Monitoring Road Treatments in the Island Park Watershed

Caribou-Targhee National Forest

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Table of Contents

List of Tables

List of Figures

Executive Summary

The USFS, Rocky Mountain Research Station (RMRS) and Intermountain (INT) Region, Pacific Northwest Region (PNW), Pacific Southwest Region (PSW) and the Northern Region (NR) are monitoring a sample of the road decommissioning and maintenance projects to assess their effectiveness in reducing impacts and risks to key watershed processes. Risk profiles are being developed and compared, before and after road treatments, with the Geomorphic Road Analysis and Inventory Package (http://www.fs.fed.us/GRAIP). This suite of robust inventory and analysis tools evaluates the following road impacts and risks: road-stream hydrologic connectivity, fine sediment production and delivery, shallow landslide risk, gully initiation risk, stream crossing failure risk, and drain point condition.

In FY 2009, pre-treatment inventories have been conducted at five sites in the Intermountain Region. A site consists of a group of road segments totaling four miles treated with either decommissioning or Storm Damage Risk Reduction (i.e., storm-proofing) techniques. Inventories were also completed on four miles of control sites for each locale. Four post-treatment inventories were also executed. This status report focuses on work implemented by the Caribou-Targhee National Forest in the Island Park watershed. At the Island Park sites, SDRR treatments included adding broad based dips to increase the road drainage. Some roads in the 046 road system were converted to trails or decommissioned using ripping, tilling, and outsloping techniques.

Before-after comparisons using GRAIP indicate that road treatments resulted in significant reductions of most impact-risk metrics. Road-stream connectivity was reduced by 77%, from 1,500 m of connected road to 350 m. Delivery of fine sediment was reduced by 59%, from 34.9 tons/year to 14.1 ton/year. Stream blocking index values, for the two stream crossings where it is applicable, remained at 2, indicating that there is some risk of plugging. Should these two crossings plug, they have a total of 330 m^3 of fill material at risk. Diversion potential was eliminated at all stream crossing sites.

Changes in slope stability resulting from road treatments vary by the type of treatment used. Trail conversion and decommissioning treatments reduced slope failure risks; SDRR treatments generally reduced risks by more evenly distributing water across the slope, though in some cases SDRR treatments increased the risk of failure.

Gully initiation risks in the study area are generally assumed to be low, given the lack of recorded gullies in the study area. Trail conversion and decommissioning treatments further reduced these risks at most drains. SDRR treatments slightly increased average Erosion Sensitivity Index (ESI) values, though gully risks likely remain low. Current calculations are based on conservative assumptions, so the actual performance of the treatments may exceed these initial expectations. Such assumptions will be assessed during future post-storm monitoring.

Before treatment, inventoried road segments had problems at 28% of 159 inventoried drainage points. Post-treatment monitoring of the modified and added drain points indicates only 6% of the 193 inventoried drainage points had problems, marking a 22% decrease in the rate of problems.

Taken collectively, preliminary results indicate the road treatments should be effective in significantly reducing most hydrogeomorphic impacts and risks to aquatic ecosystems.

Summary of GRAIP road risk predictions for the Island Park watershed road decommissioning project.

Impact / Risk Type	Effect of Treatment: Initial GRAIP Prediction	Effect of Treatment: Post Storm Validation
Road-Stream Hydrologic Connectivity	-77%, -1,160 m of connected road	To be determined.
Fine Sediment Delivery	-59%, -20.7 tonnes/year	To be determined.
Landslide Risk	Generally reduced, though locally increased at some SDRR drains.	To be determined.
Gully Risk	Generally low with slight decreases post-treatment. SDRR treatments show slight increase; trail conversion treatments show decrease.	To be determined.
Stream Crossing Risks		
- plug potential	Unchanged, low risk.	To be determined.
- fill at risk	Unchanged, 330 m^3 at risk.	To be determined.
- diversion potential	-100% (eliminated at 1 site)	To be determined.
Drain Point Problems	-22% (6% vs. 28% of drain points)	To be determined.

Acknowledgements

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1.0 Background

The National Forest Transportation System is vast and represents an enormous investment of human and financial capital. This road and trail network provides numerous benefits to forest managers and the public, but can have adverse effects on water quality, aquatic ecosystems, and other resources (reference?). There is currently a large backlog of unfunded maintenance, improvement, and decommissioning work on national forest roads, and many critical components of the network (e.g., culverts) are nearing or have exceeded their life-expectancy. This significantly elevates risks to aquatic resources. Many Intermountain Region forests have been actively addressing known road issues in critical resource areas. Various road treatment techniques and restoration activities are being applied throughout the region to address resource risks posed by forest roads.

The USFS, Rocky Mountain Research Station (RMRS), Intermountain (INT) Region, Pacific Northwest Region, Pacific Southwest Region and the Northern Region are implementing a roads monitoring project to evaluate the effectiveness and to learn from the successes of road restoration treatments being implemented on national forests throughout the regions. As of February 2009, post-storm event data has been collected at one site, post-treatment data has been collected on 16 sites with partial datasets collected at 17 additional sites.

This report briefly describes the overall objectives of the regional-scale study and the methods being used. Specific results presented herein, however, are focused on storm damage risk reduction and decommissioning work, including road-trail conversions, completed by the Caribou-Targhee National Forest (CTNF) in the Island Park watershed in FY2009. As other data become available, similar reports will be developed for additional sites. In addition, syntheses of results at multiple sites will be produced throughout and at the end of this monitoring project.

2.0 Study Objectives

The monitoring project is designed to assess the effectiveness of decommissioning and maintenance projects in reducing road impacts and risks to several key watershed processes. Specifically, the project is intended to address the following questions.

How effective are USFS road restoration projects in:

1) reducing or eliminating:
    a. the risk of increased peak flows resulting from road-stream connectivity?
    b. fine sediment production and delivery to stream channels?
    c. shallow landslide risk?
    d. gully initiation risk?
    e. the risk and consequences of stream crossing failures?
2) improving the performance of the road drainage system?

3.0 Methods

The Geomorphic Road Analysis and Inventory Package (GRAIP, Prasad et al. 2007, http://www.fs.fed.us/GRAIP) is being used to inventory and model the risk profile of each of the road segments included in the study. The GRAIP system consists of a detailed, field-based road inventory protocol combined with a suite of geographic information system (GIS) models. The inventory is used to systematically describe the hydrology and condition of a road system using Geographic Positioning System (GPS) technology and automated data forms (Black et al, 2009, Cissel et al 2009). The GIS models use these data to analyze road-stream hydrologic connectivity, fine sediment production and delivery, shallow landslide potential with and without road drainage, gully initiation risk, and the potential for and consequences of stream crossing failures. Detailed information about the performance and condition of the road drainage infrastructure is also supplied.

Risk profiles are being developed and compared at untreated control segments and treated segments before and after road projects. At a given site, monitored road segments typically comprise 4 miles of both treated and control sites, though additional data was collected on the Caribou-Targhee National Forest. Control sites were selected based on their similarity to treated sites with respect to road construction methods, maintenance levels, geology, and hydrologic regimes. Each site also includes a final validation evaluation at both treatment and control sites following a substantial storm event (5-10 year recurrance interval). This will allow testing of the initial GRAIP risk predictions and provide an unbiased comparison between the treated and the untreated roads.

4.0 Monitoring Locations

Regional Monitoring Sites

In FY2009, pre-treatment evaluations were completed at five sites[1] on four national forests in the Intermountain Region. Decommissioning was implemented at four of these sites and one other site was treated with Storm Damage Risk Reduction[2]" (Figure 1, Table 1). Four post-treatment inventories were also completed in FY2009. The final post-treatment inventory will be completed in 2010. The post-storm evaluations will be completed at the remaining sites as conditions allow in the

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[1] Each site will include the following evaluations: pre-treatment, post-treatment, and post-storm validation on treated road segments; and pre-treatment and post-storm validation on control segments.

[2] "Storm Damage Risk Reduction (SDRR) is used to refer to relatively low-cost treatments applied across extensive portions of the road network with the objective of protecting aquatic resources and infrastructure. These treatments are intended to reduce the chronic effects of roads (e.g., fine sediment delivery) and significantly reduce the likelihood and consequences of catastrophic failures (e.g., diversion of stream flow onto roads) associated with large storm events. A variety of tools may be used to achieve these objectives, depending on site-specific conditions. These include diversion potential dips at road-stream crossings, water bars, and broad-based drain dips. These simple, extensive treatments are intended to compliment the use of more intensive treatments (e.g., decommissioning, road realignments) that are typically implemented on relatively small segments of the network.

coming years. In addition, evaluations will be initiated at additional sites in future years, the locations of which have not yet been determined.

