2022 Erosion and Sediment Control Field School Presentations- Thomas H Leroy

Fundamentals of Road Impacts and Erosion Processes

2022 Salmonid Restoration Federation Roads Training Workshop

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Primary Impacts from Roads

- Accelerated sediment delivery
  - Episodic erosion and sediment delivery (typically a mix of coarse and fines)
  - Chronic erosion and sediment delivery (typically fine grained sediment)

- Altered surface and ground water hydrology
  - Road cutslopes can drain shallow ground water
  - Road runoff can reduce groundwater recharge
  - Road runoff can put peaks in the watershed hydrograph

Accelerated sediment delivery from roads can impact downstream beneficial uses

- *Episodic erosion and sediment delivery*- This typically results from high intensity storms that cause local and regional stream crossing washouts and landslides, this type of erosion is relatively easy to identify and is manifest as large gullies, major washouts and fillslope mass wasting.

- *Chronic erosion and sediment delivery (Stealth sediment)*- This typically results from small to moderate rainfall events that wash dust and ground up earthen material off of the road surface and into the streams, it is often hard to observe during the dry season.

Episodic erosion

Chronic erosion and sediment delivery

"Stealth Sediment"

Altered surface and ground water hydrology

- It is important to remember that roads don't only represent a source of accelerated sediment delivery to streams they also have the ability to significantly impact water resource availability throughout a watershed.

As an example: if a watershed has the following characteristics:

120 miles of road that is 12' wide

50% of the roads are hydrologically connected to the stream network

It receives 96" of rainfall in a year.

This equates to approximately 227,487,744 gallons of water a year being routed off of the landscape via the road system……

Altered surface and ground water hydrology

- 227,487,744 gallons!

Lets put this within the perspective of how much water the cultivation process actually uses

If a cultivator uses 500,000 gallons per year watering their cannabis…..

Rainfall	amount of hydrologic disconnection to offset water use
8′ (96″)	694′
4′ (48″)	1,388′
2′ (24″)	2,776

Some watershed impacts from road systems

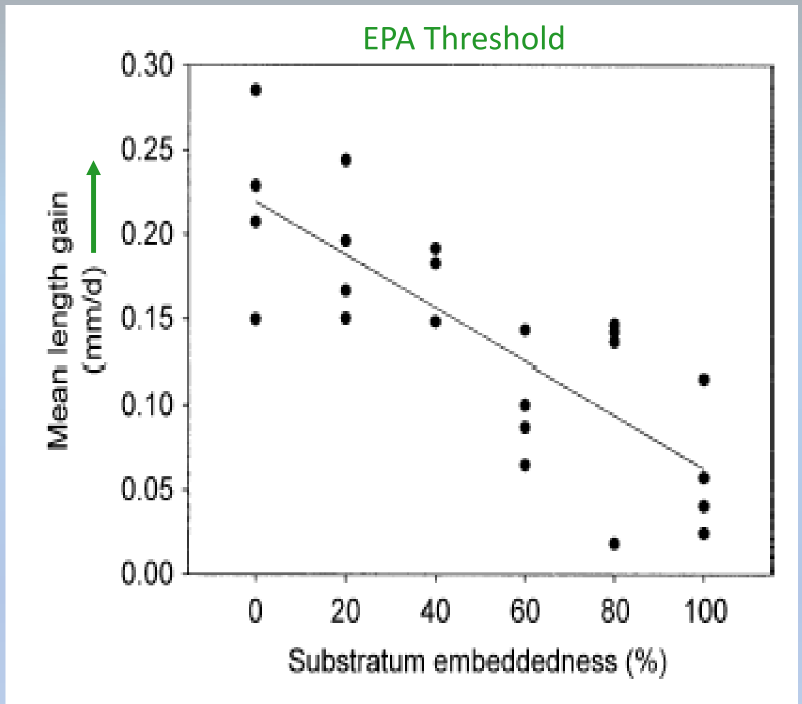
- Erosion and sediment delivery from road systems
  - Increased turbidity- impacts many downstream beneficial uses (impacts fish health, reduces drinking water quality, impacts amphibian health)
  - Increased sediment loads- impacts channel geomorphology (reduces channel capacity, increases flooding, causes channel avulsion, impacts fish spawning grounds, simplifies channel geomorphology)
  - Increased road maintenance costs

- Altered surface and ground water hydrology from road systems
  - Can drain shallow ground water (can reduce summer base flows)
  - Can put peaks in the winter hydrograph (can cause channel erosion, can increase maximum discharge and stream flow velocities)
  - Can reduce ground water recharge (can reduce summer base flows)

Fine sediment impacts on fish, their habitat and water quality

- Spawning gravel quality
- Pool habitat frequency
- Pool depth
- Inter-gravel flow rates
- Embeddedness
- Fish growth rates
- Quality and quantity of food sources
- Turbidity
- And there are others……..

Turbid water in an anadromous fish stream



Impacts on juvenile growth
(Suttle et al., 2004)

Sigler et al. (1984) found that turbidity values as low as 25 nephlometric turbidity units (ntu) caused a reduction in juvenile steelhead and coho growth.

High turbidity during winter likely impacts the feeding ability of juvenile salmon, steelhead or cutthroat trout, and the longer the duration of high turbidity the more damage is likely to fish and other aquatic organisms (Newcombe and MacDonald, 1991).

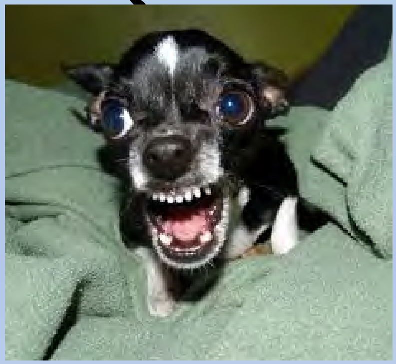
So How are these impacts to water and salmonid habitat occurring?

All land use activities can play a role in upland erosion and sediment production,

however,

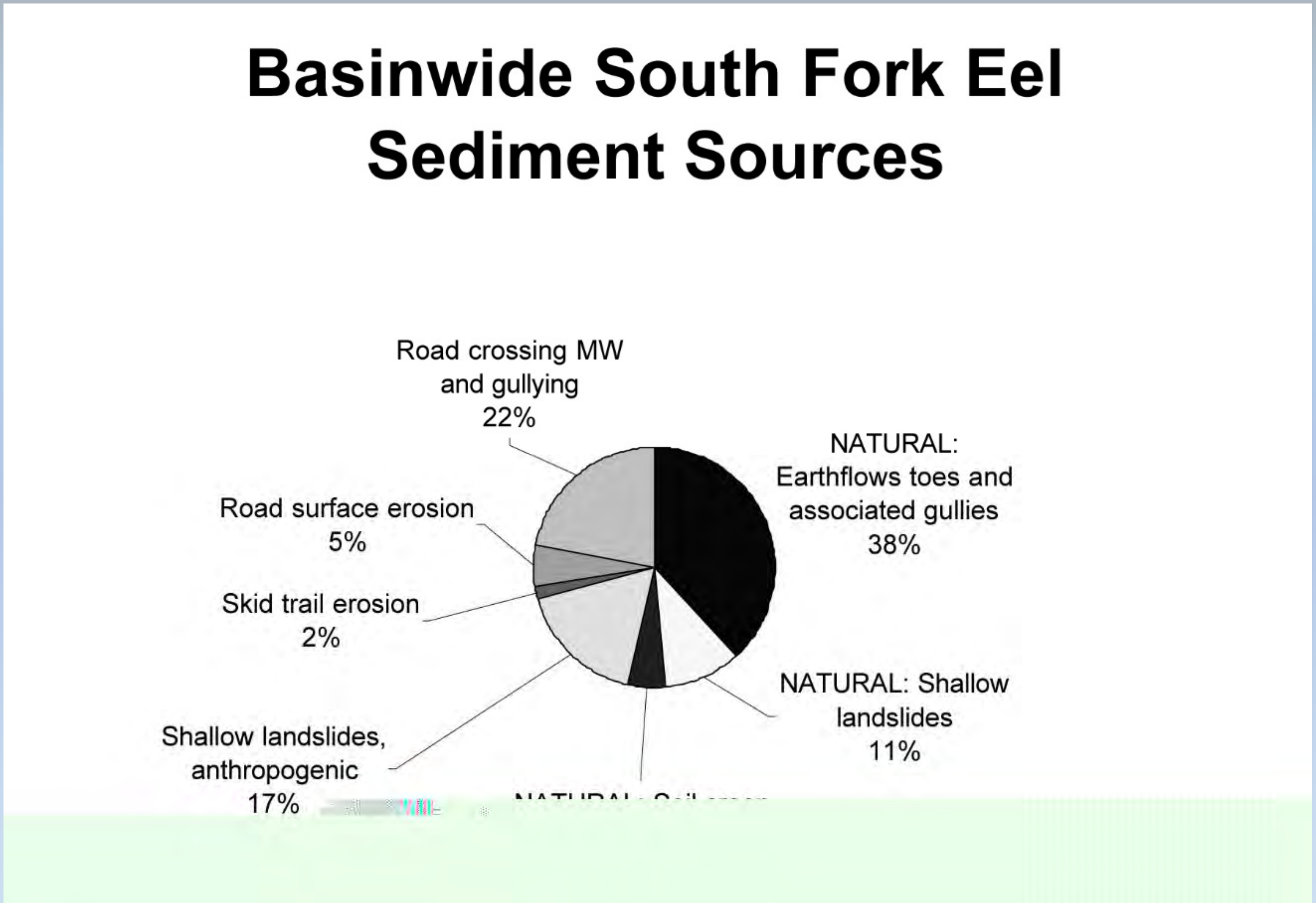
the U.S. EPA, NOAA Fisheries and State Water Quality Control Boards believe "controlling road-related erosion and sediment delivery" is a major necessity to reverse the observed negative trends.

Cumulative impacts…AKA
(The tragedy of the commons)
(Death by a thousand cuts)
(Mauled by a pack of chiwawas)



- Individuals acting independently and quasi-rationally according to each's self-interest behave contrary to the best interests of the whole group by depleting some common resource such as water volume, water quality, and fisheries resources

Lets consider typical basin wide sediment sources



Types of Erosion

- Surface Erosion
- Gully Erosion
- Channel Erosion
- Mass Wasting (landslides)

Soil Pedestals (surface erosion)

Rills (gully erosion)

Note: a rill is essentially a gully that has less than a 1'x1' cross-sectional area

Gully Erosion

Channel erosion

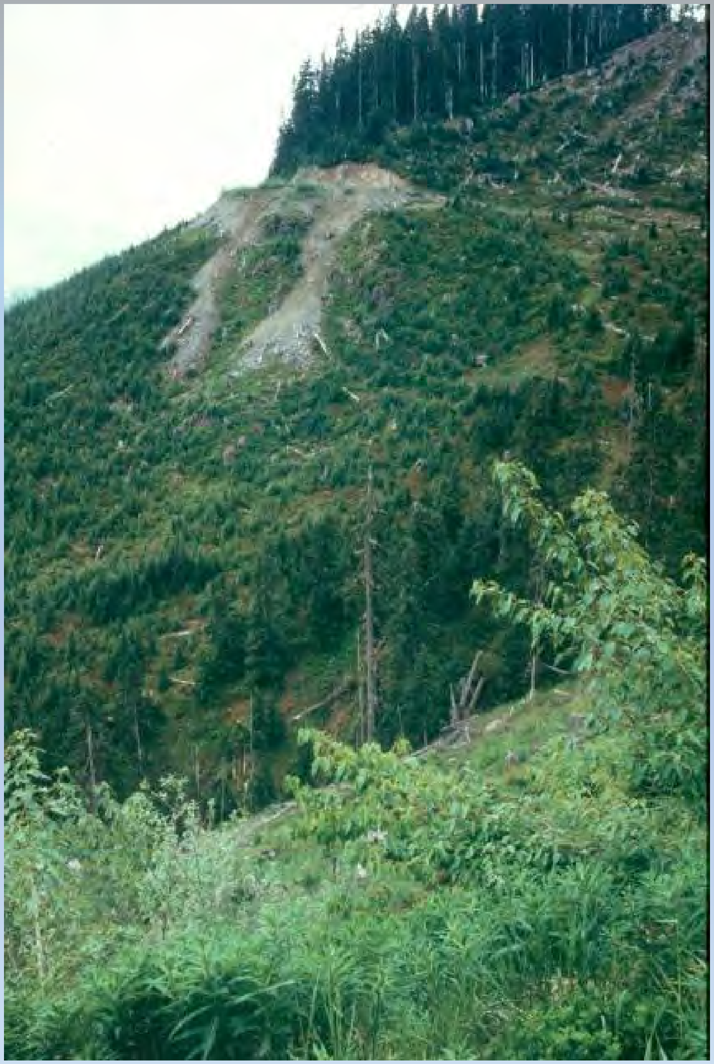
Landslides (mass wasting)

Sediment Production

versus

Sediment Delivery

Non-delivering fillslope landslides



Washed-out stream crossing

Cutbank surface erosion

Hydrologic Connectivity

Fine sediment discharge

Road Surface, Cutbank and Ditch Erosion

<u>Road surface erosion</u> is caused by mechanical abrasion and poor road surface drainage…

Sediment delivery occurs where road surfaces and ditches are "hydrologically-connected" to stream channels.

Pot holes – poor road drainage

Road Surface Erosion

Road Berms: Outsloped Road

Sediment from seasonal road

Road Surface Erosion

Road Surface Erosion

Road Surface: Mechanical Abrasion

Road Surface Rilling

Road Surface Rilling

Road Surface Gullying

Road Surface Gullying

Road Surface Rutting

Road Surface Rutting

Road Surface Rutting

Road Surface Erosion: Ruts

Road surfaces and eroding
cutbanks feed active ditches…

Cutbank Erosion

Ditch Sediment Transport

Ditch Erosion

Ditch Relief Culvert: Gullying

Ditch Relief Culvert: Gullying

Ditch Relief Culvert:
Gullying and Connectivity

Mature, Hydrologically Connected Gully

Ditch Relief Culvert Connectivity

Dispersing Road Runoff: Berms

Road Berms: Crowned Road

Road Berms: Insloped Road

Road Berms: Outsloped Road

Breached Berm and Gully

Road Surface Erosion and Sedimentation

Hydrologic Connectivity

Hydrologic Connectivity of Roadside Ditches

Connectivity of Roads and Ditches

Sedimentation from Ditch

Connectivity from upslope ditch relief culvert

Intentionally Connected Road Surface

Quiet, but common, connectivity

Classical Road Drainage Engineering: Connected Road, Cutbank and Ditch

Treated Road - Clean Connectivity

Sediment delivery occurs where the road prism, including road surfaces and ditches, are "hydrologically connected" to stream channels

What to look for… *(identifying hydrologic connectivity)*

- Road surface and/or ditch draining into or leading to a stream crossing drainage structure inlet or outlet;
- Evidence of surface flow between the drainage structure outlet and a natural stream channel/flood prone area;
- A channel or gully that extends from a road drainage structure outlet to the high water line of a defined channel or a flood prone area;
- A sediment deposit that reaches the high water line of a defined channel or a flood prone area;
- Observation of turbid water reaching the watercourse during runoff events; or
- Indications of channel widening and/or incision below a drainage structure resulting from increases in flow.

Quantifying Chronic Road Surface Erosion

road width x road length x decadal surface lowering rate = Erosion volume over next 10 years

Decadal erosion volume x percent of material that delivers to stream = Future sediment delivery

Example: 100' of road that is 15' wide flows to a rolling dip. You estimate the road is lowering at a rate of .2' / decade. At the outlet of the rolling dip there is evidence that some of the sediment is settling out on the hillside in a grass thicket. There is also evidence that some of the sediment is being routed to a proximal stream via a raw, vertical banked, active gully with dimensions 50'L x 1.5'w x 1'd. (you estimate 50% of the sediment is delivered to a stream).

What is your expected future sediment delivery over the next decade? Consider everything!

100' x 15' = 1,500 sq. ft. of road surface area

1,500 sq. ft. x .2' of surface lowering per decade = 300 cu. ft./decade

300 cu. ft. x 50% sediment delivery = **150 cu. Ft./ decade = 5.5 cu. Yds.**

Are we forgetting anything?

Quantifying Chronic Road Surface Erosion….. Continued

What are we forgetting……..the gully…..

The gully is showing evidence that it is active and has the potential to enlarge.
How do we estimate the future enlargement of the gully?.......We estimate future enlargement of the gully

This is a subjective call, like many of the calls you will be required to make, what is important in this process is consistency not necessarily accuracy.

Criteria you should be considering:
How vulnerable to erosion is the hillside?
Is it revegetating?
Will the gully enlarge under existing conditions? Will it simply lay back to stable sideslopes?

You will need to make a series of scientific, defendable observations to support your call…..There is no right or wrong answer because were making a guess founded in a scientific process.

Keep in mind, you have never seen a 100-year return interval rainfall event, but its fair to say a biblical scale event like that would likely result in significant erosion, even under some of the most stable conditions.

Features to quantify when estimating future road surface related erosion…

Road surface erosion
Cutslope surface erosion
Ditch erosion
Gully erosion

Once you have quantified all of your erosion sites (Chronic and episodic), you can begin the process of prioritizing your road segments for treatment (H, M, L)

Prioritizing Road Surface Treatments

Prioritizing any suite of treatment prescriptions relies on two primary field observations:

(1) The likelihood of the erosion to occur (Erosion Potential)

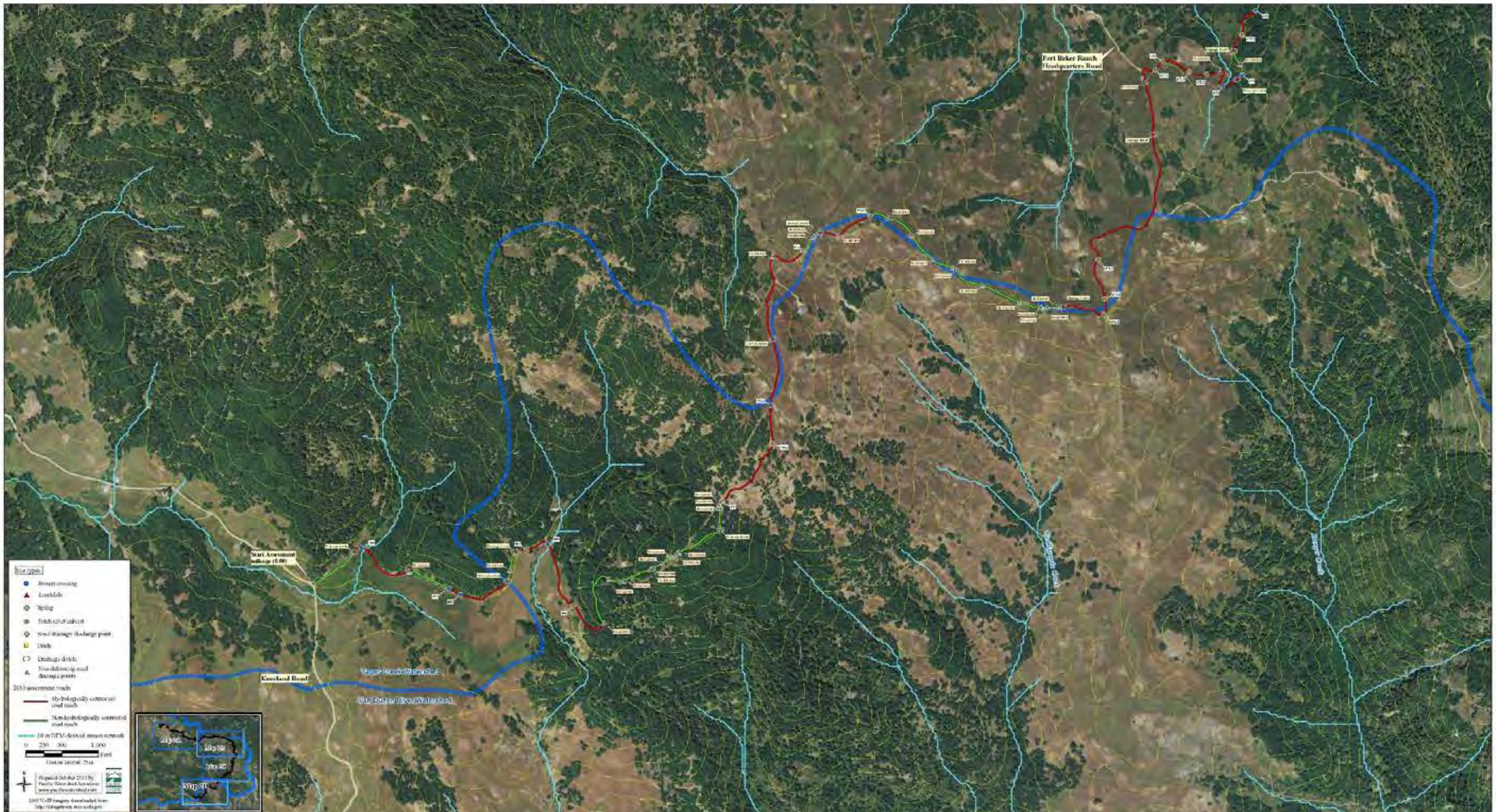
Criteria you should be considering:
How vulnerable to erosion is the hillside?
Is it revegetating?
Will the gully enlarge under existing conditions?
Will it simply lay back to stable sideslopes?

(2) The expected magnitude of future erosion (Future Potential Delivery volume)

More often than not, the individual treatment priorities for your sites will be relative to the other sites Within your project area.

The cumulative suite of treatment priorities and expected future sediment delivery for your project area can be used to prioritize several areas within the greater project area or compare to other regional projects.

Typical PWA road surface connectivity map



Map 2d. Inventoried sites by problem type in the southern project area, Showers Pass Road Sediment Source Assessment, Humboldt County, California.

Treatment Strategies for Road Surface Related Sediment Sources

Salmon Restoration Federation Roads Workshop June, 2022

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There's a time and place for everything, but there some bad ideas out there also……

Questions you should be asking yourself as you evaluate your road upgrade and maintenance plans

(1) Have you identified all of the locations where the road surface is hydrologically connected to the stream system?
(2) Are the initial treatment prescriptions based on site specific conditions and are they appropriate to minimize, to the extent possible, hydrologic connectivity and sediment delivery? Think performance based not prescriptive based
(3) In locations where hydrologic connectivity is unavoidable (such as the final approach to a stream crossing), have you prescribed road surfacing material (such as road rock) to minimize sediment production from the road surface?
(4) Have you developed a science based, property wide, prioritized action plan to address hydrologic connectivity between the road and the stream network?
(5) Do you have a thorough monitoring and adaptive management plan and is it being implemented?
(6) Does your road management plan include designating which roads are seasonal and which are for year round use?
(7) Do you or your consultant appear to have the mental and financial capacity to actively manage your road systems?

What is wrong with this conversation?

Tom—"What condition would you consider your ranch road system to be in"?

Landowner—"Our roads are in great condition, we grade them every year"……

What is wrong with this conversation? Discussion

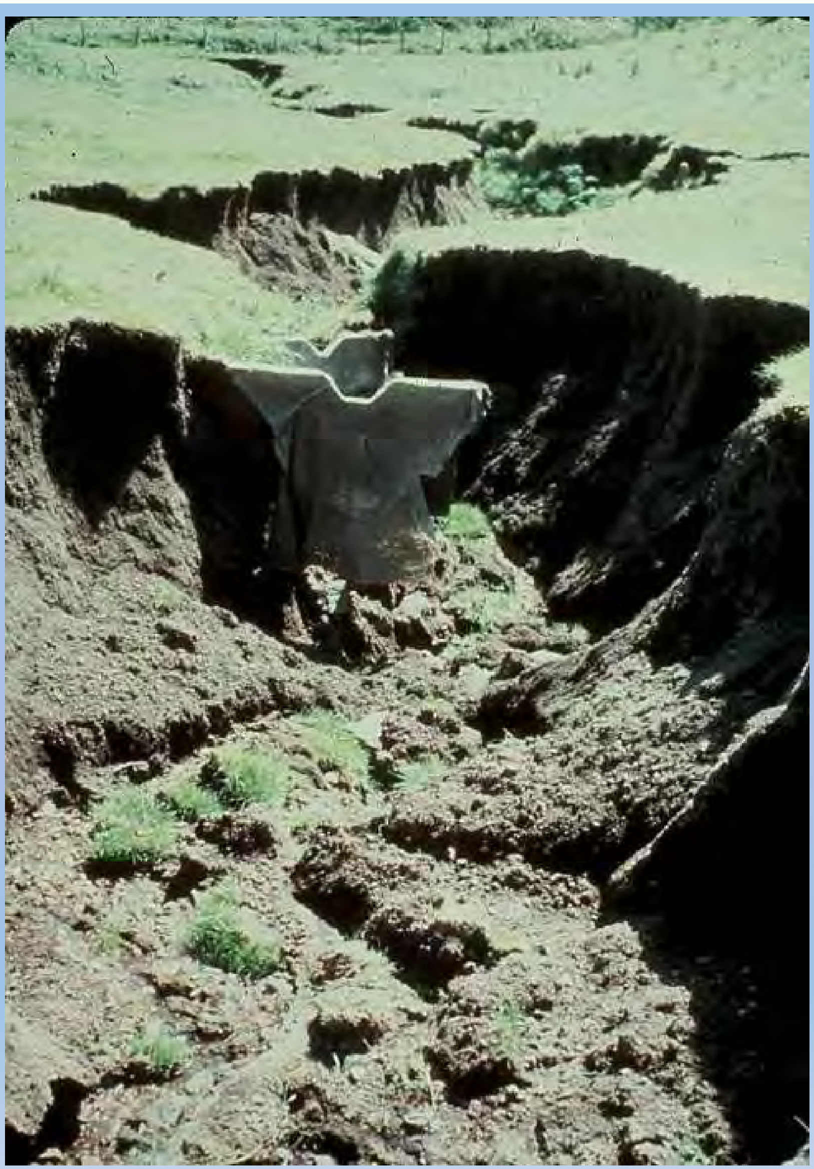
The issue here is that the landowner is focusing on drivability and not environmental protection……They view a good road as one that does not inhibit their intended use for it, without regard to the level of environmental protection is provides……This is not uncommon and can be addressed with a little education….

Typically if a landowner says something like this to me I say…. "if your road systems were in great condition you wouldn't need to grade them every year"

The reality is, an environmentally protective road is also usually a low maintenance road…

Treat the cause, not the symptom

DRC gully



Treating
the symptom

DRC gully…a symptom

Symptomatic gully…

…Symptomatic treatment

Jahnsian Steps to Geologic Safety
Remember…keep it scientific

- Modified for road-related erosion processes

1. **Recognition** of local erosional features
2. **Characterization** of the erosional features
3. **Assessment** of the risk posed by the features
4. **Mitigation** of the erosion and sediment delivery

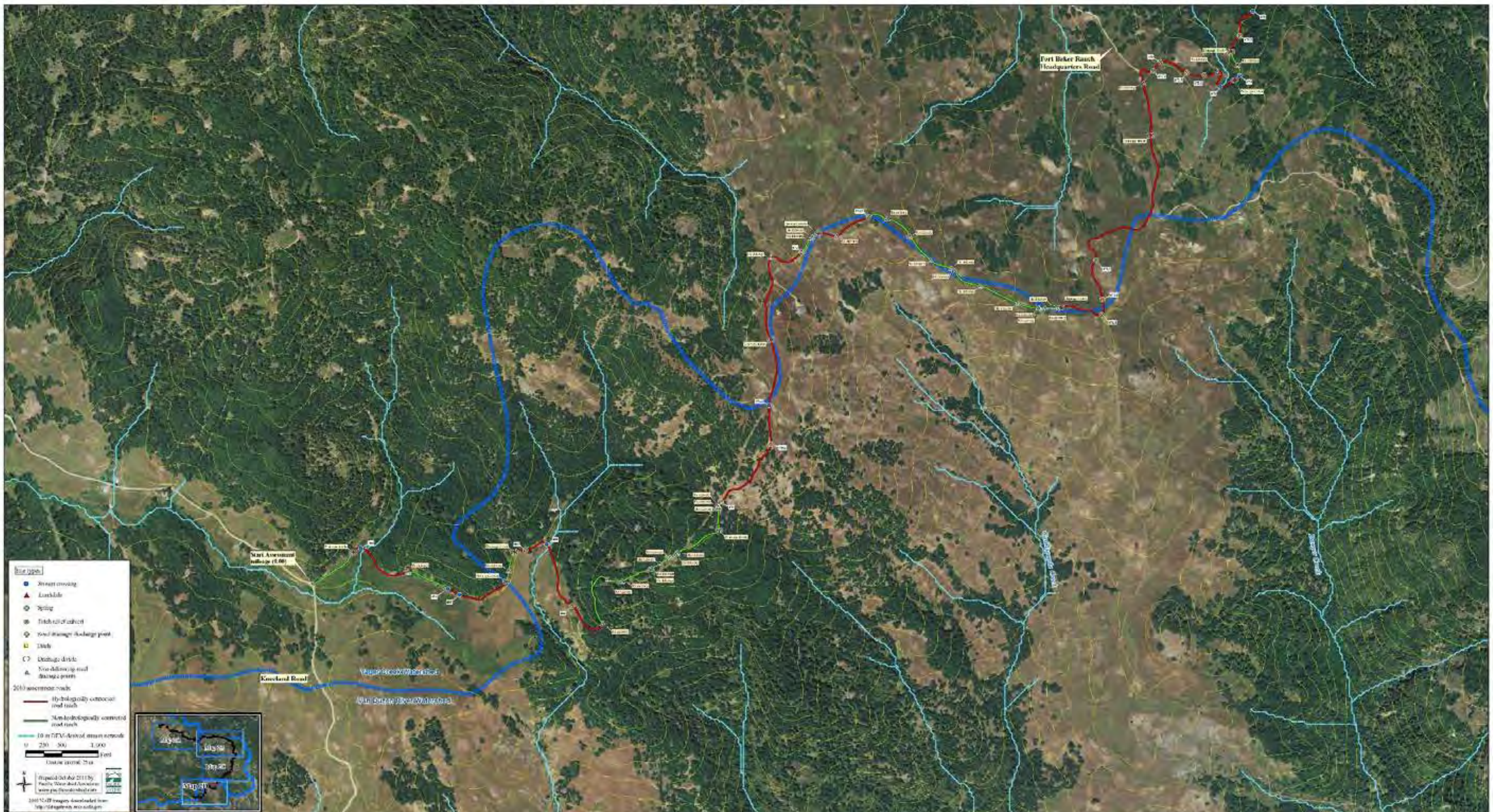
Analysis of connectivity and sediment delivery from the road system

- Ideally, the characteristics of each road surface discharge point is entered into a database and integrated into a GIS format for quantitative and spatial analysis

- This will allow the landowner to:

(1) Spatially visualize the condition their road system is in
(2) Identify specific problematic spots or road reaches on their property
(3) Estimate upgrade costs and logistics requirements
(4) Develop a prioritized treatment schedule
(5) Identify areas of increased monitoring requirements

Typical PWA road surface connectivity map



Map 2d. Inventoried sites by problem type in the southern project area, Showers Pass Road Sediment Source Assessment, Humboldt County, California.

