# Monitoring Road Decommissioning in the Mann Creek Watershed

# Payette National Forest

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**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., stormproofing). Inventories were also completed on four miles of control sites for each locale. Four post-treatment inventories were also executed. This status report focuses only on decommissioning work implemented by the Payette National Forest in the Mann Creek watershed. At the Mann Creek sites, treatments included removal of culverts and fills at stream crossings and recontouring of the road prism.

Before-after comparisons using GRAIP indicate that decommissioning treatments resulted in a large reduction of most impact-risk metrics. Road-stream connectivity was reduced by 97%, from 3,000 m of connected road to 77 m. Delivery of fine sediment was reduced by 97.6%, from 41.7 tonnes/year to 1.0 tonne/year. Values of a stream blocking index were reduced from an average of 2 before treatment to zero after treatment (n=13), indicating the risk of stream crossings becoming plugged was completely eliminated by excavation and removal of culverts and associated fills. While former crossings sites may contribute fine sediment to streams in the short term, the restoration treatments removed over 807 $m^3$ of earthen material from areas with a high potential for failure and delivery to stream channels. Diversion potential was eliminated at all stream crossing sites.

The slope stability risk below drain point locations on the original road was reduced to nearly natural conditions as water was redistributed across the hillslope by diffuse drainage.

Reductions in gully risk, as determined by a gully initiation index (ESI), were relatively low prior to treatment, and were reduced to negligible values by conversion to diffuse drainage. 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 35% of 102 inventoried drainage points. Post-treatment monitoring indicates that these problems were entirely eliminated by the decommissioning treatments and that most replacement drainage features are less vulnerable to failure.

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

**Summary of GRAIP road risk predictions for the Mann Creek watershed decommissioning project.**

| IMPACT/RISK TYPE | EFFECT OF TREATMENT: INITIAL GRAIP PREDICTION | EFFECT OF TREATMENT: POST-STORM VALIDATION |
|---|---|---|
| Road-Stream Hydrologic Connectivity | -97%, -2,923 m of connected road | To be determined. |
| Fine Sediment Delivery | -98%, -40.7 tonnes/year | To be determined. |
| Landslide Risk | Restored to near natural condition | To be determined. |
| Gully Risk | Reduced from low to negligible | To be determined. |
| Stream Crossing Risk | | |
| - plug potential | -100% (eliminated at 13 sites) | To be determined. |
| - fill at risk | -100% (807 $m^3$ removed) | To be determined. |
| - diversion potential | -100% (eliminated at 8 sites) | To be determined. |
| Drain Point Problems | -100% (0% vs. 35% of drain points) | To be determined. |

**Acknowledgements**

We would like to thank the field crews (Laura Hutchinson, Jim Peterson, Matt Steiger, and Jim Bitzenberg) for collecting the data. We would also like to thank Dave Kennell and Tom Crawford of the Payette National Forest for help in selecting these sites and logistical support during a very busy field season. Thanks also to Rick Hopson and the Region 4 staff for supporting this monitoring effort.

## 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. 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 the 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 only on road decommissioning work completed by the Payette National Forest (PNF) in the Mann Creek 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. 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 coming years. In addition, evaluations will be initiated at five new sites, the locations of which have not yet been determined.

[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.

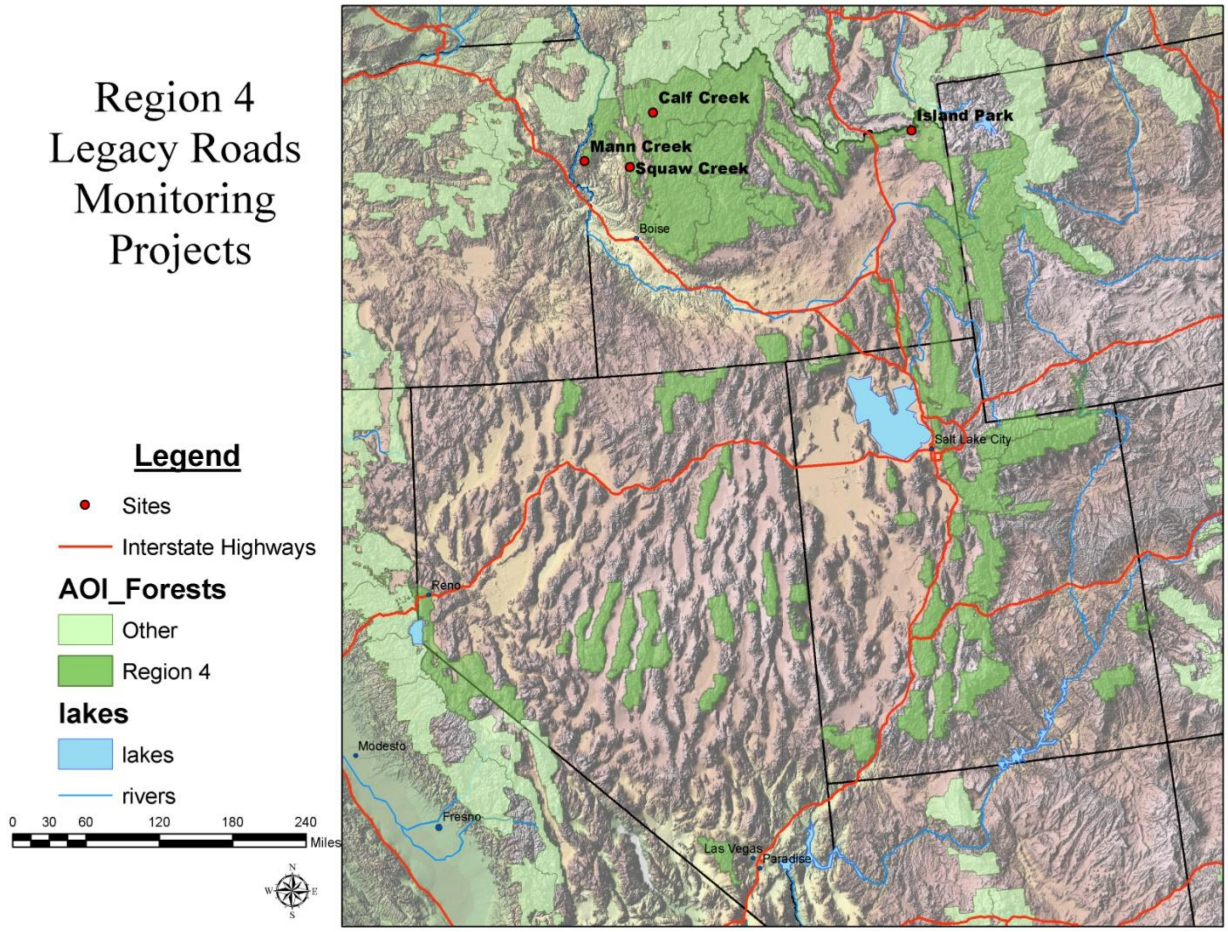



**Figure 1.** Locations of monitored sites in Region 4.

**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-Targee | Other Treatments | Island Park |
| | Storm Damage Risk Reduction | Island Park |

