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BULL RUN OCCOQUAN TRAIL

TRAIL ASSESSMENT REPORT

2018

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PROJECT OVERVIEW

ASSESSMENT ACTIVITIES

The Applied Trails Research (ATR) team conducted an assessment of the Bull Run Occoquan Trail (BROT) conditions in early August and mid-December, 2017. The results of the assessment indicate that significant issues exist throughout the entire trail. Rectifying these issues will require significant collaboration between Northern Virginia Regional Parks Authority (NVRPA) and its current trail stewardship partners, Potomac Appalachian Trail Club (PATC) and Mid-Atlantic Off Road Enthusiasts (MORE).

The purpose of this trail assessment is to provide site-based recommendations and project prioritization for NVRPA in support of the agencies goals, as outlined in the park's General Management Plan (page 3).

The assessment consisted of:

- Multiple meetings with NOVA Parks and stewardship partners,
- A hiking assessment of the entirety of the trail system, and
- A mountain biking assessment of the portion of the trail where this use is allowed.

Deliverables from the assessment, in addition to this report, include:

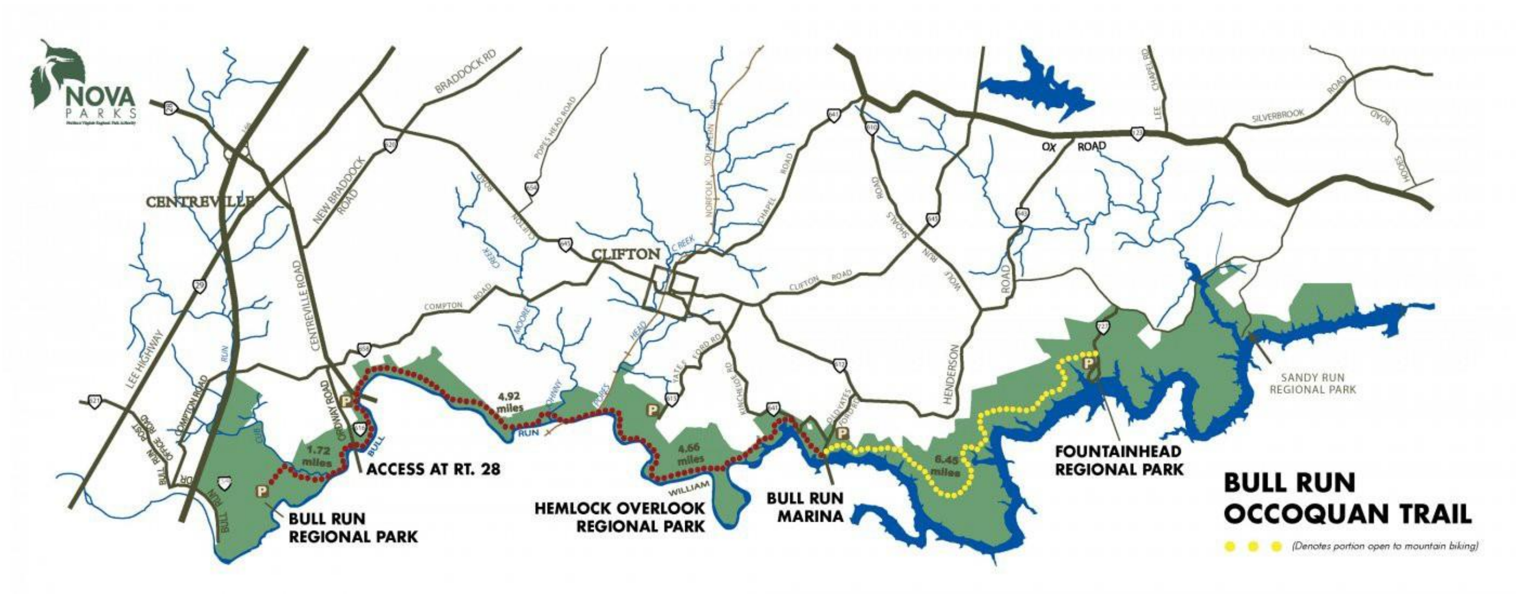
- Geo-tagged photographs were taken of current conditions and problematic areas,
- GPS tracks wof trail center line,
- GPS Waypoints of specific maintenance needs
- Trail corridor (+/- 50' in width) flagging was hung at intervisible intervals and collected as GPS tracks, where trail relocations have been recommended.

This information has been compiled into GIS layers for inclusion in the NOVA Parks spatial database.

Additionally, a high quality, high visibility project was identified adjacent to Fountainhead Regional Park. The proposed trail corridor relocations were designed in the field, marked with hang flagging and GPS tracks were collected. The project was undertaken in Fall, 2017 through grant funding allocated to MORE. The construction and closure serve as a demonstration project to initiate the sustainable redevelopment of the BROT.

PROJECT OVERVIEW

BULL RUN OCCOQUAN TRAIL SYSTEM



Winding through more than 5,000 acres of conservation land along the north side of the Bull Run valley, often overlooking the eponymous stream or Occoquan Reservoir. The 17-mile trail is the longest natural surface trail within the NOVA Parks system and access to the trail is provided as it passes through Bull Run Regional Park, Hemlock Overlook Regional Park, Bull Run Marina, and Fountainhead Regional Park. There are additional access points at Route 28 and informally through a number of residential neighborhoods.

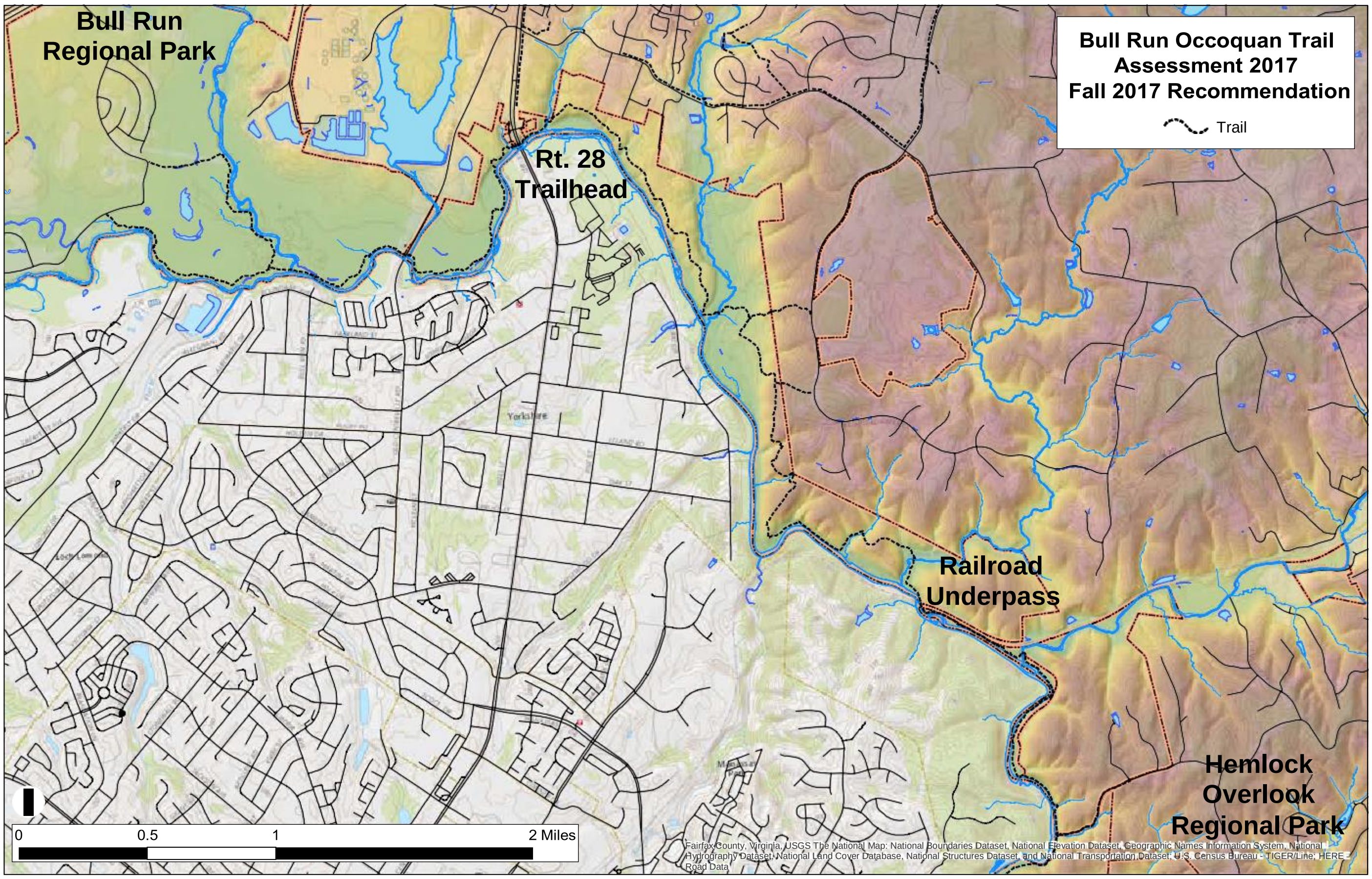
The history of the area is significant, as Bull Run was a strategic Confederate defense line during the Civil War known as the “Alexandria Line”. As such, the area near the trail includes numerous historic structures such as earthen forts and bridges.

The BROT was designated a National Recreation Trail in 2006. Hiking is the primary use of the trail. Equestrian use is allowed through most of the trail, but evidence of this use is low. Mountain biking is allowed on the trail between Bull Run Marina and Fountainhead Regional Park, where additional mountain biking trails are located east of the BROT.

The trail is located predominantly in mature hardwood forest, and the combination of land conservation and large acreage zoning maintains a natural character that is very different from the very developed area surrounding this stream/trail/conservation corridor. NOVA Parks’ desire is to maintain and enhance the natural character and backcountry “feeling” of the trail system, as it has become potentially the most compelling facet of this recreation resource.

CURRENT CONDITIONS

WESTERN HALF- EXISTING CONDITIONS

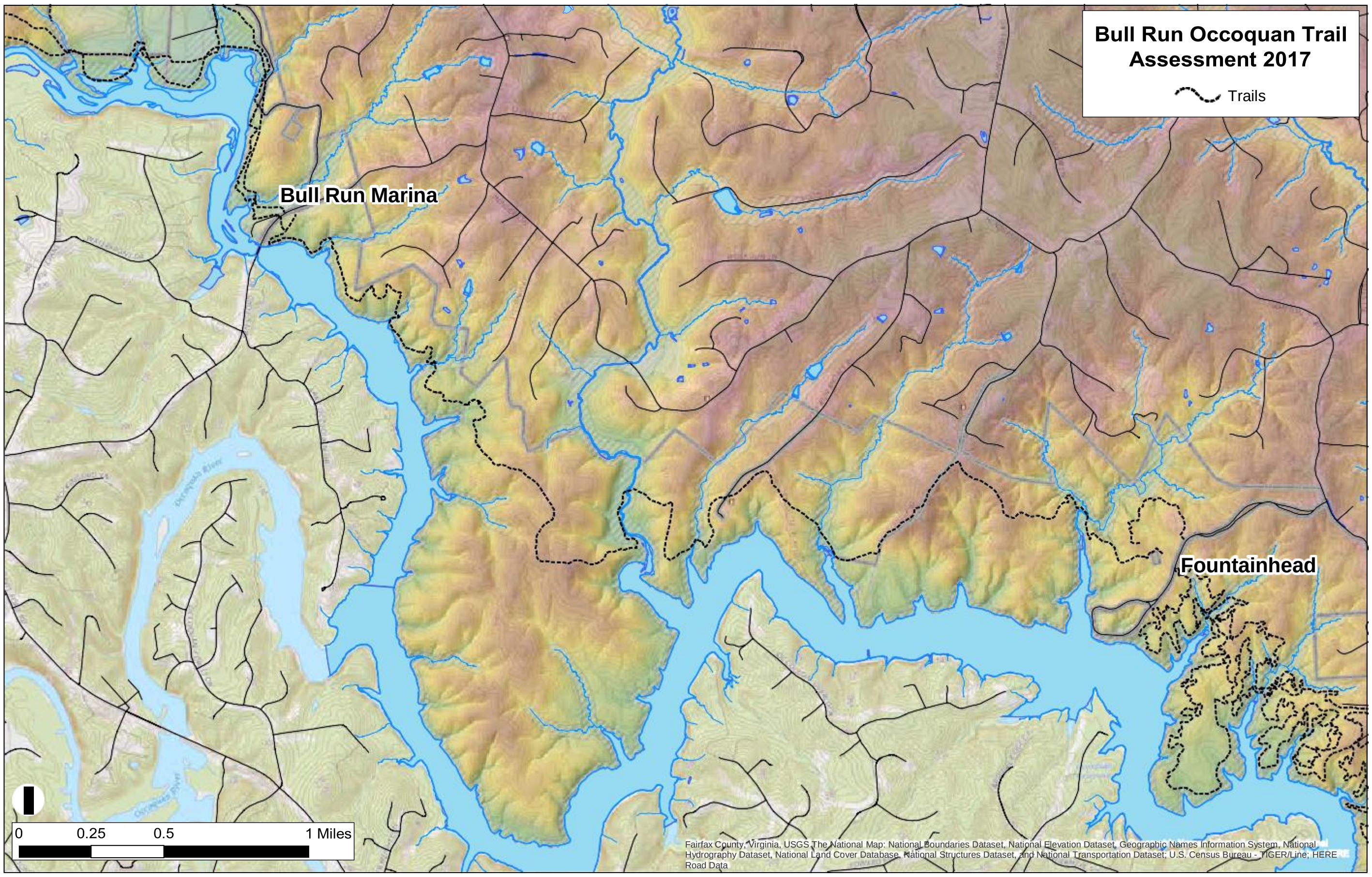


The BROT begins/ends in Bull Run Regional Park and technically includes the Bluebell Loop within this park. Within Bull Run Park and continuing to the Rt. 28 Trailhead, the trail is located almost exclusively within the broad floodplain of Bull Run. The land exhibits signs of regular inundation and some flood flow, especially in locations near small tributaries of Bull Run. As a result of these wet conditions, the trail has often migrated, with users seeking out drier or less muddy conditions. Attempts to minimize this issue in Bull Run Park include dozens of teak “mats” that have been secured to the ground with rebar to provide a firmer hiking surface. Downstream and east of the park, attempts have not been made to provide drainage to the trail, and with the easily compacted alluvial soils, the trail has become entrenched. This subgrade condition will often leave the trail wetter/muddier than the immediately surrounding land, and has resulted in parallel trail braids in many locations.