<u>Mitigation</u> objectives road drainage effectiveness

A road drainage system must satisfy two main criteria if it is to be effective throughout its design life:

1) It must allow for a minimum of disturbance of the natural drainage pattern.
2) It must drain surface and subsurface water away from the roadway and dissipate it in a way that prevents excessive collection of water in unstable areas and subsequent downstream erosion.

<u>Mitigation</u> tools for hydrologically connected road surfaces

What tools and techniques are available and pertinent for the site specific discharge point?

- *<u>Road shaping</u>* (can significantly reduce contributing road surface area and effectively disperse road runoff)
- *<u>Adding or improving road drainage infrastructure</u>* (encourages water dispersion and infiltration)
- *<u>Road and or ditch surfacing</u>* (reduces erosion potential of the road surface)
- *<u>Sediment control</u>* (captures and retains in-transport sediment)
- *<u>Road Realignment</u>* (moves road to preferable location)

<u>Mitigation</u> strategies for hydrologically connected road surfaces

- Effective and environmentally friendly road drainage treatments should be designed to allow road runoff to <u>disperse and infiltrate</u> on the native hillside

- Road drainage improvements that <u>collect and concentrate</u> runoff are inherently more likely to result in hydrologic connectivity between the road and stream network

Mitigation strategies for treating connectivity

1) Install a "disconnecting" drainage facility or structure "close" to the watercourse crossing;
2) Increase the frequency of ditch relief culverts for connected roads with inside ditches;
3) Eliminate existing ditch relief culverts with connected gullies
4) Convert crowned or insloped roads with inside ditches, to outsloped roads with rolling dips;
5) Remove or breach outside berms on crowned or outsloped roads if they result in connectivity;
6) Avoid discharging concentrated runoff onto unstable areas.

It is important to develop a road surface upgrade plan that is consistent with local environmental conditions, expected use levels, and other constraints. "Safety-Performance-Protection"

- Keep in mind that there are a lot of tools and techniques available to landowners, the ones they employ should be the ones that perform best given the characteristics of each road segment and discharge point while considering other constraints

As an example: the gold standard geometry and drainage for many roads may be outsloping with frequent rolling dips but this may not be practical for roads in the snow zone (safety) or for steeper road grades where the design vehicle may be a lowbed truck (access)

Similarly, outsloping may be a great choice for the geometry of a road system, but it still may not be a good idea on a turn where momentum may carry a vehicle off of the road

Have a “high quality” monitoring and adaptive management plan for road surface maintenance…..<u>and implement it</u>

- Its important to implement a road surface upgrade plan that is based on scientific analysis and Best Management Practices but it is just as important to develop a monitoring and adaptive management plan that identifies and treats weak spots in your original plan…..

Treat the cause and not the symptom of a problem

remember……every complex problem has a simple solution that doesn't work

Gullies from road surface runoff

Another gully !!!?

Treating the cause by dispersing road runoff

Road drainage performance is more important than meeting prescriptive recommendations

Adaptive Management

Road upgrade treatments typically require “adaptive management” to “fine tune” the road system so that it is performing to the highest possible standards……

In other words, designing and implementing a high performing, environmentally protective road system is an iterative process and may take several years to maximize road drainage performance….

Treating Hydrologic Connectivity

Hydrologic connectivity is treated by road surface shaping and the installation of road surface and ditch drainage structures

Treatments for connected roads and ditches…

- Connected stream crossing approaches (road shape, berms, relief culverts, rolling dips, and road surfacing)
- Ditch drainage structures (ditch relief culverts, rolling dips, sediment basins)
- Road shaping (insloped, crowned, outsloped)
- Road surface drainage structures (road dips, rolling dips, waterbars and rubber waterbars, open top box culverts, berms, critical dips)
- Leadout ditches (for switchbacks, crowned roads, through cuts, fall line roads)
- Berm removal and berm breaks
- Abandonment treatments (ripping, cross road drains, outsloping, crossing excavation, fillslope excavation)

"Hydrologic invisibility"

The goal is to have the road only minimally affect the water's "natural, pre-road" flow path on the hillslope…..

Water encounters the road via:
- Rainfall and surface flow from the roadbed and cutbank
- Shallow subsurface flow from the cutbanks
- Streamflow at stream crossings

ROAD DRAINAGE TREATMENTS

Road shaping

Outsloping and conforming
to the topography

Free draining, outsloped roads

Before

After

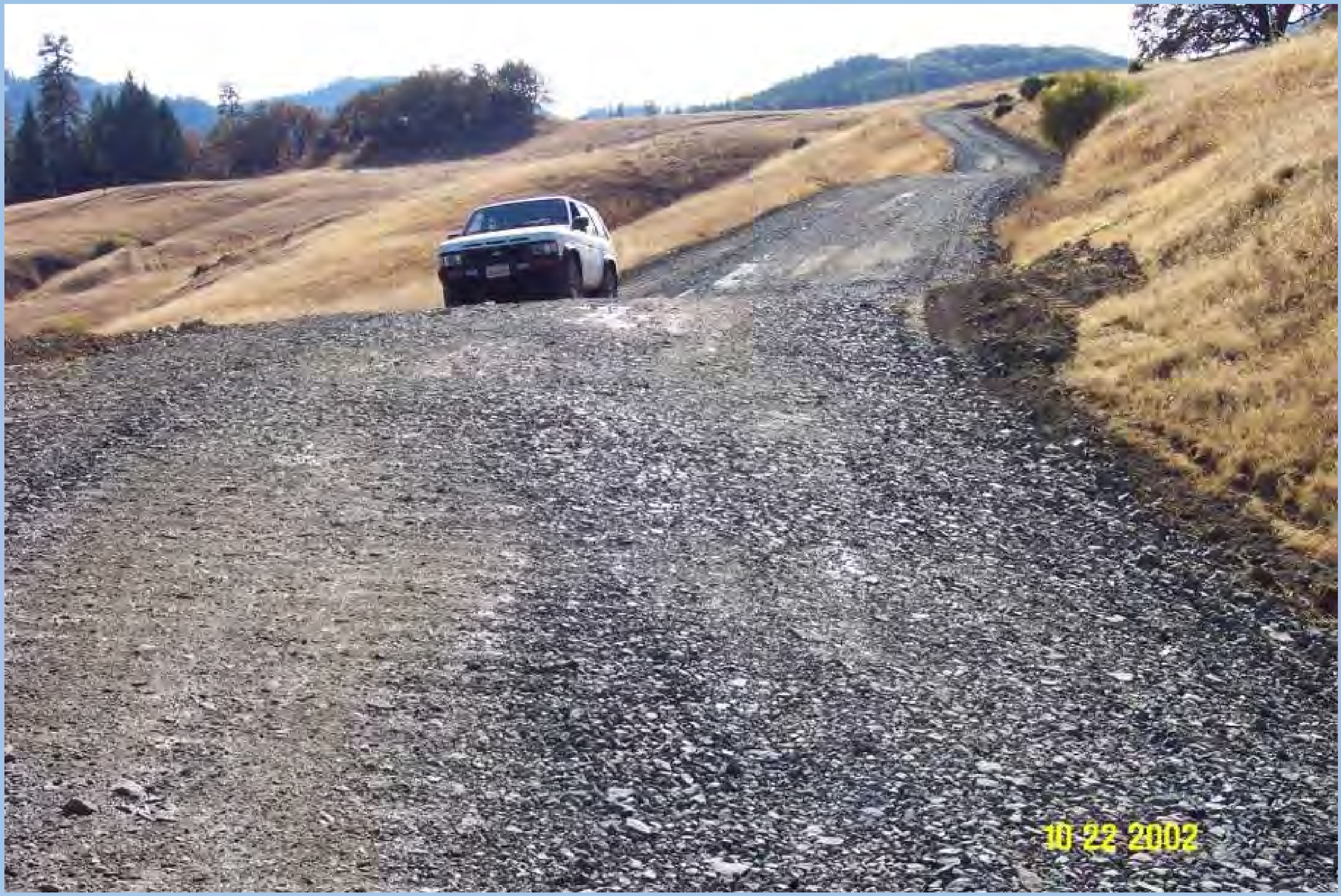
Before

During

Before

After

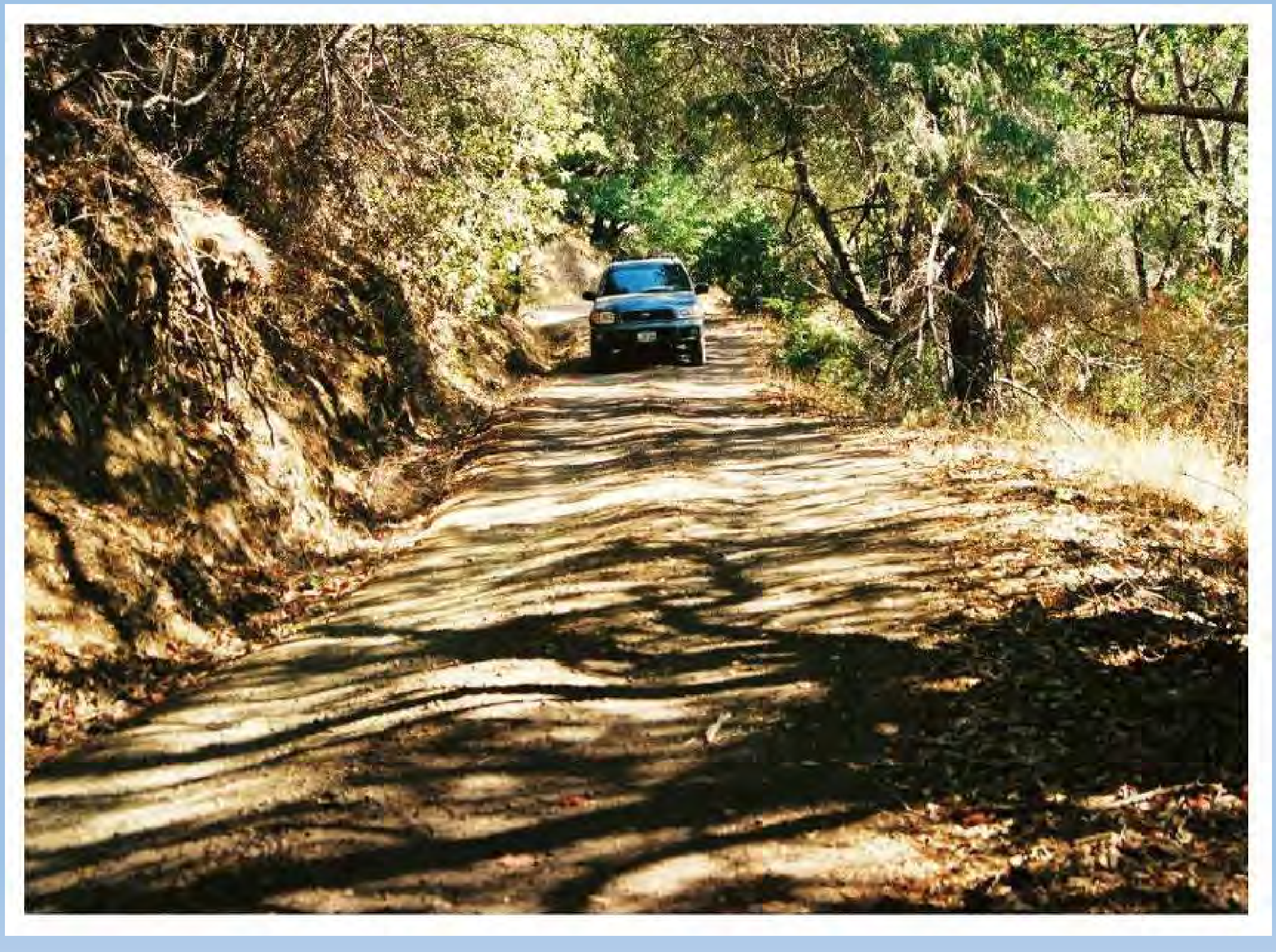
Before



After

Before

After



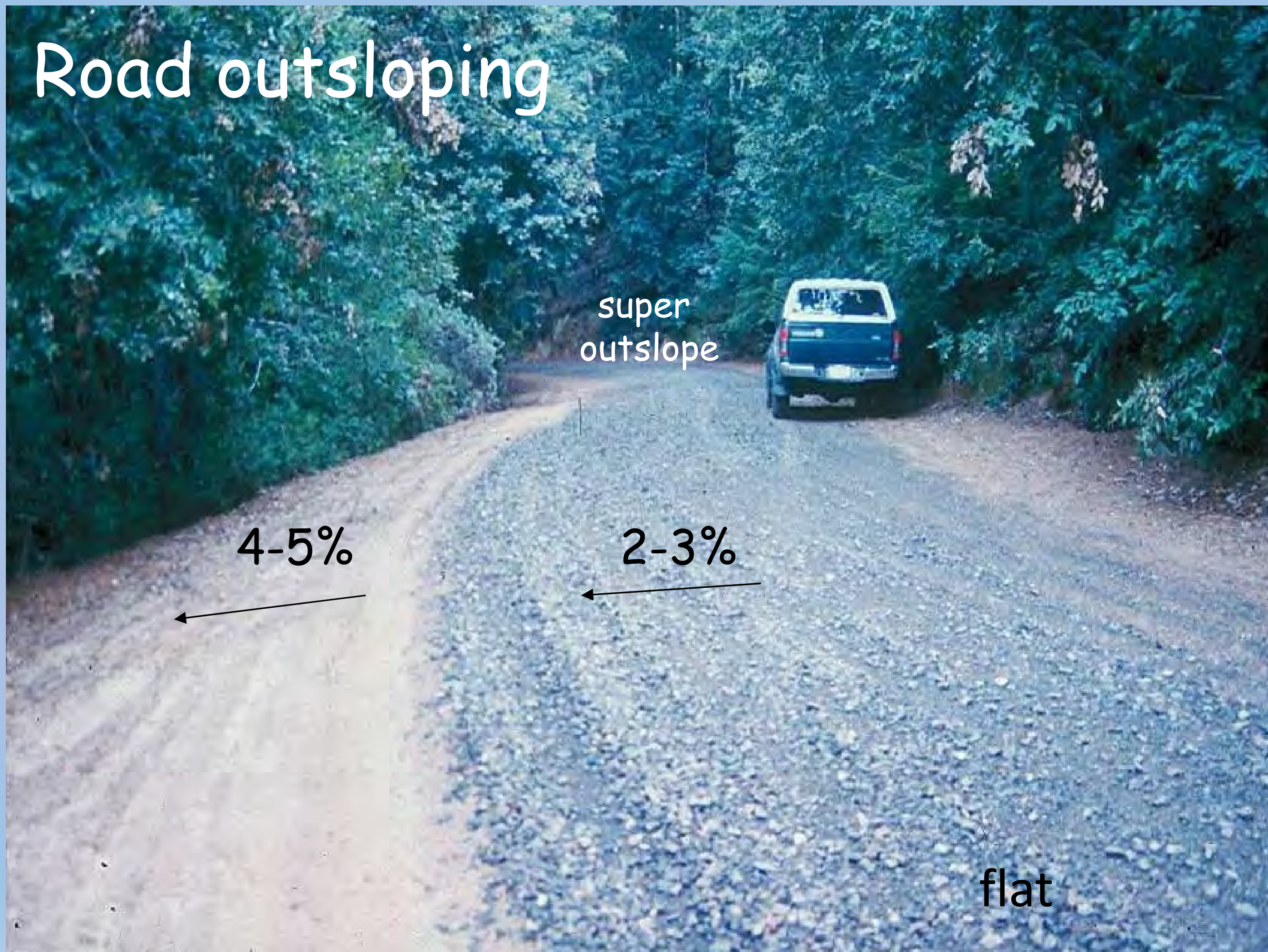
Before

After

Before

After

Outsloped with ditch



Driveability, Functionality and Safety

Turnout outsloping

Woven geotextile (road fabric) used to increase road strength and improve subsurface drainage

Tensar geogrid used to increase road strength and improve subsurface drainage

Road Upgrading

- Three treatment mantras
- Goals of road upgrading
- Road surface drainage treatments
  - Road shaping
  - **Drainage structures**
- Stream crossing treatments
  - Types of stream crossing upgrade treatments
  - Culvert accessories
- Armored fill stream crossings
- Treatment of unstable fillslopes

ROAD DRAINAGE STRUCTURES

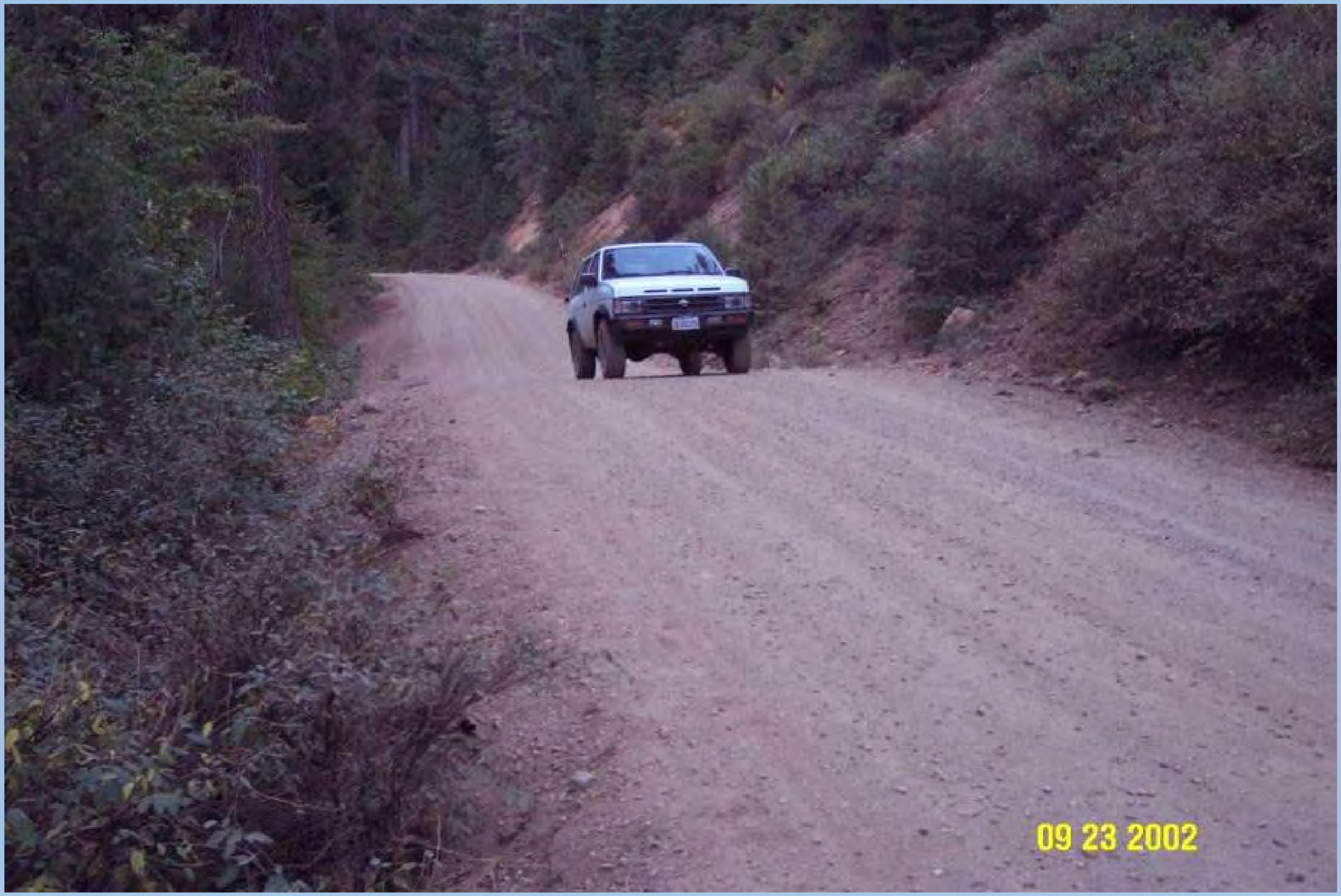
Rolling dips, ditch relief culverts and berm breaks

Road with rolling grade

Outsloped, rolling dip and inside ditch

Outsloped with abrupt rolling dip

Outsloped with rolling dips



Outsloped with rolling dips

Outsloped with rolling dips

Ranch road - Before

reverse grade in the axis of the rolling dip.

After

China Gulch Road – conversion to outslope

Rolling dip construction using ripping cat

Rolling dip: watering for compaction

Rolling dip: rolling for compaction

Functional, drivable and safe

DRC – no gully

DRC installation

Full-round downspout

Energy dissipation

Perforated DRC flex pipe spreaders

DRC drop inlet

Draining through-cuts

Berm breaks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Drainage cut-out drains road rut

Berm breaks

Silt fence ditch filter

Sediment storage on vegetated flat

Sediment basin under construction

Sediment basin

Roadside sediment retention basin

Sediment basin at end of through-cut

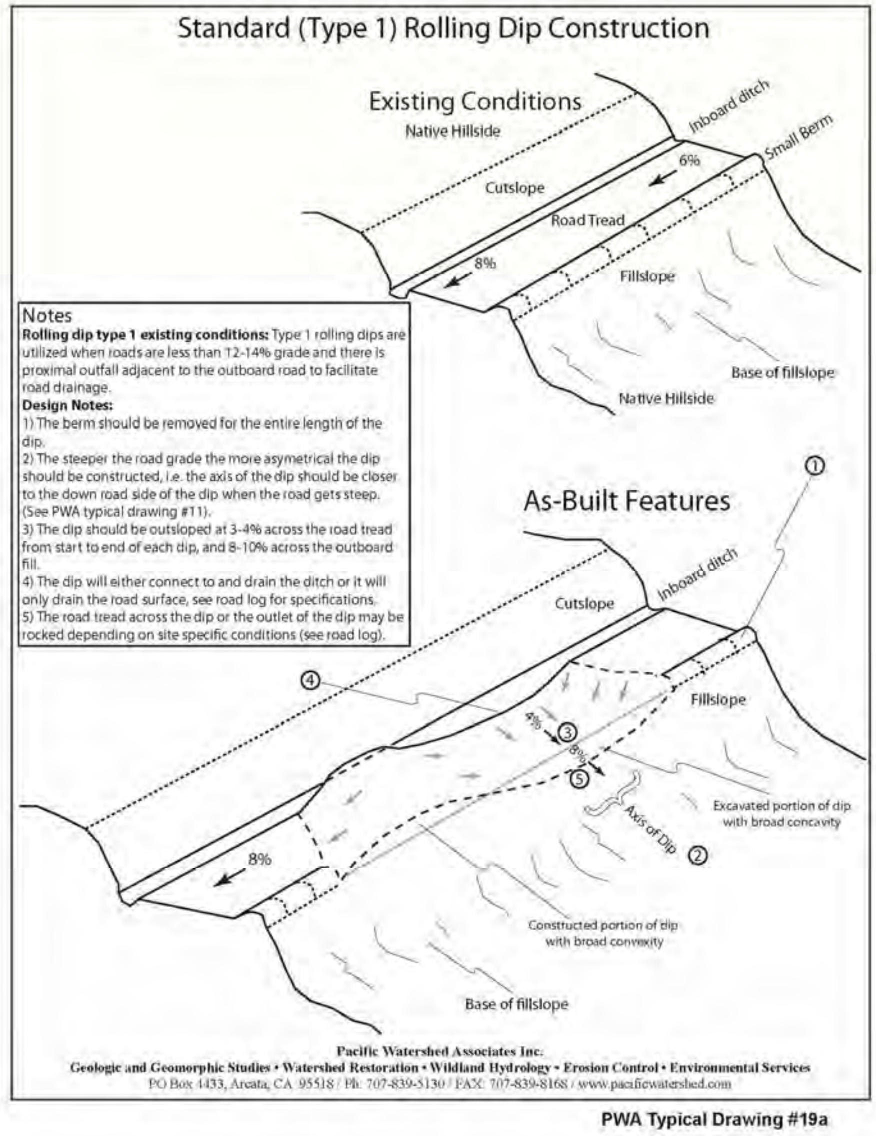
Sediment basin drainage outlet

Different types of rolling dips

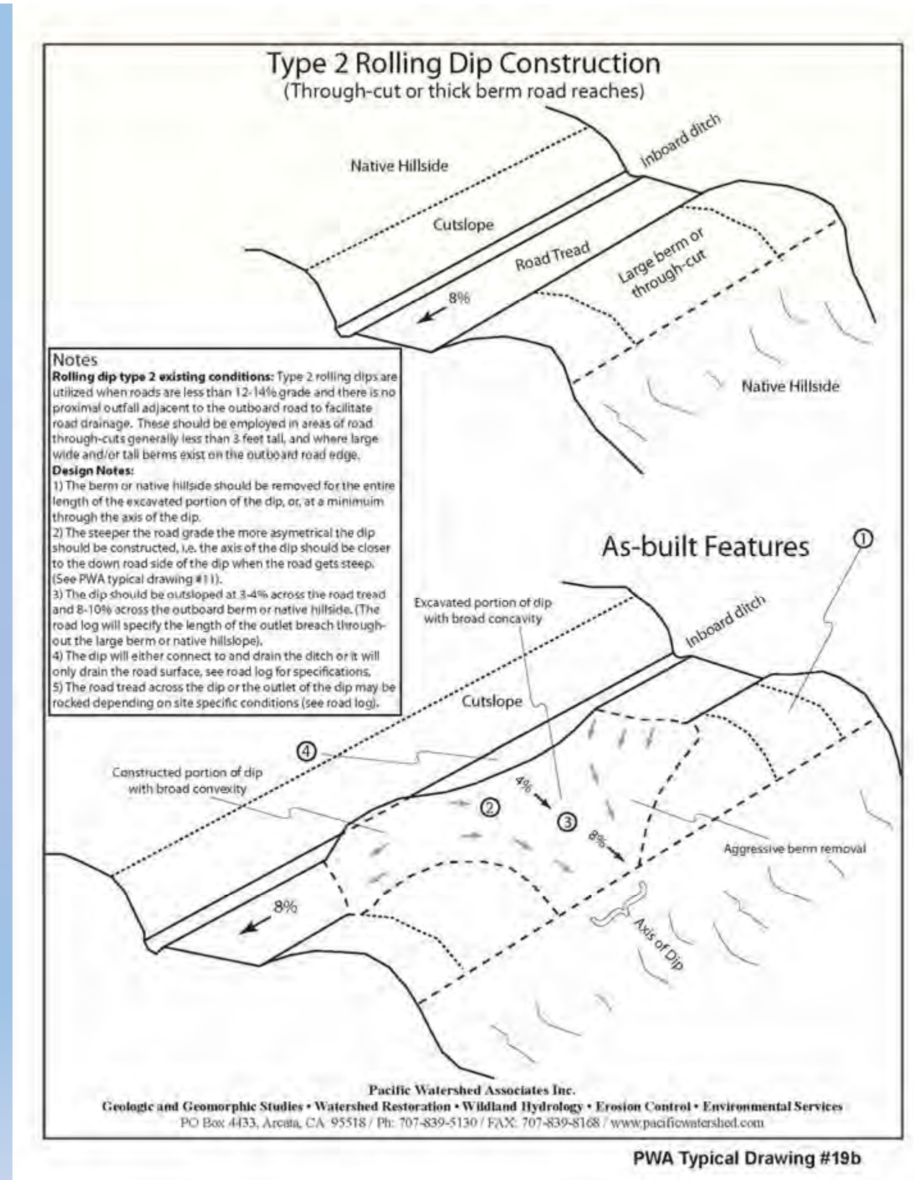
PWA has developed typical drawings for three different rolling dip types, the different dip types are meant to be employed as necessary based on the existing road and hillside geometry.

