CHAPTER 7: UNPAVED ROADS

Contents

STREAM CROSSING DATA FORM DEFINITIONS

GENERAL

Sites# give an individual number or ID to each stream crossing.

Road ID/Name give each road on the property an individual name or numeric identifier so that sites can be grouped for future treatment.

Date Record the date that this site was assessed (mm/dd/yy).

Site located up-stream of a pond/reservoir is the site located on a stream channel that drains down into a pond or reservoir (Yes, No)

Are fill slopes actively eroding Yes or No. Based upon observations of the fill slopes (and adjacent stream banks) around the inlet and outlet of the crossing are they:

1) Showing signs of rilling or Gullying?
2) Do you see tension cracks or slumps?
3) Or are the fillslopes well protected with vegetation, rock armor, concrete or other hardscape?

CROSSING TYPE

Please circle the type of crossing at the site. If there are different types of drainage features at a crossing then circle each.

Bridge is a bottomless structure that has abutments built on both of the stream banks or uses the natural stream banks as abutments.

Bottomless Arch culvert is a bottomless structure that has abutments built down by the active stream cannel. The difference of this structure from a bridge is that it is usually a continuous arch from the active channel up to its apex.

Box (culvert) functions much like a bridge except that it has a bottom built into it. Most box culverts do not have abutments associated with them. They are usually placed in the stream channel and have fill material compacted around them.

Culvert is a circular pipe or structure that is placed in the stream channel to convey flows under fill material that is compacted around it. Culverts can be round or oval and made of a virety of materials, including metal, concrete, or plastic.

Ford crossing (wet crossing) is designed so that the vehicle travels across the stream bed. No fill or armor material is placed in the stream bed to accommodate the crossing.

Armored fill usually constructed on streams with high stream banks that would require the excavation of substantial ramps to get vehicles down to the streambed. An armored fill crossing (wet crossing) is designed so that the stream flow travels across the road prism but the road fill is armored with rock, concrete or other hardened materials so that the fill material cannot be eroded by the stream flows.

Fill crossing (wet crossing) is a stream crossing where the road crosses a stream and no drainage structure has been constructed. This definition may also apply to stream crossings that have drainage structures but they have failed or washed out to the point that the drainage structure is no longer functioning. These crossing types are assumed to be actively eroding.

Pulled crossing is a stream crossing that has been decommissioned in the past. Decommissioned stream crossings are crossings whose drainage structure and fill materials have been excavated (pulled) from the stream channel, allowing for the stream to flow through the area as it had before the road was constructed. These crossings may need to be evaluated to determine if adverse 'adjustments' are occurring at the site and further treatment would be needed to reduce sediment delivery.

Culvert info

Rust/silt line at inlet. The height of the rust/silt line at the inlet gives an indication of the average flow depth that the crossing receives. A rust/silt line greater than 50% of the diameter of the culvert may be an indicator that the crossing is undersized. Though rust/silt line height may also be a result of how shallow the culvert is relative to stream channel grade.

Inlet is it crushed, plugged? For the inlet to be defined as *crushed* or *plugged* it should be greater than 20%.

Bottom rusted or separated? For the bottom of the culvert to be defined as *rusted* you should observe at least rust holes through the culvert. A separated culvert would occur if the individual lengths have become uncoupled, allowing flows to exit before the outlet.

Diversion potential would occur if a stream crossing was to flood at the inlet, onto the road and water would flow down the road (or inboard ditch) away from its original channel below the outlet. You would answer there is ***No*** diversion potential if the water would flood onto the road and flow straight across the road, spilling back into the same stream channel. Another way to determine diversion potential is to look at the road lengths on either side of the stream crossing. If both road lengths are draining down to the crossing, then there is no diversion potential. See section of 'Road lengths draining down to site for further check.

ROAD DRAINAGE TO STREAM CROSSING

If you are using a map it may be helpful to map all road/avenue lengths draining down to each site. This can be done by using a bracket ([ ]) symbol to indicate start of road length with an arrow symbol (→) pointing toward the site. Example [→ → site# ← ←]

Road/avenue lengths draining down to the site. Standing on the road surface, above the stream crossing and looking down stream, record the total distance of road length(s) draining down to the site. *Left* road length and *Right* road length are relative to looking down stream. Include all intersections and spur road/avenue lengths. If the road continues downhill through the site then cut-off your road length at the site and count the road length draining away as 0ft (see Diversion Potential section). Road surface drainage features that effectively end the road length include natural drainage break (divides and swales), rolling dips, and functional waterbars.

Road surface *Paved* roads have either asphalt or concrete surface and is adequately covered to protect against rain-drop impact and allows for wet-season use. *Rocked* roads have a surface that is adequately covered with road-base rock to protect against rain-drop impact and allows wet-season use. *Native* roads are unsurfaced or dirt roads, even though they may contain some natural rock.

Average width of the road length(s) draining down to the site, measured in feet. Take a represented measurement of the width of the road from the cutbank to the outside edge of the road prism.

COMMENTS ON PROBLEM

This is an optional field. This section is available for you to describe in more detail characteristics of the site that may or may not have been covered earlier in the data form. The summary comments for each site generally describe the nature of the erosion problem as well as other important site characteristics. Remember there is a real difference between the cause and the symptom of many erosion problems. Wherever feasible, it is important to treat the cause of the problem rather than the symptom. You may want to refer to specific photos of the site in this section as well. A discussion on the historical maintenance needs of the site may help in determining treatment options and prioritization.

STREAM CROSSINGS TREATMENT OPTIONS

Stream crossing treatments generally require permits from various resource agencies. See “Navigating the Permitting Process” in Chapter 1.

Typicals attached.

1. No treat no treatments are needed to prevent road-related sediment inputs to the stream system.

2.Consult a Professional this option can be selected in conjunction with other treatment options but is intended to allow the user to state that they don’t know what treatments to prescribe and will be consulting a professional in the future.

3. Excavate soil indicates permanent removal of soils form the stream crossing. It identifies that aggraded sediments in and around stream crossing will be removed. Cleaning plugged culverts does not solve the problem of a high plugging potential. In contrast, culvert plugging potential can be permanently reduced by the installation of a larger culvert at stream grade and a debris trash rack upstream from the culvert inlet. This option could also be selected if the user were planning to Decommission the stream crossing (See typical drawing 14).

4. Install bridge would be selected upon further investigation of the crossing requirements to pass a given storm event (example the 100-year peak storm flow) or to provide for anadromous fish passage. Design elements requirements to design a bridge will most likely involve engineering.

5. Construct an armored fill crossing work well on unpaved seasonal use roads at small to medium sized streams where there is a stable stream bottom and traffic is light. These crossing types may be needed if there is insufficient channel depth to install a culvert. These crossing types have the advantage, over culverted crossings of; never plugging, they don't rust out, they do not have diversion potential, and if constructed properly they are designed for the 100-year peak flow event. Streams with high stream banks that would require the excavation of substantial ramps to get vehicles down to the streambed may be good candidates for the construction of an 'Armored Fill' crossing. The fill material that is imported into the streams crossing needs to be rock armored to prevent erosion during periods of runoff. The fill face on the downstream side of the fill should be protected with rock armor of a large enough size class that cannot be moved by stream flows. All road lengths draining down to the Armored Fill crossing need to be will rocked with gravel size or larger material. See typical drawings 5a, 5b, 6 & 7.

6. Construct a Ford crossing works well on unpaved seasonal use roads at small to medium sized streams where there is a stable stream bottom and traffic is light. A Ford crossing is typically defined as a crossing where no fill material has been put into the stream channel. Fords of live streams, called "wet fords," are typically composed of streambed gravels in contact with the streambed so that vehicles can cross the channel. These crossing types may be needed if there is insufficient channel depth to install a culvert. These crossing types have the advantage, over culverted crossings of; never plugging, they don't rust out, they do not have diversion potential, and if constructed properly they are designed for the 100-year peak flow event. . All road lengths draining down to the crossing need to be will rocked with gravel size or larger material. See typical drawings 5a.

7. Repair culvert for repairing a culvert damaged or significantly dented by a backhoe, grader or debris from stream flows. The intention of repairing a culvert is to return it to its intended functionality. At culverts with 36" diameter or greater that have rusted bottoms, repairs could be made to the rusted portion of the culvert.

8. Install/Replace culvert at the stream crossing. When install new culverts or replacing existing ones it is best to size the culvert to accommodate large storm events (ex. the 100-year peak storm flow). Culvert sizing can be achieved by using a variety of methods. Culvert should be installed at base of fill, at stream grade and in line with stream channel. See typical drawings 2 & 4.

9. Construct critical dip is usually prescribed on unpaved roads. A critical dip is a broad rolling dip constructed on or close to the down- road hinge-line of a stream crossing that displays a diversion potential. Build a critical dip at all stream crossings in order to prevent stream diversions when a culvert plugs and water flows out onto the road. See typical drawing 1c.

Also if a road is outsloped or banked steeper than the road grade through the crossing, this may be another way to redirect flood flows back into the original channel downstream of the road.

10. Install a critical culvert this method is usually employed on paved roads or roads that are too steep to achieve the reverse in grade that a critical dip requires to be functional. A critical culvert will capture the overflow from the flooded crossing and redirect the flow back into the original channel below the road. A critical culvert is installed higher in the fill than crossing culvert and on the downhill side of the crossing, usually the location where the flood waters would overtop the road.
Also if a road is outsloped or banked steeper than the road grade through the crossing, this may be another way to redirect flood flows back into the original channel downstream of the road.

11. Remove screen from culvert inlet having a screen across the inlet of a culvert actually increases its plug potential because no material is allowed to pass through the culvert. A screen at the inlet may be appropriate if the culvert makes bends or turns within its interior, where material could plug and can't be accessed for clearing. In these cases the culvert should be recognized as a high priority maintenance site. If the culvert has a full round downspout with an elbow a hinged hatch should be constructed at the elbow to allow for cleaning access.

12. Install a single post trash rack 'T' post, Galvanized post, 'I' beam. All culverted stream crossing should have a single post trash rack installed above the inlet to reduce plug potential. Trash rack should be installed center to the culvert inlet and at a distance up channel of the inlet that is equal to the diameter of the culvert. The single post should be at least as high as the top of the culvert. T-post trash rack can be used for any culvert less than or equal to a 30" diameter. At stream crossings with larger culverts, the size of the bedload being transported should be looked at to determine appropriate material needed for the single post. See typical drawing 3.

13. Armor fill face armoring the upstream and/or downstream fill faces of a stream crossing fill to reduce rilling/gulling or to buttress areas that are expressing tension cracks or slumping. See typical drawing 1b, 4.

14. Armor below outlet of culvert with rock if a plunge pool or scour is observed.

15. Other treatment describe any treatments that will be employed but have not been covered in this data form.

ROAD LENGTH TREATMENT OPTIONS

Road surface treatments may require permits from various resource agencies. See “Navigating the Permitting Process” in Chapter 1.

Typicals attached.

1. No treat no treatments are needed to prevent road-related sediment inputs to the stream system.

2. Consult a Professional this option can be selected in conjunction with other treatment options but is intended to allow the user to state that they don’t know what treatments to prescribe and will be consulting a professional in the future.

3. Construct rolling dips Rolling dip are usually only prescribed on unpaved roads. Construction of frequently installed rolling dips will ensure the most reliant form of road drainage with the least amount of maintenance. When designing a road shape with rolling dips it is recommended that an outsloped or crowned road shape between each dip be a part of the design to insure the maximum amount of road drainage.

On average rolling dips should be constructed so that each rolling dip is capturing no more than 150’ of road drainage. Rolling dips should be constructed so that they are draining onto the downhill side of the road and not into the inboard ditch. Rolling dips can be constructed to drain either the inboard ditch and road surface, or just the road surface. If rolling dips are constructed to not drain the inboard ditch then frequently installed (every 150’) ditch relief culverts should be incorporated into your design. See typical drawings 10, 11, 19a-c.

4. Install speed bumps on paved road Though paved roads do not produce sediment they can still concentrate runoff to the stream system. When roads concentrate runoff to a stream system, the downstream portion of the stream channel usually adjusts to these increased flows by channel incision and bank failures, which in turn inputs more sediment into our waterways. As discussed above, rolling dips are not usually prescribed on paved roads but the installation of ‘speed bumps’ with the same orientation as a rolling dip could provide the same function to disperse runoff. Speed bumps will only drain the road surface so if there is an inboard ditch than frequently installed ditch relief culverts (every 150’) will need to be incorporated into your design. In some instances, paving a road with either an outslope, inslope or crown shape may be sufficient to adequately drain the road surface

5. Outslope road & remove ditch An outsloped road can be designed on both paved and unpaved roads. At least a 4% outslope from the cutbank to the outside edge of the road is the desired shape. On unpaved roads, rolling dips should be incorporated into the design to insure adequate road drainage. The Outslope can be achieved by removing any outboard berm, lowering the outboard side of the road and using pulled fill material to raise the inboard side of the road and fill the inboard ditch. Ensure that fill material is free of vegetation and well compacted. See typical drawings 8, 9a & 9b.