Downstream of Rt. 28, the trail moves higher onto the landscape, often with contour alignment, with spur trails into the Balmoral Greens residential neighborhood. From this point, back to Popes Ford Road in Hemlock Overlook Park, the trail corridor is quite constrained by the railroad and steep adjacent slopes. Forced onto narrow portions the Bull Run floodplain, the trail is impacted by high stream flows.

CURRENT CONDITIONS

EASTERN HALF- EXISTING CONDITIONS



Downstream of Hemlock Overlook Park to the Kincheloe ball fields (upstream of Bull Run Marina); the BROT has a decidedly more contour-oriented, upland location on the landscape.

From the Bull Run Marina toward Fountainhead Park, trail routing is dominated by 1) historic road corridors, including the Washington-Rochambeau Road, and 2) steep, fall-aligned segments in and out of smaller stream valleys. The routing on historic roads throughout this portion of the BROT often moves the trail away from scenic views of Occoquan Reservoir. In the centrally located “peninsula”, road-based trail routing keeps trail users away from the most backcountry-feeling portion of the entire BROT corridor.

The demonstration project just west of Fountainhead Regional Park, including purpose-developed, rolling contour trail alignment and full trail closure/reclamation provides an example of much of the future work that needs to be completed along the eastern half of the trail.

CURRENT CONDITIONS

PHYSICAL SUSTAINABILITY

Physical sustainability of a trail is a characterization of the durability of the tread surface and the trail's ability to withstand impacts of natural processes and the types and volume of use on the trail. The most durable trails are purpose-designed and constructed to minimize the impacts of natural processes and the types and volume of expected use. The BROT, in almost entirety, was not purpose-designed or constructed. Instead, the trail was routed on existing, historic road beds, connected by very informally developed (i.e. hiked-in) segments.

Hydrology is the dominant natural process affecting the BROT. In upland landscape locations where the trail has often been routed on historic road beds that have compacted with use to a subgrade condition (top photo), water cannot be moved from the trail tread and subsequent erosion and/or wet/muddy conditions ensue. In lower landscape positions where groundwater tables are seasonally close to the ground surface, trail routing in flat areas results in tread compaction, prolonged muddiness, and trail widening/braiding (2nd from top photo).

The informally hiked-in connectors between upland and lowland historic roads have been developed with alignments that run on or near the steepest path down the landscape. This fall-aligned location does not allow water to be managed off the trail. Without a steeper path of runoff available, erosion begins and results in a subgrade trail condition that further focuses runoff within the trail tread. This process exposes roots and rocks in the trail (2nd photo from bottom) and deposit sediments within stream valleys. Trail users attempt to avoid these areas that are harder to negotiate, widening the trail and further exacerbating the erosion issues (bottom photo).

There is no effective maintenance for fall-aligned trails. Rolling, contour-aligned relocations are necessary to mitigate resource damage and provide a durable trail tread that will meet the use type and volumes that are currently present on the BROT. Eroded trails should be restored to provide natural hydrology or natural resource degradation will continue.

CURRENT CONDITIONS

SOCIAL SUSTAINABILITY

Social sustainability is a function of how well a trail system manages the use it is receiving, from parking, trail orientation and navigation, to providing a high quality experience and minimizing conflicts. With its urban context but informal development, it is not surprising that the BROT experiences parking area crowding, trail orientation, and navigation issues.

Parking availability and pressures are highest at the Bull Run Marina and Fountainhead Regional Park. The marina parking has considerable area for further development that is currently utilized for other purposes. Fountainhead’s parking is constrained due to high use of the adjacent mountain bike trails. Hemlock Overlook and Rt. 28 have very little existing parking. Bull Run Park has sufficient parking, but BROT use in this area seems relatively low.

Some new signage is present throughout the trail system, mainly at Bull Run Park. Signage at Bull Run Marina and Fountainhead are not engaging and do not adequately prepare visitors for the shared-use trail experience. Trail users were seen off the official trail near both of these trailheads, walking on other historic road corridors. It was not clear if they were lost or were utilizing these other routes to form a somewhat looping experience to a scenic view of the lake or back to the trailheads.

The trail is not purpose-developed to provide a high quality, backcountry-feeling experience, as is desired by NOVA Parks. This is a result of historic road-focused routing and eroding and excessively steep trail alignments. Unfortunately, these situations also contribute to potential conflicts on shared hiking-biking portions of the trail due to steep slopes that encourage high bike speeds and longer stopping distances, as well as constrained sight lines that further increase the odds of an unexpected encounter.

Improved visitor orientation at trailheads, bringing the trail to higher quality destinations, and a purposeful design that mitigates potential use conflicts will vastly improve the visitor experience.

CURRENT CONDITIONS

TRAIL USER IMPACTS

With predominantly hiking, trail running, and mountain bike use on the BROT, trail user-created impacts are relatively low. For a heavily used trail, it is relatively sparsely littered. Some tree carving and graffiti are present, but again at relatively low levels with the urban setting.

Most of the impact that is present revolves around visitors avoiding obstacles or muddy conditions in the trail tread. The informally routed trail only laterally confines trail use width where there are historic berms on the sides of compacted/eroded road beds. Where trails have been hiked in, there is no width confinement and trail users have trampled widening paths when they encounter obstacles such as roots, rocks, water bars (which further reduces the utility of these structures), or muddy conditions. Eventually, some trees will be permanently damaged as their root structures are undermined. Additionally, the trail widening and braiding, along with the historic road routing, reduces the backcountry feeling of the BROT. Redeveloping eroding sections as relatively narrow, contour-aligned routes will confine use to the trail tread and improve the trail's intended backcountry nature.

There are numerous stream-proximal trail segments where trail users have developed access to the river/reservoir. As these "slides" down the banks are more heavily utilized, the roots that act as steps degrade; visitors create a new access close by, and further destabilize the stream banks for access. Especially in high use areas, such as the rapid/pool structures upstream from Hemlock Overlook, it would be prudent to provide semi-permanent access down the stream banks at the obvious upstream and downstream points of entry.

CURRENT CONDITIONS

MANAGERIAL SUSTAINABILITY

Maintenance of the BROT is highly dependent on a sizable and skilled volunteer trail stewardship contingent. More effective management of water off of the trail is the highest level need currently. As previously stated, this is not possible on most old road segments that have reached a subgrade condition (see top photo, water bar acting as check dam to catch water without redirecting it off trail), nor is it possible on fall line-oriented trails.

Some past attempts have been made to install water bars to better manage water off the trail. In most instances, these structures were poorly sited and/or constructed. When these structures proved ineffective (2nd photo from top, bar directing water into rather than away from the trail), they have regularly been buttressed with additional materials that further exacerbate the drainage management problem and increase user avoidance of the structure. Removing these structures is necessary to minimize trail widening. Retrofitting drainage with natural rolling grade dips is necessary throughout the BROT, though siting and implementation of these structures must be improved for proper water management.

Bridges over side streams are abundant throughout the BROT. Upstream development has resulted in storm water discharges from these streams that regularly scour and overtop banks. Many of the existing bridges are small, built on floodplains at bankfull elevations where they risk being carried away in a moderate flood (middle bottom photo), and reaching the end of their lifespan with foundations degrading, stringers rotting, and deckboards breaking. Additionally, with storm water-related degradation, some repairs have been completed in a haphazard manner with insufficient materials such as discarded concrete culverts (bottom photo). With many of the suggested trail relocations occurring in proximity to these bridged crossings, the bridge location has been moved to a higher position on the landscape where flood and rotting effects will be mitigated, but bridge spans and coincidentally costs and construction efforts will increase. When these bridges are replaced, they footers should be located well outside the current channel, structures should have sufficient width to allow for bidirectional passage, and railings should be constructed when bridge decking is three feet or higher above the channel bottom.

CURRENT CONDITIONS

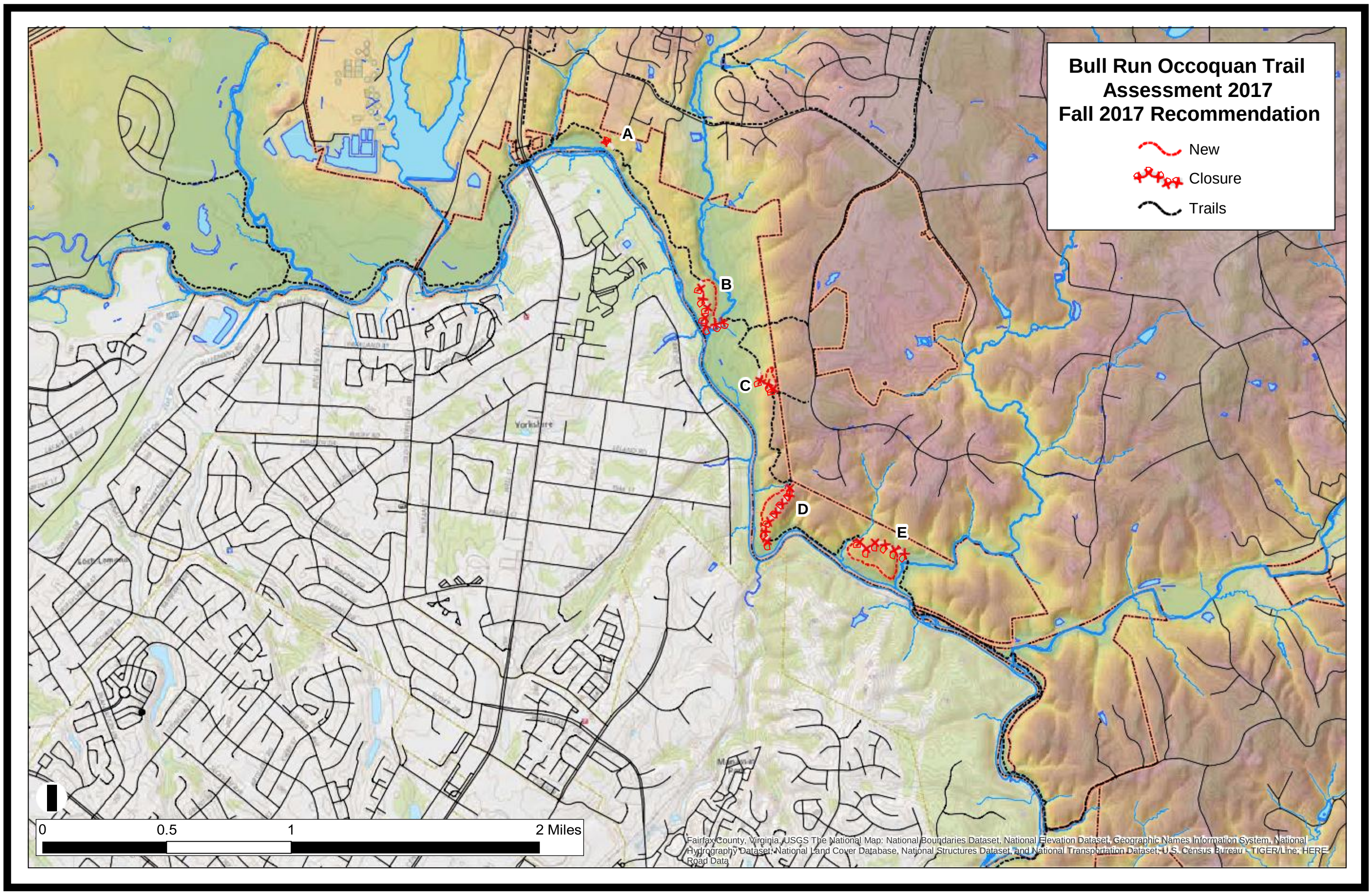
There are a number of notable perennial stream crossings, where large and/or unstable structures currently exist and hare problematic. The telephone pole-based bridge structures crossing of Cub Run (top photo) and the crossing near Ordway Road have considerable deflection. The assessment team was able to create 6 inches or greater vertical "bounce" with a single individual on the middle of each bridge. These bridges are quite long and wide and can reasonably allow passage of many individuals at a time, potentially magnifying the deflection. This deflection, along with a lack of railings above relatively high elevations above the typical water level, results in an unnecessarily hazardous situation and should be replaced with engineered structures as soon as is practicable. Designated equestrian fords should be signed and maintained in close proximity to the replaced bridges.