Type 1- employed in areas with low to moderate road grades and small outboard berms
Type 2- employed in areas where the road is through-cut or exhibits thick berms on the outboard road
Type 3- employed where the road grades are relatively steep and developing reverse grade on the dip would inhibit vehicle traffic

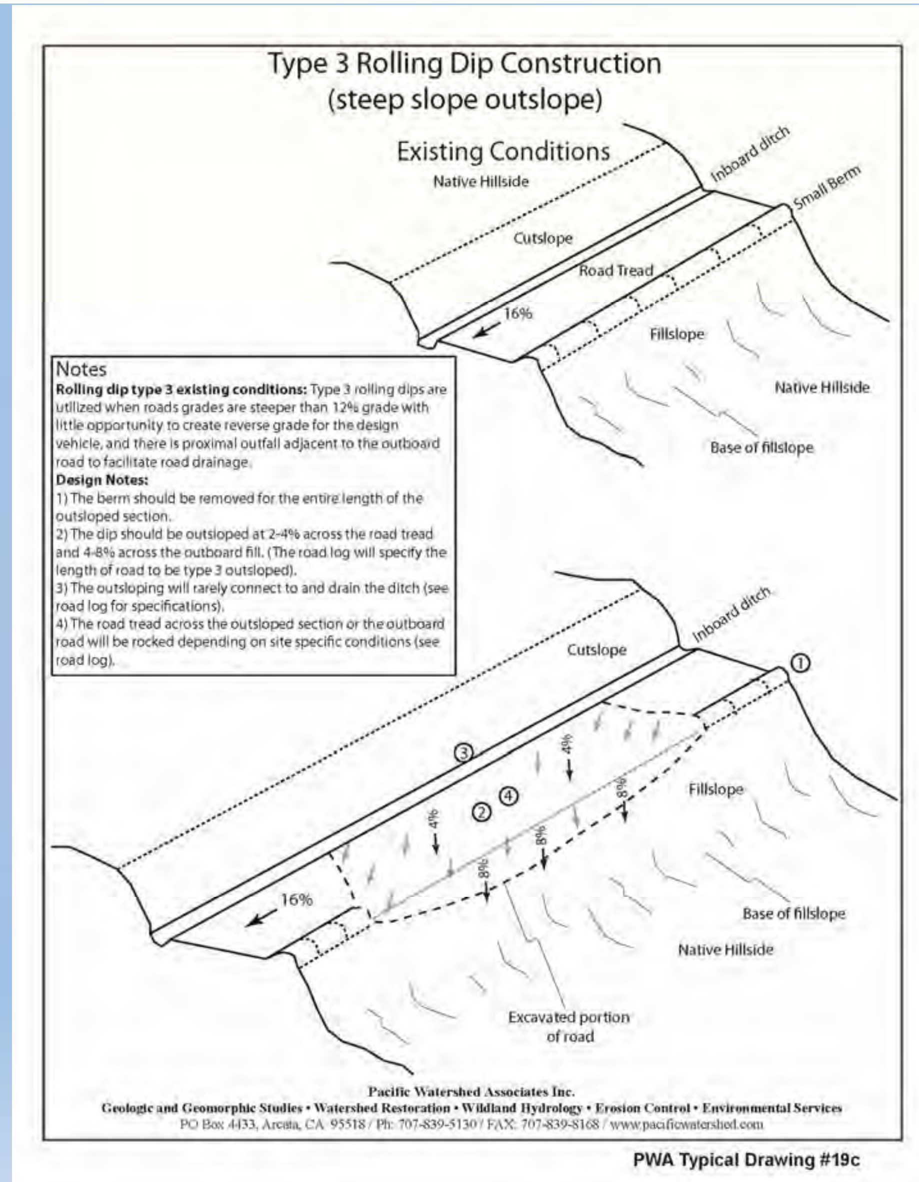
Rolling dip-Type 1



Rolling dip-Type 2

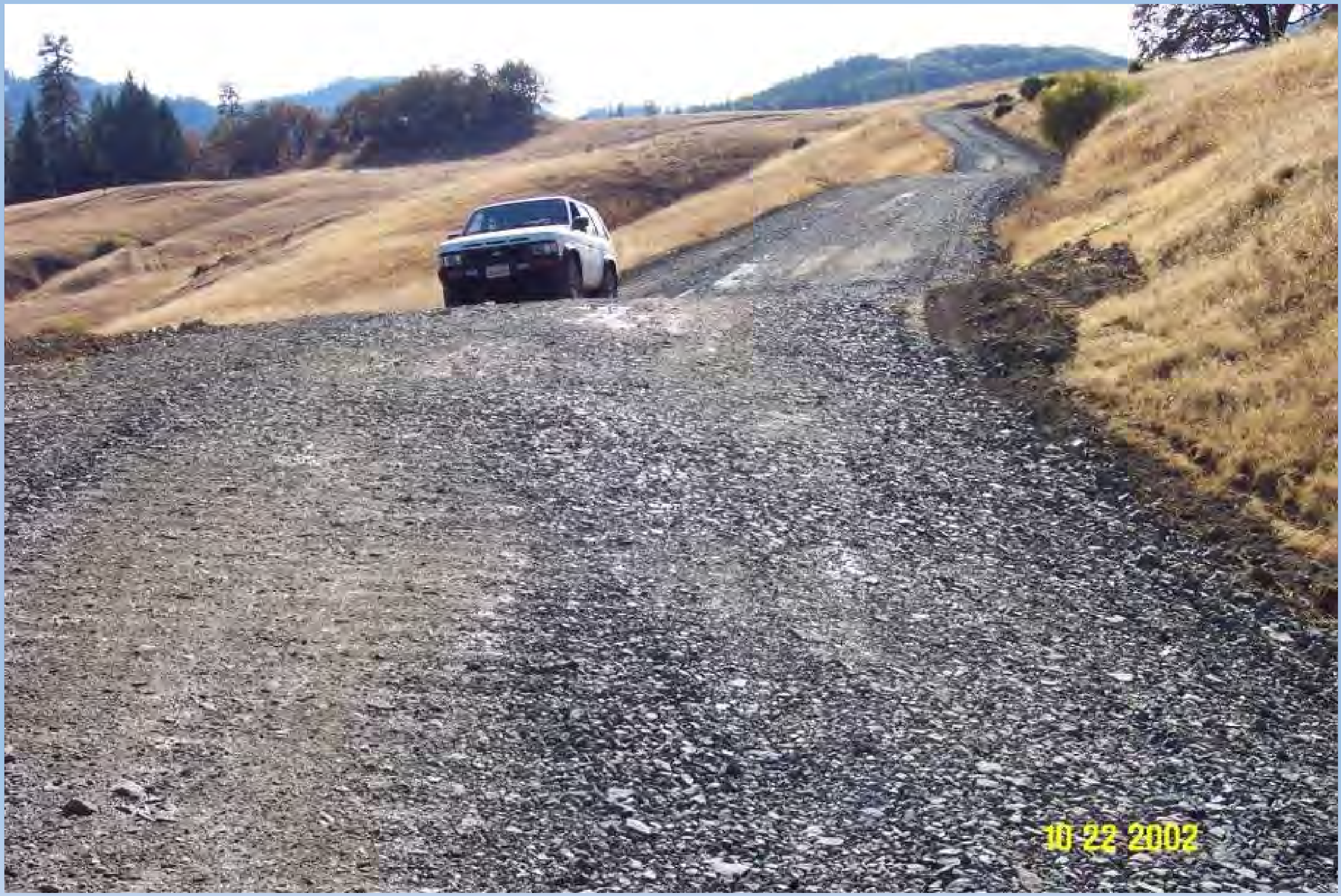


Rolling dip-Type 3



Lets look at some examples of road reaches upgraded with road shaping and rolling dips

Rolling dip spacing on outsloped road with no ditch or berm



Note:

(1) There are several rolling dips on this photo

(2) The final road approach is heavily rocked

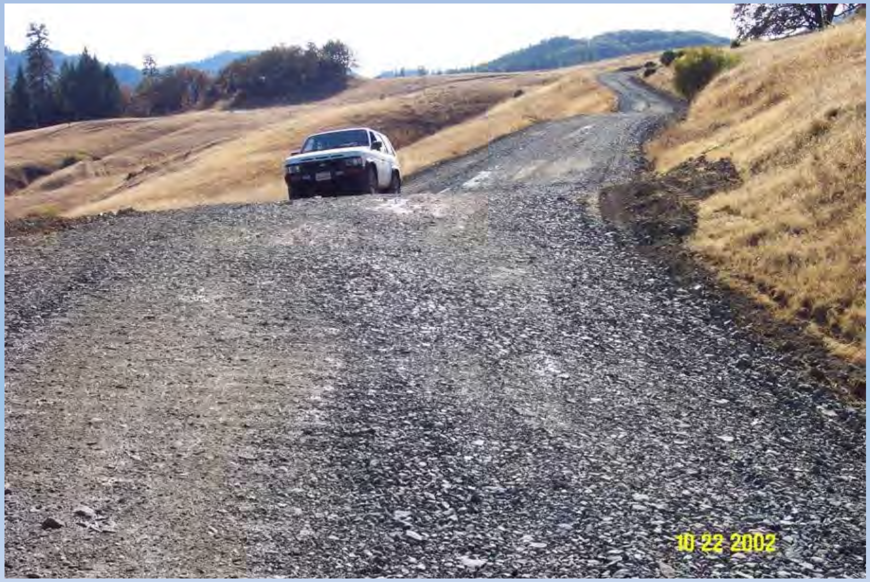
(3) The road is generally shaped to conform to the natural hillside

Rolling dips on a stream crossing approach

Adding frequent road drainage structures

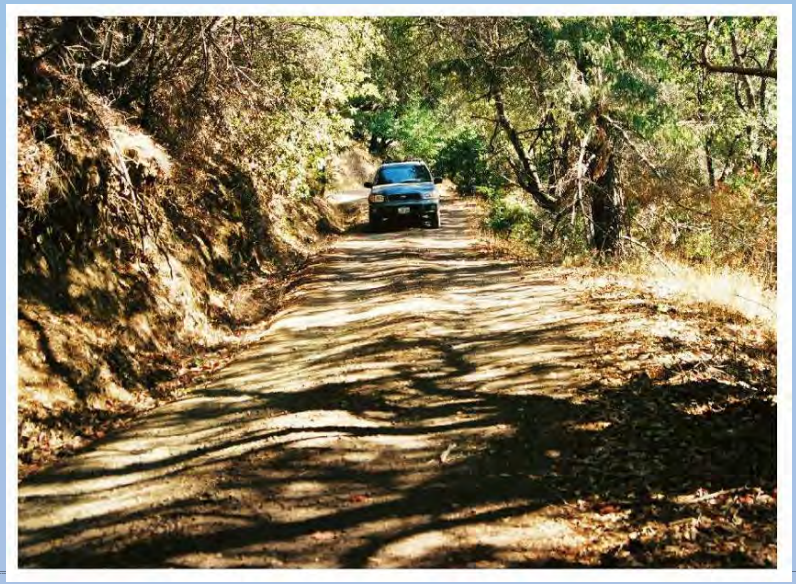
Insloped with ditch

Outsloped with rolling dips



Conversion of a road from insloped with a ditch to outsloped with rolling dips

Before



After

Road shape conversion

Insloped with ditch, wheel ruts & berm – Gullied with 100% connectivity

before

Outsloped with rolling dips – No connectivity

after

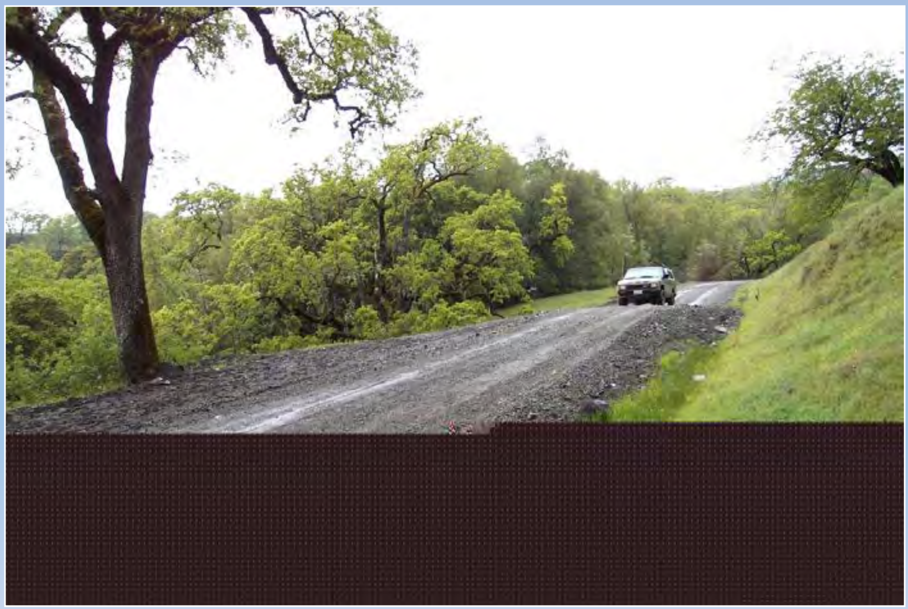
Rolling dips designed for different expected vehicles

Rural subdivision
(Cars, trucks with trailers, ect)

Logging haul road
(Log trucks, pick ups)

Insloped road with ditch – hydrologically connected

Outsloped road with rolling dips – ditch retained



Choosing rolling dip frequency and discharge locations need to be well thought out

Where to place rolling dips and other road drainage infrastructure

- On convex surfaces to encourage dispersal and infiltration of road runoff
- On highly vegetated hillsides
- On low gradient hillsides
- *As far as practical from the stream network* (the closer you get to a stream crossing the more frequent your dips should be)
- On stable geologic surfaces (in other words, not on landslides or hillsides prone to gully erosion)
- On straighter sections of roads (not on or right before a hard turn to the inside of the road)
- On outside turns in the road (like a NASCAR turn)
- On vegetated river terraces when there is no other choice

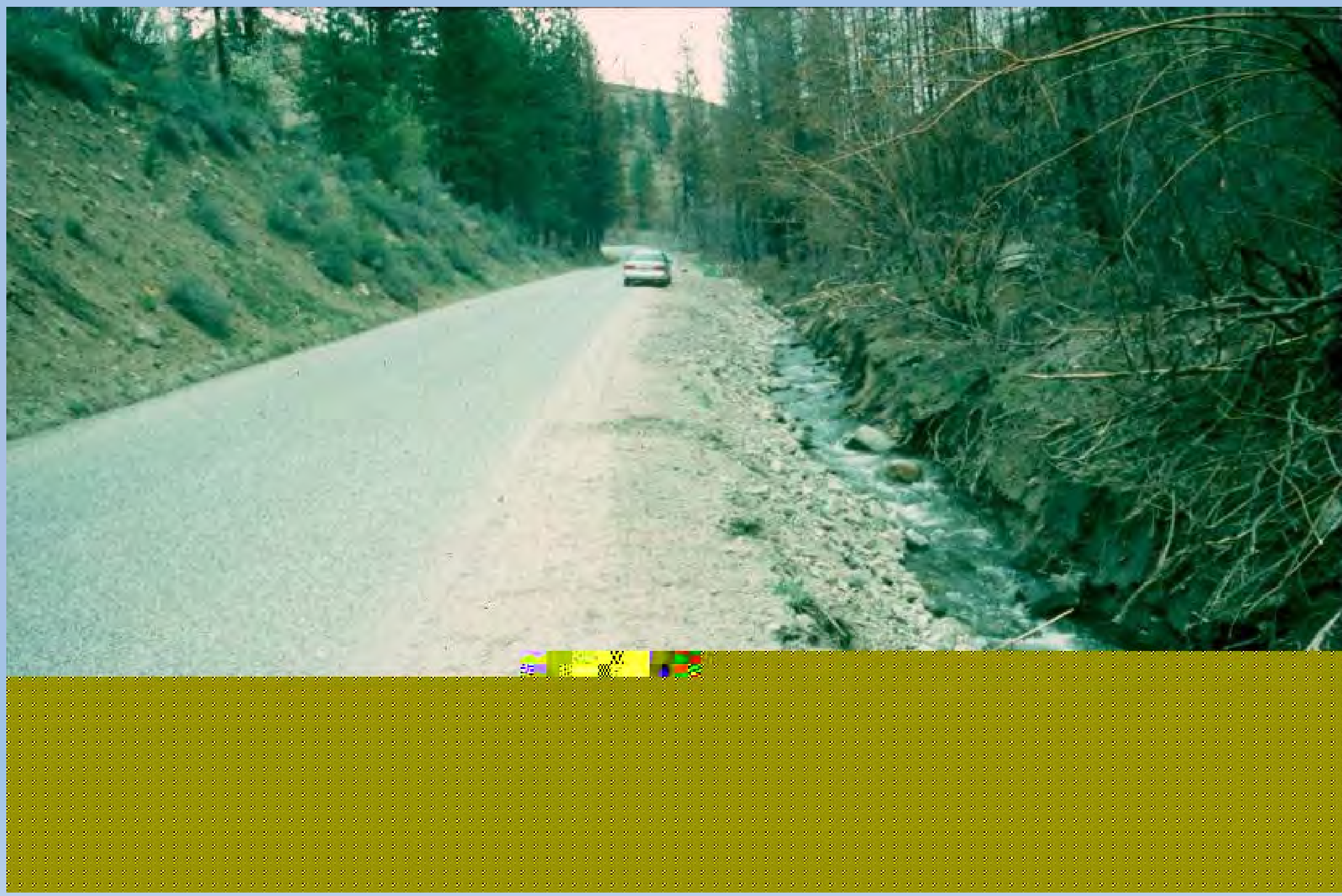
Tips for determining the appropriate frequency for rolling dips

(1) Dip frequency should decrease as the road approaches a stream crossing…
(2) In general, steeper road grades and roads proximal to streams require more frequent road drainage structures
(3) Dip frequency should be based on the performance of the existing road drainage, not based on prescriptive measures..
(4) Road drainage performance should be monitored through the winter months and adaptively managed by prescribing more frequent dips where appropriate

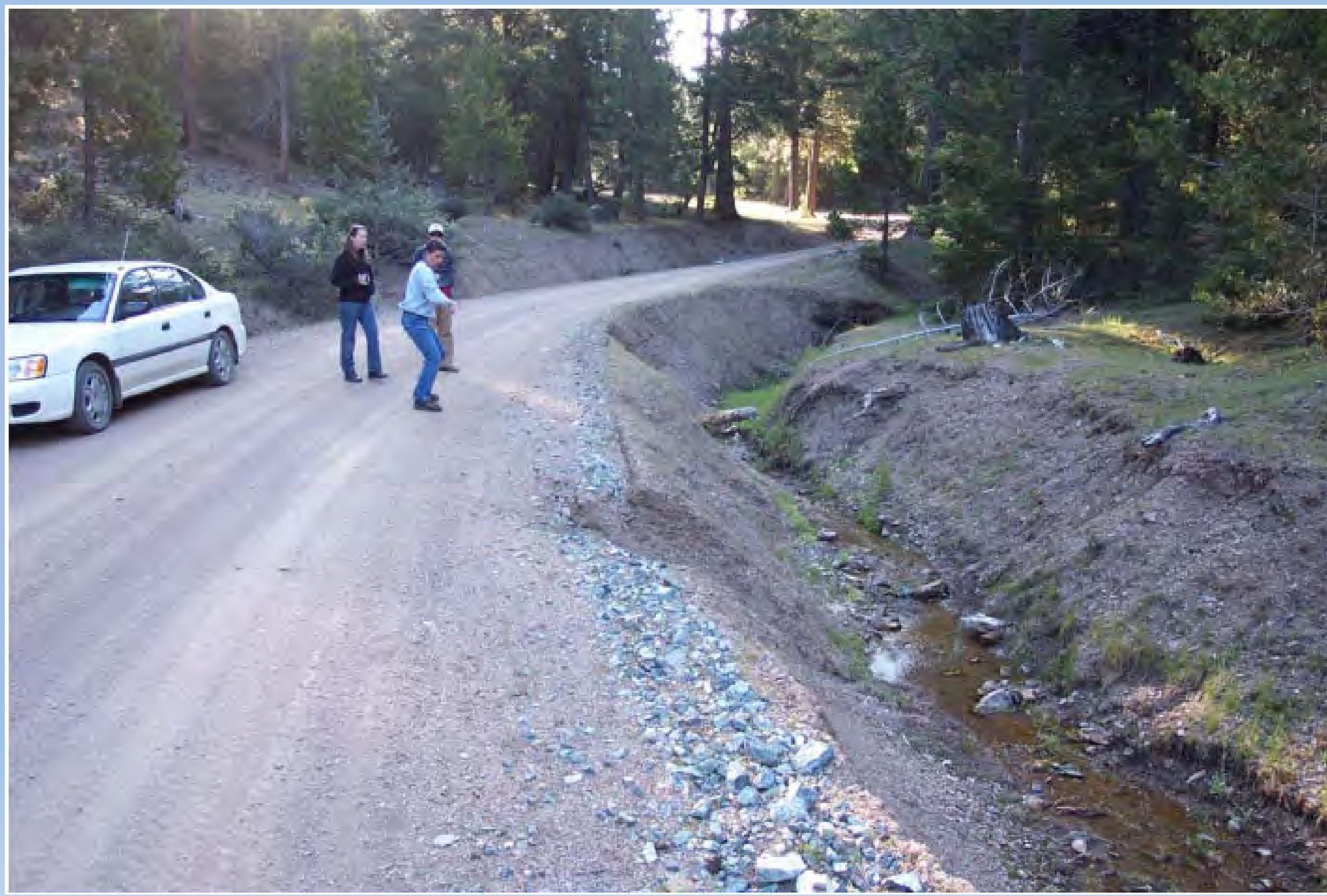
Maintain a large riparian buffer of vegetation between grading projects and streams. Steeper and less vegetated hillsides require longer riparian buffer strips to protect water quality.

Roads where streams should be:

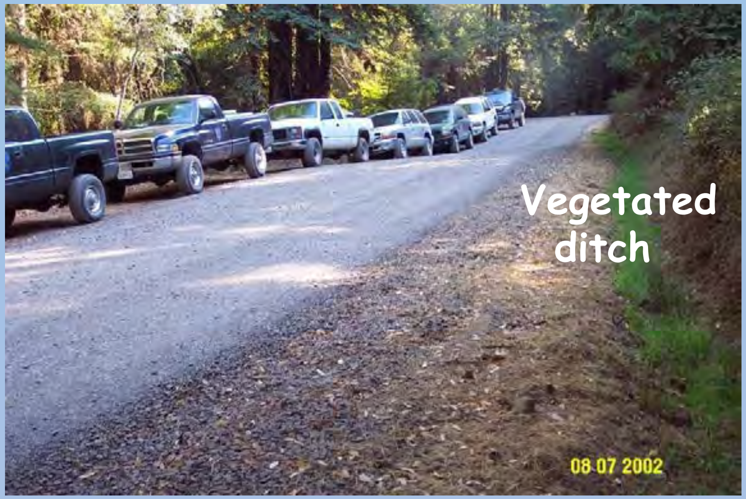
Road Surface and Stream Bank Erosion and no Riparian Buffer

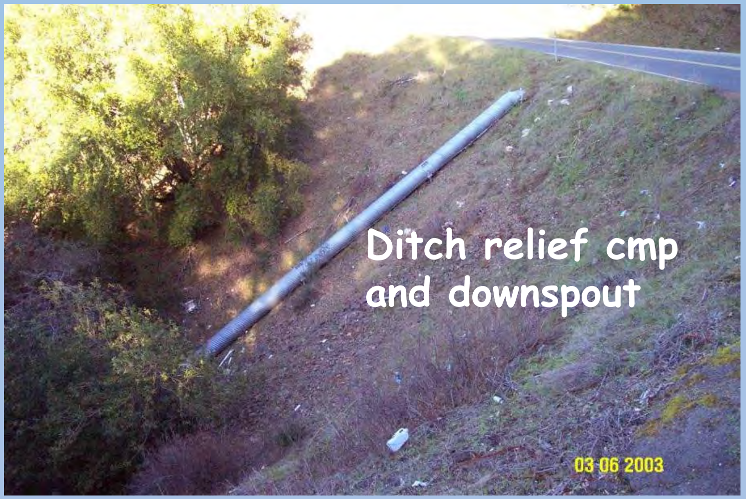


Roads where streams should be, no riparian buffer

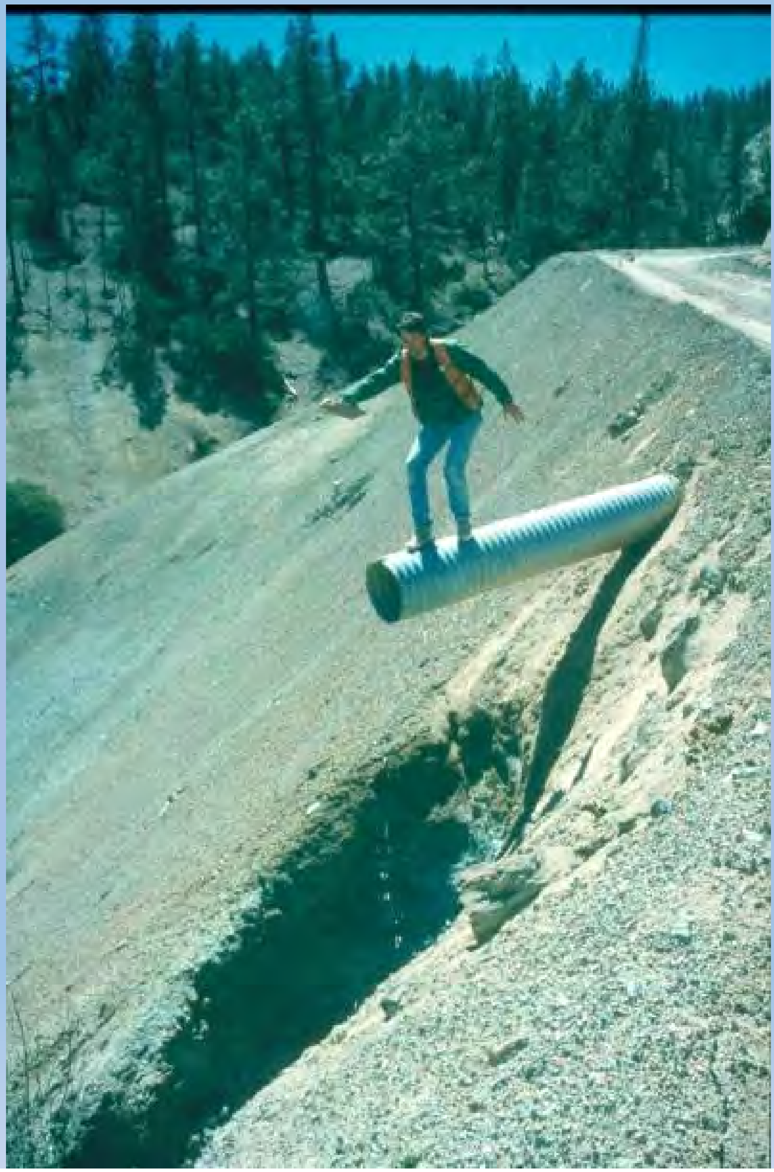


Other road drainage treatments





Ditch relief culverts



When are inside ditches and ditch relief culverts a good option?

- Wet hillside conditions- In really wet areas or where the ditch is draining a hillside spring, DRCs are a good option…
- On steep road grades- On steep road sections where outsloping or rolling dips are not feasible, ditch and ditch relief culvert can be employed…
- To minimize discharge onto geologically unstable areas- Its best to carry water in a ditch rather than allow it to discharge where erosion and or sediment delivery could occur…
- Where berms are required to assure vehicles stay on the road…
- In areas of run-on from the hillside..
- Any location where you don't want to discharge run off over the fillslope
- On paved road sections….

DRC – no gully

Full-round downspout

Energy dissipation

Perforated DRC flex pipe spreaders

DRC drop inlet

Berms

Bermed fillslope

Bermed fillslope

Berm breaks on a fall-line road

Drainage cut-out drains road rut

Sediment Traps

If erosion control techniques are not effective, sediment control becomes the next viable option

Silt fence ditch filter

Sediment storage on vegetated flat

Sediment basin under construction

Sediment basin

Roadside sediment retention basin

Sediment basin at end of through-cut

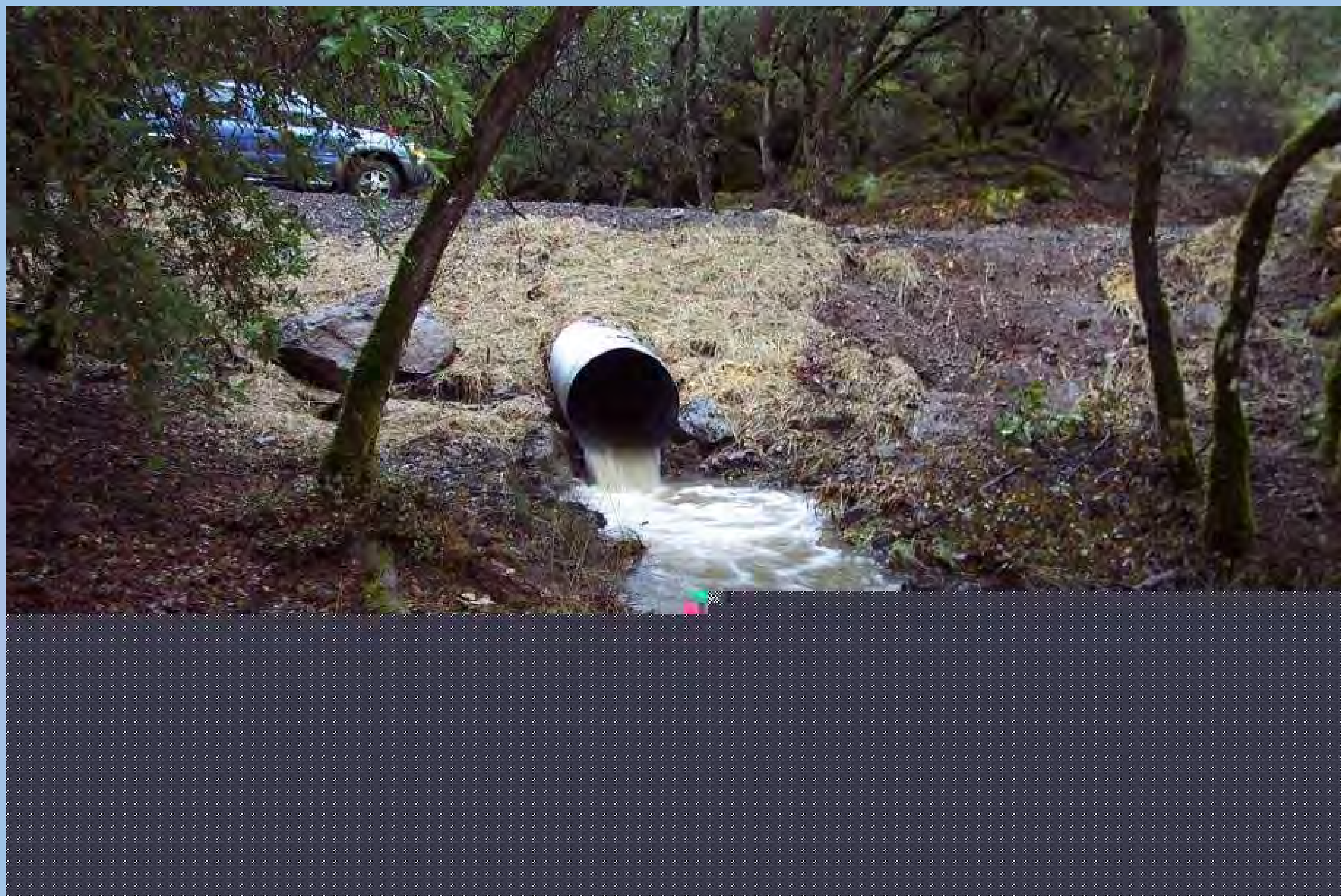
Sediment basin drainage outlet

Other techniques and accessories

Slotted road drain and ditch infiltration gallery

Critical dip

Critical dip down-road from crossing



After overtopping and directed over critical dip

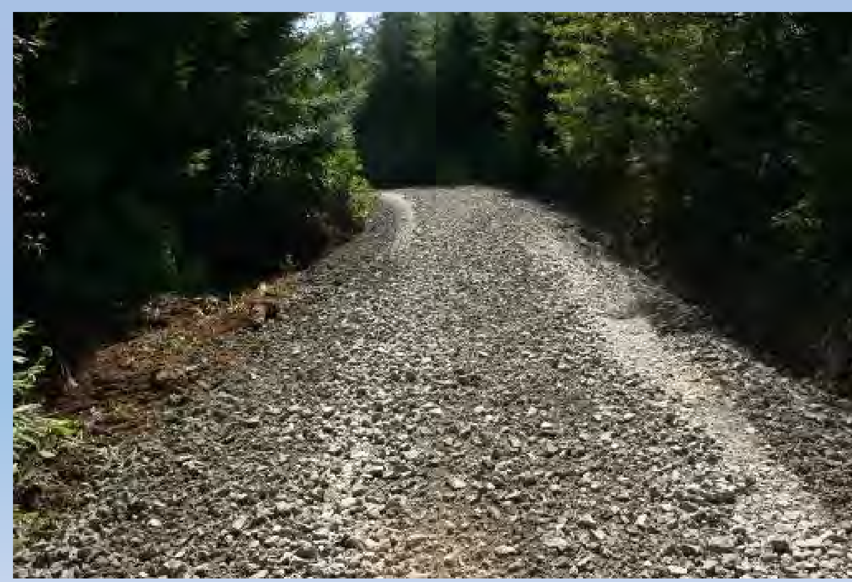
Road surfacing

Road surfacing- tips and techniques

Pit run rock is the best option- Pit run rock is angular and typically contains enough fine grained material to bind the rock together…
River run rock is a less preferable option- River run rock is rounded and will likely be pushed off the road by vehicle traffic. This will decrease the rock surfacing durability and increase the required maintenance of the road…
Crushed river run- better but does not contain the binding fines
When rocking a road moisture conditions of the surfacing material is critical to achieve proper compaction
Vibratory rollers enhance compaction of road surfacing materials
Be careful who maintains your road….

Woven geotextile (road fabric) used to increase road strength and improve subsurface drainage

Tensar geogrid used to increase road strength and improve subsurface drainage



Some final thoughts

And a little review

Common issues with treating connectivity…

Not all road segments are hydrologically connected and complete hydrologic disconnection is not possible for most roads (typical levels).

Connectivity has two forms to be treated:

- Hydrologic connectivity – the emergence, collection, rapid routing and discharge of road-related runoff to stream channels (channel stability and drought implications)
- Pollutant connectivity – the generation and transport mechanism for sediment and other pollutants to be delivered to streams, lakes and wetlands (aquatic habitat implications).

Common issues with treating connectivity…

Connectivity is not linearly associated with sediment delivery volumes or rates.

- Some roads have low erosion rates, so significant connectivity may not result in a large volume of fine sediment delivery. The opposite is also true.
- Erosion and sediment generation on roads is a function of soil erodibility, road surfacing road grade, runoff volumes (contributing area and flow depth), as well as traffic types and traffic volumes.
- Some roads are located where climate/weather is extreme, while others are not.

