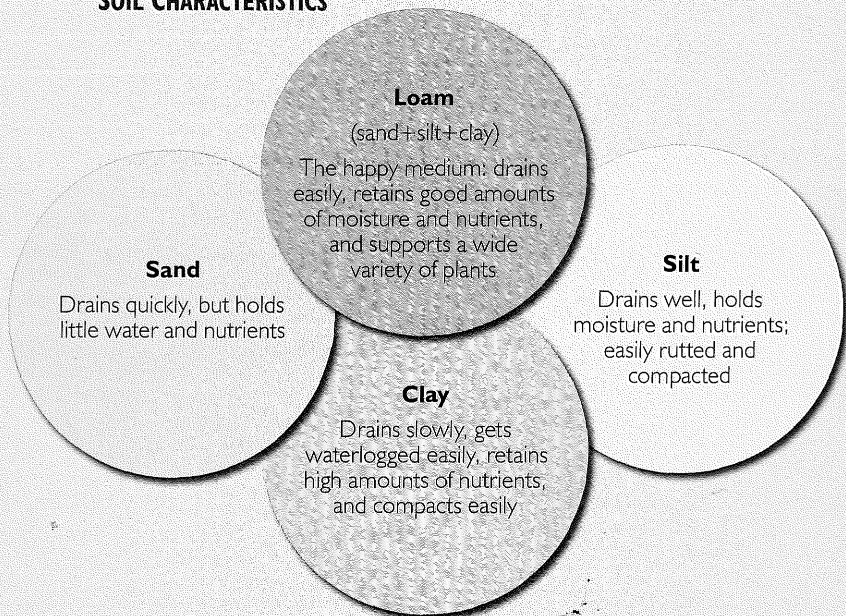
Soil texture: Refers to the size of particles that make up the soil. Particles are classified by size as sand, silt, and clay. Clay particles are very small. Silt particles are a moderate size. Sand particles are relatively large. Loam refers to a mixture of the three.

Different soils have different proportions of each particle size.

Sands have large pore spaces between soil particles. Water drains through them quickly, so they tend to be drier than other soils. Sand feels gritty and does not stick to your hands.

Clay soils have a large water-holding capacity, but water adheres so tightly to the soil particles that much of the water is unavailable for plant use.

Silt soils have the most favorable texture for moisture absorption and drainage. Wet silty soil feels slippery and smooth.

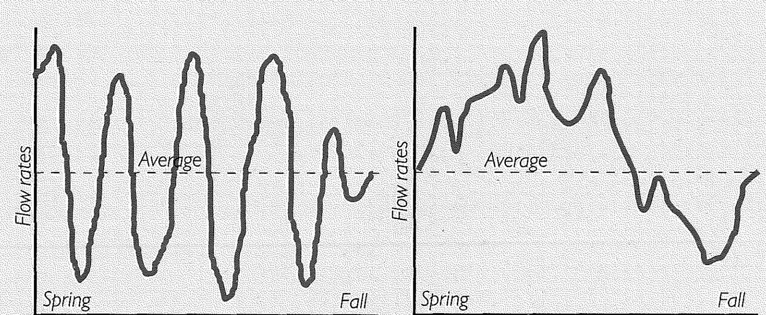


The character of the soil affects the size of the buffer zone needed adjacent to a sensitive ecological system to accommodate natural infiltration. The size and scale of the first two components of the natural infiltration system described on the previous page are most affected by soil types because that is where much of the infiltration is to occur.

Hydrograph Associated With Natural and Flow Rate Control Approaches

A natural infiltration system also produces a much more natural hydrograph than does a typical engineered flow rate control approach, with lower peak flows and higher base flows as illustrated in the following graphic.

Annual Hydrologic Graphs



Engineered Flow-Control Approach:
- *Unpredictable swings in water levels*
- *Creates biological instability*
- *Promotes habitats for weeds and invasives*
- *Poor aesthetic qualities*
- *Promotes poor water quality*

Natural Infiltration System:
- *Annual seasonal high- and low-water levels*
- *Predictable hydraulics and seasonal trajectory*
- *Promotes habitat for stable yet dynamic plant communities*
- *Supports a diversity of plants and animals*

Natural infiltration has numerous advantages over a flow rate control approach to stormwater management, and should be used whenever possible.

Regulatory Reminder!

Minnesota has specific regulatory and permitting requirements associated with stormwater management and applicable to trails. These are considered in more detail in Section I – Framework for Planning Sustainable Trails.

Best Practices for Stormwater Management

The use of natural infiltration for managing stormwater should also be supported by the use of other best management practices (BMPs) that address common development circumstances likely to be encountered as trails are developed. There are a variety of BMPs related to managing stormwater, preventing erosion, and limiting nonpoint water pollution that have application to trail development and complement the guidelines provided in this manual. The following table highlights three publications that are recommended resources covering many relevant best practices.

MPCA

The MPCA has developed a manual entitled *Protecting Water Quality in Urban Areas* to help local government officials, urban planners, developers, contractors, and citizens prevent stormwater-related pollution. The manual contains detailed information about BMPs that can be used to protect lakes, streams, and groundwater from stormwater-related pollution. The manual is available at www.pca.state.mn.us/water/pubs/sw-bmpmanual.html and covers the following topic areas:

- Water quantity and quality
- BMP selection
- Comprehensive stormwater policies and plans
- BMPs for stormwater systems
- Stormwater-detention ponds
- Erosion prevention and sediment control
- Pollution prevention
- Models and modeling

Metropolitan Council

Available through the Metropolitan Council, *The Urban Small Sites Best Management Practices (BMPs) Manual* provides information on tools and techniques to help municipalities and watershed management organizations (WMOs) guide development and redevelopment. The manual includes detailed information on 40 BMPs aimed at managing stormwater pollution for small urban sites in a cold-climate setting. The manual is available at www.metrocouncil.org/environment/watershed/bmp/manual.htm. Key sections that have application to trail development include the following:

- Runoff pollution prevention
- Impervious surface reduction
- Pavement management
- BMP maintenance
- Landscape design and maintenance
- Grading practices
- Soil erosion control
- Mulches, blankets, and mats
- Vegetative methods
- Sediment control
- Silt fences
- Inlet protection
- Temporary sedimentation basins/traps
- Check dams
- Stormwater treatment BMPs
- Infiltration systems
- Infiltration basins
- Infiltration trenches
- Filtration systems
- Bioretention systems
- Filter strips
- Wet swales
- Retention systems
- Wet ponds
- Detention systems
- Dry ponds
- Dry swales

Minnesota Stormwater Manual

Available through the MPCA, the Minnesota Stormwater Manual is a valuable tool for those involved in stormwater management and conserving, enhancing, and restoring high-quality water in Minnesota's lakes, rivers, streams, wetlands, and ground water. The manual is revised every two years, and posted at www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual.

Individuals involved in the planning, design, development, and maintenance of trail corridors should become familiar with and apply pertinent BMPs whenever a new trail is being developed. Existing trails should also be periodically assessed in terms of compliance with these BMPs to minimize their ecological impacts.

Guiding Principle #5 – Provide Ongoing Stewardship of the Trail and Adjoining Natural Systems

Stewardship refers to the initial restoration, ongoing management, maintenance, and monitoring of natural systems that adjoin a trail. Maintenance of the trail itself is also an aspect of stewardship since the lack of it can result in ecological impacts to adjoining natural systems.

Stewardship of the Trail Tread

Stewardship of the trail tread starts with a sustainable design followed by routine monitoring and maintenance. This is typically the responsibility of an agency or LGU, although trail user groups often play a role in maintenance. Preparation of a stewardship plan for the trail tread is recommended when the trail is first developed to ensure routine monitoring and maintenance requirements are understood, consistent with the trail's classification, and adopted as part of the initial plan for the trail. This should include anticipated maintenance schedules and cost projections.

Typically, maintenance of the trail encompasses the tread and the adjoining clearance zone. Notably, a well-implemented stewardship plan for the trail tread helps reduce the need for stewardship of adjoining natural systems. By limiting the concentration of stormwater and preventing erosion in the first place, the impact of a trail on adjoining natural systems can be limited. (Other sections of this manual should be referred to for detailed recommendations on trail design and maintenance.)

Stewardship of Adjoining Natural Systems

In this context, stewardship refers to 1) preserving and protecting ecosystems outside the actual development footprint, and 2) restoring and maintaining ecosystems directly impacted by construction. An ecosystem is defined as an interacting group of natural physical elements (soils, water, plants, animals, etc.) found within or inhabiting a particular place. All of these elements and their interactions need to be considered in developing goals and plans for stewardship of these systems.

Development of a trail carries with it an expectation that impacts to adjoining ecological systems will be kept to a minimum and some level of stewardship will be provided. Specific stewardship goals to this end should include:

- Preserving or enhancing the health of adjoining ecosystems
- Enhancing the biological diversity of native habitats that are encountered
- Providing an appropriate balance between resource preservation and recreational use

Stewardship programs should focus on achieving a sustainable ecological quality, which is defined as the point at which the ecosystem along the trail functions in a manner consistent with adjoining natural systems. If, for example, a trail traverses a very sensitive and pristine natural area, a very high level of stewardship would be appropriate. In less sensitive areas, such as an urban park, a less intensive stewardship program may be appropriate. In all cases, stewardship programs should be scientifically sound and economically sustainable.

By preparing a well-conceived and -defined stewardship program as part of the planning process, a certain level of confidence can be gained that natural systems adjoining a trail can be ecologically sustained and the natural qualities of the area preserved.

Note, however, that even well-conceived stewardship programs need to be flexible due to the changing nature of any living system. Rather than being seen as conclusive or absolute, stewardship plans should be considered starting points in an ongoing process that relies on monitoring and research to provide feedback on program effectiveness.

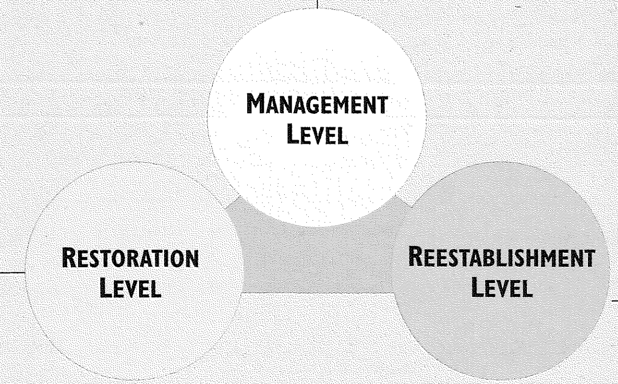
Stewardship Based on Site-Specific Needs

Depending on site-specific circumstances, ecological stewardship typically falls under one of three levels of intensity, as the following graphic illustrates.

INTENSITY LEVELS ASSOCIATED WITH ECOLOGICAL STEWARDSHIP

Least intensive approach *– refers to taking care of existing systems and encouraging the growth of natural communities already in place on a site. Also relies more on natural processes to restore disturbed areas associated with trail construction or to take over once a trail has been closed or realigned – although some remedial work (e.g., grading rutted areas, stabilizing erosion) is often needed to establish the conditions for natural processes.*

More intensive approach *– refers to undertaking a process of restoring a degraded natural community that is consistent with its original structure and species composition. Areas to be restored usually offer the "basic ingredients" necessary for a natural system to thrive, but the quality of the overall community is less than what it should be. Restoration efforts focus on enhancing what is already present and improving the overall quality and long-term viability of a given natural community.*



Most intensive approach *– refers to attempting to reestablish natural plant communities on a disturbed site with few, if any, native plant remnants remaining. Of all the approaches, this is the most challenging because it entails reestablishing something that no longer exists in its historic form. A reestablishment approach to stewardship is usually undertaken within the context of an ecological stewardship program for a site that goes beyond that of a trail corridor alone.*

The "management level" is the base line for all stewardship programs and the minimum required to ensure that a trail corridor will remain sustainable and that natural systems will be preserved or enhanced. All trail development programs should include at least this level of stewardship.

The "restoration" and "reestablishment" levels are used when a higher level of intervention is needed to ensure that the trail corridor will be sustainable, as determined in the field by a trained natural resource specialist. These levels of stewardship tend to be applied on sites that are already degraded and when the likelihood of natural processes alone being successful in restoring healthy natural systems along the trail is uncertain. The determination of stewardship needs should be made by a trained natural resource specialist familiar with the site and associated restoration and management techniques.

Recommended reference material!

Guidelines for Managing and Restoring Natural Plant Communities Along Trails and Waterways (DNR – Division of Trails and Waterways) covers this subject matter in more depth and is a recommended reference for stewardship of natural systems along trails. The publication covers:

- Guiding principles for sustainable resource management
- Managing, restoring, and reestablishing prairie, savanna, woodlands, and forest plant communities and riparian environments
- Controlling exotic species
- Planting and pruning of woody plants

Another worthwhile publication is the Minnesota Forest Resources Council's *Voluntary Site-Level Forest Management Guidelines,* which covers virtually all aspects of forest management by homeowners, loggers, and resource managers.

Watch for more on this subject!

Since treatments continually change, the following websites are a good sources of current information:

- DNR, Invasive Species (www.dnr.state.mn.us/nr/index.html)
- The Nature Conservancy Element Stewardship Abstracts, Invasive Species Initiative (tncweeds.ucdavis.edu/esadocs.html)

Preventing the Spread of Invasive Plants

DNR natural resource specialists continually work to educate the public about controlling the spread of invasive plants into the natural landscape and including prevention as part of stewardship programs. The following excerpt from a draft publication entitled *Best Management Practices: To Prevent the Spread Terrestrial Non-Native Invasive Plants on Trails and Waterway Lands* is presented here to underscore its importance.

Invasive terrestrial plants have caused unwanted impacts to thousands of acres of grasslands, forests and nonforested native plant communities. Impacts include loss of native plant communities, degradation of wildlife habitat and loss of recreational use. Recognizing which activities facilitate the movement of invasive plants into natural settings and what can be done to limit this is vital to preventing their spread. The following table defines the type of activities that can contribute to the spread of invasive plant species and actions that can be taken to limit the potential spread.

PREVENTING THE SPREAD OF INVASIVE PLANTS (PART I OF 2)

The following provides an overview of techniques for preventing the spread of invasive plants (as excerpted from a draft DNR publication, *Preventing the Spread of Terrestrial Invasive Plants on DNR Managed Lands).*

Type	Discussion and Solutions
Trail Maintenance	Trails provide corridors along which invasive species move. Seeds and plant parts are common hitchhikers on equipment such as mowers and graders. **Solutions:** • Segregate work activity in infested areas from work in "clean" areas. Always clean mower prior to mowing natural area trails. • Clean maintenance equipment of seed and plant parts between uses, especially when moving between infested areas and areas free of invasive plants. • Consider less frequent maintenance activity in areas where concern over invasive plant spread is high – roads and trails that abut infestations but lead into areas clear of the invasive plant. Minimize mowing and grading in areas infested by invasive species when such activity is likely to spread the infestation. Postpone activities until the infestation can be reduced, or time them to occur when seed is not present on the invasive plant species. • Minimize the amount of area mowed to encourage existing native species. Where mowing is necessary, raise the mower height during the growing season. The more above-ground plant mass, the better the native plants resist competition from non-native weedy species. Above-ground mass also allows less sunlight to penetrate to the ground surface, which inhibits invasive species seed germination. • When re-vegetating disturbed areas, native plants usually provide a reasonable alternative to both hybrid cultivars and non-native species. In general, natives require less maintenance in terms of watering, mowing and tending, are often drought resistant and cold hardy, and often provide better wildlife habitat. • Woodchip piles can create a growing medium for exotics when they suppress the native plant cover. Such piles should be removed immediately to preserve native vegetation.
Construction Projects	Development activity that disturbs the soil surface exposes a dormant, weed-containing seed bank and creates a growth medium that favors invasive plants. Landscaping after new construction often also introduces undesirable invasive plants. **Solutions:** • Minimize/eliminate trail cuts that create new openings into either high quality natural areas or areas adjacent to endangered species. Invasive species nearly always move along trails. Avoid designing or constructing new trails that will link areas of existing infestations to high quality natural areas and/or endangered species. • Keep trail improvement activity to one side of the corridor when possible to limit disruption to native plants and reduce the extent of open soil, which helps minimize the flush of weed growth. An established native plant community is usually more resistant to invasion by aggressive non-native species. • Preserve existing native vegetation. Peel topsoil that contains natives away from the work zone, stockpile and then replace it at the end of construction. This quickly reestablishes natives back into the construction zone. Avoid impacting high quality natural areas if possible. • Keep construction activity confined. Use temporary fences to reduce the harm caused by equipment, such as root compaction and plant crown damage. Signs at the perimeter of native areas also helps construction workers recognize the boundary of their work or parking zones. • Examine purchased fill material. Insist that it is free of invasive plants or seed. • Landscaping post construction: a. Purchase weed-free fill material if stockpiled topsoil is inadequate. b. Mulch is source of invasive plant seed, so purchase only certified weed-free mulch, and also use caution. c. Planting native vegetation can reduce the need for purchased black dirt and mulch since native plants are already adapted to local growing conditions. Drought tolerant native grasses often accept mowing to normal lawn height. d. Soils that come with purchased container plant material can be a source of unwanted invasive plant species. Minimize such purchases and monitor such planting areas for unwanted plant growth. • Manage storage areas to prevent weed growth, especially stockpiled fill and top-dressing material. Covering stockpiles with tarps or black plastic (to force seed to germinate and eliminate open soil exposure to airborne seed) or periodically applying glyphosate (Round-UpTM.) to growing unwanted plants is recommended. • Prevent trail equipment from carrying seed or plant parts into non-infested areas. • Herbicide treatments that eliminate the native, nonwoody ground cover, are an invitation for an invasion by unwanted plants and should not be used. Use selective herbicides rather than broad spectrum ones for reforestation work and apply as band or spot treatment, rather than broadcasting.

Preventing the Spread of Invasive Plants (Part 2 of 2)

Type	Discussion and Solutions
Planning and Site Preparation	Design access routes, assign trail classes, and close trails as needed to minimize spread by trail users. It is especially difficult to control the spread of invasive species by motorized forms of transportation. Access routes should be located away from high quality natural areas. Creating public awareness of the threat to such areas from invasive species is also very important.
Recreation Activities	Recreational users can contribute to the spread of invasive species. **Solutions:** • Educate recreational users about invasive plants and what they can do to avoid spreading seed or plant parts (i.e., boots causing the spread of garlic mustard seed). Signs promoting "stay on designated trails" to help minimize spread is one example. • Keep horses on trails and horse feed in designated areas. Handle horse manure with caution as it often contains large amounts of viable plant seed. Stockpiling and covering with plastic can help force seed to germinate. • Target infestations in high recreational use areas for aggressive control. High use areas with invasive plant infestations (i.e., parking lots, trail heads, trails, campgrounds) should be a high priority for control efforts. • Use areas or trails with rampant invasive plant infestations should also be considered high priority for control efforts until such infestations pose less of a spread threat by recreational users. If labor is not available to control the infestation, consider closing or limiting access to the area. • Trails leading from infested areas to high quality natural areas should be high priority for control. If control measures cannot be implemented, consider closing or limiting access to the trail. Rerouting may be needed if the problem persists. When designing trails, isolate high quality natural areas from all forms of motorized transport, mountain bikes, or other related activities when possible to prevent spread into these sensitive areas.
Off-Road Use for Work Purposes	ATVs and vehicles are an effective, convenient way to access remote areas for research or resource management activities. However, invasive plant seed/parts can be easily spread long distances by these means. **Solutions:** • Minimize spread into natural areas by keeping vehicles, ATV's, etc. on designated roads and trails. • Remove plants and seeds from vehicles, tires and undercarriages, before entering uninfested areas.

Limited trail corridor. *The corridor for this hiking trail with compacted soil and vegetated tread is only a few feet outside the trail clearance zone since there is very limited likelihood of erosion or major concentrations of stormwater.*

Wider trail corridor. *On this ATV trail, the corridor includes the buffer area between the trail and ponding area because maintaining healthy natural systems in this area is critical to ensuring the quality of the adjoining wetland and pond system.*

Defining the Stewardship Zone

In the context of site-specific trail development, stewardship programs can be limited to the trail corridor or incorporated as part of a larger program associated with a greenway, natural park, or other open space setting. Whatever the scale, stewardship of surrounding ecological systems at some level is fundamental to creating sustainable trails.

Trail Corridor

The trail corridor refers to the trail tread itself and the ecological buffers on either side of the trail. This zone encompasses areas needed for managing stormwater, preventing sediment transfer due to erosion, and managing invasives that migrate to the site through trail construction and use. The photos at left illustrate the direct impact zone for a couple of trail situations. As illustrated, the impact zone can vary from one type of a trail to another, so site- and use-specific evaluation is needed to determine the impact zone.

Greenways, Parks, or Open Space Settings

The stewardship program for a trail should be consistent with any program already established for a larger greenway, park, or open space area where it is located. When a stewardship program does not exist, stewardship along the trail corridor should still occur within a defined trail corridor, at a minimum.

Stewardship Relative to Trail Classifications and Economic Resources

Part of what defines a particular trail classification (or system of trails) is the level of stewardship or maintenance required to keep it sustainable, which carries with it significant practical and economic implications. This pertains to both the trail tread itself and the adjoining ecological systems. The implications of this can be significant when planning a system of trails and should not be taken lightly. *As a general rule, the length of a given trail or the extent of system of trails should never exceed the implementing agency's capacity to provide stewardship.* This underscores the importance of considering this issue at the point a trail or system of trails is first planned to ensure that the implementing agency does not overextend its capacity (human and economic resources) to provide ongoing stewardship.

Importance of Educating User Groups About Stewardship Issues

Trail users must also be made aware of the limitations an implementing agency has on providing stewardship for a system of trails, and the ramifications if an unsustainable condition is found. This should be clearly defined when a trail or system of trails is first developed to ensure all stakeholders have a clear understanding of individual and collective stewardship responsibilities. (Guiding Principle #6 – Ensure That Trails Remain Sustainable considers this issue in more depth.)

A pertinent example of the limitations of stewardship relates to forest access routes (as defined in Section 4 – Trail Classifications and General Characteristics), which are essentially the *informal* use of existing corridors in the forest for recreation and other uses. These networks can be very extensive and it is unlikely that forest resource managers would be able to provide much, if any, maintenance associated with recreational uses. As long as use is relatively low, users are responsible, and uses are consistent with an overall forest management plan, these routes can be sustainable. However, should use levels or improper use of a forest access route cause unsustainable ecological or other impacts, use of the area would likely have to be restricted or the corridor decommissioned.

Redefining a forest access route as a designated trail (e.g., reclassifying it as a designated OHV trail) creates considerably higher design, management, and stewardship requirements (and substantially higher costs) that must be borne if the route is to remain open in a sustainable condition. Since decommissioning or even changing a classification is never easy, it is imperative that trail planners and implementing agencies give extensive consideration to the long-term costs and commitment to stewardship and clearly define as part of the development plans what will happen if a trail turns out to be unsustainable. User groups should be part of this discussion so that they too understand the importance of stewardship and personal responsibility for keeping trails (or forest access routes) sustainable and open for public use.

Guiding Principle #6 – Ensure That Trails Remain Sustainable

Trail classification, management, and stewardship (maintenance) all factor into a trail's long-term sustainability, as the following graphic illustrates.

Factors Influencing Trail Sustainability

Interlinked Factors Associated With the Sustainability of a Trail

The classification defines the intended use, design parameters, and general characteristics of the trail to meet the needs of the specific user group(s).

Trail management defines operational procedures, marketing approaches, rules, and enforcement levels to ensure the trail serves the targeted user group(s) and is responsibly used. More intensive and/or specialized uses typically require higher levels of management.

Trail stewardship relates to the routine preventive maintenance of the trail and stewardship of adjoining natural areas. The higher the classification and more intensive the use, the more maintenance required to ensure sustainability.

Each of these factors need to be in alignment to ensure that a trail remains sustainable. In most applications, trail management and stewardship are linked to a specific classification to ensure consistency across a system of trails. For example, a designated OHV recreation area entails a fairly intensive level of development and a higher level of day-to-day management and maintenance than would be the case for a designated OHV trail or a forest access route. Making this distinction when trails are first planned and designated is critical to making sure user groups understand what types and levels of use will allow the trail to remain sustainable and therefore open. If established thresholds are passed and the trail becomes unsustainable, the possibility of closure must be clearly articulated to user groups.

Sustainability of Natural Versus Paved Trails

The sustainability of natural surface trails is much less assured than that of paved trails for several reasons:

- Hard surfacing is specifically designed and engineered to sustain extensive use and withstand climatic conditions
- Landscape architecture and engineering practices that are typically applied to paved trail design limit the potential for impacts to adjacent areas
- Paved trail users are more inclined to stay on the trail given their mode of use, such as bicycles, in-line skaters, and pedestrians wanting a hard, consistent surface

The most likely unsustainable condition associated with paved trails is erosion occurring adjacent to the trail due to increased hard surfacing and concentrated stormwater runoff. The best solution is to follow the guidelines provided in this and other sections and other applicable best practices to prevent the problem in the first place.

Lacking a hard surface, natural surface trails are inherently more subject to sustainability issues and require an attention to detail design and stewardship on an ongoing basis. With natural trails, once a minor problem occurs, it tends to grow quickly into an unsustainable condition. For these reasons, the sustainability of natural surface trails is given the majority of the attention in this section.

Sustainability/Impact Thresholds

Thresholds provide trail managers and user groups with a common basis for determining if a trail is sustainable. Each threshold triggers a certain type of action to ensure the trail either remains sustainable or is decommissioned due to an unacceptable level of environmental impact. The following graphic provides guidelines for sustainability thresholds.

Sustainability/Impact Thresholds

Sustainability or impact thresholds provide trail managers and the public with a rational and consistent basis for determining the type of action necessary to ensure that a trail remains sustainable. Each trail classification will have its own set of thresholds consistent with its intended use and level of trail management and stewardship.

Unsustainable Use – Action Mandated

Increasingly unsustainable use requires either reclassification (redesign) or decommissioning (closure) of the trail to curtail environmental impacts.

Sustainability of Use Questionable – Action Required

This threshold is purposefully limited to underscore the importance of taking action as soon as the sustainability of a trail becomes questionable. Otherwise, more drastic action will be required, creating a much more challenging situation to resolve with the affected user groups.

A higher level of monitoring and enforcement is required to reverse the trend toward becoming unsustainable. The trail's classification, design, and use all have to be analyzed to determine the best course of action.

Sustainable Use – No Action Required

The trail is sustainable through proper classification, appropriate design, and responsible use. It is performing as anticipated and no action is required.

Sustainability or impact thresholds should be defined as part of the trail planning process to ensure that trail managers and user groups have a common understanding and expectation about actions will be taken if a trail proves unsustainable.

If a trail's condition does become unsustainable, the action taken depends on the trail classification, management approach, and stewardship program. Natural surface trails and forest access routes tend to fall into three categories, as defined in following graphic.

For more on trail classifications!

Refer to Section 4 – Trail Classifications and General Characteristics for more information on the listed classifications.

Categories for Natural Surface Trail and Forest Access Routes as Related to Sustainability

The action taken if a trail or forest access route becomes unsustainable is related to its classification and the level of management and stewardship (maintenance) that is intended to be provided. In trail planning, it is important to educate trail users about this so that they form appropriate expectations.

Designated Natural Trails

Potential Actions if Trail is Unsustainable:
- Redesign to be sustainable
- Reclassify to lower impact use
- Decommission trail

- Designated trails designed for a specific use
  - Hiking Trails
  - OHV Trails
  - Equestrian Trails
  - Multiuse Natural Trails
- High level of use promoted
- Routine management provided
- Routine stewardship (maintenance) provided

Forest Access Routes

Potential Actions if Forest Access Route is Unsustainable:
- Redefine as a designated trail* for a specific use and provide additional design, management, and stewardship to ensure sustainability
- Restrict use, such as limiting use to nonmotorized activities (hunter/walker trail designation, for example)
- Decommission restore corridor to natural vegetation

- Open for informal *motorized* and *nonmotorized* use (if sustainable and consistent with overall forest management plan)
- Lower level of use promoted
- Very limited management provided
- Very limited stewardship (maintenance) provided

Hunter/Walker Trails

Potential Actions if Trail is Unsustainable:
- Reclassify to a higher classification* (requires more design, management, and stewardship)
- Decommission trail and restore corridor to natural vegetation

- Open for informal *nonmotorized* use (if sustainable and consistent with overall forest management plan)
- Low level of use envisioned and promoted
- Very limited management provided
- Very limited stewardship (maintenance) provided

* Since forest access routes and hunter/walker trails are typically only made available if they are used in a sustainable manner, they are not routinely or extensively redefined or reclassified to a higher level. More typically, uses become more restricted or the route or trail is decommissioned if use makes it unsustainable.

Defining Sustainability Thresholds

A sustainable trail is one that can be indefinitely maintained for its intended purposes, assuming routine management and stewardship is provided consistent with its classification. If a trail is well designed and appropriately used, site impacts will stay within acceptable parameters.

A trail becomes unsustainable when its physical condition passes a defined threshold where site impacts are no longer within acceptable parameters. Under these circumstances, action is required to avoid continued degradation of the trail and adjoining ecological systems.

For general application, sustainability can be reasonably described using written criteria and photographs. The following complements the guidelines found in Section 6 – Sustainable Natural Surface Trails by providing a physical description of sustainable and unsustainable conditions common to various natural surfaced trails. These are general guidelines that can be used as a means to alert trail managers and users if the sustainability of a trail is in question. Note that these criteria may have to be refined based on site-specific conditions, including soils, vegetation types, hydrology, and other factors.

Sustainability Relative to Trail Classifications

In practice, all natural trail types tend to exhibit similar physical signs of being either sustainable or unsustainable, as reflected by rutting, erosion, by-passing, and impacts to adjoining ecological systems and hydrology. The main difference between classifications is the extent to which a particular problem is likely to occur and the type of action taken should an unsustainable condition be found.

For example, if rutting occurs on a designated OHV trail due poor design or unforeseen conditions, realignment would be appropriate to solve the problem to keep the trail operational. This contingency would be part of the management plan for this class of trail. On the other hand, if that same level of rutting was found on a forest access routes (where the commitment to management and maintenance is much less), closure of the area might be in order since OHV use was only allowed if the route remained sustainable.

Sustainable Trail Characteristics – No Action Required

With all natural trail types, a certain level of compaction and displacement is expected and acceptable. It is also acceptable to cross natural drainageways and create a corridor wide enough to accommodate the trail as long as it is done in a sustainable manner and site impacts are kept to a minimum.

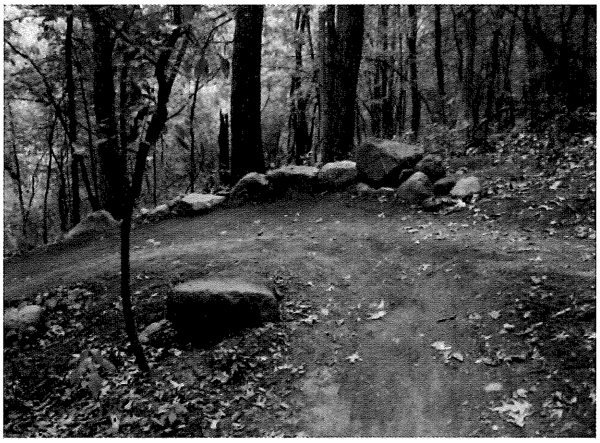
In general, trails are considered sustainable if the following conditions are found:

- Trail tread is stable and compacted, with a constant outsloped grade preferred (the depression on a well-worn trail should average less than 3 inches in most soil types)
- Displacement of soils from the trail tread is minimal relative to the use and soil type (only limited berming on the outside of curves)
- Tread drains well with minimal to no signs of ongoing erosion, especially into water bodies of any kind
- Tread does not restrict site hydrology and impact surface- or ground-water quality
- Impacts to surrounding ecological systems is limited to the trail tread and directly adjacent clearance zone, with no bypassing and cross-country travel occurring

The following photographs illustrate sustainable conditions associated with a variety of natural trails.

Forest access routes must be well suited for the use to remain sustainable*, especially since these are minimal maintenance areas. Corridor closure is the typical result if these routes prove unsustainable.*

Rolling grade design and alignment *ensures that this ATV trail will remain sustainable. If runoff is managed through dips and crests, erosion can be largely prevented with normal use.*



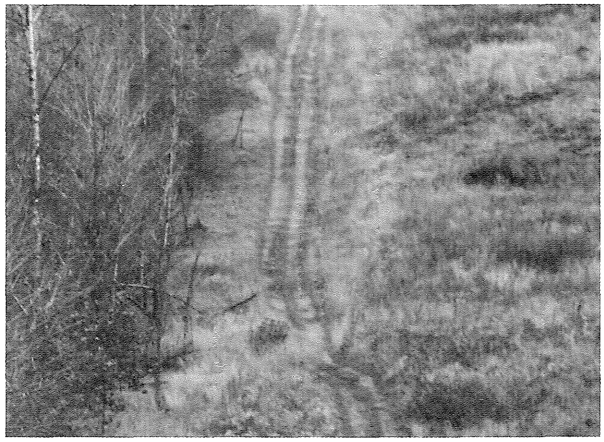
A superelevated curve plus embedded rocks help ensure that this mountain bike trail will remain sustainable. *Simple considerations like this are vital to creating trails that can handle years of heavy use.*

This sustainably designed trail naturally follows site contours, *which also make the trail more appealing. Notice the trail drainage dip that drains water off the trail (to the left).*

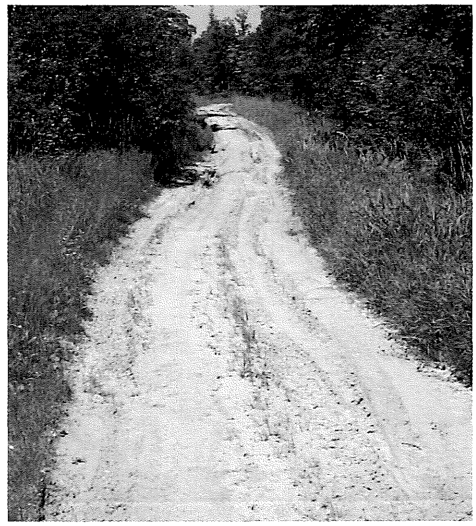
Sustainable forest access route. *The grasses on this lightly used trail will help keep it sustainable, perhaps over decades.*

Although this OHM trail is in sandy, noncohesive soil, systematic displacement on the curve has formed a superelevated curve that limits further displacement. ***Since the tread remains porous and the site has only gentle slopes, erosion is not a problem and trail is sustainable.***

Superelevated corners can be very sustainable if they stay within the established treadway. *However, if trail "creep" begins to occur, the trail starts to slide into an unsustainable condition.*



This rolling grade trail is both fun and sustainable*, in spite of its heavy use. Notice how the dips and crests help manage stormwater and prevent erosion.*



Soil variability factors into sustainability. *Compactible soils, such as well-graded gravel (left), are best suited for natural trails due to their inherent stability. On these soils, displacement and rutting should be minimal. On sandy soils (right), more displacement can be expected and cause somewhat deeper ruts than would be expected in other types of soils. As long as erosion, migration of soil into water bodies, excessive rutting, and bypassing are kept in check, this trail can remain sustainable even though the tread itself shifts a bit over time. Trails on sandy soils generally require more monitoring and prompt action if a problem occurs.*

Questionable Sustainable Trail Characteristics – Action Required

A trail that is improperly designed for its intended use or is irresponsibly used is susceptible to becoming unsustainable. In general, the sustainability of a trail is considered questionable if one or more of the conditions are found:

- Tread is showing signs of becoming unstable, with the surface not capable of supporting the intended use (most often exhibited by ruts 3 to 6 inches deep)
- Displacement of soils from the trail tread is more than desired for superelevated corners, causing concerns that trail users will start to bypass the area
- Trail is showing signs of poor drainage, with water ponding, standing water, and mud holes
- Erosion is becoming an issue, with soil starting to move into adjacent water bodies
- Trail tread is starting to restrict site hydrology and alter surface and subsurface water flows
- A growing potential for impacts to ecological systems (especially wetlands and rare and endangered species) is becoming evident, often due to the factors listed above

Where these signs begin to manifest themselves, *action is required to forestall a worsening of the situation*, which would require even more drastic action, possibly even trail closure. The following photographs illustrate questionable conditions associated with a variety of natural trails that suggest the need for action.

Problem: Trail creep. *This low spot on a mountain bike trail is routinely wet, forcing trail users to go around it. Either a reroute or hardening with rocks or a boardwalk is necessary to avoid continued expansion of the trail.*

Problem: Soil limitations. *With sandy soils, trail creep can become a sustainability issue. If this is limited to an occasional stretch, no major action is required. But if this problem persists over a significant distance, rerouting or closure may be necessary.*

Problem: Lack of underlying soil stability. *Organic soils are inherently prone to rutting. Although still within rutting limits, this trail is close to becoming unsustainable, especially if soils begin to migrate to adjacent systems and water bodies. If foot traffic is low, periodic reseeding and filling may be the best approach. If the problem continues, rerouting may be necessary.*

Problem: Bypassing trail protrusions. *Even a few rocks and roots in a hiking trail can entice trail users to find another route. Left unchecked, this type of activity can slowly detract from the trail experience and the natural setting. Stronger anchors (and "stay on trail" signs) are needed to keep this from getting worse.*

Problem: Erosion due to fall-line alignment. *In both of these cases, the trail follows the fall line (i.e., is aligned straight up the slope), creating an opportunity for erosion. In the left photo, erosion is becoming a problem and soil is migrating to the base of the slope. If periodically maintained, this trail could remain reasonably stable, although a better solution is to realign it. In the right photo, erosion of a forest access route is clearly becoming an issue with increasing use and exposure to the elements. Realignment or closure of this segment will ultimately be necessary to keep this trail sustainable.*

Problem: Perpetual seepage. *This seepage/drainage area is a growing problem and will continually push trail users farther toward the edge, causing trail creep. A simple boardwalk could remedy this situation.*

Problem: New trail too steeply traverses a rocky slope. *The trail will capture all of the rainfall on the tread, plus that from the slope above it (right). This will cause unsustainable erosion and, ultimately, the trail will have to be redesigned.*

Problem: Growing impact to driveway approach. *One of the most pressing concerns associated with forest access routes and right-of-way trails is the impact to driveway and road approaches. This example is close to the threshold for being unacceptable. If it gets worse, closure of the route by the local government engineer is likely.*

Problem: "Social" play area. *This sandy area is undoubtedly fun to spin around in. At an OHV recreation site, this might even be acceptable in a controlled area. But as part of a forest access route system, this would be the sign of a growing problem that if not controlled would result in the eventual closure of the area.*

Important qualifier!

The initial finding of an unsustainable trail condition does not have to automatically lead to closure. Instead, it should trigger a very assertive process of trying to solve the problem by working with user groups and law-enforcement agencies. If that good-faith effort proves unsuccessful, then more dramatic action which could include trail closure is indeed required to avoid further degrading of ecological systems.

Notably, the time frame on taking action can be very short if the situation is of major concern, such as illegal cross-country travel through a wetland. In such situations, temporary closures can also be used to limit further degradation, call attention to the situation, and allow enough time to work toward a solution.

Unsustainable Trail Characteristics – Action Mandated

Trails reach an unsustainable threshold when a problem cannot be reasonably solved and/or past maintenance has not proven successful. Trails are considered unsustainable if one or more of the conditions are found:

- Tread is not stable and does not retain a surface capable of supporting the intended use (most often exhibited by rutting of 6 inches or more in depth)
- Displacement of soils from the trail tread is excessive, causing extensive berming on the outside of curves beyond that which was intended in the design of the trail
- Trail does not drain well and erosion is occurring on an ongoing basis
- Trail tread is restricting site hydrology, causing changes in surface and sub-surface water flows, and/or creating mudholes
- Impacts to ecological systems (especially wetlands and rare and endangered species) are caused by poor trail alignment or cross-country travel and bypassing

Unsustainability can be caused by a single event or a collection of events. Of all the factors that create an unsustainable condition, illegal bypassing and cross country travel are the most likely to lead to trail closure due to the impact they have on adjoining ecological systems and the difficulty of resolving the problem through trail maintenance and enforcement.

The following photographs illustrate unsustainable conditions associated with a variety of natural trails.

Problem: Compacted and displaced tread in lowland area makes the tread unstable. *Attempting to drain this tread would drain the entire area, unacceptably changing the hydrology of an adjacent wetland. Rerouting or closure of the trail is mandatory.*

Problem: Severe soil erosion adjacent to a hillside due to poor trail design. *This will indefinitely continue and cause increasing levels of downstream sediment. Rerouting or closure of the trail is mandatory.*

Problem: This ATV trail goes across a shallow drainage that has been deepened through use. *This will continue until the hole is too deep to go through, which will force riders to bypass the area, which will cause further problems. Proactive rerouting is the best solution, although closure might be necessary if the problem is persistent in the area.*

Problem: Compaction and displacement on a near-level site deepening the tread of this relatively new ATV trail. *Water ponds on the tread because it is the lowest point. Fixing the problem by improving drainage and perhaps hardening the tread through this section are possible solutions.*

Problem: Trail sprawl. *If seemingly minor holes and ruts are left unchecked, it is inevitable that a trail will keep expanding and/or new bypasses will be created. These problems are common in areas of organic soils and solving them is no small challenge. Avoiding organic soils is the best solution. Where that is not possible, careful alignment using rolling grade techniques and site anchors to keep riders on the trail can help curtail problems.*

Problem: Severe, ongoing erosion on a modest slope. *Disregarding the drainage characteristics of a site is a prescription for this kind of problem. This trail will have to be redesigned using rolling grade techniques if it is to be sustainable. Otherwise, closure will ultimately be necessary as the problem gets worse.*

Problem: Excessive displacement. *Heavy use, erodible soils, and lack of rolling grade have combined to excessively displace soils along this trail. Rerouting and/or closure is necessary since fixing this is almost impossible.*

Problem: Ignoring gated areas causes damage to other trails and reinforces a poor public image. *Lack of respect for closed areas only leads to increased pressure to restrict use. Peer pressure is the most successful means of instilling responsibility in trail users.*

Problem: Bypassing causing unacceptable ecological impacts. *Immediate closure of the trail will be necessary to curtail this from getting worse. The area is simply not well suited for an ATV trail.*

Problem: Cross-country travel through sensitive natural area, creating unacceptable impacts. *Immediate closure of this trail is in order to avoid continued degradation.*

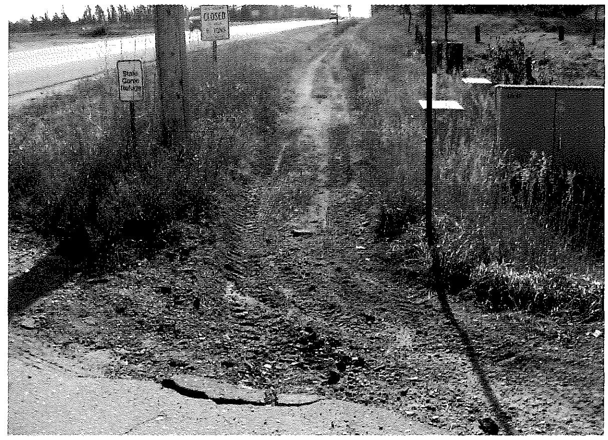
Problem: "Social" cross-country trail follows steep fall line on erodible soils. *Continued erosion of this trail on sandy soils is almost assured, eventually causing riders to create yet another bypass that will result in the same outcome. Unchecked cross-country travel is not sustainable, and efforts to curtail this activity through peer groups and enforcement are necessary if long-term access to an area is to be assured.*

Problem: Bypassing. *The deep rutting on the right encouraged riders to create a new route, which over time will also likely rut in these organic soils. Since this is a designated OHV trail, realigning the trail to higher and more stable ground is the best solution.*

If natural trail systems are monitored on an ongoing basis, many unsustainable conditions can be caught and resolved before damage becomes severe. By staying abreast of changing conditions and working with user groups to solve problems, resource managers help ensure continued access to designated and forest access routes. Lacking this attention to sustainability, it is reasonable to expect that public pressure to curtail the use of public lands for recreation will mount and ultimately result in more restricted access.

Use of road rights-of-way for ATV travel is an increasingly challenging issue due to public concerns about safety, aesthetics, and impacts driveway approaches, vegetation, and soil stability. In select situations, rights-of-way are being used as a legitimate part of a larger OHV trail system, primarily serving as a means to provide reasonable access to designated OHV or forest access routes. Equally common is not allowing any ATV travel in roadway rights-of-way due to unacceptable levels of impacts.

At present, local jurisdictions determine the degree to which ATVs are allowed in road rights-of-way based on technical evaluations of impact and public opinion. Given the increasing public concern about this issue, local jurisdictions are encouraged to clearly define and enforce restrictions on the use of road rights-of-way for OHV use. The following photos highlight increasingly unsustainable conditions that, if left unchecked, often lead to more restrictive policies on ATV access.



Problem: Increasingly unsustainable impacts to driveway approaches. *In each of these cases, the loss of stabilizing vegetation and rutting/displacement of soils is exposing the pavement edge and undercutting its structural integrity. Of all the conditions that concern local roadway engineers, this is the one that gets the most immediate attention simply because of the safety concerns and ongoing maintenance costs.*

Problem: Excessive impacts to roadway rights-of-way. *In each of these examples, ATVs are illegally using rights-of-way as de facto corridor trails, which impacts the roadside aesthetic and often causes varying degrees of environmental degradation. Damage to roadside wetlands (top left), steep, erodible slopes (above), and arbitrary roadway crossings (bottom left) are all cause for concern and often result in broader restrictions on the use of ATVs in these areas.*

ACCEPTABLE CONDITIONS RELATED TO SUSTAINABILITY

In certain prescribed situations, seemingly unsustainable trails are acceptable within specific space and design parameters. This is almost exclusively limited to designated OHV recreation areas and very select OHV trails, as the following photos illustrate.

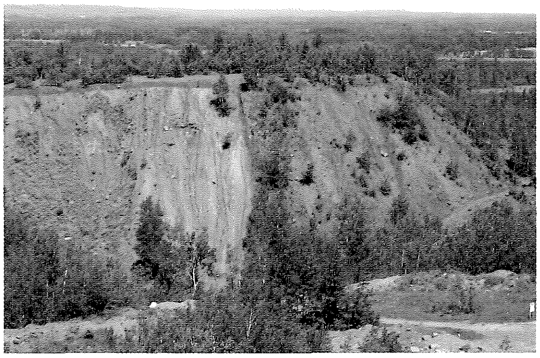
This water crossing challenge area is purposefully isolated to prevent sediment from getting into larger hydrologic systems. The whole area is less than an acre and is sufficient to meet this limited need.

This scramble area allows riders to mess around in a confined space. This helps prevent such activity from happening somewhere else where it would be less controlled and pose a greater environmental concern.

This fall-line trail challenges rider and machine climbing ability. Although steep, this trail is relatively stable due to soil conditions and routine maintenance.

This rock crawl area provides hours of entertainment to a select group of ORVs who otherwise would have a hard time finding a legal place to use their vehicles.

This short but very challenging ATV technical course provides an outlet for advanced riders to test their skills. Again, this is in a controlled space where runoff and erosion can be reasonably managed. The heavily anchored trail (tree cover) also keeps riders from straying from the designated corridor.



This seemingly impossible OHM climb would likely never be provided outside the confines of a designated OHV recreation area.

These examples highlight that providing an outlet for high impact activities reduces the likelihood of them occurring elsewhere in an unauthorized manner. Such facilities make it possible to hold users more accountable for the responsible use of trails and public lands where such activities would be less sustainable and inappropriate.

Taking Action on Unsustainable Trails

Occasionally, trails will become unsustainable due to poor design, improper use, or higher-than-expected use levels for the given classification. Whatever the cause, action is necessary to avoid further degradation of the trail and surrounding ecological systems.

When an unsustainable threshold is reached, the options are to restrict use, reclassify, or decommission the trail.

Restricting Use of a Trail

Restricting use is one option when trails become unsustainable. Of all of the options, use restrictions offers the most flexibility in that they can be applied as warranted by a given situation. With respect to recreational pursuits, options for restricting use of trails and forest access routes include the following:

- Temporary closure to allow time to resolve the situation with user groups
- Limited restrictions on the type of use allowed on either a seasonal or specified-time basis (e.g., closing an area for a year or two to allow it to recover)
- Full restrictions on a given type of use

Reclassifying a Trail

If a trail is found to be unsustainable, reclassifying it to a higher or lower level trail is an option as long as the consequences are understood. If a trail classification is raised, that usually entails a higher level of design, management, and stewardship, each of which has cost implications. If a trail classification is lowered, it typically means some former use will no longer be allowed. The difficulty of either of these options underscores the importance of making sure that trails are properly classified in the first place and that if sustainability cannot be assured to begin with, then the viability of a trail should be closely scrutinized.

OHV trails require the most planning and design diligence because they are most prone to becoming unsustainable; followed by trails for horseback riding, mountain biking, and hiking in descending order.

For OHV uses, the most likely scenario for reclassifying a trail relates to forest access routes, which are typically existing low-maintenance or lower-level routes and old logging trails through county, state, and federal forests or other public lands that are open to general recreational use. Under this classification, these trails are made available to motorized and nonmotorized activities only *as long as those uses remain sustainable with limited maintenance* since these routes can be very extensive and it is unlikely that resource managers would ever be able to go beyond very basic maintenance. As long as use levels are relatively low and users are responsible, these trails can be sustainable.

Should a forest access routes become unsustainable, there are two options:

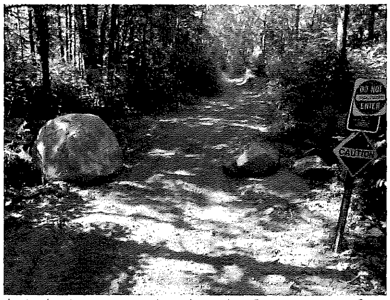
- Raising the classification level to "designated OHV trail," which brings with it higher design and stewardship requirements needed to achieve a sustainable condition
- Lower the classification to "hunter/walker trail," which eliminates motorized uses and therefore greatly reduces the likelihood of further impacts

Notably, classification should be raised to a designated OHV trail only if the route is needed as part of a larger OHV trail system plan. Otherwise, arbitrarily raising it without the capacity to redesign and manage the new trail only leads to more impacts and more dramatic restrictions to access later on. This same logic holds true for other types of trails as well, albeit the likelihood of unsustainable conditions occurring is smaller.

Decommissioning a Trail

Decommissioning a trail simply means taking it out of use and restoring it to some semblance of the pretrail conditions. The goal is to enable nature to reclaim the site quickly and in a cost-effective way. The following Guiding Principle #7 – Formally Decommission and Restore Closed or Unsustainable Trail Corridors covers this issue in greater detail.

Guiding Principle #7 – Formally Decommission and Restore Closed or Unsustainable Trail Corridors



A single sign mounted to the side of an expanse of seemingly intact trail is nearly always ignored.

Decommissioning relates to closing a trail and returning it to a natural state consistent with the surrounding landscape. Whether due to an unsustainable condition or the need to reroute a trail to improve performance, formal closure and some level of site restoration is necessary to prevent further use of the corridor. This is especially the case with natural surface trails that have well-established use patterns, where it can be quite difficult to change existing use patterns.

When a trail is closed or a trail segment is rerouted, at a minimum the visible ends of the old trail should be regraded back to the original slopes, the eroded soil there should be replaced, and the trail end should be replanted with native plants. The use of a physical barrier *and* reducing the visibility of the old trail tread are both necessary to effectively close a trail. Experience has shown that relying solely on fences and gates to block entrances of decommissioned trails is not very effective. Lacking other visual cues that the trail is closed, users tend to bypass a barrier to continue accessing a trail, as the following photos illustrate.

A trail closed with a gate remains inviting to use, and the gate, even when combined with fencing, is often bypassed. Although gates are commonly used for seasonal closures, they are not typically enough to formally decommission a trail.

The barrier stones in the foreground are easily bypassed, and ATV tracks are visible where users have gone around the stone on the left. Again, the visible trail is too enticing for some visitors to resist.

Seen from the top of the hill, this grassy area was a former hill climb and scramble area for OHVs. Even though it was planted with grass and closed to motorized use, some users directly penetrate the barriers while others go around them to form new side trails. The temptation is visual and is caused partly by sightlines. Filling the area with planted trees would greatly reduce the temptation and improve compliance.

Given the difficulty of breaking established use patterns, site repair should be performed on all closed trails as soon as possible after decommissioning. The following provides some guidelines for blocking and restoring entrances to reduce the appeal of using decommissioned trails.

DENSE PLANTING AT TRAIL ENTRANCES AND ALONG TRAIL CORRIDORS

Densely planted trees, shrubs, and herbaceous species (depending on landscape and location) help create a sense of permanence, stability, and naturalness in a decommissioned trail corridor. Most trail users will respect a closed area planted with dense plants, especially large trees.

If the entrance to a decommissioned trail corridor is wooded, site repair should include native trees or woody shrubs to match or even exceed the density of the surrounding site. Since rehabilitation is intended to create a visual repair, tree planting is most effective if the planted trees are of a variety of ages and heights. If possible, transplant large conifers from nearby forest and/or plant balled-and-burlapped trees of any indigenous species in a natural pattern as long as site conditions or regular maintenance can reasonably ensure tree survival. The following photos illustrate this approach.

This band of even-aged conifers was once an OHV scramble area. Trail users repeatedly tore down a chain link fence across the access. After the trees were densely planted on the hillside behind the repaired fence, all illegal usage ceased and no new scramble areas developed.

Transplanted trees, large stones, and piles of dense slash were used to visually and physically block the entrance to this restoration area. Planting more trees would have further blocked the sightline, although visitor compliance has been very good even with the existing effort.

Transplanted trees of various sizes were used to narrow a road/trail that was widened by off-trail OHV use. Visitor compliance is good, but some visitors still enter the area as shown by the ATV tracks on the far right of the photo. Adding more trees or naturalizing bare soil would further improved compliance.

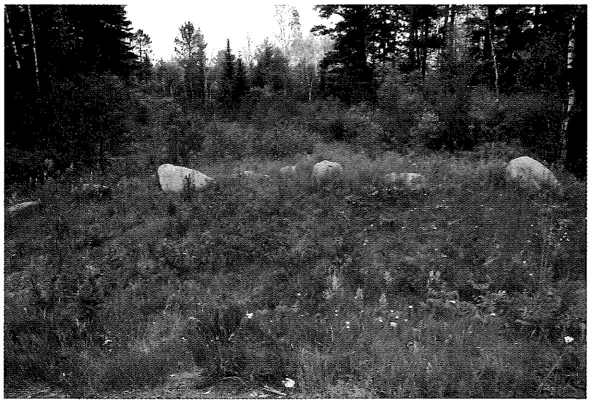
Not enough trees! Although the conifers in the center were planted to block lake access by OHVs, such an enticing destination requires a much more dense blockade of trees. Note how visitors readily formed a new bypass around the trees (right). In this location, many more trees are needed, and trees alone may be insufficient for an effective physical barrier.

CLOSURE BERMS TO BLOCK ENTRANCES OF SELECTED DECOMMISSIONED TRAILS

Physical closure of roads and trails wider than 6 feet can be reinforced with a constructed earthen berm at least 54 inches high to send a clear message to trail users. Entrances to trails less than 6 feet can be bermed as deemed appropriate.

The intent is to physically and visually block the former entrance with a steep berm that purposefully looks like an intentional, reinforced, "we mean it" closure. The sides of the berm should be left at or near the angle of repose to make them steep and to look like a barrier. Both ends of the berm should extend beyond the former trail entrance for as long as necessary to prevent visitors from seeing a closed trail behind the berm. For at least the first few years, the berm should be posted with signs such as Restoration Area – Keep Off or Seedlings Planting – Keep Off. Multiple signs should be used for each site, and the signs should look utilitarian and authoritative. Construction fence, such as orange plastic mesh fence, should also be used in front of the berm to reinforce the message until vegetation is well established.

Note that much of the purpose of a closure berm is psychological – it needs to send a strong signal that the area behind the berm is permanently closed. Avoid softening the edges, tapering the ends, or making "friendly" signs since these will undermine the psychological signal. Unlike other aspects of trail work described in these guidelines, closure berms should look rigid, unyielding, angular, and authoritative. Some visitors will climb the berm just to see what's on the other side, but the berm still serves as a strong psychological barrier that is more effective than a fence-type barrier. Once the trail has been completely restored, the berm can often be reshaped or removed to blend into the natural setting. The following photos illustrate a variety of closure berms.



A road closure berm with embedded rocks has prevented traffic from entering this closed trail. Planting trees on the berm would help even more. Behind the berm, the forest is filling in through natural processes.

This recently constructed berm closes a rerouted trail. Conifer seedlings were planted behind and on the berm. The sign reads, "Seedlings Planted – Keep Off" and the tops of the wood posts are emphasized with red paint. This berm has kept motorized traffic out of the closed area.

A straight forest road/trail was rerouted to the left (where the vehicle is heading) and the old route was hidden with a low berm (behind the orange fence) and planted conifers. The conifers largely hide the berm and the former route. This closure would have been even more successful if more trees had been planted and if the grade and ground cover in front of the berm were completely restored.

In addition to a closure berm, this road/trail was also closed with intermediate berms and slash. This is most effective in heavily wooded areas where off-trail travel is difficult.

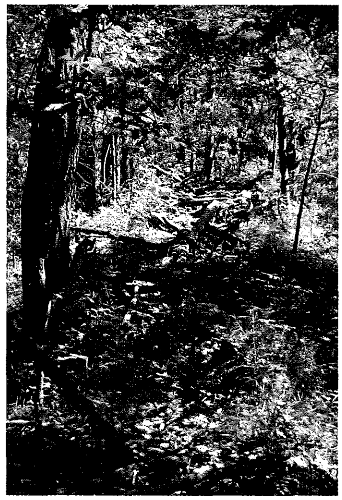
To maximize effectiveness, the berm must be densely planted with native ground vegetation and, if possible, trees. Trees for the site – especially a dense wall of 6- to 10-foot high conifers planted on and around the berm – greatly help to reinforce the closure message and invoke a sense of permanence that enhances compliance in many trail users. If large trees cannot be successfully transplanted, planting many seedlings is an alternative approach. Note that conifers should only be used in sites where they occur naturally. In other locations, area-appropriate trees or shrubs should be used.

Using Slash to Reinforce Trail Decommissioning

Under certain conditions, slash can be used to reinforce closed areas. This is especially the case where restoration efforts will take more time to reestablish native vegetation and an interim solution is needed to reinforce trail closure.

To be effective, slash should be thick, tangled, and obvious so that it forms an unambiguous visible barrier. In order to best disrupt the line of the trail, arrange branches and trunks across the trail at various angles, rather than parallel to or at right angles to the trail. Seeds, preferably collected from a local source, could then be added over time if the slash isn't too thick. The following photos illustrate the use of slashing to reinforce trail closure.

Slash was used to close the entrance to an eroded fall-line OHV trail in the upper center of the photo. Ideally, the entire visible section of the decommissioned trail should have been restored or closed with slash.



The entrance to a forest trail was filled with slash in lieu of backfilling and restoration. Natural processes are restoring native vegetation without seeding.

This deeply eroded horse trail in sandy soil was closed with slash and a trail closure sign pending further action. Further erosion could be reduced by adding considerably more thick slash.

This resource rest area sign explains the concept in a friendly yet authoritative way designed to attempt to elicit cooperation and create stewardship.

RENATURALIZING DECOMMISSIONED TRAIL CORRIDORS

Renaturalizing a decommissioned trail refers to restoring the ecosystem and surface drainage of the corridor to reasonably replicate its original condition. Renaturalization cannot fully restore a site to its pretrail condition, but it can significantly enhance natural ecosystem structure and function. Hence, site repair is important and should be performed at some level on all decommissioned trail segments.

General Renaturalization Considerations

Ideally, all decommissioned trail corridors should be renaturalized as thoroughly as possible to replicate surrounding natural systems. Realistically, major re-naturalization can prove difficult or even undesirable because of associated costs, risk of introducing exotic species, or risk of causing excessive damage during repair operations. Therefore, different parts of the same corridor can be repaired to varying standards depending on the extent of impact, location, and type of ecosystem. For instance, the ends of a decommissioned trail may be extensively repaired to restore the original landform and vegetation as much as practical, while in the center of the trail repair may simply involve stabilizing the site and encouraging natural vegetation succession with or without soil amendment, seeding, planting, or transplanting.

If the repair budget is limited, concentrate on stabilizing the most unstable sections, restoring the most visible or ecologically critical sections, and naturalizing sections that lend themselves to recovery. Volunteers may provide valuable assistance.

Limit Impacts of Renaturalizing Operations

The collateral impact of site repair should be kept to a minimum and generally not exceed more than 20 percent of the surface area being repaired. If the desired level of site repair would cause more extensive adjacent impact, a lower level of naturalization or an alternate means of repair should be used. For wet or fragile sites, consider working while the ground is frozen.

On deeply eroded trails too narrow to be repaired with ground machinery, or in sites where machine access would cause excessive further impact, helicopters may be a feasible way to transport bulk materials without further damaging the site. Depending on the site, ATVs and/or pack animals can sometimes be used without creating additional damage. Volunteers can also do small-scale site repair by hand or with ATVs (where appropriate) with minimal impact.

Develop a Vegetative Management Plan

All renaturalizing activities should follow a vegetative management plan to encourage growth of native plants and control exotic species. The larger the impact area, the more comprehensive the vegetative management plan should be.

During excavation and new construction, organic soil should be stockpiled for revegetation. To be effective, the organic soil layer should be at least 4 inches thick and preferably match that of the surrounding undisturbed area.

Avoid Introducing or Spreading Exotic Plant Species

The following practices will limit the introduction and spreading of exotic plant species:

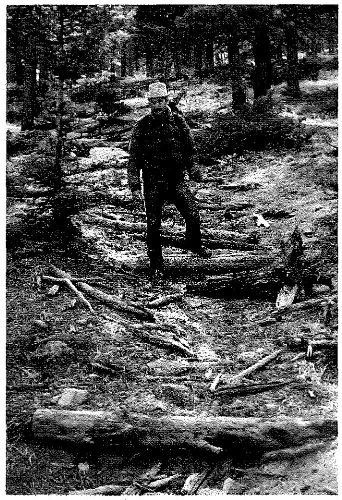
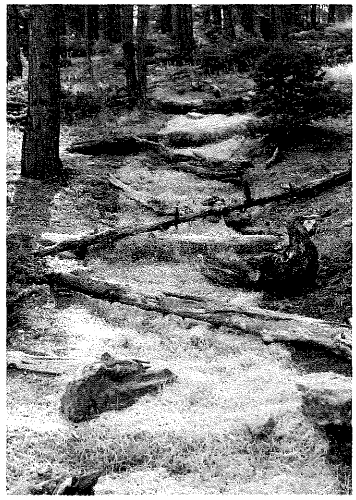
- Soil for fill should be obtained nearby to avoid importing exotic seeds or organisms
- All imported seeds and mulch should be certified as weed-free
- Hand-harvested native local seed and/or transplants can be used when restoring vegetation in highly sensitive areas or areas to be kept as biologically undisturbed as possible.
- Seeding a nurse crop that will die off over time can also help prevent exotic species from becoming established, especially if native seeds are seeded along with the nurse crop. The nurse crop creates a quick vegetative cover which improves germination and survival for slower-growing natives while occupying the ecological niche that might otherwise be filled with exotics
- In ecologically sensitive sites, all seeding can optionally be avoided, with revegetation relying on transplanting nearby plants, scarification, and natural regrowth
- The vegetative management plan should address exotic species eradication or control, including exotic species that are already be growing on the site

Nonvisible Decommissioned Trail Segments Brought to Various Levels of Renaturalization

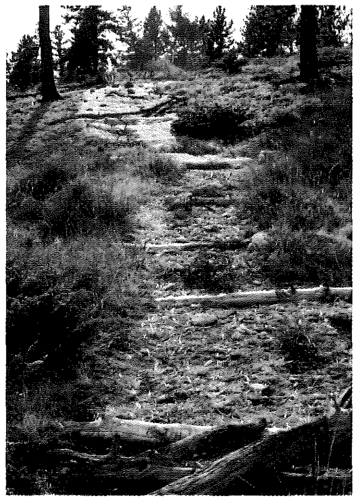
Decommissioned trail segments not visible from any access point can be renaturalized to different levels depending upon the character of the site, the level of damage, and the risk of creating additional physical or ecological damage during repair. The following criteria should be used for determining which level is most appropriate for a given site:

- **Stabilization** – at a minimum, this is required along the full length of decommissioned trails and surrounding areas. This includes adding drainage control and/or erosion control measures to prevent erosion from increasing; adding slash to eroded ruts to keep visitors out and create protection for seeds; and draining introduced mudholes
- **Scarification** – should be performed where soil is compacted to the point where natural revegetation will be slow, stunted, or will likely consist mostly of weeds. This includes loosening of compacted soil by manual or mechanical means and partially restoring the predamage landform by reshaping and/or through the use of erosion control devices. The soil surface is typically left relatively rough so seeds have many protected and moist niches in which to sprout. The area may or may not to be reseeded
- **Naturalization** – should be performed where accelerated revegetation, quick visual concealment of damage, and reestablishment of historic surface water movement is needed. This includes filling or reshaping trail ruts and site scars to blend with or match the original landform; seeding with indigenous plants or transplants from the surrounding areas according to the vegetative management plan; covering bare soil with forest duff and fallen trees as appropriate using a natural pattern to seamlessly blend the site into the surrounding area; and planting or transplanting indigenous live trees of various age classes as appropriate for the ecosystem

The following photos highlight the various levels of trail corridor renaturalization.

Stabilization of gullied fall-line trail with check dams made from dead trees (left) and with check dams plus erosion control blanket in steeper areas (right). Erosion control blanket doubles as mulch.

(Left) Scarification of a former compacted trail surface was mechanically ripped and topsoil and organic material from the replacement trail were added to partially fill the old tread.

(Right) Compacted soil was loosened and the tread was reshaped to more closely match the surrounding hillside, with dead logs and some erosion control blankets used for stabilization (right).


(Left) Naturalization extends the duff and moveable site features (soil, fallen trees, branches, rocks) into the repair area in naturalistic ways. The area behind the stone wall is a decommissioned trail recently naturalized without planting. The stone retaining wall supports a new trail in a higher alignment, foreground.

(Right) The foreground trail was just naturalized with soil removed from the reroute (visible horizontally across the top of the photo). The small spruce near the center of the photo was planted in the old trail rut. The backfilled trail was not seeded.

Blend Trail Back Into the Original Landform

For naturalization and rehabilitation, the trail bed, trail ruts, and associated earthwork should be blended back into the original landform. In level areas, this often requires substantial filling of trail ruts and erosion.

On a sideslope alignment, the cutslope and fillslope (below the tread) should be considered impacts. Even if these slopes have revegetated, renaturalization may require pulling the fillslope back up onto the cutslope in order to restore the original surface drainage and landform. Since this creates a larger scar in the short term, the extent to which this should be done can be decided on a case-by-case basis. It can also be done intermittently so that some existing trees or plant species of concern can be preserved.

Vegetated berms, including superelevated curves on OHV and mountain bike trails, may form on one or both sides of many trail segments. These berms should also be considered as a site impact and be removed during renaturalization.

Good and poor trail blending. *(Left) Since the edges of the rut on this trail were filled to the top, the physical trail scar will largely disappear with revegetation. (Right) With the vertical edges of the trail rut left exposed, this trail tread will remain visible. More fill and/or shaving down the vertical edge is needed to form a gradual edge that would revegetate without leaving a telltale scar.*

Remove Structures Requiring Ongoing Maintenance

Culverts, boardwalks, bridges, and other structures that are no longer needed or that will fail over time should be removed when a trail is decommissioned. Exceptions can be made for well-crafted structures or those of historic significance, such as stone bridge abutments or a stone-paved drainage crossing.

Regulatory Reminder!

In Minnesota, there are specific regulatory and permitting requirements associated with trail work impacting water bodies. These are considered in more detail in *Section 1 – Framework for Planning Sustainable Trails.*

Reshape Stream Crossings and Creating Breaks in Floodprone Areas

When removing water crossing structures, the crossings should be reshaped to approximate the original channel and stabilize the stream-banks and approaches. If the decommissioned trail has any long fills across floodplain areas, removal of sections of fill should be considered to accommodate natural water fluctuation.

Backfill Decommissioned Trails With Material from New Trails

If a new trail is being constructed nearby, use excavated material to backfill the old trail as needed. Although some organic soil should be reserved for topping cuts and fills associated with the new trail, some can often be used for nearby site repair.

Native plants salvaged from the new trail can also often be transplanted into the decommissioned trail. If heavy equipment is used, salvageable plants should be removed by hand and transplanted as quickly as possible. If plants have to wait, their soil should be kept moist. Plants should also be watered thoroughly after transplanting.

Managing Drainage and Erosion When Renaturalizing Decommissioned Trails

A variety of techniques can be used to manage drainage and control erosion when trails being renaturalized are most vulnerable to stormwater runoff. Many of these techniques complement the BMPs associated with protecting adjoining natural areas as previously considered in this section. The following considers the most common techniques for this purpose.

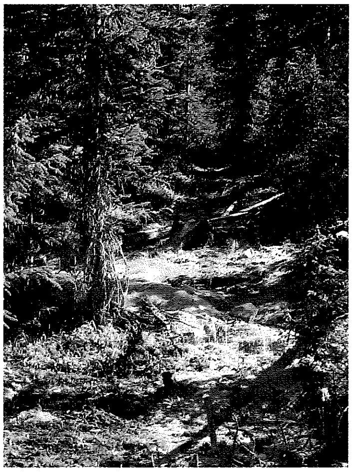
Drainage Dips and Crests

Shaping drainage dips and/or crests into the closed trail tread can be an effective way of managing stormwater runoff to prevent erosion of the restored corridor while new vegetation is taking hold. This usually requires cutting through a berm on the outside edge of the trail. The principles of rolling grade as defined in Section 6 – Sustainable Natural Surface Trails can be used to determine spacing between dips.

Although discouraged on active trails, timber waterbars can be used on decommissioned trails as a stopgap measure to prevent erosion while the site is revegetated and stabilized. Because timber waterbars are more prone to failure than are trenches, some of the drainage dips should be dug in and made permanent so the treadway will always drain at manageable intervals.

Erosion Control Blankets

For steep or exposed (south- or west-facing) slopes and high-runoff areas, such as the bottoms of swales or unvegetated drainages, erosion control blankets act as mulch and stabilization against water and wind erosion. Blankets are available with different thicknesses and mixtures of straw, coconut fibers, aspen shavings, or other materials with biodegradable or photodegradable meshes. Blankets are stapled into place with steel or biodegradable (cornstarch) staples, or sometimes held down by wood and rocks. A benefit is that the treated area is clearly intended for revegetation and people tend to stay off of it. Drawbacks are relatively high cost and probable need to later remove any remaining mesh and staples that did not decompose. Planting early succession plants or nurse crops in the blankets could accelerate revegetation. The following photos illustrate the use of erosion control blankets.



(Left) Erosion-control blanket of woven aspen shavings in photodegradable plastic mesh is used as mulch on a filled and exposed fall-line trail being decommissioned. Deadfall and rocks help to anchor the blanket.

(Right) Erosion control blankets, stapled down, were used liberally on this gullied fall-line trail.

Thick Slash and Check Dams

Adding thick slash (tree limbs and/or removed trees) to deeply eroded trails and areas can help natural vegetation become established. In many cases, the sediment collected in the slash becomes new seed beds. The slash also provides cover, wind protection, and sun protection for seeds. This technique is often used in wooded areas to both demarcate a trail as closed and help establish vegetation without seeding. The slash should not be so dense as to prevent vegetation from growing beneath it.

In stabilizing fall-line gullies and moderately steep, deeply eroded trails, check dams made of straw wattles, straw bales, deadfall timber, or stone can be constructed to periodically slow runoff. The dams themselves may be removed or allowed to decompose once vegetation is established behind them. The following photos illustrate the use of check dams and straw wattles.

Trees are used as check dams to reduce erosion down this decommissioned, gullied, fall-line trail until vegetation is firmly established.

This straw wattle serves as a temporary device for slowing and diverting water.

Soil Bags for Terracing Slopes

Steep, deep gullies and deeply eroded fall-line alignments can be stabilized by terracing with soil bags, which are burlap bags filled with soil and stacked like a battered retaining wall to form terraces within the gully. Vegetation and trees growing on the terraces and spreading onto the biodegradable soil bags eventually stabilize the gully without completely backfilling it. This technique partially fills the gully while providing a permanent, yet natural, solution without artificial remnants.

Brush Layering

Fillslopes can be stabilized in the short term by burying live branches of willow, dogwood, and select other species in the fill with their tips protruding. Even in upland areas, many of the branches will sprout roots and live for a few years, providing cover and some erosion control for the slope while allowing grasses, ground covers, and woody plants to become established. In riparian areas or on moist hillsides, some of the buried branches may form new trees. Brush layers can also be used with other slope stabilization methods such as check dams and soil bags.

Soil Bioengineering for Slopes

For steep slopes in riparian areas, shorelines, wet hillsides, and upland hillsides, soil bioengineering measures such as live stake, live fascine, brush layering, live cribwall, vegetated geogrid, branch-packing, and live slope grating may be effective and naturalistic site repair methods. All of these methods use live vegetation to repair and protect slopes.

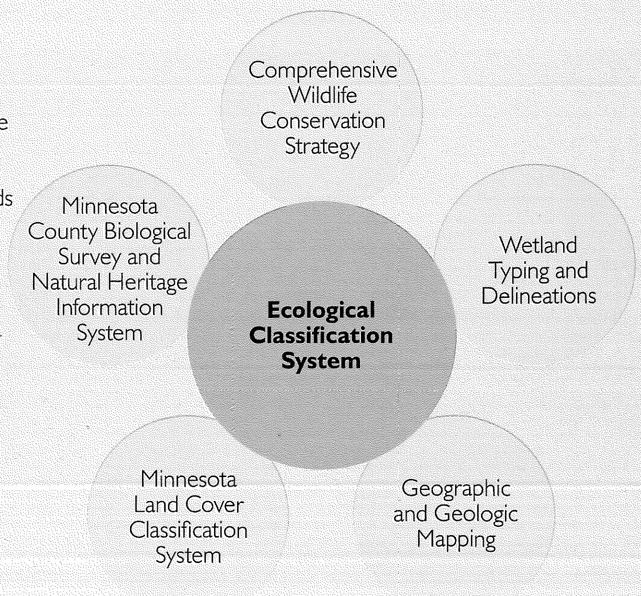
Biotechnical slope stabilization can be used for steep slopes in riparian areas, shorelines, wet hillsides, and upland hillsides. This includes the use of flexible mats, cellular revetments (geocells), gabions, and open-front cribwalls that are engineered yet still retain a naturalistic appearance if designed appropriately. All of these methods use live vegetation, especially woody plants, to repair and protect slopes.

Common Methods for Defining Natural Areas and Sensitive Ecological Systems

Developing sustainable trails relies upon a common definition of natural areas and sensitive ecological systems. Scientific and technical analysis of these systems provides the underpinning necessary to make sound planning decisions that will result in sustainable trails. Within Minnesota, there are a number of established methods of defining natural areas and sensitive ecological systems, as highlighted in the following graphic.

Common Methods for Defining Natural Areas and Ecological Systems

The base-line method for defining natural areas and ecological systems is the Ecological Classification System (ECS), which is part of a nationwide mapping initiative developed to improve the ability to manage natural resources on a sustainable basis. This system is supported by a variety of other methods that provide increasingly detailed information about a site. The diagram defines the most commonly used methods in Minnesota.



> ***For more information!***
> Check out the DNR website for more information on the ECS at www.dnr.state.mn.us/ecs/index.html

The following provides an overview of each of these methods.

THE ECOLOGICAL CLASSIFICATION SYSTEM (ECS) AS THE FRAMEWORK FOR MANAGING NATURAL RESOURCES

The Ecological Classification System (ECS) scientifically delineates and describes meaningful units of the natural landscape to form a basic framework for research and management. It identifies interrelationships and interactions among ecological components, such as climate, geomorphology, soil, topography, vegetation, hydrology, animals, and land history.

As a framework for sustainable natural resource management, the ECS:

- **Provides a common means of communication** among resource managers, as well as with the public
- **Improves predictions about how vegetation will change over time** in response to various influences
- **Improves our understanding of the interrelationships** among plant communities, wildlife habitat, water quality, and human needs

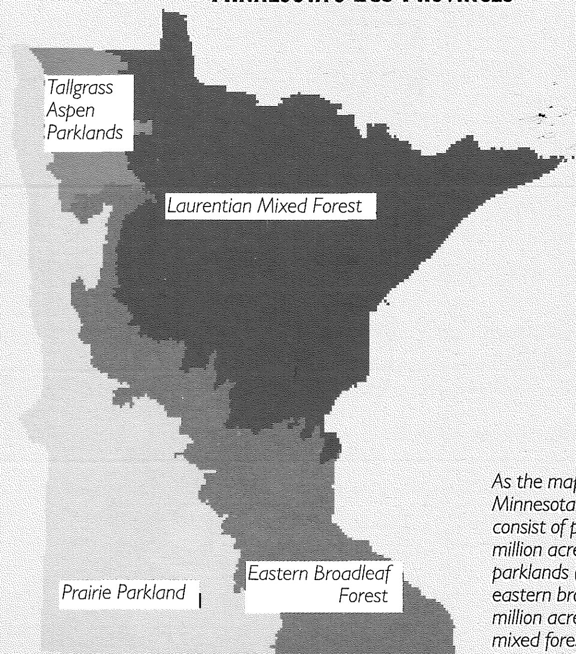
The Minnesota ECS identifies six ecological units. It follows the methodology used by the U.S. Forest Service and is part of the Great Lakes Region ECS.

The classification is hierarchic, with smaller ecological units contained within larger ones. The following defines the six levels of ecological units.

LEVEL I: PROVINCE

Minnesota has four ECS provinces, defined by climate (temperature and moisture), geology, and associated major vegetation patterns:

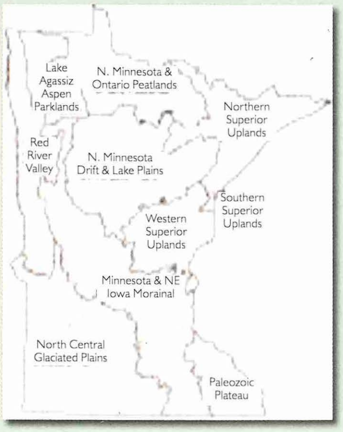
MINNESOTA'S ECS PROVINCES



As the map illustrates, Minnesota's four provinces consist of prairie parkland (16 million acres), tallgrass aspen parklands (3 million acres), eastern broadleaf forest (12 million acres), and laurentian mixed forest (23 million acres).

- **Prairie Parkland Province** covers about 16 million acres of southern and southwestern Minnesota. Before settlement, this area was primarily covered by tallgrass prairie. Its topography is mostly level to gently rolling; major landforms include lake plains and ground moraines.
- **Tallgrass Aspen Parklands Province** covers about 3 million acres in northwestern Minnesota. Part of an extensive lake plain, it is level in the western portion with small dunes and a series of low beach ridges and swales to the east. Before settlement the vegetation consisted of aspen savanna, tallgrass prairie, wet prairie, gravel prairie, and floodplain forest along rivers.

MINNESOTA'S 10 ECS SECTIONS



- **Eastern Broadleaf Forest Province** covers 12 million acres through the heart of the state. It forms a transitional zone between the prairie to the west and the boreal forest (conifer, conifer-hardwood mix, or hardwood forest) to the northeast. Topography varies from level lake plains to very steep slopes in the Paleozoic plateau of the southeast. Major landforms include lake plains, outwash plains, moraines, and drumlin fields.
- **Laurentian Mixed Forest Province** covers the northeastern 23 million acres of Minnesota. It is the boreal forest region of our state. Before settlement, this area consisted primarily of coniferous forest, coniferous-hardwood mix, or northern hardwood forest. Topography is variable. Landforms range from lake plains and outwash plains to ground and end moraines.

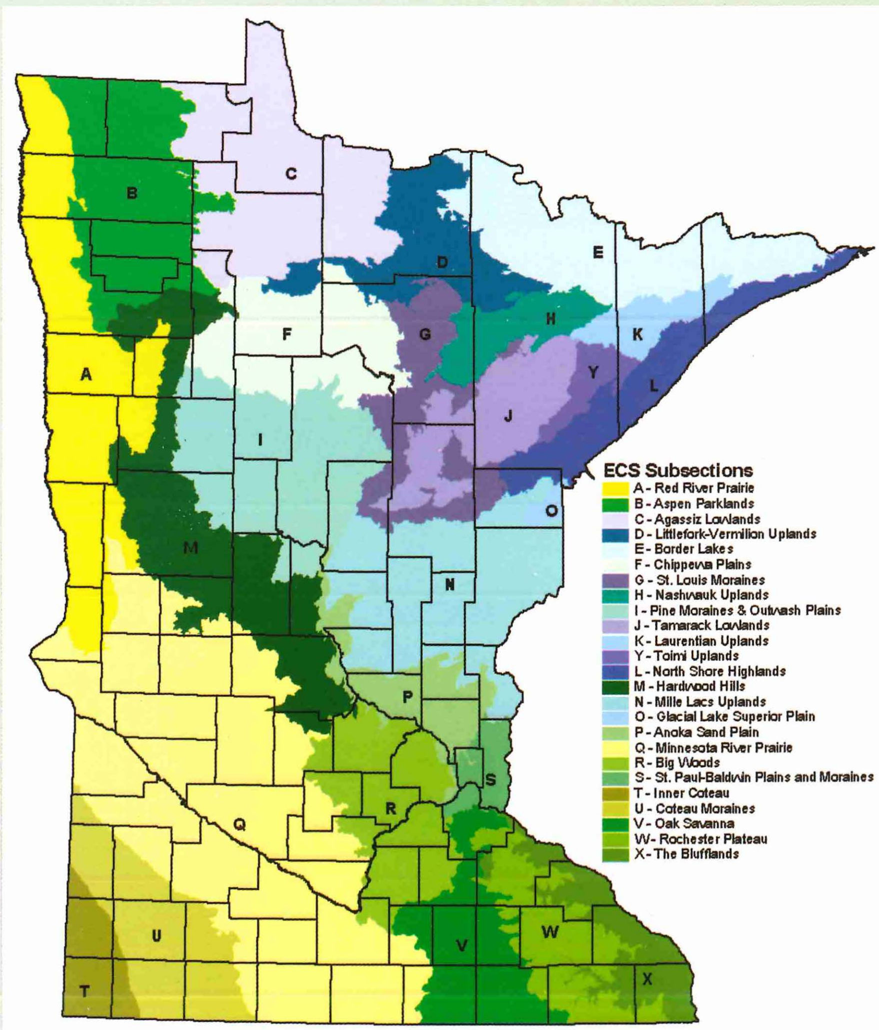
LEVEL 2: SECTION

Provinces are subdivided into sections. Sections are defined by the origin of glacial deposits, regional elevation, distribution of plants, and regional climate. Minnesota has 10 sections, as illustrated in the box to the left.

LEVEL 3: SUBSECTION

Sections are further divided into subsections. These county-sized areas within sections are defined by glacial land-forming processes, bedrock formations, local climate, topographic relief, and the distribution of plants. Minnesota has 25 subsections, as illustrated in the following box.

MINNESOTA'S 25 ECS SUBSECTIONS



Level 4: Land Type Association (LTA)

Land type associations (LTAs) are landscapes within subsections. Land type associations are characterized by glacial formations, bedrock types, topographic roughness, lake and stream patterns, depth to groundwater table, and soil material. For example, the Alexandria Moraine is an LTA characterized by a particular glacial formation.

Level 5: Land Type (LT)

Land types (LTs) are the individual elements of an LTA. Land types are defined by recurring patterns of uplands and wetlands, soil types, plant communities, and fire history. A fire-dependent dry pine–hardwood association is an example of a land type.

Level 6: Land Type Phase (LTP)

Land type phase (LTP) or habitat type is a unique combination of plants and soils within an LT. Land type phases are defined by characteristic trees, shrubs, and forbs; by landscape position; and by soil texture and moisture. A sugar maple–basswood forest is an example of a land type phase.

Importance of the Ecological Classification System (ECS)

A basic understanding of the ECS is essential for effective management of natural resources along trails, as well as understanding their relationship to the surrounding landscape. The ECS can also help in understanding the interrelationships among plant communities, wildlife habitat, and water quality, thereby helping in recognizing the potential impact of recreational activities on natural resources. In addition, the ECS serves as a framework for planning and development of new trails and for the management and restoration of natural plant communities on existing sites.

Minnesota County Biological Survey (MCBS) and Natural Heritage Information System (NHIS)

For more information!

Check out the DNR website for more information on the MCBS at www.dnr.state.mn.us/ecological_services/mcbs/index.html.

The *Field Guides to the Native Plant Communities of Minnesota* series is also a valuable set of references available through the Minnesota Bookstore.

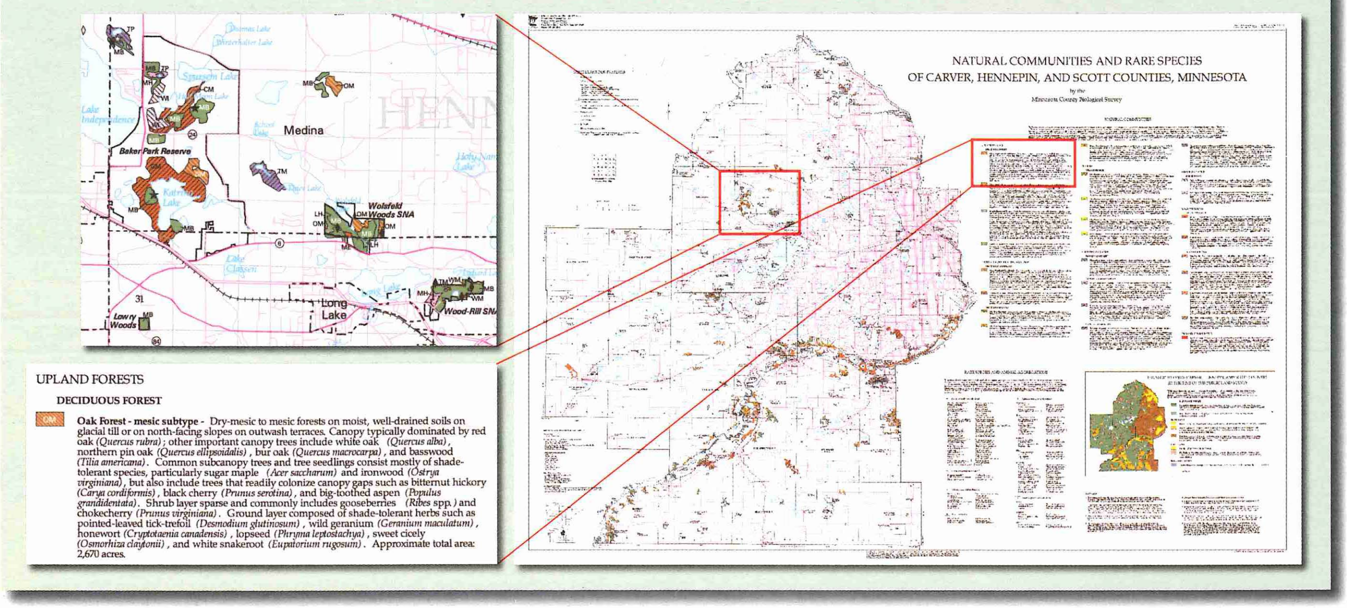
A detailed list of native plant communities and associated information is also available on the DNR's website (www.dnr.state.mn.us/ecological_services/nativeplantcommunities).

The Minnesota County Biological Survey (MCBS) began in 1987 as a systematic survey of rare biological features. The goal of the survey is to identify significant natural areas and to collect and interpret data on the distribution and ecology of rare plants, rare animals, and native plant communities. Native habitats surveyed by MCBS contribute to a sustainable economy and society because they:

- Provide reservoirs of genetic materials potentially useful in agriculture, medicine, and industry
- Provide ecological services that contribute to the quality of air, soil, and water
- Provide opportunities for research and monitoring on landscapes, native plant communities, plants, animals, and their relationships within the range of natural variation
- Serve as benchmarks for comparison of the effects of resource management
- Are part of natural ecosystems that represent Minnesota's natural heritage, and are sources of recreation, beauty, and inspiration

The MCBS provides valuable base-line information for determining the location of sensitive ecological areas and the appropriateness of routing a trail through a given area. Review of the survey is a recommended starting point for individual trail and trail system planning throughout the state. Review and consideration of the survey is fundamental to developing sustainable trails. The following box provides an example of a MCBS map.

Example of a Minnesota County Biological Survey Map



Remember the law!

Minnesota's endangered species law (Minnesota Statutes, Section 84.0895) can be reviewed on the DNR's website (www.dnr.state.mn.us/ets/index.html).

Data from the MCBS and all other rare features data in the state are stored in the Natural Heritage Information System (NHIS), which is continually updated as new information becomes available. The system is the most complete source of data on Minnesota's rare or otherwise significant species, native plant communities, and other natural features. Its purpose is to foster better understanding and conservation of these features. The most commonly used feature of the system is the Rare Features Database, which comprises locational records of the following features:

- **Rare plants,** including all species listed as federally endangered or threatened or as candidates for federal listing; all species that are state-listed as endangered, threatened, or special concern. Several rare species are also tracked that currently have no legal status but need monitoring to determine their status.
- **Rare animals,** including all species listed as federally endangered or threatened (except the gray wolf), as well as all birds, small mammals, reptiles, amphibians, mussels, and butterflies listed as state endangered, threatened, or special concern.
- **Native plant communities,** groups of native plants that interact with each other and with their environment in ways not greatly altered by modern human activity. They are classified and described by considering vegetation, hydrology, landforms, soils, and natural disturbance. Although most native plant communities have no legal protection in Minnesota, the Natural Heritage and Nongame Research Program and the MCBS have evaluated and ranked community types according to their relative rarity and endangerment and include high-quality examples in the database.
- **Geologic features,** including examples of geology throughout Minnesota if they are unique or rare, extraordinarily well preserved, widely documented, highly representative of a certain period of geologic history, or very useful in regional geologic correlation.
- **Animal aggregations,** including nesting colonies of water birds (herons, egrets, grebes, gulls, and terns), bat hibernacula, prairie chicken booming grounds, and winter bald eagle roosts, regardless of the legal status of the species that comprise them. The tendency to aggregate makes these species vulnerable because a single catastrophic event could result in the loss of many individuals.

The Minnesota Land Cover Classification System (MLCCS)

For more information!

Check out the DNR website for more information on the MLCCS at www.dnr.state.mn.us/nrplanning/community/index.html.

The Minnesota Land Cover Classification System (MLCCS) fills an important informational niche for natural resource managers and planners by categorizing vegetation patterns and urban or built-up areas in terms of land cover rather than land use. The system consists of five hierarchal levels. At the highest level, land cover is divided into either "natural/semi-natural" or "cultural" cover types, as the following considers.

Natural/Semi-Natural Cover Types

The natural/semi-natural classification system is a hybrid of the National Vegetation Classification System (NVCS) and the Minnesota Natural Heritage plant communities. The NVCS is used for the top three levels of the system, while the fourth and fifth levels rely on Minnesota Natural Heritage community types. The levels include:

- Level 1 - General growth patterns (e.g., forest, woodland, shrubland)
- Level 2 - Plant types (e.g., deciduous, coniferous, grasslands, forbs)
- Level 3 - Soil hydrology (e.g., upland, seasonally flooded, saturated)
- Level 4 and Level 5 - Plant species composition, (e.g., floodplain forest, rich fen sedge, jack pine barrens)

Cultural Cover Types

The cultural classification system is designed to identify built-up/vegetation patterns and an area's imperviousness to water. Most other land inventory classification systems, such as the U.S. Geological Survey (USGS) Anderson system, employ land-use terminology (e.g., urban, commercial, residential). This system distinguishes among land cover types at five levels:

- Level 1 - Presence of built-up elements (i.e., built-up vs. cultivated land)
- Level 2 - Dominant vegetation (e.g., trees, shrubs, herbaceous)
- Level 3 - Plant type (e.g., deciduous, coniferous)
- Level 4 - Percent of impervious surface or soil hydrology
- Level 5 - Specific plant species

This cultural classification is unique in that it emphasizes vegetation land cover instead of land use, thus creating a land cover inventory especially useful for resource managers and planners.

The following box graphically illustrates a MLCCS map of a geographical area.

Example of MLCCS Map

The development and institutionalization of the MLCCS by the DNR has brought much-needed consistency to technical evaluation of land cover across the state. The aerial photo illustrates a common visual perspective of a site. The accompanying MLCCS map provides a detailed mosaic of land cover classifications that has great value for natural resource and development planning. Completion of this type of mapping is a major step toward defining and understanding the ecological systems on a site and their quality, as well as providing a base-line for developing practical restoration and management strategies that will enhance the quality and sustainability of plant communities and ecological systems. The mapping is also an invaluable tool for determining which trail routes pose the least impact to the environment while also exposing visitors to the natural and cultural values offered by a site.

The MLCCS complements the information provided by the MCBS and provides greater detail for determining which land areas are ecologically sensitive to development and which lands have been disturbed and perhaps are more suitable than other areas for development. Reviewing existing surveys or conducting land cover surveys using MLCCS is recommended to enhance trail planning, help protect ecologically sensitive environments, and ensure consistency with the guiding principles for sustainable trails as presented in this section.

For more information!

Check out the DNR website for wetlands and the regulatory framework in Section 1 – Framework for Planning Sustainable Trails for more information on requirements associated with protecting Minnesota's wetlands and water bodies.

Preserving wetland and lake systems is at the core of Minnesota's ecological protection strategy. Routing trails to avoid or at least minimize impacts to these resources is a key underpinning of sustainable trail development.

WETLAND TYPING, DELINEATION REQUIREMENTS, AND PROTECTION STRATEGIES

The Wetland Conservation Act (WCA) maintains and protects Minnesota's wetlands and the benefits they provide. Enacted in 1991, it is one of the most sweeping wetlands protection laws in the country. The Legislature has amended the WCA significantly three times, mostly to accommodate the varying needs of the different geographic areas of Minnesota.

Local government units – cities, counties, watershed management organizations, soil and water conservation districts, and townships – implement the act locally. The Minnesota Board of Water and Soil Resources (BWSR) administers the act statewide, and the DNR enforces it.

The WCA recognizes the value of a number of wetland benefits, including:

- Water quality, including filtering pollutants out of surface- and ground-water, using nutrients that would otherwise pollute public waters, trapping sediments, protecting shoreline, and recharging groundwater supplies
- Floodwater and storm water retention, including reducing the potential for flooding
- Public recreation and education, including hunting and fishing, wildlife viewing, and experiencing nature
- Commercial benefits, including wild rice and cranberry growing and aquaculture
- Fish and wildlife benefits and low-flow augmentation during times of drought

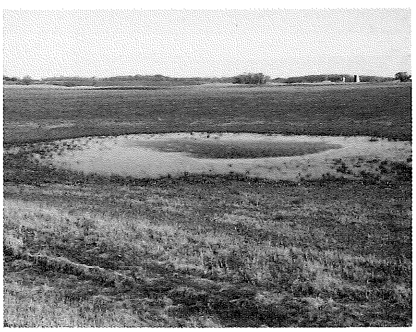
To retain the benefits of wetlands and reach the goal of no net loss of wetlands, the WCA requires anyone proposing to drain, fill, or excavate a wetland to first try to avoid disturbing the wetland; second, try to minimize any impact on the wetland; and, finally, to replace any lost wetland acres, functions, and values. Certain wetland activities are exempt from the act, allowing projects with minimal impact or projects on land where certain preestablished land uses are present to proceed without regulation.

WETLAND TYPES IN MINNESOTA

Nationally, there are several wetland classification systems. In Minnesota, the U.S. Fish and Wildlife Service Circular 39 Classification System is commonly used. Under this system, eight wetland types are recognized in Minnesota, not including rivers and lakes. The following provides an overview of each of these.

Type 1 - Seasonally Flooded Basin or Flat

Soil: Usually well drained during much of the growing season
Hydrology: Covered with water or waterlogged during variable seasonal periods
Vegetation: Varies greatly according to season and duration of flooding from bottomland hardwoods to herbaceous plants
Common sites: Upland depressions, bottomland hardwoods (floodplain forests)
National wetland inventory (NWI) symbols: PEMA, PFOA, PUS



Seasonally flooded basins may be kettles in glacial deposits, low spots in outwash plains, or depressions in floodplains. They are frequently cultivated.

When these basins are not cultivated, wetland vegetation can become established, including smartweeds, beggarticks, nut-grasses, and wild millet.

Type 2 - Wet (Sedge) Meadow

Soil: Saturated or nearly saturated during most of the growing season
Hydrology: Usually without standing water during most of the growing season but waterlogged within at least a few inches of the surface
Vegetation: Grasses, sedges, rushes, various broad-leaved plants
Common sites: May fill shallow basins, sloughs, or farmland sags; may border shallow marshes on the landward side and include low prairies, sedge meadows, and calcareous fens
NWI symbols: PEMB

Sedge meadows are dominated by the sedges growing on saturated soils. The forb species are diverse but scattered, and may flower poorly under intense competition with the sedges.

Soils are usually composed of peat or muck. Some sedges form hummocks.

Sedge meadows often grade into shallow marshes, calcareous fens, wet prairies, and bogs.

Type 3 - Shallow Marsh

Soil: Usually waterlogged early the during growing season
Hydrology: Often covered with 6 inches or more of water
Vegetation: Grasses, bulrush, spikerush, and various other marsh plants, such as cattail, arrowhead, pickerelweed, and smartweed
Common sites: May nearly fill shallow lake basins or sloughs; may border deep marshes on landward side, commonly as seep areas near irrigated lands
NWI symbols: PEMC and F, PSSH, PUBA and C

Shallow marsh plant communities have soils that are saturated to inundated by standing water up to 6 inches in depth throughout most of the growing season.

Herbaceous emergent vegetation such as cattails, bulrushes, arrowheads, and lake sedges characterize this community.

Type 4 - Deep Marsh

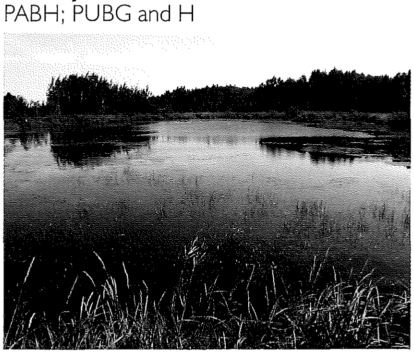
Soil: Inundated
Hydrology: Usually covered with 6 inches to 3 feet or more of water during growing season
Vegetation: Cattail, reed, bulrush, spikerush, and wild rice; open areas may have pondweed, naiad, coontail, watermilfoil, waterweed, duckweed, waterlily, and spatterdock
Common sites: May completely fill shallow lake basins, potholes, limestone sinks, and sloughs; may border open water
NWI symbols: L2ABF, L2EMF and G, L2US, PABF and G, PEMG and H, PUBB and F

Deep marsh communities have standing water depths of between 6 inches and 3 or more feet during the growing season.