**Mann Creek Sites**

During the summer and fall of 2009, field crews inventoried decommissioning sites in the Intermountain Region, including the Mann Creek watershed (Table 1, Figure 1). This watershed is principally underlain by basalts, with Columbia River Group basalts dominating the mid-elevation band. The higher elevations are underlain by sedimentary rocks of the Olds Ferry and Izee terranes as well as mafic plutons of the Blue Mountains island arc terrane. The average annual precipitation for the basin ranges from 10 - 30 inches per year. The watershed is managed for multiple uses including timber harvest, grazing, and recreation. The inventoried sites are located between 4,800 and 6,000 feet above sea level just east of the Snake River.

The Mann Creek watershed is located in Washington county between U.S. Highway 95 and the Snake River. Mann Creek Reservoir, located near the mouth of the watershed, is about halfway between Weiser and Cambridge.

Data were collected on roads in the spring of 2009 before the decommissioning treatments began, and once again in summer of 2009 once the treatments were completed (Figure 2). Pre-treatment roads were native or gravel surface roads that were generally in good shape. With the exception of road 501641000, the roads were classed as maintenance level 2 or 3. The maintenance class of road 501641000 is unknown, as the forest did not classify it, though it appears to be similar to maintenance level 2 based on photographs and comparisons to descriptions of road maintenance classes. Flow on the roads was generally contained in wheel tracks or a ditch. Both treatment and control sites included roads on a range of hillslope positions, though dominantly valley-bottom, and included frequent live stream crossings. The watershed has moderately steep topography, so stream crossing fills are not typically large.

Decommissioning treatments were performed by USFS equipment and staff, and involved removing stream crossing culverts and fills and partially to fully recontouring the road prism.

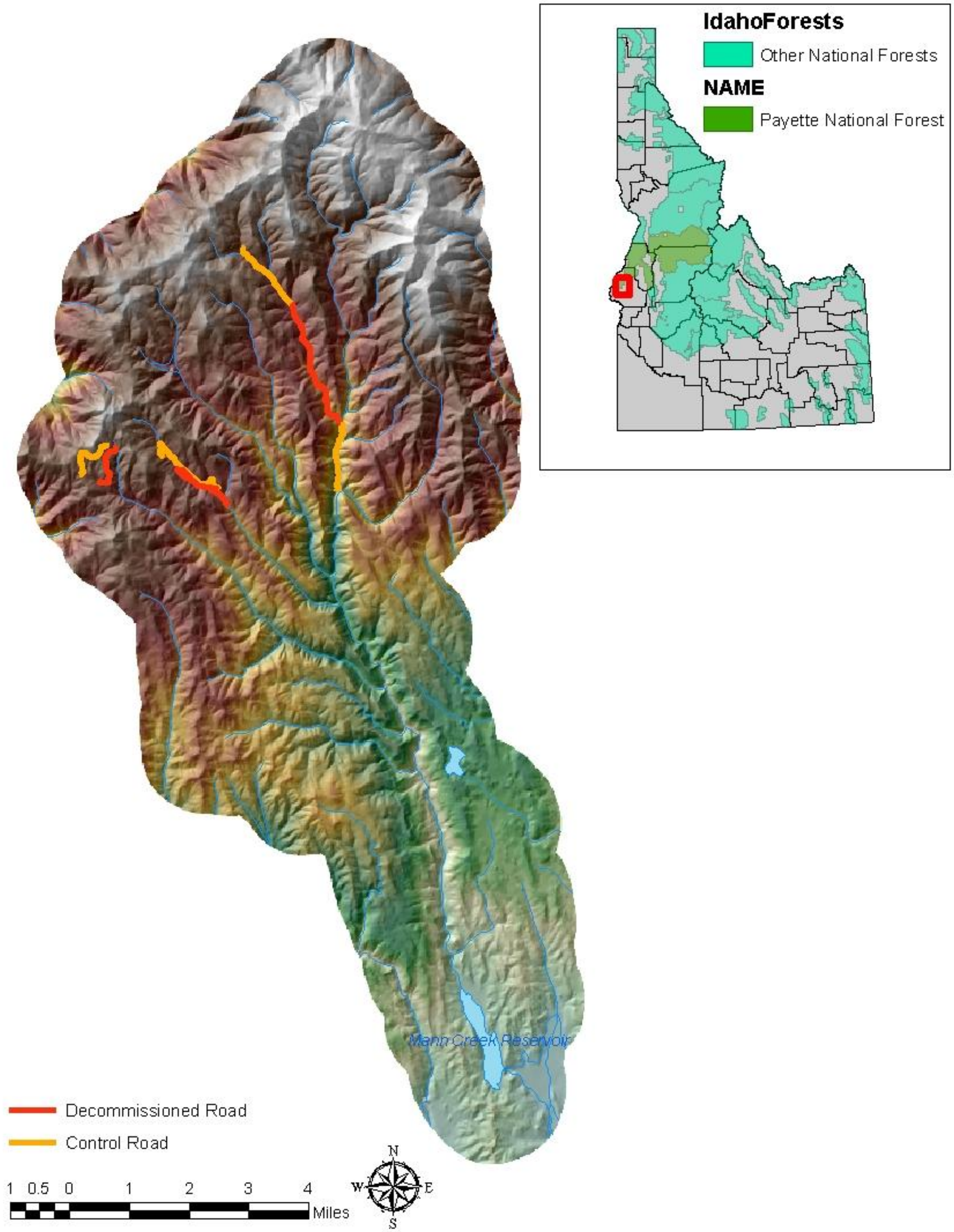



**Figure 2.** Map of road locations within the Mann Creek watershed.

**Table 2.** Decommissioning treatments applied by road number.

| Decommissioned Road | | | Control Road | | |
|---|---|---|---|---|---|
| Road # | Maintenance Level | Treatment | Road # | Maintenance Level | Treatment |
| 50007 | 2 | Stream crossing extraction, recontouring, and culvert removal | 50029<br>50473? | 2 | None |
| 50029 | 2 | Stream crossing extraction, recontouring, and culvert removal | 50029<br>50473? | 2 | None |
| 50470 | 1 | Stream crossing extraction, recontouring, and culvert removal | 50029<br>50473? | 2 | None |
| 50019<br>Old 51189 | 3 | Stream crossing extraction, recontouring, and culvert removal | 50019<br>Old 51189 | 3 | None |
| 50164100<br>0 | Unclassified | Stream crossing extraction, recontouring, and culvert removal | 500100500 | Unclassified | None |

