Sustainable Mountain Trails Sketchbook

Tools & Techniques for Successful Trails Advocacy

Hugh Duffy, Greg Seabloom,
John Giordanengo and Danny Basch for the
Colorado Outdoor Training Initiative

Colorado Outdoor Training Initiative

Biographical Sketches

Danny Basch

Currently	Eastside Trails Supervisor, Rocky Mountain National Park, Colorado Outdoor Training Initiative (COTI) Master Instructor (MI). As the Eastside Trails Supervisor at Rocky Mountain National Park, Danny's responsibilities include maintenance, construction and rehabilitation of approximately 250 miles of trail, 900 trail signs and 200 bridges.
E-mail	danny_basch@nps.gov
Phone	970-586-1248

Hugh Duffy

Currently	Project Manager (PMP), Landscape Architect (RLA, ASLA), National Park Service, Denver Service Center; Colorado Outdoor Training Initiative (COTI) Master Instructor (MI).
1985 – 1990	Various Roles @ Volunteers for Outdoor Colorado, including Projects Committee Chair, Technical Advisor and Board Member.
1997 – 2002	Various professional consultations including production of Trail Assessments, Trail Plans and Trail Designs.
E-mail	hugh_duffy@nps.gov duffyfamily7@aol.com
Phone	303-969-2452
Mobile	303-981-5120

Cover Photograph: The eastern flank of Arthur's Rock at Lory State Park testifies to the enduring nature of landscapes, their ability to be restored and heal, and their appropriateness for recreational settings.

John Giordanengo

Currently	Restoration Manager Colorado Fourteeners Initiative Board of Directors, Colorado Native Plant Society Master Instructor (MI) and co-author of Colorado Outdoor Training Initiative (COTI) *Master Instructor Curriculum*, and author of *Restoration Curriculum* for COTI
2002-2003	Restoration Ecologist Blue Mountain Environmental Consulting
2000-2002	Natural Resource Specialist City of Boulder, Department. of Open Space and Mountain Parks
E-mail	john@14ers.org
Phone	303-996-2760

Greg Seabloom

Currently	Adopt-A-Peak Supervisor Colorado Fourteeners Initiative
2004	Pacific Northwest Trail Association, MT Rocky Mountain Regional Coordinator
1998 - 2004	Various Conservation Organization & Trail Advocacy Roles, including Youth Corps of Southern Arizona, Arizona; USGS, Sequoia National Park, California; Sustainable Trails, Inc., Lakewood, Colorado; and Lory State Park, Colorado
Education	Bachelor's of Science in Natural Resource Management and Minor in Rangeland Ecology from Colorado State University, 2001
E-mail	greg@14ers.org
Phone	303-996-2758

Table of Contents

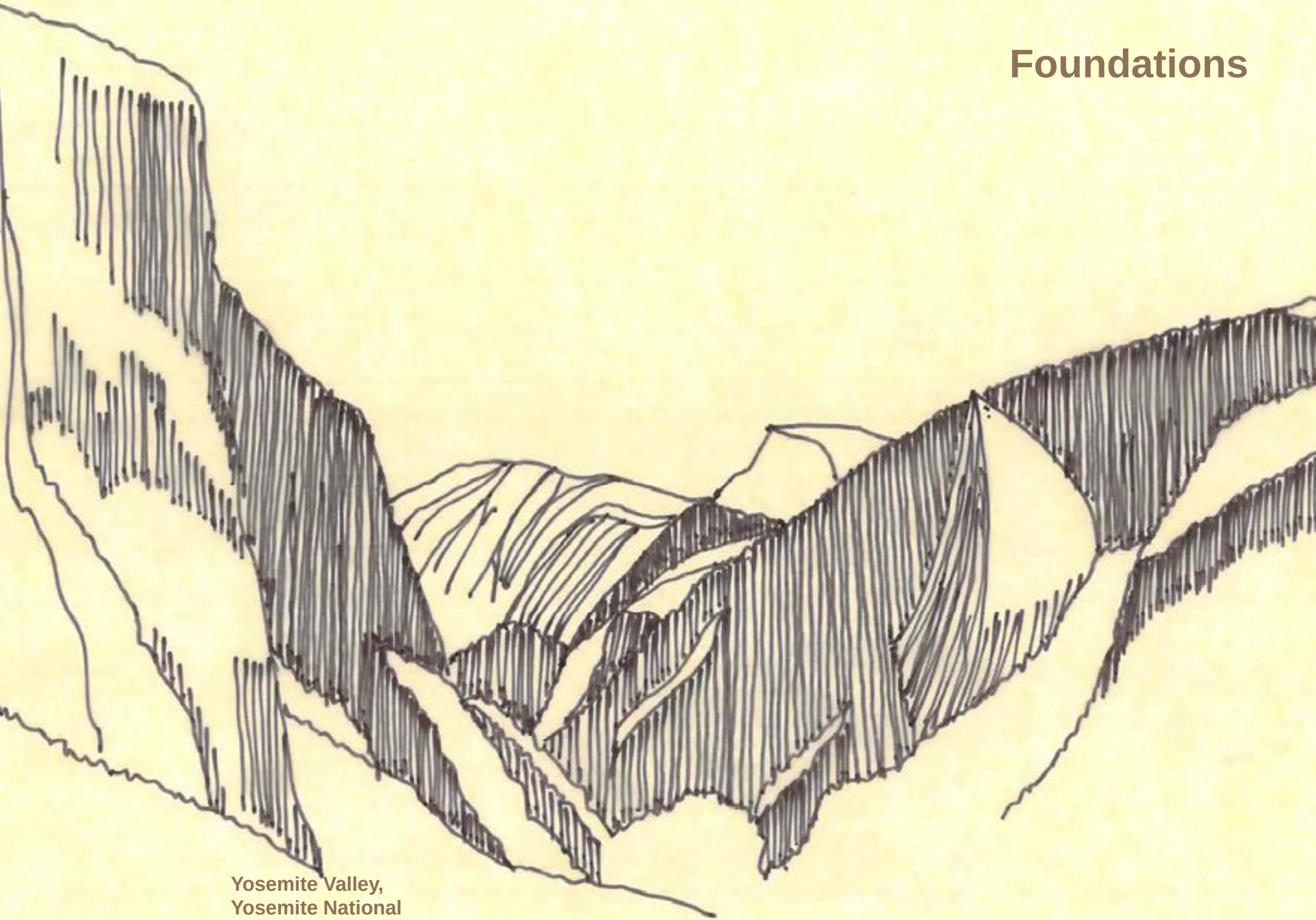
Biographical Sketches 2
Table of Contents 3
Foundations 5
The Olmsted Report 6
Mountain Trail Sustainability 8
Trail Project Management 11
PMI's Lessons Learned Technique 12
Trail Project Cycle Tool 13
Trail Sustainability Assessment 15
Mountain Trail Planning 23
Basic Design 53
New Trail Design 57
Restoration Design 71
Mountain Trail Bridges 83
Maintenance … Rehabilitation … Armor Design Spectrum 89
Implementation Techniques & Options 99
Trail Management Techniques 119
The Challenge … 120
Patience! 121
More Tools 125
Towards a Mountain Trail Sustainability Ethic … 131

Recreational trails near urban centers experience increased volumes of trail use as is the case near Denver, Colorado. Strategies must be developed to allow for safe access while also preventing impacts to natural and cultural resources.

Interdisciplinary trail teams not only must protect natural and cultural resource qualities and values, but also must not overlook the social fabric that natural areas and trails support.

The variety of natural qualities of landscapes is as infinite as the stars. Care must be taken when developing mountain trail projects not to impact natural and cultural resource values.

Foundations



Yosemite Valley,
Yosemite National
Park, California

The Olmsted Report

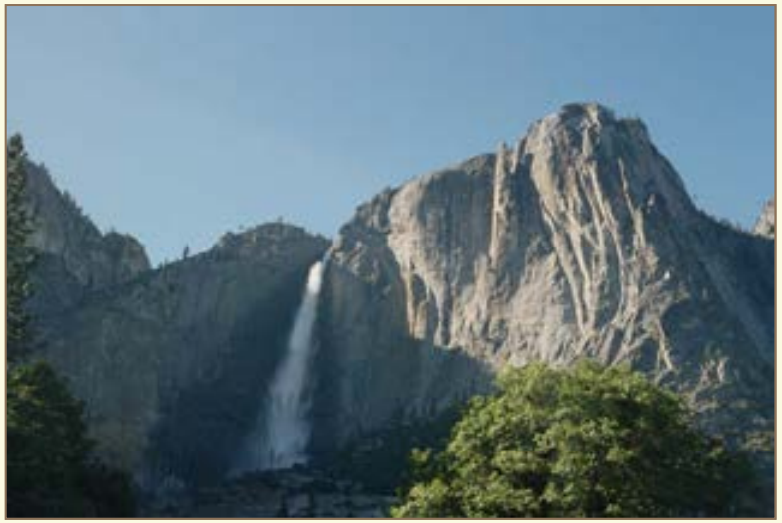
The publication of the *"Olmsted Report"* in 1865, which described recommendations for preservation and management strategies for Yosemite Valley and Mariposa Grove of Giant Sequoia trees, was a watershed event in the preservation community. The *"Olmsted Report"* pre-dated the establishment of Yellowstone National Park and no doubt influenced preservation and conservation initiatives of the late 19th and early 20th centuries.

Quoting from the report:

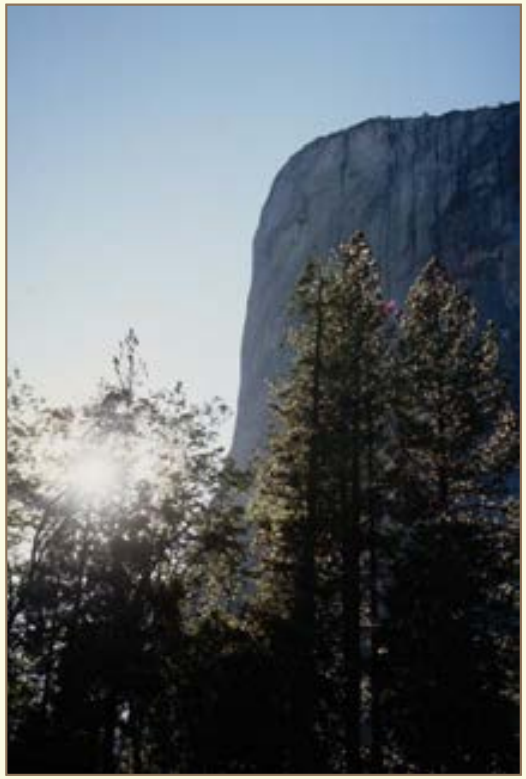
> *"The first point to be kept in mind then is the preservation and maintenance as exactly as is possible of the natural scenery; the restriction, that is to say, within the narrowest limits consistent with the necessary accommodation of visitors, of all constructions and the prevention of all constructions markedly inharmonious with the scenery or which would unnecessarily obscure, distort or detract from the dignity of the scenery."*
>
> *"Second; it is important that it should be remembered that in permitting the sacrifice of anything that would be of the slightest value to future visitors to the convenience, bad taste, playfulness, carelessness, or wanton destructiveness of present visitors, we probably yield in each case the interest of uncounted millions to the selfishness of a few individuals."*

Preservation and conservation of public lands is a complex endeavor, and many times significant effort goes into actually drawing lines on a map establishing conservation area boundaries. Interdisciplinary trail teams of today are wise to be mindful of this fact and take specific care to develop strategies that protect the very resources that public lands are set aside to protect. Recreationists of all types are relying on public land managers to develop projects that provide for safe and enjoyable access, while also protecting sensitive resources.

Foundational principles of landscape architecture, the preservation of naturally occurring scenery and the restriction of development in the narrowest sense possible, still apply today. All too often, however, haste or improper planning and design, lead to developments that are out of scale with their environment, or diminish the naturally occurring landscape features. Every effort should be made to preserve landform and soil resources as these are the most foundational of natural resources, lest impacts occur which detract from the natural setting of the area.



Opposite Page. Yosemite Valley in Yosemite National Park has been the source of inspiration to the preservation, conservation and recreation communities for many years. Left, Frederick Law Olmsted.



As much as our natural and cultural resources inspire us, so too, should our trailside improvements, so as to not detract from their settings or the reasons why land was set aside for enjoyment.

No less important to citizens of our country today, are all conservation area lands. Yosemite National Park was indeed an inspiration for preservation and conservation of public lands in our country and around the world. However, not all Americans are able to visit the crown jewels of our National Park system.

State governments, cities, counties and special districts all across the country provide conservation area lands for their citizens to enjoy. A mature understanding of the inherent natural values of a landscape, the reasons people visit and recreate upon public lands, as well as a mature mountain trails' sustainability ethic are required to ensure that wise decisions are made regarding the safe access to – and enjoyment of – our public lands.

Mountain Trail Sustainability

The concept of mountain trail sustainability is based upon the premise that mountain trail projects should not unnecessarily impact landform, soil, vegetation and cultural resources, but should be developed within the narrowest confines possible to allow for safe and enjoyable passage. It is based upon paramount criteria of optimum profile grade relative to prevailing cross slopes (fall line). Subordinate criteria to consider include cross slope, aspect (compass orientation), elevation, climate, as well as soil and ecosystem types.

Interdisciplinary Team

For over 50 years, interdisciplinary teams have been assigned to trail projects. The National Park Service's ***Construction of Trails*** and the Parks Canada ***Trails Manual*** both describe this foundational ethic. The education, skills and values of both the landscape architect and civil engineer are equally vital to the (assessment, planning, design or implementation) team. Other specialists such as a naturalists or field personnel bring important skills and values to the team. Assembly of an interdisciplinary trail team as well as the development of rational, defensible, and repeatable processes are foundational ethics of mountain trail sustainability.

What is Mountain Trail Sustainability?

Sustainability of natural surface trail corridors is the ability to support recreational trail use with minimal impact to the natural processes of an area. Sustainable trails have negligible soil loss or movement while allowing the naturally occurring plant systems to inhabit the area. Sustainable trails will accommodate existing and future uses while only allowing appropriate uses. The sustainable trail corridor will require little relocation and minimum maintenance over extended periods of time.

Protection of Natural & Cultural Resources

Protection of natural and cultural resources is a foundational ethic of mountain trail sustainability. The ***Trails Manual*** recognizes the importance of the protection of resources these ways:

> *"The protection of the environment is (also) of major importance; if environmental quality is seriously affected the very attributes that have made areas attractive for development in the first place may be lost. Effort should be made to ensure that trails fit their environment as harmoniously as possible so that ecological processes and environmental character are not significantly altered… The carrying capacity of an area is the amount of use by man that the area can withstand without undue environmental degradation. … The task of the [interdisciplinary trail team] development team is to plan, build and manage the trail so that the carrying capacity of its environment is not exceeded. … Detrimental impact of trail use upon the environment is directly affected by type of trail activity and how intensively the trail is used."*

As soil is the substrate for most terrestrial plant and animal life, protection of soil substrate materials is the most foundational ethic of trail sustainability. Areas where soil unnecessarily or excessively erodes, as well as areas where eroded soils are deposited, too often testify to poorly established trails, influencing additional impacts, less than optimum recreational experiences and increased costs. Introduction or spreading of non-native plants are common impacts of trail projects.

Optimum Prevailing Cross Slope Ranges & Trail Profile Grades

There is a limited prevailing cross slope range and optimum trail profile grade combination which yield the most sustainable mountain trail corridor. Field experience along Colorado's Front Range indicates that sustainable mountain trails not only have good maintenance programs in place, but they also have trail profile grades (elevation change along the trail centerline) that are <8% (in *"frontcountry"* areas), and that are less than ¼ the prevailing cross slope (fall line) in the immediate section of trail.

Due to topographic variation, the optimum profile grade along a length of trail will vary, with steeper topography being able to sustain a steeper optimum profile grade. This suggests a 2.5% optimum profile grade in 10% cross slope areas, 5% in 20%, 10% in 40%, and 12% maximum profile grade in 48% cross slope areas or greater. Experienced trail teams realize that 8% is an optimum trail profile grade in most *"frontcountry"* areas.

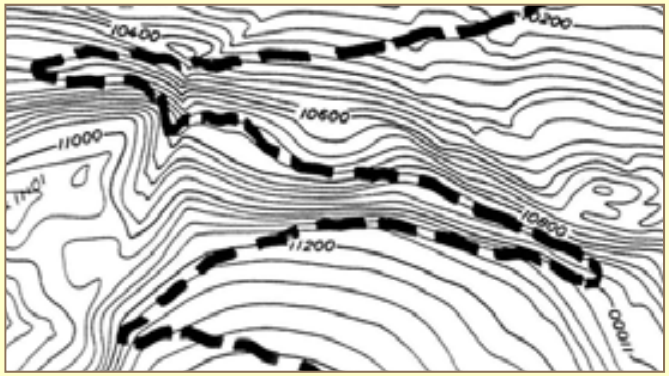
Natural surface trails in cross slope areas of less than 20% usually require drainage improvements, a.k.a.: armoring because they do not drain quickly. Natural surface trails in cross slope areas exceeding 70% require significant investments (armoring) which correspondingly could be considered non-sustainable.

Prevailing cross slopes between 20% and 70% provide the best combination of cross slope for drainage with the commonly preferred trail profile grades near 10% to allow proper drainage across or off a trail surface without undue erosion.

Trail profile grades >12% in most cross slopes and soil types are prone to erosion. These trail profile grades also need to consider the effect of moisture (frost, rain, ice and snow), aspect, season of use, and volume of use on user comfort and safety. Diligent efforts can usually avoid using these profile grades in "*frontcountry"* areas! Conscious decision-making when utilizing steeper profile grades, understanding anticipated costs as well as the probability or required armoring is recommended.

This preferred ***Prevailing Cross Slope*** location provides for equestrian uses while protecting important natural resources at Steamboat Lake State Park, Colorado.

The concept of mountain trail sustainability was first published in 1991 in the Colorado State Trails Newsletter and later in the NPS' Resource Management Guideline "NPS-77" that same year.



Gently climbing trail profile grades located on gentle to moderate prevailing cross slopes and predominantly coarse soils will yield the most sustainable mountain trail corridor.

Wildlife Viewing. Mountain Goats from the Mount Evans heard are a common source of interest for hikers on popular Greys and Torreys Peaks, both Colorado 14,000-foot-plus (14er) peaks.

Hiking. Happy hikers on the Green Ranch Property, Golden Gate Canyon State Park. Discovery of natural or cultural resource values in a natural setting contributes significantly to long lasting memories – a source of hope and inspiration for the future.

Equestrian. Opportunities for equestrian activities abound on public lands. Larger clearing zones and more stable treads are required to prevent resource impacts.

Natural areas are the setting for many activities, including weddings.

Mountain Bicycling. Mountain bicycle use of public lands is increasing, especially near urban areas. Comprehensive strategies need to be developed which accommodate this use.

Trail Project Management

Inputs

- Typical Inputs
- Foundations

Tools & Techniques

- Typical Tools & Techniques
- *Lessons Learned* Technique
- *Trail Project Cycle* Tool

Outputs

- Typical Summary Package Outputs
  - Draft for Review; Final

Typical Inputs

- Foundations
- Stakeholder Analysis & Summary
- Popular Literature
- Aerial Photos, Annotated Aerial Photos
- Maps, Annotated Maps
- Data Bases

Foundations

- Inspirational Literature / Organic Act / Enabling Legislation
- Agency Management Policies & Guidelines
- Interpretive Plans
- Environmental Compliance Regulations

Typical Tools & Techniques

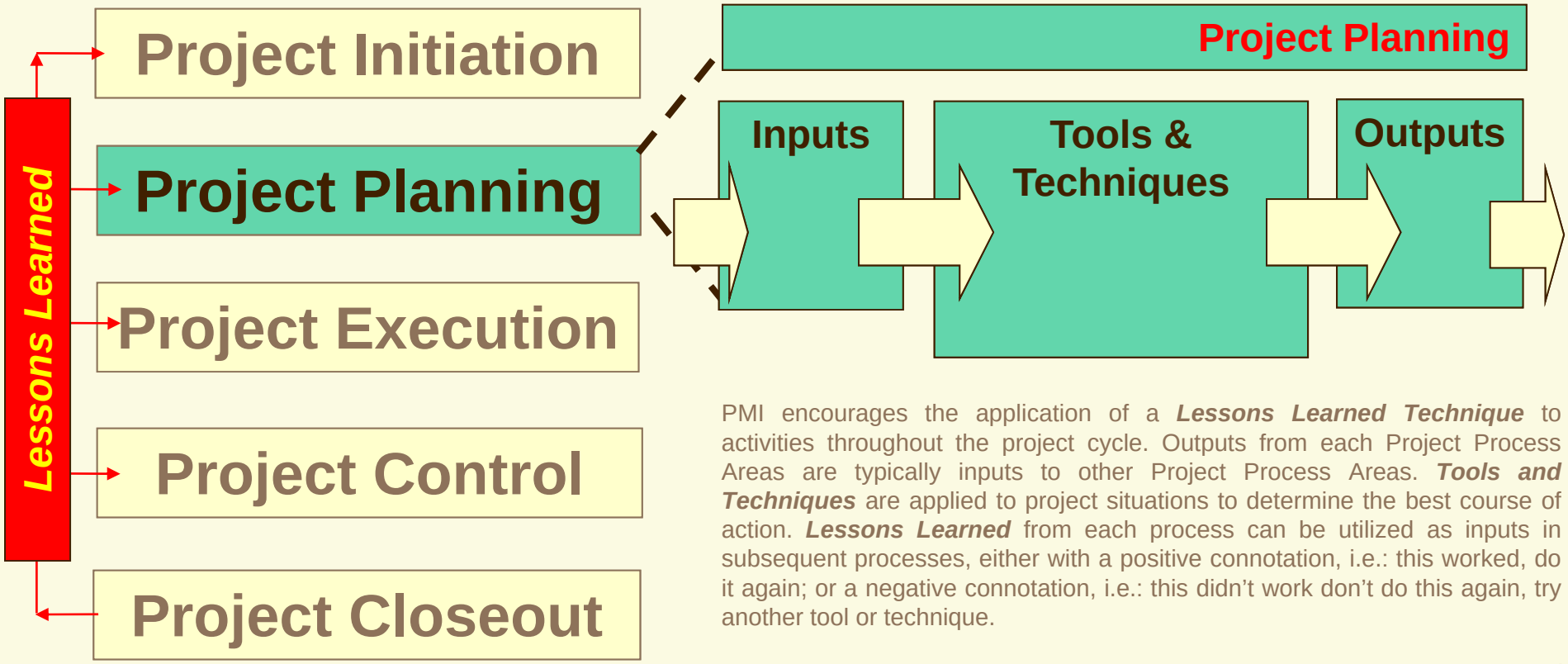
- Assemble Interdisciplinary Team
- Popular Literature Review – Internet & More Tools
- Research / Science
- Field Work, i.e.: Field Notes, Design Notes, Thumbnail Sketches
- Drawings, Examples, Photo Collages
- GPS, GIS, Analytical Techniques
- Estimating Tools
- Stakeholder Analysis
- Charette Techniques
- Actions Sequences
- Review

Typical Summary Package Outputs

- Written Summary
- Plans Set
- Thumbnail Sketches / Drawings
- Stakeholder Summary
- Photographs
- *Lessons Learned* Summary
- Trail Management Techniques
- Checklists

Utilizing a project management framework enables the interdisciplinary team to streamline their efforts when producing specific deliverables.

PMI's Lessons Learned Technique



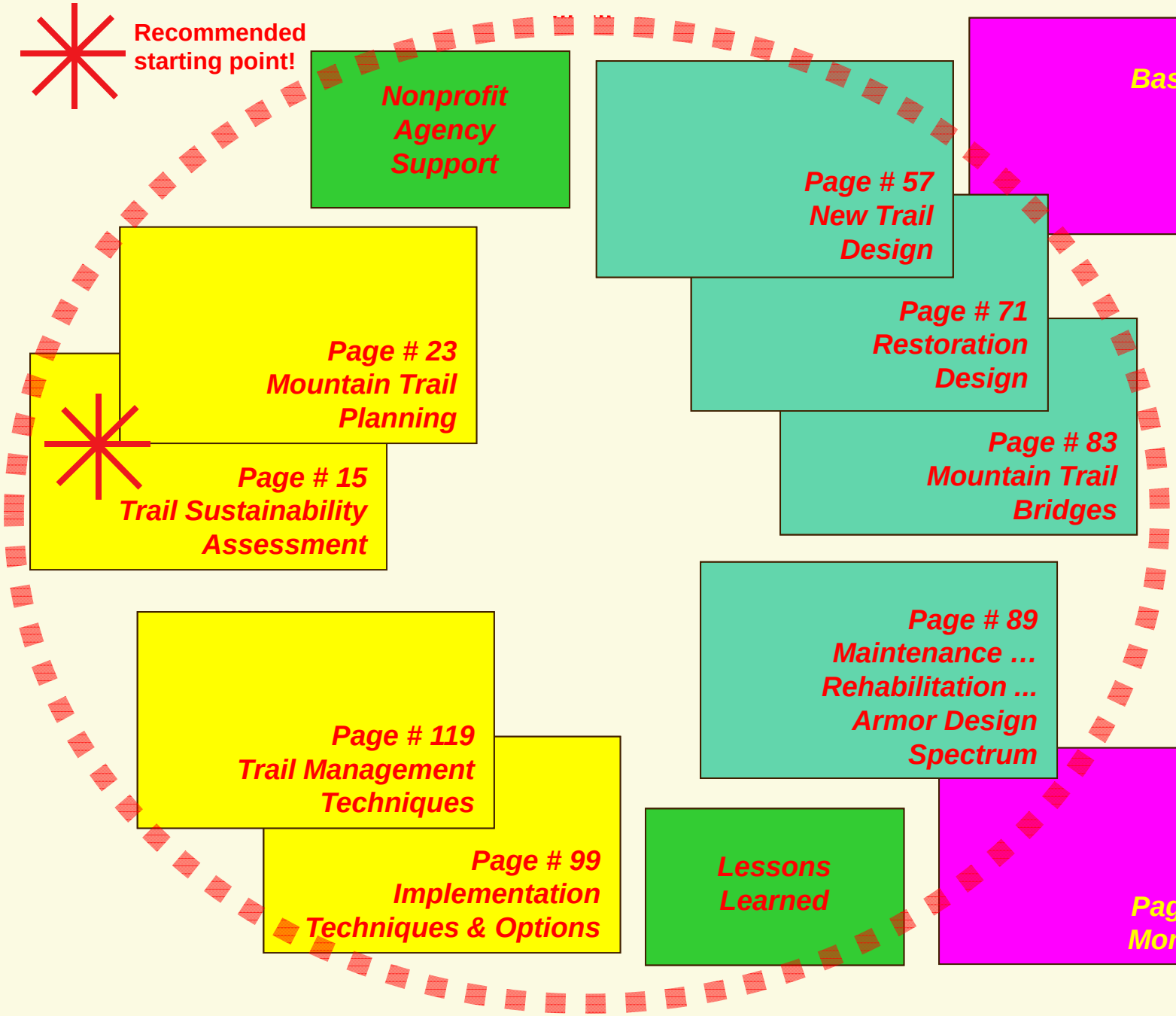
PMI encourages the application of a ***Lessons Learned Technique*** to activities throughout the project cycle. Outputs from each Project Process Areas are typically inputs to other Project Process Areas. ***Tools and Techniques*** are applied to project situations to determine the best course of action. ***Lessons Learned*** from each process can be utilized as inputs in subsequent processes, either with a positive connotation, i.e.: this worked, do it again; or a negative connotation, i.e.: this didn't work don't do this again, try another tool or technique.

Project Closeout in the PMI ***PMBOK Guide to Project Management, 3rd Edition*** specifically addresses ***Lessons Learned*** as part of the closeout process to be incorporated into the project archive files, and to be used as an input into subsequent ***Project Process Areas*** or projects.

Short of having an archive of existing hard-copy project data, trail planners can review existing projects near to their project at hand, as well as reviewing similar projects in the area, such as roadway projects or other development projects. For example: if cut slopes on a road project are not healing quickly in an area proximate to your project with similar soil types, you can deduce that backslopes on your project will also not heal quickly. Overall attention to ***Lessons Learned*** from other trail projects will ensure that your projects continue to strive to even higher percentages of success and sustainability.

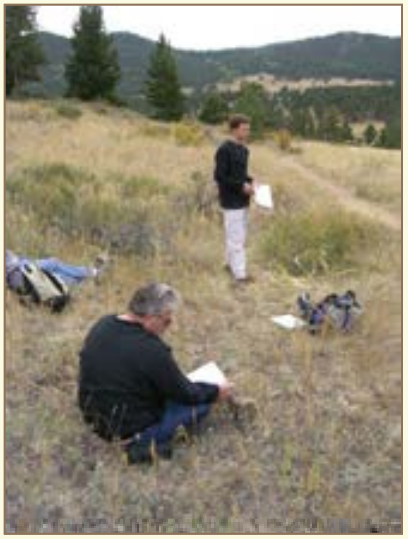
- The ***Project Management Institute (PMI)*** recognizes 5 process process areas where interrelated project activities task place. PMI does not advocate a linear project process, but rather a process based upon inter-relationships between the project process groups inputs, tools and techniques and outputs.
- Shown is the ***Project Planning*** process area schematic as defined by PMI. Outputs from Project Initiation would be inputs to *Project Planning*, and outputs from *Project Planning* are inputs to *Project Execution*, *Project Control* and *Project Closeout*.

Trail Project Cycle Tool – Deliverables / Milestones



Nonprofit agency support is required, now more than ever, to ensure continued success of recreational trails on public lands. All cogs in the ***Trail Project Cycle*** would benefit from such support.

Lessons Learned, ***Basic Design*** and ***More Tools*** offer strength and depth to the trails program.



Providing training opportunities for activities across the ***Trail Project Cycle*** is a valuable part of any trail program.

Trail Sustainability Assessment

Near Cadillac Mountain, Acadia National Park, Maine

Sustainability assessment techniques must be customized to specific physical sustainability criteria as well as the anticipated user type, volume of use and frequency of use.

Trail Sustainability Assessment

Inputs

- *Typical Inputs*

Tools & Techniques

- *Typical Tools & Techniques*
- Recreation Accessibility Potential Rating Tool
- Trail Corridor Assessment Tool
- Travel Surface Assessment Tool
- Review

Outputs

- DRAFT *Trail Sustainability Assessment Package* for Review
  - Trail Sustainability Annotated Plan
  - Trail Corridor Assessment Rating
  - Travel Surface Sustainability Rating
  - Recreation Accessibility Rating
  - Trail Management Techniques
  - Checklists
  - *Lessons Learned*
- FINAL *Trail Sustainability Assessment Package*

Assessing trail corridors as well as travel surfaces according to sustainability criteria will assist decision-makers in prioritizing corridors or segments for improvements. It is also hard work, but offers one of the best offices one could hope for. Trail workers are entitled to 2 rest periods of 15 minutes each per day, plus lunch.

Trail Sustainability Assessment Tools

Just one afternoon thunderstorm produced this damage to the (old) Mule Deer Trail at Golden Gate Canyon State Park in 2002.

Conducting an assessment particular to natural surface trail sustainability for your project area will help agency managers put perspective on their trail program needs.

Focused on fulfilling a need to communicate *natural surface mountain trail sustainability* issues, the tools used in Lakewood City Regional Parks (Hayden Green Mountain Regional Park and Bear Creek Lake Regional Park) have proven successful in helping portray individual trail corridor sustainability as well as area-wide sustainability. It is another tool that can be used by interdisciplinary trail teams to communicate issues of sustainability. Just two people can assess from seven to ten miles per day using this method.

Trail sustainability assessment is a two-step process: 1) ***Trail Corridor Sustainability Questionnaire and Rating Tool***, and 2) ***Trail Surface Sustainability Rating Tool***. Trail corridors rated as sustainable can be assessed for trail surface sustainability. Trail corridors not rated as sustainable will eventually be abandoned and restored to natural conditions through the ***New Trail Design*** or ***Restoration*** processes.

Conducting ***Trail Sustainability Assessments*** of an individual trail or an area-wide system may help support professional efforts to improve trail sustainability. They will help you quantify your needs for presentation to agency decision makers or funding or grant organizations, as well as to engage a nonprofit or volunteer agencies' interest.

Trail corridors that start at appropriate origins, utilize appropriate control points (intermediate linkages), have appropriate profile grades across appropriate cross slopes, and end at appropriate destinations have the most opportunity to be sustainable.

Recreation Accessibility Potential Rating Tool

High	**Three or four season use** **0-20% cross slope grades, gentle profile grades (<5% Average)** **Complementary trailhead facilities**
Medium	**Two season use** **0-20% cross slope grades, gentle profile grades**
Low	**Single season use** **Steeper than 20% cross slope grades** **Moderate profile grades (>5%)** **Non-complementary trailhead facilities**

Trail Corridor Sustainability Questionnaire

Answering the following questions will assist the trail team in determining trail corridor sustainability:

Meets Trails' Established Purpose?	**Y N**
Originates at Appropriate Location?	**Y N**
Destination at Appropriate Location?	**Y N**
Allows Appropriate Uses?	**Y N**
Appropriate (Major) Corridor Control Points?	**Y N**
Scenic Viewpoints Taken Advantage of?	**Y N**
Interpretive Opportunities Taken Advantage of?	**Y N**
Protects Natural Resources?	**Y N**
Protects Cultural Resources?	**Y N**
Nonprofit Agency or Individual Volunteer Support	**Y N**

Trail Corridor Sustainability Rating Tool

S+	**Sustainable corridor; Sustainable travel surface (approximately 85%), trail in good condition, with seasonal maintenance, Adopted by non-profit or maintenance program in place**
S	**Sustainable corridor, Sustainable travel surface (approximately 85%), needs rehabilitation, some *Armor* improvements or minor reroutes**
S-	**Sustainable corridor Non-sustainable surface Needs some Armor improvements, structures and / or major reroutes**
U	**Unsustainable**
A	**Abandonment recommended**
R	**Restoration recommended**

A trail surface sustainability assessment taken at stations along an existing trail's centerline and then tabulated in a matrix will yield insights into the decision making process across the ***Maintenance, Rehabilitation & Armor Design Spectrum***. Interdisciplinary trail teams are encouraged to customize these criteria to their specific project as well as across the distance from trailhead spectrum.

Recreation accessibility many times is considered after a trail is implemented and oftentimes cannot be upgraded economically. Planning for recreation accessibility in advance of implementation is the more prudent way. Assessing a trail corridor alternative for recreation accessibility potential is easily accomplished when using ***Recreation Accessibility Potential Rating Tool***. Frontcountry zones, near visitor facilities, are the best candidates for Recreational Accessible routes.

Travel Surface Sustainability Rating Tool

Station (Civil Engineering Notation)	**1+00**
Aspect	**W SW S SE E NW N NE**
Sustainable Soil Substrate	**Y N**
Prevailing Cross-Slopes 10% - 70%	**Y N**
Average Profile Grades <8% (Frontcountry)	**Y N**
Profile grade <1/4 Prevailing Cross Slope	**Y N**

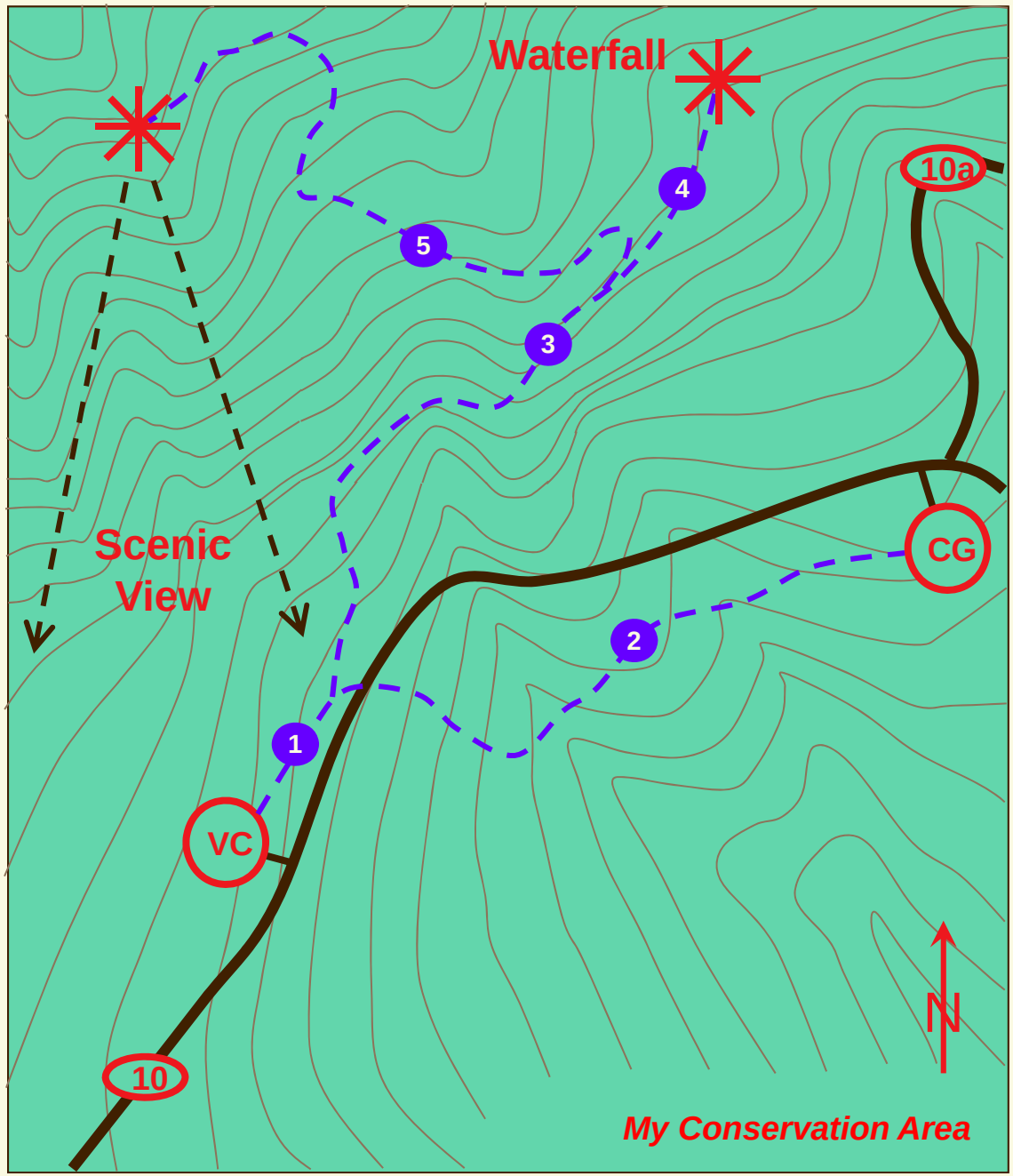
Appropriate

What is appropriate for a specific project? Identifying …..

- *Geographic Context*
- *Land Management Agency Policies*
- *Increasing Distance from Trailhead*
- *Specific User Groups or Multiple – User Groups*
- *Plan or Project Goals*
- *Stakeholder Interests*

….. all contribute to the definition of ***Appropriateness*** *for each project.*

Trail Sustainability Assessment – Annotated Plan



In this area, trails developed over a period of time without the benefit of professional planning or design services. No guidelines were applied. Trails have been heavily used, and the season of use has increased substantially from summer use to shoulder season through summer through shoulder season with some intermittent winter use. Some of the trail segments go straight uphill.

- Trail Segment 1 leaves the Visitor Center in an apparently acceptable location.
- Trail Segment 2 crosses County Road 10 at an unsafe location, and leaves County Road 10 quickly, a common mistake, and goes straight downhill for an extended distance.
- Trail Segment 3 has several sustainable locations, but other locations go straight uphill, an unsustainable condition.
- Trail Segment 4 approaches the waterfall (a significant landscape feature in this area) from the side, contradicting a design principle when determining trail location.
- Trail Segment 5 has some sustainable locations, but goes straight uphill in other locations.

If major control points are missed, corridors can rarely be rated as sustainable and caution should be exercised before investing time, labor or material resources.