Herbaceous emergent, floating and floating-leaved, and submergent vegetation compose this community, with the major dominance by cattails, hardstem bulrush, pickerelweed, giant bur-reed, Phragmites, wild rice, pondweeds and waterlilies.

Type 5 - Shallow Open Water

Soil: Inundated
Hydrology: Usually covered with less than 10 feet of water; includes shallow ponds and reservoirs
Vegetation: Fringe of emergent vegetation similar to open areas of Type 4
Common sites: Shallow lake basins; may border large open water basins
NWI symbols: L1; L2ABG and H; L2EMA, B, and H; L2RS; L2UB; PABH; PUBG and H



Submergent, floating, and floating-leaved aquatic vegetation including pondweeds, waterlilies, water milfoil, coontail, and duckweeds characterize this wetland type. Floating vegetation may or may not be present. Shallow open-water communities seldom, if ever, drawn down. These communities provide important habitat for many species.

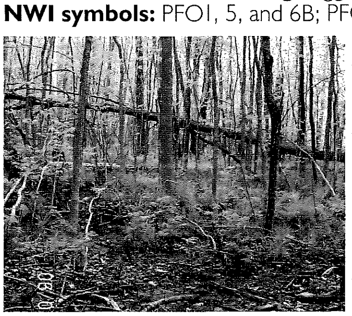
Type 6 - Shrub Swamp

Soil: Usually waterlogged during growing the season
Hydrology: Often covered with as much as 6 inches of water; water table is at or near the surface
Vegetation: Includes alder, willow, buttonbrush, dogwood, and swamp privet
Common sites: Along sluggish streams, and drainage depressions; occasionally on floodplains
NWI symbols: PSSA, C, F, and G; PSS1, 5, and 6B

Shrub swamps are wetland plant communities dominated by woody vegetation less than 20 feet high and with a dbh of less than 6 inches. Shrub swamps of Minnesota are categorized as shrub-carrs and alder thickets depending on the dominant shrub species. Both occur on organic soils (peat/muck) as well as on the alluvial mineral soils of floodplains.

Type 7 - Wooded Swamp

Soil: Waterlogged within a few inches of the surface during the growing season
Hydrology: Often covered with as much as 1 foot of water; water table is at or near the surface
Vegetation: Hardwood and coniferous swamps with tamarack, northern white cedar, black spruce, balsam fir, balsam poplar, red maple, and black ash; deciduous sites frequently support beds of duckweed and smartweed
Common sites: Mostly in shallow ancient lake basins, old riverine oxbows, flat terrains, and along sluggish streams
NWI symbols: PFO1, 5, and 6B; PFOC and F



Wooded swamps are forested wetlands dominated by mature conifers and lowland hardwood trees. This includes the northern wet-mesic forest and the southern wet and wet-mesic hardwood associations.

Wooded swamps are important for stormwater and floodwater retention. They also provide habitat for wildlife including white-tailed deer, furbearers, songbirds, ruffed grouse, barred owl and amphibians.

Type 8 - Bogs

Soil: Usually waterlogged
Hydrology: Water table at or near the surface
Vegetation: Woody, herbaceous, or both supporting a spongy covering of mosses; typical plants are heath shrubs, sphagnum mosses, sedges, leatherleaf, Labrador tea, cranberry, and cottongrass; may include stunted black spruce and tamarack
Common sites: Mostly on shallow glacial lake basins and depressions, flat terrains, and along sluggish streams
NWI symbols: PFO2, 4, and 7B; PSS2, 3, 4, and 7B

Bogs are found on saturated, acid peat soils that are low in nutrients and support a unique assemblage of trees, low shrubs, and herbs on a mat of sphagnum moss. Bogs are one stage in succession from open water lake to climax mesic hardwood forest. They originate on a floating mat of sedges that becomes colonized by sphagnum mosses.

METHODS FOR DELINEATING AND ASSESSING WETLANDS

Technical expertise is required to determine the type and extent of wetlands on a site. Typically, a trained wetland specialist completes a site inspection and wetland delineation using the *1987 Corps of Engineers Wetlands Delineation Manual, Technical Report Y-87-1,* U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi, which is required under the WCA and Section 404 of the Clean Water Act. Other publications that may have pertinence include:

- *Minnesota Routine Assessment Methodology for Evaluating Wetland Functions.* Board of Water and Soil Resources, Version 3.0, April 2004.
- *Minnesota Wetland Evaluation Methodology for the North Central United States.* U.S. Army Corps of Engineers, September 1988.
- *The Hydrogeomorphic Functional Assessment Methodology.* United States Army Corps of Engineers based on Wetland Research Program Technical Report WRP-DE3, August 1993.
- *Oregon Freshwater Wetland Assessment Methodology.* Oregon Division of State Lands, December 1993.
- *Method for the Comparative Evaluation of Nontidal Wetland in New Hampshire.* New Hampshire Department of Environmental Services, March 1991.

Regulatory Reminder!

Minnesota has specific regulatory and permitting requirements associated with wetlands that have application to trails. These are considered in more detail in Section I – Framework for Planning Sustainable Trails. Review these requirements to determine their application to any specific trail project.

PROTECTION STRATEGY FOR WETLANDS RELATED TO TRAILS

When developing trails the first and most desirable approach is to avoid wetlands, followed by minimizing impacts and, finally, replacing lost wetland acres, functions, and values.

As a general guideline, trails should only be routed through wetlands if there are no other options or if the trail is expressly designed for interpretive value. In these instances, every reasonable precaution should be taken to minimize disruption, as the following photos illustrate.

A simple boardwalk is often sufficient to provide trail access through a wetland with limited impact. In this case, there were no other options available to get through a 300-foot section of a trail that is 15 miles long.

Access to this aesthetically appealing pond is limited to an observation blind, with the main trail being several hundred feet away and safely buffered from this sensitive system.

PROTECTING NAVIGABLE BODIES OF WATER

Regulatory Reminder!

Minnesota has specific regulatory and permitting requirements associated with the CWA that have application to trails. These are considered in more detail in Section I – Framework for Planning Sustainable Trails. Review these requirements to determine their application to any specific trail project.

Review the DNR Public Waters Work Permit Program for its application to a trail project affecting water bodies at www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/index.html.

Through Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers has oversight of navigable bodies of water and associated wetlands. Understanding which bodies of water this encompasses is important in trail planning and the corps' mapping and related requirements are necessary planning tools whenever trails are near these areas.

Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Activities in waters of the United States that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry. Trails fall under infrastructure development.

The basic premise of the program is that no discharge of dredged or fill material can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if the nation's waters would be significantly degraded. When applying for a permit, the permittee must show that steps were taken to avoid and minimize wetland impacts where practicable and compensation for any remaining impacts was provided through restoration activities or creating new wetlands.

For more information!

Check out the DNR website for more information on the CWCS at www.dnr.state.mn.us/cwcs/index.html.

COMPREHENSIVE WILDLIFE CONSERVATION STRATEGY (CWCS)

Minnesota is an ecologically diverse state with more than 1,100 known wildlife species. About a quarter of the known species are identified as "species in greatest conservation need" by the Minnesota Comprehensive Wildlife Conservation Strategy (CWCS) project because they are rare, their populations are declining, or they face serious threats of decline. The U.S. Congress has mandated that partnerships within states and territories develop a CWCS to manage their "species in greatest conservation need." The Minnesota CWCS project is DNR's response to this congressional mandate.

STATE WILDLIFE GRANT PROGRAM

Congress created the State Wildlife Grant (SWG) program in 2001 to protect and manage wildlife species in greatest conservation need. It is the first-ever federally funded, state-implemented program to proactively address species endangerment and habitat conservation.

MINNESOTA'S COMPREHENSIVE WILDLIFE CONSERVATION STRATEGY

In order to participate in the SWG program, states were required to develop a CWCS by October 2005. The DNR is leading the effort to identify wildlife species in greatest conservation need in partnership with a variety of conservation organizations including the U.S. Fish and Wildlife Service, The Nature Conservancy, University of Minnesota, Audubon Minnesota, U.S. Geological Survey, Natural Resources Research Institute, and many others.

The CWCS used existing information about Minnesota's wildlife species. In addition, it documented research and information needs regarding Minnesota's most challenged species. All told, the analysis took about one year and includes:

- A preliminary list of species in greatest conservation need developed from existing lists and efforts. Additional species may be added based on expert opinion.
- Use of a coarse-fine filter assessment that at a coarse scale clarifies vital habitats and habitat zones, while at a fine scale identifies species with specific needs and species that are impacted by threats other than habitat loss.
- Identification of problems, threats, and opportunities that face these species.
- Explicit, 10-year objectives for species populations, habitats, and priority research and information needs.
- Conservation actions to address the 10-year objectives.
- An established system to monitor the status of these species.

The result of this effort is a plan that guides conservation of species in greatest conservation need and implemented through a stronger partnership among Minnesota's conservation organizations focused on sustaining all of Minnesota's wildlife species.

GEOGRAPHIC AND GEOLOGIC MAPPING

In addition to MLCCS and wetland-related mapping, site topography, drainage analysis, soils, and historic cultural resources are all important considerations in understanding a site and how a trail is best situated relative to its many physical features. At a gross scale, USGS mapping is a common starting point for topographical mapping.

At a more detailed and comprehensive level, integrated Geographic Information Systems (GISs) are becoming more available each year at the state, regional, county, and even city level. These systems, which include a whole host of data layers, help planners manage information related to aerial photography, aerial-generated topographic mapping, soils mapping, and cultural resources (along with MLCCS, MCBS, and wetlands mapping). Property addresses and boundary lines, along with public rights-of-way, are also data layers in these systems. The most common starting point for obtaining this information is at the county level.

Soils, topography, and drainage patterns are all major factors in designing sustainable trails. Fortunately, GIS systems make it much easier to understand these influences in a comprehensive way.

For more information!

Check out the USDA website for more information on the soil surveys for select counties in Minnesota at http:/soils.usda.gov/survey/online_surveys/minnesota/.

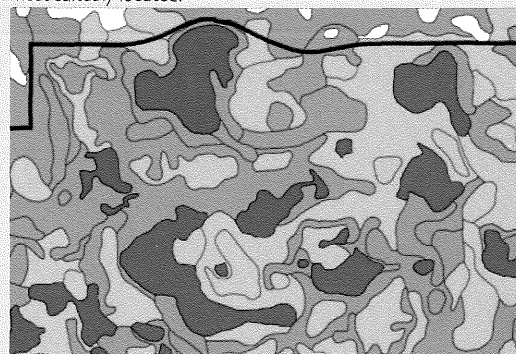
The most reliable source for *general* soils information is the U.S. Department of Agriculture (USDA). In Minnesota, a soil survey has been completed for each county and is typically available through county offices or USDA field offices. These surveys are general and often require refinement at the site level to determine the suitability of the soil for trail or other development. (Most often this information is included as a data layer on a county's GIS system.)

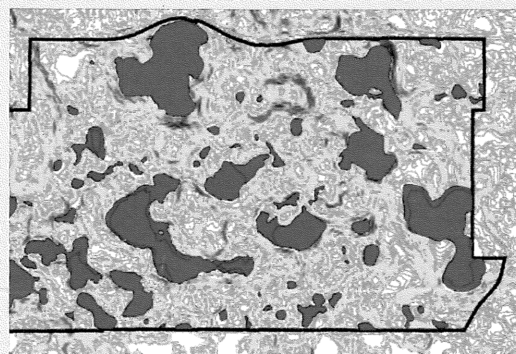
Examples of Physical Conditions Mapping

In concert with the MLCCS land cover mapping, soils, topographical, drainage, and historic cultural resource mapping collectively define the physical nature of a site and provide the base-line rationale for trail routing options. Using GIS-based computer imaging technology, it has become profoundly simpler to overlay these various forms of mapping to more clearly depict the physical story of a site. This capacity is invaluable for both trail alignment planning and locating the trail where it is in sync with the site's aesthetic qualities, appealing landscapes, and culturally interesting areas.

Aerial mapping gives a birds eye view of the site.

In soils mapping, colors represent different bands of soils across the site relative to their suitability for development of trails. As with vegetation patterns, soils can be complex across a site. Collapsing soil types into broader categories based on suitability for development can make it easier to discern where a trail is most suitably located.





Red areas clearly illustrate the steep slopes across the site, most of which being unsuitable for trails to easily traverse. Green areas are where grades are much more suitable for trails. Blue represents lakes and ponds.

Historic Cultural Resources

The Minnesota Historical Society (MHS) is a private, nonprofit educational and cultural institution established in 1849 to preserve and share Minnesota history. The society collects, preserves, and tells the story of Minnesota's past through interactive and engaging museum exhibits, extensive libraries and collections, 25 historic sites, educational programs, and book publishing.

For more information!

Check out the MHS website for more information at www.mnhs.org/about/departments/index.html.

For information on historic and cultural resources, the Minnesota Historical Society is the primary authority in the state. Contact the society in all situations where historic cultural resources may be encountered on a site. In some cases, these resources can be highlighted for their interpretive value as part of an overall trail experience.

SECTION 4 - TRAIL CLASSIFICATIONS AND GENERAL CHARACTERISTICS

SECTION 4

Trail Classifications and General Characteristics

Overview

This section establishes classifications and general characteristics for trails common to Minnesota. The classifications establish a common language to ensure consistency in how trails are described and planned. The general characteristics of each trail type define key design aspects important to meeting user needs and expectations.

Service Levels

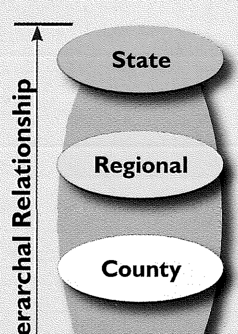
Service level refers to the capacity of a given trail or trail system to meet the needs and expectations of a defined population or specific user group within a geographical context. In Minnesota, trail systems are planned at a number of service levels, including local (city and township), county, region, and state.

Hierarchal Relationship Between Service Levels

As with a roadway system, there is a hierarchal relationship between service levels, with local trails meeting the needs of smaller, localized populations and county, regional, and state trails incrementally meeting the needs of broader-based groups and larger populations.

The following provides a general definition of the various service levels associated with trails. The key distinctions are the size of the service area, type of groups and populations being served, length of trail, site-specific setting, and level of specialization provided by the trail.

TRAIL SERVICE LEVELS



Service level increases as user groups become broader, more specialized, and/or more resource dependent.

Local Trails

Local trails provide close-to-home trail opportunities (within a five-minute drive or 10-minute walk), often with direct access from individual neighborhoods. Trail linkages to county, regional, and state trails and parks are desirable. Local trails are predominantly nonmotorized. Depending on the classification, lengths range from 1/4 mile to many miles of interconnected trails within a given site or within and between cities. Cities and townships typically have jurisdiction and funding responsibilities for local trails.

County Trails

County trails are one level higher than local trails and are often located in rural or less developed areas where local or regional trail systems are not provided. County trail systems often fill gaps between regional and local trail systems in the Twin Cities metropolitan area. In rural areas, county trails are often the de facto local trail system. Trail lengths can vary considerably, with individual shared-use paved trails commonly traversing through an entire county or several counties.

County shared-use paved trails are most prevalent along roadway rights-of-way, abandoned rail lines, and county parks, the latter two of which offer higher recreational value consistent with many regional and state trails. Motorized trails become more common at the county level, especially where there are no state level trails available. Minnesota counties typically have jurisdiction and funding responsibilities for county trails.

Regional Trails

Regional trails serve a regional population within the Twin Cities metropolitan area and multiple cities and/or counties in greater Minnesota. Travel time to a trailhead is typically up to 30 minutes, or more. For nonmotorized uses, the trail must be long enough for at least an hour of visitor experience, which translates into at least 5 miles for walking and 20 miles for bicycling. Significant emphasis is placed on the recreational value and setting of the trail. Trail corridors exhibiting scenic qualities with numerous natural resource attributes are the highest priorities.

Regional trails must be adopted as part of the Regional Park and Trail System Plan when in the Twin Cities metropolitan area and provide a consistent level of service throughout the region. They must also complement, not duplicate, other trails and trail systems provided at the local level. The Metropolitan Council has jurisdiction and funding responsibilities for regional trails within the Twin Cities metropolitan area. Because of its size, the regional park system is well suited for developing longer natural surface trails, most often accommodating hiking, cross-country skiing, horseback riding, and mountain biking.

Regional trails outside the Twin Cities metropolitan area need to provide the same general values as those within it to qualify for DNR grant funding. Motorized natural surface trails are not common at the regional level, especially the Twin Cities metropolitan area.

State Trails

State trails are almost always destination trails (defined on page 4.9) and serve a statewide population. Travel time to a trailhead is often one to four hours. As with regional trails, significant emphasis is placed on the recreational value and setting of the trail. Trail corridors exhibiting scenic qualities with numerous natural resource attributes are the highest priorities. Typically, state trails are a minimum of 20 miles long, and often much longer. Abandoned rail lines traversing the Minnesota landscape are common corridors. State trails are often connected to state parks or other local, regional, or state attractions. They must fit into the overall state trail system as mandated by the Legislature. State parks and forests provide extensive opportunities for developing both paved and natural surface trails, including trails for motorized uses not routinely allowed at other service levels. Funding appropriations typically require direct authorization from the Legislature.

Private Trails

Private trails refer to trails that traverse private property as part of a larger system of trails. The most common example of this is grant-in-aid snowmobile trails, which traverse private land through agreements secured by local snowmobile clubs. This approach has been generally successful with snowmobiles in part because of the limited direct impact on the land after the snow melts, which is a major consideration for a private property owner. Private trails are crucial to maintaining the expansive network of snowmobile trails in the state.

The potential for OHV trails to follow this practice holds some promise and does occur on larger tracks of private land where the property owner controls and limits access, often to family and friends. Since OHV trails have more impact on the land than do snowmobile trails, the likelihood of a network of private trails developing is smaller.

Changes to Service Levels

The service level of a trail or system of trails can change over time in response to use patterns and other factors. For example, a series of local nonmotorized shared-use paved trails that are linked together may, on occasion, be reclassified as a regional trail if they collectively meet regional trail service level criteria. Likewise, county and regional trails linked together may be reclassified as a state trail if they meet state trail service level criteria.

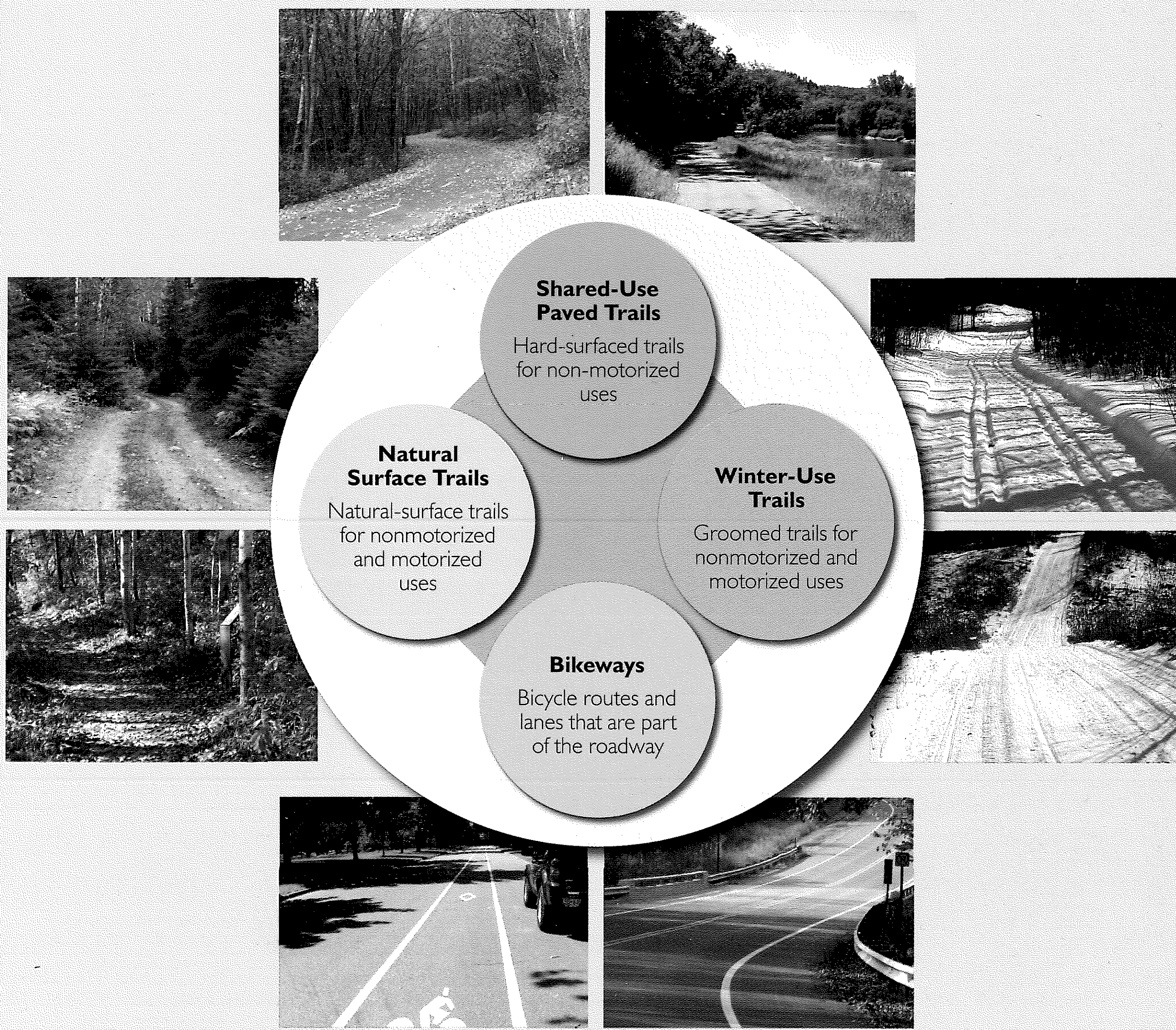
The process for changing a service level follows established protocol by the appropriate agencies. The criteria for change are based on those provided in this manual and any additional requirements established by the implementing agencies.

Overview of Trail Classifications

Trail classifications define the various types of trails commonly found in Minnesota. The classifications are used to establish a level of consistency in trail planning and design throughout the state. The guidelines are not intended to be rigid or inflexible. Each implementing agency must refine the classifications to suit localized needs. The individual trail classifications fall into one of four categories, as described in the following graphic and table.

Trail Classification Categories

Trails within Minnesota fall into four categories based on type of use, surfacing, location, or season.



Typical Trail Classifications In Minnesota

Trail Category	Classifications	User Groups	Service Levels
Shared-Use Paved Trails	Neighborhood Trail City Trail County Trail Regional Trail State Trail *Sub-Classifications* Destination trail Linking trail Destination trails emphasize the setting and recreation value. Linking trails emphasize safe travel and are often located in road rights-of-way.	Walking, jogging, bicycling, and in-line skating are typically accommodated on all classifications and subclassifications when asphalt paved. In-line skating and some bicycling are not accommodated when aggregate surfacing is used.	These trails occur at local, county, regional, and state service levels. Service levels are based on location, length of trail, and size of user population.
Natural Surface Trails	Hiking Trail - General Hiking Trail - Nature Interpretive Trail Equestrian Trail Mountain Biking Trail Off-Highway Vehicle Trail (OHV) - Off-Road Vehicle (ORV) - All-Terrain Vehicle (ATV) - Off-Highway Motorcycle (OHM Forest Access Routes and Roads (these are not designated trails) Shared-Use Nature Trail	Trail user groups are consistent with classifications. Forest access routes and roads accommodate a range of authorized motorized and nonmotorized user groups on an informal network of routes through the forest. Shared-use natural trails can be either nonmotorized or motorized trail uses, but not typically both.	Hiking trails are common at local, county, regional, and state service levels. Equestrian and mountain biking trails are most common at the county, regional, and state level. OHV trails are almost exclusively at the state and county level. Local access trails usually traverse larger tracks of forested lands at the federal, state, and county level.
On-Road Bikeways	Bike Routes Bike Lanes Both of these classifications are provided on streets and roads as shoulders or designated lanes.	Bicyclists are the primary users of bikeways. In-line skaters are secondary users.	Bikeways are common at local, county, regional, and state service levels. Bikeways augment, but do not take the place of, shared-use paved trails.
Winter-Use Trails	Cross-Country Ski Trail Snowshoeing Trail Winter Hiking Trail Dogsledding Trail Skijoring Trail Snowmobile Trail	Trail user groups are consistent with classifications.	Groomed cross-country ski trails and winter hiking trails are common at county, regional, and state service levels. Dogsledding and skijoring trails are most common at the regional and state level. Snowmobile trails are common at the county, state, and private level.

Each of the trail classifications defined in the previous matrix:

- Accommodates a specific type of user
- Provides a certain type of recreational experience and value to the visitor
- Is located in a specific type of setting appropriate for the activity
- Follows design guidelines that allow for the safe and enjoyable use of the trail

The following profiles the trail classifications and their interface with each other. Other sections of the manual consider the technical planning and design of each type of trail in greater detail.

SHARED-USE PAVED TRAILS

Shared-use paved trails typically accommodate pedestrians, bicyclists, in-line skaters, and wheelchair users. The following profiles define the preferences of those using shared-use paved trails.

BICYCLISTS PROFILES

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of typical bicyclists.

Type	Preference Profile
Family Bicyclist	**Trail Use Pattern:** • Prefers bike trails and quiet streets (to avoid heavy traffic), with preference for trails if conveniently located • Most activity happens close to home, but will also use trails extensively on vacation **Recreation Setting Preferences:** • Controlled, traffic-free access to trails is most important consideration • Quality of the riding experience is of primary importance, with length being secondary (20 miles maximum) • Connections to parks and playgrounds are important **Motivation/Activity Style Elements:** • Rides in family groups, often including small children • Needs good information for planning trips and access to support facilities (rest areas, parking lots, water sources) and prefers restrooms to portable toilets • Prefers scenic areas but no challenging terrain, especially when children are along
Recreational Bicyclist	**Trail Use Pattern:** • Seeks out and travels to trails and bicycle-friendly areas away from home, either as a day or overnight trip • Prefer trails, but will also use roads that are safe, convenient, and not too busy **Recreation Setting Preferences:** • Trails shorter than 10 miles are not very desirable for repeat use; 20 miles is the desired minimum • Looped configurations of varying lengths are preferred over out and back systems • Sense of place and an interesting experience are important, with riders seeking places with scenic quality and interesting natural or (if in urban setting) built forms **Motivation/Activity Style Elements:** • Many seek escape from motorized traffic and value experiencing nature • Regards bicycling as an important recreational interest and is willing to make an investment in equipment • Often uses amenities, such as parks and rest areas, along the trail • As a group, interested in varying levels of trail difficulty • Destinations at reasonable distances are important to maintaining interest in a given trail
Fitness Bicyclist	**Trail Use Pattern:** • Will use a combination of roads and trails that are long and/or challenging enough for a good workout • Prefers trails if they are long enough (20 or more miles) and allow for faster speeds with minimal user conflicts • Will routinely use the same routes for challenges and timing, often daily **Recreation Setting Preferences:** • Trails need to offer varying difficulty and lengths; interconnected loops are highly preferred • Not primarily motivated by experiencing natural setting, but will select this type of trail if other requirements are met **Motivation/Activity Style Elements:** • Uses bicycle as primary form of exercise to maintain and improve health • Primarily rides alone or in small groups and often rides multiple times per week • Frequently extends the season by riding earlier in spring and later in the fall than recreational riders
Transportation Bicyclist	**Trail Use Pattern:** • Not dependent on trails, but will use them if convenient, safe, and direct **Motivation/Activity Style Elements:** • Bicycle is used as a form of transportation; motivation is fitness, environmental values, and economy • Lack of a safe "system" of roads (with bike lanes or routes) and trails is a major barrier • Trail design is critical, with ability to go fast with good sightlines and directness being most important

WALKER, JOGGER AND IN-LINE SKATER PROFILES

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of typical walkers, joggers, and in-line skaters.

Type	Preference Profile
Recreational and Fitness Walker or Jogger	**Trail Use Pattern**: • Will use the same trails daily or several times per week if they are convenient and easy to access (most live within 3 miles of the trail they are using) • Recreational user wants trails that provide social interaction, scenic beauty, or both • Will use sidewalks to get to a trail system in urban and suburban settings • Will use trails year-round, although spring, summer, and fall are most popular **Recreation Setting Preferences:** • Recreation user finds sense of place, natural setting, scenery, and being away from traffic important (less so with fitness user) • Prefers looped configurations in all settings, with 2 to 4 miles suitable for beginners and 5 to 9 miles for fitness walkers • Has a strong desire for safety and security, with the lack of this being a major reason a trail would not be used **Motivation/Activity Style Elements:** • Recreational users have a wide range of motivations, with a desire for social interaction being important to some and solitude to others • Exercise for health benefits is prime motivator for fitness walkers and joggers; health is of growing importance to recreational users as well • Walkers and joggers of all types will go out alone or with friends or family
Recreational In-line Skater	**Trail Use Pattern:** • Seeks out nearby trails for daily use, but will travel to a specific trail on weekends • Prefers loop system, with 10 to 15 miles minimum (will use out and back if there is no other choice) **Recreation Setting Preferences:** • Seeks trails that are not heavily used • Does not prefer technically difficult trails with sharp turns, too many steep hills, or poor stopping conditions • Does well on trails designed similar to bike trails, especially when they are 10' feet wide or wider • Routine sweeping of the trail is important **Motivation/Activity Style Elements:** • Highly values smooth, wide trails; rough trails are especially troublesome for beginners • Primarily motivated by getting exercise, enjoying skating, being outdoors, and socializing • Will skate alone, with friends, and occasionally with family
Fitness In-line Skater	**Trail Use Pattern:** • Uses routes that are challenging with enough distance to get in a good workout (10 to 25 miles) • May go out daily or several times per week and will routinely use the same trails close to home • Prefers loop system **Recreation Setting Preferences:** • Primarily uses a series of streets, roads, and trails to create a long enough route • Does not desire technically difficult trails with sharp turns, too many steep hills, or poor stopping conditions • Has facility needs similar to those of bicyclists **Motivation/Activity Style Elements:** • Highly values smooth, wide trails; rough trails are especially troublesome for beginners • Primarily motivated by getting exercise and enjoying skating • Will skate alone, in couples, or in small groups
Commuting In-line Skater	**Trail Use Pattern:** • Uses skating as a form of transportation • Uses trails where available, but will also use streets and roads • Other preferences are similar those of transportation bicyclists **Motivation/Activity Style Elements:** • Needs traffic enforcement, security, skate-friendly routes to and from work sites • Needs accommodations at work, such as lockers, changing areas, and showers

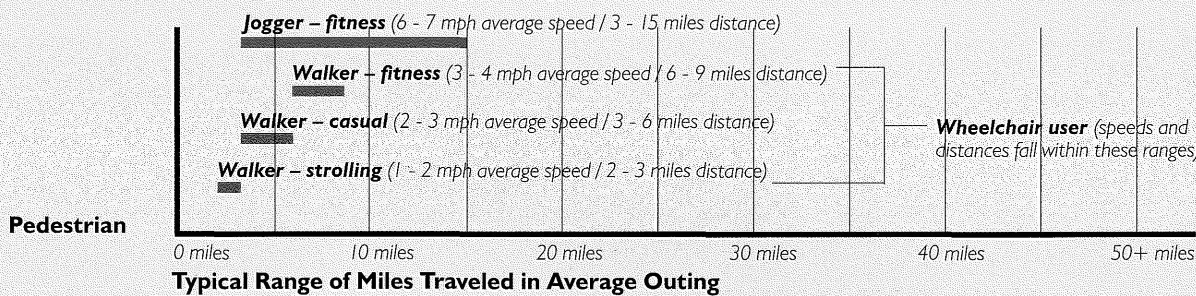
General Travel Speeds and Distances Associated With Paved Trails

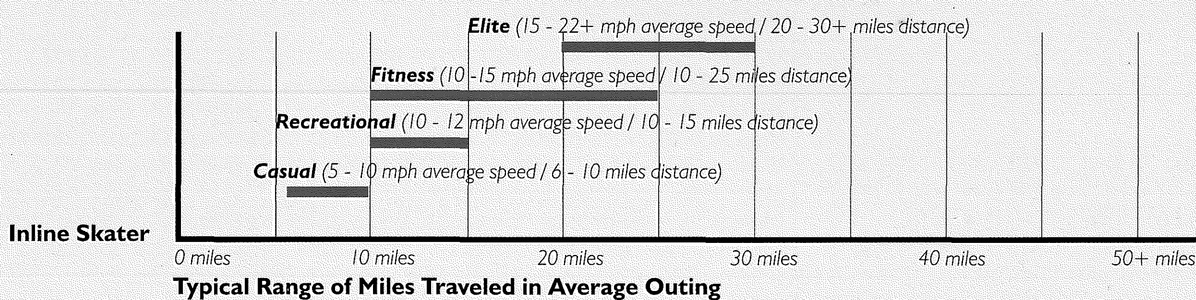
The recreational value of a trail or trail system depends in part on the number of *continuous* miles available for a given type of trail user. This is an important consideration in trail system planning to ensure that trails are long enough to be of value to the targeted user group. For example, a single looped trail of 20 or 30 uninterrupted miles provides considerably different recreational value than five independent trails of 4 or 5 miles each.

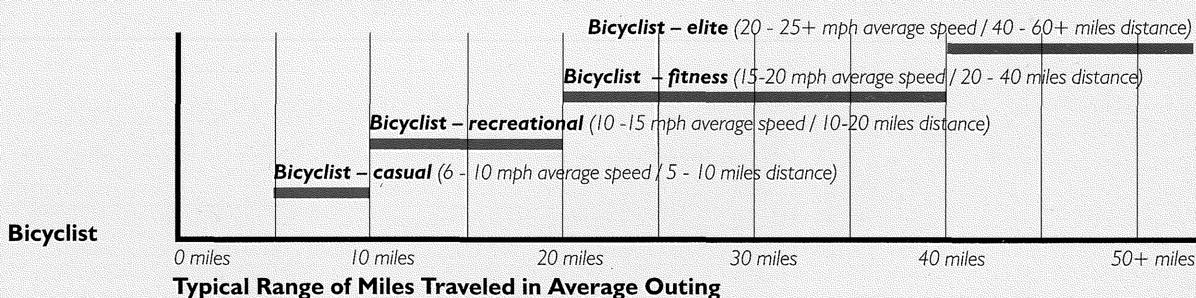
The type of use envisioned for a trail plays a major role in determining the miles necessary to satisfy the needs of the targeted user groups. The following graphic illustrates the travel speeds and distances associated with various types of trail users.

General Travel Speeds and Distances for Various Types of Trail Users

The average travel speed and distance traveled per trail user outing varies considerably within and between trail user groups. As travel speed and distance traveled increase, so do user expectations on the design and development standards used for the trail. The most important of these is trail width and geometric form, with wider and more liberal curvilinear layouts being appropriate as a trail accommodates a broader array of users. For example, a trail user has a different expectation for distance and travel speed for a local neighborhood trail than would be the case for a major citywide, regional, or state trail. In developing trail system plans, it is important to clearly define the targeted user groups, then use an appropriate trail classification and accompanying development standard to safely accommodate them. The following illustrates common travel speeds and distances for the most common multiuse paved trail user groups.







Finding detailed design information!

Refer to Section 5 – Shared-Use Paved Trails for technical design information for this type of trail.

SHARED-USE PAVED TRAIL CLASSIFICATIONS

Shared-use paved trails are specifically designed to accommodate one or more of the profiled trail user groups. This type of trail is appropriate within local, county, regional, and state trail systems. There are five classifications that fall under this trail category:

- **Neighborhood Trail** – is used to connect local residential areas to the citywide trail system. Typically 8 feet wide.
- **City Trail** – is used to create the core system of trails that traverse a city via greenways, open space, trail corridors, or following road rights-of-way. Typically 10 feet wide, 12 feet where use volumes are high.
- **County Trail** – is similar to a city trail, only at a county level. County trails typically traverse the county via greenways, open space, trail corridors, or following road rights-of-way. Typically 10 feet wide.
- **Regional Trail** – traverses one or more cities, townships, or counties as part of the regional trail network. Regional trails typically follow greenways, open space, and designated trail corridors. They are often used to link regional parks and open spaces together, as well as being destinations unto themselves. Typically 10 feet wide, 12 feet where use volumes are high.
- **State Trail** – traverses one or more counties, anywhere in the state. State trails typically follow abandoned rail corridors, greenways, and large-scale open spaces. They are almost always destination trails. Typically 10 feet wide (12-foot trails are not as common as for regional trails due to lower levels of use.)

SERVICE LEVELS

As the titles suggest, there is a general hierarchal relationship between classifications and service levels, with neighborhood and city trails typically under the jurisdiction of a municipality, city, or township, and county, regional, and state trails under corresponding jurisdiction.

To the trail user, the primary distinction among trail classifications and service levels is geographic location, type of users accommodated, levels of use, and trail length. As trails serve more people and traverse or connect together larger geographical areas, the level of service tends to go up, as do some of the development standards, most notable of which is trail width as defined in Section 5 – Shared-Use Paved Trails.

Critical to the development of shared-use paved trails is maximizing their value, whether they are traversing a greenway in a suburb or the rural countryside. As described in Section 2 – Principles of Designing Quality Recreational Trails, values include safety, convenience, recreation, fitness, and transportation/commuting. Of these, recreation is one of the most important in terms of predicting a trail's level of use, assuming that safety and convenience are sufficiently provided for or held constant. In general, trails offering high-quality recreational experiences are those that:

- Are scenic and located in a pleasant parklike setting, natural open space, or linear corridor that is away from traffic and the built environment
- Provide a continuous and varying experience that takes visitors to a variety of destinations and is a destination unto itself
- Offer continuity with limited interruptions and impediments to travel

This underscores that trail planning should be based on the *quality* of the trail experience as well *quantity* of trail miles.

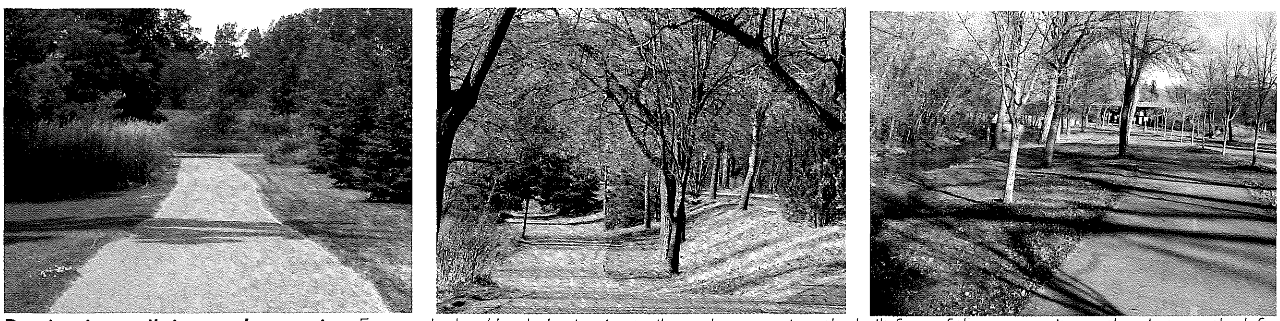
MULTIUSE PAVED TRAIL SUBCLASSIFICATIONS

To emphasize the importance of trail quality in system planning, shared-use paved trails have two subclassifications that distinguish between trails that are destinations (due to their higher recreational value) and those that are primarily used to link the trail system and greater community or region. The following considers each of these in greater detail.

Destination Trails

Destination trails are located within a greenway, open space, park, parkway, or designated trail corridor separated from vehicular traffic. As the name implies, the high recreational value of this type of trail often make it a destination unto itself. Destination trails have a particular emphasis on continuity and are the major conduits for travel within and between trail systems. The following images highlight a number of optimal settings for destination trails offering high recreational value.

Destination trails in natural open space/greenway settings. *These photos illustrate the general character of trails that are located within a greenway or separated linear trail corridor away from roadways and traffic. As the progression of photos from left to right illustrates, the recreational value of one trail setting versus another is clearly discernible to the trail user. Even at a local trail system planning level and when opportunities are limited, maximizing the use of destination trails as the core system of trails is desirable.*



Destination trails in an urban setting. *Even at the local level, destination trails can be woven into the built form of the community, as the photo on the left of a trail weaving through a new subdivision illustrates. Destination trails are also located in very urban areas that exhibit a natural amenity, such as Lake Harriet in Minneapolis (middle photo). In this case the lower trail is for walkers and the upper is for bicyclists and inline skaters. As the photo on the right illustrates, destination trails are also commonly found along designated parkways that exhibit a parklike setting. All of these trails provide higher recreational value than most linking trails.*

As the photos illustrate, destination trails place a great deal of emphasis on location and creating a sequence of interesting events that make a trail appealing to the user.

Linking Trails

Linking trails emphasize safe travel for pedestrians to and from parks and around the community or region. Linking trails still offer recreational value, but typically not to the same level as destination trails. The following images highlight a number of settings for linking trails.

Linking trails in varying forms. *These photos illustrate a progression of trail settings from a utilitarian corridor to a more naturalistic setting along a roadway. In the first, the trail provides a safe conduit for pedestrian-level travel. In the middle photo, the open countryside location gives this trail more recreational value even though it is located very close to the edge of the road. In the right photo, the linking trail is more appealing due to its location relative to the adjacent roadway. As illustrated, providing more separation from the road along with natural grasses and trees improve the character of this trail corridor.*

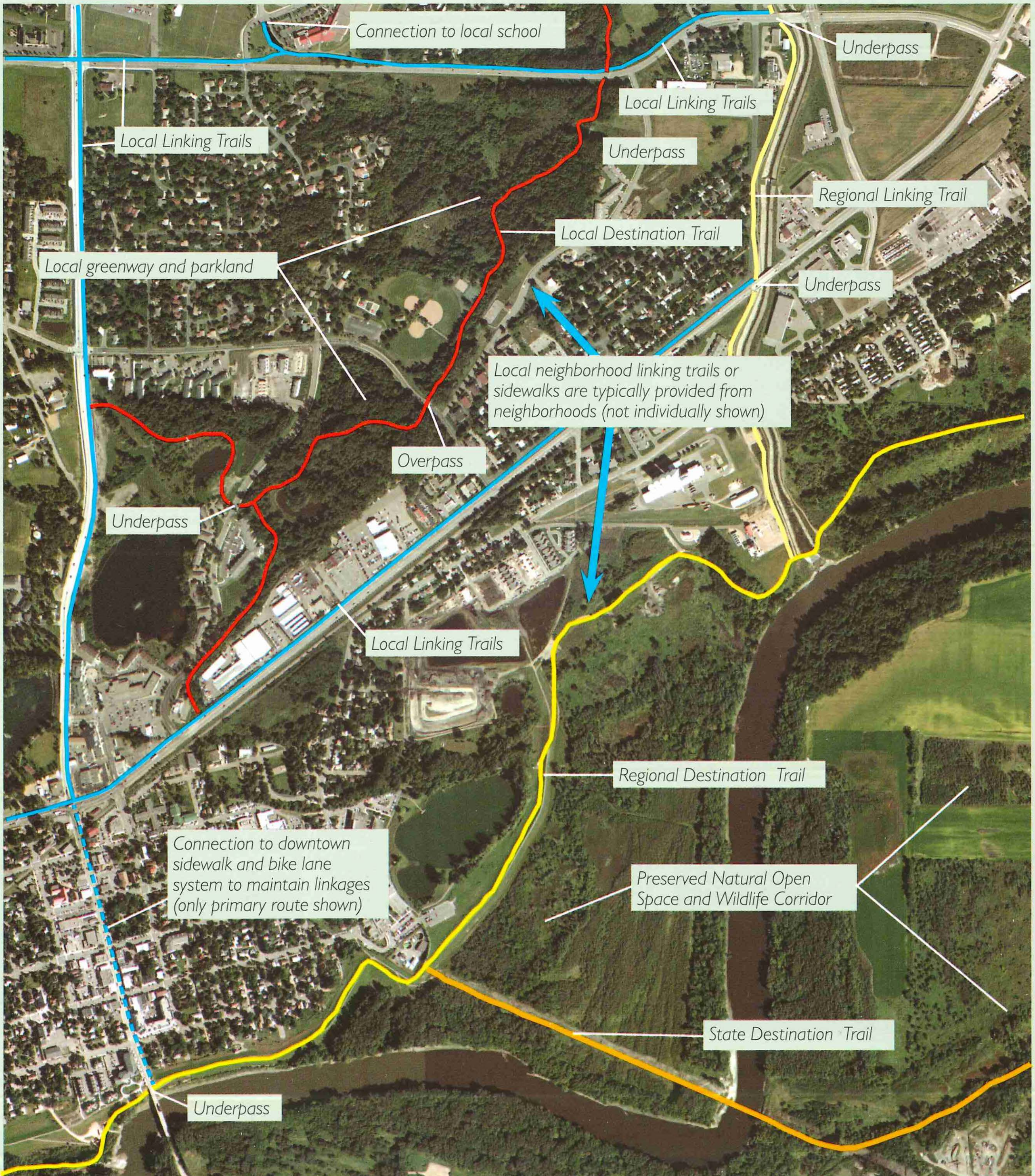
As the images illustrate, the setting for linking trails greatly affects their recreational value as judged by scenic quality, continuity, and sense of separation from vehicular traffic.

INTERRELATION OF DESTINATION AND LINKING TRAILS AT A SYSTEM LEVEL

The following aerial image illustrates the optimal interrelationship between local, regional, and state destination and linking trails in a hypothetical fully integrated trail system.

DESTINATION AND LINKING TRAILS IN AN INTEGRATED TRAIL SYSTEM CONTEXT

The aerial image below illustrates the optimal use of destination and linking trails in a hypothetical integrated trail system at the local, regional, and state trail level. As illustrated, destination trails within each of these classifications form the core system of trails. Assuming that personal safety is not perceived to be an issue, these trails will tend to be very popular due to their high recreational and other values. Although the linking trails offer less recreational value, they remain very important to creating a functioning and comprehensive trail system. But having a whole system of linking trails would not offer the same values as the trail system in the illustrated example.



The interrelationship between destination and linking trails at a system level is important. By making a qualitative distinction between trails within a given system, greater weight can be given to those that offer the highest overall value to the community. This will result in trail systems that are the most satisfying to use and consistent with user preferences, which in turn results in higher levels of use.

Trail Difficulty Rating

Paved trails are generally designed for family use with gradients averaging 5 percent or less, as defined in Section 5 – Shared-Use Paved Trails. In instances where trail grades are steeper, signage is usually provided to caution the trail user. Otherwise, there are no established difficulty ratings per se for shared-use paved trails.

Natural Surface Trails

Finding detailed design information!

Refer to Section 6 – Sustainable Natural Surface Trails for technical design information for this type of trail.

The natural surface trails category encompasses a number of trail classifications, including hiking, equestrian, mountain biking, OHV, local access, and nonmotorized shared-use trails. The following considers the distinguishing features of each of these.

Hiking Trails

Natural hiking trails are pedestrian-only trails for hikers and joggers. These trails attract users seeking a natural experience in a scenic setting. The following profile defines the preferences and motivations of users.

Hiker Profiles

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of each type of hiker, which greatly influences trail design.

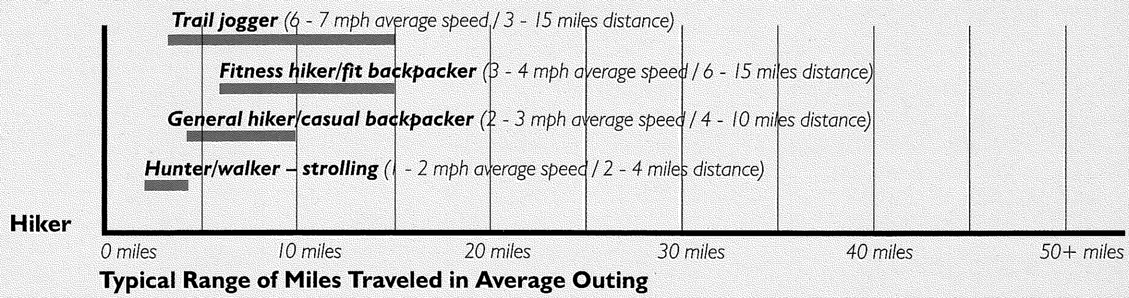
Type	Preference Profile
Destination Hiker	**Trail Use Pattern:** • Seeks out trails for a desired experience (such as solitude), whether near home or some travel distance • Prefers looped systems over out-and-back trails to vary the experience • Will seek out trails of varying difficulty • Likes to stop along the trail to rest, observe, and socialize if hiking in a group • Expects trail to be of varying difficulty consistent with the landscape characteristics **Recreation Setting Preferences:** • Large percentage seeks escape from motorized activity, and value experiencing nature in its most basic form • Natural setting is important to all, with wooded, rolling terrain with wildlife viewing opportunities commonly preferred • Trail difficulty is an important determinant in trail selection, with a desire for a wide range of challenges • Access to the trail is a major predictor of use levels • Length preferences vary widely with skills and preference, with beginners liking shorter loops of 2–4 miles and day hikers preferring 5–9 miles • Minimum preferred width should be 18" • The scenic value of the trail is important, especially for repeated use **Motivation/Activity Style Elements:** • Motivations for using natural trails vary widely, ranging from physical challenge to experiencing nature • Likes diverse trails that appeal to a variety of interests and skills levels • Highly willing to travel to obtain a desired trail experience • Travels as an individual, as a couple, or in small groups of family and friends • Typically needs maps, route guides, and general information about trail features
Overnight Backpacker	Overnight backpackers have many of the same preferences as a destination hiker, only with a few nuances associated with overnight stays. Additional preferences include: • Camping areas at intervals of 5–10 miles is desired, with average daily hiking distance up to around 10 miles • Access to water is necessary, especially at camps • Pit toilets are important at designated camp areas • Outing length varies from 5–100 miles, with 25–35 miles being a common distance over a few days to a week

General Travel Speeds and Distances Associated With Hiking Trails

As with shared-use paved trails, the recreational value of a hiking trail is predicated on the number of continuous miles available. The type of use envisioned for a trail plays a major role in determining the miles necessary to satisfy the needs of the targeted user group(s). The following graphic illustrates the travel speeds and distances associated various types of hiking trail users.

General Travel Speeds and Distances for Various Types of Hiking Trail Users

The average travel speed and distance traveled by a hiking trail user depends on whether a person is out for a stroll, walking briskly, or jogging. The expectations of each user varies as well. Strollers want to observe the finer points of nature, while joggers are often more focused on the terrain and challenges of the trail. Hiking trails should be designed with a specific user or group of users in mind. For example, a general hiking trail needs to appeal to all types of users. On the other hand, an interpretive trail needs to highlight natural details if it is to appeal to its target user. The following illustrates common travel speeds and distances for the most common hiking trail user groups.



Classifications

Natural hiking trails are specifically designed to accommodate trail users seeking a natural setting. This type of trail is appropriate within local, county, regional, and state trail systems. Under this classification, there are four subclassifications, as the following considers.

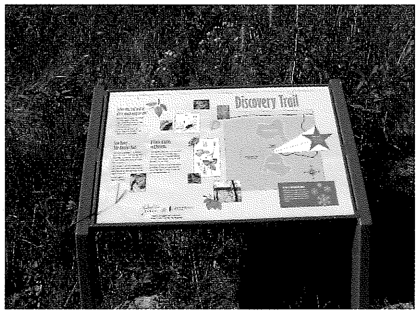
General Hiking Trail

General hiking trails are natural surface trails most often located in larger local, regional, and state parks or greenways where there is adequate open space for a trail loop. Hiking trails are most often associated with natural settings offering scenic beauty, solitude, and wildlife observation opportunities. As the following photos illustrate, the width and character of hiking trails relate to the setting and site-specific trail needs.

Natural hiking trails to meet varying needs and settings. *In general, grass and native soils are preferred surfacing for natural trails. Grass is typically suitable where use is light to moderate. Where trails receive heavier use, native soil surfacing prevails. The width of hiking trails typically responds to the setting and type of use. Narrow single track (left) is common in larger parks and open spaces or along long linear trails such as the Superior Hiking Trail. As use increases, a wider trail often develops so people can walk side by side (middle). Where hiking trails are used for cross-country skiing, a wider corridor is required, most often with a grass surface to aid snow retention and limit erosion (right).*

Nature Interpretive Trail

Nature interpretive trails have much in common with general hiking trails with the exception of placing greater emphasis on interpretation and education. Typically, interpretive trails are found within designated nature or conservation areas and arboretums. Interpretive kiosks and signage is provided along the trail. These trails are often linked to an interpretive center or other educational facility. Significant emphasis is also placed on accessibility of nature interpretive trails to all populations.



Nature interpretive trails are distinguishable by the usually intimate scale and interpretive signage. *These trails often are less than a couple of miles long and linked to an interpretive center. As the three photos illustrate, the character of the signage can vary from park system to park system. The key is to be consistent so trail users become familiar with signage patterns.*

Walker/Hunter Trail

Walker/hunter trails are most commonly found in northern Minnesota forests and typically take advantage of old logging access roads and trails. The primary distinction between these trails and forest access routes is that they are designated specifically for nonmotorized use only. Typically, walker/hunter trails are defined by a geographical area in which all trails within that area are designated for this use and for authorized forest management activities.

Walker/hunter trails are typically simple passageways through the forest. *Most often, these trails are old logging access roads or trails that have been left to grow in. These trails are most commonly used in the spring and fall to access hunting areas or picking berries or mushrooms.*

Forest Access Route

Forest access routes have much in common with walker/hunter trails except that their use is broader and includes motorized and nonmotorized uses. *As nondesignated, informal routes through the forest, these routes are not typically included as part of a designated recreational trail system.* (This distinction is further defined on page 4. 36)

Difficulty Ratings

The difficulty of a hiking trail has a direct correlation with user expectations. For example, nature interpretive trails are typically expected to be easy, with remote hiking trails increasingly difficult.

Hiking Trail Difficulty Rating

The table establishes general guidelines for difficulty ratings associated with hiking trails. Ratings used for individual trails should include additional descriptors consistent with their particular setting.

Aspect	Easiest	More Difficult/Intermediate	Very Difficult/Advanced
Grade	5% or less average 15% maximum for short distance	10% or less average 15% for longer distance	15% or less average 15% or more
Tread surface	Firm and stable	Mostly stable, with some variability	Widely variable, with some less stable footing
Obstacles	Avoidable or small, easy to get around	Larger and more frequent; requires some maneuvering to get around	Numerous and unavoidable, must be maneuvered around
Bridges	Minimum of 36" wide with railings where needed	Bridges minimum of 24" wide with railings where needed; short crossings may use stepping stones	Bridges 24" wide or narrower; often rustic design and more limited railings; crossings may use stepping stones

> ***A note about accessibility!***
>
> The desired level of accessibility should be clearly defined when natural surface trails are designed. An accessible trail must meet the provisions defined on page 6.72 in Section 6.

Hiking Trail Configurations

The layout of hiking trails is almost always in response to the landscape setting, with a sequence of events provided that enhances trail users' experience by taking advantage of the scenic qualities and sense of place of the site. In a park or natural area, a looped trail system is a common approach to trail layout, as illustrated in the following graphic.

Looped Nature Trail Configuration In Park Or Greenway Setting

Overall Layout

This hypothetical park map with nature trails shows a looped system that is carefully integrated with sensitive ecological systems. The trail user gets to enjoy the natural character of the park while still preserving its innate qualities.

A Sequence Of Events

With nature trails, creating a sequence of events is especially important to maximize the trail experience. This includes trying to minimize the extent to which trail users are visible from another section of trail.

Ecological Buffers

Maintaining adequate buffers between a trail and sensitive ecological system is particularly important, especially when the trail is used for nature interpretation and education. This includes limiting the impact on ecotonal areas (transition zone between plant communities).

In a larger landscape setting, the layout for a nature trail is often linear. The Superior Hiking Trail is one of Minnesota's best examples of a linear natural trail that offers a diversity of scenery. Varying land character and specific points of destination coupled with numerous access points, overlooks, and camping opportunities are necessary to offset the out-and-back aspect of these trails.

> ***Finding detailed design information!***
>
> Refer to Section 6 – Sustainable Natural Surface Trails for technical design information for this type of trail.

Equestrian Trails

Equestrian trails are for horseback riding and, less frequently, horse-drawn carriages. These trails attract riders seeking a safe and contiguous trail experience in a natural setting away from traffic. The following profile defines the preferences of equestrian trail users using natural trails.

Equestrian Trail User Profiles

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of horseback and carriage drivers, which greatly influence trail design.

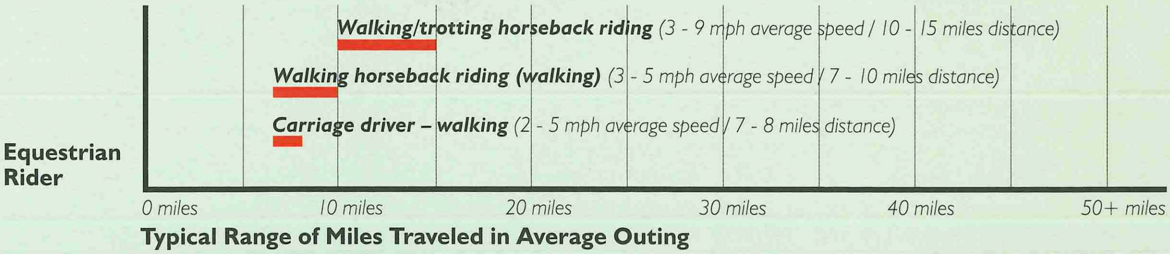
Type	Preference Profile
Local and Destination Trail Rider	**Trail Use Pattern:** • Destination trail rider will travel to trails and public land areas to ride designated trails or a network of trails through the forest; local trail rider rides in the immediate area where horses are kept • Destination rider rides 10–15 miles per day, 25–30 miles on an average weekend trip; local riders average 7–10 miles per day • Prefers looped configurations with varying conditions • Local rider require direct access to trails from boarding areas **Recreation Setting Preferences:** • A wide or highly developed trail is not required • Single-file trails make horses easier to handle and require less maintenance • Need water nearby for horse • Variety in trail is desirable, including water crossings, logs that horses can go over, hill climbs and descents, open areas and woods • Trails should be free of dangerous conditions, but some obstacles are desired to make the trail more interesting • Bridges need to be about 8' wide and clear zone above the trail has to be at least 9' high • Big, open flat field is best for parking, not paved parking lots • Picket lines are preferred over corrals and should be at least 24' long (only horses that are familiar with each other can go in a corral together, and corrals are easier to kick down and take up more space than picket lines) **Motivation/Activity Style Elements:** • Very social activity, with riders going out in small to large groups • Day outings to multiday trips are common with this group, frequently camping with friends or family • Riders like to be self-contained, with special trailers commonly used to haul horses and house riders at night • Will often travel long distances to a trail if it is publicized, especially on state lands with many miles of local trails • Riding tends to increase in the fall after the horse show seasons ends • Riders seek challenge to animals and riding skills, and also seek escape to a natural setting • Insects in the height of summer can make riding uncomfortable, especially in the northern part of the state • Desired trail length is a matter of hours people want to ride: 50% of day rides are usually 1–3 hours, 40% are 3–8 hours, and 10% are greater than 8 hours (riding speeds: walk is 3–5 mph, trot is 5–9 mph, gallop is 9–12 mph) • Most trail riding is done at a walk, with faster speeds requiring more skill and greater horse control • Growing interest in the sport by women, which increases concerns about security (66% of riders are women)
Carriage Driver	**Trail Use Pattern:** • Rides long carriages on trail either locally or hauls horses and carriages to a destination • Uses sleighs in winter and carriages in the summer • Limited number of participants means use is very spread out **Recreation Setting Preferences:** • Looped routes are preferred, but linear is acceptable if connected to a staging area • Minimum trail width needed is 8', with turnaround areas at regular intervals (or at road crossings if sightlines are adequate); trail must have a smooth surface • Mixture of open and wooded area similar to other trails is preferred • Gateway Trail and connected trail systems is a good example of a carriage trail • Need to be separated from vehicles for safety **Motivation/Activity Style Elements:** • Frequently draft horse owners are looking for something to do with them • Have often done other forms of riding and moved into carriages for various reasons, including age or injuries that prevent them from riding • Typical ride is 7–8 miles, if horses are in shape

General Travel Speeds and Distances Associated With Equestrian Trails

As with hiking trails, the recreational value of an equestrian trail is predicated on the number of continuous miles available for use. The type of use envisioned for a trail plays a major role in determining the miles necessary to satisfy the needs of the targeted user group(s). The following graphic illustrates the travel speeds and distances associated various types of equestrian trail users.

General Travel Speeds and Distances Associated With Equestrian Trail Users

The average travel speed and distance traveled by an equestrian trail user depends upon the speed the horse is traveling. For the most part, trail riders walk their horses most of the time, although riders will trot periodically. The following illustrates common travel speeds and distances for the most common hiking trail user groups.

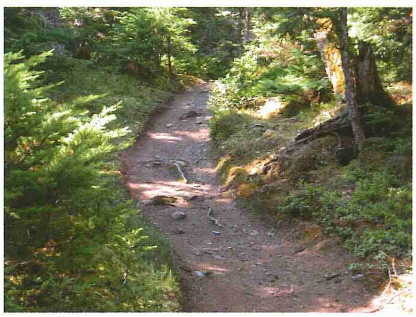


Classifications

Equestrian trails are typically located within county, regional, and state trail systems. Under this classification, there is one subclassification that accommodates carriages.

Equestrian Trail

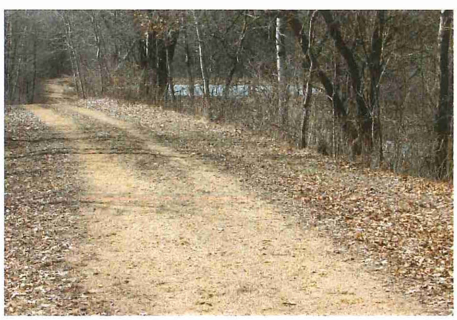
Equestrian trails are natural surface trails most often located in large county, regional, and state parks or greenways where there is adequate open space for a trail loop. Equestrian trails are most often associated with natural settings offering scenic beauty, solitude, and wildlife observation opportunities. As the following photos illustrate, equestrian trails can be either double or single track.


Horse trail widths respond to the setting. *As with hiking trails, horse trails usually take a form that is in keeping with the setting. In wide-open areas (left), a double track trail will often form to allow riders to ride side by side. In the forest or where space is more limited, a single track of varying widths will develop (middle and right). Where horse trails are used for cross-country skiing, a wider corridor is required, which often encourages a double track to be formed.*

Carriage Trail

Carriage trails are natural surface trails that are essentially double-track equestrian trails that accommodate both carriage drivers and horseback riders. Although this group is relatively small compared to horseback riders, carriage trail users are well established in certain areas of the state and their needs have to be considered when designing equestrian trails in those areas. Most notable of these considerations is trail width, with 8 feet being the minimum necessary to accommodate this type of use.

Carriage trails require stable trail beds with adequate width. *Both of these photos illustrate trail treads that can accommodate carriages. Whereas each of these trails functions well enough, each exhibits different values. The trail in the left photo offers a more social atmosphere with other types of trail uses that may appeal to some drivers. The trail in the right photo offers more solitude that would appeal to others.*

Forest Access Route

Forest access routes are also suitable for equestrian use. *As nondesignated, informal routes through the forest, these routes are not typically included as part of a designated recreational trail system.* (This distinction is further defined on page 4. 36.)

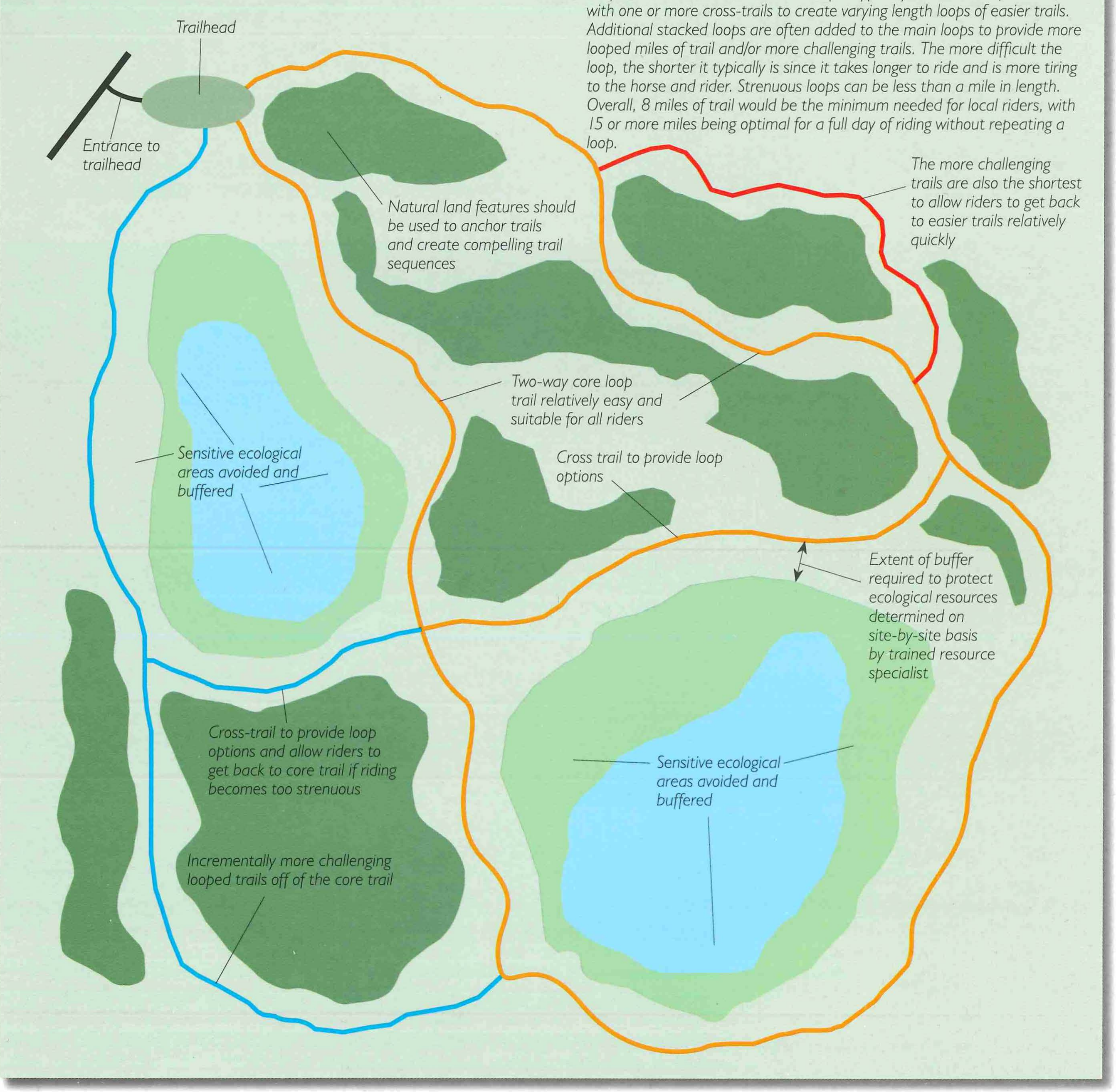
Equestrian Trail Configurations

The layout of equestrian trails has much in common with hiking trails. Providing a sequence of events that highlight the scenic qualities of an area enhances the trail user experience. Where feasible, a looped trail system is the most desirable and common approach to trail layout, as illustrated in the following graphic.

Equestrian Trail Layout Configuration

Creating a sequence of events is as important to equestrians as it is hikers. This includes trying to minimize the extent to which trail users are visible from another section of trail. Maintaining adequate buffers between a trail and sensitive ecological systems also remains important. This includes limiting the impact on ecotonal areas (transition zone between plant communities). The following illustration highlights features of a typical looped equestrian trail system.

Loop notes: The core outside trail loop is typically a minimum of 8 miles, with one or more cross-trails to create varying length loops of easier trails. Additional stacked loops are often added to the main loops to provide more looped miles of trail and/or more challenging trails. The more difficult the loop, the shorter it typically is since it takes longer to ride and is more tiring to the horse and rider. Strenuous loops can be less than a mile in length. Overall, 8 miles of trail would be the minimum needed for local riders, with 15 or more miles being optimal for a full day of riding without repeating a loop.



Difficulty Ratings

The level of difficulty categories associated with equestrian trails are consistent with those used for other types of natural trails, albeit defined relative to this particular use.

EQUESTRIAN TRAIL DIFFICULTY RATING

The table establishes general guidelines for difficulty ratings associated with equestrian trails, which are similar to those used for hiking.

Aspect	Easiest	More Difficult/Intermediate	Very Difficult/Advanced
Grade	5% or less average 15% maximum for short distance	10% or less average 15% for longer distance	15% or less average 15% –20% for short distance
Tread surface	Firm and stable	Mostly stable, with some variability	Widely variable, with some less-stable footing
Obstacles	Avoidable or small, easy to get around	Larger and more frequent, require some horse control and maneuvering	Numerous unavoidable, require considerable horse control and maneuvering
Creek crossings	Bridges minimum of 5' wide with railings where needed	Shallow ford crossings that are relatively easy to maneuver through	Deeper, more challenging fords requiring steady horse control

Finding detailed design information!

Refer to Section 6 – Sustainable Natural Surface Trails technical design information for this type of trail.

MOUNTAIN BIKING TRAILS

Mountain biking trails attract bicyclists seeking a more natural and often more challenging setting for riding than that of a multiuse paved trail. The following profile defines the preferences and motivations of this type of rider.

MOUNTAIN BIKER PROFILE

The following profiles was compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR). Note that family and recreational bicyclists are considered under the shared-use paved trail classification.

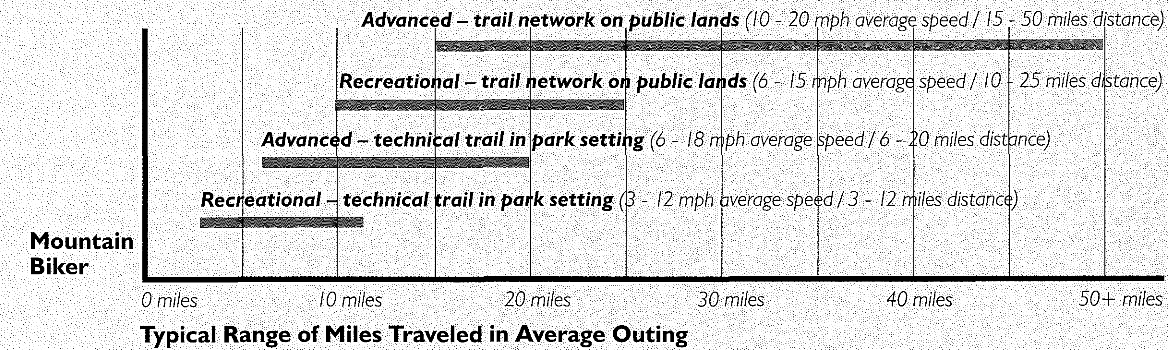
Type	Preference Profile
Mountain Biker	**Trail Use Pattern:** • Seeks and travels to trails away from home as a day or overnight trip • Should not be confused with people who own mountain bikes but do not use them on mountain bike trails • Commonly desire 2- to 3-hour riding opportunities, 20–25 miles of contiguous trail (although fewer miles are acceptable in challenging terrain **Recreation Setting Preferences:** • Best trails have a natural, challenging character and immerse the rider in nature while providing a good workout and opportunity to test skills • In rural areas or in the northern forests, will use a combination of roads, logging roads, and trails as available, safe, and convenient (with some wanting an escape from heavily used areas to find solitude) • In urban/suburban areas, highly prefer developed mountain bike trails offering looped configurations with varying levels of challenge • Appreciate having an outside water spigot to clean bikes after rides, as well as other common trailhead amenities **Motivation/Activity Style Elements:** • Getting exercise, experiencing natural setting, and testing skills are prime motivators • May take multiple day trips to a publicized trail area • Highly social activity, with groups consisting of family and friends • Will often travel long distances to a trail if it is publicized • Mostly go as individuals, couples, or in small groups of family and friends • Get information from diverse sources to find riding opportunities

GENERAL TRAVEL SPEEDS AND DISTANCES ASSOCIATED WITH MOUNTAIN BIKING TRAILS

Mountain biking speeds tend to be lower than those of general bicycling. The degree of difficulty of a given trail greatly influences travel speeds and miles of trail needed for a 2- or 3-hour typical outing. The following graphic illustrates the travel speeds and distances associated with various types of mountain bikers.

General Travel Speeds and Distances for Various Types of Mountain Biking

The average travel speed and distance traveled by a mountain biker varies considerably relative to the type of trail and the type of rider. In urban or suburban parks, where space is limited, trails tend to be single-track stacked loops of varying levels of difficulty, typically from 3 to around 10 miles in length. In forested public lands in the northern part of the state, where old logging roads or trails are extensively used, interconnected trail systems can consist of hundreds of miles of trails. The following illustrates common travel speeds and distances for various types of mountain bikers.



Classifications

Mountain biking trails are appropriate within local, county, regional, and state trail systems.

Mountain Biking Trail

Mountain biking trails are natural surface trails most often located in larger local, regional, and state parks or within county, state, or federal forest where there is adequate open space for a trail loop. Mountain biking trails are most often associated with natural settings offering varying challenges and scenery. In larger forests, a sense of solitude and opportunity to observe wildlife is important. As the following photos illustrate, the width and character of mountain biking trails relate to the setting, site-specific trail opportunities, and the needs of the targeted group of riders.

Mountain biking trails range from easy to advanced to accommodate a wide range of riders with different preferences. *From casual, dual-track trails (left) to single track (middle) to technical single track (right), mountain bike trails are designed in response to the geographic location, specific site setting, and the type of users being accommodated. In regional park settings around the metropolitan area, well-designed and specialized single-track trails are becoming more common and preferred by many riders. In greater Minnesota, designated mountain bike trails often take advantage of existing forest roads or dual-track trails as core trails, with single-track loops configured off of the main spine.*

Forest Access Route

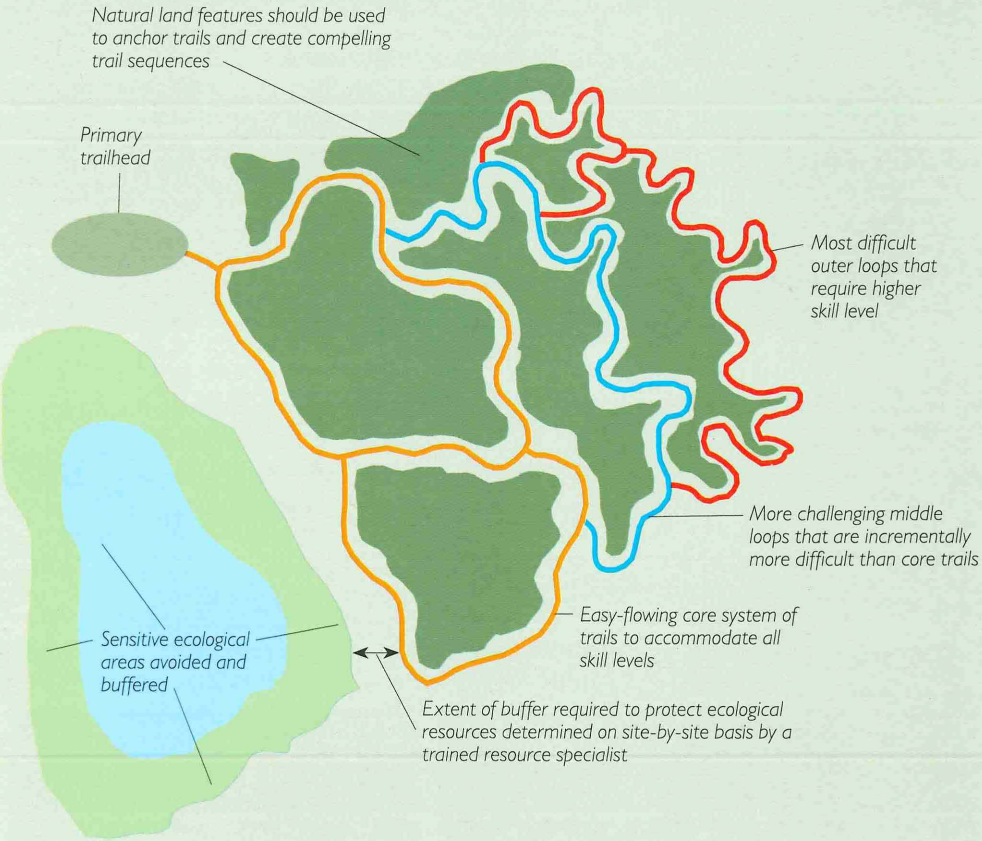
Forest access routes are also suitable for mountain bike use. *As nondesignated, informal routes through the forest, these routes are not typically included as part of a designated recreational trail system.* (This distinction is further defined on page 4.36.)

Mountain Biking Trail Configurations

The layout of a mountain bike trail is very specialized in order to accommodate the type of challenging features that appeal to riders. Trail layouts also reflect the landscape being traversed and respond to the nuances of a site that make them interesting to the trail user. Maintaining a certain rhythm and flow is important to creating an appealing mountain biking trail. In a park setting, a stacked looped trail system is desirable, as illustrated in the following graphic.

Mountain Bike Trail Layout Configuration

Where feasible, looped trails are preferred by mountain bikers because they provide more variety and avoid an out-and-back experience. (Out-and-back trails are acceptable where loops are not feasible.) The flow of a trail is important to mountain bikers. The easiest trails should be relatively gentle with predictable curves. Middle loops should include more challenging sections with increasing technical requirements. The most challenging loops can have very tight curves and be very technical. Consistency of flow is important because riders want to get into a riding rhythm. Transitions between open sections and tighter sections should be gradual and be predictable enough to allow riders to adjust their speed and maintain control of their bikes.



Loop lengths: The length of each loop varies depending on type of use and level of difficulty. An overall length of 5 miles of trails is considered the minimum needed for most local trail users, with up to 25 miles being optimal for a defined looped system. In forested areas where forest roads and trails are used as core trails, trail lengths of 50 miles or more are considered optimal.

The use of one- or two-way trails is typically determined on a site-by-site basis. For trails designed specifically for mountain biking in a parklike setting (such as a regional park), one-way trails are common so riders do not have to expect oncoming traffic, especially in highly technical zones. For forest-based trail systems, two-way trails are common, especially on the core trails. These can be augmented by one-way loops as warranted.

Helpful resource!

The International Mountain Bicycling Association (IMBA) has a publication entitled *Trail Solutions – IMBA's Guide to Building Sweet Singletrack* that provides additional guidelines on building mountain bike trails. See www.imba.com.

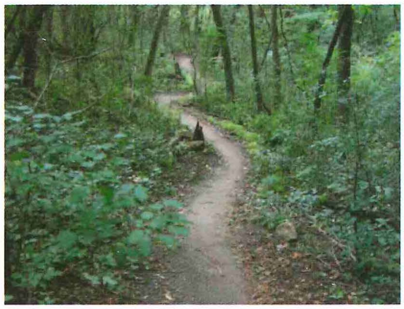
Common Design Features for Mountain Bike Trails

The technical design of mountain biking trails is of considerable importance to trail riders and worthy of additional consideration in this section. The following illustrates common design features and preferences of mountain bike riders. It is these types of features that separate designated mountain bike trails from local access routes and shared-use natural trails.

Variety

Creating a sequence of events through the use of anchors, edges, gateways, and destinations will make a mountain bike trail more exciting and challenging. If the design meets user expectations, riders are more likely to stay on the trail rather than create new routes to increase the challenge.

Trail takes advantage of existing forest trails. *Dual-track in combination with single-track can add variety if well balanced.*



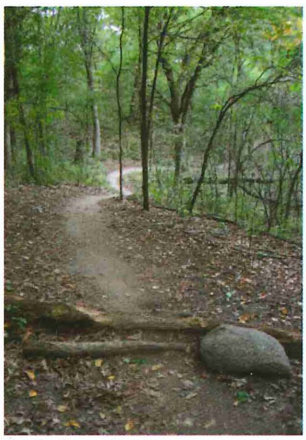
Classic single track*. If well designed, the trail can be exciting with safe riding speeds.*

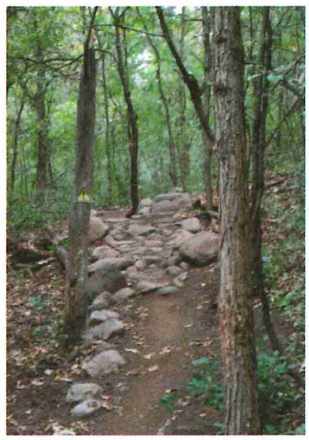
Tightening down the curve *adds to the riding experience and helps control speed. Trail flow is also very important to riders.*

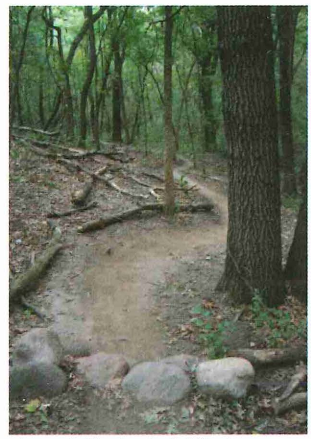
Technical Features That Add Interest and Challenge and Limit Space Requirements

A mix of technical features consistent with the trail rating is important to holding the interest of a rider. These features also help control speed and limit the overall area needed to accommodate a viable stacked loop trail, which is especially important in local or regional parks where space is generally limited.

A narrow bridge challenge *bypass provides an alternate route for more experienced riders, but also allows the more casual rider the chance to ride on the same trail.*





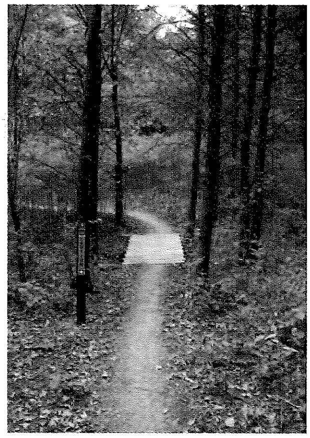


Trail obstacles *come in many shapes and sizes to add interest and challenge to the trail. The level of difficulty must be consistent with the trail rating system in order for riders to select the trail best suited to their skills. Notice the routine use of site anchors near trail obstacles to keep riders on the trail.*

Boulders for challenge and sustainability. *Vertical climbs using boulders are much more stable than soil-tread climbs. Importantly, these need to be well anchored to prevent bypassing.*

Unique and fun trail features *provide riders with unexpected thrills that are challenging yet safe. The boardwalk (left) adds a twist to the more common level version; the teeter (right) provides another unusual trail feature.*

Sustainable curves are designed *– they do not occur by happenstance. Notice the superelevation and edge stabilization on these two curves. Sustainable mountain bike trails are all about the details. The more effort that goes into the initial design and construction, the more durable and long-lasting the trail will be.*



Anchored bridge *helps ensure that riders will not create a bypass through a drainage, which is ultimately unsustainable.*

Spontaneous features *allow a rider to develop new skills, or to simply stay on the main trail for a more casual ride.*

Difficulty Ratings

The level of difficulty associated with mountain bike trails is consistent with the rating system promoted by the IMBA, as the following table highlights.

Mountain Bike Trail Rating System

The table establishes general guidelines for difficulty ratings associated with mountain bike trails. Level of difficulty ratings should be consistent throughout the state to ensure that any given trail is consistent with riders expectations.

Aspect	**Easiest** (White Circle)	**Easy** (Green Circle)	**More Difficult** (Blue Square)	**Very Difficult** (Black Diamond)	**Extremely Difficult** (Dbl. Black Diamond)
Trail Width	72" or more	36" or more	24" or more	12" or more	6" or more
Tread Surface	Hardened or surfaced	Firm and stable	Mostly stable with some variability	Widely variable	Widely variable and unpredictable
Average Grade	Less than 5%	5% or less	10% or less	15% or less	20% or more
Maximum Grade	Maximum 10%	Maximum 15%	Maximum 15% or greater	Maximum 15% or greater	Maximum 15% or greater
Natural Obstacles and Technical Features	None	Unavoidable obstacles 2" tall or less Avoidable obstacles may be present Unavoidable bridges 36" or wider	Unavoidable obstacles 8" tall or less Avoidable obstacles may be present Unavoidable bridges 24" or wider Technical trail feature 24" high or less, width of deck is greater than 1/2 the height	Unavoidable obstacles 15" tall or less Avoidable obstacles may be present, with many including loose rocks Unavoidable bridges 24" or wider Technical trail feature 48" high or less, width of deck is greater than 1/2 the height Short sections may exceed criteria	Unavoidable obstacles 15" tall or greater Avoidable obstacles may be present, with many including loose rocks Unavoidable bridges 24" or narrower Technical trail feature 48" high or greater, width of deck is unpredictable Short sections may exceed criteria

Finding detailed design information!

Refer to Section 6 – Sustainable Natural Surface Trails for technical design information for this type of trail.

OHV TRAILS

OHV trails typically accommodate three classes of vehicles: ATVs, ORVs, and OHMs. The following profiles define the preferences and motivations of ATV trail users.

ATV TRAIL RIDER PROFILES

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR).

Type of Rider	Preference Profile
Recreational Trail Rider	**Trail Use Pattern:** • Travels to trails and ATV areas to ride designated trails and road systems **Recreation Setting Preferences:** • Natural setting is an important element of experience, with highly technical areas a secondary attraction • Prefers looped configurations with varying conditions • Natural, hilly areas make for the best trails, with long, straight trails found to be boring **Motivation/Activity Style Elements:** • ATV is a source of escape to natural settings • Seeking challenge to machines and operating skill • Highly social activity, with groups consisting of family and friends • Will often travel long distances to a trail if it is publicized
Long Distance Tourer	**Trail Use Pattern:** • Rides long distances from place to place (need extensive trail and forest road system) • Prefers loop system, but will use out and back if no other choice **Recreation Setting Preferences:** • Seeks challenges with a variety of conditions with obstacles and technical requirements – although not all of the trail should be highly difficult so groups can stay together • Technical challenges should include hills, trees, logs, rocks, and winding configurations • Needs access to local services, lodging, restaurants, and businesses (40 to 60 miles max range on a tank of gas) • Will use ditches and local trails to connect trails • Frequently rides in unfamiliar areas, requiring maps, signs, and other information about trail systems **Motivation/Activity Style Elements:** • Commonly in family groups or with close friends • Travels on machines much like snowmobiles • Tends to travel slow, wanting to see the countryside; not very interested in speed and performance
Technical Challenge Rider	**Trail Use Pattern:** • Needs a relatively small area, with 2 acres being the maximum size required (trails are not used for this activity) • Only a small number of riders use these areas as a main part of the sport **Recreation Setting Preferences:** • Prefers short, wet runs or hilly terrain that challenges machine capabilities and rider skill • Natural setting is not important, with riding challenge being the most important site selection criterion **Motivation/Activity Style Elements:** • Participates in groups in this highly social activity, often taking part in events and rallies where allowed • Most riders stop after several times around the area and then spend most of their time as trail riders
Local Access/ Utilitarian Rider	**Trail Use Pattern:** • Starts trips from and return to home, with wide-ranging trip length depending on purpose for ride • Knows and rides the local forest road and trail system, but also frequently rides on road rights-of-way, private land, and other public lands as necessary to get to destination **Recreation Setting Preferences:** • Requires little or no developed trail system and uses roads and trails for convenience in getting around **Motivation/Activity Style Elements:** • Does not necessarily consider self a recreational rider, often rides for utilitarian purposes (hunting, fishing, working in the woods, traveling to and from specific destinations) – convenience of travel is key motivation
Excitement Seeker/ Careless Rider	In each of the above segments, excitement seekers and careless riders may be source of behavior problems, creating safety concerns and presenting a bad public image for this type of activity. This is as a major concern of many responsible OHV riders.

ORV and OHM riders have much in common with ATV trail riders, as well as some notable nuances, as defined in the following graphic.

ORV and OHM Trail Rider Profiles

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences specific to ORV and OHM riders. For conciseness, the nuances of these groups relative to ATV trail riders are cited. Otherwise, the general preferences of ORV and OHM riders remain relatively consistent with those of ATV riders.

Type of Rider	Preference Profile
ORV Recreational Trail Rider	• Technical trails can be short (frequently less than 5–10 miles) yet take an entire day to run • 25– 40 miles is a common distance for nontechnical drivers on scenic trails • Very social sport, with little need for solitude and much time spent working together and "bench racing" • Passengers are important participants, providing a "second set of eyes" • 4 x 4 technical challenge drivers on trails travel at low speed, frequently preferring to avoid higher speed trail riders on ATVs and OHMs
ORV Technical Challenge Rider	• The primary difference between this type of rider and ATV riders is the type of technical challenge being sought, with ORV riders sometimes seeking very challenging boulder runs that would seem impossible to negotiate • Building a vehicle to specifications is a major part of the sport, as is testing that equipment in challenging field conditions • Events are often timed and scored • Trails that satisfy this type of rider are very technical and often hard to find, resulting in riders traveling considerable distances to a trail or event area
OHM Recreational Trail Rider	• 5–50 miles of looped trails is a common range of riding distances • Very little interest in riding through wet areas • A combination of single and double track is desirable, with single track only being 24" wide • The majority of trails should be in the intermediate range, with another 10% being easy and 10% difficult
OHM Technical Challenge Rider	• Trails that satisfy this type of rider are very technical and often hard to find, resulting in riders traveling considerable distances to a trail or event area • Advanced riders are capable of traversing amazingly steep and long hillsides with relative ease
ORV/OHM Local Access Rider	Has much in common with ATV local access/utilitarian riders
Excitement Seeker/ Careless Rider	In each of the above segments, excitement seekers and careless riders may be source of behavior problems, creating safety concerns and presenting a bad public image for this type of activity. This is as a major concern of many responsible OHV riders

Average OHV Trail User Outing

The average outing (time spent afield riding) for OHV riders varies with the type of use and trail. On dedicated trails that are specifically designed for a given type of use with varying levels of challenge, 25 miles is considered an average riding distance. On road-based trails through the forest, riding distances can increase substantially and range between 80 and 140 miles. ATV and OHM riders tend to have longer outings or cover more miles than ORV drivers, as is summarized in the following table.

Outing Times and Distances for OHV Riders

Trail Type	Average Outing Length	Common Riding Distance	Maximum Riding Distance
ATV	4–5 hours riding time	18–26 miles for average rides, 26-40 for longer rides	Maximum full-day rides for OHV riders of all types can be 80–140 miles or more. Most, however, tend to ride average distances as defined in the previous column. ATVs commonly go 40–60 miles on a tank of gas.
ORV	5–6 hours riding time	12–20 miles for average rides, 20–40 for longer rides	
OHM	6–7 hours riding time	18–35 miles for average rides, 35–80 for longer rides	

CLASSIFICATIONS

In Minnesota, there are three primary classifications for OHV trails that correspond to types of riders, levels of development, and approaches to management, as the following graphic illustrates.

OHV TRAIL CLASSIFICATIONS

OHV classifications progress from forest access routes/roads (authorized for this use) to highly developed trails within a recreational site setting. The following defines the common OHV trail classifications in Minnesota.

Forest Access Routes and Roads* → **Designated OHV Trail** → **Designated OHV Recreation Site**

Informal Routes / Very Limited Management and Maintenance

Formal Trail Development / Modest Ongoing Management

Intensive Trail Development / Extensive Ongoing Management

Increasing Level of Development and Management →

** Note that "forest access routes and roads" are nondesignated, informal routes through the forest that are not typically included as part of a designated recreational trail system. However, they are still monitored for sustainability and ecological impacts and may be subject to restricted use or closure if they become unsustainable for a given type of use, including OHVs.*

The distinction among trail classifications is important, with each addressing the needs of specific types of riders. Of equal importance, the designations correlate trail development with a certain level of management to ensure long-term sustainability. For forest access routes and roads, where use is generally dispersed, the informal network of routes through the forest is often fairly extensive but receives very limited maintenance. Conversely, designated OHV trails are a managed and maintained system of trails of modest length that can be indefinitely sustained. Since designated OHV recreation sites are the most intensely developed, the overall scale of the facility is more limited and balanced against an agency's ability to manage and maintain the trails.

Designated OHV Trail

Designated OHV trails consist of a defined series of roads and trails, typically within a state or county forest or other public lands. Designated OHV trails accommodate recreational trail riders and long distance tourers who are most interested in riding for longer distances in a natural setting with varying levels of difficulty. These trails start at designated trailheads and may have multiple access points. The main trail can be either a loop or an out-and-back. Stacked loops of varying difficulty and length are optimally provided off a main, easier trail. The loops are typically designed to accommodate either a variety or a specific type of OHV, depending on local demand.

For designated OHV trails, a mix of dedicated trails, trail conversions and on-road trails is used to provide a diverse and interesting trail experience. The following photos highlight the differing character of trail types associated with designated OHV trails.

***On-road trails** take advantage of the existing road infrastructure and provide their own diversity of experience. (Typically, these are located on lower-level roadways within a forest setting.)*

***Trail conversion** takes advantage of an old road by letting it "grow in" to create a narrower, more intimate trail experience within the same developed footprint.*

***A dedicated trail** is shaped specifically for OHV use and designed to add challenge and excitement. Careful assessment of ecological impacts is a key aspect of selecting new trail routes.*

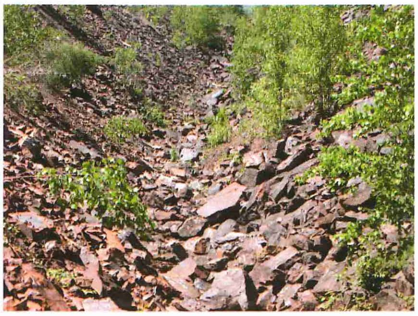
OHV Recreation Site

This is a designated area on public lands for the extensive or exclusive use of OHVs. Trails accommodate recreational riders who are seeking a more challenging series of trails and technical challenge riders wanting to test their skills and machine capabilities.

Trails within a recreation site start at a designated and controlled check-in area or trailhead. There is typically only one access point. An easier core trail typically provides access to a series of designated stacked loops that are increasingly difficult. The core trail typically accommodates all OHV types, with the looped trails designed for a designated type of use (ATV, OHM, ORV). The following photos illustrate some of the more difficult challenge levels associated with recreation sites.



Trails within an OHV recreation site accommodate ATVs, OHMs, and ORVs with trails that range from an easier core trail to highly technical challenge loops. *Core trails (left) typically accommodate all forms of OHVs. Designed looped trails offer increasingly difficult trail configurations. ATV challenges can range from rough, tight terrain (middle) to very steep hills (right).*



Technical challenges for various uses can be very intense at recreation sites. *An ORV course can include "rock crawl" areas where a driver can spend much of the day on a short section (left). Major water holes (middle) tend to draw larger groups to observe riders maneuvering their vehicles through deep water. Control and management of recreation sites starts at the entrance station, where riders are checked in and formally advised of the use of the site, which help ensure that the rules are adhered to and the site remains sustainable (right).*

Given the intensive level of trail development, previously disturbed sites where ecological impacts to adjoining areas and natural systems can be effectively managed are optimal locations for OHV recreation sites. Since challenge is the primary draw, the setting is less important to the trail rider than technical difficulty. For these reasons, abandoned mining areas and gravel pits offer some of the best site attributes for this type of trail development, as the graphic on the following page illustrates.

Forest Access Routes and Roads

Important OHV use qualifier!

Motorized use of forest access routes and roads is highly controlled and varies among county, state, and federal lands. The public land resource manager has the final authority on level of access permitted.

Certain routes in county, state, and federal forests or other public lands may allow for informal OHV use even though they are not designated trails per se. As defined later on page 4.36, *these informal routes are not typically included as part of a designated recreational trail system.* In the context of OHVs, local access and utilitarian riders use these trails (when access is allowed) for general purposes, access to public areas, and simply getting from one place to another as conveniently as possible. In certain circumstances, these routes can complement designated OHV trails, especially if they provide local access to a designated trail system. But this must be done with caution to avoid confusion as to which trails are designated and which are not.

OHV Trail Configurations

The configuration of trails associated with each of these OHV classifications varies considerably. For forest access routes, the trails simply follow existing roads and trails that are open for OHV use. For the other designations, trail configurations do matter in terms of rider satisfaction. The following considers each of these classifications in more detail and highlights the main distinctions between a designated OHV trail and a designated OHV recreation site.

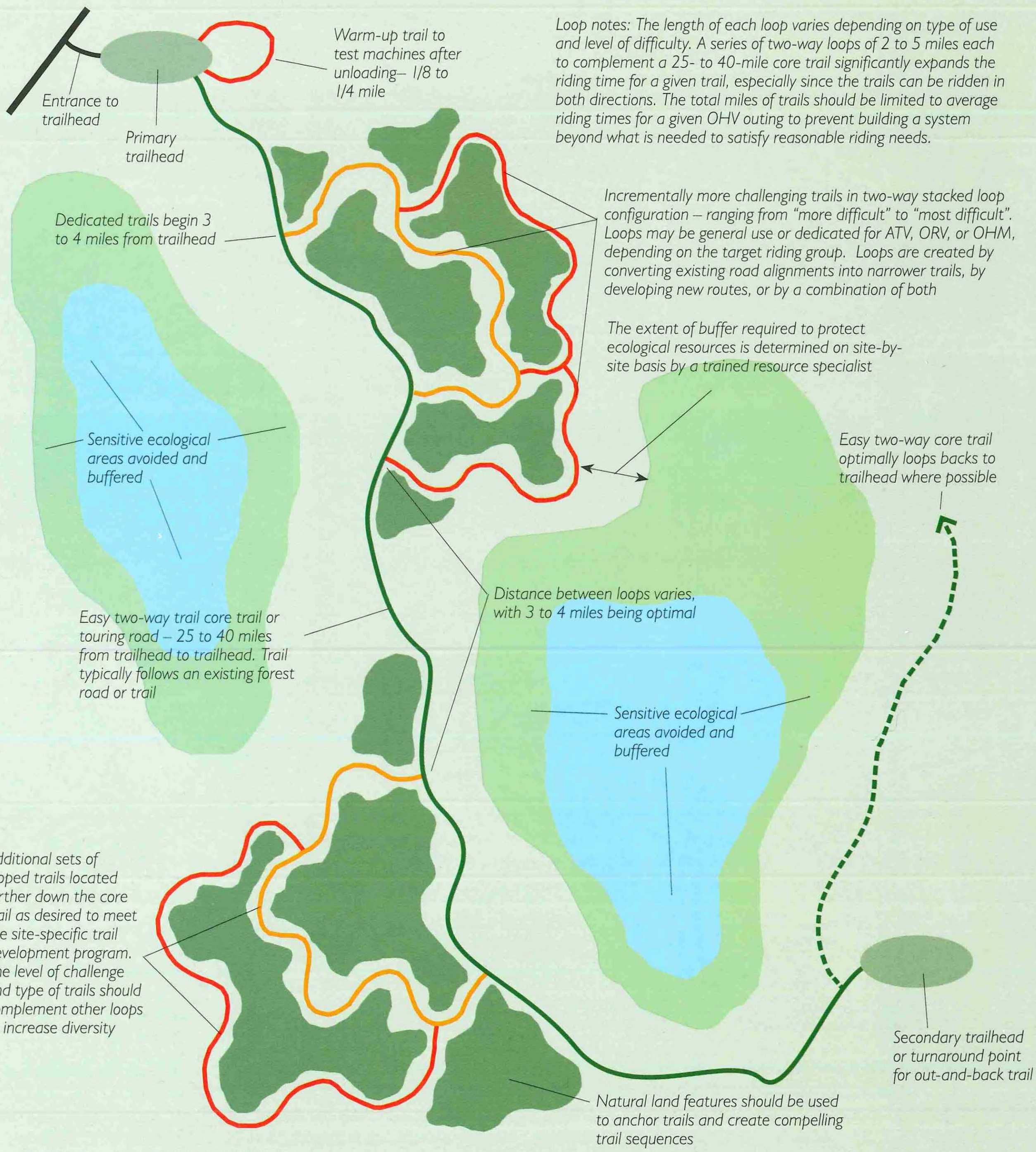
Example of a Designated OHV Recreation Site Layout Configuration

The following provides an overview of the Iron Range Off-Highway Vehicle Recreation Area near Gilbert, Minnesota, the first development of its kind in the state. The site offers an extensive and compact series of trails meant to challenge OHV riders at varying levels of difficulty. The facility is mostly within an abandoned mining area and the ecological impacts of the trails can be managed to avoid degradation to off-site areas. As the map illustrates, a variety of OHV uses are accommodated with varying levels of challenge. These trails are also closely monitored and managed to ensure sustainability. Future expansion is planned in phases.

