Design, Layout and Construction of Sustainable Multi-Use Trails

Some Things I've Learned

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Abstract: This document expresses some of what I learned about sustainable trail building under the guidance of knowledgeable members of the Central Coast Concerned Mountain Bikers organization during the Spring Quarter 2012. A brief description of some of the most pertinent trail design principals and construction techniques are also given, including the importance of proper drainage and trail grade and the consequences to trails lacking these essential design elements.

Table of Contents

Introduction

Sustainable multi-use trails provide environmental, social and personal benefits to all users. Trail design focused on maintaining proper drainage and minimizing erosion reduces sedimentation of adjacent streams and helps maintain the hillside while allowing for safe, enjoyable recreation. Construction requires cooperation between many agencies, organizations and users and provides a sense of community among those involved in the construction process. Recreational use of the end product delivers personal enjoyment and a feeling of achievement to both contributors and users.

The purpose of this project is to increase my personal understanding of sustainable trail design, layout and construction through observation, research and practice.

What I did – what the project entailed.

For this project I worked under the supervision and guidance of experienced members of the Central Coast Concerned Mountain Bikers (CCCMB) organization to develop my trail layout and construction skills. On a weekly basis for the spring 2012 quarter I met with several members of CCCMB at Montana de Oro State Park, near Los Osos, CA to help with the design of a substantial reroute of the current Oats Peak Trail. During these outings I gained much insight into the time consuming process of trail layout and the importance of proper grade, drainage, flow and switchback placement. Training in construction and maintenance aspects came during the CCCMB monthly trail workdays and other informal workdays. These events allowed me to see and work on several different types of trails throughout the community, including special bike skills areas, smooth cross-country singletrack, sandy trails and rough rocky routes. I helped bench cut new trail, clear brush, clean drains, and build waterbars, jumps, and banked turns.

I sought the help of CCCMB because of their longstanding reputation as trail advocates and exemplary work on the Central Coast. Since their inception nearly 25 years ago they have been diligently maintaining many of the local multi-use trails near San Luis Obispo, CA. While mountain biking is the core element that draws members to the organization, CCCMB strives to promote cooperation with other trail users through trail workdays open to any volunteer, trail signage, bike bells, and education on cycling etiquette (CCCMB, 2012).

Why I chose this project.

My career interest is in forestry with the goal of becoming a California Registered Professional Forester, but the path to that point will require more training and field experience. One of the many jobs of a forester is to develop roads for logging activities; though not entirely similar, trails are like mini-roads. As with forest roads, trails are limited by the topography and different grades of slope. Erosion control and maintenance are also huge factors that are influenced by design of both types of path. The experience I gained through this project has opened my eyes to a different way of viewing the landscape. Trails (and roads) are not just haphazardly blazed to the destination, there are certain points that must be reached and ones that must be avoided, turns and switchbacks are placed in specific

locations, line of sight and grade must be maintained and many other technical details; planning and collaboration are essential.

Beyond the potential applications in a future career, this project readily applies to my favorite past time; mountain biking. According to Vernon Felton "A great bike on a crappy trail makes for a crappy ride; while a crappy bike on a great trail can still make for an amazing ride" (2008). I can attest to this statement from experience. Before this project I was interested in trail building and maintenance, but had little guidance or knowledge of best construction principals and techniques. In the short time span of the project I have gained a much better understanding of sustainable trail building. This is a valuable skill that I can use on trails where ever I am, not only to enhance my trail experience, but those of other users too.

What I learned.

This project mainly focused on the more tangible and physical aspects of trail building. Starting a trail from scratch can be a lengthy arduous process that requires community support or backing by an organization of some clout (i.e. IMBA). The first step in any trail building project is approval by landowners and land managers; this may require collaboration with multiple authorities. Permits and certifications may also be required (i.e. Coastal Zone, chainsaw training, etc.) In the end the physical labor might be the easy part, but these first steps are critical. Building illegal trails can lead to many problems with landowners, city, county and park officials. It also tarnishes the image of the other trail user groups who are obeying the rules and may make future trail approvals more difficult. An article in Mountain Bike Action (2011) gives a quick synopsis of these initial steps required in the trail building process. The International Mountain Biking Association (IMBA) also provides general information on how to get the ball rolling in their Trail Solutions: Guide to Building Sweet Singletrack book (2004) and on their website at http://www.imba.com/.