Common issues with <u>treating connectivity</u>…

- DRC spacing must be based on ditch erosion, slope erosion <u>and</u> stream proximity; when "required spacing" (from tables) does not make sense!
- Drainage structure spacing will decrease as you approach a stream or stream crossing; second structure spacing is critical
- Not all filter strips are the same (when 100′ ≠ 100′)
- OS roads with inside ditches (when to use)
- Rolling dip spacing (<u>should be performance-based</u>):

Common issues with treating connectivity…

- Identifying the best discharge sites (rather than the table distance; e.g., through cuts, convex slopes, stable rocky slopes, flood plains and terraces, buffer characteristics, etc.). *Think performance!*
- Are energy dissipators always needed? If they are, what does that tell you ? (too much water)
- When a road can't be drained… (through cuts, fall line roads)
- When a road shouldn't be drained (unstable areas, connected gullies, streamside roads

Control and prevention of gully erosion

- Prevent gullies by <u>dispersing runoff</u>
- Direct concentrated flow from bare areas into <u>buffers and flat areas</u>
- <u>Dewater active gullies</u>
- <u>Secondary treatments</u>, including channel armor and grade control, are <u>the last option</u>

Recommendations to reduce or eliminate roads as a source of fine sediment:

- Construct outsloped road shapes with no berms, and periodic rolling dips, disconnecting crossing approaches,
- Utilize inboard ditches only where springs are present along the cutbank, or to collect runoff from upslope,
- Disconnect ditches using frequent ditch drains,
- Minimize ditch grading; revegetate connected ditches
- Avoid through-cut roads & roads down the axis of swales,
- Do not pipe riparian road runoff directly to streams; use perforated flex pipe on contour to disperse flow,
- Culvert spacing should result in no hillslope gullies,
- Dewater connected gullies, even if they are stable, and
- Construct properly designed and sized sediment basins.

Road connectivity comparison following road storm-proofing along 15.2 miles of forest roads.

Connectivity site type	1998 Connectivity (pre-treatment) (ft)	Connected road/ditch length of forest roads (ft)		Average connected length as of 2005
		2004	2005	
Stream crossing approach	23,930	14,100	3,630	84 ft
Ditch relief culvert	27,000	9,450	1,600 [1]	178 ft
Gully/rolling dips	3,860	5,325	800 [1]	200 ft
Other	6,350	825	0	0 ft
Total (15.2 mi):	61,140'	29,700'	6,030'	108 ft
Connectivity	**76.2%**	**37.0%**	**7.5%**	--

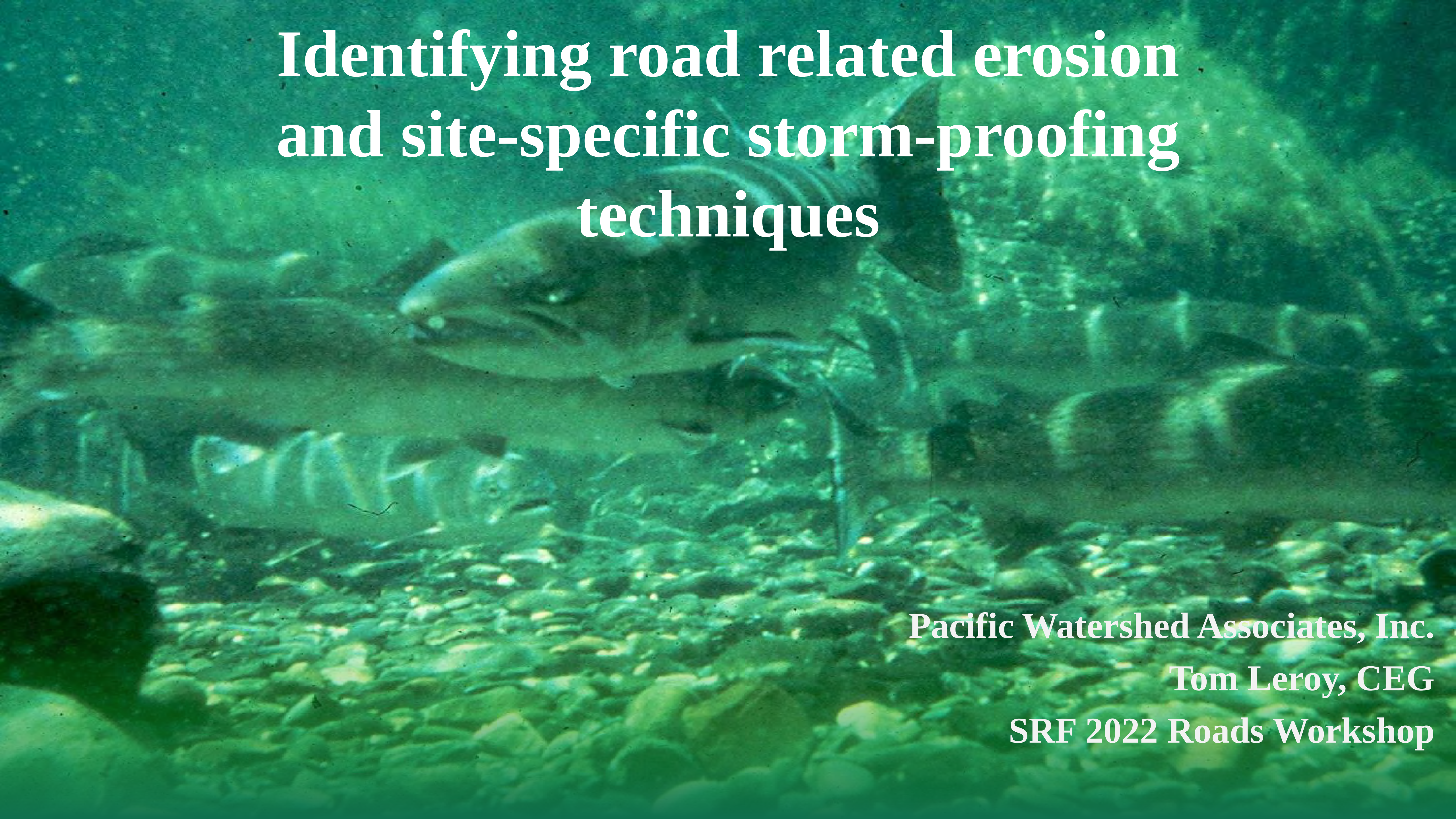
[1] Eliminating these connected sources would reduce overall connectivity to 4.5%

What to do with hydrologically connected roads…

- Install a “disconnecting” drainage facility or structure “close” to the watercourse crossing;
- Increase the frequency of ditch relief culvert spacing for roads with inside ditches;
- Eliminate existing ditch relief culverts with connected gullies
- convert crowned or insloped roads with inside ditches, to outsloped roads with rolling dips;
- Remove or breach outside berms on crowned or outsloped roads if they result in connectivity;
- *Apply treatments to dissipate energy, disperse flows, and minimize erosion at road drainage outlets not connected to watercourses*; and
- Avoid discharging concentrated runoff onto unstable areas.

U.S. EPA/State Water Board TMDL's: Required Fine Sediment Load Reductions

Watershed	Area	Road Surface Erosion Reduction	Road Gully Erosion Reduction	Skid Trail Erosion Reduction
Redwood Creek	280 mi^2	85%	**85%**	85%
Mattole River	296 mi^2	**95%**	94%	**90%**
Big River	181 mi^2	87%	---	57%
Albion River	43 mi^2	82%	---	**29%**
Garcia River	100 mi^2	**73%**	---	72%
Gualala River	300 mi^2	**95%**	**95%**	84%



Identifying road related erosion and site-specific storm-proofing techniques

Pacific Watershed Associates, Inc.
Tom Leroy, CEG
SRF 2022 Roads Workshop

Road related Sediment Delivery

- Episodic
  - Landslides
    - Cutbank slides
    - Fillslope slides
  - **Stream crossings**
    - Washouts
    - Stream diversions (gullies and hillslope debris slides)
  - Gullies (from road drainage)

- Chronic
  - Hydrologically-connected bare soil areas
    - Road reaches
    - Bare areas (quarries, landings, trails, harvest areas, etc)

Unculverted Stream Crossings

Unculverted Stream Crossings

Hardened Ford

Ford with soft bottom

Culverted stream crossing failures

Wash out (eroded) stream crossing

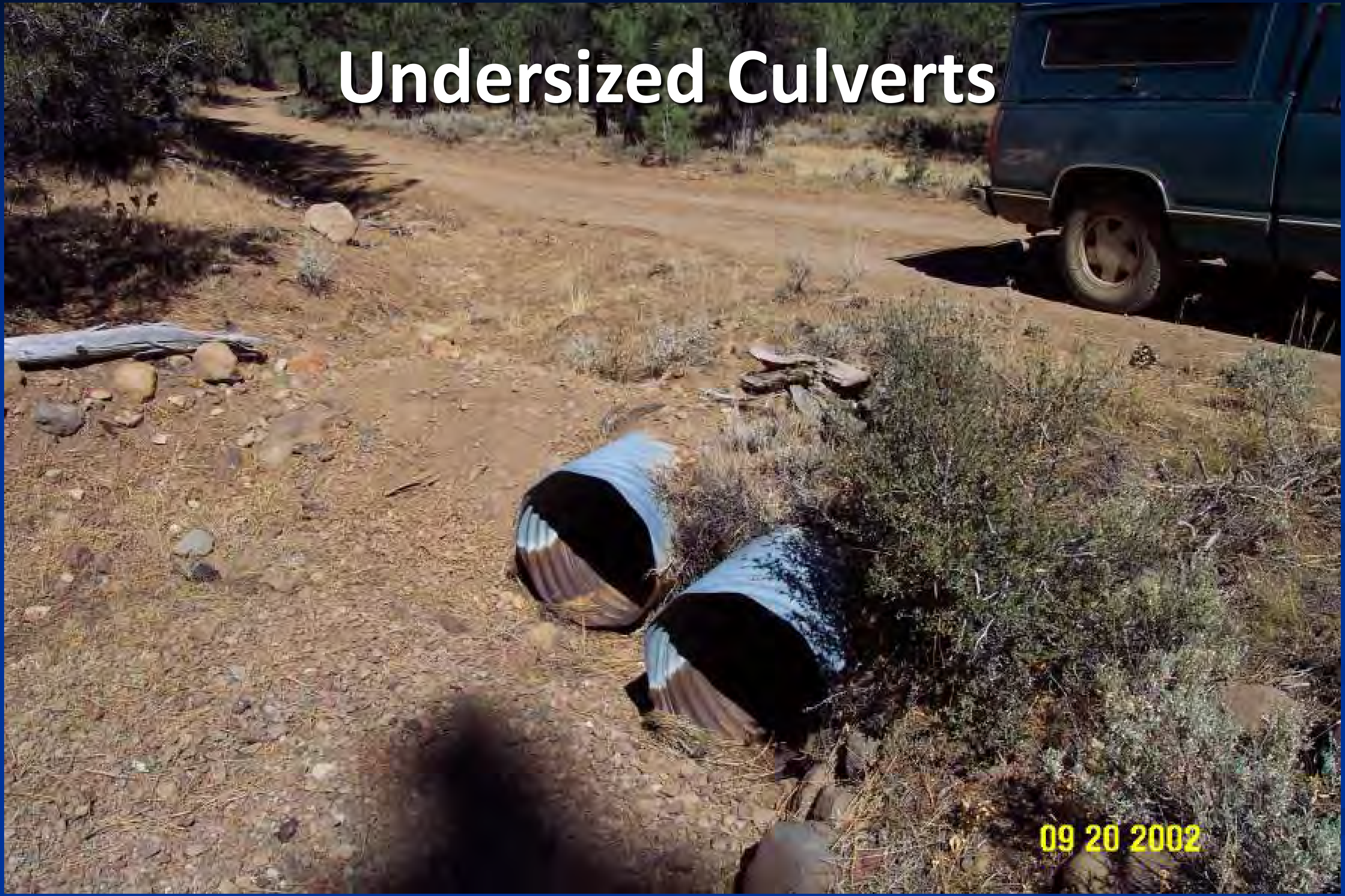
Stream diversion

Shallow, Short Culvert

Plugged Culvert – Crossing erosion

Washed Out Stream Crossing

Undersized Culvert


Undersized Culverts
09 20 2002

Culvert Plugging

Plate Arch (Poor Orientation)

Stream Diversion


Stream Diversion Gully
08 06 2002

Separated Culvert, Collapsing Fill

Humboldt Crossing, Collapsing Fill

Culvert Plugged from Debris Flow

Rusted-through culvert

Plastic Burns….

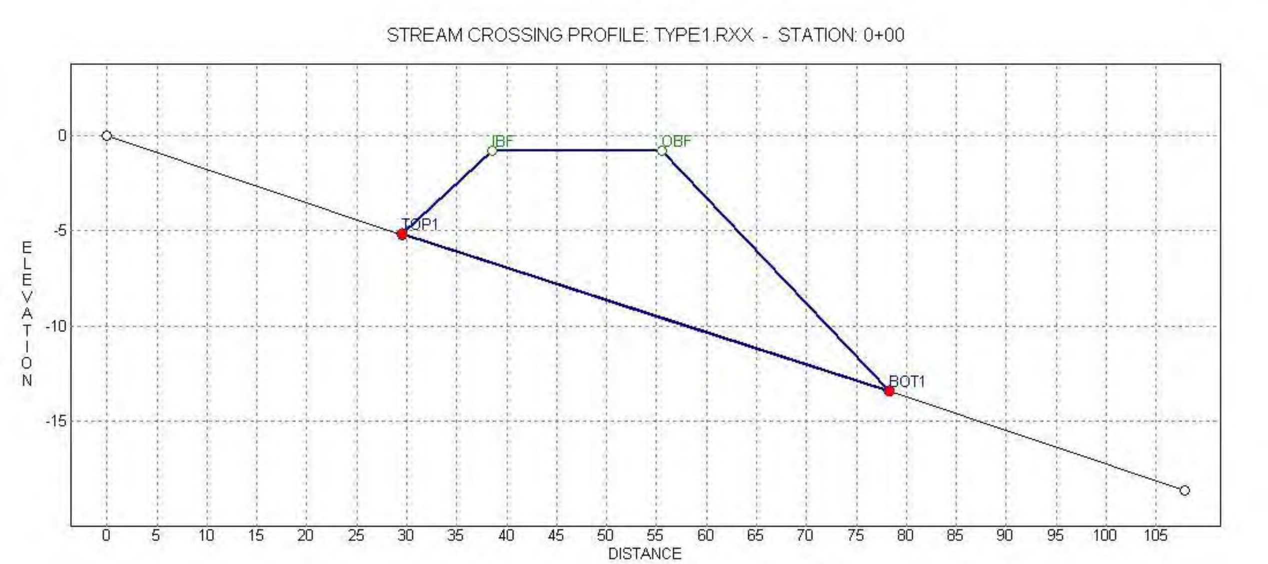
Bridge (insufficient capacity)

Reduced channel width

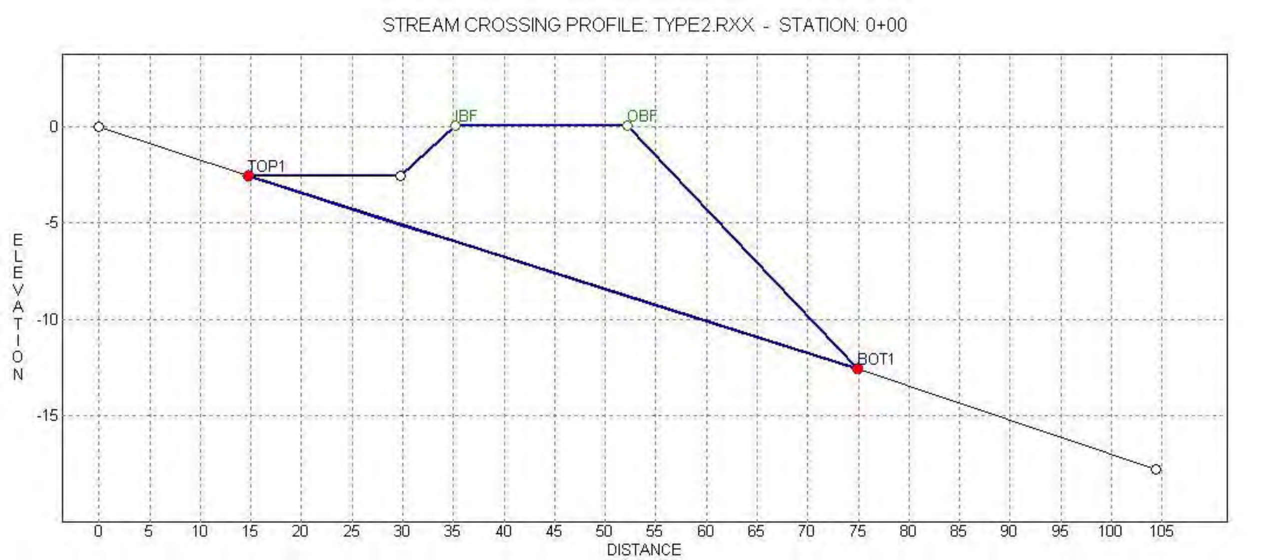
Undercut armor

Estimation of Stream Crossing Fill Volumes

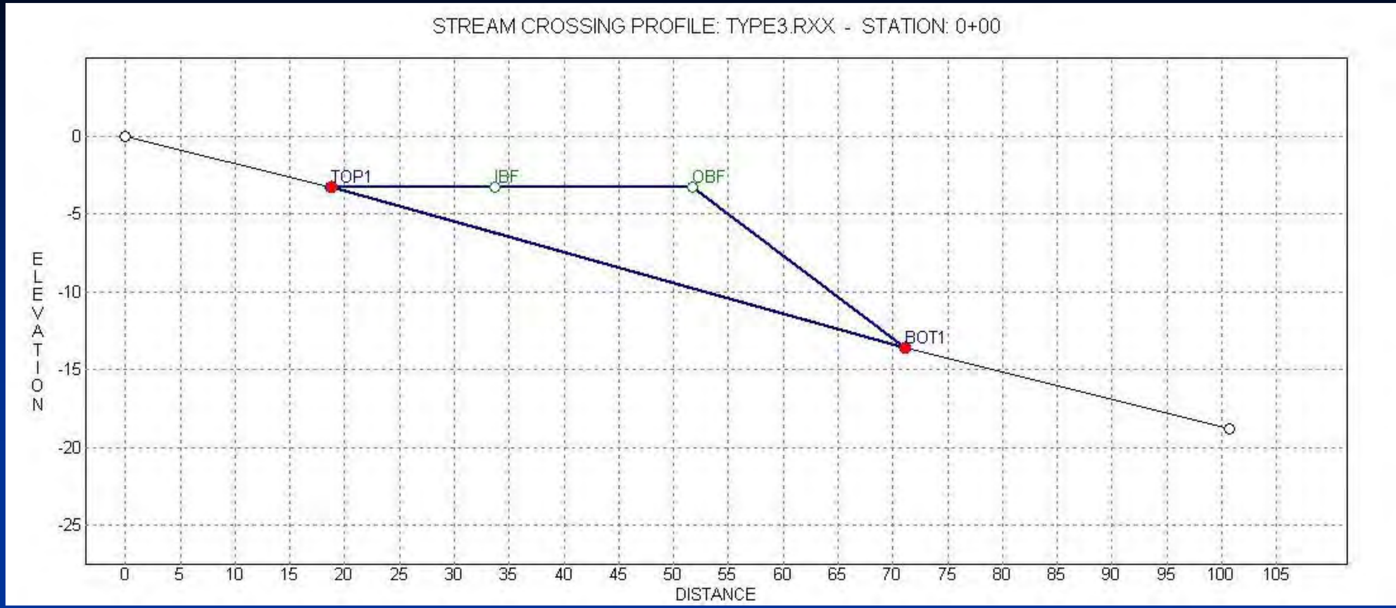
Type 1



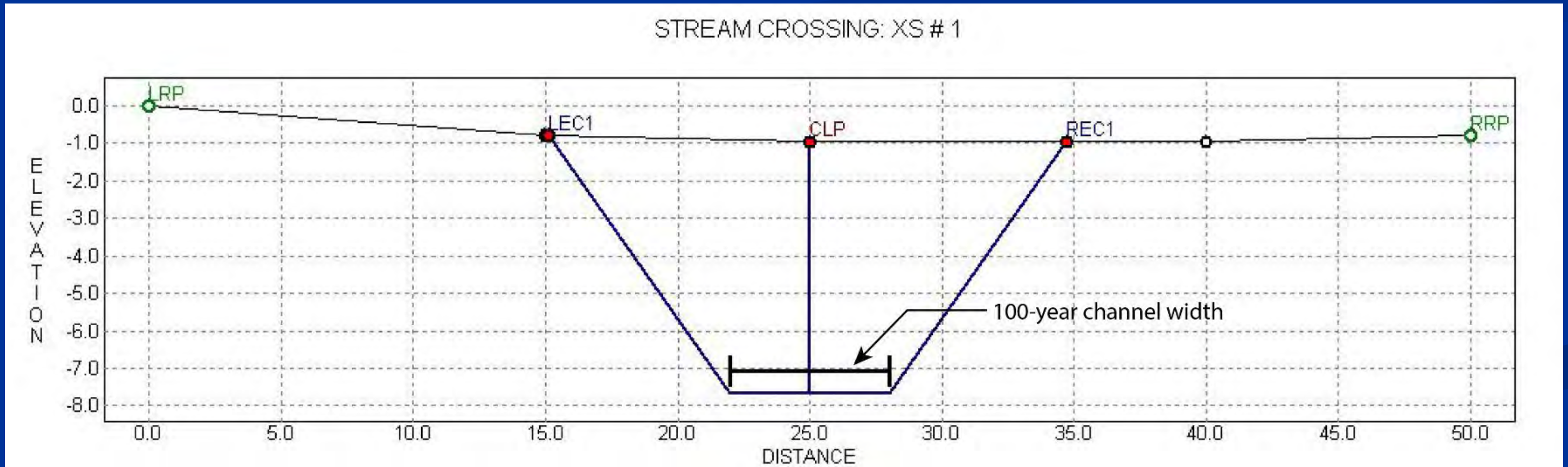
Type 2



Type 3

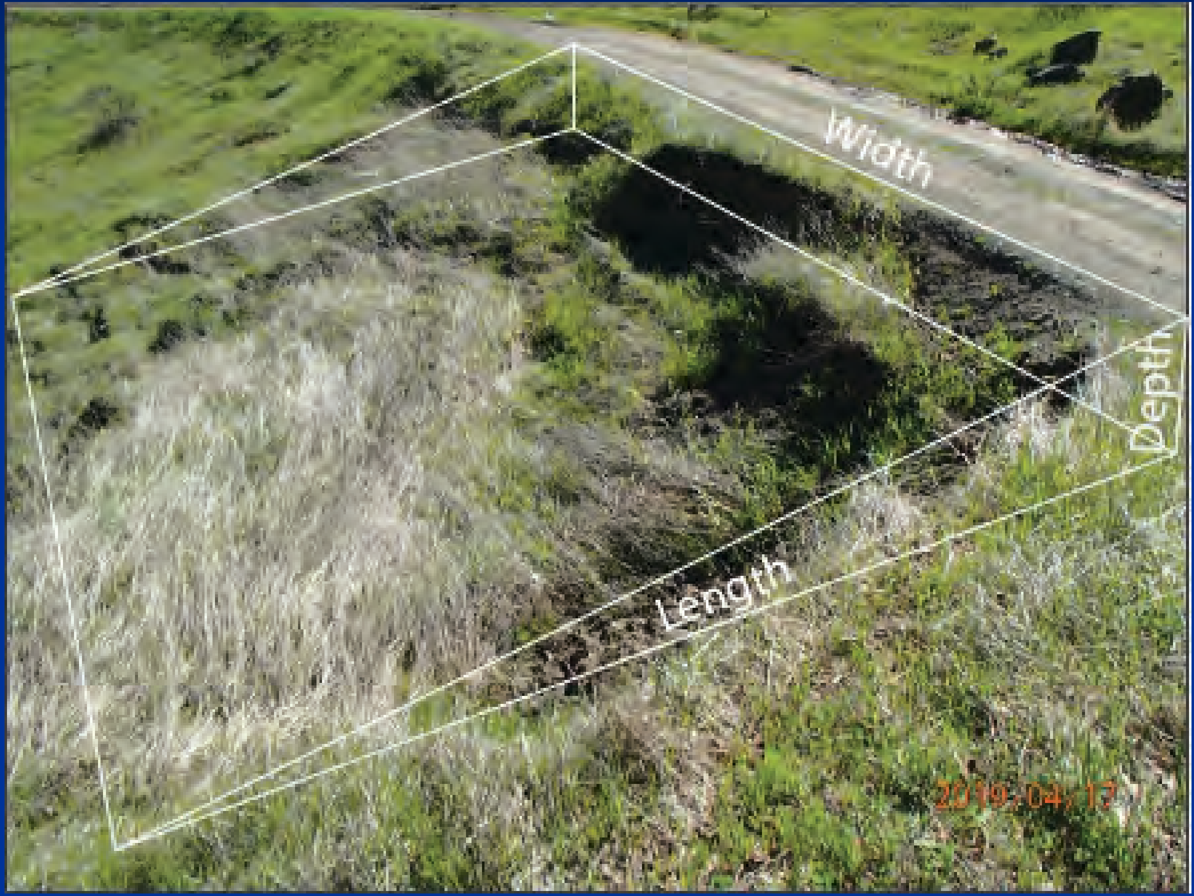


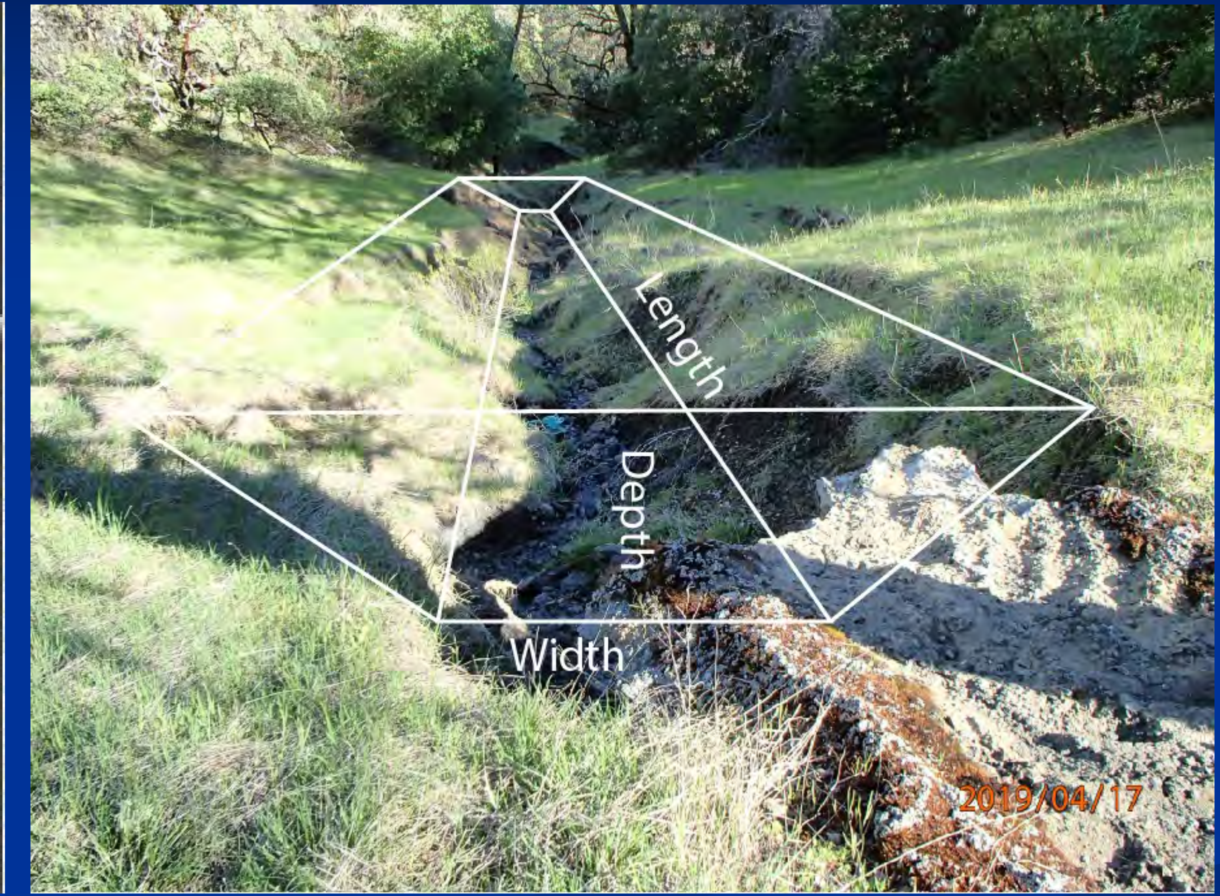
Cross Sections



Stream crossing fill volume standard (Weaver et al., 2006)

Estimating future sediment delivery from other episodic erosion features (landslides, fill failures, and gullies)





Direct measurement of feature length, width, and depth

What to inventory and upgrade…

Note: A forward-looking sediment assessment is <u>essential</u> for identification, quantification and prioritization of sites

- Stream crossings
  - ✓ Culvert capacity (100-yr+)
  - ✓ Plugging potential
  - ✓ Diversion potential
  - ✓ Site erosion (cmp outlet, streambanks, fillslopes, etc)
- Road related landslides
  - ✓ Potential road and landing fill failures
  - ✓ Potential debris slides in steep swales
  - ✓ Larger deeper landslides (1-for-1 rule)
- Road surface runoff and related erosion
  - ✓ Hydrologically connected roads and ditches
  - ✓ Gullies

Treating Road Stream Crossings

What is “Storm-Proofing”

Erosion control and erosion prevention work designed to protect a road, including its drainage structures and fills, from serious episodic erosion during large storms and from chronic erosion during intervening periods.