Designated OHV trails are not as intensely developed as OHV recreation sites, with the emphasis being on recreational riding rather than intensive technical challenge – although some challenges are provided to make the trail interesting. Since these trails often traverse miles of public lands, ecological impacts and forest management are major considerations in trail layout and design.The following graphic illustrates some of the key aspects of designated OHV trails.

Designated OHV Trail Layout Configuration

In Minnesota, the core trail or spine of this type of OHV trail is typically an existing converted road or rail bed in a state or county forest or on other public land. Most often, these trails are relatively straight and easy to ride. To enhance the riding experience, a series of loops can be added specifically designed for a particular type of OHV use and level of challenge. Although these trails have some of the same challenge features as OHV recreation sites, the level of development is less extensive to ensure sustainability and to avoid diminishing the natural setting and sense of place that many riders are seeking. The following illustration highlights features of a typical designated OHV trail that balances access and sustainability.



Must review information!

Refer to DNR website (www.dnr.state.mn.us/ohv) for up-to-date information on OHV trail planning, regulatory requirements, and grant information.

Common Design Features for OHV Trails

As with mountain bike trails, the technical design of OHV trails is of considerable importance to trail riders and worthy of additional consideration in this section. It is the technical features that separate designated OHV trails and recreation sites from general local access routes and help ensure their long-term sustainability. The following illustrates common design features and preferences of OHV riders.

General Preferences

A 2000 survey of registered Minnesota OHV owners reported that riders generally prefer forested, hilly, and less-developed sites. Since family outings are common, core trails need to have extensive easy sections so all riders can have fun and stay together. While preferences vary among ATV, OHM, and ORV riders, all three groups agreed on the following as "fun" or "really fun":

- Trails with a destination of special interest – inferred to include towns, businesses, major site anchors such as lakes and rivers, and links to other riding areas
- Primitive roads, with narrower tracks being preferred
- Easy trails through scenic areas
- Series of escalating challenges spaced out along the trail or accommodated in interlinked challenge loops

The high value of primitive roads indicates that OHV riders enjoy on-road trails and trail conversions if they are combined with trails specifically designed for OHVs. The high ranking of easy trails through scenic areas shows a desire to simply enjoy nature –although finding varying challenges is important to maintaining repeat interest in a given trail.

Overall, trails should provide a sequence of events that range from easy to challenging in a scenic setting that entices repeat use and, of equal importance, keeps riders from venturing off-trail or excessively using local access trails. The following provides an overview of trail features most desired by OHV riders.

Helpful resource!

Park Guidelines for OHVs by George E. Fogg in association with the National Off-Highway Vehicle Conservation Council, offers additional information on the design of OHV trails.

Naturally Shaped and Engaging OHV Trails

An ideal dedicated OHV trail is sustainable from trail alignment rather than construction. The most successful trails are designed to enhance the sense of place and offer an interesting sequence of events while limiting impacts to surrounding ecological systems.

Open prairie sense of place *can be an exhilarating feeling. With adequate rolling grade and ecological buffers, it can also be sustainable.*

Closed forest intimacy *is achieved by keeping the trail narrow with limited sightlines.*

Sustainable narrow track *is engaging to riders and limits site impacts.*

Controlling Speed Through Variety and Transition Zones

A mix of trail types also allows for the interspersing relatively easy, smooth segments with tighter, more technical ones requiring more attention from the rider. The transition zones between these segments encourages riders to change speed and mind-set. If the proper challenges are provided, the desire for speed becomes less pronounced.

Straight segments entice speed *and should be balanced with more intimate and challenging segments.*

The transition to more challenging section *forces riders to slow down and take more notice of their surroundings.*

Challenge sections *are inherently slower. Attention to the technical design of such sections is very important to keeping them sustainable.*

Variety Through Sequences

Creating a sequence of events through the use of anchors, edges, gateways, and destinations will make the trail more exciting. In OHV trails, well-placed anchors also keep riders from leaving the trail.

This trail is anchored by dense cover, *making the idea of going off trail less appealing than staying on it.*

The trail is anchored by slopes and rock berms *in this quarry site. The manipulation of the anchor is acceptable due to past site uses.*

A tree course *leaves little room for an OHM rider to go off trail. If it is interesting, there is also less desire to do so.*

A naturally hardened crest *offers an interesting anchor to this ATV trail. The rock outcrop is also very stable, which allows for a steeper approach.*

A rock-pile obstacle *provides an challenge that is well anchored by trees and larger rocks, minimizing the chance to go around.*

This anchored steep sideslope traverse *is interesting, slows riders down, and keeps them on the trail.*

Maintaining a More Compact Development Footprint

Regardless of the site, trails with extensive small-scale variety in their form – S-curves, small climbs, small obstacles such as rocks, limited sightlines – will seem longer than a more roadlike trail on the same site. The greater the difference in scale, the slower the speeds and the less distance traveled in the same time slot. Through insightful design, the trail experience can actually be enhanced while limiting the land base. This is a valuable tool in reducing overall site impact while still providing a rich rider experience.

Wide open and straight segment *promotes higher speeds and requires more miles to fill a given time slot.*

More intimate, smaller scale segment *provides more variety, slows riders down, and requires fewer miles to fill a given time slot.*

Other Characteristics of Interesting OHV Trails

Trail character is shaped by features that are intentionally provided to create a sequence of events. The illustrations on the next page highlight the most sought-after of these as defined by user preference surveys. The juxtaposition of trail features is what makes a trail interesting and compels riders to return.

Frequent, short grades add interest. *Instead of a single long hill climb, shape trails with short climbs of varying length, height, and spacing (left).*

Short, steep grades (as little as 30 inches high) add sustainable enjoyment to a trail (right).

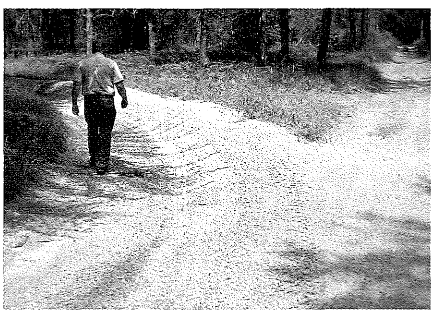
While traversing slopes is always preferred, short hill climbs can follow the fall line as long as they stay within sustainable tread grade limits and have a natural tread dip at the bottom, which is less prone to displacement than a constructed one.

Short vertical curves create small challenges. *Combined with a direction change of 45 degrees or less and a sufficient sightline, a vertical change from 30 inches to about 10 feet (depending on context) can be fun, safe, and easily maintained (left).*

When traversing a sideslope, form short vertical curves by suddenly dropping down the slope for a short distance before leveling out or climbing again (right). This creates interest and establishes a trail dip to manage runoff and prevent erosion.

Narrow tread is standard practice. *Most new, dedicated OHV trails should be only as wide as needed for the widest permitted use (left).*

Only the busiest sections of trails need to be two lanes wide. Pullouts and wider spots can be formed as needed on two-way trails (right).



Wider tread may be needed. *On easier trails, treads can be up to twice the normal width in places such as blind curves or where trails come together at odd angles (left).*

Consistently wide tread is used primarily on on-road trails (right).

Exposure creates drama. *Sideslope trail alignment creates an increasingly dramatic feeling of exposure as the sideslope increases. At the same time, alignment on steeper sideslopes maximizes tread drainage and physical sustainability (left).*

Where topography allows, use exposure to add excitement, challenge and sustainability to the trail flow. An earthen berm on the outside edge can help prevent falls down the slope (right).


Water and mud as a small-scale feature. *OHV trails can have constrained mudpits that are not in a natural water body or perennially flowing natural drainage (left).*

On easy trails, most riders choose to avoid mud and mudpits. Configure the trail so the mudpit is a detour from the main trail or can otherwise be skirted (right).


Challenging mudpits. *When placed at the bottom of a tread climb, mudpits serve to "grease the wheels" and make the climb more difficult. The pit also serves as a sediment trap for runoff from the tread above (left).*

Constrained, constructed mudpits of any size are often desirable trail features as long as they are sustainable. Depending on the difficulty level, riders are either forced (by barriers on both sides) to ride through the mudpit (right) and/or are provided with a sustainably stable, dry bypass.

No other forms of mudpits are sustainable!


Rough tread sections formed through use. *Trying to create "rough" sections can be a challenge and cause additional site impacts. It's best if rough sections are formed though trail use, as long as they remain sustainable).*


Native or imported rocks provide many challenges. *For stability and anchoring, the larger the obstacle, the better. Rocks and boulders can be used to require skillful negotiation with narrow clearance and create rough tread to cause vehicle articulation (left).*

Rocks can be used to form series obstacles on a variety of tread grades. Combined with water, mud, and steep grades, rocks can be used to create sustainable yet slippery treads (right).


Logs also add challenge and interest to a trail. *Sections of tree trunks can be used as obstacles (left). Angling logs relative to the tread direction increases the challenge.*

Partially buried logs in combination with rocks can be used as erosion control devices, rustic waterbars, and/or obstacles (right).

For ORVs, logs can be cabled together and/or to the ground as a challenging feature. For OHVs, loose logs can be present on tread climbs as floating obstacles.

Tight clearance limits maneuvering space. *Limiting clearance increases challenge by removing opportunities to take easier courses around obstacles. Use trees, rocks and sideslope alignments to limit clearance (left).*

Anchors and gateways can create points of tight clearance for even narrower tracked uses such as OHMs (right).

Tight and very tight curves create challenges, if not used excessively. *Increase challenge by anchoring the inside of the curve on a larger tree or rock at the very edge of the tread. Further increase challenge with tree, rock or earth anchors on the outside of the curve.*

Beware of creating conditions for excess displacement, such as very steep vertical curves, and starting/stopping zones. Consider soil strength, superelevation and drainage (right photo).

Sightlines

Managing sightlines is one of the major tools for controlling speed and promoting safety. Unlimited sightlines can actually pose more of a safety concern than those that are more constricted because they encourage excessive speed. Finding the right amount of sightline to maximize safety is a key design challenge. The following table provides an overview of minimum sightline distances for OHV trails.

Desired Minimum Sightlines for OHV Trails

All distances are in feet and measured from the driver's eye to a spot 12 inches above the trail ahead. For shared-use trails, use the longest sightline of any approved use. Note that these distances are general guidelines and not a substitute for site-specific determination of safest sightline distances.

Type of	Two-Way Trail			One-Way Trail		
Use	Easy	More Difficult	Most Difficult	Easy	More Difficult	Most Difficult
OHM	110'	70'	40'	80'	40'	20'
ATV	100'	60'	35'	70'	35'	20'
ORV	120'	75'	45'	90'	40'	15'

Limited sightlines control speed. *A narrow track through a dense forest with vegetation encroaching on the trail adds excitement and keeps speeds from escalating (left).*

In more open settings, the use of rolling grade can limit sightlines and hence control speeds (right).

Through good design, all aspects of a trails use can be effectively managed for excitement, safety, and sustainability.

Speed Reduction Signals

Providing visual cues to signal the need for a change of speed is an important design consideration, especially as a rider approaches a blind curve or other situation requiring heightened caution. Examples of visual cues include:

- Reducing the tread width (even slightly) while adding small, naturally shaped curves into the alignment
- Using a gateway with tight clearance but good visibility on approach from both sides
- Aligning the trail with a climb up to the slow-down zone on both sides
- Roughening the trail in the approach zone from both sides
- Reducing a sightline earlier and more gradually by decreasing vegetative clearance

Warning signs can also be used where deemed appropriate.

Visual cues can be used to reduce speeds. *Stones can be used to create a sustainable drainage crossing and also reduce speeds on an otherwise open stretch of trail (left).*

Speed can be reduced and trail variety increased by a well-placed S-turn (right).

High Displacement Braking and Acceleration Zones

Certain trail designs create situations where ATV and OHM riders suddenly brake or accelerate. A sharp curve, a bump at the bottom of a grade, a sharp tread dip at the bottom of a steep grade, a stop sign, a final approach at the end of an open trail segment, and switchbacks all create situations prone to soil displacement. In general, avoid situations causing high displacement braking and acceleration. When that is not possible, trail hardening should be considered a part of the trail's design before the situation becomes a problem.

Displacement is best limited through good design. *Where that is not possible, the tread must be adequately hardened to remain sustainable, as at a stop sign where compacted aggregate can be used in the start/stop zone (left).*

On steep, erosion-prone climbs that are unavoidable, significant trail hardening may be required, including the use of concrete planks for the most challenging situations (right).

General Guidelines for OHV Levels of Difficulty

The level of difficulty of a trail should be purposefully considered relative to the intended user groups. Trails that are too easy will entice OHV riders to go off trail to find adventure. Trails that are too difficult will be self-limiting and many riders will go elsewhere.

For general public trails, the overall trail should accommodate the average rider, which often consists of a family group or a group of friends with varying skills. The needs of the most advanced rider should be accommodated with increasingly difficult loops off a less difficult main trail. The table on the next page provides general guidelines on tread difficulty levels for OHV trails.

OHV Tread Guidelines for Difficulty Levels

The following guidelines are adapted from *Off-Highway Motorcycle & ATV Trails Guidelines for Design, Construction, Maintenance and User Satisfaction*, by Joe Wernex, 2nd.-ed., p. 6. and modified for ORVs and Minnesota conditions.

Aspect	Easiest	More Difficult	Most Difficult
Grade	8% max sustained 15% short pitch (~25' long max) 25% very short pitch	12% max sustained 25% short pitch (~15' long max) 35% very short pitch	15% max sustained 35% short pitch (~12' long max) 50% very short pitch (rare)
Tread width	OHM 18"–30"* ATV 72"–96"* ORV 120"–144"*	OHM 18"–24"* ATV 60"–84"* ORV 96"–120"*	OHM 12"–24"* ATV 56"–72" * ORV 80"–102"*
Curve radius	Easy flowing curves that do not tax the machine or rider	Approaches the minimum turning radius of a given type of OHV and requires some maneuvering	Can exceed the minimum turning radius of a given type of OHV and can require extensive maneuvering to make a turn
Minimum clearance	2' downhill side 3' uphill side 1.5' each side if sideslope < 15%	1.5' downhill side 3' uphill side 1.5' each side if sideslope <15%, Clearance of occasional trees can be as little as 10" for added difficulty	0–1' downhill side 1.5'–2.5' uphill side 0–1.5' each side if sideslope <15%, Clearance of occasional trees can be as little as 5" for added difficulty
Clearance height	9'	8'	8'
Tread surface (ATV)	Relatively smooth throughout, no rocks or roots protruding more than 3"	Sections relatively rough, rock outcrops OK	Relatively rough with short sections very rough; lot of up and down, long stretches of sand, some mud
Tread surface (OHM)	Relatively smooth throughout, no rocks or roots protruding more than 3"; avoid sand and loose materials	Sections relatively rough, some loose sand, etc.	Relatively rough with short sections very rough; long stretches of sand or loose rock desirable on occasion
Tread surface (ORV)	Relatively smooth throughout, no rocks or roots protruding more than 5". Many sections negotiable by 2 wheel drive pickup in dry conditions	Sections relatively rough, rock outcrops OK; ledge climbs, mudhole negotiations, deep dips in trail water diversions and small drainage crossings	Relatively rough with short sections very rough; lot of up and down, long stretches of sand, some mud, deep and frequent trail water diversions, the rockier the better
Mud	If any mud is present, should be easily bypassed on dry tread	Wide range of muddy areas OK, but all significant mud has a dry bypass route	Some muddy areas have no bypass, but worst muddy areas have dry bypass

* For both OHMs and ATVs, widen 6"–20" on switchbacks or where sideslopes exceed 50%. Widen curves on outside corners by 4"–6" for OHMs, 12"–24" for ATVs, 48"–60" for ORVs.

For all three OHV uses, highly skilled riders seek trails requiring precise judgment and precise control in tight, difficult conditions. Speed is a secondary concern. The most challenging trails require riders to crawl slowly through natural and shaped obstacles such as boulders, rocks, logs and steep grades. This allows the most challenging trails to be developed in a relatively small area where site impacts can be more limited.

Nuances of Trail User Groups

There are some notable nuances associated with various OHV uses. For ATV trails, extensive use of short-radius, high-angle curves should be avoided since these are near the minimum ATV turning radius and tend to create horizontal displacement. The recreational value of this type of trail does not justify the cost to sustain it when well-designed, low-angle, short-radius curves can be equally enjoyable and much more sustainable.

For OHM trails, curves are highly desirable. On trails designed to be more challenging, curves can be frequent and tight and optimized for body flow. Since OHM riders lean into curves, treads should be shaped with sequences of varying, anchored S-curves combined with short and frequently changing grades.

For OHV trails, features that differentiate them from roads, such as occasionally narrow tread, tight clearance, very rough and/or rocky tread that causes articulation, and very tight curves are most desired.

Forest Access Route and Forest Roads

Under DNR's terminology, "forest access route" is a generic term used to describe a corridor or treadway through the forest that allows machinery, vehicles, or people to traverse a property. Typically, access routes are recognized as abandoned roads or old logging trails through the forest.

"Forest roads" are developed roads open to motorized vehicles that are not posted and designated as closed. State forest roads are open to highway-licensed vehicles, ORVs, ATVs, and OHMs unless the road is in a "closed" forest, where only highway-licensed vehicles are allowed (unless otherwise permitted by the DNR commissioner following specified public notice and comment requirements).

On state lands, DNR has a program in place to inventory forest access routes and roads. Similar programs are being undertaken by federal and many county land managers using their own set of criteria. These inventories are being conducted to determine the extent to which forest access routes and roads exist and how their use factors into the overall management of the forest. The following photos illustrate common examples of forest roads and access routes.



Forest access roads and routes can take on numerous forms. *Lower-level roads (left), dual-track access routes (middle), and old logging skidding treadway (right) can all be used to accommodate informal motorized and nonmotorized forms of recreation.*

Distinction Between Forest Access Routes and Roads Relative To Designated Recreational Trails

Important distinction!

The distinction between forest access routes and roads relative to designated trails is important.

The distinction between forest access routes and roads relative to recreational trails is that the former *are not managed or maintained for any specific type of recreational use* unless formally designated as part of a recreational trail system. Any use of these corridors is at the discretion of the individual within the context of applicable laws and regulations that otherwise govern their use. Inherently, there is an element of personal responsibility regardless of where one operates, whether on a designated trail or following an informal forest access route and road. Persons using public lands have a responsibility for their own safety, and are subject to citation for careless or reckless use and to prohibiting on rutting, erosion, or damage to living vegetation.

As informal corridors, individual forest access routes and roads are not commonly included as part of a designated recreational trail system. More commonly, areas where forest access is permitted are defined as part of an overall forest management plan. In this broader context, local land managers responsible for county, state, and federal lands establish forest access policies specific to the lands that they govern. This includes determining which areas of the forest are suitable for any particular recreational or other use, taking into consideration resource management plans and environmental protection strategies associated with a given forest or region. The extent to which these areas are formally mapped is determined by the local land managers based on their forest access policies. It is important, however, to make a clear distinction between designated trails and forest access routes and roads to avoid ambiguity with user groups.

Forest Access Routes and Roads Used as Part of a Designated Trail System

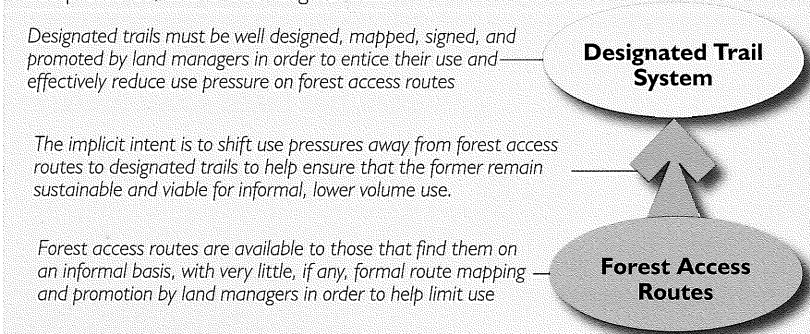
Consistent with the principles of ecological sustainability defined in Section 3, redefining an existing forest access route or road to a designated recreation trail for a specific use often has merit to limit the built footprint and minimize ecological impacts. In these instances, the guidelines for developing sustainable natural surface trails as defined in Section 6 have relevance and should be applied to ensure consistency in trail development standards. The discussion in that section related to using existing roads versus forming new trails is especially pertinent.

Encouraging The Use Of Designated Trails Over Forest Access Routes

One of the main reasons for developing designated recreational trails is to shift some of the use pressure away from forest access routes to trails that are designed, managed, and maintained to accommodate higher levels of use. By making this shift, there is a greater chance that informal access to the forest can remain sustainable even as overall recreational demand increases. The following graphic illustrates this important point.

Shifting Use Away From Forest Access Routes To Designated Recreation Trails

The challenge for local land managers is finding a balance between providing access for recreation and responsibly managing and protecting the forest resource. Designated recreation trails can play an important role in accommodating growing use pressures, as the following illustrates.



Connections Between Designated Trails And Forest Access Routes

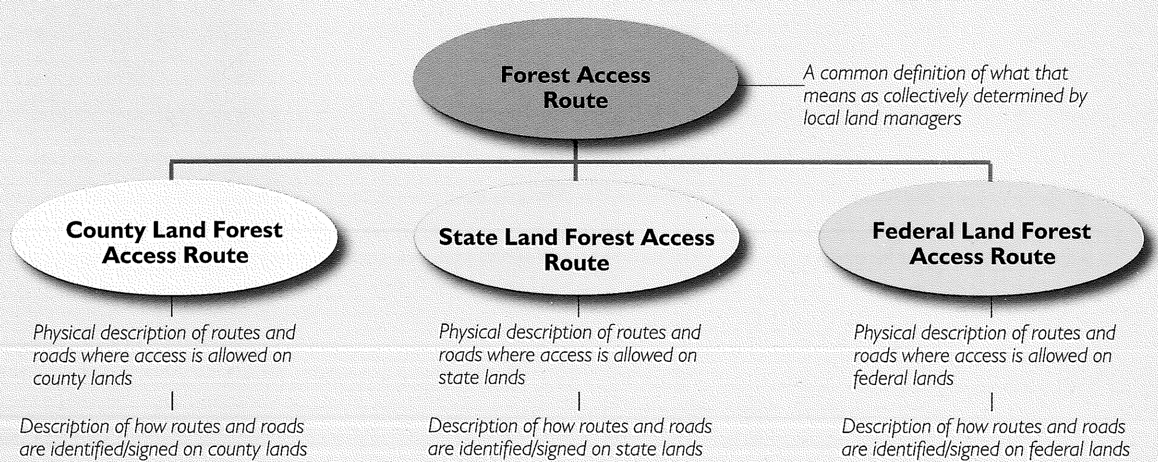
Direct connections between designated trails and forest access routes should be carefully considered to avoid having the latter becoming a de facto expansion of the former. In general, direct connections should be at controllable locations, such as designated trailheads.

Coordination of Forest Access Routes and Roads

There is likely to be at least some difference in the way forest access is defined by various land managers based on local interests and resource management considerations. In these instances, a coordinated effort is recommended to inform the public about which forest access roads and routes under their individual jurisdictions are open for recreational use. The following graphic illustrates this approach.

Coordinated Forest Access Route Identification

Roads and routes on public lands are often defined in different ways by county, state, and federal land managers, which can be confusing to the recreational user. To help alleviate this problem, land managers should work together to define where specific types of recreational activities are allowed. The following diagram highlights how information could be provided on a printed waterproof card that recreational users could keep with them while out in the forest.



The following photos illustrate some of the nuances associated with defining a forest access route. The more clarity land managers can provide on this issue, the less ambiguity and confusion there will be with user groups accessing public lands.



Old trails and logging trails that are substantially grown in with vegetative cover can provide a basis for defining where certain types of uses are no longer allowed. *Each land manager will have to make a determination based on local considerations and levels of use. Nonetheless, land managers are encouraged to define these limits as clearly as possible to limit ambiguity as much as possible.*

Ensuring That Forest Access Routes Remain Sustainable

For more information!

Refer to Guiding Principle #6 – Ensure That Trails Remain Sustainable in Section 3 for additional information on sustainability thresholds.

Although forest access routes are not designated recreational trails, the principles of ecological sustainability as defined in Section 3 still have application since much of their use will be for recreation. This is especially the case with guiding principle #6, which describes sustainable and unsustainable conditions associated with recreational uses.

Whether a designated trail or a forest access route, protection of the resource from undue harm caused by overuse, aggressive use, or wanton destruction by irresponsible users is vital to maintaining public support for recreational access to public lands. For this reason, the sustainability thresholds and evaluations described under Guiding Principle #6 have equal application for forest routes as they do for designated trails.

The thoughtful use of the sustainability guidelines also provides a basis for land managers and various recreational users to work more closely together. By establishing a common understanding of sustainability and taking a prescribed and predictable action when problems occur, the ethic of individual and collective responsibility for the stewardship of Minnesota's natural resources can be strengthened.



Excessive levels of use, poor rider judgment, and illegal off-trail operation pose the greatest threat to keeping forest access routes open for general use. *Each of these photos illustrates unsustainable use practices that often cause local resource managers to restrict or decommission forest access routes, leaving responsible users with fewer recreational areas to enjoy.*

Approaches to Signage and Control of Forest Access Routes and Roads

Signing of forest access routes and roads is handled in a number of ways by county, state, and federal agencies. *Forest Access Signing and Placement Guidelines* (DNR Division of Trails and Waterways) describes the type of signs commonly used for signing designated trails within the forest. It also provides guidelines for signage associated with forest access routes.

Shared-Use Natural Surface Trails (Nonmotorized)

Shared-use natural surface trails can accommodate any select combination of the previously described nonmotorized trail uses. (Motorized uses were already considered under OHV trails). With the exception of local access trails, motorized and nonmotorized uses are typically kept separate in most Minnesota applications.

Shared or Single Use

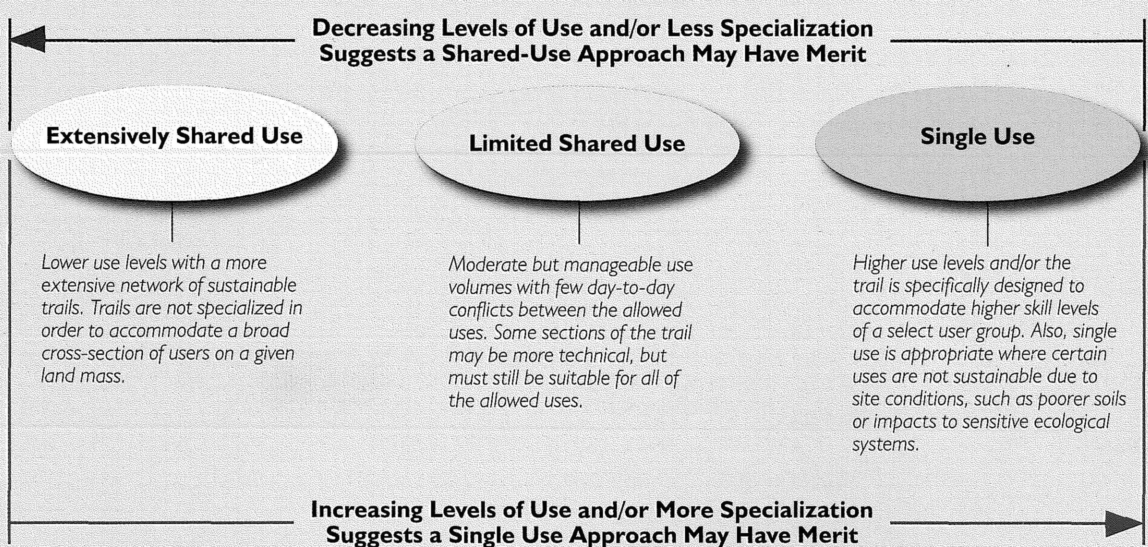
For nonmotorized trails, the location, anticipated use levels, level of specialization, and specific site characteristics all influence whether shared or single use on a trail is appropriate and sustainable. User expectations also play a role in determining the appropriateness of shared or single use. When trails feel crowded or users are seeking a challenging trail experience with few interruptions, users will become less tolerant of those pursuing other activities and use conflicts may start to rise.

In urban areas, where use levels are typically high, separate trails for different uses is common, but not exclusive. In some regional parks, for example, horseback riding and hiking occur on the same trail if use levels are modest enough to avoid conflict. In rural or more remote regions of the state, where use levels are lower and more dispersed, hiking, horseback riding, and mountain biking are more routinely found to be acceptable on the same trail.

There are no set guidelines as to when a shared or single use approach is the most appropriate for any given situation. Local public input coupled with site-specific evaluations of user group needs are recommended as the basis for making this determination. The following graphic highlights the key considerations that favor either shared or single use of a given trail.

Shared-Use Versus Single-Use Trails

Whether a trail should be shared or single use is based on numerous factors, including anticipated levels of use and degree of specialization. The more a trail is shared, the less technical it can be in order to accommodate divergent user groups.



Shared-Use Natural Surface Trail Configurations

The configuration of shared-use natural surface trails is based on the uses being accommodated and the land available. In some cases, all of the trails in a given area are shared use and designed to reasonably accommodate all trail users. Because of the multiuse nature, this type of trail is usually much less technical and challenging than single-use trails.

Another approach is to establish a core trail (most often a loop) that provides the common trail for all approved uses, with single use spur trails tying into it that are for specialized use and, subsequently, more technical and challenging.

Trail signage is important on shared use trails, especially when single-use spur trails are attached to a common core trail.

ON-ROAD BIKEWAYS

Bikeways note!

Although not a trail per se, the bikeway classification is included in these guidelines to underscore bikeways importance as part of an overall trail system to accommodate the full range of bicyclists and in-line skaters.

On-road bikeways (i.e., bike lanes and bike routes) are paved segments of roadways that serve as a means to safely separate bicyclists from vehicular traffic. For advanced bicyclists and some in-line skaters, bikeways are one of the most important elements in the trail system and should not be overlooked.

Bikeways generally allow a cyclist to go faster than on trails and offer more continuity in surfacing and intersections. Complementing shared-use trails with on-road bikeways enhances the overall trail system by making it more complete and user friendly. The following box defines the preferences of those using on-road bikeways.

ON-ROAD BICYCLIST PROFILE

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of typical road bicyclists and in-line skaters willing to use roads.

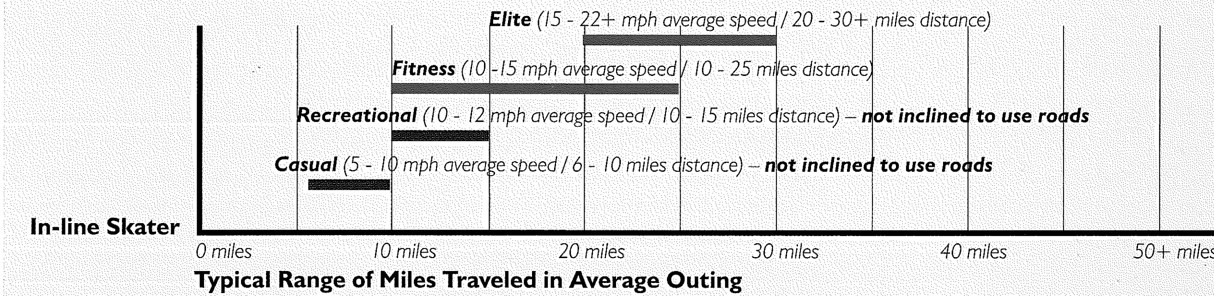
Type	Preference Profile
Family Bicyclist	**Trail Use Pattern:** • Will not routinely use busy roads
Recreational Bicyclist	**Trail Use Pattern:** • Prefers trails, but will also use roads that are safe, convenient, and not too busy
Fitness Bicyclist	**Trail Use Pattern:** • Will use a combination of streets, roads, and trails that are long and/or challenging enough for a good workout • Prefers trails if they are long enough (20 or more miles) and allow for faster speeds with minimal user conflicts • Will routinely use the same routes for challenges and timing, often on a daily basis **Motivation/Activity Style Elements:** • Uses bicycle as primary form of exercise • Primarily rides alone or in small groups and often rides multiple times per week • Frequently extends the season by riding earlier in spring and later in the fall than recreational riders
Transportation Bicyclist	**Trail Use Pattern:** • Not dependent on trails, but will use them if convenient, safe, and direct **Motivation/Activity Style Elements:** • Bicycle is used as a form of transportation; motivated by fitness, environmental values, and economy • Lack of a safe "system" of roads (with bike lanes or routes) and trails is a major barrier to this group • Trail design is critical, with ability to go fast with good sight distances and directness being most important
Road-Only Cyclist	**Trail Use Pattern:** • Does not use trails **Motivation/Activity Style Elements:** • Believes trails are too crowded, unconnected to destinations, inconvenient, or unsafe due to design flaws
Fitness In-line Skater	**Trail Use Pattern:** • Will use a series of streets, roads, and trails to create a long enough route **Motivation/Activity Style Elements:** • Smooth, wide skating area is needed to feel safe
Commuting In-line Skater	**Trail Use Pattern:** • Use skating as a form of transportation • Use trails where available, but will also use streets and roads to get from point to point **Motivation/Activity Style Elements:** • Needs traffic enforcement, security, skate-friendly routes to and from work sites • Needs accommodations at work, such as lockers, changing areas, and showers

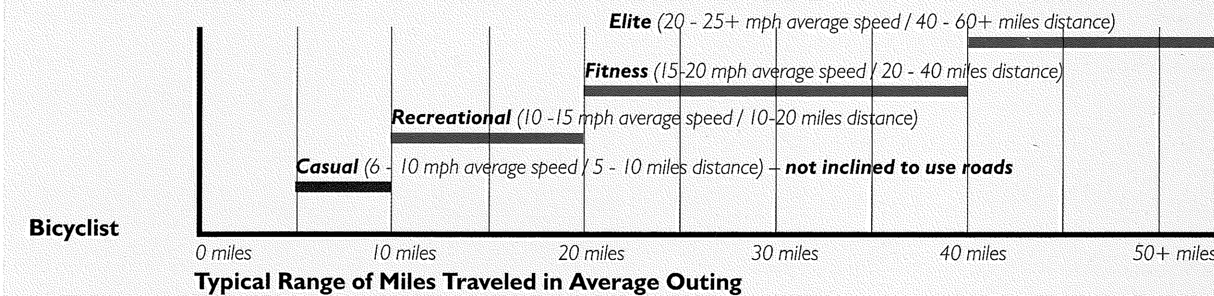
GENERAL TRAVEL SPEEDS AND DISTANCES ASSOCIATED WITH ON-ROAD BIKEWAYS

One main advantage of bikeways is the unlimited number of interconnected miles that are available to a rider, assuming that the roadways have adequate space for safe riding. The following graphic illustrates the travel speeds and distances associated with on-road bicyclists and in-line skaters.

General Travel Speeds and Distances for Various Types of Users

The average travel speed and distance traveled by a road bicyclist or road in-line skater tend to be on the higher and longer relative to a bicyclist or in-line skater that would use a trail, as the following illustrates.





Bikeways technical design requirements resource!

Since bikeways are part of the roadway infrastructure, their technical design is not considered in any section of these guidelines.

For consistency refer to the standards defined in the Mn/DOT *Bikeway Facility Design Manual* as it relates to bike lanes and bike routes (shoulders) for technical design. The most recent version can be found at www.dot.state.mn.us/transit/bike/bikedesign.html.

Bikeways Classifications

The distinction between a bike lane and bike route is the level of exclusiveness and the setting, as the following considers.

Bike Lane

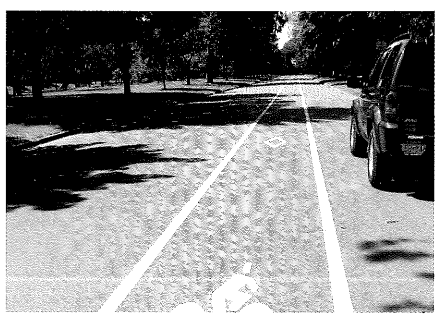
A bike lane is a designated portion of the roadway defined by striping, signing, and pavement markings for the preferential or exclusive use of bicyclists. All bike lanes are one directional consistent with traffic.

Bike lanes are generally used on arterial and major collector roads with average vehicle speeds greater than 30 mph and average daily traffic exceeding 10,000 average daily trips (ADT). Bike lanes provide the separation needed for bicyclists to feel comfortable riding in this level of traffic.

The width of a bike lane on roads with a curb should be a minimum of 5 feet from the face of the curb, with 4 feet desired to the left of the joint between the gutter and the road pavement (3 feet minimum). If daily traffic exceeds 10,000 ADT or when average speeds exceed 30 mph, 6-foot lanes are recommended from the face of the curb where space allows.

When parking is provided, the parking lane should be 8 to 10 feet wide and the adjacent bike lane bike lane should be a minimum of 5 feet wide, with 6 feet preferred where space allows. The following photos illustrate the most common bike lanes.

Bike lane with curb and no parking. *5 feet wide from face of curb, with a 4 feet desirable from left of the gutter edge. On one-way streets, the bike lane can be on the right or left side of the road, depending on parking and other site characteristics.*



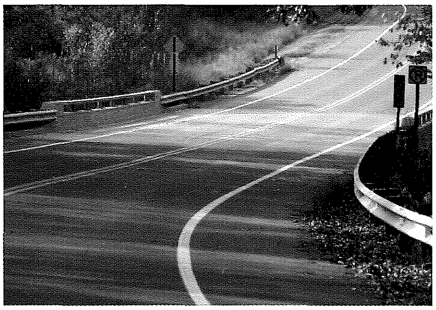
Bike lane with parking. *5 feet wide is the desired minimum. Provide pavement markings to alert drivers of the designated lane.*

Center-located bike lane. *On Hennepin Avenue in Minneapolis, the bike lane is located in between traffic lanes going in one direction and bus-only lanes going in the opposite direction.*

Bike Route

A bike route is a shared portion of the roadway that provides some separation between motor vehicles and bicyclists. State statutes define a bike route as a "roadway signed for encouragement of bicycle use." Most people would recognize an bike route as a paved shoulder with signage. A minimum of 4 feet is the recommended shoulder width for roadways where bicycles are present. A 6-foot shoulder is recommended once traffic speeds exceed 50 mph. If rumble strips are provided on the edge of the drive lane, the smooth biking surface should be at least 5 feet wide.

Most bikeways in suburban or rural settings will be designated as bike routes. The need for designated bike lanes is most often associated with downtown areas and major business districts in urban core areas where traffic is heavy. The following photos illustrate the most common bike routes.



Bike route in narrower, slower speed roadway. *Where space is limited and traffic speeds are 30 MPH, such as along this scenic byway, a minimum shoulder width of 4 feet would be adequate.*

Bike route on wider, higher speed roadway. *Once speeds get above 50 mph, a minimum 6 foot shoulder is recommended to provide reasonable separation between bicyclists and motor vehicles.*

Bikeway Configurations

There are no set standards for the configuration of a bikeway. The primary determinant is the likelihood that bicyclists will use a particular road based on its directness, accessibility from a given location, continuity, comfort and attractiveness, and, above all, perception of safety. In many communities, bikeways are established in a de facto manner as part of roadway projects where paved shoulders are provided for operational safety and maintenance. Where this is the local policy, coordination between trail planners and roadway engineers is critical to ensuring that any nuances associated with bikeways are factored into the design of the roadway at the point of construction planning. Through this approach, many cities have successfully expanded bikeway systems without substantial capital expenditures.

As a general guide, the *Mn/DOT Bikeway Facility Design Manual* provides tables that relate bikeway types to roadway characteristics, as the following illustrates.

Bikeway Design Options for Roadways

The following tables provide recommended bikeway design options for various roadways. The tables relate to urban section (with curb and gutter) and rural section (no curb and gutter) roadways. Note that *wide curb lane* refers to a right through-traffic lane is wider than 12 feet. *Shared lane* relates to travel lanes that can be legally used by bicyclists, but are less than 12 feet. *ADT* relates to average daily motor vehicle traffic.

Urban Section Guidelines

ADT (2 lane)		< 500	500–1,000	1,000–2,000	2,000–5,000	5,000–10,000	>10,000
ADT (4 lane)		N/A	N/A	2,000–4,000	4,000–10,000	10,000–20,000	>20,000
Posted Speed	≤ 30 mph	Shared lane	Wide curb line	Wide curb lane	Bike lane	Bike lane	Bike lane
	30 mph	Shared lane	Wide curb lane	Bike lane	Bike lane	Bike lane	Bike lane
	35–40 mph	Wide curb lane	Bike lane	Bike lane	Bike lane	Bike lane	Bike lane
	> 40 mph	Bike lane	Bike lane	Bike lane	Bike lane	Bike lane	Bike lane

Rural Section Guidelines

ADT/Lane		< 1000*	1,000–2,500	2,500–5,000	5,000–10,000	>10,000
Posted Speed	≤ 30 mph	4' paved shoulder	4' paved shoulder	4' paved shoulder	4' paved shoulder	6' paved shoulder
	30–35 mph	4' paved shoulder	6' paved shoulder	6' paved shoulder	6' paved shoulder	8' paved shoulder
	35–45 mph	6' paved shoulder	6' paved shoulder	6' paved shoulder	8' paved shoulder	10' paved shoulder
	> 45 mph	6' paved shoulder	6' paved shoulder	8' paved shoulder	10' paved shoulder	10' paved shoulder

* Shoulders are not necessary when the ADT is less than 500, unless the roadway is heavily used by truck or heavy commercial vehicles. In these situations, bicyclists should be accommodated with a shared lane.

Winter-Use Trails

The winter-use trails category encompasses a number of trail classifications, including cross-country skiing, snowmobiling, snowshoeing, winter hiking, dogsledding, and skijoring.

Finding detailed design information!

Refer to Section 7 – Winter-Use Trails for technical design information for this type of trail.

Cross-Country Ski Trails

Cross-country ski trails are typically ski-only trails. These trails attract traditional (classic), skate, and back country skiers, each requiring specialized trail grooming. The following profile defines preferences and motivations of trail users using cross-country ski trails.

Cross-Country Skier Profiles

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of cross-country skiers, which greatly influence trail design.

Type	Preference Profile
Recreational/ Family Skier	**Trail Use Pattern:** • Seeks out and travels to designated, groomed trails • Often skis as a family unit, but couples and individual skiers are also common • Prefers looped configurations with varying conditions, especially easier trails since many do not ski often **Recreation Setting Preferences:** • Prefers larger natural settings • Attracted to convenience and diverse activity opportunities in the area to accommodate all family members • Strong preference for well-groomed trails offering a mixture of difficulty and length, with places for children to practice • Generally does not want all skate skiing or too many fast skiers on the trails • Prefers a combination of traditional/classic and skate-ski styles to accommodate varying skills and preferences, even within one family • Prefers that skate skiers and traditional/classic skiers be on different trails (not side by side) at least once in a while in order to have their own space • Drinking water at trailheads is important, as are restrooms and warming areas **Motivation/Activity Style Elements:** • Family outing in the winter and socializing are strong desires • Large percentage seek escape from motorized activity and value nature • Not dependent on technically challenging trails given wide ranging skill levels • May do multiday trips and stay at local lodging or resorts
Fitness Skier	**Trail Use Pattern:** • May go daily or several times per week; many are routine users of local trails • Primarily skis on local trails in a park or on a golf course that offers trails that are long and challenging enough for a good workout **Recreation Setting Preferences:** • Needs trail of varying difficulty and length, with looped systems preferred for training • Well-groomed trails are a must and a significant factor in trail selection • Prefers a natural setting, but having ample trail distance is most important • Prefers a combination of traditional/classic and skate ski styles to accommodate varying skills and preference; many participate in both kinds of skiing • Needs and highly supports lighted trails to enable training in the evening during the work week • Drinking water at trailheads is important, as are restrooms and warming areas **Motivation/Activity Style Elements:** • Use skiing as a means for exercise and maintaining good health • Generally highly skilled, capable of taking on a various levels of trail difficulty • Skis alone or in groups • Not primarily motivated by experiencing nature, solitude, or socialization, but enjoys these if the trails are in long enough and well groomed

Cross-Country Skier Profiles (continued)

Type — **Preference Profile**

Racer/Event Skier

Trail Use Pattern:
- Uses trails as part of an organized event or competition
- Often falls into the fitness skier category on a day-to-day basis and commonly trains on local trails

Recreation Setting Preferences:
- Prefers hilly terrain for good skiing and avoiding boredom during longer events
- Needs support facilities for rest, staging, and comfort
- Needs same trail facilities as fitness skiers for training, including lighted trails
- 10–20 km loops are good for events, as are long linear courses of up to 51 km

Motivation/Activity Style Elements:
- Not as interested as recreational skiers in natural settings
- Generally highly skilled
- Participates in organized events, either competitive or noncompetitive
- Values exercise and competition and strongly identifies with the sport
- May train throughout the year using roller-ski, running, or bicycling

Backcountry Skier

Trail Use Pattern:
- Prefers natural areas with extensive opportunity for skiing
- Groomed trails are not needed
- May winter camp as part of an outing

Recreation Setting Preferences:
- Beginners require marked trails with maps and some level of basic maintenance
- Traditional/classic style is predominant
- Prefers looped system, but linear is acceptable if shuttle service is available
- Length of trail can be less than 5 miles for a day outing and up to 50 miles for a winter camping trip
- Prefers remote settings free of motorized activity

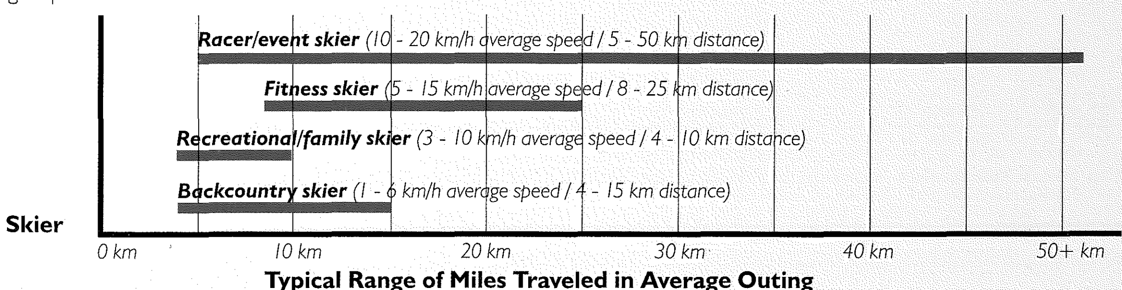
Motivation/Activity Style Elements:
- Commonly desires solitude
- Often will combine skiing with snowshoeing
- Skis alone or in groups
- Not primarily motivated by experiencing nature, solitude, or socialization, but enjoys these if the trails are long enough and well groomed

General Travel Speeds and Distances Associated With Cross-Country Skiers

The type of use envisioned for a trail plays a major role in determining the miles necessary to satisfy the needs of the targeted user group(s). The following graphic illustrates the travel speeds and distances associated with various types of skiers.

General Travel Speeds and Distances Associated With Cross-Country Skiers

The average travel speed and distance traveled by skiers depends upon their skill and fitness level, which can vary considerably between groups or even within a group. The following illustrates common travel speeds and distances for the average skier in each group.



Classifications

Cross-country ski trails are most often part of county, regional, and state trail systems. Due to the need for specialized grooming, these trails are less common in local trail systems, especially smaller communities that can be served by county or regional trail systems. All trails fall under a common classification and accommodate traditional (classic) and skate-style skiers on groomed trails. Backcountry skiers typically follow routes with little to no formal grooming.

Traditional and skate-style ski trail configurations come in several forms, as the following photos illustrate.

Traditional (classic) style - one track set/one direction. *This configuration is generally used in a casual park setting and less used county, regional, and state parks. Grooming is limited and trails are often tracked by local users. Total width is 6 to 8 feet.*

Traditional (classic) style - two track set/one or two directions. *This is the most common type of groomed trail in state parks and less frequently used regional or county parks. Such tracks are routinely groomed, especially after a snowfall of a couple inches or more. Total width is 8 to 10 feet.*

Skate style - single width/one direction. *These trail are occasionally used in a county, regional, or state park where use pressures are high and/or where separation of skiing styles is preferred. They also occasionally are used as connector trails from one loop to the next. Total width is 8 to 10 feet.*

Skate style - double width/one or two directions. *This trail type is occasionally used in a county, regional, or state park where use pressures are high and/or where separation of skiing styles is preferred. They are not as common as combination trails due to increased kilometers needed to accommodate separated uses, and the more time needed for grooming. Total width is 14 to 16 feet*

Combination traditional and skate style - one direction. *This is the most common trail configuration in county, regional, and state parks where use levels are high and a diversity of skier types needs to be accommodated. One-directional use helps avoid confusion and conflict and keeps overall tread width narrow. Total width is 12 to 14 feet.*

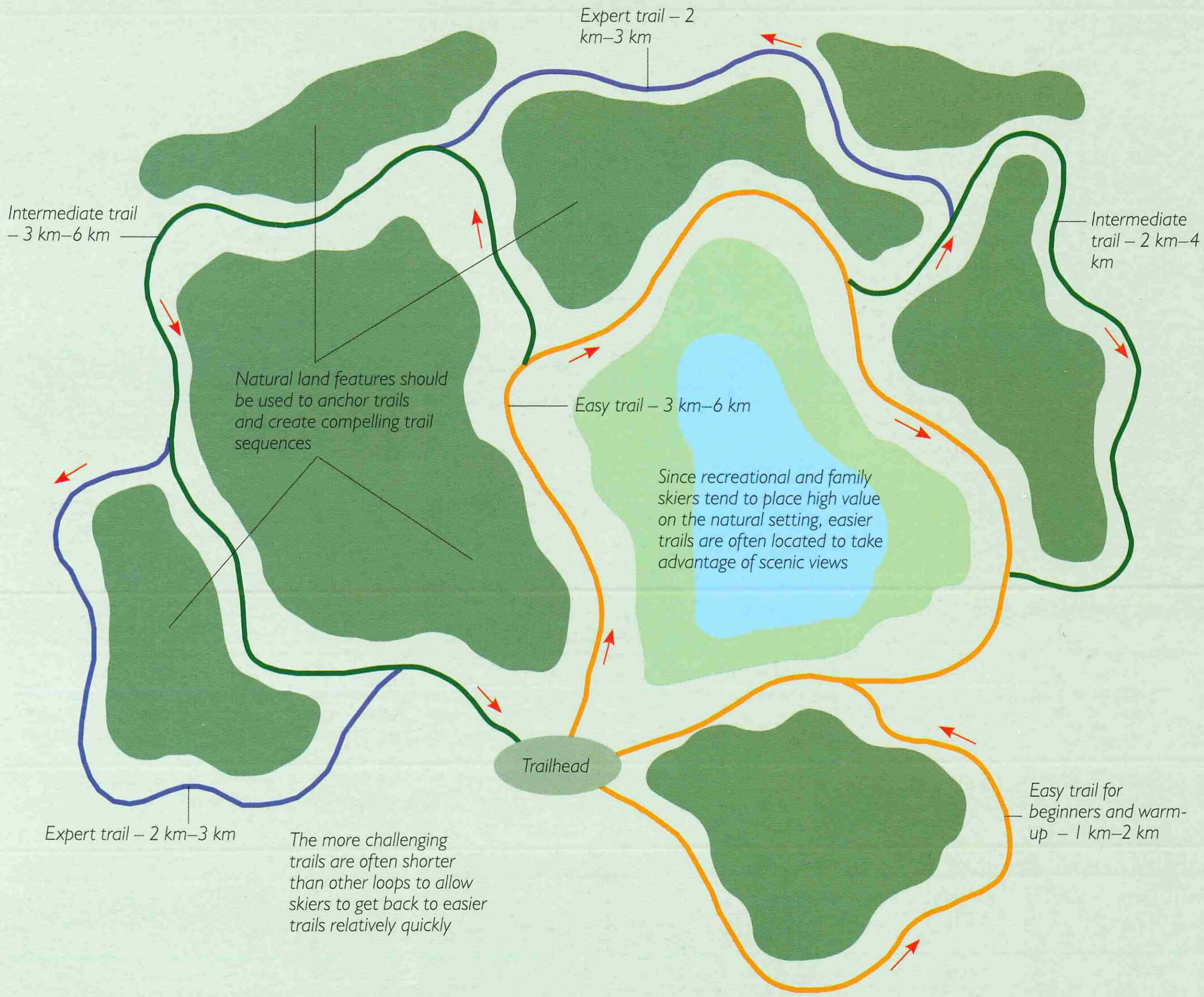
Combination traditional (classic) and skate style - two direction. *These are generally used as a linear connector between loops or at trailheads where two-direction use is needed. Otherwise, they are not commonly used due to width requirements and the fact that most skiers prefer one direction on busy trails so they encounter fewer skiers. Total width is 16 to 20 feet.*

Ski Trail Configurations

The layout of ski trails has much in common with many natural surface summer use trails, although with more emphasis on providing a balance of uphills, downhills, and undulating or rolling terrain. Where feasible, a looped trail system in most park settings is the most desirable and common approach to trail layout, as illustrated in the following graphic.

Looped Ski Trail Layout Configuration

Looped cross-county ski trails should provide a variety of terrain consistent with the difficulty level. As a general rule, one-third of a given trail should be uphill, one-third should be downhill, and one-third should be undulating or rolling grade. The height and steepness of uphills and downhills should be consistent with the trail difficulty rating (on the following page). The following illustration highlights features of a typical looped ski trail in a regional or state park setting.



Trail directional note: Most combination traditional and skate-style ski trails are one direction from the trailhead to reduce the potential for user conflict and keep the trail narrow. This approach is very common in regional parks that cater to skiers. In state parks, where traditional ski trails are more common and use levels often lower, two-way, two-track traditional set is commonly used.

Loop note: The typical system consists of a stacked loop of trails, with the core trail being relatively easy and outer loops increasingly more challenging. The easy trails tend to be longer than the more challenging simply because they take less skill and stamina to complete, with advanced skiers being able to cover considerably more ground than beginners or recreational skiers.

In addition to looped systems, linear or point-to-point cross-country ski trails are used for events. Linear systems are also becoming more commonly associated with greenways or trail corridors that traverse through urban and suburban areas. The following graphic highlights a couple of examples of linear trail layouts.

Linear Ski Trail Layout Configuration

Major event venues often use linear layouts. Linear or point-to-point ski trail layouts following greenways and trail corridors are also getting more consideration in urban and suburban areas where skiing is popular. The major advantage to this approach is convenience, where nearby trail users can ski almost from home. The following illustrates these types of layouts.

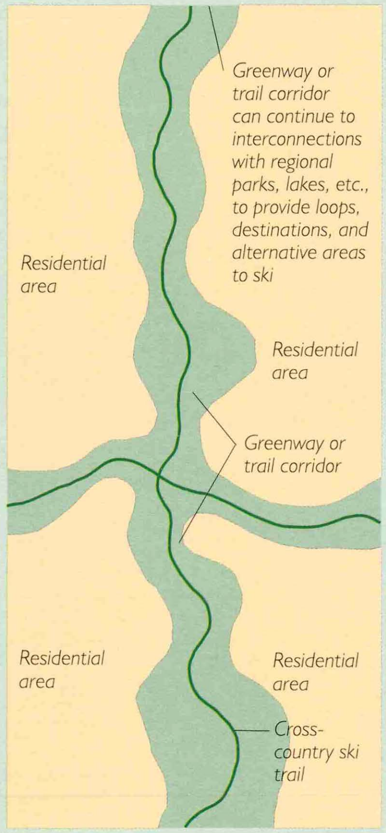
City of Lakes Loppet Course

The City of Lakes Loppet is a popular venue in Minneapolis, with races up to 35 kilometers. It weaves through the city, taking advantage of greenways, lakes, and even streets.

American Birkebeiner Course

The American Birkebeiner is a classic mid western race held in Wisconsin each year, with races up to 51 kilometers.

Linear Greenway Ski Trail



The growing greenway and linear trail systems in urban and suburban areas provide new opportunities for close-to-home cross-country skiing.

Difficulty Ratings

The following table defines the level of difficulty categories associated with cross-country ski trails.

Cross-Country Ski Trail Difficulty Rating

The table establishes general guidelines for difficulty ratings associated with cross-country ski trails.

Aspect	Easy	Intermediate	Expert/Advanced
Length	2 km–5 km	5 km–15 km	5 km–30 km
Avg. trail grade	4%–10%	6%–12%	> 12% (most challenging loops)
Max. hill grade	10%–12%	12%–18%	> 18%, with 40% max. practical
Character of trail	Wide trails with ample run-out on hills, nice rolling terrain with easy grade changes	Introduction of steeper, longer, and more frequent hill climbs, but with ample rolling grade in between; wide trails with ample run-out on hills still important; steepest hills are relatively short; intermediate trails should be combined with easy trails to provide skier with diversity and opportunity to work on various skills and endurance	More frequent, steeper, and longer hills with less recovery time in between; run-out area on hills is more constricted, but still safe for skill level; expert trails should be combined with intermediate and easy trails to provide skier with diversity and opportunity to work on various skills and endurance; upper-end hill grades should be shorter than 40 meters.

Finding detailed design information!

Refer to Section 7 – Winter-Use Trails for technical design information for this type of trail.

SNOWMOBILE TRAILS

Snowmobile trails are typically single-use trails and are the most extensive system of groomed trails in Minnesota. The following profiles defines the preferences and motivations of snowmobilers.

SNOWMOBILE RIDER PROFILES

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences specific to snowmobilers.

Type of Rider	Preference Profile
Recreational Trail Rider/ Touring Snowmobiler	**Trail Use Pattern:** • Heavy user of formal snowmobile trail system and is highly dependent on maps and signage • Commonly rides from a meeting place and explores trail systems on day or overnight trips • Most often stays on established trail system, often not familiar with local areas • Will use ditches on occasion, primarily to get to services from an established trail • Will routinely research routes well in advance, and check snow conditions before traveling to a trail **Recreation Setting Preferences:** • Grooming and snow quality is of primary importance • Needs access to rest stops and local services, lodging, restaurants, and businesses, preferably directly from the trail • Natural setting is desirable, with looped configurations preferred • Variety of trail character is important **Motivation/Activity Style Elements:** • Motivation is to operate machines, escape, see new places, view scenery, and socialize • Interest in speed is highly variable within group • Frequently travels in groups of 5 to 10 riders • Will travel long distances to find good snow, even for a day's worth of riding
Local Snowmobiler	**Trail Use Pattern:** • Starts and ends trips at home each day • Not dependent on trails and knows and rides ditches and local club trails to get to local destinations • Will ride frequently if conditions are good **Recreation Setting Preferences:** • Route choice is based on what is immediately available and where rider wants to go **Motivation/Activity Style Elements:** • Seldom ventures out overnight and typically rides alone or in small local groups • May ride for short outing on spontaneous basis • May use snowmobile to get places, such as restaurants or bars for socializing • High percentage are teenagers and young adults
Local Access/ Utilitarian Rider	**Trail Use Pattern:** • Uses snowmobiles to travel to work, run errands, fish, trap, hunt, get to cabin, gain access to private property, and visit neighbors • Will use trails only if convenient and direct to where rider wants to go **Recreation Setting Preferences:** • Will use trails, ditches, lakes, etc., often seeking most direct route • Will use trails instead of ditches if they are more pleasant and not too far out of the way **Motivation/Activity Style Elements:** • Not very dependent on trail quality, information, or signing and tend to know the way around • Overall utilitarian use is diminishing due to fewer people trapping and winter fishing
Excitement Seeker/ Careless Rider	In each of the above segments, excitement seekers and careless riders may be source of behavior problems, creating safety concerns and presenting a bad public image for this type of activity. This is as a major concern of many responsible snowmobile riders.

Average Snowmobile Trail User Outing

The average outing (time spent riding) for snowmobilers varies with the type of rider. On dedicated, well-groomed trails, 100 to 150 miles for a day outing is common, with 180 miles being the upper end. The average speed of a snowmobiler is 20 mph to 30 mph, with some comfortable traveling 50 mph if trail conditions allow.

Classifications

Snowmobile trails fall under a common classification. In most cases, snowmobile trails are two-way with a minimum width of 10 feet. A width of 12 to 14 feet is optimal for most trails to allow for ease of passing oncoming traffic, but wider is not always desirable since it requires more grooming and takes away from the setting and experience of being close to nature. Occasionally, a wider trail is provided where traffic is especially heavy, such as near a trailhead for a one-quarter to one-hallf mile. The following photos illustrate common characteristics of the type of snowmobile trails in Minnesota.

Two-way, groomed track from 10 to 14 feet wide is very common in Minnesota. *Extensively maintained by a wide network of snowmobile clubs (as part of a statewide grant program), the snowmobile trails in Minnesota have long been regarded as some of the finest in the country. The photos illustrate the character of trails common in the state.*

A variety of terrain is sought when snowmobile clubs establish their routes. *As with cross-country ski trails, a rolling grade makes trails more interesting. Variety also helps keep speeds lower and trails safer since riders need to pay more attention to other traffic on the trails.*

Grant programs are extensively used to build the trail infrastructure. *Given the miles of trails within any given system, bridges and other structures are fairly common. In many cases, the bridges are also used in the summer for other activities.*

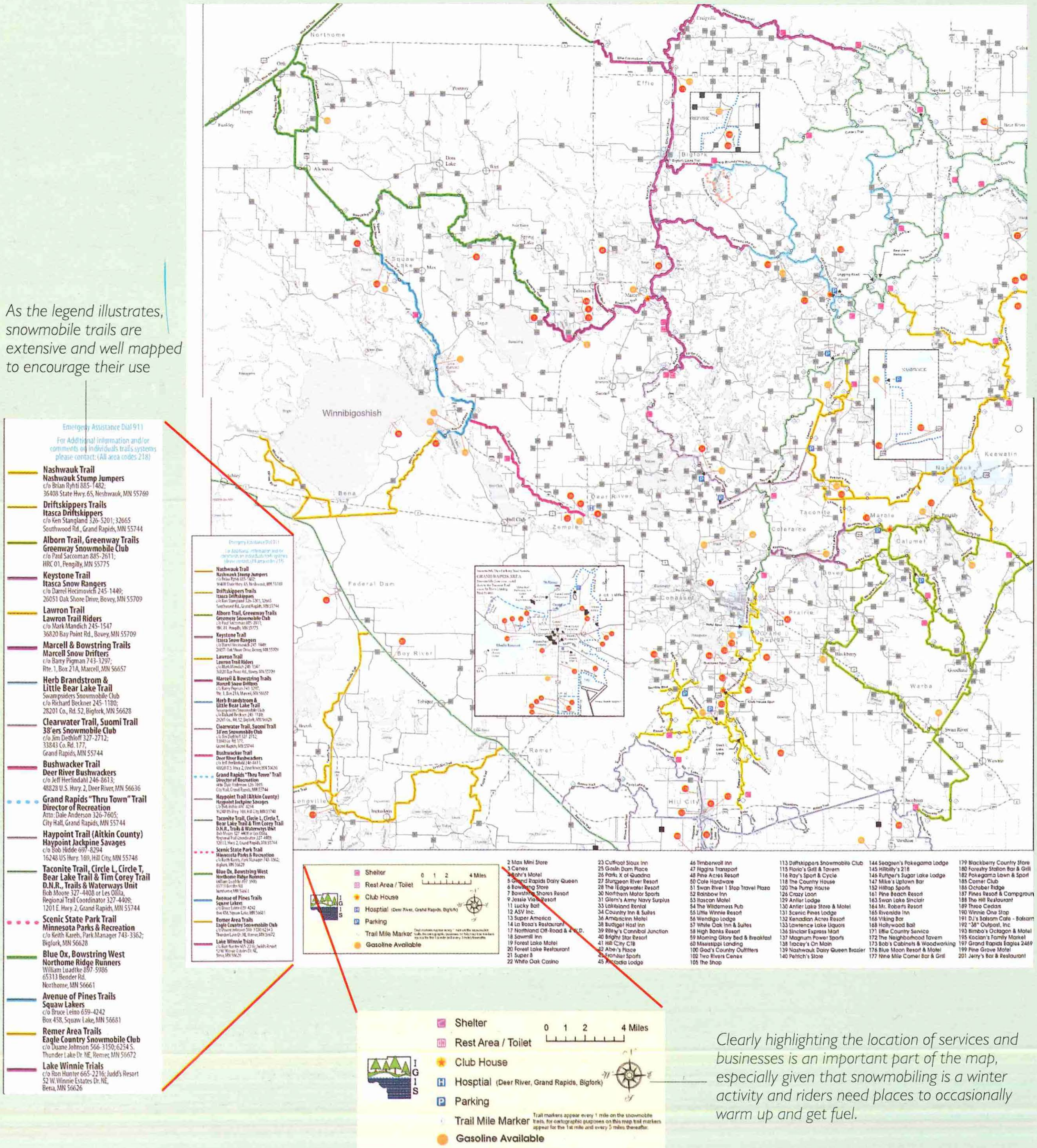
Trail corridors are sometimes pragmatically laid out. *Snowmobile clubs routinely rely upon a variety of public lands, public rights-of-way, and easements across private property to complete the trail network. The public/private partnership approach to securing trail corridors is critical to the continued success of the system.*

Snowmobile Trail Network

The snowmobile trail network in Minnesota is extensive and well established but not static. It evolves over time in response to changes in property ownership and easement rights and new trail opportunities fostered by local snowmobile clubs. In partnership with the DNR and local units of government, local clubs have been very successful in maintaining an extensive and wide-ranging network of trails that are used by Minnesotans and out-of-state tourists alike. As an example, the following graphic illustrates a snowmobile route map for the Grand Rapids area.

Snowmobile Trail Route Mapping

Virtually all of the snowmobile trails in the state that have received state aid to develop and maintain trails have been mapped. The maps typically include route information and identify services that may be useful to the user. This particular map is for the Grand Rapids area. The maps are further augmented by trail and information signs and markings.



As the legend illustrates, snowmobile trails are extensive and well mapped to encourage their use

Clearly highlighting the location of services and businesses is an important part of the map, especially given that snowmobiling is a winter activity and riders need places to occasionally warm up and get fuel.

Finding detailed design information!

Refer to Section 7 – Winter-Use Trails for technical design information for these trails.

Snowshoeing, Winter Hiking, Dogsledding, and Skijoring Trails

These activities are covered under one broad classification due to their relative similarities and more limited participation levels relative to other winter activities. The following profile defines the preferences and motivations of the listed type of trail users.

Snowshoer, Winter Hiker, Dogsledder, and Skijorer Profiles

The following profiles were compiled from various sources, particularly the *Profiles of Trail User Populations – Minnesota Border to Border Trail Study* (DNR) to highlight the preferences of these user groups.

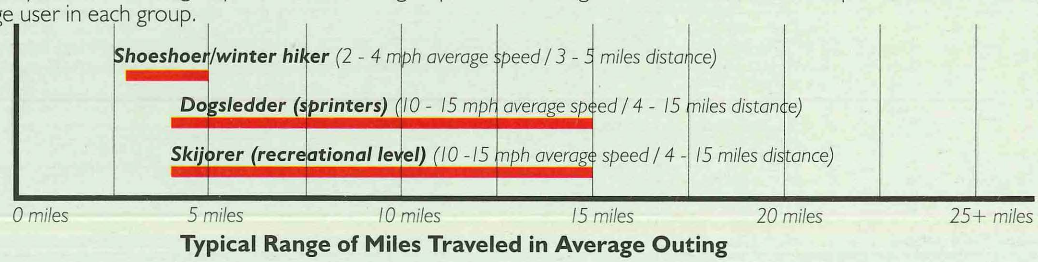
Type	Preference Profile
Snowshoer	**Trail Use Pattern:** • Uses trails that are either groomed or ungroomed, depending on personal preference and type of showshoe • Frequently leaves the established trail • May walk along groomed ski trails **Recreation Setting Preferences:** • Needs unplowed, ungroomed surfaces, although some prefer to follow a groomed trail • Prefers natural areas • Snowshoers interested in exercise seek a trail with hills and adequate length **Motivation/Activity Style Elements:** • Growing sport, attracting people who may not want to ski but still like getting outdoors in winter • Wide variation exists in skill and desired difficulty levels • Becoming a primary form of exercise for some people to maintain or improve health • Participants tend to go alone or in small groups
Winter Hiker	No profile was provided in the border to border trail study, but winter hikers have the same general characteristics as the destination hiker for summer use natural trails, only they tend to go shorter distances due to winter conditions. They prefer either groomed (packed) or plowed trails for ease of walking.
Dogsledder	No profile was provided in the border to border trail study. Participants tend to fall into one of four groups: sprinters, mid-distance, long-distance, or wilderness mushers. Dogsledding remains a relatively small but stable activity. Except for wilderness mushers, each group prefers a groomed trail similar to that of a cross-country ski skating or snowmobile trail.
Skijorer	No profile was provided in the border to border trail study. Skijorers tend to fall into one of three groups: recreational, sprint racing, and distance racing. Recreational skijorers are the largest segment and have an emphasis on fun, fitness, and camaraderie between dog and owner. Sprint racers can average speeds of 20 mph over a 5 mile sprint course. Distance racers generally travel 20 miles or more. Each group prefers a groomed trail similar to that of a cross-country ski skating or combination trail.

General Travel Speeds and Distances

The type of use envisioned for a trail plays a major role in determining the miles necessary to satisfy the needs of the targeted user group(s). The following graphic illustrates the travel speeds and distances associated with the listed winter trail users.

General Travel Speeds and Distances Associated With Various Winter Trail Users

The average travel speed and distance traveled by various winter trail users depends upon their skill and fitness level, which can vary considerably between each group or even within a group. The following illustrates common travel speeds and distances for the average user in each group.



DIFFICULTY RATINGS

Snowshoeing, winter hiking, dogsledding, and skijoring trails generally use the same difficulty ratings used for cross-country ski trails. The following table defines the level of difficulty categories.

SNOWSHOER, WINTER HIKER, DOGSLEDDER, AND SKIJORER TRAIL DIFFICULTY RATING

The table establishes general guidelines for difficulty ratings associated with these trails. Note that easy and intermediate trails are the most commonly provided trails, with expert/advanced only provided when a specific need is clearly defined.

Aspect	Easy	Intermediate	Expert/Advanced
Length	1.5–3 miles	3–10 miles	3– 20 miles
Avg. trail grade	4–10%	6–12%	> 12% (most challenging loops)
Max. hill grade	10–12%	12–18%	> 18%, with 40% max. practical
Character of trail	Wide trails with ample run-out on hills, nice rolling terrain with easy grade changes	Introduction of steeper, longer, and more frequent hill climbs, but with ample rolling grade in between; wide trails with ample run-out on hills still important; steepest hills are relatively short; intermediate trails should be combined with easy trails to provide user with diversity and opportunity to work on various skills and endurance	More frequent, steeper, and longer hills with less recovery time in between; run-out area on hills is more constricted, but still safe for skill level; expert trails should be combined with intermediate and easy trails to provide user with diversity and opportunity to work on various skills and endurance; upper end hill grades should be shorter than 50 yards

TRAIL CONFIGURATIONS

The layouts for snowshoeing, winter hiking, dogsledding, and skijoring trails are generally consistent with those defined for cross-country skiing trails. Where feasible, a looped trail system in most park settings is the most desirable and common approach to trail layout.

Given the limited demand, it is common for some of these uses to be accommodated on the same trail. This is especially the case with hiking and snowshoeing. If the snow is deep, snowshoers tend to frequent the trail the most, with hikers using the trails most often when snow depths are less than a foot on unpacked trails. If trails are groomed, hikers will tend to use them once the base hardens. Snowshoers will also use groomed trails, as well as go cross country.

If snowshoers are allowed to go cross-country, access is typically limited to a specific area. Designated but ungroomed routes are also becoming more common for snowshoers. In some cases, these follow existing summer trail corridors. In others, relocatable trail blazes are provided to define a route, which keeps users in an acceptable area and reduces the likelihood of getting lost. To keep it interesting, the blazes are relocated from time to time during a season.

When overall use is low, skijorers can be accommodated on the same groomed trail as snowshoers and hikers. Dogsledders are almost always accommodated on a designated or a time-slotted trail.

Time Slotting

In some situations there is adequate demand to make provisions for accommodating dogsledding or skijoring on a more routine basis, but not enough to justify a designated trail. In these instances, time slotting is a common approach, whereby a given time slot on a cross-country ski or snowmobile trail is set aside for dogsledding, skijoring, or both. This approach seems to have gained some popularity because it allows park districts to accommodate these activities without creating specialized trails or substantially increasing grooming costs.

Section 7 - Winter-Use Trails provides additional information on trail widths for each of these uses.

SECTION 5 - SHARED-USE PAVED TRAILS

NATURAL SURFACED TRAILS

SECTION 5

Shared-Use Paved Trails

A Minnesota classic. *The Gateway Trail in Washington County sets the contemporary standard for high-value recreational trails. It also illustrates how trail standards continue to evolve, with the two-way, 8-foot-wide sections proving to be too narrow to accommodate the heavy use patterns and increasingly diverse types of users.*

Overview

Shared-use paved trails serve a variety of user groups, including pedestrians (walkers and joggers), in-line skaters, and bicyclists. With hard surfacing, these trails provide a high level of accessibility to users of all abilities. This section considers the general and technical planning and design guidelines for shared-use trails.

Shared-Use Paved Trail Classifications

As defined in Section 4 – Trail Classifications and General Characteristics, shared-use paved trails function at a number of service levels within local, county, regional, and state trail systems. There are five trail classifications of multiuse paved trails:

- Neighborhood Trail
- City Trail
- County Trail
- Regional Trail
- State Trail

The major distinction between these classifications and service levels includes location, types of users being accommodated, levels of use, character, width, and length. As trails serve more people and traverse larger geographical areas, the level of service tends to go up, as do some of the development standards (most notably trail width).

Critical to the development of trails at all levels is maximizing their public value, whether they are following an urban trail corridor or traversing a greenway in a suburban community or the rural countryside. As described in Section 4 – Trail Classifications and General Characteristics, public values include safety, convenience, recreation, fitness, and transportation/commuting. This is an important factor in planning and designing trail systems and should not be overlooked or taken lightly.

General Design Guidelines

The following guidelines provide general design parameters for shared-use paved trails at various service levels. Note that the guidelines are not intended to be a substitute for site-specific design and engineering that responds to local conditions, development requirements, and safety concerns.

TRAIL WIDTHS AND CONFIGURATIONS

Trail widths and configurations vary for each of the listed trail classifications. Even within a given classification, site-specific circumstances often require alternative configurations to accommodate the anticipated types and levels of use. The following provides guidelines for determining the appropriate width and configuration for a given situation.

BASIC PHYSICAL INTERRELATIONSHIPS BETWEEN TRAIL USERS

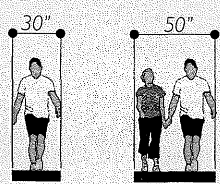
The physical space required for different trail users provides a base-line for determining the optimal width for a given trail. Trail widths increase in line with use levels and the diversity of users being accommodated. The following graphic illustrates the relationships between trail users and trail width.

RELATIONSHIP BETWEEN TRAIL USERS AND TRAIL WIDTHS ON MULTIPURPOSE PAVED TRAILS

BASIC TRAIL USER SPACE REQUIREMENTS

The typical space requirements for common trail uses are shown below. The dimensions denote operating space, which includes the physical space needed for basic maneuvering.

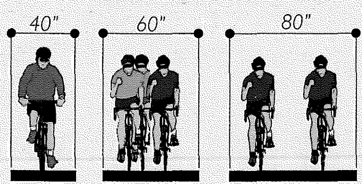
Typical Pedestrian (Walker/Jogger)



Walkers either walk alone or side by side. Typically, they do not have to markedly change position on paths 10 feet or wider when approaching opposing walkers.

Single walker *Side-by-side walkers*

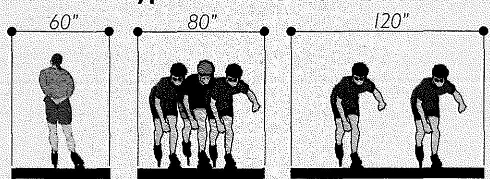
Typical Bicyclist



Single bicyclist *Staggered bicyclists* *Side-by side bicyclists*

Bicyclists ride alone or side by side. It is also very common for bicyclists to ride in a staggered pattern to take up less space and be ready to maneuver for oncoming traffic.

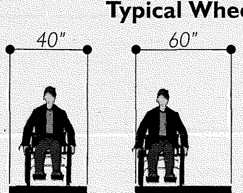
Typical In-line Skater



Single skater *Staggered skaters* *Side-by side skaters*

In-line skaters skate alone or side by side. It is also very common for skaters to use a staggered pattern to take up less space, draft, and be ready to maneuver for oncoming traffic. Note that dimensions are at full stride, with a "passing stride" being closer to 36" when approaching oncoming traffic.

Typical Wheelchair User



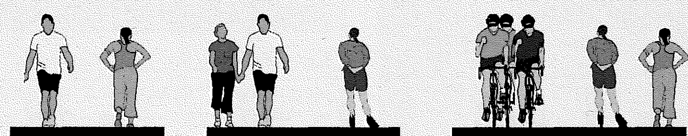
In addition to suitable grades, the most critical aspect for wheelchairs is having enough maneuvering spaces on the trail and landings at road crossings and curb cuts.

Single wheelchair *Maneuvering room*

TRAIL WIDTHS REQUIRED TO ACCOMMODATE VARIOUS COMBINATIONS OF TRAIL USERS

Trail widths should be based on the public values offered and a clear understanding of the type of users that will be drawn to it and accommodated. For example, if the setting is scenic, location convenient, and/or length is suitable for elite users, the trail will likely attract many types of users with various skill levels. The trail's width *must* be based on these realities if the trail is to be successful. Doing otherwise could lead to higher levels of conflict, an increased propensity for accidents, and general visitor dissatisfaction – none of which is a desirable end.

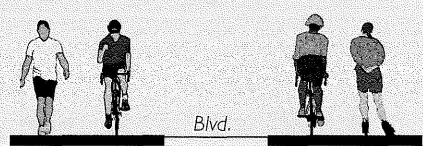
Typical Two-Directional Trails at Various Widths



8-foot trail *10-foot trail* *12-foot trail*

As trails widen, people begin to use them differently. Understandably, the most successful trails are those that accommodate the patterns of use people are inclined toward. At a neighborhood level, a "strolling width" is appropriate. On a major trail, the expectations of more specialized users and higher volumes of use should rightfully be accommodated.

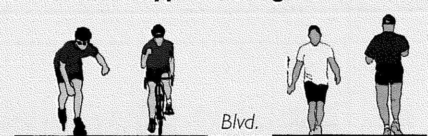
Typical Shared-use Separated Trails



8- to 10-foot trail *8- to 10-foot trail*

The first level of separated directional trails has shared uses going in a common direction, as illustrated. This is most common in wide-open areas with moderately heavy use patterns.

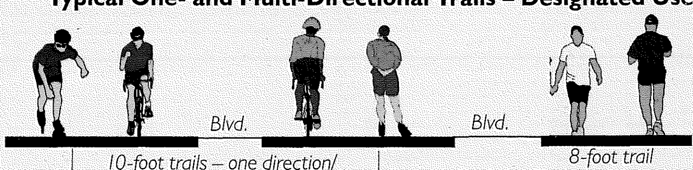
Typical Designated Use and Direction Trails



10-foot trail – one direction (bicyclist and inline skaters) *8-foot trail – two direction (pedestrians)*

The second level of directional trails separates bicyclists and in-line skaters from walkers and joggers. Bicyclists and in-line skaters are limited to one direction. This is most common around an urban recreational lake or loop within a popular park where users can return to their starting point.

Typical One- and Multi-Directional Trails – Designated Use



10-foot trails – one direction/ (bicyclist and in-line skaters) *8-foot trail (pedestrians)*

The third level of directional trails continues to separate bicyclists and in-line skaters from walkers and joggers. Bicyclists and in-line skaters are separated but can go both directions. This is typically used to create a bicycle "freeway" in major urban areas where use levels are high and space is less limited.

TRAIL WIDTHS RELATIVE TO CLASSIFICATIONS

Trail widths are one of the distinguishing features between trail classifications, as the guidelines on this page highlight.

However, Section 4 – Trail Classifications and General Characteristics considers other factors that distinguish one trail class from another, including the size of the service area, the length of the trail, and the context relative to local, county, regional, and state trail plans.

TRAIL WIDTHS ASSOCIATED WITH MULTIUSE PAVED TRAIL CLASSIFICATIONS

Anticipated levels of use *and* the relationship between trail users (as illustrated on the previous page) are the primary factors used for determining the optimal width of a trail in a given situation. These factors were used as the basis for the width guidelines for each of the paved trail classifications, as the following considers.

Neighborhood Trails

These trails generally receive relatively low volume and function to link a residential area to the larger citywide trail system. An 8-foot minimum width with two-way traffic is the typical standard, although a 10-foot width is used where a higher level of use is expected, such as a mixed-use development area with high population densities. One-way directional and/or separated use trails are not commonly used at the neighborhood trail level. Center striping is not typically provided on this level of trail.

*This is a typical **neighborhood trail** integrated into a residential development.*

City Trails/County Trails

The volume of use on these trails can vary considerably depending on location and the population being served. A 10-foot minimum width for all major trails is recommended for all cross-city or countywide trails that form the backbone of the local trail system. An 8-foot minimum width for secondary or lower volume trails or within local or county parks is acceptable when use volumes are lower. 12-foot widths are only recommended for core areas in an urban setting or within a destination park with high use levels. Two-way traffic on all but the busiest trails is typical, but one-way and/or separated trails are common in very popular park settings, such as around a local lake. Center striping is more common, but not mandatory.

*This is a typical **city** or **county trail** through an established greenway corridor. A 10-foot width is optimal on most trails, but 12-foot widths are also used in very heavy use areas.*

Regional Trails/State Trails

These trails are 10 feet minimum in width irrespective of use levels, with a 12-foot width being an option for major trails in high use areas. Two-way traffic is the general standard for most trails, although higher-use trails in metropolitan areas may require one-way directional and/or separated trails. An 8-foot minimum width is occasionally used for looped trails within smaller or less frequented regional or state parks, but 10 feet is generally preferred for most situations for new trails.

*This is a typical **regional** or **state trail** through an established rails-to-trails greenway corridor. A 10-foot width is the minimum recommended.*

ONE DIRECTIONAL AND SEPARATED TRAILS

As noted above, one directional and/or separated trails are used on occasion for higher use areas at several service levels. On separated trails, walkers and joggers are on one trail, with bicyclists and in-line skaters on another. Directional trails typically relate only to bicyclists and in-line skaters. One directional trails are used to increase capacity, improve safety, and provide a more pleasant visitor experience.

These types of trails have become more common as trail use has increased over the last decade or so. In urban settings, such as around the Chain of Lakes in Minneapolis, separated and directional trails are prevalent due to the high levels of use. They have proven to be very successful in this type of setting.

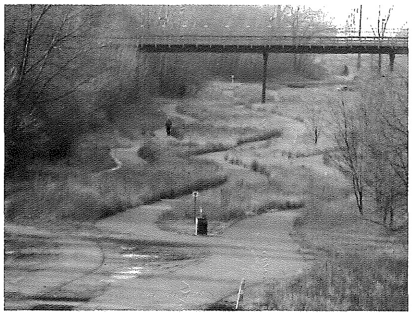
TRAIL CORRIDOR WIDTHS RELATIVE TO CLASSIFICATIONS

Given the vast array of trail settings – from narrow urban retrofits to wide open greenways and parks – no minimum or maximum optimal standard is provided for trail corridor width.

In retrofit situations, the trail corridors can be as narrow as 20 or 30 feet as long as safety is not compromised. In greenways, trail corridor widths should respond to the recommendations defined in Section 3 – Principles of Ecological Sustainability.

As illustrated on page 5.2, separated two-way trails are a minimum of 8 feet wide for walkers and joggers, with 10 feet preferred. A 10-foot width is the minimum for a two-way bicycle and in-line skating trail, and is preferred for one-way traffic as well. A 10-foot minimum green boulevard between trails is preferred, with 20 or 30 feet more optimal. The following photos are examples of separated and directional trails.

Separated and directional trails. *The trail farthest to the left on this photo is for two-way walking and jogging. The trail to the right is a one-way trail for bicycles and in-line skaters. The one-way trail works in this situation because the trail loops around an urban lake. The high use volumes justify the 10-foot width for both trails. The green boulevard between the trails adds to the character of the trails and helps reduce conflicts between users.*



Trail "freeway" *located in a major greenway in Minneapolis, the Cedar Lake Trail is designed for heavy use. It features a separate two-way trail for walkers and joggers (far left) and two separate one-way trails for bicycles and in-line skaters. The walking trail is 8 feet wide with a 10-foot width used for each of the bicycle trails. This combination has proven exceedingly successful in this setting, but may be more than necessary for most applications outside heavily populated areas.*

Shoulder Width (Recovery Zone)

Shoulders provide a recovery area for trail users to avoid conflicts and regain control after slipping off the trail. Ideally, shoulders should be 3 feet wide, with 2 feet being the minimum on each side of trail. No obstructions should be in this zone whenever possible, including signs.

Shoulders can be aggregate or turf and should be free of brush and other woody material or excessively long grasses. Grasses should not overhang the trail to avoid reducing its usable width, which can increase conflicts between trail users and make it frustrating to walk or bike side by side. An 18- to 24-inch mowed strip is common along most trails.

In situations where the trail corridor is reduced or compromised due to retaining walls, fences, or other obstructions, shoulder width may have to be reduced. In these instances, adequate visual cues should be provided to ensure that a trail user recognizes that a change in shoulder width is coming. Where sightlines are adequate, the obstruction itself can be a suitable visual cue. In situations where a blind corner prevents a user from seeing a reduction in the shoulder, a warning sign and pavement marking may be necessary.

In cases where the trail traverses significant sideslopes or other hazards, the shoulder should be widened to increase the margin of safety. In most cases, a minimum shoulder of 5 feet is recommended, but this can vary considerably based on the site-specific circumstances.

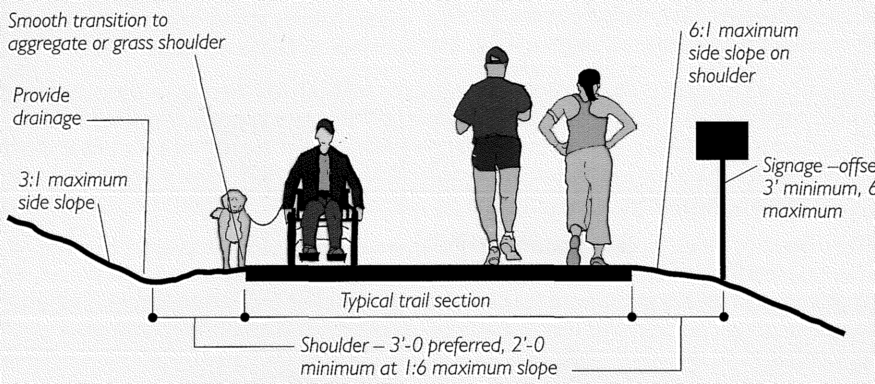
When the separation between a hazardous slope or drop-off is compromised, a physical barrier, such as a handrail or wall, should be used to protect the trail users. The height for a handrail is a minimum of 48 inches for most situations. Examples include a handrail adjacent to a deeper stream edge, over a bridge crossing a small channel, or on the side of a elevated boardwalk. A 54-inch handrail height is recommended in hazardous situations, such as a major bridge suspended well above a river crossing.

When a trail is following along the top of an old rail bed, the area for the trail and a shoulder may be limited and the shoulder will be steeper than would otherwise be desirable. In these situations, the clearance zone adjacent to the trail should be widened to a minimum of 5 feet (6 to 8 feet is preferred where space allows) to provide a bicyclist or other user who slips off the trail more space to recover. The graphic and photos on the next page illustrates some of the key aspects of trail shoulders.

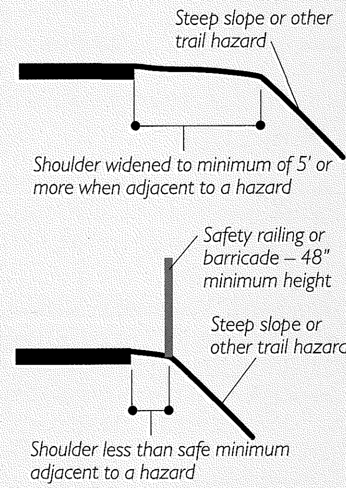
Adequate signage and visual cues alert trail users of the narrowed trail section. Although maintaining a minimum 2-foot shoulder is ideal, that is not always possible in retrofit situations, as is the case with this trail.

Even prairie grasses can be a significant impediment to travel along a trail. The extensive encroachment along this trail effectively narrows it from 10 feet down to 8 feet and is annoying to many bicyclists. Simply mowing a 2-foot strip on each side would vastly improve this situation. Encroaching vegetation also can shorten the life of a trail by getting under the pavement edges.

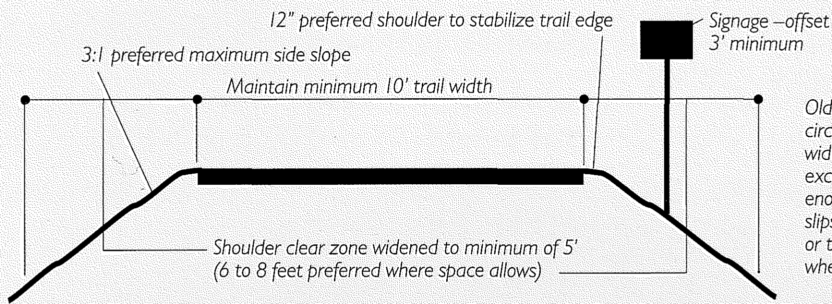
Shoulder Widths and Recovery Zones



Shoulders for a Typical Trail Section



Shoulders Next to Hazards



Shoulders for a Rail Bed With Limited Top Width

Old rail beds with a limited top width pose a unique circumstance often requiring modified shoulder widths. Since the grade adjacent to the trail is in excess of 6:1, a wider shoulder is desired to allow enough space for recovery if a bicyclist or other user slips off the edge of the trail due to lack of attention or to avoid a collision. This approach should be used when it is impractical to widen the top of the rail bed.

Adequate shoulders. *Both of these trails exhibit shoulders that provide a margin of safety for trail users. In the left photo, the trail sign is about 2 feet from the edge of the trail, with heavy brush cut back from the trail edge 4 feet or more. In the right photo, the heavy grass edge is cut back about 18 inches to prevent taller weeds from encroaching onto the trail and narrowing it, which is annoying to most trail users.*

Visual cues. *The neighborhood trail shown in the left photo is shoehorned into a greenway corridor. Although the shoulders are less than generally optimal, it does not pose a significant concern here because the trees are very visible, the trail is very curvilinear, and it is designated for walking and jogging only. On bridge approaches, as shown in the right photo, shoulders are inherently reduced. Adequate sight distances allow trail users to easily see the bridge coming and take precaution, such as slowing down.*

Unique circumstances. *The retaining wall in the left photo is imposing enough to alert trail users. Although hard to notice, the trail was widened by about 2 feet to create more maneuvering space. Also notice that the right shoulder drops off quickly from the top of this old rail bed. This requires a widening of the shoulder zone to give users more space to recover if they slip off the trail. The right photo illustrates a narrow section of a trail corridor that required a retaining wall and barrier fence to keep it safe. This section's visibility from both directions makes it a safe trail segment even with limited shoulders.*

Clearance Zones

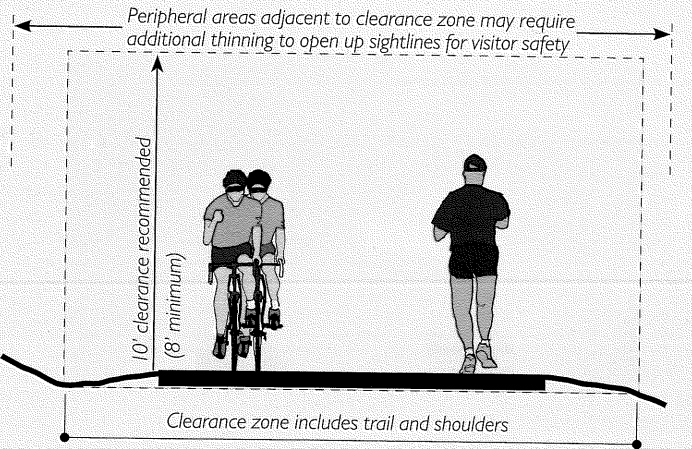
The clearance zone is defined as the physical space that lies above and on either side of the trail and is free from all obstructions. This includes all of the shoulder area.

A 10-foot vertical clear area is recommended throughout the clearance zone, especially where sightlines are obscured on steeper downhill sections approaching a turn. This clear zone is especially important when larger maintenance equipment is used and also to allow emergency vehicles easy passage. An 8-foot-high clear zone is the minimum for a multiuse paved trail.

The clearance zone should increase around corners where sightlines are obscured. The extent to which this should happen is a function of trail type and design speed. On neighborhood level trails, where trail widths are narrower and travel speeds less, the clearance zone can be more modest around a corner and along the trail in general. On regional or state level trails, where trails are wider and travel speeds greater, a more generous clearance zone is often needed and appropriate.

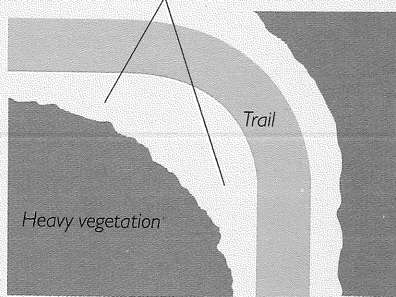
Clearance zones should also increase where personal safety may be of concern. Longer segments of trails through tunnel-like vegetation can be intimidating and may require additional clearing to increase the sense of security for some trail users. This is especially the case with curvilinear trails where the trail user cannot see far enough ahead to feel secure about proceeding. In all cases, site-specific sightlines should be carefully considered and an adequate clearance zone maintained to ensure user safety and security. The following graphic and photos illustrate some of the key aspects of clearance zones.

Clearance Zones

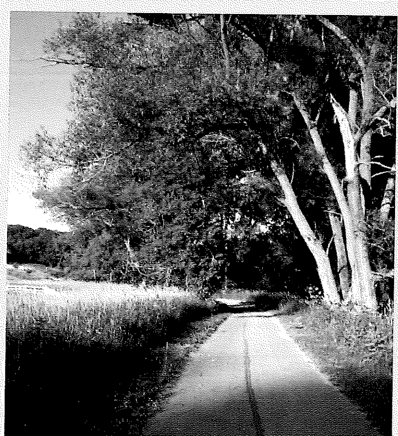


TYPICAL TRAIL CLEARANCE ZONE

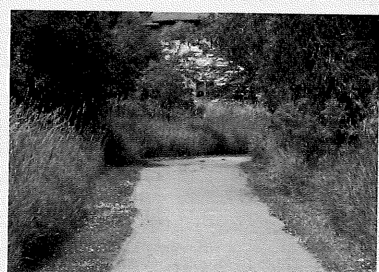
Clearance zones need to be widened around curves and other areas where impaired sightlines can cause a hazard. The best approach is to field test and adjust sightlines at design speeds until safe.



ENLARGED CLEARANCE ZONES



The trees and other vegetation along this trail create a gateway affect while still providing adequate clearance for trail users and maintenance and emergency vehicles.



The top middle photo illustrates a neighborhood trail where the clearance is appropriate for the setting. Note that this trail is adjacent to many homes, so the vegetation is used to screen the trail.

The top right photo illustrates a trail in a wooded state park. With reasonable site distances, this trail remains safe even though vegetation creates a tunnel affect.

The bottom photo illustrates a well-balanced clearance zone that provides for a safe but compelling trail experience.

Design Speeds

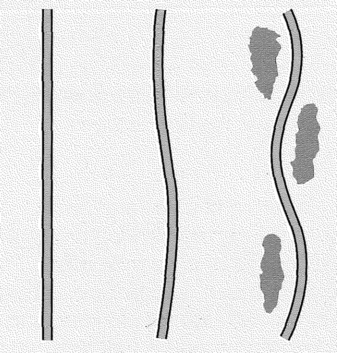
Actual travel speeds on paved trails vary due to trail width, surface material, and trail setting. Trail user expectations also play a role in determining design speeds. At the local level, where a trail often winds through a neighborhood and is only 8 feet wide, an 8 to 15 mph speed is fairly common. Once a neighborhood trail connects to a longer and wider city trail, faster user speeds can be reasonably expected and the design of the trail needs to keep pace. Major city, regional, and state trails typically have design speeds up to around 20 mph, with most bicyclists riding comfortably between 8 and 20 mph (elite recreational riders can maintain speeds of 25 mph or more). Generally, trail design speeds need to take into consideration the setting, width of the trail, gradients, sightlines, and expected levels of use.

Design speeds also need to be higher for longer and steeper downslopes. Trails with a slope of 4 percent or more may require a design speed of up to 30 mph. The same holds true for trails where prevailing winds encourage elite riders to go faster. Notably, designing trails for over 20 mph is the exception rather than the rule. Above this mark, there is a greater propensity for user conflicts since higher speeds encourage riders to go too fast with increased risk of not being able to react to others on the trail. (Many accidents are collisions with other trail users, not users missing a turn because they were going too fast.)

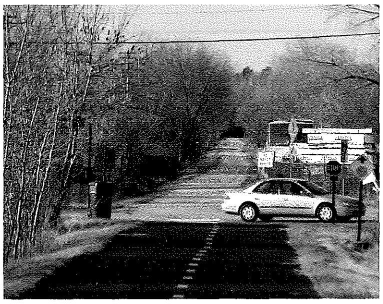
Whenever possible, trails should be designed to provide visual cues that alert users to slow down to a more safe speed. Certain design techniques, such as introducing more curves (even subtle ones) and bringing vegetation closer to the trail, give bicyclists visual cues that tend to slow them down. On the other hand, design speeds cannot easily be artificially lowered. For example, a long, straight rail grade conversion will result in a trail with a higher design speed because there is little to slow riders down, especially with a tail wind or slight downslope. Under these circumstances, the trail should be designed to accommodate the speed at which riders are likely to travel.