Trail Slope

Trail slope is one of the most important, if not the most important element to building a sustainable trail. It can determine whether a trail acts as a conduit for water and eroded soil or a recreation route that lasts for decades. The members of Central Coast Concerned Mountain Bikers (CCCMB) are very adamant about having a precise slope. Clinometers are a relatively inexpensive, yet effective way of measuring slope. When using a clinometer for an accurate reading, it is important that the operator be looking at a point at an equal height from the ground as the tool. To reduce variability between measurers, CCCMB uses monopods of equal height so that the person measuring can steady the tool on one rod while another person holds a rod at a desired point to be measured to (see photo).

Greg Bettencourt, New Oats Peak Trail Montana de Oro State Park, CA 27 March, 2012

The International Mountain Bicycling Association recommends that a sustainable trail be constructed with an average grade of 10% (Felton, 2004), however the members of

CCCMB beg to differ. CCCMB aims for a 5% average grade on the trails they build. Greg Bettencourt, CCCMB Director, contends that the 10% rule was a compromise with land managers who argued that using a lower average grade would require longer trails to reach destinations and increase the cost of construction too much (personal communication, 2012). While there is truth to the need for longer trail and greater cost of using a lower average grade, there are also benefits. It is unrealistic to maintain a consistent grade from trailhead to finish; the topography will dictate the trails slope, which may at times be greater or less than the desired average. Trail grades in the teens (and higher) even over short distances, like 25 feet or so, will erode much faster than those below 10% (Bettencourt, personal communication, 2012). Aiming for a 5% average grade allows for short sections of trail to be steeper (even double the average) and still not produce the erosion potential of a 10% average grade trail.

One of the factors that controls trail grade is the pitch of the sideslope or angle of the natural hillslope that the trail is cut into. A guideline advocated by IMBA, known as the ½ Rule, states that "A trail's grade should not exceed half the grade of the sideslope that the trail traverses." For example, if the hillslope is only 10% then the trail grade should not exceed 5%. If a trail exceeds the ½ Rule water may be channeled down the trail rather than across and off, also known as a fall-line trail (Felton, 2004).

Outsloping at trails surface is also essential. It simply means, when cutting in the new path, to angle the trails surface so that water will flow off the trail in the direction of the natural hillslope and not pool on the trail. A 5% outslope is adequate to allow runoff to sheet off the trail while still maintaining a more or less level surface for people to traverse (Felton, 2004). Though a trail may have been created with an outslope, over time soil displacement from the center of the trail and compaction by different users and natural erosion may cause a lip to develop on the outer edge of the trail, which may encourage water to funnel down the trail (Parker, 2004). The funneling action caused by the cupped trail makes it very important that waterbars and grade reversals are not too widely spaced so that water can drain off the trail before serious damage occurs. Knocking down the outer lip of the trail to restore the outslope can reduce the erosive power directed at the trail surface.

Runoff and Drainage

Waterbars are diagonal speed-bump like furrows of dirt cut across a trail at regular intervals to direct any water and eroded soil flowing down the trail off into dense vegetation, a rocky catchment or some sort of armored surface. Waterbars should be angled across the trail at no less than 30 degrees to create a smooth transition to shift water off the trail (USDA Natural Resource Conservation Service, 2000). The more perpendicular a waterbar is, the greater the erosive force against it by the flowing water which increases the possibility of it being breached. Waterbars can easily be incorporated into existing trails and if adequately spaced can help prevent rutted or saturated trails. However, waterbars require routine maintenance to ensure that outlets do not fill with fine soil and eventually allow water to spill over the top back down the trail.

Grade reversals, also known as rolling dips or drain dips, are a much better alternative to waterbars. They are wide "u" shaped dips incorporated into trails to divert water off the tread and add diversity to the user's experience by interrupting sections of constant grade. Any water flowing from the uphill leg of the dip is inhibited from flowing down the trail by the lower leg of the reversal and instead forced to

drain in between at the low point. IMBA recommends that these be installed every 20 to 50 feet on trails (2004). They are more effective and require much less maintenance that waterbars, but should ideally be incorporated into the original design of a trail, as it is difficult to retrofit them into an existing trail. Also, from the perspective of a mountain biker, they are much more enjoyable to ride through than the abrupt speed bump like waterbars that cross the trail.