Sustainability Assessment – *Field Notes Technique* – Example

Station	Prevailing Cross Slope (%)	Trail Profile Grade %	Aspect	Soils	Back-slope	Tread Width	Surface Materials	Rating	Trail Sustainability Assessment Notes
0+00	0%		E	Coarse	OK	2'-7"	Cupped	S	*Regular Basis Activities* Required
		1%							
1+00	0%		E	Stone	OK	2'-9"	Cupped	S	*Perform as Needed Activities* Req'd
		10%							
2+00	25%		SE	Coarse	OK	3'	Cupped	S	*Regular Basis Activities* Required
		10%							
3+00	40%		SE	Silt	Eroded	3'	Outsloped	S-	*Perform as Needed Activities* Req'd
		0%							
4+00	25%		SE	Organic	Eroded	3'-9"	Outsloped	S-	*Regular Basis Activities* Required
		4%							
5+00	15%		E	Coarse	OK	3'-5"	Outsloped	S	*Perform as Needed Activities* Req'd
		12%							
6+00	10%		E	Coarse	OK	3'	Cupped	S	*Perform as Needed Activities* Req'd

Prevailing cross slope (fall line) and trail profile grade readings taken with a clinometer, while also recording additional sustainability notes, will assist the trail team in assessing trail corridors or surfaces for planned activities. Readings are recommended for each 100-foot (engineering) station.

The higher the percentages of unsustainable soils, excessive cross slopes or steep trail profile grades, the more likely it is the corridor should be simply maintained, rehabilitated, armored or relocated to more sustainable sites. If over 50% of a corridor is unsustainable, it is likely that the entire corridor needs to be abandoned, restored, and then a new corridor relocated to better soils or prevailing cross slope locations. ***Armor Improvements*** (sometimes just minor spot improvements) will almost always be required to keep a trail corridor and travel surface in sustainable condition.

Optimum Prevailing Cross Slopes grades are evident for a multiple use trail connection at Fox Hollow Golf Course in Lakewood, Colorado.

Mount Bierstadt, near Denver, Colorado

Mountain Trail Planning

Emerald Lake Trail, Rocky Mountain National Park, Colorado

This rock outcrop at Lory State Park will present a significant challenge to trail planners to find an easy-to-construct corridor.

Soil types play a predominant role is sustainable trail corridor site selection.

Trail planners hard at work at Bear Creek Lake Regional Park, Lakewood.

Cultural resources such as home sites, mine shafts and Native American sites must be identified in the planning process.

Mountain Trail Planning

Inputs

- *Typical Inputs*
- Outputs from Other Process Areas
- Stakeholder Analysis
- Aerial Photos, Maps, Data Bases
- *Lessons Learned*

Tools & Techniques

- *Typical Tools & Techniques*
- Establish Background Information / Foundations
- Establish Plan Goals
- Establish Climate & Geographic Context
- Identify Ecosystem Type
- Identify Rare Species & Habitat
- Physical Planning Tools
- Trail Profile Calculations
- Off-Site Connections & Network Analyses
- Optimum Trail Corridor Identification
- Compare Existing Corridors to Optimum Corridors
- Corridor Implementation Action Prioritization
- Develop Corridor Framework By Assembling Individual Corridor Plans
- Review

Outputs

- DRAFT Mountain *Trail Plan Package* for Review
  - Sustainability Assessment Summary
  - Base Map
  - Landscape Characteristics Summary
  - Annotated Site Analysis
  - Corridor Control Points
  - Corridor Framework
  - Trail Management Techniques
  - Checklists
  - *Lessons Learned*
- FINAL *Mountain Trail Plan Package*

NPS Organic Act

The purpose of the National Park Service is *". . . to promote and regulate the use of the . . . national parks . . . which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."*

Other land management agencies have similar documents guiding their mission.

Aspen trees provide habitat for a variety of birds and mammals, and are naturally striking in their appearance, and as such must be accounted for in the trail plan.

A plan is a fundamental tool land managers use to coordinate existing and proposed trail activities with agency initiatives and policies. A trail plan serves as a guide for land managers in their decisions regarding the location, funding, and construction of trails under their jurisdiction. A common intent of trail plans is to standardize and systematize the management of trails. Trail plans can also be used for the coordination of trail projects across agency boundaries where neighboring agencies have mutual goals.

A plan is best developed by an interdisciplinary trail team of resource and design professionals. The trail plan will identify where and when trail activities will occur and what uses will be allowed. The plan may include both short range (up to 5 years) and long-range goals (up to 50 years). Updates to plans can address the long-range goals identified in the original plan.

A professional trail planning process will involve all stakeholders who might have an interest in the project: the public, agency resource professionals, and neighboring land management agencies.

During development of a plan, many issues will come up and be addressed by the team which can adequately respond to situations as they arise. The land manager is then presented with a professional plan which addresses the issues that will face the design team.

Thoughtfully planned trails on the Green Ranch Property at Golden Gate Canyon State Park near Denver, CO will include views of Mount Evans, a Colorado 14er, in the distance.

Implicit in ***Mountain Trails Planning*** is the understanding that different user groups will have different corridor needs. Also, visitation must be analyzed to ensure appropriate solutions are developed.

Including an ***Trail Sustainability Assessment*** of sustainability of existing trails as an input into the plan ensures that their condition as well as their fitness for continued inclusion in the trail system in their current condition is considered over the life of the plan.

Climate Summary

Understanding and describing climatic influences in a particular area assists park managers and interdisciplinary trail teams in the establishing a baseline of information from which trailside decisions can be made. Example ***Climate Summary***:

> *"A semi-dry, continental climate characterizes the Roxborough State Park vicinity. Summers are long, hot and relatively dry. Winters are short, cold and dry. Average rainfall is considered slight (approximately 15 inches), with evaporation high. Most precipitation is uniformly distributed from April to October. Mean air temperatures decrease as elevations increase, along with increases in precipitation also as elevations rise. Winter precipitation falls as snow and persists, especially on north facing slopes. Wind is common, predominantly from the northwest, and is strongest in spring and fall …*
>
> *Average spring temperatures vary from 30d F to 60d F;*
> *Average summer temperatures vary from 50d F to 80d F;*
> *Average fall temperatures vary from 30d F to 60d F; and*
> *Average winter temperatures vary from 20d F to 40d F.*
> *Frost occurs in the winter months, and extends to a depth of approximately 2 feet, and deeper on north facing slopes.*
>
> *… During summer months, soils are dry and can be dusty*."

Shoulder season use, in the spring and fall, must be considered when implementing trail projects. Warm weather along Colorado's Front Range draws visitors to Mt. Sherman near Fairplay, Colorado.

Boundary Constraints

Starting a trail project with an accurate boundary and property survey in hand, especially if your unit adjoins private land, ensures an understanding of boundary locations and easement opportunities or constraints. A property survey might yield some insights into your challenge and expose some opportunities for easements or other creative solutions. Undertaking a trail project without an accurate survey can create legal problems. Be sure to request and obtain written permission to scout trails on private lands before venturing afoot.

Easement Opportunities or Constraints

Obtaining an easement across private land within your park boundary, or negotiating with an adjacent landowner for an easement is a preferred way of assembling trail corridors. Large expense can sometimes be avoided when using this method of trail establishment. Easements are best determined and negotiated by experienced professionals. Easements can easily be a constraint, if there are specific activities allowable or precluded by the language of the easement.

Off-Site Connections

Your area's neighbors may have trail projects in place or planned which may affect where you do or don't develop trails. Consultation is wise to ensure compatibility with your neighbor's plans.

Good Fences …

"Good fences make good neighbors" is a paradigm that applies to trail planning and design. It can be said that "good off-site connections make good neighbors."

… Make Good Neighbors

Geographic Context Summary

Establishing the geographic context for your area assists in putting the unit in proper perspective with neighboring and regional conservation area land masses and corresponding recreation opportunities. Example ***Geographic Context Summary***:

"Roxborough State Park is located just 15 miles southwest of Denver, Colorado, at the ecotone between the Montane and short-grass prairie life zones along Colorado's Front Range. Elevations above sea level vary from approximately 6,000 feet to approximately 7,200 feet.

… It is in this zone that the eastern plains of Colorado give rise to the rugged mountains for which Colorado is famous. Here travelers across the eastern plains of Colorado have encountered a series of formations which would give a glimpse of the formidability of the Rocky Mountains. First encountered would be the Dakota formation (commonly known as the Hogback), a prominent rock outcrop which appears intermittently along Colorado's Front Range from Pueblo to Fort Collins. Moving further west into this landscape, visitors to this landscape encounter the Lyons formation, then the Fountain formation, then the foothills of Colorado's Front Range.

… The Morrison formation, apparent as a ridge in other areas along Colorado's Front Range, is a valley former at Roxborough. For all of recorded history, these formations have yielded little towards the feeble strength of man.

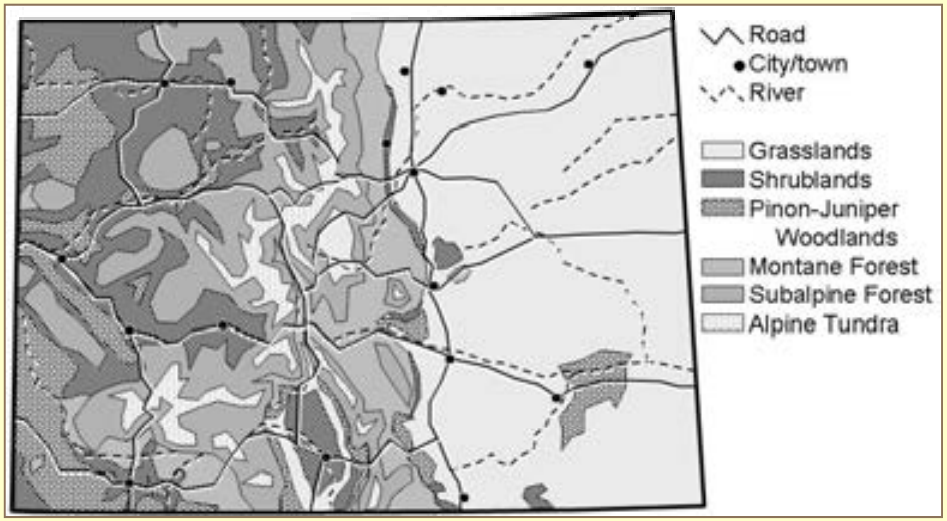
… Willow Creek drains part of the southern portion of the park. Little Willow Creek drains part of the northern portion of the park. Additional minor drainages and gulches drain western or eastern portions of the park. All of the drainages are part of the larger South Platte River basin.

… The most prominent mountain peak in the park is Carpenter Peak, rising above the eastern plains to approximately 7,125 feet in elevation above sea level. From Carpenter Peak, one has a nearly panoramic view towards Mount Evans to the west, Longs Peak towards the north, the city of Denver and Colorado's eastern plains towards the east, and Front Range foothills towards the south.

… Putting the topography of Roxborough in the context of the Rocky Mountains of Colorado will assist park managers in developing trails appropriate to the setting of Roxborough State Park. Colorado is famous for 13,000-foot and 14,000-foot-high peaks accessible only by very rugged trails or scramble routes. Roxborough's relatively low elevations, combined with its relative proximity to a large population center and the expected high volume of frontcountry users – gives rise to the premise that trails in this area that provide the most gentle profile grades would provide the most benefit to the widest variety of trail user types."

Downtown Denver is 25 miles distant from Roxborough State Park.

Colorado Ecosystems



Colorado Ecosystems
Based upon "*Distribution of Ecosystem Types in the Southern Rocky Mountain Region*" from "*From Grassland to Glacier*" by Cornelia Fleischer Mutel and John C. Frederick.

From the 3,300-foot high plains in the eastern part of Colorado to the 14,000-foot-plus summits of its high peaks, Colorado displays a vast variety of ecosystems. Extensive grasslands, evergreen forests, and expanses of alpine tundra cover the state, each providing trail users with rich and diverse recreational experiences.

Understanding the natural characteristics of Colorado's ecosystems, especially within your land management area, will help you to plan and design trails that function well with each ecosystems' natural characteristics.

If the trail planner has a basic understanding of local vegetation, they will be able to identify ecosystem types. This will help them to understand associated soil types, moisture levels, and habitat concerns. All of these factors will give the trail planner information towards proper trail location and alignment, and are important to understand for trail restoration projects.

The following slides outline the seven major ecosystem types that can be found in Colorado. For each ecosystem, the following information is given:

- Range and Elevation: approximate location of ecosystem in terms of the geography of Colorado;
- Common Soils: soil texture types for each ecosystem;
- Common Vegetation: general vegetation types (grasses, forbs, shrubs, etc) and some common species;
- Vegetation-Soil Type Indicators: information on identifying soil types based on vegetation; and
- Trail Considerations: trail planning information specific to that ecosystem type.

Montane forest along Colorado's Front Range is just one of six major ecosystem types in Colorado.

Grasslands

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
Eastern Colorado plains; blends into foothills shrublands & Ponderosa Pine forests. < 5,600’	Deep organic clay & silt soils; frost free >150 days per year. Occasionally soils are sandy or cobbly.	Grasses & forbs, some shrubs. Common weed species include Cheatgrass, Thistles, and Knapweeds.	Pockets of shrubland may exist on north-facing cool slopes. This indicates higher soil moisture retention and later season snowmelt.	• Difficult soils for trail construction due to high potential for erosion & mud. • Gentle profile grades recommended. • Trail location on south-facing (aspect) slopes is beneficial (dry), and a more sustainable location than on north-facing (aspect) slopes. • Imported surfacing (***Armor)*** (i.e.: “crusher fines”) with landscape / geotextile fabric may be needed. • Prevalence of weeds in these ecosystems may spread into trail corridors. • Lack of tall vegetation helps to speed drying of muddy trails. • Excellent opportunities for trail revegetation / restoration.

The West Valley Trail at Lory State Park near Fort Collins, Colorado is in the transition from the Grasslands to the Shrubland Ecosystem.

Mountain Grasslands & Meadows

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
Interspersed in intermountain basins. 7,300' – 10,000'	Deep & fine-textured. Wet meadows may have large amounts of accumulated organic matter.	Dry meadows: grasses & forbs. Shrubby Cinquefoil is common. Wet meadows: sedges, rushes, Willow, Bog Birch, Shrubby Cinquefoil, forbs.	Mountain Greasslands & Meadows are interspersed throughout the Montane Forest and Subalpine Forest Ecosystems. Wet meadows are dominated by sedges & rushes, not grasses.	• Wet meadows require intensive trailside improvements (i.e.: imported surfacing, turnpikes, boardwalks (***Armor***)). • Gentle profile grades recommended. • Management issues such as with trail braiding, widening, or short-cutting may arise. • Meadows offer excellent opportunities for memorable visitor experiences, including changes of scenery and wildlife viewing. • Prevalence of weeds in these ecosystem may spread into trail corridors. • Trail restoration is generally quickly accomplished.

The Green Ranch Property at Golden Gate Canyon State Park offers spectacular views towards the south, including Mt. Evans. Trails here will avoid the Meadows.

Riparian

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
Corridors along rivers, streams, & moist valleys; interspersed statewide. Elevation variable.	Variable in depth & texture; high moisture levels (may be seasonal).	Lowland: Cottonwood Trees, shrubs (Wild Plum, Hawthorn, Currant, Wild Rose, Snowberry, Willow), Salt Cedar (western slope invasive). Mountain: Alder, Cottonwood, Willow, Birch, Colorado Blue Spruce, White Fir.	Riparian ecosystems are interspersed throughout Colorado. Rushes and sedges can be an indicator of deep, fine-textured, wet soils.	• Biologists can add expertise for the trail advocacy team to consider. • Use careful design when designing trails which cross riparian areas. • Gentle profile grades recommended. • Bridges, boardwalks, or other trail surface improvements may be required (***Armor***). • In mountain riparian areas, frost-free season is usually shorter than surrounding hillsides and ridges due to cold-air drainage. This results in late-season snowpack and potentially muddy trails in the early hiking season. • Riparian areas have rich biodiversity, so trails can be a disturbance to important wildlife habitats. • Riparian areas offer excellent opportunities for memorable visitor experiences, including changes of scenery and wildlife viewing.

Riparian areas offer many recreational opportunities, yet require much care when creating trails near them or across them.

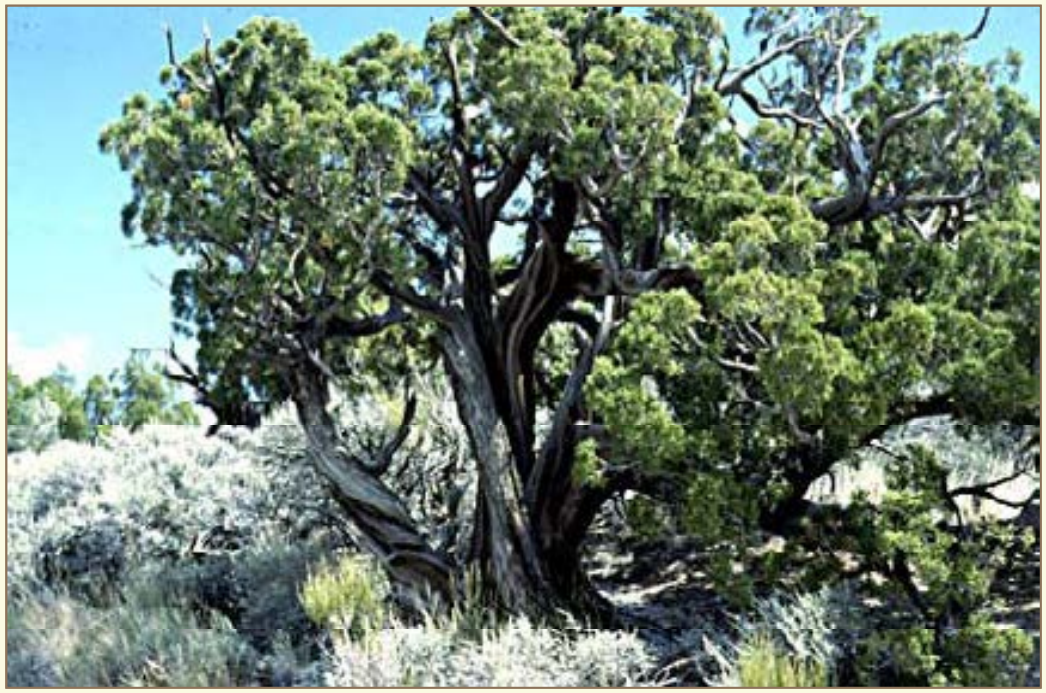
Shrublands

Shrublands offer unique trail opportunities, they are usually very suitable for trails.

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
Interspersed throughout foothill and mountain regions & Colorado Plateau. 5,500' – 10,000'	Semidesert regions: clay, silt, or sand. Sagebrush regions: deep, fine-grained (clay & silt). Mountain & foothill regions: well-drained, coarse-textured to rocky (sand).	Semidesert regions: Greasewood, Shadescale, Four-winged Saltbush, Rabbitbrush, Winterfat, Big Sagebrush. Sagebrush regions: Big Sagebrush. Mountain & foothill regions: Gambel Oak, Mountain Mahogany, Skunkbrush, Serviceberry, Antelope Bitterbrush, Wild Rose, Currants.	You may find pockets of shrubland on north-facing cool slopes in grassland areas. This typically indicates higher soil moisture retention and later season snowmelt.	• In mountain regions, shrublands are typically a sustainable location for trail placement due to their commonly coarse, well-draining soils. • Gentle to moderate profile grades recommended. • Open views of surrounding landscapes are common in shrubland ecosystems.

Pinon-Juniper Woodlands

Pinon-Juniper Woodlands offer spectacular forms and spatial variety for the trail user to enjoy, and are usually very suitable for trails.



Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
Western & southern Colorado, southern part of eastern foothills, southeast plains (patch). 4,800’ – 8,200’	Typically are coarse (sandy / gravelly), but can be fine-textured (clay).	Pinon pine, Rocky Mountain Juniper, One-Seed Juniper (> 7,600’ in Southern Colorado), variety of shrub species (similar to shrublands).	Pinon pine is more tolerant of cold, thus it dominates stands at higher elevations. Conversely, juniper is more drought-tolerant and dominates stands at lower elevations and dry sites.	• Prevalence of sandy / gravelly soils (coarse) in pinon-juniper woodlands is a sustainable characteristic of these ecosystems. • Gentle to moderate profile grades recommended. • Pinon-Juniper Woodlands provide for a complex variety of fore-, middle- and background viewsheds, significantly increasing variety for trail users.

Montane Forests

Montane forests provide richness and diversity to the landscape.

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
Throughout mountainous regions of Colorado. 5,500’ – 9,000’	Coarse (sandy), rocky, can be fine-textured.	Ponderosa Pine, Douglas-fir, Rocky Mountain juniper, Aspen, Lodgepole Pine.	Pine species and Juniper are more dominant on dry sites and slopes. Douglas-fir and Aspen typically occupy cool, moist sites.	• Soils are typically good for locating sustainable trail corridors. • Gentle to moderate profile grades recommended.

Subalpine Forests

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
9,000’ to tree line or approximately ~11,500’-12,000’	Coarse (sandy), rocky, can be fine-textured.	Aspen, Lodgepole Pine, Limber Pine, Bristlecone Pine, Engelmann Spruce, Subalpine Fir.	Pine species are more dominant on warm, dry sites.	• Late-season snowpack can keep trails hidden into early summer, creating muddy conditions. • Thick layers of organic material may have accumulated in some sites. • Soils are typically good for locating sustainable trail corridors. • Gentle to moderate trail profile grades recommended. • Subalpine Forests provide for more varied views, similar to fore-, middle- and background views offered in the Pinon-Juniper Woodlands, but from higher elevations.

Subalpine Forests offer significant trail opportunities, providing more enclosed experiences for trail users.

Alpine Tundra

Range and Elevation	Common Soils	Common Vegetation	Vegetation-Soil Type Indicators	Trail Considerations
High mountain ridge tops and peaks. > 11,500’	Coarse soils, can be fine-textured in low-lying wet areas or wet mountain ranges (San Juan Mountains)	Cushion plants, forbs, grasses, sedges, low shrubs (at lower elevations).	Lush alpine meadows can have fine-textured soils and remain wet well into the summer. Vegetation height is a good indicator of soil moisture (taller plants = higher soil moisture).	• Gentle profile grades recommended. • Seasonal snowpack can last well into the summer (observe over several seasons), creating muddy conditions. • Improvements which mitigate sometimes continuous snowmelt are recommended. • Alpine plants are slow to establish and grow in disturbed areas. Limit trail activities to the trail surface. • Waterbars are discouraged due to the potential for sediment build up over neighboring alpine plants. If waterbars are needed, drain into talus or willows. • Few physical barriers exist above timberline to prevent trail shortcutting. • Scree fields are best avoided. • Talus fields are difficult sites to implement trails, but provide a sustainable trail surface. • Restoration is difficult due to short growing season and harsh growing conditions.

Alpine Tundra is very sensitive to disturbance and care is to be taken when implementing trail projects.

“Environments of an extremely fragile character (i.e.: marshy and alpine areas) require special attention in order to protect their sensitive natural uniqueness. Thus it is essential that the delicate balance be maintained between maximizing hiking opportunities and the environmental carrying capacity of the ecosystem. Overuse can destroy the natural environment, which is an essential segment of the hiking experience.” – William G. King, 1979.

Rare Species & Habitats

Protecting rare plants is easy but bringing them back is very difficult! Natural ecosystems support a diverse and fascinating flora. Some plant species may be endemic (known from nowhere else in the world) though wide-spread, while others are found only in microclimates of a single mountain range. Some rare plants may be part of very isolated populations, found infrequently in similar habitats around the world.

Protection of rare species is a foundational goal of many land management agencies.

What Makes a Plant Rare?

Knowledge of what makes a rare plant “rare” can be used to help protect it. Rare plants, like other rare species, are specialists and as such have very specific habitat requirements. Several variables interact to create the unique habitats required by rare plants including: soil texture, hydrology, soil chemistry, elevation, associated vegetation, aspect and snow pack.

Where the correct habitat exists, a rare plant can in fact be represented by thousands of individuals. The key point to remember is that the number of suitable habitats is often limited, and most rare plants occur in much lower numbers and / or in few populations scattered across the region. In contrast, a generalist plant such as alpine avens (Geum rossii), can occur by the tens-of-thousands in a specific area, and can be found on several continents.

According to a 1995 report by the *Colorado Natural Heritage Program,* which gathered data from 6 peaks in the Sawatch Range of Colorado, concentrating hiker impact along a single well-planned trail is a positive alternative to a maze of social trails in order to protect rare plant populations. By encouraging hikers to stay on established routes, you can prevent trampling of vegetation, including rare plants.

Rare species are especially a concern for new trail alignment and implementation which may jeopardize known populations of rare plants or animals, or the habitats of these species (even though no species may be currently present there). However, knowledge of existing populations of rare plant is also important for restoration crews to be aware of in order to avoid disturbance while sourcing materials (i.e., rocks, logs), removing transplants, and collecting seeds.

Consult the compliance documents for your plan or project for complete information on ***Rare Species and Habitats***.

Aquilegia saximontana, credit: USDA, Gary A. Monroe.

Aspect

Aspect is the compass orientation of a particular parcel of land. Aspect affects trailside decisions in that obviously, one would want a cross-country ski trail on north facing slopes, as these slopes will tend to hold snow, for longer periods of time. For anticipated year-round multiple-use trails use, southeast, south or south slopes would offer the best opportunity for soils to dry out after rains or snowfall. See tables on page 42.

Elevation

Elevation affects trailside decisions in that higher, more inaccessible trails will likely have less use, and will be used by more accomplished users. Elevation is also a significant factor in precipitation rates in Colorado. Lower elevation trails can be expected to have more use, with more novice users. Trail standards which are customized to specific uses, locations, distances from trailheads and elevation change from trailheads will ensure optimum fitness for the intended uses. See tables on page 42.

Extent of Impact

By applying the trail width guideline for the specific trail at hand to the prevailing cross slopes, average extent of impact widths can be determined. For instance, a 24” wide trail on a 40% cross slope will impact approximately 36” horizontal. By walking the proposed trail corridor with the ***Extent of Impact*** in mind, interdisciplinary trail teams can visualize if the trail will unnecessarily impact resources.

Vertical Calculations

Mathematical calculations will assist the trail team in determining feasibility of varying trail profile grades for a corridor, including length of trail and required improvements. See page 43.

Corridor Control Points

Key, appropriate origins, destinations and ***Corridor Control Points*** must be established for each corridor to ensure that the corridor will work in design and can be studied further in the compliance process. It is incumbent upon the trail advocacy team to recommend alternative origins or destinations if existing facilities are in inappropriate locations. ***Corridor Control Points*** are locations which the corridor must utilize or avoid in order for the corridor to be considered sustainable. They can be either functional and aesthetic control points. Functional control points are things such as impenetrable rock outcrops, stream crossings, or archaeological sites where entry is not permitted. Switchback locations are usually major control points, i.e.: locations where trail corridors must pass. Aesthetic control points are areas that attract trail users. These include overlook areas, high points, interesting water features or an ecological zone of interest.

Applying planning guidelines such as ***Optimum Trail Profile Grades, & Prevailing Cross Slope Ranges*** and studying a potential corridor with consideration to major control points is the basis of planning sustainable trails. Minor control points, those where flexibility is allowed, may be looked at during design.

Optimum Corridors

The optimum corridor starts at appropriate origins, utilizes appropriate corridor functional and / or aesthetic control points, and terminates at appropriate locations. The optimum corridor also considers boundary constraints, adjacent corridor locations, easements and off-site connections. When the optimum corridor is compared to existing trails, the percentage of the existing corridor that is sustainable, as well as degree of impact in that corridor, will assist the interdisciplinary trail team in determining appropriate actions (***New Trail Design, Maintenance, Rehabilitation, Armor, Restoration***). Multiple corridors are easily assembled into plans.

Soils

Soils result from the mechanical or chemical breakdown of rock substrates, and can be classified as coarse (cobbles, gravels, sands) and fine (silts and clays). Coarse soils offer the best setting for trails, and usually coincide with preferred prevailing cross slope conditions. Fine soils usually coincide with flat (unfavorable) cross slope conditions. Organic matter is present in both coarse and fine soil conditions, and on the one hand needs be removed during trail construction as it prevents soil from binding together well and contributes to muddy conditions upon decomposition, while on the other hand encourages revegetation during restoration activities.

Optimum Soil Types

Optimum soils for natural surface trails are predominantly coarse soils, with some small amount of fines mixed in to act as a binding material. Optimum soil types are often referred to as *"mineral soils."* Corridors with less than optimum soils identified in the planning process must be programmed for additional work during design or implementation.

See tables on page 42.

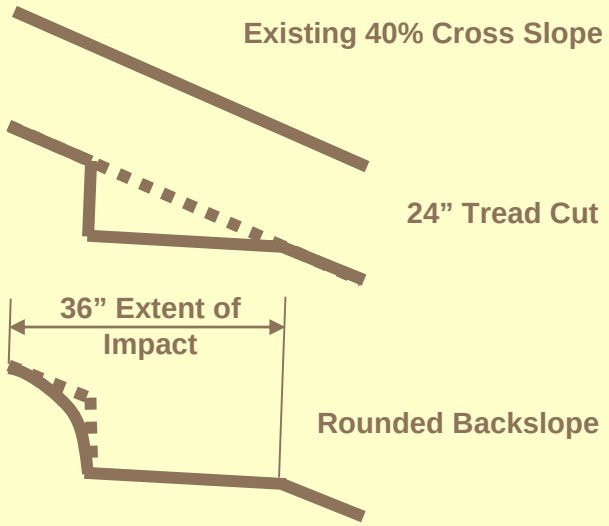
Soils Comparison Matrix

	Coarse Soils	Silts	Clays
Particle Size	Large	Medium – Small	Small
Erosive Potential	Low – Moderate	Moderate – High	High
Drainage Capability	Excellent	Poor – Moderate	Poor
Organic Content	On Surface Only	Moderate – High	High
Restoration Potential	Difficult	Good	Good
Trail Considerations	Coarse soils leaves large pore spaces for water to drain through soil. Blocky particle shape keeps a solid trail surface. Occasionally, sandy soils can be too loose if there is not enough binding material, i.e. small amounts of clay and / or silt.	Silt does not leave enough pore space for water to seep through soil, and erodes easily.	Clay does not have enough pore space for water to drain through, and holds water in soil, creating long-lasting mud. Clays have high potential for erosion because water runs over it, not draining through it, and small particles of clay are carried away easily by wind and water.

This document!

Distance from Trailhead Spectrum Comparison Matrix				
	Distance	Optimum Trail Profile Grades	Optimum Prevailing Cross Slopes (%)	Tread Width
Recreation Accessible (ADA)	Not Defined	< 5%	0-20%	36" min.
« Frontcountry »	**X < 3 miles**	**0 - 8%**	**20 - 40%**	**24" - 36"**
« Middlecountry »	**3 < X >7 miles**	**0 - 12%**	**20 - 60%**	**18" - 24"**
« Backcountry »	**X >7 miles**	**0 - 15%**	**20 - 70%**	**12" - 18"**
Scramble Routes	Any Distance	15% <> 100%	> 60%	NA
Technical Climbing Routes	Any Distance	NA	NA	NA

Extent of Impact Tool



Most trails will impact 1.5x – 2x the trail surface width when implemented.

Distance from Trailhead Spectrum

Trail use is more substantial closer to trailheads, with use tapering off as distance from trailheads increases. Interdisciplinary trail teams are encouraged to customize their plans and projects to their specific physical and social context. *"Frontcountry"* can be generically defined as up to 3 miles from the trailhead, *"middlecountry"* can be generically defined as 3 miles – 7 miles from the trailhead, and *"backcountry"* can be generically defined as over 7 miles from the trailhead. Investment in trailside improvements may vary over the ***Distance from Trailhead Spectrum***.

"Build it …

Correspondingly, trail use almost always goes up over time. *"Build it and they will come"* is more than a catchy baseball cliché. Project criteria which take this into account will more likely result in trails which are more sustainable.

… And They Will Come"

Table A. Opportunity for Trail Sustainability – Prevailing Cross Slope (%) & Aspect								
Prevailing Cross Slope (%)	West (W)	Southwest (SW)	South (S)	Southeast (SE)	East (E)	Northwest (NE)	North (N)	Northeast (NW)
0 – 20%	Good	Good	Good	Good	Good	Poor	Poor	Poor
20 – 40%	Excellent!	Excellent!	Excellent!	Excellent!	Excellent!	Poor	Poor	Poor
40 – 60%	Very Good	Very Good	Very Good	Very Good	Very Good	Poor	Poor	Poor
60 – 70%	Good	Good	Good	Good	Good	Poor	Poor	Poor
70% +	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

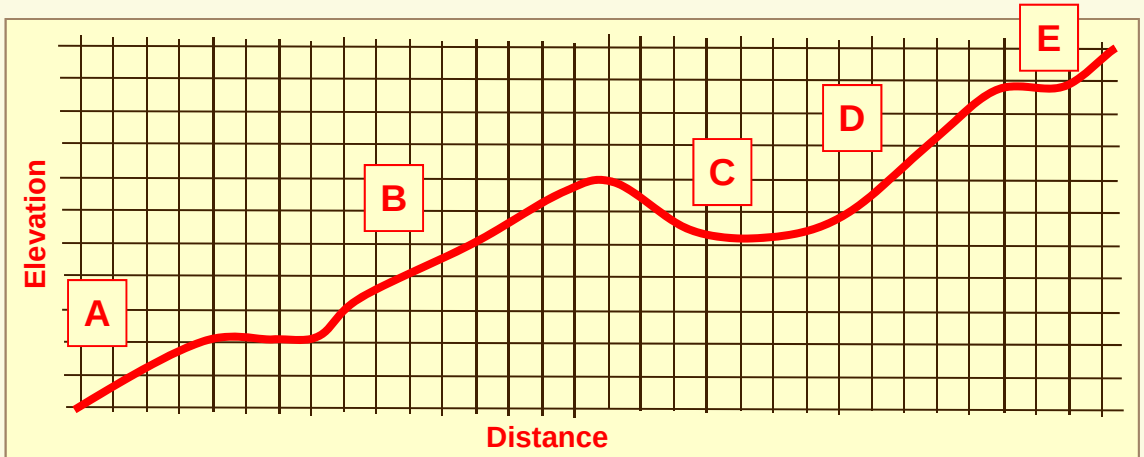
Table B. Opportunity for Trail Sustainability – Prevailing Cross Slope (%) & Soils			
Prevailing Cross Slope (%)	Coarse Soils	Silts	Clays
0 – 20%	Good	Poor	Poor
20 – 40%	Excellent!	Good	Poor
40 – 60%	Excellent!	Good	Poor
60 – 70%	Good	Poor	Poor
70% +	Poor	Poor	Poor

Table C. Opportunity for Trail Sustainability – Elevation & Aspect								
Elevation	West (W)	Southwest (SW)	South (S)	Southeast (SE)	East (E)	Northwest (NW)	North (N)	Northeast (NW)
5,000 – 7,000’	Excellent!	Excellent!	Excellent!	Excellent!	Excellent!	Good	Good	Good
7,000 – 9,000’	Very Good	Excellent!	Excellent!	Excellent!	Very Good	Good	Good	Good
9,000 – 10,000’	Good	Very Good	Very Good	Very Good	Good	Poor	Poor	Poor
10,000 – 11,500’	Poor	Good	Good	Good	Poor	Poor	Poor	Poor
> 11,500’	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Vertical Calculations

Several profile grades calculated out over the anticipated total vertical gain will portray how many horizontal linear feet of trail would be required at each profile grade.

Be sure to account for drops in grade between corridor control points, not just the raw vertical distance gain. In the case of Option #1, **A, B C, D** and **E** must be added together to determine the combined vertical climb.



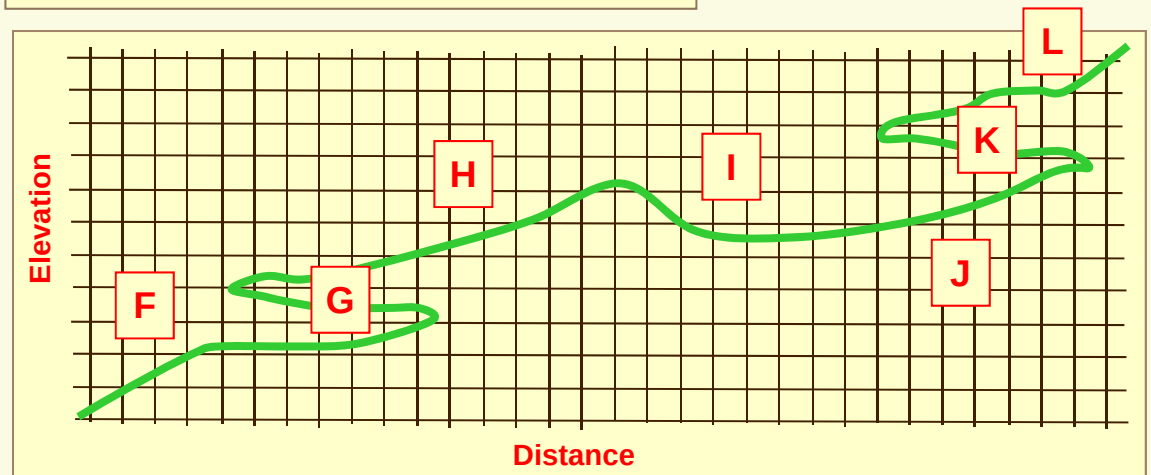
Trail Profile Option #1 – 7% Average Grade

Profile Option #2

% Grade = Vertical Difference / Linear Feet
.05 = F + G + H + I + J + K + L / LF
.05 = 1,500 / L
L = 30,000 Linear Feet of Trail **(5.68 miles)**

Profile Option #1

% Grade = Vertical Difference / Linear Feet
.07 = A + B + C + D + E / LF
.07 = 1,500 / L
L = 21,429 Linear Feet of Trail **(4.05 miles)**



Trail Profile Option #2 – 5% Average Grade (Including 4 Switchbacks)

Vertical Calculations ensure that high investment improvements such as ***Mountain Trail Bridges*** are located in permanent locations.

Recommended Daily Requirements Per Mile of Trail Estimating Tool							
↓ Trail Worker	Assess.	Plan	Design	Implementation	Maintenance	Rehabilitation	Armor
Trail Planner	1	1	NA	NA	NA	NA	NA
Trail Designer	1	NA	6 - 10	.25 - .5	NA	2 – 5	2 - 5
Trail Associate	0.25	1	3	3	1	1	1
Volunteer Crew Manager	0.05	0.05	3	3	1	1	1
Volunteer Crew Leader	0.05	0.05	3	25	3	1	1
Volunteer Crew Person	0.25	0.25	0.25	250	25	250	250
Day Labor Crew Leader	0.05	0.05	3	20	1	20	20
Day Labor Crew Person	0.25	0.25	3	250	8	250	250

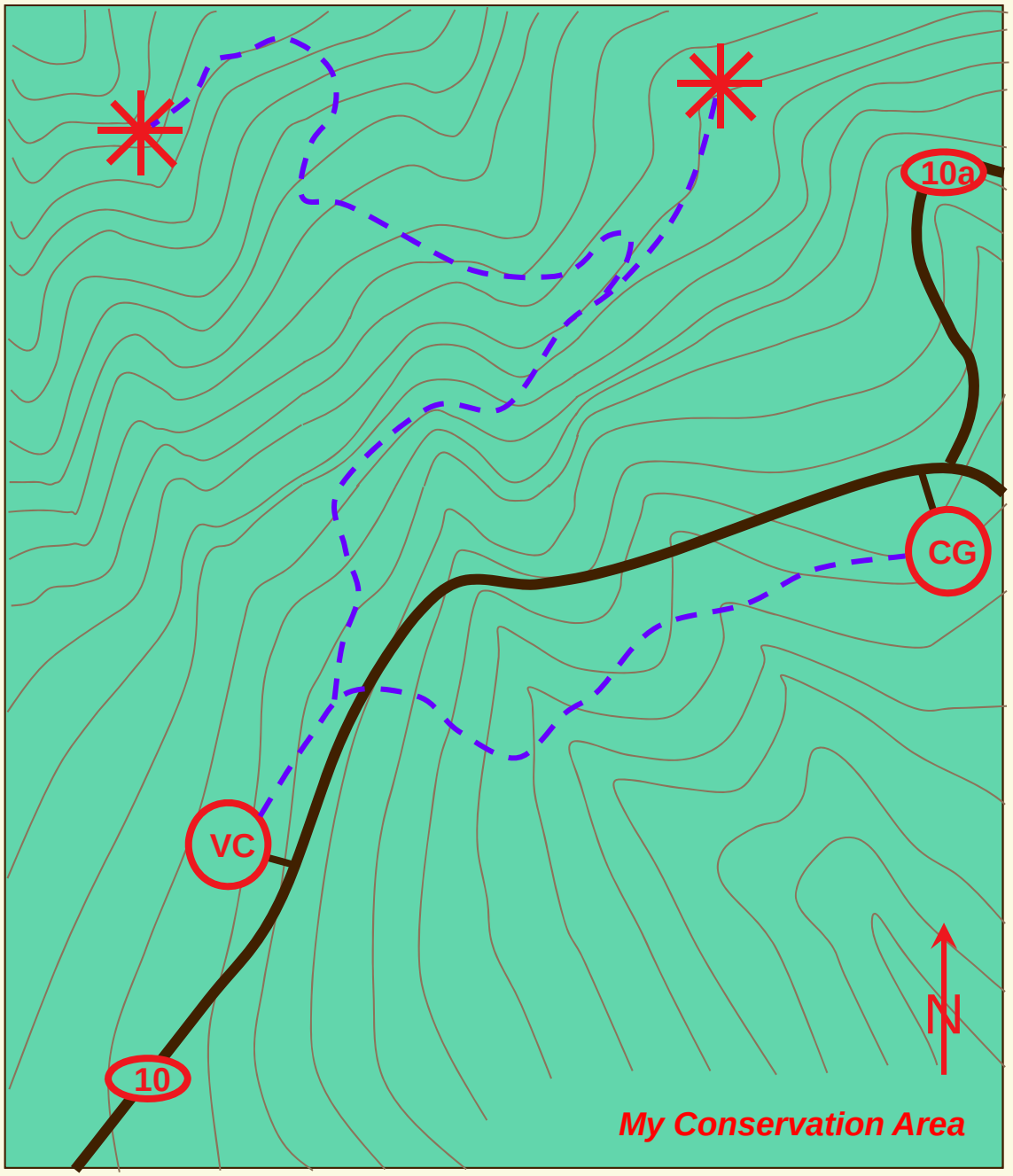
NOTE: ***Armor & Restoration*** projects usually require significantly more investment of resources than other projects require.