## 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 decommissioning 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 Mann Creek, the decommissioning treatments decreased the total number of drain points and redistributed water back onto the hillslope through diffuse drainage. This substantially reduced the length of road surface connected to the channel. Prior to the treatments, 3,000 m out of the 8,100 m of inventoried road (37%) were hydrologically connected to stream. After the treatments, 77 m of the 8,100 m of monitored road (1%) were connected. Thus, the treatments resulted in a net reduction of 2,923 m of hydrologically-connected road, which is 97% less than 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 fine sediment occurs through a mix of road drainage features including ditch relief culverts, non-engineered drain points, stream crossings and others. Delivery of eroded sediment to the channel network is determined by observations of 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, under most circumstances, there is insignificant hillslope sediment storage in locations where there is a clear connection to the channel; all sediment is assumed to be delivered to the stream if a connection is present. For this analysis, uncertain observations were treated as delivering. A map of the road surface sediment

[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.

production and the accumulated sediment delivered through drain points is shown for the 50007, 50029, and 50470 roads (Figure 3).

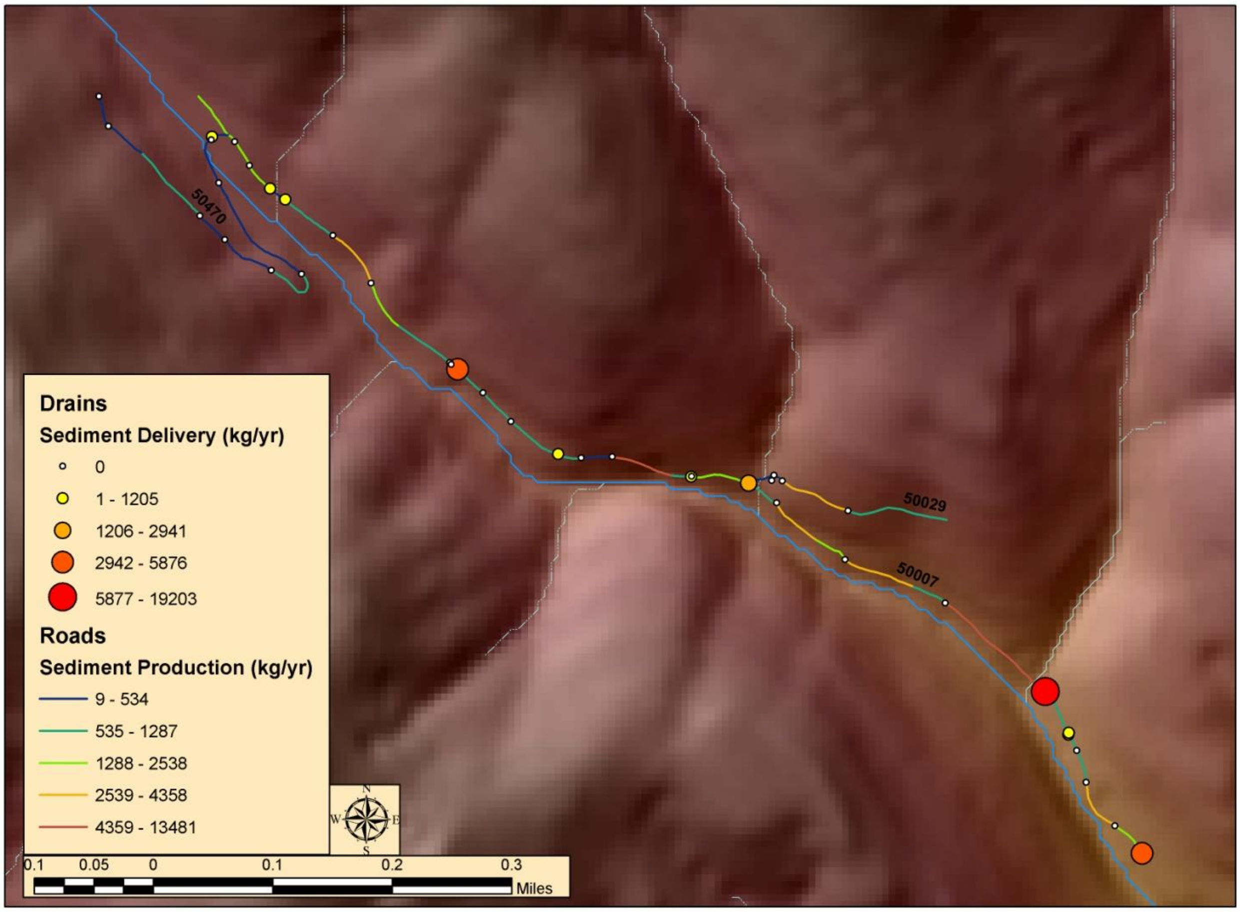



**Figure 3.** Fine sediment production and delivery to channels by road segment and drain point, pre-treatment road. The road line is colored to indicate the mass of fine sediment that is generated on the road. The size of the circle indicates the accumulated mass of sediment delivered to the stream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

### Pre-treatment

Sediment delivery is broken out by drain type to assess their effectiveness in preventing sediment from entering the channel (Table 3). However, the sample size, a total of 102 drain points, collected for the Mann Creek study is too small for extensive statistical analysis to determine trends by drain point type. One-hundred and two drain points were documented, 37% of which were hydrologically connected to stream channels. These points delivered 41.7 tonnes/year of sediment, or 31% of the sediment generated by the road surfaces and ditches.