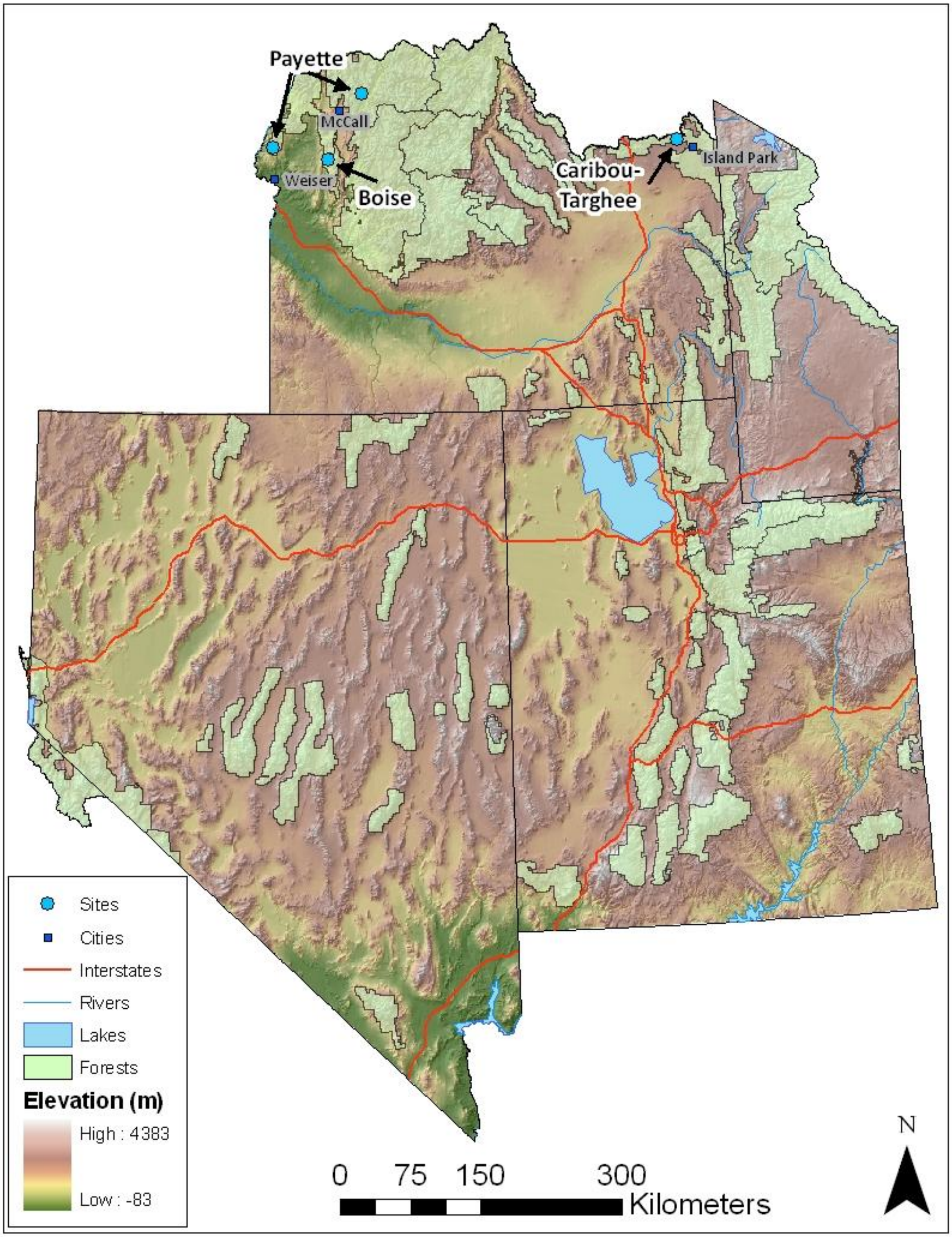

Figure 1. Site Locations in Region 4.

Table 1. The locations and types of road treatments monitored**.**

National Forest	Treatment	Watershed
Payette	Decommissioning	Mann Creek
Payette	Decommissioning	Calf Creek
Boise	Decommissioning	Squaw Creek
Caribou-Targhee	Other Treatments	Island Park
	Storm Damage Risk Reduction	Island Park

Island Park Sites

During the summer and fall of 2009, field crews inventoried road treatment sites in the Intermountain Region, including the Island Park watershed (Table 1, Figure 1). The northern portion of the watershed is underlain by uplifted sedimentary and volcanic rocks. The average annual precipitation for the basin ranges from 20 - 50 inches per year. National Forest lands within the watershed are managed for multiple uses including timber harvest, grazing, and recreation. The inventoried sites are located between 6,000 and 8,000 feet above sea level just north of Island Park Reservoir. Some of the study area was affected by the Willow WFU (Wildland Fire Use) fire in 2008, which burned ~5,400 acres at generally low severity.

Data were collected on roads in the spring of 2009 before the treatments began, and once again during the summer of 2009 once the treatments were completed. Pre-treatment roads were generally native surfaced roads that were in generally good shape. Flow on the roads was generally contained in wheel tracks, though sometimes present along a berm or ditch. Both treatment and control sites included roads on a range of hillslope positions, though dominantly valley-bottom, and included live stream crossings. The watershed has moderately steep topography, so stream crossing fills are not typically large.

Road treatments applied in the Island Park watershed are described in two categories (Figure 2). First, several roads received storm damage risk reduction (SDRR) treatments consisting predominantly of the installation of additional drainage features, mostly broad-based dips. Second, several roads in the 046 system received more intense treatments consisting of outsloping, ripping/tilling, and/or road to trail conversion (described hereafter as “other treatments”).