Patience?

Knowing when trail corridors are unsustainable and must be relocated to sustainable sites, and having the ***Patience*** to do so is the foundational sustainability ethic. Establishing a sustainable corridor and implementing it according to sustainable ethics is just the start of a long process. Spot improvements, maintenance, rehabilitation and some armoring are understood to be required in most corridors over long periods of time.

A happy trails day volunteer at ***"Trails Day at Lory State Park"*** in 2002 with then-Park Manager Dick Fletcher.

Physical Planning Criteria Summary



Existing cross slope ranges are generally moderate. Approximately 55% of the property has cross slopes of 10 – 60%; approximately 15% over 60%; and approximately 40% of the parcel is in the less than 10% range.

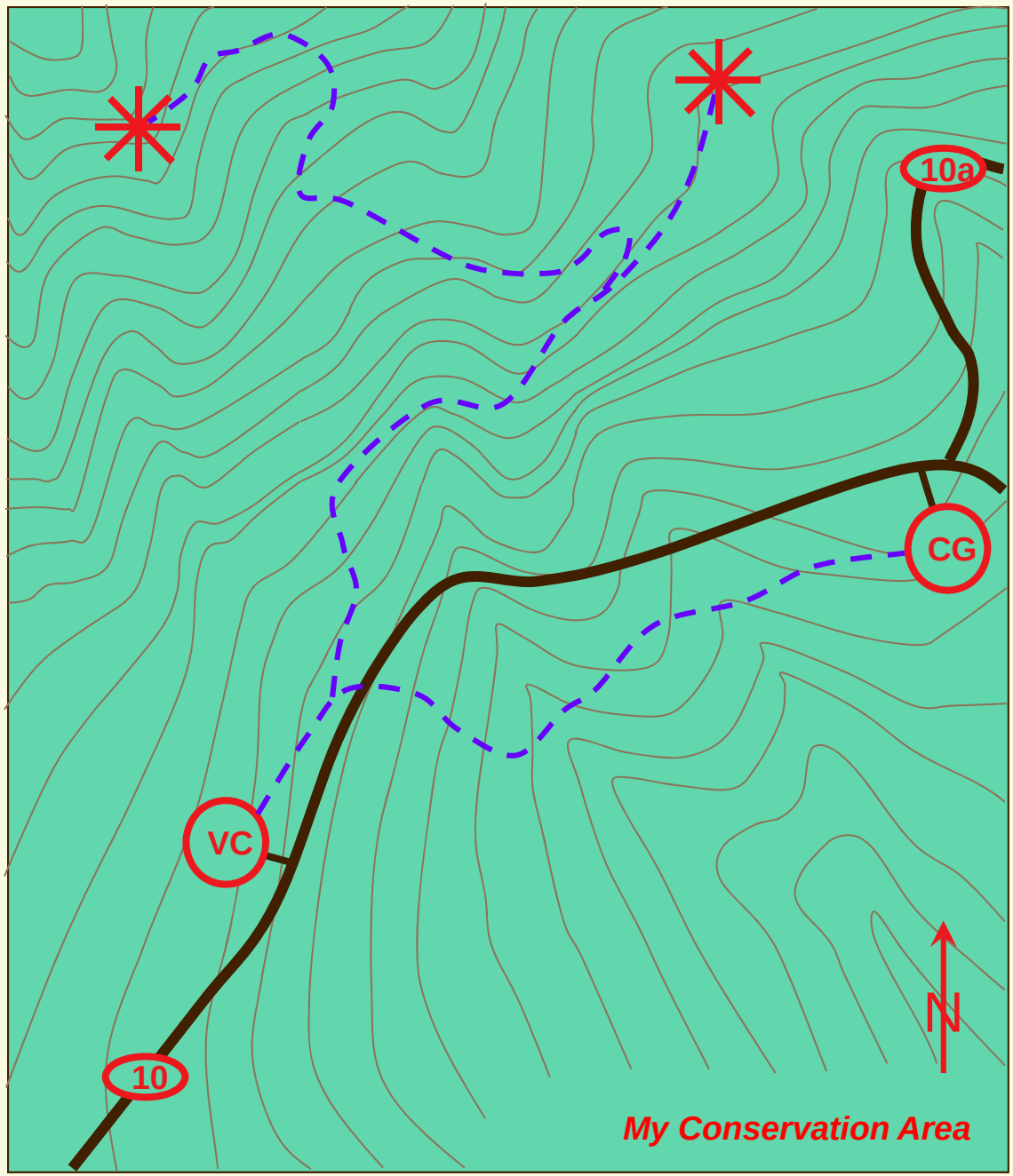
There are several rock outcrops on the property, a hazard, as they are fragile rocks and erode easily. Elevations are moderate, between 6,000 and 7,000 feet, which are moderate.

Approximately 60% of the parcel has an aspect of south; approximately 25% of the parcel has an aspect of east, and approximately 15% has an aspect of west. No land on this parcel has a north aspect.

Some of the open lands have substantial topsoil. The more upland slopes are have predominantly coarse soils. There are several intermittent streams on the parcel.

The Eastern Plains of Colorado extend as far as the eye can see east of the foothills of Colorado's Front Range. The cross slopes in the foreground are favorable for trail corridor locations.

Base Map / Existing Conditions



Summary

This conservation area was acquired by a conservation non-profit organization and transferred to a land management agency. It originally was a homestead and cows were run on this property, as there are many grassy openings. When the land was acquired, game and cattle trails were converted to trails. Currently a trail dead-ends at the waterfall, coming in from the side, offering an uninspiring view.

There is a scenic viewpoint which is taken advantage of.

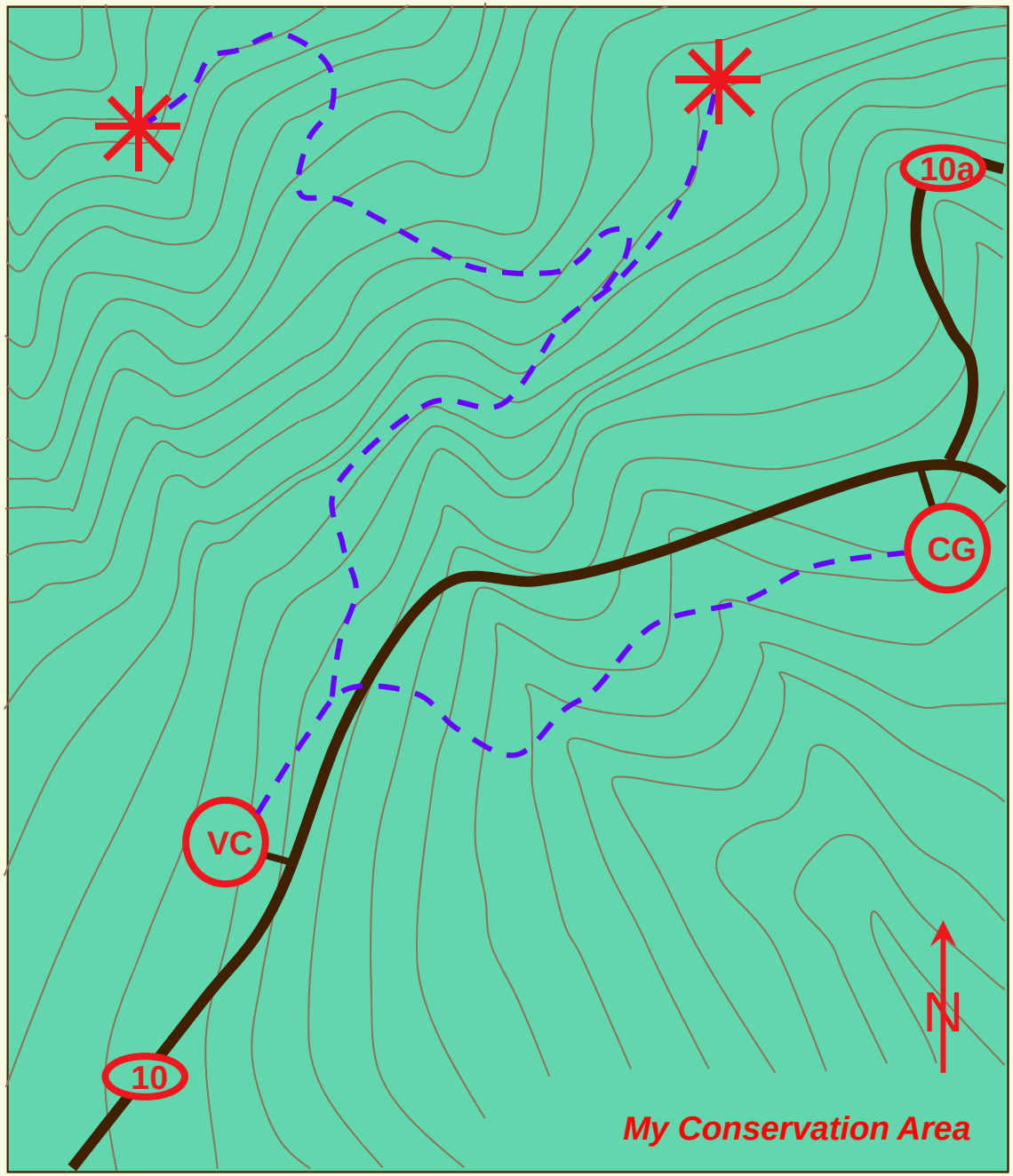
Climate

Climate is semi-arid, with most moisture falling as snow from December through April totals 150 inches per year. Frequent summer thunderstorms occur, and can drop 1” of rain in just one hour. Frost depth is 40”. Winds are from the northwest in winter and can be severe. Summer winds are predominantly from the southwest.

Geographic Context

This parcel is about 50 miles from major population areas, which invites year-round users. Local destination resorts publicize the area as a great place for weekend getaways and recreational activities. Now that the park has been open for several years, neighboring conservation land managers are also encouraging trail connections and increased trail use.

Landscape Characteristics



This parcel would be characterized as Montane Forest in the Colorado Ecosystem types, and sits at the base of several mountains which rise to over 10,000'. There are several of Colorado's popular 13,000-foot peaks just 10 miles away.

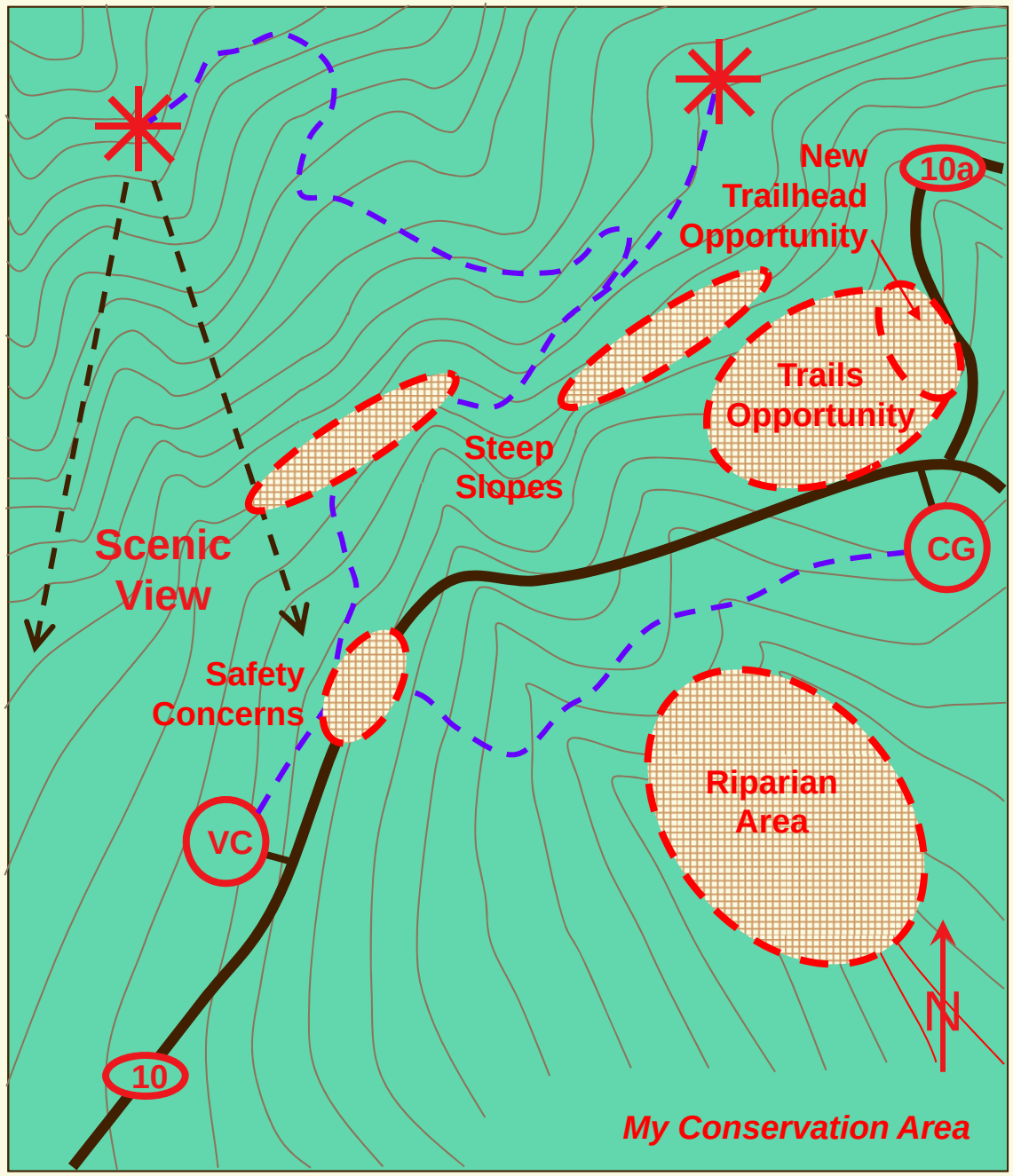
Ponderosa Pine is a dominant tree in this area, with scattered pockets of Aspen as well as scattered under story plants. The Ponderosa Pine forest is mature, and park-like in nature. It has not burned in over 100 years. On-site views are attractive due to the openness of the forest stands.

The landform is bold in nature but is dwarfed by the higher peaks nearby.

Off-site views are impressive, as the valley to the south is dramatic, with a clearly western flavor of hay fields and ranch roads.

Texture in the landscape is an important landscape characteristic to consider when implementing trails.

Annotated Site Analysis

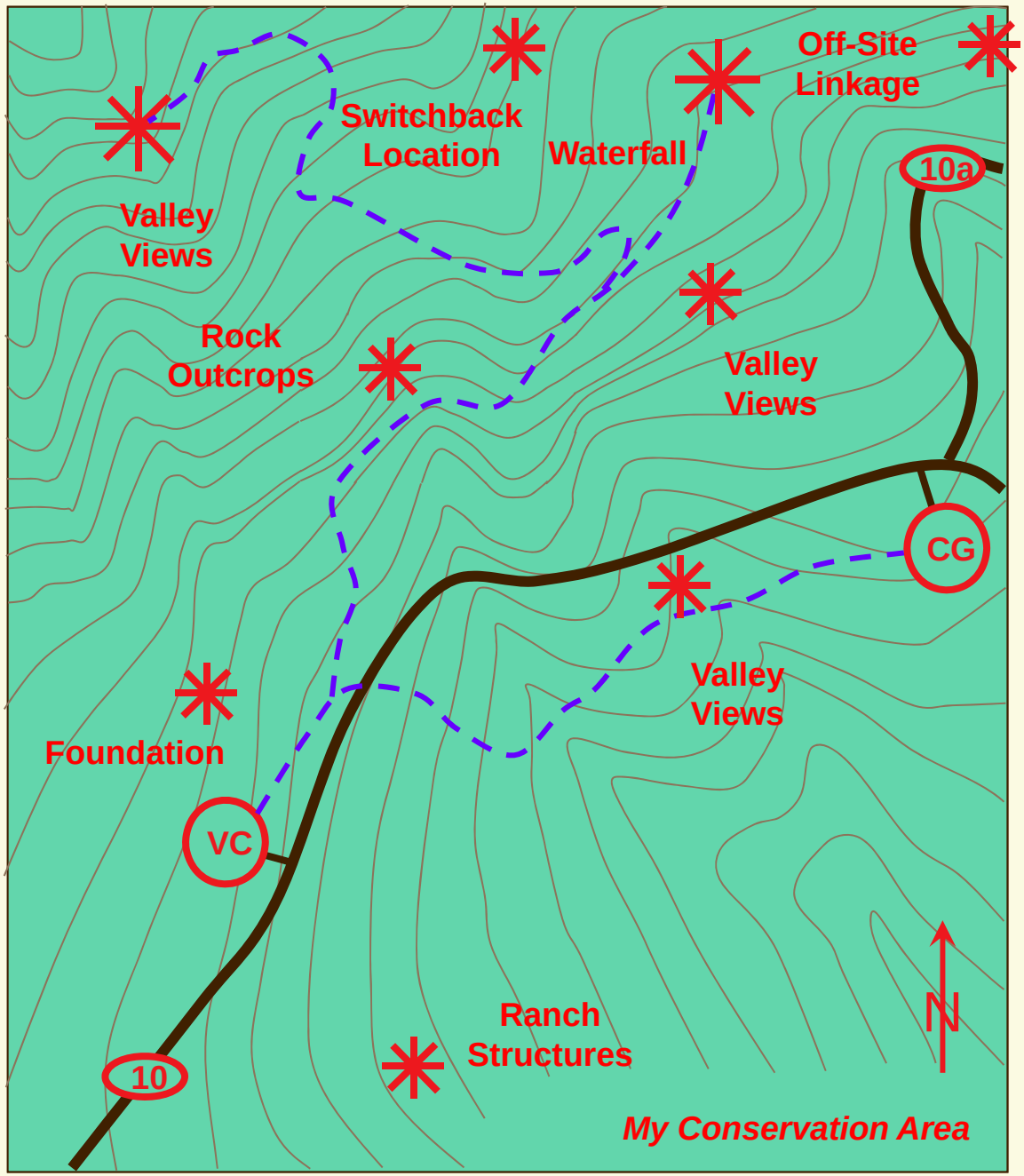


Summary

- Scenic views to the valleys and ranch lands below are to be capitalized upon.
- Steep slopes are to be avoided.
- County Road 10 is crossed in an unsafe location, and the trail should be re-routed to a safer location.
- Neighboring land offers the opportunity for network linkages, and there is a gentle slope where a new trailhead can be established.
- An opportunity exists to approach the waterfall from below, a more desirable observer location.
- Constraints, such as property boundaries, are not a concern in this project.

Nearly flat two-track ranch roads usually become muddy when converted to trails. They are inherently unsustainable.

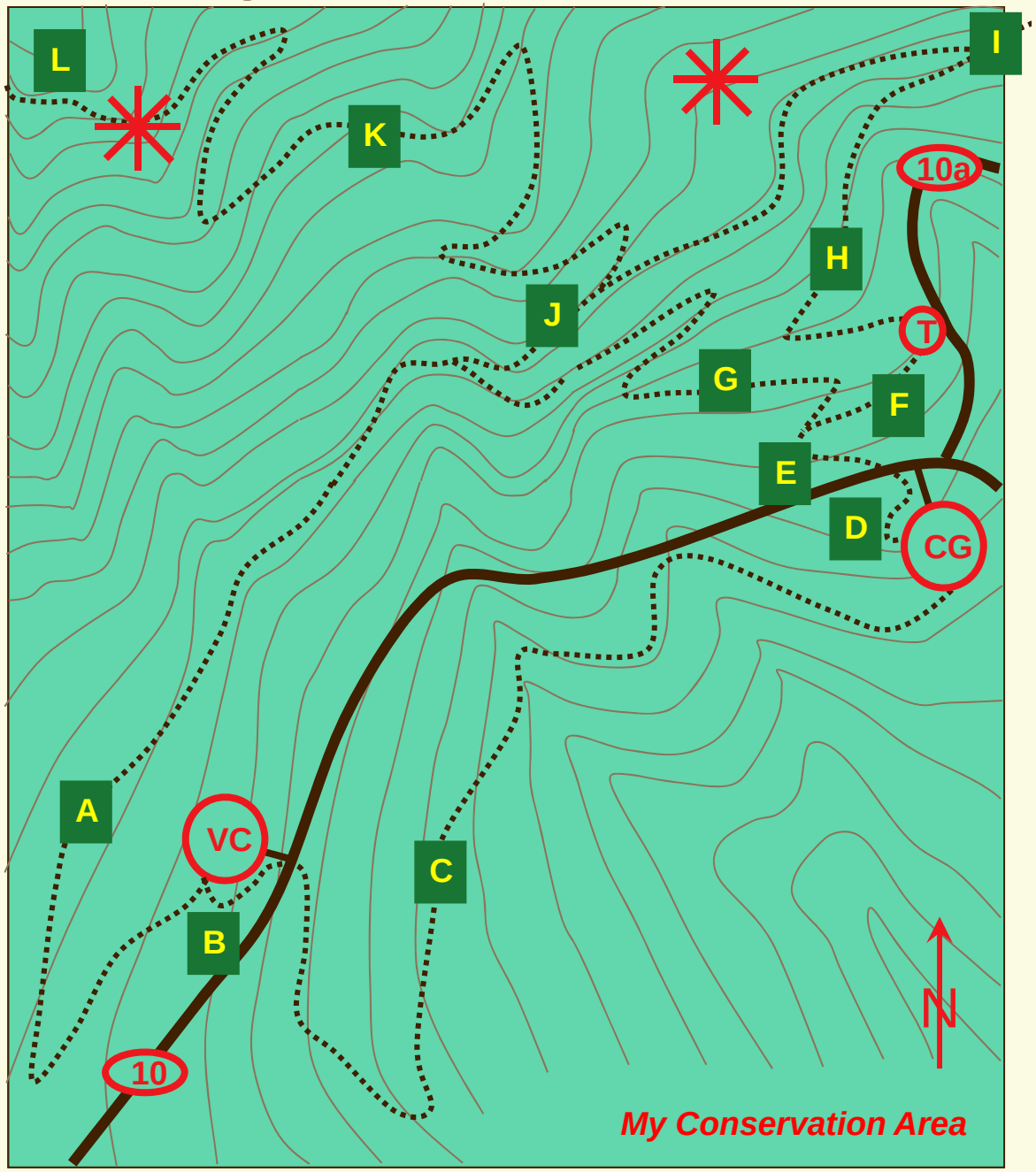
Corridor Control Points



Woodpecker snags or elk rubs may be desirable places to bring a trail. Scenic viewpoints have long been identified as desirable trail features to include along a trail. Cultural resource remnants, such as ranch structures and foundations may be desirable places to bring trail users. Rock outcrops, in this case, are corridor constraints, places to avoid. Off-site linkages are key to successful network connections and increasing trails-related benefits.

Discovery of natural and cultural resource values strengthens the overall recreation experience, as is the case with this child and an elk rub.

Summary for Mountain Trails Plan – Segment C Summary



Trails that link appropriate origins and destinations with appropriate intermediary linkages form the basis of a ***Mountain Trail Plan***. Most of the identified corridor control points are accommodated in this plan.

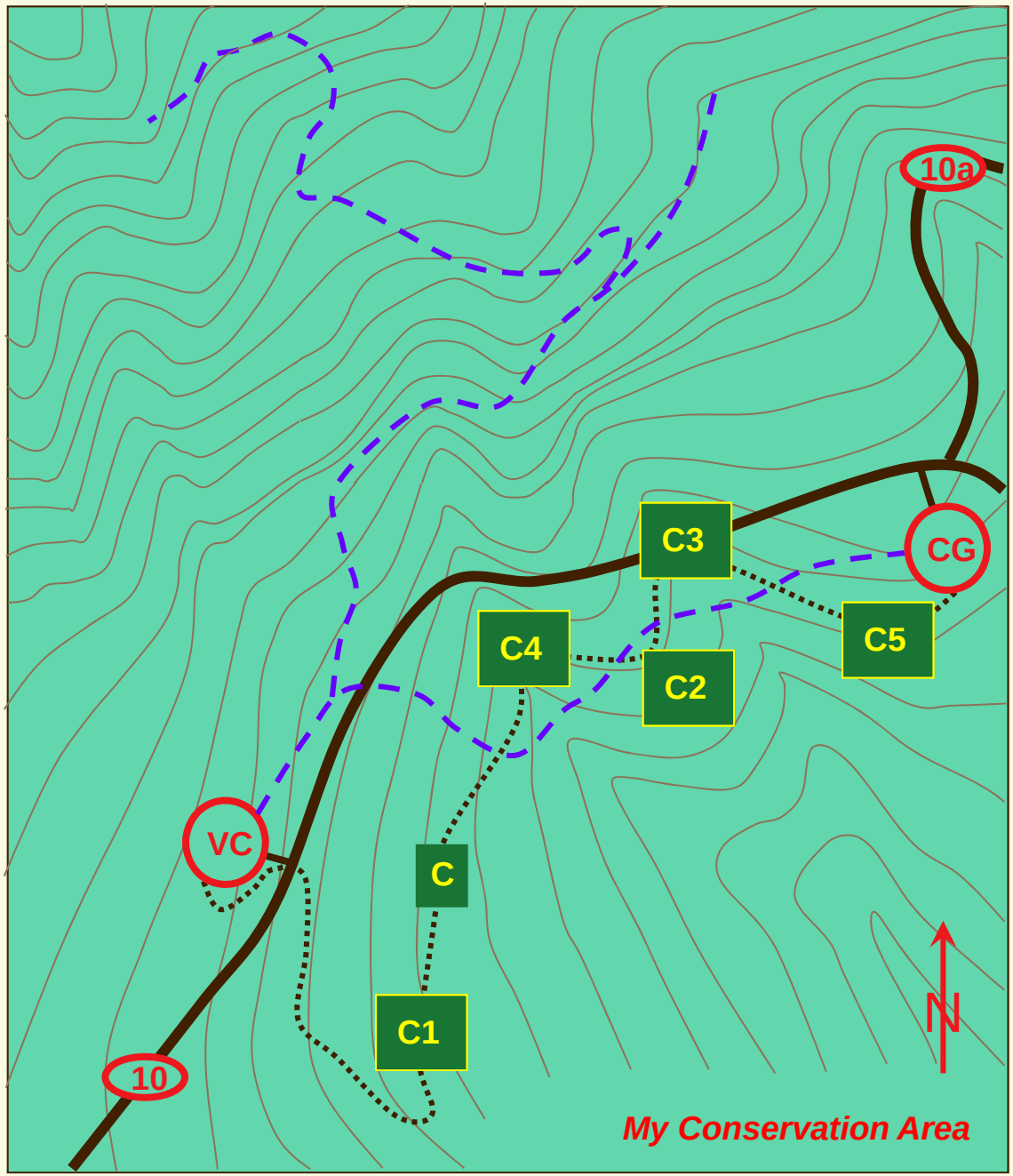
Establishing this plan allows resource professionals to have input into corridor locations, allowable uses, and potential resource impact determination.

Tabulating origins, destinations and linkages for each trail corridor, combined with describing the trail purpose, elevation gain, anticipated trail length, appropriate users types, and interpretive story opportunities yields the framework for the trail plan.

Segment C (Example)

- Segment C originates at county road 10, traverses southeast to an appropriate switchback location (***Corridor Control Point***), then heads north and northeast to its destination, the campground.
- The purpose of Segment C is to provide multiple use access to the lower elevations of the park and to connect the visitor center and Segment B with the campground.
- The estimated length is 1.2 miles, with a vertical change of approximately 120 feet for an average profile grade of about 2%.
- Prevailing cross slopes are moderate.
- Appropriate uses are hiker and mountain bicyclist.
- Interpretive stories include cultural resource history, riparian values and forest ecology.

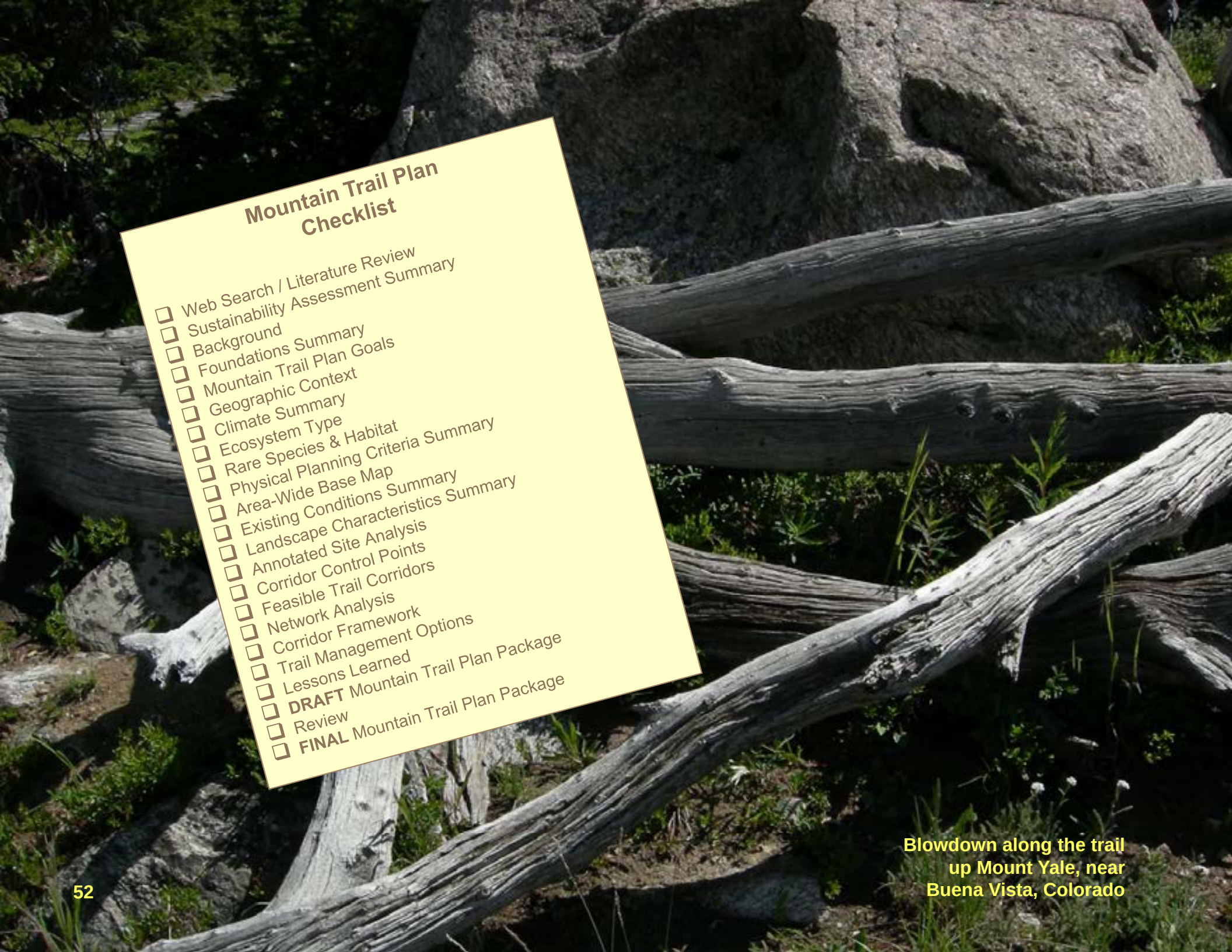
Corridor C Implementation Actions Sequence



Patience is a virtue! It is also a foundational ethic of sustainability as well as a project management skill key for implementation of successful trail projects. Looking over a Trails Plan for trail needs, and prioritizing corridors (C) and actions (C1, C2, C3, C4, C5) within sustainable corridors is a foundational ethic of sustainable mountain trails.

Outlining the needs of the priorities will yield insight into the appropriate crew skill level to carry out the task. Many times it makes sense to develop trails in a linear fashion, sometimes resources impacts or seasonal wildlife concerns may indicate the need to leap-frog some actions ahead of other segments.

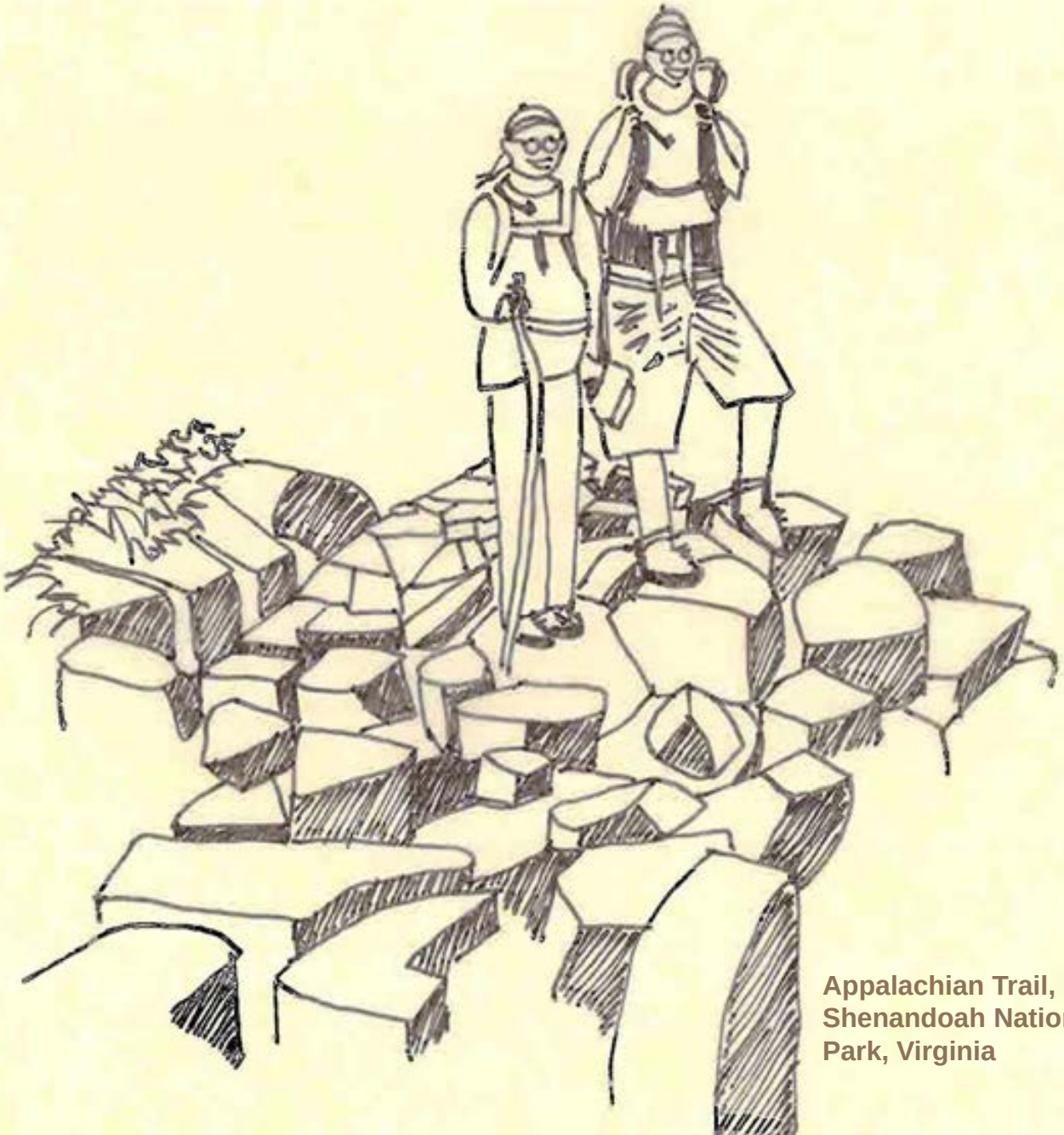
Supervisors should check more frequently with their crews and make sure that they do not have too much fun designing or implementing trails.



Mountain Trail Plan Checklist

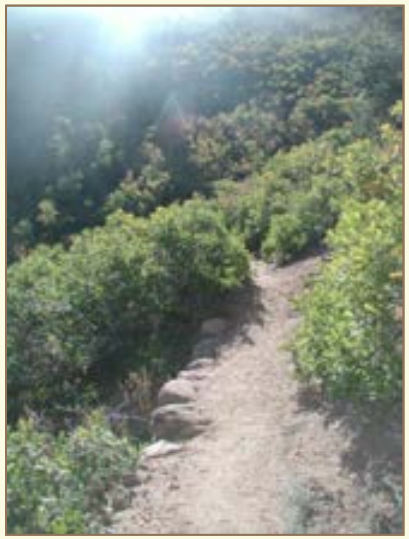
- ❑ Web Search / Literature Review
- ❑ Sustainability Assessment Summary
- ❑ Background
- ❑ Foundations Summary
- ❑ Mountain Trail Plan Goals
- ❑ Geographic Context
- ❑ Climate Summary
- ❑ Ecosystem Type
- ❑ Rare Species & Habitat
- ❑ Physical Planning Criteria Summary
- ❑ Area-Wide Base Map
- ❑ Existing Conditions Summary
- ❑ Landscape Characteristics Summary
- ❑ Annotated Site Analysis
- ❑ Corridor Control Points
- ❑ Feasible Trail Corridors
- ❑ Network Analysis
- ❑ Corridor Framework
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** Mountain Trail Plan Package
- ❑ Review
- ❑ **FINAL** Mountain Trail Plan Package

Blowdown along the trail up Mount Yale, near Buena Vista, Colorado



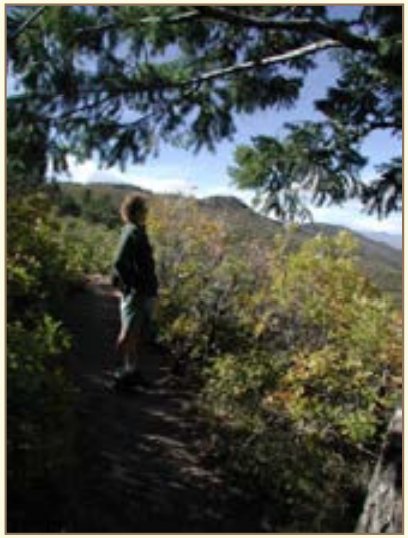
Appalachian Trail,
Shenandoah National
Park, Virginia

Atmospheric conditions create differing effects dependent upon time of day, season or solar aspect.



Seasonal color in the ground plane creates interest for the trail user and views of rock outcrops in the background.

Harmony with nature is created with this curvilinear trail – The Carpenter Peak Trail, at Roxborough State Park.

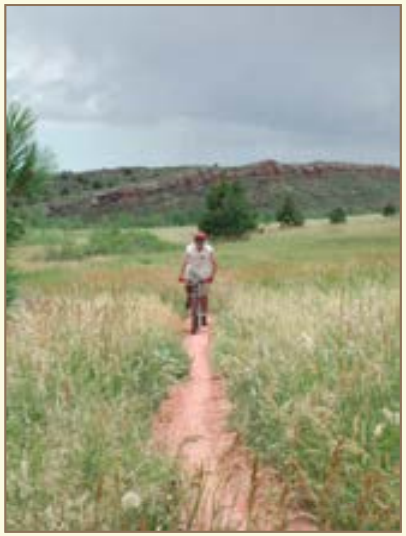


Foreshadowing Carpenter Peak at Roxborough State Park, in the distance…..