**Table 3.** Summary of sediment production and delivery at drain points, pre-treatment road.

| Drain Type | Count | Sediment Received at Drain Point (kg) | Sediment Delivered by Drain Point (kg) | % Sediment Delivery | % Effective Length Connected |
|---|---|---|---|---|---|
| Broad Based Dip | 3 | 15,230 | 0 | 0% | 0% |
| Diffuse Drain | 32 | 27,601 | 1,619 | 6% | 7% |
| Ditch Relief Culvert | 20 | 8,272 | 2,201 | 27% | 32% |
| Lead Off Ditch | 3 | 823 | 251 | 30% | 33% |
| Non-Engineered | 29 | 55,977 | 16,847 | 30% | 46% |
| Stream Crossing | 14 | 20,764 | 20,764 | 100% | 100% |
| Sump | 0 | 0 | 0 | 0% | 0% |
| Waterbar | 1 | 7,919 | 0 | 0% | 0% |
| **All Drains** | **102** | **136,586** | **41,682** | **31%** | **37%** |

**Post-treatment**

Decommissioned roads in the Mann Creek watershed were, for the most part, recontoured (Figure 4), though some short sections were tilled. The recontoured surface is intended to mimic the natural hillslope hydrology and result in increased infiltration and diffuse flow and minimized surface drainage from the road. A heavy application of straw was applied in addition to the use of locally available organic matter and transplant material. The disturbed, recontoured surface is likely to generate higher sediment production prior to revegetation; however, the disturbed surface is substantially disconnected from the stream network. Without the previous stream connections, the decommissioned roads do not deliver nearly as much sediment (Table 4). Nineteen (29%) of the drain points were found to be connected to the stream network. However only five of these nineteen drain points are likely to actively deliver sediment due to the redesign and treatment; the other fourteen are orphans. The total sediment delivered is reduced to 1 tonne/year (2% of the sediment delivered before treatment).

**Figure 4.** Photo of a typical rocky, fully recontoured road with straw mulch.

**Table 4.** Summary of sediment production and delivery at drain points, post-treatment road.

| Drain Type | Count | Sediment Received at Drain Point (kg) | Σ Sediment Delivered by Drain Point (kg) | % Sediment Delivery | % Effective Length Connected |
|---|---|---|---|---|---|
| Broad Based Dip | 1 | 0 | 0 | 0% | 0% |
| Diffuse Drain | 47 | 59,999 | 528 | 0.9% | 0.6% |
| Ditch Relief Culvert | 0 | 0 | 0 | 0% | 0% |
| Lead Off Ditch | 0 | 0 | 0 | 0% | 0% |
| Non-Engineered | 0 | 0 | 0 | 0% | 0% |
| Stream Crossing | 14 | 486 | 486 | 100% | 100% |
| Sump | 0 | 0 | 0 | 0% | 0% |
| Waterbar | 4 | 0 | 0 | 0% | 0% |
| **All Drains** | **66** | **60,485** | **1014** | **1.7%** | **0.9%** |

The modeled change in sediment delivery following the treatments indicates a decline from 41.7 tonnes/year to 1.0 tonne/year, a decrease of over 40 tonnes (Table 5). The largest reductions occurred at stream crossings (through shortening of contributing segments) and non-engineered features (through removal of the features), with smaller reductions from the removal of ditch relief culverts. There was an increase in the number of diffuse drains (15); diffuse drains and water bars were the only drain types to mark an increase in total number. Even with the increased number, and increase in sediment received by diffuse drains (117%), sediment delivery decreased by 67% because diffuse drains rarely connect (Table 5). Rapid revegetation of recontoured sites is expected to reduce the production estimates substantially in the future.

**Table 5.** Changes in sediment production and delivery, pre-treatment vs. post-treatment.

| Drain Type | Count | Δ Sediment Production (kg) | Δ Sediment Delivery (kg) | Δ Sediment Production (%) | Δ Sediment Delivery (%) |
|---|---|---|---|---|---|
| Broad Based Dip | -2 | -15,230 | 0 | -100% | 0% |
| Diffuse Drain | 15 | 32,398 | -1090 | 117% | -67% |
| Ditch Relief Culvert | -20 | -8,272 | -2,201 | -100% | -100% |
| Lead Off Ditch | -3 | -823 | -251 | -100% | -100% |
| Non-Engineered | -29 | -55,977 | -16,847 | -100% | -100% |
| Stream Crossing | 0 | -20,278 | -20,278 | -97.7% | -97.7% |
| Sump | 0 | 0 | 0 | 0% | 0% |
| Waterbar | 3 | -7,919 | 0 | -100% | 0% |
| **All Drains** | **-36** | **-76,101** | **-40,668** | **-55.7%** | **-97.6%** |

## 5.3 Landslide Risk

### Existing Landslides

No road related landslides were reported by field crews working in the Mann Creek watershed. 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 5).