Types of road storm-proofing

Road Upgrading

Road Decommissioning

Road Upgrading and Watershed Restoration

(face the facts…it must be addressed)

- Open, maintained roads are common and often generate and deliver large volumes of sediment to streams
- Most roads in most watersheds are not abandoned and will be upgraded and maintained for future management
  - decommissioning is comparatively rare
- Most open, maintained roads were built decades ago to now-outdated standards and have weak points that are susceptible to failure
- Most culverted stream crossings are undersized and many have diversion potential
- Most forest roads have high levels of hydrologic connectivity and associated fine sediment delivery

Storm-Proofing Your Roads

- Types of road storm-proofing
- **Objectives and standards**
- Measures of success
- Common techniques

Practical objectives for road upgrading sediment control treatments

- Reduce failure potential (likelihood)
- Reduce failure magnitude (volume)
- Reduce road related sediment delivery
- Lower, more predictable aquatic and water quality impacts
- Lower cost of storm damage repair
- Less time "out of service" after storms –fewer washouts and road failures
- Potential increased ability to work under "wet" conditions – less turbidity
- Increased ability to manage forest resources

Technical Standards: Road Upgrading

- Stream crossings
  - Upgraded for 100 year capacity, including organic debris
  - Culvert set on-line and at natural channel grade
  - Plugging potential minimized
  - Diversion potential eliminated
  - Fish passage is accommodated for all life stages
- Road and landing fills
  - Unstable fills that could deliver are excavated/stabilized
  - Spoil is placed where it will not enter a stream
- Road surface drainage
  - Road surfaces and ditches are disconnected from streams
  - Road drainage structures do not drain onto unstable areas

Technical Standards: Road Decommissioning

- Stream crossing side slopes: Excavated and sloped at 2:1 or to the grade of natural side slopes above and below the crossing

- Stream crossing channel profile: Excavated at natural channel grade through the crossing with no abrupt grade changes at the top or the bottom of the excavation – the standard is to exhume original channel bed

- Stream crossing channel width: Excavated to match or exceed the natural channel width outside of the influence of the crossing; the design standard is the 100-year flow width

- Road approaches and all road reaches: Hydrologically disconnected to minimize direct runoff into the crossing or into nearby streams

- Road related fill slope landslides: Fillslope landslides with potential for sediment delivery are excavated and removed

Storm-Proofing Your Roads

- Types of road storm-proofing
- Objectives and standards
- **Measures of success**
- Common techniques

Measures of success

- **Road upgrading – *resiliency & threat reduction***
  - Decreased culvert plugging
  - No unexpected stream diversions
  - Lower frequency of stream crossing washout
  - Lower sediment delivery from crossing failure
  - Lower frequency and delivery from road fill failures
  - Hydrologic connectivity reduced to 10% to 20%, or less
- **Road decommissioning – *eliminate threats***
  - Excavated stream crossings exhibit less than 5%, preferably less than 2%, loss of erodible fill volume
  - Lower frequency & delivery from road fill failures
  - Hydrologic connectivity reduced to less than 5%

Storm-Proofing Your Roads

- Types of road storm-proofing
- Objectives and standards
- Measures of success
- **Common techniques**

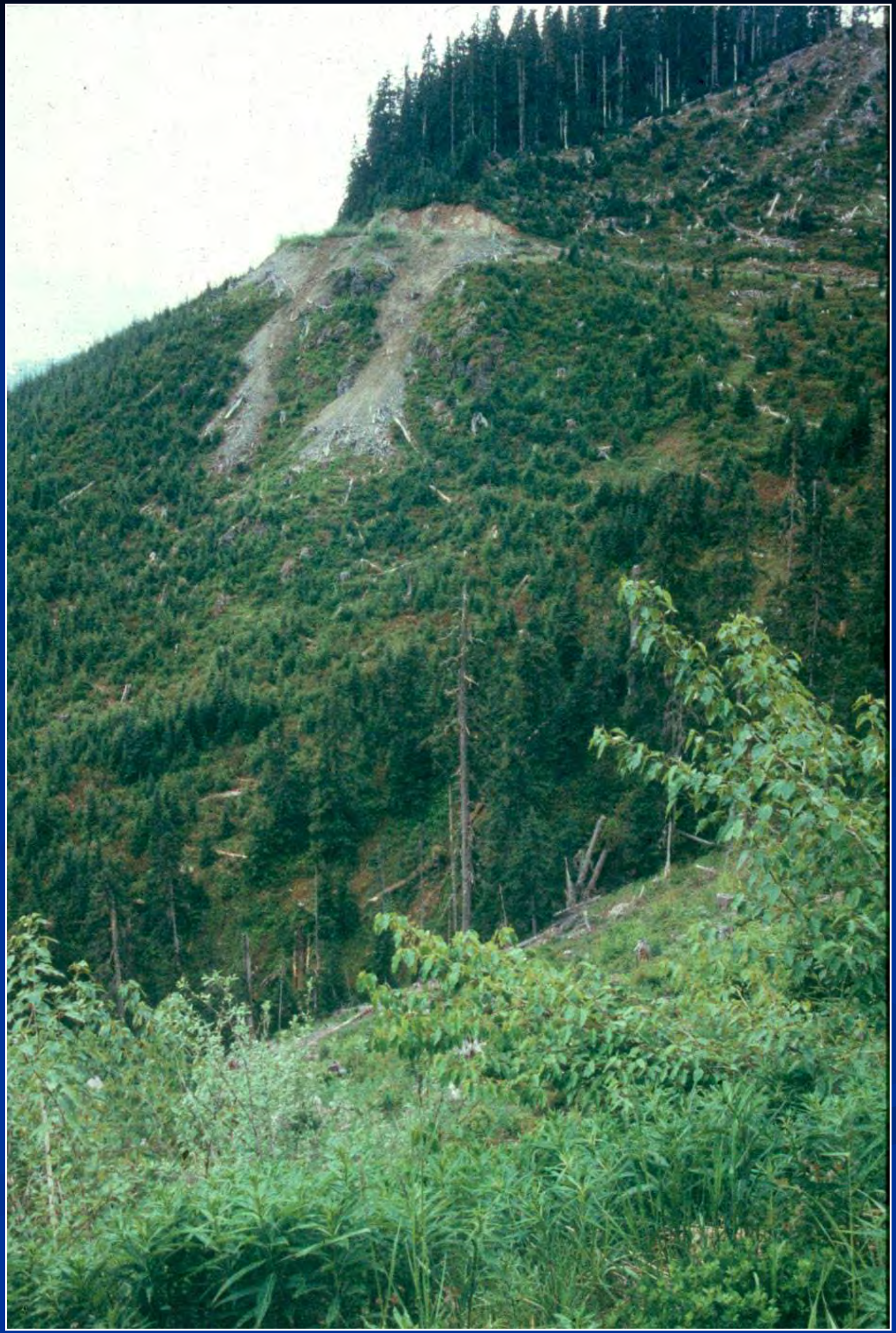
Road Upgrading Treatments

Four Road Upgrading Treatment Mantras

1) Treat sites of sediment delivery
2) Treat the cause, not the symptom
3) If you don't change anything, it's just going to happen again
4) Prevent erosion before you have to try to control it

Erosion versus sediment delivery:

1) Treat sites of sediment delivery



Road erosion treatments - upgrading

2) Treat the cause, not the symptom

3) If you don't change anything, it's just going to happen again…

4) Prevent things from happening in the first place!

1) Treating Stream Crossings

Reducing stream crossing vulnerability

- **Culverted stream crossings** are naturally susceptible to failure. Failures include:
  - Plugging and overtopping
  - Washout (erosion from various causes)
  - Stream diversion*
- **Bridges and fords** are usually designed to minimize failure potential

**Stream diversions cause from 2 to 10 times the volume of erosion and downstream sediment delivery (through gullying and landsliding) compared to simply eroding and washing out a stream crossing fill.*

Methodologies for estimating design storm discharge (Q_{100})

- Rational method equation – drainage basins 80 acres and less
- Magnitude and frequency method – drainage basins larger than 80 acres
- Flow transference – uses discharge records from a nearby hydrologically comparable gaged basin

Rational Method equation

$$Q_{100} = C\ I\ A$$

Q_{100} = predicted peak runoff from a 100-year storm (cfs)
C = runoff coefficient
I = rainfall intensity for the 100-year storm (in/hr)
A = drainage basin area in acres

Culvert Sizing Information	
Existing culvert diameter (in)	48
Drainage area (acres)	54
Runoff coefficient value C	0.35
Length from top of watershed to the culvert inlet (ft)	3,100
Elevation difference between the top of watershed to the culvert inlet (ft)	1,055
24-hr Rainfall intensity (in/hr)	4.44
Q100 (cfs)	66
Recommended culvert size HW/D (ratio) = 1.0	54
Recommended culvert size HW/D (ratio) = 0.67	72

Rational Method

$Q_{100} = CIA$

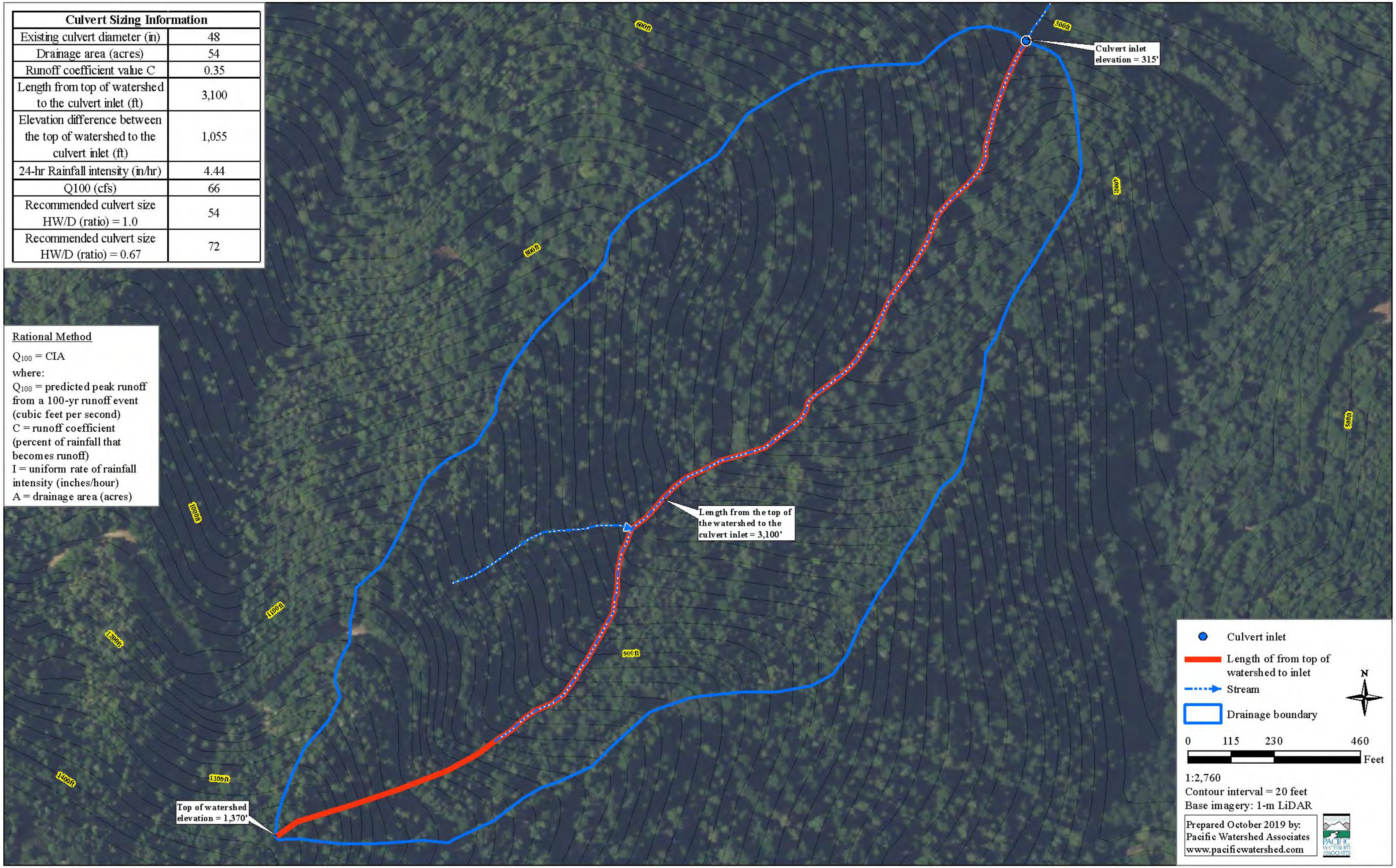
where:

Q_{100} = predicted peak runoff from a 100-yr runoff event (cubic feet per second)

C = runoff coefficient (percent of rainfall that becomes runoff)

I = uniform rate of rainfall intensity (inches/hour)

A = drainage area (acres)



1:2,760
Contour interval = 20 feet
Base imagery: 1-m LiDAR

Prepared October 2019 by:
Pacific Watershed Associates
www.pacificwatershed.com

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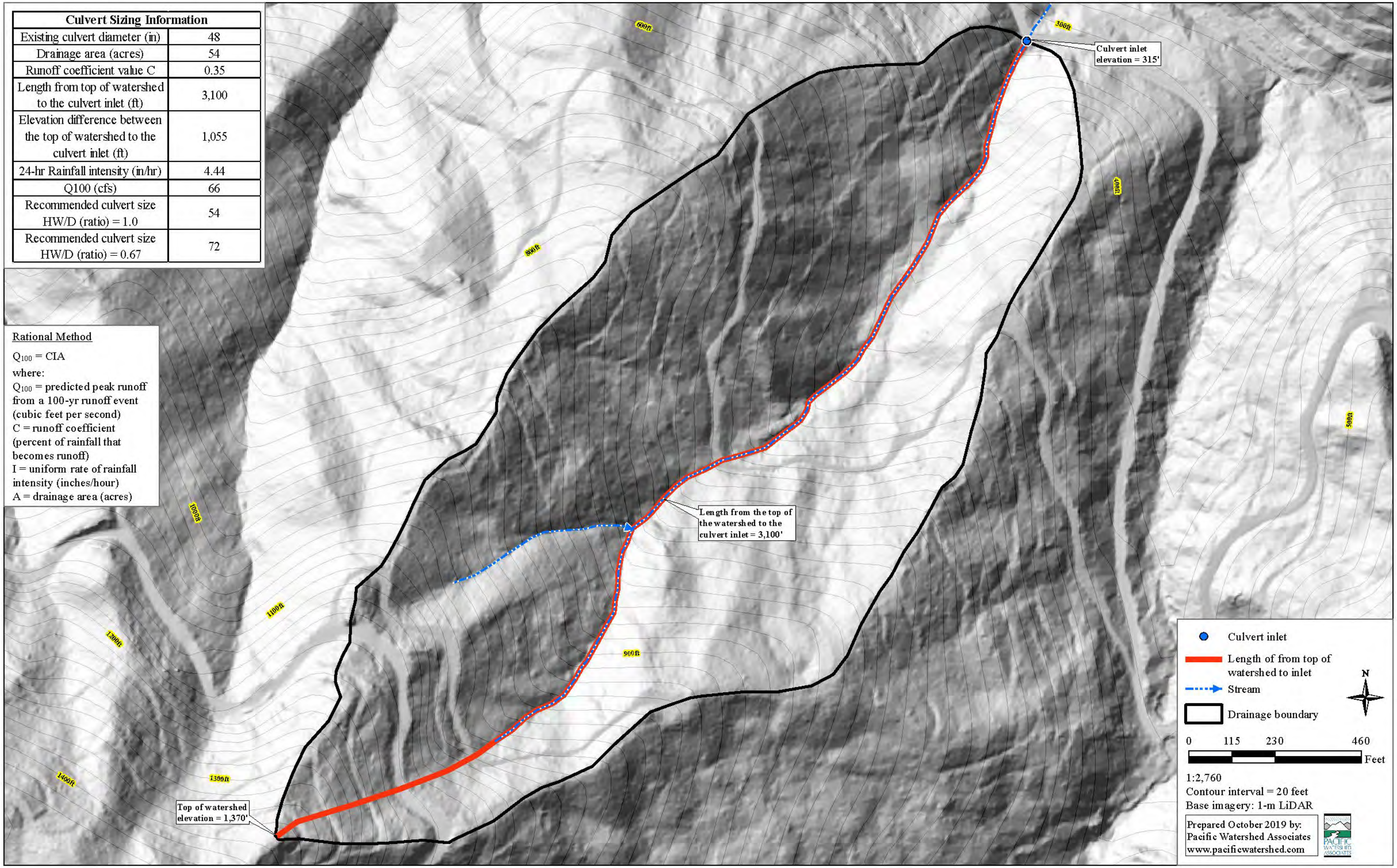


Updated USGS Magnitude and Frequency Method

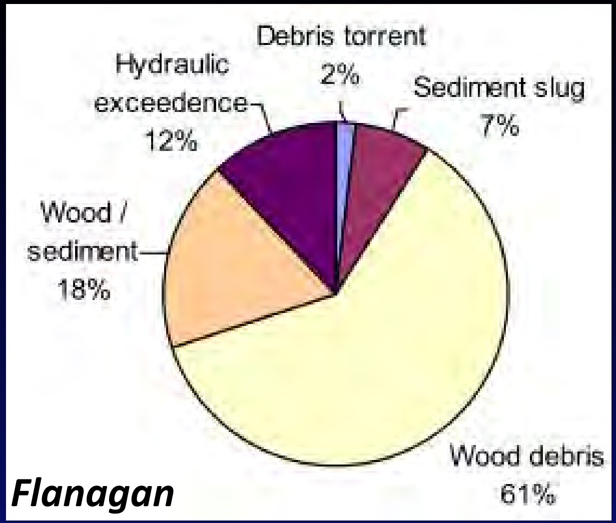
(Gotvald et al., 2012)

Q_{100} = predicted 100-year flow (cfs)
A = area draining to crossing (mi^2)
P = mean annual precipitation (in)
H = mean basin elevation (ft)

North Coast	$Q_{100} = 48.5\ A^{0.866}\ P^{0.556}$
Sierra Nevada	$Q_{100} = 20.6\ A^{0.874}\ P^{1.24}\ H^{-0.250}$
Lahontan	$Q_{100} = 0.713\ A^{0.731}\ P^{1.56}$
Central Coast	$Q_{100} = 11.0\ A^{0.840}\ P^{0.994}$
South Coast	$Q_{100} = 3.28\ A^{0.891}\ P^{1.59}$
Desert	$Q_{100} = 1350\ A^{0.506}$

Post-fire sediment loading

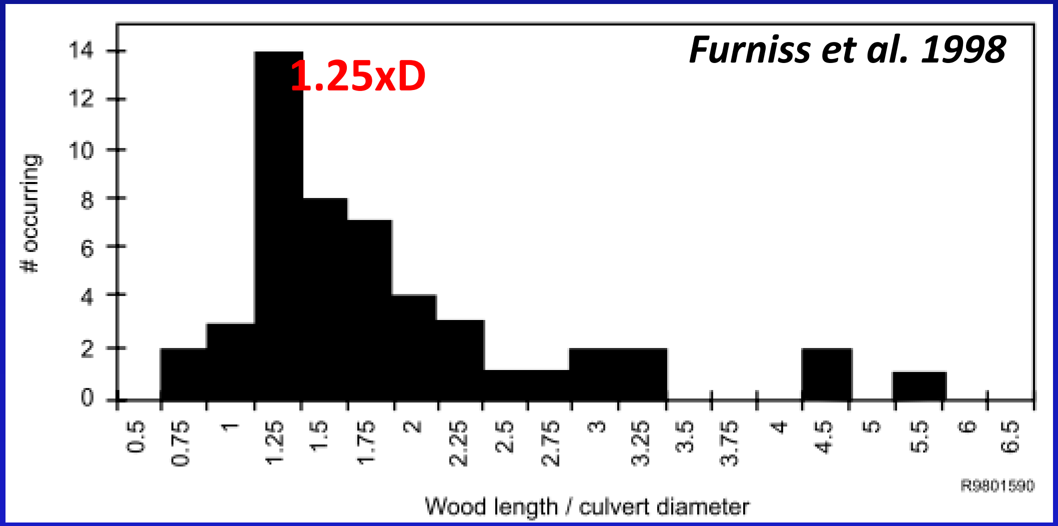
Predict, prevent, mitigate



Sizing culverts for peak flows,

...including sediment and debris

- Increase culvert diameter to account for debris (so HW/D = 0.67) (per Cafferata, et al. 2004)
- Install a wider culvert (oval or arch)
- Install flared or mitered inlet
- Install trash barrier or deflector
- Install overflow culvert or snorkel
- Install arch or bridge



Reducing stream crossing vulnerability

New culverts can be **sized** and **designed** (shaped) to reduce the risk of plugging.

In-channel and **drainage structure** treatments can be applied to new and *existing culverted stream crossings* to reduce the chance that a culvert will become plugged, with subsequent flood flows overtopping or diverting down the road.

Culvert replacement at base of fill

Culvert replacement at base of fill

Culvert replaced in alignment of stream channel

Reducing stream crossing vulnerability

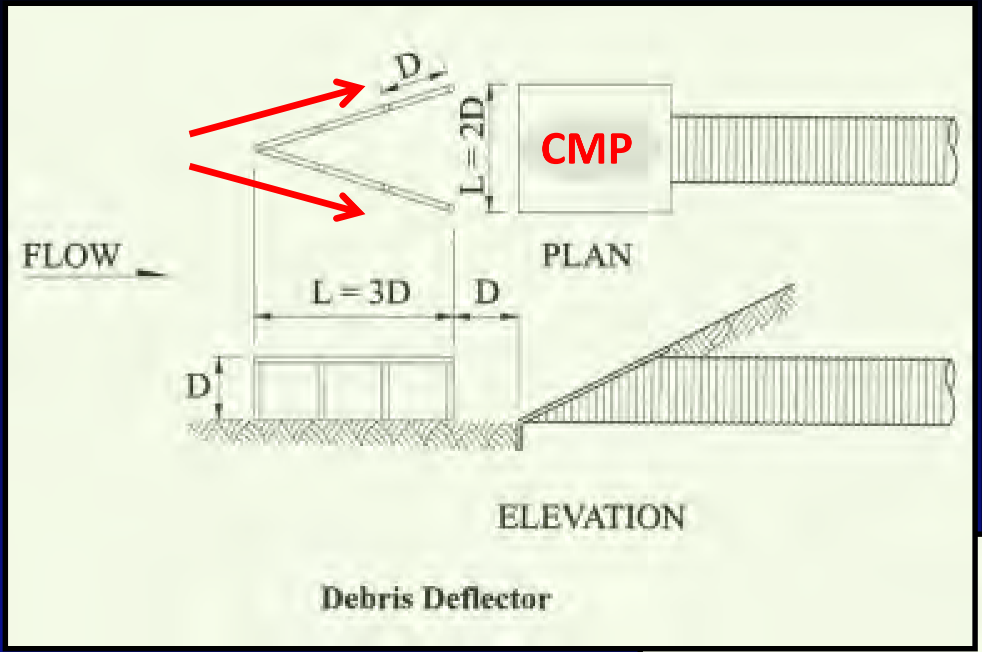
Common techniques for reducing the risk of stream crossing failure:

- Culvert upsizing
- Culvert widening (width and shape)
- Installing wingwalls, flared inlets, mitered inlets and/or beveled inlets
- Installing debris barriers or debris deflectors
- Installing emergency overflow culverts and/or snorkels
- Replacing the culvert with a bridge
- Decommission (abandon) the crossing

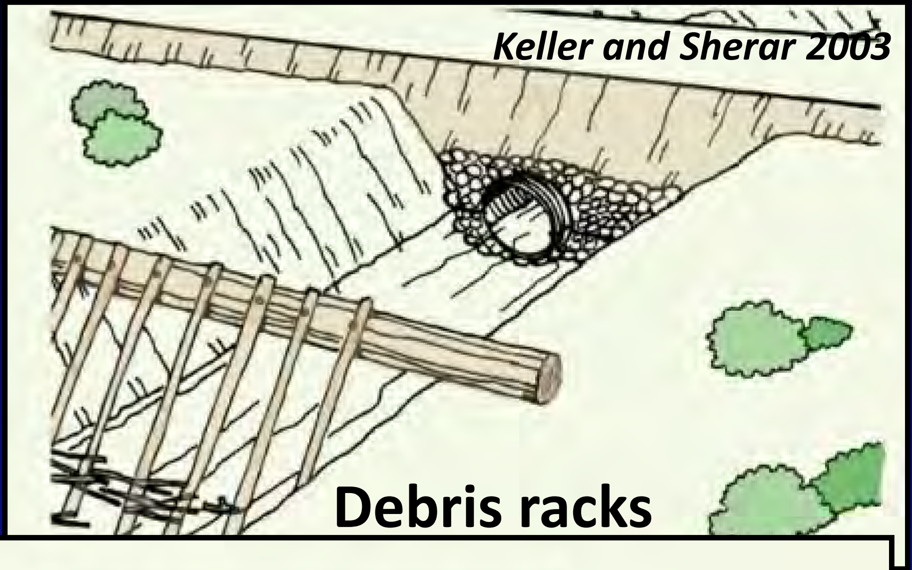
Culvert with single post trash rack

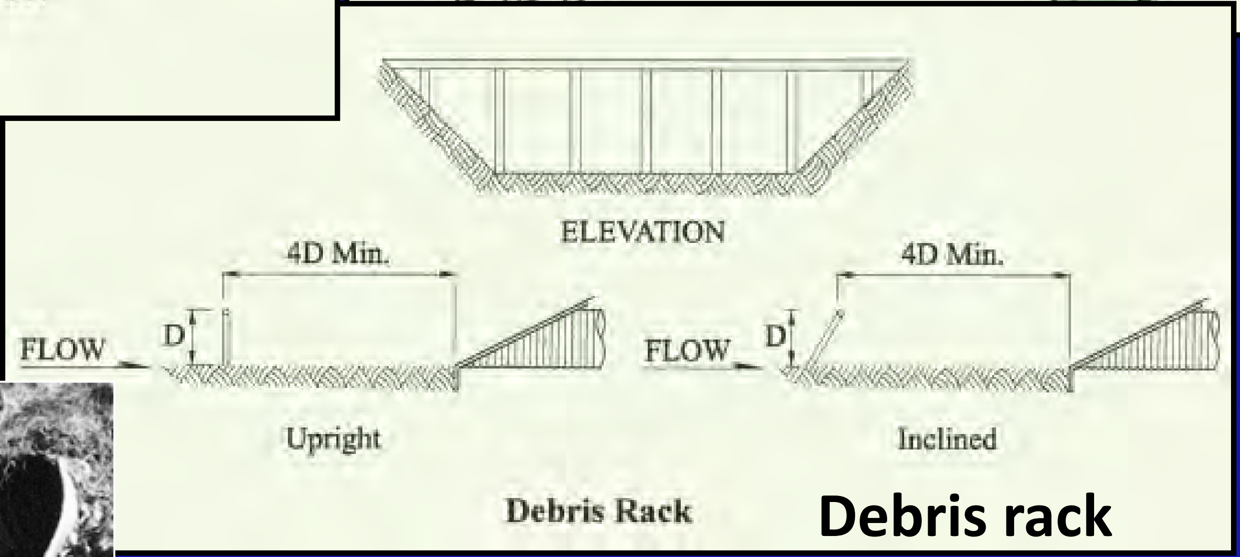
Some measures used to reduce the risk of crossing failure

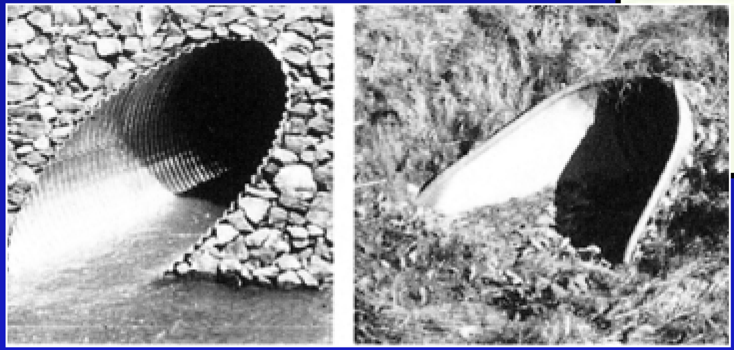
Reducing the risk of stream crossing failure



Debris deflector







Mitered and flared inlet

Reducing the risk of failure

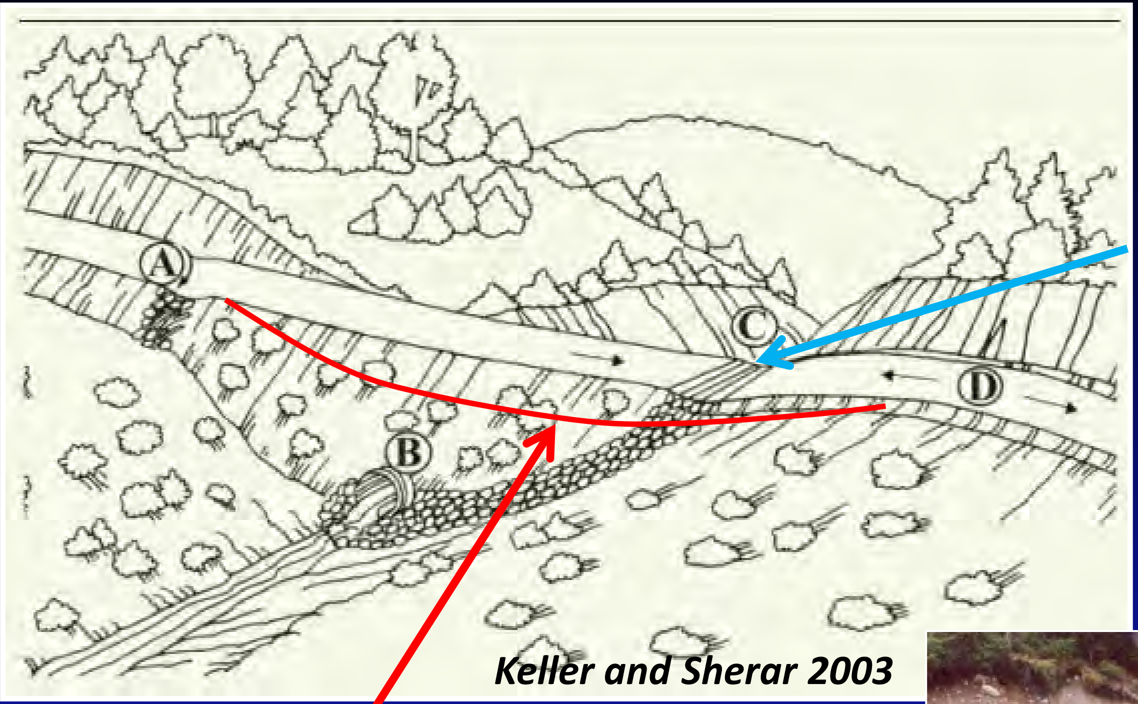
Culvert upsizing

Reducing stream crossing vulnerability

Common techniques for reducing the risk of stream diversion:

- Install a critical dip (properly designed)
- Dip the entire stream crossing fill (lower the fill)
- Install an emergency overflow culvert, with downspout

Reducing (eliminating) risk of stream diversion



Critical dip

Lowered fill

Critical dip

Predict, prevent, mitigate

Reducing stream crossing vulnerability

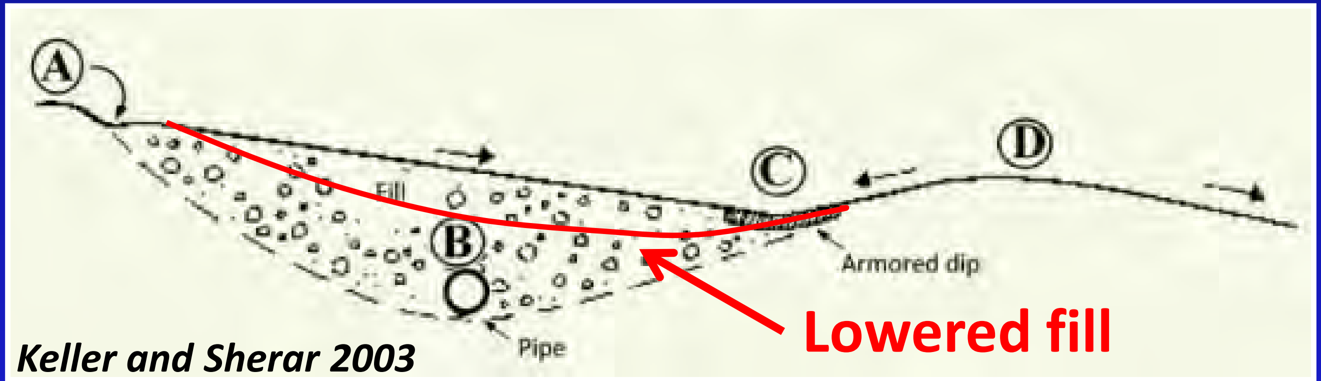
Common techniques for reducing the magnitude of stream crossing failures:

- Minimize the erodible fill volume (dip or lower the entire crossing fill)
- Minimize overtopping erosion rates (ensure overtopping occurs at a hardened or resistant location – usually the down-road hingeline)
- Armor or harden the overflow spillway (armor the axis of the overflow dip, down the fill face (used only where overtopping is common))

Reducing the magnitude of crossing failure

Reducing erodible fill volume

Reducing overtopping erosion rates



Predict, prevent, mitigate

Fish passage at stream crossings

Preferred stream crossing designs for fish-bearing streams (NMFS):

- **Preferred** - No stream crossing structure (find another place for the road or decommission the existing crossing)
- Bridge (channel spanning)
- Bottomless arch, embedded culvert, embedded or high VAR vented ford (channel width with natural streambed)
- Non-embedded culvert or hydraulic design (low gradient channels only)
- **Least preferred** - On steeper gradient channels, install baffled culvert or a structure with a designed fishway.