Light and shadow, color and texture … offer enjoyment to mountain bicyclists.

Use of Lodgepole Pine log for a ***Simple Foot Log Bridge*** on the Colorado Trail near Breckenridge evokes the forested character of the surrounding area.

This corral on a historic ranch lies in a saddle (***Corridor Control Point***) which is the focus of several planned trails at Golden Gate Canyon State Park.



This single track trail in Lory State Park replaced a severely eroded trail. Its rolling alignment, averaging less than 5% profile grades, is great for beginners.

General design philosophies guide the trail designer. A few good books or courses in human physiology, human responses to the environment, and basic ecology can benefit interdisciplinary trail teams. A key to accomplishing good trail design is understanding how people perceive the environment, and how they move about and enjoy the landscape.

Characteristic landscape qualities, as determined by examining design elements such as form, line, color and texture as they occur naturally in the vicinity of the corridor will form the basis of design decisions. Working with what nature has given us is a palette many artists envy.

Design principles such as sequence, axis, and rhythm; design perception principles such as enclosure and openness, enframement and expanse, contrast and accent, dominance and codominance, variety and uniformity, convergence and divergence; as well as design variables such as motion through the landscape, apparent light or darkness, atmospheric conditions, seasonal conditions, distance, observer position, scale and time would all be given consideration during design.

Physiological concerns, including posture, gait and turning radius will be considered. Molding these principles into a design is a significant challenge, but a very rewarding process.

Naturally occurring form, line, color and texture of the ***Characteristic Landscape*** is accented by this sustainable trail at Lory State Park west of Fort Collins.

This curvilinear alignment accents Hahn's Peak at Steamboat Lake State Park in northwest Colorado.

The form, line, color and texture of the Carpenter Peak Trail at Roxborough State Park matches the characteristic landscape qualities of the area.

New Trail Design

Mount Bierstadt Trail, near Denver, Colorado

Topographic Map Study is essential to successful ***New Trail Design***.

This two-track road in Colorado's high country, like most old 4-wheel drive roads, will not support sustainable trail use and therefore should not be considered for ***New Trail Design***. It is too steep and crosses the prevailing cross slope at too great an angle.

The South Rim Trail at Roxborough State Park benefited from a clean palette and is a successful example of ***New Trail Design***. It was built by **Volunteers for Outdoor Colorado** in 1988 & 1989, and was maintained by VOC in 1991.

The West Valley Trail at Lory State Park was designed and implemented according to ***New Trail Design*** sustainability criteria and was built by a variety of volunteer groups, including the **Diamond Peaks Mountain Bike Patrol**. The park's only road is in the background.

New Trail Design

Inputs

- *Typical Inputs*
- Outputs from Other Process Areas
- *Lessons Learned*

Tools & Techniques

- *Typical Tools & Techniques*
- Assemble Trail Advocacy Team
- Establish Design Goals
- Base Map
- Topographic Map Study
- Slope Analysis
- Landscape Feature Analysis
- Annotated Site Analysis
- ¼ Cross Slope Criteria
- Apply Basic Design Principles
- Network Analysis
- Review

Outputs

- DRAFT *New Trail Design Package* for Review
  - Written Summary
  - Thumbnail Sketches
  - Drawings
    - Base Map
    - Analysis Summaries
    - Trail Corridor Plan
    - Typical Section
    - Typical Details
    - Custom Details
  - Trail Management Techniques
  - Checklists
  - Cost Estimates
  - Specifications
  - *Lessons Learned*
- FINAL *New Trail Design Package*

"Probably the most crucial step in constructing a trail is to line out the entire path from start to finish." – Guy Arthur, 1975.

Field Work is best accomplished by 2 people, and with the appropriate tools including a clinometer and a 100-foot engineer's tape.

Collaboration during design is necessary to ensure all opportunities are explored and analyzed.

New Trial Design is a creative endeavor, and especially so in mountain trail projects. It involves the processes of identifying and determining the fitness of alternative solutions on the ground to ensure that they are build-able. It also involves the process of specifically determining what trail experience is intended for the trail user. Experience is the best way to accumulate good trail design skills.

Design of multiple-use natural surface sustainable mountain trails must address the most stringent of the various design parameters. Hiking, equestrian, and mountain bicycling trails have very similar criteria, however equestrian uses have the most stringent criteria. More than just a connection between two points, trails are based on a sequence which optimizes perception of the natural environment, resulting in purposeful enjoyment of the landscape for a wide range of users.

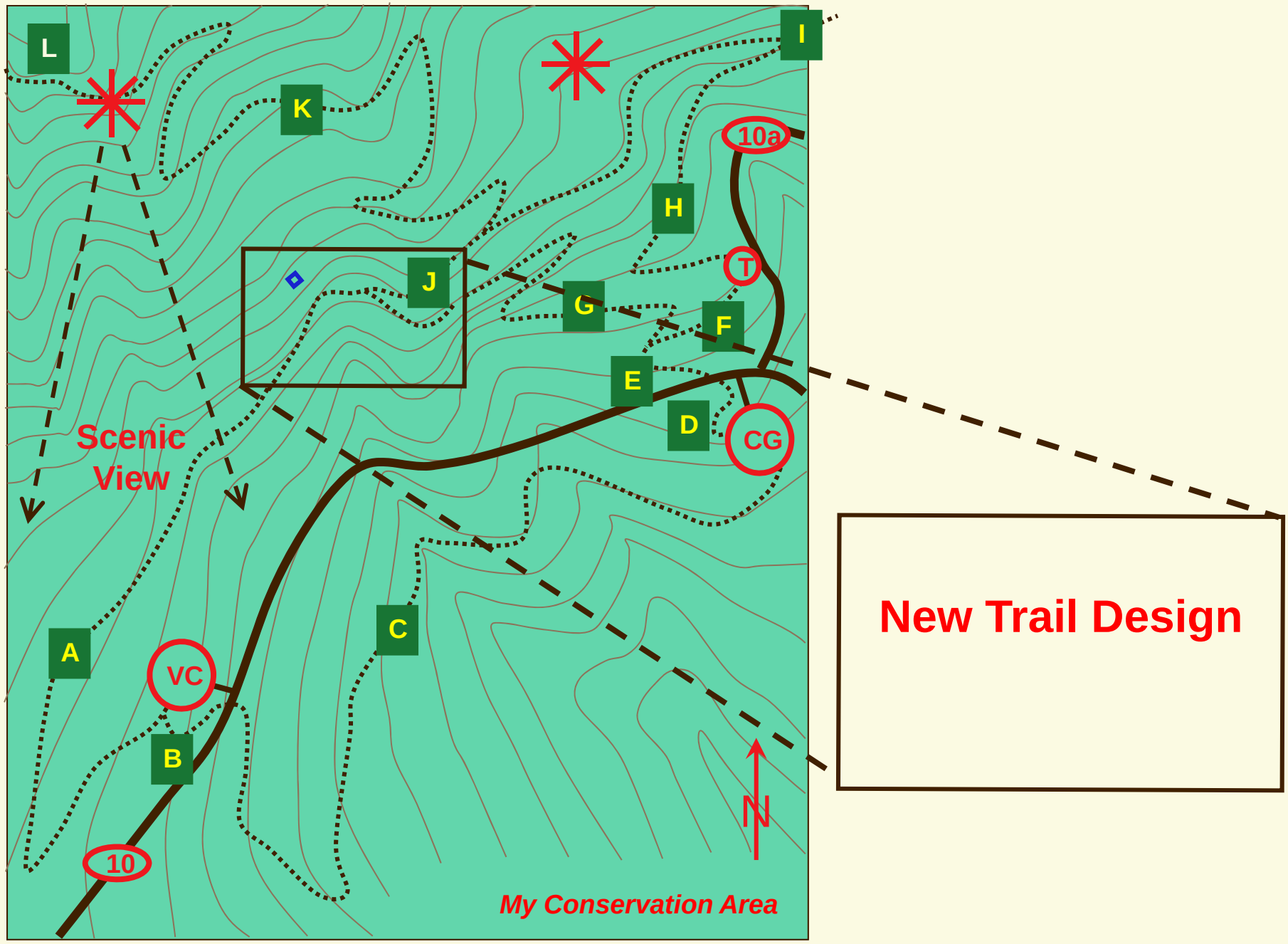
Alignment Design Technique

Once the trail corridor has been established in a ***Mountain Trails Plan***, interdisciplinary trail teams must establish appropriate intermediary control points, develop the horizontal alignment and vertical alignments, stake the trail summarize the project for implementation.

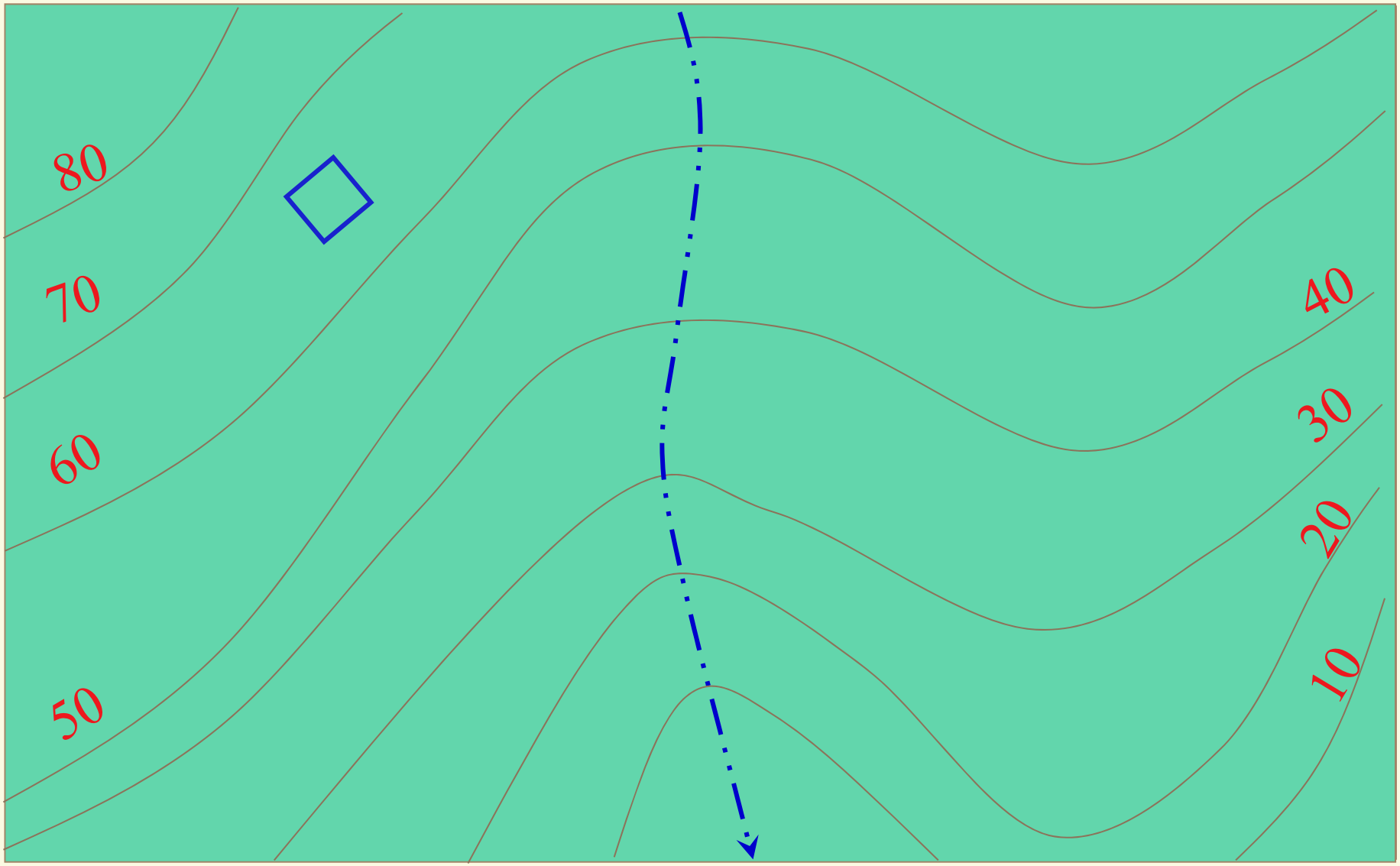
Paramount to successfully developing horizontal and vertical alignments for the trail is an understanding of profile grades as well as physiology of the various users of the trail. Construction staking for the trail defines the horizontal alignment of the trail. Many times, failure to accurately predict and describe the vertical alignment of the trail creates situations where impacts to resources occur because vertical grades are too steep for short, local sections of trails. It is therefore incumbent on crew leaders to ascertain design intent from the construction notes and adjust the vertical alignment to the proper location during construction.

Field Notes are an important ***Field Work*** technique used to document trailside decisions and communicate design intentions to trail crews.

Key Map

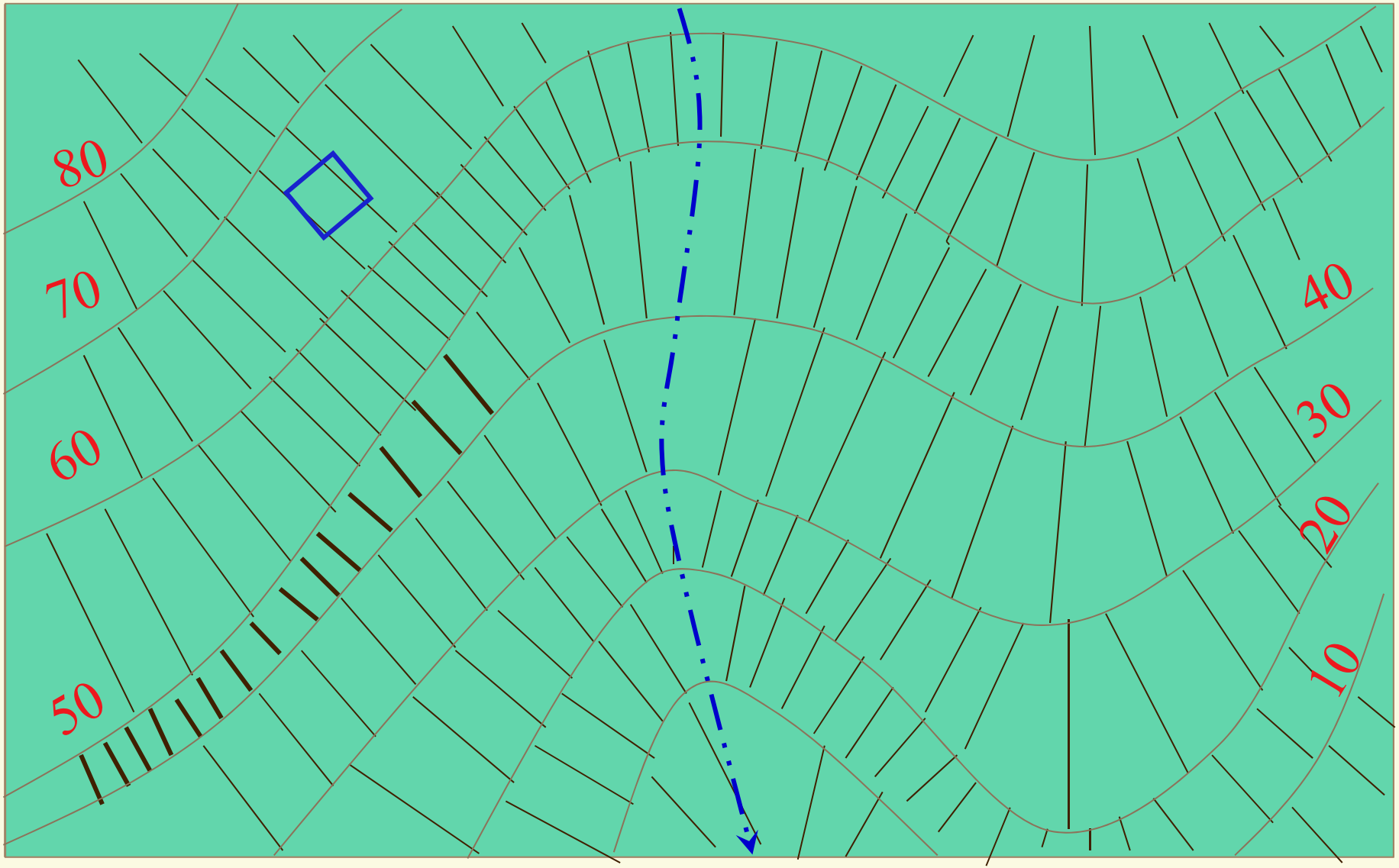

L
K
I
10a
H
T
J
G
F
E
D
CG
Scenic View
C
A
VC
B
10
N
My Conservation Area
New Trail Design

Base Map / Existing Conditions Tool



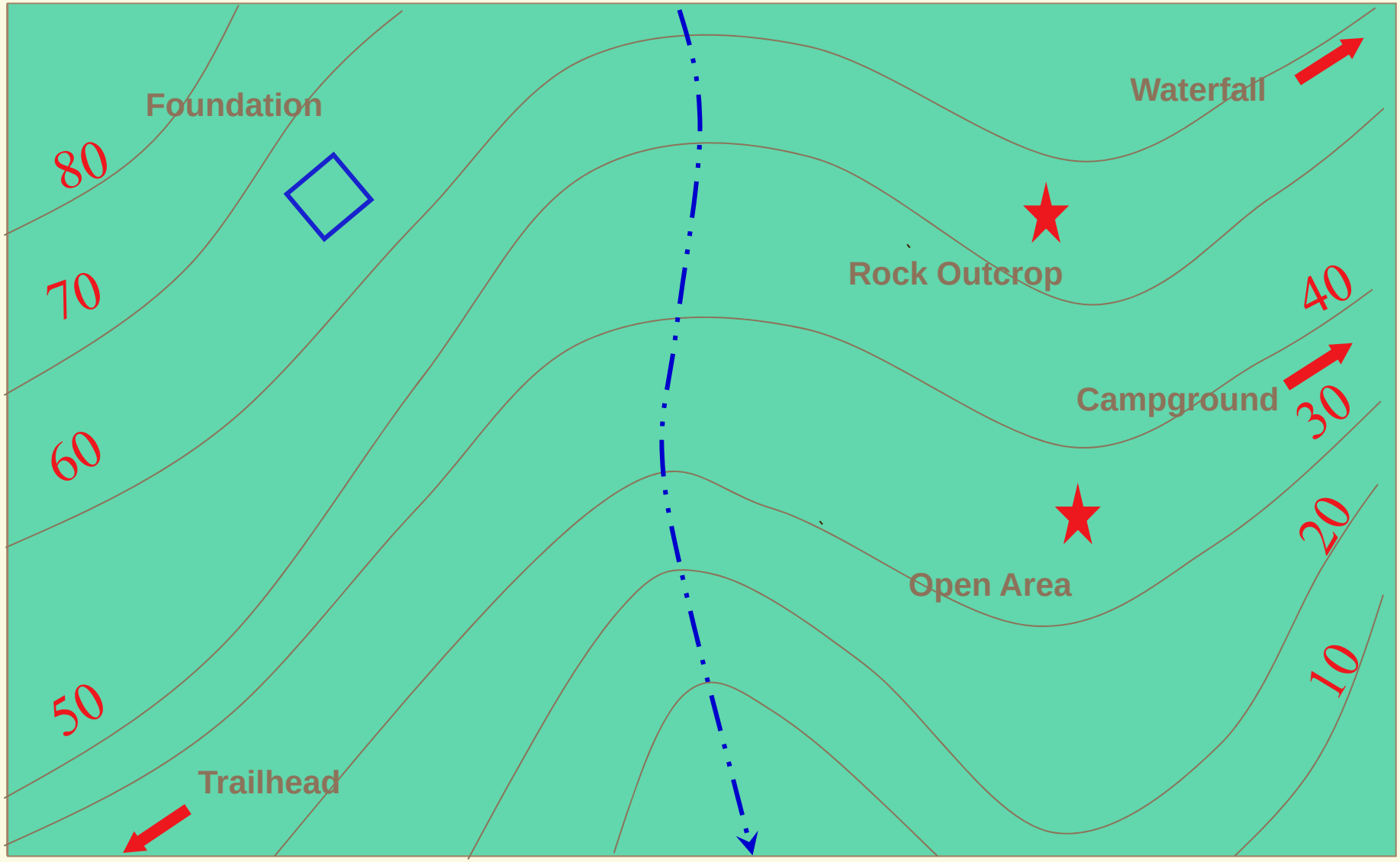
Creating a ***Base Map*** and mapping existing conditions enables the interdisciplinary team to record observations, share thoughts and exchange information.

Slope Analysis Tool



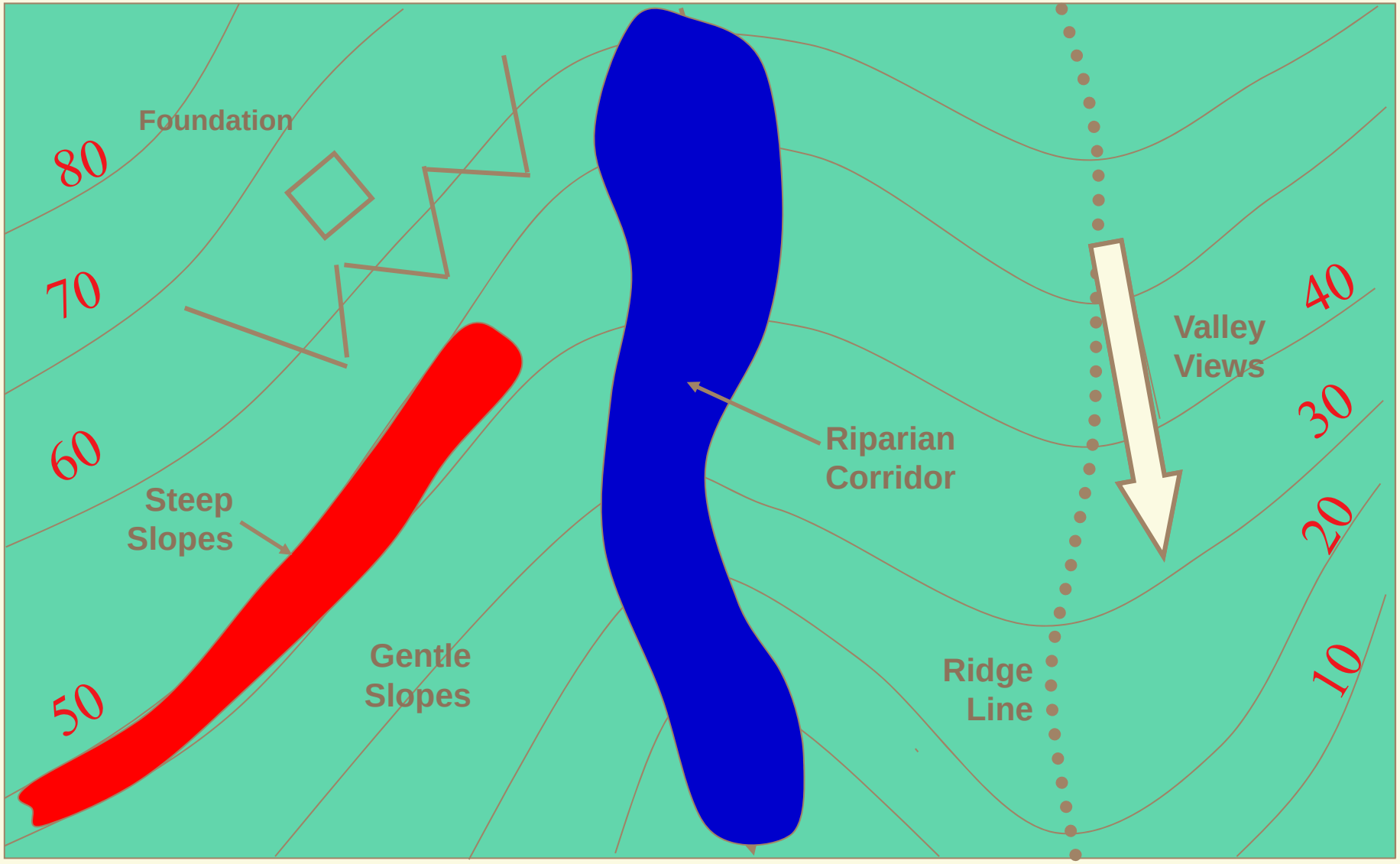
Slope Analysis is the most fundamental landscape architectural site planning tool. ***Slope Analysis*** will yield insights into the degree of modification required to fit a trail solution onto the ground. Steeper prevailing cross slopes should either be avoided or mitigated by higher investment in trailside structures, i.e.: ***Stone Retaining Walls*** and / or ***Stone Waterbars***.

Landscape Feature Analysis Tool



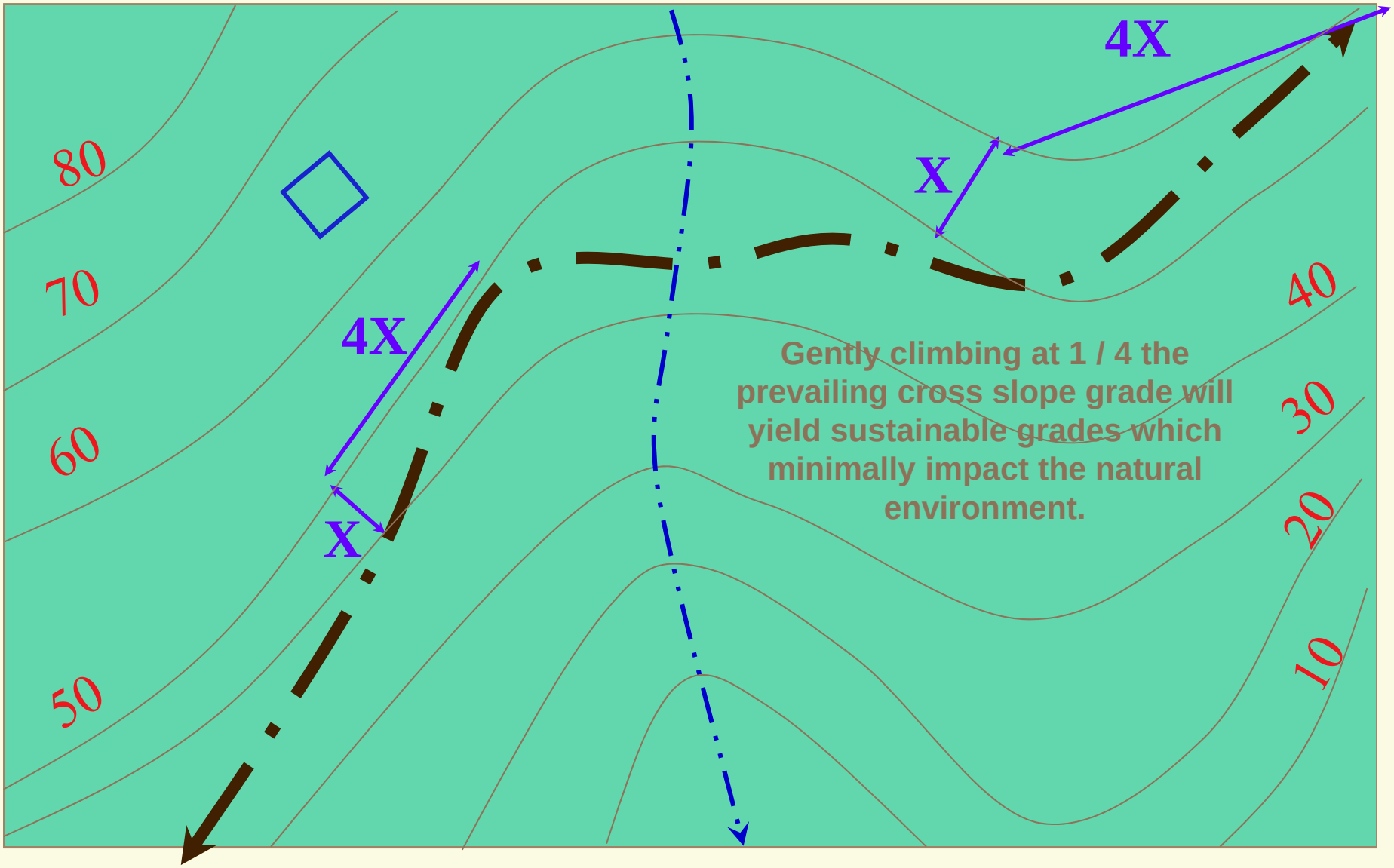
Landscape Feature Analysis records landscape features that are pertinent to the design at hand. Open areas may allow views, or on the contrary, may provide views to undesirable areas. Rock outcrops may be areas to avoid with a trail for novice hikers, and foundations may attract illegal artifact gathering.

Annotated Site Analysis Tool



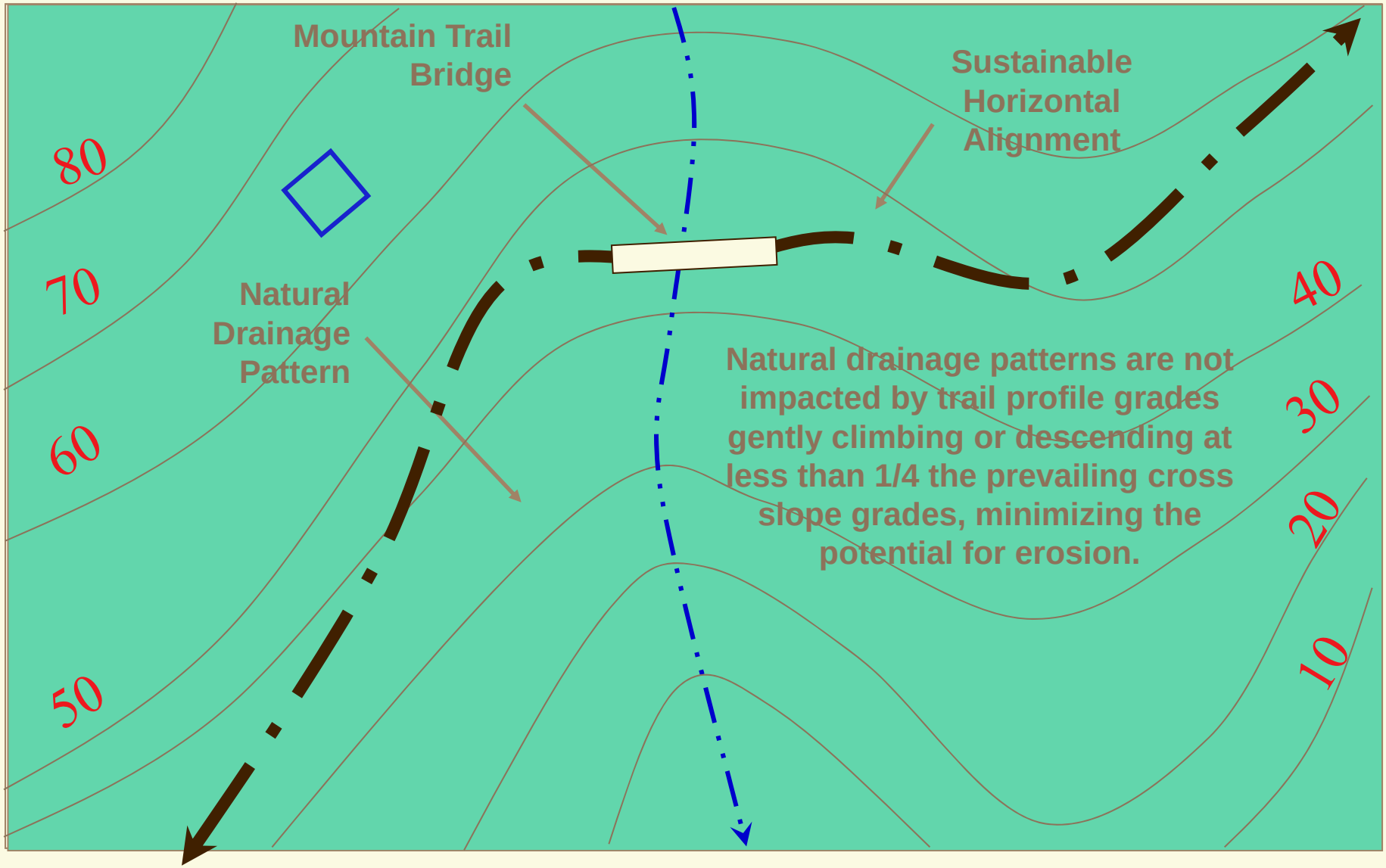
An ***Annotated Site Analysis*** is a synthesis of the previous studies. It is used for communication of site opportunities (valley views) and constraints (steep slopes) amongst the interdisciplinary team members, agency management staff and stakeholders. It is a powerful tool for ***Review***.

¼ Cross Slope Criteria Tool



Using a pair of engineering dividers or a map tool from popular topographic map software, interdisciplinary team members can layout trail alignments on the base map by first measuring the prevailing cross slope (X) and extending out four times (4X) parallel to the contour.

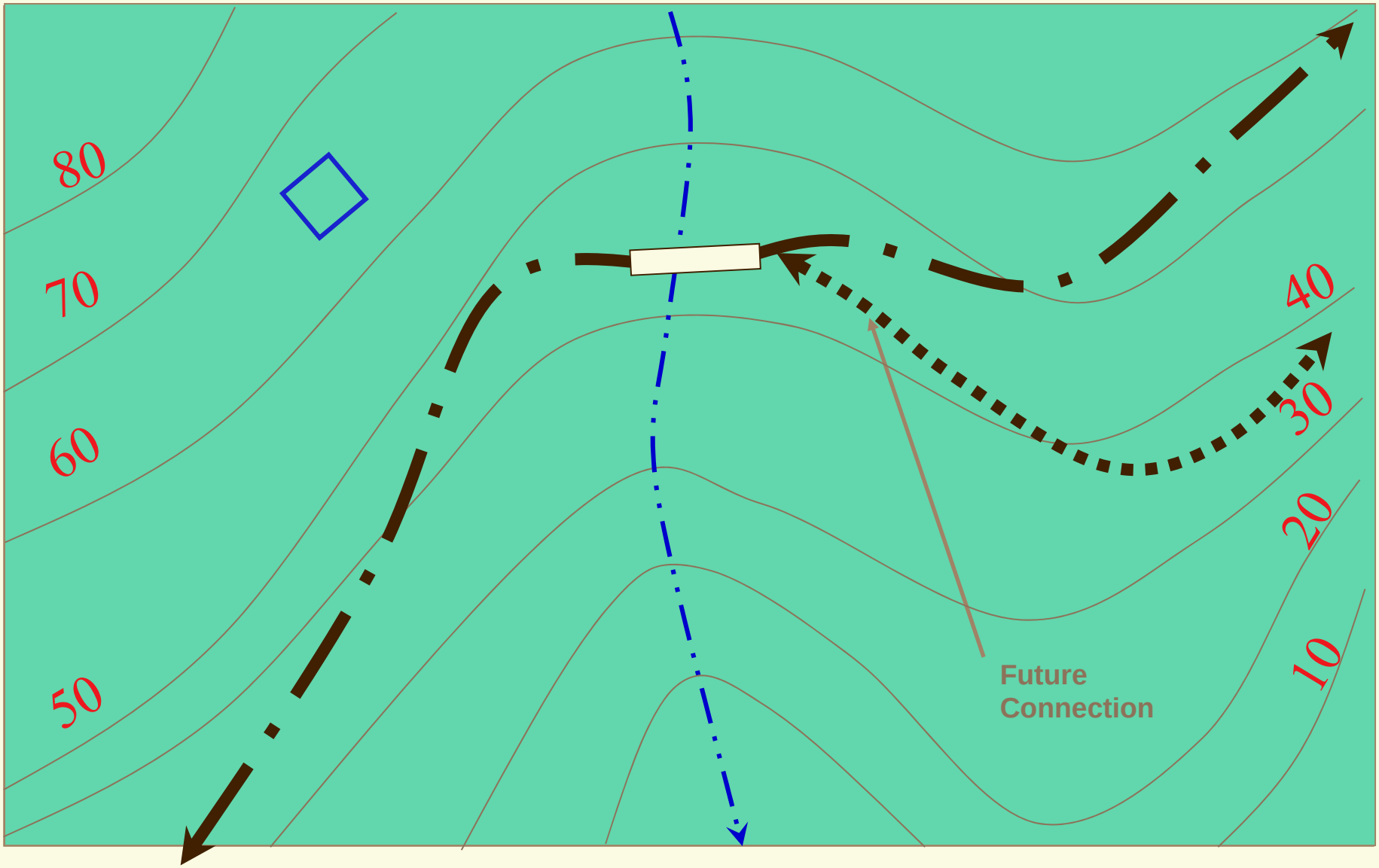
Sustainable Trail Design



Sustainable Trail Design is built upon sufficient field work which investigates all opportunities for natural surface trails which obliquely, yet gently, cross contours while climbing or descending. Significant investments, such as bridges, are located in permanent locations.

Sustainable trail corridors, like the one in the sketch plan above, will minimally impact the natural processes of the area. Recreational use will not likely impact natural resources as much as natural processes (rainfall, runoff, snowmelt runoff, and wind) will after initial impact is created by human traffic, in any form.

Network Analysis Tool



Once one alignment is confirmed, it is incumbent upon the interdisciplinary team to study future connections to ensure that future opportunities are not precluded by decisions made for the project at hand. This ensures sustainability of the trail network, not just one trail corridor.