Similarly, the Johnny Moore Creek (middle photo) and Popes Head Creek bollard crossings are problematic. While these structures are solid, stationary, and level when installed, they are not affixed to footers and move under regular storm water flow events. This renders the bollards unstable and angled at different and sometimes significant angles, increasing the hazardous nature of these crossings. In both locations, removal of the bollards and replacement with bridges spanning the active floodplains are recommended.

Finally, the existing crossing of Wolf Run Shoals has been problematic, washing away in multiple storm water flow events. The backcountry-style bridge footing will not ever withstand the types of flow that is present in this watershed and a new bridge location with have to span the existing floodway. No adequate, narrow location was found upstream of the current crossing during the field assessment, as the floodplain remained wide to the private property boundary. To address this problematic watershed condition, a bridge location has been recommended at a downstream location (bottom photo) above the pool elevation of the reservoir. While this will require a long span, the location will minimize the scouring effects that have hindered the existing bridge.

REDEVELOPMENT RECOMMENDATIONS

WESTERN HALF- PRIORITIZED ACTIONS



1. (2018, PATC) Improved water management in the form of rolling grade dips should be considered the highest immediate priority, as this maintenance of the existing single-track trail will assure minimal future changes to the overall good condition of the tread. 40+ rolling grade dip locations have been way pointed in this area.
2. (2018-2019, PATC/NOVA Parks) Improved puncheon structures in Bull Run Park to replace the teak and corduroy mats, placing trail users above the muddy conditions. Additional puncheon and/or turnpike work could be completed in seasonally wet/muddy locations between Cub Run and the Rt. 28 Trailhead to raise the trail tread above the surrounding floodplain.
3. (2019, PATC) Rolling grade dip development on historic road/trail from Hemlock Overlook Trailhead, rock armoring (300+), puncheon (48'), and creek access structure (2-4)development work up to railroad bridge
4. (2020, NOVA Parks) Redevelopment of the large bridges over Cub Run, near Ordway Road, Johnny Moore and Popes Head Runs.
5. (2020, NOVA Parks) Rt. 28 Trailhead drainage and parking improvements.
6. (2022, PATC) Trail relocation/closure projects B and E (3,911 linear feet of single-track trail construction and 2,804 linear feet of trail closure/reclamation). This also includes the construction larger bridge projects to replace the concrete bollard crossings present on Little Rocky Run (60') and Johnny Moore Creek (48').
7. (2023, PATC) Trail relocation/closure projects A, C, and D (3,140 linear feet of singletrack trail construction, 2,456 linear feet of trail closure/reclamation, 16' of puncheon, and a 32' bridge).

REDEVELOPMENT RECOMMENDATIONS

Segment: A **New Trail:** 339 linear feet/0.06 miles **Trail Closure:** 235 linear feet/0.04 miles
Structures: 16’ puncheon
Description:

Segment: B
New Trail: 1,389 linear feet/0.26 miles **Trail Closure:**1,532 linear feet/0.29 miles
Structures: 60’ bridge or redevelop pillars, 8 steps install or repair, 2 puncheons, 104’ total
Description:

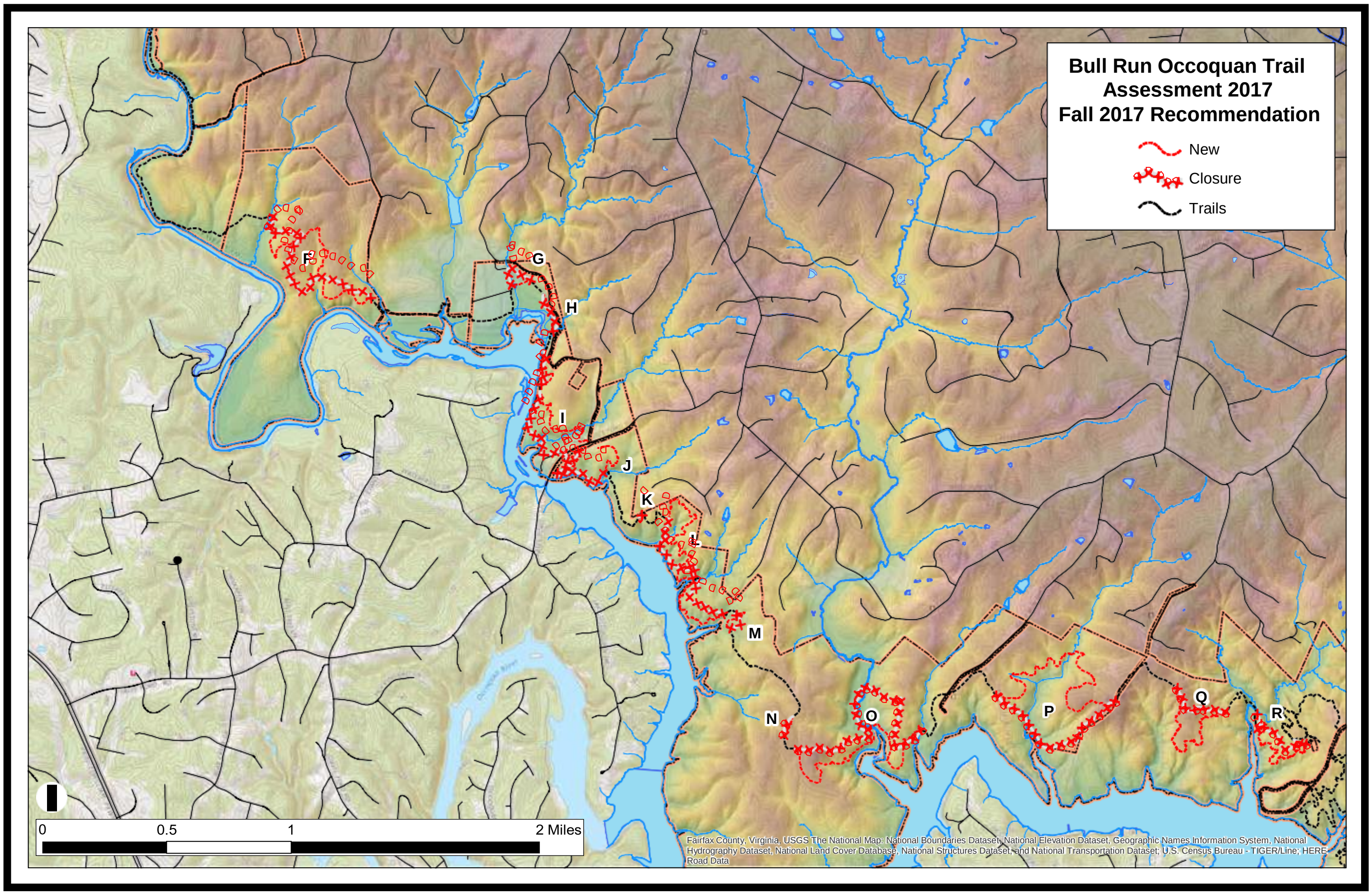
Segment: C
New Trail: 1,177 linear feet/0.22 miles **Trail Closure:** 688 linear feet/0.13 miles
Structures: 1 switchback turn
Description: Medium Priority. The relocation removes an eroding, fall-aligned segment of this otherwise very sustainable trail segment.

Segment: D
New Trail: 1,624 linear feet/0.31 miles **Trail Closure:**1,533 linear feet/0.29 miles
Structures: None
Description: Low Priority. Water management on the existing trail is not feasible due to a subgrade condition that can be replaced with a contour-aligned corridor with dramatic river valley views.

Segment: E
New Trail: 2,522 linear feet/0.48 miles **Trail Closure:**1,272 linear feet/0.24 miles
Structures: 32’ bridge
Description: Medium Priority. Very eroded, fall-aligned trail segment with no possibility of drainage to be replaced with a contour-aligned corridor on steeper, rocky slopes with dramatic river valley views.

REDEVELOPMENT RECOMMENDATIONS

EASTERN HALF



1. (2018, NOVA Parks, PATC, MORE) Relocation/Closure projects I, J, G, and H (4,526 linear feet of singletrack trail construction and 1,350 linear feet of shared-use trail construction, 8,643 linear feet of trail closure, 650 feet of puncheon and a 36' bridge) and the reorientation of the BROT Trailhead that brings users to the eastern portion of the parking area to access the trail and/or cross Old Yates Ford Road at a location with longer sight lines.
2. (2018, PATC/MORE) Improved water management in the form of rolling grade dips should be considered the highest immediate priority, as this maintenance of the existing singletrack trail will assure minimal future changes to the overall good condition of the tread where future relocations have not been recommended. 50+ rolling grade dip locations have been way pointed in this area.
3. (2019, PATC/MORE) Relocation/closure projects K, L, and M (7,035 linear feet of shared-use trail construction, 4,252 feet of trail closure, 3 bridges of 24', 36' and 36' and 8 puncheons totaling 450+ linear feet).
4. (2020, PATC/MORE/NOVA Parks) Relocation/closure projects N and O (6,634 linear feet of shared-use trail construction, 6,197 linear feet of trail closure, 3 puncheons of 68', and 400' of road to trail conversion). This project also includes the 70' bridge over Wolf Run Shoals and the subsequent downstream tributary.
5. (2021, PATC/MORE) Relocation/closure projects F and P (5,459 linear feet of singletrack trail construction, 7,139 linear feet of shared-use trail construction, 7,999 feet of trail closure, two bridges of 24' and 48'.

REDEVELOPMENT RECOMMENDATIONS

SEGMENT F

Segment: F
New Trail: 5,459 linear feet/1.03 miles **Trail Closure:**4,529 linear feet/0.86 miles
Structures: 1 switchback turn
Description: Low Priority. The relocation addresses a number of fall-aligned trail segments that are carrying sediment to the stream crossing locations. Removing the crossing of the eastern stream and a contour-aligned approach to the western stream will mitigate this issue. The relocated segments at the brow of steep slopes down to the river provide enhanced views of the Bull Run valley.

Segment: G
New Trail: 433 linear feet/0.08 miles **Trail Closure:** 989 linear feet/0.19 miles
Structures: 400’ puncheon
Description: Medium Priority. The relocation moves the trail off the main portion of the gravel road entrance to the ball fields and follows a marginally drier ditch that, with puncheon, will provide a drier trail experience.

Segment: H
New Trail: 874 linear feet/0.17 miles **Trail Closure:** 922 linear feet/0.17 miles
Structures: None
Description: High Priority. The relocation moves the trail approximately 25’ laterally, out of the floodplain, where trail muddiness, braiding and maintenance will not be as challenging.

Segment: I
New Trail: 3,219 linear feet/0.61 miles **Trail Closure:** 3,915 linear feet/0.74 miles
Structures: 32’ bridge, 6 puncheons totaling 250’, 36' bridge, Yates Ford Road crossing fix
Description: Medium Priority. The relocation addresses a number of fall line issues and increases safety with a road crossing with improved sightlines.

Segment: J
New Trail: 1,350 linear feet/0.26 miles **Trail Closure:**2,817 linear feet/0.53 miles
Structures: 1 switchback turn
Description: High Priority. The relocation reduces the deferred maintenance of the fall-aligned fishing access trails and requires reorienting the trailhead to the opposite end of the existing parking area.

Segment: K
New Trail: 272 linear feet/0.05 miles **Trail Closure:**97 linear feet/0.02 miles
Structures: 2 rolling grade dips
Description: High Priority. The relocation is short and replaces a rapidly degrading fall-aligned segment.

Segment: L
New Trail: 3,662 linear feet/0.69 miles **Trail Closure:**2,232 linear feet/0.42 miles
Structures: 24’ and 36’ bridges, 4 rolling grade dips, 8 puncheons totaling 180’
Description: Medium Priority. The relocation replaces numerous fall-aligned segments and eroding, retaining -walled trail with more sustainable, bridged crossing locations higher in the watershed with portions near private property located on existing equine trail.

REDEVELOPMENT RECOMMENDATIONS

Segment: M
New Trail: 3,101 linear feet/0.59 miles **Trail Closure:**1,923 linear feet/0.36 miles
Structures: 36' bridge
Description: Medium Priority. The existing trail is fall-aligned as it enters the two stream valleys and the required maintenance to retain this alignment will be significant and recurring. The relocation provides for a contour-aligned route and enhanced views of the lake. An improved bridge crossing will span the channel and immediate floodplain, which demonstrates signs of considerable seasonal muddiness.

Segment: N
New Trail: 449 linear feet/0.09 miles **Trail Closure:** 469 linear feet/0.09 miles
Structures: None
Description: Low Priority. This relocation moves the trail to a side hill, contour-aligned location outside the existing, incised historic roadbed.

Segment: O
New Trail: 6,185 linear feet/1.17 miles **Trail Closure:**5,728 linear feet/1.08 miles
Structures: 44' and 70' bridges, 3 puncheons totaling 68', 400' road to trail conversion
Description: High Priority. The bridge over Wolf Mill Shoals has been damaged/removed by flood waters on multiple occasions, the floodplain location of the existing trail is braiding and widening as trail users search for the driest conditions, and the fall-aligned segments of trail down to the valley are not maintainable and pose use conflict risks.

