Date: October 17, 2018

To: Claudia Luke, PhD
Director, SSU Preserves
1801 East Cotati Avenue
Rohnert Park, CA 94928

From: Colin Hughes, PG # 8549
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Subject: 2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve

This *Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve* (Plan) has been developed by PWA to aid in storm-proofing the roads and improving road drivability for the 2019 water year and beyond. Specifically, implementation of this Plan pertaining to the portion of the Main Road located within the Galbreath Wildlands Preserve (GWP), will result in road shaping and installation of road drainage structures sufficient to effectively hydrologically disconnect road, cutbank, ditch, and travel way surfaces from watercourses, reduce the potential for surface erosion, and facilitate drivability of the roadway by 4-wheel drive and 2-wheel drive vehicles.

Plan Components

The Plan is comprised of four components: 1) this plan memorandum; 2) Attachment A, a linearly stationed treatment road log for the Plan Area; 3) Attachment B, a map set displaying the location of road features and treatments; 4) Attachment C, a photo log pertaining to treatment sites and 5) Attachment D, typical design drawings of recommended treatments. All treatment locations were flagged or staked in the field along the Main Road and Barn Spur Trail alignments by PWA on August 30, 2018. The segment of Main Road to be treated by the Plan is approximately 6.2 mi in length (Attachments A and B). One treatment site (site 30.9) is not located on the Main Road, but is located along the Barn Spur Trail segment of abandoned road to the east of the barn (Maps 1 and 2).

The treatment road log, Attachment A, is to be referred to by the heavy equipment contractor to identify the location of each treatment (by road station in feet), specific treatment measures at each location, and quantities of needed materials. To best implement the Plan, the contractor must refer to the treatment log in conjunction with the maps and photos at each treatment location.

The plan map set, Attachment B, shows the location of all recommended treatments in the Plan and correlates with the treatment road log. The contractor should use the maps in combination with the treatment log and field staking/flagging to aid in the identification of specific treatment locations. Background aerial imagery on Plan maps was taken in 2016.

Typical design drawings, Attachment D, provide details regarding the construction and installation of the recommended road drainage treatments and road shaping. The design drawings should be referred to by the contractor throughout implementation of the Plan.

The treatment recommendations provided in this plan are based on the techniques presented in the *Handbook for Forest, Ranch, and Rural Roads* (Weaver, Weppner, and Hagans, 2015) and the California Salmonid Stream Habitat Restoration Manual, Chapter X (Weaver et al., 2006). Construction of all treatments within the Plan should principally conform to the specifications of the detailed treatment road log (Attachment A), and secondarily to design specifications within the typical design drawings (Attachment D) and the *Handbook for Forest, Ranch, and Rural Roads.*

Contractor and Equipment Needs

PWA recommends that this plan be implemented by a licensed heavy equipment operator (general contractor, appropriate specialty contractor, or licensed timber operator) with experience in the successful implementation of similar road drainage treatment plans, including construction of rolling dips and road shaping treatments. Use of an experienced heavy equipment contractor will increase efficiency and minimize technical oversight requirements and increase cost-effectiveness.

To efficiently implement the Plan, we suggest the use of the following heavy equipment and labor: 1) small hydraulic excavator with thumb or backhoe to clean culvert inlets and remove or replace culverts; 2) a bulldozer with 6 way blade and rippers (D4 or D5 equivalent) to outslope road surfaces, construct rolling dips, spread road rock; 3) a water truck to "moisture condition" graded fill materials; and 4) a laborer to limb trees, remove organic debris from fills, couple culvert segments, install geotextile fabrics, and apply secondary erosion control weed-free straw mulch. If heavy vehicular use during the first winter after construction is expected, a vibratory roller should also be used during road shaping and resurfacing to increase compaction of fills and surface aggregate.

Permit Requirements

It is PWA's opinion that armored fill installations at Site #s 19 and 36, rock armor installation at Site #3, culvert removal at Site #30.9, and culvert installation at Site #40 are required to be performed under an executed Lake and Streambed Alteration Agreement (LSAA) with the California Department of Fish and Wildlife. The base fee for the LSAA Notification is expected to be $2,886.25 (5 projects at $577.25 per project). The term of a "standard agreement" with CDFW is 5 years and would allow for implementation of plan treatments as prioritized by GWP administration staff.

Technical Oversight

We recommend that construction oversight be provided by PWA staff during implementation of the Plan. At a minimum, we recommend that PWA review the Plan with the heavy equipment contractor prior to construction and perform inspection of the work prior to final road surfacing. Technical oversight by PWA will provide for correct interpretation of the plans and ensure the effectiveness of road shaping and road drainage treatments.

Cost Estimate

Cost estimates for implementation of the Plan treatments for Galbreath Wildlands Preserve are shown in Table 1. PWA recommends implementing Plan treatments at all identified locations in a single season or at a selection of sites which would minimize costs for heavy equipment to travel between work sites. If Plan treatments are to be implemented across multiple work seasons, mobilization and demobilization costs would apply to each season of work.

Table 1. Estimated heavy equipment costs and materials costs per treatment site to implement the 2018 Storm-Proofing Road Drainage Treatment Plan for Galbreath Wildlands Preserve.

Site #	Treatment Immediacy[a]		Heavy Equipment and Labor Cost[b, c] ($)	Material Costs[d] ($)	Total Estimated Cost ($)
	Sediment delivery	Drivability			
3	H	L	$1,525	$900	$2,425
RD 16 and RD 17	L	M	$2,600	$1,870	$4,470
RD 31	L	L	$450	-	$450
19	M	M	$750	$270	$1,025
RD 41 and RD 42	L	M	$2,850	$2,095	$4,945
RD 51.1	L	M	$950	$450	$1,400
Windy Pass	L	M	$2,100	$2,940	$5,040
90	L	M	$450	-	$450
RD 62	M	M	$950	$450	$1,400
36	H	H	$2,200	$1,350	$3,550
36.1	M	M	$2,150	$1,575	$3,725
40	H	H	$4,025	$1,950	$5,975
42	M	M	$700	-	$700
48.1	M	H	$500	-	$500
30.9	L	L	$1,025	-	$1,025
Mobilization/ Demobilization Per Season	-	-	$5,050	-	$5,050
TOTALS	-		*$28,275*	*$13,850*	**$42,130**

[a]Treatment immediacy for each location is ranked as either high (H), moderate (M), or low (L) based on PWA's evaluation of the priority to either prevent sediment delivery or improve road drivability.

[b]Heavy equipment costs include operator, fuel, and mobilization between treatment sites. Costs listed are estimates for favorable local private sector equipment rental and labor rates at prevailing wage.

[c]Minimized costs for vibratory roller compactor have been included at select site and mobilization/demobilization line item costs.

[d]Material Costs include culvert costs, geotextile costs, and local sourcing of rock. Material costs are subject to change. It is assumed that water would be obtained from onsite GWP facilities without material costs.

At your request, PWA can provide references for local heavy equipment operators experienced in the implementation of the road drainage treatments detailed in the Plan. Thank you for giving us the opportunity to provide our services to you. If you have any questions about this Plan or Cost Estimate, please contact either myself or Danny Hagans (PWA Principal) at 839-5130.

Sincerely,

Colin Hughes, PG # 8549
colinh@pacificwatershed.com

Personnel: **CRH** Date: **09/24/2018**

Attachment A: Treatment Log for the *2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve*

Treatment Log for Main Road

Station (ft)	Site #	Site Type	Comments/Treatment[1]	Rock Needs	CMP and Other Needs
[1]SOS = Start of Survey; DRC = Install ditch relief culvert; OSR-FD# = Outslope road by pulling berm and filling ditch; RR = pit run from local quarry or 1½ inch maximum Class 2 Aggregate Base; AR = Rock armor from local quarry or as specified; EOS = End of Survey; GCS = Grade control structure; IBD = Inboard ditch; BOF = Base of fill; IBR = Inboard edge of road; OBR = Outboard edge of road; IBF = Inboard edge of fill; OBF = Outboard edge of fill; CMP = Culvert; SB = Sediment Basin; RD = Rolling dip.					
Note: Final erosion control materials (straw mulch and erosion control seed) shall be applied to all disturbed soil areas with the potential to erode and deliver sediment to a watercourse and where designated in the road log or by landowner.					
0	-	-	**Begin road log at intersection with Main Road and Elkhorn Road. Gate Combo is 7879.**	-	-
6+74	3	Stream Crossing	Stream crossing culvert and trash rack have been upgraded in 2013. Outflow from the culvert has scoured the downstream channel to the Class I channel downstream. 1. Lay back left bank to 2:1 slope: 30'W x 20'L x 3'D, Spoil locally with no sediment delivery risk. 2. Lay back right bank to 2:1 slope: 30'W x 20'L x 3'D, Spoil locally with no sediment delivery risk. 3. Install rock armor apron at outfall 12'W x 20'L x 2'D with ¾ ft – 1 ft diameter riprap. Construct rock armor apron such that it lines the base of the channel and extends approximately 3 feet up the banks of the channel.	20 yds^3 AR	-
41+24 – 42+96	-	RD #16 RD #17	Existing RD #16 and RD #17 are located in a hummocky earthflow setting. The road surface across these dips has become rutted with winter use. 1. Regrade RD #16, Type 2, to drain road and IBD. Outslope dip axis at approximately 8% grade. 2. Regrade RD #17, Type 1, to drain road and IBD. Outslope dip axis at approximately 8% grade. 3. Install 140'L x 15'W woven Class B2 subgrade enhancement geotextile to road travelway through RD #16 and RD #17. 4. Rock road surface, installing 35 yds^3 RR to road length on top of road subgrade enhancement geotextile to a depth of 0.5'.	35yds^3 RR	2,100 ft^2 woven Class B2 geotextile -
123+27	-	RD #31	RD #31 currently does not completely drain the road surface. 1. Regrade RD #31, Type 1, to permanently drain the road surface. Outslope dip axis at approximately 8% grade.	-	-

Attachment A: Treatment Log for the *2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve*

Treatment Log for Main Road

Station (ft)	Site #	Site Type	Comments/Treatment[1]	Rock Needs	CMP and Other Needs
141+25	19	Stream Crossing	The small armored fill crossing does not currently have adequately sized rock within the upper portion of the keyway. The upper portion of the keyway has disaggregated and a small gully has eroded through the road surface. 1. Install 6 yds^3 rock armor at the top of the keyway 18'W x 6'L x 2'D. Excavate the upper portion (~3 ft) of the armored fill keyway and 3 feet back into roadway. Replace rock with ¾ - 1.5 ft diameter riprap. 2. Utilize the existing stockpiled riprap located 130' right of the site. Break stockpiled riprap into ¾ - 1.5 ft size prior to installation. 3. Regrade armored fill dip and road rock down to low point of armored fill keyway at the outboard edge of the road.	6 yds^3 AR	-
149+40 – 150+56	-	RD #41 RD #42	Existing RD #s 41 and 42 are located in a springy grassland setting. Small rills have eroded through the dip troughs, making driving difficult. 1. Regrade RD #41, Type 2, to drain road and IBD. Increase length of reverse grade to 20'. Outslope dip axis at approximately 8% grade. 2. Regrade RD #42, Type 2, to drain road and IBD. Increase outslope dip axis at approximately 10% grade. Breach dip through berm to drain. 3. Install 140'L x 15'W woven Class B2 subgrade enhancement geotextile to road through RD #41 and RD #42. 4. Rock road surface, installing 40 yds^3 RR to road length on top of road subgrade enhancement geotextile to a depth of 0.5'.	40 yds^3 RR	2,100 ft^2 woven Class B2 geotextile
166+08	-	RD #51.1	Road surface runoff in the vicinity of Site #23 runs down the road, cutting a rill across the road (no photo attached). 1. Install RD #51.1, Type 1, to drain road ONLY, and NOT connected to IBD. Outslope dip axis at approximately 8% grade.	-	-
170+30	-	Windy Pass Road Surface	Near surface groundwater in a grassland setting at Windy Pass results in a soft road surface and rutting during use in wet periods. 1. Install 200'L x 15'W woven Class B2 subgrade enhancement geotextile to road. 2. Rock road surface, installing 56 yds^3 RR to road length (200'L x 15'W x 0.5'D) on top of road subgrade enhancement geotextile.	56 yds^3 RR	3,000 ft^2 woven Class B2 geotextile

Attachment A: Treatment Log for the *2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve*