New Trail Design – *Design Notes Technique* – Example

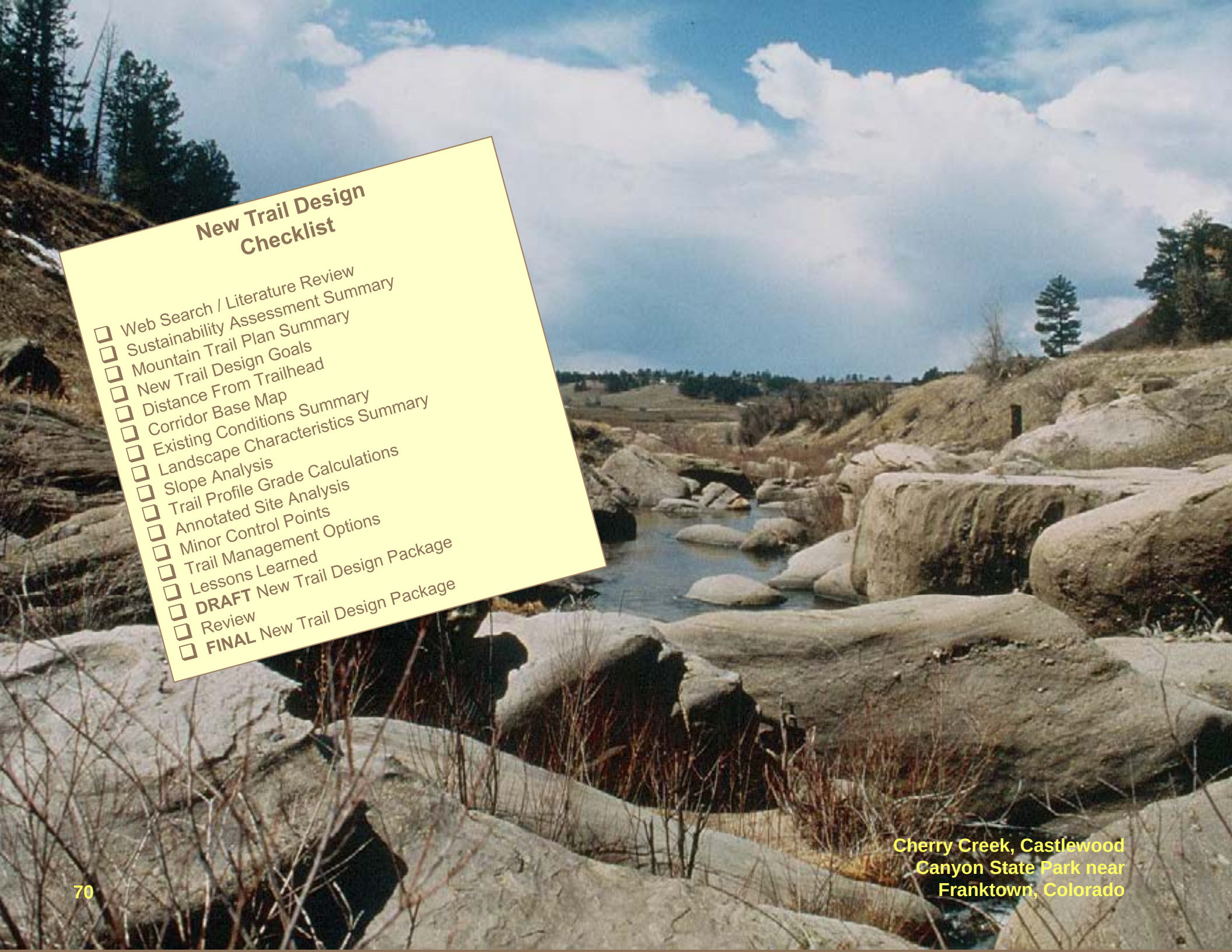
Station	Cross Slope % (Left)	Cross Slope % (Right)	Trail Profile Grade %	Azimuth	Soils	New Trail Design Notes (Example Only)
0+00	0%	0%		108d	Good	Begin Clearing D, Begin Tread Cut A, Typical Trail
			3%			
1+00	0%	0%		120d	Good	Install Trail Drains A on downhill side at 1+40, 1+75 at low points.
			8%			NOTE: Good source of stone in this area, uphill from the trail.
2+00	25%	30%		125d	Good	
			12%			
3+00	40%	45%		120d	Good	3+50 Begin Retaining Stone Wall (2' High X 10' Long).
			7%			
4+00	25%	20%		120d	Good	4+20 Begin installation of (4) Waterbars E every 50 feet.
			6%			
5+00	45%	50%		125d	Good	Begin Tread Cut C at 5+00, Typical Tread.
			7%			
6+00	45%	35%		130d	Good	
			8%			

Corridor Clearing Option	Height (H)	Width (W)
A	8 Feet	6 Feet
B	8 Feet	8 Feet
C	10 Feet	6 Feet
D	10 Feet	8 Feet
E	10 Feet	10 Feet

Tread Cut Option	Prevailing Cross Slope (%)
A	0-20%
B	20-40%
C	40-60%
D	60-70%
E	> 70%

	Drainage Options
A	Trail Drain
B	Swale Crossing
C	Paved Dip
D	Stepping Stones
E	Waterbar
F	Stone Drains

	Bridge Options
1	Simple Foot Log
2	Log w/ Handrail
3	Foot Traffic Only
4	Multiple Use
5	Boardwalk
6	Suspension Bridge

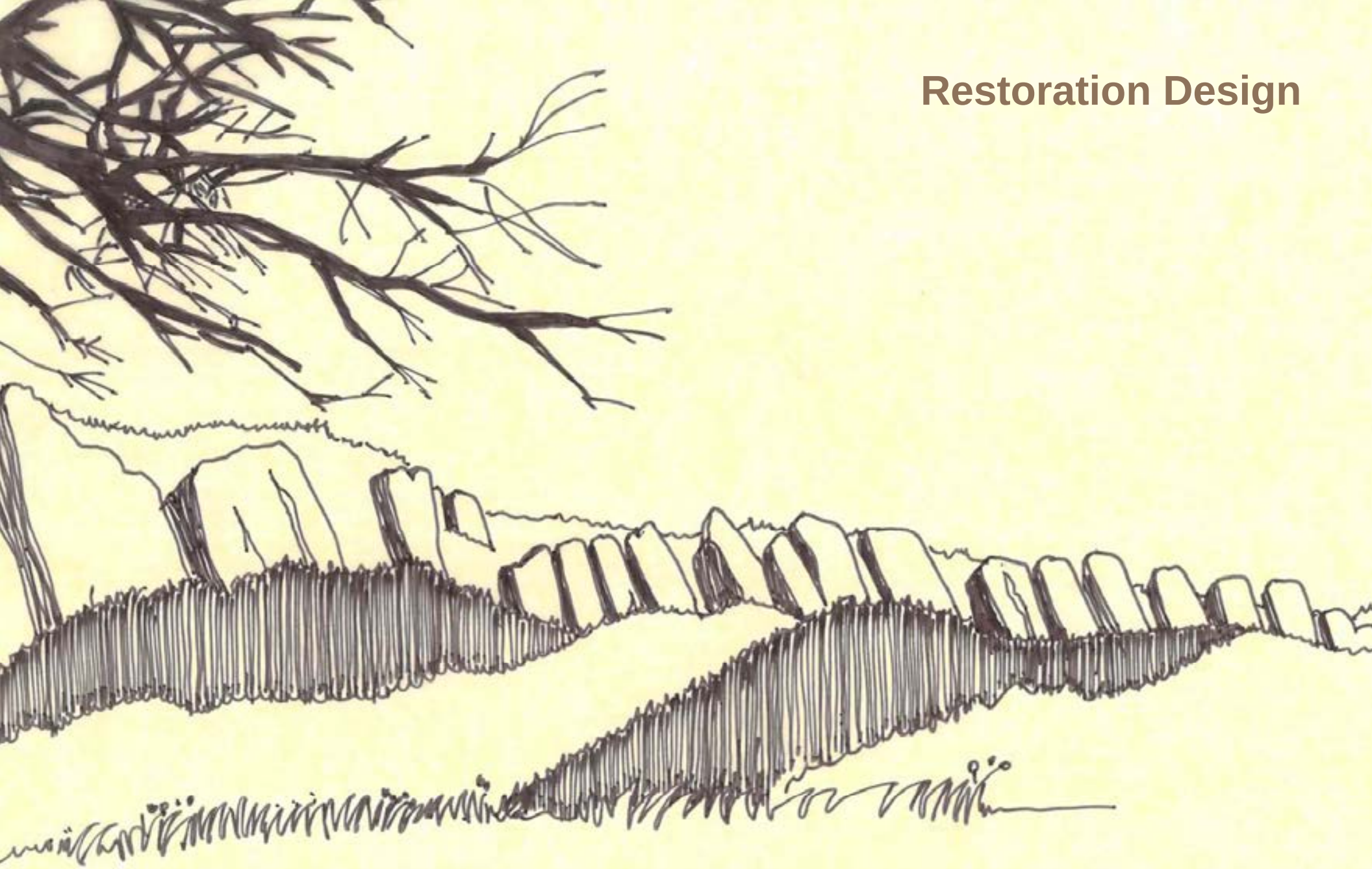


New Trail Design Checklist

- ❑ Web Search / Literature Review
- ❑ Sustainability Assessment Summary
- ❑ Mountain Trail Plan Summary
- ❑ New Trail Design Goals
- ❑ Distance From Trailhead
- ❑ Corridor Base Map
- ❑ Existing Conditions Summary
- ❑ Landscape Characteristics Summary
- ❑ Slope Analysis
- ❑ Trail Profile Grade Calculations
- ❑ Annotated Site Analysis
- ❑ Minor Control Points
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** New Trail Design Package
- ❑ Review
- ❑ **FINAL** New Trail Design Package

Cherry Creek, Castlewood Canyon State Park near Franktown, Colorado

Restoration Design



The Fountain Formation as visible
from the South Rim Trail,
Roxborough State Park, Colorado

A picture is worth a thousand words, or as in the case of these **Restoration** examples: *"several pictures are worth a million words."*

Mount Belford, 1997, 1999, 2004. ***Restoration***, in this case by the Colorado Fourteeners Initiative, is worth the significant effort required. Visitors to Mount Belford will now enjoy natural scenes where once they would have experienced significant visual impacts. Thoughtful trail planning in advance will preclude this type of impact from happening in the future.

Mount Harvard, after (above) and before (below).

Restoration Design

Inputs

- *Typical Inputs*
- Outputs from Other Process Areas
- *Lessons Learned*

Tools & Techniques

- *Typical Tools & Techniques*
- Web Search / Literature Review / Science Review
- Develop Funding Strategy
- Establish Restoration Goals
- Local Site Analysis
- Microclimate Analysis
- Estimating Techniques
- 4-Step Restoration Design Strategies
  1. Closure Strategy
  2. Stabilization Strategy
  3. Revegetation Strategy
  4. Monitoring & Evaluation Strategies
- Review

Outputs

- DRAFT *Restoration Design Package* for Review
  - Written Summary
  - Plan Drawings
  - Typical Sections
  - Typical Details
  - Custom Details
  - Cost Estimates
  - Materials List
  - Labor Estimates
  - Specifications
  - Trail Management Techniques
  - Checklists
  - *Lessons Learned*
- FINAL *Restoration Design Package*

On-site ***Review***, including management buy-in is sometimes required to ensure plan or project success, as with the New Mule Deer Trail project at Golden Gate Canyon State Park.

Restoration is a required component of trail closure and relocation projects. By integrating closure and restoration of social trails with design, users benefit from reduced confusion, increased landscape aesthetics, and well-managed natural resources.

In areas where multiple social trails exist, closing and restoring those trails helps protect natural resources by:

- Reducing habitat fragmentation;
- Maintaining adequate soil moisture levels on site necessary to support natural plant communities; and
- Creating a self-sustaining plant community that will protect the restored site from excessive soil erosion and provide wildlife habitat.

Unplanned social trails often experience high rates of soil erosion. The result is often trail braiding, trail widening, and deep erosion gullies (up to 4 feet deep and 80 feet wide in some areas of Colorado's alpine ecosystem). Mere closure of these areas is often not adequate to promote natural revegetation to occur. Restoration is designed to create conditions that hasten the recovery process that leads to a self-sustaining plant community in disturbed areas.

Implementation of new projects requires ***Restoration*** of impacted areas, as this case shows at Lory State Park near the Arthur's Rock Trailhead.

What is Restoration Ecology?

Restoration ecology is a science that strives to understand the ecological effects of human disturbance to natural ecosystems and the treatments that are most effective at restoring natural processes. The natural recovery of impacted areas is not a single event, rather an ongoing process. Restoration treatments are one step in that process, aimed at speeding up the natural recovery rate of the ecosystem and helping to create a self-sustaining plant community that has the ability to withstand the wide range of environmental variability. As such, a practitioner does not attempt to recreate a plant community with one set of treatments but rather works to determine an adequate level of treatments necessary to start the impacted area on a natural path to recovery.

Restoration Ecology

Restoration ecology has been defined as the practice of re-establishing natural ecosystem processes responsible for that ecosystem's form and function, including major biotic and abiotic components, on lands where these forces have been interrupted. When land managers take direct action to restore a site, this is referred to as active restoration. Passive restoration relies exclusively on management policy and other indirect options as a means of restoring the desired condition. For social trails that have experienced minor impacts, the site could be restored passively, by merely closing the social trail, providing an alternative trails, and installing adequate signage.

The damage on many public lands in Colorado is often to a higher level of impact, requiring active restoration to achieve conservation goals. Complete loss of native soil and vegetation, and disruption of hydrologic patterns is all too frequent and regrettable.

Why Restoration?

In most trail projects, a common goal is to reduce the number of social trails that exist on the landscape. However, creation of a sustainable trail is yet another disturbance to the landscape. In order to mitigate this disturbance, and reduce the overall effect of trails on the landscape, we are obligated to restore all closed trails to a state that sustains a cover of native vegetation and reduces erosion.

It is difficult to realize the value of an ecosystem until we attempt to restore it. In fact, many citizens demand restoration to be part of natural resource projects and dedicate their time as volunteers to implement restoration projects. Restoring social trails can improve water drainage patterns, rebuild the contour of the slope, reduce habitat fragmentation, and create a self-sustaining plant community.

Funding

Grant funds are available for restoration activities from local and national foundations as well as government agencies. Many trails grant programs also provide funding for restoration activities associated with trail construction projects. Volunteer labor is a great way to provide stewardship opportunities for the public, and a great way to match grant funds.

Cost estimates for restoration vary depending on the level and extent of disturbance, desired restoration goals, and whether or not volunteers are utilized to complete the project.

Goals

Restoration goals often include stabilizing slopes, recreating a natural plant community, and achieving *"visual closure"* of social trails. Besides the conservation goals associated with restoration projects, a common social goal is to maintain landscape aesthetics. This is especially important in federally designated wilderness areas and other sites where local management goals are established to enhance the quality of the recreational experience. An additional goal may be to facilitate research aimed at improving the understanding of restoration ecology or the practice of restoration.

Overriding goals for restoration projects include:

- Determine the extent and level of damage;
- Determine the appropriate levels and types of restoration treatments to apply;
- Calculate time estimates and material requirements for completing the project;
- Prioritize restoration work items and sections to ensure that work will be completed according to project goals and timelines; and
- Establish a system for monitoring effectiveness of treatments. This usually includes before and after photos, but may also include monitoring transects and / or plots.

Pastoral scenes such as this draw people to the mountains of Colorado. ***Restoration*** of impacted areas while implementing new projects will strengthen Colorado's future.

Restoration Design

Field work is necessary to determine labor and material requirements of the restoration project. Breaking down each project into individual restoration sites facilitates site-specific designs. The sites often correspond to a distinct social trail, a lengthy braid of a given trail, a unique plant community (i.e.: a riparian area), or other unique feature of a specific trail.

Before developing detailed restoration notes, it may be helpful to walk the entire section to become familiar with all of the types of disturbance along the site and what on-site resources are available, such as willows, salvageable topsoil, downed timber, and stone sources.

Restoration Design Tools & Techniques

- Assign priorities to each work item.
- Take pre-project photographs and describe their location and what they are depicting.
- Develop a site naming convention that is easy to interpret by implementation crews.
- Record the grade and aspect at a frequency (i.e.: every 100-foot station) that meets site requirements and research needs.
- The plant community should be noted at a frequency that meets site needs and research needs. This information is useful to characterize the site and provide a suggested list of plants available for crews during revegetation efforts. Plant species should be listed in order of abundance or dominance in each section (based on general observation).
- General information about soil conditions (i.e.: level of erosion, soil compaction, loss of topsoil, general soil type) should be recorded if possible.

Prioritizing Restoration Treatments

Prioritizing restoration treatments and sections within a project allows you to more effectively allocate limited resources. Several factors are considered when assigning priorities to work sites and work stations within a site:

- What is the level of disturbance?
- Will the site continue to degrade if no action is taken?
- Is the site visible from adjacent system trails?
- What financial and physical resources are available?
- What are the goals of the land management agency?

Items left to passive restoration should be monitored over time to determine if additional restoration is needed at a later date to achieve management goals. Coordination with the trail design team is necessary to determine which restoration sites and sections should be prioritized for completion during the main project season. These project-level priorities are based on available resources, coordination of site resources (i.e., turf transplants and topsoil generated from new trail construction), and land management goals.

Field Work & Field Notes. Customizing field work and field notes particular to the ***Restoration Design*** process will assist volunteers in ***Implementation*** activities which will help restore natural conditions & processes to the landscape.

Restoration Design Summary Package

The ***Restoration Design*** package is put together after the project is designed, the site conditions are adequately analyzed and characterized, and labor and material requirements are determined. The goal of the plan is to provide an understanding of the level of restoration to be accomplished on the site, as well as a schedule for completion. To develop an effective restoration plan:

- Address existing land management goals and objectives;
- Provide a general restoration project summary at the beginning of document;
- List materials to use, especially if non-standard;
- Explain how the plan mitigates legislated wilderness or other special management concerns;
- List species of concern that will be protected by the project;
- Summarize labor and material needs;
- Include baseline (i.e., pre-project) photos;
- Describe the restoration techniques to be employed; and
- Include a general site description for each restoration site on the project.

Restoration Implementation

Restoration Implementation generally occurs at the same time as trail construction***.*** Before implementation of ***Restoration*** projects begin, it is best is the project manager coordinates with field staff to ensure that salvaged topsoil and vegetation resources from trail construction are made available for restoration. The timing and amount of these resources are crucial to minimizing restoration efforts and maximizing results.

Volunteerism & Restoration Projects

Restoration treatments are well suited to nonprofit agencies and / or individual volunteers whose mission is compatible with restoration ecology. Restoration projects usually are repetitive in nature and usually can be accomplished by novices while still achieving high quality results. Highly trained staff should be responsible for doing the most difficult restoration work, while volunteers are employed to complete revegetation work, check dams, and other less-technical restoration work when appropriate. Seed collection and seeding, which takes place in the fall, should be completed by volunteers and led by trained staff.

The Willow Creek Trail provides a recreational respite for urban and suburban visitors to Roxborough State Park. This location was an impacted area which was been restored.

4-Step Restoration Design Strategies

Following the following four steps to successful restoration will assist land management agencies and interdisciplinary trail teams in achieving project success.

1. Closure Strategy

As long as users continue to use restored areas, erosion control and revegetation goals will be hindered. Physical structures, such as barrier walls and debris disguise, in conjunction with adequate signage are necessary to keep hikers off of the restored area. Other ***Management Options*** can also be utilized to ensure closure of impacted areas.

2. Stabilization Strategy

Stabilization of eroding social trails is often achieved by installing check dams, excelsior wattles, monowalls, or ***Stone Retaining Walls***. Diverting water off the trail, by means of outsloping, ***Stone Waterbars***, and ***Trail Drains***, is another way to reduce erosion. Installing erosion matting, especially associated with seeding, is another way to control erosion. Physical structures and erosion matting are only short-term means of controlling erosion. Within 1-5 years many erosion control structures will become full. If adequate vegetation cover is not achieved in this time frame erosion will continue between erosion control structures and many structures will begin to deteriorate. Erosion control matting is also subject to rapid deterioration (2-3 years), and adequate vegetation cover must be achieved in this time period to control erosion over the long term. Regardless of the techniques used, adequate vegetation cover is the only means to achieve long-term erosion control and should be integrated with all erosion control structures.

3. Revegetation Strategy

Once erosion is addressed, revegetation treatments should be applied to achieve long-term slope stabilization and develop a self-sustaining plant community. Revegetation can be accomplished using transplants (nursery stock, vegetation plugs, or turf blocks), seeding (preferably native seed), cuttings (willow stakes or wattles), or a combination of the above. It is important to use the right plants for the right site (i.e.: don’t use wetland plants on dry hillsides, and vise versa).

4. Monitoring & Evaluation Strategies

Monitoring is the process of making periodic observations to detect changes or trends. Not all ***Restoration*** techniques will be 100% successful. Therefore, monitoring and evaluation are important to document ***Lessons Learned***. The success of any restoration treatment depends largely on appropriate implementation and subsequent weather patterns. If implemented correctly and subsequent weather is favorable, few, if any, of restoration treatments should require ongoing maintenance.

After restoration treatments are applied, monitoring the site for 3 years will help determine how successful the project was. Monitoring could be as simple as taking post-project photos and comparing them to pre-project photos. If resources allow, various sorts of monitoring transects can be used to provide more accurate data. In either case, monitoring data, once analyzed, will help to determine if further restoration is necessary or if management goals have been met.

Seed collection is critical to ***Restoration*** project success.

Plug transplants are common Grassland and Alpine restoration actions.

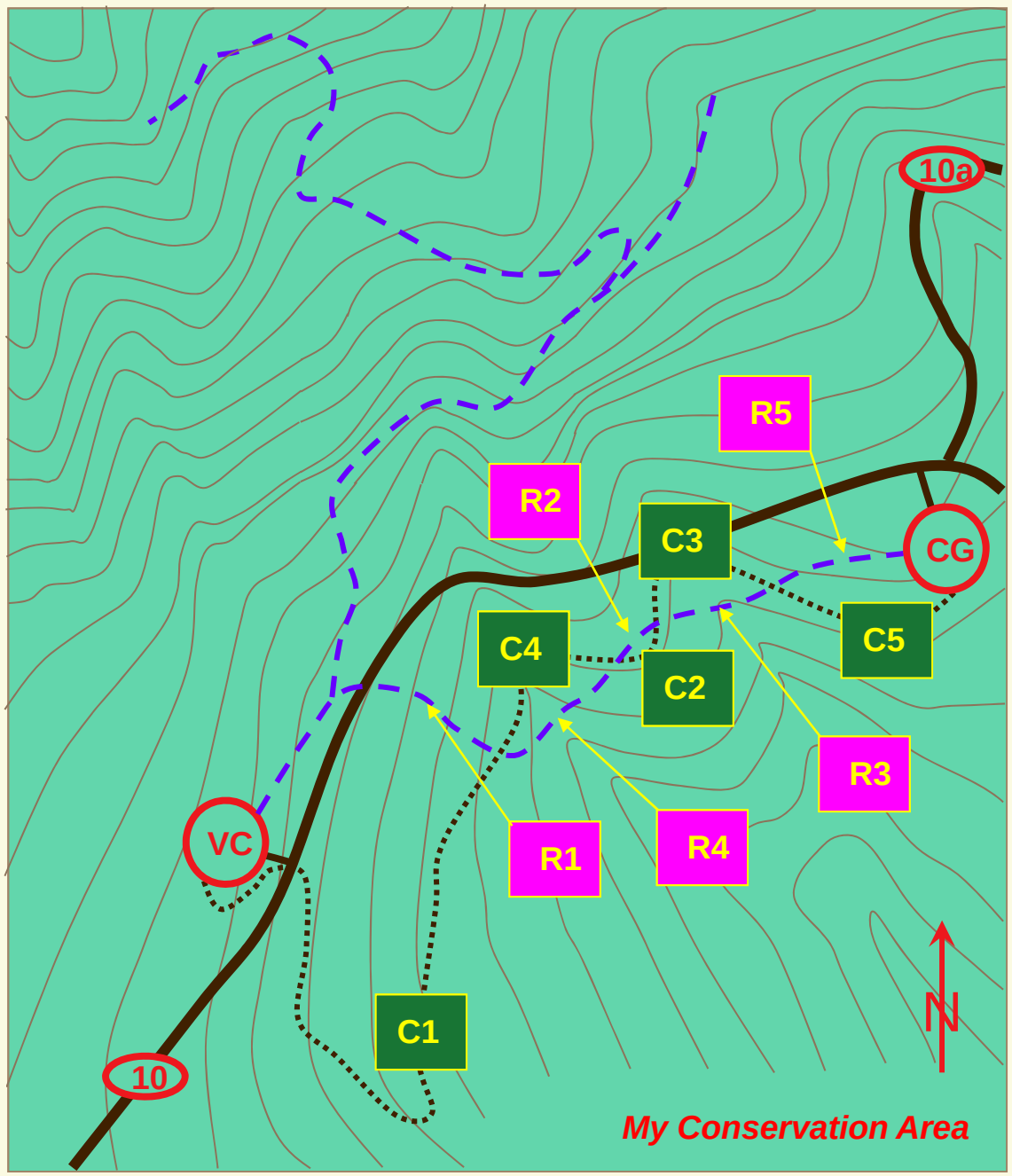
Barricades are an effective way to stop unwanted trail use. This buck and rail barricade at Lory State Park was moved many times to newly restored areas as new trails were developed.

Signage is an effective restoration strategy once soils have been recontoured and slopes revegetated.

Corridor C Restoration Actions Sequence

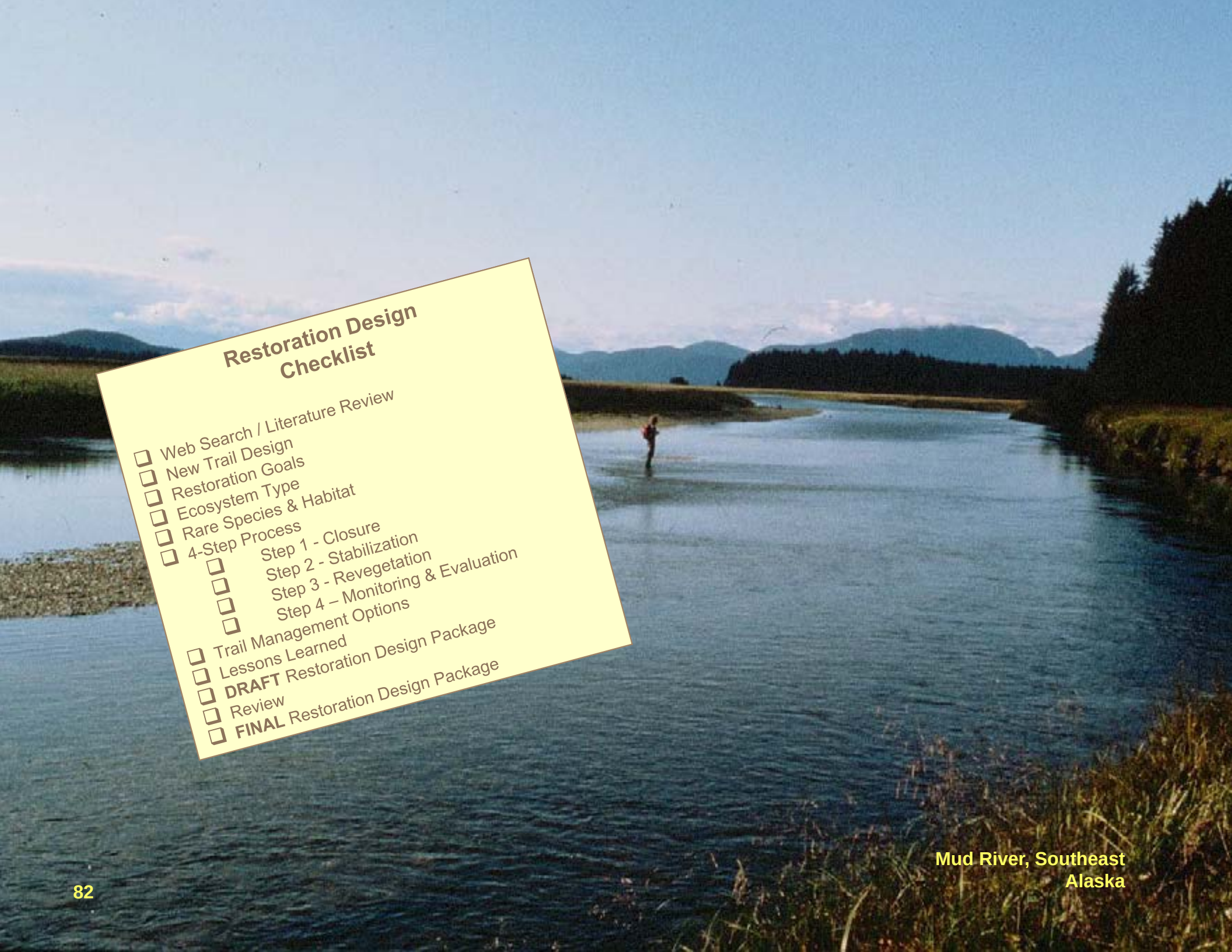
Restoration Photographs. Take photographs before restoration work is done and monitor area for three years to determine if restoration goals are being met. If additional vegetation is needed for restoration activities, remove vegetation plugs from similar plant community adjacent to restored social trails.

Restoration activities communicate a sense of responsibility towards resource stewardship.



The **Restoration Plan** to the preceding page depicts a common project. A nonprofit agency plans to construct a sustainable trail from the visitor center (VC) to the campground (CG). An unplanned social trail currently crisscrosses the planned sustainable trail route, and restoration of this trail to natural conditions is one of the project's goals. In order to most effectively close and restore the social trail, the following action sequence is planned according to management priorities:

1. **Construct trail section C1** to address safety issue: social trail section R1 currently crosses County Road 10 at an unsafe crossing. Salvage all topsoil and vegetation plugs (excluding weeds) from the construction of C1 and use in ***Restoration*** of closed areas.
2. **Restore R1** using salvaged soil and vegetation plugs from construction of C1.
3. **Install a *"Closed for Restoration—Do Not Enter"* sign** at the point where R1 leaves the VC and at the jct. of R1 and C1.
4. **Construct trail sections C3 and C4** to address urgent drainage and erosion issues caused by seasonal flow events in gulches. Salvage all topsoil and vegetation plugs (excluding weeds) from trail construction for restoration of closed areas.
5. **Restore sections R3 and R4** using salvaged soil and vegetation plugs. Fill gullies with debris, rocks, and topsoil to recontour the land. Install check dams to stabilize eroding areas that are not recontoured.
6. **Install *"Closed for Restoration—Do Not Enter"* signs** at junction between R4 and C4 (one sign at each end), and C3 and R3 (one sign at each end).
7. **Construct trail section C2** to address wetland impacts caused by existing social trail section R2. Salvage topsoil to fill in gullies in section R2. **Note:** Do not use transplants from C2 (dry upland site) to restore R2 (wetland site). Plants from C2 will not survive in R2.
8. **Restore section R2** using salvaged topsoil to fill in gullies and vegetation plugs harvested from the surrounding wetland site.
9. **Install *"Closed for Restoration—Do Not Enter"* signs** at each junction of R3 and C3.
10. **Construct trail section C5** to solve access issue to Camp Ground. Salvage topsoil and vegetation for use in restoration of R5.
11. **Restore section R5** using salvaged topsoil and vegetation from construction of C5.
12. **Install *"Closed for Restoration—Do Not Enter"* signs** at jct. of R5 and C5, and at the campground entrance from section R5.

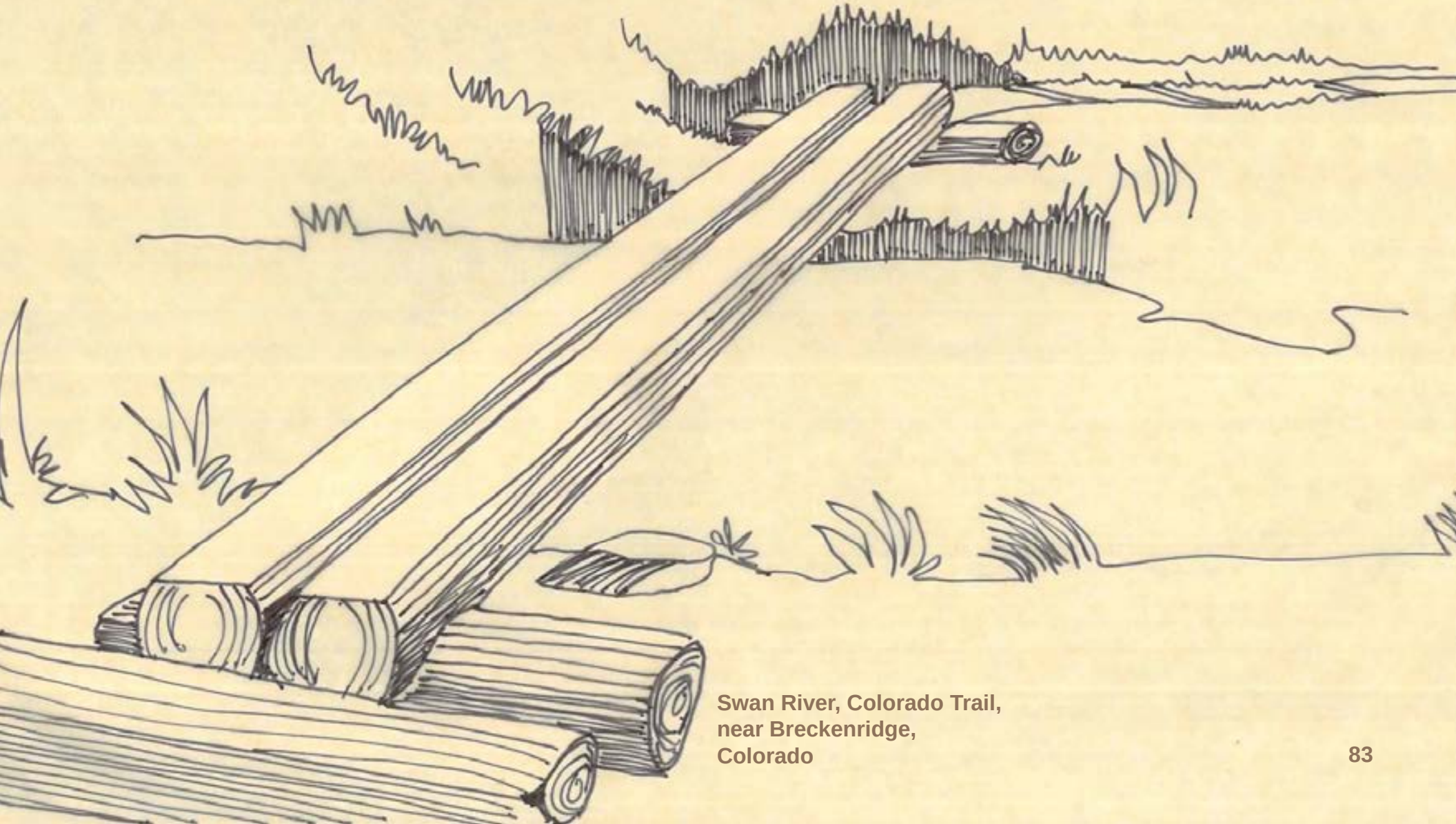


Restoration Design Checklist

- ❑ Web Search / Literature Review
- ❑ New Trail Design
- ❑ Restoration Goals
- ❑ Ecosystem Type
- ❑ Rare Species & Habitat
- ❑ 4-Step Process
  - ❑ Step 1 - Closure
  - ❑ Step 2 - Stabilization
  - ❑ Step 3 - Revegetation
  - ❑ Step 4 – Monitoring & Evaluation
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** Restoration Design Package
- ❑ Review
- ❑ **FINAL** Restoration Design Package

Mud River, Southeast Alaska

Mountain Trail Bridges



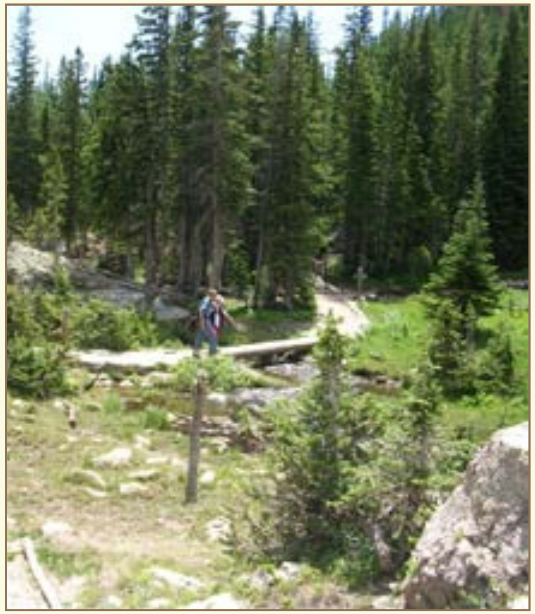
Swan River, Colorado Trail,
near Breckenridge,
Colorado

Best designed by professionals, ***Mountain Trail Bridges*** and boardwalks are many times required to prevent resource impacts while also providing recreational access. Bridges and boardwalks are best located during the planning process as a ***Corridor Control Point***, and they can be simple or complex.

Mountain Trail Bridges

Inputs

- Typical Inputs
- Outputs from Other Process Areas
- Stakeholder Analysis
- Aerial Photos, Maps
- *Lessons Learned*



Tools & Techniques

- Typical Tools & Techniques
- Web Search / Literature Review
- Site Analysis
- Identify Alternative Stream Crossings
  - Advantages & Disadvantages
- Select Preferred Crossing Location
- *New Trail Design* to Match Preferred Stream Crossing
- Bridge Option Selection
- Bridge Option Design
- Review

Outputs

- DRAFT *Mountain Trail Bridges Package* for Review
  - Written Summary
  - Annotated Site Analysis
  - Annotated Alternative Stream Crossings Plan
    - Summary of Advantages & Disadvantages
  - Plans, Sections
  - Details
  - Material List
  - Labor Estimates
  - Cost Estimates
  - Trail Management Techniques
  - Checklists
  - *Lessons Learned*
- FINAL *Mountain Trail Bridges Package*

A bridge is a structure designed to elevate a trail above running water or a waterway for resource concerns and safety. Bridges are built from a variety of materials including: wood (including pressure treated wood), native stone, metals, and plastics and recycled / hybrid materials.

Bridges are trail assets that can be standardized for economy of implementation as well as uniformity throughout an area. For safety, as well as liability concerns, bridges are to be properly designed (engineered) and constructed. The more complicated the design, obviously the more significant the investment of time, resources and investment is required to build and maintain the structure. Even the most basic bridge designs require some advancement in skills, tools and labor to construct. Handrails may be required if drop-offs over 3 feet are present, depending upon the location, land management agency policy, and governing codes.

As with planning and design, extensive field work is required to ensure that bridges are located in optimum locations, especially if the bridge requires significant investment. Comparisons must often-times be made between alternate bridge locations, length and type of trail improvements needed on either or both sides of the bridge, as well as logistical concerns and implementation crew ability.

Bridges are most commonly ***Corridor Control Points*** as outlined in the planning process. These are locations where a bridge must be located to ensure optimum location for the corridor.

Crossing a ravine or gorge or a stream are the most common uses for a bridge. The simplest circumstance is when the trail origin is on one side of a stream, and the destination is on the other side of the stream, resulting in one bridge being required. If a trail team is forced to cross to the far side of a stream away from the intended destination, a second bridge may be required, or even a third.

Design and aesthetic guidelines for bridges vary between agencies and may depend on historic president, the geographical context, and distance from the trailhead. A bridge considered appropriate across an equally large stream in one area may be considered unnecessary or inadequate in another. Bridges in legislated wilderness areas by default would have different characteristics than a frontcountry bridge near a major visitor facility.

Trail approaches to bridges are best located to minimize potential for damage from high water or erosion. Elevation transitions that are smooth so as to appear as natural as possible best conform to sustainable concepts.

Calculating profile grades and expected vertical gains will ensure that significant investments in ***Corridor Control Points*** are carried out in the correct places.

Mountain Trail Bridges fall into the general framework shown on the right developed at Rocky Mountain National Park, and the photographs below display options used there.

1 **Simple Foot Log Bridge.** For light to medium foot traffic only across small and/or intermittent water. Minimal dimensions, tools, time and labor required. Appropriate in the front, mid and backcountry zones. No vertical-drop of more that 5 feet anywhere along the span. Local materials typical.

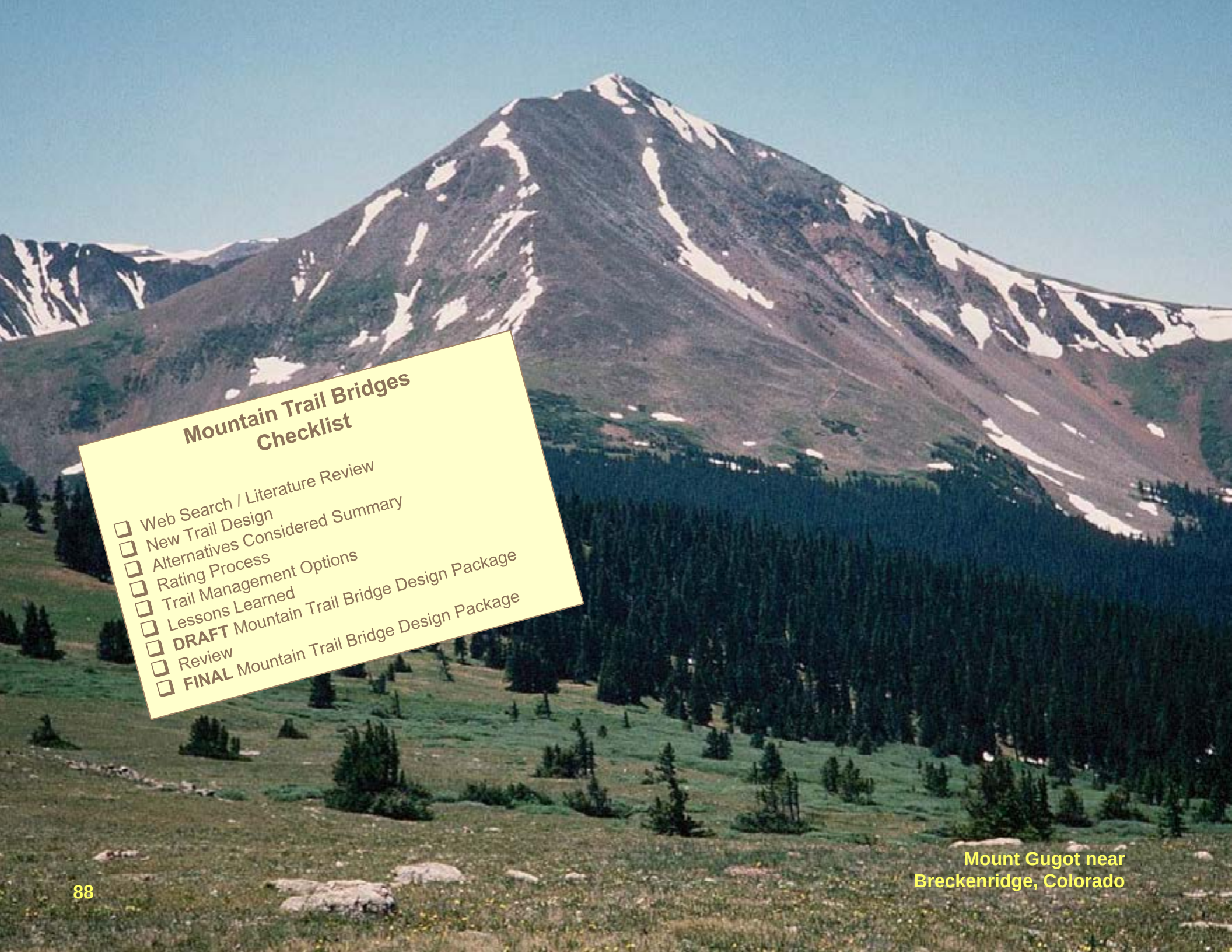
2 **Simple Foot Log Bridge With Handrail.** Light to medium pedestrian use without horse or multi-accessible fords. Medium complexity of tools, labor and skills required due to the possible size and weight of materials. May incorporate an ‘island,’ pier or abutment within the water channel to support center posts for longer spans. Utilization of local native materials is common.