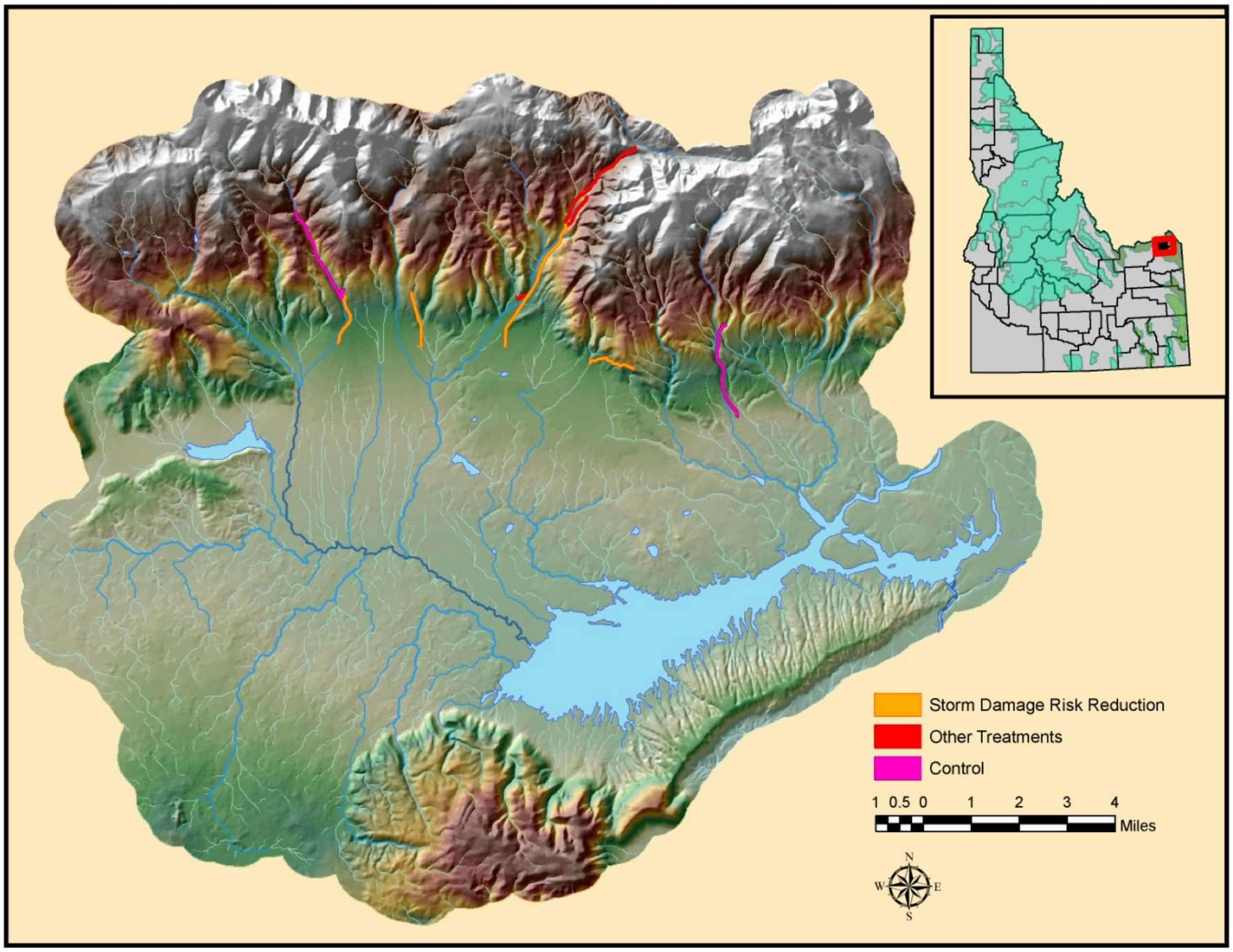

Figure 2. Map of Road Locations within the Island Park watershed.

Table 2. Road treatments applied by road number.

Treated Road			Control Road		
Road #	**Treatment**	**Maintenance Level**	**Road #**	**Treatment**	**Maintenance Level**
037 - Lower	SDRR - Improved drainage (add broad based dips), remove stream connections	2	048 -	None	non-system
042 - Lower	SDRR - Improved drainage (add broad based dips), remove stream connections	2	048 -	None	non-system
046 - Lower Spur	Decommissioned - Tilling	non-system	037 - Upper	None	1
046 - Tin Cup Creek	Trail Conversion - Ripping, recountouring, and tilling	1	037 - Upper	None	1
046 - Upper Spur	Decommissioned - Tilling	non-system	037 - Upper	None	1
046 - Willow Creek	SDRR - Improved drainage (add broad based dips), remove stream connections	2	048 -	None	non-system
047 -	SDRR - Improved drainage (add broad based dips), remove stream connections	2	048 -	None	non-system

5.0 Results

GRAIP inventory and modeling tools were used to characterize the following types of impacts and risks, all of which were expected to be reduced by the treatments:

- Road-stream hydrologic connectivity
- Fine sediment delivery
- Landslide risk
- Gully initiation risk
- Stream crossing failure risk
- Drain point problems

5.1 Road-stream Hydrologic Connectivity

Roads can intercept shallow groundwater and convert it to surface runoff, resulting in local hydrologic impacts when that water is discharged directly to channels (Wemple et al. 1996). Additional runoff is also produced from the compacted road surface. Basin-scale studies in the Oregon Cascades suggests that a high degree of integration between the road drainage system and the channel network can increase peak flows (Jones and Grant 1996).

GRAIP calculates the hydrologically-connected portion of the road using the field assessment of drain point connection and a road segment flow routing system. The flow path below each drain point is followed until evidence of overland flow ceases or the flow path reaches a natural channel. In the Island Park watershed, the road treatments increased the total number of drain points and redistributed water back onto the hillslope. This substantially reduced the length of road surface connected to the channel. Prior to the treatments, 1,500 m out of the 15,540 m of inventoried road (9.7%) were hydrologically connected to stream. After the treatments, 350 m of the 15,660 m of monitored road (2.2%) were connected. Thus, the treatments resulted in a net reduction of 1,160 m of hydrologically-connected road, which is a 77% reduction from the pre-treatment condition.

5.2 Fine Sediment Production & Delivery

Fine sediment production for a road segment (E) is estimated based on a base erosion rate and the properties of the road (Luce and Black 1999), as shown below.

$$E = B \times L \times S \times V \times R$$

B is the base erosion rate[3] (kg/m)
L is the road length (m) contributing to the drain point
S is the slope of the road segment (m/m) contributing to the drain point
V is the vegetation cover factor for the flow path
R is the road surfacing factor

Delivery of eroded sediment to the channel network is determined by observations of the flowpath below each place that water leaves the road. Each of these drain points is classified as delivering, not delivering, or uncertain. No estimate of fractional delivery is made because there is generally insignificant hillslope sediment storage in locations where there is a clear connection to the channel, under most circumstances. For this analysis, uncertain observations were treated as delivering. A map of the road surface sediment production and the accumulated sediment delivered through drain points is shown for the pre-treatment roads (Figure 3).

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[3] For this analysis, a base erosion rate of 79 kg/m of road length was assumed, based on observations in the Oregon Coast Range (Luce and Black 1999). Further work could determine if this rate is appropriate for this climate, geology and road system.

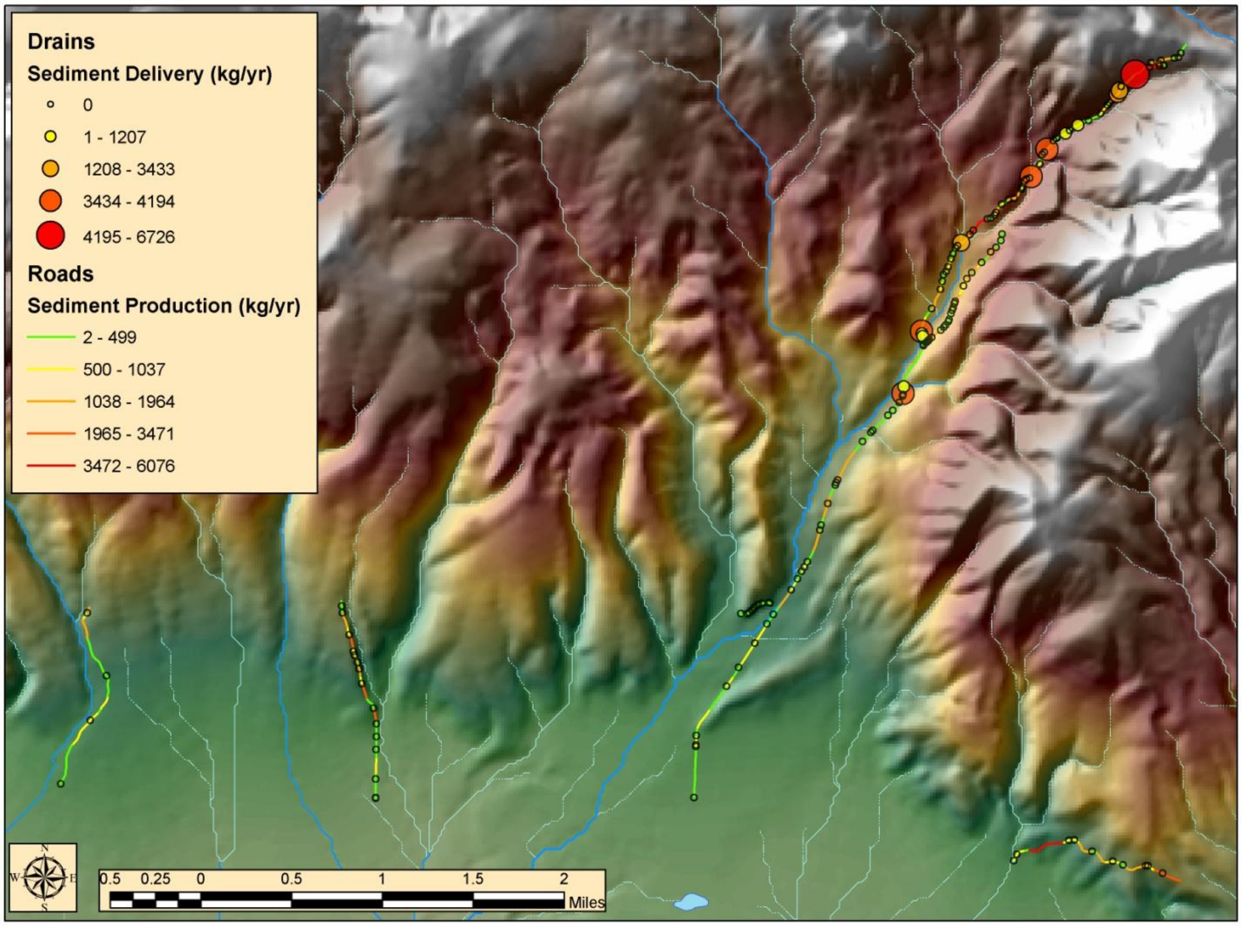

Figure 3. Fine sediment production and delivery to channels by road segment and drain point, pre-treatment road. The road line is colored to indicate the mass of fine sediment that is generated on the road. The size of the circle indicates the accumulated mass of sediment delivered to the stream network at each drain point.