Embedded culvert upgrade for fish passage

Bridge installation to facilitate fish passage

Predict, prevent, mitigate

Stable stream crossing fills

Designing stable stream crossing fills:

- Avoid clay rich or cohesionless soils
- Fills should be compacted during optimal moisture content (moist) in 6” to 12” lifts; Fill face compaction is achieved through excavation of the compacted fill
- Vibratory rollers are used for low cohesion soils, sheeps foot rollers for cohesive soils, and mechanical tampers for cohesive soils along the culvert bed and flanks; *Field compaction* using rubber tired equipment and dozer tracking may be acceptable under ideal moisture conditions
- Strive for fillslope angle less than 1½:1, preferably 2:1 or less, or buttress/armor the slope
- Revegetate fillslopes, divert road surface runoff, and armor culvert outlet and fillslopes where necessary (steep fillslopes)

Stable stream crossing fills

Vegetated 2:1 fillslope with extended culvert outlet and minimal armor

Armored 1:1 fillslope, with dense internal compaction, on steep Class III channel

Fillslope buttressing and barrel projection

Predict, prevent, mitigate

Stream crossing culverts

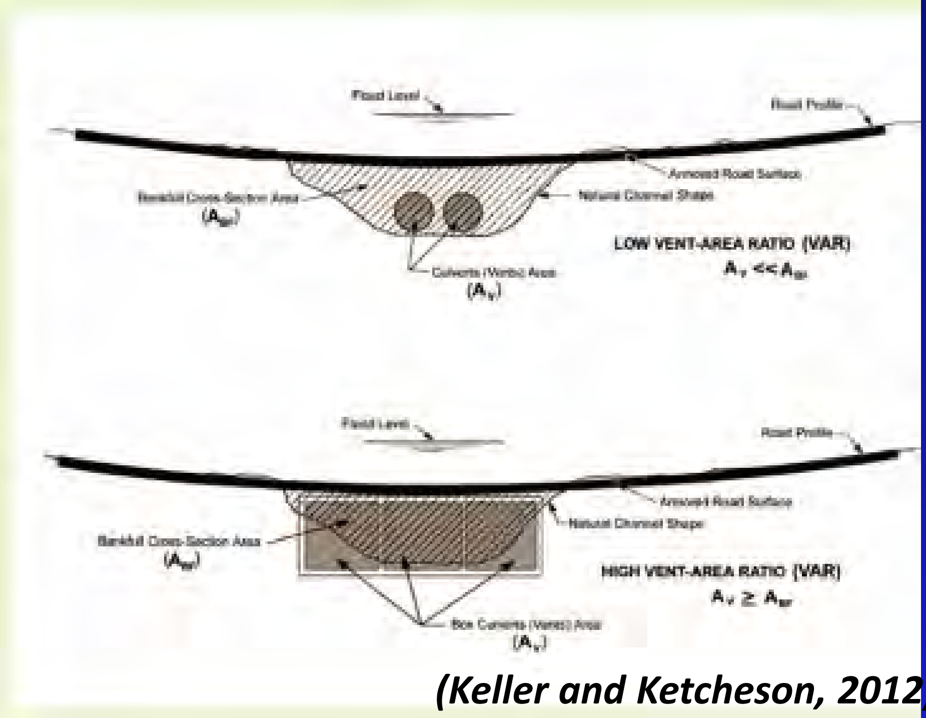
- **Culvert materials**: steel, aluminum, concrete, plastic
- **Durability**: abrasion, corrosion
- **Sizing**: Rational, USGS Magnitude and Frequency, Flow transference
- **Alignment and length**: vertical, horizontal
- **Debris treatments**: Debris rack (barriers and screens), debris deflectors, risers
- **Inlet treatments**: mitered inlet, tapered inlet, flared inlet, beveled inlet, slope collars, headwalls, snorkels, risers
- **Emergency overflow culverts:** sizing and design

Other stream crossing structures

- Bridges: Log stringer (no longer common), I-beam (engineered), truss (Bailey)(up to 200'), and rail car (up to 90')
- Armored fills and vented fills
- Fords (native), hardened fords, and vented fords
- Temporary stream crossings (fill, culverted fill, log, and bridge)

Other stream crossing structures

Other stream crossing structures



(Keller and Ketcheson, 2012)

Road erosion treatments - upgrading

Armored fill crossings

Armored fill crossings

Armored fill with large diameter rock

Armored fill displaying adequate keyway cross section


CAT

Special considerations in Upgrade Treatments

- Paved roads
- County Roads (paved/unpaved public roads)
- Main Line USFS roads (paved and unpaved)
- Roads in the snow zone
- Steep roads (>~12%)
- Road use types and levels (speed and clearance restrictions; e.g., lowboys, FedEx and BMWs; commercial roads vrs subdivision roads)
- Stream crossings in debris flow channels

SUMMARY
Measures of Success for Road Upgrading Treatments

- **Road upgrading**
  - Decreased culvert plugging
  - No unexpected stream diversions
  - Lower frequency of stream crossing washout
  - Reduced sediment delivery from crossing failures
  - Lower frequency and delivery from road fill failures
  - Hydrologic connectivity reduced to 10% to 15%, or less!

Poor rock armor application

Road Decommissioning

Common Techniques: Road Decommissioning

1) Ripping or decompaction
2) Cross-road drain construction or outsloping
3) Excavation of unstable fillslopes
4) Stream crossing removal
5) Endhauling and spoil disposal

Road Decommissioning Heavy Equipment

Ripping and decompaction

Decommissioned Road

Decompaction or Road Ripping:

- ✓Increases infiltration
- ✓Reduces runoff
- ✓Promotes vegetation

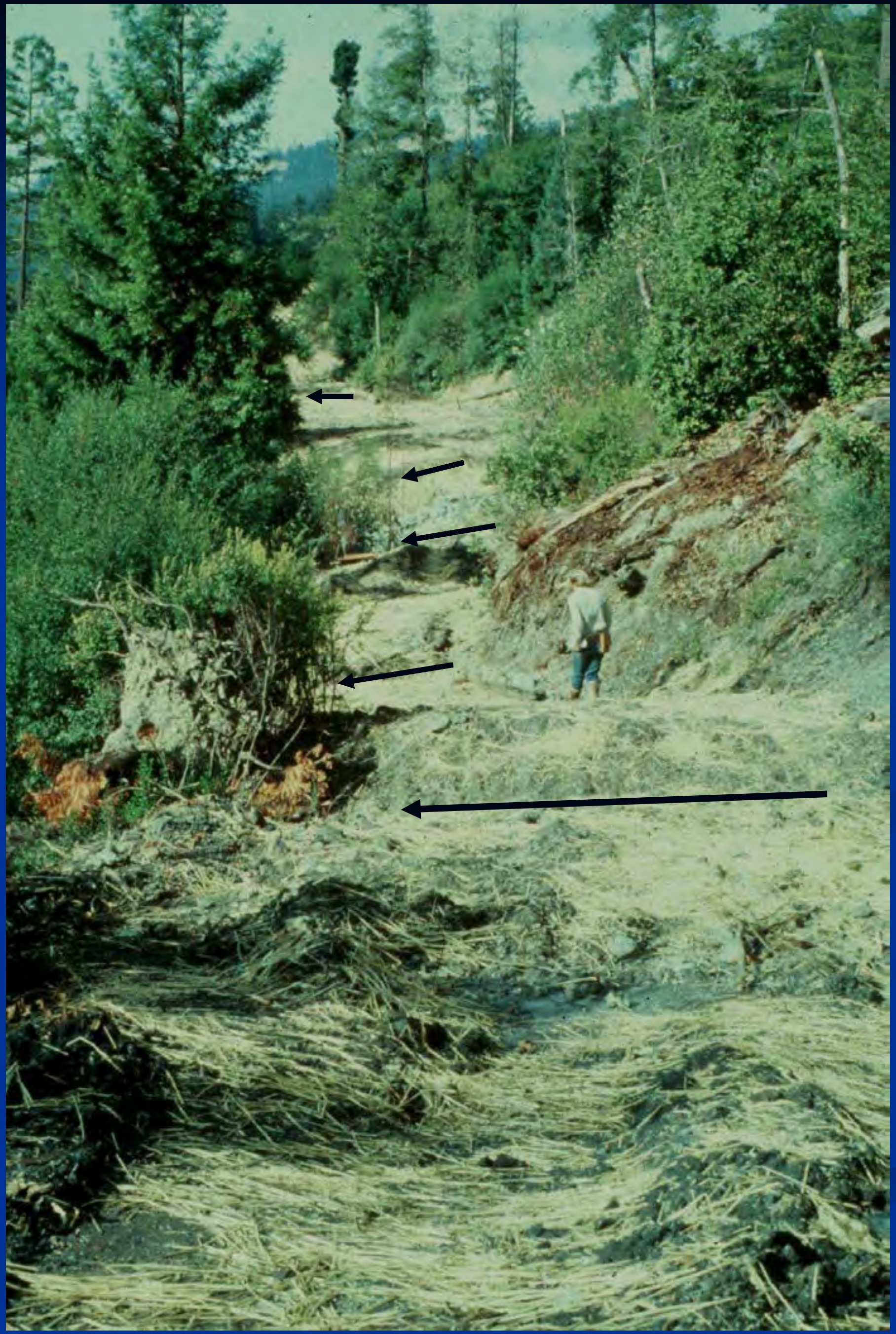
Road Decommissioning

Cross road drains

Decommissioned forest road

Road ripped and cross-road drained

(straw mulch was added to improve microclimate & promote revegetation)



Excavate unstable fill

(local spoil disposal against cutbank)

In-Place Outsloping

Local spoil disposal

In-place outsloping

(local spoil disposal)

Export Outsloping

(spoil endhauled)

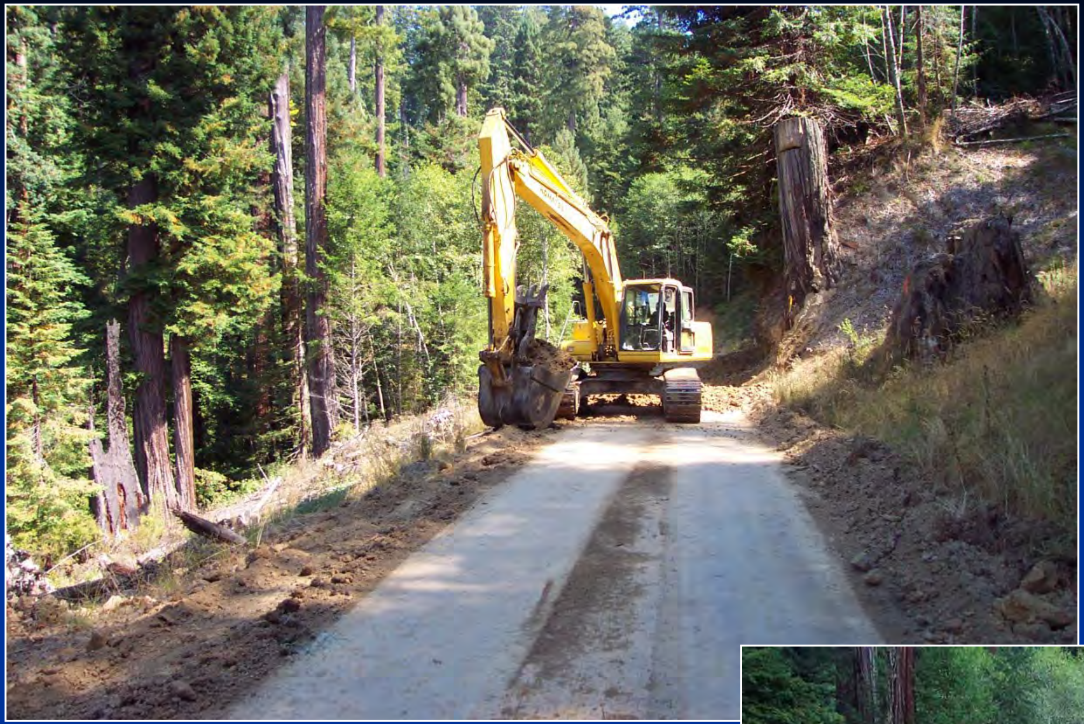
Import outsloping

(spoil hauled to site and used to outslope stable road)

Road erosion treatments – decommissioning

Trail outsloping (road to trail conversion)

Trail outsloping (road to trail conversion)



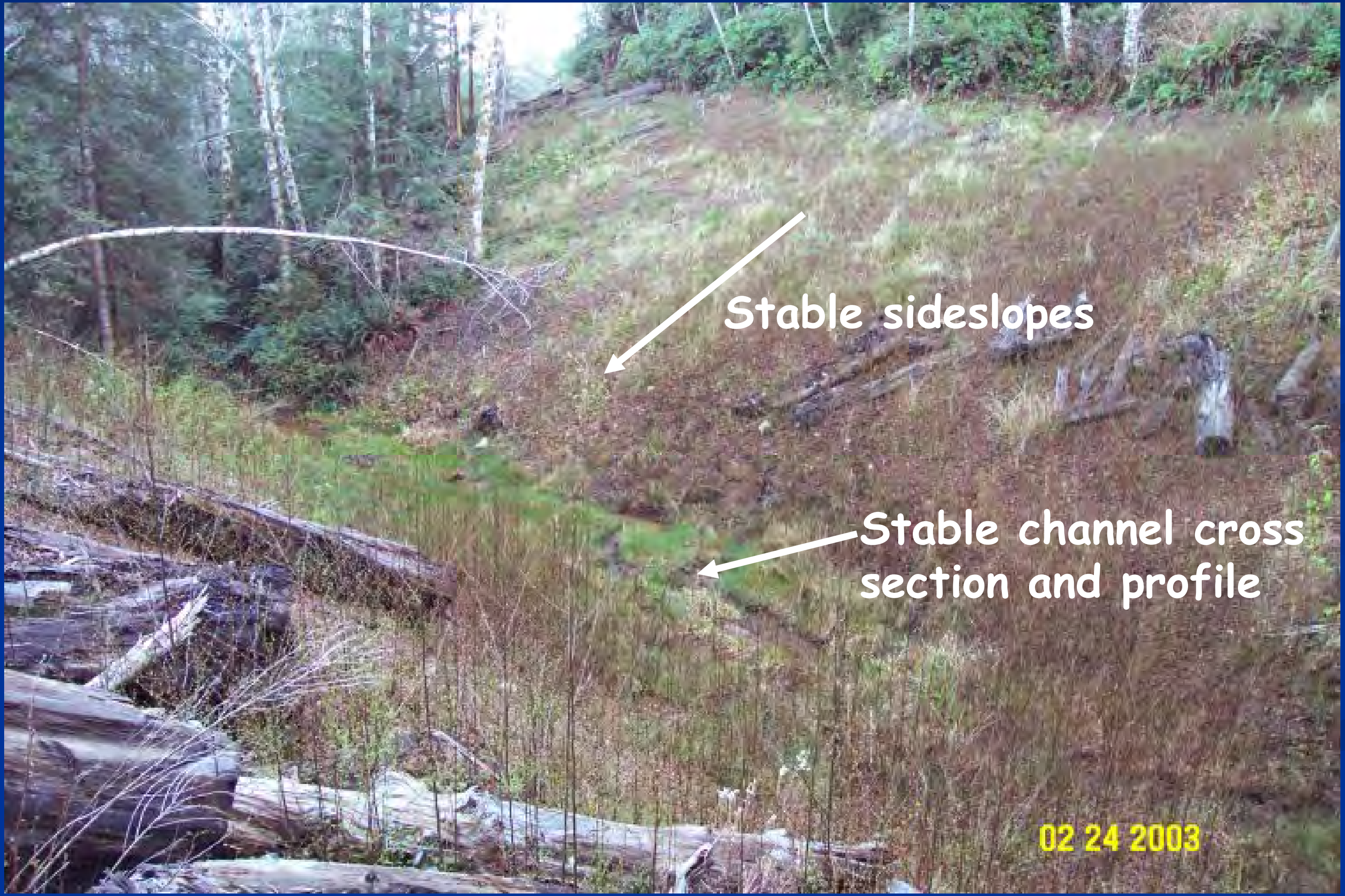
Trail outsloping (road to trail conversion)

Road Obliteration

(total recontouring)

Stream Crossing Decommissioning

(small = <250 yd^3)



Stream Crossing Decommissioning
(medium=250-500 yd^3)

Before

After

Decommissioned stream crossing

(large = >500 yd^3)

Decommissioned stream crossing (large)

Decommissioned stream crossing (large)

Decommissioned stream crossing (large)

Decommissioned Class I stream crossing

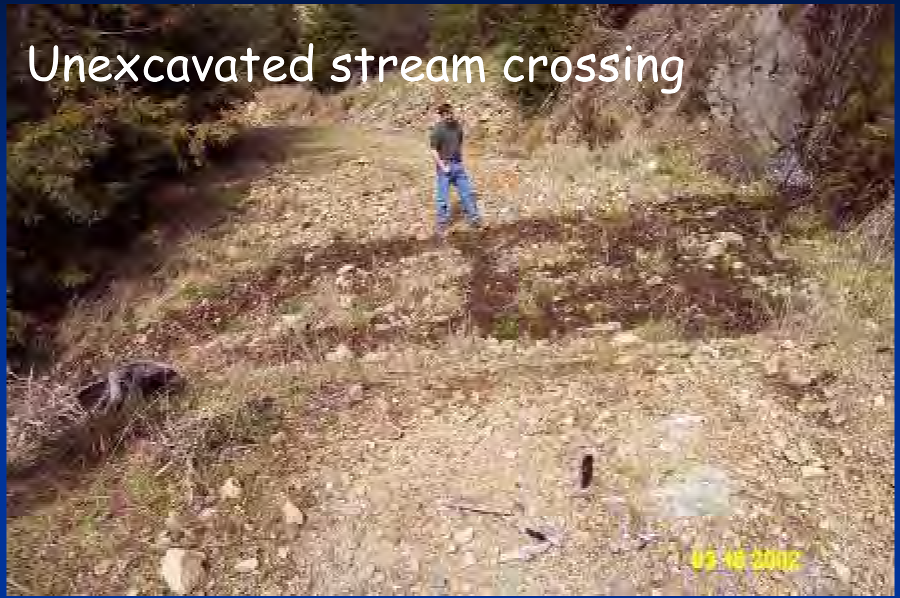
(fish passage)

Unstable road and landing fillslope excavation

Measures of success for Road Decommissioning Treatments

- **Road decommissioning**
  - Stream crossing decommissioning prevents at least 95% of predicted erosion and sediment delivery.
  - Decommissioning results in a lower frequency & delivery from road fill failures
  - Hydrologic connectivity is reduced to less than 5%

Typical errors in road decommissioning



Potential Problems: Bank Erosion and Channel Downcutting

Insufficient channel width

Incomplete excavation

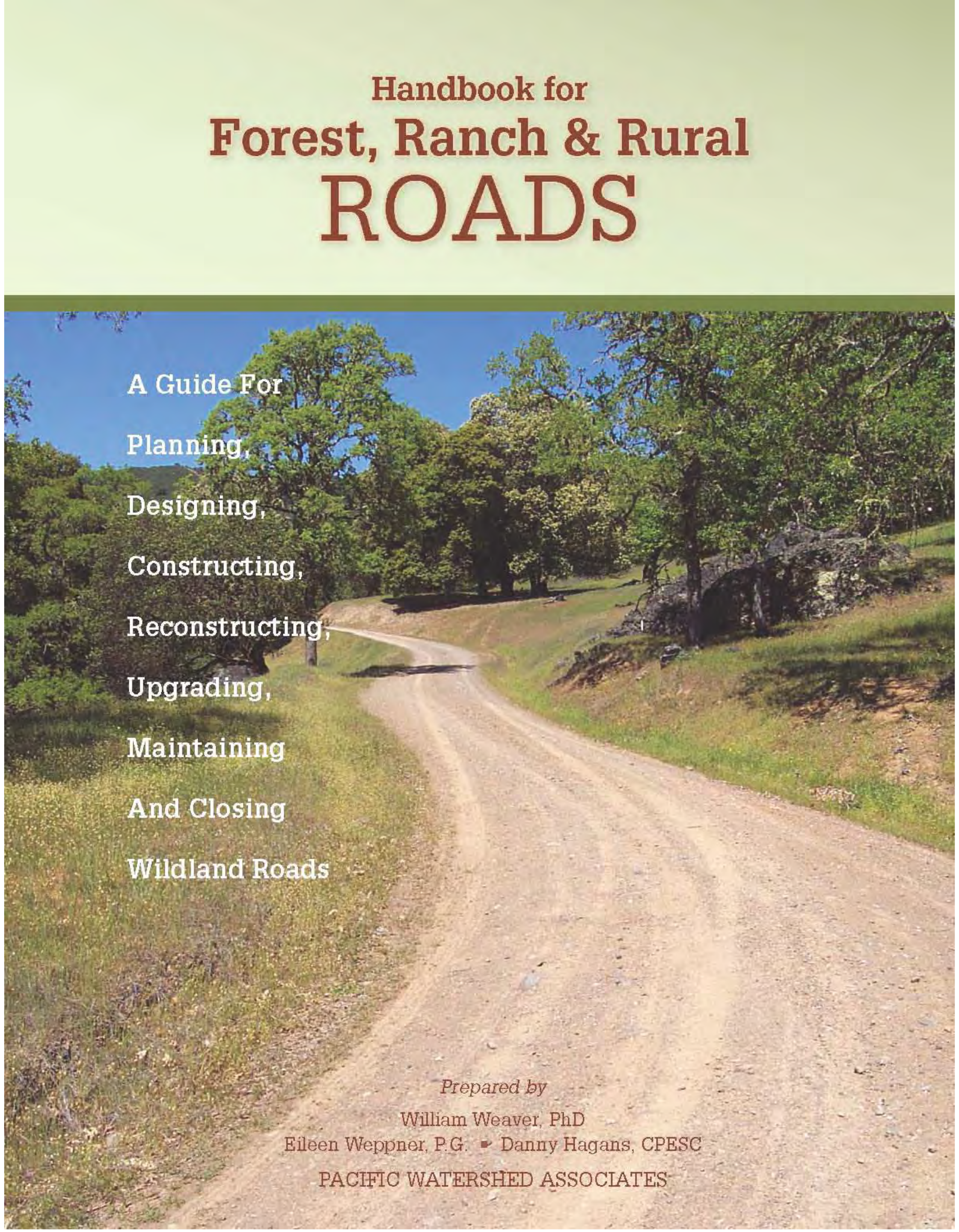
Problems: Side Slope Failures

Spoil disposal on sideslopes of decommissioned stream crossing

Additional Resources

Handbook for Forest, Ranch and Rural Roads:

Focus on stream crossings and hydrologic connectivity



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Pacific Watershed Associates

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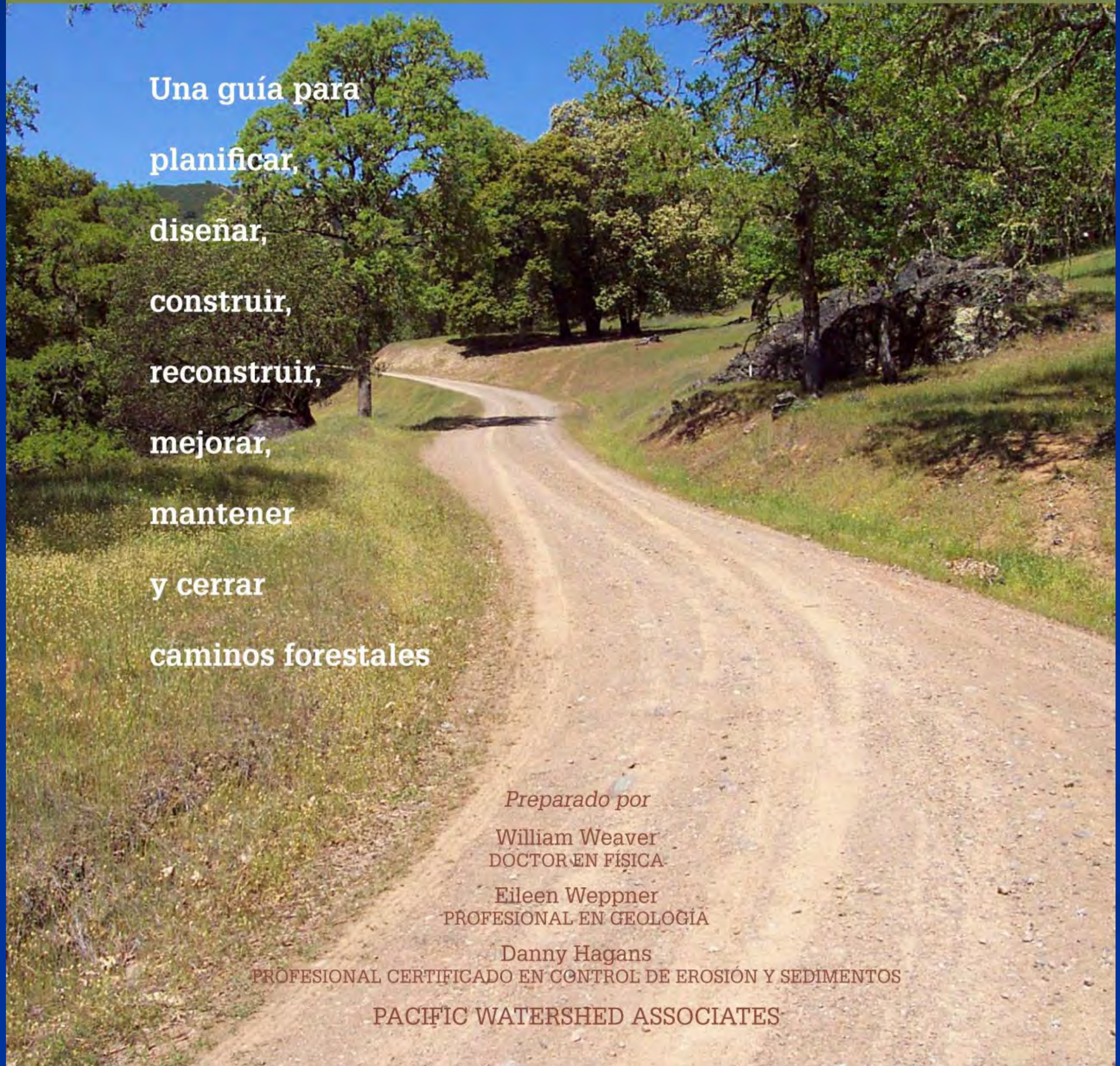
MANUAL DE CAMINOS

FORESTALES Y RURALES



Una guía para

planificar,

diseñar,

construir,

reconstruir,

mejorar,

mantener

y cerrar

caminos forestales

Preparado por

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Useful References (cont)

The goals of this video and the companion
Forest and Ranch Roads Handbook
are to assist landowners in:

- Making roads safer and more reliable in all kinds of weather
- Maintaining downstream water quality by avoiding excessive erosion caused by the road
- Reducing road maintenance costs
- Avoiding litigation as a result of excessive erosion such as violations of the Clean Water Act, or property damage to downhill or downstream neighbors
- Low impact and low cost roads in the future

Copies of this video and the
Forest and Ranch Roads Handbook
are available from

MENDOCINO COUNTY
RESOURCE CONSERVATION DISTRICT

405 S. Orchard Avenue
Ukiah, CA 95482
(707) 468-9223
www.mrcd.ca.nacdnet.org

Funded by California Department of Forestry and Fire Protection and California Department of Fish and Game

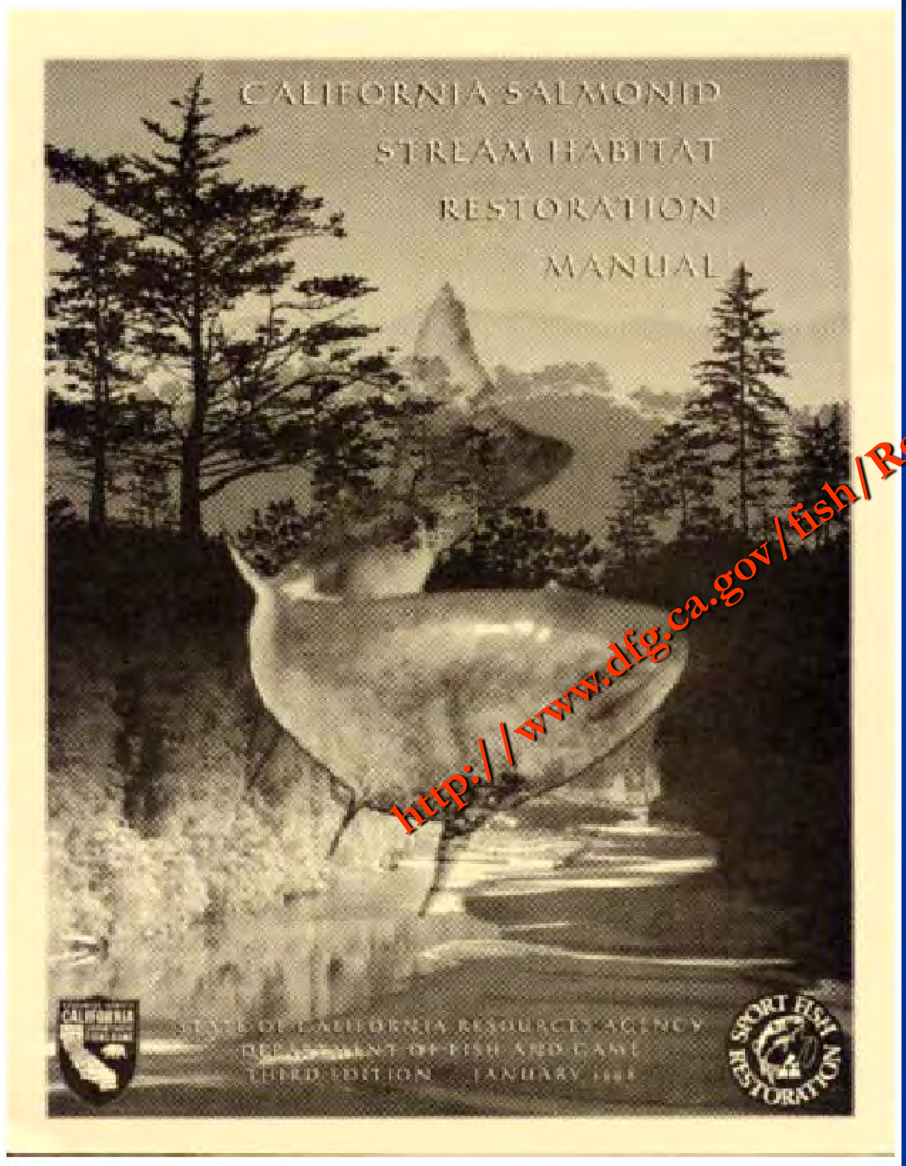
Forest and Ranch Roads
A guide to improving, repairing and restoring roads for water quality, fish and humans.