Treatment Log for <u>Main Road</u>

Station (ft)	Site #	Site Type	Comments/Treatment[1]	Rock Needs	CMP and Other Needs
186+40	-	-	Intersection with decommissioned Quarry Road	-	-
237+49	90	Stream Crossing	A small rill has developed through the road rock in the trough of the armored fill dip. 1. Enhance the existing armored fill dip. Define the dip through the crossing to increase the cross sectional area.	-	-
246+40	-	-	Intersection with decommissioned Quarry Road	-	-
248+04	-	RD #62	Concentrated road surface runoff from Site #93 and the abandoned quarry road have eroded a rill across the road surface at the trough of RD #62. Some rock armor has been placed on the outboard fillslope at the rolling dip outfall but most flow is flanking the rock protection. 1. Regrade RD #62, Type 1, to drain road and IBD. Outslope dip axis at approximately 8% grade. 2. Install 10 yds^3 of well mixed ¼' -1.5' rock armor to the outboard edge of road and outboard fillslope. Install rock armor in a concave "U" shape grade control structure such that outflow from the rolling dip cannot flank the rock armor.	10 yds^3 AR	-
284+95	36	Stream Crossing	A debris flow from the steep spring-fed channel upstream plugged the existing stream crossing culvert during the winter of 2016-17. This crossing may be subject to future debris flows and any replaced culverted would have a high plug potential. 1. Excavate CMP and fill at OBF 2. Install an armored fill crossing; establish a broad 1.5' deep dip through the axis of the crossing that conveys stream flow through the crossing, excavate a keyway 20'W at the OBR x 20'L x 3'D and 7'W at the bottom and armor with 30 yds^3 of mixed 0.75'-2.0' diameter rock armor.	30 yds^3 AR	-

Attachment A: Treatment Log for the *2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve*

Treatment Log for Main Road

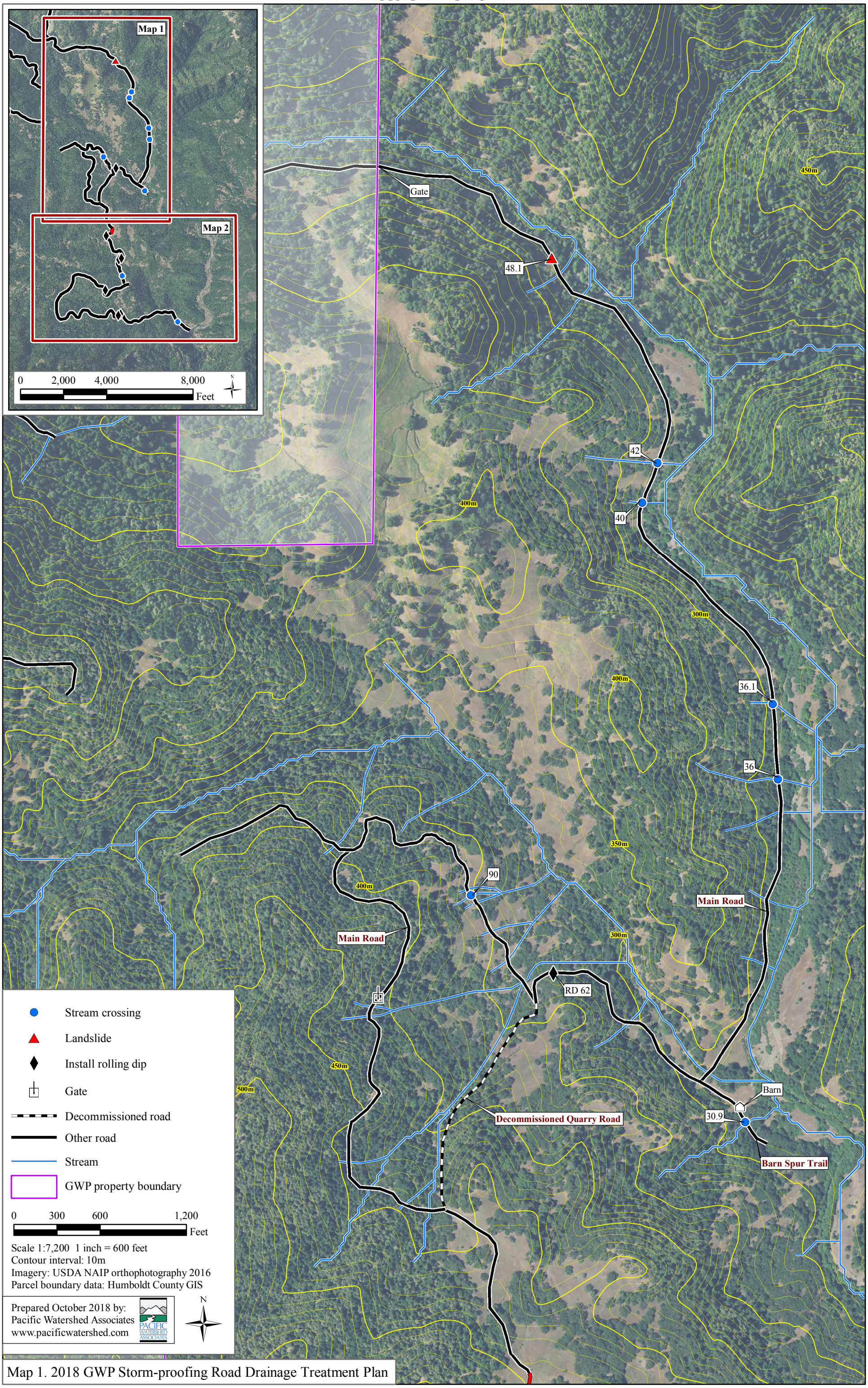
Station (ft)	Site #	Site Type	Comments/Treatment[1]	Rock Needs	CMP and Other Needs
285+75	36.1	Stream Crossing	Flow from a small Class III stream and springy cutbank have destabilized the road fill at this location. The constructed fill portion of the roadway is beginning to fail in a slump and debris slide type failure. 1. Install an armored fill crossing in the axis of the Class III channel; establish a broad 4' deep dip through the axis of the crossing that conveys stream flow through the crossing by lowering the road 4' through the axis of the dip, excavate a keyway 18'W at the top x 25'L x 3'D x 6'W at the bottom and armor with 35 yds^3 of mixed ¾' - 1.5'diameter rock armor. 2. Remove large woody debris during armored fill construction.	35 yds^3 AR	-
308+05	40	Stream Crossing, CD	Flow from a Class III stream is diverted down left road bed for 210' and is eroding a gully through the road fill at Site #41. 1. Excavate from TOP to BOT and install 24"x40' culvert at the base of fill. 2. Armor the outboard fillslope with 10yd^3 of 1 foot diameter riprap. 3. Install single post trash rack 24" upstream of culvert inlet 4. Install a critical dip on the left hingeline of the stream crossing to remove diversion potential. 5. Rebuild the road at the location of the diversion gully by excavating local fill materials from the outboard edge of road and constructing a 14 ft wide roadbed with 2:1 outboard fillslope	10 yd^3 AR	24"x40' CMP 1 coupler
310+65	42	Stream Crossing	The existing undersized culvert is currently plugged. 1. Excavate sediment plug from inlet	-	-
326+70	48.1	Landslide	The road at this site is located at the streamside toe of an earthflow. The road fill is actively failing into Rancheria Creek. 1. Lower road approximately 3 ft at the inboard edge of the road, keeping the IBD, to permit passage. Road width should be at least 12 ft wide. Outslope the lowered road bench.	-	-
-	-	-	**END ROAD LOG**	-	-

Attachment A: Treatment Log for the *2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve*

Treatment Log for Barn Spur Trail

Station (ft)	Site #	Road Tmt [1]	Comments/Treatment	Rock Needs	CMP and Other Needs
[1]SOS = Start of Survey; DRC = Install ditch relief culvert; OSR-FD# = Outslope road by pulling berm and filling ditch; RR = pit run from local quarry or 1½ inch maximum Class 2 Aggregate Base; AR = Rock armor from local quarry or as specified; EOS = End of Survey; GCS = Grade control structure; IBD = Inboard ditch; BOF = Base of fill; IBR = Inboard edge of road; OBR = Outboard edge of road; IBF = Inboard edge of fill; OBF = Outboard edge of fill; CMP = Culvert; RD = Rolling dip.					
Note: Final erosion control materials (straw mulch and erosion control seed) shall be applied to all disturbed soil areas with the potential to erode and deliver sediment to a watercourse and where designated in the road log or by landowner.					
0	-	-	**Begin road log at intersection with Main road and the Barn Spur trail**	-	-
4+27	30.9	Stream Crossing	This stream crossing is completely washed out. The old 24" diameter x 18' long CMP lies in the washed out channel. Landowner wants to decommission the crossing and allow trail access to the abandoned road beyond. 1. Remove existing CMP and properly dispose. 2. Lay back left bank within the road alignment to a 3:1 slope: 20'W x 10'L x 2.5'D average. 3. Lay back right bank within the road alignment to a 3:1 slope: 20'W x 10'L x 2.5'D. 4. Spoil locally.	10 yds^3 RR	-
-	-	-	**END ROAD LOG**	-	-

Attachment B



Map 1. 2018 GWP Storm-proofing Road Drainage Treatment Plan

Attachment B

Stream crossing
Landslide
Install rolling dip
Gate
Road surface maintenance
Other road
Stream

0 300 600 1,200 Feet

Scale 1:7,200 1 inch = 600 feet
Contour interval: 10m
Imagery: USDA NAIP orthophotography 2016
Parcel boundary data: Humboldt County GIS

Prepared October 2018 by:
Pacific Watershed Associates
www.pacificwatershed.com

N

Windy Pass Road Surface Maintenance
RD 51.1 (T1)
RD 42
RD 41
19
Main Road
RD 31
Field Station
RD 17
RD 16
Main Road
3
Elkhorn Road
Main Gate
End of County Road

500m
450m
500m
550m
500m
400m
650m
650m
350m
300m
600m
450m
450m

Map 1
Map 2
Elkhorn Road

0 2,000 4,000 8,000 Feet

N

Map 2. 2018 GWP Storm-proofing Road Drainage Treatment Plan

Photo Log

Photos of treatment sites,
2018 Storm-Proofing Road Drainage Treatment
Maintenance Plan, Mendocino County, California

Road Name	Site	Photos
Main Road	3	1
Main Road	19	2a, 2b
Main Road	RD 41, RD 42	3
Main Road	RD 62	4a, 4b
Main Road	36	5a, 5b
Main Road	36.1	6
Main Road	40	7a, 7b
Main Road	42	8
Main Road	48.1	9a, 9b
Barn Spur Trail	30.9	10a, 10b

Photo 1: Site #3, looking downstream at outlet from the outboard edge of the road.

Photo 2a: Site #19, looking downstream, from the inboard edge of the road.

Photo 2b: Site #19, looking upstream from the outboard edge of road.

Photo 3: Rolling Dips #41 and #42.

Photo 4a: Rolling Dip #62, looking up the road from the outboard edge of road fill.

Photo 4b: Rolling Dip #62, looking at the outboard fillslope.

Photo 5a: Site #36, looking upstream from the outboard edge of fill.

Photo 5b: Site #36, looking from the left road. Note the debris deposited on the roadbed.

Photo 6: Site #36.1, looking north from the outboard edge of fill.

Photo 7a: Site #40, looking upstream from the centerline of the road at the diverted stream channel.

Photo 7b: Site #40, looking at the large diversion gully from left road.

Photo 8: Site #42, looking upstream at outlet.

Photo 9a: Site #48.1, looking at the failing outboard edge of fill from left road.

Photo 9b: Site #48.1, looking from right road.

Photo 10a: Site #30.9, looking downstream at washed-out stream crossing and left bank.

Photo 10b: Site #30.9, looking upstream at washed-out stream crossing and vertical banks.