Pre-treatment

Delivery of fine sediment occurs through a mix of road drainage features including ditch relief culverts, non-engineered drain points, stream crossings and others. Sediment delivery from all roads is summarized by drain type to assess their effectiveness in preventing sediment from entering the channel (Table 3). However, the sample size collected for the Island Park study is too small for extensive statistical analysis by drain point. One hundred and fifty-nine drain points were documented, 9% of which were hydrologically connected to stream channels. These points delivered 34.9 tons/year (34,856 kg/year) of sediment, or 12% of the sediment generated by the road surfaces and ditches.

Road sections chosen for trail conversion – decommissioning or SDRR treatments have distinctly different levels of sediment delivery. Pre-treatmnet trail conversion and decommissioning sections had much higher delivery rates (Table 4) than the SDRR sections (Table 5).

Table 3. Summary of Sediment Production and Delivery at All Drain Points, including Decommissioning, Trail Conversion, and SDRR, Pre-treatment Road.

Drain Type	Count	Sediment Received at Drain Point (kg/yr)	Sediment Delivered by Drain Point (kg/yr)	% Sediment Delivery	% Effective Length Connected
Broad-Based Dip	54	105,928	306	0.3	0.7
Diffuse Drain	28	28,023	4,770	17.0	15.8
Ditch-Relief Culvert	10	519	0	0.0	0.0
Lead-off Ditch	8	5,103	376	7.4	18.5
Non-engineered Drain	40	100,898	3,766	3.7	4.1
Stream Crossing	5	11,814	11,814	100.0	100.0
Sump	0	0	0	0.0	0.0
Water Bar	14	31,478	13,826	43.9	27.6
All Drains	159	283,763	34,856	12.3	9.7

Table 4. Summary of Sediment Production and Delivery at Drain Points, Pre-treatment Road, Decommissioning and Trail Conversion Sections.

Drain Type	Count	Sediment Received at Drain Point (kg/yr)	Sediment Delivered by Drain Point (kg/yr)	% Sediment Delivery	% Effective Length Connected
Broad-Based Dip	45	52,163	306	0.6	2.1
Diffuse Drain	20	16,629	1,207	7.3	4.6
Ditch-Relief Culvert	0	0	0	0.0	0.0
Lead-off Ditch	0	0	0	0.0	0.0
Non-engineered Drain	13	32,118	3,766	11.7	20.6
Stream Crossing	4	11,814	11,814	100.0	100.0
Sump	0	0	0	0.0	0.0
Water Bar	14	31,478	13,826	43.9	27.6
All Drains	96	144,202	30,918	21.4	18.9

Table 5. Summary of Sediment Production and Delivery at Drain Points, Pre-treatment Road, SDRR Sections.

Drain Type	Count	Sediment Received at Drain Point (kg/yr)	Sediment Delivered by Drain Point (kg/yr)	% Sediment Delivery	% Effective Length Connected
Broad-Based Dip	9	53,765	0	0.0	0.0
Diffuse Drain	8	11,394	3,563	31.3	0.3
Ditch-Relief Culvert	10	519	0	0.0	0.0
Lead-off Ditch	8	5,103	376	7.4	0.1
Non-engineered Drain	27	68,780	0	0.0	0.0
Stream Crossing	1	0	0	0.0	0.0
Sump	0	0	0	0.0	0.0
Water Bar	0	0	0	0.0	0.0
All Drains	63	139,561	3,939	2.8	4.4

Post-treatment

Roads in the Island Park watershed received two types of treatments. First, several roads received storm damage risk reduction (SDRR) treatments consisting predominantly of the installation of additional drainage features, mostly broad-based dips. Second, several roads in the 046 system received more intense treatments consisting of outsloping, ripping/tilling, and/or conversion to trail.

By improving road- stream connections, the treated roads do not deliver nearly as much sediment (Table 6). Nine (5%) of the drain points were found to be connected to the stream network. The total sediment delivered is reduced to 14.1 tons/year (41% of the sediment delivered prior to treatment). Following treatment, trail conversion and decommissioning sections continued to deliver sediment to the stream network (Table 7), while the SDRR sections do not (Table 8). In both cases sediment production, the amount of sediment routed to drain points, increased while the amount of sediment delivered to water bodies, % sediment delivery and % effective length connected decreased.

Figure 4. Example of new broad based dips added as SDRR treatments.

Table 6. Summary of Sediment Production and Delivery at All Drain Points, including Decommissioning, Trail Conversion, and SDRR, Post-treatment Road.

Drain Type	Count	Sediment Received at Drain Point (kg/yr)	Sediment Delivered by Drain Point (kg/yr)	% Sediment Delivery	% Effective Length Connected
Broad-Based Dip	87	157,367	11,249	7.1	3.5
Diffuse Drain	74	159,826	0	0.0	0.0
Ditch-Relief Culvert	12	7,251	0	0.0	0.0
Lead-off Ditch	5	987	0	0.0	0.0
Non-engineered Drain	9	9,034	0	0.0	0.0
Stream Crossing	6	2,898	2,898	100.0	100.0
Sump	0	0	0	0.0	0.0
Water Bar	0	0	0	0.0	0.0
All Drains	193	337,362	14,147	4.2	2.2

Table 7. Summary of Sediment and Delivery at Drain Points, Post-treatment Road, Decommissioning and Trail Conversion Sections.

Drain Type	Count	Sediment Received at Drain Point (kg/yr)	Sediment Delivered by Drain Point (kg/yr)	% Sediment Delivery	% Effective Length Connected
Broad-Based Dip	42	45,497	11,249	24.7	18.8
Diffuse Drain	63	137,325	0	0.0	0.0
Ditch-Relief Culvert	0	0	0	0.0	0.0
Lead-off Ditch	0	0	0	0.0	0.0
Non-engineered Drain	1	966	0	0.0	0.0
Stream Crossing	4	2,898	2,898	100.0	100.0
Sump	0	0	0	0.0	0.0
Water Bar	0	0	0	0.0	0.0
All Drains	110	186,685	14,147	7.6	6.2

Table 8. Summary of Sediment and Delivery at Drain Points, Post-treatment Road, SDRR Sections.

Drain Type	Count	Sediment Received at Drain Point (kg/yr)	Sediment Delivered by Drain Point (kg/yr)	% Sediment Delivery	% Effective Length Connected
Broad-Based Dip	45	111,870	0	0.0	0.0
Diffuse Drain	11	22,501	0	0.0	0.0
Ditch-Relief Culvert	12	7,251	0	0.0	0.0
Lead-off Ditch	5	987	0	0.0	0.0
Non-engineered Drain	8	8,068	0	0.0	0.0
Stream Crossing	2	0	0	0.0	0.0
Sump	0	0	0	0.0	0.0
Water Bar	0	0	0	0.0	0.0
All Drains	83	150,677	0	0.0	0.0