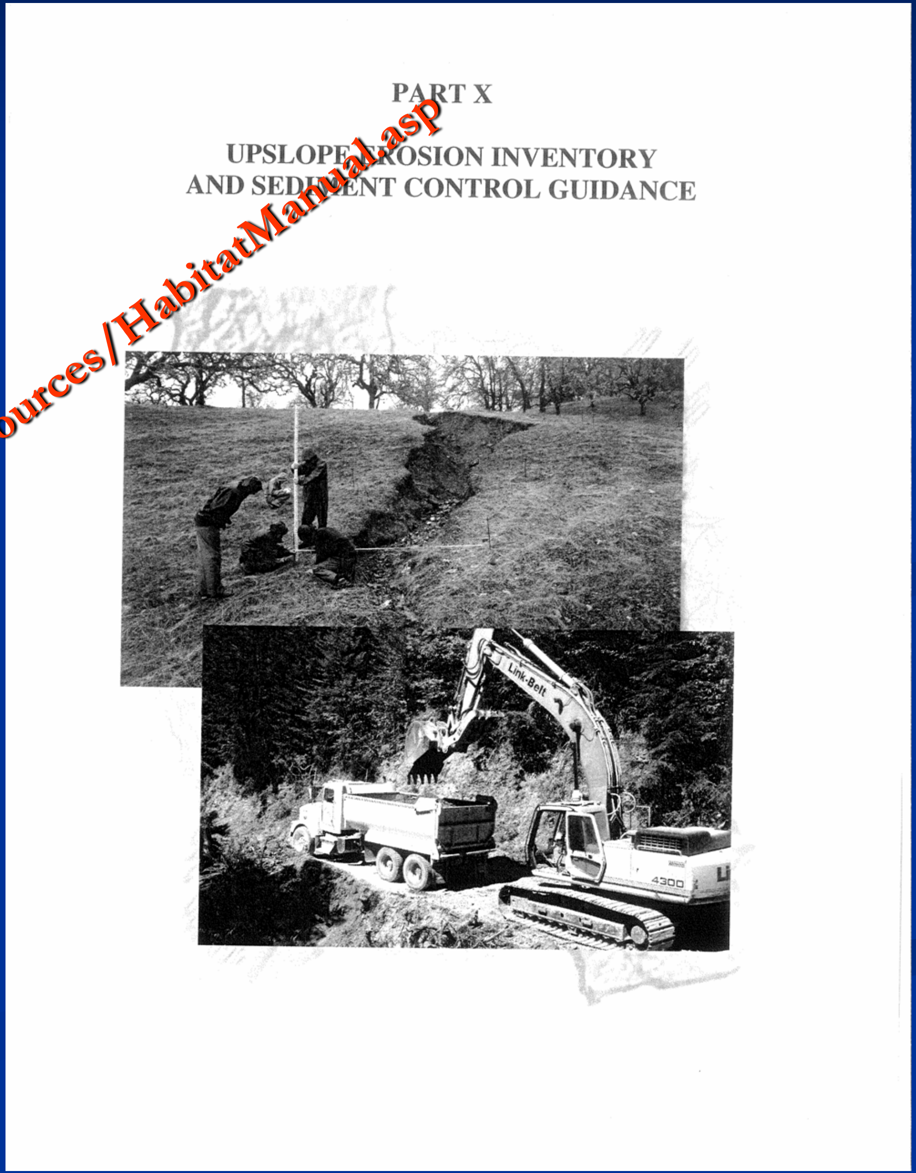
High Low Media Video Productions
Pacific Watershed Associates
Ridge to River
58 Minutes

Forest and Ranch Roads

A guide to improving, repairing and restoring roads for water quality, fish and humans.

Upslope Inventory and Sediment Control Guidance





http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

State of California
California Natural Resources Agency
Department of Forestry and Fire Protection

Designing Watercourse Crossings for Passage of 100-Year Flood Flows, Wood, and Sediment (Updated 2017)

California Forestry Report No. 1 (revised)

Peter Cafferata, Donald Lindsay, Thomas Spittler, Michael Wopat, Greg Bundros, Sam Flanagan, Drew Coe, and William Short

August 2017

Identifying,Characterizing, andTreating Unstable Fillslopes

Treating Unstable Fillslopes

- CAUSE: Unstable road and landing fillslopes are caused by sidecasting onto steep slopes. Debris flows are caused by filling steep, wet swales during road construction.
- TREATMENT: Only those instabilities or potential instabilities that could deliver sediment to a stream are treated.
- Unstable fillslopes and potential debris flow sites are usually treated by direct excavation of unstable fill material, and redirection of runoff
- Large, complex landslides in high risk environments should have an engineer or engineering geologist involved in the project

Cutbank Debris Slide

Cutbank Slump

Delivering cutbank landslide

Fillslope Debris Slide at Stream Crossing

Fillslope Slump

Potential Fillslope Failure

Deep Seated Landslide

Deep Seated Landslide - Earthflow

2) Treating Unstable Fillslopes

Treating Unstable Fillslopes

- CAUSE: Unstable road and landing fillslopes are caused by sidecasting onto steep slopes. Debris flows are caused by filling steep, wet swales during road construction.
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Excavation of unstable fillslope on upgraded road

Cutbank Debris Slide

Before and after fillslope failure excavation

Before and after fillslope failure excavation

Wildfire in coastal watersheds: A systematic post-fire erosion assessment and sediment reduction plan

Coastal & Island Specialty Conference
Center for Watershed Protection, Inc.
November 17, 2020

Creator: Todd Kraemer
PRESENTER:
Tom Leroy and Nolan Marshall , Engineering Geologist,
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2020 SPECIALTY CENTER FOR WATERSHED PROTECTION COASTAL & ISLAND CONFERENCE

High intensity wildfires have severely impacted coastal watersheds in California and Oregon.

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WE LIVE IN A HIGH- RISK LANDSCAPE

- Wildland fire suppression practices
- Natural resource management practices
- Climate change
- Drought-induced dieback
- Lightning strikes
- Wind-dominated fire storms
- Human-ignited fires

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Wildfires trigger changes in understory plants and tree canopy cover…

… cause the exposure of large expanses of bare soil and aggraded stream channels.

The onsite and downstream impacts on water quality and aquatic habitat can be significant before ecosystem recovery occurs.

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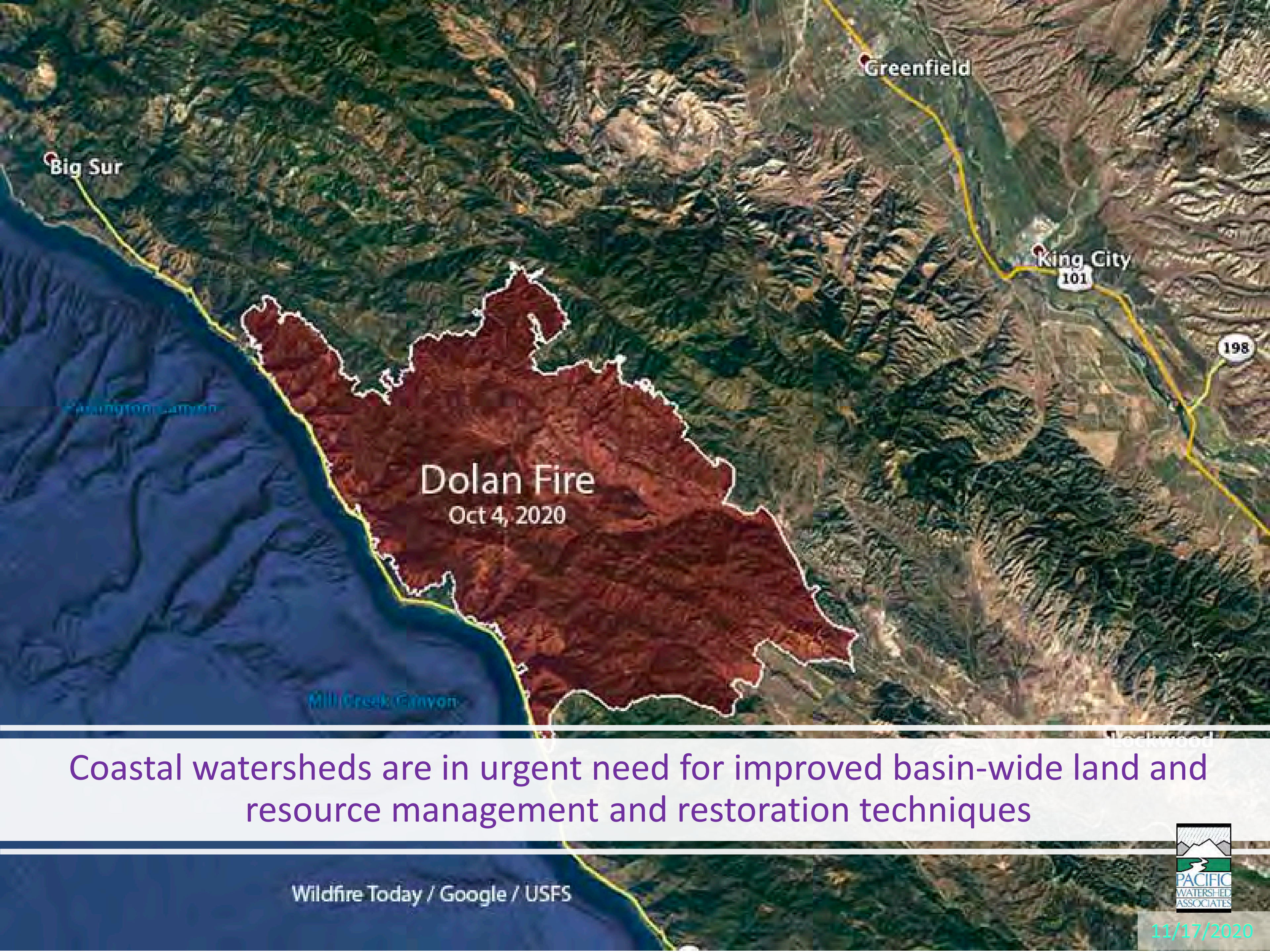

Coastal watersheds are in urgent need for improved basin-wide land and resource management and restoration techniques

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Climate Change will amplify the hazards of wildfires for years to come

What is the PWA strategic erosion assessment plan? - Central Question

Given all we know; which actions will target vulnerable resources and severely burned hillslopes to greatly reduce sediment delivery to streams and provide benefits to native fish species?

- What projects do watershed stakeholders consider critical?
- Is there a best way to prioritize and sequence watershed restoration projects?
- Is there a best way to spend limited watershed restoration funds?
- How much post-fire restoration is needed?
- What are the adaptive management processes that must be incorporated?

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Systematic post-fire erosion assessment and sediment reduction plan:

The 4 key principles for planning and evaluation

1) Integrate a whole basin approach

2) Employ a GIS-based multivariate prediction model

3) Follow special modeling and identification of high-risk areas

4) Conduct a rapid field-based "forward-looking" erosion inventory

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Systematic post-fire erosion assessment and sediment reduction plan:

The 7 key physical elements for planning and evaluation

1) Physical topography
2) Stream channels
3) Vegetative cover type
4) Geologically unstable areas
5) Soil erodibility
6) Fire and road construction history
7) Burn area characteristics

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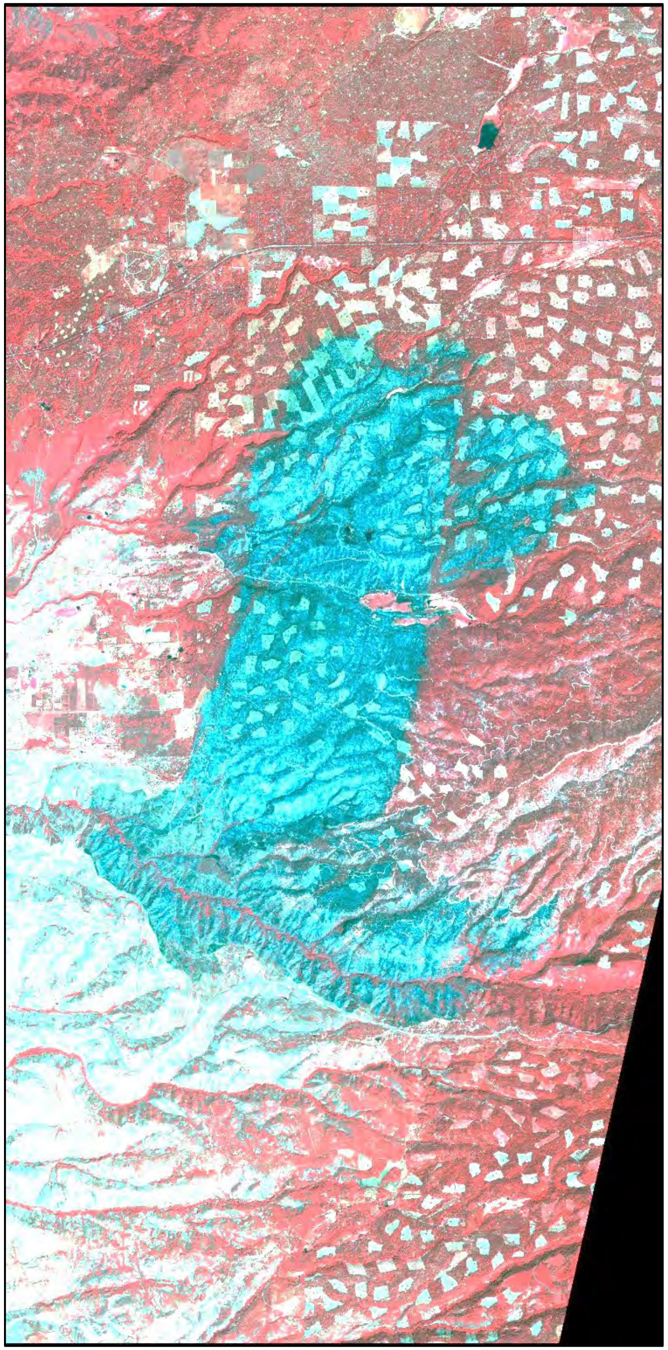

Burn severity maps and heat maps from satellites are simply not enough

Systematic post-fire erosion assessment and sediment reduction plan:

The 6 key components

1) Air photo analysis and remote sensing analysis

2) A GIS-based Erosion Hazard Rating (EHR)

3) A GIS-based predictive model of post-fire hillslope erosion

4) A complete field inventory to document all current and potential sediment delivery sources

5) Development of a prioritized action plan

6) Selection of sediment control projects to be implemented

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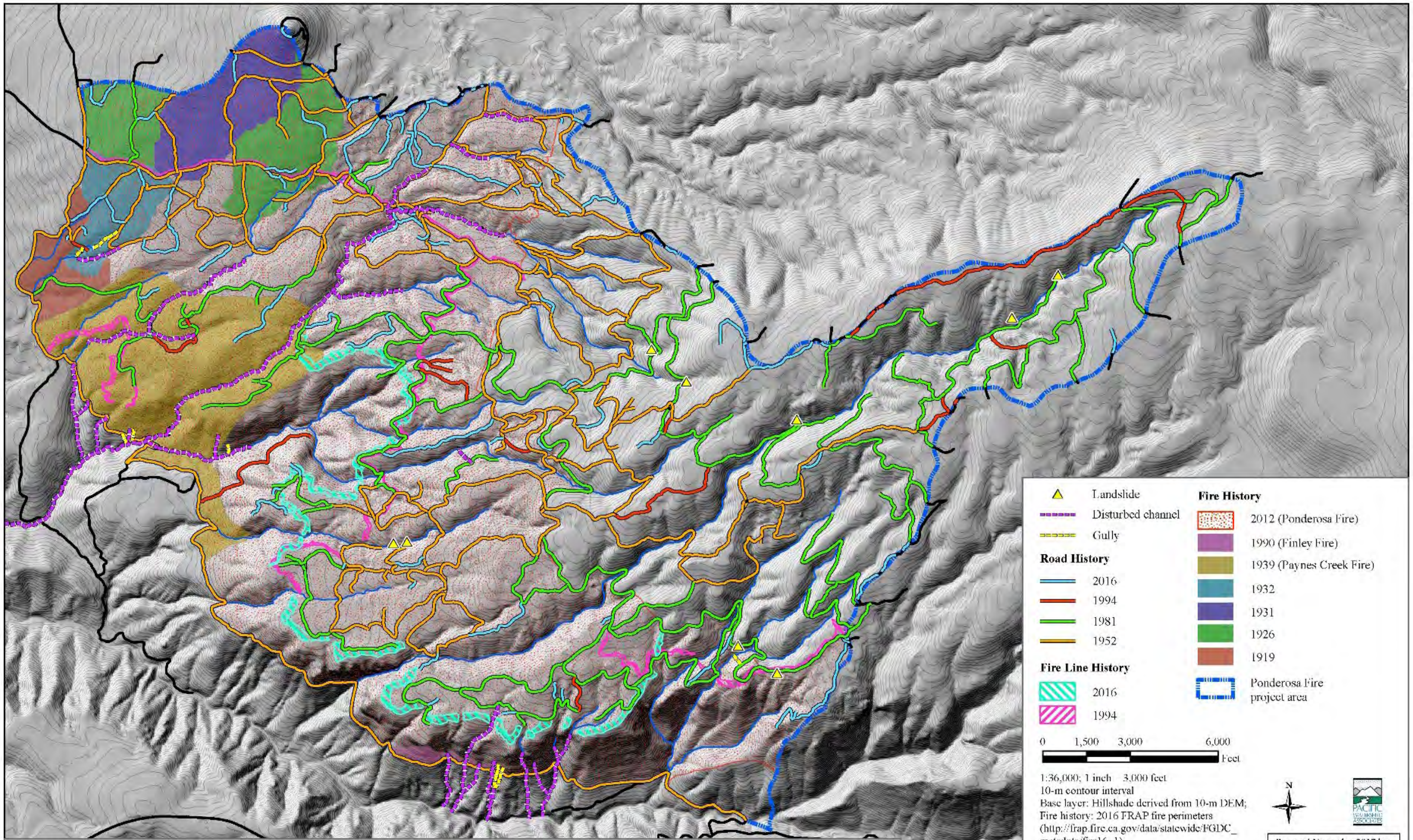
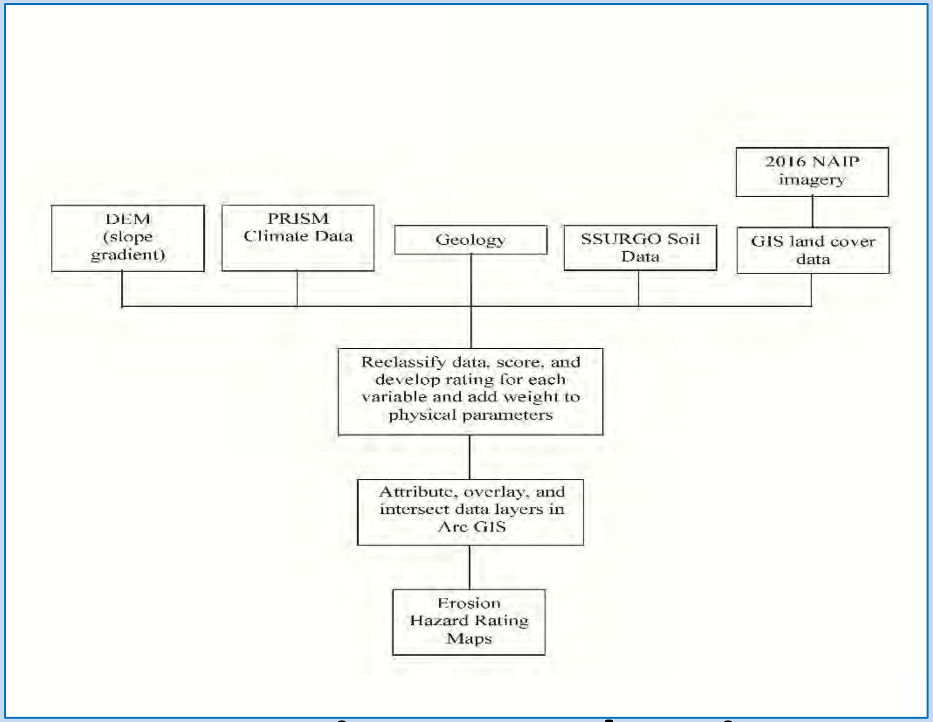


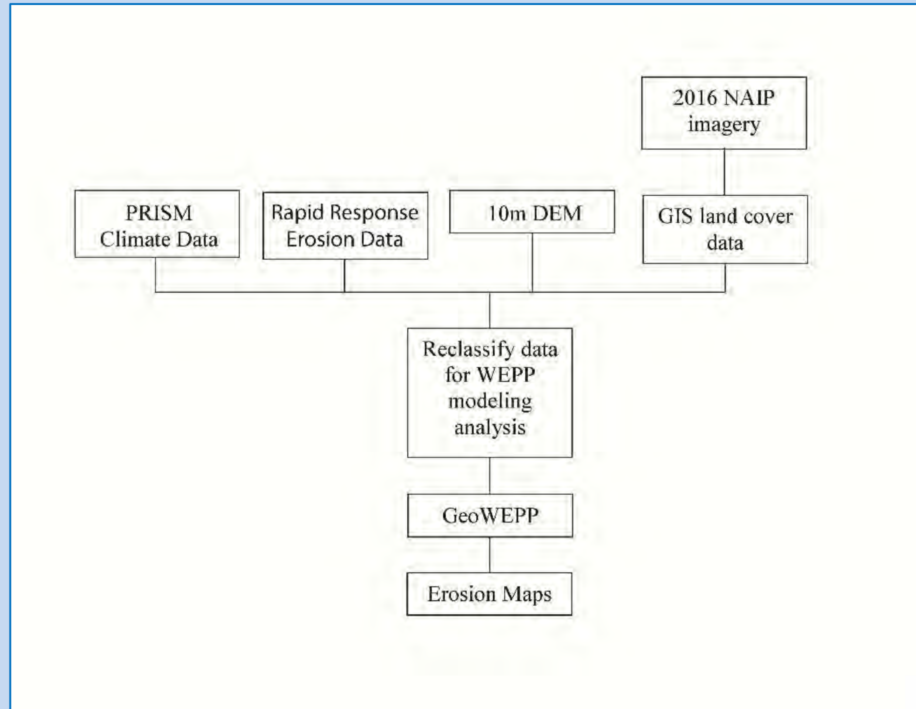
Map 3. Fire history, road construction, and landslide histories for the Ponderosa Fire project area in the South Fork Battle Creek Watershed, Part 3, Tehama County, California.

Results of of extensive research, air photo, and remote sensing analysis

123 miles of road construction
308 acres of fire line construction
63% of the watershed has been burned

Predictive strategies to minimize post-wildfire impacts



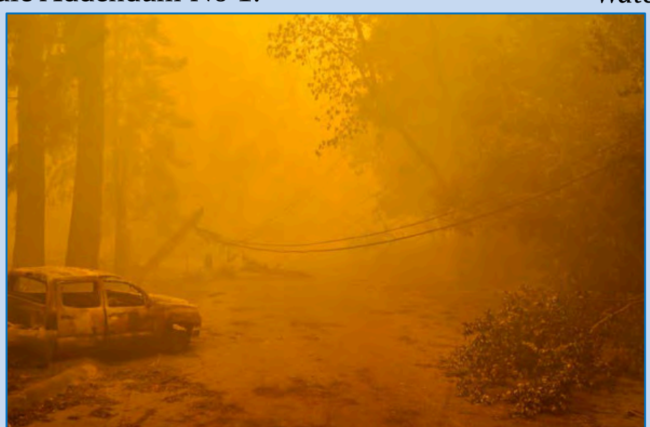


Erosion Hazard Rating

Modified CDF technical Rule Addendum No 1.

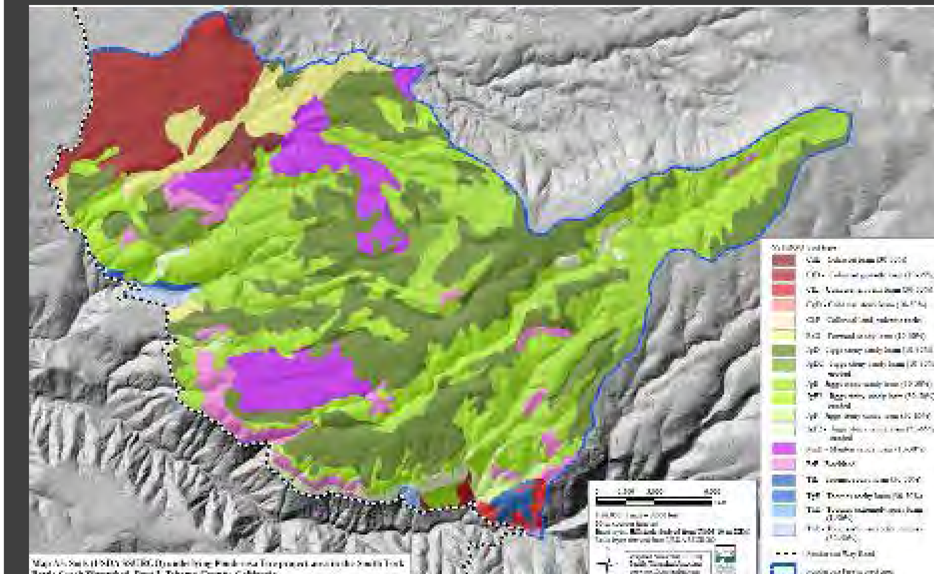
Predictive Model: GeoWepp

Water Erosion Prediction Project



11/17/2020

Annual Rainfall



Geologic Units

Erosion Hazard Rating Maps

- PWA linked 6 components to spatially analyze project area.
- Using a Geographic Information System (GIS), The ranking process of the EHR was developed by assigning a numeric value to differentiate types or ranges of 1) rainfall, 2) geology, 3) soils, 4) slope gradients, 5) post fire land cover, and 6) burn severity across the project area.
- Maps were synthesis of the identified post-fire physical conditions