Appropriate signage and pavement markings (e.g., painted warnings, striping) should be used wherever field conditions requires the user to slow down below the design speed of the trail. For example, the trails around the Chain of Lakes in Minneapolis limit speeds on bicycle trails to 10 mph, which is appropriate given the potential for conflicts between trail users. The following photos illustrate key aspects of design speeds.

Trail Shape and Speed



Varying travel speeds can be promoted through the use of different design shapes. Notably, many bicyclists seek out trails with higher design speeds for recreation, training, and commuting. Importantly, trail systems need to appropriately accommodate all user groups with trails designed for varying needs.



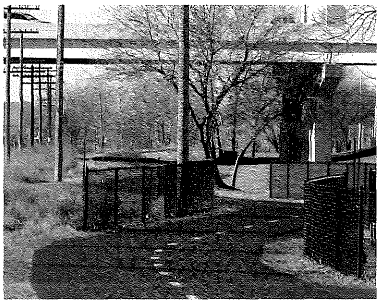
The transition from one surface to another can dramatically change trail speeds. On this trail, travel speeds on the asphalt surface could reach 20 mph. On aggregate, a 12- to 15-mph travel speed is more common.

The visual cues provided by the lake and fishing pier coupled with a curve in the trail (to the left) alert bicyclists and in-line skaters to slow down coming into a busier use area.

A simple curve introduced into a long stretch of trail will often cause travel speeds to go down. It also makes the trail more visually interesting.

The design speed for a neighborhood trail such as this is lower than that for a regional or state trail. Most often, trail users will travel in the 8- to 15-mph range on a bicycle, a more leisurely 2- or 3-mph on foot.

On this regional level trail on a rail grade with long sight lines, a 20 mph travel speed would not be uncommon – faster on downslopes and with a tail wind. Although the trail can accommodate the speed, above 20 mph trail conflicts can become more likely.



Where trail speeds must be kept low for general safety, signage and pavement markings are required – as is enforcement. Although speed limits help curtail speeds, the innate character and design of a trail are the most likely determinants of bicyclist's travel speeds.

Curve Radius Formula

The AASHTO recommended formula for determining curve radii is:

$$R = \frac{0.067\,V^2}{\tan\theta}$$

R = max. radius of curvature (ft)
V = design speed (mph)
θ = Lean angle (degrees*)
* (15% is the recommended maximum)

Applying this formula with a lean angle of 15% (recommended), the desirable minimum radii for multiuse paved trails should be:

- 36' for 12 mph
- 100' for 20 mph
- 156' for 25 mph
- 225' for 30 mph

If the lean angle is increased to 20%, the minimum radii for multiuse paved trails changes as follows:

- 30' for 12 mph
- 90' for 20 mph
- 155' for 25 mph
- 260' for 30 mph

Curve Radius

Curve radii are usually determined for bicyclists, who tend to go the fastest. Radii are functions of design speed, degree of superelevation, lean angle, and surface friction coefficients. In practice, most trail design is based on computed tables that reflect desired minimum guidelines that are consistent with AASHTO and other applicable standards to gain assurance that curves in a trail are reasonable for the design speed.

Generally, most bicyclists lean at about 15 degrees while in the seat. If the lean angle approaches or goes over 20 degrees, the degree of superelevation and the coefficient of friction (i.e., level of friction between the tires and trail surface) come more into play. To accommodate accessibility standards, superelevations on a trail should not exceed 3%. The coefficient of friction is a bit more complex and depends on speed; surface type, roughness, and condition; tire type and condition; and whether the surface is wet or dry.

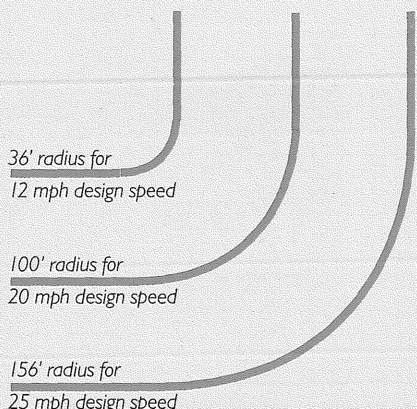
Taking all of this into consideration, the AASHTO *Guide for the Development of Bicycle Facilities* (1999) recommends using the radius formula shown in the left column to determine the minimum radius of curvature. In practice, applying the more conservative of the lean angles ensures that the curvature of a given trail will meet or exceed commonly accepted standards.

In actual field conditions other factors often affect the curvature of a trail and must be accommodated. For example, curve radii smaller than the recommended are often required in retrofit situations due to limited space and rights-of-way or other constrictions. Anytime a curve in a trail requires a change in speed, adequate visual cues should be provided to alert users. In instances where curve radii are substandard and sightlines inadequate for the trail user to realize that a change in speed is needed, curve warning signs and pavement markings should be installed. This could include center striping through tighter curves to alert bicyclists.

Increasing the trail width by a couple of feet through curves with less than the desired radius can also help improve safety.

Curve Radii Comparisons and Illustrations

As the curve radius comparisons illustrate, anticipated bicycle speed greatly affects the selection of an appropriate curve radius. Whenever a curve in a trail is inconsistent with the design and actual travel speeds for the overall trail segment, adequate visual cues are necessary to alert a trail user that a change in speed is coming. This could range from clear sightlines that make the curve highly visible to signage and pavement markings.



Sweeping curve. *This curve has a nice feel to it from a user's perspective. The vegetation on the edge is set back enough to provide reasonable sightlines, yet still encroaches enough to get bicyclists to slow down a bit.*

Curves used to slow down traffic. *As these trails converge into a narrow corridor under a bridge, curves and visual cues were added to slow down bicycle traffic. The long, open sightlines make this approach suitable for this situation.*

Relaxed curves. *When there is adequate space in a trail corridor, curves can be laid out to meet or exceed desirable standards and still fit well into the surrounding landscape. In this case, the curvilinear nature of the trail adds considerably to its character.*

Curve sets up a crossing. *This easily visible curve slows trail users down as they approach a road. The open sightlines ensure that the curve and crossing can be seen in more than adequate time for the trail user to slow down and stop.*

GRADIENTS

Trail gradient is one of the most important factors in designing trails for general family use. For asphalt-surfaced trails, gradients should average less than 5 percent to be considered an accessible trail, with 3 percent the preferred average gradient over longer distances. Gradients of 6 percent are sustainable for moderate distances (800 feet). Beyond 6 percent, grade restrictions become more pronounced, as the following grade/length ratios suggest:

- 7 percent for up to 400 feet
- 8 percent for up to 300 feet
- 9 percent for up to 200 feet
- 10 percent for up to 100 feet

Grading Caution!

Note that increasing the grade of a trail inherently increases concerns about stormwater management, especially controlling erosion due to increased flow rates. Refer to Section 3 for additional information on best practices to prevent erosion.

Grades between 10 and 12 percent are only practical for very short distances (under 100 feet), with most bicyclists having to dismount and walk their bikes up these gradients. Above 12 percent trail grades become impractical.

For aggregate-surfaced trails, grades steeper than 3 percent may not be practical nor recommended for extended distances due to increased potential for erosion and loss of handling.

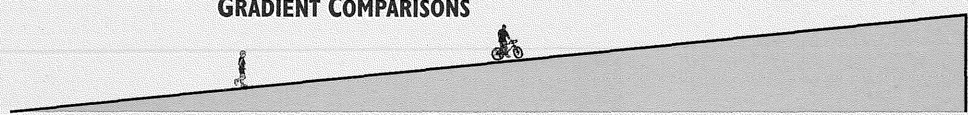
In design application, segments of steeper-than-desirable trail grades may not be avoidable. Options to mitigate excessive grades include:

- Widening the trail by 4 to 6 feet to allow riders to pass walkers
- Providing signage to alert bicyclists of upcoming steeper grades (and possible alternate routes)
- Extending stopping distances and alerting bicyclists of abrupt stops well in advance if they occur at the bottom of a long, steep downhill
- Exceeding minimal clearance zones, recovery areas, etc.

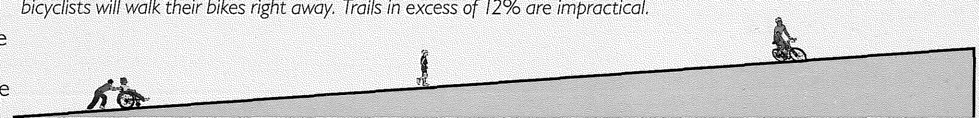
Warning signs are recommended when downhill grades approach 7 percent or more, or where visual sightlines to significant changes in trail grades are obstructed. Also, trail grades around a curve should not exceed 5 percent whenever possible. The following graphic box illustrates key aspects of trail gradients.

GRADIENT COMPARISONS

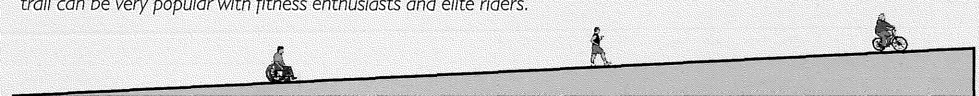
These grade comparisons illustrate the relative difference between grades. Although visually not overwhelming, in reality a percent or two change in gradient will significantly affect people's ability and desire to use a trail. Notably, it is also appropriate to have a balanced system where some trails are purposefully more challenging to appeal to a broader set of users.



At 8%–10% grades, many bicyclists will walk their bikes after a limited distance (100–300' or less). Above 10%, most bicyclists will walk their bikes right away. Trails in excess of 12% are impractical.

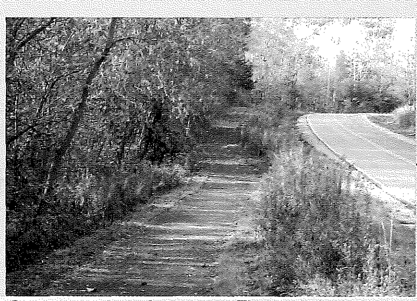


A 6%–7% grade is acceptable for modest distances, but can deter some riders from routinely using the trail. This type of trail can be very popular with fitness enthusiasts and elite riders.



A 5% grade is suitable for long distances for most bicyclists and in-line skaters, with 3% preferred.

Ramp up to old rail grade. *Although this ramp exceeds 5 percent, it is short enough for most people to negotiate. This could have been improved by providing larger landing areas at top and bottom.*



Steep grades alters use. *This trail climbs at up to 10 percent through a ravine. At this grade, bicyclists will often use the adjoining road to go faster on the downhill than the trail would accommodate.*

Winding up the grade. *By traversing up a steeper grade with modest switchbacks and landings, this trail is less imposing (and more fun) than it might otherwise be if the trail climb were more direct.*

Sight Distances

Sight distances along a trail are critical to user safety. Bicyclists and in-line skaters in particular must be able to see far enough ahead to react to something that might be occurring on the trail – whether expected (e.g., a curve in the trail) or unexpected (e.g., someone standing or riding on the wrong side of the trail).

Sight distances down a trail should be adequate for users to come to a complete stop if they are traveling at the design speed of the trail. The distance required to bring a bicycle to a complete stop is a function of speed, reaction time (usually about 2.5 seconds), and coefficient of friction to account for poor or wet braking conditions. For two-way paths, the descending direction controls the design formula.

The AASHTO *Guide for the Development of Bicycle Facilities* (1999) suggests the formula in the upper left box for determining the minimum stopping distance on a downward gradient. Using this formula, stopping distances on all trails should typically be a minimum of 50 feet for relatively slow biking (6 mph on 3 percent grade) and 150 feet or more for a bicyclist traveling 20 mph on a 5 percent downslope. For practical application, sight distances for trails with a design speed of 20 mph should have minimum sightlines of 150 to 200 feet, depending on the grades.

Where curves and other constrictive situations are present, consideration should also be given to increasing sight distances to equal the total of stopping distances for bicyclists going in either direction. This is due to bicyclists' tendency to ride side by side or near the center of the trail. When going around a curve or through a constricted area, the tendency is for riders to focus on the trail and not necessarily pay attention to someone coming in the opposite direction. A longer stopping distance gives more time to both riders and accidents can often be avoided. Where this is not practical, consider widening the trail through constricted areas to give everyone more maneuvering space.

Longer sight distances may also be required when trails traverse long open stretches or encounter steeper down gradients where higher riding speeds occur. It is also important to factor in the vertical curve of a trail, whereby bicyclists (with an eye height of about 54 inches) may lose sight of the trail in the distance because the crest of the hill obscures the view. AASHTO suggests the formula in the lower box in the left column for determining the minimum vertical curve length. Using this formula, the vertical curve for a trail with a 5 percent grade, 20 mph design speed, and 150-foot stopping distance is 120 feet. For a 10 percent combined grade (5 percent grade in each direction from crest), a 250- foot vertical curve is required.

The following graphic illustrates a number of sightline issues. As a general rule, even after formulas are applied, sight distances should be field verified to ensure adequate visibility around curves, over hills, and approaching intersections. Signage should be also be provided where sight distances are obscured and the trail users' ability to see what lies ahead is compromised.

Stopping Distance Formula

The AASHTO recommended formula for determining stopping distance is:

$$S = \frac{V^2}{30\,(f \pm G)} + 3.76V$$

S = stopping sight distance (ft)
V = design speed (mph)
f = coefficient of friction (use 0.25)
G = grade (ft/ft) (rise/run)

Vertical Curve Formula

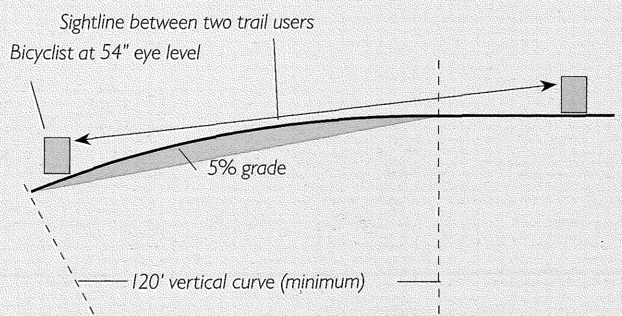
The AASHTO recommended formula for determining a vertical curve based on stopping distance is:

When S > L, then: $L = 2S - \frac{900}{A}$

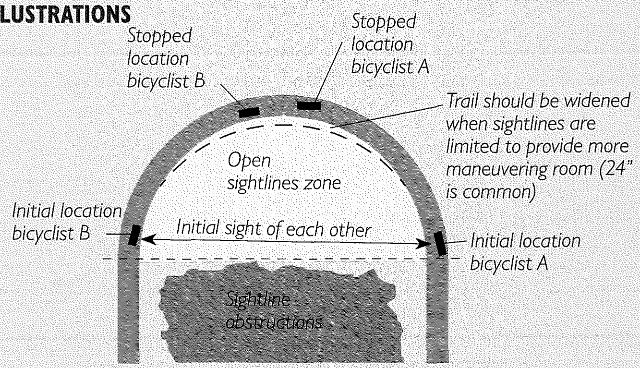
When S< L, then: $L = \frac{AS^2}{900}$

S = stopping sight distance (ft)
L = minimum length of vertical curve (ft)
A = algebraic grade difference

Sightline Illustrations



With a proper vertical curve, one bicyclist will not lose sight of another within a prescribed stopping distance, in this case 150 feet.



The lateral clearance zone must be adequate to allow bicyclists to first see each other and then safely come to a stop. On turns such as this, the stopping distance for both riders needs to be factored in. Lacking adequate sightlines, trailside warning signs, pavement markings, and pavement widening through the turn are recommended.

In Minnesota, the most common and preferred surface for multiuse trails is asphalt. Occasionally, trails in urban settings are bordered by a concrete band to reduce edge wear and provide a more finished look.

SURFACING

In Minnesota, asphalt is the most common and desirable surface for general multiuse trails. Crushed compacted aggregate surfacing is also acceptable for less traveled trails and those located in a natural setting. The cross-slope on a trail should be 1.5 to 2 percent. Excessive cross-slope (beyond 2 percent) is too noticeable and an annoyance to walkers and makes the trail less accessible to those in wheelchairs and using walkers. Superelevating trails greater than 3 percent around curves can also cause accessibility issues and encourage higher speeds and is therefore generally not recommended.

Concrete is occasionally used, but poses some limitations, including expense and crack control joints making for a rougher ride for bicyclists and in-line skaters. In limited application, concrete can be used around buildings and structures to get bicyclists to slow down in response to a changed surface and an expectation of more congestion. It also has application in areas prone to flooding, such as under a bridge adjacent to a river. Otherwise, the use of concrete for miles and miles of trails is impractical in Minnesota.

SEPARATING TRAILS AND ROADWAYS

Where a trail follows a roadway right-of-way, maximizing the separation between the edge of the road and the trail is desirable for three reasons. First, the margin of safety is improved. Second, the impact that traffic will have on the recreational value of the trail is reduced. Third, plant material and landscaping will be more healthy and vibrant with a wider boulevard.

Where right-of-way space is very limited or physical constraints require reduced separation, the minimum setback from the back of the curb to the edge of the trail should be 3 feet if road signs are required in the boulevard. If space is extremely limited, the trail can be directly adjacent to the back of the curb and the signs placed on the opposite side of the trail. Both of these cases should be the exception and not the rule, with a 10-foot minimum desired standard being much preferred. The following graphic highlights the key aspects of trail and roadway separation.

SEPARATING TRAILS AND ROADWAYS

Boulevard guidelines:

Rural section:

10' minimum for speeds under 40 mph, 20'+ preferred

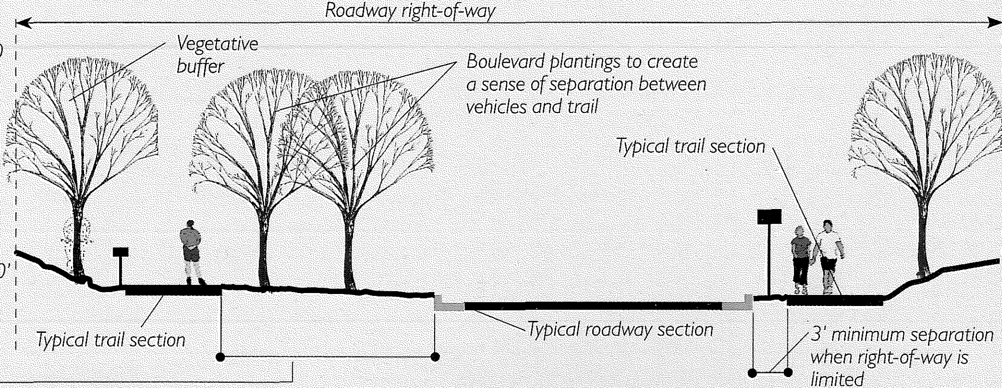
24' or more for speeds over 40 mph, 24'–35' typical

Urban section:

3' minimum for speeds under 30 mph if parking is allowed, 5' preferred

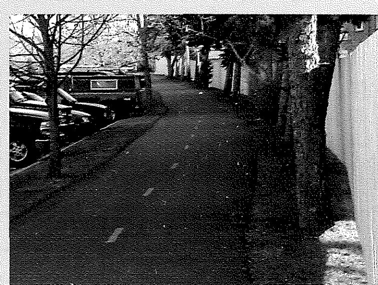
5' for speeds from 31–45 mph, 10' for speeds over 45 mph

10'+ minimum preferred for plantings



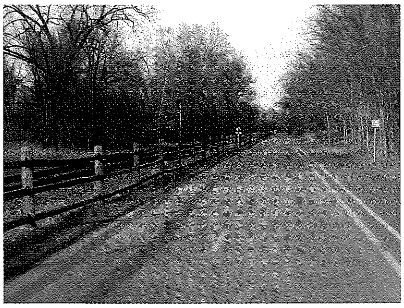
Optimal separation in urban setting. *This parkway trail is separated enough for the street to avoid a sense of encroachment.*

Concrete boulevard. *In select situations, replacing turf with concrete has merit. In this case, the concrete provides a walking area for seniors from a nearby senior housing complex. This helps separate faster users from those simply ambling along.*



Trying to do too much. *Too small of a boulevard makes plantings very difficult to sustain. Also, over time, the roots of these trees will likely reduce the design life of the trail. Sometimes not providing vegetation is the prudent, albeit less appealing, approach.*

A chainlink fence was used along this trail/rail corridor to provide safe separation between uses.



A split-rail fence was used along this trail/rail corridor to provide safe separation between uses.

SEPARATING TRAILS AND ACTIVE RAILROAD TRACKS

In situations where a trail parallels an active railroad track, maximizing the separation between the two is desirable for the same reasons cited for trails along roadways. Where space is not a constraint, the setback from the edge of the nearest track to the edge of the trail should be 25 feet or more if a physical barrier, such as a fence, is not provided.

In situations where right-of-way space is very limited or physical constraints require a reduced separation less than 25 feet, a physical barrier should be provided. Typically, a 6-foot-high chainlink fence or a wood split-rail fence is used. The trail location must conform to any requirements stipulated by the railroad authority.

GENERAL TRAIL LAYOUT GEOMETRIC CONSIDERATIONS

Shared-used paved trail classifications establish a general hierarchal relationship between trails from the local to the state level. At a planning level, these relationships help make sense of how trails interrelate across a city, region, or state.

At the actual design and use level, the geometric layout of a trail is most closely linked to user expectations. For example, a trail user would expect a relatively short neighborhood trail to be slower paced and more intimate than a city or regional trail that traverses an entire community or region. At the neighborhood level, the design of the trail should be such that higher bicycle speeds are purposefully discouraged.

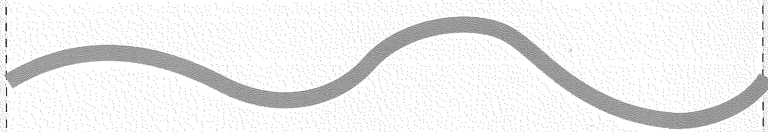
A longer regional trail is expected to be wider and allow users to go faster. Therefore, the geometrics of this type of trail must accommodate higher speeds and provide longer sightlines to be consistent with user expectations.

This is not to suggest that all city, regional, and state trails must be bicycle freeways. Depending on the setting, a slower, more intimate trail may be appropriate at any service level. Therefore, the most important factor in determining the layout of any given trail is defining the target user groups and then designing the trail to meet their expectations. Service level, targeted user groups, geographic location, physical landscape, and desired design speeds are all important factors that must be considered in the geometric layout of the trail if the trail is to be successful and safe. The following graphic illustrates how geometric forms affect the character of a trail.

TRAIL LAYOUT AS A REFLECTION OF USER EXPECTATIONS

NEIGHBORHOOD TRAIL

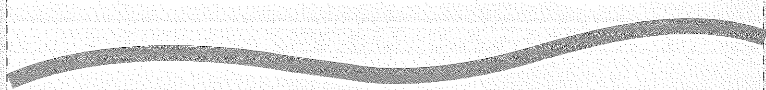
The user expectation for a paved trail through a local open space linked to a residential development is for an intimate, slower paced experience, such as an evening walk or bike ride with the kids.



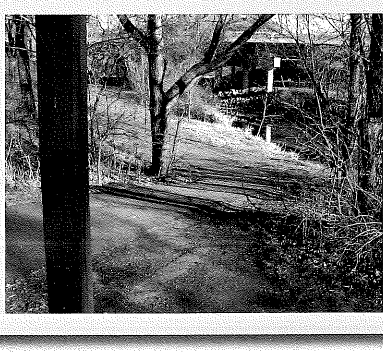
The trail is purposefully curvilinear and responsive to the details of the landscape, with a more relaxed feel and sightlines less open to create a sense of intimacy.

REGIONAL OR STATE TRAIL

In a larger open space, such as a linear greenway or regional or state park, users expect a faster pace with more open sightlines and miles of trail to cover.



The trail is less curvilinear (but still interesting) and has some straight sections between curves to make it more predictable to bicyclists traveling at a higher speed.



Context and user expectations matter in laying out a trail. *In the left photo, the trail follows a narrow greenway through a neighborhood. At 8 feet and winding, the trail feels very intimate and family-oriented.*

In contrast, the right photo illustrates a regional or state trail through a larger greenway. In this case, higher design speeds and longer sightlines are very appropriate and necessary to satisfy the trail user. If the trail were too windy and slow, the expectations of the target audience would not be met.

At-Grade/Grade-Separated Crossings at Road Intersections

For more information!

Refer to Mn/DOT's *Bikeway Facility Design Manual* (2006) at www.dot.state.mn.us/transit/bike/bikedesign.html for additional information.

Roadway crossings at intersections are one of the most critical design considerations for shared-use trails due to the potential conflict between motorists and trail users. Determining whether an at-grade or grade-separated approach is best depends on a number of variables, including traffic volumes, roadway speeds, crossing distance, and practical issues such as site topography and the amount of space available. In day-to-day application, the need for and viability of a grade-separated crossing is intrinsically linked to the engineering of the roadway and will have to comply with Mn/DOT standards.

The following table provides recommendations for various types of roadway intersections. Note that these are general guidelines and each application requires site-specific engineering to determine the best course of action to maximize safety.

Guidelines for Determining Roadway Crossing Treatment

The following table provides general guidelines for roadway crossings at intersections based on speeds, and vehicular volume. The "good" standard is recommended when the trail is used by a large number of children, seniors, or disabled people. Good is also recommended if the trail crossing is heavily used and if the trail is a main recreational corridor. Source: Mn/DOT's *Bikeway Facility Design Manual* (2006).

<table>
<tr><th>Posted Speed</th><th>Standard</th><th colspan="4">Type of Crossing Depending on Speed and Volume of Traffic</th></tr>
<tr><td>50+ mph</td><td></td><td colspan="4">Grade Separated</td></tr>
<tr><td rowspan="2">45 mph</td><td>Good</td><td colspan="4">Grade Separated</td></tr>
<tr><td>Satisfactory</td><td colspan="4">Traffic Signals</td></tr>
<tr><td rowspan="2">40 mph</td><td>Good</td><td colspan="2">Traffic Signals</td><td colspan="2">Grade Separated</td></tr>
<tr><td>Satisfactory</td><td colspan="2">Crosswalk + Median Refuge Island</td><td colspan="2">Traffic Signals</td></tr>
<tr><td>30 mph</td><td>Good</td><td>Crosswalk + Median Refuge Island</td><td colspan="2">Traffic Signals</td><td>Grade Separated</td></tr>
<tr><td></td><td>Satisfactory</td><td>Crosswalk</td><td colspan="2">Crosswalk + Median Refuge Island</td><td>Traffic Signals</td></tr>
</table>

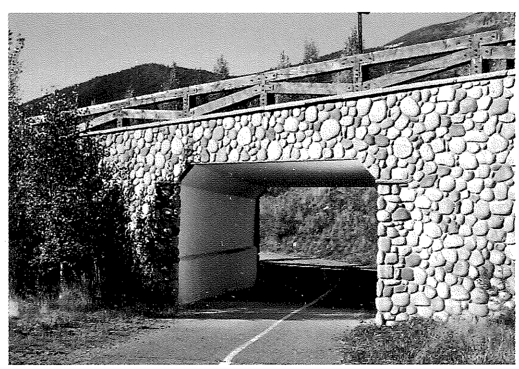
Vehicular Volume (Average Daily Traffic): 2,000 | 4,000 | 6,000 | 8,000 | 10,000 | 12,000

Notes:

- The type of crossing selected at an intersection between a main and secondary road is usually the same as for the main road.
- If more than three lanes are to be crossed, the intersection should have a refuge or median island. Where pedestrians or bicyclists wait at an island, a push button or bicycle-sensitive traffic detection device may be desirable.
- At large intersections of very busy roads, pedestrian and bicycle traffic should be separated by grade from both the main and secondary road, instead of using signals.
- Along main roads, crossings should be at intersections. If a midblock crossing is unavoidable, there must be good sight distances. If the speed limit is over 40 mph, consider lowering the speed limit through the crossing area to 40 mph.

Based on the above table, a grade-separated crossing is desirable once speeds reach 45 mph or when a combination of speed and average daily traffic (ADT) volumes reach the thresholds highlighted in the table.

A grade-separated crossing is recommended when speeds and ADT reach thresholds as defined in the previous table.

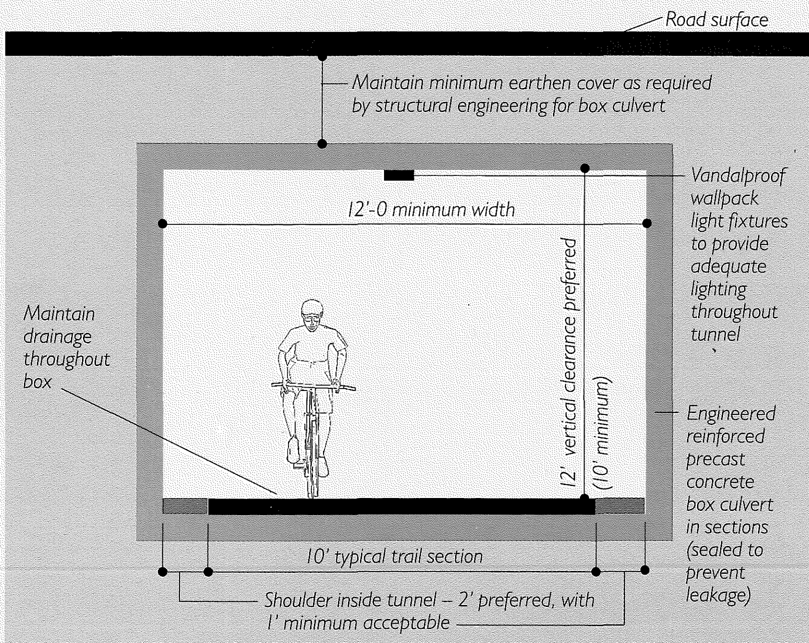


GRADE-SEPARATED CROSSINGS – UNDERPASSES

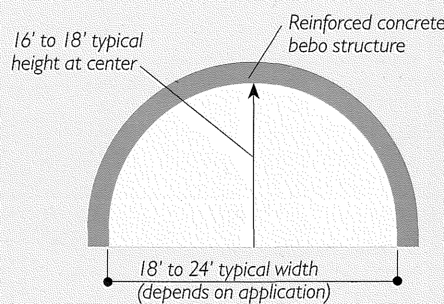
The clearance zone for trails under bridges and through box culverts and bebos is generally consistent with or greater than the other clearance zones for a trail. Three major considerations with any type of tunnel are sightlines, space for emergency and maintenance vehicles, and lighting.

In general, a trail user should be able to clearly see all the way through a tunnel-like structure from entry to exit. Lurking areas should be avoided on either end of the tunnel to avoid any perception of entrapment while passing through the tunnel. Lighting should be adequate for safety. The box should also ideally allow enough space for maintenance vehicles to pass through with adequate clearance. The following graphic illustrates some of the key aspects of a clearance zone for a box culvert and bebo structure.

CLEARANCE ZONE FOR BOX CULVERTS AND BEBOS

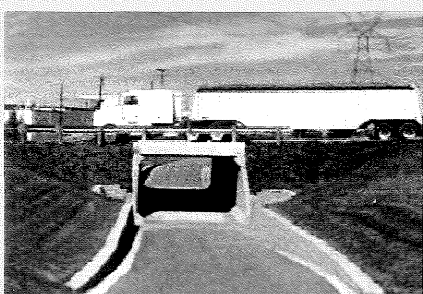


TYPICAL BOX CULVERT TUNNEL

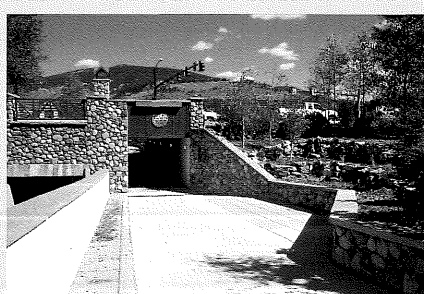


Bebo-type arched structures are used when a larger underpass is needed for trail uses. The height and width of the structure are greater than a traditional box culvert to allow adequate space for maintenance vehicles under the arch.

BEBO ARCH SPECIAL-USE TUNNEL



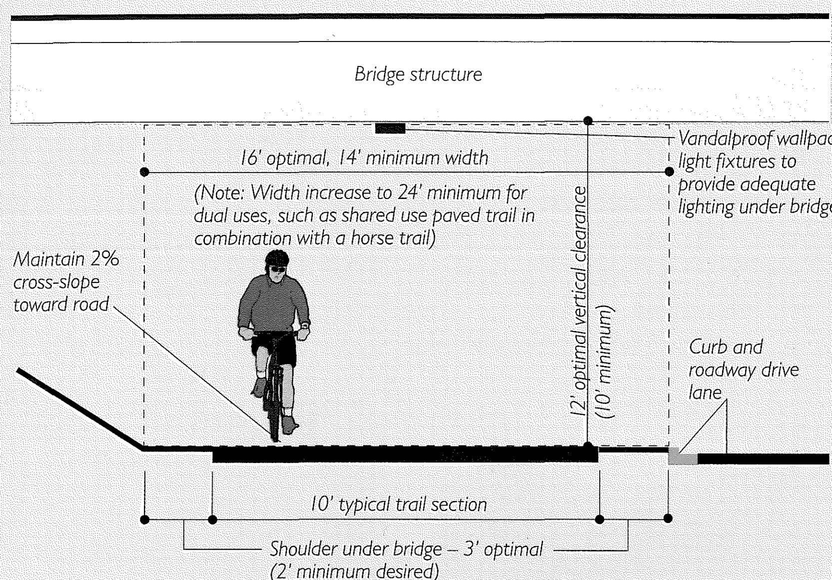
Contrast of sightlines. *Both of these box culverts provide adequate light for visitor safety. The light opening in the center of the box culvert in the right photo greatly improves visibility and will be more accepted by the user. Notably, in both of these cases the shoulder is minimal due to site limitations. For this not to be an issue, visual cues, adequate sightlines, and signage before entering the tunnels are important to alert trail users to a narrowed section.*



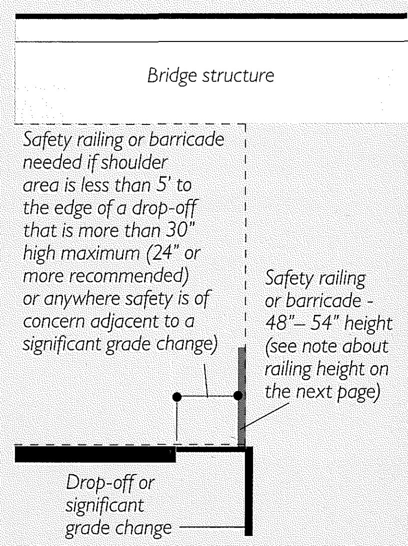
Ornate. *Both of these tunnels are appealing visual features of the trail, rather than a distraction. In the left photo, the box is wide and provides a shoulder and drainage all the way through the tunnel. In the right photo, the ornate character of the box culvert makes it more of a gateway than an impediment to travel. The hardscape around the entrance is also a visual cue for bicyclists and in-line skaters to slow down.*

The clearance zones associated with bridge underpasses have much in common with box culverts, albeit with some notable nuances, as the following graphic illustrates.

Clearance Zone Under Bridges



Under-Bridge Clearance Requirements



Requirements With Grade Change or Drop-off

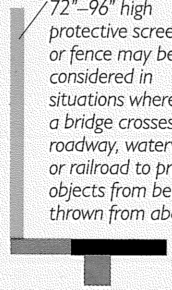
Trail hazard management. *The trail in the left photo illustrates a potentially unsafe condition due to the lack of a fence barrier adjacent to a drainageway of uncertain depth. The limited sight line from both directions make this even a more questionable situation. In contrast, the underpass on the right is also narrow but has a fence barrier to protect trail users from slipping off the trail into a drainageway. The sightlines in this area also allow trail users to see what is coming ahead. The only limitation of this trail is the lack of a shoulder, which only poses a small constraint in this situation.*

Different shapes and forms. *Bridge underpasses take on many characteristics, as these two photos illustrate. The important common denominator is that the clearance zone requirements are adequately met in each case, making these trails very safe and suitable.*

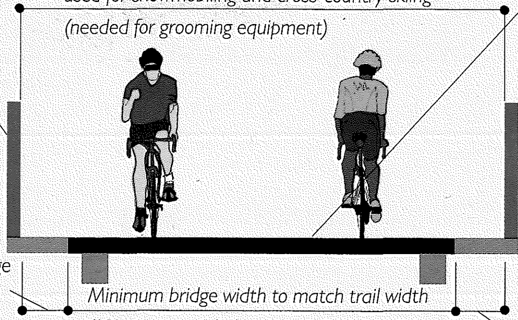
Grade-Separated Crossings – Bridges

In general, bridge widths should, at a minimum, match the width of the trail. In cases where the trail is groomed for cross-country skiing or snowmobile use, a wider trail is recommended. The following graphic illustrates the key aspects of trail bridge widths.

Bridge Widths and Characteristics



Bridge With Protective Screening



Typical Bridge Requirements


Modern bridges. *Most contemporary bridges are premanufactured steel bridges with an all-weathering steel finish that requires limited maintenance. Decking is primarily treated wood planks laid perpendicular to the trail to prevent bike tires from catching on an edge and throwing a bicyclist off balance. Although steel is often the material of choice, its character can be softened with other materials, such as wood aprons. Note that the bridge is the same width as the trail in the right photo (10 feet). The aprons help alert trail users to the lack of shoulders.*


Contrast of styles. *In many applications, the use of alternative materials has merit to be in sync with the setting. Also, trail widths should be consistent with the intended use. In the left photo, the trail and bridge are 10 feet wide for multiple use. In the right photo, a 6-foot width is appropriate for this pedestrian-only bridge across a small ravine.*


Bridge designs to be cautious about. *In the left photo, the bridge is only 8 feet wide, which is less than the adjoining trails. This can cause conflicts if those using the trail do not go single file across the bridge. In the right photo, the planking runs in the direction of the trail. If used for ATVs or horses, this poses few problems. But bicycle tires can catch on the edges and throw the rider off balance.*

Bicycle Railing Height Guideline

The AASHTO Subcommittee on Design guidelines for railing heights associated with bicycle facilities is the recommended standard for along trails and bridges in Minnesota. The most up-to-date information can be found on the web at cms.transportation.org/?siteid=59&pageid=849. Follow the link entitled Bicycle Railing Height Report and reference pages 34, 35, and 36 for specific railing height recommendations.

In general, the report recommends that railings be a minimum of 48 inches for most applications, with 54" recommended where there is significant potential for a high-speed angular collision with a railing.

At-Grade Crossings and Curb Ramps

The proper design of driveway, roadway, railroad track crossings and curb ramps is an often overlooked yet important aspect of well-designed trails. The following considers the key aspects of these features.

Driveway Crossings

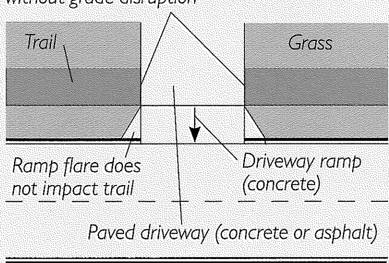
When trails run parallel to a roadway, driveway crossings are routinely encountered. Along urban roads, the curb cuts and ramps for driveways should be designed to minimize disruption to trail gradients and alignments. With rural road sections, maintaining trail continuity is simpler since grade changes due to curb lines do not need to be accommodated. The following graphic illustrates a couple of common examples of driveway crossings associated with an urban road.

Driveway Crossings

The most important aspect of driveway crossings is minimizing disruption to the trail grade as it crosses a driveway or series of driveways. When a ramp is required, it should be at an accessible gradient and long enough to maintain trail flow.

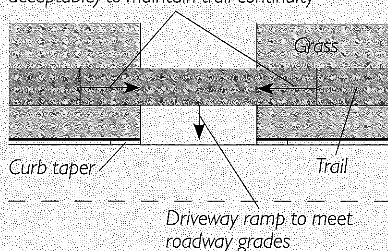
Level Trail With Ramped Driveway Crossing

Trail continues through crossing without grade disruption



Ramped Driveway and Trail Crossing

Trail gradient modified to meet driveway grade (7.1% or less gradient preferred, 8.3% acceptable) to maintain trail continuity



Ramped Trail With Level Driveway Crossing

Ramps follow curb taper to meet driveway grade (7.1% or less gradient preferred, 8.3% acceptable) to maintain trail continuity

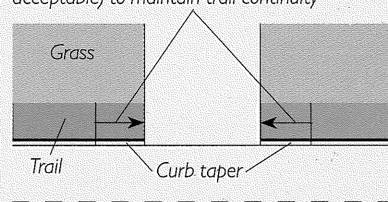


Photo Illustrations Of Various Conditions

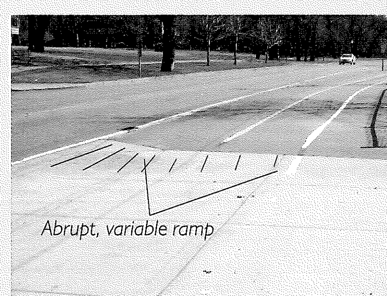
The curb cut is as wide as the trail. *By placing the ramp flares and curb tapers to the side of the trail, overall continuity and ease of use is maintained, with trail users flowing through the crossing unimpeded.*

The consistent trail grade across this driveway is ideal. *Although the driveway crossing gains the attention of the bicyclists, it does not adversely affect the continuity of the trail or pose a nuisance to the rider.*

Although the curb taper is short, this trail grade remains fairly constant and acceptable. *The mailbox is less than ideally located, however.*

Trail accessibility and continuity is compromised by the design of this driveway apron. *The ramp is difficult for wheelchairs to maneuver through and frustrating for bicyclists.*

The use of concrete can help remind trail users to look both ways at a driveway crossing. *The consistent grade is also a positive aspect of this crossing.*



Abrupt pavement changes can catch trail users off guard. *Although difficult to see in the photo, the ramp is uneven and short. This can cause bicyclists and in-line skaters to drift out of their lane into oncoming traffic.*

> ***For more information!***
> Refer to Mn/DOT's Bikeway Facility Design Manual (2006) at www.dot.state.mn.us/transit/bike/bikedesign.html for additional information.

ROADWAY CROSSINGS

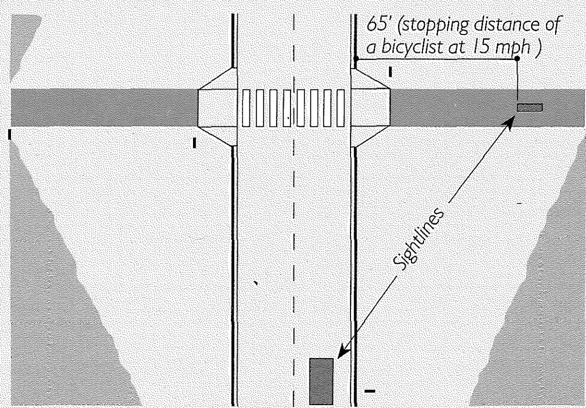
Roadway crossings come in a variety of forms due to site-specific roadway configurations and right-of-way limitations. This is especially the case where trails are retrofitted into an existing infrastructure of roads. All road crossings should be designed to be safe, which means having adequate sightlines, appropriate signage and traffic control devices, and ample time to cross the road between traffic flows. The following graphic provides an overview of sightline distances relative to a motorists speed and reaction time.

SIGHTLINE DISTANCE CONSIDERATIONS

The table defines the distance traveled in three seconds at listed speeds, which is the time a motorist needs to react to a bicyclist about to cross the road.

Distance Traveled in Three Seconds at Listed Speeds

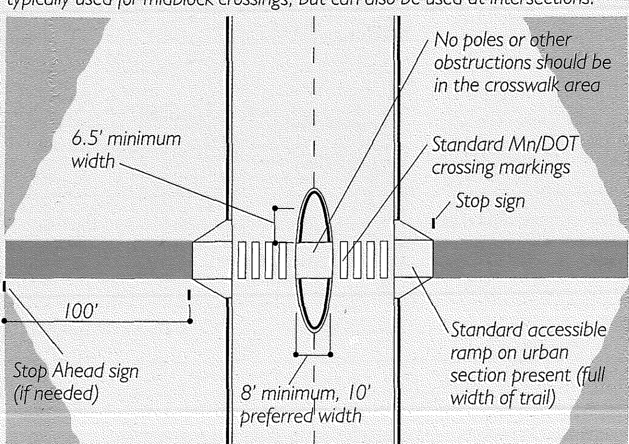
Vehicle Speed (mph)	30	40	45	50	55	60	70
Distance Travel (ft)	132	176	198	220	242	264	308



In general, trail crossings at intersections are favored over midblock crossings because motorists and trail users are inherently more aware of traffic issues at intersections. That said, midblock crossings are common in urban and rural settings and must be accommodated. The following graphics provide design guidelines for the most common forms of at-grade roadway crossings.

CROSSWALK MEDIAN/RAISED ISLAND

The Mn/DOT road design manual recommends pedestrian median islands at intersections wider than 75 feet or when a pedestrian walking at 2.5 feet per second cannot cross the street completely in one green cycle. Islands are most typically used for midblock crossings, but can also be used at intersections.

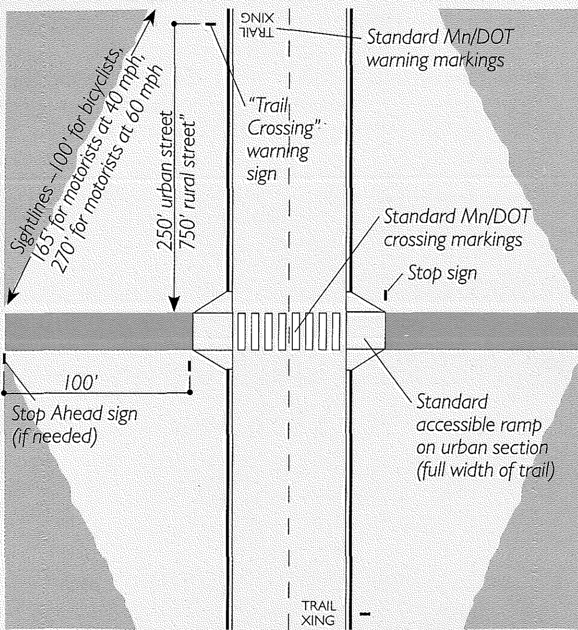


The width of the crosswalk and curb cuts should be 10' minimum. Raised islands should be cut through or have ADA accessible curb ramps with a minimum landing area of 4 feet between ramps.

This midblock crossing has a raised median with a cut through. *This allows trail users to proceed without any ramps or grade changes, so they can focus on the traffic and other trail users.*

Raised island with partial ramp cut-through. *Although the island is a good idea, the cut-through is too narrow, which forces opposing trail users to wait in the middle of the road to pass one at a time. This can pose a safety risk when motorized traffic is approaching from both sides.*

BASIC CONFIGURATIONS OF ROADWAY CROSSINGS

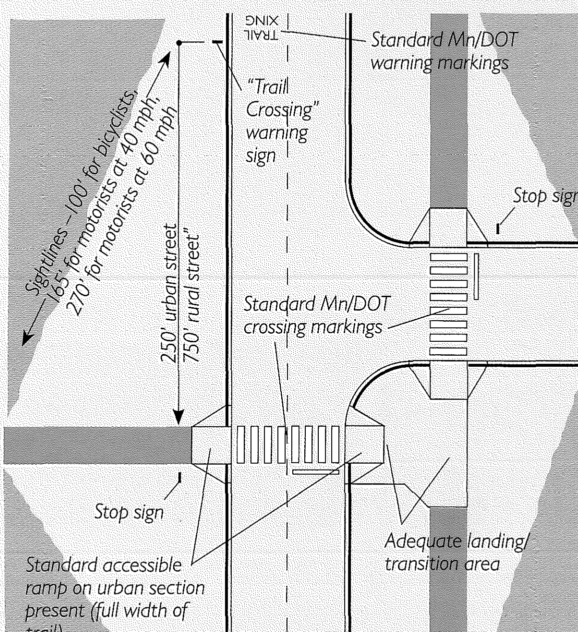


MID-BLOCK TRAIL CROSSING

Midblock crossing in an urban setting works. *Clear sightlines and slower traffic speeds allow for a safe crossing.*

However, this crossing could be improved by widening the ramp to match the width of the trail. (This is considered in more detail on page 5.21)

Standard, easy-to-see at-grade trail crossing in rural area. *This highly visible trail crossing works well in this setting. Although not shown, sightlines from the roadway are open and trail users are easy to see.*



INTERSECTION TRAIL CROSSING

Standard, appropriately positioned crossing. *This crossing at an intersection works well. The only limiting factor is that the accessible ramp is not as wide as the trail, which can cause problems if bicyclists meet on the ramp and are both forced to the center.*

Nicely integrated with streetscape. *Integrating the trail crossing with the streetscape makes it less intimidating to the user. Sightlines and the center island also improve the safety of this crossing.*

The following photos provide examples of at-grade trail crossings of roads to highlight various design techniques.

(Left) The safety of this crossing of a busy road is enhanced by the median. This space gives trail users some protection if they fail to make it all the way across.

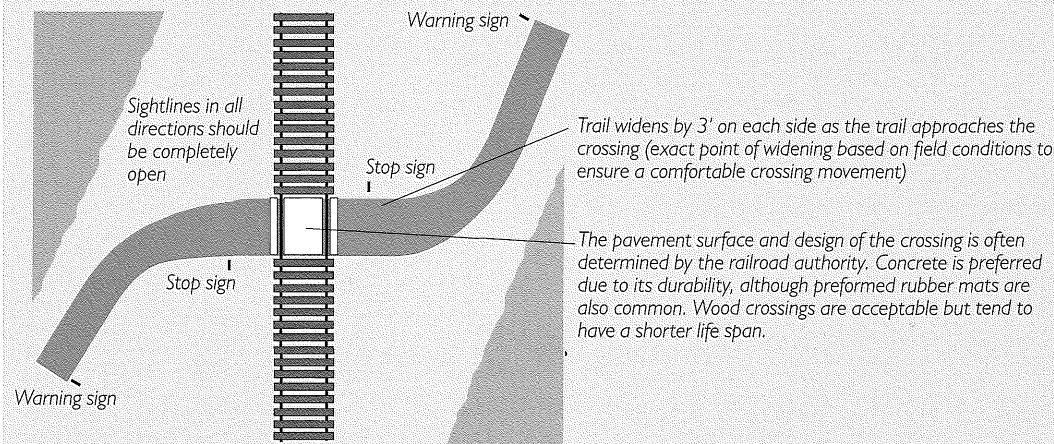
(Right) This landing area is in between the main road and an access ramp to a freeway. Although it is large enough to accommodate a few trail users, the narrow curb forces users to the center of the ramp just when everyone is grouped-up at a constricted point. If the ramp were as wide as the trail, people headed in either direction could stack up beside each with little interference.

Railroad Track Crossings

Railroad crossings require special care. Whenever possible, the approach to the crossing should be at 90 degrees to the track to allow bicyclists and in-line skaters to ride over the pavement gap caused by the rails at a perpendicular angle and to allow trail users to look both ways down the track as they approach the crossing. Crossing angles of between 60 and 90 degrees are acceptable, but should only be used if 90 degrees is not possible. The following graphic and photos provide guidelines and examples of railroad crossings.

Railroad Track Crossings

The preferred crossing width of a railroad track is equal to the width of the trail plus 3 feet on each side to provide adequate maneuvering space at the actual crossing. This is especially important when the trail is adjacent to the track and then curves to make the crossing, which should be as close to 90 degrees as possible. The combination of making the turn and crossing the tracks while looking for trains, observing oncoming trail traffic, and making sure that a wheel does not catch in the rail gap can take trail users attention away from staying in their lane. The extra width provides some recovery space if a user misjudges the corner. Since trains are usually infrequent, trail users often do not stop at the tracks, which underscores the need for plenty of maneuvering space at the crossing area.



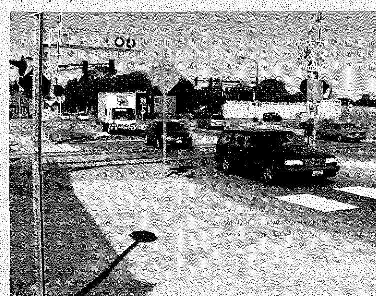
This trail crossing, constructed with concrete with steel framing, provides ample shoulder width for maneuvering through this congested area.

The concrete and steel framing of this crossing is very durable and stable. Although acceptable, the less-than-90-degree crossing angle increases the chance of catching a wheel.

Although smooth, this crossing is only as wide as the trail. Given the abruptness of the crossing, more width would make the turn more comfortable and increase the margin of safety.

Wood crossings are common in rural settings and work well if maintained. This crossing could be improved by widening it.

This rail crossing is at an odd angle and could result in a bicyclist catching a wheel while watching for motorists. The formed concrete with steel frame crossing helps limit the chance of that occurring.



This confusing light-rail transit (LRT) and roadway crossing area near a busy intersection poses a challenge even to elite bicyclists. It is also confusing to motorists who are easily distracted from paying attention for trail users.

A handy guide to have!

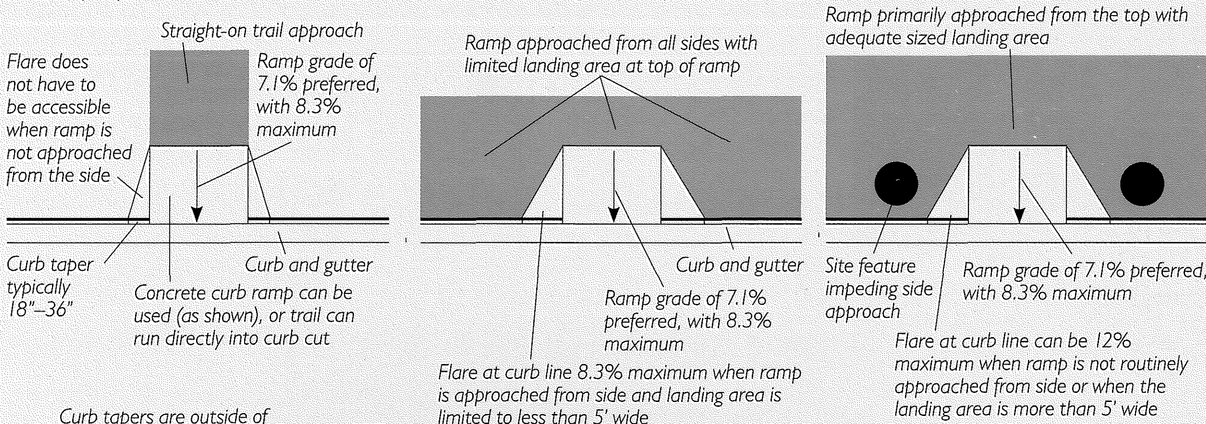
Accessible Sidewalks and Street Crossings – On the Safe Side (see Accessibility of Shared-Use Trails on the next page).

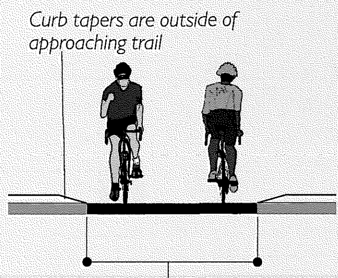
Curb Ramps

For accessibility, curb ramps should meet or exceed all federal, state, and local requirements. For use with paved trails, curb ramps should also be conveniently located and minimize conflicts between trail users and with vehicular traffic. The following graphic highlights desirable aspects of curb ramps for common trail situations.

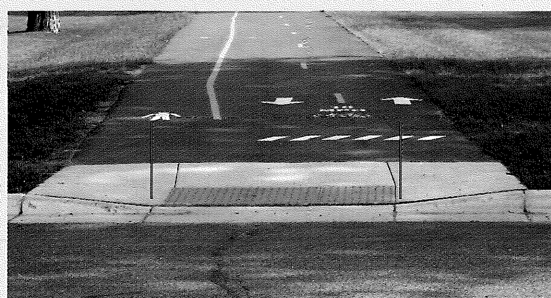
Basic Aspects of Curb Ramps

The most important aspect of curb ramps is gradient. A 7.1 percent slope is preferred for the ramp to allow for construction tolerance, with 8.3 percent the maximum allowed. The gradient on ramp flares at the curb line should also be a maximum of 8.3 percent when the landing area is restricted or where the ramp is routinely approached from the side. *The ramp width (excluding flares/tapers) should match the width of the trail* to avoid forcing two-way traffic into the center of the ramp.





Trail users should not have to change their alignment when traveling through a curb cut. This is especially important on busy trails where numerous trail users can congregate at a crossing and want to get across the ramp at the same time.



This curb cut is not wide enough for bicyclists, in-line skaters, and walkers to maintain their line of travel through the ramp, creating the potential for conflict and congestion. The bottom of the ramp should match the width of the trail. Notice the location of the 2-foot wide detectable warning strip (as compared to the below photo).

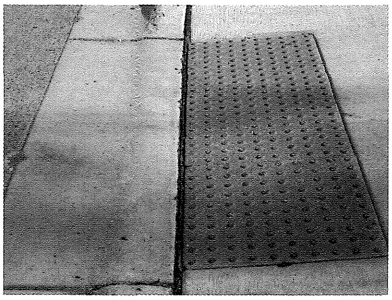
This ramp is as wide as the trail, relatively flat with no significant gutter lip, and protected on each side with bollards. Sightlines are also clean to reduce conflicts with motorists.

This curb cut is appropriately wide enough for bicyclists, in-line skaters, and walkers to maintain their line of travel through the ramp, reducing the potential for conflict and congestion. Notice how the bottom width of the ramp matches the width of the trail. The 2-foot wide detectable warning strip is only provided for the walking section of the trail, allowing for a smoother ramp transition for wheelchairs, bicycles, and in-line skaters.

ACCESSIBILITY OF SHARED-USE TRAILS

Accessibility is a broad subject with many practical and legal implications that cannot be completely considered in this manual. Trail planners and designers are encouraged to stay abreast of changing requirements as they affect trails. For convenience, the accessibility-related resources listed in Section I are reiterated here and include:

- The United States Access Board is a commonly referenced resource for up-to-date information on accessibility, including trails. The ADA Accessibility Guidelines for Buildings and Facilities (ADAAG) can be found at www.access-board.gov/adaag/html/adaag.htm.
- *Designing Sidewalks and Trails for Access,* published by FHWA, is an exhaustive two-part publication that covers virtually every aspect of accessible sidewalks and trails and complements the guidelines presented in this section. The publication has particular application to the detailed aspects of curb ramps, pedestrian crossings, and sidewalks. The publications (FHWA -EP-01-027 and FHWA-HEP-99-006) can be found on the web at safety.fhwa.dot.gov/ped_bike.htm.
- A handy accessibility guideline is a fold out brochure entitled *Accessible Sidewalks and Street Crossings – On the Safe Side* published by FHWA. The publication (FHWA -SA-03-017) can be found on the web at safety.fhwa.dot.gov/ped_bike.htm. This brochure covers day-to-day accessibility issues associated with trails and sidewalks and is a worthwhile tool to have for quick reference.
- Other related information can be found on the FHWA general safety website (safety.fhwa.dot.gov/index.htm).



Detectable warning strips and other tactile cues should conform to the standards of the United States Access Board at www.access-board.gov.

BASIC PRINCIPLES OF CREATING ACCESSIBLE TRAILS, RAMPS, AND CROSSINGS

Applying a number of basic accessibility-based design principles will ensure that the vast majority of shared-use paved trails are accessible irrespective of specific legal requirements. These include:

- Keeping trail grades to 5 percent or less wherever possible (recognizing that the innate terrain of an area often dictates trail grades)
- Limiting the cross-slope of trails to 2 percent
- Making all ramps at road crossings and access points ADA compliant and fully accessible, including making sure the ramp (not the tapers) are as wide as the path
- Keeping the gutter lip as minimal as possible so as to not impede wheelchairs
- Making landing areas big enough to accommodate all users and meet all ADA standards
- Making all support facilities accessible, especially at trailheads and restrooms

This steep approach with no landing at a mid-block crossing of a busy street proves challenging for even the most capable of trail users, much less so for those who are less ambulatory. Avoiding these types of circumstances can go a long way toward making trail access more inclusive.

The "social" trail shortcut here (red dashed line) clearly defines where trail users want to go. Reconfiguring this intersection would make the trail more accessible to those attempting to make a run up this very steep uphill grade. (Having to almost come to a stop at the intersection takes away a rider's momentum, forcing many to ultimately walk. It also creates a poor braking situation coming down the hill.) Clear sightlines in all directions are critical to user safety in this area.

Users of this long crossing are met with a curb, not a ramp. This is far too abrupt and annoying to trail users trying to get across an intersection. The light standard in the middle of the path is also an unnecessary obstacle. It is not an accessible solution.

TRAILHEADS FOR SHARED-USE TRAILS

Trailhead facilities are typically provided at strategic locations along a trail or within a trail system. The need for these facilities is based on the service level of the trail and the relative ease of finding services in proximity to the trail. Most higher-level trailheads are located in a local, county, regional, or state park where the facilities serve a broader purpose than just trail needs.

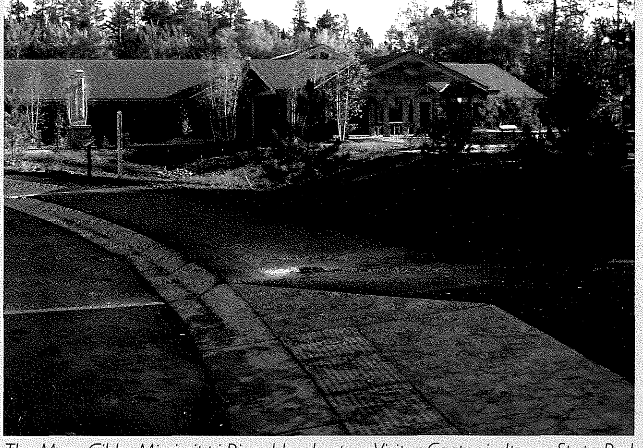
At the local level, trailheads are most often provided at a trail terminus, which is typically a park. At the state level, where trails are often more linear through the countryside, trailhead facilities can be located at key points of access. For longer trails, first- and second-level trailheads are commonly spaced about every 20 miles. Third-level trailheads are common where trails intersect with major roadways, where they traverse a business district, or every 10 miles.

The level of service provided at trailheads varies depending on site-specific demands. The following highlights three service levels for trailheads that can be used as the basis for determining the right mix of facilities for a given situation. The size and type of facility, land requirements, parking spaces, and other factors are all site-specific issues for which there is no set standard.

TRAILHEAD SERVICE LEVEL I – COMMON FACILITIES AND LOCATIONS

Trailhead Level	Typical Facility Considerations	Typical Locations
Level I Major Trailhead	• Permanent structure with restroom facilities • Picnic shelter • Parking, with accessible spaces and overflow parking area • Drinking fountains • Telephone for emergency and event coordination • Seating area • Security lighting • Trail information kiosk • Bicycle racks • Shady area and green space for resting and open picnicking • Waste receptacles • General landscaping • ADA accessible throughout	Level I trailheads are almost exclusively located in a county, regional, or state park to serve a broader need. At the local level, this level trailhead is most often only provided in situations where a key access point coincides with a community park. Otherwise, providing a permanent restroom facility is cost prohibitive.

LEVEL I TRAILHEAD IMAGES



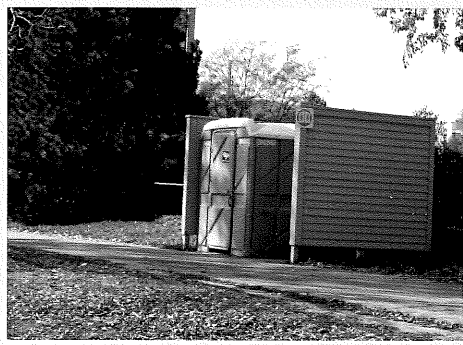
The Mary Gibbs Mississippi River Headwaters Visitor Center in Itasca State Park (left photo) and the visitor center in Jay Cooke State Park are examples of Level I trailheads that serve a broader purpose than the trail alone. As with these examples, trailheads can be trail destinations.

The Mary Gibbs facility provides an extensive interpretive display, restrooms, deli, gift shop, and restrooms. The Jay Cooke facility is the main visitor contact area and includes a check-in counter, gift shop, heated shelter, and restrooms. Each facility has kiosks and outdoor sitting areas and observation points of two very different rivers.

Trailhead Service Level II – Common Facilities And Locations

Trailhead Level	Typical Facility Considerations	Typical Locations
Level II Trailhead	• Permanent or portable restroom facilities • Parking, with accessible spaces • Drinking fountains • Telephone for emergency • Seating area • Security lighting • Trail information kiosk • Bicycle racks • Shady area • Waste receptacles • General landscaping • ADA accessible throughout	Level II trailheads are of a smaller scale than Level I and often located in a local, county, regional, or state park to serve a broader need. Level II trailheads can also be located at designated major trail access points.

Level II Trailhead Images



(Left) A simple parking area with 10 to 20 spaces is typically adequate for most access points.

(Right) Portable restrooms are desirable amenities if there is a clear need. Otherwise, they can be costly to maintain.

Trailhead Service Level III – Common Facilities And Locations

Trailhead Level	Typical Facility Considerations	Typical Locations
Level III Trailhead	• Portable restroom facilities (only if needed) • Limited parking, with accessible spaces • Drinking fountains (where feasible) • Seating area • Trail information signage • Waste receptacles • Basic landscaping • ADA accessible throughout	Level III trailheads are of a smaller scale than Level II and located in a local, county, regional, or state park where use levels are modest. In urban or suburban settings, level III trailheads are often found at more popular access points.

Level III Trailhead Images

A simple but functional trailhead with an adjoining small parking lot or on-street parking is adequate for many level III trailheads.

A sitting area with basic amenities (left) along with signage kiosk and drinking fountain (right) is all that is needed in many situations.

Shared-use Trail Signage and Striping

For more information!

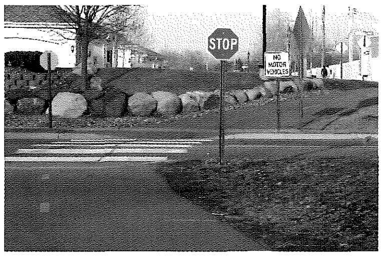
Refer to Mn/DOT's website (www.dot.state.mn.us/trafficeng/otepubl/mutcd/index.html) for the complete MN MUTCD manual.

The MN MUTCD is the primary reference for general traffic control and safety sign standards along shared-use trails. Part 9 – Traffic Control Devices for Bicycle Facilities and Appendix C – Sign Listing are particularly useful in defining the standards for various types of signs found on trails, including stop, speed, hazard warning, grades, curves, directional, and authorized uses.

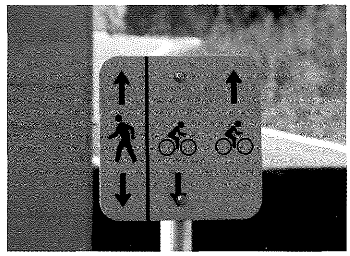
In addition to traffic control and safety, signs should provide useful trail and destination information in a consistent, uncluttered manner. This means only providing the signs really necessary in order to minimize visual distraction, maintenance, and ongoing costs. It is also important not to place signs that may inadvertently confuse motorists. (When signs are within a road right-of-way, it should be obvious to motorists that they are intended for trail users and signed in conformance with MN MUTCD standards.) The following provides examples of various types of signs most often associated with shared-use paved trails.

Regulatory/Traffic Control/Warning Signs

These signs are used to notify trail users of rules and laws associated with trails and alert users of potentially hazardous conditions on or adjacent to a trail, as the following photos illustrate.



Stop signs are classic warning signs and recommended at all roadway crossings. Note the difference in the size of the sign in these two photos. In general, smaller signs consistent with MN MUTCD standards are recommended for general application and to avoid visual clutter, with larger ones being used to get trail users' attention at more dangerous crossings.



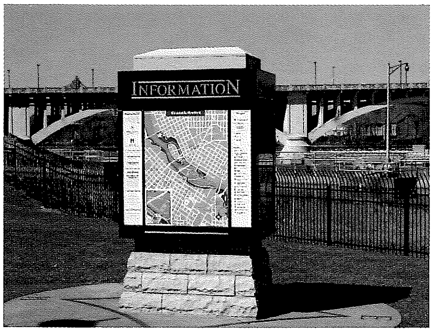
Small, simple signs alerting trail users to which side of the path to use are appropriate at access points or wherever the trail configuration changes. The character of these signs should be consistent throughout the system to make reacting to them second nature to the trail user traveling at different speeds.

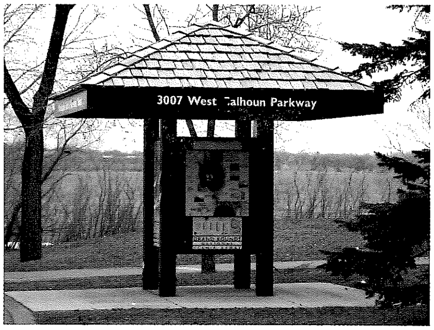
Warning signs alert trail users to a changed condition, such as a curve, narrowing of the trail, or steep grade. Such signs convey an important message and should be consistent with uniform standards. Consistent signing helps trail users' reaction to the signs become second nature and increase their reaction time, resulting in a safer trail experience.

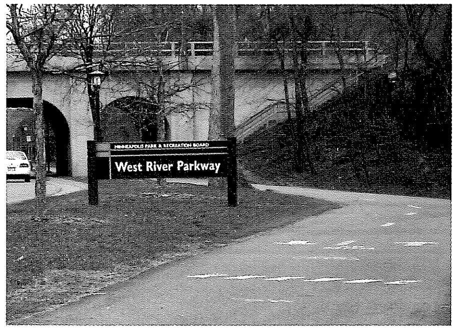
Regulatory and rules signs alert trail users to limitations on trail use and their responsibilities in using the trail. As with all signs, these should be of a consistent style and character so trail users become familiar with the set of rules and regulations common to a system of trails.

Trailhead/Orientation Signs

These signs highlight trail features and interconnections with other trails, and provide general "You Are Here" information. Trailhead and orientation signs come in many forms depending on the setting and information needs. In an urban area, trail kiosks are often informational as well as an architectural element and common identifier of a particular system. In a rural setting, these types of signs are often simpler. The following photos highlight a few examples of these types of signs.

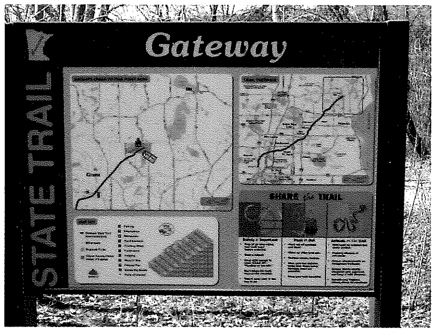


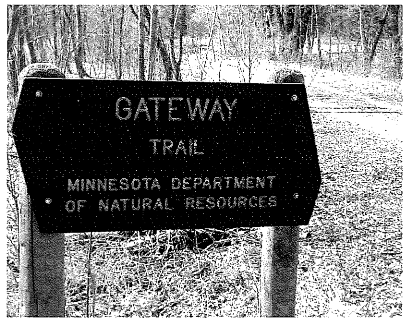




An ornate architectural style is appropriate for an informational kiosk in a historic district, as is this one along the Mississippi River in Minneapolis.

The distinctive style of the information kiosks of the Chain-of-Lakes Grand Rounds in Minneapolis provides users with consistent information at expected locations. The kiosk is also an important architectural statement.

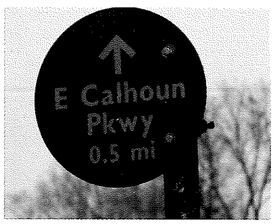




The style of the information signs along the Gateway Trail is purposefully simpler and appropriate while still being consistent and successful at providing trail users with information at expected locations.

Directional Signs and Route Guides for Trail Users

These signs provide useful information at key decision points along a trail. They are used to sign roadway crossings, identify where connecting trails lead, and highlight major destinations in the vicinity of the trail.



The style of directional signage and route guides for the Root River Trail (far left) is consistent with the setting, as is that found along the Cedar Lake Greenway (middle).

Although signage is important, excessive or cluttered signage loses its impact and detracts from the trail experience (right).

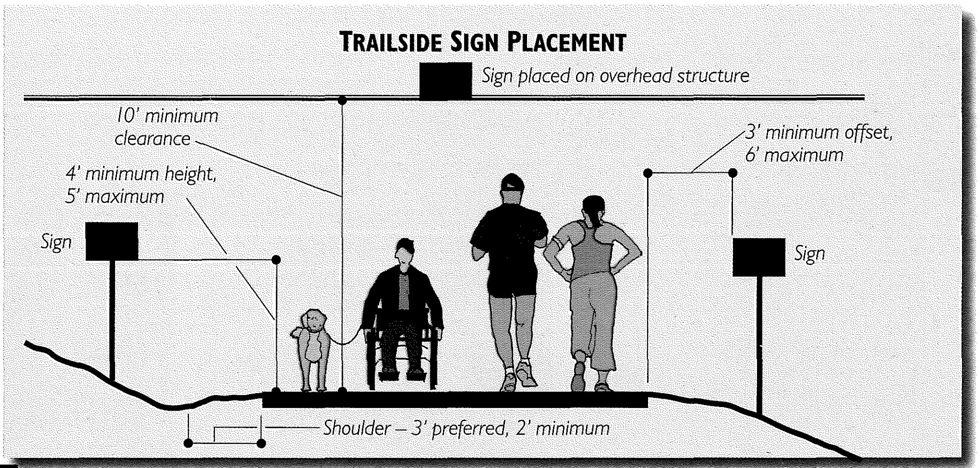
Trail Identification/Warning Signs for Motorists

These signs alert motorists about the existence of a trail crossing or related facility. Consistently signing can help motorists become more aware of the trail and thus more likely to proceed with caution.

Each of these signs gets across a simple message to motorists. It is especially important for roadway signs to be consistent with MUTCD standards, since those are the ones motorists are used to.

General Sign Placement Guidelines

Part 9 – Traffic Control Devices for Bicycle Facilities of the MN MUTCD provides guidelines for signs along trails. The following graphic illustrates the most important aspects of these guidelines.



It is common not to provide striping on trails where use levels and hazards are minimal and sightlines adequate. Nonetheless, trail users are responsible to stay in their lane when approaching opposing traffic.

Shared-Use Trail Striping Guidelines

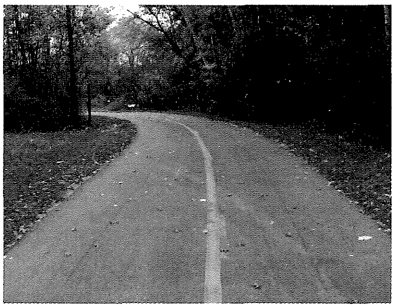
Trail striping and markings are used to indicate the separation of trail lanes in congested areas and highlight potential hazards. Part 9 – Traffic Control Devices for Bicycle Facilities of the MN MUTCD provides general guidelines. In general, striping and pavement markings are used to address a specific safety concern, including:

- Trail hazards, which are defined as anything that would be unexpected or difficult to see and/or may require a trail user to make a maneuver or change speed
- Areas of heavier use where striping is used to remind trail users to stay in their lane, especially with oncoming traffic
- Any curve, hill, or roadway crossing where sightlines are compromised and/or where trail users should stay in their respective lanes

The following photos highlight the most common striping situations.

A solid white line may be used on a shared-use path to separate uses, with a broken yellow line used for separating opposing lanes. Pavement markings clarify proper uses and direction.

A broken solid yellow line is used on busier trails to remind trail users to stay in their lane. Consistency of use along a trail is important in order for trail users to understand the pattern.



A solid yellow line is used to identify a no-passing area when approaching a curve or hill with limited sightlines. This is often accommodated with a trailside warning sign.

MN MUTCD standards are recommended for all roadway crossings to ensure consistency across the state.

A solid white line can be used to highlight a particular trail hazard, alerting trail users to pay attention, maneuver around an obstruction, or change speed.

In some systems, a green center line is used in lieu of yellow as an identifier of a system of trails. If this approach is taken, maintain consistency to avoid confusion.

Accessibility reminder!

Amenities should be consistent with accessibility provisions as defined on page 5.22.

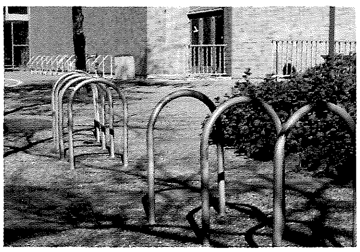
SITE AMENITIES AND ACCESS CONTROL

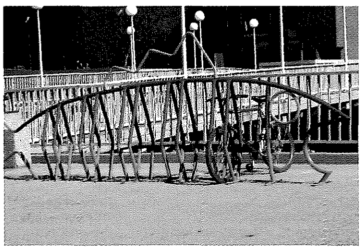
Site amenities complement the trail experience. They include benches, overlooks, trash receptacles, bike racks/lockers, gathering plazas, and even children's play equipment. Signage is also considered a site amenity, especially when it adds an architectural element to the trail setting.

The extent to which amenities are provided depends on the site. In an urban setting where a social atmosphere is being created, it is common to provide numerous benches and gathering areas. Along a state trail in a rural area, a few benches and an occasional overlook are sufficient. The following photos illustrate a variety of amenities that can be considered.

Depending on the setting, overlooks can range from the ornate (left) to the simple (middle) and rustic (right).

Amenities such as benches, drinking fountains, and trash containers are common along trails – as long as the commitment to maintain them is considered when they are installed.





Bike racks can range from the common (left) to the ornate (middle).

Bike lockers are also becoming more popular to promote bike commuting (right).

Access control refers to providing physical barriers to prevent unauthorized motor vehicles from accessing the trail. Access barriers impede trail users and should only be used when they are really needed. The following photos illustrate common examples of barriers.

Bollards are commonly used to deter motorists from accessing trails. Typically, bollards are set 48 to 60 inches apart when across a trail, often with the center bollard being removable for authorized vehicles.

If used when not needed or set improperly, access barriers can become an impediment to trail users. In the left photo, the cross pieces are set at a height where the bicyclist can best judge their location. In the right photo, the cross pieces are set too high and can take a bicyclist off guard and not be lined up properly to slip through. The added paint stripes, which serve to alert the trail user of constricted space, highlight the issue.

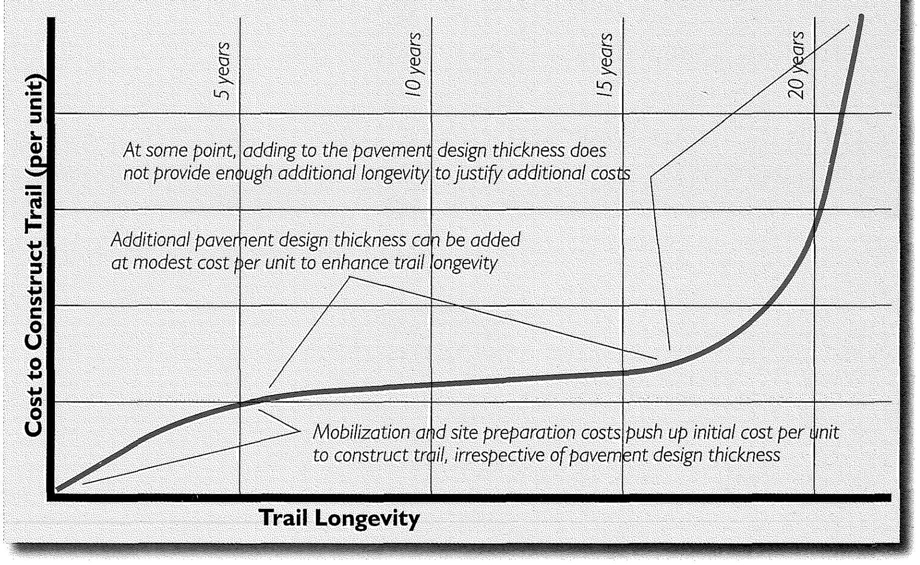
TECHNICAL DESIGN GUIDELINES

The following guidelines provide parameters for constructing paved trails. The guidelines are based on common practices in Minnesota and take into consideration climate and other site conditions. However, they are not a substitute for site-specific design and engineering that responds to local soil, use loads (including maintenance equipment), and other conditions.

OPTIMAL PAVEMENT DESIGN STANDARD

The optimal pavement design for a shared-use paved trail balances structural strength (to increase longevity) and the cost of construction and maintenance. The optimal pavement design is the point at which increased longevity and reduced maintenance costs no longer justify increased construction cost. The following graphic illustrates this relationship.

TRAIL COST/DESIGN LIFE RELATIONSHIP



As the graphic illustrates, at some point, increasing the pavement design thickness cannot be justified relative to expected increases in longevity. For asphalt trails, a 15-year design life is common, assuming routine maintenance. With proper construction and maintenance, the design life of a trail may be extended somewhat beyond 15 years, but that is likely to be the exception more than the rule. The guidelines presented in this manual are generally based on a 15-year design life for asphalt trails.

BASIC TECHNICAL DESIGN CONSIDERATIONS

Underlying factors that greatly impact trail construction and longevity include soils, drainage, and vegetation growth patterns.

SOIL CHARACTERISTICS

The character and texture of soils greatly influences pavement design. The ability of the subgrade (i.e., soils below the pavement section) to support loads transmitted through the pavement is one of the most important factors in determining pavement thickness. A stable subgrade is critical to minimizing deflection and soil movement that allows cracks and uneven surfaces to develop. The following photos illustrate classic problems with paved trails due to either poor soils, poorly compacted soils, or an inadequate depth of pavement to support the load and accommodate yearly freeze-thaw cycles.

This trail, which is only 3 years old, illustrates poor pavement design and construction. Although initial costs were less than they would have been for a heavier design, increased maintenance and short design life make long-term costs much higher. Of equal importance, the user experience is diminished because the trail becomes rough and hard to walk, bicycle, or in-line skate on.

In contrast, this trail has been properly designed with a heavier cross-section on a stable base. It is reasonable to expect 15 years of design life from this trail.

(Left) The longitudinal crack in this trail is a classic example of an unstable or inadequately compacted subgrade. The only real solution is to rebuild it.

(Right) This trail, which lies over slumping soils on top of a bluff, is showing the wear of time with less-than-ideal soil conditions. The fence is leaning out due to unstable soils, increasing redevelopment costs.

(Left) Where shoulders are too narrow and adjoining sideslopes are steep, edge stability can become a problem. This asphalt patch is only a temporary solution.

(Right) Even though a curb was used to help manage stormwater runoff, the subsoils in this case were very organic and thus not a stable base. This section of trail will need to be rebuilt after only a couple of years of service.

As these photos illustrate, pavement design and subgrade preparation does matter.

In general, the tighter the soil, the more prone it is to holding water, frost heaving, and creating an inconsistent base for the trail. The following graphic illustrates the general characteristics of major soil categories relative to their structural integrity for trail construction.

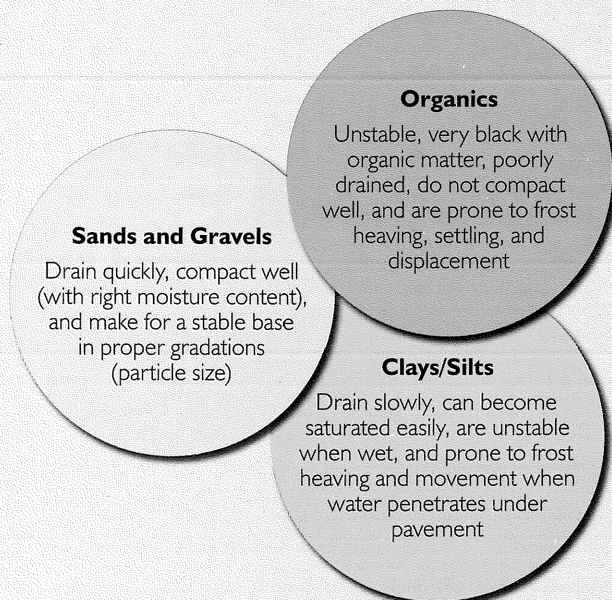
SOIL CHARACTERISTICS

SOIL CLASSIFICATIONS

Under the AASHTO system, soils are classified by their load-carrying capabilities, as well as other factors such as soil texture. The appropriate pavement design for a trail depends on which of Minnesota's many soil types are present.

For the purposes of this manual, soils can be divided into three major categories, as shown on the right.

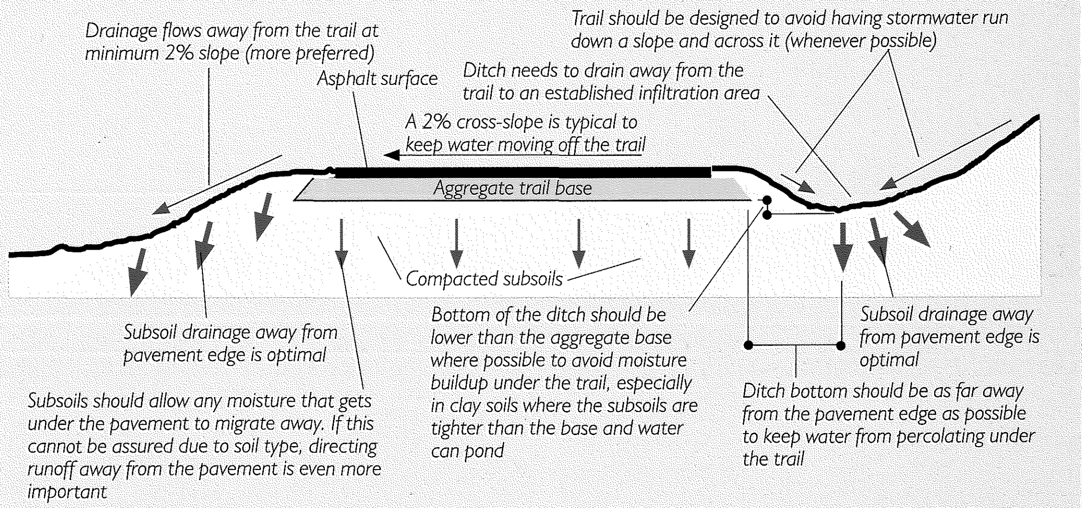
Pavement design has to respond to the inherent qualities and limitations of the soil if it is to reach its design life. Sands and gravels form the most reliable base for trail pavements, clays and silts require special precautions, and organics are best avoided.



TRAIL DRAINAGE FACTORS

Drainage is a key aspect of trail design for a number of reasons. First, moisture penetration under the pavement creates the conditions for frost heaving, movement, and instability of subgrade materials. In sands and gravels, the moisture passes through and the pavement is not excessively compromised. In clays and silts, the water is often trapped and causes problems. In all pavement designs, trail longevity depends, in part, on managing drainage to minimize impacts on the pavement, as the following graphic illustrates.

Drainage Characteristics to Ensure Longer Trail Design Life



The above trail cross-section highlights important trail drainage considerations that can extend the design life of an asphalt trail. In all pavement sections, the more that runoff can be directed away from base and subsoil materials under the trail, the less likely moisture-related problems will occur. In clay and silt soils, this becomes even more important for trail longevity.

Diligence toward drainage issues promotes longevity and user satisfaction in a smoother, less cracked trail. The following photos highlight a variety of conditions associated with trail drainage.

(Left) Proximity close to a road is not ideal but not uncommon when trails are retrofitted. In this case, drainage still works well even though road runoff can run across the trail. With proper grading away from the trail, runoff has little chance to pond or get under the trail surface.

(Right) This classic old rail grade trail sits high and drains well into adjacent ditches, which then drain to infiltration areas. This kind of construction promotes trail longevity and minimizes inconvenience to the trail user.

(Left) Although not really noticeable to the trail user, this trail is perched high enough to consistently drain into adjoining natural areas, where water can percolate into the ground.

(Right) During the summer, the sandy soils of this trail corridor infiltrate runoff fast enough that standing water is not a major problem, even though the trail is very flat and slightly depressed. However, if the soil were clay, water could pool and eventually cause problems with the trail surface. Even in this case, standing water can be an issue during shoulder seasons.

Another reason drainage is important is to ensure that the trail is ecologically sustainable. Natural infiltration can help reduce the amount and flow rate of runoff from a trail, limiting impact on adjacent ecological systems.

Minimizing inconvenience and danger for trail users is another reason drainage is a key aspect of design. The most common of these instances are flooding of a trail during even modest periods of rain and ice forming when runoff cascades across the trail and freezes during shoulder seasons. The following photos illustrate some examples of these occurrences.

Traversing a north-facing slope is always a challenge during late spring and fall with snow and ice buildup. Where this simply cannot be avoided, place warning signs on either end of this type of trail segment.

"Bird baths" are largely avoidable if the contractor is paying attention to subgrade preparation and cross slope prior to laying down the pavement. This dip should be corrected.

Through thoughtful trail design, most of the highlighted drainage problems can be managed, resulting in a more enjoyable experience to the trail user and increased longevity of the trail's pavement section.

VEGETATION FACTORS

An often overlooked but important aspect of trail design is managing vegetation in the construction zone to prolong a trail's design life. Vegetation can impact the integrity of the trail, especially in natural settings where deep-rooted grasses and woody plants are abundant and aggressive. In trail construction, there are several approaches to controlling weed growth and root penetration through or under the trail.

Asphalt Depth as Related to Weed and Root Penetration

In trail construction, the depth of asphalt is typically based on creating a structurally sound trail that can stand up to site conditions and uses. Part of this evaluation is preventing weed and root penetration through the asphalt to extend the design life of the trail.

Too light of an asphalt pavement section increases the propensity for cracking, which is an open door for weed growth. Light pavement also tends to produce voids (air spaces) in the asphalt due to lighter use loads than is the case with a roadway. Over time, if the asphalt is not thick enough to compensate, these voids can be exploited by weeds and roots. Once weeds take root, they increasingly undercut the integrity of the trail.

For most applications, 2.5 to 3 inches of asphalt is optimal for structural integrity and for helping block weed growth through the surface. The 2 inch asphalt depth commonly used in the past most often proves too thin to prevent weed penetration.

Both of these trails have 2 inches of asphalt over a 4-inch aggregate base. As shown, both are structurally failing. Because they weren't built with adequate structural integrity to begin with, each will have to be completely replaced well before the end of a typical design life of 15 or more years.

Geotextile Fabric Weed/Root Barrier

If vegetation in the construction zone is dense and aggressive, the use of a fabric weed barrier is recommended. Determining when these fabrics are necessary is done on a site-by-site basis and through review of trails in similar situations. The following photos provide some indicators on what to look for in determining whether a weed barrier is justified.

This trail, which is only three or four years old, is showing the impact of shallow-rooted trees on the trail pavement. Left unchecked, this segment will continue to degrade and become rougher to ride on. A root barrier would be reasonable in this situation.

This trail, which is also only three or four years old, is showing the impact of prairie grasses and weeds growing in pavement cracks. Keeping the shoulder mowed and filling cracks each year is a reasonable and cost-effective solution here, rather than using a root barrier.

To determine whether a weed or root barrier is needed, evaluate older trails on or near the site where a new trail is being constructed. If none is present, review trails of similar characteristics and setting.

Weed and root barriers can be laid horizontally under the trail, vertically to its side, or both. Horizontal placement is for preventing weed growth from under the trail, with vertical placement suitable for preventing roots from growing in from the side of the trail.

Generally, geotextiles for use as a weed barrier under a trail are a minimum of 4 mils thick for normal application, and 6 to 9 mils in organic soils. When geotextiles are used for the structural purposes, they replace the need for a weed barrier.

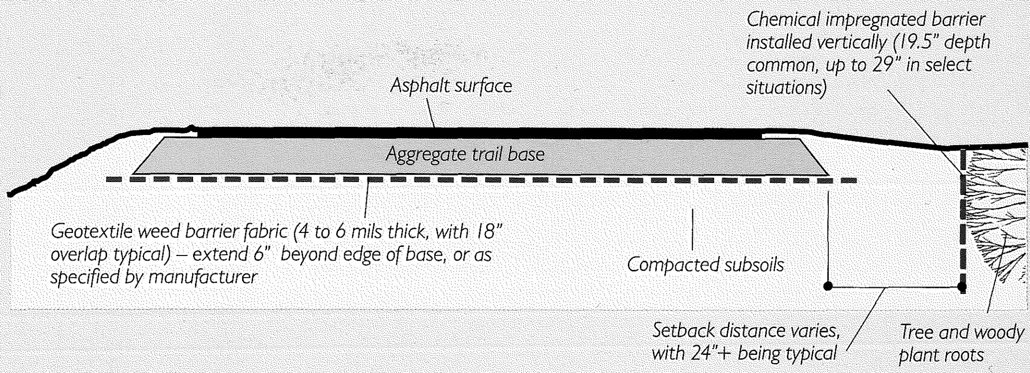
Where roots are a particular problem, a chemical barrier can be added to the fabric as long as it does not have any ecological impacts outside the treatment zone. The most common such barrier is Trifluralin, a herbicide that is bonded to the fabric and releases a 2-inch vapor that extends around each nodule in time-release form. As tree roots approach the chemical, it stops root tip cell division and the root grows in another direction. The chemical has been used for 35 years in agricultural applications, does not migrate, and leaves the plant unaffected other than the root tips that come in contact with it.

Vertical root barriers are a bit different than horizontal weed barriers. Tree and woody plant roots are very aggressive and routinely penetrate untreated fabric weed barriers. There are two common ways to prevent this: (1) using plastic panels, and (2) using a chemically-treated fabric.

Plastic sheeting and panels are routinely used for root barriers, with mixed results. Thinner sheeting tends not to work as well as thicker panels since roots can often penetrate thinner membranes. Panels are more expensive but are worth it in specific applications, such as adjacent to an occasional large tree along a trail. In most cases, the most economical approach is using a heavy Trifluralin-embedded fabric suitable for horizontal application.

The following graphic illustrates common application of weed and root barriers.

PLACEMENT OF WEED AND ROOT BARRIERS

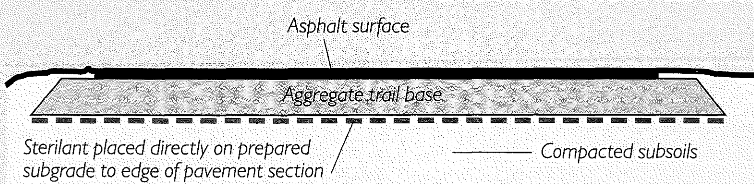


Whatever product is used, understand its environmental impacts, limitations, longevity, and strictly follow manufacturer installation instructions.

Soil Sterilization

Chemicals can be used to prevent vegetative damage to trails. The aforementioned bio-barrier available using Trifluralin bonded to the fabric is one such approach. There are also spray-on or granular types of soil sterilant that can be used, the most common of which is monobor-chlorate (such as Bare-Spot Monobor Chlorate, produced by Pro-Serve). Any chemical in the environment must be used with extreme care and applied by trained applicators. When in doubt, err on the side of safety and environmental safeguards. That said, the use of chemicals is appropriate when their benefits are clear, the quality and longevity of the trail enhanced, and their environmental impacts controllable. In using these products, follow manufacturer instructions and get input from ecologists on the specific application. The following graphic highlights one such product and its application – along with its precautions.

PLACEMENT OF WEED AND ROOT BARRIERS



Monobor-chlorate ingredients: *Sodium metaborate (68%) + sodium chlorate (30%) (can vary with product)*

Use: *Apply to the soil surface after the final grade has been established before placing aggregate. Granules may be dissolved in water and sprayed on or may be applied dry and followed with at least 2 gal water per 100 sq ft. Do not apply over the root zone of existing desirable trees and shrubs.*

Mode of Action: *Nonselective, residual herbicide that is effective at controlling weeds and inhibiting plant life under any pavement. Both of the ingredients are readily absorbed by leaves or roots, but the extent of translocation is not known. Can be applied as a pre- or post-emergence herbicide. Sodium metaborate may bind to and inactivate calcium in the plant. Sodium chlorate is a strong oxidizer, and may inhibit protein sulfonation. Can be applied at any time with reasonable safety to bees. Monobor-chlorate is persistent in soil. Manufacturer claims these chemicals are toxic to soil microorganisms extending the residual activity of the product, while also reducing the rate of herbicide degradation. (Note: This is not necessarily a desirable quality for an herbicide, but not limited to just this product.)*

Sites: *Terrestrial applications only! Do not use near water (trained ecologist should determine limits of use).*

Personal Protection Issues: *Due to relatively high toxicity, corrosiveness, and extreme use rates, applicator risk is relatively high. Monobor chlorate is corrosive to eyes, causing irreversible eye damage and can produce corneal opacity in humans – so personal protection, especially for eyes, is important during application, and avoid breathing dust or spray mist. Applicators need to wear goggles, face mask, or safety glasses with side shields. The product may be harmful or fatal if swallowed. Avoid contact with eyes, skin, or clothing, and wash thoroughly with soap and water after handling. Remove and wash contaminated clothing before reuse.*

Notes: *Mammalian toxicity is fairly low-acute oral LD50 dosage to rats is 6,810 mg/kg body weight and acute dermal LD50 to rabbits is 20,000 mg/kg body weight. Product cannot be stored in opened bag – all material must be used upon opening.*

Trail Pavement Design – Paved Trails

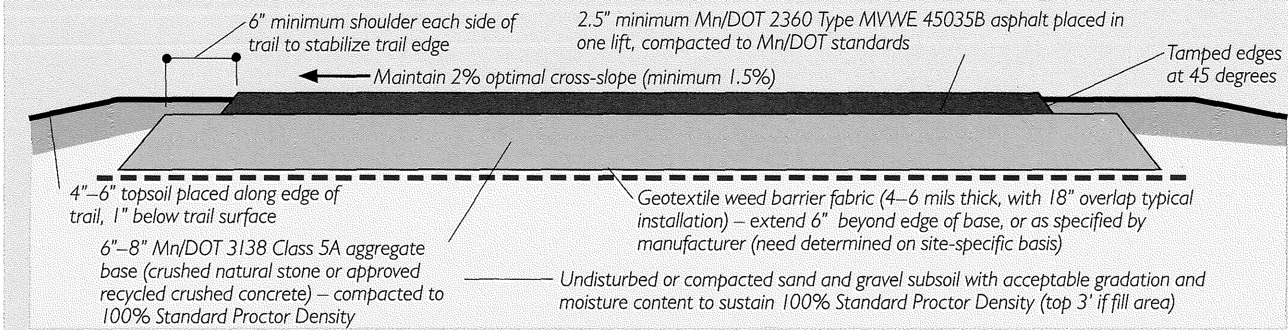
Specifications note!
All listed Mn/DOT specifications should be verified since the numbers occasional change.

The following considers the technical design for asphalt trails (over various soils and on old rail grades), aggregate trails, and concrete trails.

Asphalt Trail Pavement Design – Sand and Gravel Subsoils

Sand and gravel are the most reliable subsoils for constructing a trail due to their structural characteristics, most notable of which is stability and capacity to drain well. These soils also retain a substantial amount of their load-bearing capacity when wet. The following graphic illustrates a common pavement design for this type of soil.