Outsloping on paved roads is not recommended if those roads are driven during frost or snow events. If paved roads are driven in these types of conditions then a crowned road shape may be more appropriate.

6. Outslope road & retain ditch At least a 4% outslope from the inside portion to the outside edge of the road is the desired shape. The (inboard) ditch would be retained if the road receives heavy traffic during the rainy season or along sections of the road where emergent spring flow persists after storm events. If the inboard ditch is retained then frequently installed (every 150') ditch relief culverts will need to be incorporated into your design. On unpaved roads, rolling dips should be incorporated into the design to insure adequate road drainage. See typical drawings 8, 9a & 9b.

Outsloping on paved roads is not recommended if those roads are driven during frost or snow events. If paved roads are driven in these types of conditions then a crowned road shape may be more appropriate.

7. Inslope road At least a 4% inslope from the outside portion of the road to the top of the inboard ditch is the desired shape. On unpaved roads, rolling dips should be incorporated into the design to insure adequate road drainage. With all insloped sections of a road the inboard ditch needs to be drained with frequently installed (every 150') ditch relief culverts. See Typical drawing 8, 9a & 9c

8. Crown road Crown road with a ¾ road width outslope and a ¼ width inslope. Because a portion of the road will be draining into the inboard ditch, frequently installed (every 150') ditch relief culverts will need to be incorporated into your design. On unpaved roads, rolling dips should be incorporated into the design to insure adequate road drainage. See typical drawing 8 & 9a.

9. Install or replace DRC Ditch relief culvert (DRC) are utilized when an inboard ditch is draining any cutbank, hillside or road surface. On average DRCs should be installed so that each is capturing no more than 150' of inboard ditch drainage. See typical drawing 8.

10. Cut or clean ditch length An inboard ditch should be utilized in areas that experience hillside runoff (ex. grassland settings or springy cutbanks or hillsides) and experience vehicle use when these flows are occurring.

11. Rock armor inboard ditch Rock armor should only be needed in instances where frequently drained inboard ditches are still experiencing incision or gullying.

12. Construct waterbars Waterbars are usually only recommended along vineyard avenues that cannot accommodate rolling dips, along roads that are gated off to vehicle use during the rainy season or along sections of road that are too steep to construct rolling dips. Waterbars are not a preferred method of road winterizing because they can be easily rendered dysfunctional. All it takes is one vehicle pass over waterbars in saturated conditions to compact soils into the drainage feature. See typical drawing 20.

13. Construct Cross rd. drains This treatment is recommended for road decommissioning prescriptions. See typical drawing 17.

14. De-compact road surface This treatment is recommended for road decommissioning prescriptions. De-compacting of the road surface is usually done with a bulldozer dragging its rippers along the road surface to allow for greater infiltration and vegetation growth. Road de-compacting treatment is always associated with the construction of cross road drains. See typical drawing 17.

Stream Crossing Types


BRIDGE


ARCH


BOX CULVERT


OVAL CULVERT


CULVERT


FORD


ARMORED FILL


FILL


DECOMMISSIONED CROSSING

Photos taken from Weaver et al. (2014). *Handbook for Forest, Ranch, & Rural Roads* or provided by Napa RCD.

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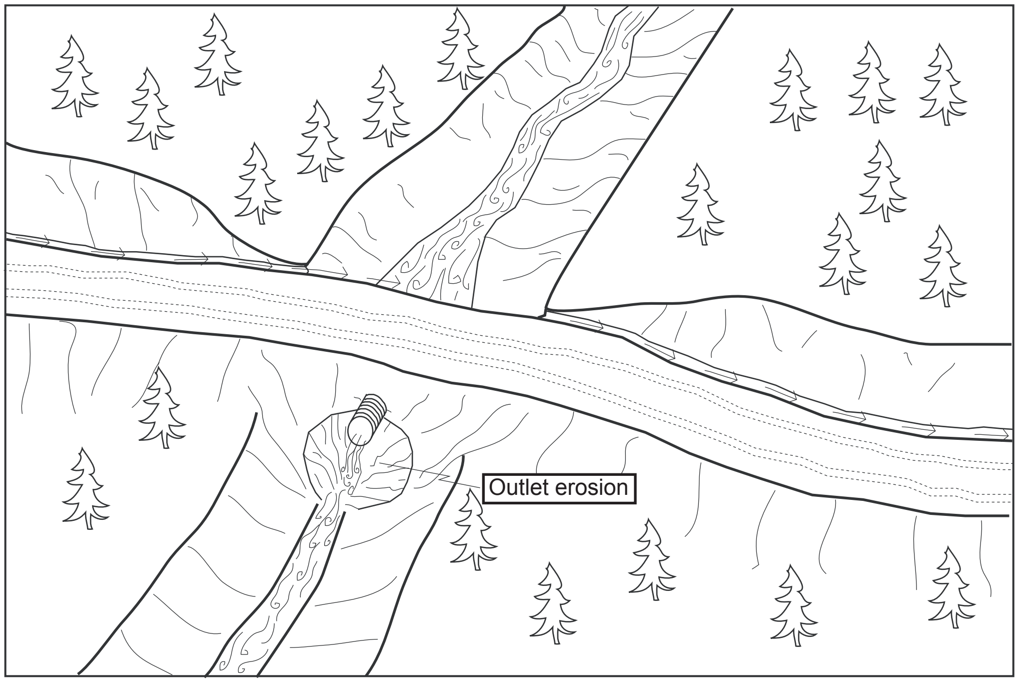
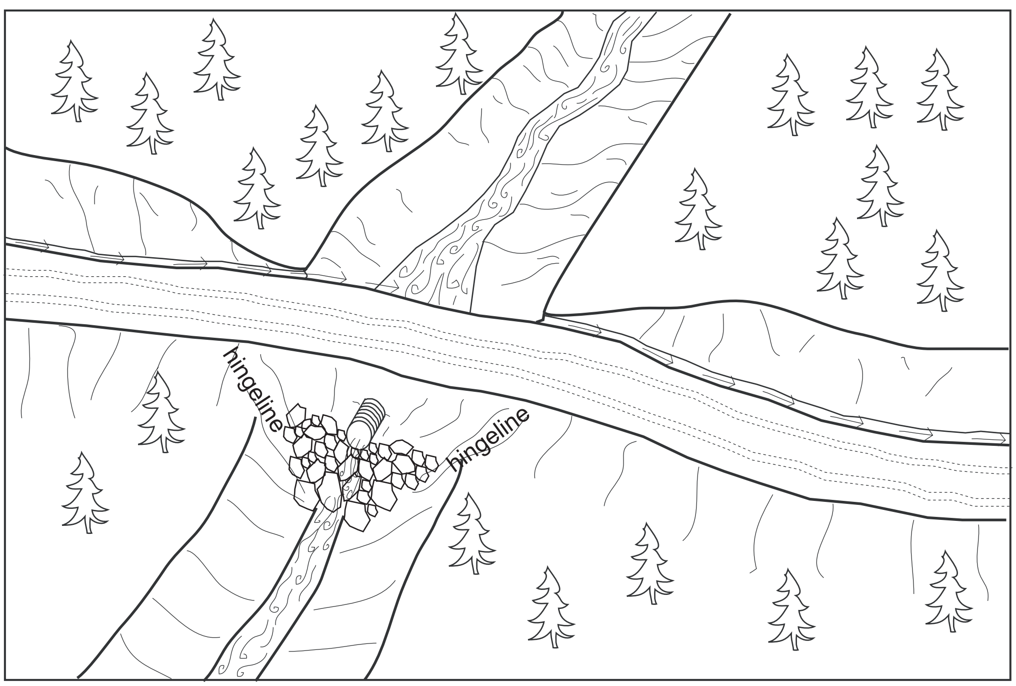
Armoring Fill Faces to Upgrade Stream Crossings



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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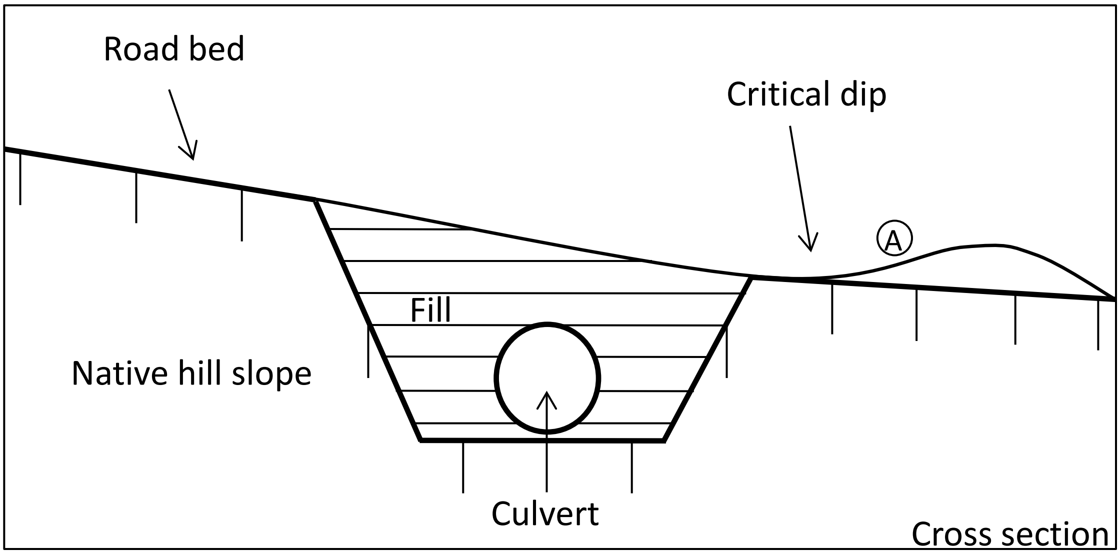
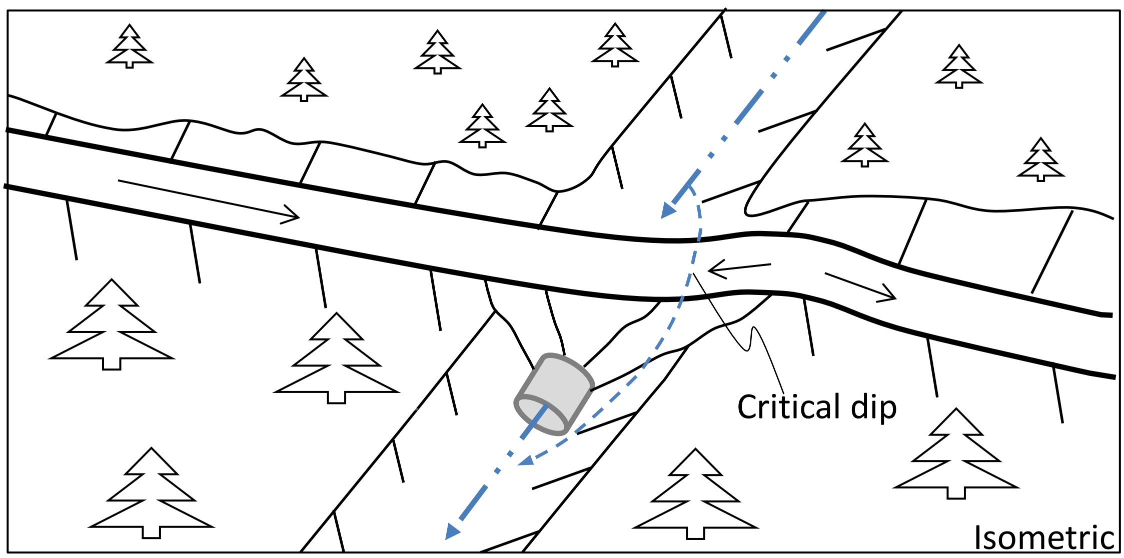
Typical Critical Dip Design for Stream Crossings with Diversion Potential





Critical Dip Construction:

1. Critical dip will be constructed on the lower side of crossing.
2. Critical dip will extend from the cutbank to the outside edge of the road surface. Be sure to fill inboard ditch, if present.
3. Critical dip will have a reverse grade (A) from cutbank to outside edge of road to ensure flow will not divert outside of crossing.
4. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to original slope.
5. The transition from axis of bottom, through rising grade, to falling grade, will be in the road distance of at least 15 to 30 feet.
6. Critical dips are usually built perpendicular to the road surface to ensure that flow is directed back into the stream channel.