3 **Foot Traffic Only Bridge.** Frontcountry to backcountry distance zones with medium to heavy volume of use. May be multiple-member foot log or decked stringer type. Approach and abutment need to accommodate ford for light to heavy horse and / or multiple users. May require additional skills and tools for harvesting, moving and assembling materials for larger structures.

4 **Multiple Use Access Bridge with Handrail.** Medium to heavy volume of use. Frontcountry to backcountry distance trail zones. Decked multiple stringer design with steel super-structure preferred. Design may include mixed materials for optimum strength, life cycle and aesthetics. Will require complex logistics, skills and tools, and material handling techniques.

5 **Boardwalk.** Many design variations and definitions vary from region and agency. Basic design elevates the corridor or walking surface over wet, unsustainable tread areas. Common designs and names include turnpike, puncheon, corduroy and gadbury. Kick-rails are common with many designs.

6 **Suspension or Box-Frame Design Bridge (Not Shown).** Usually for crossing long spans or gorges. The most challenging and complex type of bridge structure. Significant cost, skills and complex tools like helicopters and high-lines will very likely be necessary for these more complex designs.

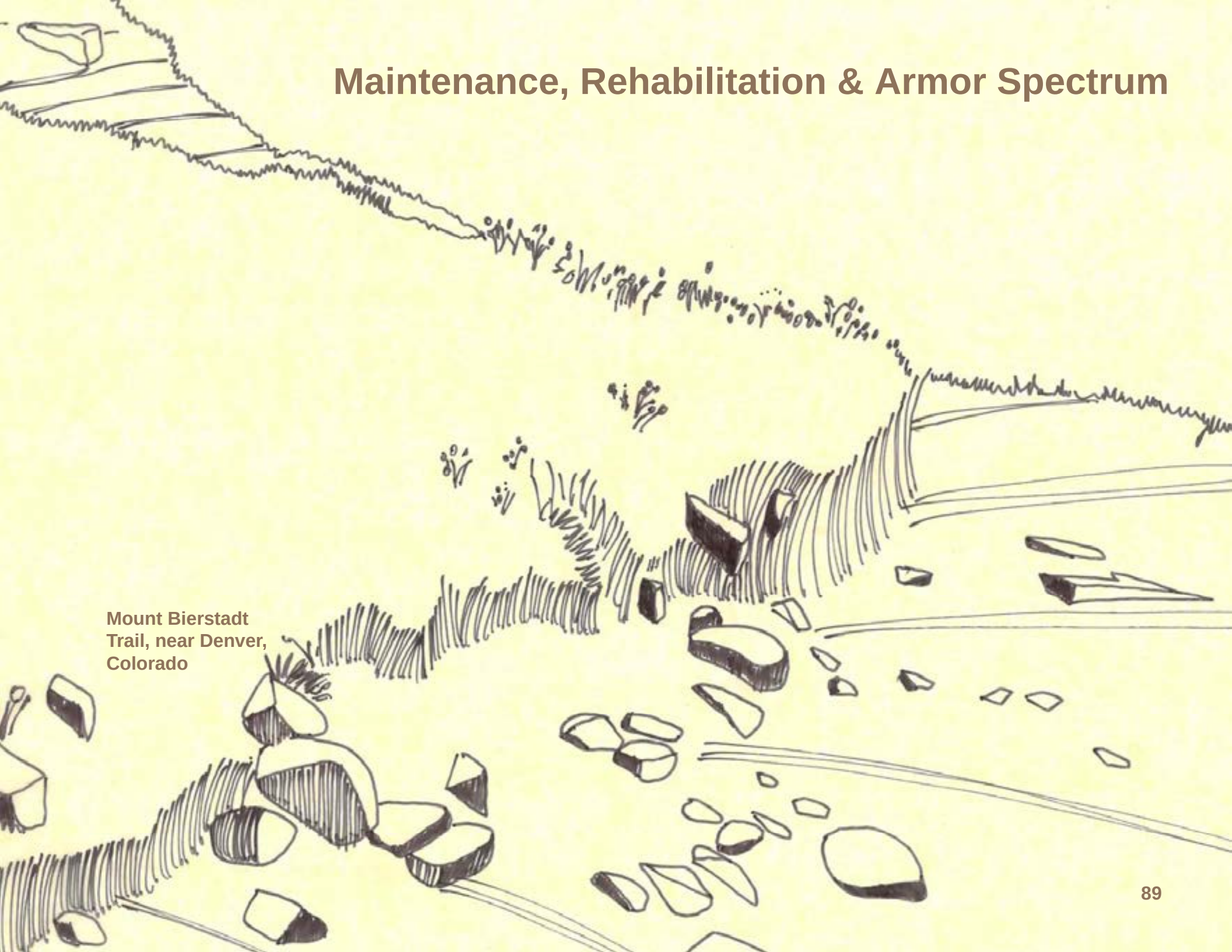


Mountain Trail Bridges Checklist

- ❑ Web Search / Literature Review
- ❑ New Trail Design
- ❑ Alternatives Considered Summary
- ❑ Rating Process
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** Mountain Trail Bridge Design Package
- ❑ Review
- ❑ **FINAL** Mountain Trail Bridge Design Package

Mount Gugot near
Breckenridge, Colorado

Maintenance, Rehabilitation & Armor Spectrum



Mount Bierstadt Trail, near Denver, Colorado

This trail is in tip-top shape, no rutting, good outslope, good backslope.

An ***Armor*** *improvement* here will ensure sustainability into the future.

This trail needs ***Maintenance*** activities performed on the ditch on the uphill side of the trail to ensure sustainability.

This trail needs ***Rehabilitation,*** including tread work as well as installation of ***Trail Drains*** to ensure peak rain events do not impact the trail.

Cleaning waterbars is a common ***Maintenance*** activity, including restoring the drain so that water will drain off the trail.

Maintenance … Rehabilitation … Armor Design Spectrum

Inputs

- *Typical Inputs*
- Outputs from Other Process Areas
- *Lessons Learned*

Tools & Techniques

- *Typical Tools & Techniques*
- Local Site Analysis
- Maintenance Strategies
- Rehabilitation Strategies
- Armor Strategies
- Actions Sequences
- Review

Outputs

- DRAFT *Maintenance … Rehabilitation … Armor Design Package* for Review
  - Document Summary
  - Spot Improvements Summary
  - Plan Drawings
  - Typical Sections
  - Typical Details
  - Custom Details
  - Cost Estimate
  - Materials List
  - Labor Estimates
  - Specifications
  - Trail Management Techniques
  - Checklists
  - *Lessons Learned*
- FINAL *Maintenance … Rehabilitation … Armor Design Package*

Differentiating out focused projects across the ***Maintenance … Rehabilitation … Armor Design Spectrum*** will assist interdisciplinary trail teams in economizing on their trailside activities. It *"is a good thing"* benefiting trail users and concessionaires alike.

Maintenance Strategies	Rehabilitation Strategies	Armor Strategies
Up to 4X per Year Frequency	**Up to 5 - 20 Year Frequency**	**Once In Up to 50 Year Frequency**
Low Investment to Bring Corridor to Sustainable Status (<10% of Original $)	Moderate to High Investment to Bring Corridor to Sustainable Status (10%<X>50% of Original $)	High to Very High Cost to Bring Corridor to Sustainable Status (>50% of Original - $ 5X Original $)
Sustainable Topography	Sustainable Topography	Unsustainable Topography
Sustainable Soils	Sustainable Soils	Unsustainable Soils
Existing Cross Section Generally in Good Condition	Restore Cross Section	Existing Cross Section is Unsustainable
Minor Management Activities (i.e.: Build Barriers, Plantings, Signage, Interpretive)	Some Management Activities	Management Activities Proven Unsuccessful
Minor Earthwork Activities	Moderate Earthwork Activities	Significant Earthwork Activities Required
Little or No Off-Site Materials Required	Off-Site Materials Make Up a Small % of Required Improvements	Off-Site Materials Make Up a Large % of Required Improvements
Routine Trail Maintenance Activities Will Upgrade the Corridor to Sustainable Status	Limited Sections of the Overall Corridor, Maybe Less Than 25%	Over 50% of the Corridor is Unsustainable / Management Concerns Prohibit Moving the Trail Corridor
Typical Sections & Typical Details Apply	Rebuild - or - Add New Structures	Build New Cross Section on Unsustainable Topography or Soils
Outline Design Notes Only	Competent Design Drawings / Design Notes Required	Complex to Very Complex Solutions Required
No Problem Solving by Crew Required	Problem Solving Required by Trail Crew	Expert Construction Skills Required
High Production Per Person or Crew	Moderate Production Per Person or Crew	Low Production Per Person or Crew
Minimum Design Time Required	Some Design Time Required	Expert Design Skills Required / Extensive Time and Substantial Cost May Be Required
Simple Tools Required	Simple to Difficult Tools Required	Difficult to Complex Tools Required
Some Supervision Required	More Supervision Required	Extensive Supervision Required
Some Training Required	More Training Required	Extensive Training Required
Loads of Time to Still Go Hiking or Fishing!	Some Time Left to Go Hiking or Fishing!	Little Time Left to Go Hiking or Fishing!

Trail Maintenance Design

Trail maintenance activities are those activities which restore the original design features of the trail and its accompanying structures. Maintenance activities are usually only appropriate for trails that are in good condition and already deemed sustainable, or have already gone through an intensive rehabilitation or armoring process. Trail maintenance does not involve intensive addition of structures or trail relocations. ***Trail Maintenance Design*** is a relatively fast process, as most maintenance tasks are not physically or resource intensive.

Plan to spend up to a half day per mile of trail to plan maintenance activities. It is wise to visit the trail in various seasons of weather and use to observe problem areas. Note the locations of areas that need the type of action shown in the Maintenance Activity Matrix below. "***Regular Basis Activities"*** must be performed regularly, whenever a trail is being maintained, and "***Perform as Needed Activities"*** indicates activities that only need to be performed as noted in the ***Maintenance Design Summary Package***.

Maintenance Strategies & Techniques	*"Regular Basis Activities"*	*"Perform as Needed Activities"*
Prune vegetation overgrowth	X	
Remove fallen logs		X
Ensure proper trail outslope and removing minor berms	X	
Block and restore switchback shortcuts		X
Clean waterbars	X	
Restore backslope		X
Switchback drainage maintenance	X	
Clear culverts, side ditches, and other drains	X	
Sign replacement or maintenance		X
Replace worn structures (waterbars, steps, retaining walls or other structures)		X
Relocate structures (waterbars, steps, walls or other structures) that are in less than optimum locations		X

Trail Rehabilitation Design

Trail Rehabilitation is upgrading an existing trail to a sustainable standard. This is typically done on a trail that has suffered resource damage beyond what typical trail maintenance can alleviate. It is important to determine the cause of the trail's degraded condition. It may be due to a lack of past maintenance, or improper design to start out with. Understanding this will help you to program your trail rehabilitation efforts in anticipation of future impacts and conditions.

Determining whether a trail needs to be rehabilitated or relocated is a delicate process. Considerations include:

- Potential for future impact and erosion;
- Land management goals and regulations;
- Resource and financial investment costs of rehabilitation versus re-routing, keeping in mind that re-routing will also involve closing and restoring the old trail; and
- Safety to trail users.

Rehabilitation will likely involve the addition and / or reconstruction of a number of erosion control structures. Waterbars and check dams are very frequently added to divert water off of the trail and hold soil in place. Switchbacks may need to be re-built, retaining walls added, and steps installed. Be sure to consider re-locations of sections that are a recurring problem, of significant natural resource impact, unsafe, or beyond the scope of what typical trail structures can solve (such as very deep erosion or in highly erodible soils).

Observing problems in several seasons or under different types of use will strengthen your problem solving skills. See the table on the following sheet for ideas for ***Rehabilitation Tools & Techniques***.

A ***Trail Rehabilitation Package*** will be required to guide the efforts of trail crews and document where and when structures and improvements were made on the trail. Details such as GPS coordinates or civil engineering stationing markers for work items and dimensions of work items will be needed to estimate resources needed for the project and to guide trail crews.

This trail is insloped and needs ***Rehabilitation*** activities to restore the proper outslope.

Rehabilitation Tools & Techniques	
Problem	**Potential Solutions / Spot Improvements**
Soil Erosion	• De-berming (for minor erosion). • Combination of waterbars and check dams or check steps works well (check dams hold soil in place, waterbars divert water off of the trail). • Rock or log steps or staircases on steep grades. • Re-fill trail with mineral soil to original grade. Consider waterbars and check dams as well to prevent re-erosion.
Muddy Areas	• French drains. • Turnpikes with culverts or French drains. • Boardwalks. • Replace trail surface with mineral soil, crushed rock, or crusher fines (only if the trail has minor mud problems).
Trail Shortcuts	• Natural physical barriers (large rocks, logs, etc.). • Structural barriers (buck-and-rail fences, stone retaining walls, etc.). • Signage. • ***Restoration*** with transplants, seeding, etc.
Unsafe Sections	• Typically these are site-specific. • Trail widening. • Strongly consider ***New Trail Design***.
Trail Braiding	• Strongly consider ***New Trail Design***. • Re-fill trail to natural grade and stabilize with check steps, waterbars, etc.

"Oh-oh … here she comes … get back to work." When the crew leader reviews construction, all is to be in tip-top shape.

Trail Armor Design

While the foundational goal of sustainable mountain trail development is to provide the best experience to the user with the least short and long-term impacts and cost, most trails – even in ideal conditions – will have segments where sustainable criteria are exceeded or unachievable. In these segments, ***Trail Armor Design*** may be required to achieve trail improvements that are easy to maintain.

These situations may be the result of:

- Poor or inadequate original planning and design;
- Poor, inadequate or impatient original construction;
- Overuse of a trail or the unplanned increase or change in the type, pattern and volume of use;
- Lack of adequate maintenance;
- Natural events like wildfires, floods and rockslides that significantly impact or alter the environment; and
- Corridor constraints.

Corridor constraints may be caused by:

- Topography / environment (nowhere else to locate the trail or no better corridor options);
- Compliance restrictions – a historically significant corridor, or proximity of sensitive natural (i.e.: wetlands) and / or cultural resources (i.e.: archaeological sites);
- Property boundaries / easements; and
- Management restrictions, policies or decisions.

Trail Armor Design can cause extensive short term resource impacts, and can be very costly, very complex and a logistical challenge. Substantial amounts of time and materials may be required to complete each segment. However, an appropriately designed and constructed armored solution can provide a sustainable, easily maintainable trail for many years. Armor solutions require higher percentages of improved / complex tread construction or water management structures, activities or practices. Armor solutions require thorough planning, thoughtful design and expert skill to properly implement.

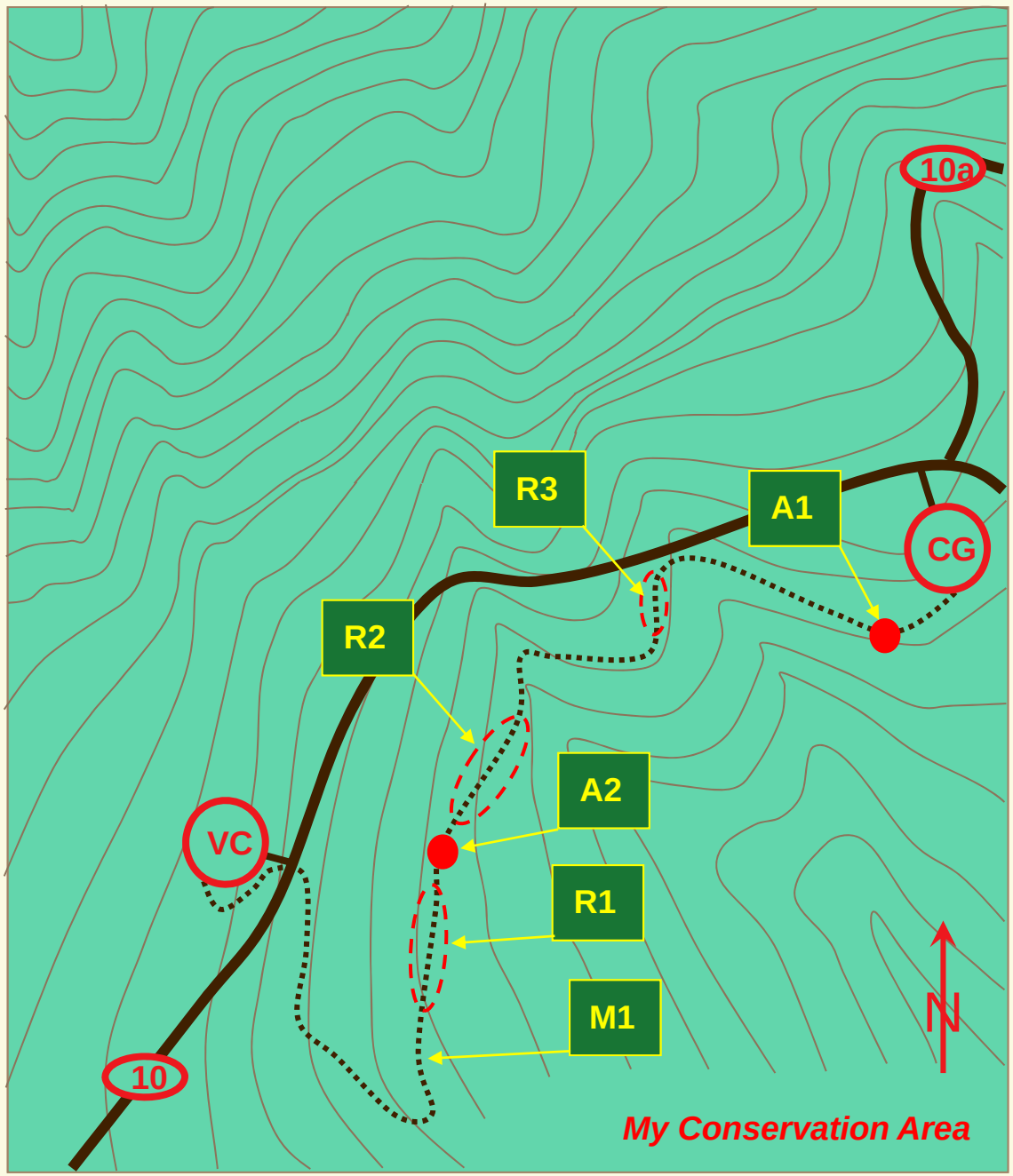
Armoring is characterized by:

- Short sections are typical, however longer sections are sometimes required;
- Found in areas with steep grades and / or where water is a major seasonal or annual factor in the local trail conditions;
- Excellent for the long-term management of surface and sub-surface water (i.e.: stream crossings, boggy areas);
- Usually undesired by equestrian users, but not unsafe if properly constructed;
- Labor and material-intensive, i.e.: slow linear foot production per day per person or crew;
- Heavy impacts and challenging logistics (usually requiring temporary trail closures during construction);
- May require complex tools, intense training, or specialized / experienced labor force;
- High cost of installation / ownership, but very long life-cycle expectancy if properly constructed (50+ years);
- Common in the ‘High Sierra’ trail tradition and other areas similar in topographic and environmental factors (abundant slick rock, generally shallow, sandy soils, plentiful, good building rock, multiple and/or high-use trails); and
- Very challenging yet equally rewarding for the trail crew to implement.

Refer to *A Handbook on Trail Building and Maintenance* by Steven Griswold at Sequoia National Park for more ideas where sustainable criteria are exceeded or unattainable, and where significant trailside improvements may be required.

A ***Trail Armor Design Package*** will be required to guide implementation of these complex solutions.

Corridor C Maint. / Rehab. / Armor … Actions Sequence



M1 Regular Basis activities 4x/year are planned for the entire segment.

R1 This backslope on this section of trail (50') has collapsed and the trail needs to be rehabilitated to its original design.

R2 A wet seep appeared here and damaged the trail. Ditches (75'-long) need to be cut uphill from the trail to collect runoff to a low point.

A1 Yikes, this section was in deep topsoil. Coarse soils need to be brought in to strengthen the trail surface, and drainage improvements need to be provided, length = 75'.

R3 The backslope on this section of trail (40') also collapsed. Rehabilitation is required.

A2 Another armor improvement is required here, in this case, deep topsoils were encountered for only 25', hence a low priority.

Properly planning out the sequence of ***Maintenance*** (M), ***Rehabilitation*** (R) and ***Armor*** (A) improvements will help nonprofit agencies and volunteers focus their efforts where they are most needed, when they are most needed.

Maintenance Design Checklist

- ❑ Web Search / Literature Review
- ❑ Sustainability Assessment
- ❑ Mountain Trail Plan
- ❑ Maintenance Design Goals
- ❑ Distance From Trailhead
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** Maintenance Design Package
- ❑ Review
- ❑ **FINAL** Maintenance Design Package

Armor Design Checklist

- ❑ Web Search / Literature Review
- ❑ Sustainability Assessment
- ❑ Mountain Trail Plan
- ❑ Armor Design Goals
- ❑ Distance From Trailhead
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** Armor Design Package
- ❑ Review
- ❑ **FINAL** Armor Design Package

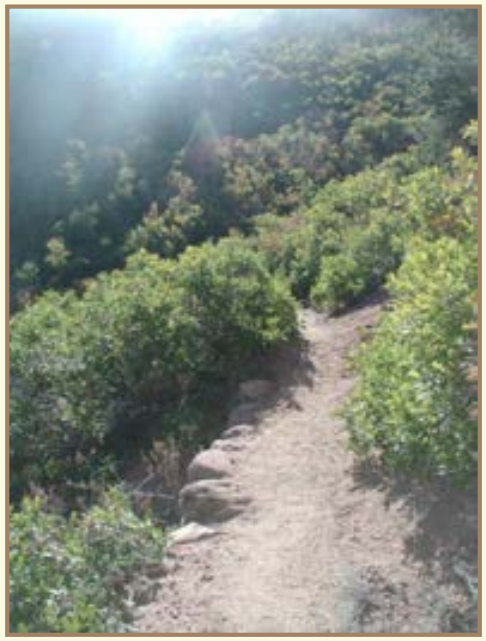
Rehabilitation Design Checklist

- ❑ Web Search / Literature Review
- ❑ Sustainability Assessment
- ❑ Mountain Trail Plan
- ❑ Rehabilitation Design Goals
- ❑ Trail Management Options
- ❑ Lessons Learned
- ❑ **DRAFT** Maintenance Design Package
- ❑ Review
- ❑ **FINAL** Maintenance Design Package

Lake Agnes, in North Park, Colorado

Implementation Techniques & Options

Near Tennessee Pass,
near Breckenridge,
Colorado



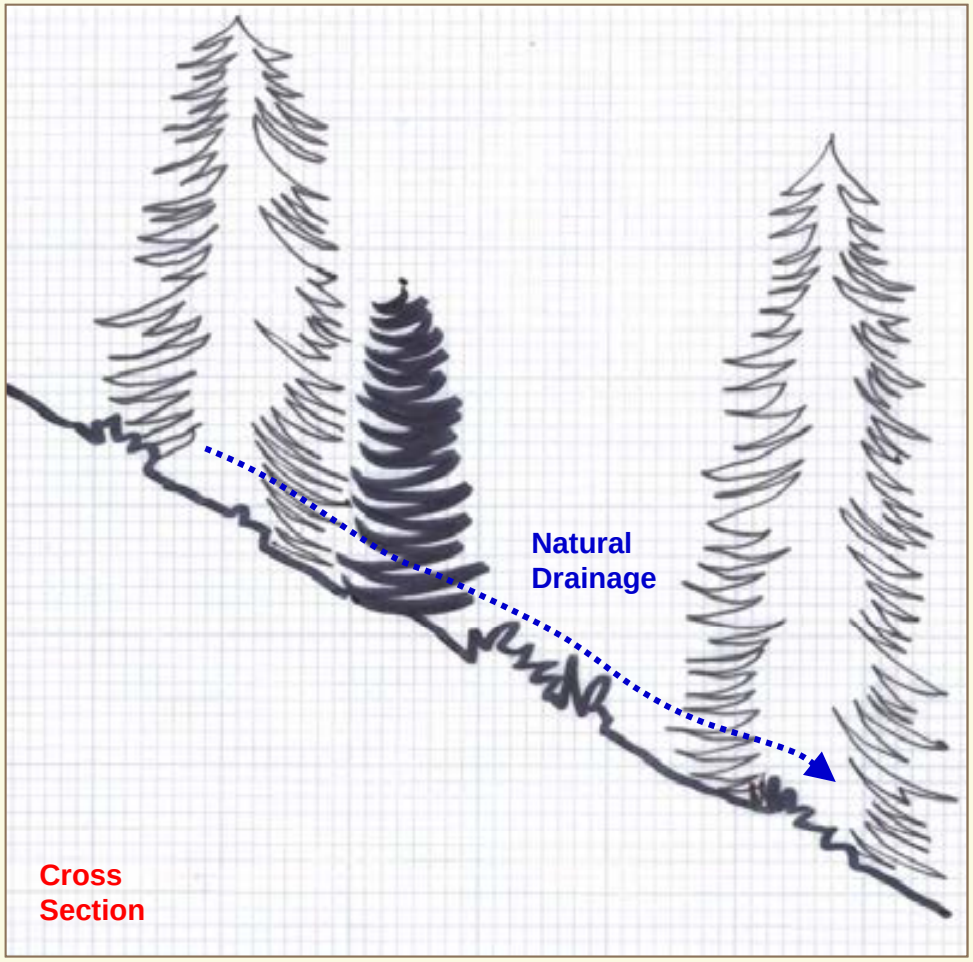
Trailside improvements contribute to the trail user's overall recreation experience. Care is to be taken when carrying out all trailside activities to ensure as natural a solution as possible.

Implementation Techniques & Options

Existing Conditions 102
Corridor Clearing Options 103
Tread Cut Options 104
Crowned Trail 105
Trail Cut with Ditch 106
Trail Drain 107
Swale Crossing 108
Paved Dip / Stone Paving 109
Stepping Stones 110
Stone Waterbar 111
Stone Drains 112
Stone Stairs / Check Steps 113
Alpine Tread Cut Options 114
Stone Retaining Wall 115
Switchback 116
Cairn / Causeway 117
Talus Crossing 118

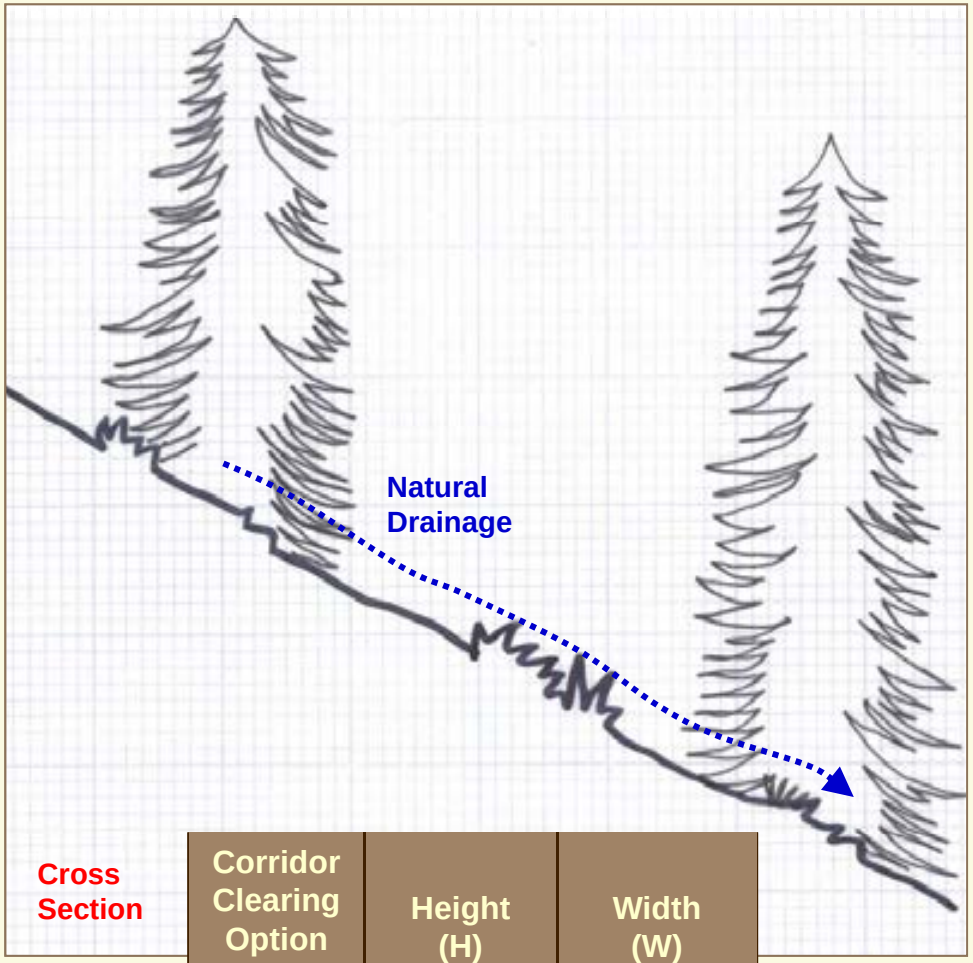
↓ Package	Design Notes	Specifications	Typical Sections	Typical Details	Custom Details
Trail Maintenance Design	Yes	NA	NA	NA	NA
Trail Rehabilitation Design	Yes	NA	NA	NA	NA
Trail Armor Design	Yes	Yes	Yes	Yes	Yes
New Trail Design	Yes	Yes	Yes	Yes	Yes
Restoration Design	Yes	Yes	Yes	Yes	Yes

Existing Conditions



Many mountain trail projects are on moderate to substantial prevailing cross slopes. This example is drawn on a 40% cross slope. Earthwork quantities can be estimated from the cross slope condition. A variety of vegetation types are typically encountered, and sometimes significant clearing of trees is required before tread construction can begin.

Corridor Clearing Options



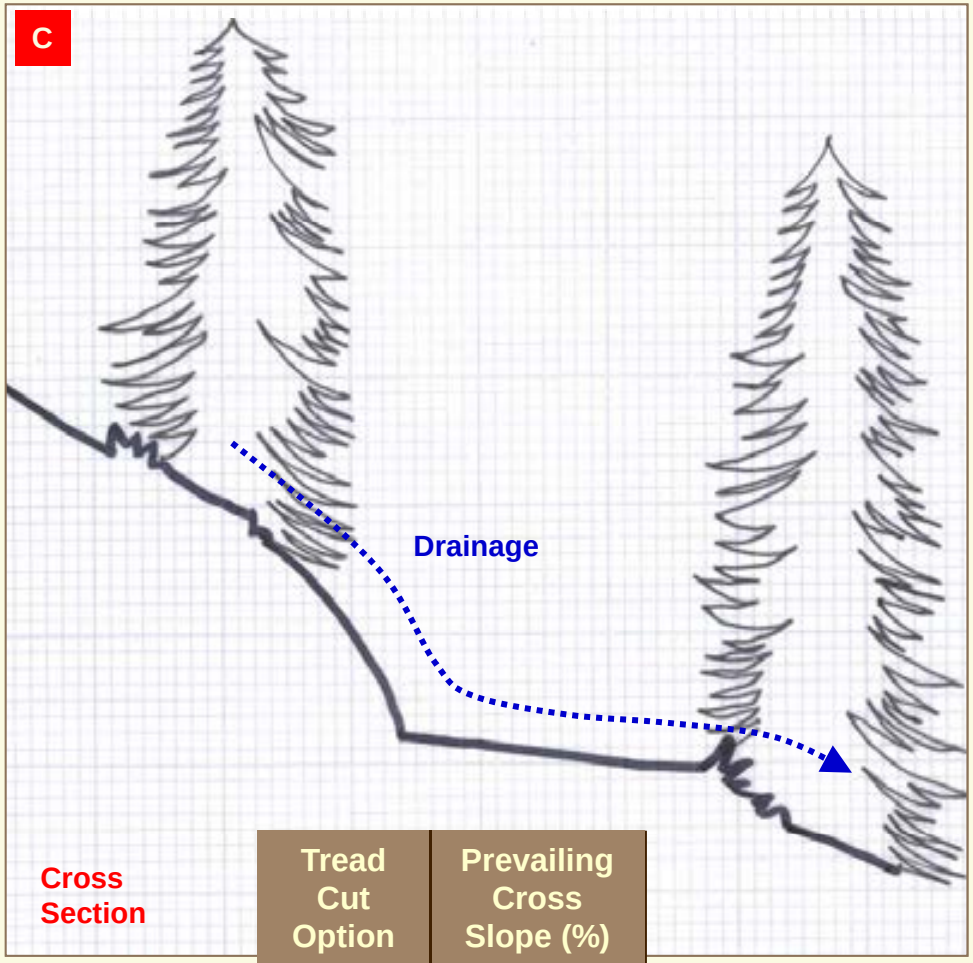
Cross Section

Corridor Clearing Option	Height (H)	Width (W)
A	8 Feet	6 Feet
B	8 Feet	8 Feet
C	10 Feet	6 Feet
D	10 Feet	8 Feet
E	10 Feet	10 Feet

Proper clearing / pruning can be achieved through the following:

- Proper identification of species.
- Understanding ecology of plant in question.
- Accurately predicting beneficial / adverse impacts on trail corridor.
- Deciding what to do.
- Doing this correctly.
- Realize that some plants cannot be pruned, but must be removed.

Tread Cut Options

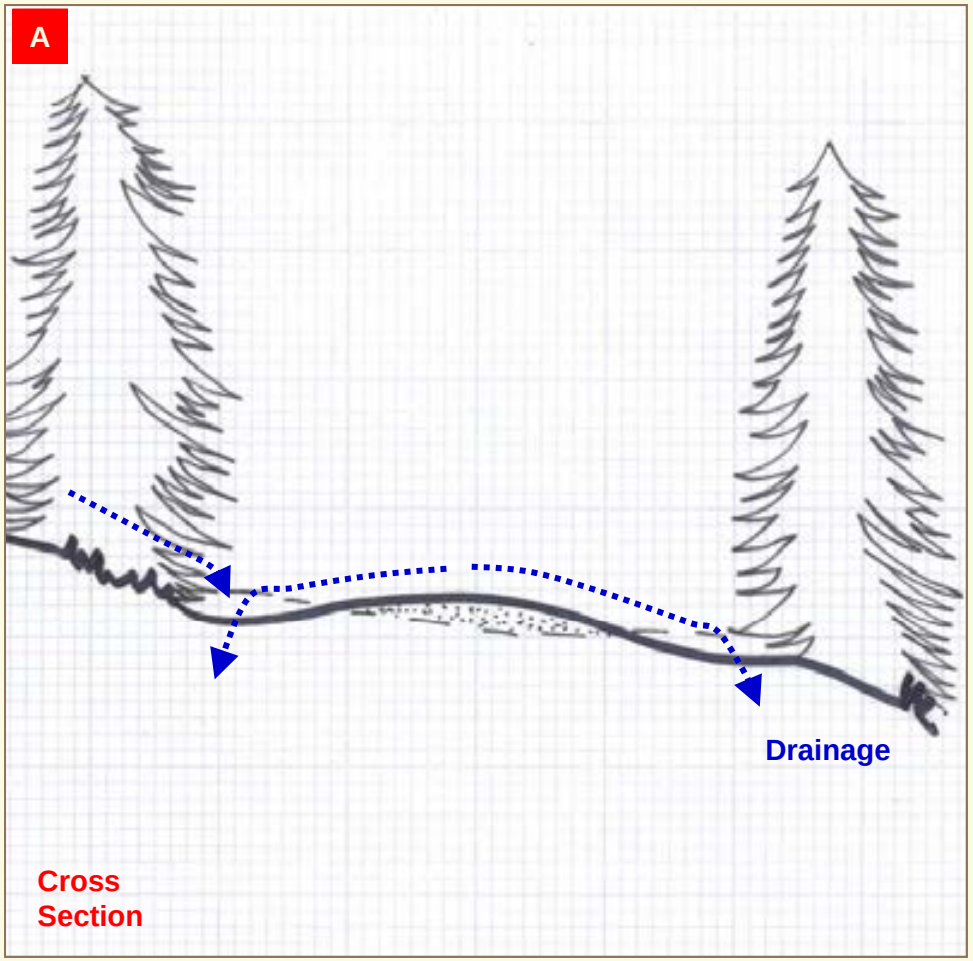


Tread Cut Option	Prevailing Cross Slope (%)
A	0-20%
B	20-40%
C	40-60%
D	60-70%
E	> 70%

Well constructed, properly sloped, and well compacted trail tread can be attained through the following:

- Work across the trail for efficiency when cutting tread.
- Out slope trail approximately 10% (1 inch in 10 inches) to allow for drainage.
- Remove all vegetative material from the trail tread, and allow for drainage off the trail's edge.
- Back slope trail approximately 1:1 (45 degree angle) to allow for quick revegetation, see individual project specifications – back slope may approach 5:1.
- Improve inadequate surfaces with imported materials if necessary.
- Excavated materials must be disposed of according to project specifications.
- As soil is at a premium, leave as much as possible!
- Broadcast or dispose of excess materials only according to individual project specifications.

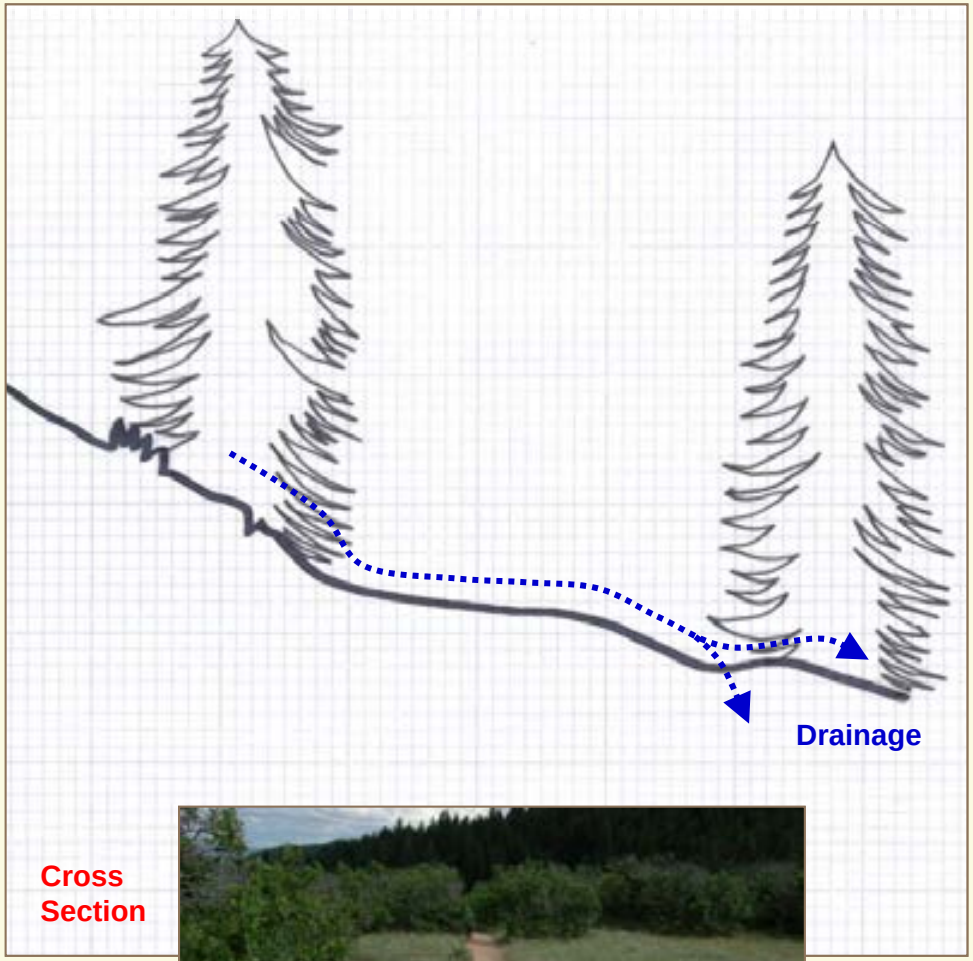
Crowned Trail



Trails in prevailing cross slope grades of less than 20% can be crowned to improve the opportunity for drainage.