Asphalt Trail on Sand and Gravel Soils

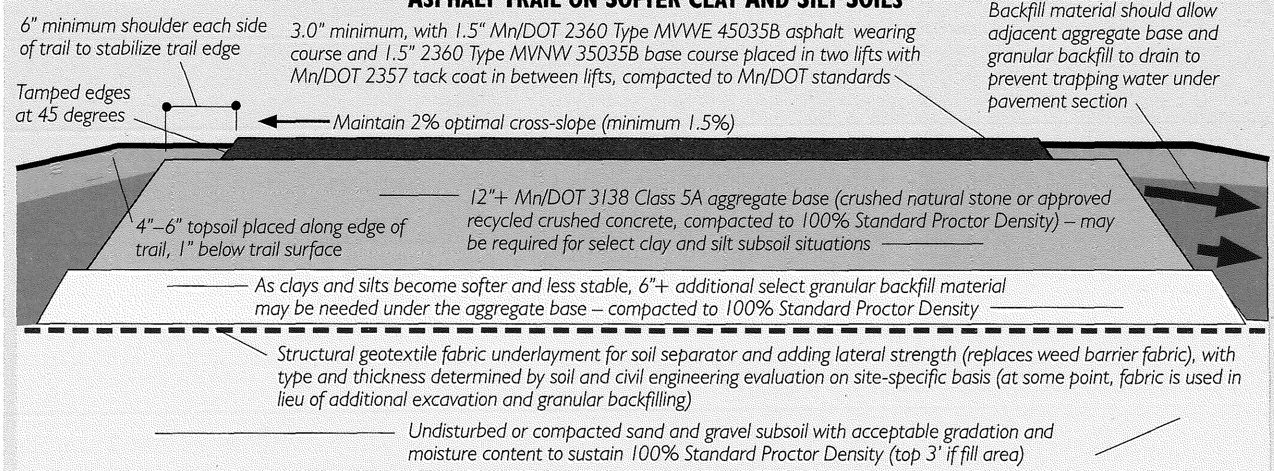


Site preparation requirements: *Strip vegetation to 5' beyond the edge of the trail. Remove topsoil to minimum 3' feet beyond the edge of the trail or as required for paving equipment. Stockpile topsoil in piles 8' or less in height for later reuse.*

Asphalt Trail Pavement Design – Clay and Silt Subsoils

Clays and silts are less reliable subsoils for construction. The type of clay and silt also makes a significant difference. For hard, dry clays that are well compacted under optimal moisture content and where drainage migrating under the finished trail can be minimized or avoided, the trail cross-section illustrated for sands and gravels is often suitable. If clays become "softer," where firmness is lost and the subsoil is prone to becoming unstable and more plastic when wet, a heavier pavement cross-section is needed. This is also the case when the water table rises close to the pavement surface. The following graphic illustrates a common pavement design for clay soils that are soft and not reliably stable. Be sure to use soil testing and engineering to determine the depth of granular subgrade.

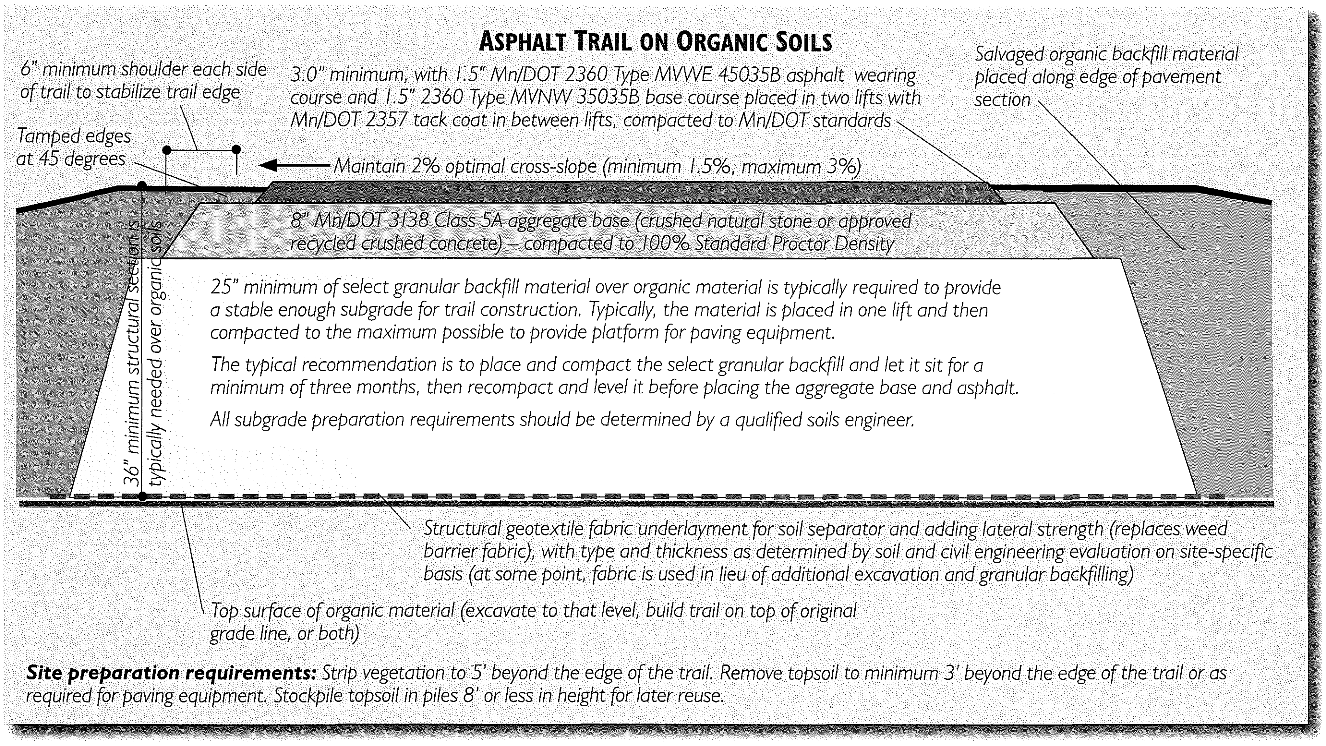
Asphalt Trail on Softer Clay and Silt Soils



Site preparation requirements: *Strip vegetation to 5' beyond the edge of the trail. Remove topsoil to minimum 3' beyond the edge of the trail or as required for paving equipment. Stockpile topsoil in piles 8' or less in height for later reuse.*

Asphalt Trail Pavement Design – Organic Subsoils

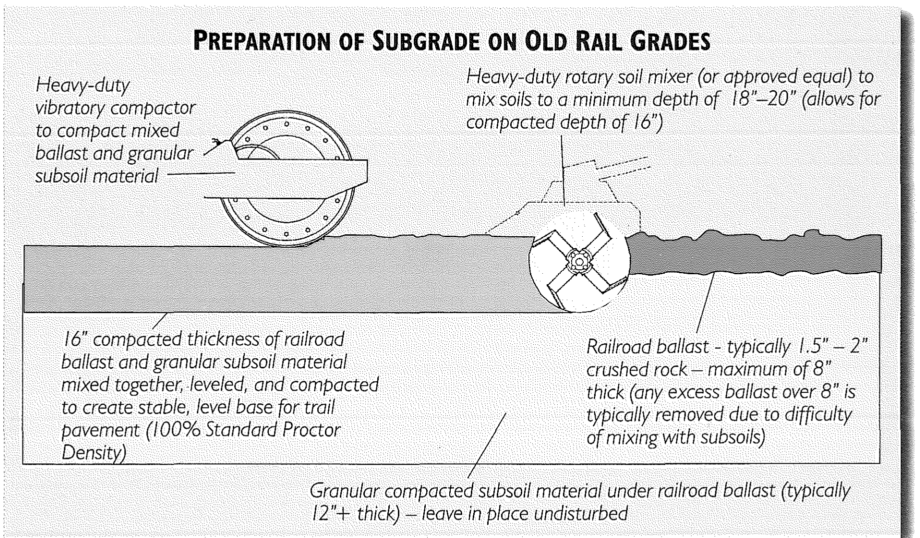
Organics and peats are the most unreliable subsoils for construction and most expensive to build a trail across. They also tend to be located in ecologically sensitive areas that are best avoided in many cases. Should a trail be justified in an area with this type of soil, additional precautions are required to create a firm enough base for construction. The following graphic illustrates a general pavement design for organic soils. As with clay soils, determining the depth of granular subgrade requires soil testing and engineering.



Asphalt Trail Pavement Design – Old Rail Grade With Ballast

Once ties and steel tracks are removed from a typical railroad grade, the remaining ballast is uneven and too coarse for placement of trail pavements. Typically, the subgrade is prepared using a rotary soil mixer that mixes the top 16 inches into a well-graded subgrade mixture.

In general, rail grades make for a solid structure to support a trail. They also require some special preparatory work to deal with existing ballast in a cost-effective way. The following graphic illustrates a common technique for preparing the subgrade on old rail grades before paving the trail.



When the rail grade is prepared, the pavement design is consistent with that used for sand and gravel subsoils (above).

AGGREGATE TRAIL PAVEMENT DESIGN – GENERAL SUBSOILS

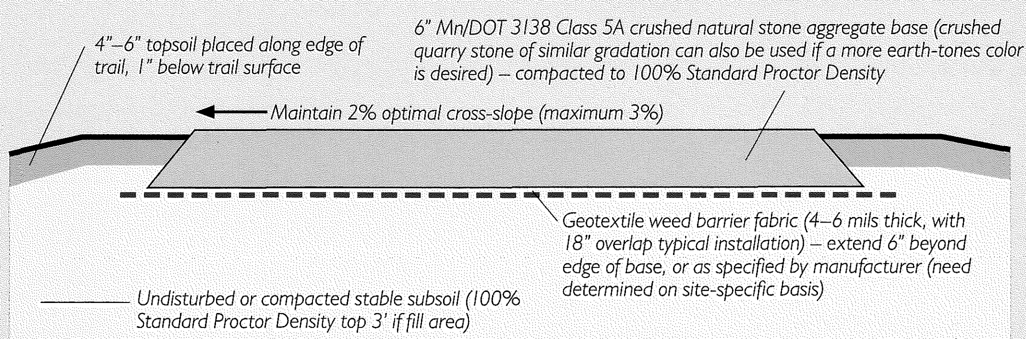
Aggregate surfacing is occasionally used for multipurpose trails to provide a more natural character, keep the cost down, or limit the type of users accommodated. For example, in some natural areas a 6-, 8-, or 10-foot-wide accessible aggregate trail might be desired for its character and to limit use to walkers and wheelchairs.

If there is any chance the trail may one day be paved, prepare subsoil as for asphalt trails under the various soil conditions. On sand and gravel soils, the same practices for asphalt trails is recommended even if the trail is to be permanently aggregate surfaced. On clays and silts, the degree to which subsoils are modified depends on willingness to accept surface unevenness and increased maintenance over time. The more the subsoils are modified consistent with recommendation for asphalt trails, the less maintenance that will be required to keep the trail in good form.

Since aggregate is much more prone to erosion, good drainage of the trail surface is important. Where trails traverse varying topography with steeper grades and side slopes, refer to Section 6 – Sustainable Natural Surface Trails for additional design practices that can be used to prevent erosion and promote trail stability.

The following graphic illustrates a common aggregate pavement design over a stable subsoil material.

AGGREGATE TRAIL ON STABLE SUBSOILS



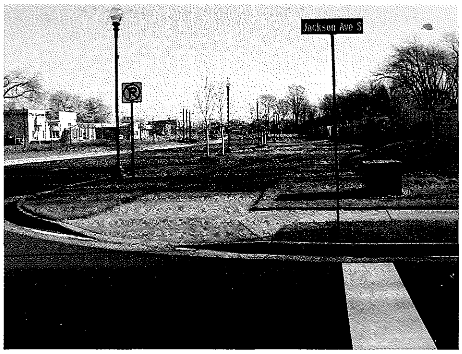
Site preparation requirements: *Strip vegetation to 3'–5' beyond the edge of the trail. Remove topsoil to a minimum 3' beyond the edge of the trail or as required for paving equipment. Stockpile topsoil in piles 8' or less in height for later reuse.*

Structural geotextile fabric underlayment: *May be added as soil separator and for lateral strength (replaces weed barrier fabric), with type and thickness as determined by soil and civil engineering evaluation on site-specific basis (at some point, fabric is often used where additional excavation is too costly for an aggregate trail yet some additional stability is still needed). Note that to gain some structural value, a minimum of 12" of compacted aggregate is needed on top of the fabric.*

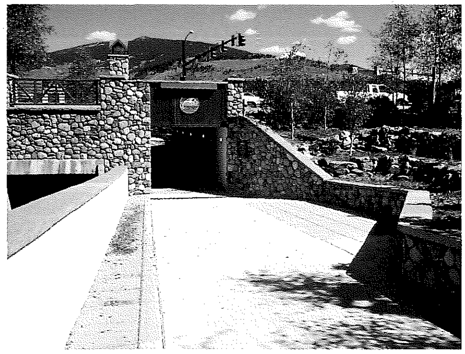
CONCRETE TRAIL PAVEMENT DESIGN – ON STABLE SUBSOILS

In Minnesota, concrete has both advantages and limitations. Concrete is very resilient and has a long design life. However, crack control joints and the propensity for panels to shift over time through freeze-thaw cycles often create uneven surfaces. For walking, this is not a major problem; concrete is routinely used for sidewalks. For bicycling and in-line skating, it is a major annoyance and will affect trail use. Concrete is also considerably more costly than asphalt.

Given its limitations, concrete is not recommended for general trail construction. However, it does have application in several instances, such as landing areas associated with accessible ramps and in transitional areas where the contrast in surfacing is a visual cue to bicyclists and in-line skaters to slow down and respect other users in the area. It also has application in flood-prone areas, where it has proven to be more durable than asphalt. The photos on the next page highlight a number of examples where concrete is effectively used.



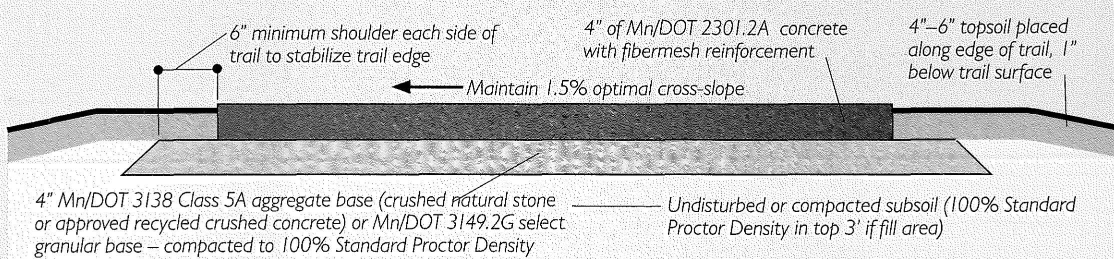
Landing areas and ramps. *Concrete can be very effectively used to highlight a landing area or accessible ramp where a trail intersects with a street crossing. In these instances, bicyclists and in-line skaters are going slow so the crack control joints in the concrete are not much of a bother. Notably, in the left photo, it is easy to understand how the joints in the concrete would become annoying to trail users over an extended distance.*



Transition areas. *Concrete can be very effectively used in transitional areas where the area is shared with a variety of trail users and can become congested. The change in pavement can alert bicyclists and in-line skaters to slow down and pay more attention, which is similar to traffic calming techniques used in roadways.*

The following graphic illustrates a common concrete pavement design over a stable subsoil material.

CONCRETE PAVEMENT ON STABLE SUBSOILS



Site preparation requirements: *Strip vegetation to 5' beyond the edge of the trail. Remove topsoil to minimum 3' beyond edge of the trail or as required for paving equipment. Stockpile topsoil in piles 8' or less in height for later reuse.*

Concrete reinforcement: *Fibermesh reinforcement (fibers mixed into the concrete to increase structural integrity and keep cracks from splitting apart) is recommended for general use. Welded wire mesh may also be recommended by an engineer on a site-specific basis for structural reasons.*

Concrete crack control joints: *Saw cut joints are recommended at regular intervals to control the location of inevitable cracking. Control joints should be at least one-third the depth of the concrete thickness. Sawcuts joints tend to be a bit smoother than troweled.*

Maintenance Guidelines

The following maintenance guidelines provide general recommendations for monitoring and maintaining paved trails. The objective is to prolong the life of the trail and provide a safe surface to travel on. The guidelines are based on common practices in Minnesota and take into consideration climate and other site conditions. Note that the guidelines are generic and not a substitute for trail-specific maintenance tailored to local soils, use loads (including maintenance equipment), and other conditions.

Monitoring and Inspections Schedule

Trail monitoring and inspections should occur throughout the year to detect maintenance issues before safety is compromised. The following table provides an overview of inspections that can be completed during each season.

Inspections Schedule

A routine inspection schedule is important for staying on top of maintenance issues and taking care of problems at an early stage. The following is a suggested seasonal schedule for inspections.

Season	Inspection Focus
Spring	Inspect for damage from winter use and freeze-thaw cycles. Check for erosion, plugged culverts, user and maintenance vehicle–caused damage, slumping, cracking, and other visible signs of surface imperfections. Record problems and schedule maintenance on a priority basis.
Summer	Inspect regularly. In addition to items listed for spring, also inspect vegetation growth and encroachment and pay special attention to drainageways and ditches that may have received erosion during the spring runoff. Record all problems and schedule maintenance on a priority basis.
Fall	Inspect regularly. Focus on maintenance that should be done before winter to avoid more damage during spring thaw. Pay special attention to culverts and drainageways that will be needed to handle spring runoff. Fill cracks.
Winter	This is good time of year to check low areas and drainages that cannot be easily accessed during the summer. This includes culverts, ditches, and beaver ponds.

A good reference to have!

The U.S. Army Corps of Engineers Special Report 81-21 for asphalt maintenance and repair is a useful reference that can be found at www.hnd.usace.army.mil/techinfo/UFC/ufc-3-270-01.pdf#search='Army%20Corps%20of%20Engineers%20Pothole%20Primer'.

General Maintenance Guidelines

Maintenance of shared-use paved trails falls into a number of basic categories.

Vegetation Management

To maintain an acceptable clearance zone and preserve the integrity of the trail surface, vegetation along the trail must be managed. Preventing vegetation from breaking up the edges of the asphalt surface is especially important to trail longevity. If vegetation is left unchecked, cracking, crumbling, and surface holes can rapidly develop.

Woody vegetation close to the trail can send root suckers under and then through the asphalt, destroying the integrity of the pavement. This vegetation needs to be removed by cutting and/or spraying of an approved herbicide by a licensed applicator. Cutting is the preferred method whenever possible, and the only acceptable approach in ecologically sensitive areas.

Herbaceous cover along the shoulders should be mowed to minimize encroachment problems. A 2- to 3-foot mowing strip is typically the minimum along most trails.

If erosion has taken out vegetative cover, solve the problem before restoring vegetation.

This crack is getting very close to being too wide for filling, with the next step being to remove and patch the area or do an overlay.

Without addressing the underlying problem, this edge patch will likely only be a temporary solution. It is also fairly rough, meaning that trail users will drift into the opposing lane to get around it.

Asphalt Crack Repair

Routine crack repair is critical to trail longevity. It is especially important to complete this work before winter.

In general, all cracks wider than three-eighths inch should be filled. Those wider than one-half inch should be cut out and patched. Longitudinal cracks, which are typically structural problems, should be cut out and patched, not filled. Common crack filling materials include Mn/DOT specifications 3719 or 3723 or a rubberized product meeting Craftco AR-1 specifications. Field tests suggest that the results of these products are similar, although the rubberized mixture may be somewhat more resilient.

In areas where cracking is extensive and the subgrade is deemed stable by an engineer, an overlay should be used since the problem will not be resolved through crack filling.

Repairing Crumbling Edges

Broken or crumbling edges are typically caused by either poor subgrade preparation before paving or heavy maintenance vehicles deflecting the asphalt surface and causing it to fail, especially in the spring during the frost-out period. Poor subgrade drainage can also be a factor in edge failure. If the trail, subgrade, and base material are poorly drained and remain wet, especially through freeze-thaw cycles, pavement failure can be expected, typically starting at the edge where the pavement is the weakest.

Cutting out the damaged area and inspecting the subgrade is required in these instances. If the subgrade is confirmed to be stable, the area can be patched using Mn/DOT specifications for asphalt repair, which include the use of a tack coat to seal the patch from moisture. If the patching area is large, removal of the entire area and replacement is recommended, since patches can annoy trail users.

Pitting and Grooving

Pitting and grooving are caused by snowmobilers using a trail during times of marginal snow or by trail grooming or snowplowing equipment. If the damage is extensive enough to be of concern, an asphalt overlay of at least 1 inch is recommended. In the most severe cases, or when this is a routine problem (such as the approach to a bridge), using concrete for a section 30 feet or less of trail is a common approach.

Slumping, Caving, and Holes

Slumping, caving, and holes can be attributed to many factors, including animals, erosion, culvert failure, settling at bridge approaches, and subgrade problems.

To repair holes caused by animals, smoothed them out, repack the subgrade, and fill with an asphalt patch, which should be compacted. The patch should be level with or slightly crowned (but not lower than) the adjoining surfaces to avoid trapping water and causing future problems.

In situations where erosion and culvert failure are the problems, identify and address the cause before making the repair. Use the patching approach described above

The area where an asphalt trail surface abuts a bridge deck is highly susceptible to separation, cracking, and slumping. Although specific repairs depend on the bridge design, the typical problem is the lack of a solid backing for the asphalt surfacing to be placed against or over. Either concrete or pressure-treated wood can often be used in these situations, although site-specific solutions are most common due to the variability of what can be encountered. The bridge manufacturer, who should be contacted to ensure that solutions do not compromise the bridge's integrity, may have additional suggestions.

SEALCOATING

This trail was sealcoated with a black sealcoat with no sand or crushed rock chips, which makes for a smooth surface, although a bit more slippery than asphalt. For many, the value of sealcoating remains uncertain.

> ***Specifications note!***
> All listed Mn/DOT specifications should be verified since the numbers occasional change.

Sealcoating relates to a surface treatments used to cover minor surface imperfections and asphalt deterioration from weathering and oxidation. Although sealcoating has its advocates, it also poses some significant limitations, including:

- Short life span – with extreme variability between products
- Tendency for the finished surface to become slippery when wet unless a material such as sand or crushed rock chips are added (which is not desirable for most bicyclists and inline skaters)
- Incompatibility and inconsistency in products – with some products found to not bind to asphalt very well

For these reason, the cost/benefit of sealcoating is uncertain and some maintenance departments forgo it and do an overlay on a shorter rotation with the money saved. Note that as products improve, the cost/benefit of sealcoating may become more justifiable.

If sealcoating is used, it should typically not be placed over certain types of crack filler due to adherence issues. If it is used, the following products are recommended by the Mn/DOT (verify before use):

- Slight deterioration – use Fog Seal (Mn/DOT 2356)
- Moderate deterioration – use Seal Coat (Mn/DOT 2356, FA-1 or FA-2 or Slurry Seal Type 1)
- Serious deterioration – use asphalt wearing course overlay

For best results, seal coating should be applied in the second year to prevent moisture from seeping into surface cracks and voids and to prevent the surface from drying out. Thereafter, seal coating every 3 to 5 years is common.

OVERLAYMENTS

This trail is simply so old and cracked that an overlayment or total reconstruction are the only practical approaches to improving it.

Overlayments should conform to standards Mn/DOT specifications. The following provides an overview of some of the basic products, although it is recommended that an engineer familiar with current practice verify any specific products or mixes that are used. Each of these also require the use of sweeping, paving, and packing equipment.

Hot Mix

Mn/DOT specification 2360 Type MMVWE 45035B asphalt wearing course is recommended in most applications. A minimum of 1 inch depth is typically necessary. A tack coat (Mn/DOT specification 2357) should be used as a binder with the existing asphalt surface. Hot mix is considered the most durable overlay material.

Cold Mix

This typically consists of asphalt cement mix that has been liquefied with solvents, which then evaporate and allow the mix to cure. The type of mix is critical to performance and an engineer or maintenance supervisor should determine the right product for the circumstances. Cold mix is not considered as durable as hot mix and should only be used when weather conditions do not allow hot mix to be used.

Note that infrared heaters can be used in surface repair to heat the surface and improve cohesion. Also, sweepers and blowers should be used to clean debris off the trail prior to repair work.

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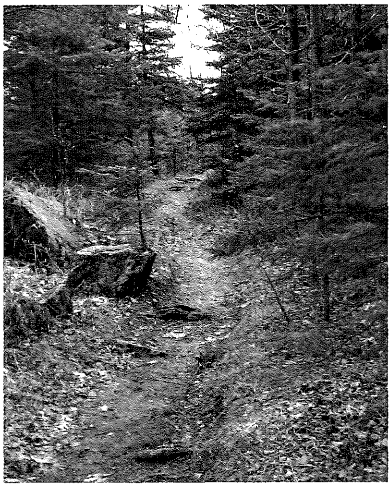
SECTION 6 - SUSTAINABLE
NATURAL SURFACED TRAILS

SECTION

6 Sustainable Natural Surface Trails



This simple, timeless hiking trail in a Minnesota park has served hikers well for decades with little year-to-year maintenance. The longevity and sustainability of this trail is due entirely to its design.

Important additional information!

The descriptions for each of these trail types in Section 4 includes considerable information on layout configurations and common design features.

OVERVIEW

Sustainable natural surface trails serve a variety of user groups, including hikers, horseback riders, mountain bikers, and OHV riders. Although these groups are quite varied, the process of designing trails for any of them follows similar principles and design techniques, as defined in this section.

KEY PRINCIPLES OF SUSTAINABLE NATURAL TRAILS

A multiuse paved trail and a sustainable natural surfaced trail are decidedly different. The former is hard surfaced, geometric in form, and comparatively stable, while the latter is soft surfaced, follows the contours of the land, and is much more susceptible to natural forces. These differences dictate decidedly different approaches to trail development. Three key principles set the foundation for designing sustainable natural trails:

1. **Natural surface trails are shaped, not built.** These trails reflect the landscape being traversed and respond to the many nuances of a site that make them interesting to the trail user.
2. **Carefully considered tread alignments, site slopes, and tread grades are favored over extensive grading and other mechanical means to create a trail.** This is especially the case with drainage, where the design of the trail is used to control erosion and prevent displacement of the trail tread.
3. **Potential changes to tread shape due to compaction, displacement, and erosion must be anticipated as part of the design process.** This means the tread must be designed so it will still drain with limited potential for erosion even if it changes shape through years of use.

NATURAL TRAIL CLASSIFICATIONS

As defined in Section 4 – Trail Classifications and General Characteristics, there are a number of classifications for natural surfaced trails, including:

- Hiking Trail
- Equestrian Trail
- Mountain Biking Trail
- OHV Trails (including ORV, ATV and OHM subclassifications)

Although each of these types of trails has individual nuances, their design follows common principles and techniques.

PUBLICATIONS THAT COMPLEMENT THE GUIDELINES

A number of natural surface trail development-related publications are referenced in this section. Each has relevance to specific trail development issues that require greater detail than can practically be provided here. Trail designers are encouraged to obtain a copy of the relevant publications to become familiar with their content and application.

Trail Solutions – IMBA's Guide to Building Sweet Singletrack

Published by IMBA , this resource provides user-friendly guidelines on building high-quality mountain bike trails. Find it at www.imba.com/resources/trail_building/trail_solutions.html.

Forest Service Trails Reports 2004

This collection of reports related to trails covers a wide variety of subjects pertinent to developing natural surface trails. A CD-ROM of the reports is available at www.fhwa.dot.gov/environment/rectrails/trailpub.htm, under the publication 0423-2C03-MTDC Forest Service Trail Reports 2004.

General Design Guidelines and Considerations

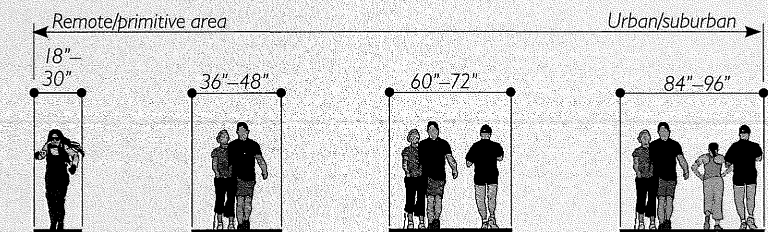
The following guidelines provide general design parameters for creating sustainable natural surface trails. These guidelines are not intended to be a substitute for site-specific design that responds to local conditions and safety concerns.

Trail Tread Widths

The physical space required for different trail users provides the base-line for determining the optimal width for a trail. Even within a given classification, site-specific circumstances often require alternative configurations to accommodate the anticipated types and levels of use. The graphics on this and the following page illustrate the basic trail width requirements for different types of uses associated with natural surface trails.

Typical Trails Widths For Natural Surface Trails – Nonmotorized Uses

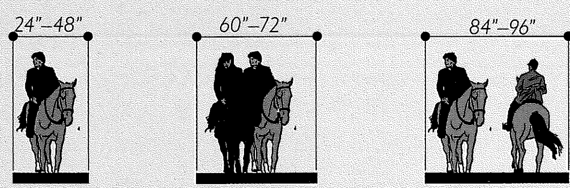
Trail widths vary considerably depending on type of use and whether a trail is single or double track and one or two directions. Trail width must also be based on a solid understanding of how a trail will be used since over time it will take the shape users give it irrespective of how it was originally designed. This is a distinct difference between paved and natural trails and must be accommodated in trail design. The following defines the basic trail widths and directional configurations for each type of natural surface trail use.



Single hiker | *Staggered or side-by-side hikers* | *Staggered and single hikers with room to pass* | *Staggered or side-by-side hikers with room to pass*

Hikers walk alone, staggered, or side by side, depending on the setting and character of the trail. The more remote or primitive an area, the narrower and more rugged the trail tends to be. In more urban areas, hiking trails tend to be wider due to heavier levels of use. For hiking-only trails, a width more than 96 inches (8 feet) is uncommon.

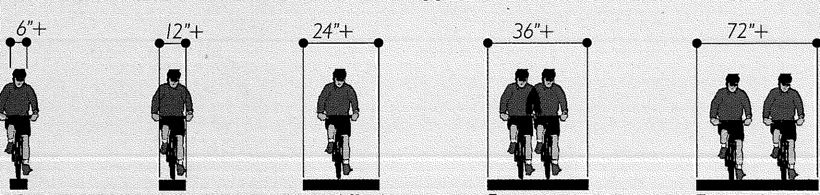
Typical Hiker



Single rider, one-way | *Staggered or side by side riders* | *Side by side and two-way riders and carriages*

Horseback riders walk single-file, staggered, or side by side, depending on the setting and character of the trail. As with hiking, the more remote or primitive an area, the narrower and more rugged the trail tends to be. In regional and state parks and along linear trail corridors, equestrian trails tend to be wider due to heavier levels of use and the desire to ride side by side. Carriage trails need to be at least 8 feet wide, plus a shoulder.

Typical Horseback Rider



Extremely difficult (dbl. black diamond) | *Very difficult (black diamond)* | *More difficult (blue square)* | *Easy (green circle)* | *Easiest (white circle)*

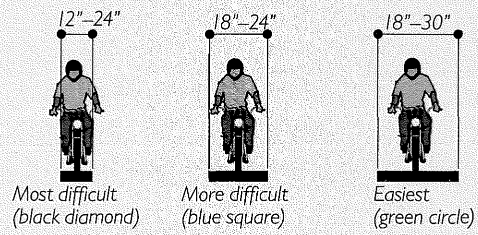
Mountain biking trail widths typically correspond to the trail rating system for difficulty as defined in Section 4 - Trail Classifications and General Characteristics. Two-direction trails are typically easier and wider trails.

Typical Mountain Biker

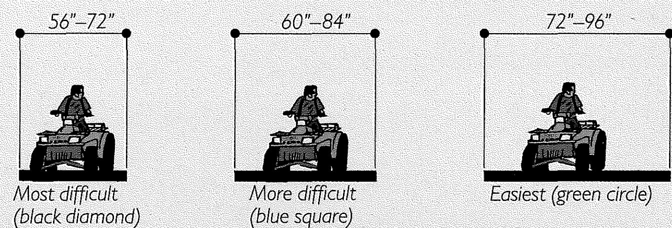
Typical Trails Widths for Natural Surface Trails – Motorized Uses

For OHV trails, tread widths vary considerably with type of use and level of difficulty. As with nonmotorized natural trails, trail width must also be based on a solid understanding of how a trail will be used since over time it will take the shape users give it irrespective of how it was originally designed. The following defines the basic trail widths and directional configurations for each type of natural surface trail use consistent with the difficulty levels defined in Section 4 – Trail Classifications and General Characteristics. Note also that trail widths are only one aspect of difficulty levels for OHV trails. Grades, curve radius, clearances, tread surface, and other characteristics are other factors in establishing a trail difficulty rating.

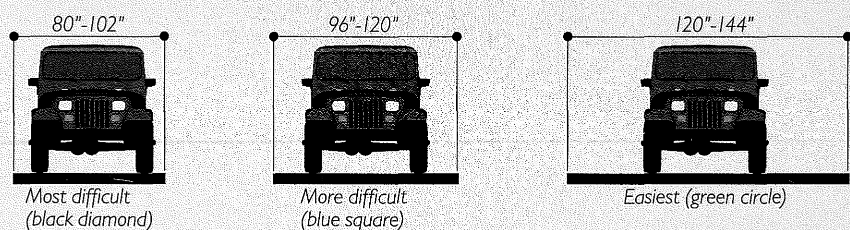
The tread widths shown for each type of use are for one-way travel, especially on the "more" and "most" difficult trail levels. For two-way use, provisions need to be made for passing. This can take the form of a wider trail or a series of well-placed pullouts. Refer to Section 4 – Trail Classifications and General Characteristics for additional information on trail layout configurations for OHV trails.



OHM Rider



ATV Rider



ORV

Forces Acting Upon Natural Surface Trails

Three fundamental forces acting upon all natural surface trail treads:

- **Compaction** – a downward force from the weight and impact of feet, hooves, and wheels
- **Displacement** – a sideways shearing force from friction and impact of feet, hooves, and wheels
- **Erosion** – the transport of materials by water or wind

Every tread problem is caused by one or more of these three forces acting alone or in combination. While standing water (mud and mudpits) and moving water (erosion) are generally perceived as the most obvious tread problems, compaction and displacement create the conditions for both to occur. The following considers each of these forces in more detail.

Compaction and Displacement

Different uses impart different compaction and displacement forces. Walking humans produce mostly compaction with slight displacement as particles are scraped and kicked forward and to the sides. The tread is deepened and hardened as the voids in the soil collapse and soil particles are pressed into tighter contact.

Horses exert a much higher compaction force and more displacement as they flip their hooves. Since horses tend to walk single file, the tread tends to deepen into a narrow slot while displaced material piles up on each side. OHMs with knobby tires and quick acceleration and braking exert more displacement force, which tends to throw soil completely out of the tread.

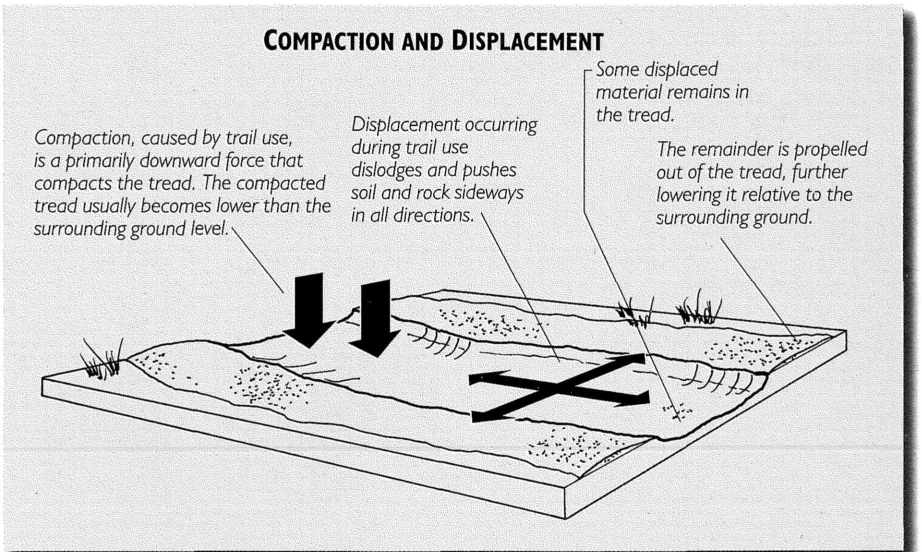
Compaction and displacement nearly always lowers the tread. On level ground, the sunken tread becomes the lowest point around and its compacted bottom prevents or slows water percolation. In wet conditions, this sunken tread will collect water. Trail users may try to make dry detours around the mud and water, which unfortunately spreads the tread across a larger area.

Displacement increases in wet or muddy conditions when bonding between soil particles is weakened or lost. Mudpits result from concentrated displacement and erosion as loosened soil is sloshed out of the pits.

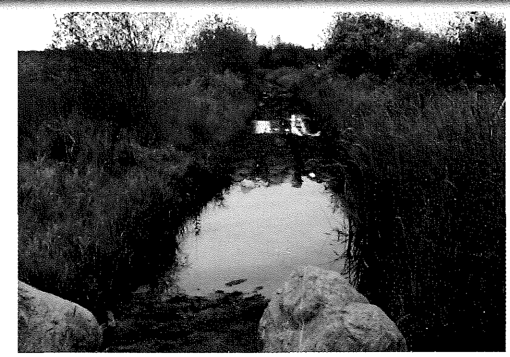
Foot tread. *Compaction and displacement from extensive use deepened this tread. The compacted tread is firm. Some soil loss is due to erosion from water flowing down the trench initially formed by compaction and displacement.*

Horse tread. *Horses flip their hooves as they walk, displacing soil a short distance in all directions. In loose soil, displacement forms distinct berms on each side of the trail. In firmer soils, horse trails can be firmly compacted (desirable).*

OHM tread. *Rapidly spinning knobby tires can cause high displacement, especially in looser soils. While soil is displaced in all directions, the throw pattern changes in response to curves and grades. This causes patterned displacement such as banked curves.*



Compacted treads, with reduced air spaces between particles, are firmer and more resistant to displacement and erosion. But they also absorb less water, increasing the amount standing on or flowing down the trail. In this level area, water puddles on the tread, while it sinks into the ground everywhere else.



On level or near-level ground, compaction and displacement sink the tread below the surrounding soil level. The tread then ponds water, causing mud and mudpits.

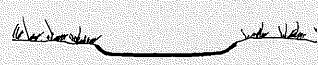
The extent to which compaction and displacement occur on natural surface trails is greatly affected by the type of use. Heavier, more powerful uses tend to have a greater propensity for compaction and displacement. The following graphics illustrate the compaction and displacement characteristics of six types of trail uses.

Natural Trail Uses and Impact on Trail Stability and Sustainability (Part I of 2)

Human – Hiking, Walking, and Running

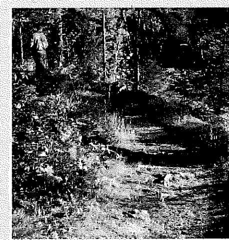
Compaction: Low–Medium.
Displacement: Low.

Most force is concentrated at one part of a person's foot, creating a relatively high force per square inch. As the foot rolls through a step, most of the force is angled downward at slow speed, causing moderate compaction. Part of the force is angled laterally (more or less parallel to the ground), creating some displacement. At walking speed, there is no appreciable centrifugal displacement on curves. Running increases speed, downward force and lateral force, causing somewhat faster compaction and a bit more displacement, especially on curves.



Hiking treads develop a pan-shaped tread with a nearly flat bottom and rounded edges. Most of the indentation is from compaction.

This typical shallow pan of a hiking trail reflects the tendency to walk in the center.

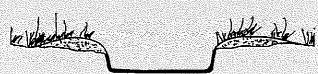


Compaction and erosion leave rocks and roots protruding from an otherwise smooth trail.

Horse – Riding or Pack

Compaction: High.
Displacement: Medium.

High force created by the weight and motion of animal and rider is concentrated on a small foot, imparting very high force per square inch and a high compaction force. A high displacement force is also created as horses kick their hooves, displacing soil entirely out of the tread and forming berms on both sides. These factors can quickly cause ruts in soils lacking displacement resistance. If the tread does become compacted, it typically is hard and strong enough to resist additional displacement. At walking speeds, no appreciable centrifugal displacement occurs on curves. The typically low speed of the animals also keeps most displaced material close to the tread.



Horse hooves create 18"-wide treads with flat bottoms and vertical side. In sandy soils, the tread can become quite deep from displacement.

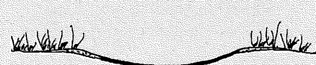
Frequent horse use typically produces an 18"–wide entrenched tread.

Horses rapidly displace sandy soil. Displaced soil forms a berm at the edge of the used trail.

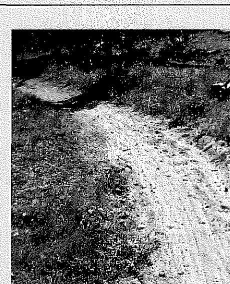
Mountain Bike

Compaction: Low.
Displacement: Low–Medium.

Tires with knobby tread impart a quick but strong downward force on a trail tread, creating a strong compaction force on the small area of the knobs. Since the tires are spinning, usually with acceleration or deceleration forces, they also impart lateral force. Most of this force is parallel to the tread and displaces soil accordingly. Some soil, however, is displaced out the tread, especially dust and larger particles. The faster the tire spins and the more force is applied, the more displacement occurs. In time, mountain bike trail treads tend to develop a gentle depression in the middle from compaction and displacement. On curves, bikes create strong centrifugal force that displaces soil toward the outside, tending to cause superelevated curves to form.



Mountain bike tires form gently swaled treads from compaction and displacement. Displaced material can go completely out of the tread.



Mountain bikes can cause extensive displacement in sandy soils.

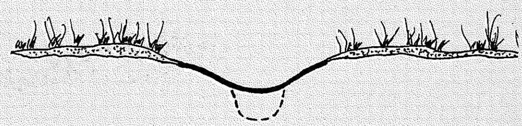
This superelevated curve resists horizontal displacement while draining well.

Natural Trail Uses and Impact on Trail Stability and Sustainability (Part 2 of 2)

OHM

Compaction: Medium. **Displacement:** Extreme

The type and direction of forces of OHM tires are almost identical to those exerted by mountain bikes, but OHMs have far greater weight, speed, and acceleration forces. Coupled with deep knobby tires designed to dig in to soft soils, OHMs create more compaction and many times more displacement force than bicycles. Displacement on a narrow OHM tread can be severe and highly focused, resulting in deep ruts where tread lacks resistance. Displaced tread material is often thrown far from the tread. On curves, strong centrifugal force tends to form superelevated curves in many tread materials. Note, however, that while displacement force can be extreme, the point of contact and the amount of material moved is small. Displacement can be high in dry, wet, and muddy conditions.



OHM treads develop a narrow, rut-shaped tread with high displacement.

(Left) At best, dedicated OHM treads are bowl-shaped swales with no vertical edges.

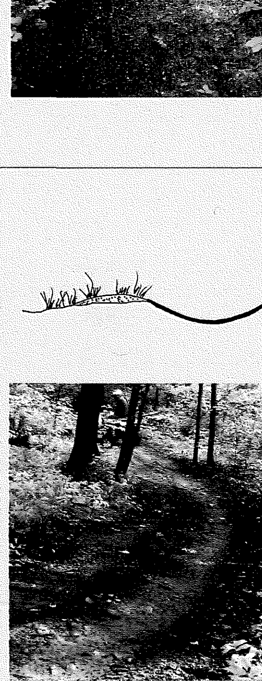
(Right) OHM treads are prone to rutting in soils with low cohesion.

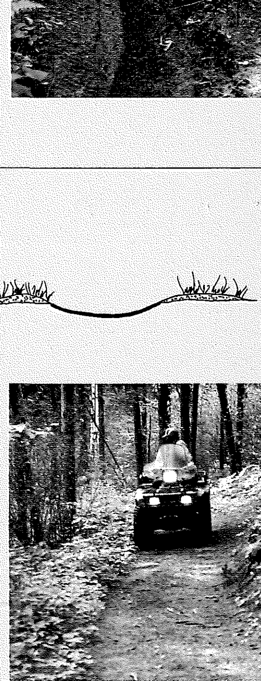
ATV

Compaction: Medium. **Displacement:** Very High.

The relatively low weight of ATV and rider are distributed across four wide tires. This imparts relatively little compaction force per unit area, leaving trail tread only partially compacted. Yet ATVs, with engine power and relatively small-diameter tires, produce great torque. Combined with high travel speeds, quick acceleration and braking, and aggressive tread designed to dig part-way into soft soil, ATVs create a very high displacement force. The impact of little compaction but very high displacement can quickly rut a trail tread, with displaced material flung wide. At higher speeds, ATVs tend to skim along the surface, imparting extreme displacement force on the tread particles they do touch. On curves, especially tight curves, rapid displacement and centrifugal force nearly always creates superelevated tread over time unless the tread is well compacted. Displacement can be high in dry, wet, and muddy conditions.

ATVs create dual depressions through displacement by small tires with high torque.





(Left) ATVs can cause rapid displacement on new trails in uncompacted soils.

(Right) ATVs on this compacted former roadbed cause little displacement.

ORV (SUVs and Pickups)

Compaction: High. **Displacement:** Low–Very High.

Greater vehicle weight creates much more compaction than ATVs, while greater weight and engine power can create greater lateral displacement force. ORVs, however, tend to travel much more slowly than ATVs or OHMs, reducing the displacement that would occur at higher speeds. High compaction force tends to strengthen the tread under the wheels, often greatly reducing the amount of displacement that actually occurs. High-flotation, low-pressure "mudder" tires create less compaction than stock highway tires. Generally, though, the visitor-hardened tread of ORV trails tend to be strong unless the tread material cannot be compacted or has lost internal strength due to moisture. On sharp curves, most ORV drivers travel slowly and hence centrifugal force is low. On steeper slopes and in muddy tread, displacement can be very high.

Heavy weights and slower speeds create less displacement on ORV trail than on ATV or OHM trails.

(Left) Like most unpaved roads with room to move side to side, ORV treads tend to be smooth and hard.

(Right) Confining horizontal movement concentrates ORV forces in two narrow ruts.

EROSION

Even on slight grades, erosion caused by water can wash away tread material. Soil already loosened by displacement is the first to go. The higher the water volume, the more extensive erosion will be, especially on steeper trail segments. Although light rains may not cause much erosion, heavy rains can cause significant damage to the trail.

Compaction through trail use actually helps prevent erosion by hardening the tread materials, except in cases of pure sand and other large particles without binders. Even compacted tread, however, can be overwhelmed by high runoff volumes or speeds. Although a given segment of tread may be able to withstand erosion during a rainstorm that drops 1 inch per hour, it may erode under the onslaught of 2 or more inches per hour (a likely event in much of Minnesota). To be sustainable, the trail needs to be able to accommodate any conceivable runoff event, even a "catastrophic" one.

This five-foot-wide sandy tread is eroded up to 30 inches deep. Subsequent trail use displaces more soil that quickly smooths over the ruts. This smoothing can disguise the severity of erosion, making it seem as if the problem is not as bad as it actually is.

Years of truck traffic compacted the tread of this long-established on-road trail. The trail erodes, but the eroding channel stays to the softer edge of the active tread. Note that even this gentle grade erodes because it has a large surface area that captures a large amount of rainfall and runoff from the slope at left. Becuase trail users impart far less compaction force than trucks, trails tend to erode inside their treads rather than beside them.

USING NATIVE SOIL FOR NATURAL SURFACE TRAIL TREADS

***Tomorrow's problem!** While this new OHM tread may seem sustainable today, it has already compacted and displaced into a trench. Since it runs directly up the fall line of this slope, it will soon erode as water follows the tread straight downhill. After only one year, erosion has already begun, with the bottom of the tread being deeper than the top.*

Natural surface trails typically use native soils and rocky materials as the trail surface, with little or no vegetative cover. To be sustainable, the tread must accommodate the compaction, displacement, and erosion caused by trail use. With well-designed treads, abrupt, unanticipated changes in shape through use or erosion should not routinely occur. The tread should also not require major maintenance, reconstruction, or relocation for decades as long as frequent light maintenance is performed.

IDEAL TREAD SOIL MATERIAL

An ideal tread material is a mix of all soil textures that exhibits high stability, becomes firm and stable when compacted, holds its shape even when wet, and has sufficient drainage to prevent saturation under most conditions.

The behavior of soil in terms of stability for trails is fairly predictable, with particle size classifications being the most important determining factors. Clays are very small particles, silts a bit larger, sands considerably larger, and stones (of various sizes) are the largest particles. Each particle size has advantages and disadvantages in treads.

Soils composed primarily of particles of one size have some inherent limitations. Pure sand, for example, has excellent drainage but almost no cohesion, making it difficult to sustain any distinct tread shape. In a soil with a mix of various particle sizes, the strengths of each size combine to help counteract their inherent weaknesses. The ideal tread soil has mineral-based particles of many sizes, including some rock. It also becomes hard and cohesive when compacted and remains firm even when wet.

Loams, which are blends of two or more soil textures, make much more suitable trail treads than treads principally composed of mostly clay, mostly silt, or mostly sand. Wherever displacement and erosion are likely, rocky material can greatly improve the strength of the tread by adding large structure that helps resist displacement and erosion. Mixing humus with loams usually weakens the loams as trail tread, but mixing humus with pure sand, pure silt, or pure clay may improve the tread slightly.

General Properties of Native Soils for Natural Surface Trail Uses

A basic understanding of how different soils function for trail treads is critical to creating sustainable trails. The following provides a general overview of the properties of the most common native soils types.

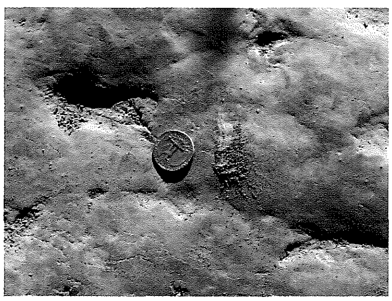

Silty clay is firm when dry but slippery when wet. The quarter provides a sense of scale.

Clays

Clay consists of extremely fine-grained particles less than 0.002 mm in diameter. The fine-textured particles have undergone mineralogical change for millennia resulting from decomposition of minerals in water. Clay particles are platelike and oily, and each particle carries ionic (electric) charges that attract and hold water in two layers – a tightly held layer close to the clay particle and a weakly held layer farther away. Compared to silts and sands, clays have tremendous surface area and can attract and hold large amounts of water, which is why clays tend to be muddy and poorly drained when wet. The platelike shape of the particles and the weakly held outer water layer helps explain why clays are slippery when wet – the plates slide past each other on water cushions. When clay is dry, the charges cause the particles to bond to each other, especially when compacted, giving dry clay a strength useful for trail treads. When rubbed between the fingers, wet clays feel smooth and sticky.

Characteristics of clay tread:

- Clay is very strong and dusty when dry, but extremely slippery when wet
- Undisturbed clays remain firm even when covered with ponded water, but disturbed or uncompacted clays become soupy when saturated
- A tread on undisturbed clay will compact to an extremely hard surface
- Once disturbed, clays may settle for years unless mechanically compacted
- Due to high internal strength, displacement of clays is minimal unless wet and disturbed, in which case strong shear forces can severely damage the tread
- The surface hardness of compacted clay makes it very resistant to erosion
- Mudholes will develop slowly wherever water ponds – the high strength of clay tends to resist rapid mudhole enlargement


Loess (windblown mineral silt from glacial grinding) on the Southeast Minnesota ATV Trail becomes so hard in places that the surface is polished with tire marks and is difficult to scratch with a coin. Soil this strong is found only in a few Minnesota locations.

Silts

Silt consists of mineral particles from 0.002 to 0.05 mm in diameter. Silt particles are medium-textured, small pieces of minerals knocked off of rocks with no subsequent mineralogical change. Silts sometimes have natural binders (raggedly shaped small particles with electrically charged edges) that can form very firm trail treads once compacted and when dry. Because Minnesota's four major glaciations ground so much rock into dust, many of Minnesota's soils contain some silt. Silts hold water to varying degrees but not nearly as much as clay, so silts are generally considered moderately to well drained. When rubbed between the fingers, silts feel slightly gritty. A more accurate test is to put some on your tongue – if it feels at all gritty, there is some silt or sand present, whereas pure clay is smooth.

Characteristics of silt tread:

- Silt is smooth, firm and dusty when dry but can be soupy when saturated under disturbed or uncompacted conditions, or during spring thaw when frost action breaks soil bonds
- Undisturbed and compacted silt high in mineral content, such as loess (windblown rock silt from glacial grinding) in southern Minnesota, can be remarkably resistant to displacement and erosion
- In general, treads high in silt have varying resistance to displacement and erosion depending on particle size, size mix, particle shape, mineral content, and other factors
- When wet, treads high in silt are usually slippery and partially to very muddy.
- Muddiness decreases with compaction
- With less internal strength and small particles, mudholes can form quickly wherever water chronically ponds

Round-grained "sugar sand" has zero cohesive strength and cannot hold any tread shape.

Sand

Sand consists of mineral particles from 0.05 to 2.0 mm in diameter, usually quartz. Sands are coarse-textured, carry no electric charge, and have no natural binders that can form firm and strong trail treads. Because of repeated glacial grinding, many of Minnesota's sands lack sharp edges that could create mechanical interlock and instead have rounded edges. Hence sand is loose and does not hold its shape, even when wet. Because the silicon and oxygen that comprise sand are both lightweight elements, sand is light in weight compared to other minerals. Sands are usually excessively drained, meaning that they can't hold much water.

Characteristics of sand tread:

- Treads high in sand content undergo little compaction and cannot maintain detailed specific shape
- With its light physical weight and lack of binders and charge, sand is easily displaced and eroded
- Sharp-grained sands are stronger than rounded grains due to increased mechanical interlock
- Trails in very sandy soil with high-displacement use typically become ruts with berms of displaced sand along one or both sides. If erosion is not a factor, the rut stops getting deeper when displaced particles are no longer propelled out of it
- Predominantly sandy soils are so well drained that muddiness is eliminated, runoff from surrounding areas is minimal, runoff puddles in the trail tread quickly percolate into the tread, and mudholes are impossible

Loam

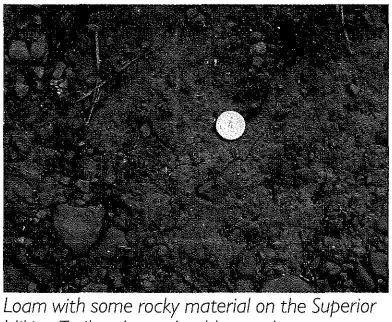
Loam is a varying blend with a high percentage of silt, a moderate percentage of sand, and a low percentage of clay, making it medium textured. Most Minnesota upland soils are loams of varying blends—sandy loam, silt loam, clay loam, silty clay loam, loamy sand, or sandy clay loam. Like most blended soils, loams have the strengths of their constituent classes while the weaknesses of any given class tend to be compensated by the other classes. In loam, silt provides moderate structure and moderate binders, sand provides more structure and good drainage, and clay provides excellent binders and excellent water-holding capabilities that keep soil moist but not soaked.

Rocky material adds structure that usually improves soils used for trail treads, especially for heavier types of uses. Use of organic soil from decomposed vegetation as trail tread is discouraged due to its inherent limitations, as defined on the next page under humus.

A slightly gravelly loam has clay, silt, sand and small rock particles. It is firm when dry and makes a relatively durable tread surface. Shrinkage cracks indicate the presence of expansive clays, which are excellent binders but very slippery when wet.

Characteristics of loam tread:

- The blend of the compressive strength, good drainage, and structure of coarse-textured sand; the range of binders and particles of moderate-textured mineral silt; and the excellent binding action of fine-textured clay creates a firm tread with both ionic and mechanical interlocks
- Loams form a firm, compacted tread surface with moderate resistance to displacement and erosion
- When wet, the more sand there is, the less muddy the loam will be and the less it will displace through shear pressure
- Spring thaw or saturation of disturbed or uncompacted loam can suspend soil particles in water and break internal soil bonds, causing extreme mud conditions
- When dry, the more clay or silt binders there are, the more resistant loams will be to dry displacement caused by trail use
- Mudholes can easily form in loams; when they do, all the weaknesses of the constituent soil contribute to mudhole enlargement



Loam with some rocky material on the Superior Hiking Trail makes a durable tread.

Rocky Material

Gravel, cobbles, stones, and boulders are soil particles too large to be considered soil separates and are classed by size:

- Gravel: 2 to 75 millimeters (from sand to 3 inches)
- Cobbles: 75 to 250 mm (3" to 10")
- Stones: 250 to 600 mm (10" to 24")
- Boulders: larger than 600 mm (24")

Rocky soils make some of the most durable treads. The cohesive structure distributes weight and functions equally well wet or dry. Rock size, however, needs to be matched to the type of use or visitors will tend to go around, rather than over, the rocks.

Organic soil makes a relatively poor trail tread because it maintains air spaces between particles that can become replaced with water. Hence this soil lacks bonding between particles, does not become solid when compacted, and holds a high amount of water when wet.

Characteristics of rocky material in tread:

- On trails, all rocky materials resist compaction—the more stone there is in the tread, the more it resists compaction
- Rocky materials also resist displacement—the larger the stones, the more resistance they offer (but the more bumpy the tread can become)
- Rock particles resist erosion themselves, but can accelerate erosion in soils around them as water flows concentrate when passing around individual rocks
- All rocky materials drain extremely well, do not absorb water, do not become muddy, add significant resistance to displacement and erosion, and add traction surfaces, making them highly beneficial to trail treads in mud-prone, slippery, or excessively sandy soils
- Rocky materials, particularly cobbles, stones, and boulders, are ideal for strengthening tread to accommodate high-displacement trail use
- If rocky material is sorted (all the same size), it will always remain loose and prone to displacement; avoid sorted material; use rocky material with a full mix of sizes from dust all the way up to the desired maximum size; with this mix, the larger rocks create the major structure while the smaller rocks and dust fill in the voids and act as binders to lock the entire tread into a single mass
- If the rocky material is angular, it will create more mechanical interlock with additional resistance to displacement and erosion; nevertheless, Minnesota's abundant round granite rocky material is a welcome addition to many trail treads as long as there are enough small particles and binders to create a voidless mass

Humus

Humus (organic soil), while not technically considered a soil texture or soil separate, is sometimes used as trail tread. Often comprising the surface 3/8 inch to 4 inches " in forested and undisturbed areas, humus is the dark, spongy, top soil layer in aerobic soils resulting from the decomposition of organic (vegetable and animal) materials. Essentially an advanced compost, it is very light weight, absorbs water very well, and lacks cohesive strength unless held together by plant roots.

Characteristics of humus tread:

- Although it remains spongy and largely rebounds with light use, under heavier use humus can compact to a fraction of its original thickness; compaction will almost always form a depression in a humus tread
- For lightly traveled trails in areas that dry out quickly, humus can be used as a trail tread, but on more heavily traveled trails its lack of strength, light weight, and water retention cause it to be rapidly displaced and/or eroded
- Humus is too uncohesive to hold any sharp shape, maintain a sharp edge, or withstand displacement and erosion on steep grades
- Unless it is sustainably held together by plant roots, traveled only lightly on well-drained tread grades of less than 5 percent, and protected from splash erosion by a tree canopy, humus is not recommended as a tread material.

CREATING SUSTAINABLE NATURAL SURFACE TRAILS

Sustainable trails can be created through a combination of good design and the proper use of native soil materials and/or hardening techniques that result in treads that resist compaction, displacement, and erosion. The following considers the fundamentals of creating sustainable treads for natural trails.

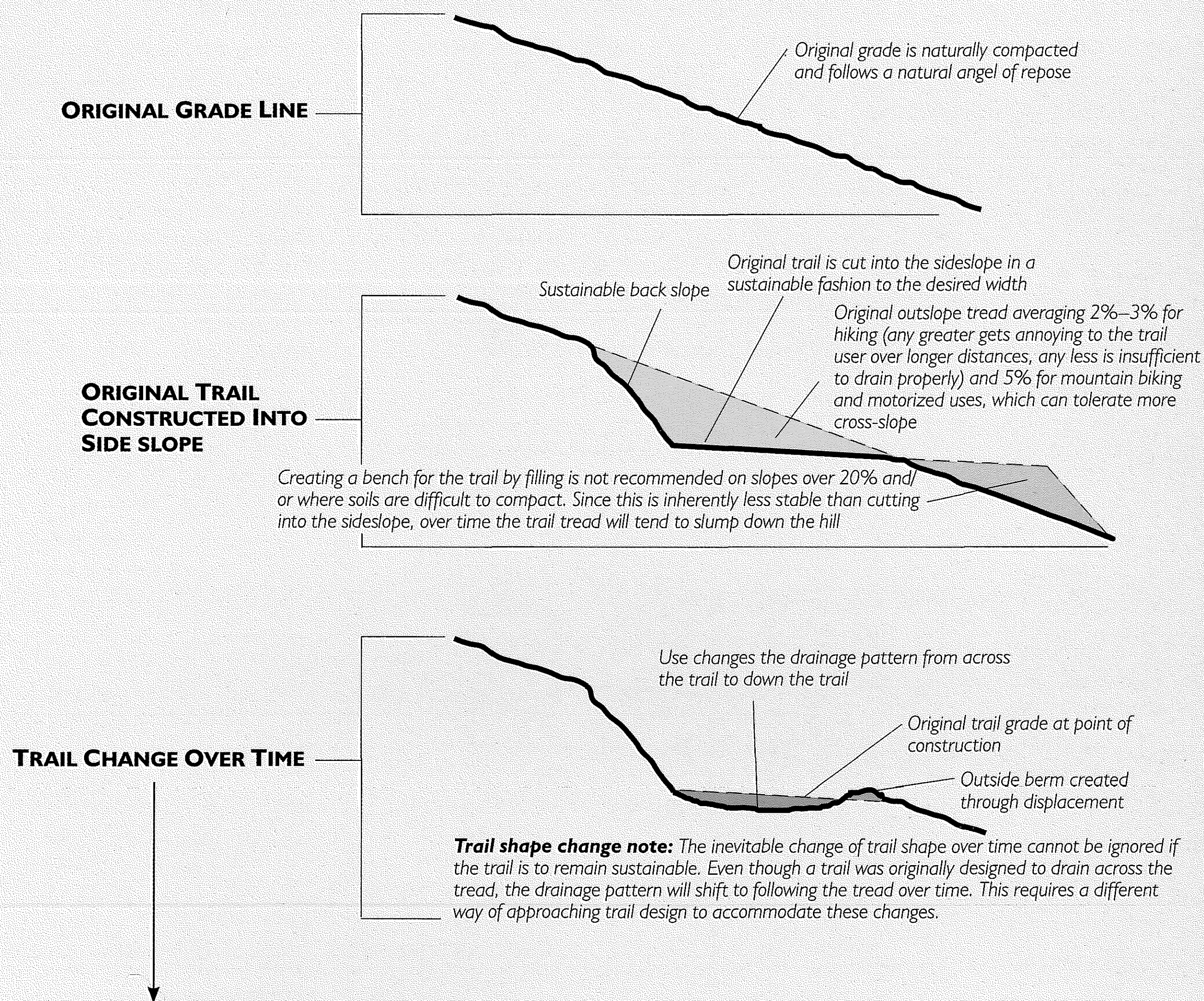
KEYS TO SUSTAINABILITY

Sustainability is being able to retain the desired functional shape of the tread over time. For native treads, it is certain that:

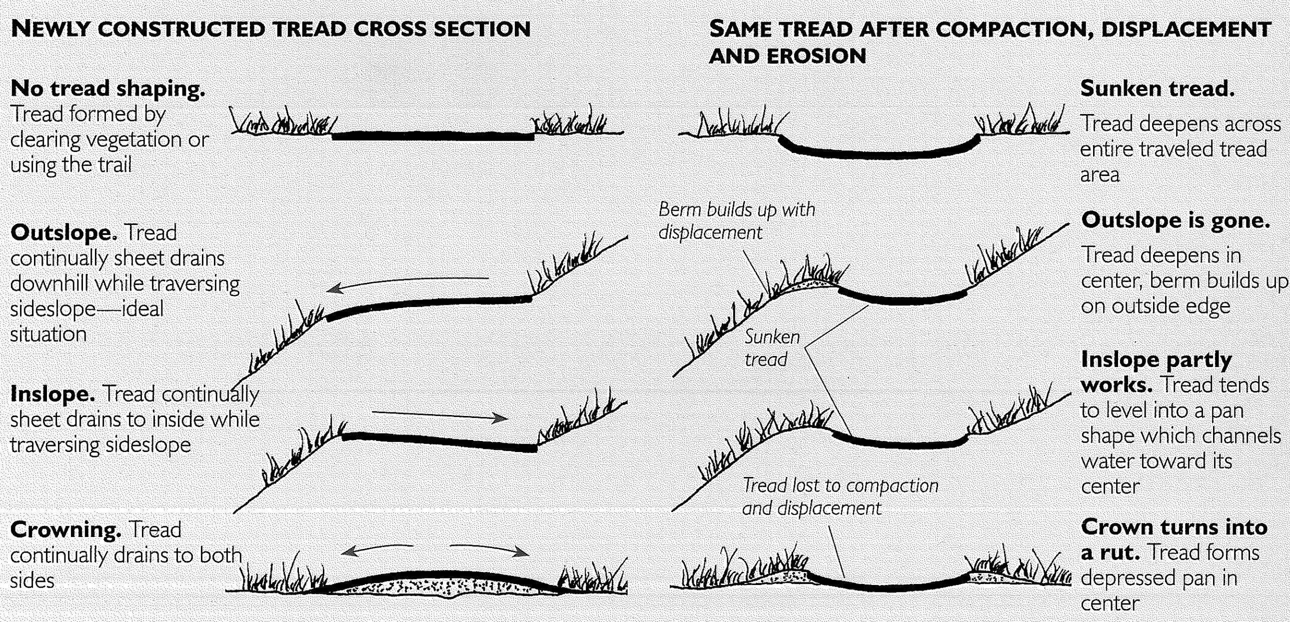
- Compaction will tend to deepen the heavily traveled portion of the tread
- Displacement will not only deepens the tread but also raises the untraveled edges somewhat
- Erosion will follow deepened treads with any grade and deepen them further

The following graphic illustrates how properly constructed trails change over time.

Natural Surface Trail Tread Changes Over Time



For new or rebuilt native treads, these changes generally occur within a few months to 3–7 years. Timing and the amount of change depend on the tread material, trail use type and levels, and many other factors – but the direction of change is always the same.



The key to sustainable native tread is to expect and accommodate predictable change in the tread shape.

Characteristics of Sustainable Natural Surface Treads

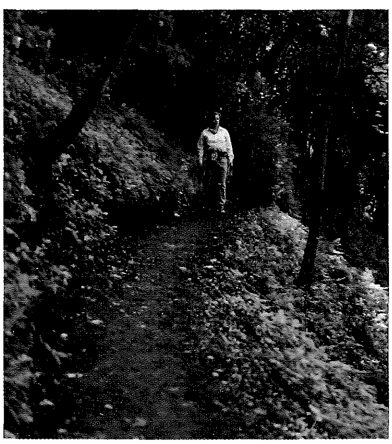
Limiting erosion. *Limiting tread grades to short segments prevents major erosion by limiting the amount of water flowing down any segment. Each segment must drain to somewhere lower than itself. This is easiest when a trail traverses a slope.*

Ideally, natural surface tread would continually drain to the side. As the previous images illustrated, outsloping, insloping, and crowning initially effectively drains the tread. Unfortunately, even subtle tread reshaping by compaction, displacement, and erosion will make these trails difficult to sustain except on very firm and stable treads used only by low displacement uses. To be sustainable, a natural trail tread has to have the following characteristics and management:

1. **Stable, compacted tread material.** The tread material exhibits moderate to high stability in both wet and dry conditions. The tread is compacted for increased stability and resistance to displacement and erosion. If the tread material is less stable and/or does not compact well, sustainable tread may still be possible if all of the following characteristics are present.
2. **Limited displacement.** The tread material, tread shape, usage restrictions, and/or maintenance minimize and/or accommodate displacement. Wheeled uses may need superelevation on curves to minimize displacement.
3. **Tread drainage with limited erosion.** Tread shape and location frequently drain surface and subsurface water to somewhere lower than the tread itself, typically to the side, before average runoff from the tread and the site accumulates to erosive volumes and/or speeds. Limited erosion, however, may be expected during very high and extreme runoff events. It is critical that the tread continue to drain during and after tread shape changes from compaction, displacement and erosion. New tread is formed with outslope, inslope or crowning even if that shape is not expected to be sustainable. While they last, those shapes create sheet drainage and minimize erosion from new earthwork. Highly porous tread material (sand, gravel) may improve tread drainage, especially on low or near-level tread grades.
4. **Narrow tread.** To concentrate compaction and reduce impacts, the tread and bare soil width are as narrow as feasible.
5. **Minimal hydrologic impact.** Tread shape, location, and drainage minimize changes in local hydrology.
6. **Trail maintenance and management.** Trail maintenance and management concentrate on proactive, frequent, small actions, including:
   - Performing routine light maintenance
   - Finding and correcting problems while still minimal
   - Predicting and preventing future problems
   - Closing trail during extremely adverse tread conditions, typically during spring thaw and other saturated soil conditions
   - Protecting tread from overuse and from uses it was not designed to support
   - Planning and supporting tread as a permanent facility with an indefinite lifespan

The degree to which any of the above characteristics and management are lacking will limit tread options. Depending on the circumstances, this could include rerouting the trail, reconstruction, making additional drainage improvements, using tread hardening techniques, making management changes, and even decommissioning.

Note that subtle tread shapes cannot routinely be relied upon to ensure a sustainable trail. With drainage, tread can be subtly shaped to initially do the job. With compaction and displacement occurring over time, a subtle shape is easily defeated unless the tread can be reshaped every few weeks. Using larger, more robust shapes and forms to begin with will ensure that more change in the tread can be tolerated before problems occur.



Ideal, but rare. *This new outsloped tread has an ideal combination of steep sideslope, stable and cohesive tread material, narrow tread, and low displacement use (hiking). Even outslope – usually the most difficult tread shape to sustain – is easier to sustain here because of the tread material and use.*

Note which part of the tread the hiker chooses to use. Eventually, visitors staying away from the outside edge will deepen the center of the tread. This will likely cause the outslope to fail unless maintenance reshapes it.

Caution: This tread works because all of its factors work together. To the extent that any of these factors – such as sideslope, stable tread material, narrowness, and low displacement use – are reduced or missing, the tread may need a modified approach for sustainability.

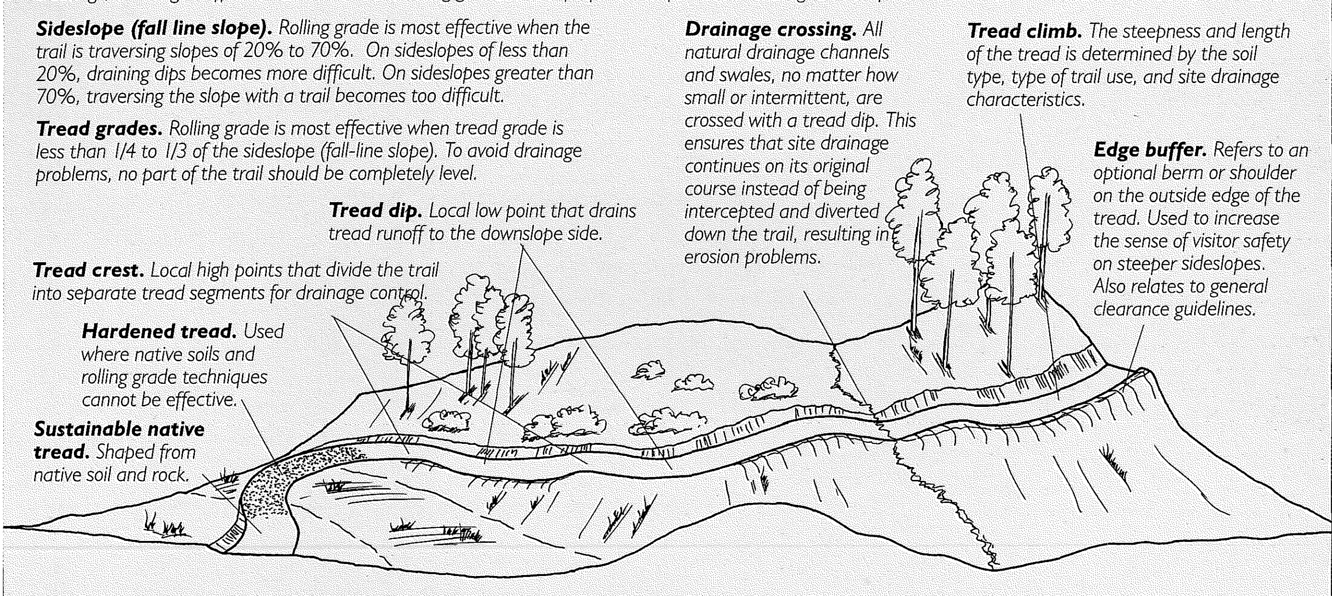
PRIMARY DESIGN PATTERN FOR SUSTAINABLE TRAILS – ROLLING GRADE

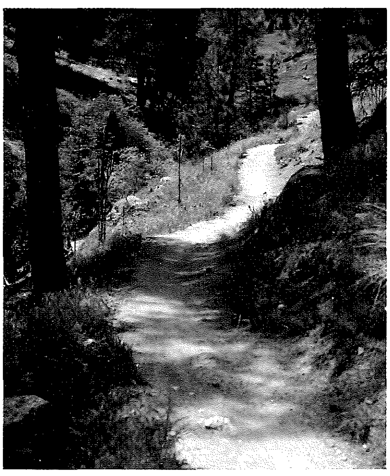
"Rolling grade" is the primary design pattern used for developing sustainable natural surface trails. This pattern is best described as a series of dips, crests, climbs, drainage crossings, and edge buffers that are intrinsically linked and purposefully designed to form a sustainable trail. Unlike the geometric form associated with paved trails, rolling grade is inherently more responsive to the nuances of the landforms encountered on a site.

The rolling grade design pattern takes many variables into consideration, including: tread material and compaction, displacement, and erosion forces; types and amount of use; wet and dry conditions; topography and drainage patterns and flow rates; site vegetation; tread width and grade; and user safety. The following graphic illustrates the fundamental aspects of the rolling grade design pattern for natural trails.

OVERVIEW OF ROLLING GRADE AS THE PRIMARY DESIGN PATTERN FOR NATURAL SURFACE TRAILS

Rolling grade is the primary pattern for designing and building natural surface treads. Rolling grade trails are a series of tread dips, crests, climbs, drainage crossings, and edge buffers. In this illustration, rolling grade is used for portions of a trail traversing a sideslope.

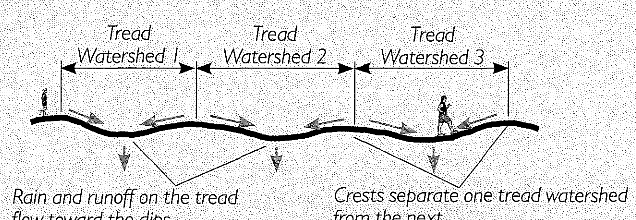




Ideal rolling grade. *Crests and dips are formed through tread alignment. Compacted through trail use, this tread is stable enough to resist displacement in most places. Steep slopes above the trail (to right) pour large volumes of runoff onto the tread, but the tread handles it with gentle grades and small tread watersheds.*

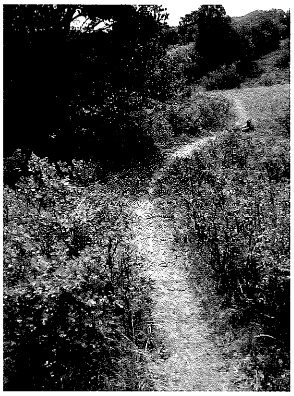
The basic concept behind rolling grade is that a sustainable trail must be able to drain to somewhere lower than itself at all times. Instead of hardening the tread to withstand these forces, rolling grade is used to manage water flows down or across the trail. By using a series of dips and crests like a roller coaster, the tread is divided into a series of small watersheds that drain into a dip, as the following graphic illustrates.

TREAD WATERSHEDS



A tread watershed consists of the tread surface plus any uphill area where runoff flows onto the trail and down to a dip between two crests. The only way to prevent erosion is to form tread watersheds so they will not produce enough water to seriously erode the trail. Every dip must also drain to somewhere lower than itself. The most sustainable way to arrange this is by traversing a slope, as the following graphics and accompanying photos illustrate.

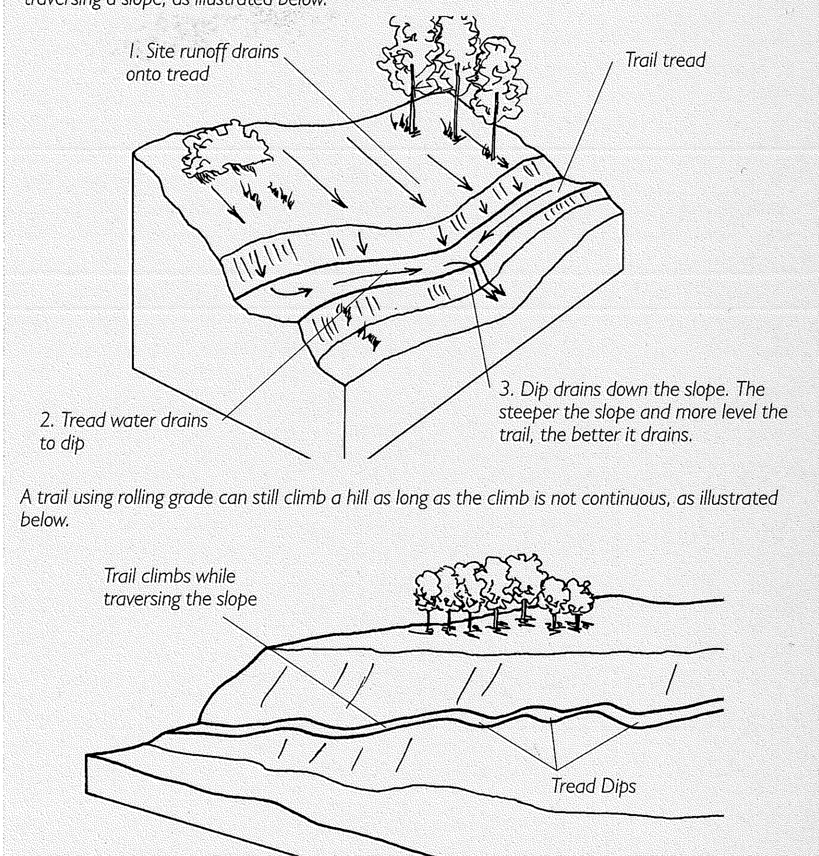
This OHM trail is at least 25 years old and has had virtually no maintenance. Rolling grade, coupled with gentle grades and the tree canopy, prevent erosion. The sandy loam tread absorbs much of the runoff, along with well-placed tread dips draining the rest.



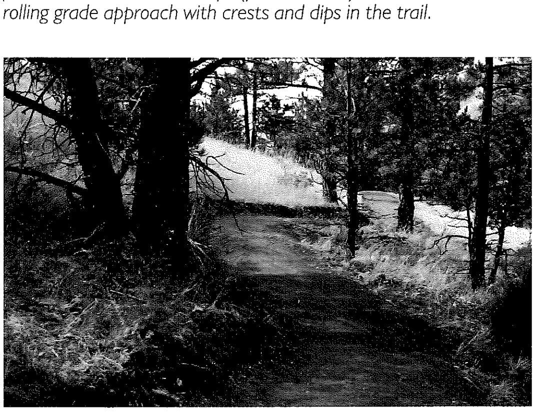
Gentle slopes require careful attention to draining tread dips. Without a steeper slope to quickly drain the dips, puddles and mudpits can quickly form.

Traversing a Slope to Prevent Erosion

Every dip must drain to somewhere lower than itself. The most sustainable way to achieve this is by traversing a slope, as illustrated below.



***The "easiest" route is not necessarily sustainable.** The "easiest" way to climb the ridge from left to right is along the ridgeline (the horizon). However, if that were the case, the trail would not be able to drain water to the side because the "local" downhill at any point on the trail would be down the ridgeline (and trail), not to the side. By using rolling grade adjacent to the ridgeline, side drainage is created, forcing water to flow off the side of the tread at predictable intervals defined by low points. To work, all tread dips (yellow arrows) must drain to somewhere lower than the tread. As the photo illustrates, it is still possible to climb the hill when using a rolling grade approach with crests and dips in the trail.*



(Left) This trail climbs faster than it might appear. Rolling grade is used to limit tread watersheds on this erosive soil. With tree anchors, it is also used to make the trail more interesting to visitors.

(Right) Rolling grade is used on this OHV trail to drain the tread, control erosion, and create challenges for ORV drivers. The tread is intentionally rough and extreme – yet erosion is limited by very short tread watersheds.

Minimizing the Risk of Tread Erosion

Used properly, rolling grade can prevent large-scale tread erosion, although smaller-scale erosion will always remain an issue within each tread watershed. The following box highlights some erosion risk factors.

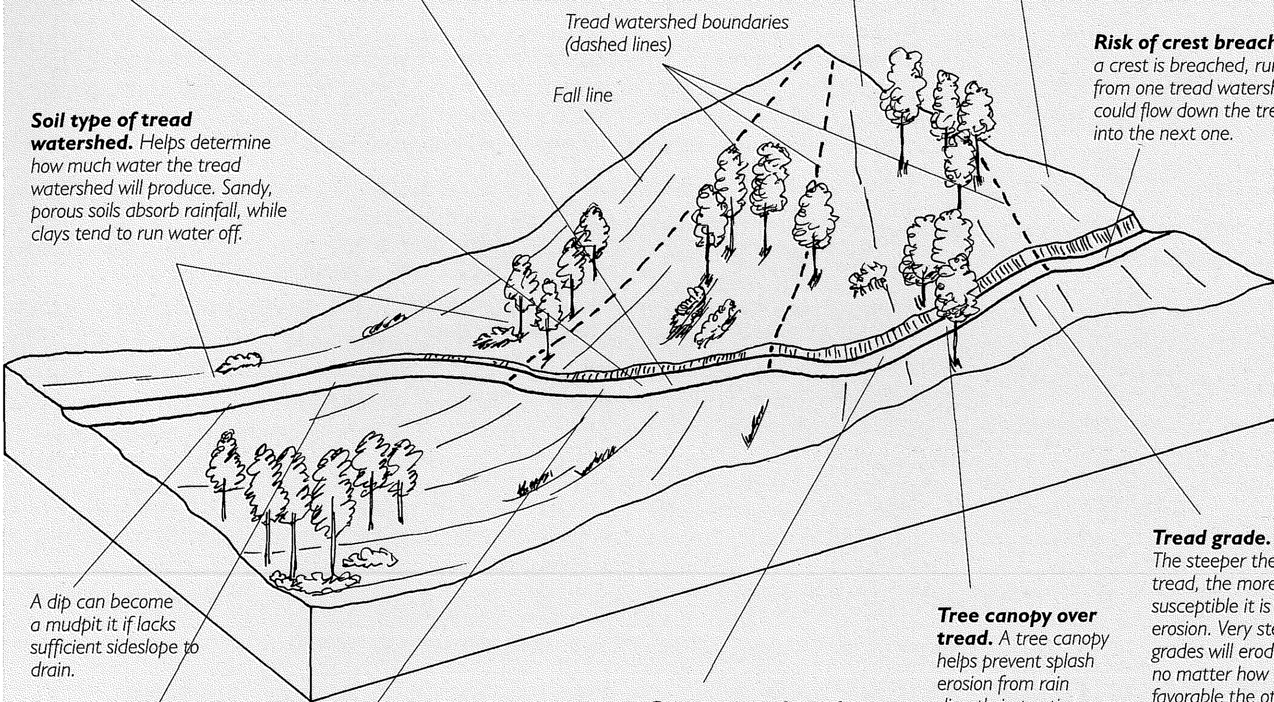
Erosion Risk Factors

Tread length in tread watershed. *The longer the tread is, the more water that can accumulate and the more likely it will erode. Even minimal tread grades can erode with enough water flow.*

Stability of tread material. *Some treads withstand erosion better than others. Treads and watersheds are designed around the ability of the tread material to withstand erosion.*

Surface area of tread watershed. *Larger watersheds receive more rain and cause more runoff than smaller ones. Tread watersheds should be kept as small as possible to reduce erosion risk.*

Vegetation on tread watershed. *This is a major factor in tread watershed runoff. Thick forest and grasslands produce limited runoff that flows slowly across the land. Rocky areas and bare soil produce instant, fast runoff that can deluge a downstream tread.*



Soil type of tread watershed. *Helps determine how much water the tread watershed will produce. Sandy, porous soils absorb rainfall, while clays tend to run water off.*

Risk of crest breach. *If a crest is breached, runoff from one tread watershed could flow down the tread into the next one.*

Tread grade. *The steeper the tread, the more susceptible it is to erosion. Very steep grades will erode no matter how favorable the other factors are.*

A dip can become a mudpit if it lacks sufficient sideslope to drain.

Tread is close to the fall line, but grade is minimal. A dip at the top protects this segment from tread water above.

Tread grade as relates to fall line. *The closer the tread grade is to the fall line, the less geometry there is to drain it. Except on short hills, slopes should be traversed with a tread grade not exceeding 1/4 to 1/3 of the fall-line slope.*

Compaction of tread material. *Compacted treads have more resistance to displacement and erosion and can be used on steeper grades than can uncompacted treads.*

Tree canopy over tread. *A tree canopy helps prevent splash erosion from rain directly impacting bare soil. A heavy canopy is especially beneficial on steeper tread grades.*

There are two primary ways to minimize the risk of tread erosion: limiting tread grade and limiting the size of the tread watershed.

Limiting Tread Grade

Predictably, less erosion is likely when trail grades are less steep. In highly erosive situations, minimal grades provide the best erosion control.

> ***Important consideration!***
>
> Tread grade relative to slope grade is important to creating sustainable natural surfaced trails.

Tread should traverse slopes with a grade that is ideally less than one-fourth of the fall-line slope grade, with up to one-third being acceptable if soil conditions allow. For example, on a 36 percent slope, the tread grade should be ideally 9 percent. This ratio helps ensure that the tread is not following the fall-line and that side drainage without excessive erosion is possible.

As tread grade increases, native soil treads need to be drained more frequently to prevent accumulation of erosive flow volumes. This is most often accomplished by placing tread crests closer together.

Limiting the Size of the Tread Watershed

Limiting the size of the tread watershed limits the amount of erosive runoff that can be produced and the amount of water the tread has to carry. The total water in each tread watershed is that which lands directly on the tread plus water that drains onto the tread from the surrounding upstream area. Note that the maximum possible flow from a severe storm must be handled without major damage to the trail, although some erosion should be expected. Lesser runoff events should cause no or minimal erosion. By making sure that each watershed is not excessively large, the damage caused by a larger storm can be controlled.

In most cases, the rainfall that will cause the most erosion is that which falls on the tread itself. Compacted or hardened treads produce nearly 100 percent runoff on the entire length and width of the tread. Grass-covered trails hold back more runoff and tend to be less erosive, However, these trails also are only suitable where use is limited. By placing crests closer together the risk of erosion is reduced. Keeping the tread narrow and protecting it with adjacent vegetation also helps.

The watershed draining onto the tread can add additional water, especially in heavier runoff events. The flow rate and quantity varies depending on the size of the watershed, plus its vegetative cover and soil type and porosity. Heavily forested areas with good ground cover or native grasslands adjacent to a trail produce much less runoff than barren land and are less of an erosion concern.

The following table defines some erosion risk factors and suggests adjustments that can be made to the trail to reduce the risk. As the table illustrates, this requires balancing many factors, using some factors to mitigate others, and using judgment and experience to form appropriately sized tread watersheds with appropriately aligned treads.

TREAD EROSION RISK FACTORS FOR WATERSHEDS

Risks are classified as "lower," "moderate," or "higher." These are relative classifications that have to be balanced against in-the-field judgment, experience, and real-world conditions. In general, the higher the extreme – too steep, too long, too much, too fast – the higher the risk of erosion. Tread grade is the single most important factor, with even a 2 percent grade being susceptible to eroding in some situations.

How To Use This Table: Preventing erosion starts with identifying the weakest link, which is the most erosion-prone aspect. This tends to set the erosion risk for any given tread watershed. Since tread grade is the single most important factor, a number of factors in the "higher risk" category will have little effect if tread grades are low. For example, while a high tread displacement rating for trail uses may be in a higher risk category, if the tread grade remains low and the tread length is short, high displacement may not pose much erosion risk.

Special Note: If tread grade is 5 percent or steeper and one or more factors in the "higher risk" category are not mitigated by other factors, erosion risk should be lowered by reducing the size of the tread watershed or adjusting other factors.

Risk factor	Lower risk	Moderate risk	Higher risk
For the trail tread itself			
Tread grade (tread climb)	< 5%	> 5%	> 10%
Tread grade as relates to fall line	Tread grade < 1/4 of fall-line	Tread grade 1/4 to 1/3 of fall-line	Tread grade > 1/3 of fall-line
Tread length in tread watershed	Short	Medium	Long
Tread width	Narrow	Medium	Wide
Stability of tread material	High	Moderate	Low stability
Compaction of tread material	High	Moderate	Little or none
Amount of trail usage	Low	Moderate	High
Trail use displacement rating*	Low	Moderate	High
Risk of crest breach†	Low	Moderate	High
Tree canopy over tread	Thick or continuous canopy	Intermittent canopy	No canopy
For the tread watershed above the tread			
Surface area of tread watershed	Small	Medium	Large
Vegetation on tread watershed	Thick forest w/ thick leaf litter	Grassland, shrubby, no leaf litter	Rocky, bare soil, thin vegetation
Soil type of tread watershed	Sandy, well-drained, uncompacted	Loamy, moderately well-drained	High rock content, clay, poorly drained, compacted or impervious
Chance of voluminous and/or rapid surface runoff	Low	Moderate	High

* Each type of trail use has a displacement rating that indicates the amount of displacement force it typically imparts.

† Likelihood that a tread crest will be breached and allow water to flow from one tread watershed to the next. On a trail that is climbing through two or more tread watersheds, a crest breach (like a failed waterbar) could create a domino effect that would overwhelm tread watersheds down the trail.

GENERAL GUIDELINE FOR TRAIL-BUILDING PROCESS

The process for developing high-quality natural surface trails centers around two important considerations:

1. **Defining the user group(s).** Each type of user group brings with it trail development nuances that must be considered if the trail is to be sustainable with minimal maintenance.
2. **Planning a route that is sustainable and enjoyable.** An interesting, exciting, and rewarding route is critical to trail success and sustainability. If trails do not meet user expectations, the likelihood of bypassing and creating new routes increases. With higher impact uses, bored users are more likely to use the trail recklessly and cause additional impacts to surrounding vegetation.

BASIC STEP-BY-STEP PROCESS FOR DEVELOPING TRAILS

The following outlines the basic step-by-step process for developing a natural surface trail. These steps complement the trail project planning guidelines in Section 1 – Framework for Planning Sustainable Trails, which should be referred to for more extensive checklists and standard requirements when developing a trail. IMBA's *Trail Solutions* is also a suggested reference, especially when laypersons are involved in building a trail with hand tools and require a basic understanding of the process. Typical trail-building steps include:

1. **Confirm property limits** – to ensure that the trail is being built on the right property.
2. **Confirm trail users** – to understand the exact trail requirements and the design parameters that must be applied. Refer to Section 4 - Trail Classifications and General Characteristics to determine the specific requirements and layout considerations for each type of use. This also includes defining the different type of users within each group. For example, trails within a designated OHV recreation site are often designed to a different standard than a designated OHV trail.
3. **Layout the trail** – including control points and desired places to visit and avoid. Loop configurations, trail flow, and rolling grade character are all important factors in creating an appealing trail. (Refer to Section 2 – Principles of Designing Quality Recreational Trails and Section 4 – Trail Classifications and General Characteristics for pertinent information on creating trails that will meet user expectations.)
4. **Flag the trail corridor** – incorporating all of the desired features and creating a sequence of events that will make the trail interesting and meet the desired level of challenge. Remember that trail quality is closely related to how well the trail builders pay attention to detail design issues.
5. **Prepare a construction plan** – which includes input of key participants and land managers to ensure that construction techniques and equipment used are well suited for the type of trail being built. Equipment selection is particularly important in that its size and maneuverability will be reflected in the final form of the trail. For example, an intimate hiking trail is often better built with hand tools then a mechanized dozer if keeping the trail narrow with limited disruption to the surrounding landscape is important.
6. **Construct the trail** – following the construction plan and making sure that each section of trail is stable and sustainable before moving on to the next section. Avoid exposing extensive sections of the trail to erosion during construction.
7. **Formalize a management and maintenance plan** – to ensure that ongoing maintenance is being considered at the point when the trail is being constructed. Routine inspections are especially important during the initial season or two that the trail is open to ensure that it is stable and sustainable. Problem areas should be immediately addressed before use patterns are established and realignments become more difficult.

Trail-Building Tools and Equipment – An Important Consideration

Choosing the right tools and equipment for building a rolling grade natural surface trail is a subject that is too broad to cover in detail in this manual. There are, however, a number of resources worth reviewing that cover various types of tools and equipment best suited for any trail-building situation. The following illustration provides an overview of trail-building tool and equipment selection, along with resource links for more in-depth information.

Resources for Selecting Tools and Equipment for Building Trails

Resources for Tool/ Equipment Selection

- IMBA's *Trail Solutions* handbook (www.imba.com/resources/trail_building/trail_solutions.html) offers a practical guide for building natural surface trails, with particular attention given to common hand tools and smaller walk-behind mechanized equipment.
- The Professional Trail Builders Association website (www.trailbuilders.org/suppliers.html) provides an extensive listing of trail building equipment and services that are available.
- The American Trails website (www.americantrails.org/resources/consultants/index) provides a listing of tools and supplies for trail-building and maintenance – including links to equipment manufacturers offering specialized equipment.
- *Forest Service Trails Reports 2004* is a collection of reports (www.fhwa.dot.gov/environment/rectrails/trailpub.htm) under the publication 0423-2C03-MTDC. This CD offers several publications that describe tools and equipment. Publications *8823-2601-MTDC Handtools for Trail Work* and *9823-2837-MTDC OHV Trail and Road Grading Equipment* have particular application.

Narrow Hiking or Mountain Biking Trail

For intimate trails, hand tools are most often used to keep the trail intimate and narrow, limit construction impact, and avoid moving heavier equipment into often remote areas with challenging terrain. This particular trail was built with hand tools by a group of volunteers.

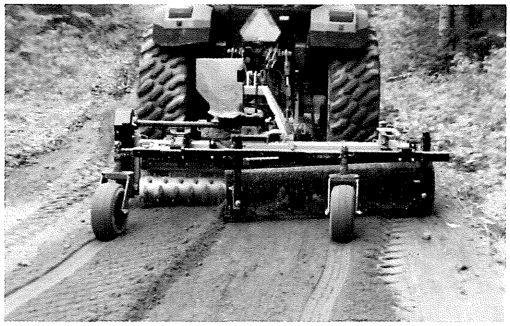
Wider Hiking, Mountain Biking, Horseback Trail/ Narrower ATV Trail

As trails become wider, walk-behind and smaller ride-on mechanized equipment is commonly used to gain efficiency and the capacity to move more soil. As equipment size increases, trail intimacy decreases. Walk-behind mechanized equipment with a mounted front blade was exclusively used for developing this new trail, along with select hand tools.

Wider OHV Trails

For wider OHV trails, ride-on mechanized equipment becomes more useful and necessary. Even then, however, the equipment used for trail building is often considerably smaller and more specialized than typical road-building equipment. A variety of specialized mechanized pieces of equipment were used to develop this trail segment where importing fill material was necessary.

Whereas most of the hand tools used for trail building have been in use for many years, the type and level of specialization of mechanized equipment continually evolves in response to new demands. This is especially the case with equipment for building OHV trails, where newer trails are often many miles long and require specialized equipment to cost-effectively develop and maintain them. The photos on the next page highlight a few of the pieces of equipment and attachments that are becoming more commonly used for building natural surface trails.



(Left) Walk-behind or small ride-on pieces of equipment remain the workhorses for building natural surfaced trails of all types.

(Right) The correct equipment for trail maintenance is also critical. This attachment first tills or scarifies a rough trail surface, then blades it smooth in one efficient operation.

(Left) This mid-sized excavator is extremely useful in building OHV trails where efficient earth moving is necessary.

(Right) A tiller/box blade mounted on a ride-on tracked implement carrier effectively reconditions a heavily used ATV trail.

(Left) This small ride-on tracked transporter is an essential piece of equipment for larger-scale trail projects.

(Right) New models of transporters dump in multiple directions and accommodate a variety of attachments using a universal hitching assembly.

A variety of new implement carriers enter the market each year, each with an extensive array of implement attachments that can till, scarify, blade, level, cultivate, condition, and compact trail surfaces.

ROLLING GRADE TRAIL-BUILDING TECHNIQUES

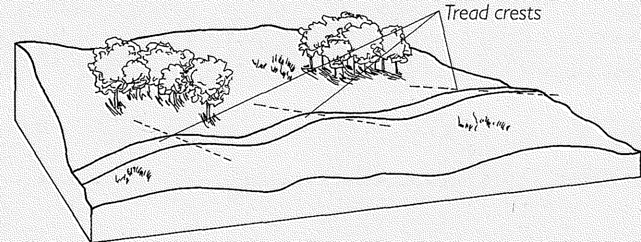
Tread crests, dips, climbs, drainage crossings, and edge buffers give form to the rolling grade design pattern. IMBA's *Trail Solutions* provides an introduction to building these elements into natural surface trails and is a suggested reference to complement this manual. The following takes trail building to the next level by expanding on basic rolling grade techniques to give the trail planner or builder a more extensive understanding of how natural surface trails can be constructed to remain sustainable even after years of hard use.

TREAD CRESTS

Tread crests divide the trail into individual watersheds. Each crest is a local high point in the trail and must be sufficiently long, high, and durable to permanently remain as a high point even as tread compaction, displacement, and erosion occur. The larger and longer a crest is, the less likely it will be to be breached by displacement. In some cases, it may also be necessary to harden an entire crest to keep it in place. As trail grade increases, basic physics also make tread crests increasingly difficult to form and sustain.

TREAD CRESTS

Tread crests divide the trail into individual tread watersheds. A combination of tread crests and dips are used to manage the flow of stormwater runoff to prevent erosion.



Displacement and compaction. *This small former crest has lost its top to displacement and compaction. It was simply too small. A larger, longer crest would have lasted much longer.*

Sedimentation. *This flexible waterbar is no longer functional because of sedimentation, which allows water to now flow over the top of it.*

Visitor bypass. *Some hikers perceive these rough stone waterbars as obstacles and bypass them. Note how new treads are forming on both sides of the waterbars.*

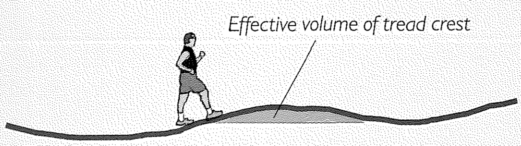
Tread crests are vulnerable to breaching when runoff from one watershed flows through an adjoining crest into the next. The three main causes of crest breach are:

1. **Displacement and compaction.** Displacement from trail use can quickly grind the tops off small, steep, pointy, or soft crests. High-displacement uses can wear the tops off of even larger crests, especially on steep tread grades. Compaction can also lower the top. Using a combination of design techniques and carefully selecting crest locations to withstand displacement can help prevent breaches.
2. **Sedimentation.** When a crest is on a climbing trail grade, sediment from erosion and dry displacement can pile up on the uphill side of the crest, eventually reaching the top and enabling water to flow over. Although this is a problem more associated with a tread dip, appropriate construction can help prevent it. Regular trail maintenance can also help prevent and remove sediment accumulation.
3. **Visitor bypass.** If a crest is not comfortable or convenient – too high, too sharp, too rough, perceived as obstacle – some visitors will attempt to go around it, which defeats the purpose. If smaller crests are placed along a climbing trail grade, bypassing them can carve new channels for water to flow around a crest and continue down the trail. Carefully using site anchors and integrating crests into the site will reduce the tendency to create crest bypasses.