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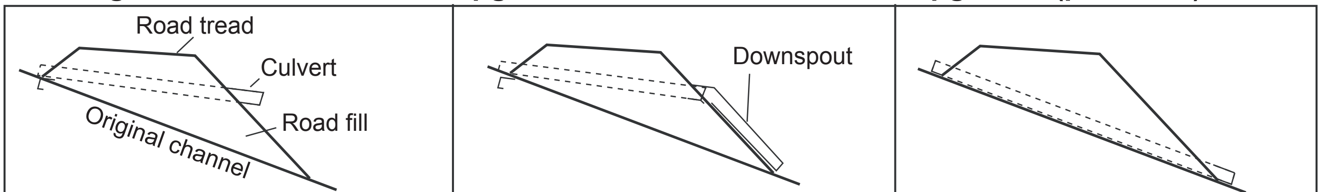
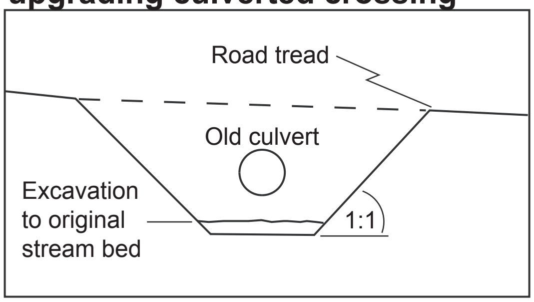
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing | **Upgraded** | **Upgraded (preferred)**

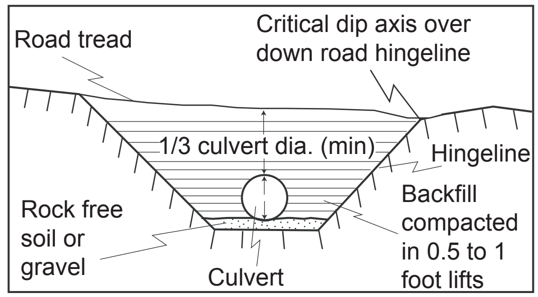


Existing	Upgraded	Upgraded (preferred)
1. Culvert not placed at channel grade. 2. culvert does not extend past base of fill.	1. Culvert not placed at channel grade. 2. Downspout added to extend outlet past road fill.	1. Culvert placed at channel grade. 2. Culvert inlet and outlet rest on, or partially 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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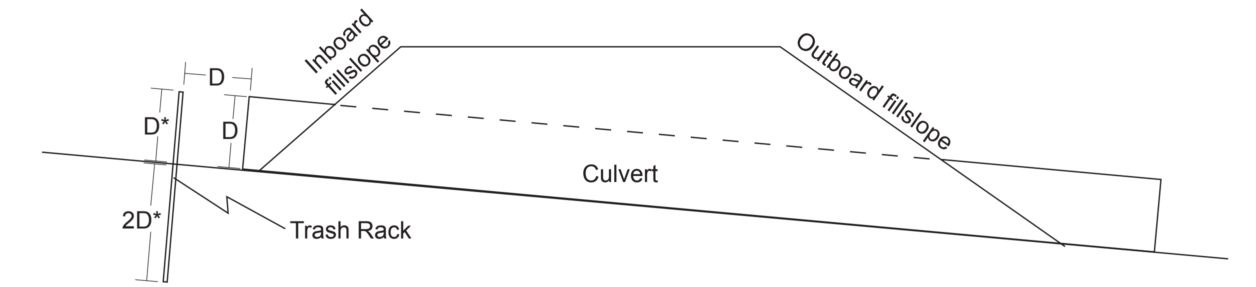
Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



D - Culvert diameter

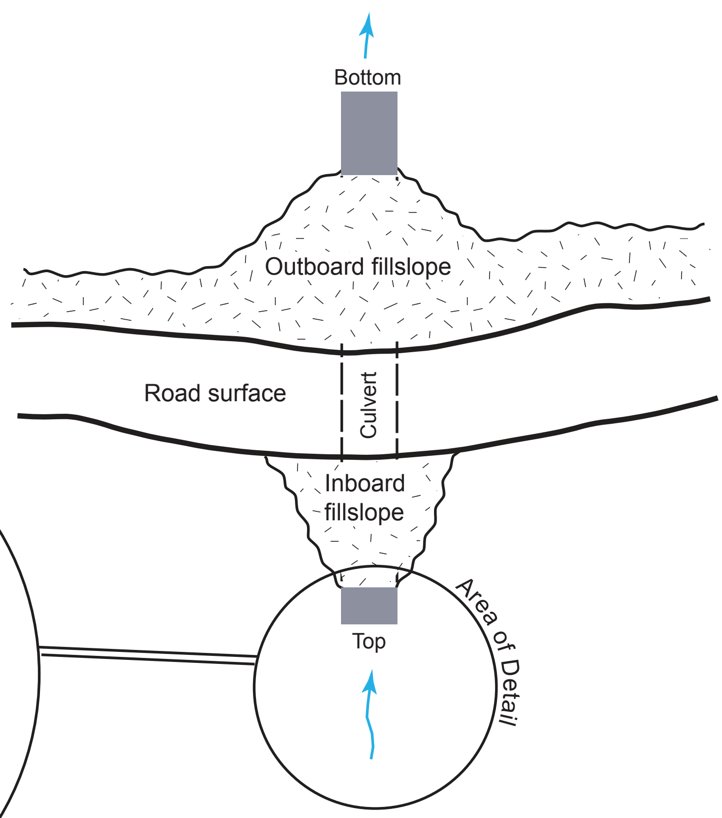
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

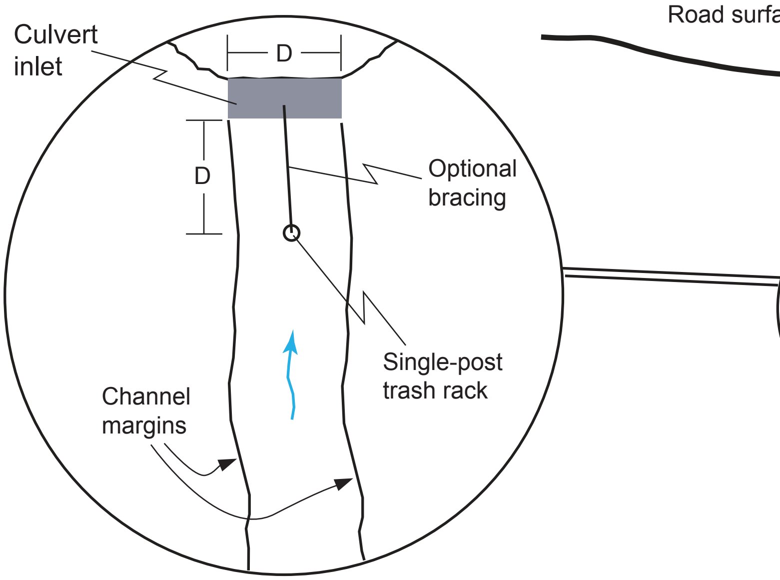
Plan view

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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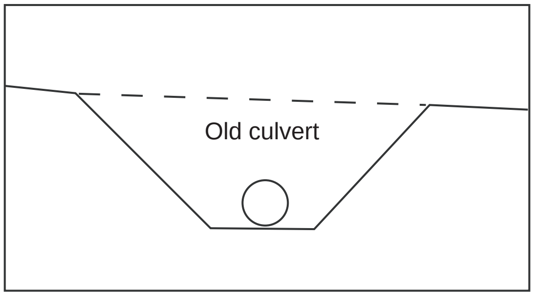
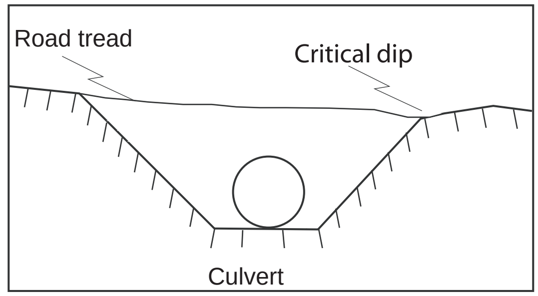
Typical Design of Upgraded Stream Crossings



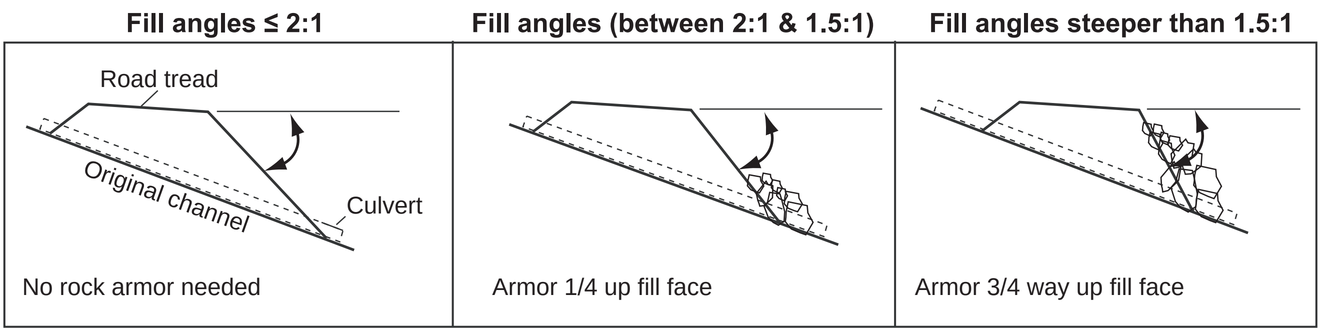


Stream crossing culvert Installation

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



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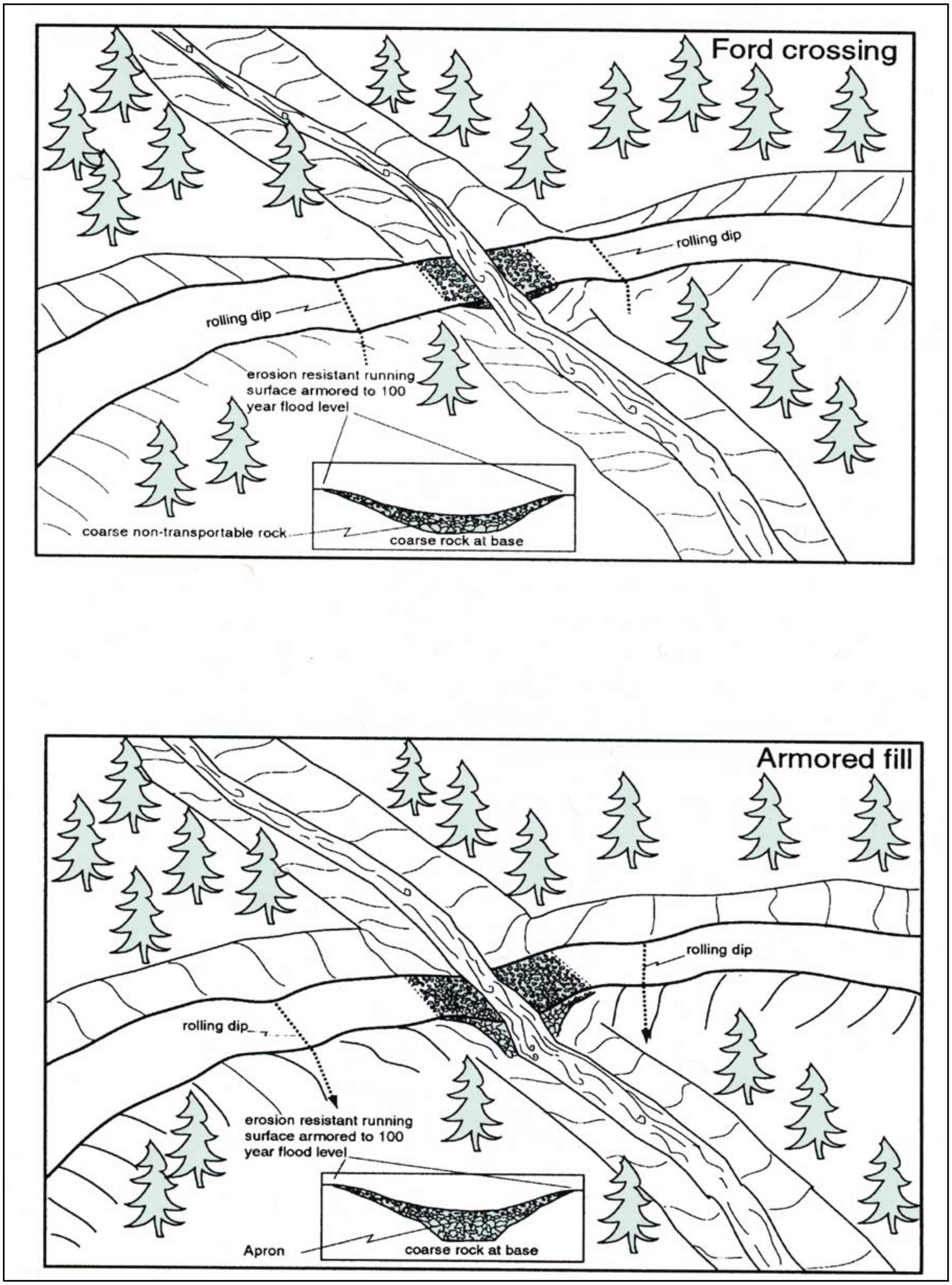
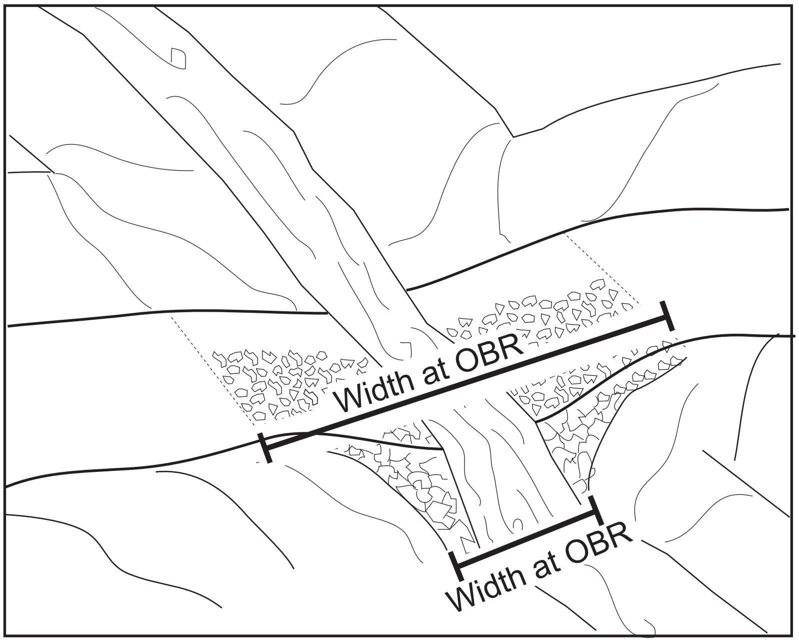