Attachment D

Typical Design Drawings for the 2018 Storm-Proofing Road Drainage Treatment Maintenance Plan for Galbreath Wildlands Preserve

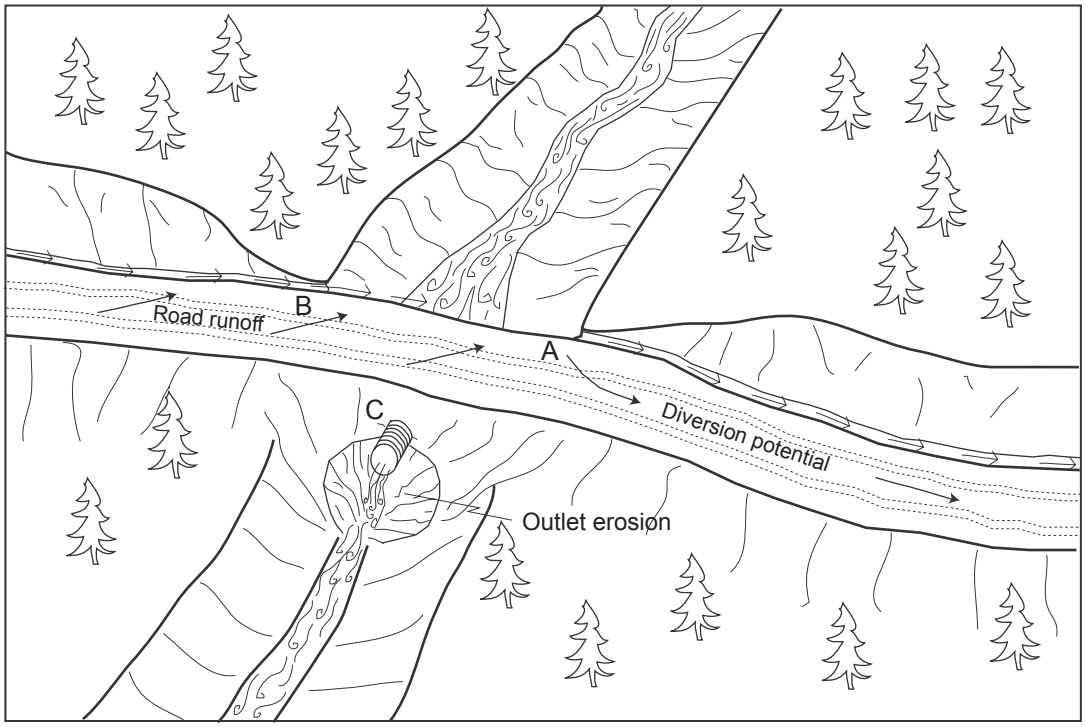
Typical Problems and Applied Treatments for a Non-fish Bearing Upgraded Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

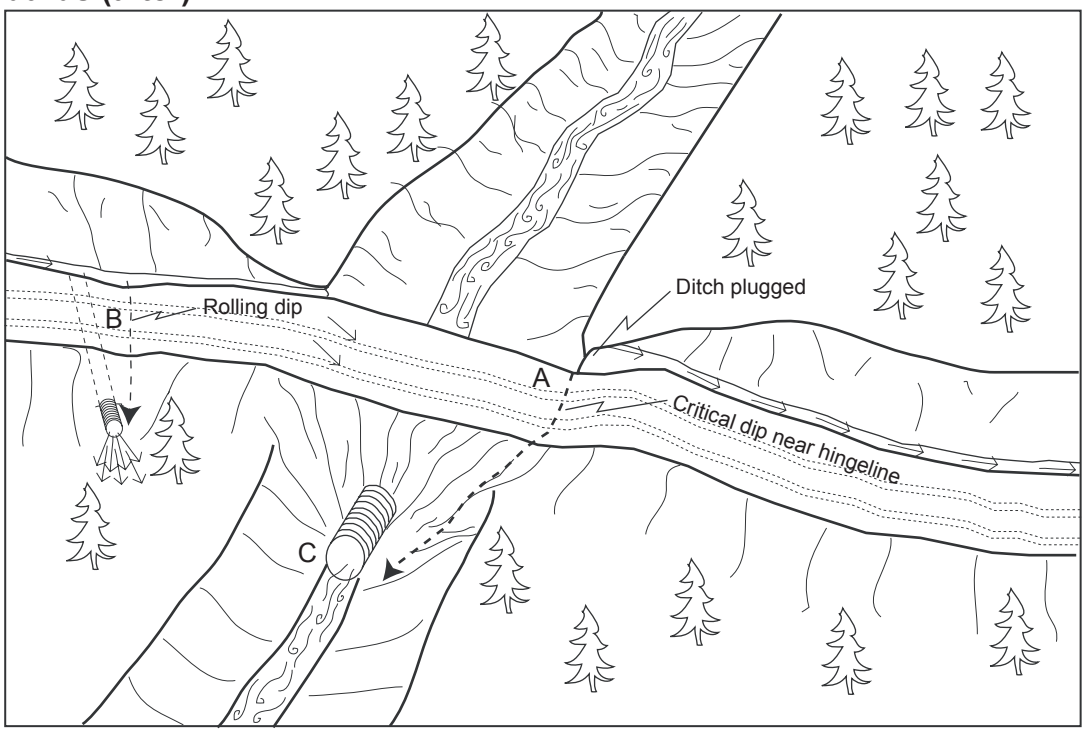


Treatment standards (after)

A - No diversion potential with critical dip installed near hingeline

B - Road surface and ditch disconnected from stream by rolling dip and ditch relief culvert

C - 100-year culvert set at base of fill



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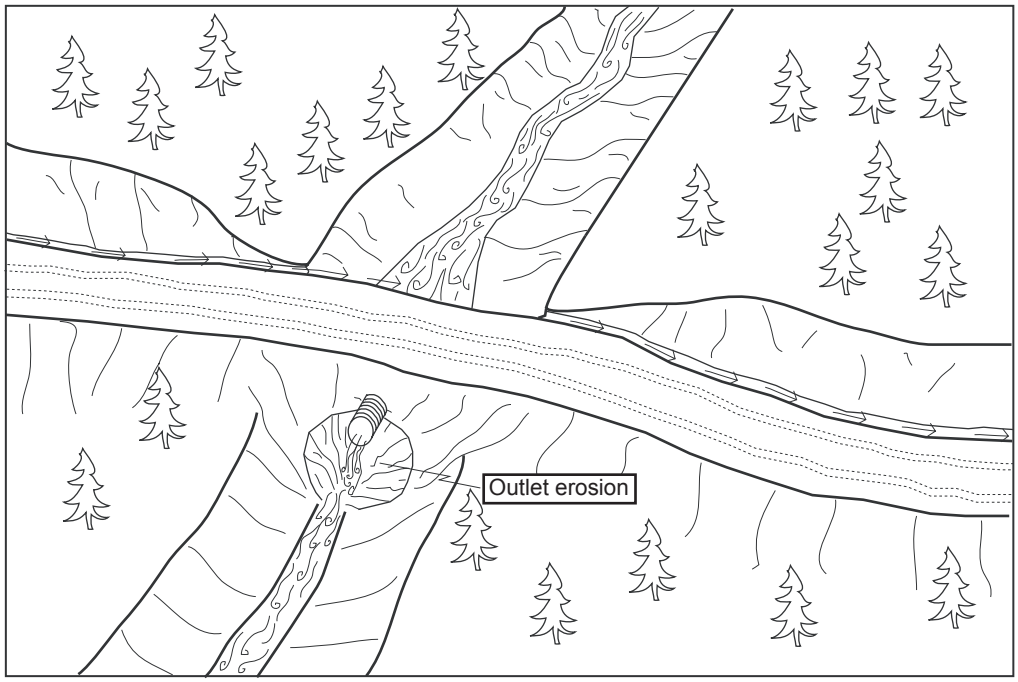
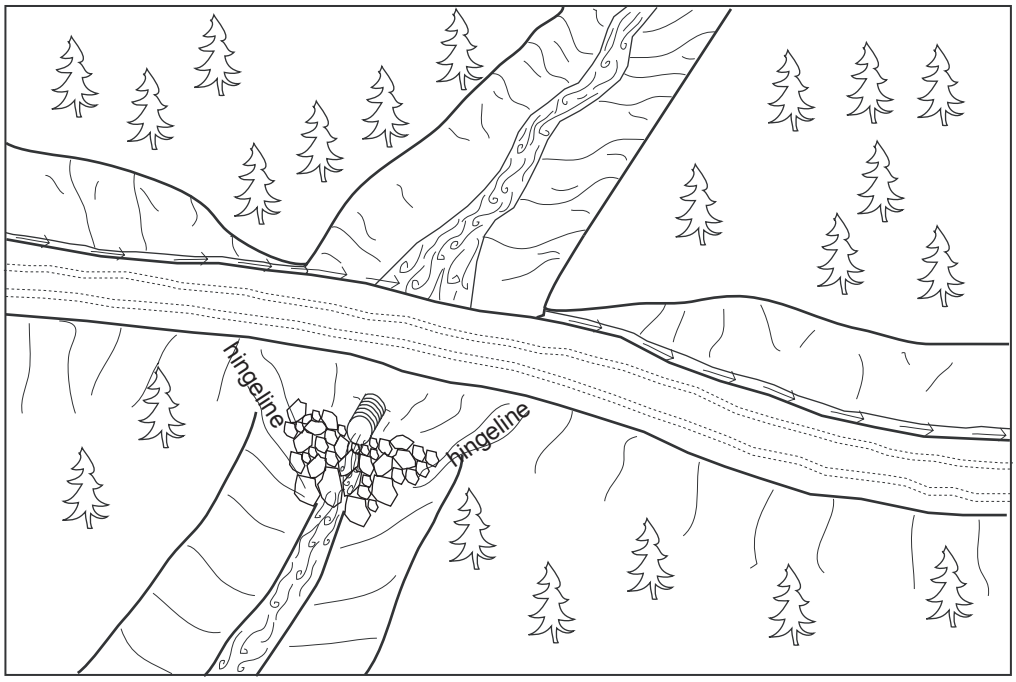
PWA Typical Drawing #1a

Armoring Fill Faces to Upgrade Stream Crossings



Problem: Culvert set high in outboard fill has resulted in scour of the outboard fill face and natural channel.
Conditions: The existing stream crossing has a culvert sufficient in diameter to manage design stream flows and has a functional life.



Action: The area of scour is backfilled with rip-rap to provide protection in the form of energy dissipation for the remaining fill face and channel.

Treatment Specifications:

1) Placement of rip-rap should be between the left and right hingelines and extend from a keyway excavated below the existing channel base level at the base of the fill slope up and under the existing culvert.
2) Rock size and volume is determined on a site by site basis based on estimated discharge and existing stream bed particle size range (See accompanying road log).

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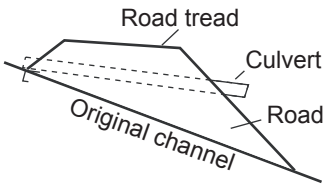
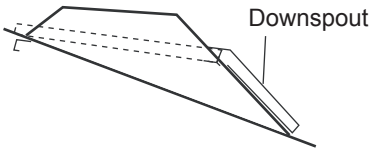
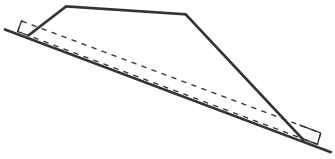
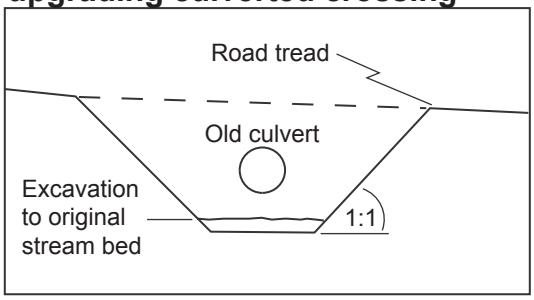
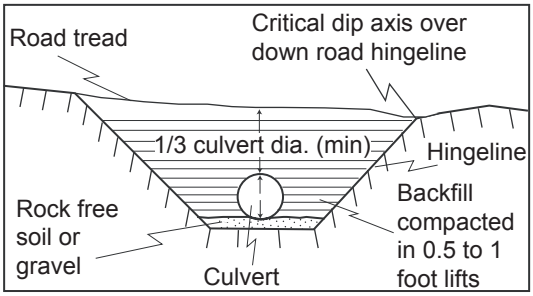
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing	Upgraded	Upgraded (preferred)
		
1. Culvert not placed at channel grade. 2. culvert does not extend past base of fill.	1. Culvert not placed at channel grade. 2. Downspout added to extend outlet past road fill.	1. Culvert placed at channel grade. 2. Culvert inlet and outlet rest on, or partially in, the originial streambed.

Excavation in preparation for upgrading culverted crossing



Upgraded stream crossing culvert installation



Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calulations using a procedure such as the Rational Formula.

Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed, or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - Backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Erosion control measures for culvert replacement

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures implemented will be evaluated on a site by site basis. Erosion control measures include but are not limited to:

1. Minimizing soil exposure by limiting excavation areas and heavy equipment distrubance.
2. Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3. Retaining rooted trees and shrubs at the base of the fill as “anchor” for the fill and filter windrows.
4. Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring, and/or benching prior to the first rains.
5. Excess or unusable soil will be stored in long term spoil disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential, or proximity to a watercourse.
6. On running streams, water will be pumped or diverted past the crossing and into the downstream channel during the construction process.
7. Straw bales and/or silt fencing will be employed where necessary to control runoff within the construction zone.