I will not bog down in the details, but soil type also has a profound effect on trail tread behavior. A well compacted mixture of silt, sand, clay, and gravel provides the most erosion-resistant trail surface. Sandy or gravelly soils lack binders and are not very cohesive which increases displacement, especially when dry. On the other end of the spectrum, primarily clay and silt soils bind together well, but remain wetter longer and displace easier when wet. Loam is a fairly even combination of silt, sand and clay particles which can result in a more durable tread surface than any of the other soil types on their own (Parker, 2004). Troy Scott Parker has developed a very informative table that predicts the ideal spacing between drainage features based on the soil type and trail grade.

Approximate Hypothetical Maximum Tread Lengths by Tread Texture, with Specific Assumptions

Tread length is the distance between a tread crest and the adjacent dip that drains the segment between them.

Assumptions:

- Most tread watershed water drains down the tread and through the dip at the lower end (i.e., sunken tread with little side drainage).
- **Although erosion will still occur even with these values—especially in extreme runoff events**—these tread length values are designed to require minimal tread maintenance and to minimize tread shape change through erosion.
- Tread is **well-compacted** and about 30" wide.
- Trail has moderate use with moderate displacement (hiking).
- Tread watershed has moderate runoff potential.
- No tree canopy (high splash erosion).
- Downpours are likely only 1-3 times each year (climates with more extreme rain should use shorter tread watersheds).
- No water sources exist besides than rain and runoff.
- **Note that these values are intended only as a conceptual guide. YOUR CONDITIONS AND RESULTS WILL VARY.**

	Tread Grade										
Tread texture	**0%***	**2%**	**4%**	**6%**	**8%**	**10%**	**12%**	**14%**	**16%**	**18%**	**20%**
Clay loam with high quantity of gravels, cobbles, and stones	215'	160'	120'	90'	67'	50'	35'	24'	16'	10'	5'
Gravelly clay	180'	132'	96'	69'	49'	34'	22'	14'	8'	4'	
Loam with high quantity of gravel and cobbles	160'	117'	83'	57'	39'	26'	17'	10'	6'	3'	
Clay†	145'	104'	74'	51'	34'	22'	13'	7'	4'		
Loam	135'	90'	57'	37'	23'	14'	8'	4'			
Crushed granite or crushed limestone, angular particles, 0.75"-minus, 5" thick	125'	78'	49'	30'	17'	9'	5'				
Organic soil	110'	68'	39'	22'	12'	6'					
Sand	100'	55'	30'	16'	8'	3'					

* Unless it is sustainably pitched to drain to the side, no tread should have a 0% grade. The 0% figures are listed as an upper dip spacing limit for grades above 0% and below 2%.

† Although compacted pure clay can be cohesive even on steep grades, it is generally too slippery when wet to be practical.

Turns and Switchbacks

Turns and switchbacks are essential in almost every trail, but they are more expensive and time consuming to build than straight sections of trail. When constructing any form of turn it is important to maintain a consistent arc. This will increase the flow of the trail, especially for cyclists, and reduce the

need for abrupt braking to accommodate for sudden changes in the curvature of the turn. Berms or banked turns are effectively insloped turns. They can prevent mountain bikers from eroding the trail surface by skidding or widening the trail by arcing the turn too wide, but they also require more maintenance than outsloped turns (Felton, 2004).

Trail anchors are large obstacles specifically placed next to the trail to encourage users to stay on the path. Placing anchors on the inside of turns can be an effective way of preventing short-cutting. They also can make a trail more technical to navigate and prompt cyclists to slow down to safer speeds while still maintaining the exhilaration of the ride (Felton, 2004).