Figure X-15. Typical ford and armored fill stream crossings.

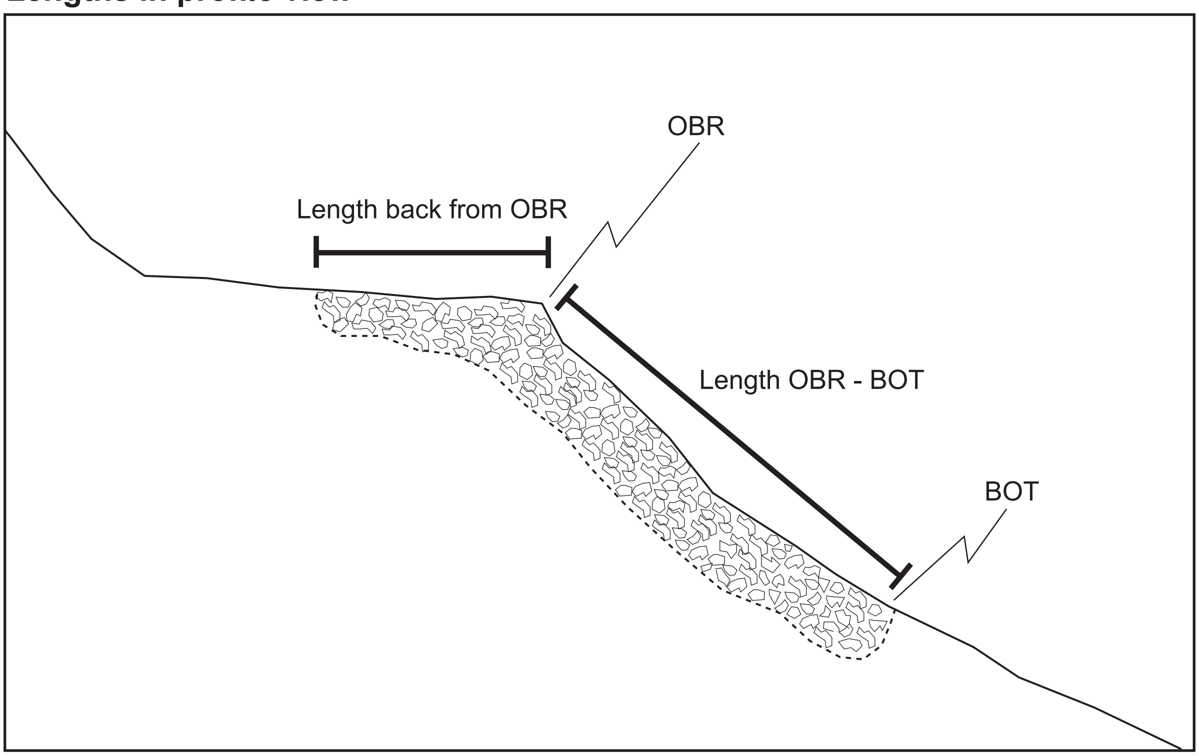
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view

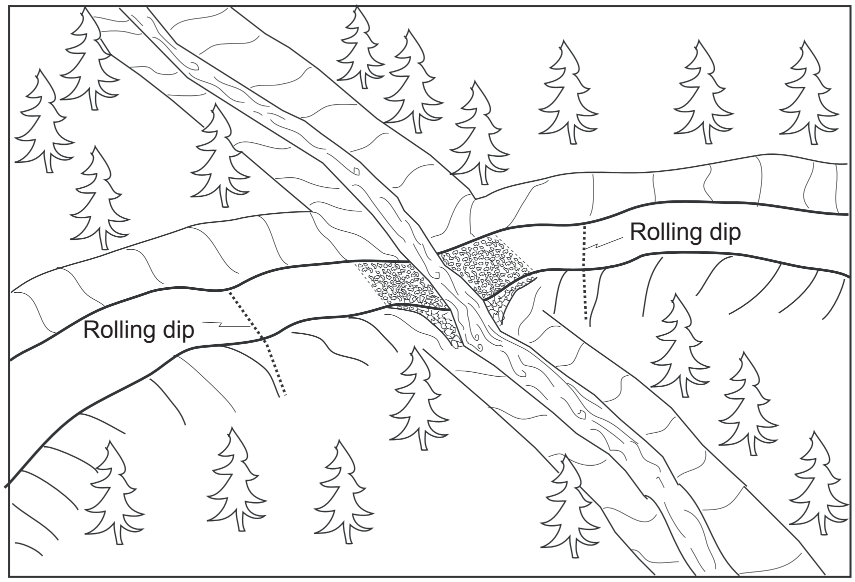


OBR - Outboard edge of road

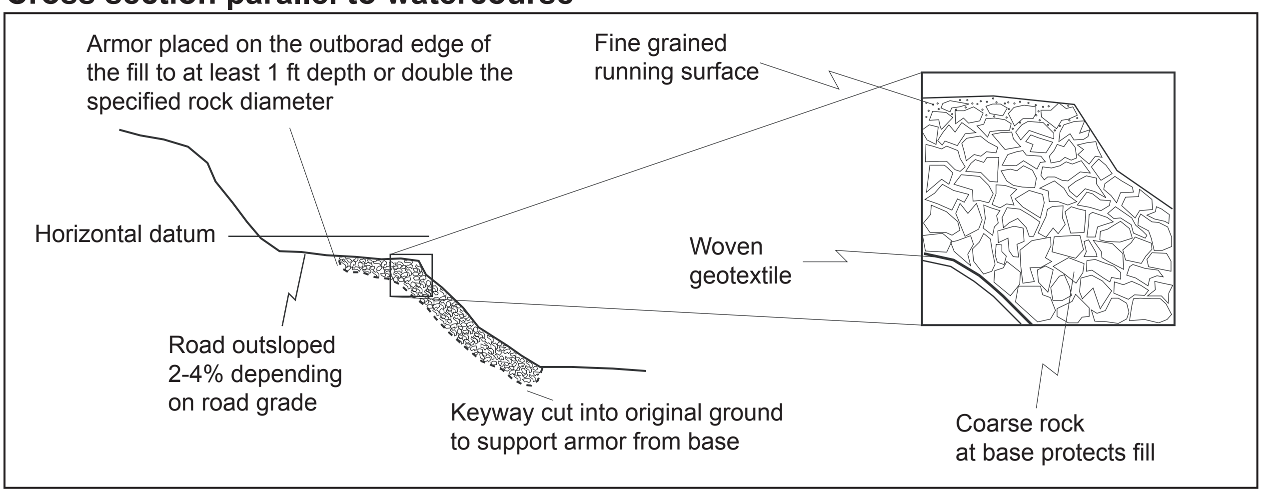
Lengths in profile view



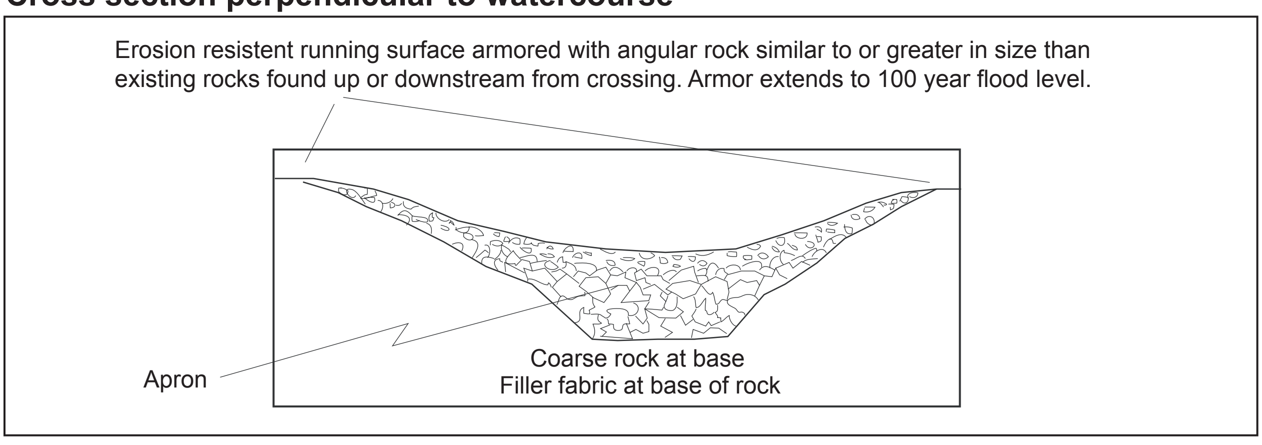
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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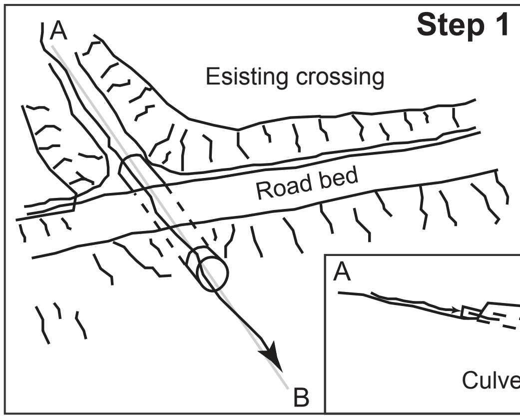
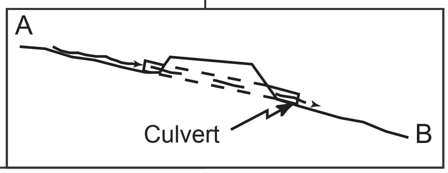
Ten Steps for Constructing a Typical Armored Fill Stream Crossing

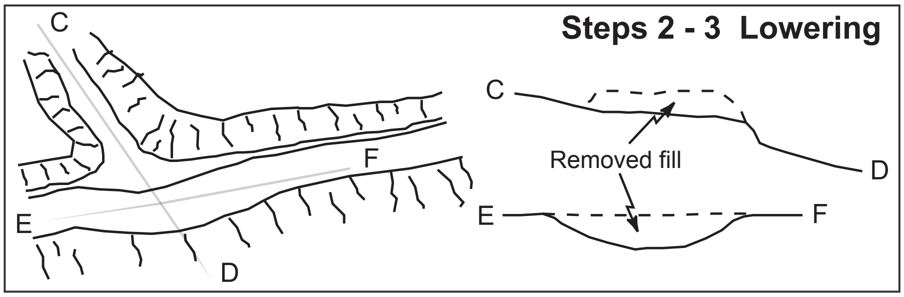




1. The two most important points are:

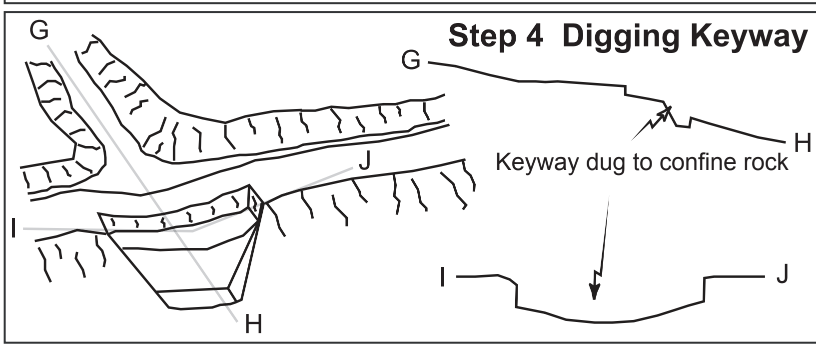
A) **The rock must be placed in a "U" shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

B) **The largest rocks must be used to buttress 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).