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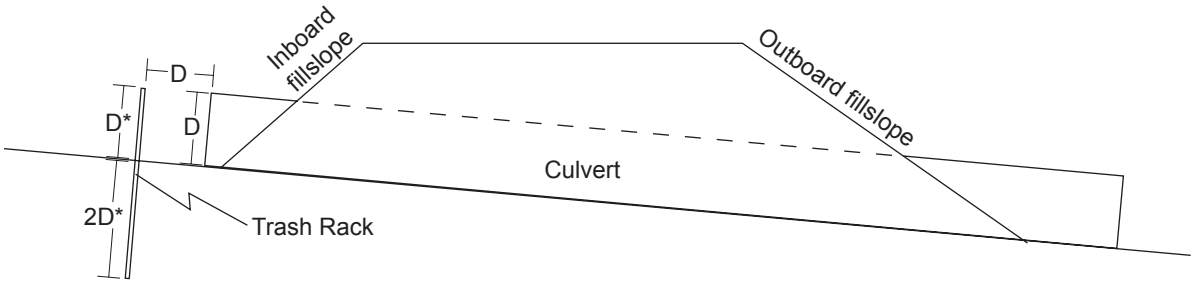
Typical Drawing #2

Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



D - Culvert diameter

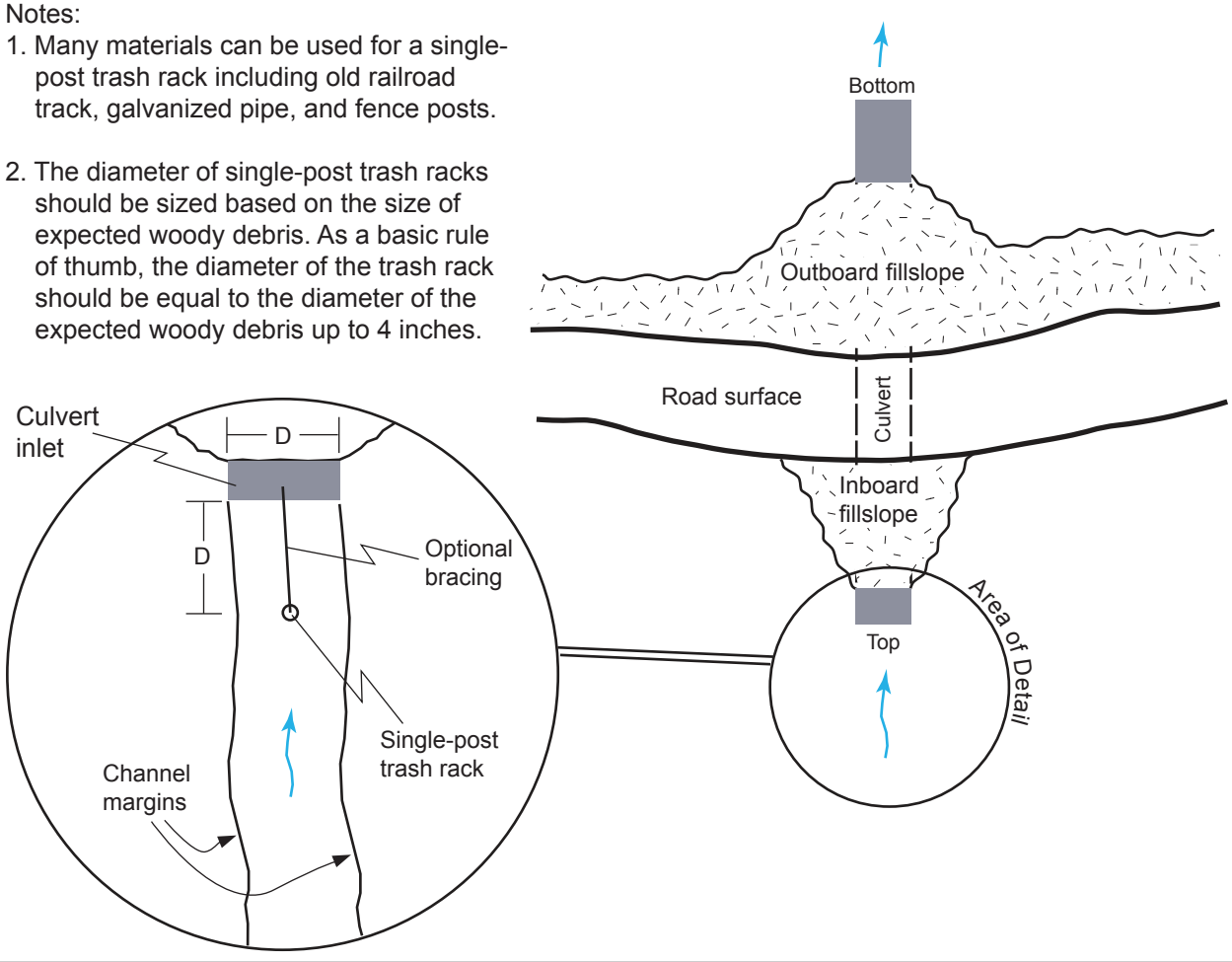
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

Plan view

Notes:

1. Many materials can be used for a single-post trash rack including old railroad track, galvanized pipe, and fence posts.

2. The diameter of single-post trash racks should be sized based on the size of expected woody debris. As a basic rule of thumb, the diameter of the trash rack should be equal to the diameter of the expected woody debris up to 4 inches.



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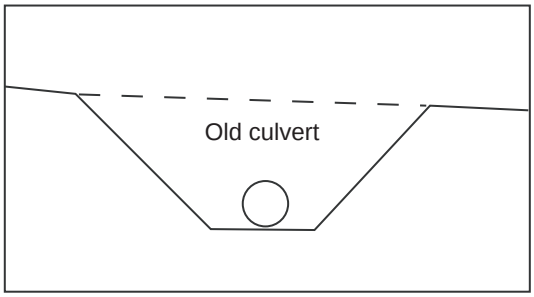
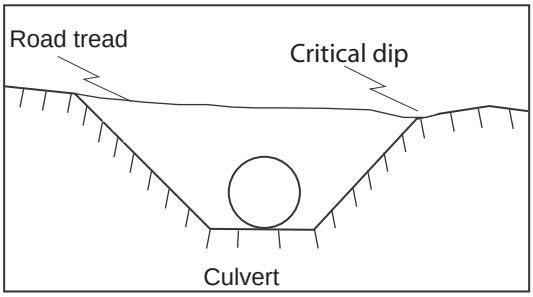
Typical Drawing #3

Typical Design of Upgraded Stream Crossings



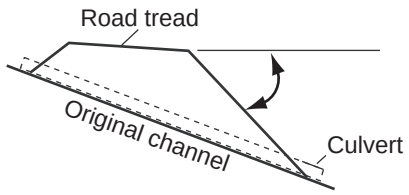
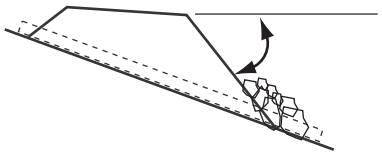
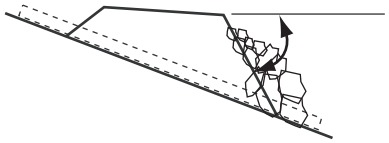


Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end and then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

Armoring fill faces

Fill angles ≤ 2:1	Fill angles (between 2:1 & 1.5:1)	Fill angles steeper than 1.5:1
 No rock armor needed	 Armor 1/4 up fill face	 Armor 3/4 way up fill face

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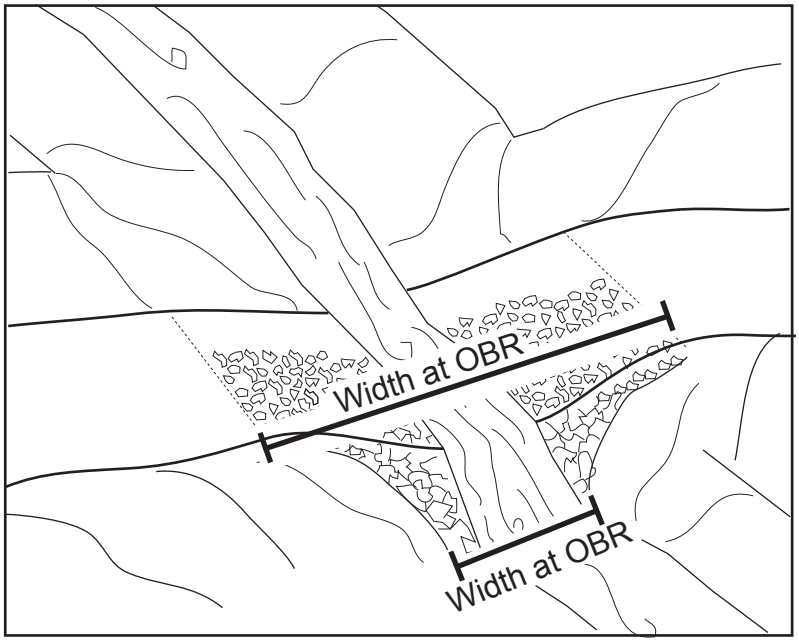
PWA Typical Drawing #4

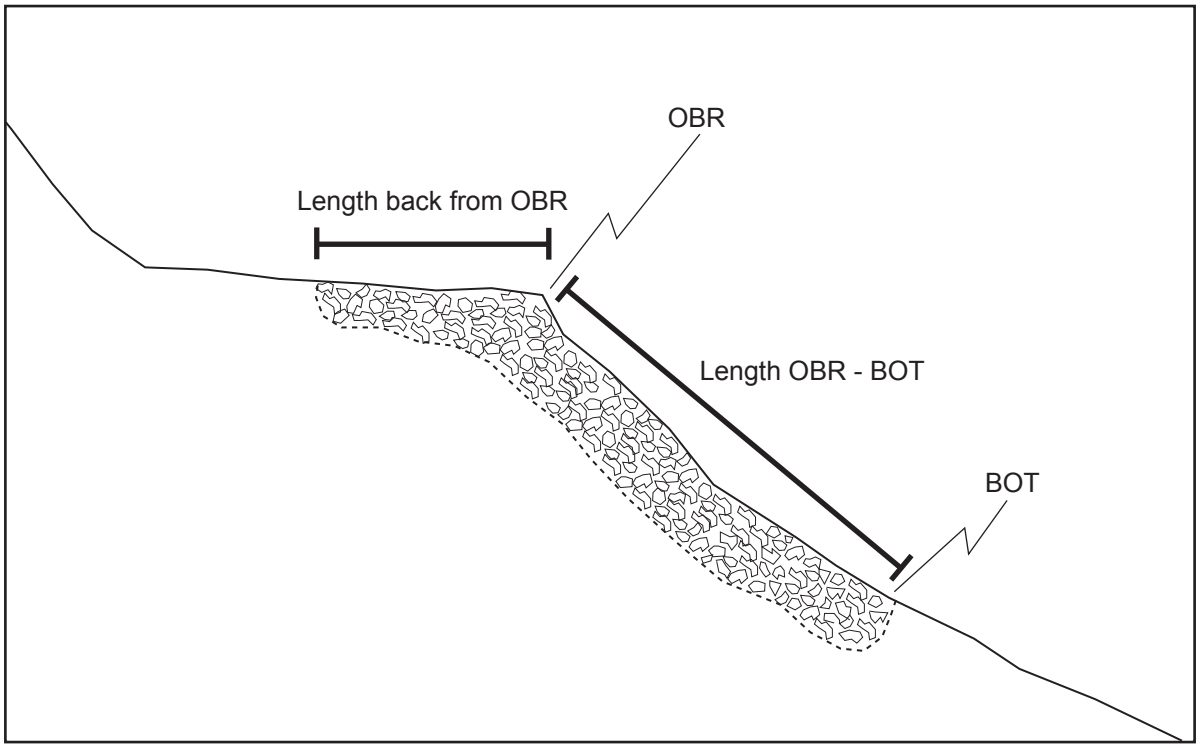
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view