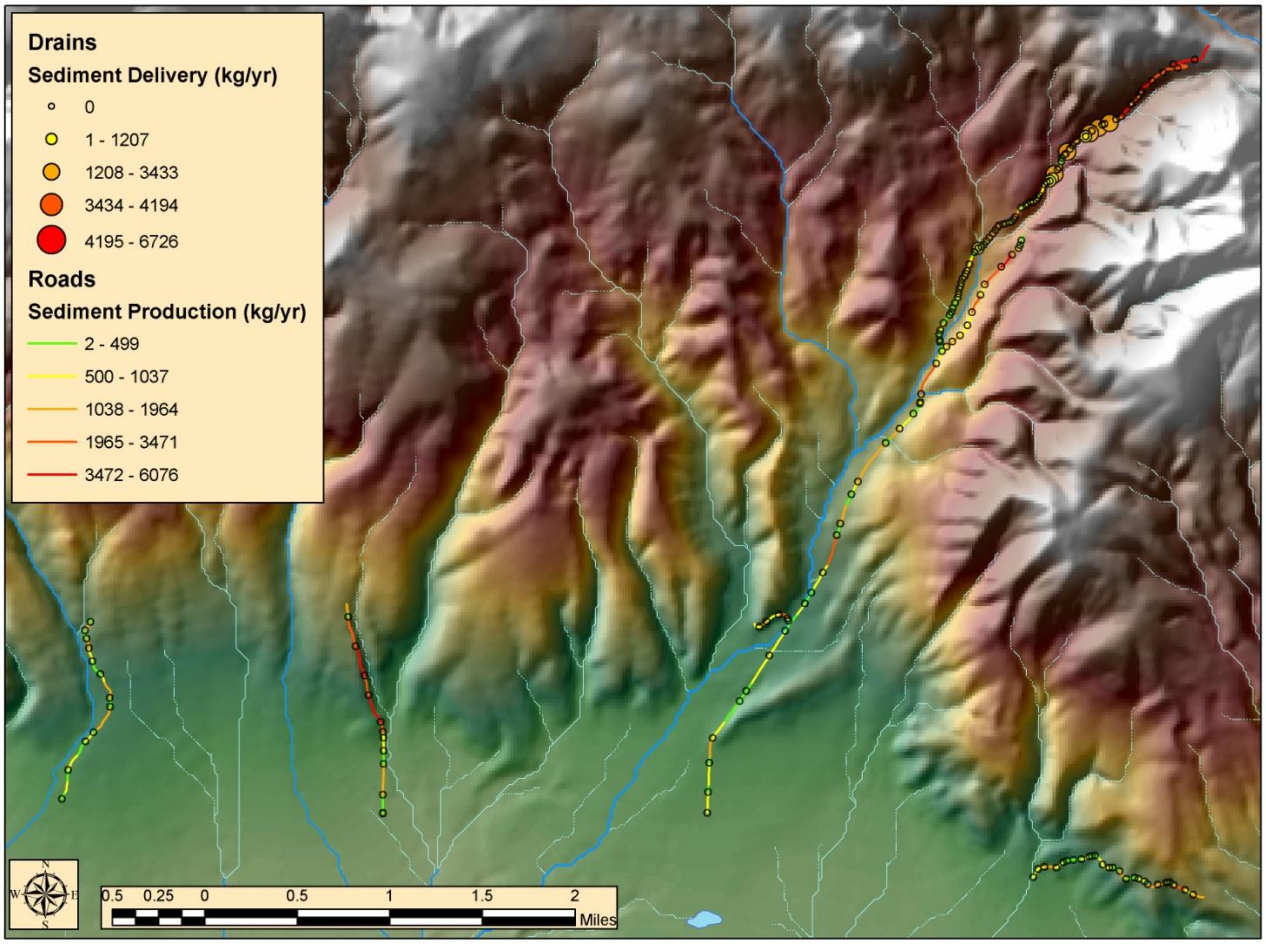

Figure 5. Fine sediment production and delivery to channels by road segment and drain point, post-treatment road. The road line is colored to indicate the mass of fine sediment that is generated on the road. The size of the circle indicates the mass of sediment delivered to the stream network at each drain point.

The modeled change in sediment delivery following the treatments indicates a 59% decline (Table 9) from 34.9 tons/year (Table 3) to 14.1 tons/year (Table 6). The largest reductions were due to removal of the waterbars and conversion to diffuse drainage (a reduction of 13.8 tons/year) and improvements to stream crossings (a reduction of 8.9 tons/year). There was a large increase in the number of diffuse drains (46). Even with the increased number, and increase in sediment received by diffuse drains (470%), sediment delivery decreased by 100% at these drains. Road treatments added 33 broad based dips, which deliver 11.2 tons/year of sediment to the stream. Broad based dips are the only drain type to show an increase in sediment delivery (3,582%), due to the large number of new broad based dips. Modeled changes for the trail conversion – decommissioning sections and SDRR sections are shown in Tables 10 and 11, respectively.

Table 9. Changes in Sediment Production and Delivery, Pre-treatment vs. Post-treatment Conditions, All Roads.

Drain Type	Count	Δ Sediment Production (kg/yr)	Δ Sediment Delivery (kg/yr)	Δ Sediment Production (%)	Δ Sediment Delivery (%)
Broad-Based Dip	33	51,438	10,944	48.6	3,582.1
Diffuse Drain	46	131,804	-4,770	470.3	-100.0
Ditch-Relief Culvert	2	6,732	0	1,296.7	0.0
Lead-off Ditch	-3	-4,116	-376	-80.7	-100.0
Non-engineered Drain	-31	-91,865	-3,766	-91.0	-100.0
Stream Crossing	1	-8,916	-8,916	-75.5	-75.5
Sump	0	0	0	0.0	0.0
Water Bar	-14	-31,478	-13,826	-100.0	-100.0
All Drains	34	53,599	-20,710	18.9	-59.4

Table 10. Changes in Sediment Production and Delivery, Pre-treatment vs. Post-treatment Conditions, Decommissioning and Trail Conversion Sections.

Drain Type	Count	Δ Sediment Production (kg/yr)	Δ Sediment Delivery (kg/yr)	Δ Sediment Production (%)	Δ Sediment Delivery (%)
Broad-Based Dip	-3	-6,666	10,944	-12.8	3,582.1
Diffuse Drain	43	120,696	-1,207	725.8	-100.0
Ditch-Relief Culvert	0	0	0	0.0	0.0
Lead-off Ditch	0	0	0	0.0	0.0
Non-engineered Drain	-12	-31,153	-3,766	-97.0	-100.0
Stream Crossing	0	-8,916	-8,916	-75.5	-75.5
Sump	0	0	0	0.0	0.0
Water Bar	-14	-31,478	-13,826	-100.0	-100.0
All Drains	14	42,483	-16,771	29.5	-54.2

Table 11. Changes in Sediment Production and Delivery, Pre-treatment vs. Post-treatment Conditions, SDRR Sections.

Drain Type	Count	Δ Sediment Production (kg/yr)	Δ Sediment Delivery (kg/yr)	Δ Sediment Production (%)	Δ Sediment Delivery (%)
Broad-Based Dip	36	58,105	0	108.1	0.0
Diffuse Drain	3	11,107	-3,563	97.5	-100.0
Ditch-Relief Culvert	2	6,732	0	1,296.7	0.0
Lead-off Ditch	-3	-4,116	-376	-80.7	-100.0
Non-engineered Drain	-19	-60,712	0	-88.3	0.0
Stream Crossing	1	0	0	0.0	0.0
Sump	0	0	0	0.0	0.0
Water Bar	0	0	0	0.0	0.0
All Drains	20	11,116	-3,939	8.0	-100.0

5.3 Landslide Risk

Existing Landslides

Field crews recorded the presence of only one road-related landslide during the inventory process (Figure 6). This cutslope slump failure was located after decommissioning treatments had been applied along the upper 046 spur road, though it predates the treatments. The risk of shallow landslide initiation was predicted using SINMAP 2.0 (Pack et al., 2008, http://hydrology.neng.usu.edu/sinmap2/). SINMAP was run initially to determine the intrinsic stability of the slopes over which the road traverses and to identify locations that are at high risk of failure without a road (Figure 7).[4]

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[4] SINMAP was run using the default input parameters. For increased precision, these values could be refined and calibration could be performed if landslide calibration data were available.

Figure 6. Slump in cutslope near the end of the upper 046 spur road. Red line indicates approximate scarp base.