Alternative crossing locations upstream of the existing bridge were evaluated, but the wide, wet, active floodplain persists north to the private property boundary. A crossing location has been proposed that is within the pool of the lake. This mitigates long-term flood damage potential, but requires a longer span. Contour-aligned trail relocations will provide for sustainable trail development with longer sight lines and enhanced lake views on both aspects of this scenic cove, while minimizing the length of trail located on the persistently.

Segment: P
New Trail: 7,139 linear feet/1.35 miles **Trail Closure:**23,570 linear feet/0.68 miles
Structures: 24' and 48' bridges, 2 rolling grade dips, 7 puncheons totaling 108'
Description:

Segment: Q
New Trail: 3,686 linear feet/0.70 miles **Trail Closure:** 1,477 linear feet/0.28 miles
Structures: 52' of puncheon
Description: High Priority, completed by MORE with REI funding in 2017

Segment: R
New Trail: 2,374 linear feet/0.45 miles **Trail Closure:** 1,898 linear feet/0.36 miles
Structures: None
Description: High Priority, completed by MORE with REI funding in 2017

COST OPINION

The following cost opinion has been developed by ATR based on recent, similar trail construction projects in similar physiographic conditions. The opinion does not reflect potential cost savings that may be possible through volunteer or other low-cost labor involvement, nor does it account for potential mobilization or on-site costs incurred by a contractor. These figures should be utilized for project planning, but it is highly recommended that multiple bids are sought in order to receive firm estimates for final budgeting.

CONSTRUCTION ITEM	EST. QUANTITY	UNIT	LOW ESTIMATE (per unit)	HIGH ESTIMATE (per unit)	MEAN ESTIMATE SUBTOTAL
Backcountry Trail-Intermediate	52,578	feet	$4.50	$5.75	$269,462.25
Trail Closure/ Restoration	40,691	feet	$1.00	$2.00	$61,036.50
Puncheon	770	feet	$125.00	$175.00	$115,500.00
Bridges	386	feet	$1,000.00	$1,500.00	$482,500.00
Armored Fords	0	feet	$10.00	$30.00	$0.00
Culverts	0	each	$250.00	$500.00	$0.00
				PROJECT EST.	**$928,498.75**

RISK MANAGEMENT/OPERATIONS

Risk is inherent to all activities. As NOVA Parks promote the public's use of their land for various activities, the agency is necessarily in the business of managing risk. Primarily, this management action is focused on promoting public safety and the duty to warn when potential hazards exist. At its simplest, this relationship can be depicted symbolically as:

RISK = HAZARDS/SAFEGUARDS

Exposure to hazards can never be fully eliminated, nor can safeguards be fully realized. A risk management program can be used as a means to reduce the ratio of hazards to safeguards, thereby increasing safety while demonstrating the exercise of reasonable care. The fundamental purpose for risk management is to prevent risk from occurring, or reduce exposure to hazard, and may include conducting analyses for system safety, feature safety, liability and third party assumption of risk.

Where trail use is the activity that an agency is providing, a number of potential hazards exist; Climatic and trail conditions, wildlife, vegetation, human interactions, access and navigation all introduce risk into a recreational activity. When multiple factors compound, the risk ratio becomes higher and consequences often increase. A plan that puts reasonable safeguards in place reduces the total risk and thereby often lowers potential consequences.

Managing risk on trails involves developing safeguards at the levels of facility development, public outreach, and operational diligence.

Specifically, this includes:

- **Proper design and construction**
- **Measured progression of difficulty**
- **Appropriate signage and mapping resources**
- **Consistent maintenance assessments**
- **Hazard Removal**
- **Practical incident response plan, and**
- **Diligent record keeping.**

The necessity of a well-developed operations and maintenance plan, including risk management strategies, increases with density of trail use and variety of route and challenge options. When trail systems are designed for shared-use, there are some additional factors to consider, including the potential speed differential of different user types as they relate to sightlines and startling encounters, as well as where and how to mitigate that speed in relation to slower users and how to provide adequate sight lines for potential speeds. While risk can never be completely removed and the perception of risk can be wildly different from one individual to another, a good risk management plan should strive to reduce unforeseen hazards and increase the public awareness of the potential hazards that are known to exist. When trail managers provide easy-to-comprehend information to recreationists about what to expect in their trail experience and whom to alert when an incident

RISK MANAGEMENT/OPERATIONS

occurs or conditions of the trails have substantially altered, the vast majority of users are satisfied, can safely navigate and negotiate the trails, and comply with reasonable regulations.

RISK MANAGEMENT STRATEGIES

Facility Development

From parking lot ingress/egress to the design and construction specifications of the trails and associated structures, a number of facets are important to consider from the standpoint of minimizing hazards and maximizing safeguards. Engineered facilities typically carry the highest potential risk, as there are standards which require adherence and periodic inspection to assure standards are still being met. Hazards are typically greatest at dynamic locations, such as trailhead entrances, especially where human-vehicle interactions are typical, or near streams where changing flow conditions can impact structures and/or safety.

Trail Design

Managing risk on trails starts with good trail system design. Designing trail alignments that maximize the opportunity for a sustainable trail surface over time minimize maintenance needs and better protects other adjacent natural resources. Proper trail design helps to manage access, funneling use to managed portals where information can be transferred from the managing agency to visitors. Trails that are designed in a manner that make navigation simple reduces the potential of a visitor becoming lost, risking exposure to changing conditions or fatigue, or becoming tempted to venture off-trail to "improve" their experience by creating a short cut or new trail. When a broad spectrum of managed uses are developed, a trail's design should reflect the experiential needs and attempt to foresee and address potential issues of use conflict and natural resource damage. and minimize the temptation to shortcut or build unsanctioned (and un-risk managed) trails and features.

Trail Construction

Trail construction that meet the clearing, width, grade, obstruction, and compaction specifications developed by an informed design process indicate that the facility is being managed in a manner to minimize unforeseen hazards and provide the safeguards that are desired and appropriate for the range of trails and visitors the system is intended to service. This commonly understood quality control concept is important for beginning the due diligence process related to later trail maintenance assessment and mitigated actions of the physical maintenance or alteration of the trail location.

Fall Zones

While trails are surrounded by features that could introduce hazards, from tree branches, to rocks, to noxious vegetation, it is important to remove unforeseen hazards from the trail corridor during construction. Stubs from cut trees or branches should be dug out entirely or cut flush with the tree trunk, "widow maker" trees should be removed prior to public use, and areas surrounding technical trail features should be made free of sharp protruding objects.

RISK MANAGEMENT/OPERATIONS

SIGNAGE, EDUCATION, AND TRAINING

Signage

Well-placed and easy-to-comprehend signage is one of the most effective strategies to promote public safety and warn trail users of potential hazards. Too often, this duty to warn is enacted with large signs full of small font text that spells out dozens of regulations for the public and immunities for the managing agency. While legally protective, this strategy is rather unproductive. Every risk and immunity can never be listed, the public is unlikely to read or understand the "legalese", the ultimate duty of helping promote public safety is undermined, and the managing agency often has to deal with incidents that were otherwise avoidable with more effective signage. Some regulations and immunities, such as hours of operation, managed uses, and public assumption of risk are necessary, but should be tempered with information directly related to promoting safety on the trails.

Signage programs can include regulatory, emergency contact, mapping, trail difficulty, way marking, and interpretive, educational and warning signs. Whatever assemblage is employed, it is important that the program employs a consistent and intuitive set of symbols or short phrases that be relatively universally understood. This is especially important for youth and non-English speaking visitors. All signs should be clearly visible from the angle and eye level of trail users. Signs within a trail system are natural locations for the public to congregate after an incident and it is wise to include a geo-location on the body of the sign so that managing agency or emergency personnel can efficiently respond to public reports of changing trail conditions or incidents. The ease of trail users to understand the opportunities presented and the ability to navigate those opportunities are the keys to any system of signage.

User Education/Training

Signs are great for very concise messaging, but it's very difficult to provide explanations, interpretation, or details on a property or trail system. It is often this deeper understanding that makes passive users of a property into advocates, volunteers, and community supporters for the agency, property, or trail system. Educated, engaged visitors often become peer-to-peer information sources themselves, working through local organizations and assisting with the promotion of public safety, proper use of property, and in the management of a property's trails.

Maps/Brochures

Maps or brochures are good places to start providing information on a property, its recreational resources, and methods of getting more involved. Accurate maps help provide confidence to trail users that they are correctly navigating the trail system and choosing an trail that meets their stamina, time, and experiential desires. These resources, like signs, should be created with sensitivity to information overload. Contact information for the managing agency, local volunteer groups, and any known schedules for events or trainings should be included in order to direct comments or future interactions. Often the creation of these resources can be outsourced to local volunteer groups (with some agency oversight on information quality), who can then coordinate support from local businesses and bolster their financial capacity to assist with the upkeep of the property.

Volunteer Stewardship

RISK MANAGEMENT/OPERATIONS

The maintenance of a trail system is a key operational risk management concern. A well-trained and engaged community of volunteers can often handle much of the regular maintenance assessments, duties, and record-keeping. Volunteers, through crew leader organizers, should have basic training in work place safety, proper use of tools, and trail maintenance skills along with clear expectations of what the managing agency desires are related to their work. With a well-developed volunteer management system, many trail maintenance issues and use of tools, and trail maintenance skills along with clear expectations of what the managing agency desires are related to their work. With a well-developed volunteer management system, many trail maintenance issues and new potential hazards can be mitigated and those actions recorded prior to any incident that endangers public safety or natural resource health.

Training/Programming

Encompassing a number of different potential activities, training and/or park and trail programming can assist a great deal in managing risk on trails. Guided tours introduce new visitors to the trails, regulations, and other opportunities to become involved. Citizen-based, peer-to-peer trail patrols can effectively increase an agency's management presence in a less authoritative manner than is sometimes possible with park rangers or law enforcement personnel. Skills training in different trail-related pursuits can help build individual skills and decision-making processes, creating inherently safer trail users. In short, trail systems can be thought of as any other brick and mortar recreational facility, needing programming/training opportunities to manage an informed and safer user base.

OPERATIONS AND MAINTENANCE

A well-designed and constructed trail system will require some amount of regular maintenance. Climatic conditions, use patterns, and changing desires of the public will necessitate an actively managed facility. Ignoring this necessity can result in trail conditions that endanger public safety and demonstrate a lack of diligence in mitigating hazards.

Maintenance Planning

Maintenance is a very important component of risk management. While the design and construction goals always focus on sustainability, all trails need periodic maintenance. Sustainably built trails and features that see a reasonable amount of use will require much less maintenance than trails that are not designed and constructed in toward a sustainable manner. Typically, much of this maintenance can be undertaken by trained agency staff or volunteers and revolves around keeping corridors and sight lines cleared and undertaking basic drainage upkeep. This work should be completed frequently enough that trail deterioration does not affect the surrounding natural resources or change the difficulty level of the trail. Whether the maintenance is completed by professionals or volunteers, a program should be developed to assess and log maintenance actions. This provides documentation that is important in demonstrating operational diligence as well as determining where, if any, consistent problem areas require an altered approach.

Maintenance Assessments

RISK MANAGEMENT/OPERATIONS

Maintenance assessments provide important documentation related to an agency or volunteer group's operational diligence in providing an experience that is free of unforeseen hazards. A regular record of the condition of known and new problem areas can help streamline the physical maintenance activities and prioritize maintenance that mitigates potential hazards. Agencies should always remain the repository of this information, but in many cases can defer the actual assessment process to trained, responsible volunteer groups.

Hazard Removal

When maintenance assessments determine that potential unforeseen hazards exist, protocol should be determined for the removal of those hazards. While typical drainage and corridor clearing maintenance accomplished by volunteers may reduce some hazards such as blind corners or ruts that could cause a tripping hazard, hazards such as "widow maker" trees, culvert and bridge work, and other activities that require heavy, potentially dangerous work and/or machines should be undertaken by agency staff. When hazard potential is mitigated, either by removing the hazard or closing/altering the trail, a record should be attached to the maintenance assessment that detailed the problem, noting the mitigation action and photographic evidence of the condition the trail after the maintenance procedure

Incident Response Planning

Systems for responding to incidents on trails are important protocols for minimizing a situation of potentially compounding hazards, to demonstrate diligence in responding to situations, and to provide confidence to visitors that a well-managed experience with minimal unforeseen hazards is being maintained. Whether the incident in question is related to a sudden and substantial climatic event, development of a hazard on the trail, an accident, a protocol should be established that dictates the immediate and future response. This system should be reflected by signage and messaging on the property so that visitors or peer-to-peer groups can assist the agency in providing oversight.

Record Keeping

Consistent file development and record keeping is vital for maintaining continuity in trail system management and demonstrating diligence is minimizing unforeseen hazards and properly warning the public about potential hazards. Good records also help streamline and prioritize the maintenance and incident response process, allowing managers to dictate actions without direct knowledge of the specific situation. Records should be kept in an organized manner and for a substantial amount of time so that the trail management process can be optimized over time.