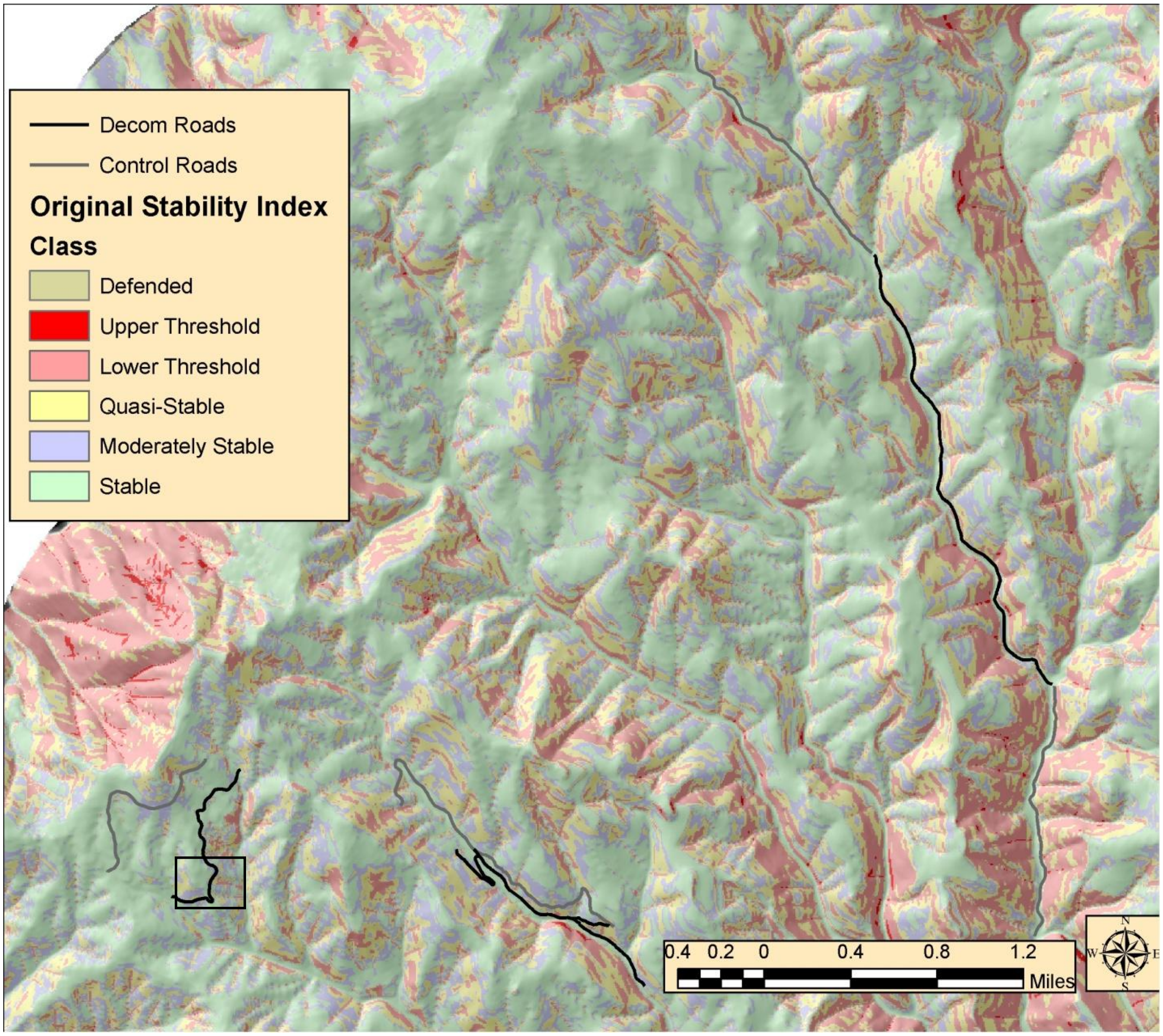



**Figure 5.** Estimated natural slope stability index classes. Slope stability was modeled using default values in SINMAP 2.0. Rectangle indicates area shown in Figure 6.

**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 6, left). This example illustrates the effect of water being concentrated and discharged at a swale. The swale locations (indicated by arrows) were previously mapped as being moderately stable to quasi-stable; the increased water discharged from the road decreased stability into the lower threshold category.

A third model run was performed to illustrate the change in risk of shallow landsliding with the modified road drainage system resulting from the restoration treatments (Figure 6, center). Recontouring treatments replaced a concentrated surface flow path with a diffuse flowpath. The design is intended to reduce the concentration of surface and groundwater and to mimic as much as possible the natural hillslope hydrology. If this treatment is successful it may return the slope stability to near the un-roaded, natural condition.

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 treated surfaces.

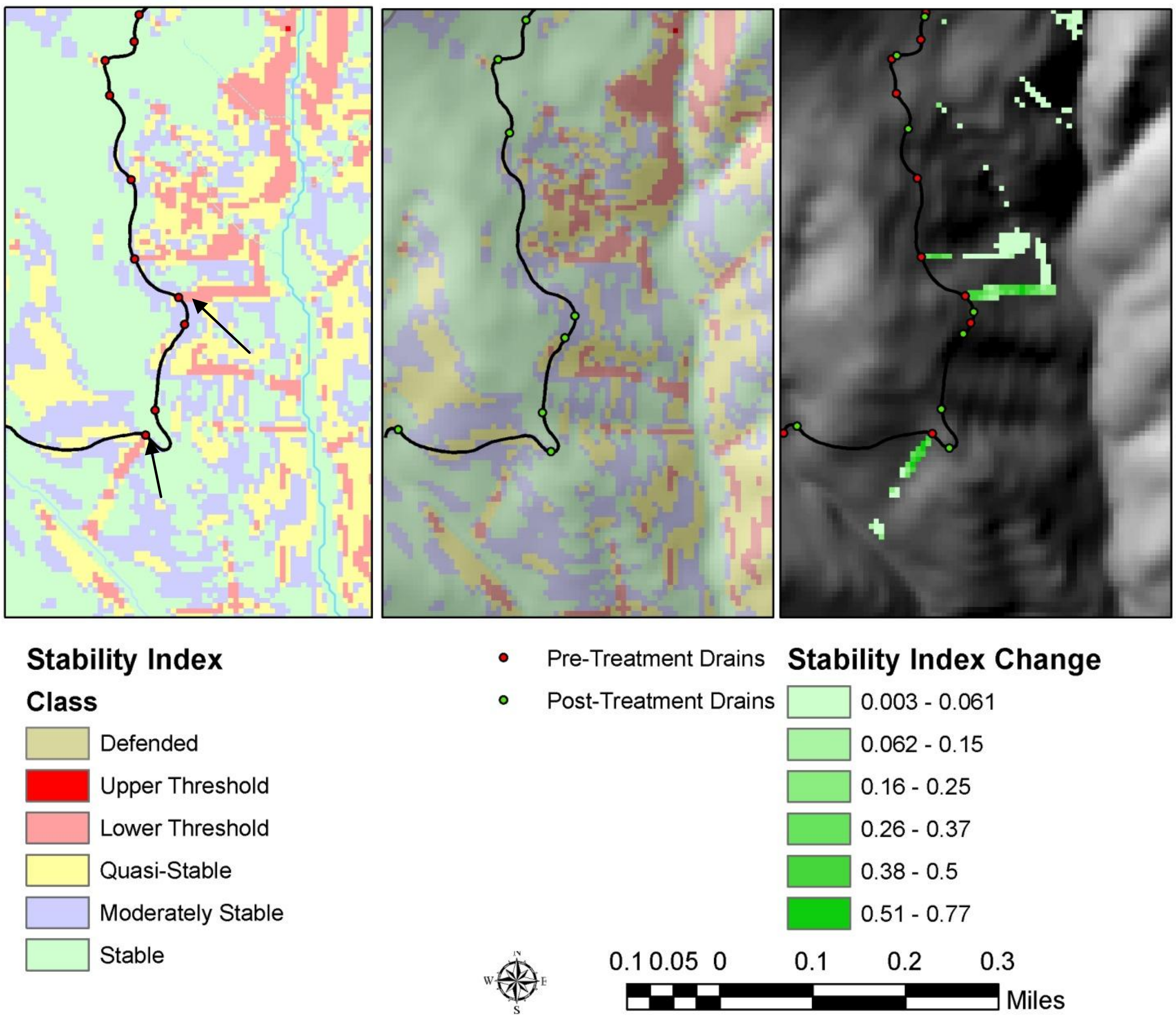



**Figure 6.** Stability index for hillslopes in the vicinity of road 501641000. Left: Stability Index classes prior to road decommissioning. Arrows point to swales affected by road drainage. Center: Stability Index classes after road decommissioning. Right: Amount of change in stability index values between pre- and post- decommissioning. Positive values indicate a predicted increase in slope stability following road decommissioning.