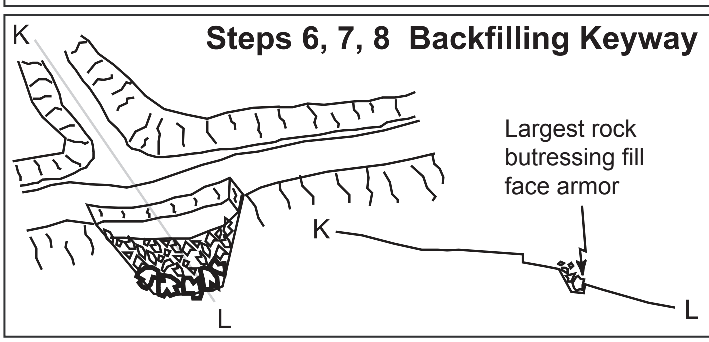
2. Remove any existing drainage structures including culverts and Humboldt logs.

3. Construct a dip centered at the crossing that is large enough to accomodate the 100-year peak storm flow 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).

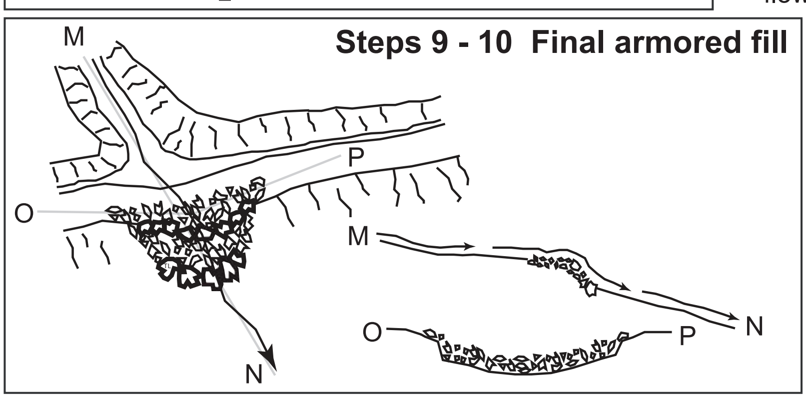
5. Install geofabric (optional) within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.



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

7. Create a buttress 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 buttress 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 accommodate the largest expected flow (O-P).

Typical Drawing #7

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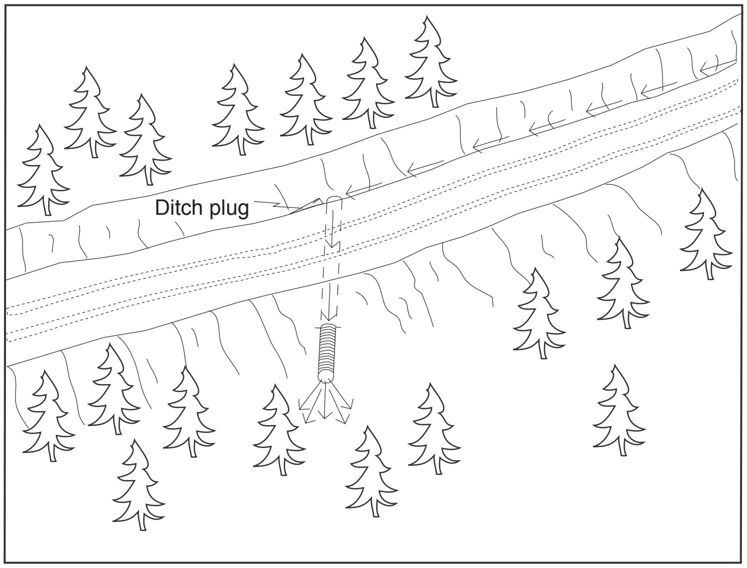
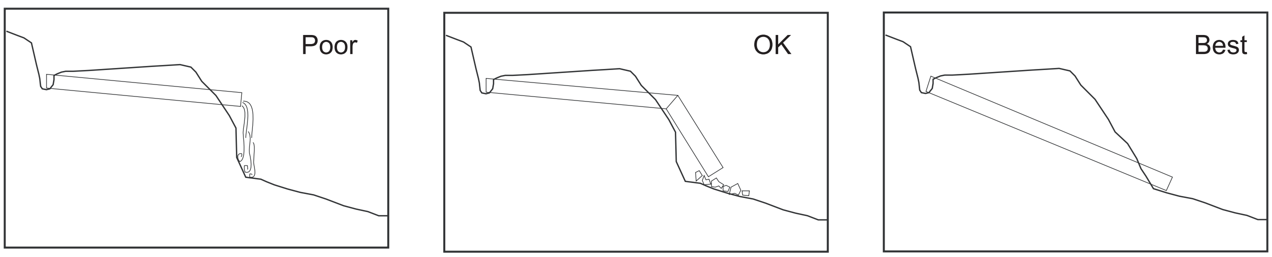
Typical Ditch Relief Culvert Installation





Ditch relief culvert installation

1) The same basic steps followed for stream crossing installation shall be employed.
2) Culverts shall be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts shall be seated on the natural slope or at a minimum depth of 5 feet at the outside edge of the road, whichever is less.
4) At a minimum, culverts shall be installed at a slope of 2 to 4 percent steeper than the approaching ditch grade, or at least 5 inches every 10 feet.
5) Backfill shall be compacted from the bed to a depth of 1 foot or 1/3 of the culvert diameter, which ever is greater, over the top of the culvert.
6) Culvert outlets shall extend beyond the base of the road fill (or a flume downspout will be used). Culverts will be seated on the natural slope or at a depth of 5 feet at the outside edge of the road, whichever is less.

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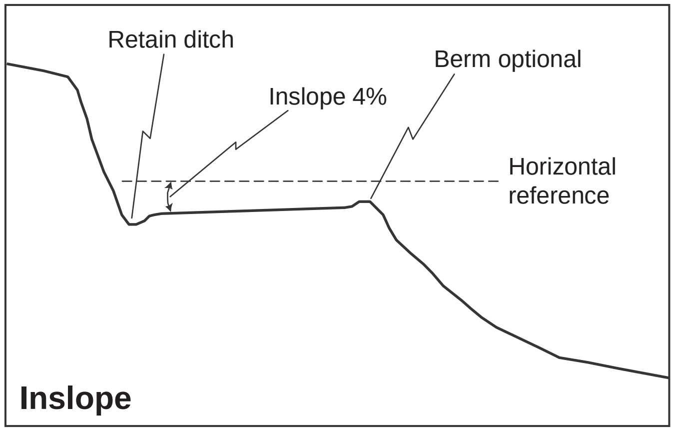
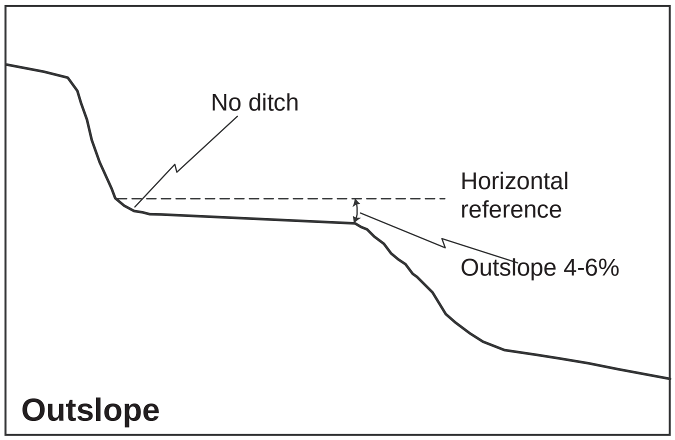
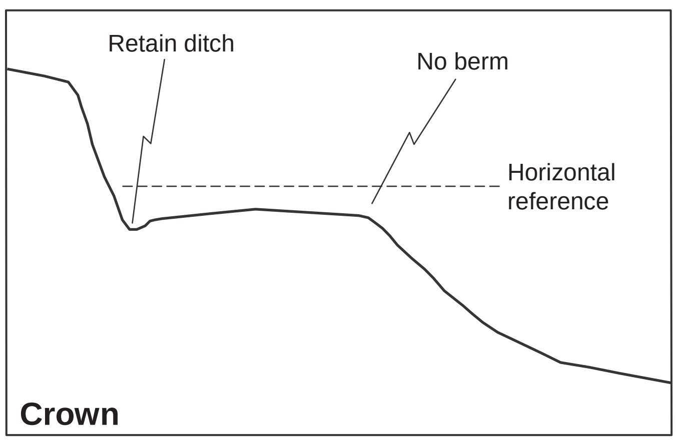
Typical Designs for Using Road Shape to Control Road Runoff







Outsloping Pitch for Roads Up to 8% Grade		
Road grade	**Unsurfaced roads**	**Surfaced roads**
4% or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8% or more	1" per foot	1 1/4" per foot

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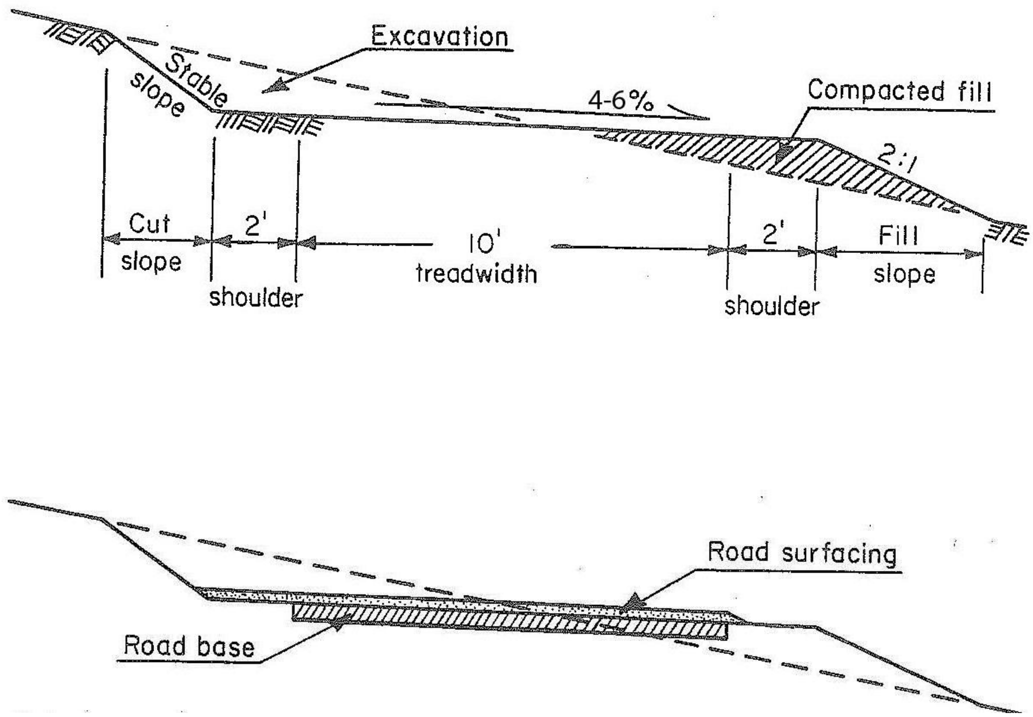
Typical Drawing #9

Typical Design for Outsloped Road



Outsloped Road Notes:

1. Road tread will have at least a 4% outslope, steepening to 6% outlsope along outside shoulder to promote drainage.
2. Edge berms from grading will be completely removed – OR – install compacted edge berm with drainage outlets every 150’.
3. All road surface and fills will be compacted to 95% of ASTM D-698 before final grading.
4. Road base and surface to be designed for road use and site conditions.
5. Cut and fill slopes will be vegetated.
6. For two-lane road, add 6’of treadwidth.
7. For turnout, add 10’ to treadwidth.