APPENDIX A: TRAIL DIFFICULTY SPECIFICATIONS

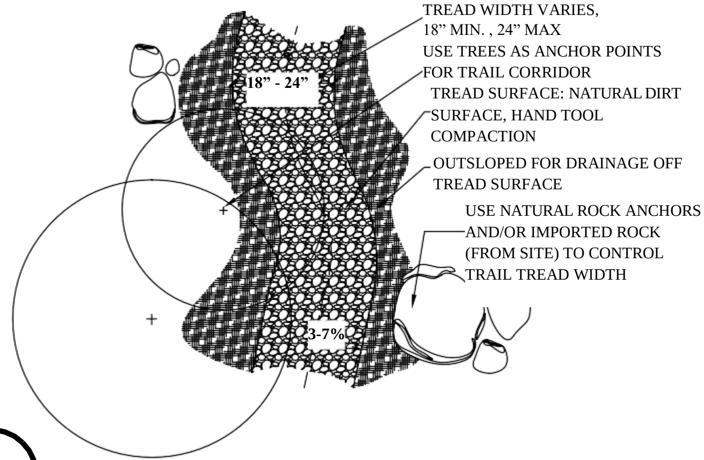
TRAIL DIFFICULTY SPECIFICATIONS

Trail Type Name: Singletrack
Difficulty Rating: Moderate
Difficulty Symbol: Blue Square

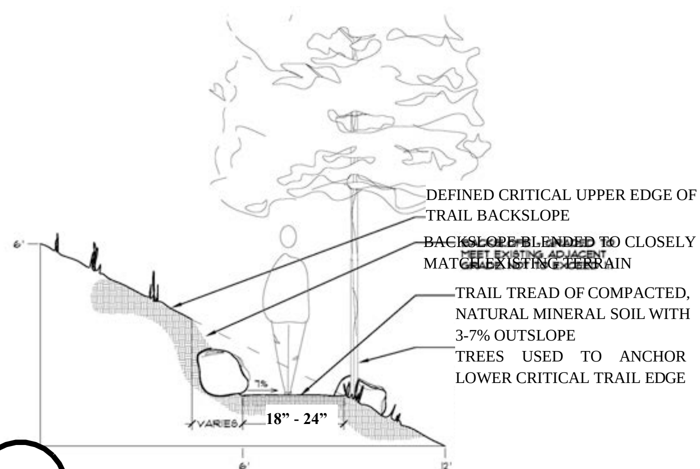
Typical Tread Width: 24-28”
Typical Corridor Width: 36”-60”
Tread Rugosity: Moderate, roots and rocks up to 6” may protrude from trail tread, steps in tread up to 12” in height

Average Gradient: <10%
Maximum Sustained Grade: 15%
Maximum Grade: 25% for short distances
Typical Tread Materials: Natural surface, may be amended with aggregate, if necessary, in seasonal wet areas
Side slope Steepness: Flat to 70%

Turn Radius: 4’ minimum
Trail/Structure Formality: Durable but rustic, 36” minimum width
Wet Area Crossing Formality: Durable but rustic bridges/puncheons for minor/major crossings
Duty of Care: Moderate



1.1 PLAN DETAIL: SINGLETRACK TYP.



1.2 SECTION DETAIL: SINGLETRACK TYP.

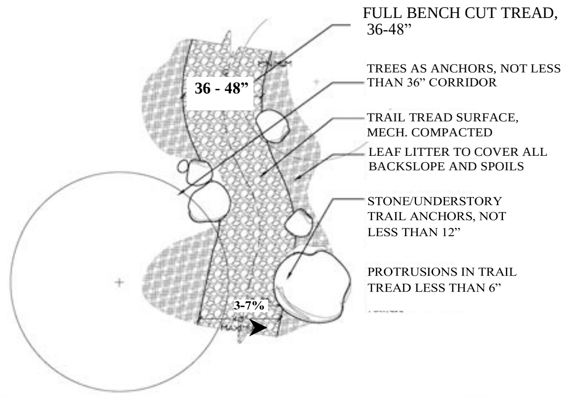
TRAIL DIFFICULTY SPECIFICATIONS

Trail Type Name: Backcountry Shared-Use
Difficulty Rating: Moderate
Difficulty Symbol: Blue Square

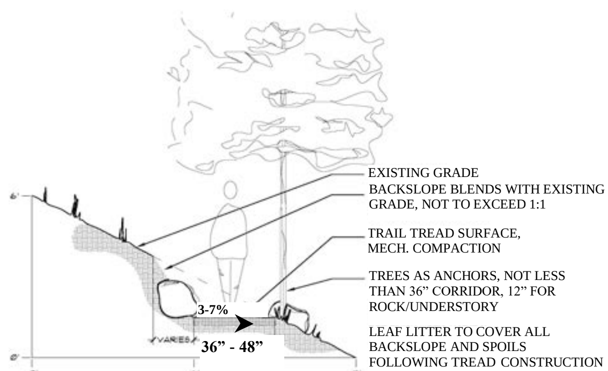
Typical Tread Width: 36-48”
Typical Corridor Width: 48-72”
Tread Rugosity: Moderate, with some rock and root protrusions <6” above trail tread

Average Gradient: 3-7%
Maximum Sustained Grade: 10%
Maximum Grade: 15% for short distances
Typical Tread Materials: Mostly natural surface (native soils) with some rock. Some loose material possible
Exposure Factor: Low to moderate, flat to 45% slopes

Turn Radius: 8’ minimum
Structure Formality: Moderate, 60” minimum width
Wet Area Crossing Formality: Bridges/puncheons to extend beyond current banks, constructed on rock/concrete abutments, and smooth entry/exit ramps
Duty of Care: Moderate



3.1 N.T.S
PLAN DETAIL: BACKCOUNTRY TRAIL TYP.



3.2 N.T.S
SECTION DETAIL: BACKCOUNTRY TRAIL- TYP.

APPENDIX B: TRAIL CLOSURE BEST PRACTICES

TRAIL CLOSURE BEST PRACTICES

Unsustainable trails impact the landscape and visitor experience. In addition to trampled vegetation, badly aligned trails (fall- and flat-aligned) often increase surface run off, which can lead to water-based erosion problems. As these trails receive more use and/or erode more, trail users spread out and widen the trampled area, create parallel routes, or introduce alternate routes; all signals that users are seeking a less challenging trail experience.

As these unsustainable trails are replaced with contour routes, the old trail corridors should be restored to reclaim naturally functioning watershed hydrology. The visual corridors should be similarly restored to prohibit use and allow for natural vegetation regeneration. Trail restoration projects in locations with relatively high moisture and vegetation levels are initiated in a "camouflage, sign, restore."

Camouflage/Barricade

Long-term success in closing trails is dependent upon camouflaging the linear corridor from users. Covering a linear feature with uprooted vegetation and/or woody debris does not disguise the trail corridor and often makes the closed trail more visually evident. Revegetation through transplanting, seeding, and natural regeneration is necessary for the long-term restoration success. If this is not possible due to the season when restoration activities are implemented, short segments of fencing should be placed as a symbolic barricade.

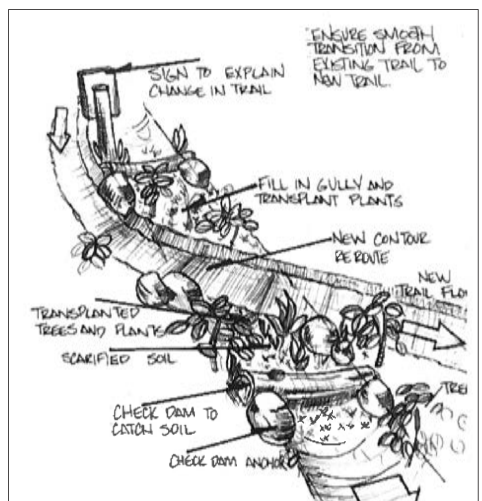


Figure 2. Plan for decommissioning an abandoned trail. (Image courtesy of ImBa)

Sign

Following the visual closure of the trail corridor, signage and messaging should be placed at the junctions of the new and closed trails to reinforce the restoration activity. This is especially true in high use trail environments. Clear and consistent messaging along the trail is vital and should be accompanied by messaging at trailhead kiosks and parking areas, focusing on the broader, underlying resource impacts and regeneration time needed to mitigate the damage.

Restore

When use of the closed route is stopped, restoration of natural hydrologic and vegetation patterns can be effectively initiated. If an erosion gully is present, filling that depression is necessary to

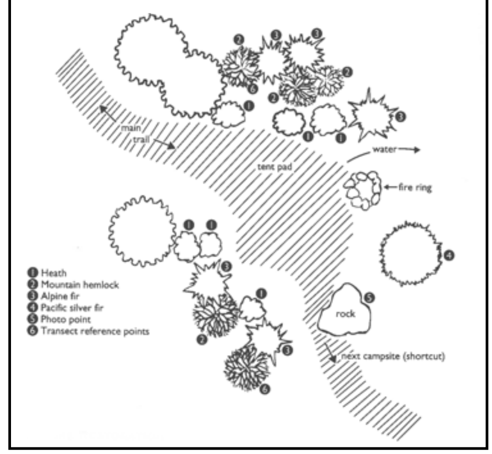
TRAIL CLOSURE BEST PRACTICES

restore natural hydrologic patterns. Check dams of the depth of the gully should be constructed at intervals to catch and retain sediment being transported downslope. These dams can be constructed with woody materials (large rounds from dead trees or smaller materials bound together with twine or bailing wire) or rock (large rocks or rip rap) where available.

If sufficient rock and/or woody debris is not available, coconut coir logs are effective erosion control products that allow water to flow through the check dam, but catch and hold rock, sediment, and seed materials upslope of the dam. These are made from natural fibers and decompose over time. The coir logs can also be used to reestablish vegetation by "plugging" live root specimens into the log. In more extreme cases of erosion and slope stabilization, use jute mat can be laid under the coir logs. This treatment adds additional organic matter to aid in vegetative regeneration and can also be used as a planting substrate for seed or live root seedlings.

In all cases, scarify the gully to aerate any potential native seed stock and improve permeability. Only revegetate with native plants that are already present in the vicinity of the restored trail. When establishing plants in the erosion gully, seedlings should be planted on the upslope edge of check dams.

Before Restoration



After Restoration

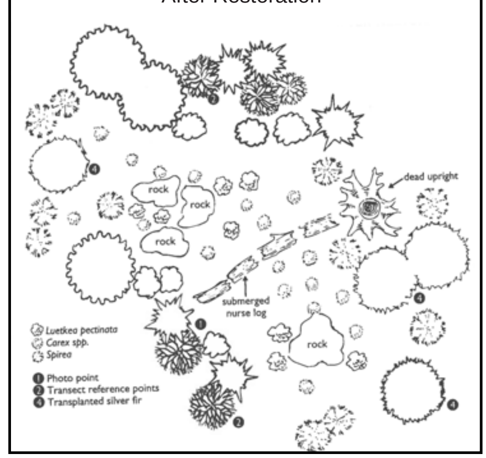
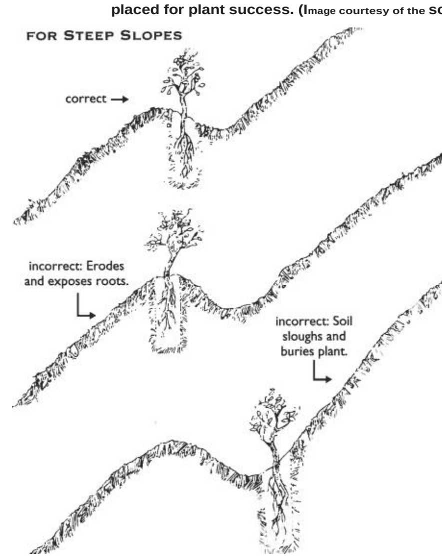
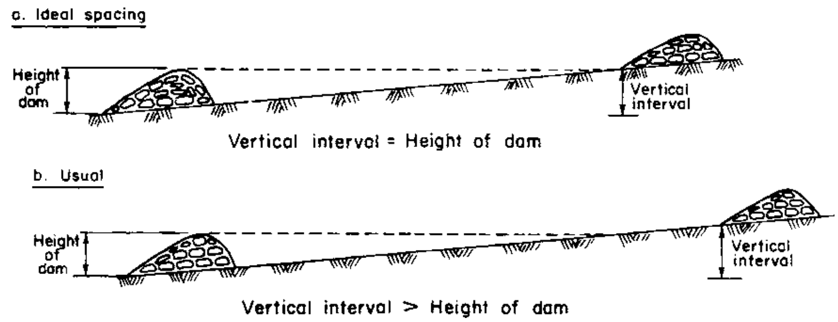


Figure 4. Transplants on steep slopes must be properly placed for plant success. (Image courtesy of the sca)



TRAIL CLOSURE BEST PRACTICES



TRAIL CLOSURE BEST PRACTICES

Efficacy of Indirect and Site Management Techniques in Reducing Off-Trail Behavior in a Fragile Biotic Community, Acadia National Park

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ABSTRACT

Striking a balance between resource protection and visitor experience is a perennial challenge for protected area managers. Some level of resource degradation must be tolerated to allow any recreational use at all, but even low levels of foot traffic can reduce vegetation cover, pulverize and remove organic litter, and increase the erosion potential of the underlying soils (Bradford and McIntyre 2007, Bayfield 1973, Cole 1995a, Olive and Marion 2009). In this companion paper to a 2008 article by Park et al. on efficacy and acceptability of adaptive management measures designed to discourage depreciative off-trail behaviors in a high use frontcountry setting, additive combinations of management techniques are evaluated for efficacy in a high use backcountry trail setting. Combinations including site management and information/education that address multiple motivations for off-trail behaviors are shown to be effective at reducing off-trail travel rates. However, a more-direct, obtrusive measure that relied on fewer additive components—low symbolic post-and-rope fencing—was shown to be the most effective among all treatments studied. Data were collected by a closed circuit video recording system assembled in the backcountry and powered by a deep cycle battery.