## 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. In this study, only one gully was located by the field crews, and that gully is located along one of the control roads rather than along a road to be decommissioned. Hence, it is not possible to, nor is it relevant to, calculate a value for $ESI_{crit}$. While gully formation appeared to be uncommon prior to decommissioning the roads, it has become far less likely following road decommissioning (Table 6).

**Table 6.** ESI population statistics for pre-decommissioning and post-decommissioning road networks.

| ESI Value | Minimum | Maximum | Average | Standard Deviation |
|---|---|---|---|---|
| **Pre-Decom** | 0 | 47.6 | 2.87 | 7.18 |
| **Post-Decom** | 0 | 0.569 | 0.047 | .143 |
| **Change** | 0 | -47.0 | -2.82 | -7.04 |

## 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.

The SBI values for the pre-treatment stream crossings were relatively high with an average value of 2 for the 13 stream crossings (Figure 7), not counting one excavated crossing. This is out of a range of 0 to 4, where 0 suggests no risk of blockage and values of 3 or 4 indicate a high risk of blockage. The stream crossings with value of 3 all had culvert to channel width ratios of <1. All 13 stream crossing pipes were removed during decommissioning, which completely eliminated the risk of pipe plugging (Figure 8). GRAIP calculates an SBI of 0 for crossings without a pipe.

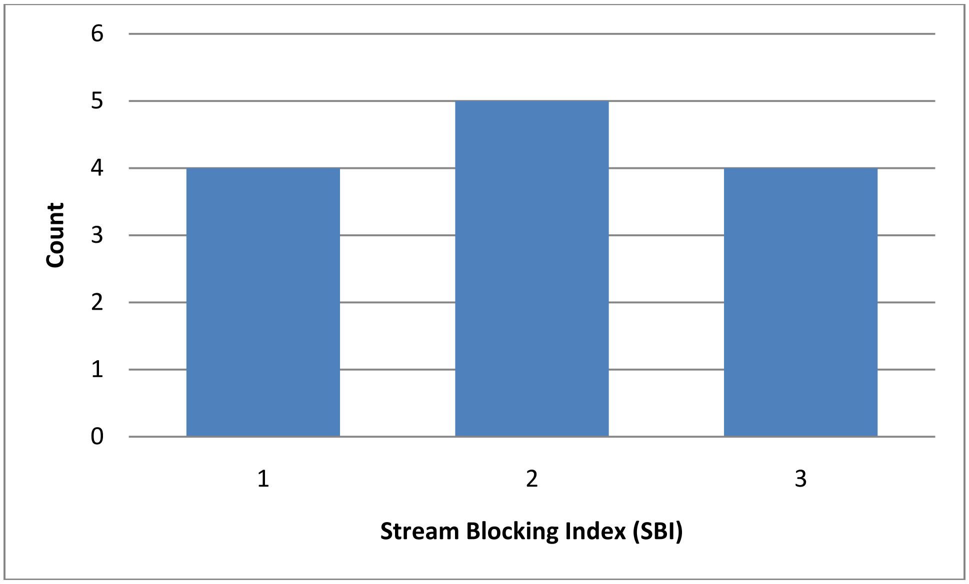



**Figure 7.** Distribution of Stream Blocking Index values for pre-treatment group. Post-treatment values were zero for all sites.

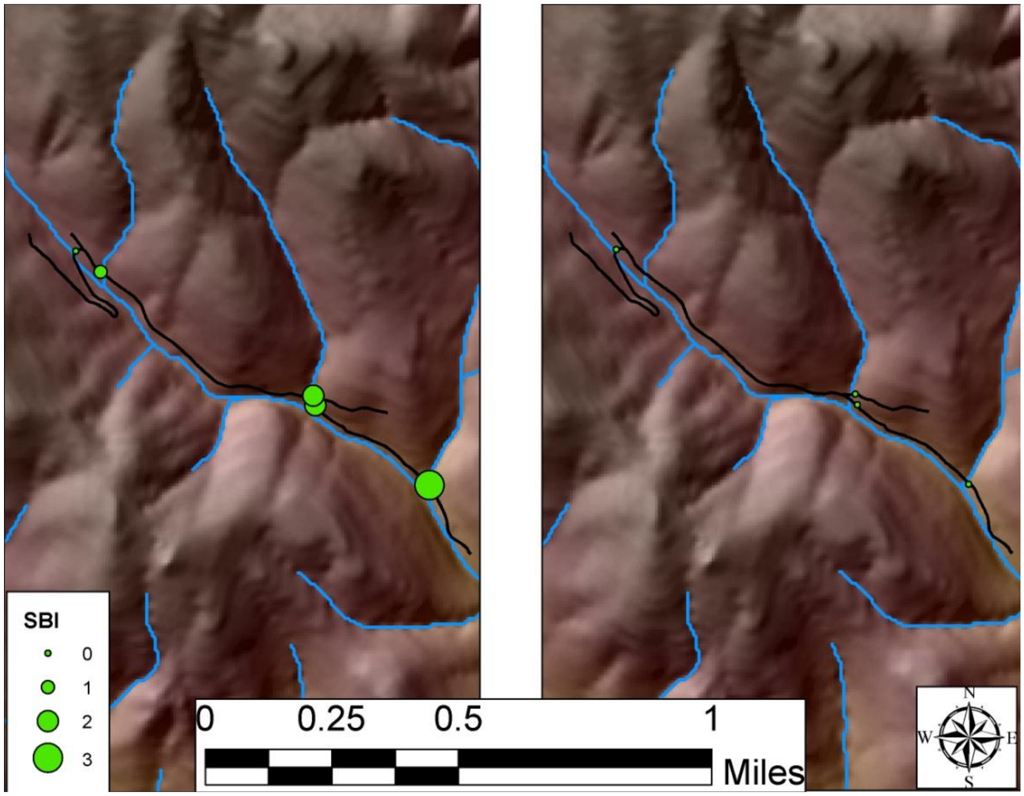



**Figure 8.** SBI values on the 2300-100 and 2300-130 road stream crossings. Left: pre-treatment. Right: post-treatment. All post treatment values are shown as 0.