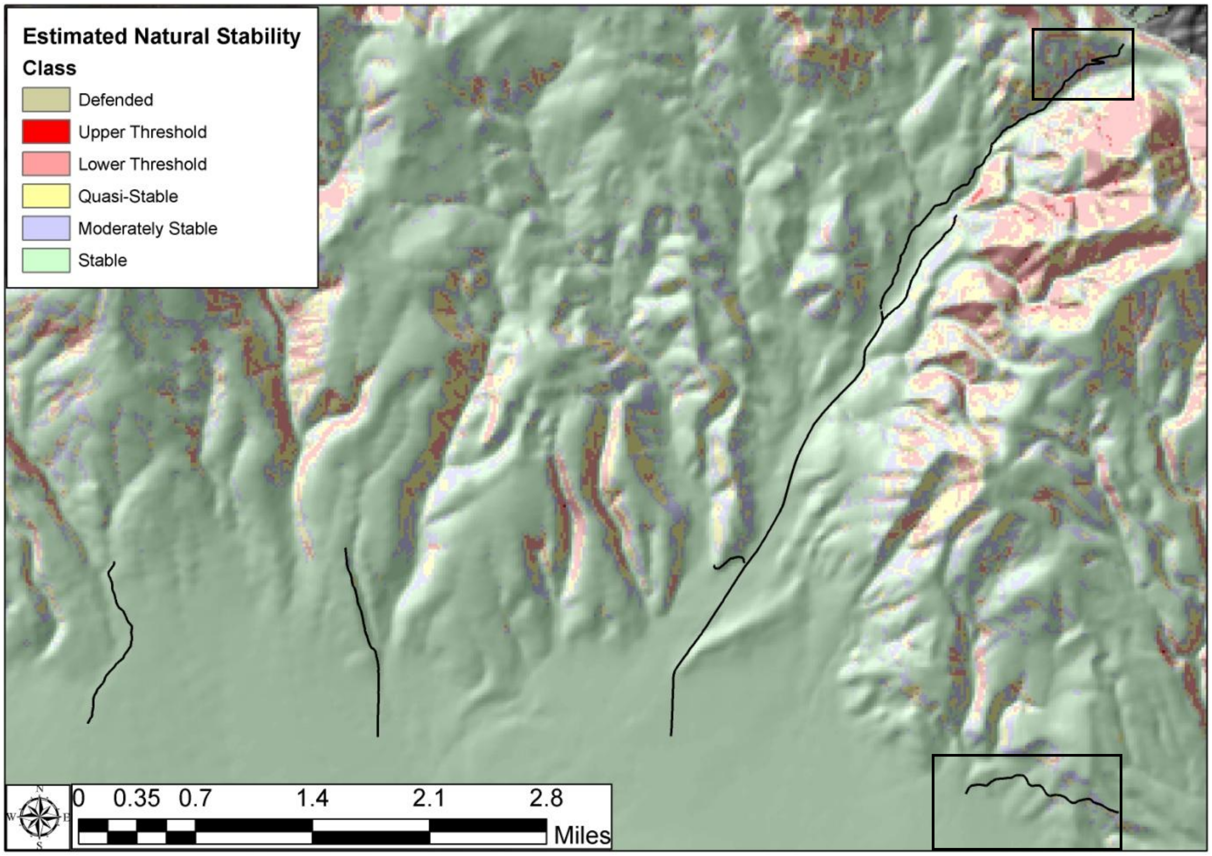

Figure 7. Estimated natural slope stability index classes. Slope stability was modeled using default values in SINMAP 2.0. Rectangles indicate areas shown in Figures 6 (top) and 7 (bottom).

Changes in Landslide Risk

A second stability index (SI) run was performed to address the effects of road water contribution to drain points on the original road network (Figure 8 left; Figure 9, top). A third model run was performed to illustrate the change in risk of shallow landsliding with the modified road drainage system resulting from the road treatments (Figures 8 and 9, center). Differences between these model runs were used to evaluate the changes in landslide risk that are due to the road treatments. Significant changes, those occurring in areas that were unstable before or after treatment, are shown as well (Figure 8, right; Figure 9, bottom). Figure 8 shows an area of more intense trail conversion and recontouring treatments; Figure 9 shows results of SDRR treatments.

Post-storm monitoring will help calibrate the SI values used in this analysis and refine these initial results. Questions to be evaluated include the amount of runoff still intercepted by cutslopes and runoff generated from ripped surfaces following treatment.

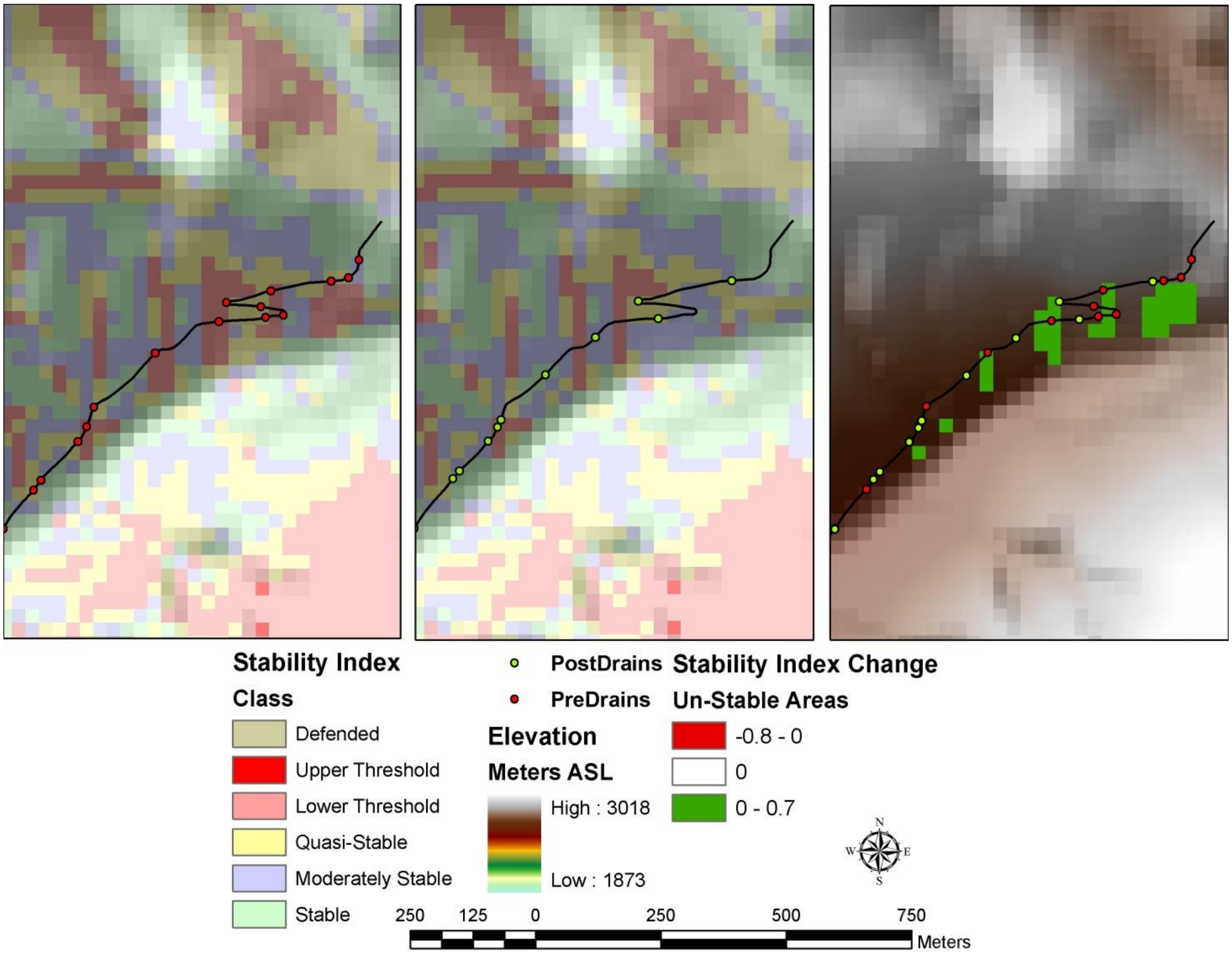

Figure 8. Stability index for hillslopes along the Tin Cup Creek section of the 046 road. Left: Stability Index classes prior to recontouring and trail conversion treatments. Center: Stability Index classes after treatment. Right: Amount of significant change (change in areas that were unstable before or after treatment) in stability index values between pre- and post-treatment. Positive values (depicted by a dark green color) indicate a predicted increase in slope stability following treatment.