OBR - Outboard edge of road

Lengths in profile view



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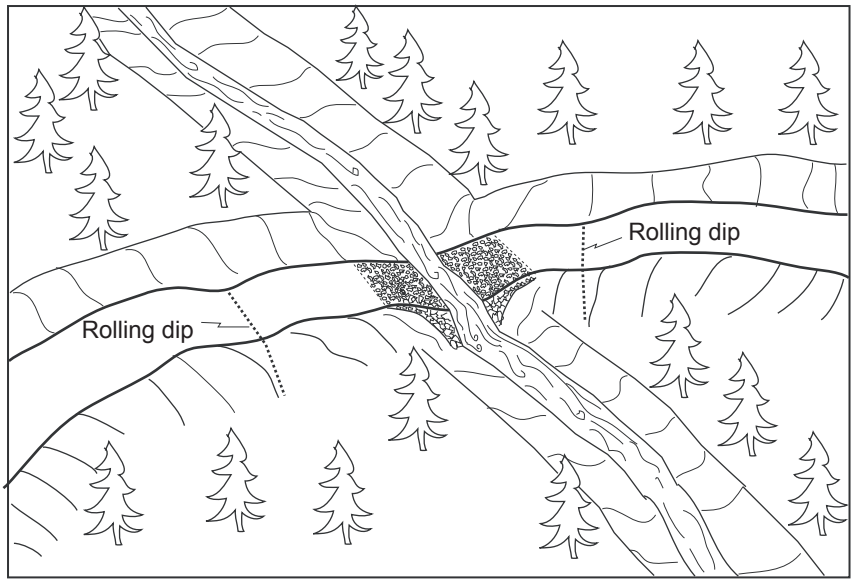
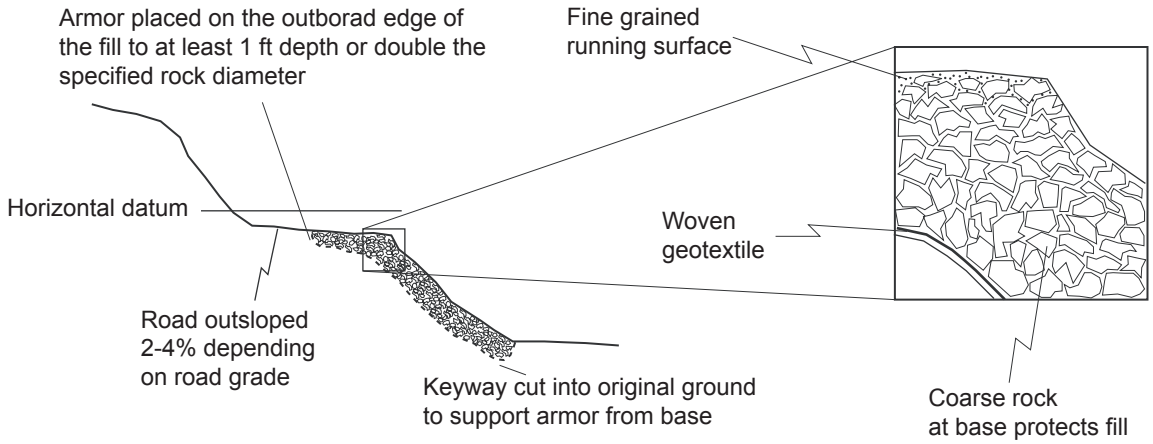
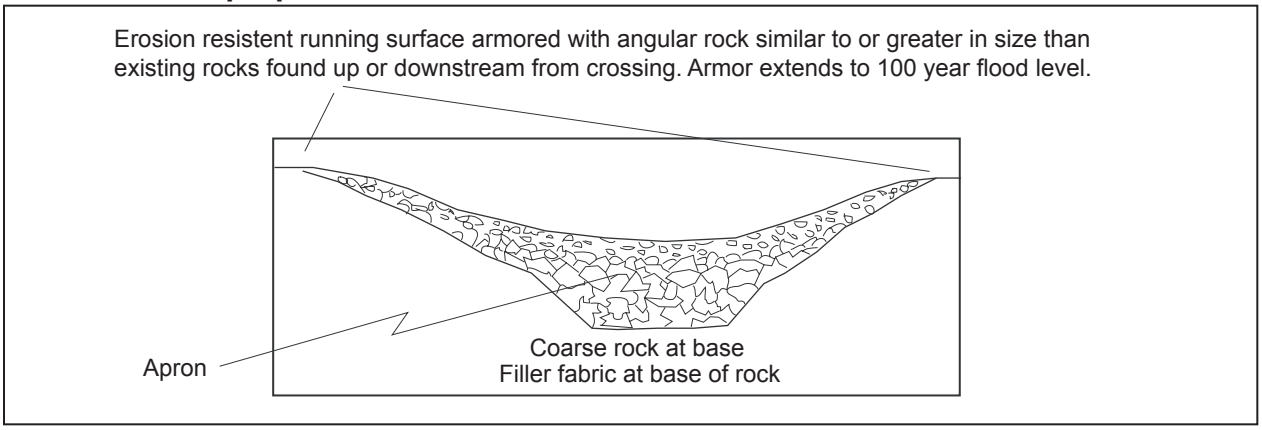
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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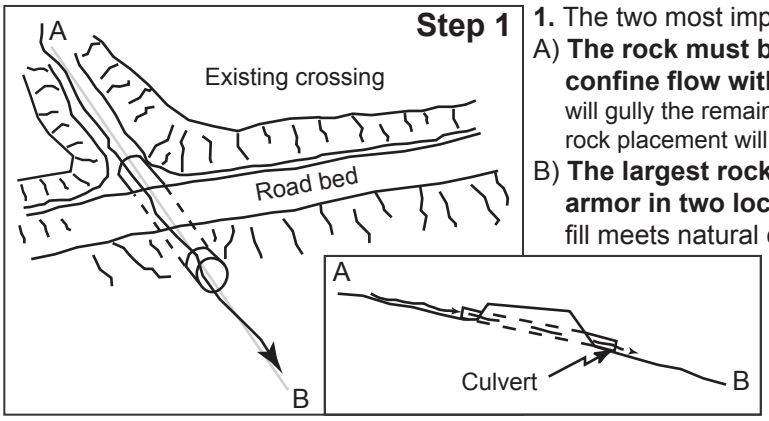
Typical Drawing #6

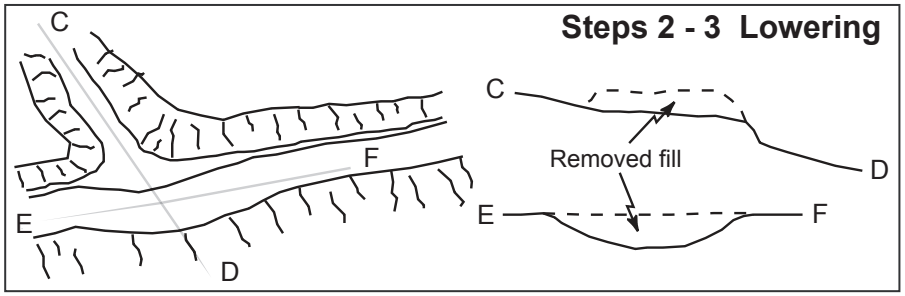
Ten Steps for Constructing a Typical Armored Fill Stream Crossing



1. The two most important points are:

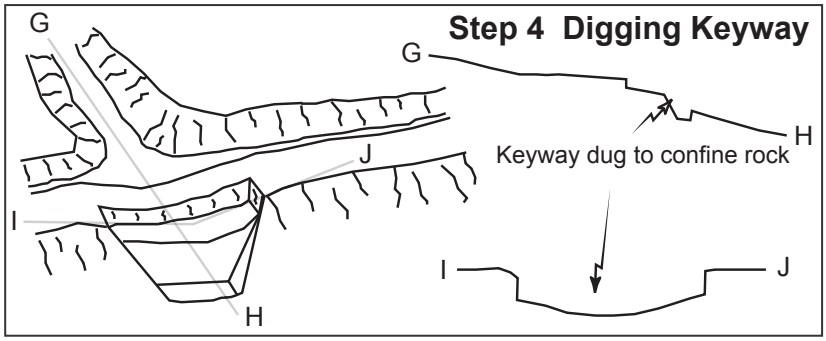
A) **The rock must be placed in a "U" shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

B) **The largest rocks must be used to butress the rest of the armor in two locations:** i) The base of the armored fill where the fill meets natural channel. (This will butress the armor placed on the outboard fill face and reduce the likelihood of it washing downslope). ii) The break in slope from the road tread to the outer fill face. (This will butress the fill placed on the outer road tread and will determine the "base level" of the creek as it crosses the road surface).



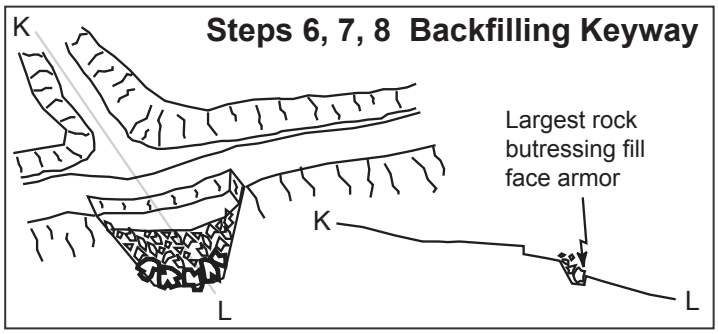
2. Remove any existing drainage structures including culverts and Humboldt logs.

3. Construct a dip centered at the crossing that is large enough to accomodate the 100-year flow event and prevent diversion (C-D, E-F).



4. Dig a keyway (to place rock in) that extends from the outer 1/3 of the road tread down the outboard road fill to the point where outbaord fill meets natural channel (up to 3 feet into the channel bed depending on site specifics) (G-H, I-J).

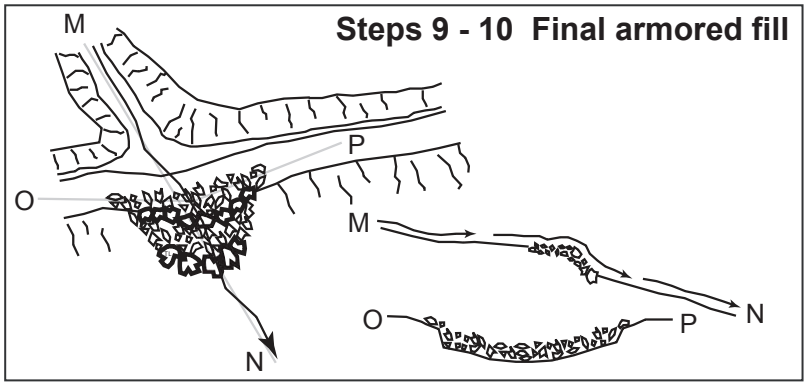
5. Install geofabric (optional) within keyway to support rock in wet ares and to prevent winnowing of the crossing at low flows.



6. Put aside the largest rock armoring to create 2 butresses in the next step.

7. Create a butress using the largest rock (as described in the site treatments specifications) at the base of fill. (This should have a "U" shape to it and will define the outlet of the armored fill.)

8. Backfill the fill face with remaining rock armor making sure the final armored area has "U" shape that will accomodate the largest expected flow (K-L).



9. Install a second butress at the break in slope between the outboard road and the outboard fill face. (This should define the base level of the stream and determine how deep the stream will backfill after construction) (M-N).

10. Back fill the rest of the keyway with the unsorted rock armor making sure the final armored area has a "U" shape that will accomodate the largest expected flow (O-P).