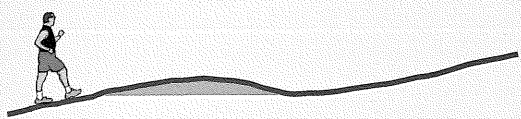
The effective volume of a tread crest (the portion that actually holds back water) is also an important factor in whether it will breach. As trail grade increases, less of the entire crest serves as the actual "dam" for water on the uphill side. The greater the effective volume, the more likely the crest will withstand displacement and compaction, as the following graphic illustrates.

Effective Earthen Volumes of Tread Crests

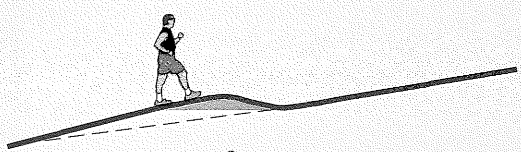
When the trail grade is close to level, crests can be long and low, giving them high volume and making them very resistant to breaching. As the overall trail grade increases, crests become smaller in volume and have steeper ramps, making them easier to breach by displacement. The following illustrations highlight this issue.



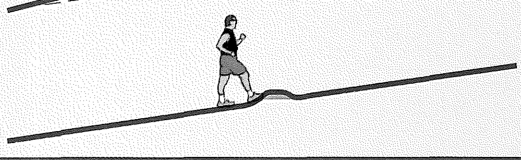
Crest with near-level trail grade. The crest is long with a high volume and shallow grades on both ramps up to it. The entire orange area would have to be breached before the crest would fail to separate adjoining tread watersheds. This is very sustainable due to the large size of crest and its intrinsic resistance to displacement.



Larger crest with climbing trail grade. The crest is still long with a high volume and shallow grades on both ramps. This is a very sustainable and ideal way to form climbing trail grades.



Smaller crest with climbing trail grade. This crest was either built up on an existing grade (dashed line) or the tread was aligned with this small crest in order to climb quickly. Either way, its effective volume is relatively small because of the steeper tread grade above the crest. Lengthening the top of the crest (to be more like the previous example) would increase its sustainability.



Tiny, constructed crest with climbing trail grade. A crest this small has almost no effective volume. If not hardened, displacement will breach it in a short time. If it is structurally hardened, such as by using a waterbar, it can be sustainable but not recommended for wheeled uses.

Well-anchored alignment crest. *The tree provides a great anchor to create a tread crest that is also a pleasant trail feature.*

Types of Tread Crests

Native soil crests with long, relatively level tops resist displacement and should be used wherever feasible. Such crests are most easily formed through trail alignment with a low overall trail grade. Where this is not feasible, tread crests can be constructed through filling or the use of some mechanical form, such as waterbars or rocks. Although waterbars and rocks do not require high volume, they can be easier to breach than high-volume crests.

Alignment Tread Crests

Alignment crests have distinct advantages over constructed ones, including:

- **Greater effective volume** – it is easier to form high-volume crests through trail alignment than by filling an area
- **Easier to form** – in new treads, alignment crests require no explicit construction since they are already there
- **Natural appearance** – trail crests that take the form of the natural landscape look natural, rather than like a managed drainage structure

Reinforced constructed crest. *This rock pile serves as a constructed tread crest on the Lower Money Talks off-road truck trail at the Iron Range OHV Recreation Area. The rocks serve double duty by challenging trail users while at the same time reinforcing the top of the crest against displacement. The crest prevented the water in the lower left corner from continuing downhill along the tread.*

Alignment crests are most easily formed by the way the trail is laid out over the local topography. This is done by either climbing over a local high point (an in-line alignment crest) or by making a jog upslope while traversing a slope (a jogging alignment crest). Both types shape a tread crest without any explicit construction. The graphic on the next page highlights in-line and jogging alignment crests.

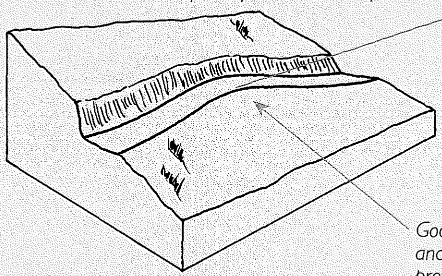
Note that alignment crests are generally much preferred over constructed crests and should be used whenever possible. Constructed crests are considerably more susceptible to failure since they tend to fight against the natural landscape and inherent forces of nature, rather than work with them.

Alignment Tread Crest Configurations

Tread crests formed by alignment have four basic configurations. Jogging configurations climb, or jog up, the sideslope and then back down to create a crest in the tread. In-line configurations simply climb up and over a natural ridge without having to jog. With near-level trail grades, the nearest tread dip can be some distance away. With climbing trail grades, the uphill tread dip is usually nearby and intrinsically tied to the crest.

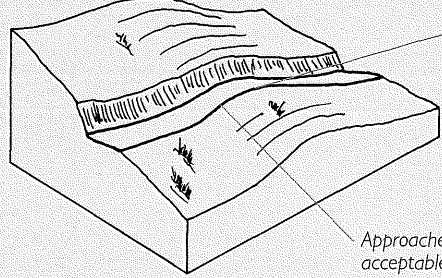
Jogging Near-Level Alignment Crest

While traversing a slope, tread jogs up and down the slope to form a crest. This is a frequently used technique.



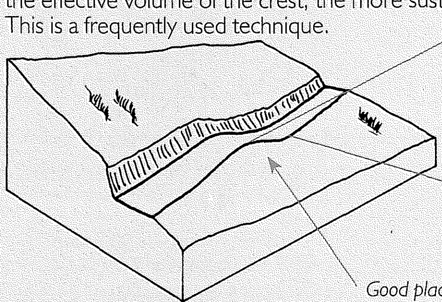
In-Line Near-Level Alignment Crest

While going relatively straight, tread climbs over a natural crest, such as a ridge top. This is very useful where a natural crest exists.



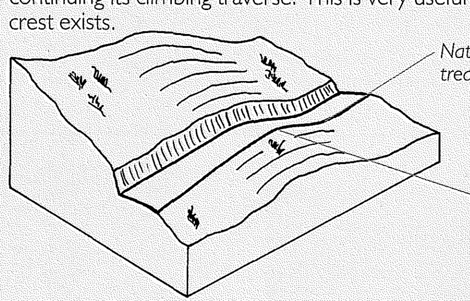
Jogging Climbing Alignment Crest

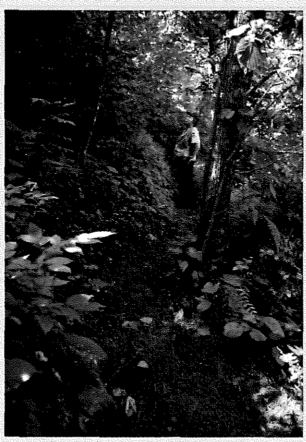
While climbing a slope, the tread must jog quickly up and down the slope to form a crest. A tread dip is also formed. The larger the effective volume of the crest, the more sustainable it will be. This is a frequently used technique.



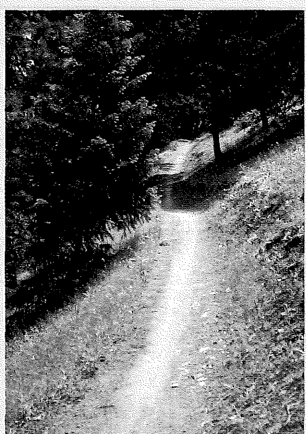
In-Line Climbing Alignment Crest

The tread is aligned to climb up and over a natural ridge, coming down from the top to shape a tread dip on the uphill side before continuing its climbing traverse. This is very useful where a natural crest exists.





Jogging, near-level. *The trail jogs up above a tree to create a crest. The tree anchors the crest and its roots help resist crest displacement. Note the very steep sideslope. (Horse trail)*



Jogging, climbing. *The trail jogs up and down the sideslope as it gently climbs. Widely spaced crests and dips form fail-safe, highly effective crest volumes. (Mountain bike trail)*

In-line, near-level. *The trail flows over a series of natural crests in glacial terrain. With almost no sideslope, tread climbs follow local fall lines, limiting future drainage options. (ATV and snowmobile trail)*

In-line, climbing. *The trail rolls over a small natural ridge. This short, steep climb is sustainable. Small crests such as this are fun for wheeled uses. (Hiking trail, with ATV tracks from recent trail maintenance)*

Constructed Tread Crests

Where creating an alignment crest is not viable, a number of constructed crest techniques can be used, depending on the site-specific circumstances. Constructed crests include filled crests, rigid waterbars, flexible waterbars, and hardened crests.

Filled Tread Crest Overview

Filled tread crests are constructed to emulate a rolling grade on existing treads with a sufficiently large effective volume to prevent breaching. Inherently, each filled crest is accompanied by an adjacent tread dip, with the shape of the crest facilitating drainage from the tread into the dip. As the trail grade steepens, the potential for failure increases due the increased fill volumes and faster, more erosive water flows. This is compounded by the fact that adding a filled crest to a tread also steepens the trail grade. The following graphic highlights these points.

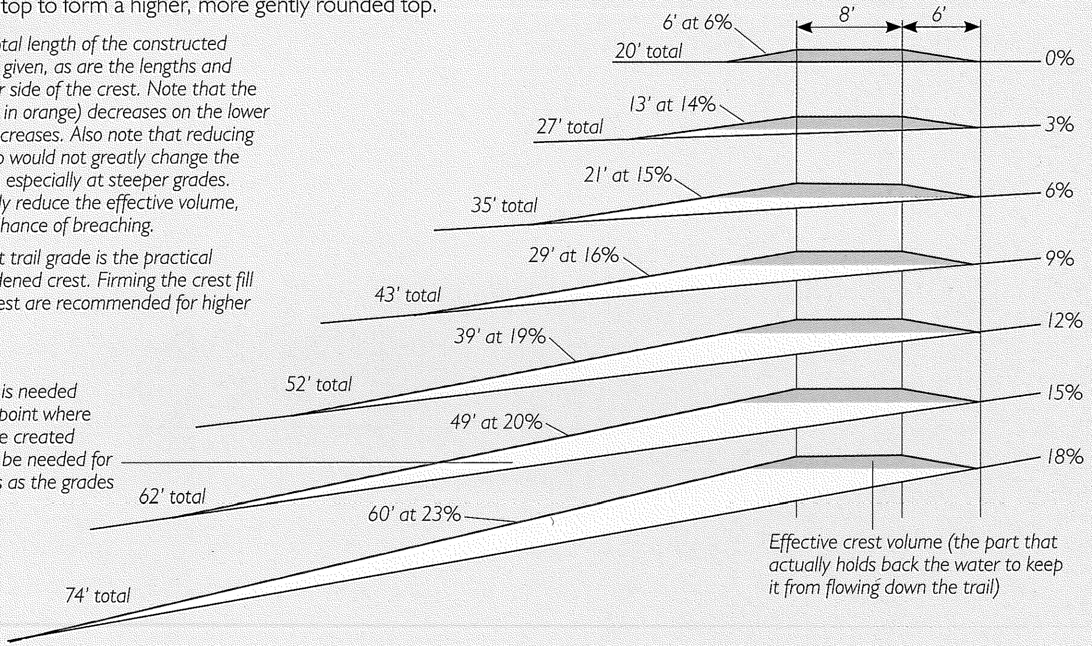
FILLED TREAD CRESTS RELATIVE TO VARYING TRAIL GRADES

As trail grade increases, filled tread crests become very large and long. The illustration shows hypothetical constructed crests for trail grades of 0 to 8 percent. Each crest attains a functional height of 1 foot (adequate for hikers, not high enough for ORVs) above the dip it forms above it. In addition, each crest has an 8-foot-long flat top (to standardize the comparisons). In practice, more material would usually be added on top to form a higher, more gently rounded top.

In the illustration, the total length of the constructed crest from end to end is given, as are the lengths and ramp grade on the lower side of the crest. Note that the effective volume (shown in orange) decreases on the lower side as the trail grade increases. Also note that reducing the length of the flat top would not greatly change the overall size or geometry, especially at steeper grades. However, it would greatly reduce the effective volume, thereby increasing the chance of breaching.

In practice, a 15 percent trail grade is the practical maximum for an unhardened crest. Firming the crest fill and/or hardening the crest are recommended for higher displacement uses.

Constructed fill material is needed to build up the trail to a point where a tread crest can then be created (hardening of tread may be needed for higher displacement uses as the grades get over 15 percent)

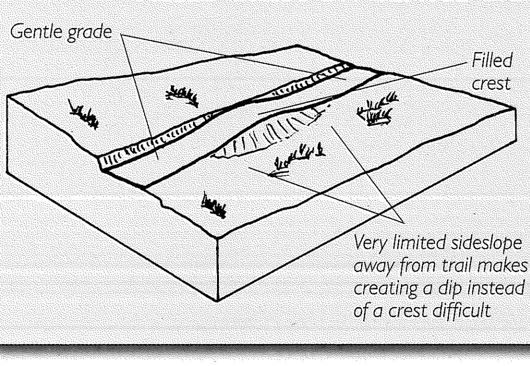


If formed using good techniques, filled crests have more capacity for water handling and often need less maintenance than other forms of constructed crests, such as waterbars. For these reasons, they are generally preferred over other forms of constructed crests. Hardening of the crest can further improve sustainability by reducing the likelihood of displacement.

Filled Crest on Gentle Grade (0 to 5%) With Some Sideslope

Crests are recommended over dips on tread grades of 0 to 5% because they are much less likely to be clogged by sediment than a relatively small dip. This is especially true with little or no sideslope where it is difficult to drain a dip. On on-road trails and trail conversions, it's also easier to see a crest on approach than to see a dip. If the trail is also used by snowmobiles, a crest should be very long and low to avoid becoming a jump. The following graphic and photo illustrate this situation.

FILLED CREST ON GENTLE GRADE (0%–5%) WITH SOME SIDESLOPE

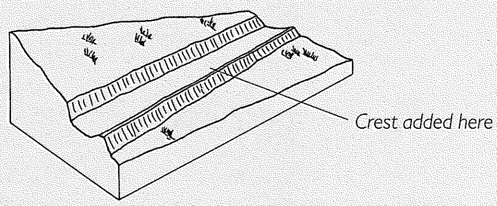


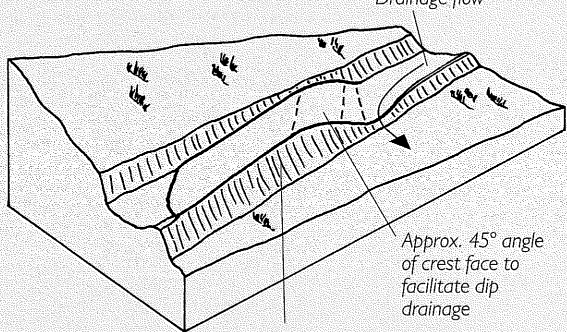
Filled Crest on Sideslope Traverse

Typically, crest–dip combinations on a sideslope obtain the fill for the crest by excavating the dip. Unfortunately, this practice accelerates water heading into the dip from above but does not carry it at that same speed through the dip outlet. This leads to clogging of the dip outlet. It is more desirable to have the crest piled high while the dip is excavated only at the actual outlet. This enables the tread to accelerate water on the way out of the crest by making the outlet slope steeper than the tread leading into it, thus helping to prevent outlet clogging and increasing sustainability. The following graphic and photo illustrate this situation.

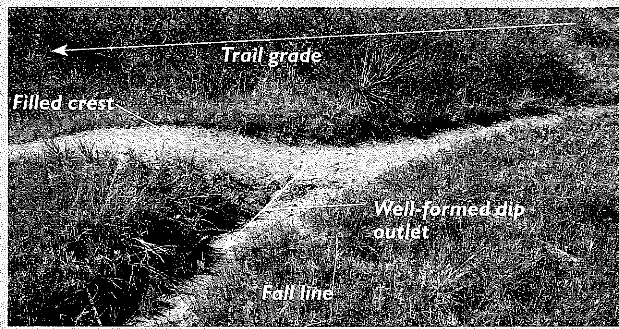
FILLED CREST ON SIDESLOPE TRAVERSE

Before crest was added. *Drawing an entrenched tread with a bermed outside edge.*

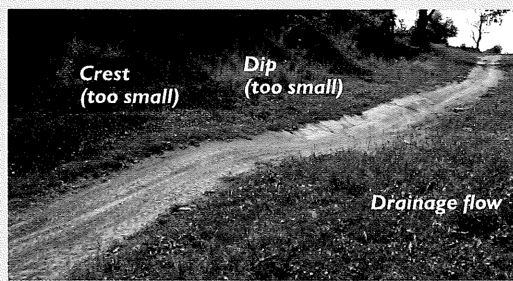




Crest added on top of existing tread and bermed outside edge. Firming or hardening is recommended in these instances, especially for high displacement uses. Note slightly rounded top here.



Excellent filled crest. *Although the crest is small, it's adequate for this hiking-only trail with a stable, well compacted tread.*

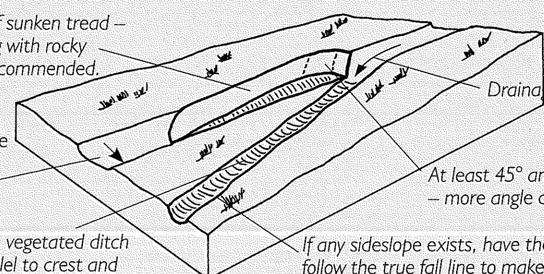


Partial implementation. *This filled crest is working for now, partly due to very stable tread soil. The crest, however, has little effective volume and the dip is very shallow. In sandy soil, displacement would quickly wear the crest down and sediment would likely clog the dip.*

Filled Crest on Fall-Line Tread

This is typically a high-maintenance technique, although the less steep the grade, the better it will work. The maximum practical grade is 12 to 15 percent. The filled crest will prevent tread water from continuing down the tread. However, any attempt to direct water off of the fall line will clog, so the crest and the dip above it must divert water into a ditch paralleling the tread on one side. On wider treads or in extreme situations, consider adding ditches on both sides planted with deep-rooted, erosion-resistant vegetation if the sideslope permits. This technique is not recommended for treads shared by snowmobiles.

FILLED CREST ON SIDESLOPE TRAVERSE

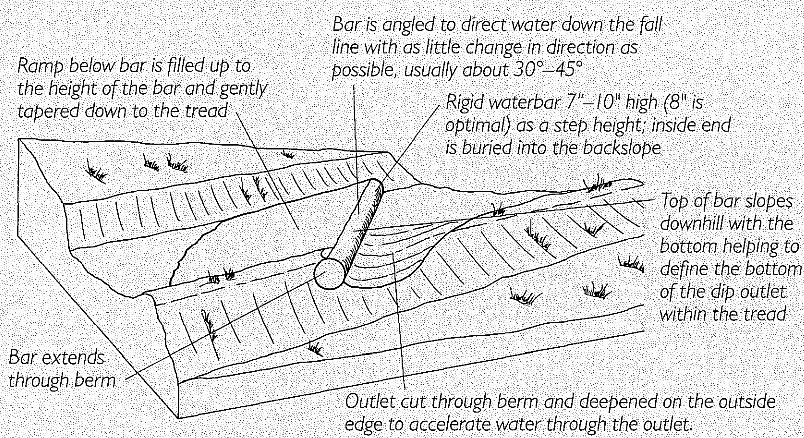


Rigid Waterbars for Constructed Crests

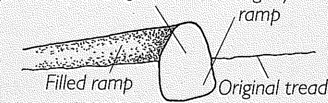
Rigid waterbars use stone or timbers to reinforce the top of the crest against displacement. In some cases, the waterbar serves as an actual "dam" for water. Due to the reduced need for a fill material, waterbars are often easier to form than filled crests on hiking and equestrian trail segments steeper than about 9 percent and less than 18 percent. Stone waterbars use closely fitted stones to minimize gaps. Although labor intensive to build, stone waterbars are rustically attractive trail structures. Where on-site stone is not available, 8-inch-round pressure-treated timber can be used. Untreated peeled logs can also be used where a more rustic appearance is desired, although these will need to be replaced every few years. As with any filled crests, rigid waterbars can be breached if the bar itself is breached or if sediment reaches the top of the crest. Generally, rigid waterbars should be used only on nonmotorized trails. Motorized users tend to go around rigid waterbars, defeating their purpose. Rigid waterbars are hazards for snowmobiles and groomers. The following graphic illustrates common placement of a rigid waterbar.

Rigid Waterbars For Constructed Crests

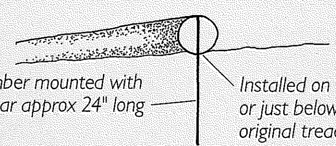
Typical Waterbar Illustration Cross Section



Stone Waterbar Cross Section



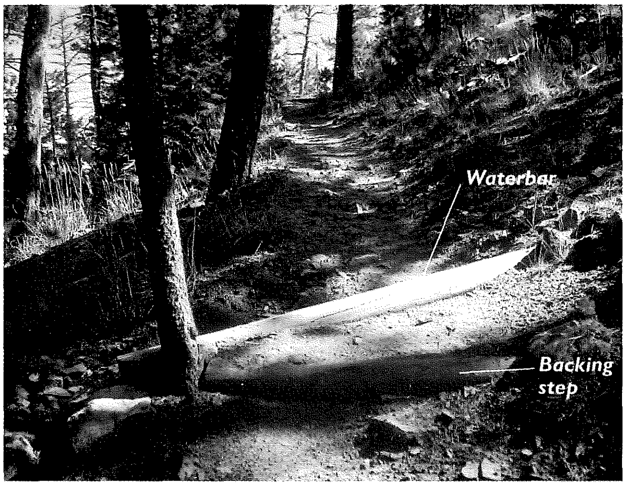
Timber Waterbar Cross Section



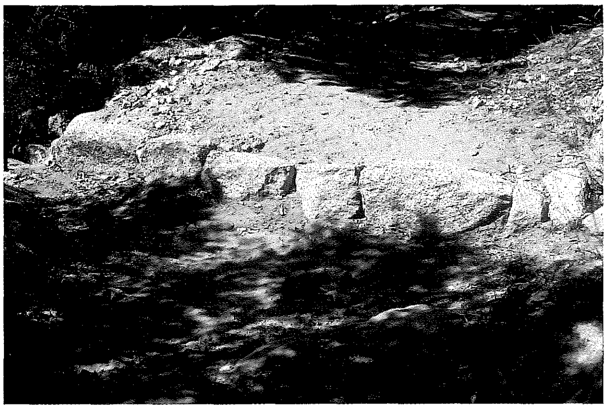
The following photos highlight common examples of rigid waterbars in field application.

This nicely formed traditional stone waterbar is at a good angle to the trail, accelerates drainage through a well-formed and sloped outlet, and exhibits good fit between stones.

Timber is used to reinforce the top of a filled crest. Note that water is smoothly diverted into the well-formed outlet without touching the timber.



A backed waterbar is sometimes necessary on steeper tread grades. It also makes for a comfortable step in the ramp behind the bar while it stabilizes the ramp. This is typically built as a riser perpendicular to the tread. Note how this waterbar is anchored on the tree at left.



Expertly fitted stones on this horse trail waterbar are well set. The small-looking stones are installed with their long axis vertical so that at least half the stone is below grade. The uneven top edge and uneven faces add desirable natural shape that help soften the line and blend the waterbar into the site.

A stone waterbar with soil on the uphill side can be used on treads with low grades where the stones are too small or do not fit together well enough to form a free-standing face. Note the wide outlet and the smooth way water flows into and through it.

Flexible Waterbars

Flexible waterbars have a thin, flexible strip of synthetic rubber that sticks up from the trail, yet folds over when ridden or walked across, then quickly springs back up again. Flexible waterbars have an number of advantages, including:

- Installation requires little or no modification of the tread level, reducing or eliminating the need for any filled crest.
- Can function on grades of up to 30 percent
- Suitable for use on trails shared with snowmobiles, without becoming jumps (as can be the case with filled crests)
- Can support occasional ORV and truck traffic
- Can be used on fall-line and near-fall-line treads (although this may require more maintenance)

Although flexible waterbars have many applications, they have some disadvantages, including:

- The low height of the bar (3 to 5 inches) makes it easy to breach if even a relatively small amount of sediment and/or displaced material deposits against it. Frequent inspection and maintenance may be necessary, especially with high uses or sandy soils.
- Installation at extreme approach angles can tend to slide the wheels of bicycles and OHMs sideways, especially in wet or muddy conditions. While there are ways to reduce this angle, doing so often entails creating an excavated dip and/or elevated crest – which defeats the purpose if the goal was to avoid modifying the tread shape.
- Some motorized users perceive flexible waterbars as safety hazards or obstacles and try to bypass them. This is best countered through visitor education and by using site anchors that make waterbars difficult or impossible to bypass.
- Synthetic materials are unnatural looking, which works against primitive trail experiences.

Synthetic bar material must be supple so it folds easily and springs back, must remain flexible at different temperatures, and must retain these properties as it ages, which makes using an appropriate bar material very critical.

Important consideration!

In general, flexible waterbars should only be using on existing treads where no other constructed crest is feasible. This typically includes one or more of the following:

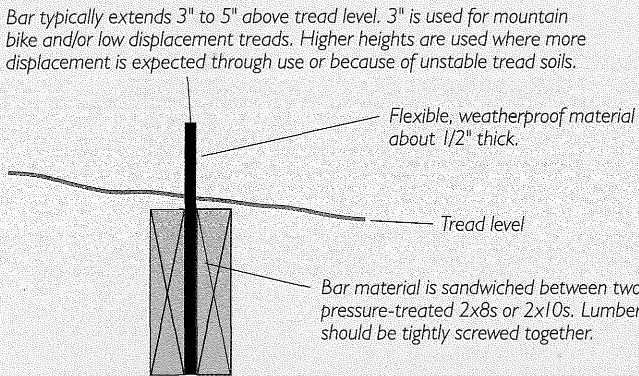
- Trail grades of 12 to 30 percent for any type of use
- Trails for wheeled uses with grades of 9 percent or greater (filled crests are recommended for grades less than 9 percent)
- Summer-use trail shared with snowmobiles

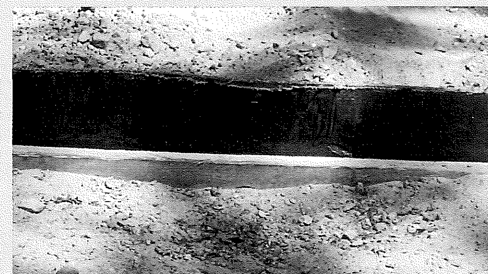
The following considers a variety of flexible waterbar applications.

Typical Flexible Waterbar Cross Section

The best flexible, weatherproof waterbar is a soft, consistent rubberlike material about 1/2-inch thick. Used conveyer belts (rubber-coated canvas) tend to stiffen and delaminate with age and use and are not recommended. In conjunction with burying the waterbar in compacted backfill, additional anchoring may be needed in unstable or high-displacement tread soil types, or to help prevent removal by vandals. The following graphic illustrates a cross section for a flexible waterbar.

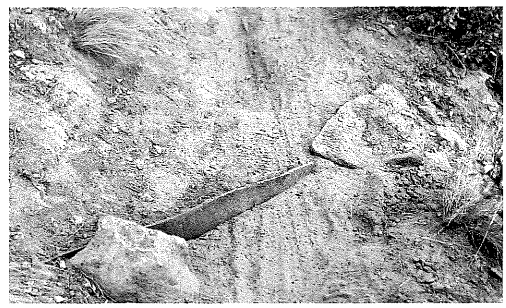
TYPICAL FLEXIBLE WATERBAR FOR CONSTRUCTED CRESTS





Close-up of flexible waterbar with part of the buried frame exposed in an unstable tread. This bar, on an OHV trail, is made of an old conveyer belt.

The following photos highlight some of the more common problems with flexible waterbars.



(Upper left) A 30 percent tread grade needs higher maintenance. The bar is silted in and partially collapsed on the outsloped tread for mountain bikes. The bar is also too short on the right side.

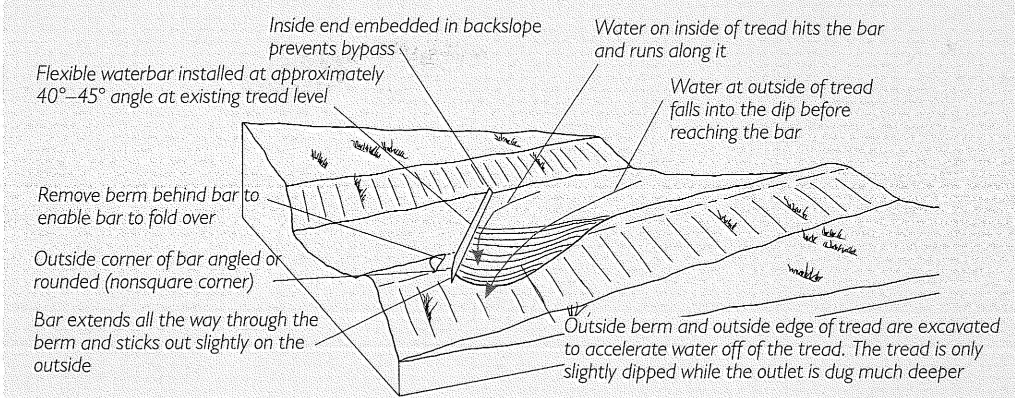
(Upper right) This waterbar was doomed from the start. The bar is too short, the outlet is blocked by rock on right, and there is not enough angle for the steepness of trail and the trail looseness of the tread.

(Lower left) Breach of this bar was caused by displacement, the low bar angle, the shortness of the bar, and the lack of an excavated dip outlet.

Sharply Angled Flexible Waterbar With Minimal Tread Modification

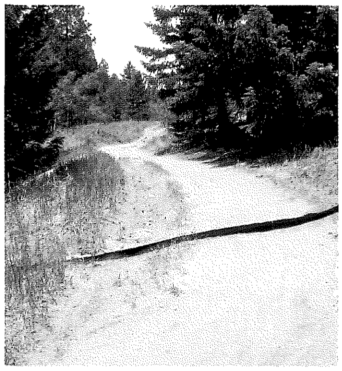
Sharply angled waterbars are placed to form sufficient pitch in order to drain. The outside edge, however, is excavated like a constructed tread dip to widen and deepen the outlet to help prevent clogging. This following graphic illustrates a flexible waterbar on a trail with an approximately 20 percent tread grade and an outside berm on a sideslope.

Sharply Angled Flexible Waterbars With Minimal Tread Modification

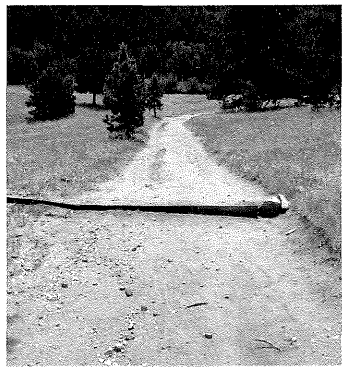


The following photos highlight sharply angled flexible waterbars.

This highly angled flexible waterbar has worked well for years on this heavily used mountain bike, hiking, and horse trail. The trail is fairly steep, with a sideslope down to the left. Tread is firm and stable with low displacement. A very long bar, extended on both ends, with anchor rocks at each end effectively convince visitors not to bypass it. Mountain bikes have no trouble with the bar angle.



The angle of this bar was reduced due to high outslope on this superelevated curve. As long as the water runs off at as steep a grade as possible, the bar can be placed more perpendicular to the tread.

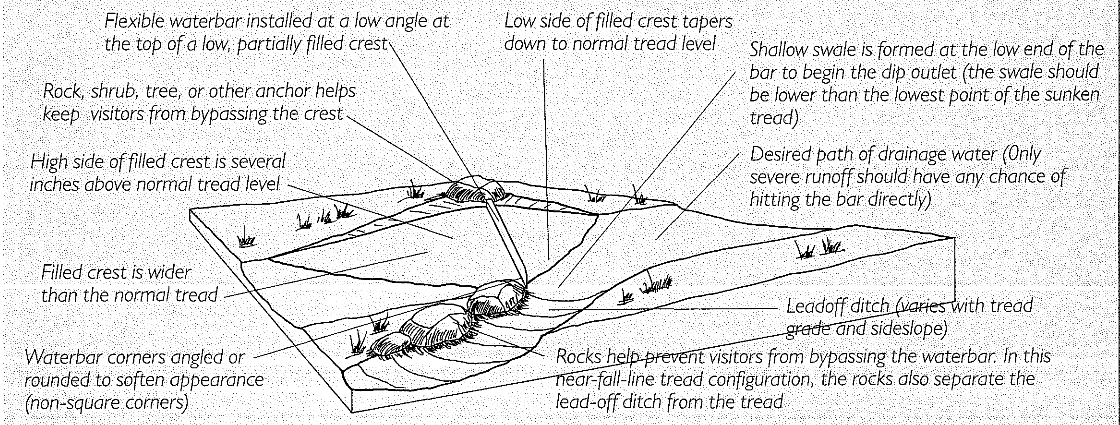


This tread runs near the fall line, with a sideslope down to the left. The bar uses outslope on the tread to accelerate water to the dip. Notice from the small gullies in the left foreground that most water never reaches the actual bar.

Less Angled Flexible Waterbar with Partial Filled Crest

To be less threatening to wheeled uses, a flexible waterbar can be placed more perpendicular to the tread with one end raised on low, relatively small filled crests. This causes greater reliance on the flexible waterbar to create the equivalent of a larger effective volume as well as a hardened top. Note that the waterbar should not be at 90 degrees to the tread, especially on steeper trail grades, to prevent it from becoming a dam rather than a diversion. The more the grade that the water follows off of the tread meets or exceeds the trail grade leading into the dip, the less likely the dip is to clog. The following graphic assumes a near-fall-line alignment with a lead-off ditch almost parallel to a sunken tread.

Less Angled Flexible Waterbars With Partially Filled Crest



Hardening Constructed Crests

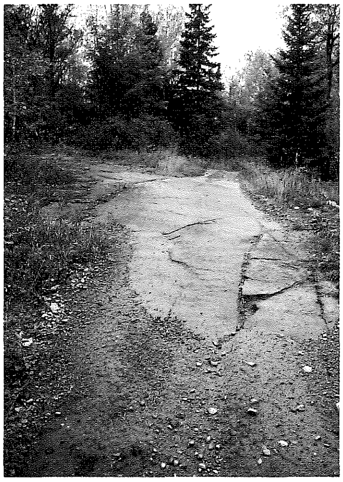
For trail uses that cause a high level of tread displacement on steeper grades and/or unstable soils, hardened crests can preserve the crest and retain a more subtle shape in a smaller footprint than a regular filled crest. Hardened crests avoid the safety (sideways sliding) concerns of flexible waterbars and can be more reliable than unhardened filled crests. A variety of hardening techniques are considered later in this section.

Anchoring Tread Crests Into the Site

Both alignment and constructed tread crests benefit by being well anchored into the site. Anchors keep trail users on the trail and integrate the crest as a seamless part of the trail experience. Well-anchored tread crests are not particularly noticeable to the trail user. The following photos help illustrate this point.

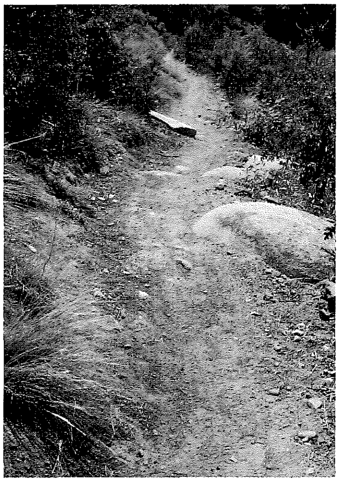
A jogging alignment crest that jogs above a tree is one of the best and most natural looking ways to anchor alignment crests.

This is another well-anchored jogging alignment crest. Locating a trail on the high side of the tree minimizes disturbance to roots.



Rock outcrop crests are very desirable because they add interest to the trail, are very stable, and are essentially maintenance-free.

Even small rocks and/or trees can create a crested squeeze that constrains the tread. Although this is a hiking and horse trail, this approach is appropriate for any trail use.



The large natural stone anchors and also forms this in-line alignment crest. Stones can also be placed in trails with heavy equipment, especially where a roadway tread is being narrowed in a trail conversion.

(Left) Although not always desirable, having a blind curve at the top of a crest is nearly guaranteed to cause visitors to reduce speed and proceed cautiously.

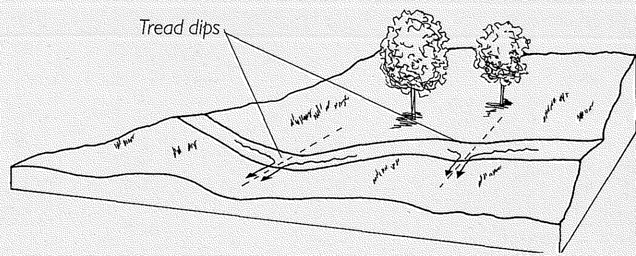
(Right) Trees and a sideslope help anchor this crest (top of photo) and dip bottom of photo) along an ATV trail.

TREAD DIPS

Tread dips are local low points in the trail tread that drain runoff to a lower elevation than the tread itself. Every tread dip must drain even while compaction, displacement, and/or erosion modify its shape. The dip must continue to completely drain the tread even if trail material or leaf litter falls into it, the outlet becomes clogged, or the bottom of the dip becomes deeper through compaction or displacement.

TREAD DIPS

Tread dips are local low points in the trail tread that drain runoff to a lower elevation than the tread itself. A combination of tread crests and dips is used to manage the flow of stormwater runoff to prevent erosion



The following considers the key aspects of creating sustainable tread dips.

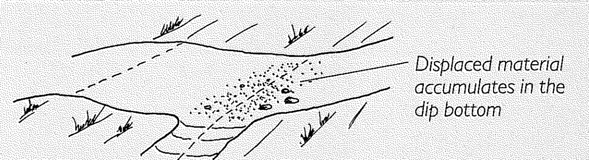
KEY TREAD DIP VULNERABILITY: CLOGGING

Tread dips serve one main purpose, which is to drain the tread in a sustainable manner. Unfortunately, environmental conditions and trail use cause dips to clog. Typically, this is can take weeks, months, or even years, although major runoff events can clog (or clear) a dip in minutes. The following graphic illustrates how tread dips clog.

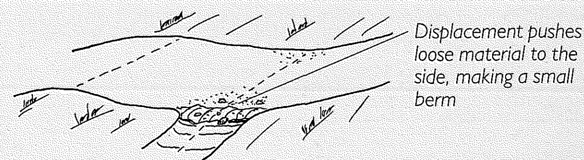
HOW TREAD DIPS CLOG

Clogging occurs through a combination of four repeating processes, which makes it a predictable and – to the extent the conditions can be controlled – preventable or at least sustainable with regular maintenance.

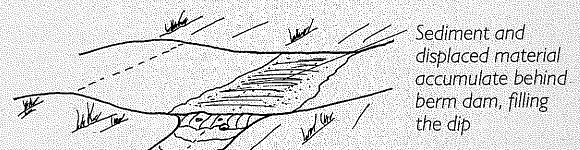
1. **Displaced material falls into the dip.** Gravity continually pulls displaced material downward. Loose material creeps down to the lowest point, which is the bottom of a dip. Even small displaced rocks and organic debris will creep downward into the dip through continual displacement.



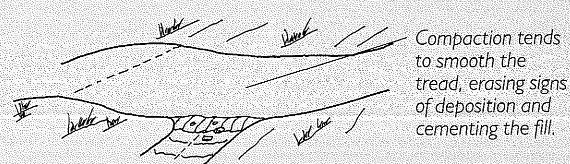
2. **Displacement forms a berm across the dip outlet.** Inside the dip, trail use pushes loose material toward the outside edge. A small berm forms like a dam across the dip outlet.



3. **Sediment fills in behind the berm.** In dry conditions, the continued flow of displaced material from above fills in behind the berm. With runoff water, material fills in behind the berm dam, slows there, and settles out. Many small rains can slowly build up layers of sediment that raise and level out the dip bottom inside the tread.



4. **Compaction and water cement the clog.** Since the sediment behind the outside edge berm is in the tread, trail use compacts it. If the material is repeatedly wetted and dried with compaction, it becomes hard and resists erosion. Subsequent runoff through the dip then flows over the compacted, raised tread.



When major storms do occur, flow can be sufficient to fill the outside of the tread. This is more likely where the dip outlet has a shallow grade that causes the dip to fail unless the outlet is cleaned out before the next major rain. It can also happen during a short, heavy rain in which there is enough water to carry sediment into the dip but not enough to flush it through.

On the other end of the spectrum, intense runoff may send so much water through a still-functioning dip that previous deposition is eroded out. The dip and its outlet may even become deeper (scouring). This is more likely when the dip outlet follows the fall line and if the outlet is relatively steep. Frequent or severe scouring indicates the need for additional tread dips to divide the flow.

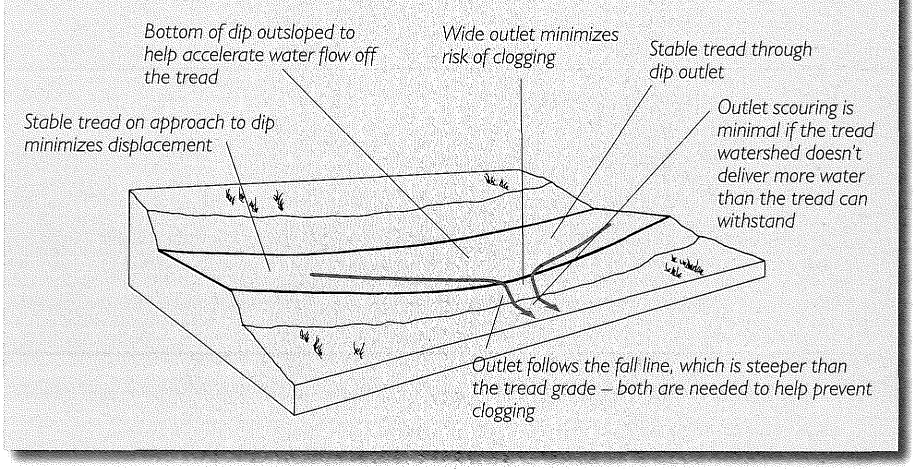
Prevention of Clogging

Physics, geometry, and the need to accommodate a changing tread drives dip design. The failure point of nearly all tread dips is in the bottom of the outlet inside the tread and immediately outside the tread, with the most common mistake being locating tread dips in inappropriate locations.

In general, a sustainable dip will require little maintenance if the following design factors all work together:

1. **Fall line is steeper than tread grade.** A tread dip cannot sustainably drain unless the fall line is significantly steeper than the tread grade. A relatively steep fall line makes the outlet harder to clog. For maximum sustainability, locate tread dips in the most level part of the tread, not the steepest. This maximizes the difference between tread grade and the fall line.
2. **Stable tread with minimal displacement.** Both the approaches and the dip bottom should be stable. If the tread above the dip has high displacement, especially small rocks, displaced material tends to fall into the dip with everyday trail use, even without water. This is a primary cause of dip clogging, especially constructed dips. Compaction and displacement can also lower the center of the tread at the bottom of the dip, thereby damming the outlet and ponding water.
3. **Outlet accelerates water.** Since clogging is caused partly by water dropping sediment when it slows, it is important to locate and shape the outlet to accelerate water through the dip. This is done by having the dip outlet at a steeper grade than the tread leading into the dip and by aligning the outlet along the fall line or at approximately a 45 degree angle to the tread, whichever enables faster through flow.
4. **Wide outlet.** This helps provide the extra volume at the outlet to move runoff quickly through the dip without scouring.
5. **Minimize scouring.** Scouring refers to erosion within the dip outlet caused by too much water and/or water moving too fast for the tread material to withstand. If scouring occurs during less-than-extreme runoff events, form additional tread dips above the scoured dip to divide and drain off the erosive flow.

IDEAL TREAD DIP CHARACTERISTICS

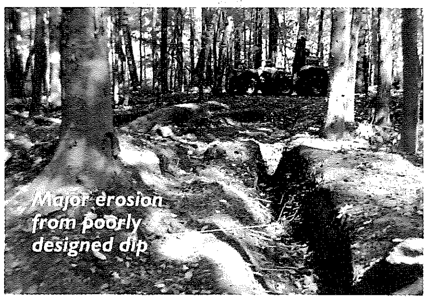


If these design factors are routinely considered as part of a trails initial design, creating sustainable trail dips is achievable. The photographs on the next page illustrate the consequences of not adhering to these principles.

Consequences of Inadequate Attention to Trail Dip Design Factors

The following photographs illustrate the consequences of not adhering to the design factors associated with sustainable tread dips as defined on the previous page.

Outlet decelerates water and is too narrow, causing sediment buildup. The dip outlet should follow the fall line to move water away from the trail faster. The sandy tread is also unstable, which suggests a need for more crests and dips.



The lack of a well-designed rolling grade on this ATV trail has resulted in too much water flowing through a dip and creating a major erosion problem that is not sustainable. This trail will have to be redesigned.

Inadequate dip outlet slope causes standing water in the dip. Even though the dip outlet, foreground, is wide, the outlet slope is not steep enough to adequately drain water from the tread.

High displacement and insufficient sideslope have allowed compaction and displacement to lower the bottom of the dip below the bottom of the outlet, ponding water in the dip.

This outlet was clogged by dry displacement that settles in the dip through everyday trail use. The tread grade is approaching the fall-line, further exacerbating clogging.

Doomed from the start, this very steep tread grade is close to the fall line. With a very narrow outlet, the waterbar slows water coming down the tread and acts as a settling point for displaced tread material, which breaches the crest.

TYPES OF TREAD DIPS

In new trails, tread dips formed through trail alignment are the most natural and sustainable. *Constructed dips are only used when there is not enough space for an alignment dip or when a new dip is needed in an existing trail.* Constructed dips – usually in the form of drainage dips and waterbars – have varying complexity and design depending on the trail situation and trail uses.

Alignment Tread Dips

Alignment dips have three distinct advantages over constructed ones:

- **Larger volume** – an alignment dip usually has a much larger breadth than a constructed dip, which means that it will have less chance of clogging.
- **Easier formation** – in new treads, alignment dips require no explicit construction because they take advantage of the natural landscape form.
- **Natural appearance** – alignment dips are just part of the landscape that is being traversed and thus not even consciously noticed by most visitors. Constructed dips usually look like managed drainage control structures.

There are four distinct ways to form alignment dips, plus some special approaches for motorized and mountain bike trails to help prevent use-created superelevations from blocking the dip outlet.

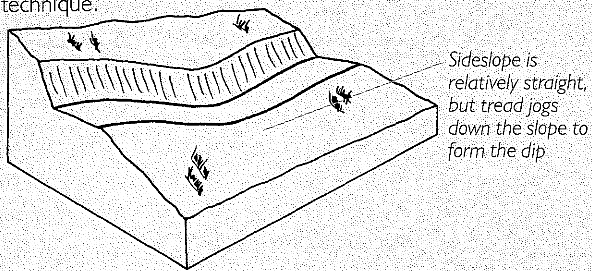
The graphic on the next page highlights in-line and jogging alignment dips.

Alignment Tread Dip Configurations

Tread dips formed by alignment have four basic configurations, plus special considerations for motorized uses (see next page). Jogging configurations briefly drop down the sideslope to create a dip in the tread. In-line configurations drop down and through a natural swale without having to jog. Jogging configurations can be formed wherever needed on a significant sideslope. In-line configurations can be used with any sideslope – including no sideslope – but are limited to locations with natural dips.

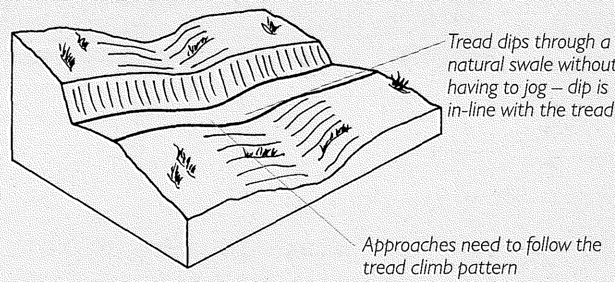
Jogging Near-Level Alignment Dip

While traversing a slope, the tread jogs down and back up the slope to form a dip through alignment. This is a frequently used technique.



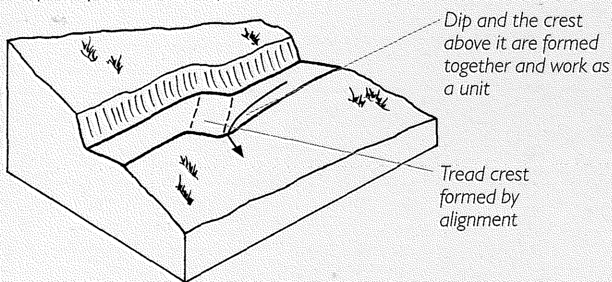
In-Line Near-Level Alignment Dip

While going relatively straight, tread drops through a natural swale or depression. This is useful where a natural dip exists.



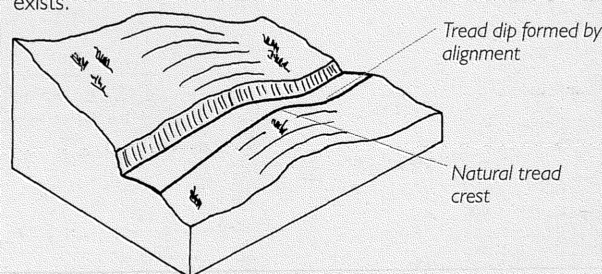
Jogging Climbing Alignment Dip

While climbing a slope in traversal, the tread jogs quickly down and up to form a dip. A tread crest is also formed. This is a frequently used technique.

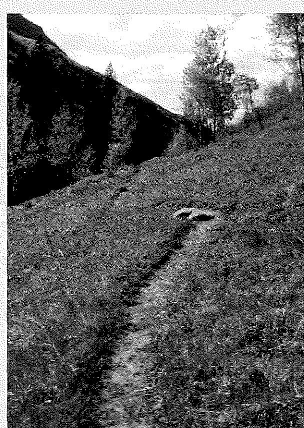


In-Line Climbing Alignment Dip

The tread is aligned to climb over a natural ridge, coming down from the top to shape a tread dip on the uphill side before continuing its climbing traverse. This is useful where a natural crest exists.



Jogging, near-level. *The trail jogs down the sideslope to form a dip. (Mountain bike, hiking, and horse trail)*



Jogging, climbing. *With no tree canopy, grasslands are highly subject to erosion. The dip in this climbing traverse prevents serious erosion. (Hiking and horse trail)*

In-line, near-level. *With a slight sideslope down to the left, this trail rolls through a small natural swale. (Hiking trail)*

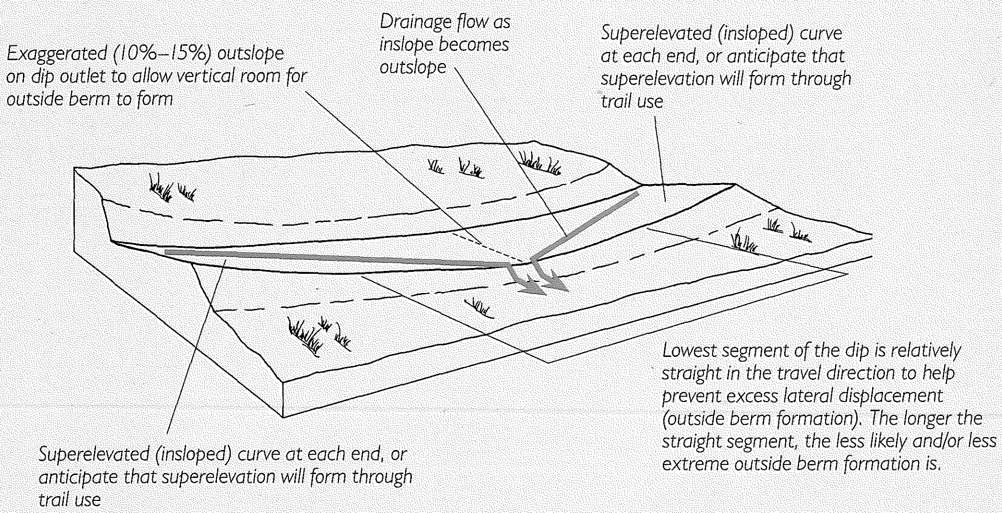
In-line, climbing. *Trail rolls through a small site drainage, making this a drainage crossing as well as a tread dip. Note the fall line alignment. (Hiking trail)*

Minimizing the outside berm on jogging alignment dips with wheeled trail uses can be a challenge. This is especially the case where a dip exists in conjunction with a short-radius curve in the trail, which becomes superelevated as the trail is used. The superelevation will form a berm on the outside edge that will dam the dip outlet, as the two photos on the next page illustrate.

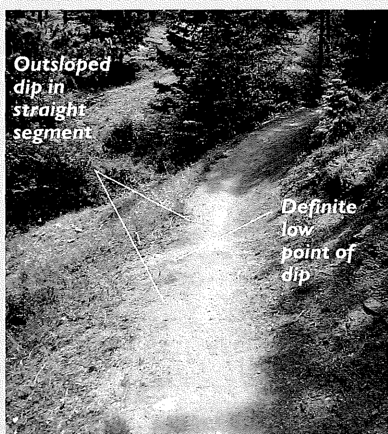
As both of these photos illustrate, superelevations can be formed through regular trail use by wheeled vehicles such as OHVs and mountain bikes.

To prevent this, jogging dips should be aligned in the center of a relatively straight segment of the trail, which will result in relatively little displacement toward the outside edge. The following graphic and photos illustrate this point.

TREAD DIP LOCATED ALONG A STRAIGHT SECTION BETWEEN SUPERELEVATED CURVES



Example of good jogging alignment dip for wheeled uses. The entire dip is long and gentle rather than short and abrupt. The bottom of the dip has an exaggerated outslope and is in a relatively straight segment of the curve. The curve is gentle enough to reduce displacement and user-formed superelevation. The dip has a definite bottom so that if ponding does occur on the tread, it can't spread lengthwise.



Dip outlet berming may still occur with high displacement uses, even if tread is straight. Outlet berms will still need to be removed during regular maintenance, and the dip and outlet should be formed to drain the tread even when a berm forms.

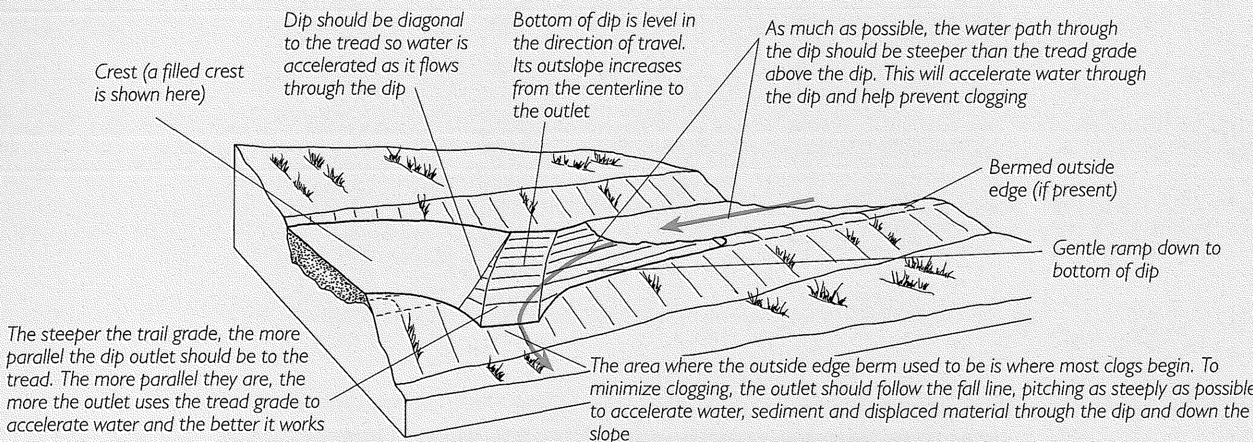
Constructed Tread Dips

In cases where creating an alignment dip is not viable, constructed dips are used. These are typically paired with constructed crests. Constructed tread dips are typically used on existing treads where the tread grade has already been established and there is little space for a large, wide, relatively clog-proof dip and outlet formed through alignment.

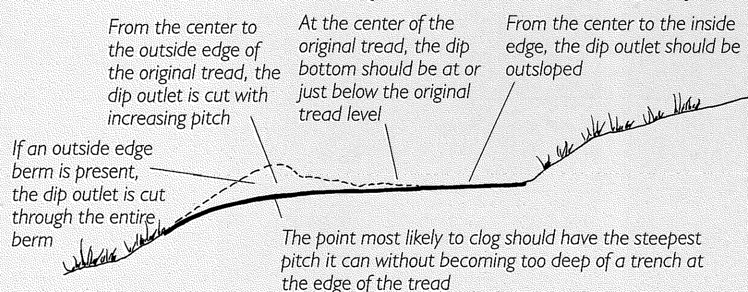
It becomes exponentially more difficult to sustain constructed dips as the tread grade increases. Dips also become more difficult to drain as the tread alignment approaches the fall line.

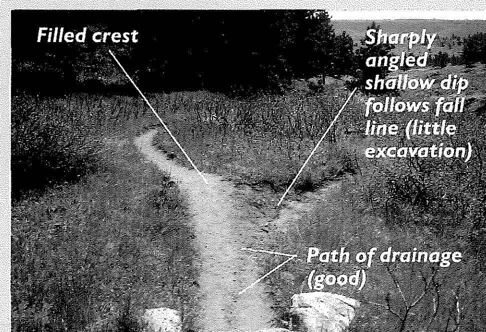
A constructed dip is formed in the same way as a constructed tread crest, as the following graphic and photographs illustrate.

Constructed Tread Dip Configurations



Cross-Section of Tread Dip (Looking Down the Trail)

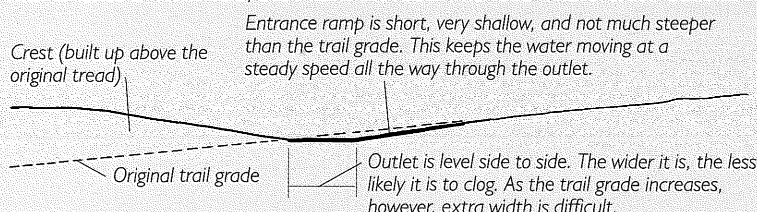


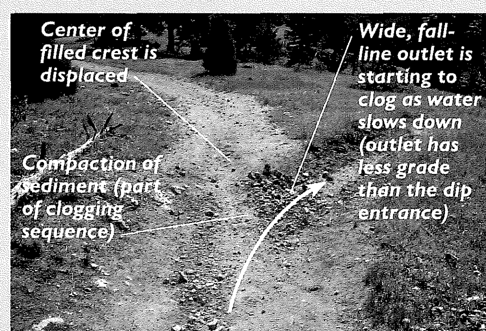


This is an excellent shallow excavated dip that routes water off the trail through a shallow outlet following the fall line. Note the angle of the water path as it enters the dip, where it gradually flows into the dip with a steady grade. The outlet will still occasionally need to be cleaned out.

Side View Cross-Section of a Shallow Tread Dip

A shallow excavated dip with a higher built crest takes more effort to form, but clogs less often than deeper dips due to the tread grade leading into it. Since maintenance is minimized, this method is recommended wherever it's feasible.

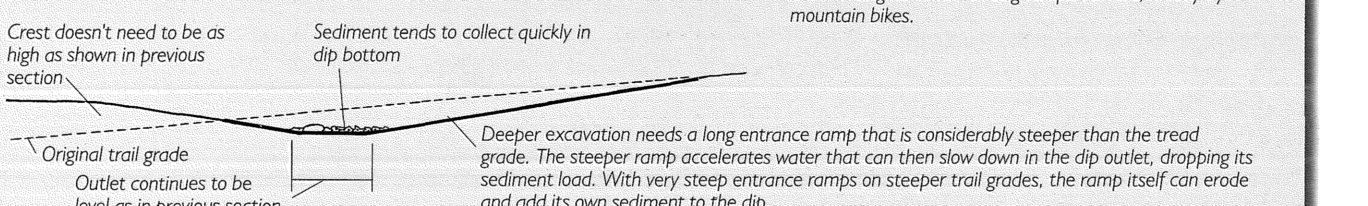




Although this deeper dip and crest are working for now, they need repair and cleanout. The deep dip is filling with displaced tread material because its outlet is less steep than the tread above it. The crest (which lacks effective volume) is also losing its center through displacement, mostly by mountain bikes.

Side View Cross-Section of a Deep Tread Dip

A deep excavated dip enables the crest to be lower. Unfortunately, the steeper entrance ramp accelerates water and enhances the potential for erosion. If the water slows at the outlet, heavier sediment drops out and leads to clogging. Dry displacement also moves in larger quantities and faster down the steep entrance ramp. Together, all forces combine to clog deep dips faster unless the outlet is pitched at least as steeply as the entrance ramp.

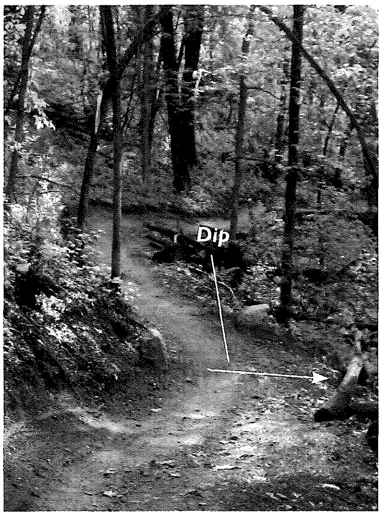


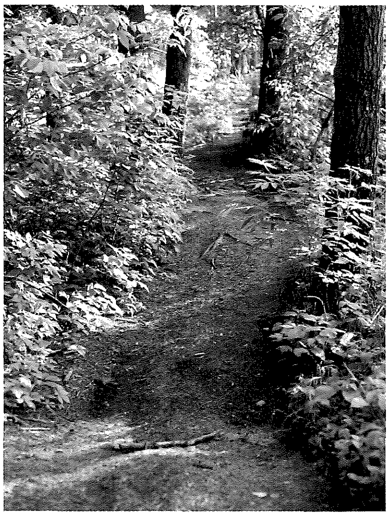
Anchoring Tread Dips Into the Site

Both alignment and constructed tread dips benefit by being well anchored into the site. Anchors integrate the dip as a seamless part of the trail. They also keep the trail users on the trail, which is critical to their function. The following photos help illustrate this point.

This dip on a hiking trail is strengthened by surrounding trees and vegetation. With a few rocks and rubble used to harden it, the dip is also the least muddy and most stable place to cross this intermittent drainage.

Given the compaction and displacement forces of OHVs, well-anchored and well-placed dips are necessary to prevent bypassing and excessive superelevations from occurring. Even these small trees help keep the user on the trail at this dip.





Both of these trails are well-anchored to keep mountain bikers (left photo) and ATVs (right photo) on the trail through an alignment dip. Note the small superelevation on the mountain bike trail, which does not clog due to enough fall-out from the dip and routine maintenance.

Tread Climbs

Tread climb relates to the steepness and length of a trail overall and between individual tread crests and dips. Tread erosion is the primary factor influencing the role of trail steepness to ensure sustainability. The desired level of accessibility and difficulty is also a factor in determining the appropriate steepness of a trail.

Types of Tread Climbs

There are two types of tread climbs: Traversing climb and fall-line climb.

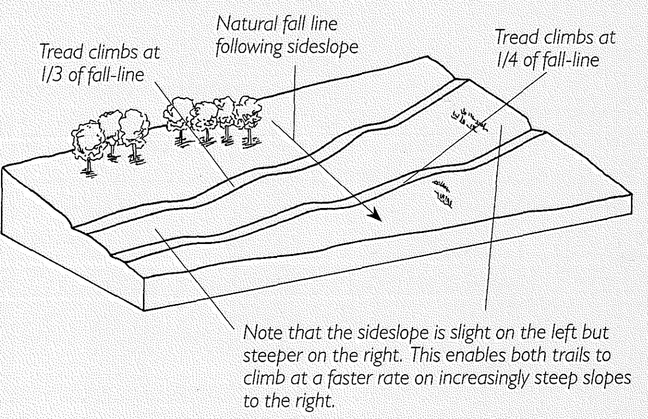
Traversing Climb

Important consideration!

Traversing climbs traverse the sideslope or fall line in a sustainable fashion to prevent erosion and keep the grade accessible for the intended users. In general, tread climbs should not exceed one-fourth to one-third of the fall-line. The steeper climb is used only when the tread has a higher-than-usual ability to withstand compaction, displacement, and erosion, and where the steepness is in alignment with user expectations. The following graphic illustrates a traversing climb.

TRAVERSING CLIMB

This is an excellent example of a sustainable climbing trail. Notice that crests and dips are woven into the trail to minimize erosion.



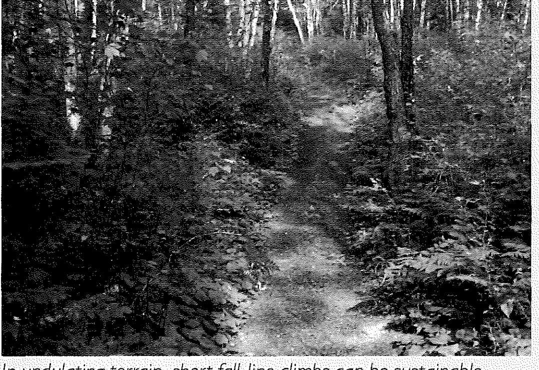
Fall-Line Climb

Although traversing climbs are inherently more sustainable, fall-line climbs can be used in certain controlled circumstances where the following conditions are met:

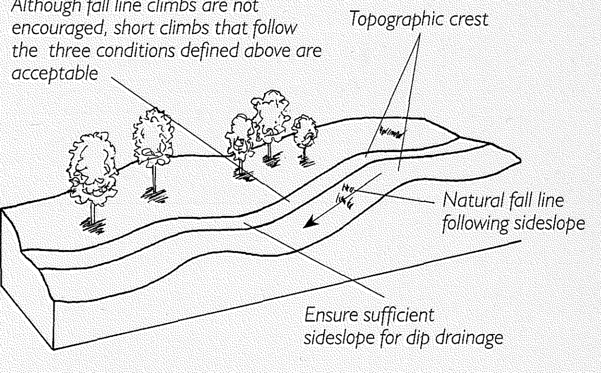
- The entire climb from a tread dip to a tread crest can be achieved within an acceptable length and grade range (as suggested in table on the next page)
- There is no possibility of water coming onto the tread from above the tread crest at the top of the segment
- The dip at the bottom cannot clog or fail from any foreseeable displacement and/or erosion of the segment

The following graphic illustrates a fall-line climb.

FALL-LINE CLIMB



In undulating terrain, short fall-line climbs can be sustainable. In this example, a gentle tread grade, gravelly and well-drained sandy loam tread, tree canopy, and low use all help protect the tread from displacement and erosion.



TREAD LENGTHS RELATIVE TO TRAIL GRADES

Quantifying tread lengths between crests and dips relative to trail grades is difficult to do with preciseness given the many site-specific factors that need to be considered. Although each site has to be evaluated on an individual basis to determine the best relationship between these factors, the following table provides a base-line for tread climb limits for regular trails (i.e., trails not specifically designed to challenge users with extreme tread conditions). In some cases, these recommendations need to be modified for individual circumstances (see table).

SUGGESTED MAXIMUM TREAD SEGMENT LENGTH FOR TREAD GRADES ON REGULAR TRAILS

Values in the table are maximum desired lengths of tread segments given different soils and trail grades. A tread segment is from a tread crest to the next tread dip. These values assume that the tread is compacted but has no functional outslope (i.e., all tread watershed water drains down the tread and through the dip at its base).

Tread material (compacted for wheeled uses)	**Tread grade (top of crest to bottom of dip that drains segment)** 2%	4%	6%	8%	10%	12%	14%	16%	18%	20%
Pit run unsorted granite, 8" minus, all sizes evenly mixed down to dust, no native soil, 10" thick (12" minus and 16" thick for >15% grade)†	500'	425'	300'	200'	140'	100'	80'	60'	40'	30'
Loam, sandy loam, silty loam evenly mixed with 8" minus gravel and cobbles for 60% total stone content, 8" thick†	350'	275'	200'	150'	110'	80'	60'	45'	30'	20'
Loess (dry)	350'	275'	180'	120'	90'	70'	55'	35'	20'	10'
Clay‡ or sandy clay‡ with some gravel	325'	220'	160'	100'	70'	40'	25'	15'	NR	NR
Loam*, sandy loam*, silty loam*, clay loam with gravels 3" minus	300'	220'	160'	100'	70'	40'	25'	15'	10'	7'
Sandy clay‡	250'	180'	120'	700'	45'	20'	10'	NR	NR	NR
Loam*, sandy loam*, silty loam*, clay loam	200'	120'	90'	60'	30'	18'	8'	NR	NR	NR
Crushed granite or crushed limestone, angular, 0.75" minus, 6" thick†	200'	100'	70'	35'	18'	8'	NR	NR	NR	NR
Organic soil*	120'	80'	50'	30'	15'	NR	NR	NR	NR	NR
Sugar sand (very smooth sand with rounded edges)	175'	100'	500'	25'	NR	NR	NR	NR	NR	NR

* Found in many Minnesota state forests

† Requires augmentation with imported stone material, primarily intended for ATV and ORV trails

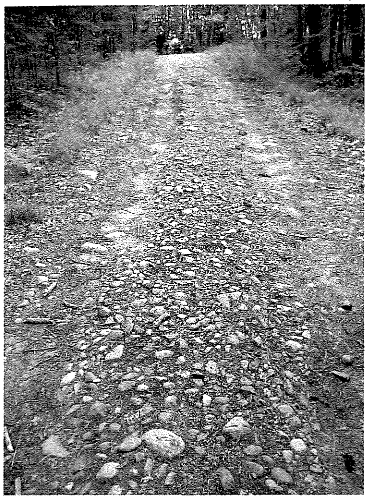
‡ Soils with abundant clay content may become extremely slippery or unusable on grades when wet

NR – Not recommended due to lack of resistance of tread material to displacement and erosion

Note: The values are for general-use trails and not explicitly designed to challenge users with extreme tread conditions.

Modifiers for Tread Segment Length: The following factors affect dip spacing and should be used to modify the base-line figures:

Condition	**Dip spacing** (decrease = have dips closer together; increase = have dips farther apart)
Sideslope steepness	Decrease spacing as sideslope increases.
Rocky tread material	Increase spacing as rock content increases. Cobbles and stones 4"+ diameter provide much more stabilization than smaller cobbles or gravels. Having a wide range and mix of rocks provides better tread stabilization and erosion control than having rocks of one size.
Runoff onto tread from above	Decrease spacing as runoff increases. Greatly decrease spacing or lower trail grades if there are substantial areas of rock, bare soil, or nonporous areas above.
Seeps into tread from below	Greatly decrease spacing in the affected areas with dips every 8' or less, or use tread-hardening techniques to help stabilize the tread.
Tree canopy above tread	Spacing can be increased as canopy thickness and percentage of canopy cover increases.
OHV or equestrian use	Decreased dip spacing is optional but will reduce tread erosion. Lower tread grades are desirable, especially in soils that have little displacement resistance.
Amount of trail use	Decrease spacing, decrease trail grades, and/or increase maintenance for heavy use. Can increase spacing slightly for light use.
Risk of tread dip failure	Decrease spacing if a long, climbing stretch is divided into smaller tread watersheds by constructed tread dips or if tread dips or crests are otherwise subject to clogging or failure. If one dip fails, it can lead to a domino effect.



These natural rock cobbles form a stable ATV trail tread on this fall line downslope that has withstood years of use. It sustainability is due to considerations of many of the factors listed on the previous table.

ADAPTING THE TREAD CLIMB GUIDELINES TO FIELD CONDITIONS

Follow these principles in adapting the tread climb guidelines on the last page for use in actual field conditions:

- **Traversing climb is preferred over following the fall-line** – traversing climbs with tread grades less than one-fourth or one-third of the fall-line provide opportunities for intermediate tread drainage. Fall-line climbs are very difficult to sustainably drain at a midway point, making them increasingly susceptible to erosion and displacement as the tread lengthens.
- **Use the tread length table as a basic guide only** – modify it as needed based on field conditions. A first-hand look at erosion risk factors provides the best insights for trail design.
- **Plan and design conservatively** – where in doubt, use lesser tread grades and shorter tread segments. The shorter and less steep tread segments are, the better the tread can accommodate severe runoff and heavy trail use.

TREAD HARDENING – BASIC TECHNIQUES AND CONSIDERATIONS

Since natural trails are meant to be natural, hardened treads are used only in situations where there is no reasonable alternative to reroute the trail in a sustainable way. With the exception of boardwalks and possibly porous pavement panels, all of the techniques in this section are considered "fill" and must be consistent with regulatory and permitting requirements.

Where hardening is required, numerous techniques are available depending on the circumstances. Each has advantages and disadvantages, most challenging of which is visual character.

CONSIDERATIONS IN CHOOSING A HARDENING TECHNIQUE

The following table highlights key considerations in selecting a hardening technique.

CONSIDERATIONS FOR SELECTING A HARDENING TECHNIQUE

Reason for hardening – ranging from forming an all-weather tread in normally stable soils to forming a stable tread in unstable soils to preventing rutting and erosion.

Suitability for type of use – the technique that is selected will affect tread roughness and firmness and its ability to withstand use-imparted compaction and displacement. *The willingness and ability of users to travel on the chosen form of hardened tread is also a major consideration.*

Use weight characteristics – heavier types of use and those that concentrate weight in a small area, such as ORVs and horses, need a technique that will spread the weight over a wider area to reduce rutting and displacement.

Material source and transport – ability to obtain and deliver materials to a site often drives the choice of technique. Minimizing site damage during transport is often one of the more difficult aspects of tread hardening.

Stability of underlying soil – highly unstable soil requires techniques with excellent load-transfer characteristics.

Amount of water and/or flooding – relatively few techniques are appropriate for use in standing and/or moving water.

Consequences of failure – the likelihood that a hardening technique will fail is a major consideration. The decision should consider the worst-case scenario for failure. User safety is of particular concern, as is the extent to which site damage would occur if the hardened tread is washed away or becomes unusable.

Permanence and sustainability – other factors being equal, techniques that use durable materials that do not require replacement or can be replaced and disposed of safely are preferred.

Green hardening – some techniques enable plants to grow through the tread, reducing trail impacts and forming a more natural tread.

Natural appearance – always desirable on natural trails, though the adverse consequences of tread failure are considered most important in selected a hardening technique. Unfortunately, the best technique does not always result in the most natural in appearance.

Installation cost and difficulty – some techniques are more expensive in material cost, delivery cost, and/or labor than are others.

Maintenance needs – some techniques, particularly those using earth and wood, need more maintenance than others – sometimes considerably more.

Removability – in sensitive areas, consider the ability to remove the hardened tread if necessary.

Hardening Techniques

These deep and spreading mud tracks on this ATV trail represent a clear case where thread hardening (or rerouting) is needed. The lack of physical barriers to keep the trail to a desired width is also evident in this photo.

Hardened tread techniques fall into three major categories:

1. **Mechanically stabilized rock and soil** – suited for a range of situations from smooth to rough treads in varyingly wet applications for many types of trail uses.
2. **Unitized wear surfaces** – provide a nonaggregate-based load-bearing surface with high lateral strength. Techniques are varyingly suitable for very unstable soils, underwater applications, steep tread grades, and any type of use, including high displacement modalities.
3. **Chemical binding** – generally used to form smooth, firm treads from small soil particles on level or low tread grades in reasonably well-drained sites for low and medium displacement uses.

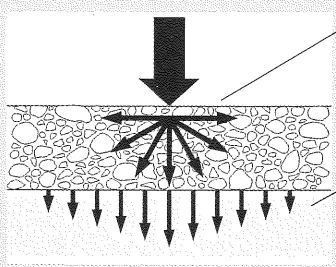
The following considers each of these categories in greater detail.

Mechanically Stabilized Rock and Soil

Mechanical stability of a tread comes from three interacting factors: aggregate thickness; particle size, compaction and drainage; and lateral stability. Aggregates spread loads throughout their structure. When all particles are tightly packed with no voids, the weight of a point-source load is distributed through an aggregate layer like a pyramid, reducing the per-unit-area force at the base. The following graphic highlights this principle.

Mechanically Stabilized Rock And Soil

Aggregate Load-Bearing Structure

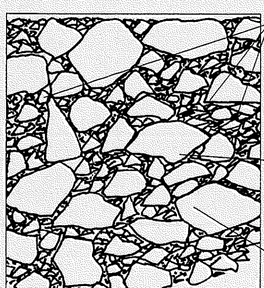


Increasing the aggregate thickness spreads the load over an increasingly wide area.

Downward force is greatest below the load point, with diminishing distribution outward

This well-graded aggregate tread is very stable with the right subgrade soil conditions. In other soils, this may not have enough variety in size and shape of rocks and soil particles to be stable. Site evaluation is critical to determining the type of aggregate needed to create a sustainable trail.

Filling Voids In Aggregate Materials



Various sizes of angular particles mechanically interlock into a solid matrix with no voids.

Ungraded, unwashed crushed stone contains the original rock binders (natural cements) in the rock dust. The binders in the dust help rebind the crushed aggregate into a solid, compact mass.

To prevent particles from shifting under a load, all voids must be filled. This is done by compacting particles of all sizes from dust up to a specified maximum. Rock dust, particles smaller and larger than sand, and all other sizes should be thoroughly mixed and compacted to firmly embed the larger particles in a matrix of smaller ones. The larger particles act as the skeleton of the structure, transmitting and spreading forces, while compacted dust and small particles act as binders and a medium to transmit force from one large particle to the next.

Note that in any compacted aggregate tread, drainage is essential to long-term stability. If properly graded and compacted, aggregate treads should not hold water.

Increasing aggregate thickness helps improve load distribution up to a point. Increasing lateral stability makes it possible to reduce or contain the horizontal spread caused by shear force. This increases load-bearing capacity and reduces the thickness of aggregate needed. Combinations of four techniques and materials are recommended to increase lateral stability:

- Adequately graded aggregate
- Geotextile soil stabilizer
- Geocell soil stabilizer
- Edge containment

The following considers each of these in greater detail.

Pit run sand and 2- to 4-inch cobbles were used to harden this forest road segment with an approximately 10% grade. Although ATVs displace some of the smaller cobbles and gravels, larger particles – imbedded in sand and compacted – remain in place.

Adequately Graded Aggregate

Moderate and high displacement uses need larger aggregate particles to reduce the propensity for surface displacement. Large particles in the surface form a rocky bearing surface that resists tread abrasion from visitor use. Surface displacement is a serious problem because it can remove the top from hardened tread, which in turn changes its drainage, reduces its effective hardening, and results in increased erosion – which is the exact opposite of what was intended in the first place.

The largest particles need to be large enough to be firmly bedded in the aggregate layer with only their tops exposed. Rounded particles, such as glacially or water-rounded stones, are most suitable – although a full range of aggregate particle sizes need to be present to enable firm bedding and compaction. The following graphics on this and the next page define the function of rock and soil materials in greater detail.

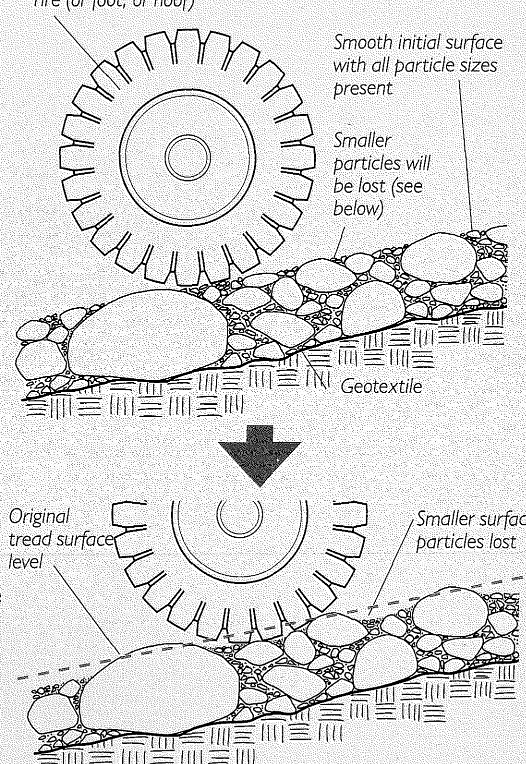
Aggregate Loss on Tread Climbs

With any aggregate hardening on a nonlevel tread, some of the surface aggregate is lost through displacement and erosion. At installation, the tread surface is smooth with all sizes of particles from dust to the maximum size in the aggregate layer. The top illustration shows tread hardening with pit run (rounded river rocks and sand).

After trail use, however, smaller surface particles – and some larger ones – are lost to displacement and/or erosion, as shown in the bottom illustration.

The depth and amount of surface loss increases with:

- Steeper tread grades
- Higher displacement uses
- Larger tread watersheds
- Smaller maximum size of aggregate particles (i.e., where the largest particles are not large enough to be buried deeply enough to withstand surface displacement)



The larger cobbles of this pit run and Class 5 material resist surface displacement on this on-road ATV trail. Note how centrifugal displacement has migrated the thin cap of Class 5 to the outside edge of the curve while the cobbles remain firmly embedded in sand and fines. For high-displacement uses, cobbles should be the final tread-bearing surface. Cobbles also prevent the curve from becoming superelevated.

Although crushed limestone can work well for low displacement uses, it is too lightweight and does not contain enough natural lime binders to resist surface displacement by high-displacement uses. Performance in this case could have been improved somewhat by superelevating this curve. (Note that use is already forming superelevation.)

Rock and Soil Materials

Avoid Graded Rock Products

"Grading" is sorting by particle size to eliminate certain sizes as too large and/or too small. Grading often eliminates dust and fines essential for bedding and compaction. For tread hardening, avoid graded products for tread surfaces (e.g., railroad ballast, washed rock, and pit run cobbles without fines).

Aggregate Screening

Screening limits the maximum size of particles. For instance, a "3/4 minus" screen limits the aggregate to particles that can fit through 3/4-inch openings in a screen. Screened material should contain the full range of smaller particles, fines and dust.

Crushed Stone

Pure crushed stone (100 percent from crushing quarried, solid rock including all fines and dust) can form a dense, stable aggregate layer. Nearly all of the particle faces are angular, contributing to mechanical interlock and strength.

Pit Run

Glacially or river-rounded rock and sand found in deposits make excellent hardening materials. Larger stones are rounded, making them smooth when exposed in trail tread, and sands and gravels act as bedding fines. Material should include sand and fines as well as the full range of particle sizes.

Sand and Mineral Soil

In a geocell application, if rocky products are not readily available to pack geocells, sand and well-drained, compactable, nonexpansive mineral soils can be used. The resulting geocell layer will not be as strong as rock aggregate, but it may be adequate for trail use. Geocell layers can be stacked for extra load-bearing strength if needed.

Rocky aggregate is highly recommended as a cap layer and tread-wearing surface. If aggregate is not available, locally gathered stones and gravels can be added to the top tread layer. Even a few stones are better than none.

Favor Heavyweight Aggregates for Tread Surface

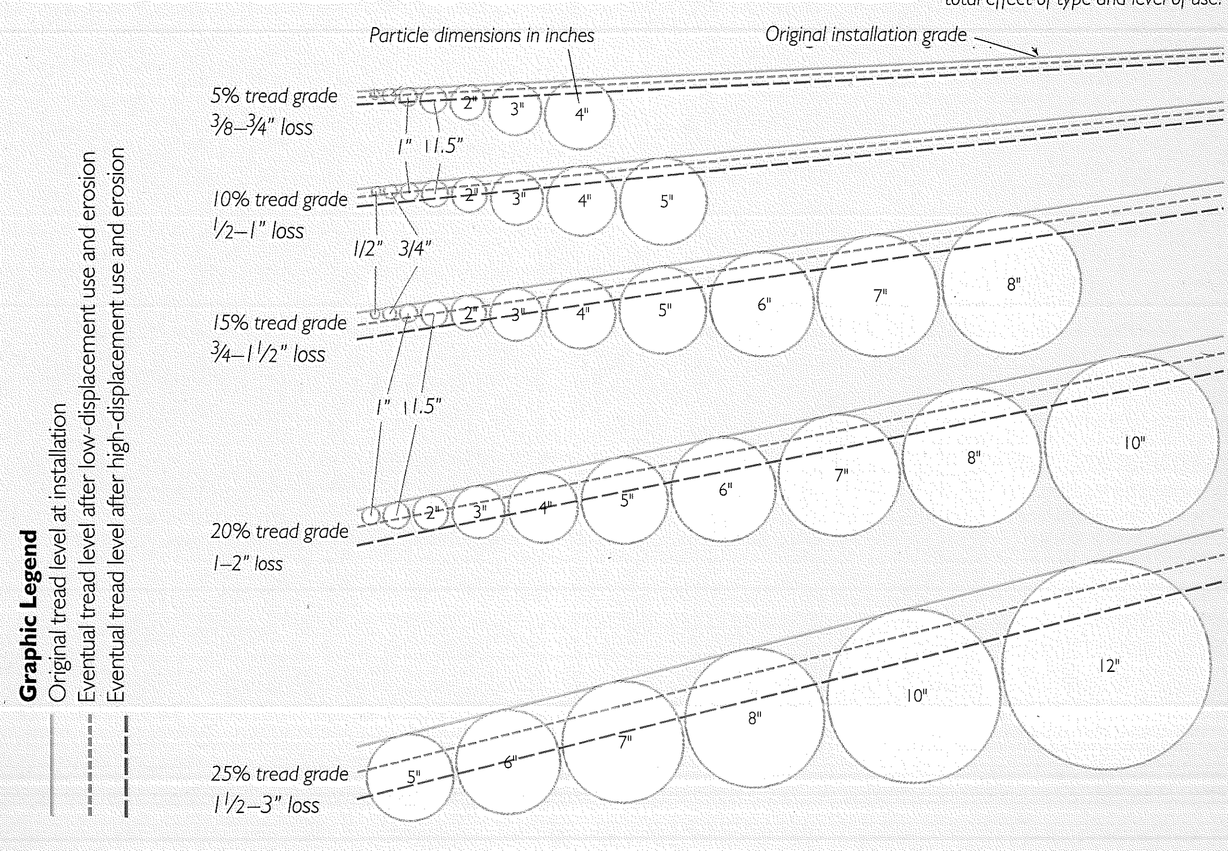
Where there is a choice, use the heaviest available aggregate material for the tread wearing surface or any place exposed to moving water. In particular, granite is preferred over limestone because of its greater weight and density. The weight of individual particles, including dust, helps reduce displacement and erosion.

Minimum Aggregate Particle Sizes Likely to Remain Bedded in Tread Grades

After trail displacement and erosion remove smaller particles from the surface, only those that are still more than half buried will be able to resist displacement. The table and diagram below define the minimum particle size that can be expected to resist displacement. For example, on a 20 percent tread grade with a high-displacement use, the minimum particle size likely to remain embedded is 5 inches. Particles smaller than 5 inches will be largely displaced from the tread surface, leaving a bearing surface of particles 5 inches and larger. Yet those smaller particles – all the way down to dust – must be present in order to bed the larger particles.

Tread Grade	5%	10%	15%	20%	25%
Low-displacement trail use	1"	1.25"	1.5"	2.5"	3.25"
Moderate-displacement trail use	1.25"	1.75"	3"	4"	6"
High-displacement trail use or high traffic level	1.75"	2.5"	3.5"	5"	8"

Note that the listed sizes are minimum sizes. Within the parameters of the trail type and desired experience, larger particles than those listed will increase stability and tread roughness. Important note: The extent of displacement is the total effect of type and level of use.

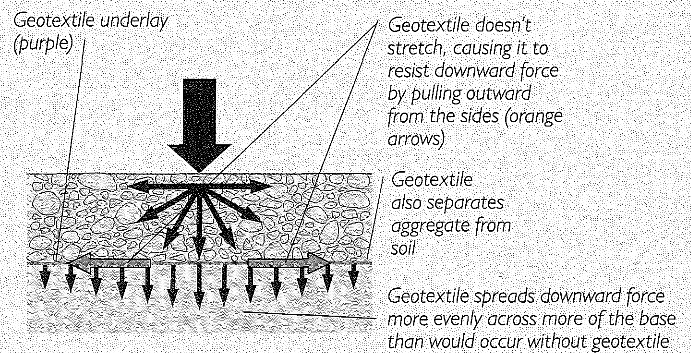


Geotextile, Geocells, and Edge Containment

Geotextile, also known as construction fabric, is a strong, synthetic (polyester), porous, permanent ground fabric that resists stretching. Buried under an aggregate layer, it adds lateral strength by using the weight and compaction of the aggregate itself to prevent aggregate spread under load. Geotextile works even when the soil below it is somewhat unstable. Geotextile also separates aggregate from the soil below, preventing it from mixing with soil and losing effectiveness. Geotextile should always be used between aggregate and underlying soil, as illustrated in the following box.

Aggregate Load Bearing Structure With Geotextile Underlayment

Geotextile laid before fill material is placed to create a stable trail tread through a stretch of unstable soil. Geotextile strengthens the tread and prevents the fill material from mixing with the soil below.



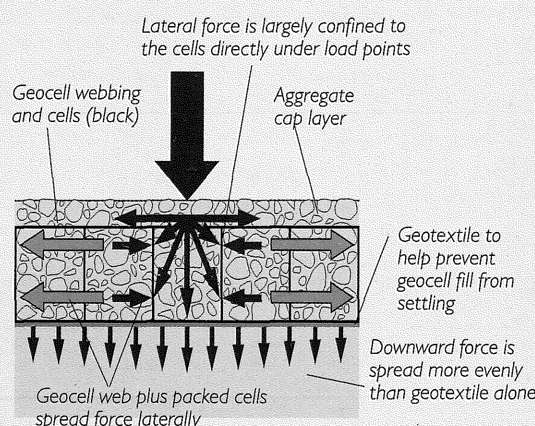
Geotextiles are available in woven and nonwoven forms. Nonwoven forms are preferred because they are easier to handle and spread forces in more directions. Geotextiles will last indefinitely when buried, but are photodegradable and should not be used where they would be exposed to light –including in situations where tread displacement would expose them.

Geocell, also know as cellular confinement system and by trade name such as Geoweb, is a synthetic webbing of cells with open tops and bottoms. Aggregate is compacted into each cell. The tighter the compaction, the better it works. When each cell is tightly packed, horizontal spreading under load is resisted by the entire cell wall vertically through the web. The entire geocell layer becomes stiff like a slab, spreading loads over a larger area and enabling a relatively thin layer of aggregate to carry more than geotextile can with the same thickness of aggregate, as illustrated in the following box.

Aggregate Load-Bearing Structure With Geocell

Geocell over wet organic soils. Behind the staked board, the cells have already been filled with crusher fines and compacted. This is 4" thick geocell installed in a turnpike, but the wood sides serve mostly to hide the edges of the raised geocell webbing. Although not used here, geotextile should be used under the geocell to help prevent cell fill from mixing with unstable soil below.

On this ATV trail, the crushed limestone cap layer used is too lightweight and too small in particle size to withstand displacement. While the stiff geocell webbing will prevent further deepening, it will need to be top dressed with replacement limestone every year.



Given the expense, geocell is best used over unstable soils. It can also help prevent erosion on steeper tread grades and in flood-prone drainage crossings. It is currently manufactured in 4-, 6- and 8-inch vertical cell heights. Geocell is also available with perforated cell walls to facilitate horizontal water movement. Although geocell is not photosensitive, cell walls should not be exposed in the tread. Exposed cell edges are unsightly and can cause less traction or a tripping hazard. Therefore, geocell should always be used with an aggregate cap layer with sufficiently large aggregate particles to withstand displacement by trail uses.

Timber edge containment is discouraged because of few benefits, high cost, and drainage problems.

Edge containment helps prevent horizontal aggregate from spreading at the edges of the tread. It can be achieved with stones or timber, or burying the aggregate in a trench in stable native soil. The benefit is most apparent in narrow treads where visitors have to travel near the edges. An extra width of hardened tread also provides edge containment for the heavily used center portion of the tread. Hence no added edge containment may be necessary for many hardened treads. The use of wood or timber edging for hardened tread is discouraged in most cases. Wood is not that effective as containment, tends to trap water on the tread, and decomposes too quickly to make it worthwhile unless there is a clear need in a certain spot.

Additional Considerations for Mechanically Stabilized Rock and Soil

The following provides additional information on mechanically stabilized aggregate techniques.

MECHANICALLY STABILIZED AGGREGATE TECHNIQUES FOR NEAR-LEVEL TREAD

SUGGESTED AGGREGATE HARDENING SPECIFICATIONS FOR LEVEL AND NEAR-LEVEL TREADS

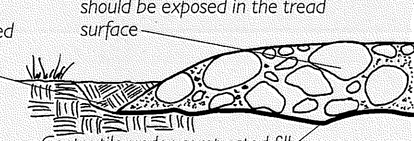
Letters A, B, and C in the table refer to layers in the drawings below. For each layer, the first number is the thickness of that layer. The second number is the maximum screen size in inches for aggregate particles. For example, "(A) 6", 1" means that Layer A should be 6 inches thick of particles passing a 1-inch screen (i.e. particles from dust to approximately 1-inch in diameter). "(B) 4" geocell, 3" means that Layer B should be 4-inch geocell filled with particles passing a 3-inch screen. Some situations only need Layer A or A+B. All techniques assume geotextile under the bottom layer. If Layer C is used, geotextile between B and C is recommended.

For particles 2 inches and larger in layer A, glacially rounded pit run particles are preferred since they will be exposed in the tread surface. For Layer C, "aggregate" can be any particle screen from 1-inch minus upward. For wheeled uses, curves should be superelevated and/or additionally hardened to better withstand centrifugal surface displacement. Note that 1-inch minus aggregate is equivalent to Mn/DOT Class 5, a common crushed stone road base in Minnesota. Aggregate in screens smaller than 1-inch should be from crushed rock and contain a high percentage of fines and rock dust as physical binders.

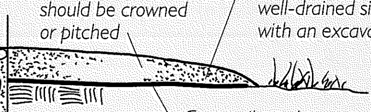
	Soil with good to fair weight-bearing ability	Soil with moderate to low weight-bearing ability *	Highly and deeply unstable soil with poor weight-bearing ability *
ORV	(A) 6", 1	(A) 16", 1 or (A) 4", 3 (B) 8" geocell, 3	(A) 24-36", 10 or (A) 4", 3 (B) 8" geocell, 3 (C) 12" agg
ATV	(A) 5", 2.5 preferred or 6", 1	(A) 10", 3 or (A) 3", 3 (B) 4" geocell, 3	(A) 4", 3 (B) 6" geocell, 4 (C) 6" agg
OHM	(A) 5", 2	(A) 8", 2 or (A) 3", 3 (B) 4" geocell, 3	(A) 3", 3 (B) 6" geocell, 3 (C) 6" agg
Horse	(A) 6", 1 with mod. % fines	(A) 10", 1.5 or (A) 3", 2.5 (B) 6" geocell, 2.5	(A) 3", 2.5 (B) 8" geocell, 2.5 (C) 6" agg
Mountain bike	(A) 4", 5/8 with high % fines	(A) 8", 1.5 or (A) 2.5", 1.5 (B) 4" geocell, 1.5	(A) 2.5", 1.5 (B) 4" geocell, 1.5 (C) 6" agg
Hiking	(A) 4", 5/8 with high % fines	(A) 6-8", 1 or (A) 2", 5/8 (B) 4" geocell, 1	(A) 2", 5/8 (B) 4" geocell, 1 (C) 6" agg
Wheelchair	(A) 4", 1/4 with high % fines	(A) 8", 1/4 or (A) 2", 1/4 (B) 4" geocell, 1	(A) 2", 1/4 (B) 4" geocell, 1 (C) 6" agg

* Suggested starting points. Site conditions vary widely, professional advice is advised.

LAYER A – ON TOP OF EXISTING SUNKEN TREAD OR IN EXCAVATED SOIL



LAYER A – NEW TRAIL ON WELL-DRAINED MINERAL SOIL



LAYERS A, B, AND C – MOSTLY BELOW GROUND

In a well-drained site, can be partially or fully buried to any depth needed

LAYERS A, B, AND C – MOSTLY ABOVE GROUND

Can be partially or fully above ground as needed for drainage

The following photos illustrate a variety of mechanically stabilized rock and soil-hardening techniques used for trail treads.

Hardening material found near the site. *In many cases, well-graded pit run gravels can be used for tread hardening to create a stable trail at reasonable cost (left). For some uses, hardening also serves as a trail challenge, as is the case with this OHV trail in an OHV recreation site (right). Both of these will likely prove to be very stable over an extended period of time.*

Crushed stone. *In this nearly level site for a multiuse trail, native soil was replaced with crushed stone. The tread surface is only slightly raised above the surrounding ground.*

Firming. *This is done by compressing stony material into the top layer of native soil rather than modifying the entire tread. Firming may sometimes be sufficient for lightweight, low-displacement uses.*

Mechanically stabilized rock and soil-hardening techniques are often used for drainage crossings.

UNITIZED WEAR SURFACES

Unitized wear surfaces provide a nonaggregate-based load-bearing hardened surface with high lateral strength. There are a variety of materials or products that may be suitable for unstable soils, underwater applications, steep tread grades, and wet applications. The following considers the most common.

Concrete Block, Concrete Planks, and Poured Concrete Slabs

Concrete blocks, planks, and slabs are very artificial but highly effective means of hardening OHV trails, especially where weaker soils are prevalent. These materials are only used where other less-obtrusive options are not suitable or resilient enough for the intended use. This type of material is used less often for hiking, mountain biking, or horse trails, where other techniques are more suitable and visually appealing. Concrete blocks can be used for drainage crossings, trail approaches, and steep trail sections that need additional protection from erosion. Concrete planks and poured concrete are generally used for low-speed water crossings.

Advantages: Concrete planks and blocks and poured concrete are very effective hardening techniques that can stabilize challenging trail sections and crossings that cannot be remedied any other way. They also tend to be relatively low maintenance.

Disadvantages: These materials are not very natural looking, and it can be a challenge to get materials to remote sites. Paving material may be slippery when wet. Also, concrete block installation requires excavation in a drainageway, which can be challenging to restore.

Installation: Generally, topsoil is removed and stockpiled along the edges for reuse. In some cases, compacted aggregate material is needed to provide a solid base under planks, blocks, and poured concrete. Occasionally, geotextile is used in combination with aggregate to form a stable base for planks. Installation requirements are site-specific and often require technical evaluation by an engineer. Poured concrete also requires reinforcement, such as wire mesh and or fiber mesh.