TRAIL CLOSURE BEST PRACTICES

Resource Impact, Resource Protection

Striking a balance between resource protection and visitor experience is a perennial challenge for protected area managers. This issue is particularly salient for those working in national parks, where visitor use measured in millions of visits per year can lead to substantial ecological and experiential impacts. Therefore, investigations of effective management approaches that prevent (or minimize) visitation-associated impacts can provide valuable information and assistance in visitor experiences and resource conditions.

For protected areas that receive high levels of visitation, the management of the effects of foot traffic and associated trampling impacts are particularly acute. Some level of resource degradation must be tolerated to allow any recreational use at all, but even low levels of foot traffic can reduce vegetation cover, pulverize and remove organic litter, and increase the erosion potential of the underlying soils (Bradford and McIntyre 2007, Bayfield 1973, Cole 1995a, Olive and Marion 2009). Repeated off-trail excursions create and proliferate informal visitor-created trails. Over time, short cuts and additional access routes are cut across vegetation and exposed soils (Johnson and Vande Kamp 1996). When visitors go off-trail or use informal trails, they can accelerate the spread of exotic invasive species into native biotic communities (Cole 1995a). Low levels of off-trail travel lead to compositional and species richness changes as fragile species are crushed underfoot (Frissell and Duncan 1965). These species (esp. ferns and other nonwoody herbs) are not resistant to impact and can be severely impacted in a single season of consistent use. Further off-trail travel slowly overwhelms more resilient species as stored resources are channeled into tissue repair. Eventually trampled areas suffer reduced biomass and vegetative cover (Cole 1995b, Sun and Liddle 1993). Continued use exposes soil by pulverizing surface organic litter into fragments and further into humus, which is easily removed by wind or

TRAIL CLOSURE BEST PRACTICES

overland water flow. With reduced organic covering to cushion impacts, exposed mineral soil is made susceptible to erosion in a positive feedback cycle (Monti and Mackintosh 1979). At this stage, recovery to an –unimpacted‖ state can occur on a geologic timescale in some places. Localized impacts can vary in size; considered across the scale of a trail network or national park, the aggregate impact can be immense (Lawson and Manning 2002). Moreover, informal trails are quick to appear and slow to recover (Cole et al. 1997). Managers seek to limit trampling impacts by concentrating visitor traffic to networks of formal trails and designated recreation sites designed to accommodate intensive use. However, visitors frequently venture off or away from these designated trails and sites, expanding the boundaries and aggregate area of intensive trampling disturbance and creating new informal or visitor-created networks of trails and recreation sites (Leung and Marion 2000).

Accommodating more than two million visits every year since the 1960‘s, Acadia National Park (ANP) is an example of these visitor impact management challenges (PUSO 2008). ANP is among the most visited national parks in the United States, and due to its comparatively small size, less than twenty thousand hectares, its density of use is exceptionally high. As a result, ANP has experienced substantial use of its popular icon areas—with associated trampling impacts—in recent years.

The Gorham Ridge Trail is one such area. Hundreds of hikers enjoy this high-use, backcountry trail each day during peak season use (personal communication to Jacobi 2007). The trailhead is vehicle accessible from the high-use park loop road, offers commanding views of coastal Maine and the ocean, and features short and comparatively easy hikes to these views. Unfortunately, a small proportion of Acadia‘s visitors in past years have evidenced a functional understanding of ―Leave No Trace‖ principles, an international program of low impact practices and ethics adopted by ANP management (Evans 2002, Turner and LaPage 2001).

Gorham Ridge Trail hikers frequently venture off-trail once they pass the lower forest vegetation and reach the more open summit environment, characterized by exposed bedrock with thin lenses of soil and low shrubby or grassy vegetation. Trampling of the fragile subalpine vegetation and soils is a significant management concern and challenge for park staff (Turner and LaPage 2001). The thin granitic soils overlying the summit bedrock regenerates slowly given the harsh weather conditions and the bedrock‘s natural resistance to erosion/soil generation processes (Davis 1966). Because of these thin soils and adverse weather, the ―heath summit dwarf shrubland mosaic complex‖ in the area grows and regenerates slowly from foot traffic impacts and may be more vulnerable to exotic invasive incursion (Turner and LaPage 2001, Leung et. al. 2002). A century of off-trail exploration, photography, and blueberry picking has resulted in substantial, immediate, and long-lasting resource degradation (Liddle 1997, Baldwin and LaPage 2003).

Responding to these impacts, park management has erected trailhead maps and educational signage encouraging low-impact behaviors seeking to persuade hikers to remain on the formal trail or on durable rock surfaces. In addition, park managers have erected pagoda-like Bates rock cairns at regular intervals and used paint blazing in an attempt to clearly mark the designated path. However, the literature suggests that the success of these measures can be improved through adaptive management, an iterative process of flexible and ―deliberately experimental‖ refinements to management practices (Walters 1986, Walters and Holling 1990). As successive trials of management interventions are applied in light of the insights gained from past trials, resource protection is improved. The process relies on ―incremental knowledge

TRAIL CLOSURE BEST PRACTICES

growth‖ to adequately manage dynamic natural and social systems as an ongoing series of experiments (Reid 2003). This study seeks to enrich the small corpus of research on adaptive management approaches to trail-proximate resource protection in a backcountry setting.

A companion study of this research was undertaken to examine similar concerns at a popular frontcountry site at ANP, the summit of Cadillac Mountain (Park et al. 2008). Several thousand visitors access the summit each day, spreading out from a short, paved summit loop trail onto bedrock, exposed soil and patches of vegetation. That research suggests that particular combinations of site management and information/education management approaches may be effective in enhancing the protection of the area‘s biota and soil without unduly burdening the visitors‘ experiences there. However, measures appropriate and effective for a frontcountry setting (as investigated by the companion piece) may not be appropriate for a backcountry setting as studied on Gorham Ridge and places like it. Another study at ANP by Cahill (2003) examined the suitability of a range of management interventions in terms of frontcountry versus backcountry settings. Cahill‘s stated choice analyses found that setting had a strong effect on the acceptability of management actions arranged along a spectrum of –naturalness.‖ Specifically, management actions that reduced the natural aesthetic were less acceptable in backcountry settings than they were in frontcountry settings. Similarly, management interventions that increase visitor encounters between groups were more acceptable to respondents for frontcountry settings than for backcountry settings. This important finding suggests that areas of degraded environmental quality in the backcountry should not be managed in the same way as analogous impacts in the frontcountry. But which measures are effective at reducing depreciative behaviors along trails in the backcountry? Measures must first be found effective before they can be considered for their potential experiential impacts or setting suitability.

TRAIL CLOSURE BEST PRACTICES

This research explores the protection effectiveness of a variety of measures drawn from management strategies and tactics suggested in the literature, though few basic research studies exist to examine the effectiveness of combinations of site management and educational messages in preventing trailside resource degradation. This information could prove invaluable in protected areas land management. The findings of this study may be useful to other land management agencies as well as larger private organizations that manage publically accessible lands.

Management Frameworks

The literature describes several frameworks or strategies useful in constructing management options for limiting off-trail travel. One management framework groups impact-mitigation tactics into four broad strategies: (1) reducing use via permit requirements or restricting access; (2) increasing the supply of the resource by distributing use and making more of the area accessible; (3) reducing use impacts by altering uses, e.g., restricting type of use or behavior or educating visitors about high-impact practices; or (4) hardening the resource to better accommodate use with limited impact, e.g. installing gravel or rockwork to a trail (Manning 1999). However, not all techniques within this framework are feasible or appropriate to the aesthetics or experiences associated with a given protected area management unit.

Specific techniques derived from one of this fourfold framework‘s strategies (or combination of strategies) for protecting natural and experiential resources may in several ways affect visitors‘ experiences while recreating (Park et al. 2008). For example, techniques that limit use may be received unfavorably by visitors, given that such techniques generally reduce the perceived freedom of recreationists. Just as importantly, use-limiting techniques can entirely exclude some recreationists from being able to access a recreation area. Also, management techniques that are appropriate for one site may not be appropriate for another in terms of

TRAIL CLOSURE BEST PRACTICES

aesthetic considerations or the recreation opportunities of the site (Cheung 1972). For example, fencing may be appropriate for reducing off-trail behaviors at frontcountry cultural and archaeological sites, but wholly aesthetically inappropriate in most backcountry settings. In addition, the management strategy used can affect perceptions of crowding (Shelby, Vaske, and Heberlein 1989). One example is the effect of alternative spatial arrangements of parking lots that concentrate or disperse equivalent numbers of visitors. Thus, it is important for managers to select techniques that are appropriate and minimally obtrusive on recreation experiences.

Another way of organizing management approaches is to locate them on a spectrum of direct to indirect actions (Gramann, Christensen, and Vander Stoep 1992; Manning 1999). Direct management actions target visitors' actions and associated outcomes (Manning 1999, Crandall 1980). Common direct management actions include fining noncompliant visitors, site management measures such as restrictive permitting schemas. At Gorham Ridge, one example of direct techniques could include use of low native stone scree walls as a visual cue of trail boundaries in exposed bedrock areas where only erosive, degraded soil (which can appear to visitors to be a thin gravel) is present to fill this role. Site alterations, posted use regulations, and other direct techniques are often effective in changing visitor behaviors but can be aesthetically intrusive or perceived to impair visitor freedom (Wohlwill and Harris 1980, Carls 1974). The aesthetic intrusion may even be tied to effectiveness. A previous study demonstrated that wooden split rail fences were less effective at keeping visitors on a trail than were less-attractive yellow nylon rope fences, even though the wooden fencing was more physically substantial (Swearingen and Johnson 1988). This tradeoff of aesthetics/perceived experience quality versus impact prevention is a common issue with site management techniques.

TRAIL CLOSURE BEST PRACTICES

Indirect management actions, by contrast, seek to prevent depreciative behaviors by influencing visitor reasoning and decision-making, for example through information/education measures designed to increase awareness of the consequences of specific visitor behaviors (Gramann Christensen and Vander Stoep 1992; Gramann and Vander Stoep 1986). Previous studies have suggested that most depreciative behaviors by visitors are the result of uninformed behavior, not of malicious intent; such behaviors are thought to be effectively remedied through information/education management approaches (Eagly and Chaiken 1993, Harrison 1992, Namba and Dustin 1992). Common examples are the use of educational messages to inform and appeal to visitor ethics as a persuasive technique. For example, Roggenbuck and Berrier (1982) found that informational pamphlets had a significant effect on altering visitor dispersal at a crowded park location. Managers often prefer indirect techniques for the simple idea that they are less conspicuous in the visitor experience (Manning 1999). However, indirect techniques are sometimes perceived by managers as less effective than direct techniques, and in some cases have been empirically demonstrated to be less effective (e.g., Alessa Bennett and Kliskey 2003). This perception has been substantiated in the literature as well (Park et al. 2008).

A degree of synergy may exist between direct and indirect techniques; combinations of direct and indirect techniques may be more effective in reducing noncompliant visitor behaviors (Johnson and Swearingen 1992, Roggenbuck and Berrier 1982). A study of off-trail behavior at a hiking area in the Blue Ridge Parkway found that closing informal trails through sensitive habitat through various kinds of brushing (i.e., site management) was not effective (Johnson Bratton and Firth 1987). Brushing the informal trails (without information/education present) not only failed to close the trails, but overall impact also increased as some visitors went through the brushing (keeping the trails open) and other visitors went around the brushing, creating new impacts in the sensitive biological community there. Again, managers must take care to ensure that an incorporation of a variety of techniques is not too burdensome or intrusive on the visitor experience. In the example of the brushing at the Blue Ridge Parkway hiking area, information/education measures may have helped visitors to understand why off-trail areas were being closed for restoration.

Regardless of any specific combination of techniques, careful thought must be given to ensuring that the measures in place address a variety of motivations for going off formal trails (Gramann and Vander Stoep 1987, Christensen and Dustin 1989, Knopf and Dustin 1992). Past research has suggested that such motivations can range from unintentional or accidental reasons (e.g., difficulty in distinguishing between formal and informal trails), through ―releaser cues‖ (e.g., going off-trail after reaching informal trail junctions or seeing others already off-trail), to intentional/purposive off-trail behavior (e.g., traveling to a vista outcrop not routed with a formal trail) (Gramann and Vander Stoep 1987).

Research has suggested that indirect information/education approaches may be effective in changing careless or unintentional behaviors. However, direct measures are appreciably more effective at curbing intentional depreciative behaviors (Swearingen and Johnson 1994, Johnson and Swearingen 1992). For example, earlier research at Acadia‘s nearby Cadillac Mountain summit found that tall wooden exclosures protecting patches of sensitive vegetation were highly effective, but appeared to suggest to visitors that all other areas of the summit (including unnaturally exposed soils and other vegetation patches) were acceptable for visitor foot traffic (Baldwin and LaPage 2002). Thus, it is important to make certain that the messages presented to visitors are explaining site management measures in place.