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 total of 807.2 $m^3$, into the stream channel. This material was excavated during the restoration work.

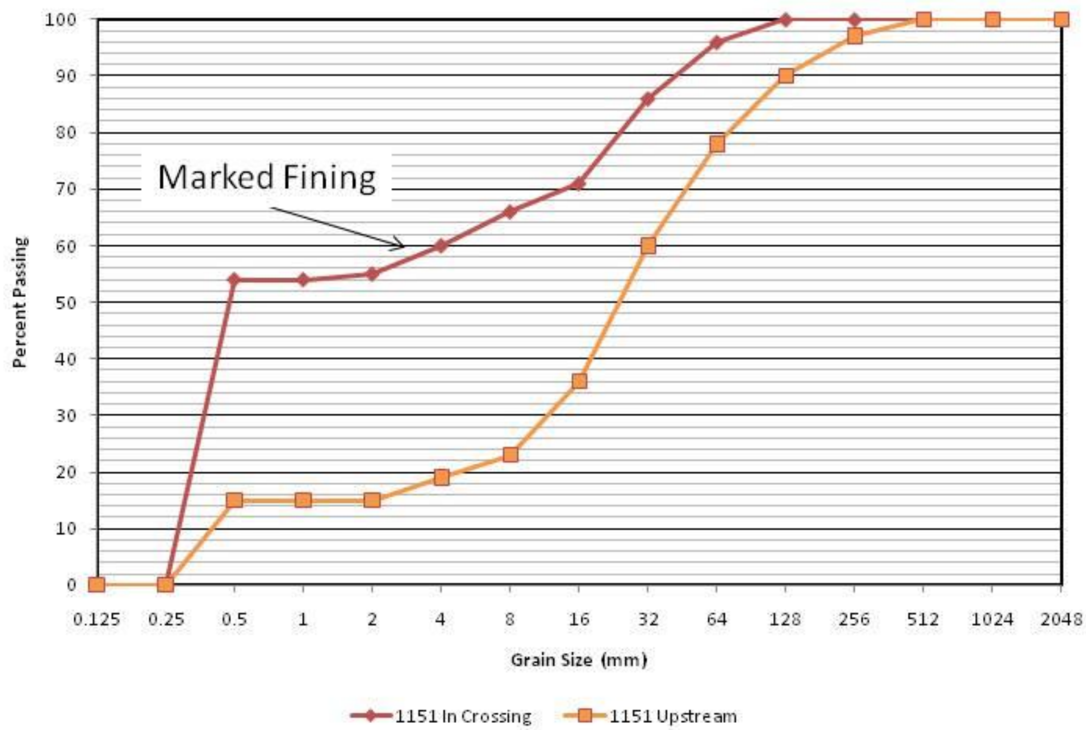
A second, and perhaps greater, consequence of concern at failed stream crossings is the diversion of stream flow onto road surfaces and unchannelled hillslopes. Once a crossing becomes occluded and begins to act as a dam, failure can occur in several ways. If the road grade dips into and rises out of 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, 57% (8 of 14) of the stream crossings on the original roads had the potential to divert streamflow down the road in one direction. The restoration treatments eliminated these risks at all sites.

GRAIP field crews also took more detailed measurements at excavated stream crossings during the post-treatment assessment. These metrics include the length and grade of side slopes, Wolman pebble counts both in the crossing and in an upstream reach, and measurements of mass-wasting volumes, if any. These measurements are intended to provide baseline metrics against which the amount and type of future stream crossing adjustment can be gauged.

Measurements of channel slope and sediment characteristics can be used to evaluate how well the excavated crossing mimics the natural channel characteristics. Most of the excavated crossings show some fining of bed materials compared to the upstream reach (Table 7; Figure 9), though the D84 increased at four of the stream crossings. Since the material at these excavated crossings appears the same as on adjacent recontoured road segments, it is likely that the armoring effect is not intentional; armoring may prevent excessive incision or lateral erosion at the crossing. We would expect that over time, grain size distributions will shift toward those recorded in upstream reaches as fine sediment is removed.

Three of the crossings were found to have channel slopes that differed from upstream channel slopes by 5% or more. In all three cases, measured slopes in the crossing are less than those observed upstream. Such crossings may be prone to greater amounts of incision as the stream adjusts its bed.