Interlocking concrete block *(left) was used to harden both the approach and the drainage crossing. While not natural, it effectively controls displacement and erosion. Extensive use of concrete block is recommended only where more natural hardening methods are not feasible. Note that one of the main advantageous of blocks over stones is that they interlock, creating a stronger bond.*

Porous concrete block *(right) hardens only the bottom of this drainage crossing on a popular mountain bike trail. The block extends well under the soil tread to eliminate any lip.*

Concrete boat ramp planks. *Planks laid on aggregate fill can provide lateral stability for slow water crossings. Planks are laid perpendicular to the trail.*

Water flow undermined small diameter aggregate under some of the planks. *Larger diameter cobbles are needed as a foundation in channels with higher flow speeds.*

Paved dip for ATVs. *Small concrete planks have diagonally scored faces for traction. Since this is a low flow, seasonally flowing drainage, planks are set directly in native soil tread.*

These crushed stone treads use poured concrete swales to prevent tread erosion by concentrated surface flows. *Both trails are accessible. At left, loose stone particles have collected in the dip, partly clogging it and possibly forming a slipping hazard. At right, the concrete dip is barely visible – crushed stone from the tread itself was used as concrete aggregate and exposed during curing. As a result, concrete color and texture exactly matches the tread.*

Porous Panels

Porous panels are one of the most promising emerging OHV trail-hardening systems for wetlands and sensitive areas. The panels are long lasting, low maintenance, and good at transferring lateral loads. The panels are suitable for OHV use, but a poor choice for horses and only fair for foot traffic.

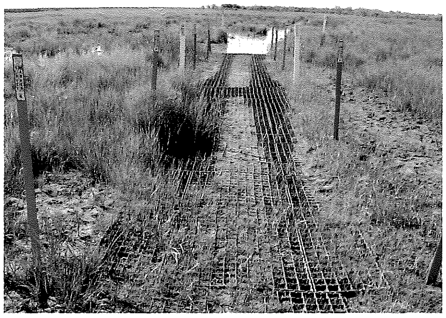
The grid-like plastic panels are designed to lay on the ground surface. The bottoms of the panels have many holes to allow plants to grow through and enough strength and stiffness to be able to spread a load across the panel (or several connected panels). The top edge of the panel cells are designed to directly support traffic, but can also be ballasted or capped with soil or gravel to completely hide them.

The panels allow for wetland crossings with minimal disturbance to vegetation and the ground. They are less disruptive to vegetation than a boardwalk, which largely kills all vegetation beneath it. The panels can also be used to carry a trail over a cultural site without damaging the site.

Advantages: Panels are quite rigid, strong, and durable, yet lightweight. They can be completely removed with no remnants and no soil disturbance and can be reused elsewhere. Panels are hidden by wetland vegetation until one is near it on the trail (unlike a raised boardwalk, which can be seen from a distance).

Disadvantages: Panels are more expensive than some other surfaces. Uncapped plastic material does not look as natural as do some other hardening materials. Panels are not suitable for wheelchairs, foot traffic, or horse unless they are filled with soil or aggregate.

Installation: There are two major brands of porous panels available on the market as of this publication: GeoBlock (Presto Products, Appleton, WI) and SolGrid (SolPlastics, Montreal, Quebec, Canada). Installation of these or other suitable products should be in accordance with manufacturer specifications and instructions. In general, GeoBlock does a good job of transferring weight between rigid panels, whereas SolGrid has connectors between panel subsections that makes it more flexible. For both products, panels are screwed together to make long continuous surfaces. GeoBlock can be laid directly on top of existing soils and vegetation even in wetland areas, with vegetation growing up through holes in the panels to both anchor and hide the product. If used underwater, panels must be anchored since they will float just below the water surface if submerged. The easiest anchoring method is to fill the cells with aggregate as ballast. The panels can also be diagonally pinned into the ground with custom bent rebar or commercially available L-angled spikes. The panels tend to expand in direct sun so expansion joints are needed for continuous runs. Note that the current panels on the market can support OHMs and ATVs, but ORVs might break the joints or the screws at the joints unless they are on load-bearing soil.



Green hardening. *A major advantage of plastic porous pavement panels (top) is their ability to support vegetation. Each cell has a relatively large hole in the bottom through which vegetation can grow. This enables a drainage crossing to support plants even while serving as part of the trail.*

Porous pavement panels work underwater. *Ballasted with small rock, filled with soil and planted, or otherwise anchored, panels function well underwater, making them highly suitable for drainage crossings. They spread the load enough to carry vehicles, including ATVs, without sinking into the wet soil below. Unlike currently available geocell, porous pavement panels do not need to be protected from sunlight.*

Hidden paneled drainage crossing. *Ballasted with soil, panels can almost disappear. The top edges of the plastic cells will reappear with trail use when the top layer of soil displaces, but the tread will be laterally unified. Ruts cannot form, displacement and erosion are limited, and plants can potentially grow in the drainage channel and tread for further stabilization.*

Paneled drainage crossing installation. *Some panels (left) have flexible joints built in to enable them to contour to irregular treads. This photo illustrates a drainage crossing in an early stage. Grids can be left exposed or ballasted with soil or rock.*

Stone Paving

Stone paving can be used for drainage crossings, trail approaches, and steep trail sections that need additional protection from erosion. Because they do not interlock, stone paving is more susceptible than concrete blocks to displacement on steep approaches.

Advantages: Stone paving is a relatively effective hardening when care is taken to fit stones together. Flat stones can be used to stabilize challenging trail sections and crossings. Stone paving also tends to be relatively low maintenance if well constructed. Stones are more visually appealing than concrete-based products.

Disadvantages: If not readily available on the site, the cost to import material is high. Stone paving is labor intensive to install and it can be a challenge to get materials to remote sites. Smooth stones may be slippery when wet. Also, stone paving installation requires excavation in a drainageway, which can be challenging to restore.

Installation: Generally, topsoil is removed and stockpiled along the edges for reuse. In some cases, compacted aggregate material is needed to provide a solid base under stones. Occasionally, geotextile is also used with aggregate to form a stable base for the stones. Stones have to be sized relative to the intended use, with smaller stones being adequate for hiking trails and much larger and heavier ones being necessary for OHVs.

Hand-fitted stones carry relatively constant spring outflow across the trail. The shallow, ramped dip enables mountain bikes to pass through without muddying the water. This technique is recommended primarily for relatively constant yet low volume flows where water quality is to be protected. Although installation is labor intensive and requires a supply of stones with flat faces, the result can be an attractive trail feature that accentuates the water passing through it.

Where there is little sideslope, the stone paving should extend beyond the tread on both sides to ensure full coverage. Attractive stone paving is considered a desirable feature on nonmotorized trails, especially hiking trails. Using a variety of stone shapes adds natural shape and enhances rustic appearance.

CHEMICAL BINDING

Chemical binding is generally used to form smooth, firm treads from small soil particles on level or low tread grades in reasonably well-drained sites for low- and medium-displacement uses. Chemical binding tends to be a very specialized approach to trail hardening requiring specific products and installation techniques. The following provides an overview of the common choices. However, the use of any of these approaches requires independent evaluation to ensure that the product is suitable for the application. Generally, chemical binding is not used when other, more standard techniques are sufficient.

Crusher Fines

100% finely crushed stone with all fines and dust can sometimes bond to itself with its original natural cementing agents. How much this occurs is specific to each mix, but the best mixes can bond quite tightly when dry.

Recycled Asphalt

Recycled asphalt forms a durable tread on grades up to 8 percent when laid 6 inches thick and thoroughly compacted. It has to be located in sun because it does not bond to itself unless it is heated. The surface may partially unravel under ATV use, especially on curves. Although the surface can be seal coated with slurry seal to bond the surface, this would make it look like regular asphalt.

The asphalt can be strengthened with copolymers or other treatments. It can also work well in geocell, especially on steeper grades.

Copolymer Soil-Bonding Agents

New copolymer soil bonding agents are being introduced by several companies, although their application in Minnesota has yet to be fully tested in many cases. Light application of these agents can lightly bond soil particles. Heavier applications create very hard polyurethanelike waterproof bonding, essentially turning compacted soil into a bricklike surface.

The one advantage of some of these products is that the trail tread maintains a near-natural appearance. If these products perform as promoted, they do hold some promise as a nontoxic, durable soil hardener that may be easier to apply and more natural looking than other hardening methods. Given the limited field testing of most of these products, none are listed here. Contact manufacturers of these products for technical information.

Hardening Techniques To Avoid

There are a number of hardening techniques that should generally be avoided. These include:

- **Wood chips** – in a thick layer, chips are temporarily effective but quickly decompose into organic soil that is most often unsuitable as tread. Wood chips also float, readily wash away, and form an excessively spongy tread. Avoid wood chips as a permanent solution.
- **Gabions** – these have been used as tread in some cases, but the exposed wire mesh eventually breaks and becomes hazardous.
- **Soil cement** – adding bagged cement mix to native or amended soil simply does not work.
- **Flexible surface mattings** – when laid on unstable surfaces, these mats lack load-bearing characteristics and typically fail. They also tend to be very expensive.
- **Metal grids and platings** – these are unsightly and tend to rust and bend.
- **Shredded tires and other recycled aggregate products** – these tend to have little hardening ability while adding difficult-to-remove synthetic materials to the natural environment.

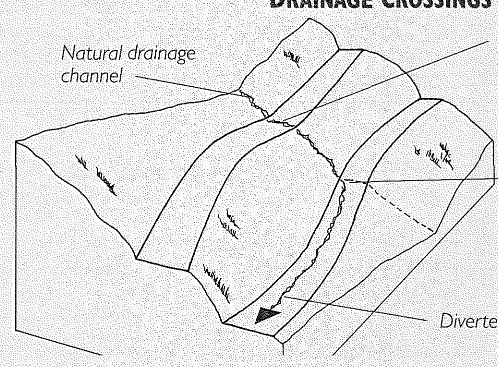
Drainage Crossings

Drainage crossings occur wherever the tread crosses a concentrated site drainage channel, including runoff swales that are typically dry except after rainfall. In all cases, drainage flow *must* continue on its original course and in its original channel. In no instances should water be intercepted and redirected down the tread itself. This is especially the case when trails traverse significant sideslopes, where intercepted storm runoff channels and even small streams can cause serious tread erosion and alter site hydrology.

Incorrect drainage crossing. *Runoff from an intercepted stream runs down this tread and creates extensive and unsustainable erosion.*

A drainage crossing is designed to prevent treads from intercepting drainages. In all cases, drainage crossings are a form of tread dip with water crossing the tread at its bottom. This ensures that the tread will climb up from the drainage on both sides of the crossing even when the tread is climbing and traversing. The following graphic illustrates correct and incorrect drainage crossings.

Drainage Crossings



Correct drainage crossing. *This ORV trail properly crosses a drainage swale by dipping through it and climbing on both sides. After climbing out of the crossing (background), the trail continues dropping while traversing the slope.*

Types of Drainage Crossings

Any concentrated site runoff or other side drainage intersected by the tread is considered a drainage crossing. There are basically three types of drainage crossings that need to be considered:

- Defined flow or stream channels that intermittently or continuously carry water
- Swales that collect and concentrate intermittent runoff (swales are depressions in the side of a slope, vary greatly in size, and lack a defined channel)
- Seeping or chronically wet slopes

Whether a seep, swale, or flowing stream, all drainage crossings must be at low spots in the trail and be formed to continue the natural flow of water across the landscape that is being traversed.

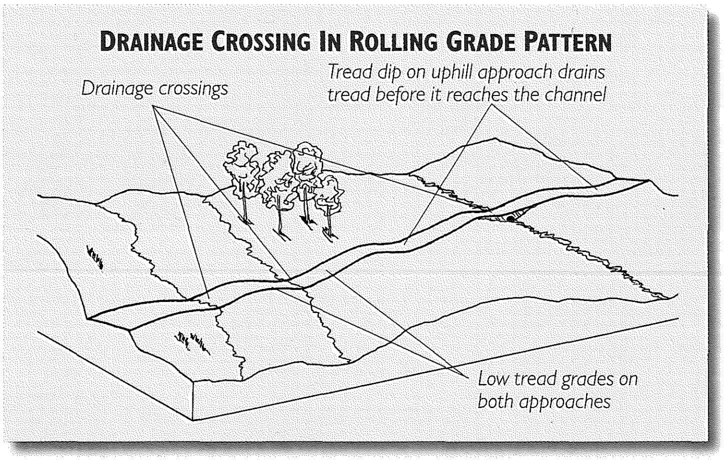
Suitable technique. *On this steep sideslope, the trail is aligned relatively level and curved around the inside of the drainage to minimize tread erosion and improve safety. Enough of a dip must be provided to keep water in the drainage. In this case, the limited drainage requires only a small dip at each crossing.*

Correct drainage crossing. *Most drainages crossed are very small and shallow but long enough to not clog.*

Correct drainage crossing. *The tread directly crosses a small yet defined runoff channel (the light-colored soil in the immediate foreground). Well-drained soil prevents muddiness on this ATV trail.*

Drainage Crossings in Rolling Grade Pattern

In a rolling grade pattern, drainage crossings are a special form of tread dip. In practice, rolling grade is commonly planned and aligned as a series of dips and drainage crossings that divide longer tread watersheds, as illustrated in the following graphic.



Correct rolling grade drainage crossing. *The trail crosses this channel in a tread dip. Since this drainage is usually dry and the soil is sandy, water can cross directly on native tread without extensive erosion. The tread climb out of the drainage is visible in both directions.*

Incorrect rolling grade drainage crossing. *This trail is intercepting and diverting water from a site drainage crossing behind the photographer, sending it down the tread. If the tread had a rolling grade on the slope at left, this diversion could be prevented.*

Ecologically Sustainable Drainage Crossings

Crossing any drainage inherently brings up concerns about ecological sustainability given the potential for the trail to disrupt natural water flows, erosion, and sediment transfer downstream. Drainage crossings can also introduce nonnative plants, causing impacts to native aquatic plants or ecosystems. Drainage crossings also tend to be richer ecotonal areas with a very delicate balance of native plant species.

To be sustainable, drainage crossings must respect and protect five components of river systems: 1) the flow (hydrology); 2) the shape (geomorphology); 3) the connections (connectivity); 4) the quality (water quality); and 5) the life (biology). For this reason, all drainage crossings should be consistent with the guiding principles for sustainable trails as defined in Section 3 - Principles of Ecological Sustainability. The most important of these is avoiding sensitive ecological areas and critical habitats wherever possible.

If a drainage crossing is necessary, preventing erosion and minimizing sediment transfer into drainages is the most important consideration in determining which crossing approach is the most appropriate. Inevitably, drainage off the tread flows into the drainage being crossed. The box on the next page considers approaches to drainage crossings to ensure that in the process erosion and sediment transfer are prevented or kept to a minimum.

Approaches to Various Types of Drainage Crossings

The following describes approaches to crossing various types of drainage. A conservative approach to selecting a crossing approach is recommended to avoid having to do expensive and often difficult remedial work to resolve problems caused by erosion and sediment transfer.

Low Flow Intermittent Storm Runoff Channels

There are no limitations on draining the tread into low-flow or intermittent channels as long as water flowing off the tread does not significantly contribute to sedimentation of the channel or any nearby water body. If it would, manage the drainage crossing as defined below for seasonal flow or natural open water channels.

Seasonal Flow Channel

This refers to channels with a continuous flow for days or weeks at a time. The amount of trail use, soil type, likelihood of tread erosion, and other relevant factors all need to be considered in determining the potential for sedimentation. General suggestions for reducing sedimentation include:

- Minimize trail grades on final approaches to the channel
- Use tread dips some distance from the channel to drain tread water before it can reach the channel
- Consider using hardened tread on approaches where natural soils are insufficient to prevent sedimentation from occurring
- Consider using a culvert or built structure to span the drainage entirely

Natural Open Water Channel – Flowing and Standing on a Perennial Basis

The tread should be designed to minimize or completely eliminate direct sedimentation into a natural open water channel with flowing or standing water.

Potential sedimentation control measures include, but are not limited to:

- Use same measures suggested for seasonal flows, especially culverts or built structures.
- Use "green" hardening techniques for relatively steep approach grades, high displacement uses, highly erosive tread, or other factors that cause sedimentation despite other countermeasures.
- Plant appropriate native vegetation in all nontread areas disturbed by trail construction and maintenance, including all surfaces of drainage channels.

Channels in Primitive Areas or Along Challenging Trails

Crossing natural water channels, including fording streams, can be an enjoyable part of the experience of primitive trails. Although direct contact of visitors with water is discouraged even on these trails, it can be considered where impacts can be kept to a minimum. Any crossing also requires careful evaluation and surveying of in-stream habitat in order to maintain the integrity of the riparian corridor to avoid degradation of the stream banks and water quality.

If a ford is acceptable, natural rock bottomed in-channel crossings are preferred. Hardening channel bottoms with boulders, rock, cellular confinement systems, concrete or other heavy, stable materials can also be considered as long as its appearance is consistent with the setting.

Reducing or eliminating sedimentation from water flowing off the trail may be difficult. This is especially the case with wheeled uses, which push and lift water from the channel that then flows back into the channel. In many cases, approaches will likely need to be hardened, preferably with naturalistic methods such as larger native rock. (Do not use gravel and aggregate for hardening approaches and channel bottoms.)

In primitive areas and along challenging trails, ensuring that the crossing will not widen or move through trail use is also very important to managing sedimentation and maintaining the desirable trail character. Careful use of anchors in these instances is typically the most successful approach.

Drainage Crossing Options

There are four primary options for crossing drainages:

- **Direct crossing** – suitable where intermittent and low-flow runoff from a storm does not pose any significant crossing challenges and is sustainable.
- **Hardened tread crossing** – used where needed to reinforce a channel crossing to handle more intense storm runoff or to harden mud-prone areas.
- **Culverts** – used for deeper channels and those that carry water for extended periods.
- **Built structures** – bridges, boardwalks and other such structures are favored over culverts for open and/or flowing water that can support fish.

Important consideration!

As a general rule, avoid direct user contact with water unless the water flow is transient (such as storm runoff) and minimal and trail use does not produce excessive mud or sedimentation. The following provides examples of each of these options.

Direct Crossing

If flows are spread out and clearly intermittent, a direct crossing can be used. However, all direct crossings should be designed to allow a more aggressive approach (in most areas, hardening the crossing) should the trail change the flow enough to require it.

Sustainable crossing across a low-flow drainage. *This should be sustainable for many years with little maintenance.*

Low- flow crossing. *This crossing only occasionally flows during heavy rains and dries up quickly thereafter, requiring no hardening to keep it sustainable.*

Hardened Tread Crossing

Hardening is used to reinforce a crossing to handle intense storm runoff or to stabilize mud-prone areas. The following considers a variety of common techniques where the water is not too deep or too fast, and where trail traffic is relatively low and/or water quality disturbance in the crossing is expected to be minimal. These techniques are most commonly used in storm runoff channels that may otherwise scour through native tread, or in normally shallow, slow-moving, low-flow, seasonal channels.

Road Base

Road base provides a simple drainage crossing solution and can be used where crossings are usually dry and water speed and volume is periodic and low.

Advantages: Smooth surface and easy to construct.

Disadvantages: Displacement increases under wet conditions, and can lead to formation of a puddle or mudpit. Rock dust washes away, leaving unconsolidated aggregate. Aggregate can wash away with higher water speed. Displacement rapidly increases with visitor speed. A berm can form on the lower edge, causing ponding on the tread. Road base is not very natural in appearance.

Installation: Larger cobbles of varying sizes are highly recommended. Use geotextile and/or geocell underneath if the soil is unstable or if the aggregate is at risk of sinking into the underlying soil. Otherwise, simply use a sufficiently thick layer of aggregate (at least 6 inches) to spread traffic load over the underlying soil.

Typically dry equalizer drainage crossing. *Class 5 plus larger cobbles stabilize this dip on a former railroad grade across wetlands.*

Low-speed, low-flow crossing. *Class 5 plus larger cobbles cross this drainage on a forest road and on-road trail. With a seasonal flow that washes away small particles, the cobbles help reduce displacement and provide the tread surface.*

Ponding caused by displacement. *Class 5 by itself does not withstand displacement with higher water flow rates – the particles are too lightweight. The higher the flow and the longer the period of flow, the more large cobbles are needed.*

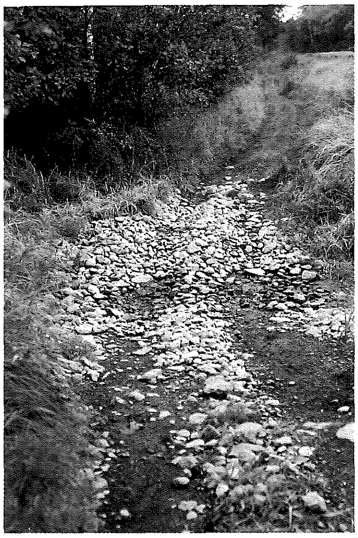
Stone Cobbles

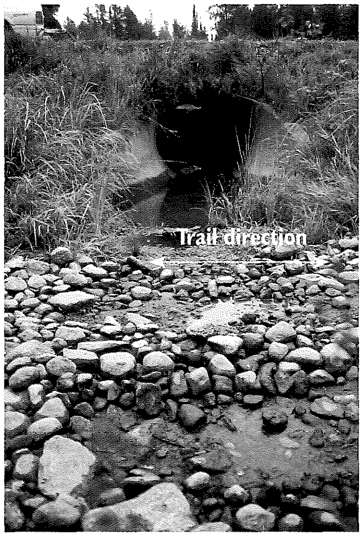
Cobbles are used for OHV trails with low to medium water speed and volume. They are preferred over road base for any crossing with regular water flow.

Advantages: Cobble crossings are easy to construct. They do not contribute to sedimentation. They are more difficult to displace or erode and more natural than road base.

Disadvantages: Stones can become loose and roll around. Stones can be rough and uncomfortable for any use without wide tires. Stones may become slippery if continually wet.

Installation: Rounded stones should be used. In unstable soils, a base layer of stones 14 to 24 inches and up may stabilize the crossing, even for ORVs. For ATVs and OHMs, smaller rocks can provide sufficient stability. Use a variety of stone sizes to improve stability. Use a sufficiently thick layer of cobbles to spread the load over the underlying soil. Geotextile under stones greatly improves stability.





Cobbled crossing of a wetland drain. *On this ditch trail, cobbles were used below the road culvert to provide a stable, nonmuddy crossing for ATVs. The usual ATV displacement is not a problem because water flows between and over the stones.*

Cobbled overflow drainage crossing. *This crossing handles wetland overflow when necessary. Because it is a floodway, geotextile beneath the cobbles adds resistance to scouring. Note the dip in this forest road.*

Geocell and Aggregate

Geocell under aggregate supports heavier traffic – even in flood conditions – and resists erosive flood flows.

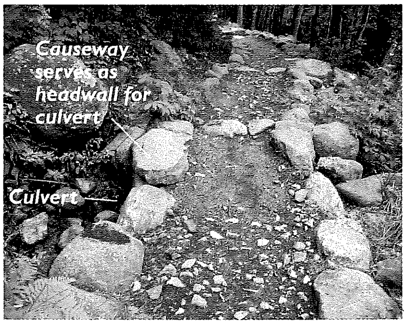
Advantages: Geocell and aggregate reduce displacement under heavy traffic and flood conditions. It has a natural appearance and requires little maintenance.

Disadvantages: Installation may require excavation.

Installation: The base layer is geotextile and a geocell product of appropriate thickness for the traffic, filled with compacted cobbles and rock particles of all sizes. This is topped with more cobbles to protect the geocell from sunlight. The final tread can be smaller cobbles and/or Class 5, although larger cobbles are less susceptible to washing away during higher flows.

Forest road wetland crossing with laterally stabilized aggregate. *This entire crossing (viewed from two directions) was stabilized and a dip was formed to channel low flows. Geotextile and 8-inch-thick geocell is under grapefruit-sized and smaller stones with a layer of smaller cobbles and soil on top. Cobbles are exposed in the dip where they form relatively more of the wearing surface. Driving through produces very little water clouding.*


Overflow crossing with laterally stabilized aggregate. *Geotextile and geocell were used on both the top and sides of this causeway to stabilize for flood flows in case culverts fail. The tread was capped with Class 5, but cobbles and soil were left exposed on both flanks. Note the dip, right, which concentrates low flows.*



Causeway

When large stones are available and soil is stable enough to bear weight, a causeway can be used to raise the tread across low-lying areas and seeping hillsides.

Advantages: A causeway is a rustic, attractive structure that adds a strong anchor and natural shape to the tread. It is permanent, since the main structure cannot decompose. Causeway walls serve as a headwall for pipe culverts beneath the structure.

Disadvantages: Construction is labor intensive. It requires relatively large stones, plus rocky material for backfill. Causeways can only be used where soils can support the weight of stones. Fill can leak out between stones.

Installation: A base layer of geotextile may be needed over unstable soils. Rocks are placed on the edges and the tread is filled with compacted material.

Channelization and Stepping Stones

Use channelization and stepping stones only for hiking and equestrian trails to cross drainages not likely to flood beyond a defined channel. Water can be seasonal or perennial.

Advantages: This approach can be used for drainages in very shallow channels. It is a relatively clog-proof and easy to clean. It can be an attractive feature on a trail.

Disadvantages: It requires carefully fitted stones and a shallow channel with a flat, naturally rocky or stone-hardened bottom. It is not suited for motorized uses.

Some users find stepping stones difficult to use.

Installation: Stones are embedded on side of the channel to keep them in place. They must be tightly fitted to prevent erosion.

Turnpike

Turnpike can be used to form a raised approach in areas of unstable soils. A timber or conventional culvert can convey water under the structure, or a paved dip can carry water through it. In a near-level drainage crossing with boggy soils, ditches may need to be dug on both sides to lower the local water table below the level of the logs.

Advantages: Turnpike provides strong tread delineation, with logs minimizing tread width. It has a rustic appearance. It can be built from locally obtained materials, making it suitable for remote locations.

Disadvantages: Logs have high degree of soil contact, accelerating decomposition. Displacement from trail use can cause a sunken center that holds water.

Installation: Logs are set on each side with wooden stakes to keep them in place. Rocky fill under the surface material helps prevent sunken centers. Geotextiles should be used to contain the fill between the logs and make it easier to replace the logs over time.

CULVERTS

Elevated crossings (bridges) are preferred over culverts for crossing any amount of perennially flowing or standing water. Culverts can be used and are best suited for drainages with periodic flows that run in a deep, narrow, and defined channel that enables the tread to span the drainageway without building up the approaches. The major advantage of culverts is total separation between tread and water, keeping trails users dry and preventing flow disturbance.

Advantages: Culverts are relatively easy to construct. Little or none of the culvert is visible from the trail if properly installed. Stone headwalls and tailwalls help visually anchor culverts and better integrate them into the trail.

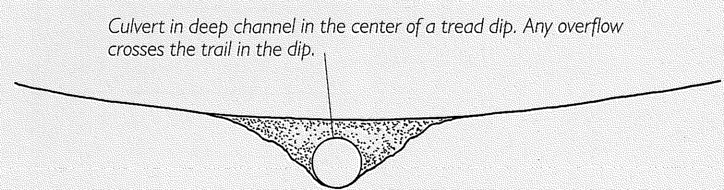
Disadvantages: Small-diameter culverts tend to clog easily and are difficult or impossible to clean out. Culverts require several inches of fill over the top to avoid revealing the pipe. Incorrect installation can lead to blowout, especially if pipes are spliced. Plastic culverts can also collapse if not buried under several inches of tread. Any visible part of the culvert pipe looks utilitarian. If the culvert is washed out, it adds sediment to the waterway.

Installation: Culverts are typically set on solid ground and installed according to manufacturers specifications, especially those relating to ground cover to prevent collapsing. Generally, the greater of half the pipe diameter or 12 inches is the minimum cover to ensure that a culvert will not collapse under load or float up over time and become exposed. The following illustrations highlight some installation techniques.

CULVERT INSTALLATION TECHNIQUES

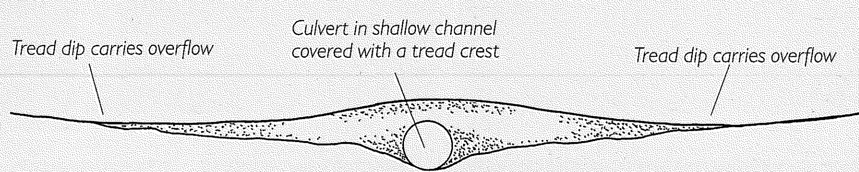
OPTIMAL CULVERT INSTALLATION

Culvert is in a relatively deep channel in the bottom of a Tread Dip. The channel is deep enough to cover the culvert with sufficient fill, making a smooth tread.



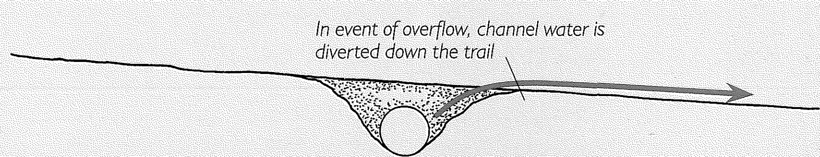
ACCEPTABLE CULVERT INSTALLATION

Culvert is in the bottom of a wide, shallow Tread Dip. But the channel is too shallow to hold the culvert below the tread, making it necessary to embed the culvert in a crest with a dip on both sides. Ensure that the crest won't be displaced away with trail use.



UNDESIRABLE CULVERT INSTALLATION

Tread crosses the culvert on a grade without a Tread Dip. If the culvert fails, water will follow the trail downhill, diverting the channel down the trail. Use only where the culvert is unlikely to clog and is oversized for expected maximum water flow.



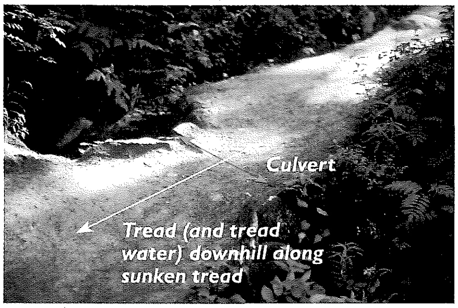
Important best practice consideration!

Reference DNR Division of Waters' *Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001* for proper siting of culverts, especially as it relates to the free movement of aquatic life through a culvert structure (www.dnr.state.mn.us/waters/index.html).

To prevent washouts and overflows, culverts must be large enough to handle the anticipated greatest water flow. In general, culverts are sized to accommodate the maximum water level of a 25- to 50-year flood. Culverts should also be placed with a slope to ensure drainage through the pipe.

Optimal. *The tread dips through a relatively deep channel, so the overflow flows over the tread above the culvert. Note the tread climbing on both sides.*

Acceptable. *Culverts are embedded in a crest to cross a shallow channel. Note the thick tread fill with larger cobbles above the pair of culverts. Ideally, however, a substantial stream crossing would use a bridge rather than culverts.*



AVOID where possible. *Although very nicely formed with stone headwalls and tailwalls, if this deep-channeled culvert were to clog, water would be diverted down the tread because there is no tread dip. Also note how tread wear has depressed the center of the tread, allowing tread water to follow the tread over the culvert.*

BUILT STRUCTURES

Built structures include bridges, boardwalks, and other structures. These structures are favored over culverts for open and/or flowing water that can support fish.

Structural Integrity of Structures Used for Natural Trails

Important consideration!

Structures come in many forms and styles consistent with the need and setting. *In all situations in Minnesota, structures must be structurally sound and designed to accommodate the anticipated uses and loads.* Although this does not preclude the use of rustic materials, it does require that those materials be fabricated in a way that duly considers user safety. For example, a round felled tree or log may appeal to some users, but is often slippery and too unstable for many other users to negotiate. This results in either bypassing or a greater likelihood of falls, neither of which is acceptable. Agencies and trail advocacy groups are highly encouraged to develop a design standard for all structures used on a particular type or system of trails that is professionally evaluated for structural integrity. Materials should be selected based on durability as well as appearance. Most often, this means using wood (using nontoxic, ecologically appropriate treatments) that come in certain dimensional form with predictable structural capabilities.

Examples of Built Structures

Built structures for use with natural trails come in many shapes and forms, as the following photos illustrate.

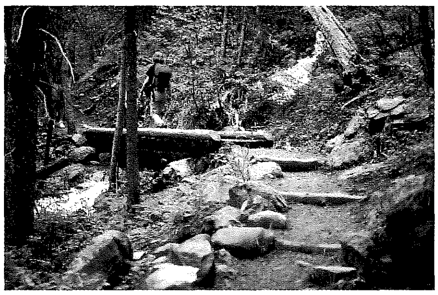
This simple drainage crossing was made from treated dimension lumber. The 24-inch width is appropriate for its level of use, where the likelihood of meeting someone at this spot is minimal. No handrail is needed since it is less than 30 inches above the ground.

This simple, low-profile crossing is located along a more popular trail. A 60-inch width is justified so people can pass each other while crossing the drainage.

Even simple, low-profile crossings must be structurally sound to handle all anticipated loads.



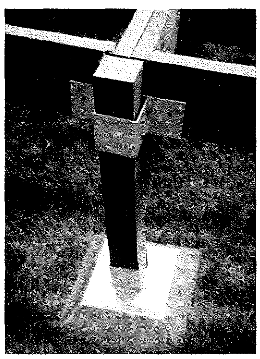
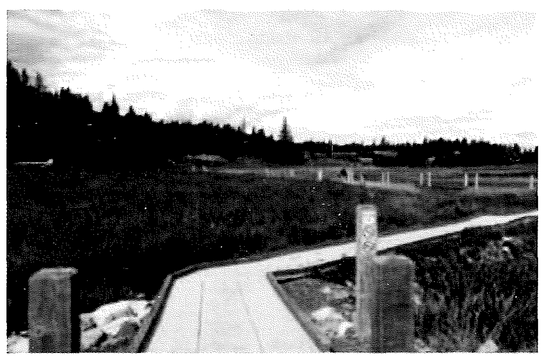




These photos highlight simple solutions to crossing drainages. Select materials based on structural integrity and site appropriateness. This is especially important on nature trails, where all built structures – even simple ones – are inherently part of the experience.



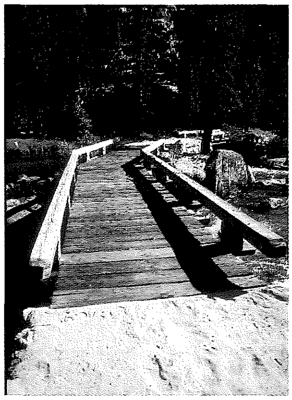

These boardwalks illustrate the range of possibilities and character. The two photos at left are associated with more remote trails where the idea is to simply get through an area without getting wet feet. This simple approach meets user expectations and there is no reason to do more. The two photos at right are associated with popular nature trails in state and regional parks, where the trail will appeal to a wider cross section of users, including those who are less ambulatory. Although more accommodating, these boardwalks still fit well into the settings.

A growing number of premanufactured products are available for boardwalks and bridges. The main advantage to these products is cost and durability. As the photos illustrate, products include treated wood on steel frame (left), patented footings that require no excavation (middle), and various forms of plastic material that can be laid directly on the ground (right). Although these products have some advantages, their aesthetic qualities have to be carefully considered relative to the setting. On more remote or rustic trails, some products may be incongruent with the sense of place.





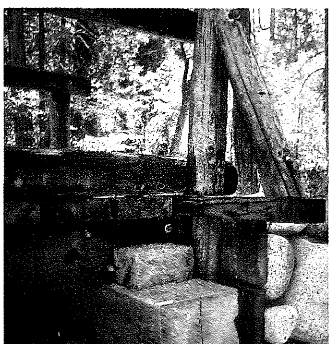



Bridges associated with natural trails also come in many shapes and forms, as these photos illustrate. With appropriate structural integrity and aesthetic quality, bridges can add to the trail experience by making drainage crossings easier and providing a viewing platform to look up and down the flowage, which can offer some of the most diverse ecological and wildlife views along a trail.

Premanufactured bridges are becoming more popular due to improved materials, aesthetic qualities, and ease of installation. Improvements in design techniques for bridge abutments and foundation systems have also made these appealing.

Taking advantage of abandoned rail bridges is common with natural and paved trails. Built decades ago, these bridges are often key destinations along trails, often offering expansive views.

On this ATV trail, bollards are used to make sure that riders are aligned to cross this low bridge. The bollards also help protect the bridge abutment.



The timber sill on this stone foundation has a mortared cap. The end cap extends behind the sill to protect it from soil contact. The wide endcap and stones harden the edge and help retain the trailbed.

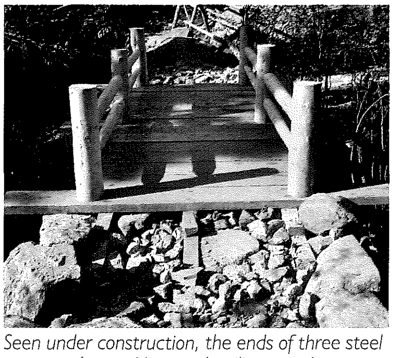
Bridge Foundation and Abutments

The selection of a bridge type and design is often driven by the type of foundation best suited to the site given local soils, the span of the bridge, and load-bearing requirements. In all cases, bridge foundations and abutments must be carefully considered and designed by a trained professional. The following provides an overview of common forms of bridge foundations.

Sills – require little excavation and are only used for small bridges that can move with frost heave. Thick, treated wood sills are often installed on a rocky base or gabions to provide drainage. Bridge stringers rest on top of sills and are protected from soil by a replaceable timber end cap. If a sill rots, the end of the bridge can be jacked up and the sill replaced without dismantling or replacing the entire bridge. Sills can also be used to create a level base for stringers on a bedrock or rock foundation.

Four helical screw piles support the center of this bridge. The piles are under a widened deck section that encourages visitors to pause on the bridge. Cross-bracing prevents side-to-side swaying.

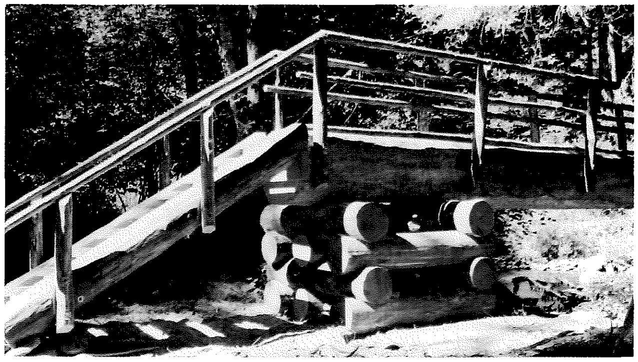
This small cribbed foundation is designed to be rustic and low impact. Logs are nailed together and rest directly on undisturbed ground.



Seen under construction, the ends of three steel stringers (topped by wood nailing strips) are embedded in this unmortared stone abutment. Stone minimizes the footprint of the raised abutment while visually anchoring it. Rock fill provides excellent drainage and reduces settling and tread displacement.

Piles – are weight-bearing columns driven or installed in holes. Friction piles are driven into soft ground until "fetched up" (cannot be driven in further). Piles such as railroad trestles are installed in holes excavated to below frost depth. Helical screw piles made of rustproof, zinc-plated steel can support trail bridges with zero excavation, making them excellent for use in firm-bottomed wetlands and riparian areas. On iced-over waters and wetlands, screw piles are driven directly through ice and frozen soil without a pilot hole. Piles are typically cross-braced to prevent side-to-side sway.

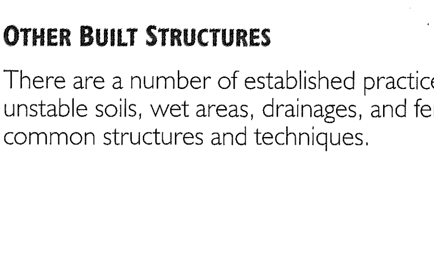
Cribbing – is usually made of squared timber or logs. It is generally not recommended as a bridge foundation (stone is preferred) because wood will eventually decay. Cribbing can be used in a remote or relatively remote area where a rustic trail experience is desired; where shorter, small and/or lightweight bridges are used and water scouring is expected and suitable stone or concrete is not available or not desired; and/or ground is firm enough to support the bridge over the broader bearing surface formed by cribbing but not firm enough to support the bridge on piles.



Native log cribbing filled with rock forms a free-standing elevated abutment for this rustic log stringer footbridge in Oregon.

Stone – where stone is available and the ground is firm and well-drained enough to support them, stone walls can be used as a supporting foundation, or at least slope retention below bridges (especially small bridges on unpaved trails, which can move with frost). Stone can be mortared or unmortared; unmortared is recommended for both naturalism and ease of construction and maintenance. Stone retaining walls can also reduce the footprint of a raised abutment while discouraging users from leaving the trail.

Concrete headwalls, wingwalls, and piers – abutment headwalls and piers transfer the weight of the bridge to bedrock or, more commonly, to a wider footer that distributes the load on suitably firm ground. Headwalls and wingwalls may also retain soil or fill on bridge approaches and protect the foundation from scouring from water flows. Footers are usually installed below frost depth, but can be a concrete pad on grade for some smaller bridges. While usually poured in place, concrete footers and abutments can be prefabricated. Typically, concrete is used for heavier load-bearing bridges requiring a strong foundation.



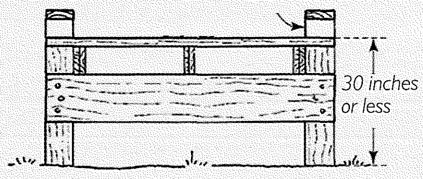
When a bridge can begin at the top of a slope, the visible portion of the headwall will be very small and pose minimal impediment to flooding. Note how the abutment is widened and the top sloped to serve as a retaining wall for the trailbed.

Other Built Structures

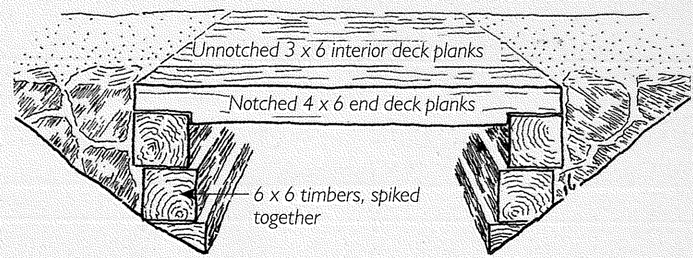
There are a number of established practices that continue have merit for crossing unstable soils, wet areas, drainages, and fences. The following graphic highlights more common structures and techniques.

Wetland Crossing Techniques

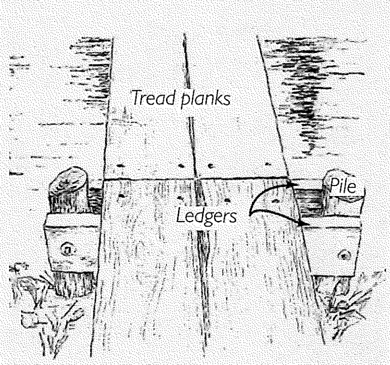
The following images are from *Wetland Trail Design and Construction,* part of the *Forest Service Trails Reports 2004* collection of reports (www.fhwa.dot.gov/environment/rectrails/trailpub.htm). Refer to this publication for additional information related to each the techniques shown, as well as information on a variety of other techniques and common tools.

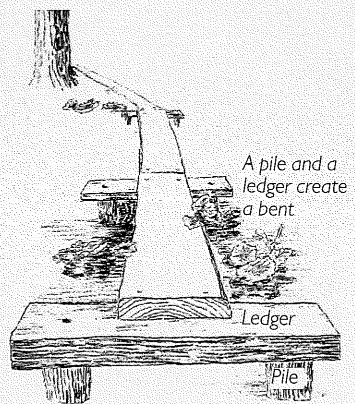


As a general rule, a handrail is required whenever the deck height of a boardwalk or footbridge exceeds 30". A curb can also be added to alert users of the edge of the deck and add character.

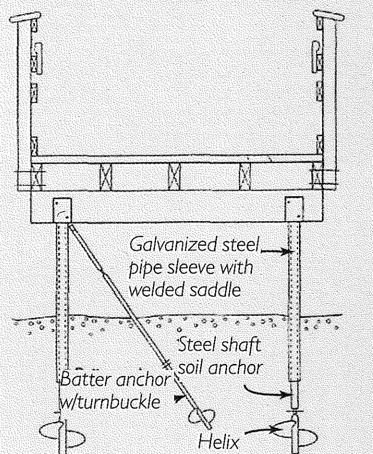


Treated timbers are occasionally used for culverts along natural surfaced trails. Notching the deck planks on both ends helps to brace the walls. Two planks with notches are adequate for a wall up to 24 inches high.

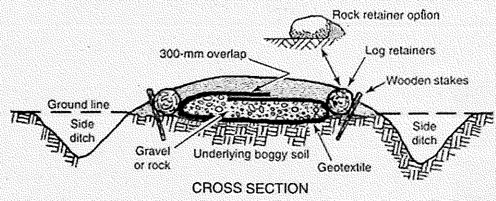


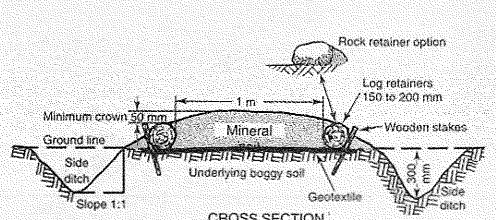


Treated timbers used as piles with either a double ledger (left) or single flat ledger (right) to support a plank tread are commonly used on rustic or remote trails where simplicity is a necessary for ease of construction.

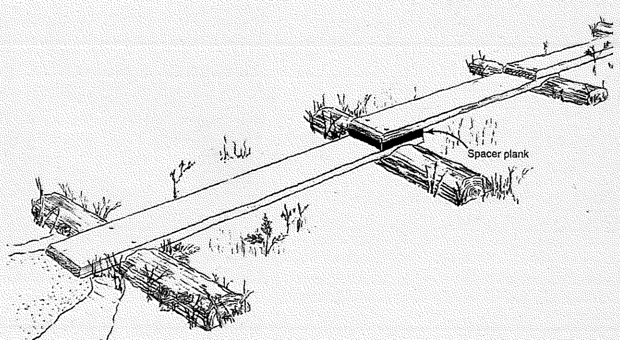


Helical piles (screw piles) are most commonly used where soil conditions make post-hole digging difficult or where minimal grade disruption is desired. Mechanized hand tools can often be used in these instances.





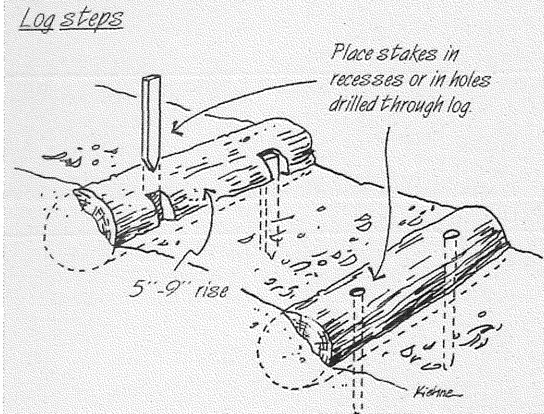
Turnpikes have also been used over the years for crossing wet areas. If this approach is used, caution must be taken to avoid blocking surface water flows or otherwise changing hydrology. If that is likely to occur, a boardwalk is recommended instead.

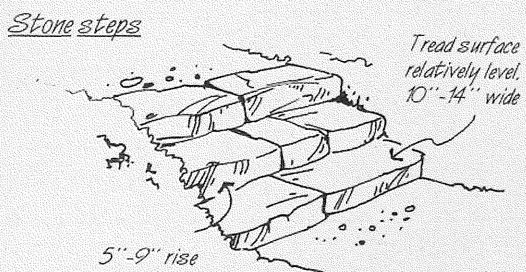


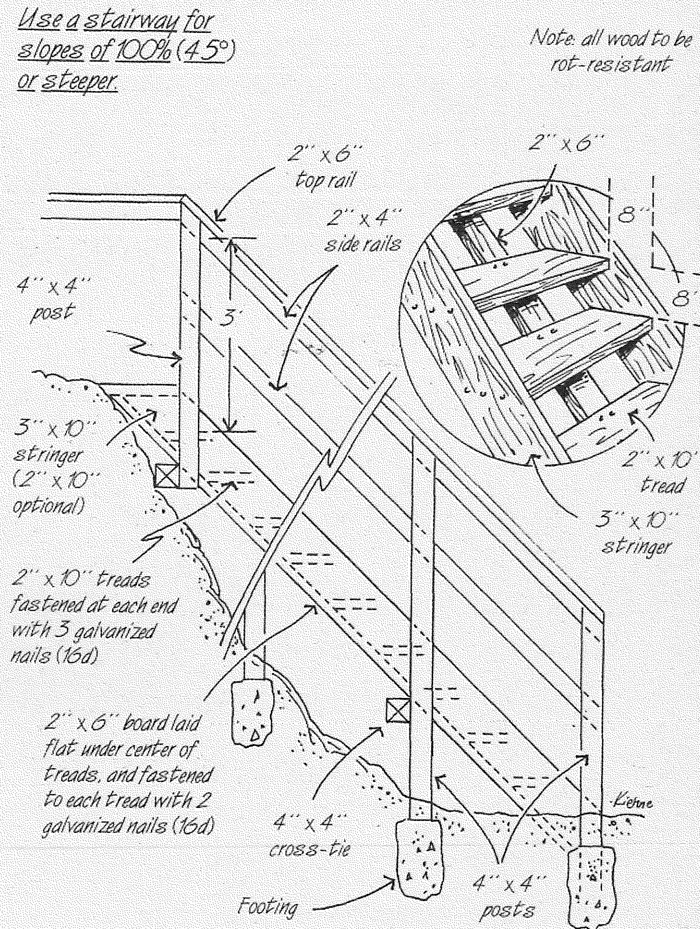
A simple bog bridge with sleepers is a historically common approach to crossing bogs in remote areas with readily available materials. The limitations of this approach is the sleepers will rot out over a period of years and have to be replaced, requiring more maintenance than other techniques.

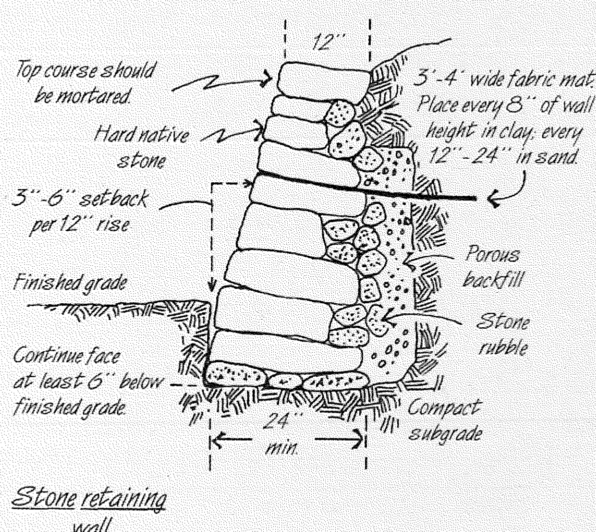
ASSORTED TECHNIQUES FOR NATURAL SURFACED TRAIL STRUCTURES

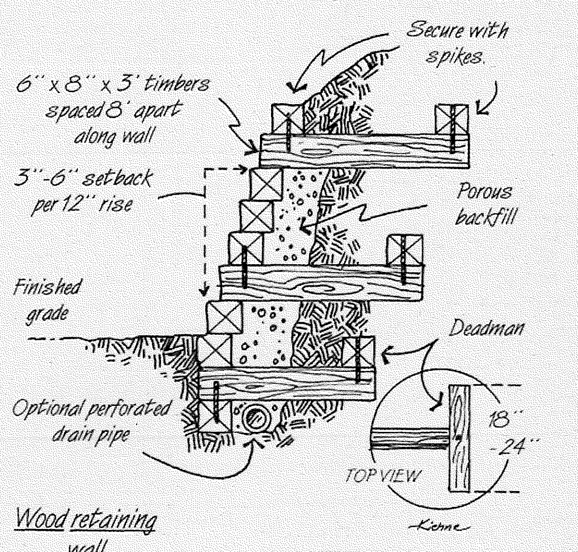
The following images are from *Recreation Trail Design and Construction* by David M. Rathke and Melvin J. Baughman. The images are provided to illustrate a variety of techniques that have proven useful in developing natural surface trails.





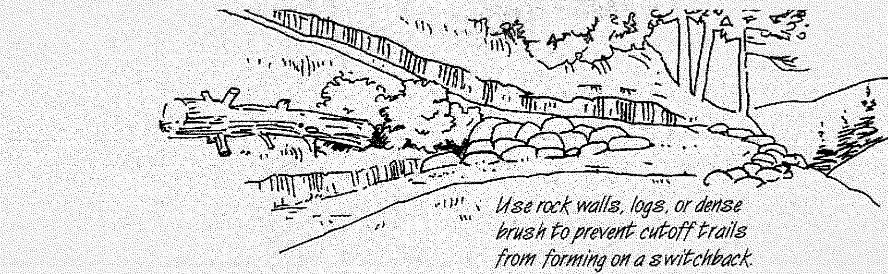


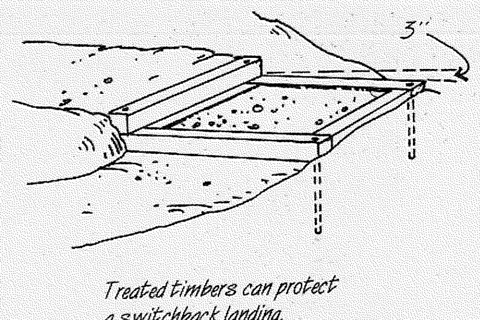


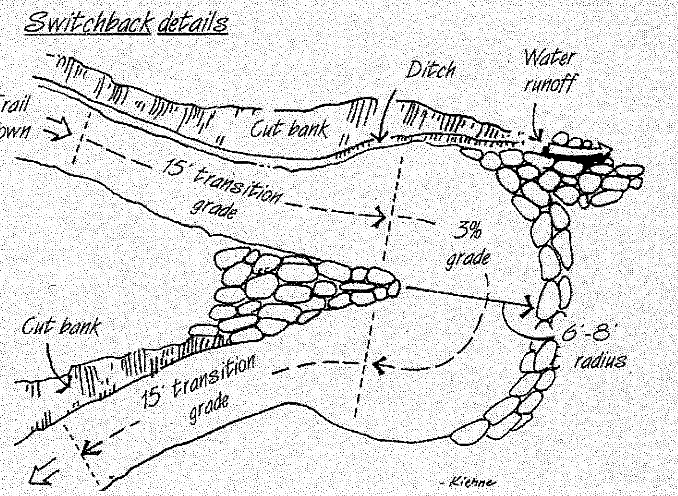


Assorted Techniques for Natural Surfaced Trail Structures (continued)

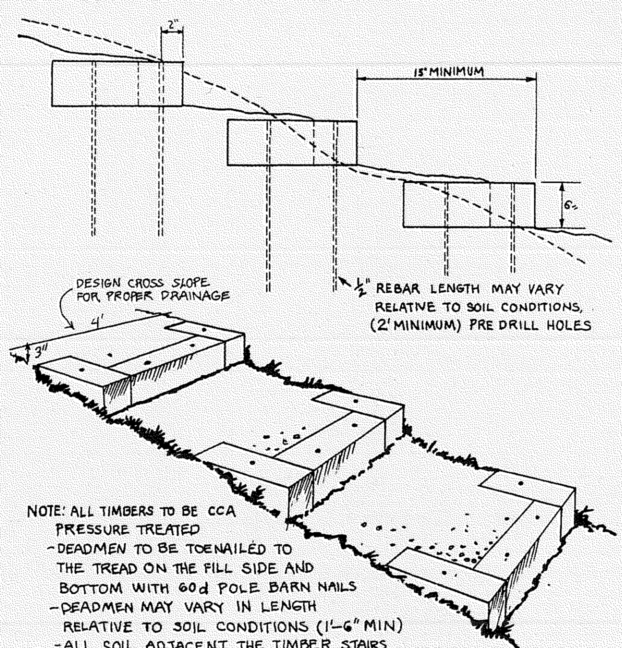
These images are from *Recreation Trail Design and Construction* by David M. Rathke and Melvin J. Baughman.

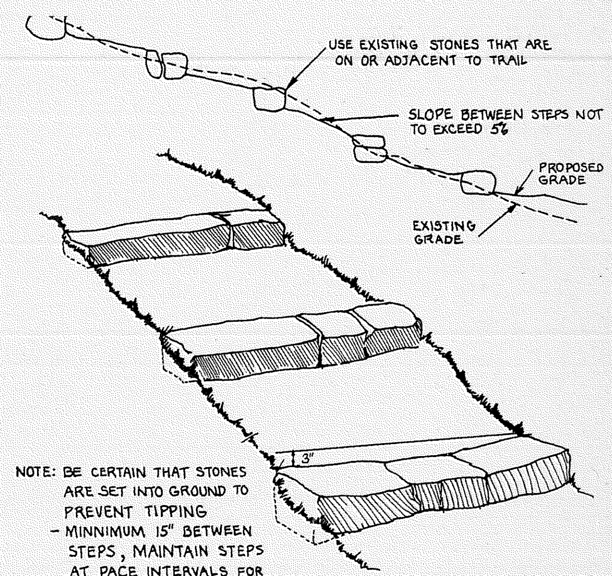






These images are from a previous DNR trail manual.





Edge Protection and Clearance Zones

Edge buffers relate to the clearance zone adjacent to a trail and protecting the edge of the tread and treadway. Factors include physical needs for clearance as well as erosion control, visitor safety, comfort, perception of risk, and the desired trail experience.

Edge protection. *This ATV trail was intentionally formed with a bermed outside edge for safety. Vegetation will eventually blend the berm into the site, strengthening it in the process.*

Edge Protection

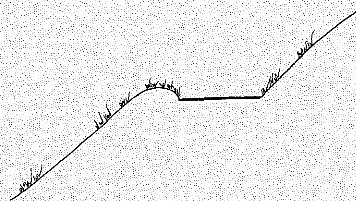
Where treads traverse a sideslope, trail users tend to avoid the 8 to 24 inches at the outside edge (depending on total trail width, type of use, and steepness of slope). The steeper and higher the drop-off below the trail, the farther away from the edge visitors prefer to stay. On steep slopes, many visitors feel more comfortable if the outside edge has a raised berm to keep them from slipping sideways off the trail. The effect of the berm is partly physical and mostly psychological – but it has strong appeal and should not be ignored.

Drainage is an important consideration in edge design. The act of visitors avoiding the outside edge of a sideslope tread often results in outsloped trails failing when compaction and displacement of the tread center deepens it and raises the outside edge. The untrammeled berm that is formed tends to grow vegetation, further discouraging travel on the edge and stabilizing the berm – even as erosion further deepens the traveled tread. If a bermed outside edge is not considered as part of the original design, tread drainage and erosion problems will tend to occur over time. Rolling grade is explicitly designed to provide tread drainage even with an edge berm.

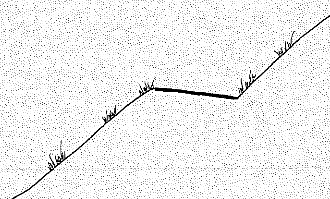
The following box considers a number of edge protection techniques.

Edge Protection Techniques

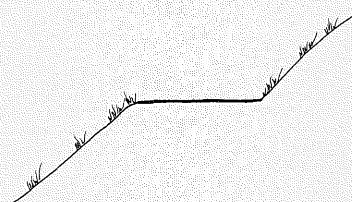
Bermed outside edge. Tread is shaped with a berm on the outside edge 8 to 30 inches wide and 3 to 18 inches high, depending on the type of use. The larger the mode of transport, the wider and taller the berm should be. Revegetation should be encouraged on the berm for strength, erosion control, and appearance.



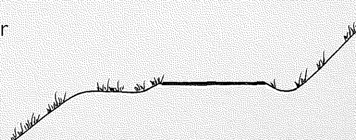
Inslope. A narrow tread can be shaped to slope and drain to the inside edge. If trail users start to slide sideways on a loose or slippery tread, they will then slide inward, away from the edge. Rolling grade is used to drain the tread. Inslope is often combined with a bermed outside edge.



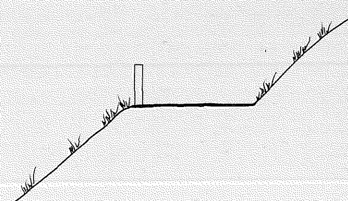
Additional tread width. The tread is 8 to 42 inches wider than it would be on a lesser sideslope. This is often useful on limited sightline or blind curves with an outside drop-off. The outside edge is not initially raised but may become bermed as the center is compacted and displaced material mounds on the widened edge.



Shoulder. A vegetated strip on the outside edge is used to create a greater sense of safety and edge stability. The shoulder is lower than the tread and often slopes slightly down toward the outside edge (outsloped). Ditches are optional. Shoulders are often used on trails formed on railroad grades and roadbeds.



Constructed barrier. A curb, bump rail, low wall, fence, or railing can be used to provide edge protection on steep slopes, narrow treads, outside curves, or hazardous drop-offs, or when additional protection supports the trail purpose. If the barrier has suitable openings at tread level, tread can be outsloped.



CLEARANCE ZONES

The clearance zone along natural trails varies in response to the character and sequencing of the trail. Although certain clearances are required for safety and proper trail function, selective clearing leaves larger trees, rocks, and some branches and brush inside the general clearance zone. Occasional clearing beyond the zone is also appropriate to create a desired experience, such as a vista. The following box and photos illustrate a number of approaches to creating an appropriate clearance zone.

CLEARANCE

Tight clearance makes a trail feel more primitive, challenging, and private. Sightlines are intentionally shorter with down-trail glimpses rather than full views. This encourages slower travel and makes the trail feel longer than it is, which is usually desirable.

Where desired, sightlines can be lengthened by selective thinning of brush outside the clearance zone. Tight clearance is recommended for less-busy trails, ATV and ORV trails, and in sensitive areas.

Generous clearance creates a more open, public feeling with longer sightlines that encourage faster movement. In dense understory, generous clearance helps reduce the tunnellike feeling. In more open forests and savannas, generous clearance happens by default.

Generous clearance is recommended for busy or mainline trails, especially where visitors are likely to meet or pass each other. It is also recommended in dense understory or where the physical safety (crime, poison ivy, etc.) or perceived safety of visitors would be improved by greater clearance.

Clearance height above ground level is related to visitors' sensitivity to horizontal clearance at eye level. Wheelchair users perceive horizontal clearance differently above and below a point 8 to 10 inches above ground level. For all other types of uses, the distance is 18 to 22 inches and possibly a few inches higher for equestrians. Below this point, trail users expect vertical natural objects such as rocks, shrubs and vegetation immediately next to the tread. Above this point, there is an expectation of additional horizontal clearance. Actual widths of tight and generous clearance zones vary by use and desired trail experience.

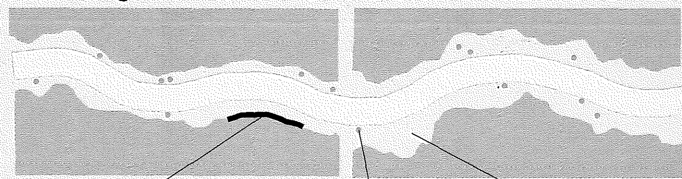
Clearance on sideslopes is skewed toward the uphill side. The steeper the sideslope, the larger the clearance zone.

Long, vertical features (such as retaining walls and railings that are taller than 18 to 22 inches, 8 to 10 inches for wheelchair use) require a widened tread or additional space between the tread edge and feature. At least 10 to 24 inches is needed, depending on the use and desirable travel speed.

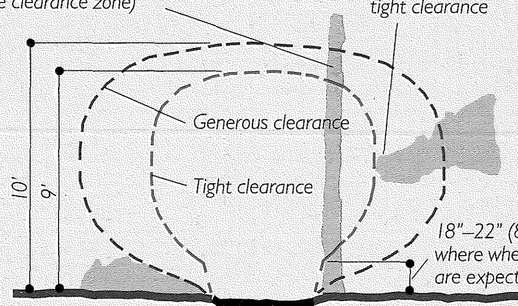
Reducing habitat fragmentation is a top priority in all clearance zones. As much of the native vegetation as possible should be retained within the context of the making the trail usable and safe. Retaining the native vegetation will also reduce opportunities for invasion of nonnative species.

Reducing splash erosion from rainfall by retaining the overhead tree canopy. This is especially the case on steep trails, where the softening of raindrops through a tree canopy can significantly reduce the likelihood of erosion.

CLEARANCE – PLAN VIEW

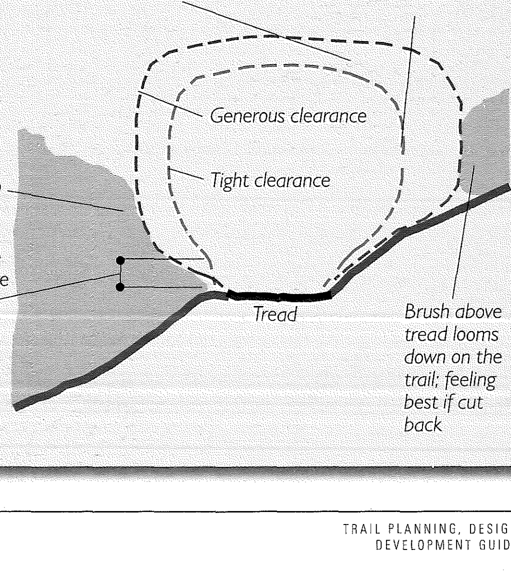


CLEARANCE – SECTION VIEW



Clearance zones are average distances. Individual tree trunks, branches, etc. can optionally extend to the tread edge. Width varies by use and desired trail experience.

CLEARANCE – SECTION VIEW ON SIDESLOPE




This tree anchor extends partway into the tread; its exposed roots are part of the tread crest.


These gateway trees provide limited width for ATVs. They help reduce travel speeds as the trail enters a parking area.


Selective clearance creates a mixture of tight spots and open areas, producing a natural character.


Selective clearance and mowing reduces the tunnel-like feel of trails in forests with thick undergrowth.

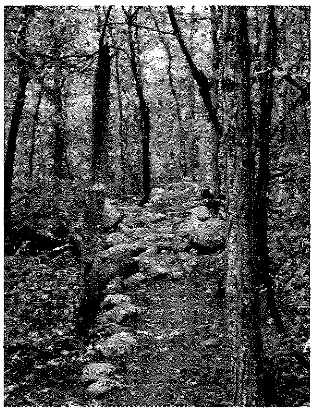

Excessive clearing along this forest road creates long sightlines, causing OHVs to travel at higher speeds and create displacement bumps.


On steep sideslopes, clearing more on the uphill side makes the drop-off seem less steep.


On very technical trails, clearance is often very tight and part of the challenge. Tight clearance also keeps uses strictly on the trail.


On many forest trails, the vegetation is kept back far enough to provide adequate sightlines yet still gives a sense of enclosure in keeping with the setting.

This designated mountain bike trail uses trees and rocks to keep riders on the trail and prevent them from bypassing the challenge.




Designated ATV trails can be purposefully tight to create the desired experience of enclosure.

Use Existing Roads or Form New Trails

For certain types of natural surface trails, a combination of existing roads and new trails appropriately accommodates the need while limiting the built footprint. This is especially the case with OHV and mountain biking trails, which need to be long to satisfy users. The following table highlights factors that favor using existing roads versus forming a new recreation trail.

Factors Favoring Using a Road or Forming a New Trail

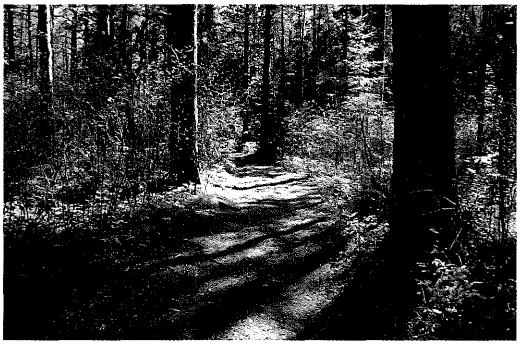
	Factors Favoring Using an Existing Road	Factors Favoring Forming a New Trail
Exclusive Route	• Existing road is clearly the only viable route to limit impacts to sensitive ecological systems or meet other land management objectives • In level, wet, or sensitive areas, especially for high-displacement uses such as OHV riding, when compacted roads have sustainable alignments and drainage	• No ecological or hydrological reasons not to form a new trail • Land management directives or legalities do not exclude new trail development
Physical Sustainability of Trail	• Road incorporates rolling grade or can be modified to sustainably have rolling grade • Roadbed has been compacted and/or hardened through use or by the addition of stony material • Road was designed as a permanent road • Site is level or near-level and the roadbed is well drained, compacted, and raised and/or ditched • Roadbed is narrow for trail conversion, or wide for on-road trail	• Road lacks rolling grade; exceeds climb recommendations; follows or nearly follows fall-line alignments; is eroding; has road surface below the surrounding ground level; and/or is otherwise not sustainable • Roadbed is not compacted or hardened • Road was designed as a temporary or skid road • Site has upland areas that can support a new trail with rolling grade designed for intended use • Roadbed is too wide for trail conversion, or too narrow for on-road trail
Ecological Sustainability – Short- and Long-Term	• Recreational use levels are low and limiting use to existing roads is most appropriate • Using existing road avoids new impacts in other areas (this is one of the strongest arguments for using existing roadways as trails) • Ecological impacts of road use are the same or lower than impacts of a new trail • Converting an existing road alignment to exclusive trail use limits disturbance to existing road corridor • On-road trail: Trail use is relatively low and is expected to remain low and compatible with other uses	• Additional forest access is consistent with management objectives for acceptable ecological impacts • Ecological impacts of the new trail are less than impacts of using the existing road (e.g., if the new trail keeps trail visitors away from a sensitive area or cultural site or the road has or may become physically unsustainable due to excessive) • The old road has been reclaimed by nature and is now well integrated into local site ecology • New trail would be narrower than the old road with less of a footprint and impact on site hydrology
Road Versus Trail Experience	• Trail purpose is primarily to provide a point-to-point connection • Recreational value is not the prime consideration and a road-like trail with long straight stretches, broad curves, and little intrinsic differentiation is acceptable	• Trail purpose is purely recreational and site can support a narrow, twisting, winding, engaging trail and provide a high-quality trail experience • Road is too straight with long sightlines, broad curves and little intrinsic differentiation and not well suited for recreation
Roadway Character and/or Cultural/Historic Significance	• Established or mature vegetation helps anchor the road and integrate it with the site • Roadway is a designated historic, scenic, or culturally significant route	• Road is relatively new, has little or no tree canopy to protect it, or feels too "roadlike" • Road has little or no historic or cultural significance that would make it attractive as a trail • Road is abandoned and reclaimed by nature, therefore forming a new trail may create less overall impact
Safety of On-Road Trail	• Low road traffic reduces likelihood of conflict • Road has good sightlines and is wide enough to safely accommodate both motorists and trail users • Roadway has curves and other characteristics to keep travel speeds low enough for trail use	• Medium to high road traffic, or commercial truck traffic, raises safety concerns • Road has blind curves, short sightlines with fast traffic, and/or is narrow • Slower travel is desired and roadway is too smooth with faster travel speed than what is considered safe

The following photos illustrate ideal examples of trails on roads, followed on the next page by situations to avoid.

Ideal Examples of Trails on Existing Roads

This trail is rolling grade on sideslope. *Very desirable and easily sustained (downhill is to the left). Much of the roadway, cutslope and fillslope are overgrown, increasing both sustainability and trail experience.*

Hardened logging road with rolling grade. *Overgrown now, this former logging road was partially compacted by logging equipment. ATVs consequently have little effect on the hardened tread.*



Compacted tread with gentle grades. *Well anchored by larger trees, this on-road trail has gentle grades in well-drained, sandy-stony soil. The tree canopy and low site runoff help protect the tread.*

Sideslope alignment on abandoned township road. *Following the lower edge of the slope at right while staying above the nearly level grassland below, this portion of the Southeast Minnesota ATV Trail is both sustainable and enjoyable.*

Minimizing ecological impacts. *This on-road trail uses the existing forest road through these and other wetlands.*

Excellent sustainability. *This portion of the Southeast Minnesota ATV Trail – a trail conversion – has rolling grade and excellent drainage to the side. Note the steepness of the sideslope – up to about 70 percent slope.*

Narrow clearance. *This sandy, low-use on-road trail remains sustainable because of low grades and narrow side clearance that tends to reduce speeds.*

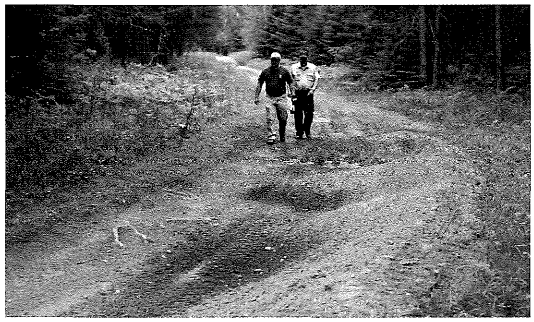
Hardened tread with vegetated center. *Nicely overgrown, this hardened former logging road feels like a dedicated trail yet withstands ATV traffic well.*

Logging road now only for ATVs. *Encroaching vegetation hides the former skid road scars while the compacted tread accommodates ATVs.*

Fall line alignment, uncohesive soils. *Even without trail use, this forest road used as an on-road trail would have severely eroded from being too steep in loose, sandy soils.*

Fall line alignment, uncohesive soils. *Continual road grading to remove erosion gullies from this steep forest road and snowmobile trail made the road 3 feet deep before it was traveled with ATVs. Note the ongoing erosion at center right.*

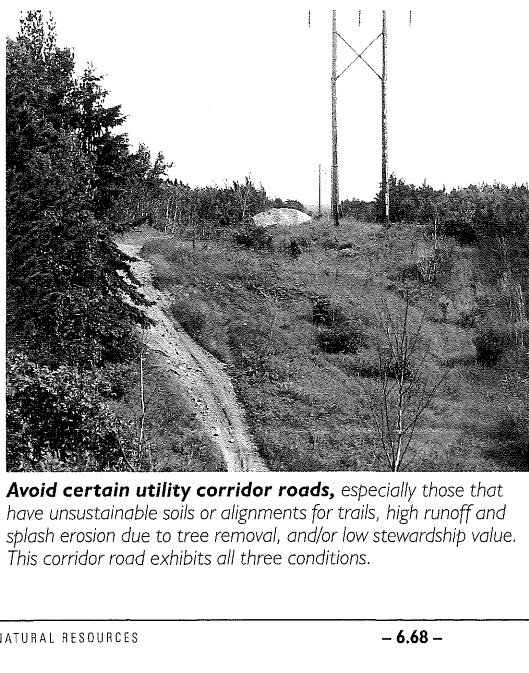
Fall line alignment, entrenched tread. *This former ice road is up to 5 feet deep. Although it does not appear to be actively eroding, it eroded once and could again. The existing fall-line trench cannot be drained and should be avoided as a trail.*



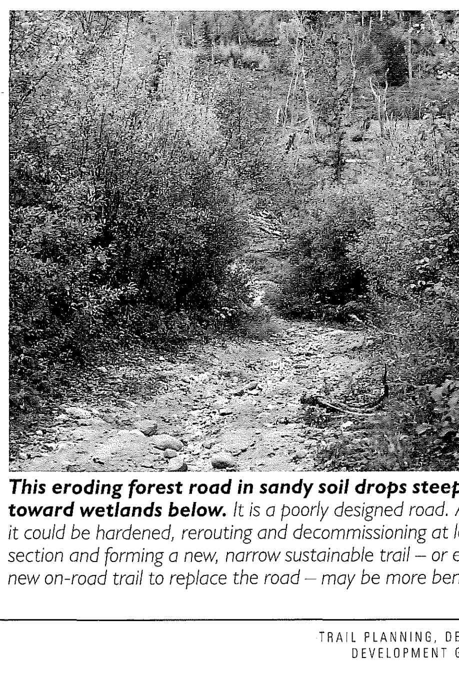
Excess clearance, excess sightlines. *Too much clearance enables higher speeds with longer sightlines. This resulted in rapid tread displacement, as seen in the foreground. Having shrubs and trees next to the tread would improve the situation.*

Wet and level. *This former railroad grade sank in a nearly level area, making it impossible to adequately drain the trail without elevating much of the tread or lowering the local water table. Avoid wet and level, or even nearly level, areas.*

Level or near-level, poorly drained or uncompacted roads, skid trails and logging areas. *Temporary forest roads in these conditions are usually unsustainable for trails unless elevated, hardened, ditched, drained, and maintained like roads.*



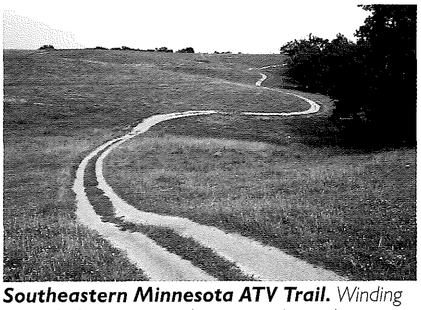
Avoid certain utility corridor roads, *especially those that have unsustainable soils or alignments for trails, high runoff and splash erosion due to tree removal, and/or low stewardship value. This corridor road exhibits all three conditions.*



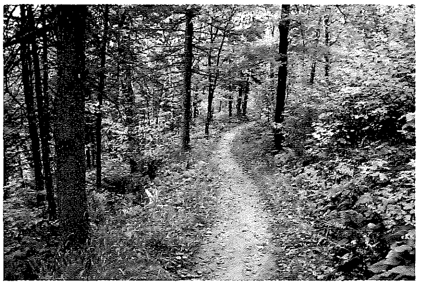
This eroding forest road in sandy soil drops steeply toward wetlands below. *It is a poorly designed road. Although it could be hardened, rerouting and decommissioning at least this section and forming a new, narrow sustainable trail – or even a new on-road trail to replace the road – may be more beneficial.*

APPLYING ROLLING GRADE DESIGN TECHNIQUES

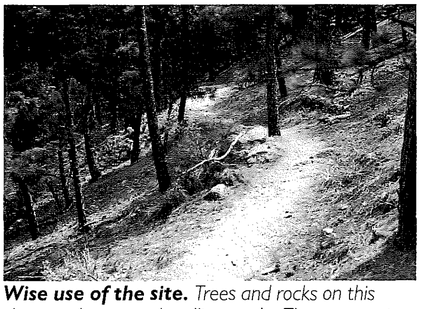
Understanding that natural surface trails must accommodate predictable change over time is the essence of rolling grade design. Compaction, displacement, and erosion are constant forces that must be accommodated if the design for a natural surface trail is to be sustainable. The following photos and graphics on this and the next page provide a number of examples of applying rolling grade techniques in the design of different types of natural surface trails.



Southeastern Minnesota ATV Trail. *Winding and sidesloping across the prairie, the trail uses all aspects of rolling grade and sustainable native tread design techniques and patterns to shape an exploration of the prairie. The fall line alignment in the foreground could be a problem in most of Minnesota, but the loess soil here makes a firm, erosion-resistant tread on this short climb.*



Jay Cooke State Park. *The Carlton Trail along the St. Louis River is one of the park's most popular hiking trails. It sideslopes high on the riverbanks with a gentle rolling grade. A tread dip is in the center of this photo. The trail, which starts at the end of a suspension bridge, has been in constant use for decades.*

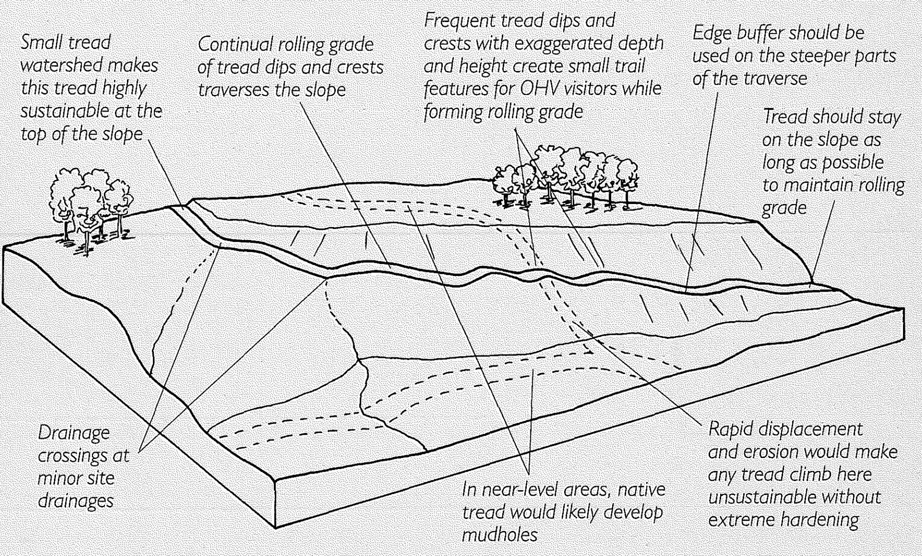


Wise use of the site. *Trees and rocks on this slope anchor a gentle rolling grade. The many twists and turns through the trees with slight roller-coaster ups and downs makes the trail engaging. The hiking trail uses outslope for some drainage and tread dips where an edge protection buffer has formed.*

EXAMPLES OF ROLLING GRADE TECHNIQUES

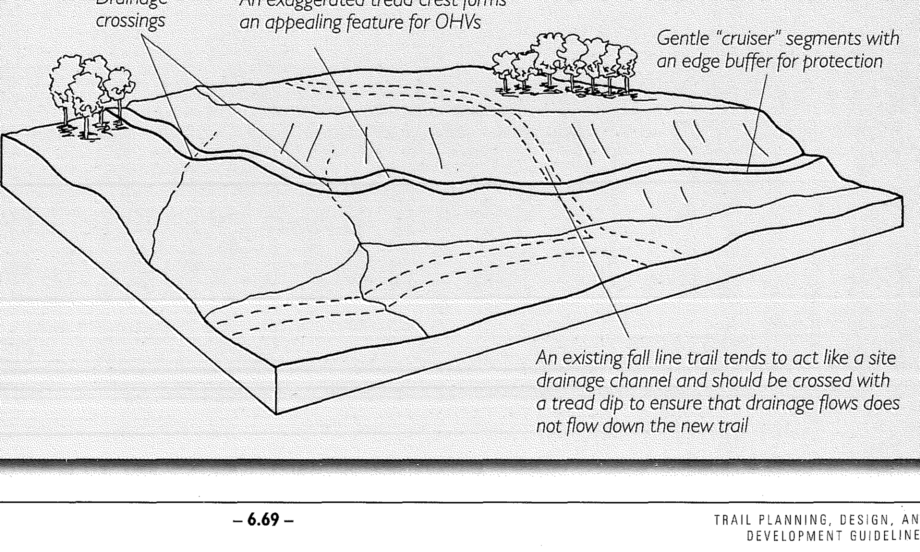
OHV TRAIL CLIMBING A SLOPE

Trail is conceived as a rolling grade with tread climbs consistent with recommended limits for soil, slope, modality, tread watershed, and other factors. For maximum sustainability, the trail should stay on the slope.



OHV TRAIL TRAVERSING A SLOPE

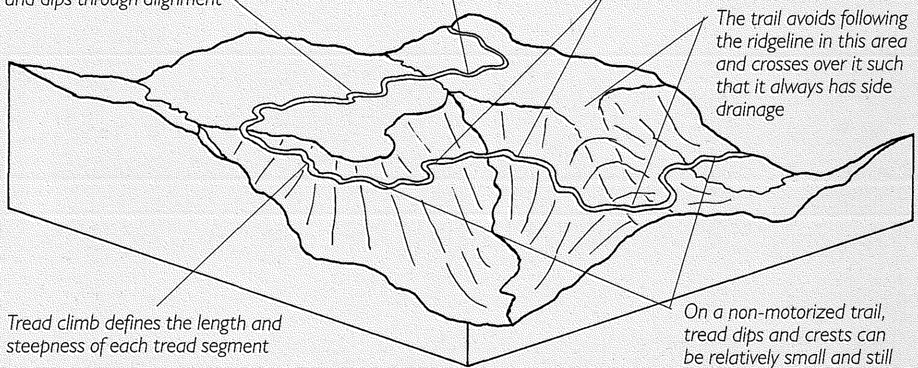
Using the same site as the above example, this alternate rolling grade trail traverses the slope without attempting to climb it. The resulting gentle grades form a more leisurely trail experience. Reducing the relative height differences between tread crests and dips would make this same alignment work well for nonmotorized uses.



Examples of Rolling Grade Techniques (Continued)

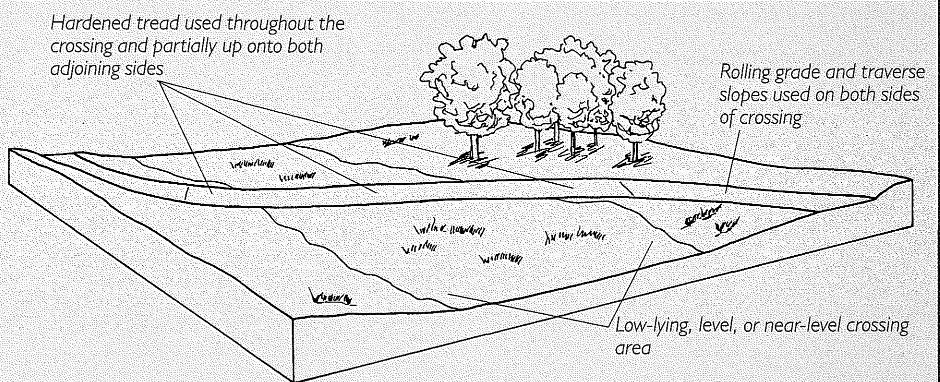
Nonmotorized Trail Traversing Hilly Terrain

Narrow, nonmotorized trails and OHM trails can traverse steep and very steep slopes with less site impact than wider treads. For OHMs, a steep sideslope makes the trail feel more challenging and tends to reduce speeds, especially if many tread dips and crests are used. In addition, by winding around slope, more tread length can fit into a smaller land area, enabling less land area to be affected by trails.



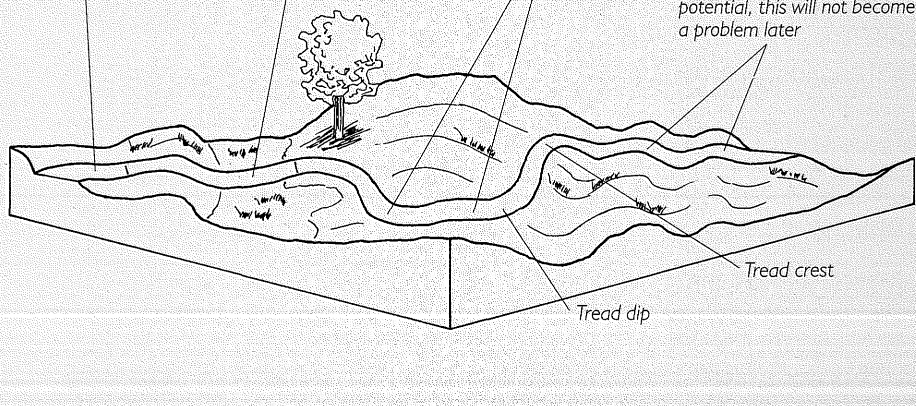
Crossing a Near-Level Area (All Summer-Use Trails)

Soils in low-lying, near-level areas and some near-level areas on higher ground can be poorly drained, making native tread susceptible to shear forces or water ponding. Where feasible, these areas should simply be avoided. If a crossing is required, hardened tread through the crossing and partially up onto higher ground on each side will likely be necessary. On higher ground, use rolling grade to traverse slopes, rather than following or approaching the fall line.



Rolling Grade on Fall Lines on a Trail for Wheeled Uses

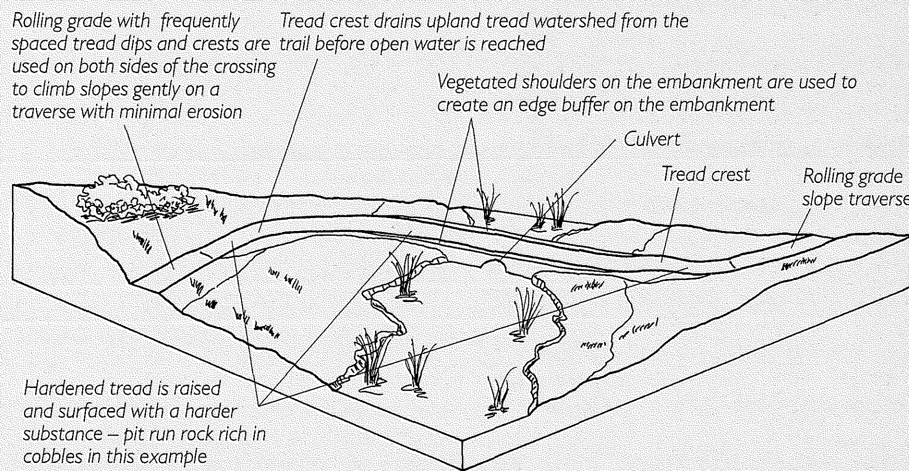
Rolling grade can follow fall lines on very short hills with limited tread watersheds. This trail uses small scale and microtopographic features to shape a sustainable tread with a blend of fall line and traversing alignments. Larger-scale slopes are traversed while small-scale features with limited erosion potential are crossed on the fall line. The trail alignment was carefully conceived to enable this to occur while staying within recommended tread climb limits.



Examples of Rolling Grade Techniques (Continued)

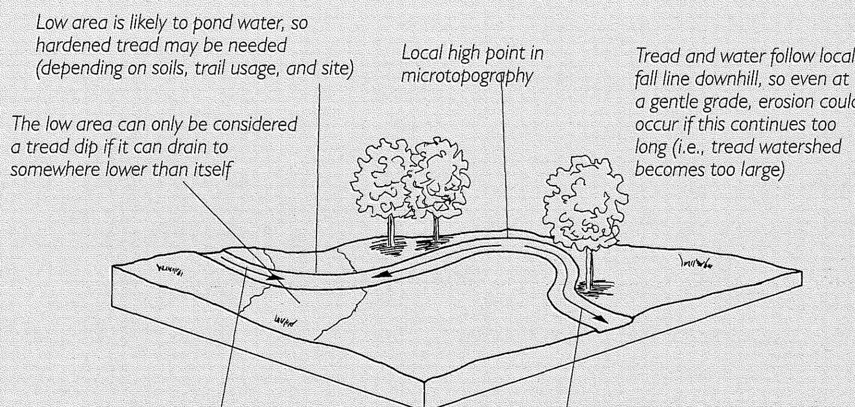
OHV Wetland Crossing

Physical and ecological sustainability challenges suggest that wetland crossings are absolutely a last resort. In such cases, this example illustrates how a tread can cross a shallow wetland using hardened tread and rolling grade techniques to minimize impact. All wetland crossings impose an ecological impact and each wetland or wet area crossing method needs to be determined in its own context.



Problems With Near-Level Sites

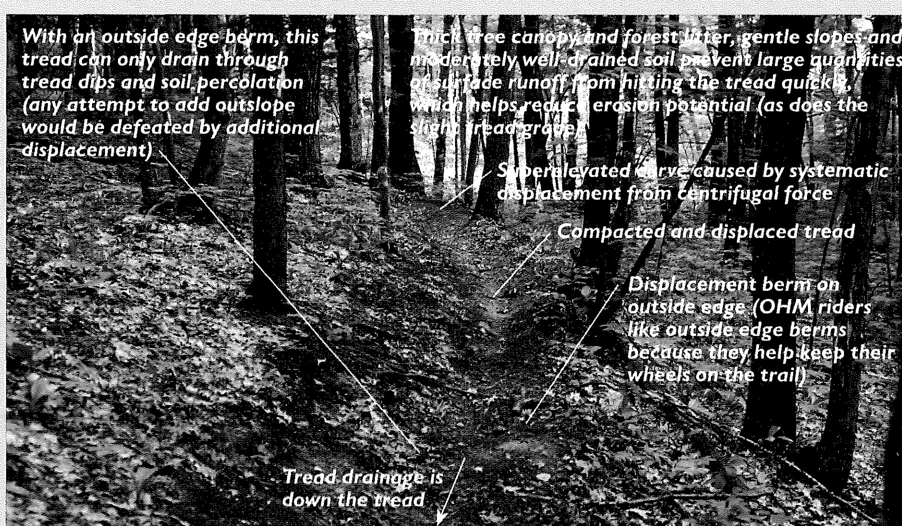
Sustainable native tread and rolling grade trails depend on being able to drain water when trails are compacted and displaced. All trails need to drain to somewhere lower than the tread. In near-level sites, the tread can be the lowest place around, causing water to pond in tread dips. In well-drained (sandy) soils, water may percolate through the tread and not pose a problem. In poorly drained soils or where the seasonal or permanent water table is high, ponded water will be an undesirable puddle at best or a mudhole at worst.



Arrows illustrate how microtopography directs water flow down the tread, with the low area on the left likely ponding water and water following the local fall line down the tread on the right

OHM Trail Case Study

This trail was formed entirely by visitors riding OHMs. Soil is sandy with some clay or silt, making it moderately well drained yet capable of being very muddy when saturated. Note the displaced tread with a berm on the outside edge that forces the tread to drain via tread dips. This type of displacement is typical of OHM trails and cannot be prevented unless the soil has excellent displacement resistance. Edge buffer clearance is tight since the tread winds around trees. Given this site, good drainage potential (tread grade less than 1/4 of sideslope) and low erosion potential, this segment of tread has good physical sustainability.



A good reference website!

The United States Access Board is a commonly-referenced resource for up-to-date information on accessibility, including trails (www.access-board.gov)

ACCESSIBLE NATURE TRAILS

The following provides technical provisions for accessible trails as recommended by the National Center on Accessibility, Indiana University Department of Recreation and Park Administration. The guidelines are a summary of various findings and rules established by the United States Access Board, which is the Federal agency responsible for creating guidelines and standards for accessible environments.

BASIS FOR THE GUIDELINES

Accessibility standards, such as the *Uniform Federal Accessibility Standards* (UFAS) and the ADAAG, have been found to be most applicable to built facilities and not readily transferable to the natural environment. Since the early 2000s, a new set of accessibility guidelines specifically geared toward natural trails began to evolve. These guidelines take into consideration that accessibility in a natural setting varies according to the type of use, desired experience, degree of remoteness, level of difficulty, and other site-specific factors.

Since the natural environment is part of the experience people wish to enjoy, the purpose of the trail and the expectations of the trail user are key determinants if a trail should meet accessibility standards. For example, the user expectation of a challenging hiking or mountain biking trail is that it will test a person's skill and physical capabilities. These expectations play a role in a person selecting one trail over another and it is therefore reasonable that a given trail may not accommodate all trail users.

On the other hand, if the purpose of a natural trail is to provide a recreational experience that everyone should have reasonable access to, then the design guidelines for accessible trails should be diligently applied. An accessible trail is defined as a trail that is accessible to and usable by people with disabilities and is identified as meeting minimum guidelines established by the United States Access Board. Since these guidelines are likely to continue to evolve, facilities need to use the best available information, which the following guidelines are based upon.

MINIMUM REQUIREMENTS

The minimum requirements found in the Outdoor Developed Areas Final Report by the United States Access Board are based on several principles, including:

- Protect resource and environment and preserve the experience
- Provide for equality of opportunity
- Maximize accessibility
- Be reasonable
- Address safety
- Be clear, simple, and understandable
- Provide guidance
- Be enforceable and measurable
- Be consistent with ADAAG (as much as possible)
- Be based on independent use by persons with disabilities

Accessible routes, outdoor access routes, and trails are all paths that have varying requirements based on their purpose. Similar to ADAAG, the guidelines apply to newly constructed or altered trails. An alteration involves changing the trail from its original condition as opposed to maintenance, which does not trigger the requirements in the guidelines. Maintenance to a trail returns the trail to its original condition. For example, changing the trail surface would be an alteration, whereas filling in holes in the trail surface that have been caused by use, animals, weather, or water would be considered maintenance.

Newly constructed trails are those constructed in an area where previously none existed. When constructing a new trail, evaluating the level of accessibility that can be achieved and is reasonable should be included in the design process. If a trail is to be accessible, these guidelines recommend taking the attitude that the entire trail should be truly accessible and not just meet the minimum requirements for compliance. Accessibility is much easier to accomplish initially instead of applying the provisions as an afterthought.

ANSI /RESNA STANDARDS FOR FIRM AND STABLE

	Very Firm/ Stable	Moder-atley Firm/ Stable	Not Firm/ Stable
Firm-ness	0.3" or less	>0.3" & <0.5"	>0.5"
Stability	0.5" or less	>0.5" & <1.0"	>1.0"

Firmness and stability are measured using a rotational penetrometer, which is available through several on-line companies.

TECHNICAL PROVISIONS

The guidelines address 10 provisions of trail accessibility, as the following defines.

1) Surface

Starting at an accessible parking lot, the trail surface must be firm and stable. Firmness refers to the penetration of the surface that occurs when force is applied. Stability refers to the displacement of the surface when a turning motion is applied. In other words, firmness is a vertical measure of penetration and stability involves how much surface material shifts when rotated pressure is applied. Examples of firm and stable surfaces include concrete, asphalt, and well-graded and compacted crushed rock. Natural surface trails can also be accessible if the soil is of the right type and texture to meet stability and firmness guidelines. Soil stabilizers can sometimes be used to make otherwise inaccessible surfaces more firm and stable.

2) Clear Tread Width

The clear tread width of an accessible trail must be a minimum of 36 inches. This allows a wide enough area for a person using a wheelchair or scooter to comfortably stay on the firm and stable trail surface.

3) Openings

Openings in trail surfaces, such as spaces between the boards of a boardwalk, may not allow the passage of a sphere 1/2-inch in diameter. In addition, the long dimension must run perpendicular or diagonal to the main direction of travel so casters from wheelchairs or tips of canes are not caught in the spaces.

4) Protruding Objects

Accessible trails must have a least 80 inches clear space above the trail free of any protruding objects, including vegetation. This space prevents people who are blind from bumping their heads. Simple maintenance of trails is often the solution to preventing accessibility issues resulting from protruding objects.

5) Tread Obstacles

Tread obstacles include tree roots, rocks, brush, downed trees, or branches projecting onto the trail. Tread obstacles cannot exceed a maximum height of 2 inches (3 inches if running and cross-slopes are 1:20 or less).

6) Passing Space

Passing space allows people who use wheelchairs to pass other hikers easily. Passing spaces need to be a minimum of 60 x 60 inches and occur at 1,000-foot intervals when the clear tread width of the trail is less than 60 inches. An alternative is a T-shaped space in which the arms and stem extend at least 48 inches beyond the intersection. The T-shape also needs to occur every 1,000 feet. Whenever possible, the 60 x 60 space should be used since it is more convenient for people to pass one another.

7) Slope

Two types of slopes are crucial to people with mobility impairments – running slope and cross slope. Except for drainage areas, the cross-slope of an accessible trail should be less than 1:50. In addition, running slopes must comply with one or more of the following four provisions with no more than 30 percent of the total trail length exceeding 1:12. The four provisions are:

- Running slope cannot exceed 1:20 for any distance, except as follows.
- If resting intervals are provided every 200 feet, the running slope may be a maximum of 1:12.
- If resting intervals are provided every 30 feet, the running slope may be a maximum of 1:10.
- If resting intervals are provided every 10 feet, the running slope may be a maximum of 1:8.

8) Resting Intervals

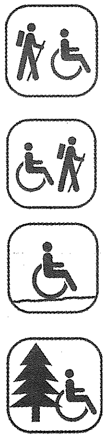
Resting intervals must be 60 inches minimum in length, and have a width as wide as the widest portion of the trail segment leading to the resting interval. The slope may not exceed 1:50 in any direction.

9) Edge Protection

Edge protection is not required but can be used where it would make the trail safe. If edge protection is provided, it must have a minimum height of 3 inches.