Additional useful means of enhancing message effectiveness lie in communication theory. Specifically, the route to persuasion construct examines how messages are evaluated by people on the bases of content (central route to persuasion) and/or delivery (peripheral route to persuasion) (Manning 1999, 2003). Several studies have suggested that message delivery through personal contact with protected area authorities can be among the most effective means at engendering a desired visitor behavior (e.g., Fennell 2001). In an ANP context, an emphasis on delivery might involve a uniformed ranger asking visitors to remain on the paved trail. One cost-reducing approach might be to utilize official-looking logos and organization identification in an attempt to access some of the same sense of authority wielded by uniformed park employees. Similarly, a more formal or prominently placed sign by itself communicates a stronger message than a less formal one with identical wording (Baldwin and LaPage 2002). However, emphasis of the central (–substantive‖) route to persuasion has been suggested to promote more lasting changes in behavior (Manning 1999). As a result, it is important to maximize messaging effectiveness through both routes to persuasion.

Methods

Study Area

Gorham is a popular backcountry mountain summit rising 525 feet above sea level with parking lot access along the busy and popular Ocean Drive Road. The trail‘s 1 mile length receives approximately 400-600 visitors per day during the summer season. The Gorham Mountain trail is the only trail over the summit, and it is marked by Bates-style rock cairns and paint blazes to help visitors navigate and remain on-trail. Off-trail hiking, while permitted to extend visitors maximal recreation freedom, is a concern because the subalpine vegetation is relatively fragile and recovery rates are low due to the shallow dry soils in the area.

A park summit steward volunteer noted that visitors often interpret eroded, exposed patches of subalpine soil along trails and at summits in the park as legitimate foot trails. Above tree-line on the mountain, informal (visitor-created) trails occur at vistas and in other flatter

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areas, with vegetation and soil loss caused by decades of intensive visitor trampling. Previous surveys by park staff have also found that the cairns used to mark the trail are under continual disturbance by visitors, adding to safety and navigation concerns. Less than 40% of cairns survive five days without alteration during the peak season (Jacobi 2003).

The objective of this study was to test the relative effectiveness of adaptive management-style combinations of educational and site management actions on reducing off-trail behavior along a high use backcountry foot trail. The efficacy of alternative treatment combinations of these actions was assessed through videography because use levels were too low to allow for the effective use of human observers. The study‘s observation site was selected based on availability of concealing vegetation for video equipment used to record video data, the variety of trail environs visible (and differing hypothesized motives for possible off-trail travel), and the high level of localized off-trail resource degradation. Hypothesized motives for off-trail travel include getting around other visitors, exploring, accessing vistas, and shortcutting (Park et al. 2008).

Treatments

This study tested a variety of educational messages and site management techniques in combination through an experimental, behavioral design. The practices used in the study were selected based on a review of the literature and consultations with park managers in a collaborative and adaptive management process. The overriding goal was to substantially reduce off-trail hiking. Combinations of actions were expected to have higher efficacy than single actions. Table 1 summarizes the control and experimental treatments undertaken in this study and the specific management techniques involved in each treatment.

Control (Baseline) – To mimic baseline existing conditions, rock cairns were placed along the trail at intervals ensuring that one was visible to hikers regardless of position and direction of travel. Any border rocks that had been placed previously for trail management were removed. The tread of the trail itself was left unchanged in this and all subsequent treatments. There were 10 pre-existing paint blazes on the trail‗s bedrock surface during the control period. No educational signage was present during this treatment.

Treatment 1 (Blazing) – The rectangular paint blazes marking the trail were supplemented with additional similarly colored and sized temporary blazes constructed from adhesive tape (n = 13). The blazes were set at short intervals (5 – 10m) to ensure that multiple blazes were visible regardless of hiker position and direction of travel. Rock cairns were removed. Beyond the upper end of the study area, additional tape blazes (n = 6) were placed along the trail to the summit to encourage as many hikers as possible to enter the study area on the formal trail. No educational signage was present during this treatment.

Treatment 2 (Educational Signs) – Large educational signs were placed at each end of the trail study area (Figure 4-1). Sign text included prescriptive injunctive (i.e., what visitors *should not* do), attributional language: ―Leave No Trace of your summit visit. Your footsteps damage fragile plants and animals. Please: do not leave paint-blazed trails. Do not move rocks.‖ The message featured Leave No Trace language as a tie-in to a broader national program and to convey the intended personal outcome. The educational signs included the NPS arrowhead logo to emphasize the official authority of the message. Rock cairns were placed along the trail at intervals ensuring that one or more was visible to hikers regardless of position and direction of travel. Additional temporary blazes were placed as in treatment 1 (blazing). Additionally, approximately 10 small trailside prompter signs (Figure 4-2, inset) were placed on informal, visitor-created side trails wherever they joined the formal trail study area. Two additional

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prompter signs were placed along the trail to the summit to encourage as many hikers as possible to enter the study area while on-trail.

Treatment 3 (Coping Stones) – Large native stones (8-24‖dia.) were placed on opposite edges of the trail; these stones were spaced along the trail at 6 foot intervals to create a continuous visual trail border across the study area‘s open bedrock. From the oblique viewing angle of hikers along the trail, the discontinuous coping stones more clearly delineated the boundary of the trail. Rock cairns were placed along the trail at intervals ensuring that one or more was visible to hikers regardless of position and direction of travel. No educational signage was present during this treatment.

Treatment 4 (Scree Wall) – Native stones were arranged as a continuous trail border throughout the study area, enough to cover the extent of the upper half of the study area. As with treatment 3 (coping stones), the rocks were large enough to create a clear visual demarcation of the trail treadway, but small enough that they were not a physical barrier. Rock cairns were placed along the trail at intervals ensuring that one or more was visible to hikers regardless of position and direction of travel. No educational signage was present during this treatment.

Treatment 5 (Symbolic Fencing) – Low rope fencing was installed with 0.5m wooden stakes along both sides of the upper section of the study area. As in treatment 4, the fencing was a symbolic visual cue, not a physical barrier. Rock cairns were placed along the trail at intervals ensuring that one or more was visible to hikers regardless of position and direction of travel. No educational signage was present during this treatment.

Treatment 6 (Integrated) – This additive treatment incorporated several of the above treatments‘ measures, using the educational signage placed at both ends of the study area, the rock cairns, coping stones, and trailside prompter signs.

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Data Collection

Video surveillance equipment was unobtrusively installed across the study area to evaluate the efficacy of each treatment. Three color closed-circuit weatherproof video cameras were trained on sequential segments of the study area. Each camera was oriented to provide a clear view of the trail without providing individually identifying features of the hikers. A fourth camera recorded a field of view of the lower educational signage for those treatments incorporating the sign. All cameras were wired to a digital video recorder unit and all were powered by a deep-cycle gel battery and configured through an electric timer to continuously record data during peak use hours. Field staff periodically reviewed footage to ensure system functionality, created field data backups to DVD, and replaced the battery as necessary.

The control and treatments were applied for up to four randomly selected days during a period of six weeks in July and August 2008, corresponding to peak season use levels. Video data were collected during fair weather days and peak use hours, from 9 am to 6 pm. Sample sizes for treatments and controls ranged from 686 to 1261 visitors, total headway (Table 1). Hikers were not counted as going off-trail unless they had first traveled any distance on-trail within the study area to ensure that they were making a decision to go off-trail in contravention of the treatment or control in place. Some hikers observed entering the study area in the downhill direction were likely hikers who had previously entered the study area in the uphill direction, though not all visitors share this itinerary.

At the conclusion of fieldwork, the video footage was evaluated for off-trail behaviors according to location, direction of travel, extent to which the visitor went off trail (i.e., ―near off‖ within 6 feet of the tread or ―far off‖), time of day, and weather conditions (i.e., rain, wind, visibility). For treatment 2 (educational signage) additional data were collected to characterize how long each individual uphill-bound hiker spent reading the sign at the lower end of the study area, how often cairn and border rocks were disturbed, and (where possible) the apparent reasons for hikers going off-trail.

To ensure data transcription quality, evaluators were trained in video interpretation techniques and used transparent screen overlays to clearly demarcate the different visual zones for each camera's field of view. In addition, the evaluators used slow motion review where necessary. Inter-rater reliability tests were performed among the teams of video evaluators with no significant differences found. Exceptional and ambiguous situations were flagged by the evaluators and scrutinized further as necessary.

The observation data were processed in Microsoft Excel from hourly totals of off-trail behavior to off-trail rates through a series of Visual Basic automating macros, then analyzed in SPSS for statistically significant differences among treatments and the control.

Results

The rates for off-trail travel by treatment are shown in Table 2. Off-trail rate reductions were examined at two ranges of distance from the formal trail, less and more than 2m distance, based on literature suggesting that off-trail behavior can occur for differing motivations, resulting in differing degrees of behavior (Park et al. 2008). For example, a visitor attempting to pass a group of other visitors might tend to stay close to the formal trail. By contrast, a visitor seeking a vista may go further off-trail. Approximately 1 in 2 visitors (49.9%) went off-trail no more than 2m from the trail under control conditions. The coping stones treatment reduced off-trail rates to 48.3% of visitors, a reduction that was not significantly different than the control result ($\chi^2 = 0.667$, $p = 0.414$, 1 df, n = 2438). The symbolic fencing treatment provided the greatest reduction of off-trail behavior, to 11.1%, from control conditions. This reduction was

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highly significant (χ^2= 323.3, *p* < 0.001, 1 df, n = 1992). Direction of travel was not found to have a significant effect on off-trail rates for any individual treatment.

Results for treatment efficacy were generally similar for off-trail behavior beyond 2m from the formal trail (Table 2). Blazing (χ^2= 1.029, *p* = 0.310, 1 df, n = 2021), as with off-trail travel within 2m of the formal trail, did not reduce off-trail travel to a rate differing from the control. The coping stones treatment did have a highly significant effect on off-trail travel rates beyond 2m from the formal trail (χ^2= 12.4, *p* < 0.001, 1 df, n = 2438), in contrast to travel within 2m of the formal trail. All other treatments had highly significant reductions in off-trail travel beyond 2m from the formal trail. Fencing had the greatest reduction of off-trail travel among all treatments, to 6.2% (Table 2).

Tukey‗s HSD and Scheffe grouping statistics were computed to understand treatment levels with similar means. Blazing and coping stones were not significantly different than control conditions in deterring off-trail travel (Table 2). The education, scree wall, and integrated treatments were shown to have similar, improved effects over control conditions. Fencing (including trailside cairns), however, was excluded from this group as the single most effective measure for reducing off-trail travel for excursions both within and beyond 2m from the formal trail.

Park et al. (2008) found that at a popular summit area in Acadia National Park, some site management measures may have a ―latent effect‖ on off-trail behaviors, after hikers continued down the trail beyond the extent of the site management measures. Latent (or carry-over) effects were investigated across the length of the study area for treatments including a continuous site management technique (fencing or scree wall). No significant carryover effect was found for the scree wall treatment (χ^2= 2.174, *p* = 0.140, 1 df, n = 719), with a near off-trail percentage 4.2%

higher than the control for this section (19.6%). Similarly, no significant carryover effect was found for symbolic fencing (χ^2 = 0.147, *p* = 0.701, 1 df, n = 776), with a near off-trail percentage only 1% lower than the control condition for this section and direction of travel (14.4%).

The number of seconds a visitor was observed to read the educational signage did not have a significant inverse effect on off-trail rates (χ^2 = 56.325, *p* = 0.303, 36 df, n = 518) (Table 3). No clear trend was shown to exist in the relationship between time spent reading the educational signage and the percentage of visitors going off-trail (Figure 4-2). Further analysis showed that near off-trail travel reduction was significant (χ^2 = 29.427, *p* = 0.043, 18 df, n = 518), and that far off trail travel (beyond 2m from the formal trail) was highly significant (χ^2 = 35.062, *p* = 0.001, 36 df, n = 518). Visitors who spent the most time reading the sign were also the most likely to go off-trail subsequently. The data are inconclusive.

–Effective group‖ ID was procedurally generated for each visitor during the educational message treatment. The ID was assigned based on temporal groupings of people entering the study area (i.e., people hiking near others in time regardless of any social relationship or lack thereof). Visitors entering the study area within 30 seconds of earlier visitors (i.e., within visual proximity of each other) were assigned the same ID. Previous research at Acadia suggested that the presence of others off-trail nearby serves as a releaser cue for a visitor to engage in off-trail behavior. This effect was highly significant (χ^2 = 562.8, *p* < 0.001, 412 df, n = 518) on off-trail behaviors. Since effective IDs were assigned irrespective of social units (e.g., families, groups of friends, or couples), shared IDs across visitors likely mix social units; the extent of this mixing is unknown.

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Discussion and Conclusions

Treatment Efficacy

This research effort investigated alternative means to discouraging off-trail traffic through a series of additive experimental trials. As has been suggested by other literature, the trials incorporating more-direct measures tended to be more effective than measures relying primarily on indirect measures (i.e., information/education). One relatively unique approach taken by this research study was to examine the cumulative effects of multiple techniques applied simultaneously, e.g., combining the information/education approach with site management. If management techniques are effective ultimately because they address specific motivations for a given depreciative behavior, it follows that additive techniques targeted to multiple potential motivations should be more effective than individual techniques. These methods were effective at substantially reducing off-trail behavior. However, the most effective method relied almost exclusively upon symbolic fencing. This result suggests that, where intensive resource protection effort is required, application of multiple techniques may be unnecessarily costly where a low symbolic fence will perform even better.