- Begin by stripping all vegetative matter.
- Cut a ditch on either side or both sides of the trail.
- Salvage any mineral soil or stones that can be utilized to improve the subgrade or trail surface.
- Compact all materials.
- Strive to establish the trail surface at the approximately the same elevation as the existing grade.

Tread Cut with Ditch



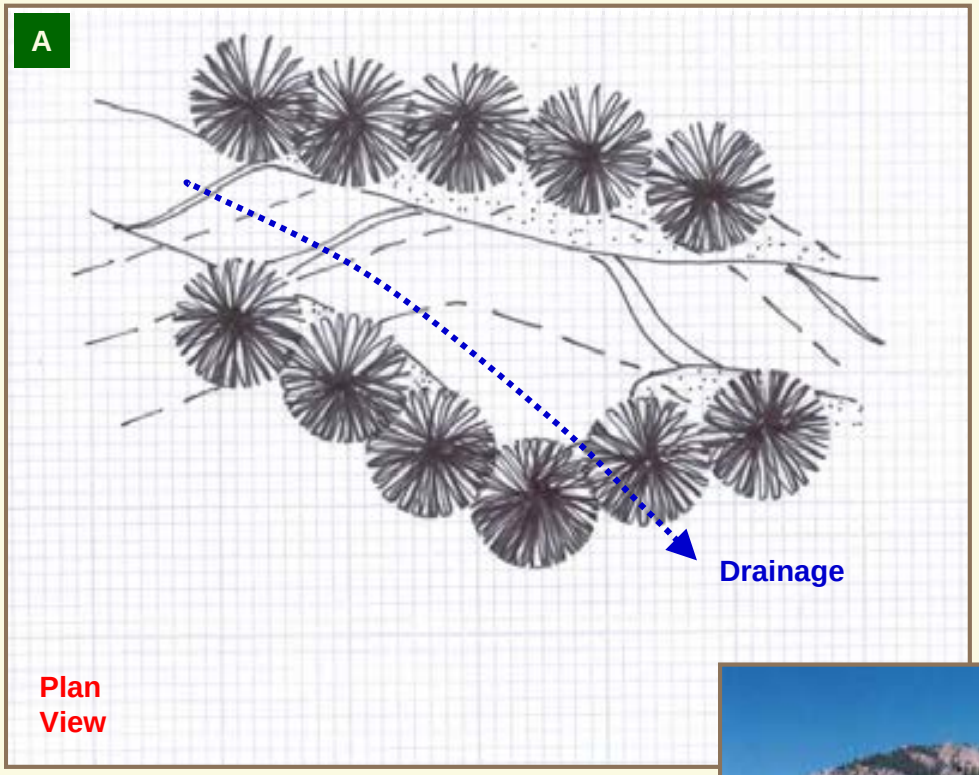
Trails in less than 20% prevailing cross slope areas can be protected by constructing a ditch parallel to the trail to allow drainage off of the trail while still allowing travel on the trail surface.

- Begin by clearing all vegetative matter.
- Cut trail tread as in ***Tread Cut***, including backslope.
- Cut a ditch parallel to the lower edge, removing all soils. Width of the ditch depends upon topography, 1 foot is minimum.
- 4:1 slopes are desired to allow for smooth transitions into the surrounding landscape.

Tread Cut Finishing

"The frequently asked question is how far to go on trail finishing. It is not practical to do such refined grading as will not stand up under relatively small amount of maintenance that those trails will probably receive in the future. The best answer to this question is that trail finishing should be carried to such a point that erosion will be discouraged and natural growth will be encouraged." – Guy Arthur, 1975.

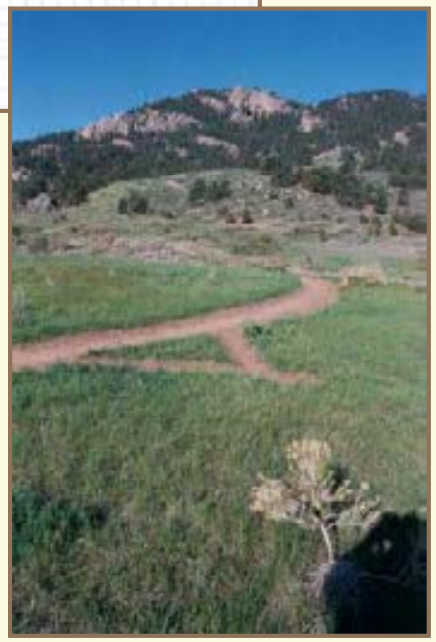
Trail Drain



Erosion is the single greatest threat to trail sustainability. Prevention of erosion is critical to achieving sustainable trails.

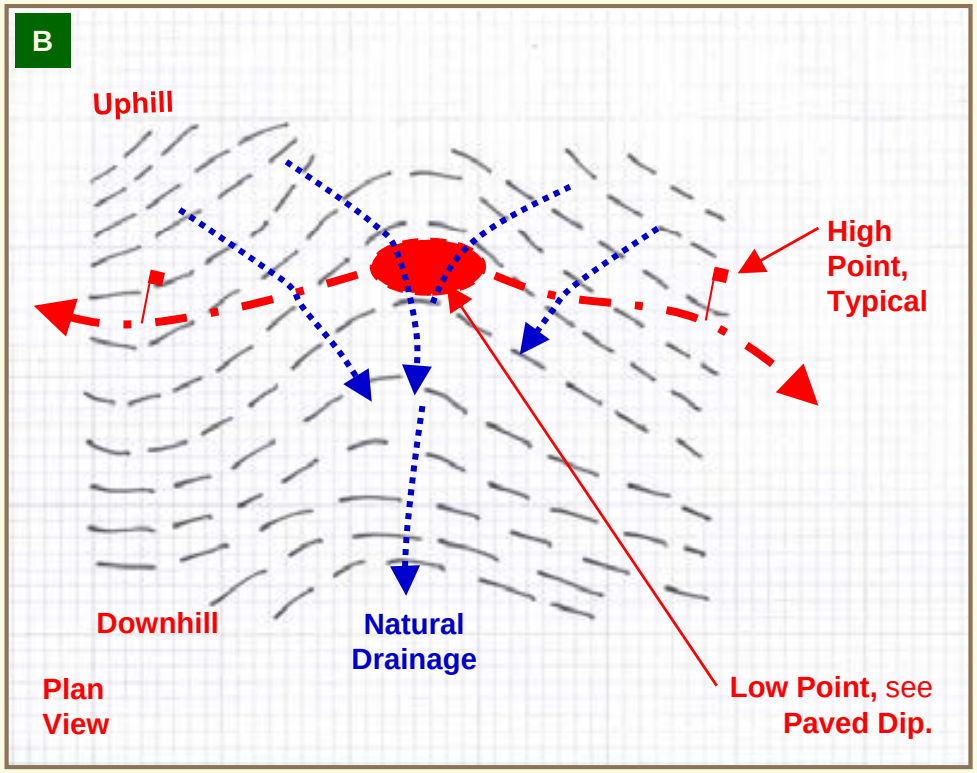
- ***Trail Drains*** should be installed on trails at locations where normal cross slope will not allow for adequate drainage. In general, drainage should be studied every 25 to 50 feet, with provision made to protect the trail.
- Careful study of topography adjacent to the trail may yield an insight to maximize protection of the trail, while minimizing structures required.

	Drainage Options
A	Trail Drain
B	Swale Crossing
C	Paved Dip
D	Stepping Stones
E	Stone Waterbar
F	Stone Drains



"No factor in trail construction is more important than proper drainage, and many sections of good trail are damaged and destroyed by erosion which could have been prevented. All drainage should be planned for ahead of construction. The method of carrying surface water off of each trail section should be determined in advance, along with the location, type, size, and construction details of all drainage structures." – Guy Arthur, 1975.

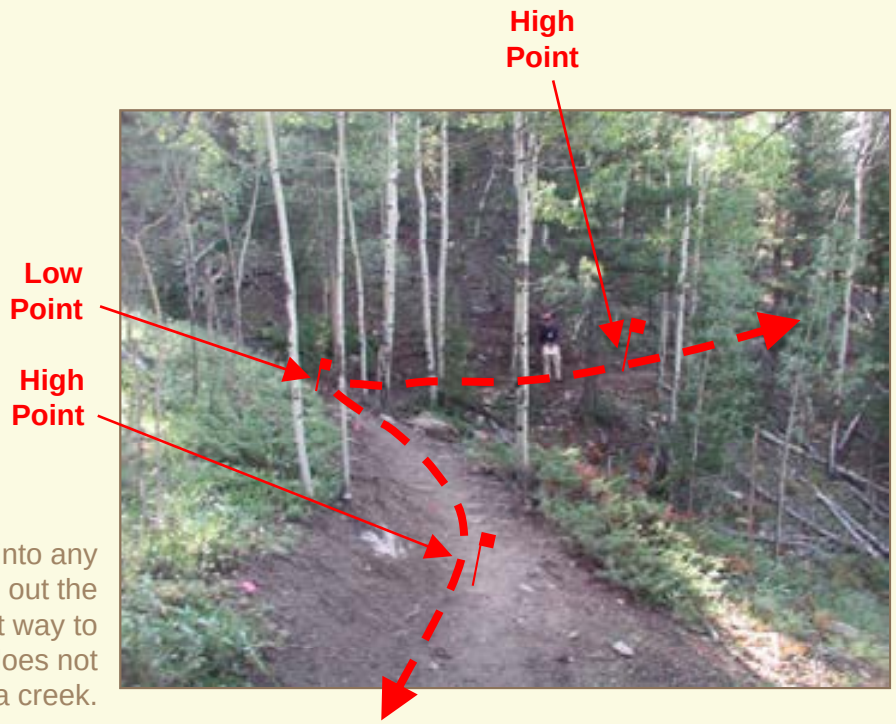
Swale Crossing



Study of the contours and trail alignment in this plan will assist trail teams with fitting their trails to the landscape to minimize drainage impacts.

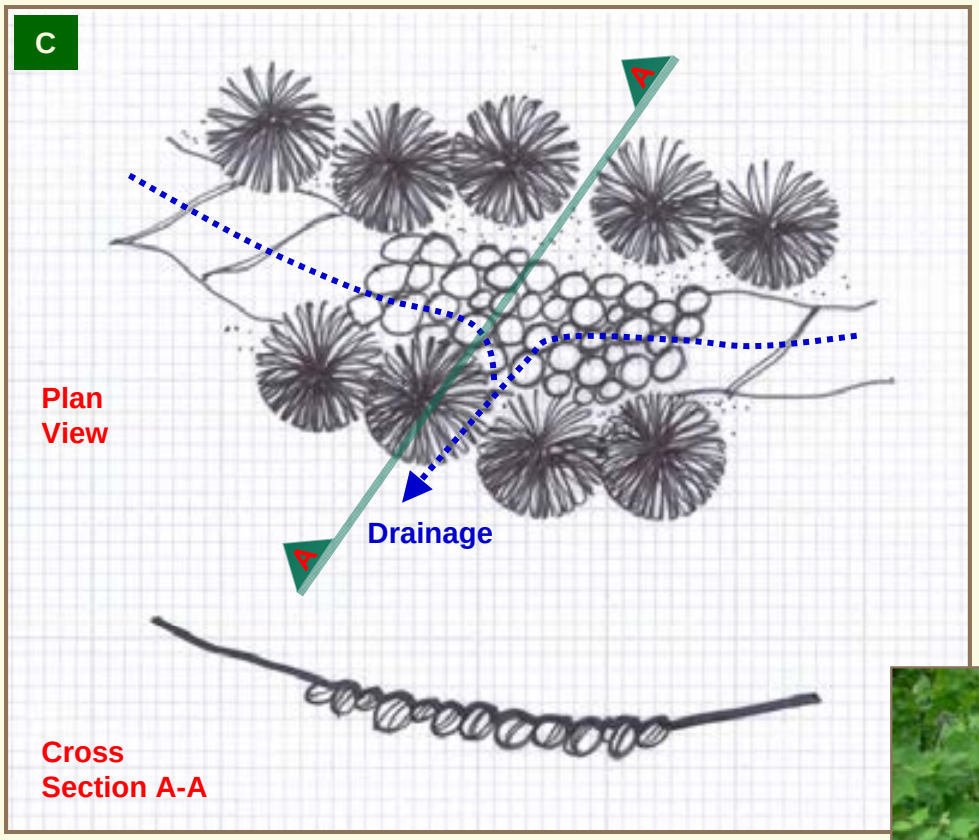
Even the slightest swale must be crossed properly to ensure protection of the trail.

- Careful study of the prevailing profile grades will assist the crew leader in successfully solving drainage crossings.
- On the downhill side of the drainage, it is required that the trail profile switch directions.
- The length of the change in grade is dependent upon the size of the swale. Usually a 10 foot change of profile direction either side of the drainage is sufficient to ensure that water will not continue down the trail.



Descending down into any drainage, then climbing out the other side is the best way to ensure that your trail does not become a creek.

Paved Dip / Stone Paving

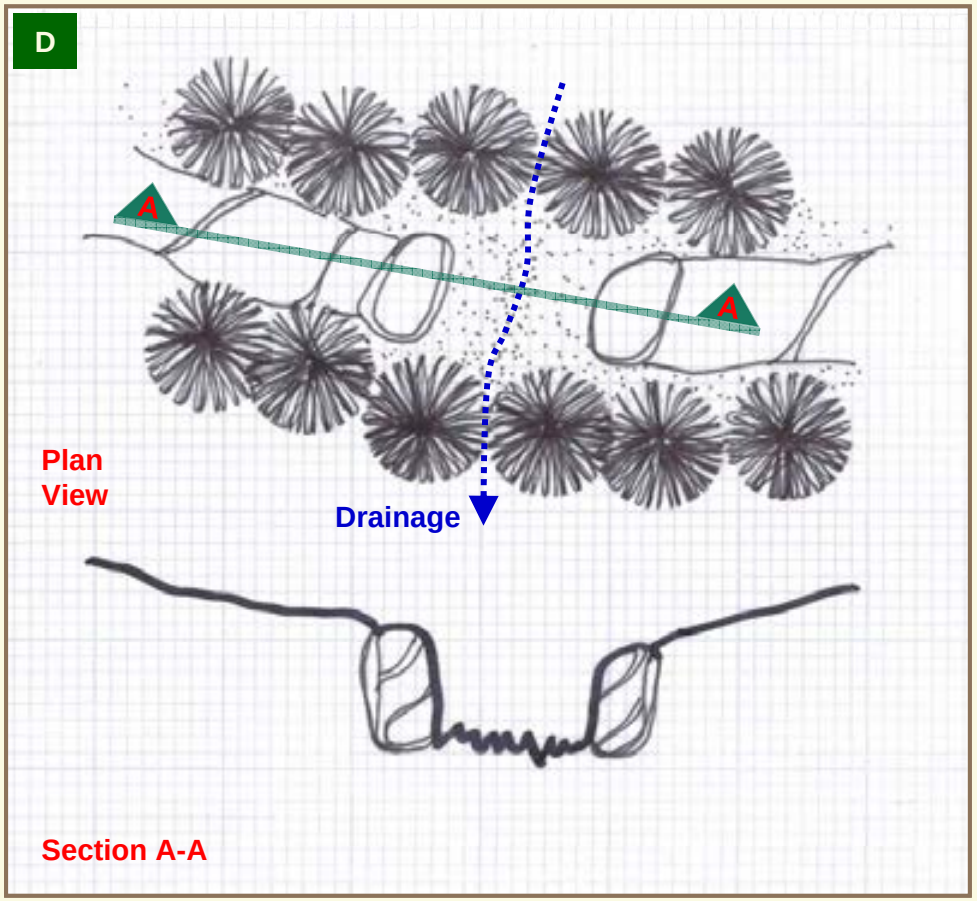


Stone Paving or a ***Paved Dip*** can be used to improve unsuitable soil conditions or in low points along the trail corridor that experience wet conditions or areas that otherwise would not support a sustainable trail surface.

- Establish the trail tread as in ***Tread Cut***. Remove all organic materials & stockpile for possible future use.
- Establish a firm and stable footing which will hold the stone paving in place, using the largest available stones.
- Pave the trail tread with additional large and medium sized stones.
- Fill voids with smaller stones or mineral soils.
- Trails surface should be relatively smooth, without projections of stone greater than 1/2-inch.

This section of the Appalachian Trail in Shenandoah National Park is improved by ***Stone Paving***.

Stepping Stones

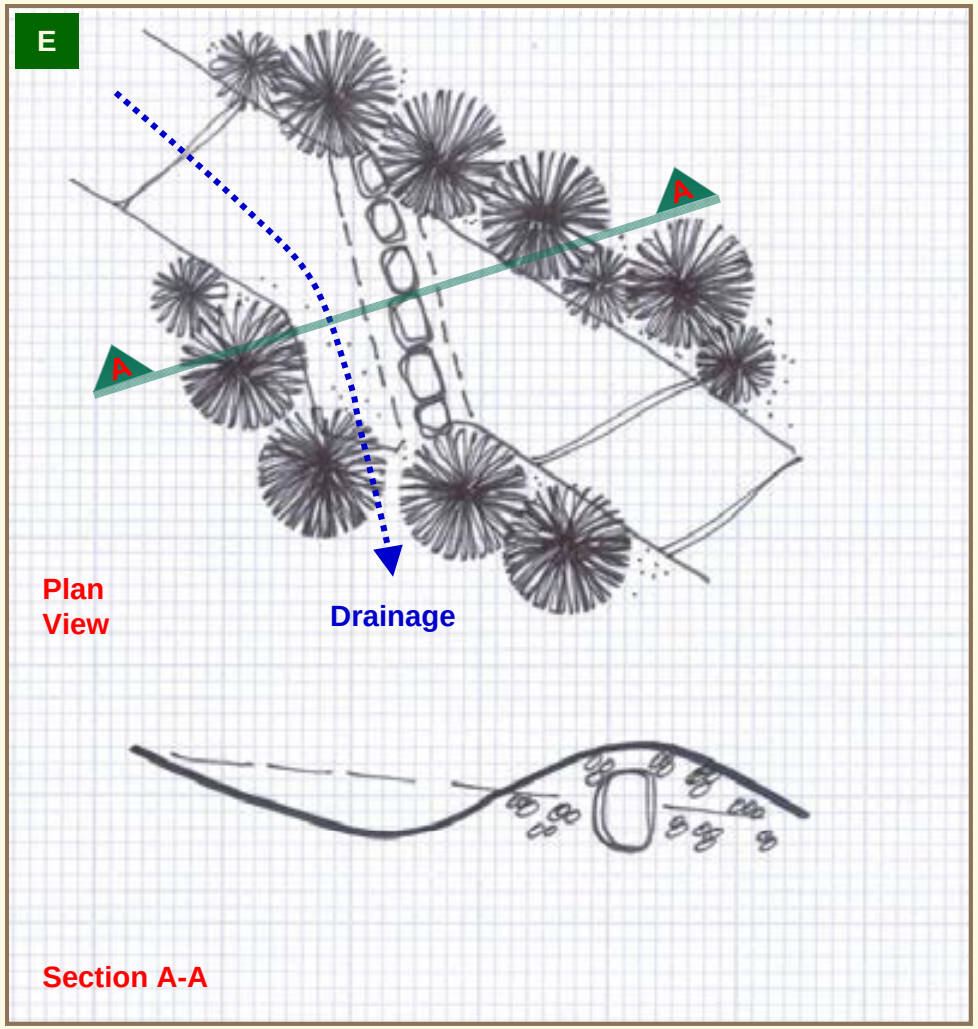


Stepping Stones can be used to provide alternative pedestrian routes across wet areas or intermittent streams. Successful installation of stepping stones depends on several factors:

- Proper stepping stone crossing location.
- Selection of adequate materials regarding type, size, and shape.
- Proper bedding (foundation).
- Accurate stone location for easy crossing.
- Cross where your work will not be impacted by high flows.
- Choose stone based upon longevity, i.e.: choose granite over sandstone.
- Choose stones of adequate size to cross the drainage. Most stones will need to have at least 2 flat sides.
- Do not over excavate and improve wet or boggy conditions.
- Place stones for a comfortable crossing. Walk the stones several times yourself and adjust them if necessary.
- Finally, analyze the work during wet conditions and make adjustments if necessary.

Note: ***Boulder Stepping Stones*** are used to cross narrow, but steep, drainages, or where evidence indicates high flows. ***Stepping Stones*** are used to cross areas on low flow. Strive to choose stones that are between 12" and 18" square for all stones.

Stone Waterbar



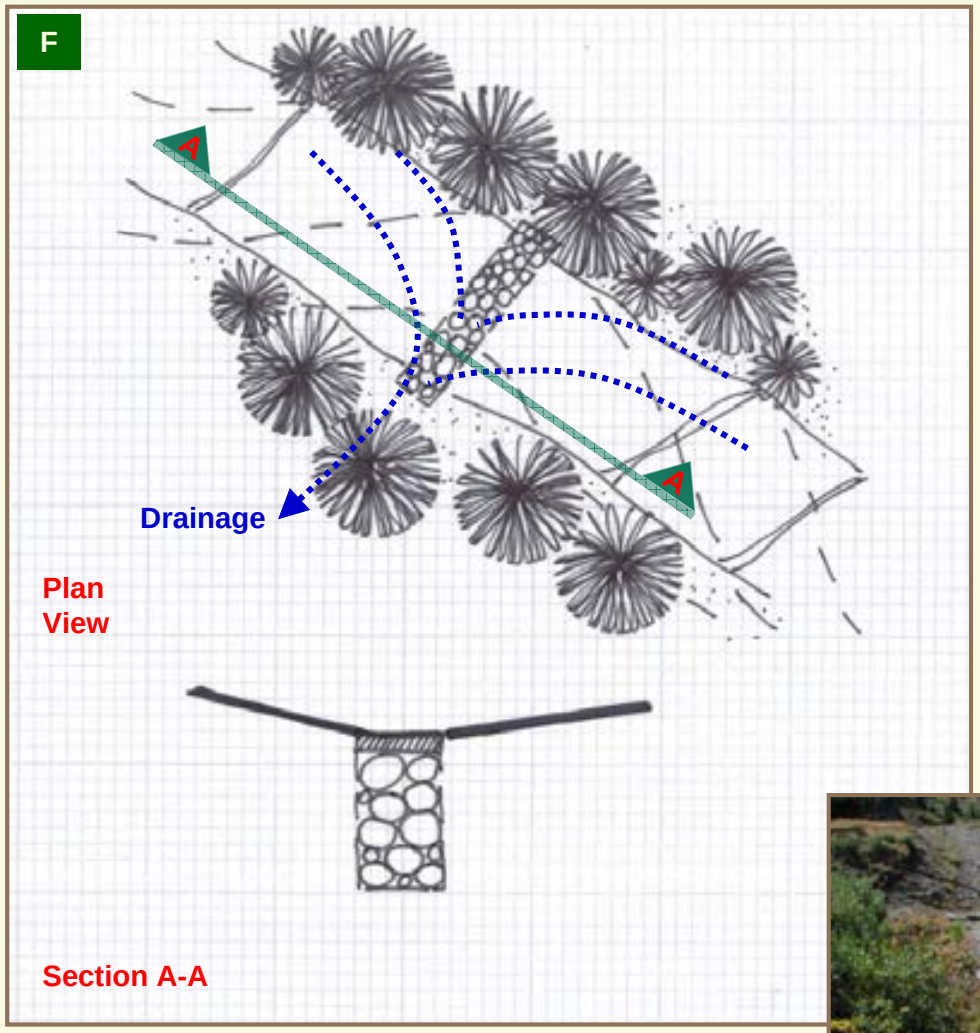
Good waterbars will cut down erosion and subsequent maintenance of otherwise well built trails. Some pointers:

- Take advantage of natural features when selecting a location for your ***Stone Waterbar***. A natural dip or a bend in the trail is a good place.
- Avoid areas without an outlet for drainage.
- Choose `waterbar stones' for use. These are 6" thick minimum and are generally rectangular in shape. Avoid round or narrow stones.
- After digging the trench, arrange the stones and see how they will work. Rearrange if necessary. Set aside unusable stones. Look for better stones.
- When you are satisfied with the choice, quality, and arrangement of stones, backfill to top of stones with miscellaneous fill and compact. Then grade over the top with 6" of select backfill.
- Test your ***Stone Waterbar*** by walking over it; adjust it if necessary.
- Create drainage outflow (in cut).
- Come back when its raining to observe your masterpiece.

Additional Notes:

- As with all stone work make a large selection of stones available to the installer!
- Save the soil from the trench for use on top of the ***Stone Waterbar*** if it is acceptable material.
- Miscellaneous fill must be free from organic matter.
- Select backfill less than 1/2" maximum dimension.
- Depth of outflow at edge of trail = 4".

Stone Drains

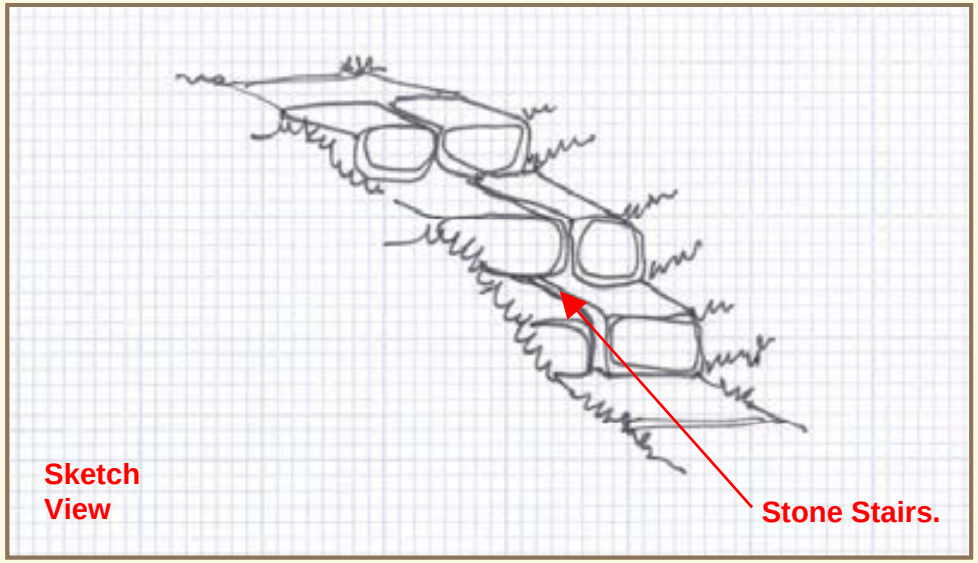


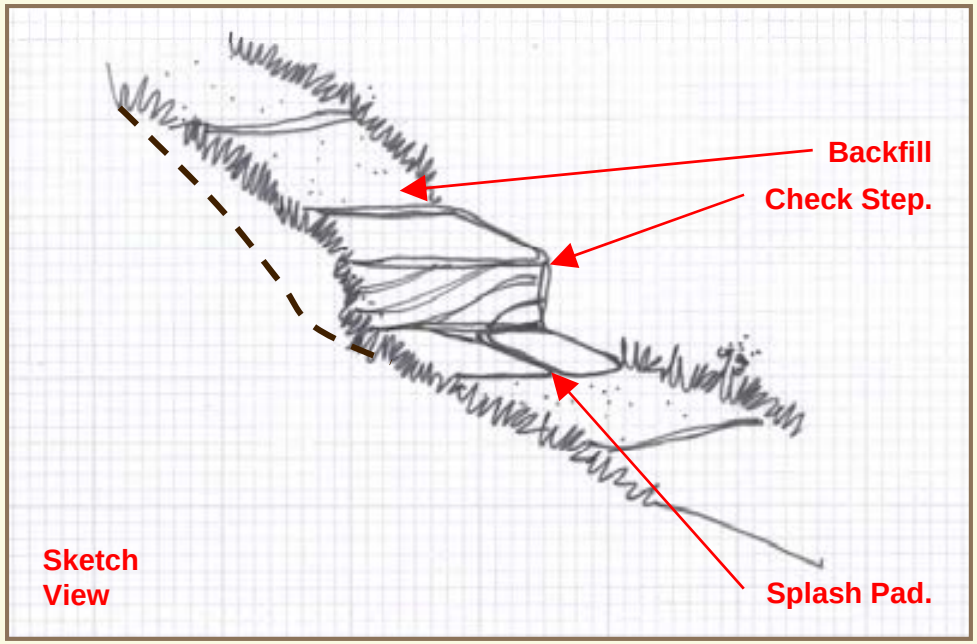
Stone Drains collect runoff and carry it across the trail. ***French Drains*** carry runoff under the trail, and sometimes parallel to the trail (yet still underground) and then under the trail. Some pointers:

- Round cobbles provide the best drainage capacity as the pore space between the stones is larger than if gravel is used. Rounded gravel is the second preferred drainage gravel type, crushed gravel is least desirable.
- Study the site conditions to determine the location, alignment and depth required to provide proper drainage.
- Fabrics can be used if they can be imported easily, and if used in a non-wilderness area.
- If desirable and available, top off the trail with finer soils to ensure a usable tread surface (***French Drain***).

Drains come in many varieties and are commonly dependent upon available materials and distance from the trailhead. The ***Cobble Drain*** at left is on a popular trail near Denver, Colorado.

Stone Stairs / Check Steps





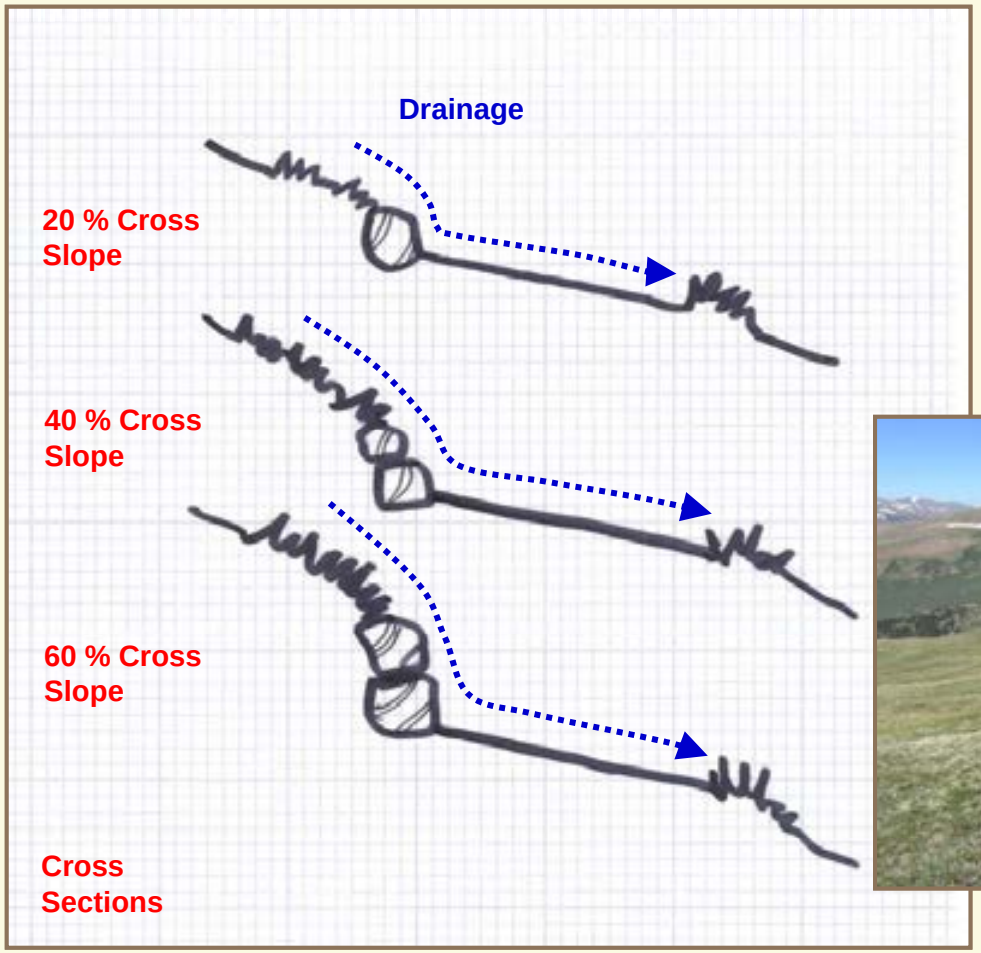
Stone Stairs can be used where grade must be gained quickly. Stairs are not intended to be used on trails that have horse or mountain bicycle use. Build Stone Stairs to withstand significant use and impact.

- Choose stones with a good shape for stairs.
- Start at the bottom and work upwards.
- Use the biggest stones possible to span the trail. Make sure strong people are on the crew! One stone would be best, two are fine, and three is maximum.
- Completely cross the trail. Choose the areas where people will stay on the trail and stairs.
- Build to the dimensions shown and make each set of stairs uniform
- Maximum grade at top and bottom of stairs as well as between stairs should be 8%.
- Walk your staircase to ensure it is smooth and uniform.

Check Steps are an option when severe erosion has gullied out a trail and relocation of the trail is not an option.

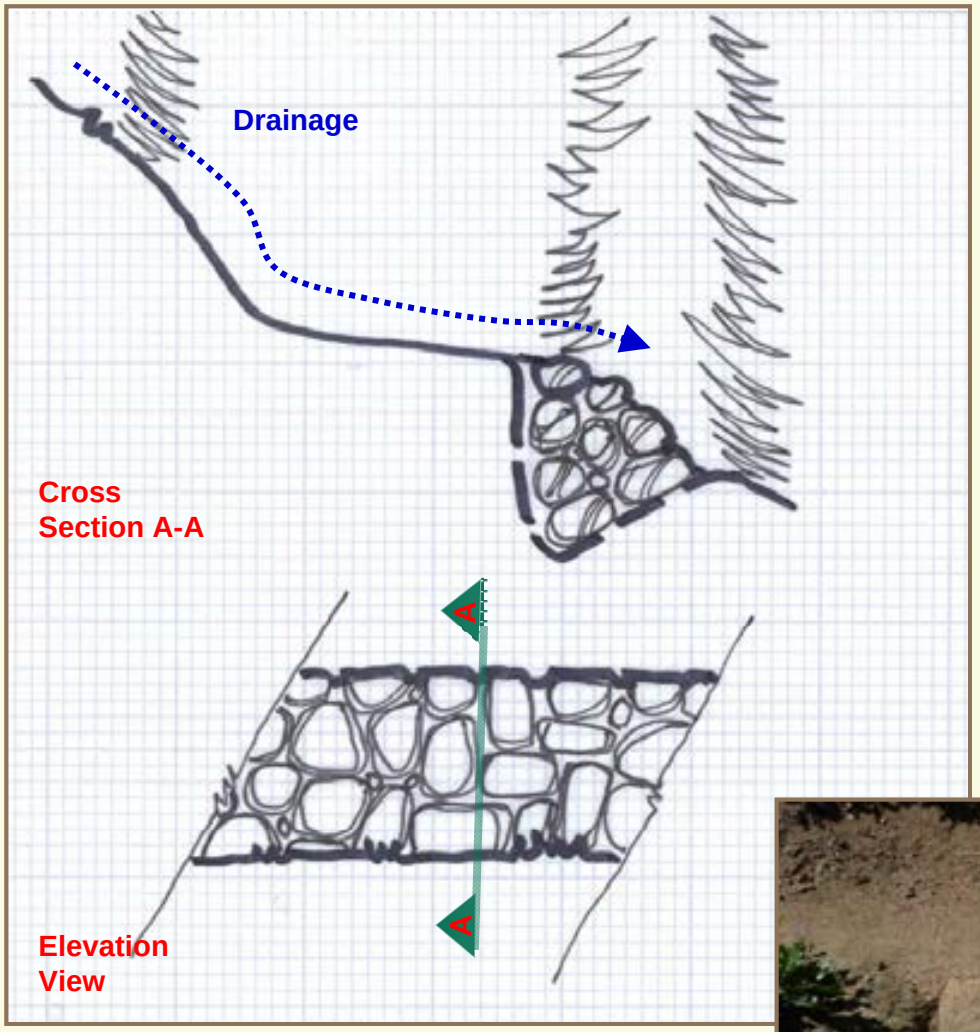
- As with ***Stone Stairs***, choose large stones, even stones that can cross the trail.
- Excavate to allow the step to sit on undisturbed ground.
- Backfill with suitable material and compact each 4-inch layer.
- A splash pad can be included to minimize the effect of drainage on the trail tread.
- ***Check Steps*** may be required for many hundreds of feet of trail in the high country, corresponding into significant amounts of resources.

Alpine Tread Cut



Alpine Tread Cut. Cutting trail without backslope rounding but rather with select stones placed in the backslope area will protect high country trails. The growing season is not sufficiently long in the high country for revegetation efforts to occur naturally.

Stone Retaining Wall

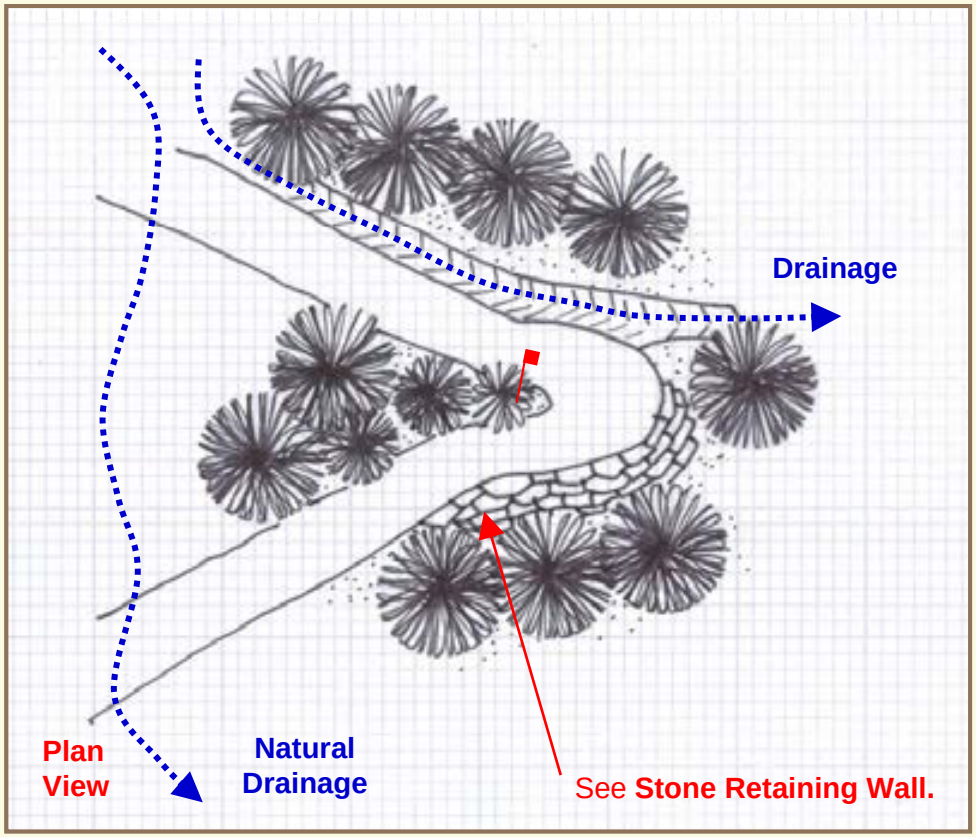


Stone Retaining Walls allow trails to be built where they normally would not be able to be built, or to improve less than adequate conditions.

- Begin by cutting a footing off the trail edge.
- The finished wall will be outside the width of the trail.
- Daylight the footing for drainage.
- Stack larger stones intermingled with medium stones near the foundation, fill voids with smaller stones.
- More contact between stones means more friction which means a better built wall.
- Stagger joints vertically and horizontally.
- Utilize gravity to advantage.
- Miscellaneous materials excavated from the trail corridor can be utilized as backfill.
- ***Stone Retaining Walls*** are indicated on the ***Design Notes*** by height (H) estimated in feet X length (L) also estimated in feet.

Stone Retaining Walls do not need to be complex. Simple walls provide great protection benefit to the trail surface and also provide easier and safer trail passage for trail users of all types.