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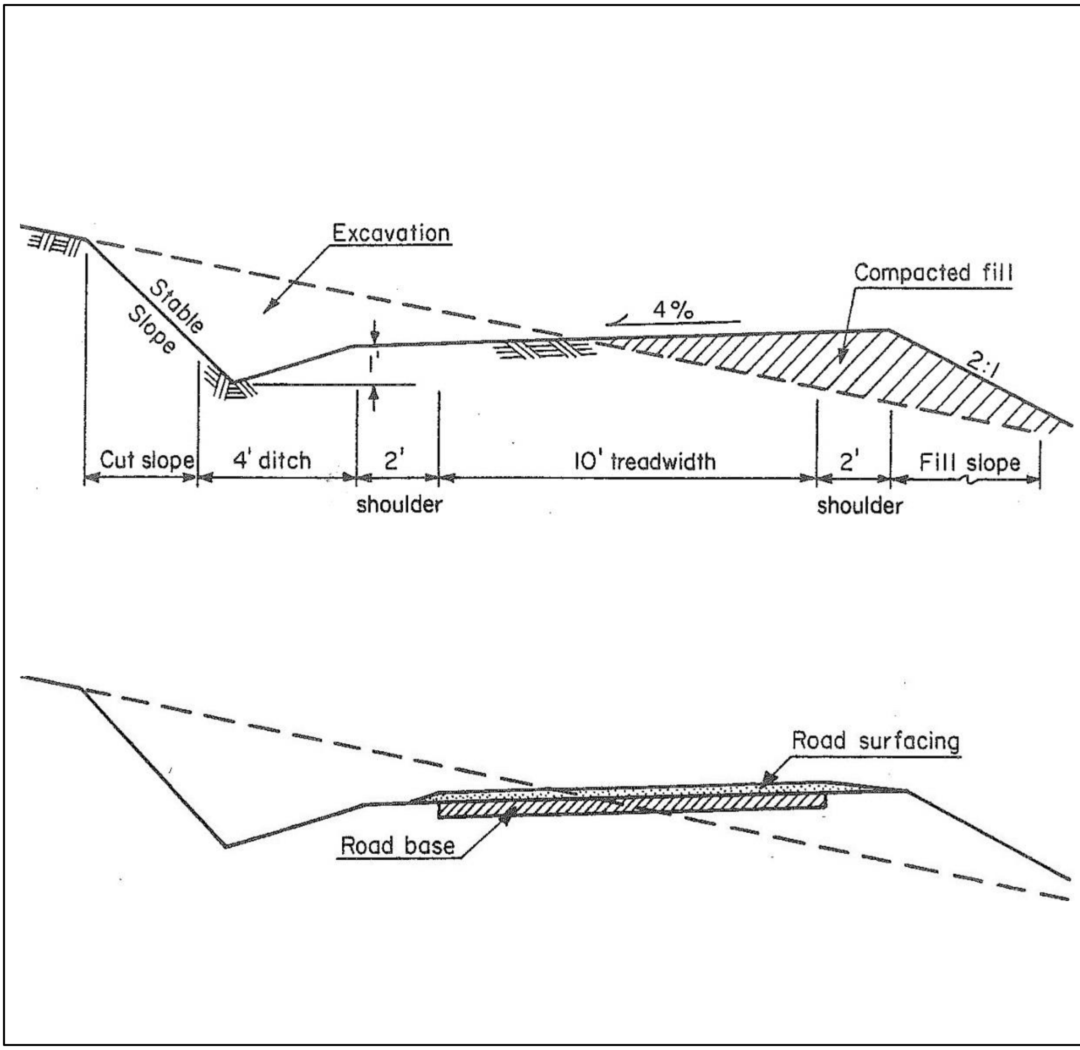
Typical Design for Insloped Road



Insloped Road Notes:

1. Road tread will have at least a 4% inslope.
2. Inboar ditch will be cut with an average 1' depth and 4' width.
3. Inboard ditch will be drained every 150' with ditch relief culverts.
4. All road surface and fills will be compacted to 95% of ASTM D-698 before final grading.
5. Road base and surface to be designed for road use and site conditions.
6. Cut and fill slopes will be vegetated.
7. For two-lane road, add 6'of treadwidth.
8. For turnout, add 10' to treadwidth.

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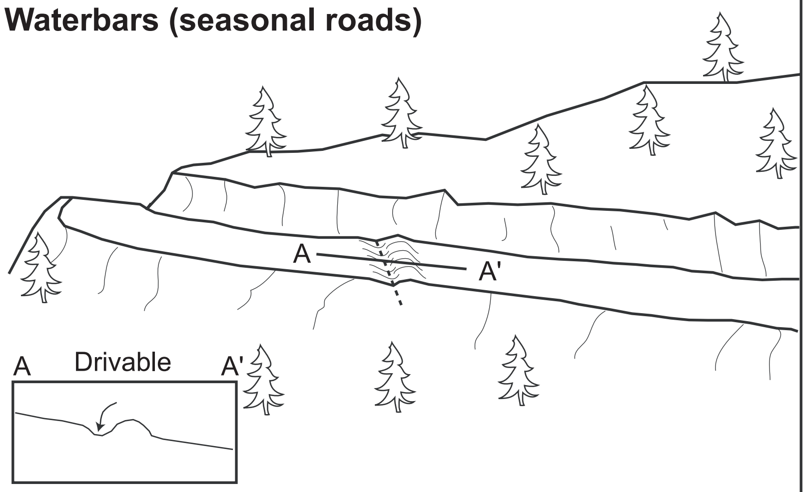
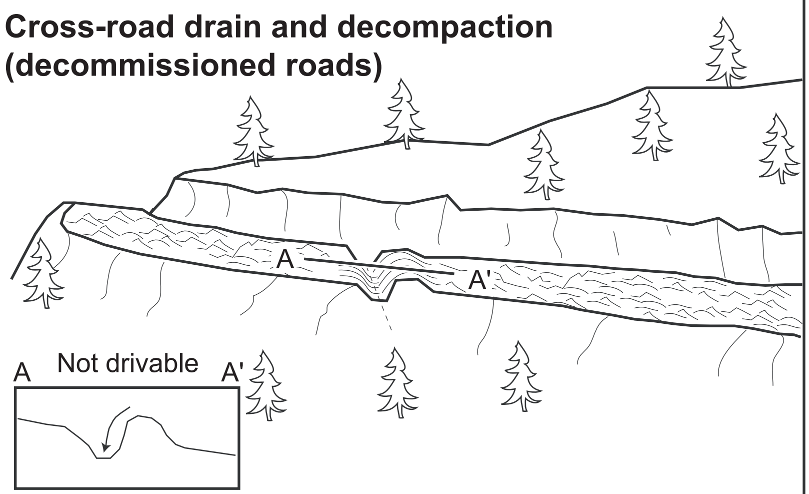
Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips

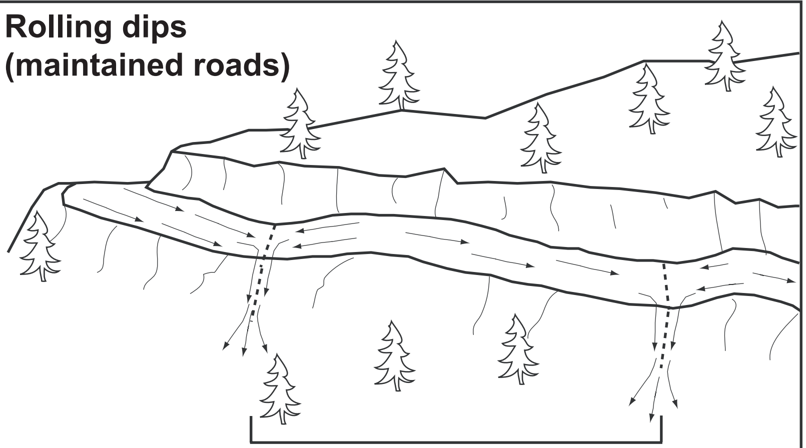
Waterbars (seasonal roads)



Cross-road drain and decompaction (decommissioned roads)



Rolling dips (maintained roads)



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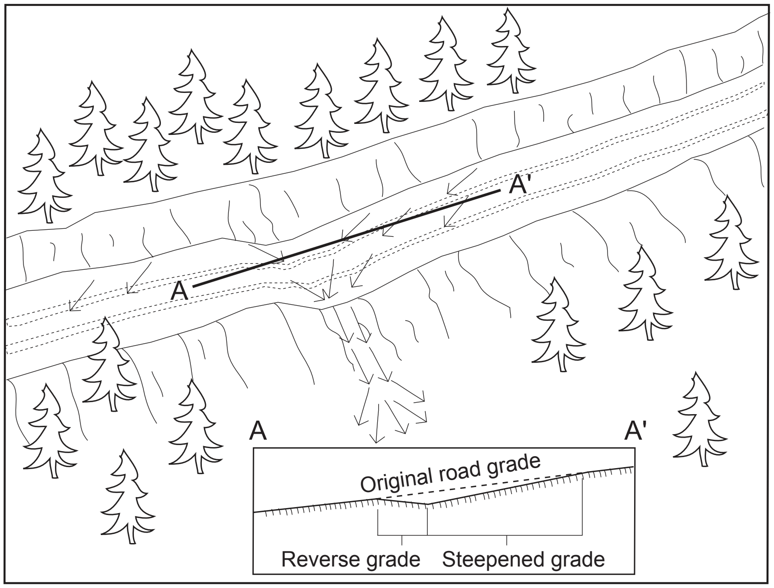
Typical Road Surface Drainage by Rolling Dips



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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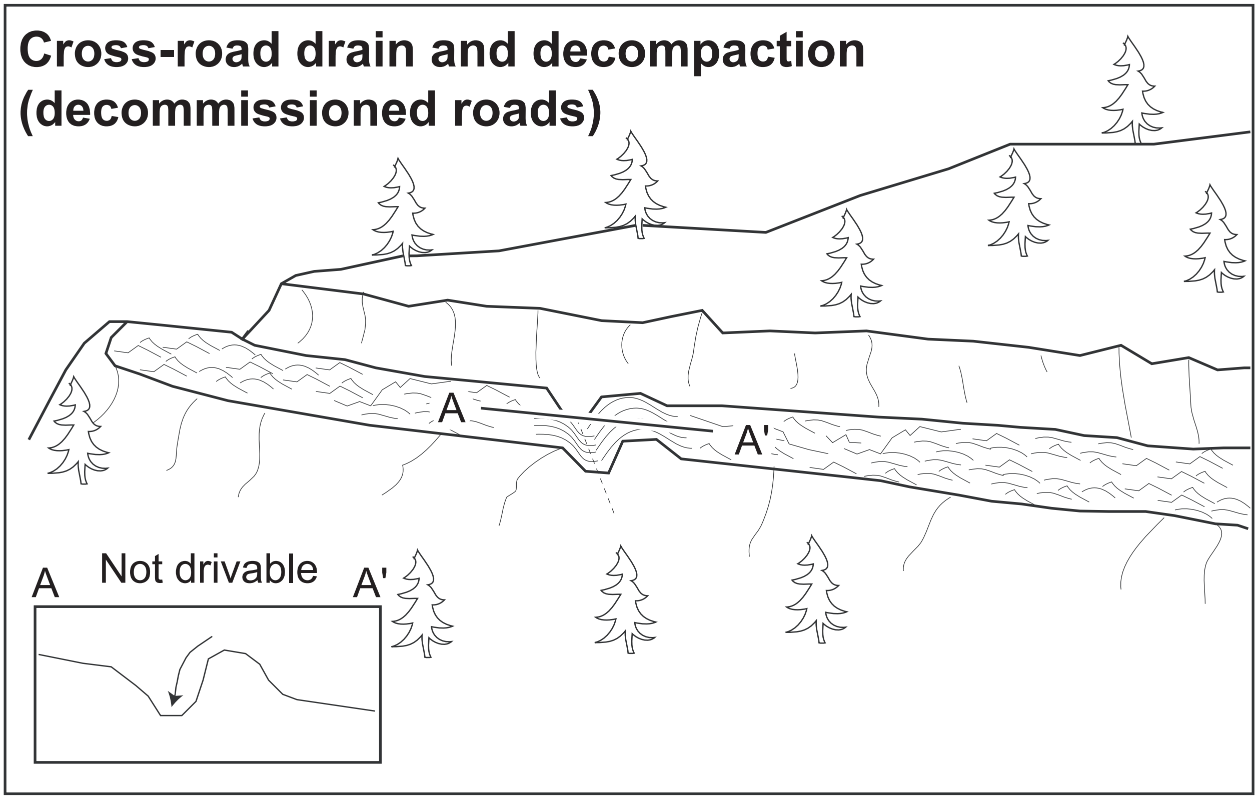

Cross road drain construction will ensure gullies, springs, road runoff and other concentrated flow will no longer collect over long lengths of road causing gully erosion and sediment delivery to streams. Cross road drains will be constructed at approximately 75 ft spacing intervals and these cross road drains will direct road surface runoff off the road onto stable hillslope locations.