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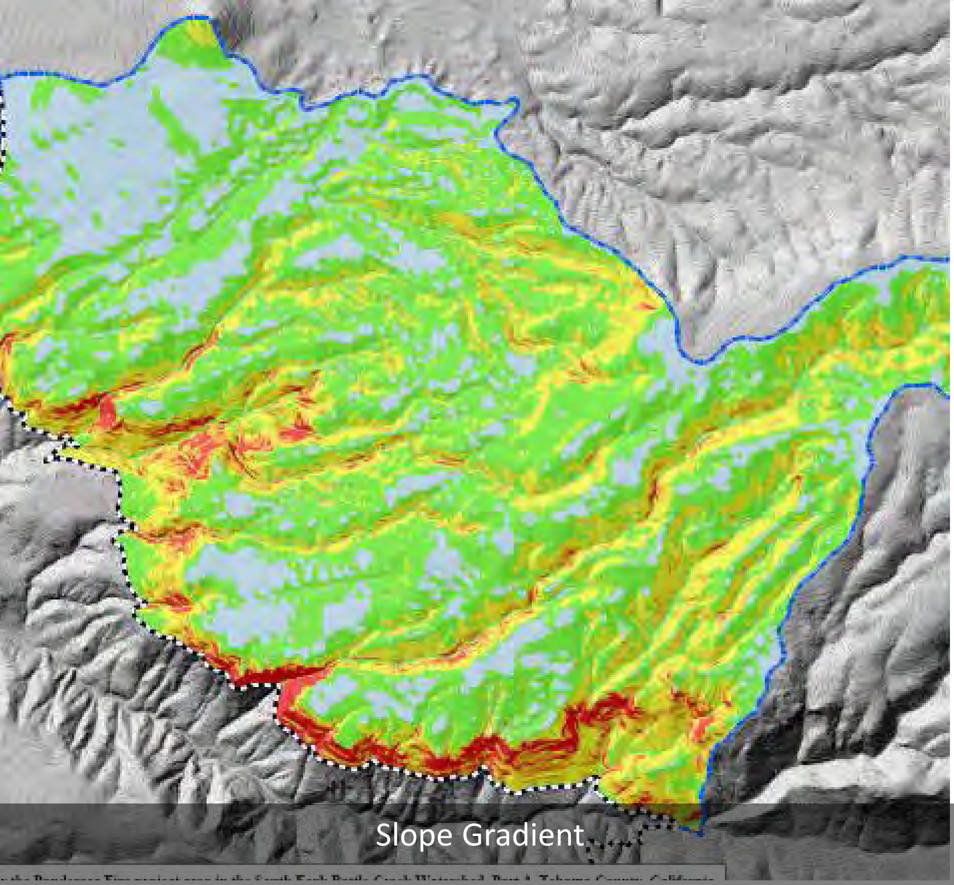
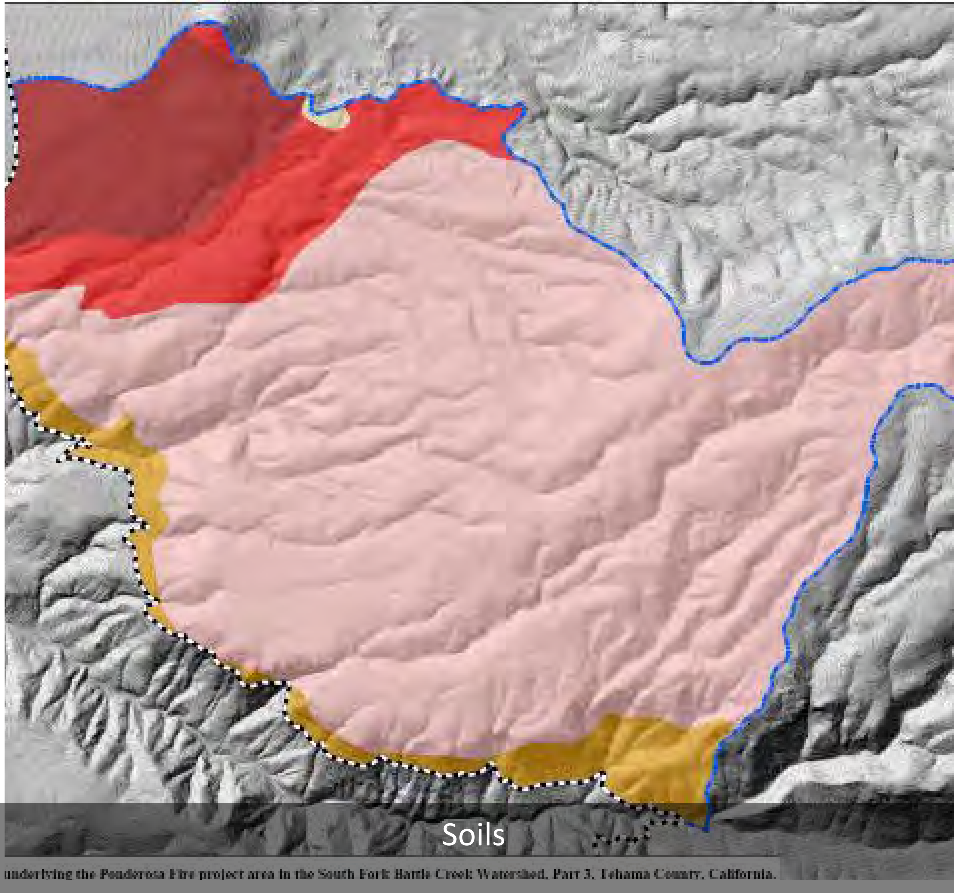
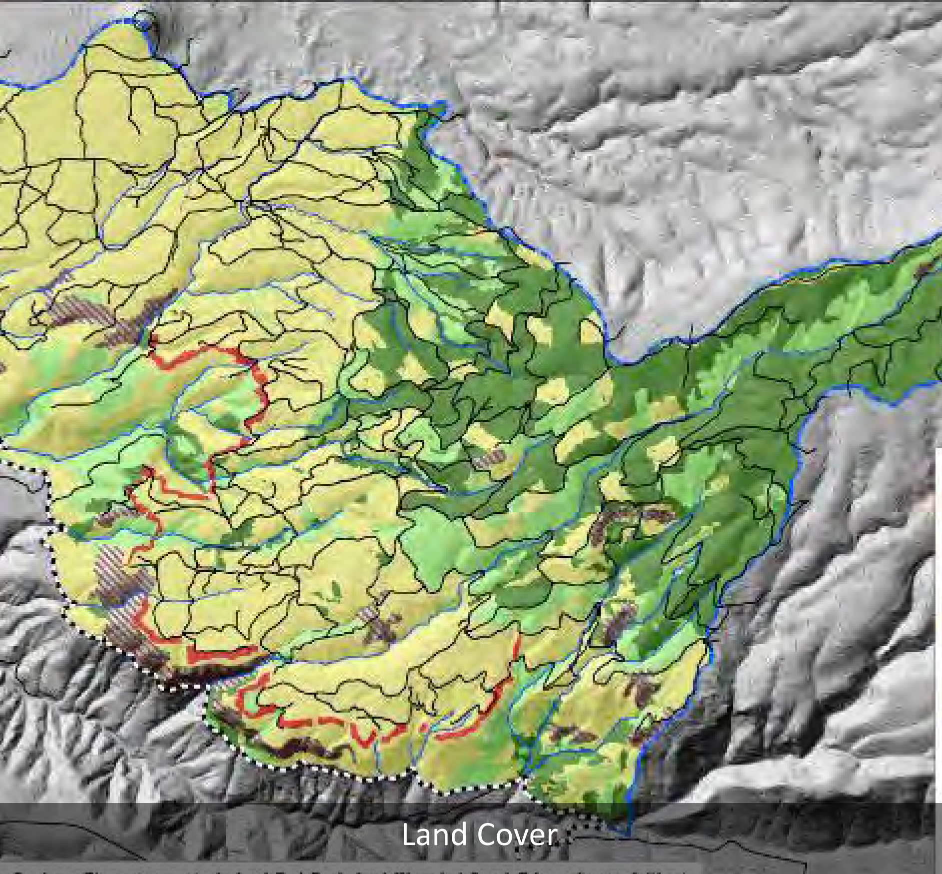
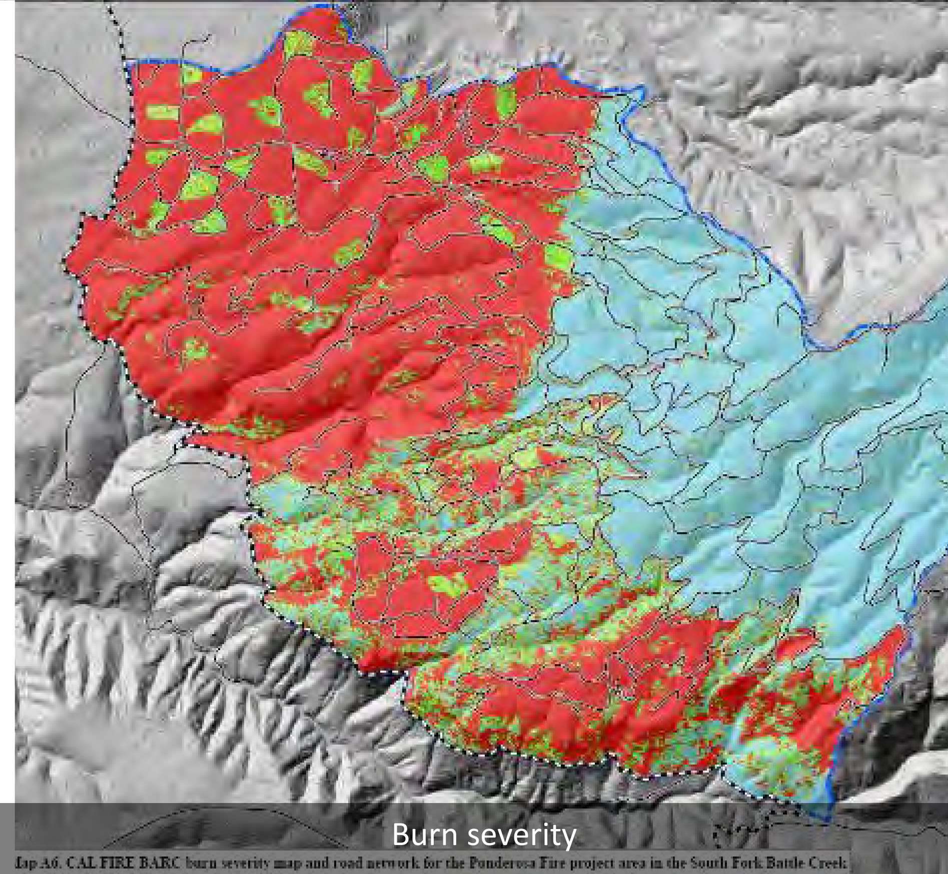




Erosion Hazard Rating Maps

- DEM (**slope gradient**): topographic layers were converted to a 10-meter Digital Elevation Model (DEM)
- **Soil types**: Soils data layers from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture Web Soil Survey, were used to develop the soil input layers used in this project (USDA SSURGO).





Erosion Hazard Rating Maps

Land cover: Land cover percentage was delineated by PWA GIS staff using 2016 NAIP imagery (USDA NAIP) and digitized using ESRI ArcGIS 10.3 to generate the current conditions regarding land cover.

Burn area - Spatial input layers were provided by Cal Fire and University California Davis (Jameson et al., 2015).

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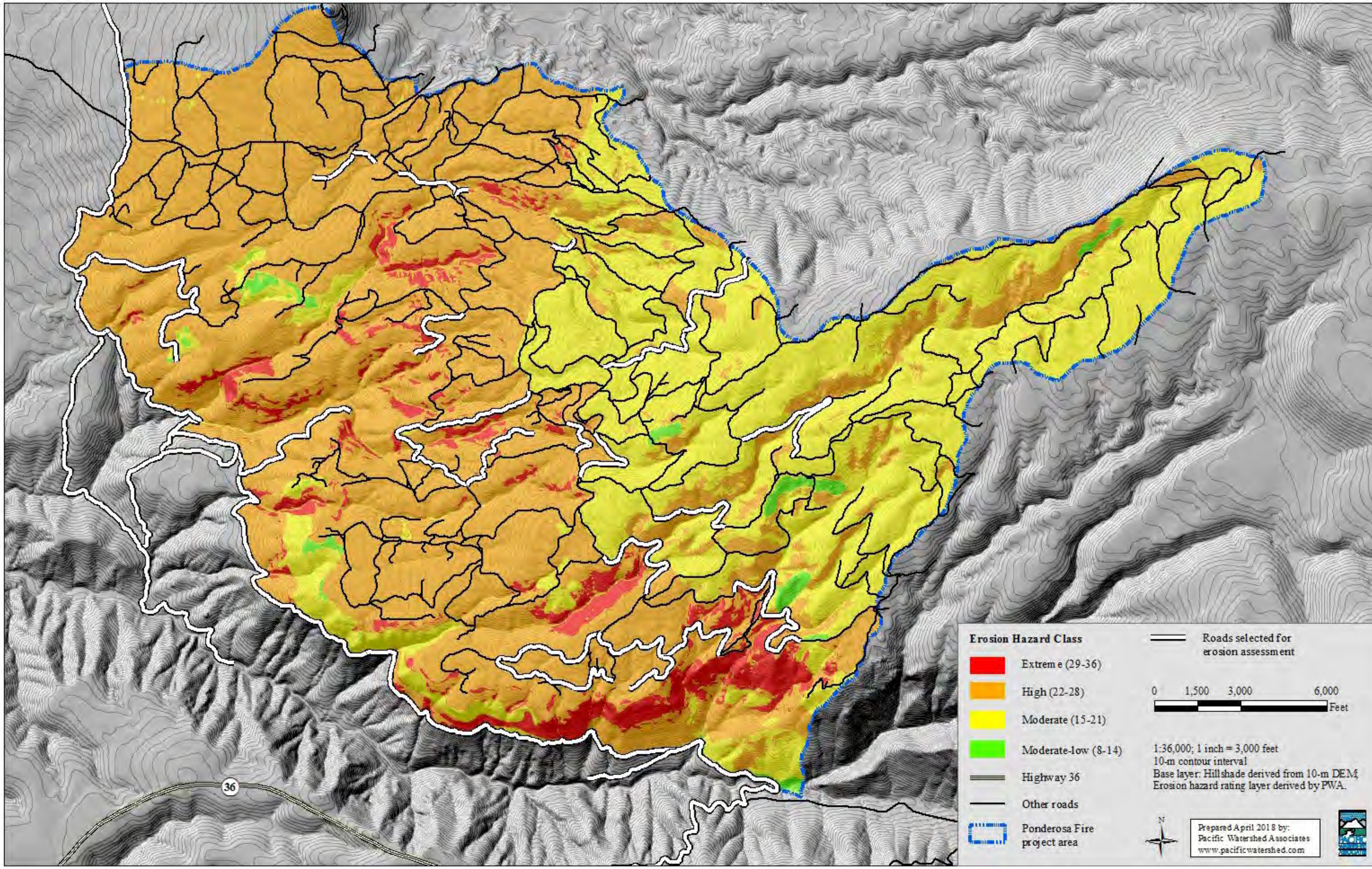
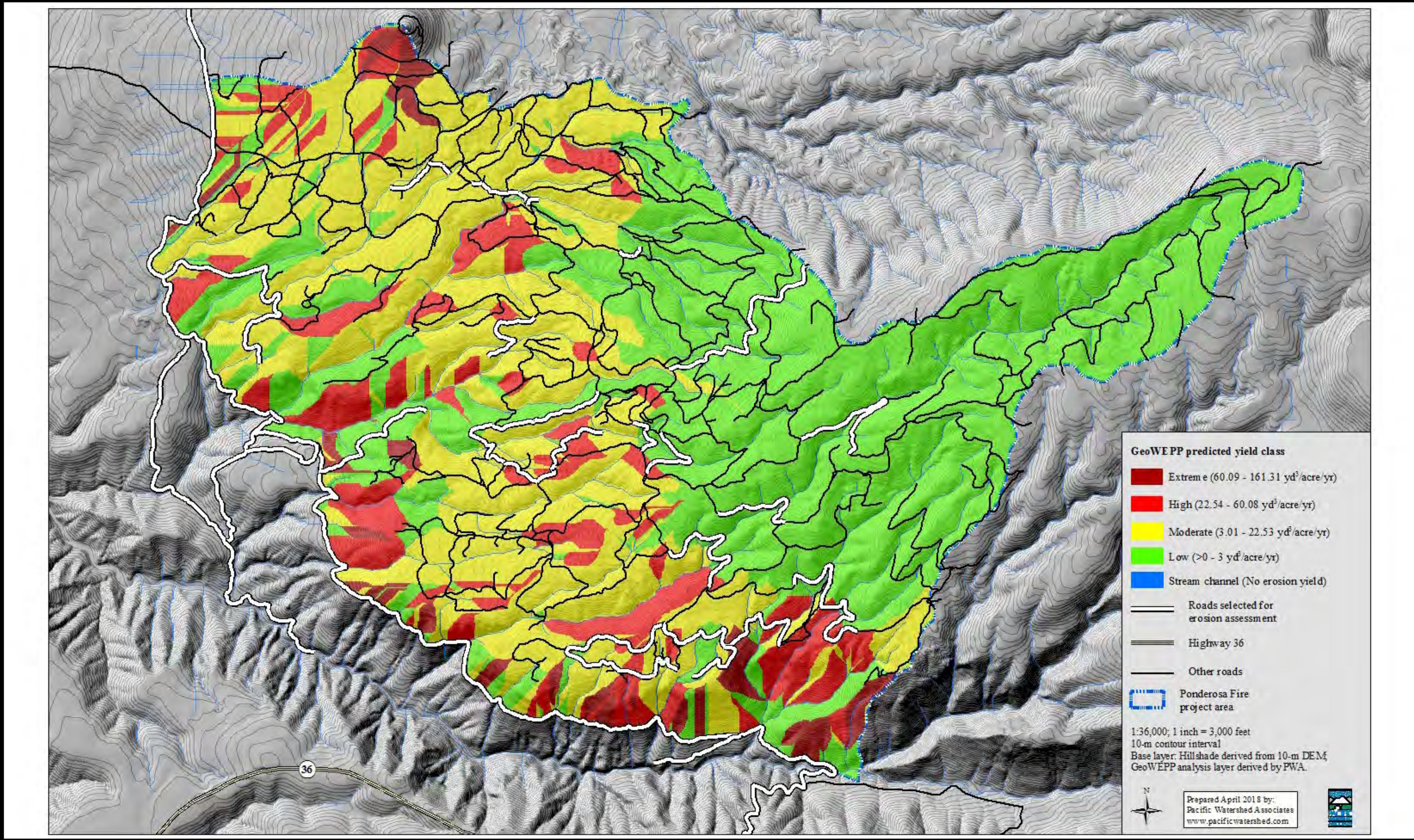


Linked Spatial Analysis and Final Erosion Hazard Rating Map

Extreme EHR 763 acres 6% - EHR score 29-36
High EHR 7,734 acres 60% - EHR score 22-28
Moderate EHR 4,242 acres 33% - EHR score 15-21
Moderate and Low 124 acres 1% –EHR score 8-14



PWA utilized the process-based model to predict hillslope runoff and estimate sediment yield from hillslopes in the project area.

Extreme 60-161 cubic yards/acre/ per year, 427 acres, 3%
High 22-60 cubic yards/acre/ per year, 1,613 acres, 13%
Moderate 3-22 cubic yards/acre/ per year, 4,643, 36%
Low >0-3 cubic yards/acre/year, 5,888, 46%
No yield 0, 293, acres 2%

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Roads are typically vulnerable to both episodic and chronic erosion and sediment delivery to streams

Roads and Erosion

- **Sources (location)**
  - **Stream crossings – washout and diversions**
  - **Landslides – road and landing fillslope failures**
  - **Surface erosion – road surface, ditch and cutbank**
- **Timing**
  - **Episodic – storm-triggered**
  - **Chronic – every runoff event, year-after-year!**
- **Magnitude – volume of sediment delivery**

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Role of Fire in Road-Related Sediment Production

- Increased hillslope runoff
- Increased in-stream sediment
- Increased organic debris transport
- Increased traffic
- Decreased root strength

- Culvert overtopping
- Culvert plugging
- Stream diversion
- Increased fine sediment delivery
- Increased landsliding
- Increased sediment delivery

11 22 2000


High intensity rainfall during storms
results in increased hillslope runoff.
02/22/2018

High intensity rainfall during storms results in accelerated hillslope erosion.


High intensity rainfall during storms results in increased stream channel erosion.
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High intensity rainfall during storms results
in increased road related erosion
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Stream crossings: Wildfires typically cause increased runoff and accelerated surface erosion from burned hillslopes and this increased sediment supply.

Stream crossings: Many stream crossing culvert failures result from culvert plugging, stream overtopping and consequent stream crossing washout.

Road surfaces, cutbanks and ditches are always vulnerable to increased post-fire runoff and surface erosion.

Road surfaces: Increased traffic levels associated with fire suppression and post-fire salvage logging increase sediment delivery.

Road surfaces: Significant levels of hydrologic connectivity link the engineered road drainage system and nearby stream channels.

Landslides: Road and landing fills and cutbanks show increased susceptibility to post-fire slumping and debris slides.

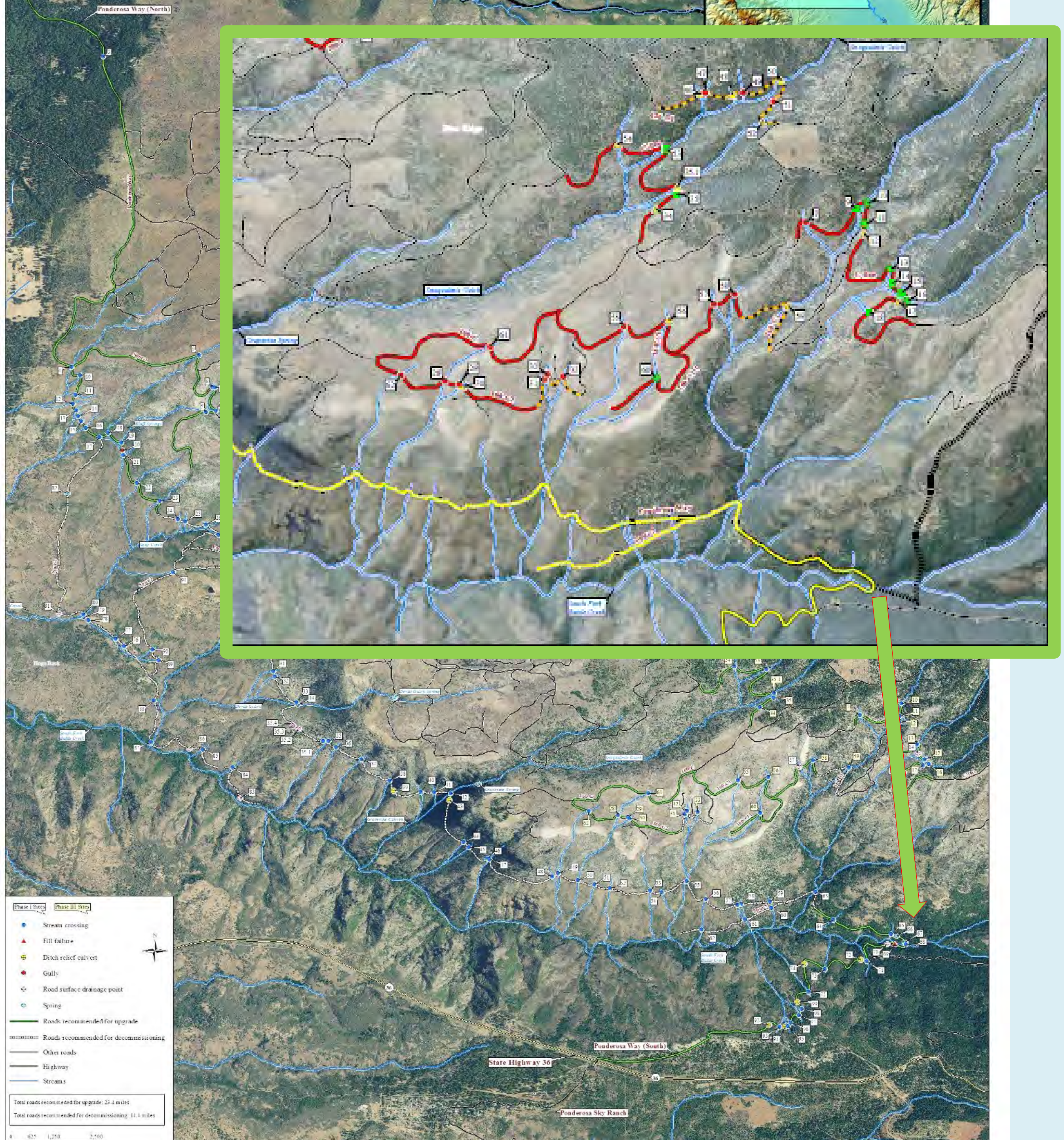
EXAMPLE OF A PRIORITIZED PLANNING MAP

Action Plan to treat road-related sediment delivery problems

Stream crossings – washout and diversions

Landslides – road and landing fillslope failures

Surface erosion – road surface, ditch and cutbank



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ROAD STORM-PROOFING GOALS

Improve road drainage, stream crossings, and hillslope stability

Road upgrading *- Procedures that upgrade a road's surface drainage, stream crossings, and stability to minimize erosion and sediment delivery, maintain hillslope stability, and re-establish natural drainage patterns.*

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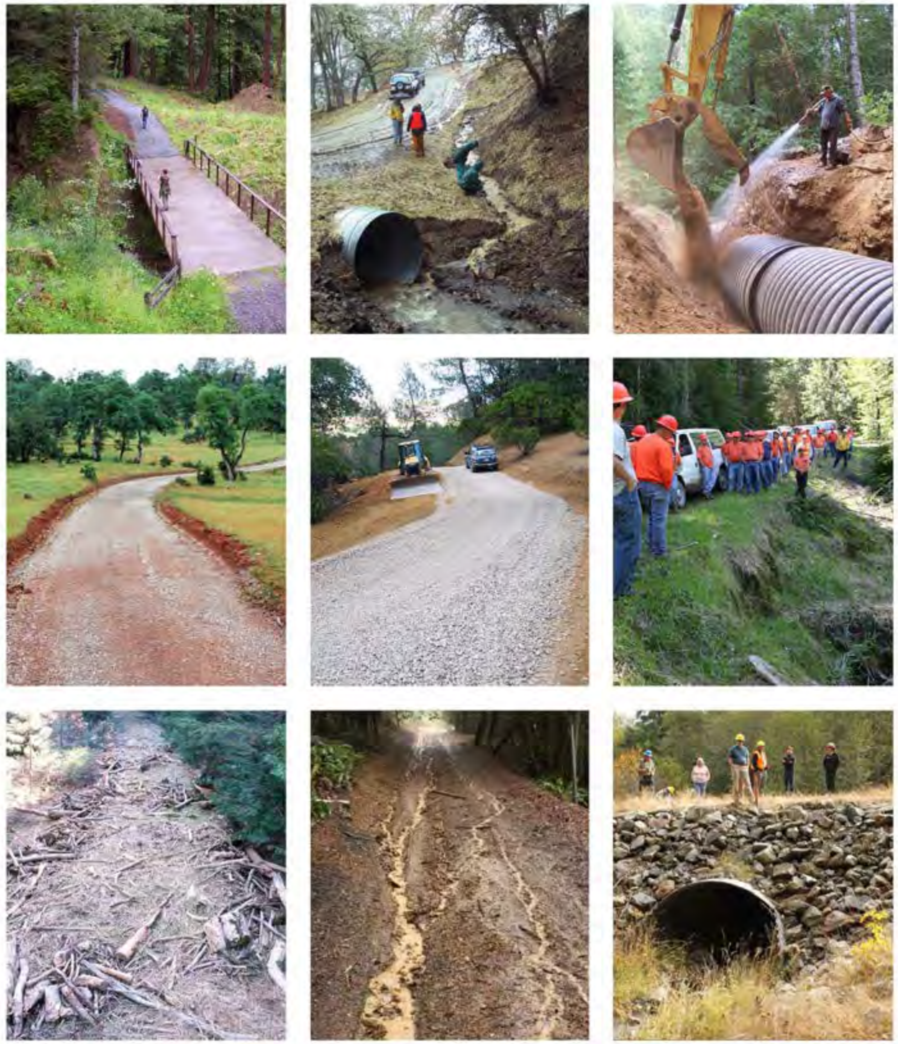
Stream crossings performance parameters

"The real voyage of discovery consists not in seeking new landscapes but in having new eyes.'

Marcel Proust 1871 - 1922



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EXAMPLES OF TYPICAL ROAD STORM-PROOFING

Stream Crossing Improvements

- Stream crossings are designed for the 100 yr flow w/debris
- Class I stream crossings accommodate fish passage for all life stages
- Bridges have stable non-eroding abutments & do not restrict flood flows

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EXAMPLES OF TYPICAL ROAD STORM-PROOFING

Stream Crossing Improvements

BEFORE

AFTER

- Culvert inlet, outlet and bottom are in sound condition
- Undersized culverts in deep fills have overflow pipes
- Road surfaces & ditches are largely disconnected from streams

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EXAMPLES OF TYPICAL ROAD STORM-PROOFING

Stream Crossing Improvements

BEFORE

AFTER

- Stream crossings have no diversion potential
- Stream crossings have low plug potential

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EXAMPLES OF TYPICAL ROAD STORM-PROOFING

Road Drainage Improvements: Road outsloping and rolling dip construction

Before

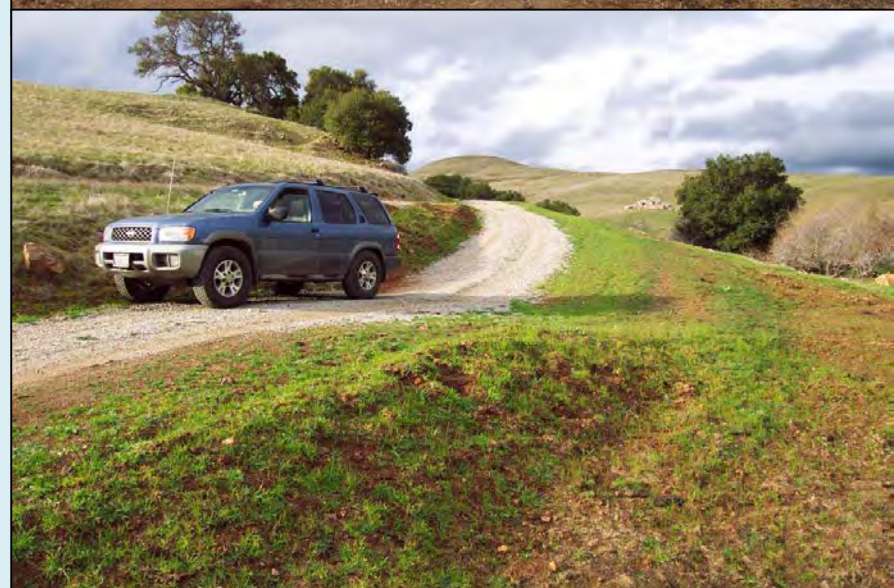
After

ROAD SHAPE CONVERSION

Road Drainage Improvements

BEFORE:
Road is insloped with ditch, wheel ruts & berm – Gullied with 100% hydrologic connectivity

AFTER:
Road is outsloped with rolling dips; resulting in hydrologic disconnection



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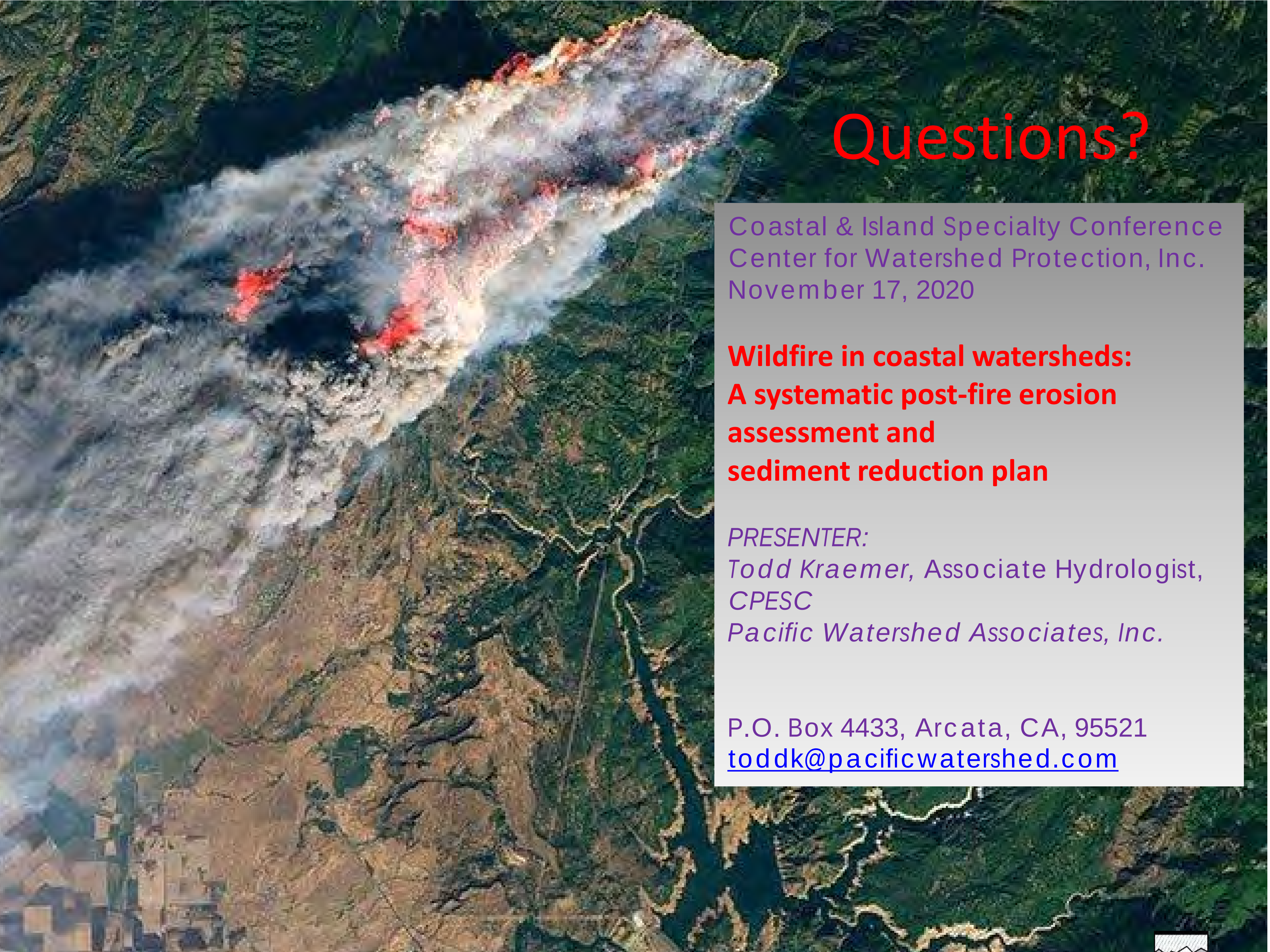
A systematic post-fire erosion assessment and sediment reduction plan

Assess current and future erosion problems in the watershed.

Provide a list of potential treatment opportunities and land management actions in a prioritized treatment site Action Plan

Develop detailed cost estimates for the recommended erosion prevention and sediment control work for roads and hillslopes.

Research , predict, sample, and prioritize post-fire erosion sites for treatment to diminish future sediment delivery to protect, restore and enhance our streams, rivers, lakes, wetlands and bays.



Questions?

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November 17, 2020

Wildfire in coastal watersheds:
A systematic post-fire erosion assessment and
sediment reduction plan

PRESENTER:
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