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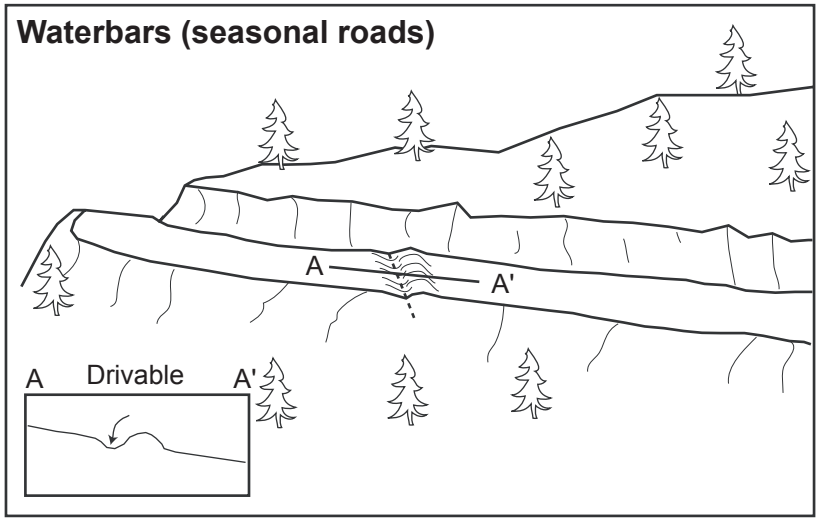
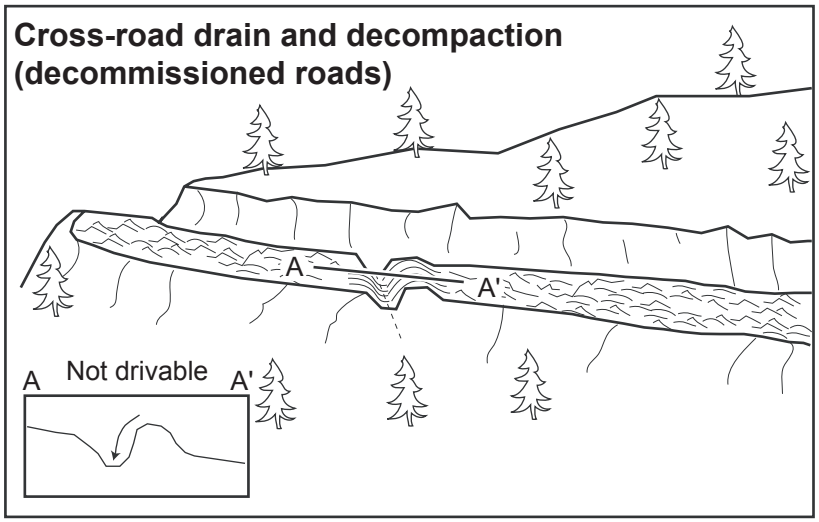
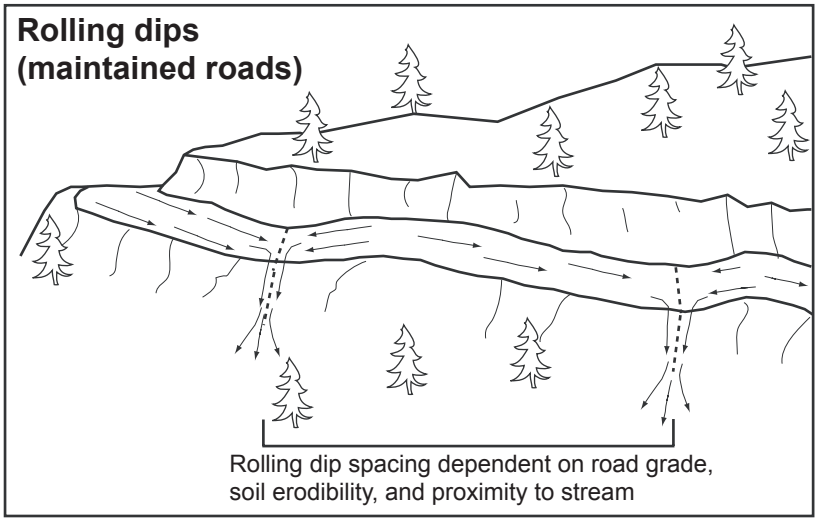
Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips







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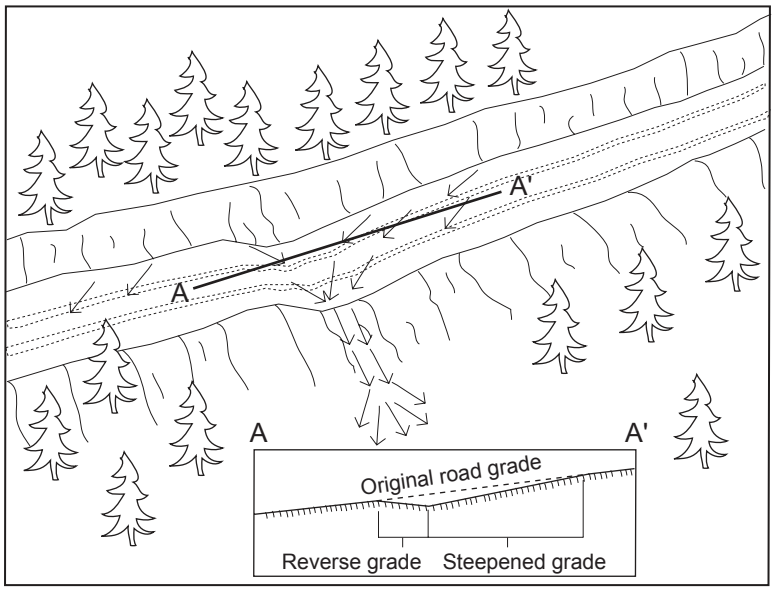
Typical Drawing #10

Typical Road Surface Drainage by Rolling Dips



Rolling dip installation:

1. Rolling dips will be installed in the roadbed as needed to drain the road surface.
2. Rolling dips will be sloped either into the ditch or to the outside of the road edge as required to properly drain the road.
3. Rolling dips are usually built at 30 to 45 degree angles to the road alignment with cross road grade of at least 1% greater than the grade of the road.
4. Excavation for the dips will be done with a medium-size bulldozer or similar equipment.
5. Excavation of the dips will begin 50 to 100 feet up road from where the axis of the dip is planned as per guidelines established in the rolling dip dimensions table.
6. Material will be progressively excavated from the roadbed, steepening the grade unitl the axis is reached.
7. The depth of the dip will be determined by the grade of the road (see table below).
8. On the down road side of the rolling dip axis, a grade change will be installed to prevent the runoff from continuing down the road (see figure above).
9. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to the original slope.
10. The transition from axis to bottom, through rising grade to falling grade, will be in a road distance of at least 15 to 30 feet.

Table of rolling dip dimensions by road grade

Road grade %	**Upslope approach distance** (from up road start to trough) ft	**Reverse grade distance** (from trough to crest) ft	**Depth at trough outlet** (below average road grade) ft	**Depth at trough inlet** (below average road grade) ft
<6	55	15 - 20	0.9	0.3
8	65	15 - 20	1.0	0.2
10	75	15 - 20	1.1	0.01
12	85	20 - 25	1.2	0.01
>12	100	20 - 25	1.3	0.01

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Typical Drawing #11

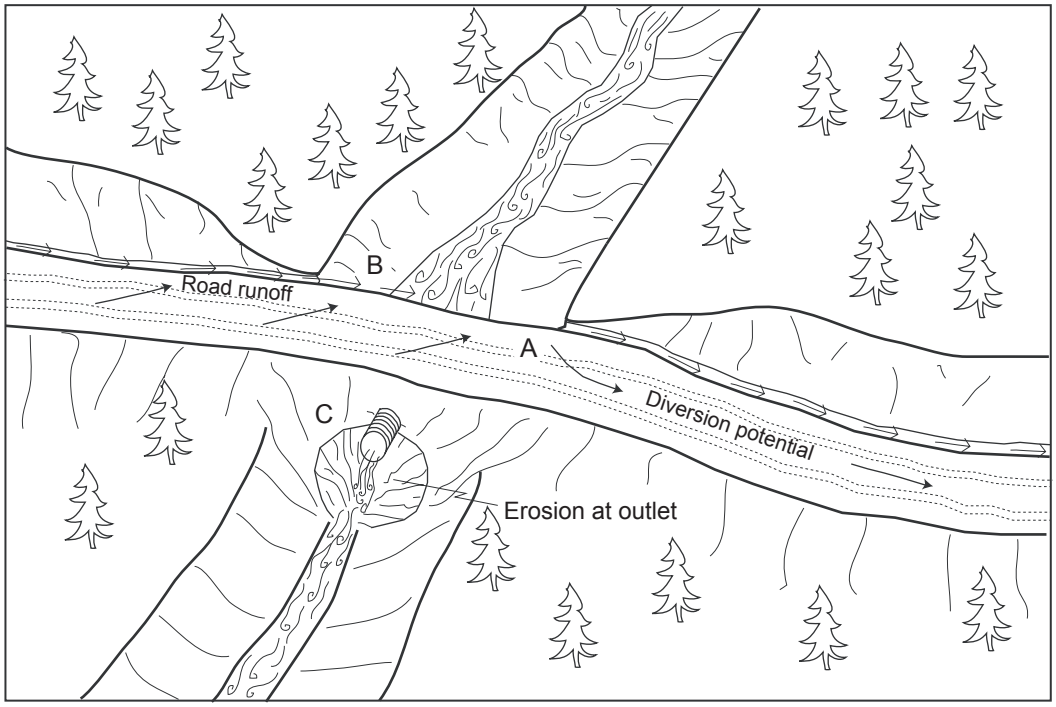
Typical Problems and Applied Treatments for a Decommissioned Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

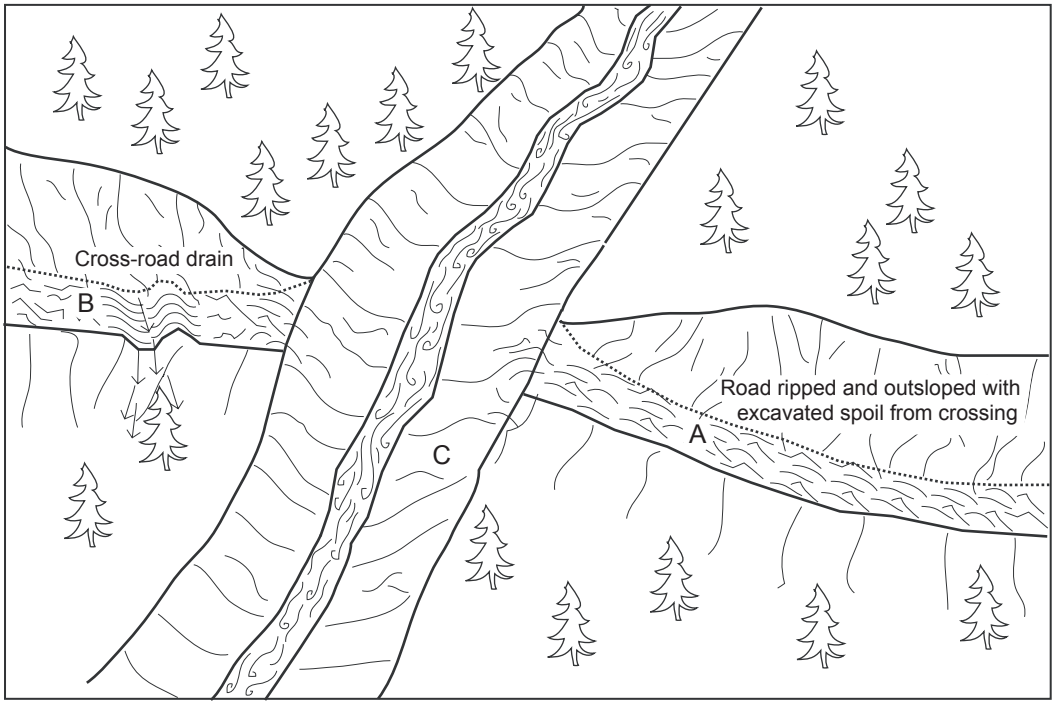


Treatment standards (after)

A - Diversion prevented by road surface ripping and outsloping using excavated spoils

B - Road surface and ditch disconnected from stream by road surface decompaction and cross-road drains

C - Stream crossing fill completely excavated



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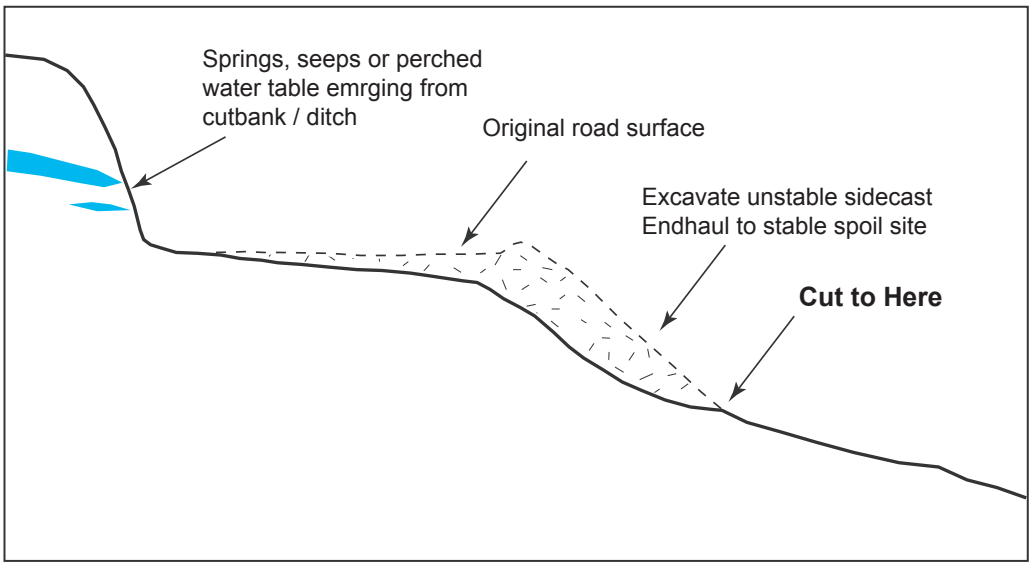
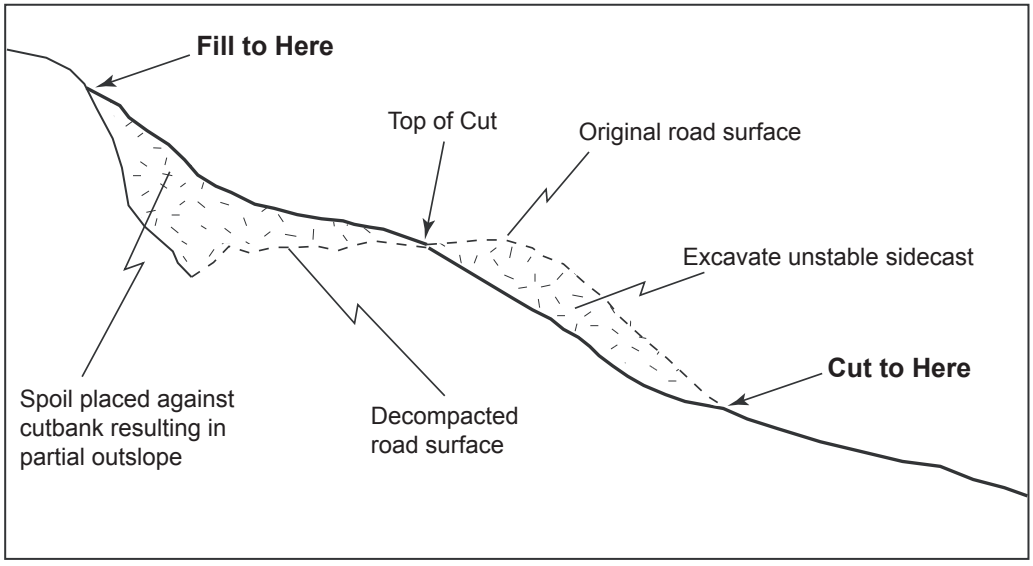
Typical Drawing #14