A switchback is a nearly 180 degree turn that allows a trail to continue to gain elevation up a hill side while maintaining a sustainable grade. Switchbacks are constructed so that the trail surface is at a much shallower angle than the sideslope so that the trail can change directions without rapidly losing elevation over a short distance. As a general rule IMBA recommends that for every 10% sideslope a retaining wall will need to be built one foot taller to support the lower leg of the switchback and maintain the desired trail grade (Felton, 2004). For this reason, when designing a trail, it is best to locate switchbacks in areas with the lowest sideslope. Proper drainage of a switchback is complicated, it is important that grade reversals be integrated into the trail just before the switchback so that no unnecessary erosive stress will be put on the tread in the turn. Shortcutting is a common occurrence at switchbacks; it effectively makes the trail steeper causing increased erosion (Proudman, 1977). The best way to avoid this is to place some sort of barrier or deterrent between the upper and lower legs like a large rock or boulder or routing the turn around a tree or large bush (Felton, 2004 & Parker, 2004).

Other Important Factors

When choosing a path to build a new trail it is important and also takes practice that you remind yourself to view the potential path from the perspective of other trail users. I prefer to mountain bike, but in most cases a trail open to cyclists will also be open to hikers and equestrians. That being the case, trails must be designed to appeal to all users; for example, building a trail near a cliff or on a very steep slope may spook horses and be dangerous for their riders or routing at trail so that two segments run nearly parallel to each other with no significant barrier in between them (as may be the case with the arm into and out of a switchback) may encourage short-cutting by hikers.

Line of sight is important on multi-use trails to prevent user conflicts. Users traveling at faster speeds require more time to react to unexpected obstacles. Blind corners or dense vegetation may limit visibility and increase the likelihood of a collision. A good line of sight cannot be preserved in all locations on a trail, but the trail can be designed to slow users down, by using trail anchors, rougher surfaces (i.e. rocky trail) or more technical routing for example.

Full bench trail are those whose tread surface is cut completely into the hillside, in other words none of the excavated material is used to build the path on top of the hillside. If a trail is not a full bench, problems with compaction may arise with use. The material used to build up the tread (fill material), though initially compacted, may consolidate even further during the wet season causing an uneven trail surface. Also displacement by users and precipitation may cause the filled portion to shift downhill. Not

all portions of trail may be ideal for full bench trail (i.e. very rocky sections) however they will last much longer and require much less maintenance than partial bench trails.

When laying out a trail there may be specific locations that the trail must go or avoid, or points of interest that if passed through or near would increase the users experience; these are known as control points. Some examples of places to avoid may include steep natural drainages, areas with protruding bedrock, or sensitive areas and habitats. On the other hand the desired end point must be reached or portions of the hill may have a more suitable sideslope for the trail than others. Control points that appeal to the user's senses may include a grove of trees, a vista point, a view into a canyon or a meadow.

This report is not meant to be a trail building guide, but simply to point out some of the key elements of sustainable trails that I have learned about. The IMBA Trail Solutions: Guide to Building Sweet Singletrack has been touted as "the Bible of trail building" (Kelli Schonher, personal communication, 2012) and rightfully so. It provide me with much of the information given here and contains simple straight-forward instructions on how to design, construct and maintain mountain bike trails, what tools you will need for the job and how to correct mistakes and fix bad trails. It also describes how to build more challenging features and aggressive trails for experience mountain bikers. For a more philosophical and well written book on trail design check out Troy Scott Parkers Natural Surface Trails by Design he gives very good examples of trails that work and ones that don't and also provides deep insight into how people affect and are effected by trails.

Why These Things Should be Considered

Trails should be appealing, fun and safe for all intended users while minimizing erosion and maintenance requirements. The name of the game in trail building is slope and drainage. Constantly thinking about these two factors will affect the trail will ultimately result in a lasting trail that requires less maintenance and is safe and enjoyable to use. In his Natural Surface Trails by Design book Scott Parker describes a harmony that users can experience when "natural shapes, anchors, safety, efficiency, playfulness, and physical factors all work to sustainably support the desired trail experience." This is true, but without getting too philosophical, simply put well-made trails make the user happy to use them. For some trail users the experience is more important than the destination. Greg Bettencourt, suggested to me that cyclist place the most value on the experience of using the trail, then hikers, then equestrians, which may or may not be accurate, but his point was similar to that of Vernon Felton; the trail can make all the difference.

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