Ripping the road surface 16 to 24 inches deep will increase road surface infiltration rates, decompact the road surface, and prevent concentrated runoff. Road ripping will also pulverize the compacted road surface or hardpan and allow for vegetation to establish and recover naturally.

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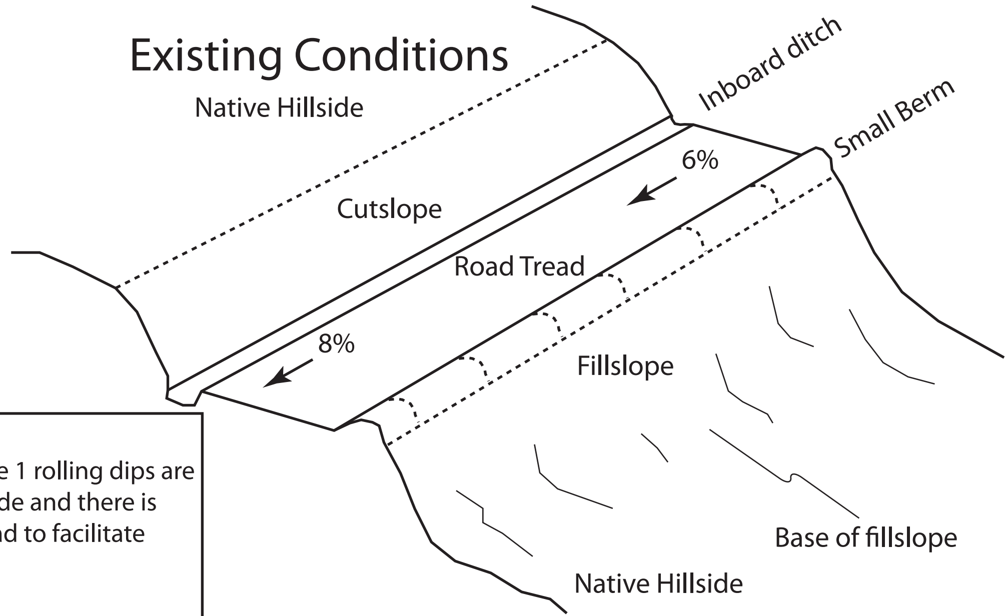
Standard (Type 1) Rolling Dip Construction

Existing Conditions



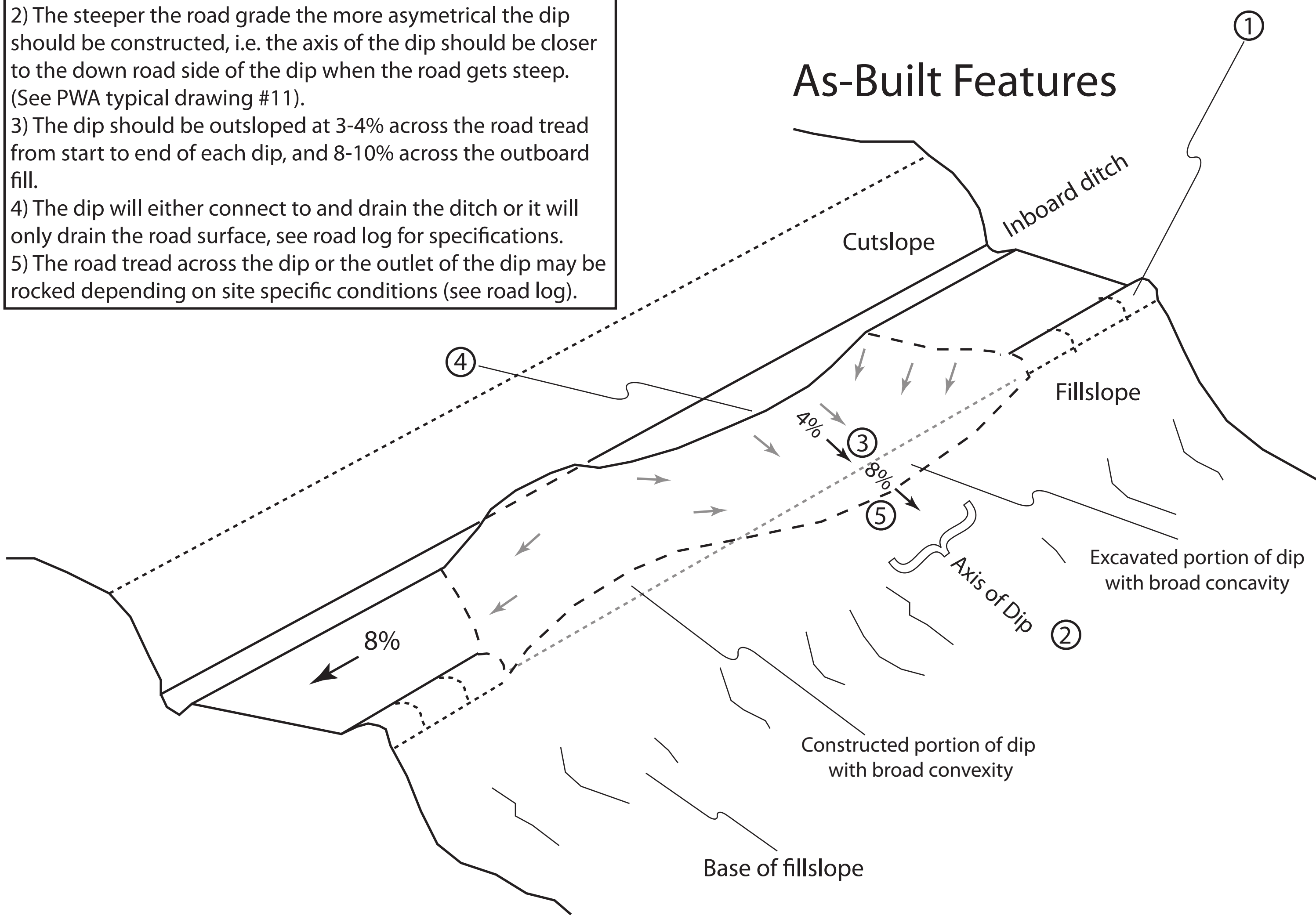
Notes

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).

As-Built Features



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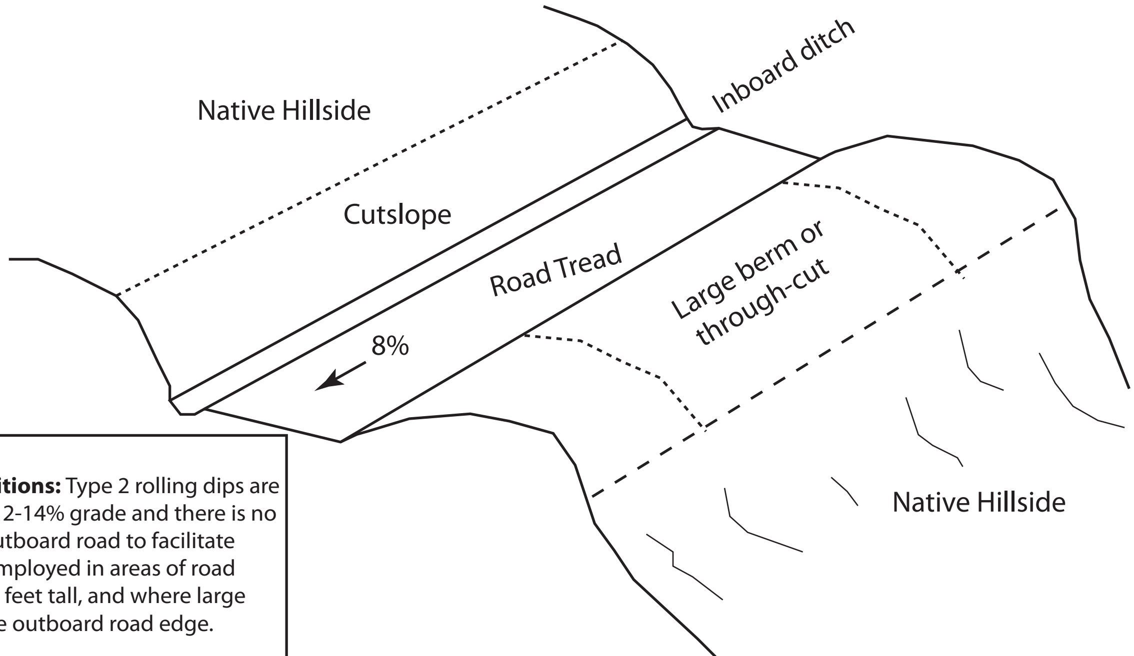
PWA Typical Drawing #19a

Type 2 Rolling Dip Construction

(Through-cut or thick berm road reaches)