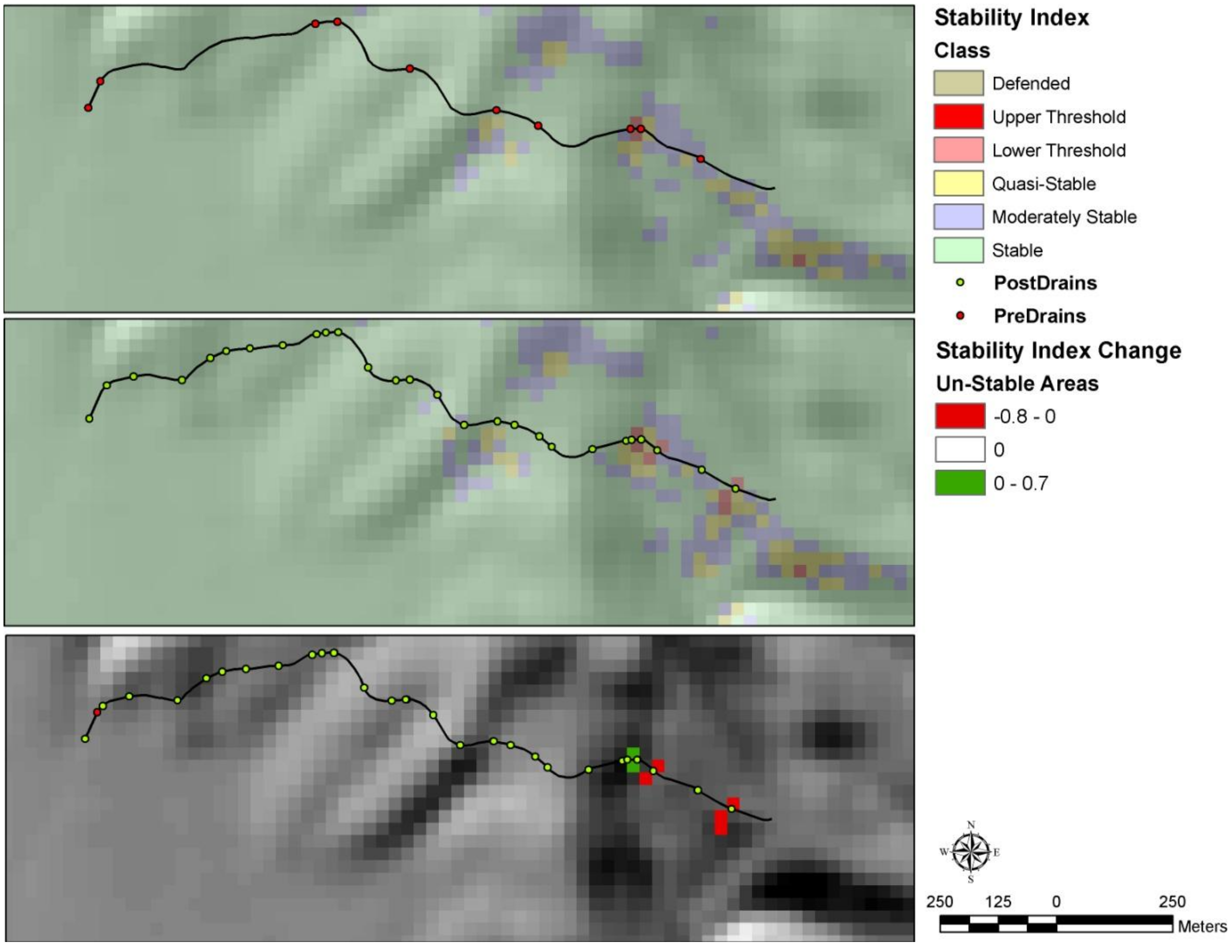

Figure 9. Stability index for hillslopes along the 047 road, SDRR treatment. Top: Stability Index classes prior to SDRR treatments. Center: Stability Index classes after treatment. Bottom: Amount of significant change (change in areas that were unstable before or after treatment) in stability index values between pre- and post-treatment. Positive values (depicted by a dark green color) indicate a predicted increase in slope stability following treatment.

5.4 Gully Initiation Risk

Gullying at drain points below roads can be a substantial source of sediment to stream channels. Gully initiation occurs when the shear stress applied by runoff exceeds the strength of the soil surface on the hillslope. GRAIP computes the Erosion Sensitivity Index (ESI) (Istanbulluoglu et al. 2003), as shown below, at each drainage point.

$ESI = L \times S^2$, where:

L is the road length contributing to the drain point
S is the average slope of the hillslope below the drain point

Calculated ESI values are then compared to a critical ESI threshold (ESI_{crit}) to identify areas with a high risk of gully formation (i.e., where $ESI > ESI_{crit}$). ESI_{crit} is empirically-derived for each study area using inventoried gullies. During this study, field crews did not locate any gullies along the study roads. Hence, it is not possible to, nor is it relevant to, calculate a value for ESI_{crit}. Drainpoints that have higher ESI values are more likely to cause gully initiation. While gully formation appeared to be uncommon prior to the application of the road treatments, it has become less likely following trail conversion and decommissioning treatments, and slightly more likely following SDRR treatments (Table 12).

Table 12. ESI population statistics for pre-treatment and post-treatment road networks.

All Drains

Time	Minimum	Maximum	Average	Standard Deviation
Pre-Treatment	0.03	24.59	1.82	3.65
Post Treatment	0.04	22.64	1.63	3.15
Change	**0.01**	**-1.95**	**-0.19**	**-0.51**

Trail Conversion and Decommissioning Sections

Time	Minimum	Maximum	Average	Standard Deviation
Pre-Treatment	0.05	14.83	2.28	3.53
Post Treatment	0.04	3.35	0.62	0.69
Change	**-0.01**	**-11.49**	**-1.66**	**-2.84**

SDRR Sections

Time	Minimum	Maximum	Average	Standard Deviation
Pre-Treatment	0.03	24.59	1.14	3.73
Post Treatment	0.07	22.64	2.33	3.90
Change	**0.04**	**-1.95**	**1.19**	**0.18**

5.5 Stream Crossing Failure Risk

Besides contributing fine sediment to streams through surface erosion, stream crossings may fail catastrophically when blocked and deliver large sediment pulses to stream channels. Stream crossing failure risks were assessed using the Stream Blocking Index (SBI, Flanagan et al. 1998). The SBI characterizes the risk of plugging by woody debris by calculating the ratio of the culvert diameter to the upstream channel width (w*) and the skew angle between the channel and the pipe inlet.

Only two stream crossings recorded in the study had culvert pipes, both along FSR 046; the rest were fords or previously excavated crossings. The larger crossing, using a culvert greater than 60” in diameter accommodates Willow Creek. The smaller crossing uses a 36” culvert at the first tributary downstream of the larger crossing. Both stream crossing culvert pipes had SBI values of 2 and their SBI values remained unchanged following treatment. An SBI value of 2 indicates that while there is some risk of blockage because the upstream channel is slightly wider than the culvert pipe, the risk is not great because the pipe is still in line with the channel.

The risk of a stream crossing failure can also be viewed in the context of the consequences of failure (Flanagan et al. 1998). A consequence of concern at these stream crossings is the erosion of fill material, a cumulative total of 330 m^3, into the stream channel. This material remains in place following treatment.

A second, and perhaps greater, consequence of concern at failed stream crossings is the diversion of stream flow onto road surfaces and unchannelled hillslopes. Once a crossing becomes occluded and begins to act as a dam, failure can occur in several ways. If the road grade dips into and rises out of the crossing, the failure is likely to be limited to a localized overtopping of the stream crossing. However, if the road grades away from the stream crossing in one or more directions, the flow may be diverted down the road and ditch and onto adjacent hillsopes, where it can cause gullying and/or landsliding (Furniss et al. 1998, Best et al. 1995). In these situations, volumes of sediment far exceeding those at the crossing can be at risk.

GRAIP addresses this issue by classifying the potential for stream crossings to divert streamflow down the adjacent road as: no potential, potential to divert in one direction, or potential to divert in two directions. At this site, 1 of the 5 stream crossings on the original roads had the potential to divert streamflow down the road in one direction. SDRR treatments at this site eliminated this risk.