10) Signage

Accessible trails should include signage with information on the total distance of the accessible segment of the trail and the location of the first point of departure from technical provisions for accessible trails. Although no specific symbol has been chosen to represent an accessible trail, one of the four examples displayed to the left may be used.



Examples of symbols that could be used to represent a trail that fully complies with the accessibility guidelines.

ACCESSIBLE ROUTES, OUTDOOR ACCESS ROUTES, AND ACCESSIBLE TRAILS

Accessible routes, outdoor access routes, and assessible trails have varying requirements based on their purpose, what they connect to and the environment they fall within. Accessible routes under the ADAAG requirements relate to the built environment where all routes need to meet accessibility requirements. Outdoor access routes relate to facilities in the outdoor environment where reasonable access is required, such as between a parking lot and a picnic area or campground. Accessible trail relates to a natural trail that is designated as suitable for all levels of ability and consistent with the guidelines defined here. The following table identifies the technical provisions that are applicable to each of the different paths.

TECHNICAL PROVISIONS FOR ACCESSIBLE ROUTES, OUTDOOR ACCESS ROUTES AND TRAILS

	Access Route (ADAAG)	Outdoor Access Route	Accessible Trail
Surface	Stable, firm, and slip resistant	Firm and stable	Firm and stable (*Exception: **)
Maximum Running Slope	1:12	1: 20 (for any distance) 1: 12 (for max 50 ft) 1: 10 (for max 30 ft)	1: 20 (for any distance) 1: 12 (for max 200 ft) 1: 10 (for max 30 ft) 1: 8 (for max 10 ft) *(Exception: 1: 7 for 5 ft maximum for open drainage structures or when * applies)*
Maximum Cross Slope	1:50	1: 33 *(Exception: 1:20 for drainage purposes)*	1: 20 *Exception: 1:10 at the bottom of an open drain where clear tread width is a minimum of 42 inches*
Maximum Clear Tread Width	36 inches 32 inches for no more than 24 inches	36 inches *(Exception: 32 inches when * applies)*	36 inches for any distance *(Exception: 32 inches when * applies)*
Tread Obstacles	Changes in level: 1/4 inch with no beveled edge, 1/4 - 1/2 inch must have a beveled edge with a max slope of 1: 2. *(Over 1/2 inch= ramp)*	1 inch high maximum *Exception: 2 inches high maximum where beveled with a slope no greater than 1: 2 and where * applies.*	2 inches high maximum *Exception- 3 inches maximum where running and cross slopes are 1:20 or less. (Exception: *)*
Passing Space	Every 200 feet where clear tread width is less than 60 inches, a minimum 60 x 60 inch space, or a T-shaped intersection of two walks or corridors with arms and stem extending minimum of 48 inches.	Every 200 feet where clear tread width is less than 60 inches, a minimum 60 x 60 inch space, or a T-shaped intersection of two walking surfaces with arms and stem extending minimum of 48 inches. *(Exception: Every 300 feet where * applies.)*	Every 1000 feet where clear tread width is less than 60 inches, a 60 x 60 inch minimum passing space or a T-shaped intersection of two walking surfaces with arms and stem extending minimum of 48 inches. *(Exception: *)*
Resting Intervals	Landings: 60 inch min length, minimum width as wide as the ramp run leading to it, if change in direction occurs, must have 60 x 60 inch space.	60 inches minimum length, width at least as wide as the widest portion of the trail segment leading to the resting interval and a max slope of 1: 33 *(Exception: A max slope of 1: 20 is allowed for drainage purposes.)*	60 inches minimum length, width at least as wide as the widest portion of the trail segment leading to the resting interval and a maximum slope of 1: 20. *(Exception: *)*

* The provision may not apply if it cannot be provided because compliance would cause substantial harm to cultural, historic, religious, or significant natural features or characteristics; substantially alter the nature of the setting or purpose of the facility; require construction methods or materials that are prohibited by Federal, state, or local regulations or statutes; or be infeasible due to terrain or the prevailing construction practices.

Conditions for Departure

Due to the dynamic nature of the outdoor environment, the Outdoor Developed Areas Final Report by the United States Access Board identifies four conditions for departure or circumstances that allow deviation from the technical provisions. These conditions apply to each of the designated areas in the report. The application of one or more of the conditions is not an overall exemption of the entire trail. When the condition for departure no longer exists, the technical provisions again apply. The exemption only applies to the pertinent technical provision; all other aspects should comply. For example, if an endangered species only allows 30 inches of clear tread width, the surface should still be firm and stable and other provisions aside from clear tread width should be applied. After passing the plant the clear tread width should return to at least 36 inches.

The first condition is where compliance would cause substantial harm to cultural, historic, religious, or significant natural features or characteristics. Examples of cultural features include archaeological sites, burial grounds and/or Indian tribal protected sites. Historic features include properties such as those listed in or eligible for the National Register of Historic Places. Examples of religious features include Indian sacred sites and other properties designated or held sacred by an organized religious belief or church. Natural features include properties protected by federal or state laws and areas with threatened or endangered species.

The second condition is where compliance would substantially alter the nature of the setting or the purpose of the facility or portion of the facility. This condition addresses concerns relating to people who choose to recreate in an outdoor setting for a higher degree of challenge and risk. If the designed purpose of the trail were a cross-country training trail, accessibility would interfere with the intended experience.

The third condition is where compliance would require construction methods or materials that are prohibited by federal, state, or local regulations or statutes. For example, mechanized equipment may be restricted in designated wilderness areas, or the introduction of imported materials may be prohibited in order to maintain the natural ecosystem. Although State and local statutes are taken into consideration, new regulations may not be initiated to prevent compliance.

The fourth condition is where compliance would not be feasible due to terrain or prevailing construction practices. If typically a team of volunteers with hand tools does alterations, there is not an expectation of bringing a bulldozer in to establish a new trail. In addition, this condition applies to disturbing soils susceptible to erosion, interfering with the natural drainage, and other issues related to the natural terrain.

Exceptions

In addition to the conditions for departure, the proposed guidelines provide general exceptions addressing the technical provisions for trail accessibility. The exceptions are based on the following conditions:

- The combination of running slope and cross-slope exceeds 40 percent for over 20 feet
- A trail obstacle 30 inches or more in height across the full tread width of the trail
- The surface is neither firm nor stable for a distance of 45 feet or more
- A clear width less than 12 inches for a distance of 20 feet or more

When one or more of the conditions for departure are met and a departure from the technical provisions occurs for more than 15 percent of the length of the trail, the provisions no longer apply after the first point of departure. In other words, if more than 15 percent of the total trail length cannot be made accessible due to the conditions of departure, the trail only needs to be made accessible up to the first point of departure.

Additional Exceptions

Additional exceptions address the provisions individually:

- Tread obstacles may be 3 inches maximum where running slopes and cross-slopes are a maximum of 1:20, unless one or more of the conditions for departure apply.
- A firm and stable surface is not required where at least one condition for departure applies.

- Where at least one of the four conditions occurs, clear tread width may be reduced to a minimum of 32 inches. If one of the four conditions prevents 32 inches of clear tread width then the provision does not apply.
- Elongated openings are permitted to be parallel to the dominant direction of travel where the opening is smaller than 1/4-inch. Openings can go up to 3/4-inch where one or more of the conditions for departure apply unless one or more of these conditions prevent an opening of 3/4-inch to be allowed.
- Where at least one of the four conditions apply, vertical clearance may be reduced to less than 80 inches if a barrier warns people who are blind or visually impaired.
- Tread obstacles may be 3 inches maximum where running slopes and cross-slopes are a maximum of 1: 20, unless one or more of the conditions for departure apply.
- Passing space may not be provided where at least one of the four conditions for departure prevent the passing space from being provided.
- For open drainage structures, a running slope of 14 percent is permitted for a maximum of five feet with a maximum cross slope of 1:20. Cross-slope is permitted to be 1:10 at the bottom of the open drain, where clear tread width is a minimum of 42 inches unless at least one of the conditions for departure applies.
- Resting intervals are not required where one or more of the conditions apply.

Trail Signage and Access Control

Trail signage and access control are important aspects of managing use of natural surface trails and ensuring trail users will have a safe experience. Proper signage is especially important when the difficulty level of a trail system varies or where different types of motorized and nonmotorized uses are accommodated in one area on separate trails. Access control refers to physical barriers used to prevent certain uses.

Trail Signage

Signage provides useful and necessary information to trail users in a consistent, uncluttered manner. This means only providing the signs really necessary in order to minimize visual distraction, maintenance, and ongoing costs.

DNR's *Sign Manual* and *Forest Access – Signing and Placement of Guidelines* are the primary references for natural surface trail signage programs and should be referred to for in-depth information. The following provides and overview of the various types of signs most often associated with natural surface trails.

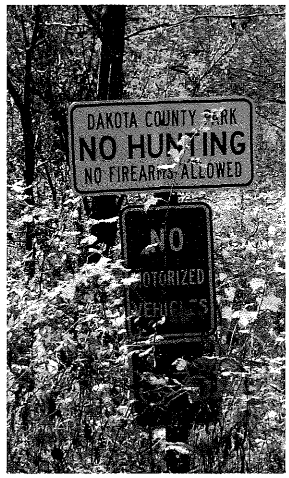
Regulatory/Warning Signs

Regulatory signs notify users of rules and laws associated with various types of trails, such as designating users, direction of travel, and code of conduct. Warning signs alert trail users of potentially hazards on or adjacent to a trail. Each of these types of signs must be positioned so trail users can easily see and read them and then react, especially when a sign is identifying a challenging technical section or trail hazard. The following are examples of regulatory and warning signs.

Limiting access to a certain type of use are some of the most common types of regulatory signs. This is mostly due to the fact that natural trails accommodate both motorized and nonmotorized uses, and these are not always compatible with each other.

Regulatory and rules signs alert trail users to any limitations on use and their responsibilities in using the trail. As with all signs, these should be of a consistent style and character so trail users become familiar with the set of rules and regulations common to a system of trails.

Due to multitude of trail conditions found on natural trails, caution signs (above) are perhaps more routine than on paved trails. For motorized and mountain bike trails, stop-related signs are needed at all road crossings and trail intersections (near right).



Regulatory and rules signs cover a variety of topics, ranging from areas that are closed for resource management to restrictions on use and general trail use rules.

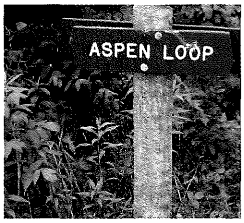
Trailhead/Orientation Signs

These signs highlight trail features, indicate interconnections with other trails, and provide general "You Are Here" type of information. Trailhead and orientation signs come in many forms depending on the setting and information needs. In a park setting, trail kiosks are often informational as well as a simple architectural element and common identifier of a particular system. The following photos highlight a few examples of these types of signs.

Trailhead kiosks provide an array of information, including trail maps, park/trail rules, unique features, and history. and are located in a prominent position at the head of a system of trails. Information on trail lengths and relative difficulty levels is also provided.

Along a trail, orientation signs are usually simple in keeping with the setting. A map with a "You Are Here" arrow, trail names and mileage, and select natural features is most often all that is provided. For more complex systems, a numbering system on the map correlated with numbered posts at trail intersections can also be useful to trail users. Trail difficulty information is also commonly found on these signs.

Directional Signs and Route Guides



These signs provide useful information at key decision points along a trail. They are used to reassure users that they are still on the trail and define their relative location, and where connecting trails lead. Directional signs can range from simple blazes to a formal sign with trail name and mileage to a destination. Directional signs can be very important on trails that are hard to follow. Although trail markings should be provided where needed, they should also not be overused to avoid taking away from the experience. The following photos highlight a few examples of this type of sign.

The extent to which directional and route guides are needed depends on the site. These photos highlight the varying character of these types of signs, ranging from a regional park setting (left two photos) to the Superior Hiking Trail (right two photos). Notice that a simple rock cairn is often adequate to tell the trail user where the trails heads. Any more would be of no real value and would take away from the setting.

Difficulty-Level Signs

Whenever a trail is rated anything other than easy, trail difficulty-level signs should be posted at every access point and throughout the trail system at key intersections and along the trail whenever the level of difficulty changes. The mileage associated with a particular segment of rated trail should also be provided. The following photos highlight a few examples of this type of sign.

Difficulty-level signs are important on mountain bike trails so that riders make informed choices consistent with their skill level.

Difficulty-level signs are very common along the trails at the Gilbert OHV Recreation Site. With the right information, trail users most often make the right choice for themselves and enjoy technical challenges that are within their skill level.

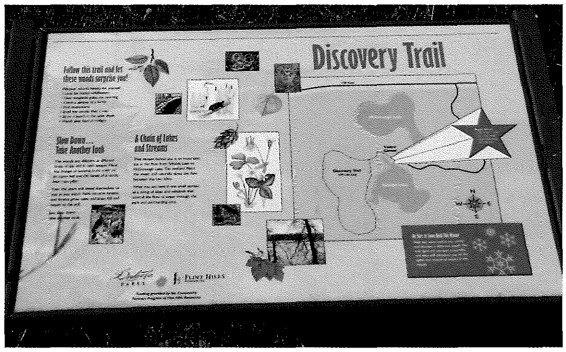
Interpretive/Educational Trail Signs

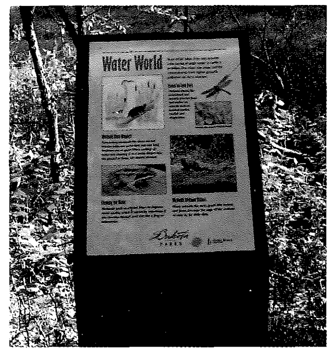
Interpretive trails are popular within established natural park areas at the local, regional, county, and state level. Signage is one of the key distinctions that separate an interpretive trail from a regular hiking trail. Often, but not exclusively, interpretive trails are associated with a nearby nature or visitor center so that the trail can be used as part of a broader educational program. The following photos highlight a few examples of interpretive/educational trail signage.

The interpretive signage program at the Mary Gibbs Mississippi River Headwaters Visitor Center in Itasca State Park is extensive and well-coordinated. The exhibit includes interpretive panels covering the cultural and natural history of the headwaters area.

(Left) Interpretive signage programs are typically linked to a trailhead or visitor center where the overall trail is described.

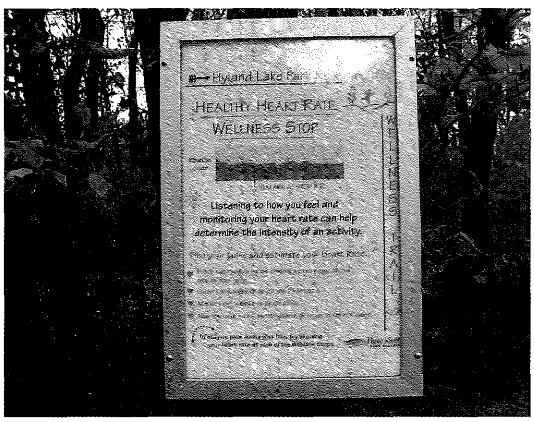
(Right) The same signage theme and character is then carried through the signage along the interpretive trail.

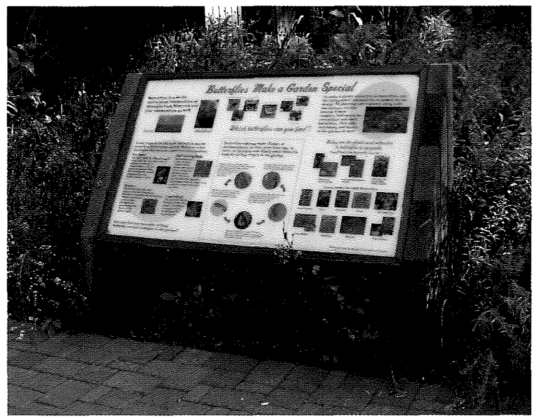




(Left) In addition to nature interpretation, educational signage can also focus on other subjects, such as healthy lifestyles.

(Right) Signage near an interpretive center is often more extensive since it is often tied into educational programs.

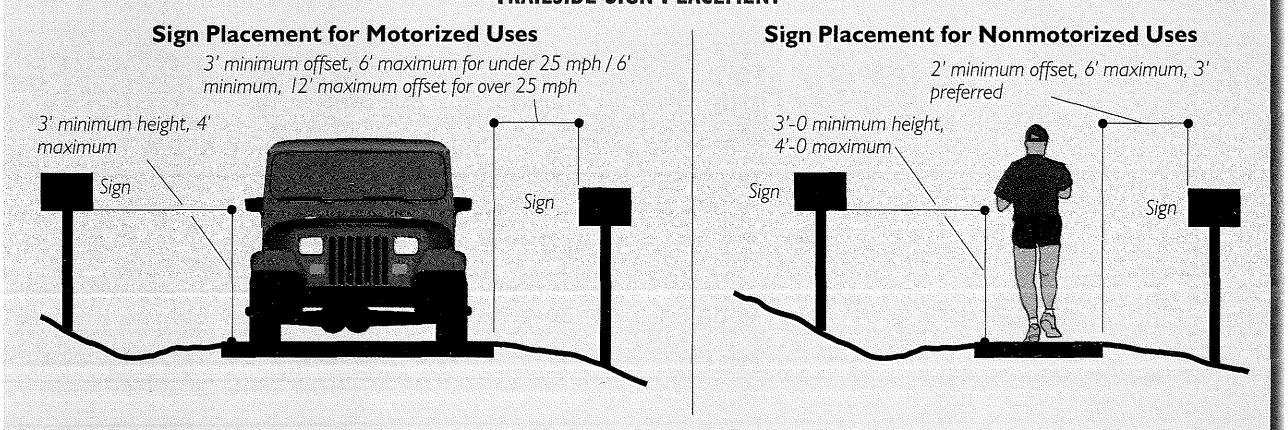




General Sign Placement Guidelines

DNR *Sign Manual* and *Forest Access – Signing and Placement of Guidelines* are the primary references for placement of natural trail signs and should be referred to for in-depth information on signage. The following graphic illustrates some of the key aspects of these guidelines.

Trailside Sign Placement



Regulatory traffic signs (e.g., Stop, Yield, Do Not Enter) should be located a minimum of 6 feet back from an intersection. For motorized uses, the recommended distance between a warning sign and an intersection or hazard varies with speed, as the following considers:

- 20 mph speed requires 100 foot sign setback
- 30 mph speed requires 150 foot sign setback
- 40 mph speed requires 300 foot sign setback
- 50 mph speed requires 500 foot sign setback

All signs associated with on-road trails should be consistent with *MN MUTCD,* as appropriate.

ACCESS CONTROL

Placing physical barriers to limit trail access is common practice, but should only be used where necessary. This is especially important when different types of trails and trail users are being accommodated in a given area.

With natural surface trails, the intent is to take away any ambiguity on the type of use that is allowed on a trail. Generally, barriers are only erected when it is expected or observed that trail users are bringing restricted uses onto trails. Notably, the use of barriers still relies upon trail users to be responsible since they are often easily bypassed. Barriers are often used as part of an educational campaign to remind trail users that if barriers are routinely bypassed, uses may become more restricted.

The following photos highlight a variety of barriers for access control.

Removable bollards, padlocked at their base to pipe sleeves embedded in the tread, prevent use of this ATV and snowmobile trail by on-road vehicles. The reflectorized bollards are removed during snowmobile season.

This modified stock gate excludes off-road trucks but allow ATVs on this on-road trail. The entire gate is opened for snowmobile use in winter and for timber management access as needed.

(Left) This simple gate is in keeping with the setting and will be effective is the users are responsible.

(Right) This management gate plus step-over trail bar for hikers, equestrians and bicyclists is intended to exclude motorized uses. Unfortunately, it also excludes wheelchairs.

Bypassing can be a major problem when trail users are not being responsible in an areas.

(Left photo.) Commonly, illegal users simple go around the barrier.

(Right photo) Is some cases, an inadequate barrier allows illegal users to even go under it, causes even more environmental impact.

MAINTENANCE GUIDELINES

The following maintenance guidelines provide general recommendations for monitoring and maintaining natural surface trails. The objective is to keep the trails sustainable and minimize adverse impacts such as compaction, displacement, and erosion. Note that the guidelines are generic and not a substitute for trail-specific maintenance procedures that respond to local site conditions, soils, types and levels of use, and other factors.

MONITORING AND INSPECTION SCHEDULE

Trail monitoring and inspection should occur throughout the year to detect potential maintenance issues before unsustainable conditions or safety concerns arise. The following table provides an overview of inspections that can be completed during each season.

INSPECTIONS SCHEDULE

A routine inspection schedule is primary to staying on top of maintenance issues and taking care of problems at an early stage. The following suggests an overall seasonal approach to inspections.

Season	Inspection Focus
Spring	Inspect for damage due to winter seasonal uses and freeze-thaw cycles. Check for erosion, plugged culverts, user- and maintenance vehicle-caused damage, unauthorized uses, and other visible signs of tread imperfections. Record all occurrences and schedule maintenance on a priority basis. Also clear debris from the trails as soon as possible in the spring.
Summer	Conduct ongoing inspections to keep trail in a safe, usable condition. In addition to items listed for spring, also inspect vegetation growth and encroachment. Pay special attention to erosion issues, drainageways, and ditches that may have received heavy spring runoff. Record all problems and schedule maintenance on a priority basis.
Fall	Conduct ongoing inspections to keep the trail in a safe, usable condition. Focus on maintenance issues that should be taken care of before winter to avoid more damage during spring thaw. Special attention should be given to tread dips, drainage crossings, culverts, and drainageways that must be operational for spring runoff.
Winter	This is good time of year to check low areas and drainages that cannot be easily accessed during the summer. This includes culverts, ditches, and beaver ponds.

GUIDELINES FOR GENERAL MAINTENANCE PRACTICES

Maintenance practices for natural surface trails falls into a number of basic categories.

PROPER DESIGN AND CONSTRUCTION

The most important factor affecting trail maintenance is properly designing and constructing the trail in the first place using rolling grade techniques and the sustainable practices described in this manual. If a trail segment is found to require extensive maintenance each year to keep it sustainable, it should be redesigned. Refer to Guiding Principle #6 – Ensure that Trails Remain Sustainable in Section 3 – Principles of Ecological Sustainability for additional recommendations on dealing with trails that are proving to be unsustainable.

VEGETATION MANAGEMENT

Vegetation along the trail must be managed to maintain an acceptable clearance zone and preserve the integrity of the trail surface. This includes removal of encroaching vegetation by cutting and/or spraying of an approved herbicide by a licensed applicator. Cutting is the preferred method whenever possible, and the only acceptable approach in ecologically sensitive areas.

Where erosion has taken out vegetative cover, the cause should be addressed prior to restoration. Guiding Principle #5 – Provide Ongoing Stewardship of the Trail And Adjoining Natural Systems in Section 3 provides additional information related to managing and restoring vegetation along trails.

Routine Maintenance

Routine maintenance should be performed on natural trails to prevent simple problems from becoming unsustainable conditions. Routine maintenance typically includes:

- Finding and correcting problems while still small
- Predicting and preventing future problems
- Protecting tread from overuse and from uses the trail is not designed to accommodate
- Closing a trail during extremely adverse tread conditions, typically during spring breakup and other times when saturated soil conditions exist

Of the items listed, the last one is the most important in terms of preventive maintenance. Implementing agencies are encouraged to have set policies defining when trails are to be closed due to adverse tread conditions.

Trail Monitoring

Trail monitoring is typically done for four primary reasons: 1) to monitor for trail conditions that would present safety concerns for users; 2) to determine relative amounts of use and use patterns; 3) to determine impacts to the environment; and 4) to monitor for and immediately address any invasive plant incursions that occur along the trail.

Trail Conditions

This relates to monitoring for debris, fallen limbs, washouts, rutting, and vegetative growth, then scheduling maintenance to address findings. It also relates to monitoring signage and other built structures to ensure that they are in place and functioning properly.

Trail/Facility Use

This relates to monitoring the extent to which trails and trailheads are being used to determine if demand and user expectations are adequately being met. Trail and facility use monitoring is often done in concert with trail condition monitoring. With advances in technology, electronic traffic counters are more routinely used to document trail usage and monitor if closed trails are being used illegally.

Environmental

This relates to paying special attention to erosion, sedimentation, vegetative damage, off-trail/illegal riding damage, noise, and other factors causing impacts to the surrounding environment.

Monitoring should occur on a scheduled as well as random basis during the use season, typically an average of at least once each week, and preferably on a Friday, Saturday, or Sunday when trail activity is likely to be highest. Persons making these visits should use a common assessment form for each type of monitoring to record conditions encountered during each visit. Information gathered while monitoring trails should be used to determine thresholds for trail management actions, including maintenance scheduling, facility development, trail rehabilitation, and trail closures. Along with written assessment forms, photographs and noise monitoring equipment should also be used to record findings – especially in situations where an environmental concern might lead to trail restrictions or closure if not successfully remedied.

Controlling Invasive Species

As defined under Guiding Principle #5 – Provide Ongoing Stewardship of the Trail and Adjoining Natural Systems in Section 3, preventing the spread of invasive plants is a major concern of resource managers. Those involved in monitoring and maintaining trails should become familiar with contemporary practices for controlling invasive species and establish preventive programs for all trails. This starts with recognizing which activities facilitate the movement of invasive plants into natural settings and what can be done to limit this.

SECTION 7 - WINTER-USE TRAILS

SECTION **7**

Winter-Use Trails

Winter trail activities have a long history in Minnesota. The extensive winter trail systems across the state allow outdoor enthusiasts ample opportunity to pursue their interests.

OVERVIEW

Winter-use trails serve a wide array of users. Although there are some common features, each trail has unique design and grooming requirements that greatly affect the user's experience.

WINTER TRAIL CLASSIFICATIONS

As defined in Section 4 – Trail Classifications and General Characteristics, a number of classifications fall under winter use trails, including:

- Cross-County Ski Trail
- Snowshoeing Trail
- Winter Hiking Trail
- Dogsledding Trail
- Skijoring Trail
- Snowmobile Trail

The following considers each of these in greater detail.

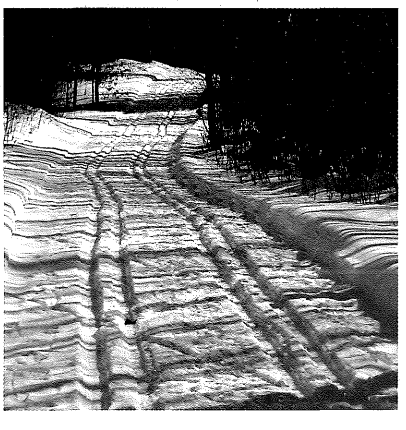
CROSS-COUNTRY SKI TRAIL

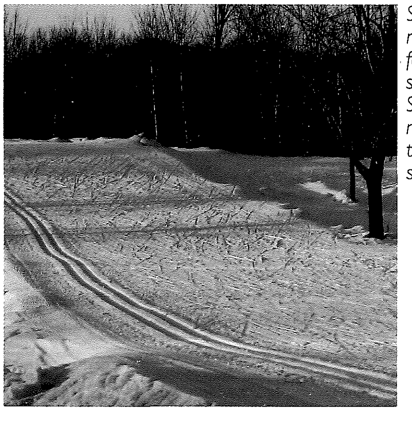
The following provides general design and grooming guidelines for cross-country ski trails. As with other types of trails, the guidelines are not intended to be a substitute for site-specific design that responds to local conditions, development requirements, and safety concerns.

CROSS-COUNTRY SKIING STYLES

Groomed cross-country ski trails typically accommodate two distinct skiing styles: Traditional/classic and skating style. Each of these styles has specific trail width and grooming requirements, as the following photos illustrate.

In traditional/classic style cross-country skiing the skier uses a kick and gliding motion to move forward within a set track – which in most park settings is machine set, as shown in this photo. In wilderness settings, the track is most often set by the lead skier "breaking" trail.





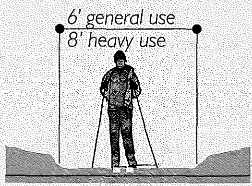
Skate skiers use a skating motion to move forward following a groomed trail surface without a track. Skating trails are almost always machine groomed, as shown in this photo (to the right of the set traditional track).

Trail Tread Widths and Configurations

The physical space required for the two styles of skiers provides the base-line for determining the optional width for cross-country trails. The configuration of trails also affects the width of the trail, as the following graphic illustrates.

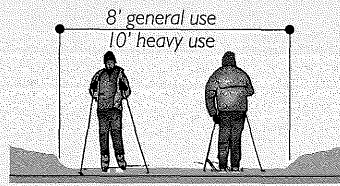
Typical Trail Widths For Cross-Country Ski Trails

Trail widths vary considerably to accommodate the two styles of skiing. The following defines the basic trail widths and directional configurations for each type of cross-country ski trail commonly found in Minnesota. (These correspond with the cross-country ski trail configurations defined in Section 4 – Trail Classifications and General Characteristics.)



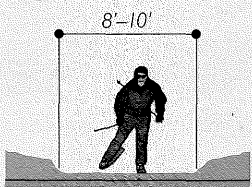
Generally used in a casual park setting or trails in less frequently used county, regional, and state parks. Grooming is limited and trails are often tracked by local users. One direction is used where use levels are higher, otherwise direction of use is often informal and two way.

Traditional (Classic) Style - One Track Set/One or Two Direction



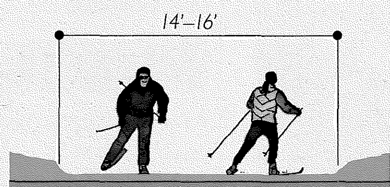
The most common type of groomed trail in many state parks and less frequently used regional or county parks. Routinely groomed, especially after a snowfall of a couple inches or more. One direction is used on busy and/or more challenging trails. Otherwise, two-way trail is most common.

Traditional (Classic) Style - Two Track Set/One or Two Directions



Occasionally used in county, regional, or state parks where use pressures are high and/or where separation of skiing styles is preferred. Also occasionally used as a connector trail from one loop to the next.

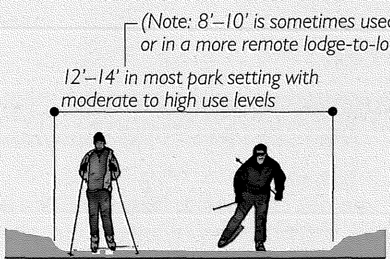
Skate Style - Single Width/One Direction



Occasionally used in county, regional, or state parks where use pressures are high and/or where separation of skiing styles is preferred.

Not as common as combination trails due to increased kilometers of trails needed to accommodate separated uses, and the additional time needed to groom the trails.

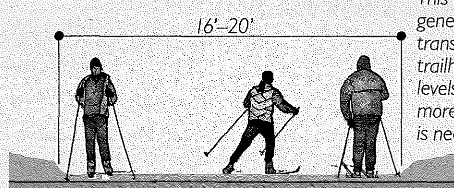
Skate Style - Double Width/One or Two Directions



The most common trail configuration in county, regional, and state parks where both styles of skiing are accommodated. Suitable for moderate to high use levels.

One directional use helps avoid confusion and conflict and keeps overall tread width a bit narrower.

Combination Traditional and Skate Style - One Direction



This trail width is generally used in transition areas, near a trailhead, and where use levels are very high and more maneuvering space is needed for skiers.

Also used as a linear connector between loops where two-direction use must be accommodated.

Combination Traditional and Skate Style - One or Two Directions

The trail widths as shown in the graphic are general and are often modified to accommodate site-specific conditions. For example, trail widths are often increased on steep hills to allow skiers to herringbone up or snowplow down, or to provide adequate space at the bottom of a slope for run-outs. Long uphills may also require extra width to allow moving skiers to pass resting ones. Trailhead areas and trail intersections and transition zones where skiers often congregate often warrant wider trails to avoid congestion. At busier trails, consider providing a wider trail for the first 1/4 to 1/2 kilometer from the trailhead to allow skiers to spread out and let faster skiers get past slower ones. The following photos illustrate a variety of situations where widening the trail has merit.

This short but steep hill climb has been widened by grooming equipment (and use) to allow faster skiers to pass slower ones without crossing skis. Notice how the track on the right ceases to exist since traditional style skiers tend to use a herringbone stride to get up the hill. Too narrow of a trail up a hill this steep can be very annoying to skiers. This segment is about 16 feet wide.

This longer hill "grind" forces many skiers to take a break part way up. Without some extra width, a hill like this can become congested quickly as resting, traditional, and skate skiers all jockey for position to avoid losing momentum. In these cases, the groomed part of the trail should be wide enough for a skate skier to pass another skier doing a herringbone maneuver. This segment is about 16 feet wide.

This uphill section does not require much trail widening since it is gentle and short enough for either style of skier to maintain form and make it up with relative ease. This segment retains the recommended 12- to 14-foot width.

Although not excessively steep, this downhill run warrants a slightly wider run-out area on the right side since it transitions quickly into a sharp curve with trees on the outside of it. Note the loss of the track as skiers break their speed using a snowplow maneuver. It only takes one snowplower to wipe out the track, forcing all that follow to also snowplow, thereby compounding the problem.

Trails are commonly widened at intersections since it is common for skiers to stop and decide on which direction to go and/or catch their breath. These areas should be wide enough to allow through-skiers to continue on unimpeded.

On this steeper uphill section, this two-track traditional trail only widens a foot or two to accommodate herringbone or snowplowing skiers. With light levels of use, there is no reason to make the trail wider on a hill.

Trail Clearance Zones

The clearance zone is defined as the physical space above and on either side of the trail that is free from obstructions. A 10-foot vertical clear area is recommended for all ski trails. This clear zone is especially important and may have to be enlarged when larger grooming equipment is used. The vertical clearance zone should also take into consideration the depth of the snow since the grooming equipment will sit on top of it.

The horizontal clearance zone should extend a minimum of 24 inches on either side of the groomed area to provide enough extra space for a skier's pole or ski to occasionally flail out and not catch on brush and tree limbs. It also provides more space for the grooming equipment to maneuver. The horizontal clearance zone should also increase around corners at the base of a hill where skiers are most likely to fall or go off the trail and catch a ski on brush or run into a tree. The extent to which this should occur is a matter of site-specific evaluation. The following photos illustrate common clearance zones adjacent to ski trails.

Make sure clearance of brush takes snow load into consideration!

Brushy material that might hang into the trail once it gets loaded with snow should also be removed when the trail is being prepared for the ski season.

This is a common example of a comfortable clearance zone adjacent to a groomed and tracked trail. The clearance zone is especially important where trees and brush are present on downhill runs.

In grassy areas, the clearance zone is less obvious and less important since this type of vegetation is less likely to catch a pole or ski and skiers are less likely to be injured if they ski off the trail.

This two-track traditional trail through the woods is nicely groomed and has appropriate clearance zones for a pleasant experience.

Trail Grades, Curves, and Sight Distances

Cross-country ski trails should provide a variety of terrain consistent with the desired difficulty level. As a general rule, one-third of a given trail should be uphill, one-third should be downhill, and one-third should be undulating or rolling grade. The height and steepness of uphills and downhills should be consistent with the trail difficulty rating as described in Section 4 – Trail Classifications and General Characteristics and the guidelines in the following table.

Cross-Country Trail Grade Guidelines

The table provides general guidelines for trail grades relative to trail difficulty ratings associated with general use cross-country ski trails.

Aspect	Easy	Intermediate	Expert/Advanced
Avg. trail grade	4%–10%	6%–12%	> 12% (most challenging loops)
Max. hill grade	10%–12%	12%–18%	>18, with 40% max. for short distance
Avg. total climb per km	10–15 m/30–50 ft	15–25 m/50–80 ft	25–35 m/80–115 ft
Max. hill height	10–30 m/30–100 ft	30–50 m/100–165 ft	50–80 m/165–260 ft

Combining easier and more difficult trails!

Note that a trail cutoff can be used to bypass challenging hill climbs or descents. This allows an otherwise expert trail to be used as part of an easier or intermediate trail loop.

The maximum hill height and grade are important considerations in trail design in that most skiers are not experts and can become frustrated (and less likely to return) if the trails are consistently too difficult. As defined in Section 4, easy to intermediate trails should make up the core system of trails, with expert level trails being "stacked" onto these trails. For beginning skiers, an average gradient of 4 percent is preferred across a pleasant, undulating terrain. Climbs should be less than 10 meters in height at a maximum grade of 9 percent.

Even on more difficult trails, steeper and longer climbs should be broken up with short, level sections for brief resting areas. This is especially the case on easy trails, where anything above 10 percent can be too challenging to negotiate for recreational skiers. As common practice, steep uphills should be kept to a minimum on all but advanced trails since relatively few skiers have the skills and stamina to really enjoy them.

Downhills

This long downhill is made easier by having open sightlines and enough undulations to slow skiers and help them avoid excessive speeds and loss of control.

The design of downhill runs is especially important with cross-country ski trails. In general, the longer and steeper the run, the straighter and longer the run-out area needs to be at the bottom of the hill. As a general guideline, the run-out should be at least as long as the slope in order to dissipate speed and allow a skier to regain any loss of control before a sharp curve or another downhill section. If space is limited, a rise in grade at the bottom of the slope can be used to offset the loss of run-out distance. Also, the clearance zone along and at the bottom of a downhill run should be ample enough to allow a skier to fall and slide off-trail several feet without running into a tree or heavy brush. Long downhills should also be avoided on most trails since the average skier is not comfortable with excessive speed.

On two-direction trails, the trail should be wide enough to completely separate uphill and downhill skiers when trail grades exceed 8 to 10 percent. This can be accomplished by widening the trail or by providing separate trails for uphill and downhill skiers.

Curves

The gentle curve of this trail controls sightlines and piques skiers' interest about what is around the corner. Juxtaposition of longer sightlines with intimate spacing using curves is appealing to skiers.

Since most skiers are not experts and are likely to lose control from time to time, sharp curves at the bottom of a hill should simply be avoided. "Sharp" is defined as any curve radius that is tight enough where the average skier can be thrown off-balance. As a general guideline, a radius of 100 feet or more is preferred, with 50 feet being the minimum on non-hill sections of the trail. For tracked trails, average skiers should be able to stay in the groomed track as they proceed down the slope. Average skiers should not have to rely upon a snowplowing technique to proceed down a slope on a recreational-level ski trail.

If a curve is needed through a downhill section, it should be as long and gentle as possible to avoid throwing the skier off balance. Widening the trail and adding additional clearance on the outside of the curve should also be considered to provide enough space for out-of-control skiers to regain their stride, or to fall and slide a few feet outside the groomed trail. A widened trail also provides more space for advanced skiers to pass slower ones through these sections with greater ease. In situations where a curve at the end of a downhill cannot be avoided, a warning sign at the top of the slope should be provided, typically about 100 feet before the beginning of the slope.

Although curves through downhills should be carefully considered, taking all of the challenge out of a ski trail by making it too straight, uninteresting, and less challenging should also be avoided. For high-level trails, curves through a downhill can be part of the desired experience as long as reasonable precautions are taken with run-out area and clear zones. An alternative approach is to provide a bypass around a more difficult section that allows skiers to choose the level of challenge best suited to their skill level. A well-placed bypass could be a de facto run-out that allows even more advanced skiers to "bail out" if they misjudge the curve. Signage is recommended in these instances to alert skiers to the options.

Where curves are provided through or at the base of a downhill, a modest superelevation may have merit to keep skiers in the set track. Since this often allows skiers to go faster, providing an adequate run-out and clearance area on the outside of the curve remains an important safety consideration. A maximum superelevation of 4 or 5 percent is recommended.

Sight Distances

Although not as critical as some types of trails, reasonable sight distances should still be provided along a ski trail. As a general guideline, a site distance of 100 feet is optimal, especially through sharp curves or downhill sections. The recommended minimum is 50 feet to ensure that skiers can see and react to approaching trail conditions.

The following photos illustrate a variety of trail grades, curve situations, and sightlines encountered on cross-country ski trails.

This gentle curve through a long but not too steep downhill is fun and skiers can stay in control. The long run-out at the bottom provides a nice, slightly uphill transition into another downhill segment.

The approach to this short but steep hill section is long and straight, allowing a skier to build momentum for the climb.

Skiers can readily see the trail ahead as they descend along this modest downhill. The curvilinear character of this trail through the woods adds to it appeal.

Managing sightlines can add excitement to a ski trail experience. In this photo, skiers get a hint of what is to come, yet the full scene is not exposed until they reach the corner and the view of a riverway is framed by the rock outcrops.

Tread Preparation

The tread refers to the underlying trail beneath the compacted and groomed snow. Proper off-season evaluation of trail alignments and tread surface preparation and maintenance is critical to setting the stage for quality cross-country ski trails. The following considers the most important aspects of preparing the tread for winter use.

Trail Alignment

Section 4 – Trail Classifications and General Characteristics, considered cross-country trail alignment in terms of laying out a system of trails with varying levels of difficulty. In the context of the tread surface, alignment refers to locating trails where snow will remain the longest and be most stable. One of the biggest factors in this regard is sun intensity, especially later in the season when the sun begins to build strength and more quickly melts the snow surface in exposed areas.

Hardwood forests help shield the trail from sun, which helps extend the season. The only downside is that maintaining a grass ground cover can be more challenging in the summer for the same reason – especially if the trail is also used for summer hiking. Limiting summer access or using an alternative surface, such as woodchips, are possible solutions.

Excessive pine needles dropping on the trail can be very annoying to skiers. Where this is a persistent problem, the trail corridor may have to be selectively opened up or the trail rerouted to a less problematic corridor.

Hardwood forests are usually well suited for ski trails because the sun is less intense and the air temperature is slightly colder than open areas. Using changes in topography to reduce the extent of direct sun on the trail can also be an effective strategy. This is especially the case along the base of north-facing slopes where the sun is usually less intense relative to wide-open flat areas. Avoid locating ski trails along the base of south facing slopes whenever possible since the sun tends to be the most intense in these areas, especially in open settings.

Running a trail through a coniferous forest also poses some problems with pine needles and cones dropping on to the trail and sticking to the skis, thereby slowing down the skier. Where this situation cannot be avoided, the clearance zone may have to be widened to prevent excessive needle accumulation on the trail.

In open, shortgrass prairie areas, wind can strip snow from or deposit drifting snow on the trail, both of which make for poorer skiing conditions and require more frequent grooming. Before a trail is permanently established, potential alignments in wind-swept areas should be field tested over one or two seasons to determine seasonal wind effects and snow displacement patterns. Even relatively minor shifts in the location of a ski trail can make a dramatic difference in the impact wind will have on it.

In tallgrass prairies, wind and sun are less of a concern since the grasses are high enough to shade the trail and reduce sun exposure. As with shortgrass prairies, field testing the alignment of a trail over one or two seasons can be beneficial to determining the most advantageous location to hold snow.

Tread Characteristics

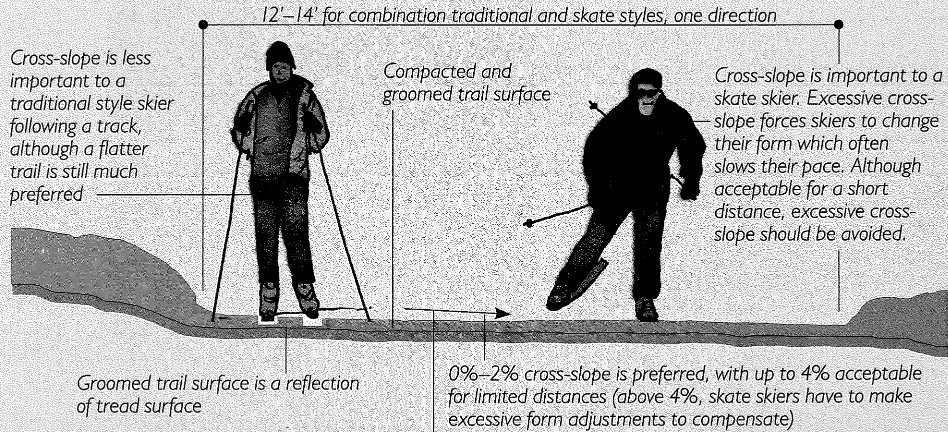
The trail tread is another major consideration in the development of quality ski trails. The cross-section, trail surface, summer uses, and erosion are all reflected in the groomed surface of the trail and factor into overall trail quality.

Trail Cross Grades

The optimal ski trail cross-section is of a consistent, even grade with a 0 to 2 percent cross-slope, as illustrated in the following graphic.

Optimal Cross-Country Ski Trail Cross-Grade Characteristics

The cross-slope of a ski trail is an important factor in creating a quality trail. Since the groomed trail surface tends to reflect what is underneath, the ground surface is worthy of due consideration as ski trails are laid out during the off-season.

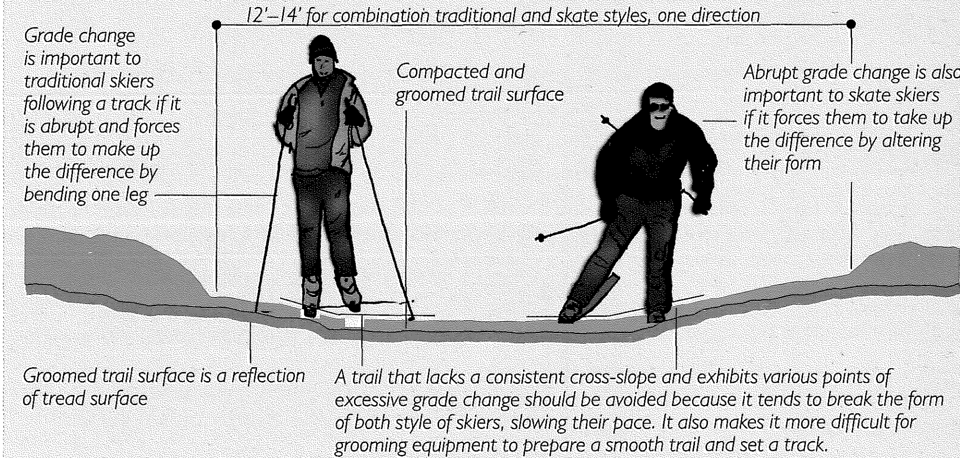


The direction of the cross-slope on a trail should be balanced along the length of the trail so skiers are not constantly leaning or changing form in one direction. If the cross-slope exceeds 2%, it should be tilted to the inside of the curve, like a superelevation on a roadway or trail. It should also be tilted away from the direction of the sun, especially in the spring.

As illustrated, an evenly sloped grade across the trail is important to both styles of skiers in order to maintain an optimal skiing form. Abrupt grade changes or general unevenness across a trail should be also avoided to make trails easier to groom and more enjoyable to ski on. The following two graphics illustrate these conditions.

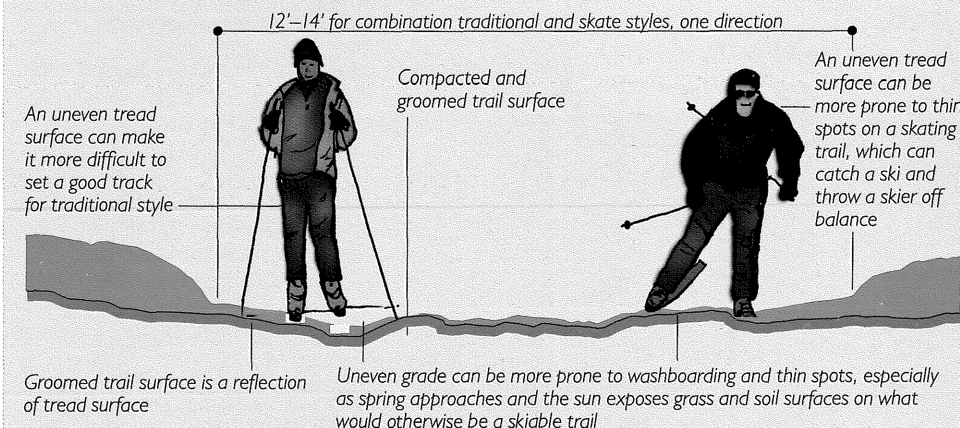
Abrupt Tread Cross Grades

Abrupt trail cross grades negatively affect the form of both styles of skiers, depending on the degree to which it occurs and the skill of the skier. While more advanced skiers can more easily compensate for grade changes in their form, novice and recreational skiers can find it frustrating.



Excessive Trail Unevenness

Excessive trail unevenness negatively affects the form of both styles of skiers. It also requires more snow to establish a base. Although good grooming technique can smooth out some of the rough spots on the tread surface, excessively uneven areas should be avoided because they can be more prone to washboarding and thin spots.



The following photos illustrate some of the previously described cross-section conditions.

The nice even trail tread with a slight cross-slope is well suited for a two-track set through the woods, making for easy grooming and fun skiing.

The cross-slope on this trail (arrow) is greater than desired but is not a major issue because it is only for a short distance. If this went on for a distance, skiers would find it annoying.

Even these simple ruts unintentionally caused by maintenance vehicles can cause an uneven surface that may be reflected in the ski trail, annoying both groomers and skiers.

A level, smooth trail with short grass cover is optimal!

This combination provides the nicest cross-country skiing and should be the standard wherever possible.

Tread Surface Conditions

The tread surface is an important trail preparation and grooming consideration. A uniform, short-mowed grass surface is preferred across the entire width of the trail for a couple of reasons: 1) grass holds snow better than bare ground or paved surfaces, and 2) grass helps prevent off-season foot traffic and erosion from creating an uneven surface.

Optimally, grass should be mowed to a length of 3 or 4 inches. For trails in nonecologically sensitive areas, a park turf grass mix is often used to create a uniform surface that will consistently hold snow. This type of trail is often mowed once a month or every other month to maintain the turf during the off-season. Regular mowing also keeps woody plant growth under control and reduces the need for brush trimming in the fall. Routine trimming of the woody material on the edge of the clearance zone is also important to maintaining the tread surface.

In natural areas where native plant species are preferred and grasses are higher and thicker, a two-step approach to mowing is often used. The first mowing is undertaken in late September after the nesting season and used to cut the grass to the desired length. The second mowing a few weeks later is used to more finely mulch the debris left from the first pass. All protruding rocks, logs, and other woody debris should also be removed from the trail shortly before the season.

Although a grass surface is much preferred, other surfaces may also be used for ski trails, albeit with certain limitations as the following considers:

- Woodchip surfaces – are not as good as grass since chips can be dislodged during grooming and skiing and stick to skies or otherwise affect skiers' stride. Once established, woodchips hold snow better than bare ground or paved surfaces and are therefore considered the next best surface after grass.
- Bare ground and aggregate surfacing – are better than asphalt and concrete, but not as good as woodchips and far behind grass. Aggregate can also pose the same problems as woodchips and scratch skies once exposed or dislodged.

Surfaces that are least desirable include asphalt and concrete, because snow does not as readily stick to them and they absorb more sun energy and lose the snow earlier. These surfaces are also harder on certain types of ski poles and skis if snow cover is thin. Limiting sun exposure is very important if paved trails are used for ski trails.

As with summer-use natural surface trails, tread drainage and erosion are important considerations for cross-country ski trails. If drainage is poor and erosion pervasive, the tread surface will be compromised and be harder to groom. The most important factor in preventing erosion is making sure the trail is covered with a stabilizing ground cover during the off-season. Ski trails that follow the fall line of a slope should also not be used for summer uses to avoid creating a single track that exposes the soils to erosion.

Wetland areas should also be avoided when aligning ski trails since these surfaces are too inconsistent and unpredictable. Potential ecological impacts are another reason to avoid wetland areas. Lakes pose numerous safety issues and surface quality uncertainties, and should be avoided whenever possible. If a lake is crossed, vigilance is required to monitor the lake surface and provide adequate signage to warn skiers of poor ice conditions and trail closures. For this reason, many park districts simply do not place ski trails on lakes.

The following photos illustrate various tread surface conditions.

This maintained trail corridor with a grass surface is well suited for a cross-country ski trail. Although used in the summer for hiking, the use levels are not high enough to cause a major problem with depressions.

Although ground cover is sparser along this trail, summer use levels are light enough and the ground hard enough to limit depressions and erosion, making for a very suitable trail surface.

Paved trails are the least desirable because they do not hold snow nearly as well as grass surfaces. They also are harder on equipment when a bare spot is encountered or the base is too thin.

On this level trail corridor through the woods (left), shredded woodchips that bind together work reasonably well for multiseason use. However, even on a modest grade (middle), woodchips can pose problems because runoff dislodges them relatively easily and erosion occurs as if the ground were bare. The key is to align trails to avoid these situations in the first place, rather than dealing with ongoing problems during each season of use.

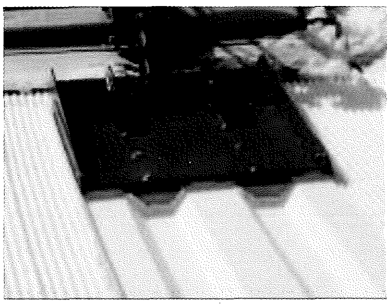
Trails through open prairies must be mowed a couple times prior to the ski season to create an acceptable surface. In sensitive areas, this should occur late in the season to avoid disrupting nesting birds.

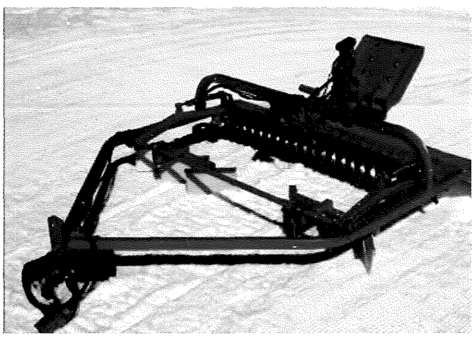
Trail Grooming

Grooming is a very important aspect of creating quality cross-country ski trails. Often considered as much art as technique, good grooming is a result of both specialized equipment and skilled operators. Whereas the following conveys some of the essential elements of trail grooming, there is no substitute for operator training and the experience gained from working with skiers to perfect grooming techniques.

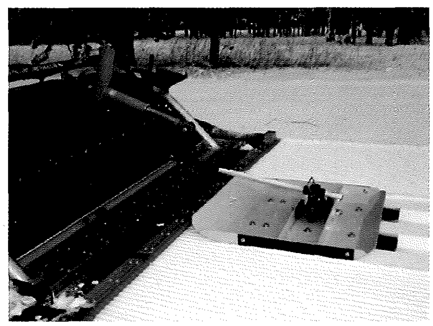
Grooming Equipment

Cross-country ski trail grooming equipment is very specialized, yet readily available. The most effective and economical system consists of a snowmobile and a tow-behind packer and track setter. This system works especially well when the snow base is limited and saving snow is critical to keeping the trails open. The most common pieces of grooming equipment are Tidd Tech and Ginzu Groomers, manufactured by different companies. The following photos illustrate each of these pieces of equipment and a few other pieces of equipment commonly used for grooming.

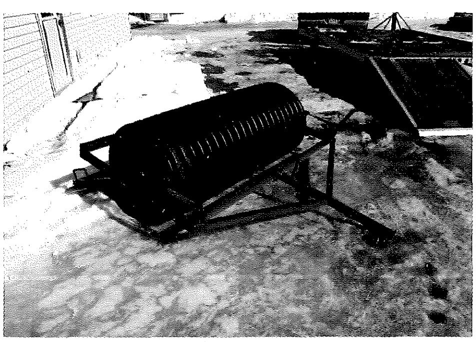




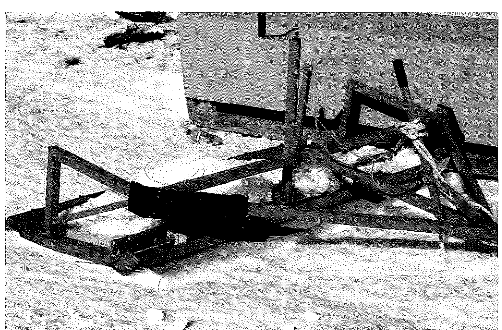
The Tidd Tech groomer (bottom photo) includes a flat pan with a grooved edge to create the desired trail texture for skate-style skiing. The pan can be tilted forward to till or peel up a layer of snow and grind it for repacking. The track setter (top photo) is the last grooming step and sets the track for traditional skiing. It is simply an attachment to the groomer that is lowered to set the track.



The Ginzu groomer has much in common with the Tidd Tech, with personal preference being the discerning factor on which groomer to use. A combination of weights, springs, and hydraulics are used to increase the level of compaction on the snow surface. One of the Ginzu's strengths is it ability to level out humps and cut hard pack snow.



A plastic roller is often used in warmer temperatures and for early season use to pack and settle snow by taking the air out of it.



A pan is used to compact and smooth a trail under various conditions. Weights can be added as needed to achieve the desired level of compactness.

Creating the "best line" is an important grooming consideration!

Groomers will sometimes set tracks as a separate operation from packing the trail to allow them to pick the "best line" for the skier to follow, especially through a curve.

For more specialized trail grooming, larger (and significantly more expensive) equipment is available. The most common machine is a tracked Piston Bully, which has all of the same capabilities as the previously defined equipment along with a variety of other attachments. Most notable of these is its front blade for moving snow around and a hydraulic grinder and packer for renovating hard-packed or crusted snow. This piece of equipment is best suited for grooming trails with artificial snow where the volume, depth, and texture of the snow warrant a bigger piece of equipment with greater snow moving capabilities. This type of equipment is not necessary for most applications and is only used when the snowmobile and tow-behind packer and track setter combination proves to be inadequate. The following photos illustrate this type of equipment.

The Piston Bully is an impressive piece of equipment that can be effective for certain types of conditions, especially moving around artificial snow, which is often heavier and deeper than natural snow. But for most applications, the more economical snowmobile and tow-behind packer and track setter produces excellent results under an experienced operator, especially when snow depths are limited and a larger piece of equipment is excessive.

Basic Grooming Techniques

Grooming ski trails starts with packing the first appreciable snowfall to establish a base. For skating trails, a minimum of 3 inches is typically needed to get started, assuming that the tread surface is level and covered with short grass. The flat pan on the grooming equipment is used to pack the snow, with the trailing edge corrugated to create a textured surface. With each new snowfall of 1-inch or more, the trail is again packed and textured for skate skiing. Once there is an adequate depth to the base, the traditional track can be set.

As the season progresses, trail groomers use a variety of techniques to keep the trail fresh. If there is adequate depth, teeth or spikes on the front edge of the groomer are lowered to fluff up the snow for repacking and texturing. For the avid skate skier, daily reworking the trail is especially desirable to get the right "bite" with the ski edge. Having a well-set track is also important to traditional skiers.

During seasons of limited snowfall, saving snow is one of the main challenges. This requires an intimate understanding of snow conditions and grooming when temperatures are just right to reshape the snow without losing it.

"Snowball-technique!

Some groomers will not groom if a snowball can be readily made, which usually means that there is too much moisture in the snow and grooming at that time would result in icy tracks or skating trails.

The ideal grooming time depends on the snow conditions and user expectations. Dry snow is best groomed during the day so the sun and increased temperature can help bind the snow once it is stirred up and compacted. Real fluffy and dry snow also takes some time to set up into a desirable consistency for skiing. Wet snow grooms better at night when temperatures are cooler.

User expectations can also be key factor in the ideal time for grooming. Grooming in the early morning is common to prepare trails for peak hours of use, with most skiers tending to get out between 10:00 A.M. and 3:00 P.M.

If moguls (snow bumps) appear on the trail, they should be cut out near or at their bases and the snow spread into a uniform layer and packed. Higher cuts will tend to leave the snow density uneven and moguls will simply reappear.

Hard-packed and icy trail conditions (especially with a thin base) are some of the most difficult trail conditions to groom. If the base is deep enough, a set of knives, tiller, or renovator is used to literally peel up a layer of snow and grind it up. A snowmobile with a tow-behind groomer can work up to a point, but harsh conditions sometimes require heavier equipment such as a Piston Bully to break up the surface, bring up the snow, and level it. The downside of the latter is that the heavier equipment requires a deeper base, which is usually not the case if the trail is icy and hard since the warmer weather likely melted some of it away.

Under harsh trail conditions, some groomers focus on maintaining a shorter loop to a higher standard than attempting to groom an entire system to what will inevitably be a lower standard given groomer limitations. This is especially the case where skier expectations for trail grooming are high and quality is preferred over quantity. In general, a 5 kilometer loop is typically the minimum desired loop length.

Most experienced groomers at high-use facilities also make an extra effort to prevent ice or hard-packed conditions from getting established. For example, on warm days some groomers will groom the trail smooth, including the classical tracks, just as the temperatures begin to drop below freezing. If the trail is groomed too early it becomes very hard. If groomed too late it becomes rutted.

Under wet snow conditions, some groomers will wait until the day after the snow to give it some time to set up and become better suited for grooming and less prone to becoming hard pack. To preserve at least some trails during spells of warmer weather, some trail managers will rotate the use of trail loops to prevent overcompaction and icing. The following photos illustrate grooming at under various conditions.

New snow cover waiting to be groomed. Depending on the moisture level in the snow, groomers will select equipment best suited to the conditions.

Grooming underway on this trail, with the left side packed under the first pass. Grooming technique is as much art as science, and "time on the machine" is the best training.

This perfectly set dual track is ready for skiers. Although the base in this case is quite thin, proper grooming technique maximizes the snow and allows for quality skiing.

(Left) This nicely groomed trail exhibits the optimal condition for skate skiers. The grooves provide perfect conditions for a ski edge to bite into the snow.

(Right) Even small amounts of debris, such as pine needles, can annoy the groomer and skier alike. Proper trail alignment and tread surface preparation before the season are critical to minimizing the likelihood of debris on the trail during the ski season.

Levels of Trail Grooming

In most cross-country ski trail systems, the level of grooming varies depending on the venue and user expectations. State, regional, county, and local parks each provide different venues offering contrasting experiences. Trail users seek out the venue that appeals to them on a given day, bringing with them certain expectations for the quality of the trail grooming.

Notably, most skiers do not expect all venues to have the same level of grooming. For example, skiers have different grooming expectations for back-country trails in remote areas (which usually means no grooming) than they do for two-track traditional trails in state parks or combination trails in regional parks. What is most important is maintaining a consistent level of grooming relative to the venue so that skiers know what to expect when selecting a trail.

A Tiered Cross-Country Ski Trail System

To stay within their working budgets, many park districts establish a tiered cross-country ski trail system based on the park setting, anticipated levels of use, and the skiing styles being accommodated. Typically, a limited number of "primary" venues are provided that target skiers with high expectations for trail-grooming quality. Most skate skiers and advanced traditional skiers seek out these venues because well-groomed trails are faster and more enjoyable to ski on. Grooming at these venues is often on a daily basis.

"Secondary" venues under a tiered system target the more casual or recreational skier where grooming is still important but less of a factor relative to other reasons for skiing, such as the experience of being in an outdoor setting. Grooming at these venues is often on a once-a-week or as-needed basis after a significant snowfall.

Trail Grooming Reports

Trail grooming reports are an important aspect of managing user expectations and keeping skiers coming back. At primary facilities, *daily* reporting through official websites, voice recordings, and notice boards is recommended. Secondary facilities require weekly updates at a minimum, preferably on a Thursday or Friday for those that might want to travel for a weekend of skiing.

Venues that do a poor job of reporting are often less frequently used even if the grooming is known to be good. Given the irregularity of snow conditions, skiers are much more likely to go where ski conditions are routinely and accurately reported and they have a sense of what to expect. The accuracy of trail conditions is also important to skiers. To improve accuracy, some venues enlist skiers to report on trail conditions, rather than rely on nonskier attendants to describe the conditions.

Lighted Cross-Country Ski Trails

With the short winter days in Minnesota, the idea of lighting ski trails has been around for many decades. Starting with candle or lantern trails (which continue to be used), trail lighting has progressed to more sophisticated electrical systems now found in larger regional and state parks. Although formal engineering is required, the basics of these lighting systems are fairly straightforward, as the following describes.

Lighted Trail Loop Length

A lighted ski trail must be long enough to attract enough skiers to the venue to justify the investment. As a general guideline, established ski venues have found a 5-kilometer loop to be reasonable for a lighted cross-country ski trail. This provides adequate length to incorporate a variety of terrain and challenge into the trail to be of interest to the skier, while still being economical enough to afford. Anything less than 5 kilometers is probably too short and skiers will lose interest if they have to make too many loops to get in a good workout.

Although a trail that is too short may not attract enough skiers, the costs and benefits of lighted trails longer than 5 kilometers should also be carefully scrutinized to avoid over-investment. Any lighting beyond 5 kilometers is recommended only when there is adequate evidence that skier satisfaction and use levels would go up enough to justify the additional costs for development and maintenance.

Technical Requirements for Lighted Trails

Lighting systems for ski trails either use pole-mounted fixtures or lighted bollards that provide enough light for skiers to see the trail without unduly detracting from the experience of skiing at night. For pole-mounted systems, light standards are commonly spaced about every 100 feet or so, with additional lighting strategically placed adjacent to challenging areas. For example, increasing the level of lighting along a steeper downhill section or on the inside of tight curve at the base of a downhill is common practice. For lighted bollards, light spacing averages about every 80 feet. The spacing around sharp corners and along downhills is reduced to around 40 feet. Light spacing in prairie areas can be expanded to 200 feet.

Since there are no established standards for ski trail lighting per se, it is recommended that new systems be based on the existing systems to take advantage of actual field experience. Providing one-half foot candle of light along the trail is a common starting point for designing a system, although actual field conditions should dictate lighting levels needed to ensure skier safety. Fixtures should be shrouded to limit light spill into the ski and away from the trail. (Light pollution is an increasing important issue to park users.)

One of the major cost and technical considerations associated with lighting trails is the efficient use of transformers, power sources, and wiring. These are major considerations in determining which trail should be lit and the overall kilometers of lighted trails than can be afforded. Also, buried wire is preferred over above-ground lines for aesthetics and maintenance purposes. This is especially important in a natural park setting where above-ground wires would detract from the setting and also be subject to being taken out by falling trees and limbs.

The following photos illustrate a variety of trail lighting options found in parks across Minnesota.

The common pole-mounted high-pressure sodium fixture faces down the trail in the direction of travel to avoid putting light in the face of the skier and night ski. With buried wire, a natural-colored pole, and a small fixture, the light serves it purpose with minimal visual intrusion.

A down-facing box light is also occasionally used on ski trails, although the lighting is more apparent. This type of fixture is more commonly used at trailheads, where a larger pool of light is desired.

This bollard-mounted light is made of PVC and inserts into a ground socket. It is removed during the off-season.

SNOW MAKING FOR CROSS-COUNTRY SKI TRAILS

Although in its relative infancy and still uncommon, snow making for cross-country ski trails is being tested at a limited number of high-use venues where there is adequate demand to justify the investment in utilities, equipment, and maintenance. Typically, snow making occurs on lighted trails to maximize the hours of use during the course of a week, especially weekday evenings.

Although no standard has been established, a 5-kilometer loop coinciding with a lighted trail is probably the practical limit for snow making. Some venues have found that 2.5 kilometer is the minimum needed to make it worthwhile. Anything less will not likely attract enough skiers to justify the investment even when no other venues are open due to lack of snow.

The utilities needed to support snow making are extensive and consist of underground electrical and water supplies that connect to portable snow-making equipment. Water service and electrical pedestals are spaced approximately 300 feet apart, which makes it reasonably convenient to hook up the hoses and cords to the portable snow-making machines. The water supply system must self-drain to avoid freeze-up.

Artificial snow is often heavier than natural snow and snow-making machines are not overly accurate or uniform in laying it down on the trail. Moving snow-making equipment around and grooming the trail under these conditions requires heavier pieces of equipment with more attachments, such as the Piston Bully. This issue alone can be a significant consideration in the cost-benefit analysis for making snow for cross-country ski trails.

The following photos illustrate some of the infrastructure and specialized equipment needed to make snow for ski trails.

Snow-making equipment is typically portable and is moved along the trail from station to station. Wind and air temperature can greatly affect the quality and placement of the snow as it is created.

Water service and electrical pedestals are spaced along the trail at roughly 300-foot intervals. This makes the length of hose and electrical cord from the machines less cumbersome. Water is supplied from a pond or high-capacity well.

The end result of snow making can be well-groomed trails that extend the skiing season in years in which natural snow is limited.

Shared and Summer Uses of Cross-Country Ski Trails

During the winter season, most cross-country ski trails are designated for skiing only to prevent nonskiers from displacing the groomed trail and set track. At popular, higher level venues, skiers are very intolerant about others being on the trail. In more remote or less frequented parks, snowshoeing is sometimes allowed on dual track trails as long as the snowshoer stays out of the traditional tracks. As a general practice, separating uses is recommended in most situations.

Always be aware of the potential for erosion!

Although ski trails sometimes follow the fall line to add interest, this should only be done when there is relative assurance that erosion will not be an issue. This requires careful consideration of soil conditions and how likelihood of maintaining an adequate ground cover to prevent erosion from occurring.

The compatibility of cross-country ski trails and summer natural surface trails following the same corridor should not be assumed. From an alignment standpoint, ski trails sometimes follow the fall line of a slope for challenge and excitement. In the winter, erosion on this type of trail is not an issue. In contrast, erosion is a serious consideration with summer-use natural surface trails and following the fall line is typically avoided. Also, hikers following a trail often prefer a more gradual and interesting route around a landform, rather than scurrying directly up a fall-line.

With respect to the trail tread, the bare ground and depressions associated with single- or dual-track summer use trails often make grooming more of a challenge in the winter. Summer users often find that the mowed width of the ski trail takes away some of the intimacy of the natural setting they are seeking.

For these reasons, using a common tread for summer hiking and winter cross-country ski trails has its limitations and requires careful consideration to avoid compromising both users. Some park districts simply keep the two separate, closing off the winter ski trails during the summer. Others take a modified, or hybrid, approach, whereby some sections of trail are common and others are not. In all cases, forcing incompatible uses onto the same tread should be avoided since it diminishes the value of each trail use. This is especially the case with OHV trails, where inevitable rutting and loss of vegetative cover caused by summer use greater impacts the grooming operation and the quality of the ski trail. These uses are generally considered incompatible.

An example of a hybrid approach is using an undulating trail through a prairie for hiking in the summer and skiing in the winter, assuming that grades are suitable for both uses and a grass tread can be reasonably maintained. When the trails traverse terrain where they are not compatible, they separate and each follows a suitable alignment. Given the smaller footprint than two entirely separate trails, the hybrid approach has particular application in settings where space is limited or where minimizing ecological impacts is a major consideration.

The following photos illustrate some of the issues associated with shared and summer uses of cross-country ski trails.

Use of cross-country ski trail corridors for motorized summer activities is generally to be avoided. The heavy machines simply compact the trail too much and cause dual tracks that make trails very hard to groom in the winter.

This wide corridor suits skiers well, but in the summer its width can make the trail less intimate and interesting to a summer hiker.

This steeper fall-line ski trail might be stable in the winter, but it could be susceptible to erosion in the summer if bare ground is exposed through use.

Trailhead Facilities

There are no set standards for trailheads for cross-country ski venues, with each facility providing the level of service consistent with local expectations. In larger park settings at the county, regional, or state level, it is common for the main trailhead to be located adjacent to a visitor center or contact station. Equipment rental, ski passes, restrooms, warming area, and vending are provided to varying degrees in these situations. At the local level, it is much more common for a trailhead to consist of a parking area, self-registration station, and portable restroom. The following photos illustrate the varying approaches to trailheads, each of which meet the needs and expectations of local skiers.

Larger regional and state parks often combine the ski trail trailhead with a visitor center to gain needed efficiencies and control costs while providing a needed service. These facilities often rent equipment and provide restrooms and concessions.

At smaller venues, trailhead facilities are fairly basic and meet the need.

Providing ski trail information is one of the most important trailhead functions. This kiosk covers all of the information needed by a skier at a state park.

TRAIL SIGNAGE

The signage for cross-country ski trails should be generally consistent with the types and placement of signs for natural trails as defined in *Section 6 – Sustainable Natural Trails*. DNR's *Sign Manual* should also be referenced for ski trail signage and should be referred to for in-depth information. The manual includes requirements and recommendations for regulatory, warning, trailhead, orientation, and directional signs and route guides. With cross-country ski trails, orientation (mapping) and trail distance, and difficulty level and warning signs are the most important signs.

Trail orientation signs should be placed at all trailheads and trail intersections. These should include a map illustrating the layout, distance, and difficulty level of each trail loop. Along the trail, distance markers, difficulty level, and hazard warning signs should be placed as needed to keep the skier informed. The following photos illustrate common approaches to signing cross-country ski trails.

Traihead signs can be very simple and give skiers only the information necessary for them to select the type of trail and distance they want to ski.

Signage along the trail should clearly illustrate which uses are allowed and not allowed on a given trail. This is especially important with cross-country ski trails, where skiers are very intolerant of nonskiers' impact on groomed trails.

Safety signage is very important and should be provided wherever necessary to highlight a hazard.

Route maps with clearly understandable "you are here" information is very important to skiers. Signage should also clearly illustrate the level of difficulty and length of trails to allow skiers to make informed decisions.

Clearly marking the trail name and level of difficulty is an important signage issue and should not be overlooked, since most skiers are not experts and do not want to get onto trails that are above their level of ability.

SNOWSHOEING, WINTER HIKING, DOGSLEDDING, AND SKIJORING TRAILS

The following provides general design and grooming guidelines for a variety of nonmotorized winter trail activities. Although each of these activities has grown in popularity over the years, the relative demand for specialized trails remains less than for cross-country skiing and snowmobiling.

The design and grooming standards for snowshoeing, winter hiking, dogsledding, and skijoring trails are generally consistent with those defined for cross-country ski trails. For each of these uses, trail grades should be consistent with "easy" or "intermediate" cross-country ski trail difficulty levels. This is especially the case with skijoring and dogsledding trails, where the dogs can gain considerable speed on a steep downhill when the person behind is trying to maintain control or slow down.

Work closely with user groups!

For emerging users such as these, the best approach is to work closely with organized groups to ensure that their trail needs are understood and met.

Trail widths are commonly based on the level of use that is anticipated and users' input. A 6 to 8 foot wide groomed tread is typically sufficient to accommodate one- or two-way snowshoeing and winter hiking. One-way skijoring and dog-sledding groomed trails are 8 to 10 feet wide since the pace is much quicker and the dogs are not always under perfect control. For dogsledding events, trail widths can match those of wider ski or snowmobile trails, reaching 16 feet in some cases.

SNOWSHOEING

Snowshoers either follow groomed trails or go cross country, depending on the setting and the type of snowshoes they use. Groomed trails are packed similar to those for cross-country skate skiing, albeit there is less of a demand for daily grooming since snowshoes easily accommodate loose or uncompacted snow on the trail. Grooming trails once a week or after a significant snow fall is common. Typically, several loops totaling 3 to 5 miles is adequate to accommodate this use. Most often, existing summer-use natural surface trail corridors are used since snowshoers can tolerate some unevenness.

For ungroomed snowshoeing, park districts either designate a route or allow snowshoers to go cross-country in a defined area. With the former, following existing summer trail corridors is common practice. Another approach gaining in popularity is to mark a varying route using simple tree markers and trail blazes that can be readily relocated each season or several times during the season. This approach provides variety while still controlling the activity and making sure people do not get lost.
For cross-country travel, maps are typically provided highlighting the areas open to snowshoeing.

WINTER HIKING

Winter hiking is either on a groomed trail similar to a cross-country ski or snowshoeing trail or following a plowed paved trail. Typically, a single or several loops totaling 3 to 5 miles is adequate to accommodate this use. It is also common in lower-use areas to allow snowshoers and hikers on the same trail.

DOGSLEDDING AND SKIJORING

Specialized trails for dogsledding and skijoring are only infrequently provided in parks in Minnesota due to the limited demand. Often, formal trails are established only for special events. Where these trails are provided on a seasonal basis, grooming standards are consistent with those for cross-country ski trails for skate skiing or snowmobile trails, although some skijorers will use set tracks if available. Skijoring distances are consistent with those for cross-country skiing, although the pace can be much quicker with a fast dog. Dogsledding trails can be anywhere from 4 to 15 miles for sprint racing, even longer for mid-distance racing.

TIME SLOTTING

In some areas there is adequate demand to make provisions for accommodating dogsledding or skijoring on a more routine basis. In these instances, time slotting is a common approach, whereby a given time slot on a cross-country ski or snowmobile trail is set aside for dogsledding or skijoring, or both. This approach seems to have gained some popularity because it allows parks to accommodate these activities without creating specialized trails or substantially increasing grooming costs.

Snowmobile Trails

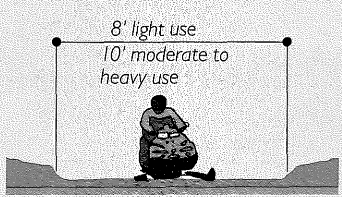
The following guidelines provide general design and grooming parameters for snowmobile trails. As with other types of trails, the guidelines are not intended to be a substitute for site-specific design that responds to local conditions, development requirements, and safety concerns.

Trail Tread Widths and Configurations

The physical space required for the one- and two-way trails provides the base-line for determining the optional width for snowmobile trails, as the following graphic illustrates.

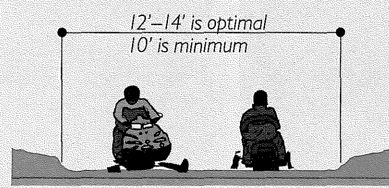
Typical Trail Widths for Snowmobile Trails

The following defines the basic trail widths and directional configurations for snowmobile trails. (These correspond with the snowmobile trail configurations defined in Section 4 – Trail Classifications and General Characteristics.)



One-way trails are occasionally used in a snowmobile trail system where a moderate length loop is provided or the corridor is particularly narrow.

One-Way Snowmobile Trail



Two-way trails are often the most practical and thus common type of snowmobile trail. These are well suited for longer, integrated trail systems with moderate to high use levels.

Two-Way Snowmobile Trail

The trail widths shown in the graphic are general and are often modified to accommodate site-specific conditions. A 12- to 14-foot wide snowmobile trail is considered optimal to allow for ease of passing oncoming traffic. Going any wider is not always desirable since it requires more grooming and takes away from the setting and experience of being close to nature.

Trails wider than the optimal width are typically only provided where traffic is especially heavy, such as near a trailhead or between popular destinations. The need for a wider trail in these situations is field determined by the local trail sponsors. At busy trailheads and trail intersections, the first 200 to 300 feet of trail is sometimes a couple of feet wider to allow snowmobilers to wait along one side for their riding group to assemble and still allow for two-way traffic on the trail. The following photos illustrate common trail widths for snowmobile trails.

These classic two-way snowmobile trails are groomed to between 12 and 14 feet wide. The trail on the left runs through a northern forest where sightlines are more limited, which helps keep riding speeds lower. In the middle photo, the long abandoned rail-grade trail is very flat with long sightlines. Here, too, 12 to 14 feet is adequate to accommodate two-way traffic.

Near trailheads, the trail is sometimes groomed a few feet wider to accommodate riders grouping up alongside the trail.

TRAIL CLEARANCE ZONES

The clearance zone is defined as the physical space above and on either side of the trail that is free from obstructions. A 12-foot minimum vertical clear area above the snow surface is recommended for all snowmobiles trails, with 14 feet being required when larger grooming equipment is used.

The horizontal clearance zone should extend a minimum of 24 inches on either side of the groomed area. The horizontal clearance zone should increase at trail or roadway crossings to at least double the width of the trail and standard clearance zone – 32 to 36 feet for a two-way snowmobile trail. The clearance width should also be enlarged near a hazard, such as a bridge or culvert. The extent to which it is enlarged should be determined in the field based on site-specific conditions, taking into consideration sightlines and anticipated speeds. The following photos illustrate common clearance zones adjacent to snowmobile trails.

This is a common example of a comfortable clearance zone adjacent to a groomed and tracked trail. The clearance zone is especially important where trees and brush are present on downhills. Note that by limiting the clearance zone, trail "creep" can be controlled, as can cross-country travel.

The clearance zone should take into consideration the terrain and sightlines. Even with rolling terrain, a couple of feet of clearance on either side of the trail is usually enough for a safe experience. However, the clearance zone should be widened whenever a rider's view is obstructed at normal riding speeds for the trail.

It is common and recommended that the clearance zone be widened at bridge approaches, hazards, and roadway crossings to give riders ample opportunity to react to trail conditions.

TRAIL GRADES, CURVES, AND SIGHT DISTANCES

Snowmobile trails should provide a variety of terrain consistent with the setting. An important distinguishing aspect of snowmobile trails is that they should cross contours at right angles to prevent the snowmobile from rolling over or sliding sideways and tearing up the trail.

As a general guideline, snowmobile trails should incorporate a variety of hills and undulating terrain to add interest. On hilly sections, grades between 10 and 25 percent are acceptable, although 10 percent or less is preferred for safety reasons and sightlines. (The grade percentage of a slope can be measured with a clinometer or calculated using the following formula: percent of grade = rise/run x 100.)

Steeper grades require adequate approaches and run-outs at least as long as the slope itself to give riders ample space to control their machines prior to entering a curve. It is important to maintain vegetation on trails traversing steeper slopes to prevent off-season erosion, which could cause a rough trail and hence grooming and snowmobile handling problems.

On grades of 8 percent or greater, consider separating the trail into uphill and downhill sections to avoid conflicts.

Longer, flowing curves with adequate sightlines are preferred for snowmobile trails. Sightlines should be long enough for the rider to react to oncoming conditions but not so long as to entice excessive speeds.

CURVES

Curves should be as gentle as possible and well signed. Longer curves enhance rider safety and also make trail maintenance easier since snow is not as easily pushed to the edge as can be the case with a sharper turn. As a general guideline, a 100-foot or longer radius is recommended, with 50 feet being the minimum if adequate run-out space and sightlines are provided. Typically, a minimum of 15 feet of clearance zone on the outside of sharp curves is needed to allow riders to regain control if they enter the turn too fast. Warning signs should be provided up to 300 feet ahead of any sharp turn, especially those that require a change in speed.

Sight Distances

Sight distances are important on snowmobile trails, with final determinations dependent on the character of the trail and anticipated speeds. As a base-line, sightlines should generally be at least 100 feet and increase from there depending on site conditions and expected travel speeds. At 50 mph, a sightline of 300 feet or more is necessary, especially if a trail is icy. Where sightlines are compromised, warning signs should be provided at least 100 feet and up to 300 feet prior to a hazard. Hazards include roadway crossings, trail intersections, steep drop-offs, and sharp curves.

The following photos illustrate a variety of trail grades, curve situations, and sightlines encountered on snowmobile trails.

The wide-open sightlines of this trail encourage riders to go faster. The lack of a clearly defined corridor also temps riders to wander off trail onto adjoining private property, which can lead to trail restrictions. Where the corridor is not obvious, blazes along the trail are recommended to keep riders on the approved trail tread – and remind them of the consequences of not staying on the trail.

Approaching hills at a right angle is important with snowmobile trails to prevent rollovers. On steep slopes on two-way trails, separating the uphill and downhill sections is sometimes used to increase safety and reduce the potential for conflict. With the open sightlines and modest grade of this hill, two-way traffic on a single 12- to 14-foot tread works well.

Provide adequate visual cues of an approaching tight curve to enhance trail safety. From this direction, the gate and other signs at the trailhead alert the rider of the approaching curve. From the other direction, a warning sign is provided about 100 feet prior to the curve to alert riders to slow down and approach with caution.

Tread Preparation

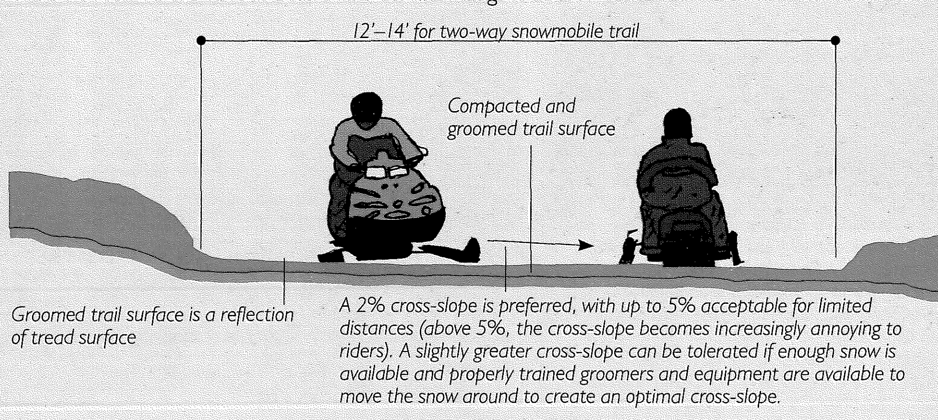
The tread refers to the underlying trail beneath the compacted and groomed snow. Proper off-season evaluation of trail alignments and tread surface preparation and maintenance is critical to setting the stage for quality snowmobile trails. The following considers the most important aspects of preparing the tread for winter use.

Trail Cross Grades

The optimal snowmobile trail cross-section is of a consistent, even grade with a 2 percent cross-slope, as illustrated in the following graphic.

Optimal Snowmobile Trail Cross-Section Characteristics

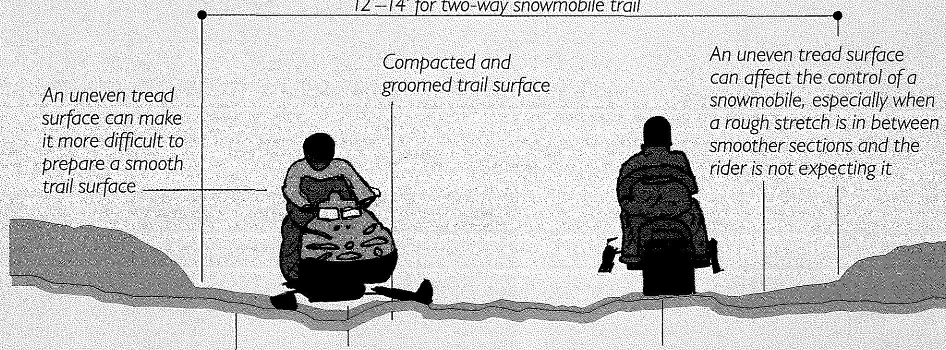
The cross-slope of a snowmobile trail is an important factor in creating a quality trail. Since the groomed trail surface tends to reflect what is underneath, the ground surface is worthy of due consideration as snowmobile trails are laid out during the off-season.



As illustrated, an evenly sloped grade across the trail is optimal for snowmobiling. Abrupt grade changes or general unevenness should be avoided to make trails easier to groom and more enjoyable to snowmobile on. The following graphic illustrates these conditions.

Excessive Trail Unevenness

Excessive trail unevenness negatively affects the ultimate smoothness of a snowmobile trail. It also requires more snow to establish a base and makes the trail more prone to washboarding.



The following photos illustrate some of the previously described cross-section conditions.


This even and smooth grade with vegetation and a slight cross-slope is ideal for a snowmobile trail.


This hard-packed, graveled route through the forest makes for a pleasant snowmobile trail in the winter as long as its use is in sync with forest access rules.


The lack of ground cover on this steeper hill is allowing erosion to take hold, making the trail unsustainable for summer use and increasingly rough for winter use.

Tread Surface Conditions

The tread surface is an important trail preparation and grooming consideration. A uniform grass surface is preferred across the entire width of the trail for a couple of reasons: 1) grass holds snow better than bare ground or paved surfaces and 2) grass helps prevent off-season use and erosion from creating an uneven surface.

The longer and heavier the grass, the more snow it will take to establish a base. Where feasible, mow the trail just before the season to prepare the tread and reduce the depth of base needed to create a usable trail. Under most conditions, a 6- to 12-inch snowfall is optimal to establish a base over a relatively short grassy ground cover.

Routine brushing/trimming of the woody material across the trail and on the edge of the clearance zone is also very important to maintaining the tread surface. All protruding rocks, logs, and other woody debris that would interfere with trail grooming and rider safety should be removed from the trail shortly before the season.

Although not as desirable as a natural or aggregate surface, asphalt is an acceptable surface when snowfall is sufficient. Laws pertaining to the use of studs should be considered when establishing a trail on an asphalt surface. Also, it should be expected that the snow cover will not last as long in the spring as it would on a grass-surfaced trail.


If not mowed, the longer grasses along this corridor require significantly more snow to create a usable base. Whereas mowing the trail just before the season has considerable merit, that has to be balanced against ecological and wildlife impacts, such as disturbing nesting birds. When trails traverse sensitive natural areas, the principles of ecological sustainability (as defined in Section 3) should be given due consideration. One important factor in this regard is waiting until as late in the season as possible before mowing to avoid disrupting nesting birds and bedded animals.

Tread drainage and erosion are important considerations for snowmobile trails. If drainage is poor and erosion pervasive, the tread surface will be compromised and become uneven, making it harder to groom and ride on. The most important factor in preventing erosion is making sure the trail is covered with a stabilizing ground cover during the off-season. Snowmobile trails that follow the fall line of a slope should also generally not be used for summer uses to avoid creating a single track that exposes the soils to erosion. In some cases, off-season grading and revegetation is necessary to fill in ruts, maintain drainage, and correct erosion problems.

Wetland and Water Crossings

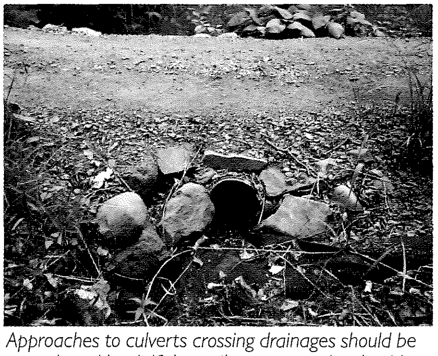
Wetland areas should be avoided when aligning snowmobile trails because the tread surface is often uneven, inconsistent, and unpredictable. Potential ecological impacts are another reason to generally avoid wetland areas. If a trail does cross a wetland, select the location carefully to minimize these impacts.

Lakes and rivers inherently pose safety issues and surface quality uncertainties and should therefore be avoided for formal trails.

Designated use of lakes for snowmobile trails should be avoided given the many safety concerns, such as slush, thin spots, and unknown surface irregularities. There is also a temptation for riders to wander far and wide and also "skip" across open water.

When water drainage crossings are necessary, culverts, boardwalks, or bridges should be used. Approaches to these structures should be smooth and level (up to a 5 percent grade) and with a clear sight distance of at least 100 feet. Bridge and boardwalk decks should be flush with the trail surface with narrow or no gaps between decking boards (to allow snow to accumulate and compact). A 10-foot-wide bridge or boardwalk is optimal, with 8 feet being the minimum acceptable. Each should have a weight capacity of 10 tons or more to accommodate maintenance equipment. All bridges must be designed to meet applicable DNR bridge standards (determined on a site-by-site basis). The following photos illustrate various tread surface and bridge conditions.

A level, grass-surfaced corridor is optimal for snowmobile trails. Mowing the trail just before the season can reduce the amount of snow needed to create a usable base.



Approaches to culverts crossing drainages should be smooth and level. If the trail narrows or the shoulder is steep, place a warning sign at least 100 feet prior to the hazard.

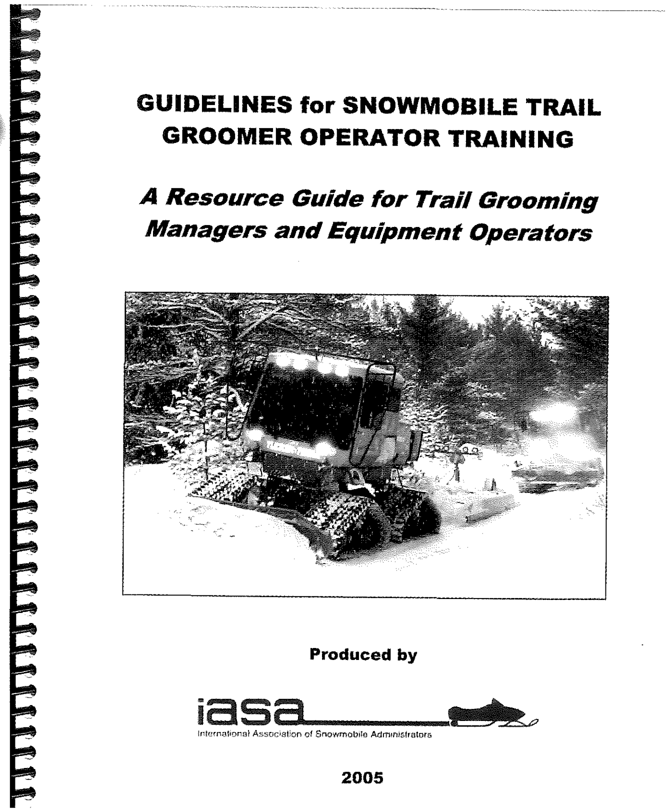
If a summer-use bridge is used for a snowmobile trail, the surface of the trail and deck should be smooth and flush. The deck boards should have minimal gaps to hold snow. Railings are also required.

Trail Grooming

Grooming snowmobile trails is a specialized activity that is part art and part technique. The International Association of Snowmobile Administrators (IASA) has done considerable research on this subject and has developed a resource guide for trail grooming entitled *Guidelines for Snowmobile Trail Groomer Operator Training.* The guide covers all of the fundamental aspects of trail grooming and is a highly recommended reference.

For more information!

The grooming guidelines can be found on the IASA website (www.snowmobilers.org/groomer_guide/GroomerGuidecomplete.pdf



GUIDELINES for SNOWMOBILE TRAIL GROOMER OPERATOR TRAINING

A Resource Guide for Trail Grooming Managers and Equipment Operators

Produced by

iasa

International Association of Snowmobile Administrators

2005

Roadway Crossings

A gateway at this midblock crossing helps snowmobilers and motorists more easily recognize the crossing. The level grade on both sides of the road (similar to a farm field access drive) also improves sightlines and allows the rider to more easily position for the crossing.

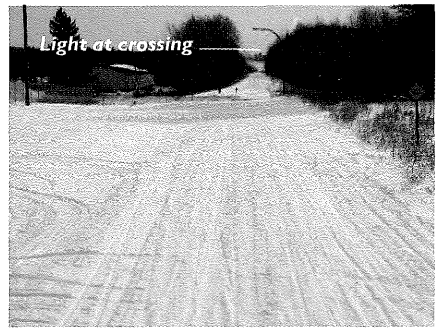
Roadway crossings are an important safety concern for snowmobilers and motorists. All crossings should be well marked with signs, including Stop Ahead signs at least 100 feet prior to a stop sign. Snowbanks should be kept low at all crossings, with ample sightlines from both the trail and the roadway.

Where feasible, roadway crossings should be at intersections where motorists are expecting traffic from the side and thus more likely to recognize a snowmobile trail crossing. If midblock crossings are required, approaches should be as level as possible and sightlines extra long. To be level during the snow season, the approach should be designed to be 3 to 6 inches lower than the road during the none-snow season, where feasible. This will allow groomers to remove the extra snow dragged across the road by snowmobiles and to avoid creating a hump right before the crossing point.

Gateways on each side of the road can also remind riders that they are about to make a crossing and extra attention is warranted. All roadway crossings should be consistent with any applicable laws and ordinances. The optimal location for all crossings should be field determined by experienced trail designers and tested during the day and at night to ensure that they are clearly visible and as safe as possible. The following photos illustrate a number of roadway crossing considerations.

Although this crossing is well marked from both sides, it is not optimal due to the guy wire from an adjoining utility pole. During the day, riders are likely to see it, but at night it poses more of a risk. Careful attention to detail is essential at all crossings given the distractions that are inherent in these situations.

A narrow tread caused by snowbanks poses two concerns: 1) it reduces the sightlines from the trail and roadway and 2) it squeezes riders into a single path just when they are about to make a crossing. On designated trails, avoid this whenever possible.



Along with proper signage, a light is added at this trail crossing to improve safety. The flatness and straightness of this rail conversion reduced the visual cues associated with identifying this intersection, warranting the addition of the light.

Trail Signage

Consistent with the grant-in-aid program administered by DNR, signage should be provided for direction, information, and enhancing the safety of trail users. Major signing areas include trailheads, trail junctions, and areas where the safety of the user is of particular concern. The primary reference for snowmobile trail signage is the *MN DNR's Sign Manual,* which provides reference numbers and in-depth information for each type of sign used along a snowmobile trail. The instructions manual for the snowmobile grant program administered by the DNR Division of Trails and Waterways also has an extensive listing of signing recommendations. The following provides a brief overview of signage that complements these resources.

Trailhead and trail junction signs provide maps showing route designations, distances, traffic flow direction, and the location of support facilities. Safety signs are used to caution users of steep slopes, bridges, highway crossings, or other trail hazards.

Signs on trails should be kept to the minimum necessary and be well placed to serve their purpose. Signs placed along the trail should include reassuring blazers along with Caution, Do Not Enter, Stop Ahead, Stop, and other related signs.

Placement of most signs is consistent with the guidelines for natural trails as defined in Section 6 – Sustainable Natural Surface Trails. Signs should be placed on the right side of the trail and set back from the main tread, but within the clearing limits. Signs should be attached to posts offset 2 feet (minimum) to 3 feet (preferred) from the edge of the groomed treadway. The signs should be placed 3 feet (minimum) to 4 feet (maximum) above the expected snow depth. Setting the signs 4 feet above the bare ground typically ensures the sign will be the desired height. Posts may be wood or plastic, depending on location and availability.

Directional signs used along the trail should include trail junction blazes, directional blazes, and reassuring blazes. These signs should be placed in open areas or in other areas where a trail user might become confused. If uncertain about the effectiveness of signing, invite a nonlocal snowmobiler to identify deficiencies.

Trailheads and Support Facilities

Trailheads typically consist of a parking area and trailhead kiosk with trail maps and related information. The parking area for trails varies considerably depending on its popularity and the number of access points. As a general guideline, parking areas should be designed to accommodate a minimum of 10 vehicles, with room for expansion. Each space should be 10 feet wide by 45 feet long. Drive lanes should be 24 feet wide with adequate turning radii. An aggregate surface is sufficient for parking areas if used primarily for snowmobile trail use. Snowbanks from plowing should also be used as the primary means to define the parking area. Posts or other barriers can also be used on the periphery of the parking area to prevent vehicles from leaving the designated area.

Given the maintenance and cost, providing portable or permanent restroom facilities should be carefully considered. If private services are available near the trailhead, providing these facilities is generally not recommended. In select locations, snowmobile trailheads take advantage of support facilities, including restrooms, at summer-use state or county trails and parks

In addition to trailheads, support facilities that should be identified on trail maps include services such as gas, repair shops, food, lodging, medical facilities, and law enforcement offices (911 or Zenith). The nearest DNR office should also be identified, along with any other helpful information. Trailheads that are in conjunction with or near gas stations and convenience stores can be especially successful.

Summer Uses of Snowmobile Trails

The compatibility of snowmobile and summer-use trails following the same corridor should not be assumed and requires site-specific evaluation. This is especially the case where snowmobile trails travel through areas of unstable or hydric soils that can support snowmobile use when frozen conditions but become unstable in summer. Summer use of these corridors should be precluded. The following photos illustrate some of these conditions.

This otherwise sustainable snowmobile corridor is not well suited to summer ATV use, as the photo clearly illustrates. An ongoing occurrence of this type of impact only leads to more restrict uses, sometimes even for those the trail was designed to accommodate.

Even seemingly stable soil conditions can be susceptible to erosion when a snowmobile trail corridor becomes a de facto ATV trail. The key point is that all trails must be designed for their purpose. It should never be assumed that a trail corridor for one purpose will be suitable for another until it is assessed for that purpose.

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TRAIL PLANNING, DESIGN, AND DEVELOPMENT GUIDELINES

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

TRAILS AND WATERWAYS

Minnesota
DEPARTMENT OF NATURAL RESOURCES