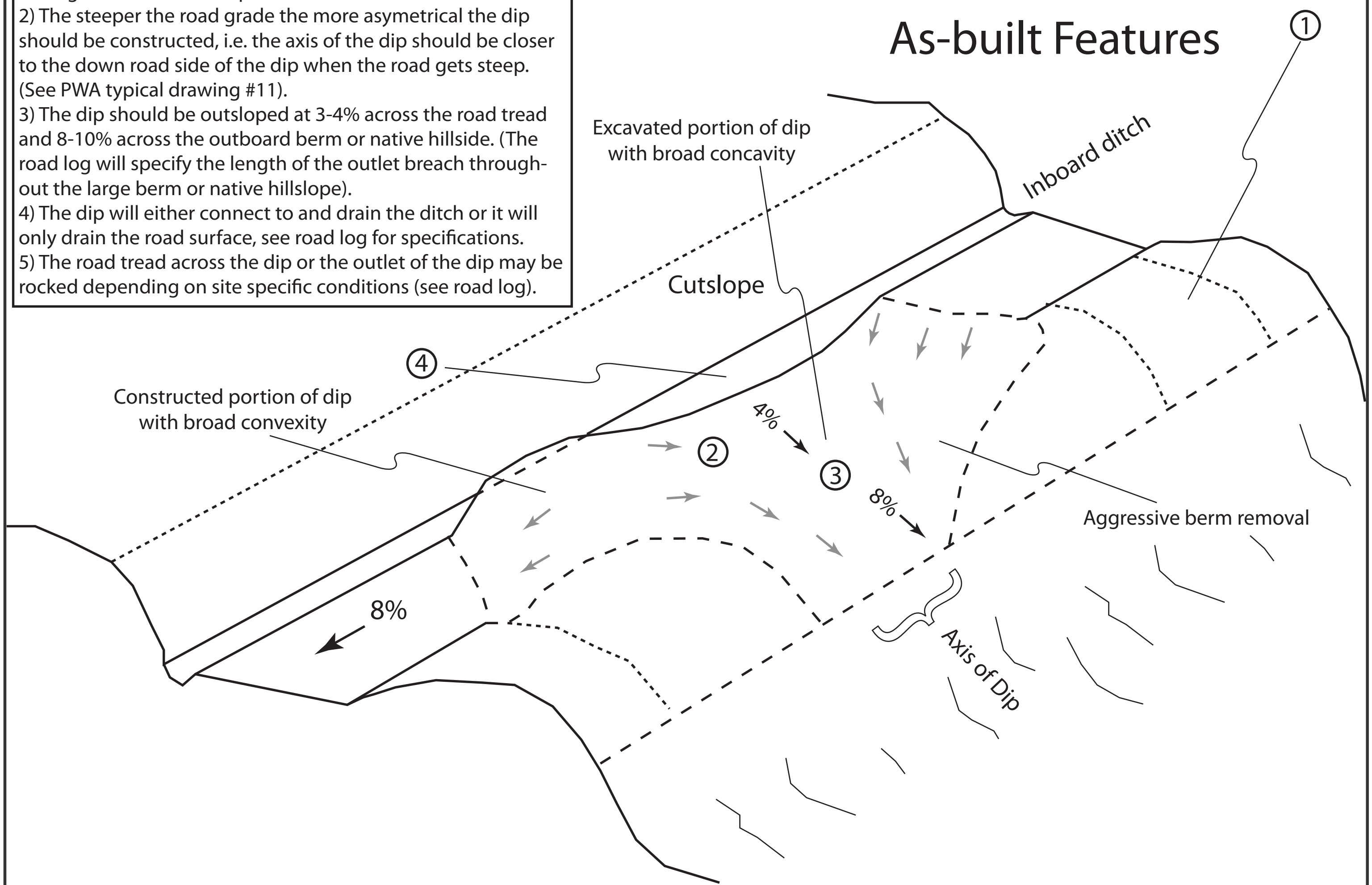
Notes

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 throughout 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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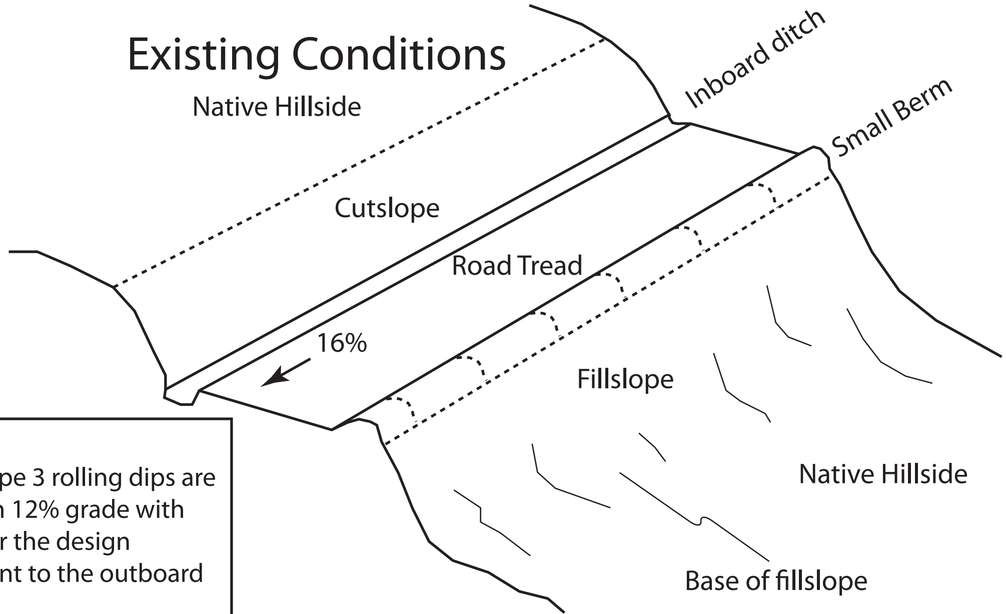
PWA Typical Drawing #19b

Type 3 Rolling Dip Construction
(steep slope outslope)

Existing Conditions

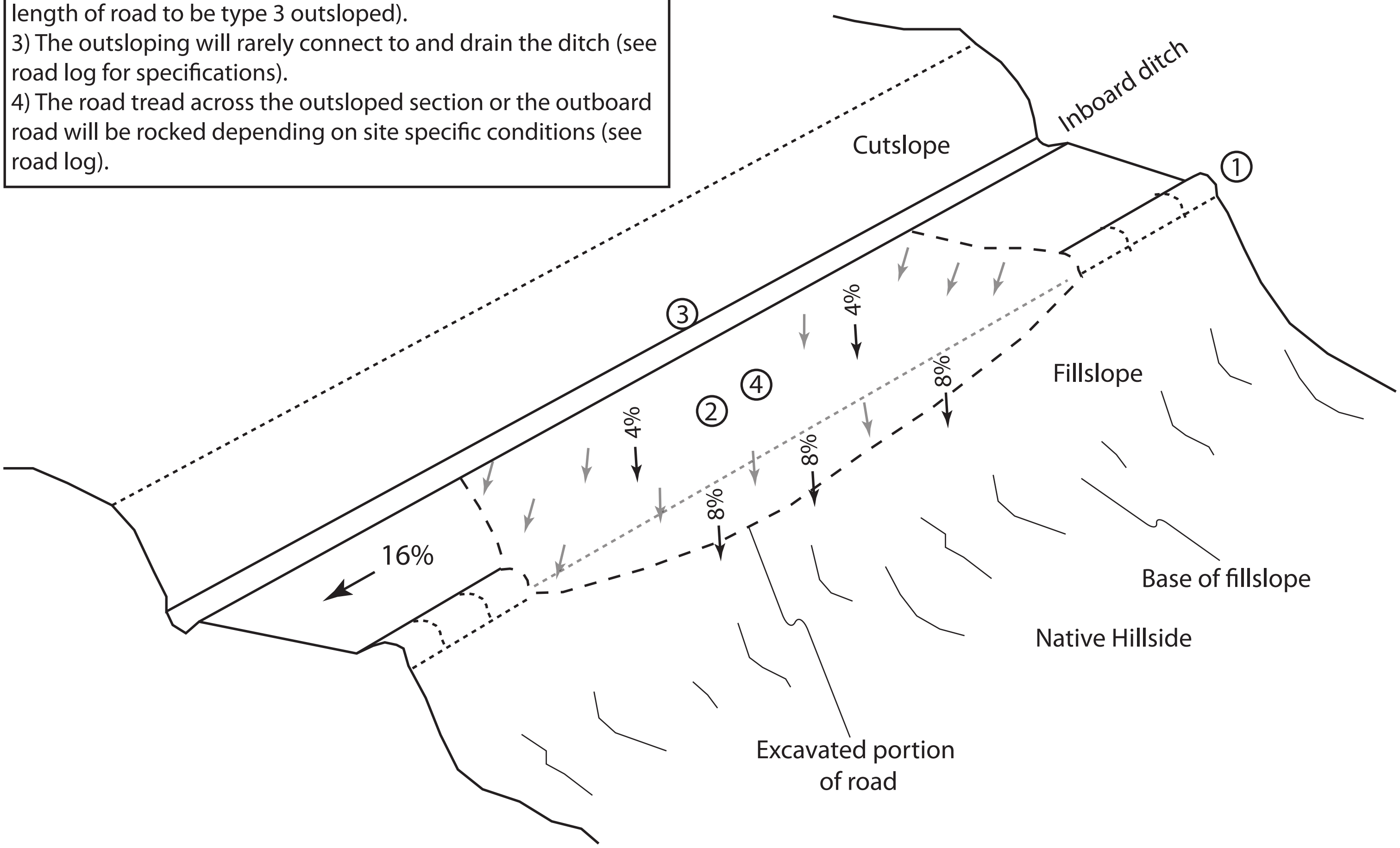


Notes

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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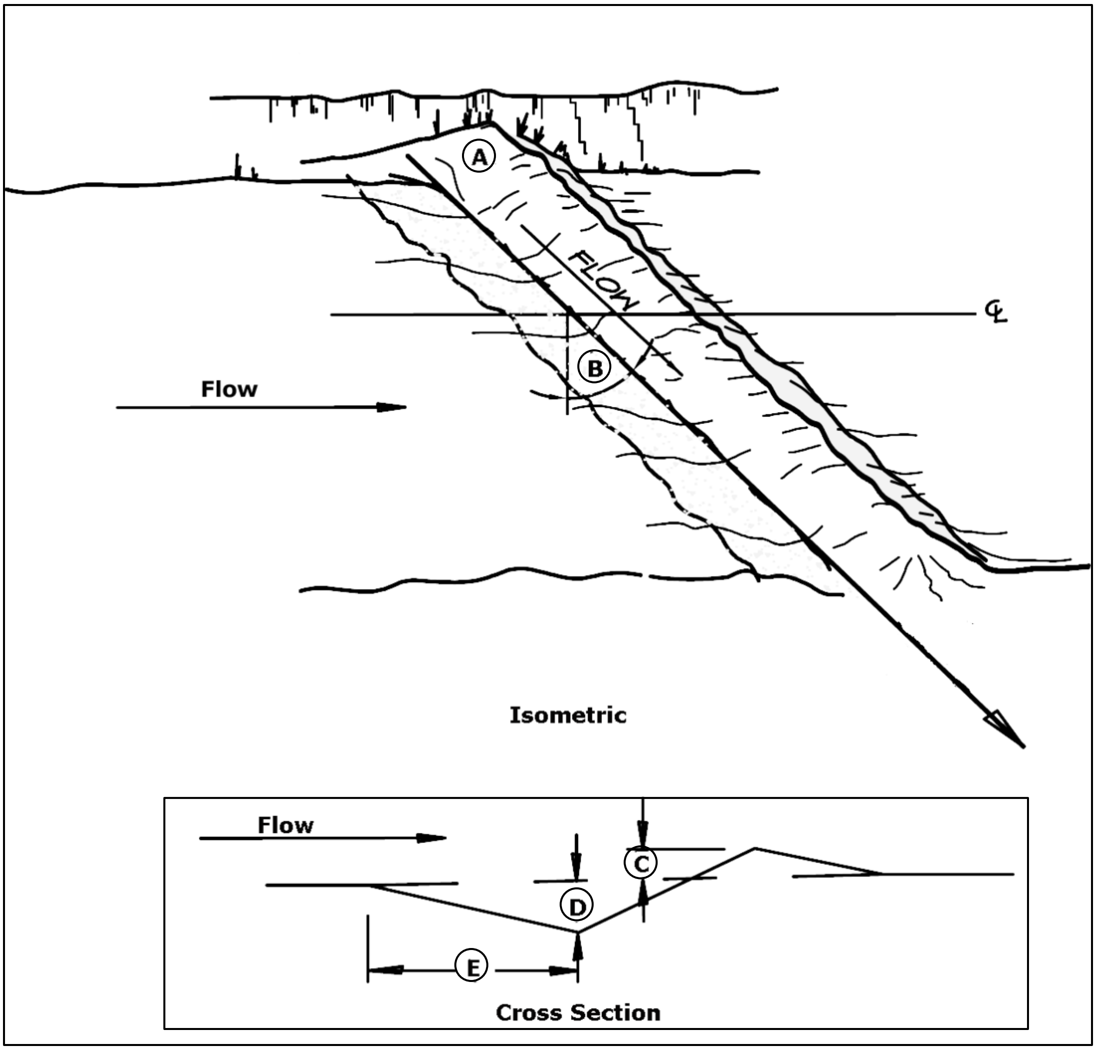
PWA Typical Drawing #19c

Typical Road Surface Drainage by Waterbars



Waterbar installation:

1. Waterbar construction for seasonal use roads. Specifications are average and may be adjusted to conditions.
2. Ⓐ tie-in cut and berm to cutbank.
3. Ⓑ angle waterbar 30^0-40^0 downgrade with road centerline.
4. Ⓒ berm height should be 4”-6” above the roadbed.
5. Ⓓ cut depth should be 4”-6” into roadbed.
6. Ⓔ approach should be 3’-4’ length.

Waterbar spacing: 1,000/slope gradient

Example: @20% slope waterbar spacing =1,000/20=***50 feet***

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Characteristics of Storm Proofed Roads

The following abbreviated criteria identify common characteristics of storm-proofed roads. Roads are storm-proofed when delivery to streams is strictly minimized. This is accomplished by dispersing road surface drainage, preventing road erosion from entering streams, protecting stream crossings from failure or diversion, and preventing failure of unstable fills from delivering sediment to a stream. All bare soils with potential to deliver sediment to streams should be seeded and straw mulched before any rain events occur.

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris).
- Culverts are set in at base of fill and at channel grade.
- Culvert inlet, outlet, and bottom are open and in sound condition.
- Culverted stream crossings have no diversion potential (functional critical dips are in place).
- Culverted stream crossing inlets have low plug potential (trash barriers installed).
- Culverted stream crossing outlets are protected from erosion (extended beyond the base of fill and/or dissipated with rock armor).
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Stream crossings on fish bearing streams meet CDFW and NMFS fish passage criteria.
- Decommissioned stream crossings have been completely excavated to original grade and side slopes are laid back to 2:1 where possible.

Storm-proofed fills

- Unstable and potentially unstable stream crossing and road fills are excavated or structurally stabilized.
- Excavated spoil is placed in locations where it will not enter a stream.
- Excavated spoil is placed where it will not cause a slope failure or landslide.

Road surface drainage

- Year round use roads are either paved or rocked well enough so that none of the native surface is visible and raindrop impact is absorbed by the applied surface.
- Un-surfaced roads are either closed during rainy periods of the year or are not used when the road surface is wet.
- All road surfaces are disconnected from streams by implementing a variety of surface drainage techniques including construction of rolling dips and /or waterbars, installing ditch relief culverts, berm removal, and road surface shaping (outsloping, insloping, or crowning).
- Ditches and cutbanks are disconnected from streams by frequently draining them with rolling dips or waterbars &/or ditch relief culverts.
- Outflow from rolling dips and ditch relief culverts do not discharge to streams or onto active (or potentially active) landslides.
- Gullies (including those below ditch relief culverts) are dewatered to the extent possible.
- Decommissioned roads have been de-compacted (ripped) and have frequently installed permanent drainage structures (cross road drain) to prevent runoff contribution to streams.