5.6 Drain Point Condition

The GRAIP inventory involves an assessment of the condition of each drain point and a determination of how well it is performing its intended function. Problems with drain point condition are pre-defined for each drain type. Broad based dips are considered to be in poor condition if they are insufficiently outsloped and pond water on the road. Culverts are defined to be in poor condition if they have more than 20% occlusion of the inlet by sediment, substantial inlet crushing, significant rust, or flow around the pipe. Lead off ditches are considered problematic if they have excess deposition or gullying. Non-engineered features are almost always a problem due to a blocked ditch, a gully, or a broken outside berm. Stream crossings are considered a problem if they are blocked by sediment or wood, crushed or rusted significantly, incising, scouring or loosing much water from flow around the pipe. Sumps are a problem if they pond water on the road surface or cause fill saturation. Waterbars that are damaged, under sized, or do not drain properly are defined as problematic. Diffuse drains (outsloped roads) are rarely observed to have drain point problems.

At this site, non-engineered features and ditch relief pipes were observed to have the highest rate of problems (79% and 30%, respectively), while diffusely drained roads were least likely to have problems (Table 13). Treatments did not resolve all problems found in the study area, but treatments did reduce the overall rate of problems from 29% to 6%. There has been little time for problems to develop at new features as a result of significant storms. Therefore, final conclusions regarding the new drainage system cannot be made until the post-storm validation monitoring is completed.

Table 13. Drain point condition problems and fill erosion below drain points, pre- and post-treatment.

All Drains						
Drain Type	**Pre-Treatment**			**Post-Treatment**		
	Count	**Problems**	**Fill Erosion**	**Count**	**Problems**	**Fill Erosion**
Broad-Based Dip	54	8	0	87	2	0
Diffuse Drain	28	0	0	74	0	0
Ditch-Relief Culvert	10	3	0	12	4	0
Lead-off Ditch	8	0	0	5	0	0
Non-engineered Drain	42	33	2	9	6	0
Stream Crossing	5	0	0	6	0	0
Sump	0	0	0	0	0	0
Water Bar	14	2	1	0	0	0
Total	**161**	**46**	**3**	**193**	**12**	**0**

6.0 Summary & Conclusions

Rocky Mountain Research Station began a regional road monitoring program in FY 2008 and included the Intermountain Region in FY 2009. As part of the study, field crews inventoried road segments on the Caribou-Targhee National Forest, before and after road treatments, as well as a set of control roads. These roads received a variety of treatments including SDRR treatments (increased road drainage), and trail-conversion or decommissioning treatments (outsloping, ripping, or tilling).

The GRAIP model was used to predict the change in level of impact/risk between the pre-existing road and the treated road. The road treatments reduced the length of the sampled road that was hydrologically connected to streams by 1,160 m, or 77%, from pretreatment conditions (Table 14). The model predicts that fine sediment delivery was reduced by 59%, from 34.9 tons to 14.1 tons annually. The risks presented by stream crossings becoming plugged by debris and sediment remained the same. The potential for streamflow to be diverted onto roads and unchannelled hillslopes was eliminated (Table 14).

The slope stability risk below drain point locations on the original road was generally reduced as water was redistributed across the hillslope by diffuse drainage; however, some SDRR treatments locally increased the risk of slope failure. Gully initiation risks, already low prior to treatment, were reduced to near negligible values in areas subjected to trail conversion or decommissioning; in areas receiving SDRR treatments, the risk increased slightly. Existing drain point problems, which were present at 28% of inventoried drain points prior to treatment, were present at only 6% of the drain points after treatment (Table 14). The new drainage system, however, has not yet been evaluated after a large storm event.

As a whole, these initial results indicate that the road treatments completed in the Island Park watershed should be effective in greatly reducing many of the hydrogeomorphic impacts and risks that these roads posed to aquatic ecosystems, particularly hydrologic connectivity and fine sediment delivery. The final post storm inventory assessment will enable a closer examination of the hydrologic function of the modified road system and will answer important questions about runoff generation, stream crossing stability, gully initiation thresholds, and landslide risk. This report will be updated when these data become available.

Table 14. Summary of GRAIP model risk predictions for the Island Park road treatment project.

Impact / Risk Type	Effect of Treatment: Initial GRAIP Prediction	Effect of Treatment: Post Storm Validation
Road-Stream Hydrologic Connectivity	-77%, -1,160 m of connected road	To be determined.
Fine Sediment Delivery	-59%, -20.7 tonnes/year	To be determined.
Landslide Risk	Generally reduced, though locally increased at some SDRR drains.	To be determined.
Gully Risk	Generally low with slight decreases post-treatment. SDRR treatments show slight increase; trail conversion treatments show decrease.	To be determined.
Stream Crossing Risks		
- plug potential	Unchanged, low risk.	To be determined.
- fill at risk	Unchanged, 330 m^3 at risk.	To be determined.
- diversion potential	-100% (eliminated at 1 site)	To be determined.
Drain Point Problems	-22% (6% vs. 28% of drain points)	To be determined.

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Appendix A – Glossary

Below is a list of terms, mostly of drainage point types, but also of some other commonly used terms, for the purpose of clarification. Adapted from Black, et al. (2009), Fly, et al (2010), and Moll (1997).

Broad based dip*. Constructed:* Grade reversal designed into the road for the purpose of draining water from the road surface or ditch (also called dip, sag, rolling grade, rolling dip, roll and go, drainage dip, grade dip). ***Natural:*** A broad based dip point is collected at the low point where two hillslopes meet, generally in a natural swale or valley. This is a natural low point in the road that would cause water on the surface of the road to drain out of the road prism.

Cross drain. This is not a feature collected specifically in GRAIP, and it can refer to a number of other drainage features. It is characterized by any structure that is designed to capture and remove water from the road surface or ditch. Ditch relief culverts, waterbars, and broad based dips can all be called cross drains.

Diffuse drain. This is a point that is characterized by a road segment that does not exhibit concentrated flow off the road. Outsloped roads or crowned roads often drain half or all of the surface water diffusely off the fillslope. Although collected as a drain point, this feature is representative of an area or a road segment rather than a concentrated point where water is discharged from the road prism. A drop of water that lands on a diffuse road segment will not flow down the road or into the ditch, but more or less perpendicular to the centerline off the road surface and out of the road prism. Also called sheet drainage or inter-rill flow.

Ditch relief culvert. This drain point is characterized by a conduit under the road surface, generally made of metal, cement, or wood, for the purpose of removing ditch water from the road prism. This feature drains water from the ditch or inboard side of the road, and not from a continuous stream channel.

Flow path. This is the course flowing water takes, or would take if present, within the road prism. It is where water is being concentrated and flowing along the road from the place where it enters the road prism, to where it leaves the road prism. This can be either on the road surface, or in the ditch.

Lead off ditch. This drain point is characterized by a ditch that moves flow from the roadside ditch and leads it onto the hillslope. Occurs most often on sharp curves where the cutslope switches from one side of the road to the other. Also known as a daylight ditch, mitre drain, or a ditch out (though this term can also describe other types of drainage features).

Maintenance Level. Please describe ML 1-5

Non-engineered drainage. This drain point describes any drainage feature where water leaves the road surface in an unplanned manner. This can occur where a ditch is dammed by debris, and the water from the ditch flows across the road, where a gully crosses the road, where a wheel rut flow path is diverted off the road due to a slight change in road grade, or where a berm is broken and water flows through. This is different from a diffuse drain point, which describes a long section of road that sheds water without the water concentrating, whereas this point describes a single point where a concentrated flow path leaves the road.

Orphan drain point. This is any drain point that does not drain any water from the road at the time of data collection. Examples include a buried ditch relief culvert, or a water bar that has been installed on a road that drains diffusely.

Stream crossing. This drain point is characterized by a stream channel that intersects the road. This feature may drain water from the ditch or road surface, but its primary purpose is to route stream water under or over the road via a culvert, bridge, or ford. A stream for the purposes of GRAIP has an armored channel at least one foot wide with defined bed and banks that is continuous above and below the road and shows evidence of flow for at least some part of most years.

Sump. ***Intentional:*** A closed depression where water is intentionally sent to infiltrate. ***Unintentional:*** Any place where road water enters and infiltrates, such as a cattle guard with no outlet, or a low point on a flat road.

Waterbar. This drain point is characterized by any linear feature that is perpendicular to the road that drains water from the road surface and/or ditch out of the road prism or into the ditch. Waterbars may be constructed by dipping the grader blade for a short segment, or adding a partly buried log or rubber belt across the road. Some road closure features may also act as a waterbar, such as a tank trap (also known as a closure berm or Kelly hump). Cattle guards that have an outlet that allows water to flow out are also considered to be water bars. These features may also be known as scratch ditches