Typical Design for Road Decommisioning Treatments Employing Export and In-Place Outsloping Techniques

Export outslope (EPOS)



In-place outslope (IPOS)



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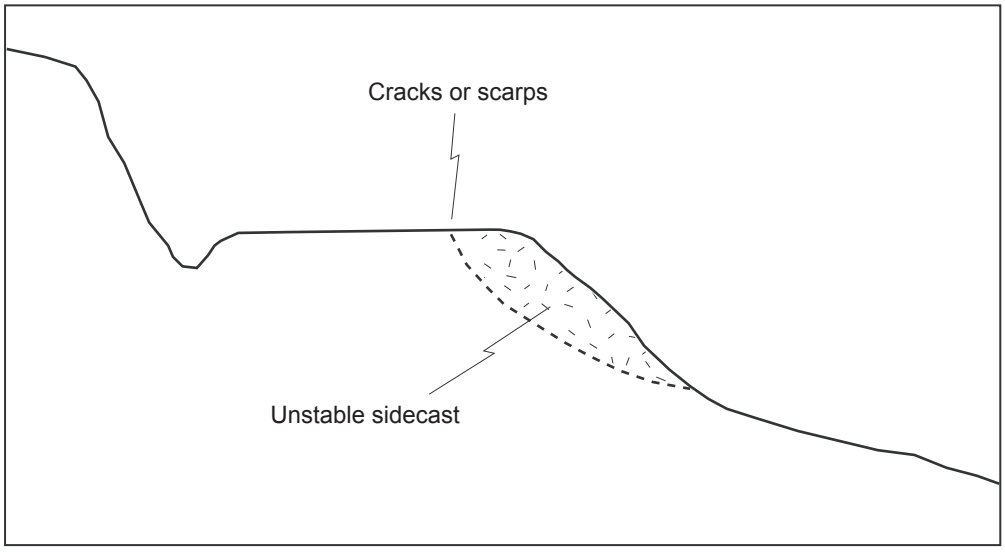
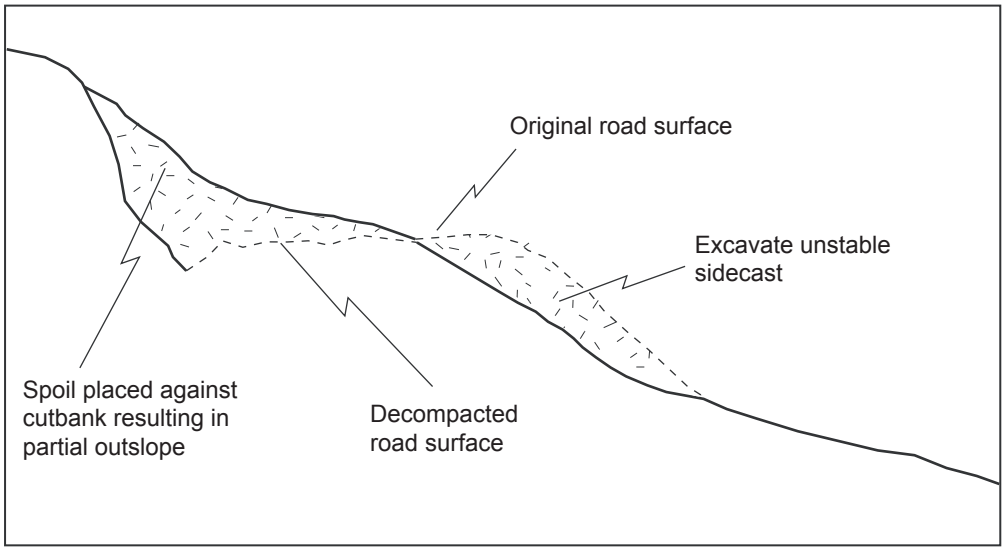
Typical Drawing #15

Typical Excavation of Unstable Fillslope on a Decommissioned Road

Before



After



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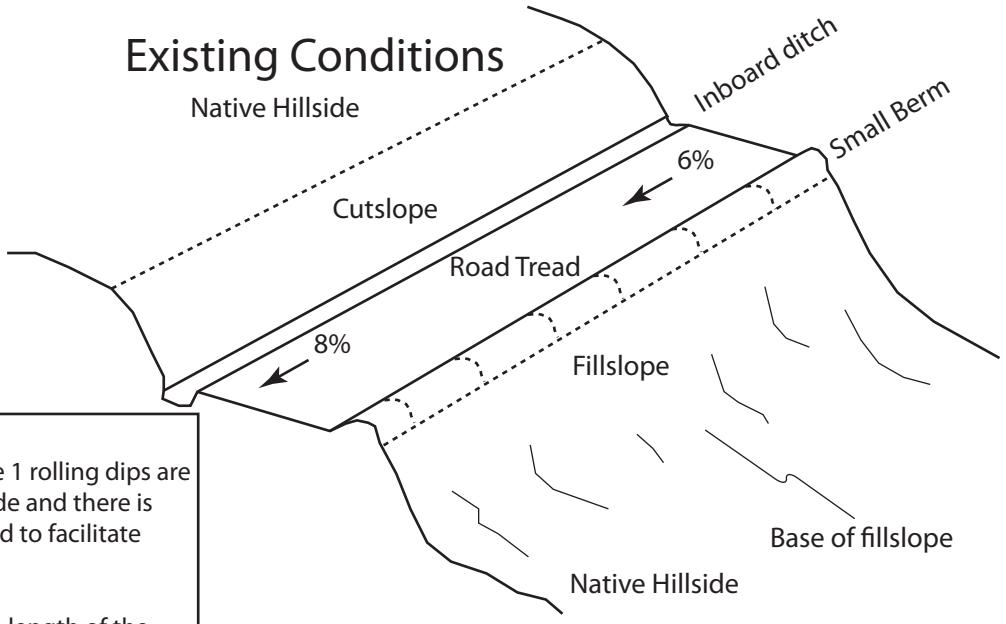
Typical Drawing #16

Standard (Type 1) Rolling Dip Construction



Notes

Rolling dip type 1 existing conditions: Type 1 rolling dips are utilized when roads are less than 12-14% grade and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

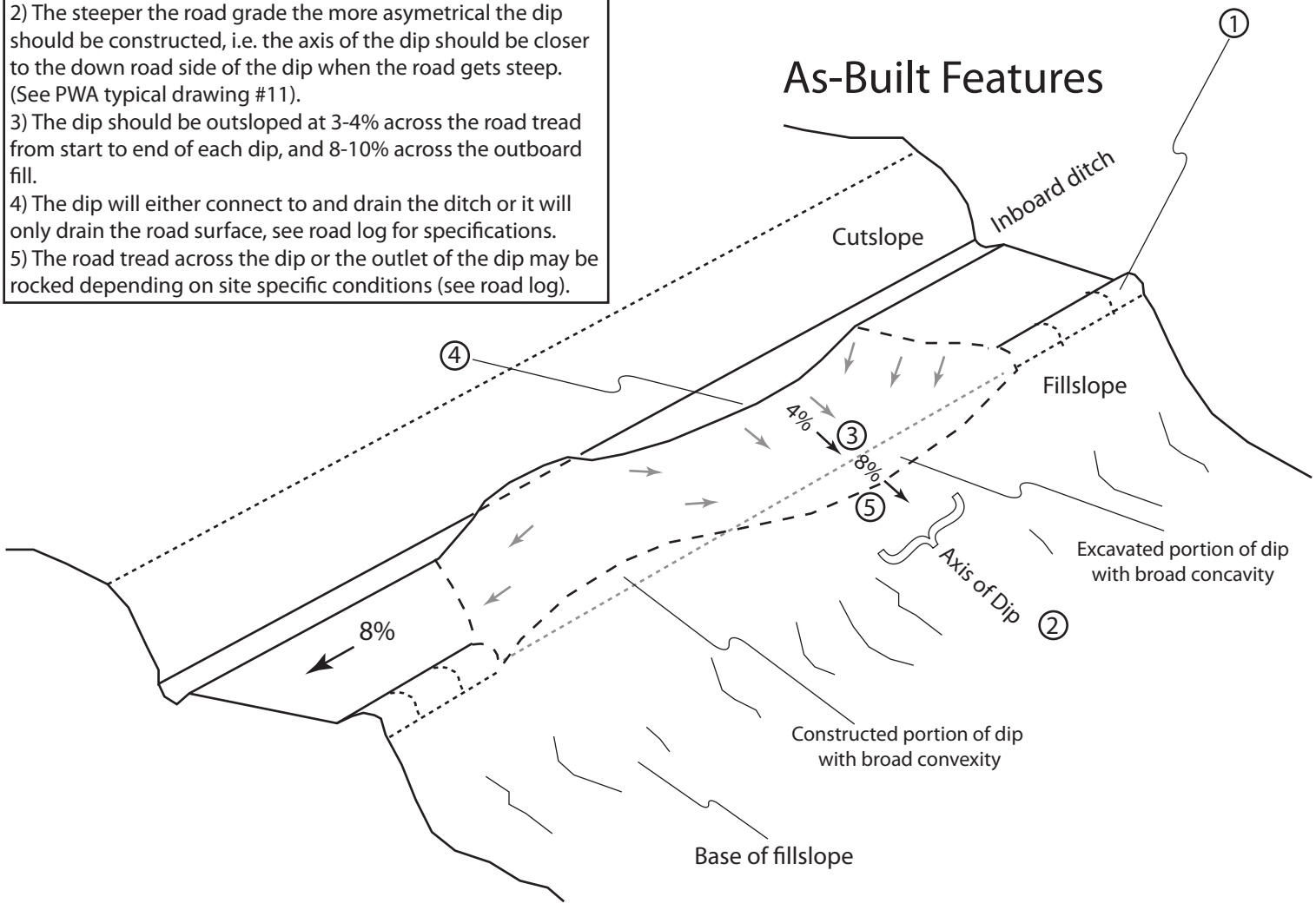
1) The berm should be removed for the entire length of the dip.

2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).

3) The dip should be outsloped at 3-4% across the road tread from start to end of each dip, and 8-10% across the outboard fill.

4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.

5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).