Switchback

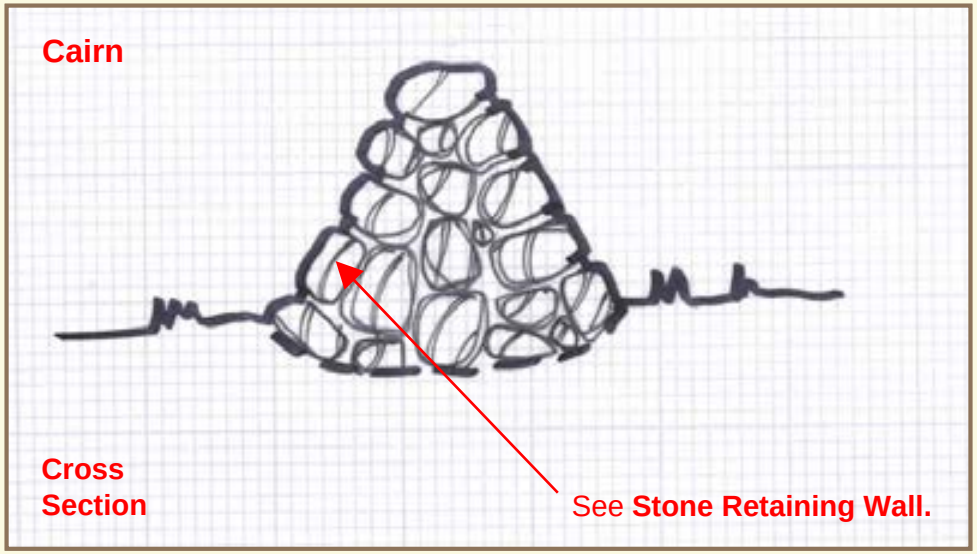


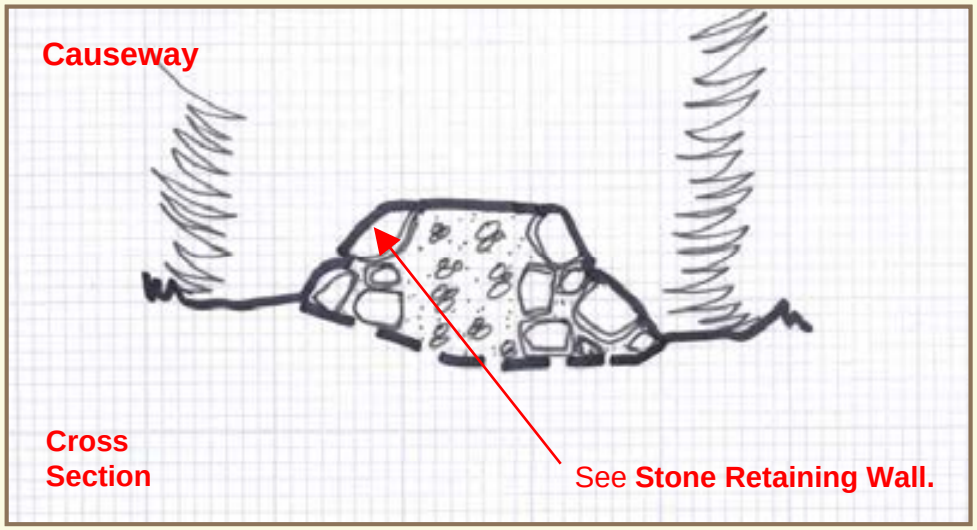
Switchbacks are utilized where it is necessary to change the direction of the trail.

- The Point of Intersection (POI) marks the theoretical intersection of the two trail legs.
- A 5-foot radius from the POI is required to accommodate hiker-only uses and an 8-foot radius is required to accommodate multiple uses (including horse or mountain bicycle use).
- ***Stone Retaining Walls*** are utilized to create a landing on which trail users turn.
- Sometimes ***Stone Retaining Walls*** or ***Freestanding Stone Walls*** are required to separate the upper leg of the Switchback from the lower leg.
- The landing is normally relatively flat, allowing easy turning without impacts.
- Provision for drainage is required, especially above the uphill leg close to the landing so that it is not impacted by rainfall or snowmelt.
- ***Switchbacks*** are best built by expert crews!

Switchbacks work best on relatively gentle prevailing cross slopes. This location is on the west side of the Promontory Ridge at Golden Gate Canyon State Park, Colorado. Detailed ***Field Work*** and ***Design Notes*** are required for proper construction.

Cairn / Causeway





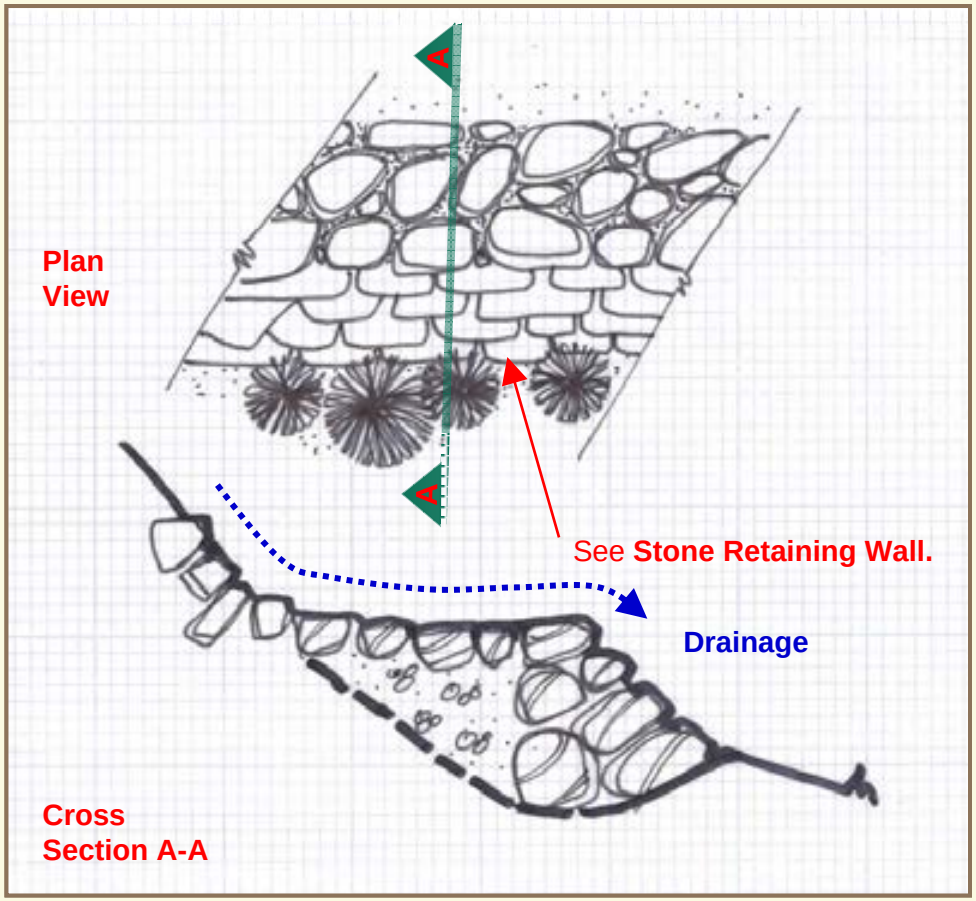
Cairns are used to mark trail corridors where they otherwise would be indistinct. In areas of abundant stone, cairns can be used to add aesthetic value to the trail, while also marking the trail corridor and guiding appropriate trail use.

- Begin by cutting a circular footing trench, removing all vegetative materials.
- Stack stones salvaged from trail clearing activities first, using the 'one over two' method shown. Other stones may be used; care must be taken to not create other impacts by taking too many stones from within sight of the trail or from one area.
- Height of cairn according to design notes, usually less than 3 feet. Where large mammals knock over cairns, greater heights can be used.
- Choose weathered stones, if possible, for sides of the cairn facing the trail corridor.

Causeways are options to consider when crossing unstable soils or for use in ***Riparian*** areas. Two ***Stone Retaining Walls*** are built to elevate the trail surface above the unstable condition.

- Width of the ***Causeway*** is dependent upon type and volume of use.
- Begin by digging a trench and removing unstable soils.
- Build the two ***Stone Retaining Walls*** at the same time back-to-back, raising each course simultaneously, and backfilling with suitable materials and compacting each 4-inch layer as you go.
- Top off the trail surface with granular soil materials.

Talus Crossing



It is occasionally necessary to cross talus in complex mountain trail projects. This is usually done by rearranging rocks in the trail corridor, and building stone retaining wall supports if necessary. It is important to point out that a talus crossing must be sufficiently wide to safely accommodate all allowable types of traffic. See ***Stone Retaining Wall***.

Talus Crossings are common on high country mountain trail projects. Sometimes they become a giant jigsaw puzzle or a *"stone-rearrange"* project.

Trail Management Techniques

4

"Please Help Protect Your Park"

Closing trails that are impacting natural resources is a difficult decision. Here at Lory State Park, several parallel tracks were recontoured, revegetated and restored. Visible results were apparent within just one year.

5

Directional signs help trail users understand their location and correspondingly help prevent impacts to natural and cultural resources.

Land management agency staff always has the prerogative to implement actions which may prevent impacts to resources, protect existing resources, improve the condition of resources or economize on the implementation of trails.

If resource impacts are occurring, the following menu of management techniques may assist park management in improving the overall experience for park visitors:

1. Establishing thresholds for muddy trail closures to minimize impacts to trail surfaces during inclement conditions; as well as seasonal trail restrictions to minimize impacts to trail surfaces during specific seasons.
2. Establishing and enforcing off-trail restrictions to prevent the continued creation of social trails.
3. Installation of barriers to prevent off trail impacts and signs to communicate the reasons for park policies.
4. Developing trail ethic brochures, signs, or seminars to educate park visitors about multiple use conflict, off trail impacts, safety and other issues.
5. Installing trail directional signs to assist park users with wayfinding.
6. Increase investment in ***Restoration*** of abandoned trails or other impacted areas to communicate to visitors city stewardship responsibilities and because the mountain needs to be repaired. Increase interpretive / educational opportunities to strengthen the overall trails program.
7. Utilization of mechanized equipment to assist in implementation activities while economizing on volunteer labor.
8. Establishing alternating clockwise or counter-clockwise trail uses to minimize multiple use conflicts.
9. Establishing ascent & descent routes on heavily used trails.

The Challenge …

Premises

Planning sustainable trails is based upon the following premises:

- Protection of natural & cultural resources;
- Where appropriate, make resources available via trails, some areas are best preserved (without trails);
- Appropriate geographically;
- Physical and social context studies (where appropriate);
- Appropriate origins, destinations & intermediary linkages;
- Recreation accessibility accounted for;
- Appropriate cross slope ranges & profile grades;
- Appropriate solutions for intended uses;
- Extensive field work is required, including the study of alternative routes; and
- Nonprofit support for individual projects.

Design Parameters

Planning sustainable trails is based upon the following parameters:

- Frontcountry conditions may exist upwards of 3 miles from the trailhead;
- Middlecountry conditions may exist 3 – 7 or 10 miles from trailheads;
- Backcountry or cross country conditions may exist 7 miles and further from trailheads;
- Multiple uses commonly include hiker (pedestrian), equestrian and mountain bicyclist uses;
- High volumes of use can be expected in frontcountry areas;
- Extended seasons of use can be expected, even year-round use, in all areas especially close to population centers;
- Public land management agencies usually have sufficient land bases to allow study of extensive systems and accommodation of many users; and
- Both monetary and labor resources are scarce, indicating decisions must be based upon long-term impacts or life cycle costs.

Caveats

Planning sustainable trails is based upon the following caveats:

- Heavily used trails may require to be surfaced with sustainable materials such as gravel or armored with materials such as stone, after long periods of heavy use;
- A hierarchy of investment both in monetary value and labor is epxected across the frontcountry – middle country – backcountry – cross country spectrum; and
- Maintenance activities, carried out up to 4 times per year will do much to ensure the protection of natural, cultrual and recreational resources and to ensure sustainability.

The Challenge …

Decisions that agency managers make influence:

- Patience
- Protection of resources
- Conservation of resources
- Optimum experience
- Wise investment of $
- Continual Improvement
- Build partnerships
- Cultivate nonprofit agencies
- Leave a legacy
- Pride in program

- OR -

- Panic
- Impacts to resources
- Loss of resources
- Less than optimum experience
- Squander $
- Continual deterioration
- Lack of support
- Lack of interest
- No infrastructure
- No worth

Many times, the hardest decision agency managers have to decide is whether or not to continue to use existing corridors, maintain them, rehabilitate them, or abandon them and start over with a new design according to sustainability criteria. Once a decision has been made, incremental and patient actions which are part of the overall design plan will result in the most beneficial project considering resource protection, land management agency goals and stakeholder interests.

… Is To Be Patient!

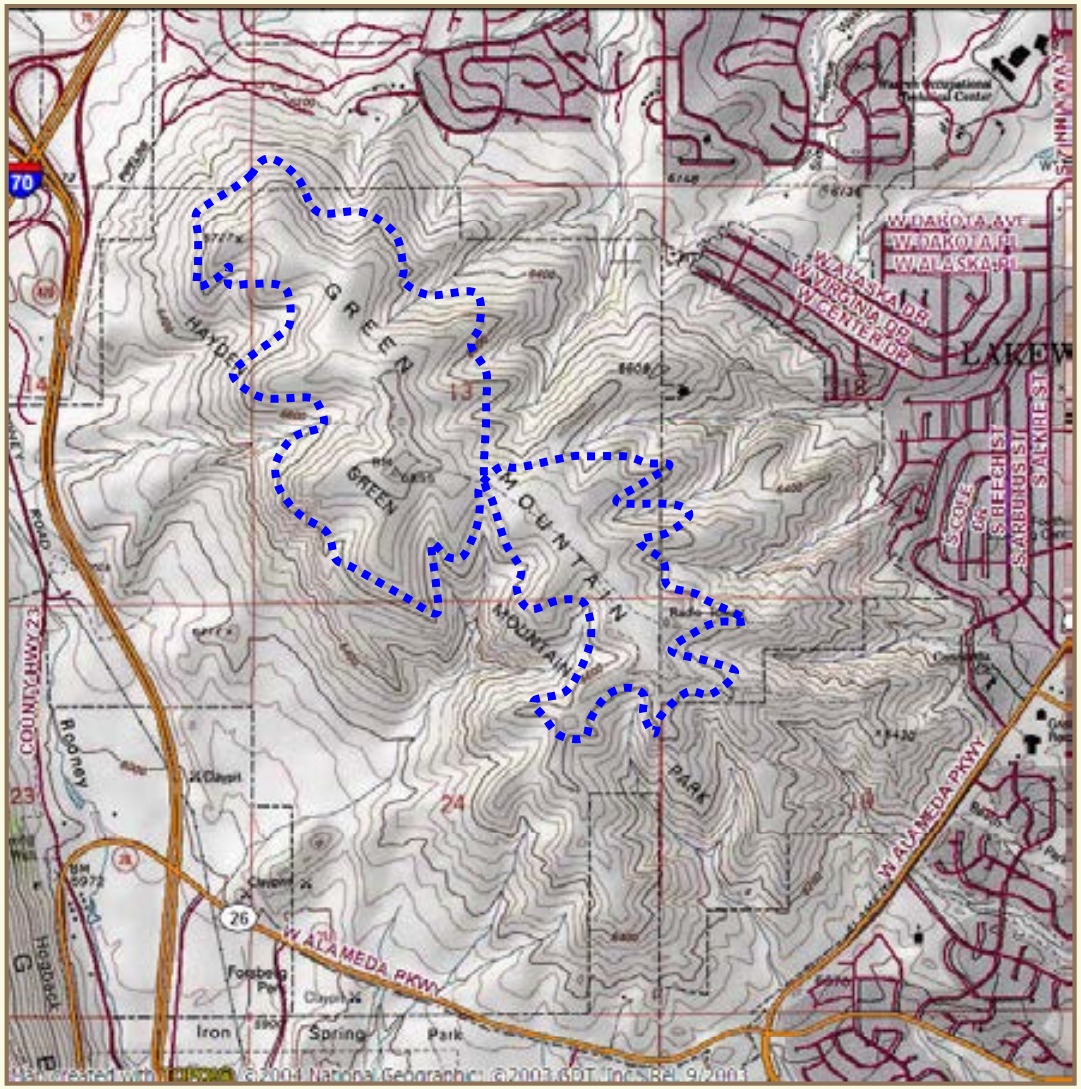
Patience! Rocky Mountain National Park – Emerald Lake Trail

Before condition.

Complex problems deserve careful thought, and many times substantial investments of time and resources. This project on the eastside of Rocky Mountain National Park restored a shoreline trail that had been heavily impacted by over use. The stone retaining wall along the lake's edge was purposely built with irregular lines to avoid the look of an unnatural structure from vantage points along the lakeshore and along the trail. Between 400 and 600 visitors per day in the peak summer season can now enjoy this more natural setting!

Hayden / Green Mountain Mountaintop Loop

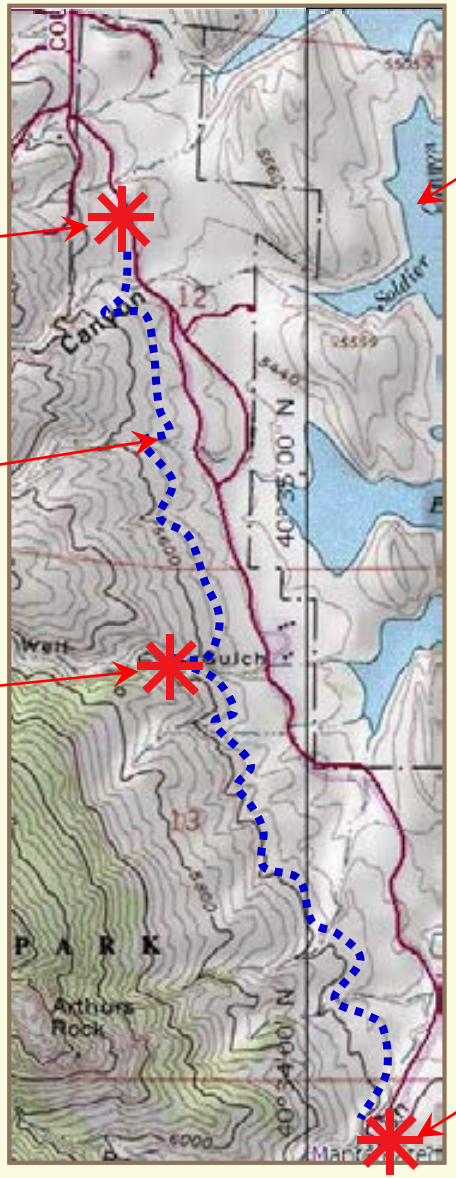
Patience!



The existing trail is on a maintenance road.

This nearly finished segment (2002) of the Mountaintop Loop Trail (photograph at right), at Hayden / Green Mountain Regional Park in Lakewood, will extensions planned for future years. Approximately 8 miles of trail will eventually be linked, providing an alternate route to a maintenance road.

Patience! Lory State Park – West Valley Trail



The West Valley Trail at Lory State Park were re-located from unsustainable locations to sustainable locations over a period of years. The original trail was parallel to the park road and ran straight up and down each successive ridge. Heavy rains, in just one storm, severely damaged the trails.

Corridor control points were mapped out using ***Mountain Trail Planning Tools & Techniques***, and the overall trails were broken into segments and designed using ***New Trail Design Tools and Techniques.***

Corridor Control Points were drainage crossings, including identification of a major bridge needed to cross Well Gulch. Minor control points were studied and mapped in design. A variety of nonprofit agency, government agency and volunteers groups implemented the trail.

As the trails are always within 3 miles of a trailhead and heavy use was expected, gently climbing grades were utilized for the West Valley Trail. Spot improvements, i.e.: ***Armor***, using crushed gravel were required in many locations. The West Valley Trail is now enjoyed by many users, including novice mountain bicyclists. Steeper areas at Lory State Park will have more challenging mountain bike routes in the future.

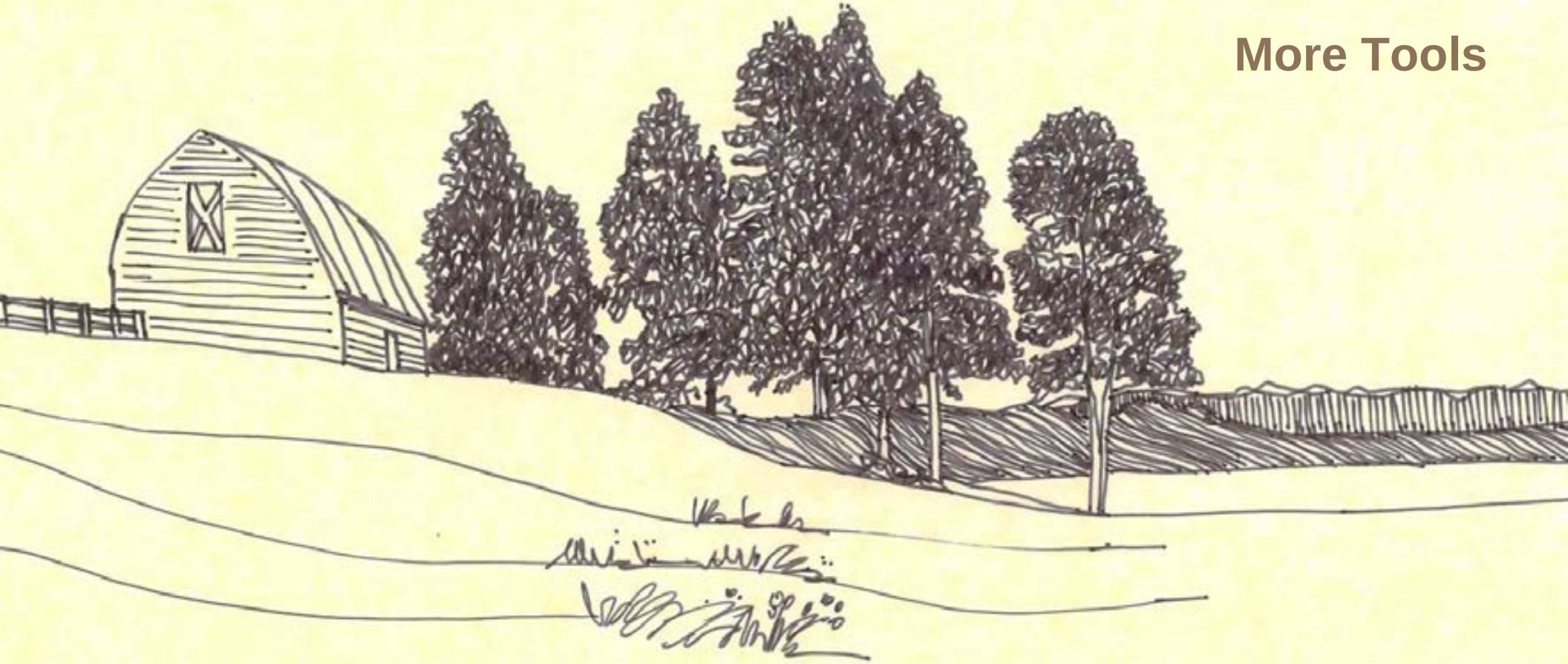
This ***Armor Design*** solution blends nicely with the setting while taking a substantial amount of time to implement.

Armor Design requires considerable understanding, skill and patience and is best done by experts, as in this trail at Rocky Mountain National Park.

The Sunrise Vista Trail. This trail at Steamboat Lake State Park evokes the character of Hahn's Peak, a prominent nearby landmark in northwest Colorado. This trail was planned and designed according to sustainability ethics and built by the Rocky Mountain Youth Corps.

Expert craftsmanship naturally ties this simple boardwalk to its setting.

More Tools



Steamboat Lake,
northwest Colorado

Alberta Parks and Recreation
1984 *Cross Country Ski Trails*. Edmonton, Alberta.

Appalachian Mountain Club
1998 *The Complete Guide to Trail Building and Maintenance, 3rd Edition*. (Carl Demrow and David Salisbury)

Appalachian Trail Conference
2003 *Appalachian Trail Fieldbook; Maintenance and Rehabilitation Guidelines for Volunteers, 2nd Edition.* Harpers Ferry, WV.
2000 *Appalachian Trail; Design, Construction, and Maintenance, 2nd Edition.* (William Birchard, Jr and Robert Proudman) Harpers Ferry, WV.
1981 *Trail Design, Construction and Maintenance*. Harpers Ferry, WV.

Arizona State Parks
1992 *Public Trail Access: A Guide to the Protection of Arizona's Trails.* Phoenix, AZ.

Arthur, Guy
1975 *Trail Construction*. Washington, D.C.: The Park Practice Program of the National Park Service (October 1975).

Bay Area Ridge Trail Council
1993 *In Support of Trails: A Guide to Successful Trail Advocacy*. San Fransicso, CA.

Beneficial Designs
Universal Trail Assessment Process. Online @ Beneficialdesigns.com.

Berry, Wendell
1981 *The Gift of Good Land.* New York, NY: North Point Press.

Binnewies, Robert, O.
2001 *Palisades: 100,000 Acres in 100 Years.* New York, NY: Fordham University Press.

Carr, Ethan
1998 *Wilderness By Design: Landscape Architecture & the National Park Service*. Lincoln, NE: University of Nebraska Press.

Colorado Outdoor Training Initiative (COTI)
2006 *COTI Instructor's Guide to Teaching Crew Leadership for Trails*. Denver, CO: COTI.
2004 *Standard Terminology for Trails.* Denver, CO: COTI.

Colorado State Forest Service
1998 *Colorado Forest Stewardship Guidelines.* Fort Collins, CO: Colorado State Forest Service.

Countryside Commission
1989 *Footbridges in the Countryside, 2nd Edition.* Scotland: Reiach Hall Blyth Partnership.

Duffy, Hugh, Kim Frederick & Lois Bachensky
1991 *Sustainable Mountain Trail Corridors*. Denver, CO: Colorado State Trails Newsletter.

Flink, Charles A, Kristine Olka, and Robert M. Searns
2001 *Trails for the Twenty-First Century, 2nd Edition. Planning, Designing, and Management Manual for Multi-Use Trails*. Island Press / Rails-to-Trails Conservancy.

Gobster, Paul H. and R. Bruce Hull
2000 *Restoring Nature.* Washington, D.C.: Island Press.

Grillo, Paul Jacques
1975 *Form, Function and Design.* New York, NY: Dover Publications.

Griswold, Stephen
1996 *A Handbook on Trail Building and Maintenance – For National, State and Local Natural Resource Managing Agencies.* Sequoia Natural History Association: Sequoia National Park.

Hellmund Associates
1998 *Planning Trails with Wildlife in Mind: A Handbook for Trail Planners.* Denver, CO: Colorado State Parks.

IMBA (International Mountain Bicycling Association)
2004 *Trail Solutions, IMBA's Guide to Building Sweet Singletrack.* Boulder, CO: IMBA.

Jackson, John Brinckerhoff
1994 *A Sense of Place, a Sense of Time.* New Haven, CT: Yale University Press.

Kaplan, Rachel, Stephen Kaplan an Robert L. Ryan
1998 *With People in Mind*. Washington, D.C.: Island Press.

Kershaw, Linda, Andy MacKinnon and Jim Pojar
1998 *Plants of the Rocky Mountains.* Renton, WA: Lone Tree Publishing.

King, William G.
1984 *Guidelines for the Rehabilitation and Preservation of the Appalachian Trail System Using the Principles of Landscape Architecture*. Recreational Impact on Wildlands: Conference Proceedings (pp. 213-216). Seattle, WA: USDA Forest Service & USDI National Park Service.

Lagro, James A.
2001 *Site Analysis, Linking Program and Concept in Land Planning and Design.* New York, NY: John Wiley and Sons.

Leopold, Aldo
1966 *Sand County Almanac.* Oxford University Press.

Lewis, James G.
2005 *The Forest Service and The Greatest Good, A Centennial History*. Durham, NC: Forest History Society.

Little, Charles
1990 *Greenways for America.* Baltimore, MD: Johns Hopkins University Press.

Lynch, Kevin
1960 *The Image of the City.* Boston, MA: MIT Press.
1984 *Site Planning, 3rd Edition.* Boston, MA: MIT Press .

Marion, Jeffery L.
2006 *Assessing and Understanding Trail Degradation: Results from Big South Fork National River and Recreation Area*. Blacksburg, VA: USGS.

McClelland, Linda Flint
1993 *Presenting Nature: The Historic Landscape Design of the National Park Service.* Washington, D.C.: National Park Service.
1998 *Building the National Parks.* Baltimore, MD: Johns Hopkins University Press.

McRaven, Charles
1997 *Stonework / Techniques and Projects*. Pownal, Vermont: Storey Communications.

Miller, Char and Rebecca Staebler
1999 *The Greatest Good – 100 Years of Forestry in America*. Bethesda, MD: Society of American Foresters.

Mirovitskaya, Natalia and William Ascher
2001 *Guide to Sustainable Development and Environmental Policy.* Durham, NC: Duke University Press.

Moore, Roger, Vicki LaFarge and Charles L. Tracy
1992 Organizing Outdoor Volunteers. Boston, MA: Appalachian Mountain Club.

Mutel, Cornelia Fleischer and John C. Frederick
1992 *From Grassland To Glacier, The Natural History Colorado and the Surrounding Region*. Boulder, CO; Johnson Books.

Nash, Roderick
2001 *Wilderness and the American Mind, 4th Edition.* New Haven, CT: Yale University Press.

National Park Service
2006 *Director's Order 77 – Resource Management Guideline.* Washington, D.C., NPS
2003 *Open Space, Protecting Open Space: Tools and Techniques.* Austin TX: NPS
1993 *Visual Quality of the Built Environments in National Parks.* Denver, CO: NPS.
1993 *Guiding Principles of Sustainable Design.* National Park Service: Denver Service Center.
1991 NPS Resource Management Guideline – NPS 77 Washington, D.C., NPS.
1937 Construction *of Trails, CCC Project Training Series No. 7*. Washington, D.C.: National Park Service for the Civilian Conservation Corps.

Parker, Troy Scott
2004 *Natural Surface Trails by Design*. Boulder, CO: Natureshape.

Parks Canada
1978 *Trails Manual*. Ottawa, Canada.

Pennsylvania State Trails Program
1980 *Non Motorized Trails / An Introduction to Planning and Development*. Harrisburg, PA.

Project Management Institute
2004 *PMBOK Guide to Project Management, 3rd Edition*. Newtown Square, PA: Project Management Institute.

Proudman, Robert D. and Reuben Rajala
1981 *Appalachian Mountain Club Field Guide to Trail Building and Maintenance, 2nd edition*. Boston, MA.

Rails to Trails Conservancy
1993 *Trails for the Twenty-First Century.* Washington, D.C., Island Press.

Robinette, G.O.
1972 *Plants/People/Environmental Quality.* Washington, DC: National Park Service & American Society of Landscape Architects.

Schmid, Jim
Trails Bibliography. On-line @ outdoorlink.com/amtrails.

Schwarz, Loring, Chuck Flink and Bob Searns
1993 *Greenways: A Guide to Planning, Design and Development.* Washington, D.C.: Island Press.

Sierra Club
http://therucksack.tripod.com/trailbuilding.htm

Simonds, John O.
1997 *Landscape Architecture.* Columbus, OH: McGraw Hill Companies.

Snow, Dan
2001 *In the Company of Stone*. New York, NY: Artisan.

Steinholtz, Robert T.
2001 *Wetland Trail Design*. Missoula, MT: US Forest Service.

The Mountaineers / Student Conservation Association
2005 *Lightly on the Land, The SCA Trail-Building and Maintenance Manual, 2nd Edition*. (Robert C. Birkby)

Thompson, J. William and Kim Sorvig
2000 *Sustainable Landscape Construction*. Washington, D.C.: Island Press.

Trapp, Suzanne and Michael Gross and Ron Zimmerman
1991 *Signs, Trails, and Wayside Exhibits*. Stevens Points, WI: University of Wisconsin-SP Foundation Press, Inc.

University of Minnesota
Bibliography of Trail Planning, Design, Construction and Maintenance Literature. http://www.umn.minerva.edu

Weaver, Tad; Dale, Donn; Hartley, E.
1979 *Guidelines for the Rehabilitation and Preservation of the Appalachian Trail System Using the Principles of Landscape Architecture*. Recreational Impact on Wildlands: Conference Proceedings (pp. 94-100). Seattle, WA: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station and USDI National Park Service.

U.S.D.A. Forest Service
2000 *Trail Construction and Maintenance Notebook, 2000 Edition.* US Department of Agriculture, Forest Service, Missoula, MT.
1994 *Forest Service Manual, 2600-Wildlife, Fish and Sensitive Plant Habitat Management.* Region 2.
1984 *Trail Construction Manual*. Washington, D.C.
1984 *Standard Specifications for Construction of Trails* (Publication Number EM 7720-102). Washington, D.C.
1987 *National Forest Landscape Management, Volume 2,Chapter 8: Recreation. Agriculture Handbook No. 666. Washington, D.C.*
1973 *Forest Landscape Management Volume 1*. Washington, D.C.
1923 *Trail Construction on the National Forests*. Washington, D.C.

U.S. Department of Transportation
www.fhwa.dot/gov/environment/fspubs/index.htm

U.S. Department of Transportation, Federal Highway Administration
2001 *Designing Sidewalks and Trails for Access – Part II of II, Best Practices Design Guide.* Washington, D.C.: Federal Highway Administration

Wisconsin Division of Tourism
2001 C*ross Country Ski Trail Development Guidelines.* Madison, WI.

Whittaker, P.L., and Bratton, S.P.
1978 *Comparison of surface impact by hiking and horseback riding in the Great Smoky Mountains National Park* (Research / Resource Management Report No. 24). Gatlinburg, TN: NPS.

Yosemite Association
1995 *Yosemite and the Mariposa Grove: A Preliminary Report,* 1865 (a.k.a.: *"The Olmsted Report"*). Yosemite National Park, CA.

Volunteerism Opportunities. Land management agencies across Colorado frequently partner with individual volunteers and nonprofit agencies to achieve mutual goals. Maybe your interest in conservation can be paired up with a pressing need!

Towards a Mountain Trail Sustainability Ethic …

Mountain trail sustainability can be summarized as the optimum investment of labor and materials into the ***Trail Project Cycle*** processes of an individual trail or a trail network over an extended period of time. It is based upon a wilderness ethic of minimum alteration of natural systems & minimum evidence of human presence. It is two-pronged:

- Establishing a sustainable corridor; implementing a travel surface within that corridor; and
- Making incremental spot improvements, or minor relocations; and carrying out required maintenance, rehabilitation or armoring activities over time to ensure protection of natural (especially soil) & cultural resources as well as safe passage.

The higher the percentage of natural surface improvements versus required armored improvements, the more sustainable the corridor is likely to be.

Review of popular trails literature indicates that poor planning or poor design leads to frustrations for agency land managers who inherit short-sighted projects. Resource impacts have resulted as well. Many trails utilized today for recreational purposes either evolved from social trails, old roads or stock or game trails, or were minimally or poorly planned. Regardless of the process nor the level of investment, modern trail planners who utilize state of the art ***Tools & Techniques*** are reversing the trend where wholesale abandonment, restoration, and ***New Trail Design*** of corridors is required to ensure recreational access. Thoughtful trailside activities throughout the ***Trail Project Cycle***, will help achieve goals for all project stakeholders over the longer term.

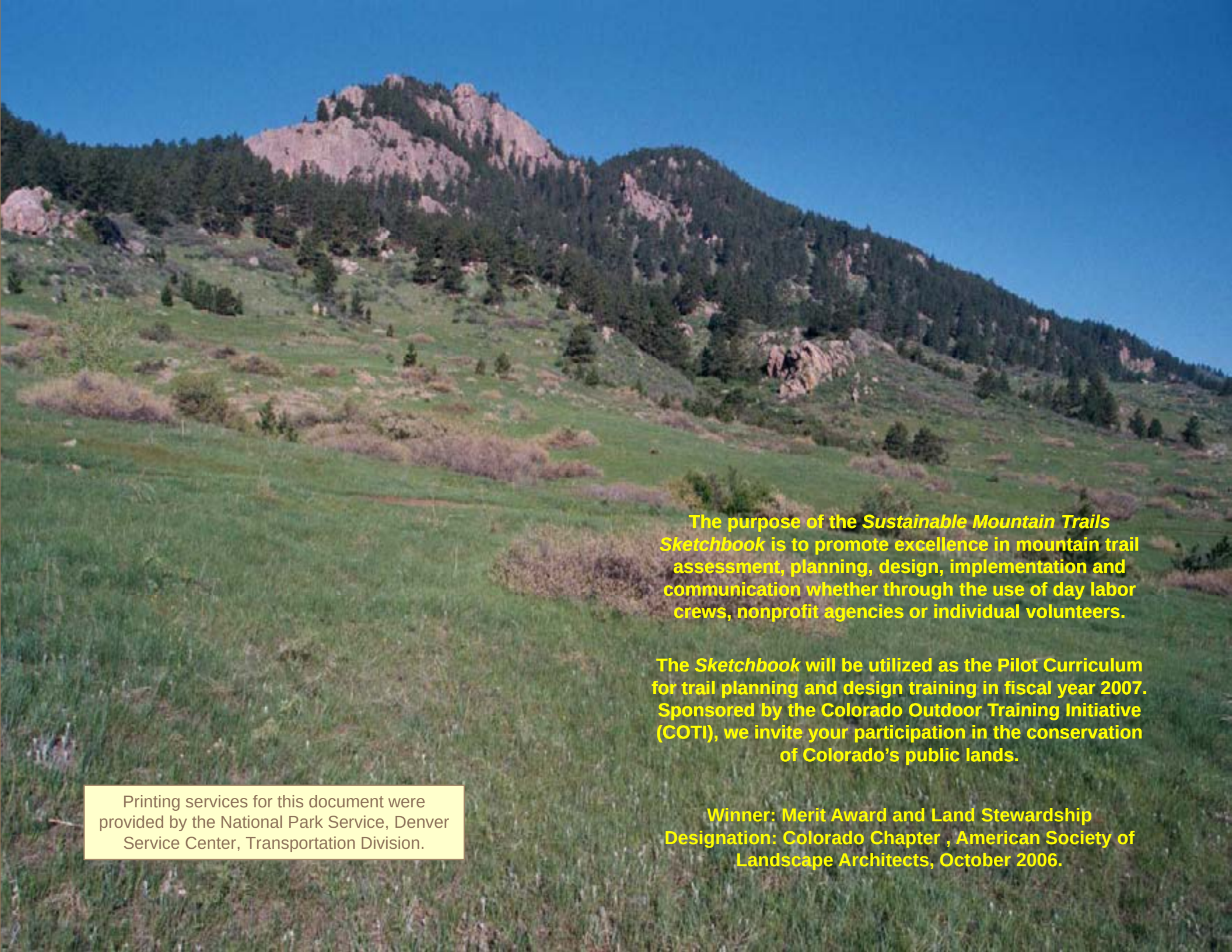
The ***Sketchbook*** advocates that sustainability criteria be applied to any trailside activity. The ***Sketchbook*** is intended to complement other trails literature. It summarizes sustainability criteria, processes and implementation options that are not published elsewhere, yet have been found to be the successful in Colorado.

Users of your trail projects tomorrow will benefit from your thoughtfulness today. It is a rewarding experience to observe people using completed trail projects, even for many years afterward. Future agency managers will also benefit from your diligence. The concurrent goals of reducing maintenance backlogs, increasing percentage of overall programs in sustainable condition while building / encouraging much-needed non-profit agency and individual volunteer support are not only achievable but worthy to aspire to.

Communicating the need to properly assess, plan, design and implement natural surface trail projects; the significance of your work to others who are relying on you; and the lasting legacy that you can leave on trails in your conservation is our paramount goal. Our hope is that …

- … we have given you ***Tools & Techniques*** which will be useful to each step in the project cycle and which you can customize to fit your specific project;
- … you adopt the ***Lessons Learned Technique*** prescribed by the Project Management Institute, and that you endeavor to test out your thoughts, develop your own new thoughts, apply them to the ground, then to subsequently assess your projects so that you may apply your ***Lessons Learned*** to future projects;
- … whether you are an agency official, nonprofit partner or individual volunteer, that you will be encouraged to provide the highest degree of excellence to your project activities; and
- … wherever you are affecting trails in the ***Trail Project Cycle***, you can be satisfied that you did the hard work and invested the time necessary to ensure the optimum investment of dollars, labor and material resources into your trail project with minimum impact on natural and cultural resources.

More research into sustainability criteria, processes and solutions is required, including use of technology, as is additional training for agency management and staff. Please join us in our efforts to increase awareness of trail sustainability issues in Colorado's High Country. Oh, and ***"Happy Trails!"***



The purpose of the *Sustainable Mountain Trails Sketchbook* is to promote excellence in mountain trail assessment, planning, design, implementation and communication whether through the use of day labor crews, nonprofit agencies or individual volunteers.

The *Sketchbook* will be utilized as the Pilot Curriculum for trail planning and design training in fiscal year 2007. Sponsored by the Colorado Outdoor Training Initiative (COTI), we invite your participation in the conservation of Colorado's public lands.

Winner: Merit Award and Land Stewardship Designation: Colorado Chapter , American Society of Landscape Architects, October 2006.

Printing services for this document were provided by the National Park Service, Denver Service Center, Transportation Division.