Similarly, it is important to note that visually-continuous site management techniques were the most effective at reducing off-trail behavior rates. Specifically, a low continuous stone scree wall performed better than coping stones made of the same material and spaced at even intervals along the trail. While the coping stones did form a somewhat continuous demarcation of the trail border when viewed from oblique angles normally experienced while hiking, it may be important that the border is present at the very moment a visitor considers walking off-trail (or approaches a location where it is easy to wander off the formal trail unintentionally). While construction of scree walls is certainly more labor and resource intensive than that of coping stone installation, it is considerably more effective, especially in rocky environments like Acadia

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ridge-top trails where it can potentially be difficult for a visitor to intuit that a given stone is, in fact, a border marker. However, it should be noted that this approach could be potentially visually obtrusive. Because intensive delineation of the trail through extended blazing did not have a strong effect on off-trail behavior rates, it is likely that confusion over what constitutes the formal trail (versus informal side trails running parallel and shortcuts) is a strong driver of off-trail behaviors.

The information/education approach did significantly reduce off-trail behavior from control levels. This approach is popular with managers because it is usually reported to be among the most acceptable of management alternatives to visitors. Gorham Ridge trail is a popular trail accommodating hundreds of visitors a day through a natural community with extremely low recovery rates. In this context, reductions in off-trail behavior may not promote resource recovery and protection. Although the educational signage in this study used multiple techniques validated in the literature for enhancing message effectiveness (attribution, prescriptive injunctive wording, peripheral route to persuasion via the perceived authority of the international Leave No Trace program and NPS logo), the reduction in off-trail behavior achieved in this manner was not sufficient on its own to protect resources. This study demonstrated that combining this information/education signage with direct site management in the form of coping stones was less effective than a continuous scree wall without the signage. Managers should not plan to rely on the effectiveness of the information/education approach at Acadia wherever trailside resources are fragile or already degraded.

Educational signage should be placed in locations that prevent visitor's ―bunching up‖ around them and blocking views to the management messages on display. Recorded video data showed that larger groups and visitors standing close to the sign occasionally obstructed it for other, passing recreationists. Recreationists cannot be alerted to types and degrees of resource degradation if they are unable to see the sign, or can easily walk by it at a distance, as is the case with many trailhead signs and bulletin spaces.

Cost Implications

Management intensity must be balanced against cost. Acadia‗s ridge trails are currently marked by historical rock cairns and blazing. Unfortunately some visitors destroy, alter, or add to these cairns, leading to ongoing maintenance costs. In this situation, continuous site management measures such as low rock scree walls or symbolic fencing may be more desirable than cairns in that they present less of an individualized ―target‖ for depreciative behaviors, and less costly long term (Doucette and Kimball 1990). A well-designed scree wall can fade into the scenery but provide a needed prompt to stay on trail wherever necessary. Replacing the cairns with additional paint blazes (less expensive in the short term), however, is not an effective off-trail behavior deterrent, particularly in settings like Acadia where the formal trail can ―disappear‖ in open bedrock areas and be one among several informal trail options at the far end of the bedrock face. This situation increases the difficulty in successfully remaining on the formal trail.

The companion study to this work suggested a latent effect among some site management treatments (i.e., treatments lowered off-trail behaviors beyond the extent of the actual site management) (Park et al. 2008). However, no similar relationship was found in the backcountry study area for fencing or scree walls. This study suggests that any latent effect may be situation and/or site-specific. However it should be utilized wherever possible, as it represents ―free‖ effects beyond the installed extent of site management measures. One potential application could be utilizing obtrusive effects in sites of maximal degradation, and relying on any latent effect for proximal, marginally degraded areas.

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Management Implications

As a result of the insights gained from this and related studies on reducing depreciative behavior on trail systems, the authors suggest an integrated, additive management approach on reducing depreciative behavior on the backcountry trail system at Acadia National Park. Where resource degradation is most intense, e.g., near perceived vista locations along ridgeline trails similar to that of the study area, it is important to adopt a direct, site management approach. This research underscores that information/education-based approaches are not efficacious alone at reducing off-trail travel to sufficient levels. Consequently, low, symbolic fencing should be installed across junctions of the formal trail with informal trails leading to appealing shortcuts or vista sites where resource degradation is a major concern. In other locations where degradation is topographically constrained, vista side trails could be formalized and managed against further resource harm. As trail realignment is a costly measure, it should in this case be used as a last resort. Where resource degradation is still a concern but to a lesser degree than that requiring low symbolic fencing, natural material scree walls should be installed.

This research confirmed the importance of a visually continuous border along the trail to help visitors understand where the formal trail is and is not, as well as providing a gentle reminder cue at any point where the visitor could have the urge to engage in off-trail behavior. The contrast in effects between the blazing treatment and continuous border treatments suggests that continuous prompts to remain on the formal trail address the motivation to go off-trail in this high use backcountry setting. To reinforce this visual reminder at key locations including informal trail junctions, low-profile symbolic prompter signs could be installed. At locations that are actively degrading, larger educational signage could be installed to sensitize visitors to the effect of careless footsteps. When these signs are used, they can be placed close to the trail so that they are easily read in a narrow section so that visitors pass it single file.

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Video-Based Data Collection

The researchers would like to note the utility and effectiveness of using a video recorder-based data collection approach. By mounting digital cameras throughout the study area, field staffing needs (aside from the setup needs of each experimental treatment) were reduced to a single technician required to change out the 60 lb. battery and make periodic data backups to DVD. The resolution and placement of the cameras ensured sufficient detail for interpretation of visitor location and behavior, but protected the confidentiality of visitors participating in the study. An added benefit was the ability to recheck observational data through later review of the video footage in the few ambiguous evaluations that arose during the course of data transcription. Perhaps most importantly, though, the video surveillance approach allowed explicit, precise, and reproducible demarcations of on-trail and off-trail locations, a difficulty usually associated with studies of this nature.

A further development of this off-trail zone demarcation technique yielded the sub-zoning of near off-trail and far off-trail behavior zones, which were mapped to potentially differing reasons for going off-trail. Specifically, near off-trail behavior (within 2m of the formal trail) appeared almost always due to a visually unclear edge to the formal trail or the need to get around a large cluster of other visitors blocking the way while standing on the trail. Far off-trail behavior, by contrast, usually was due to visitors intentionally seeking alternate routes (e.g., to explore) or to seek out vistas along the trail.

Further Study

This study did have some limitations and results suggest areas of inquiry for further research. This study examined additive approaches to combining multiple management techniques intended to encourage visitors to stay on the formal trail system. Each experimental trial was analyzed for the sum effect of all the techniques used in that trial. Constraints on staffing and the length of the peak visitor use season prevented the use of a more powerful full factorial design that would allow further insight regarding the relative contributions of individual techniques within each trial. This study also assessed the efficacy of a limited subset of techniques. Additional study is suggested to further advance our understanding of the additive effects of an expanded range of management techniques for a backcountry trail setting, e.g., alternative border materials such as downed logs.

Finally, the empirical observation approach used in this study is useful as an objective measure of visitor behaviors. However, observation tells researchers little about visitor cognitive processes and motivations for undertaking the behaviors that they do. Ideally, qualitative interviews of visitors linked to their observation data would be a powerful means of understanding visitor behaviors on trail networks on a reasoning and thought process level. For example, it would be useful to know why some visitors pause to read a sign carefully and why others walk past without a second glance. Further insights of this nature help to expand our understanding of the efficacy and suitability of management actions designed to keep visitors on-trail. Finally, in evaluating the efficacy of varying management alternatives designed to encourage formal trail use, managers and researchers must also consider the site-specific aesthetic impacts of a given technique or combination of techniques. While some research has been conducted on this effect, relatively little is known about the potential combined aesthetic impacts of multiple additive management techniques. An attitudinal survey research effort could serve to expand the field in this area.

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Tables

Table 4-1. Summary of off-trail behavior management techniques included in each treatment.

	Management Actions								
Treatments	Educational Signs	Additional Paint Blazes	Cairns	Coping Stones	Scree Wall	Trailside Fencing	Prompter Signs	# of Actions Included	n
Control (baseline)	No	No	Yes	No	No	No	No	1	1170
Blazing	No	Yes	No	No	No	No	No	1	847
Educational Signs	Yes	Yes	Yes	No	No	No	Yes	4	773
Coping Stones, 6 ft	No	No	Yes	Yes	No	No	No	2	1261
Low Scree Wall	No	No	Yes	No	Yes	No	No	2	686
Symbolic Fencing	No	No	Yes	No	No	Yes	No	2	818
Integrated	Yes	No	Yes	Yes	No	No	Yes	4	1192

Table 4-2. Efficacy of measures designed to encourage visitors to remain on-trail.

Treatment	Percentage Off-Trail Within 2 m (n)[2]	Percentage Off-Trail Beyond 2 m (n)[2]	Total n[1]
Control (baseline)	49.91 (586)[1, a]	22.91 (269)[1, BA]	1174
Blazing	40.50 (343)[2, b]	21.02 (178)[1, CB]	847
Educational Signs	31.56 (244)[3, bc]	13.71 (106)[2, DC]	773
Coping Stones, 6 ft	48.25 (610)[1, ab]	29.19 (369)[3, A]	1264
Low Scree Wall	21.72 (149)[4, d]	13.27 (91)[2, ED]	686
Symbolic Fencing	11.12 (91)[5, e]	6.23 (51)[4, E]	818
Integrated	24.55 (298)[4, cd]	11.78 (143)[2, 4, ED]	1214

1. Harmonic mean n = 918.49; Bonferroni-type correction applied to significance and grouping interpretation.
2. Tukey's HSD groupings as numbered and (conservative Scheffe's groupings as lettered).

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Table 4-3. Time spent reading educational signage and the effect on off-trail behavior rates.

Signage Reading Time	On-Trail Percentage (n)	Percentage Off-Trail Within 2 m (n)	Percentage Off-Trail Beyond 2 m (n)	Total
Less than 2 seconds	63.30 (176)	18.34 (51)	18.34 (51)	278
2 to 4 seconds	77.44 (103)	15.03 (20)	7.518 (10)	133
4 to 6 seconds	63.63 (35)	21.81 (12)	14.54 (8)	55
More than 6 seconds	57.69 (30)	23.07 (12)	19.23 (10)	52
Total	66.40 (344)	18.33 (95)	15.25 (79)	518

Note: data represent only uphill travelers within the educational signage treatment.

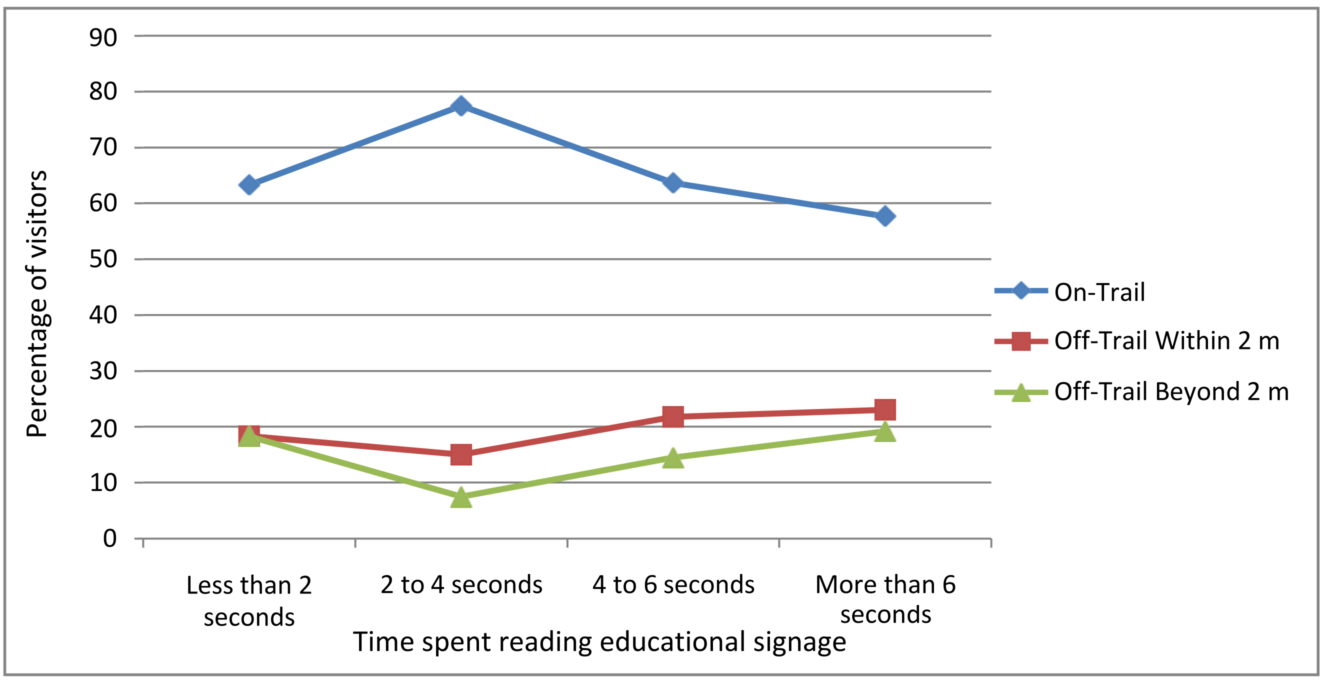

Figure 4-2. Time spent reading educational signage and the effect on off-trail behavior rates.