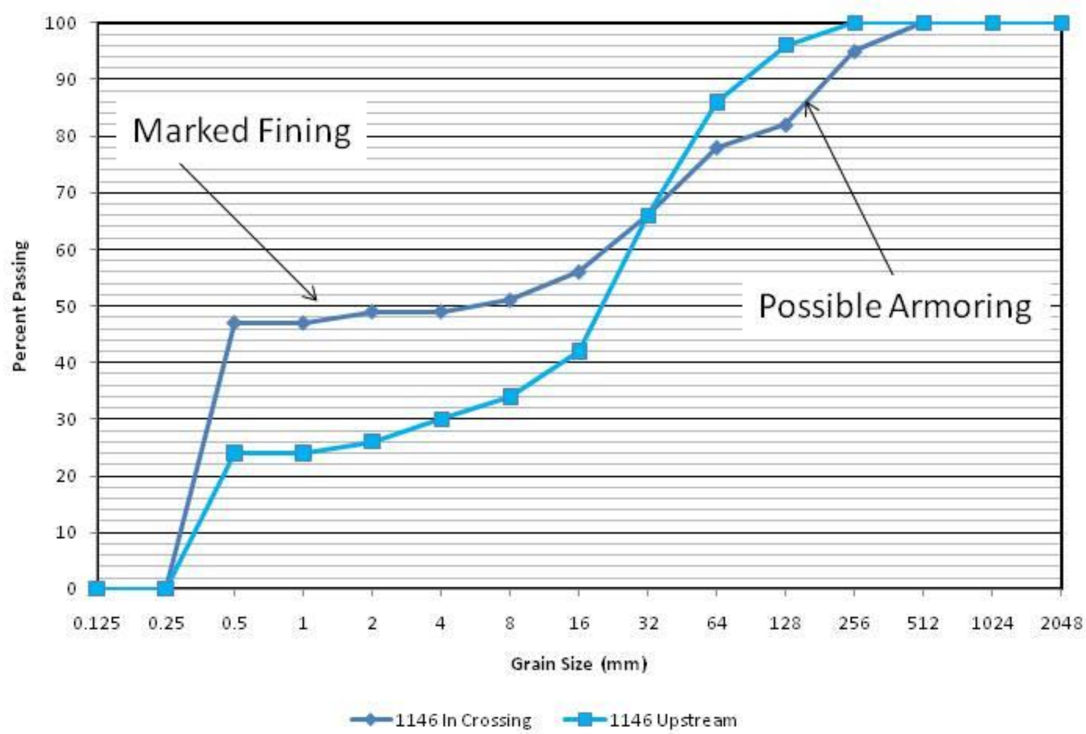




**Figure 9.** Examples of stream bed grain-size distributions. Top: The crossing shows marked fining of sediments compared to the upstream reach. Bottom: Possible armoring occurring with marked fining.

**Table 7.** Channel slope and sediment size characteristics at excavated stream crossings in Mann Creek.

| Crossing # | Slope % In Crossing | Slope % Upstream | Grain Size (mm) Crossing D16 | Crossing D50 | Crossing D84 | Upstream D16 | Upstream D50 | Upstream D84 |
|---|---|---|---|---|---|---|---|---|
| 1541 | 5 | - | 1 | 35 | 172 | 32 | 70 | 217 |
| 1706 | 10 | - | 0.5 | 27 | 167 | 20 | 52 | 118 |
| 1141 | 8 | 32 | 0.5 | 6 | 71 | 5 | 25 | 130 |
| 942 | 8 | 13 | 14 | 32 | 109 | 15 | 38 | 74 |
| 1012 | 23 | 38 | 0.5 | 14 | 90 | 0.5 | 25 | 140 |
| 1151 | 11 | 10 | 0.5 | 0.5 | 30 | 3 | 24 | 91 |
| 1345 | 14 | 18 | 0.5 | 7 | 40 | 2 | 18 | 69 |
| 1539 | 11 | 10 | 0.5 | 18 | 73 | 5 | 16 | 54 |
| 1146 | 9 | 8 | 0.5 | 6.5 | 139 | 0.5 | 23 | 59 |

**Figure 10.** Example of an excavated stream crossing.

### 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 broad-based dips were observed to have the highest rate of problems (93% and 67%, respectively), while diffusely drained roads were least likely to have problems (Table 8). So far, no problems have been observed after the decommissioning treatments. However, there has been little time for such problems to develop 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 8.** Drain point condition problems and fill erosion below drain points, pre- and post-treatment.

| | PRE-TREATMENT | | | POST- TREATMENT | | |
|---|---|---|---|---|---|---|
| Drain Type | Count | Problems | Fill Erosion | Count | Problems | Fill Erosion |
| Broad Based Dip | 3 | 67% | 0% | 1 | 0% | 0% |
| Diffuse Drain | 32 | 0% | 3% | 47 | 0% | 0% |
| Ditch Relief | 20 | 10% | 15% | 0 | 0% | 0% |
| Lead Off | 3 | 33% | 0% | 0 | 0% | 0% |
| Non-Engineered | 29 | 93% | 17% | 0 | 0% | 0% |
| Stream Crossing | 14 | 29% | 0% | 14 | 0% | 0% |
| Sump | 0 | 0% | 0% | 0 | 0% | 0% |
| Waterbar | 1 | 0% | 100% | 4 | 0% | 0% |
| **Total** | **102** | **35%** | **10%** | **66** | **0%** | **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 Payette National Forest, before and after decommissioning treatments, as well as a set of control roads. These roads received high-intensity treatments that included removal of culverts and fills at stream crossings and recontouring of the road itself.

The GRAIP model was used to predict the change in level of impact/risk between the pre-existing road and the decommissioned road. The restoration treatments reduced the length of the sampled road that was hydrologically connected to streams by 2,923 m, or 97%, from pretreatment conditions. The model predicts that fine sediment delivery was reduced by 98%, from 41.7 tonnes to 1.0 tonne annually. The risks presented by stream crossings becoming plugged by debris and sediment were completely eliminated by the excavation and removal of the culverts and fills. These locations will contribute fine sediment to the channel in the short-term until they become vegetated. The potential for streamflow to be diverted onto roads and unchannelled hillslopes was also eliminated.

The slope stability risk below drain point locations on the original road was reduced as water was redistributed across the hillslope by diffuse drainage. Treatments are predicted to return slope stability to near natural levels. Gully initiation risks, already low prior to treatment, were reduced to near negligible values. Existing drain point problems, which were present at 35% of inventoried sites, appear to have been entirely eliminated by the restoration efforts. These new drainage features, however, have not yet been evaluated after a large storm event.

As a whole, these initial results indicate that the decommissioning work in the Mann Creek watershed should be effective in greatly reducing many of the hydrogeomorphic impacts and risks that these roads posed to aquatic ecosystems. The final post storm inventory assessment will enable a closer examination of the hydrologic function of the newly decommissioned 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 9.** Summary of GRAIP model risk predictions for the Mann Creek road decommissioning project.

| IMPACT/RISK TYPE | EFFECT OF TREATMENT: INITIAL GRAIP PREDICTION | EFFECT OF TREATMENT: POST-STORM VALIDATION |
|---|---|---|
| Road-Stream Hydrologic Connectivity | -97%, -2,923 m of connected road | To be determined. |
| Fine Sediment Delivery | -98%, -40.7 tonnes/year | To be determined. |
| Landslide Risk | Restored to near natural condition | To be determined. |
| Gully Risk | Reduced from low to negligible | To be determined. |
| Stream Crossing Risk | | |
| - plug potential | -100% (eliminated at 13 sites) | To be determined. |
| - fill at risk | -100% (807 $m^3$ removed) | To be determined. |
| - diversion potential | -100% (eliminated at 8 sites) | To be determined. |
| Drain Point Problems | -100% (0% vs. 35% 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 dips). ***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 that 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).

**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 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