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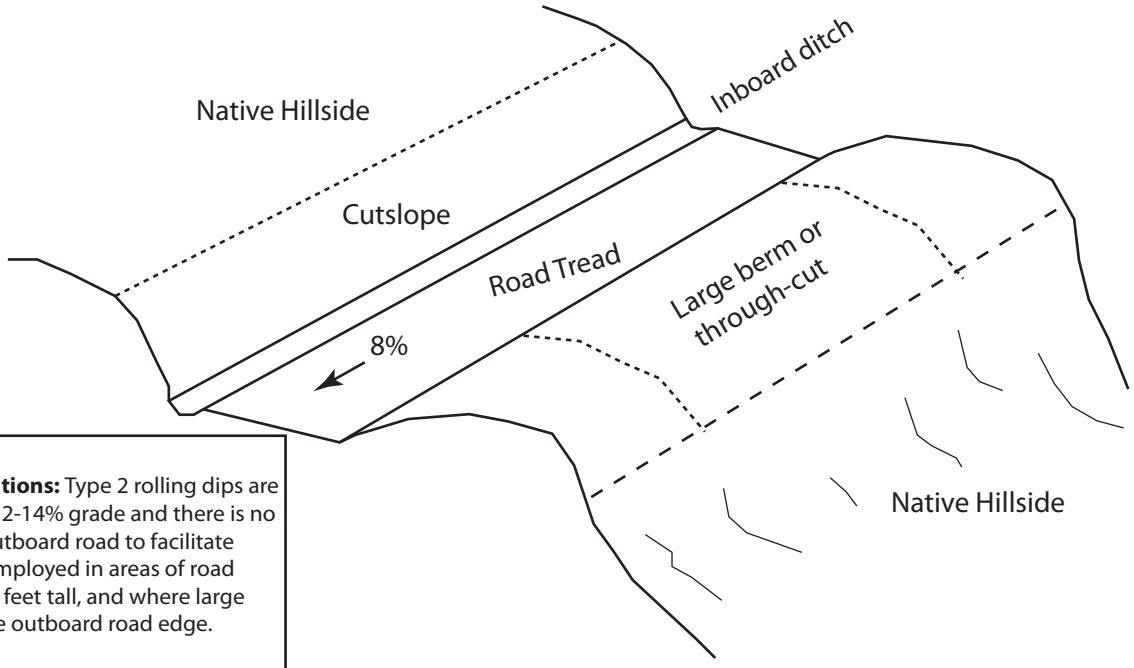
PWA Typical Drawing #19a

Type 2 Rolling Dip Construction

(Through-cut or thick berm road reaches)



Notes

Rolling dip type 2 existing conditions: Type 2 rolling dips are utilized when roads are less than 12-14% grade and there is no proximal outfall adjacent to the outboard road to facilitate road drainage. These should be employed in areas of road through-cuts generally less than 3 feet tall, and where large wide and/or tall berms exist on the outboard road edge.

Design Notes:

1) The berm or native hillside should be removed for the entire length of the excavated portion of the dip, or, at a minimuim through the axis of the dip.

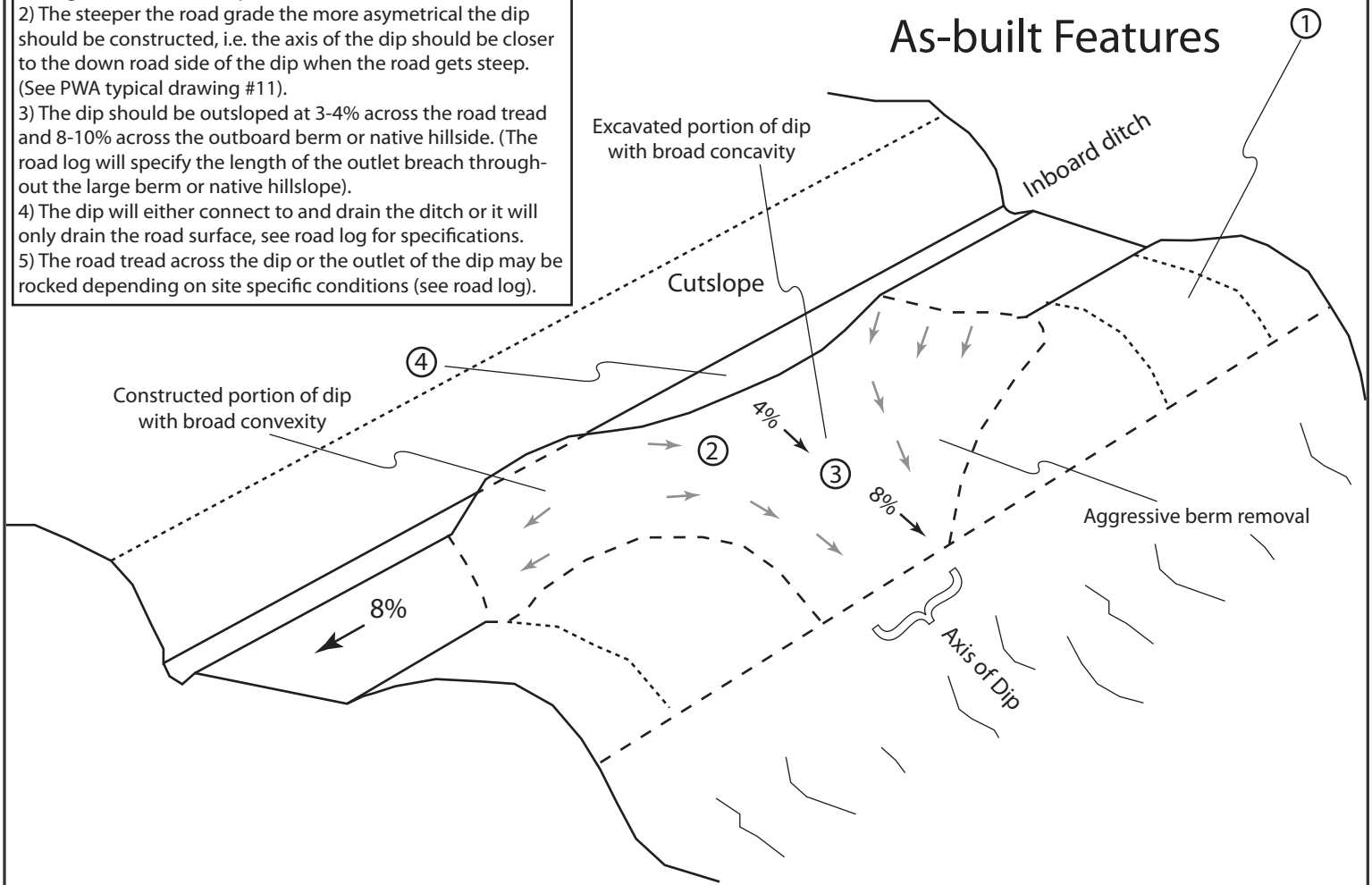
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).

3) The dip should be outsloped at 3-4% across the road tread and 8-10% across the outboard berm or native hillside. (The road log will specify the length of the outlet breach through-out the large berm or native hillslope).

4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.

5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-built Features



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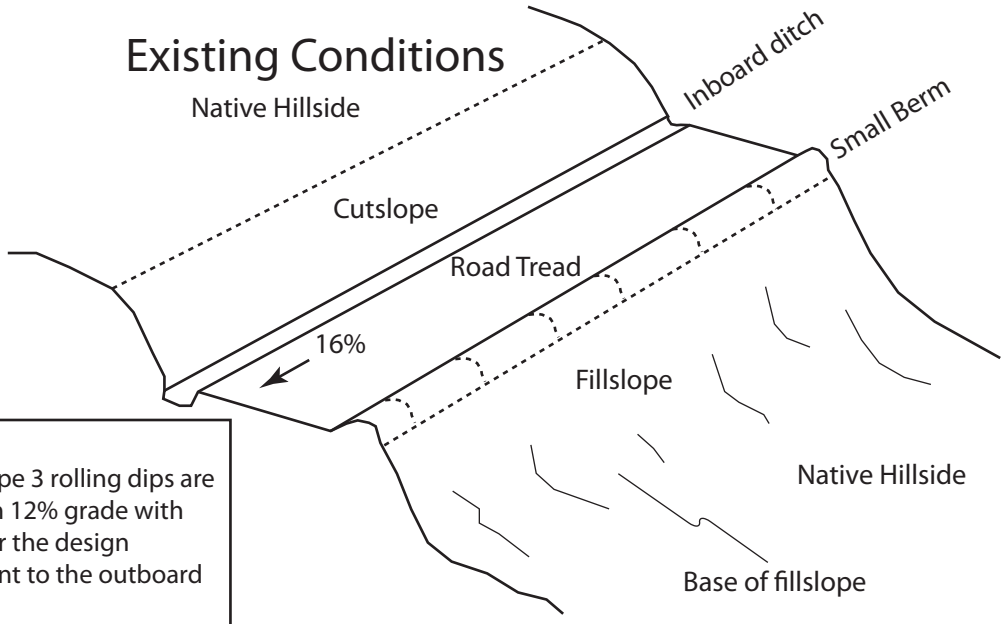
PWA Typical Drawing #19b

Type 3 Rolling Dip Construction
(steep slope outslope)



Notes

Rolling dip type 3 existing conditions: Type 3 rolling dips are utilized when roads grades are steeper than 12% grade with little opportunity to create reverse grade for the design vehicle, and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

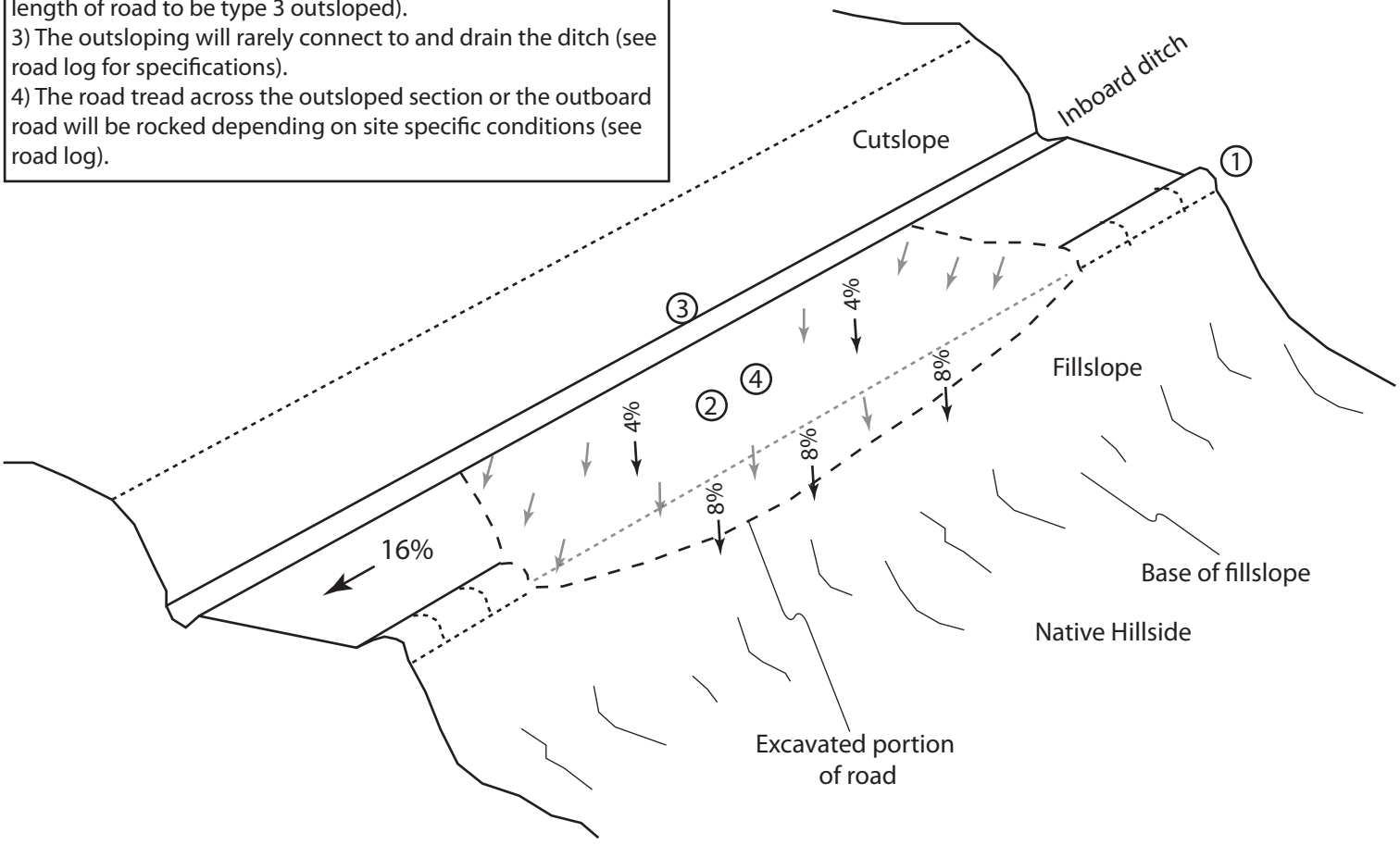
Design Notes:

1) The berm should be removed for the entire length of the outsloped section.

2) The dip should be outsloped at 2-4% across the road tread and 4-8% across the outboard fill. (The road log will specify the length of road to be type 3 outsloped).

3) The outsloping will rarely connect to and drain the ditch (see road log for specifications).

4) The road tread across the outsloped section or the outboard road will be rocked depending on site specific conditions (see road log).



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PWA Typical Drawing #19c