Stream Crossing Alternatives

July 2, 2012

Pete Cafferata

California Department of Forestry and Fire Protection

Outline

I. Introduction
II. Hydrology Basics Related to Crossing Design
III. Types of Crossings Available
IV. What Can Go Wrong at Crossings?
V. Proper Design and Construction for New or Replacement Crossings
VI. Summary—Take Home Messages
VII. References for Stream Crossings

I. Introduction

- ***Why are stream crossings a BIG deal?***

- **Monitoring results tell us that crossings often have problems (~20%) and that a high percentage of sediment delivery to streams occurs at or near crossings.**

- **Crossings are built in risky locations subject to large environmental stressors.**

- **Crossings are built with planned failure in mind.**

- **Crossing structures have an expected life.**

- **Crossing design, installation, or maintenance is often inadequate.**

No such thing as a “permanent” culvert crossing


Oregon Coast Range—
Salmonberry River,
December 2007
~50 yr RI event


Siskiyou National Forest—Streamflow diversion following plugged culvert
Photo: Furniss et al. 1998

II. Hydrology Basics Related to Crossing Design

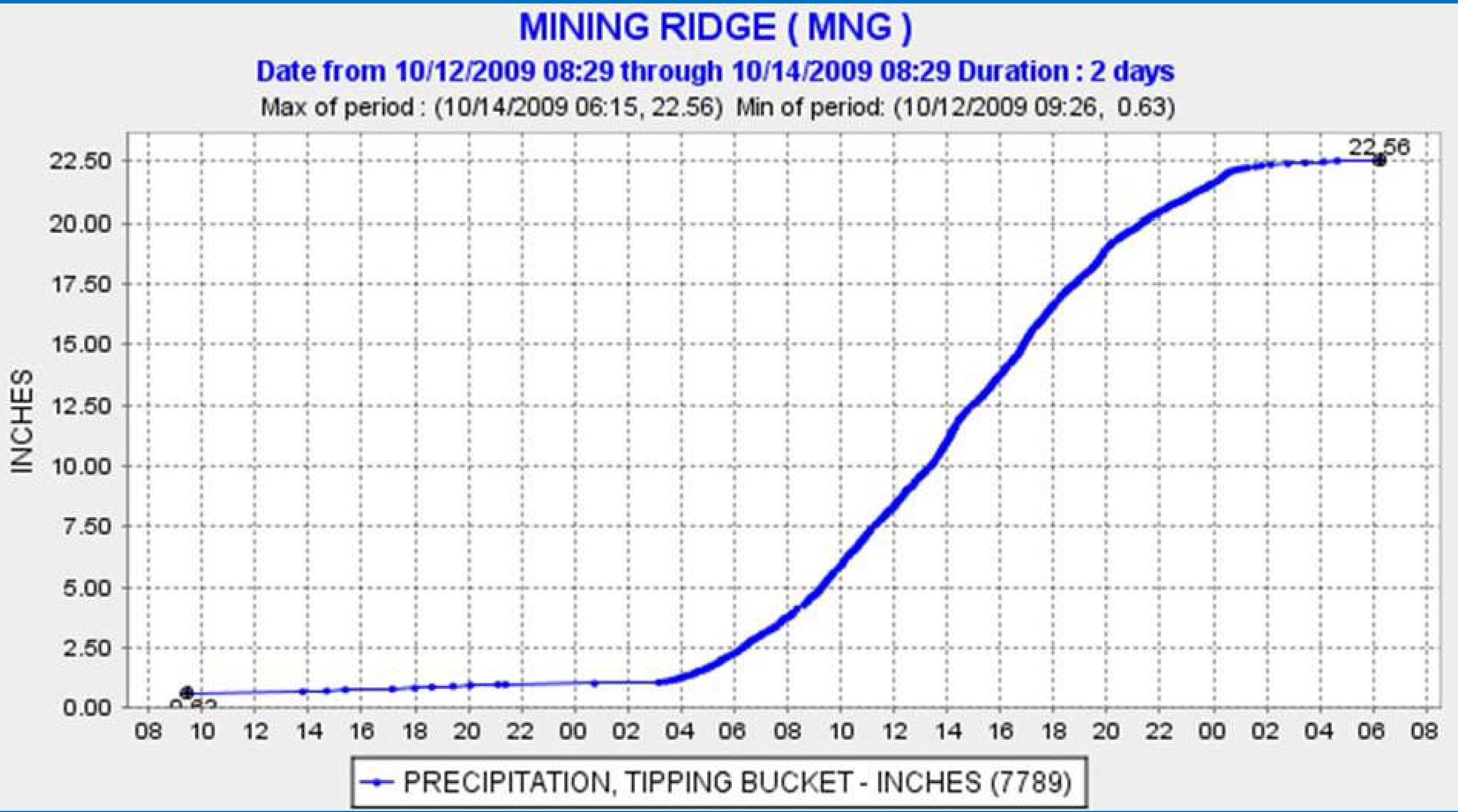
Background Information on Peak Flows (or Flood Flows)

Three Main Climatic Conditions that Produce Peak Flows

- **Spring snowmelt season**
- **High intensity/long duration rain storm**
- **Rain-on-snow event**

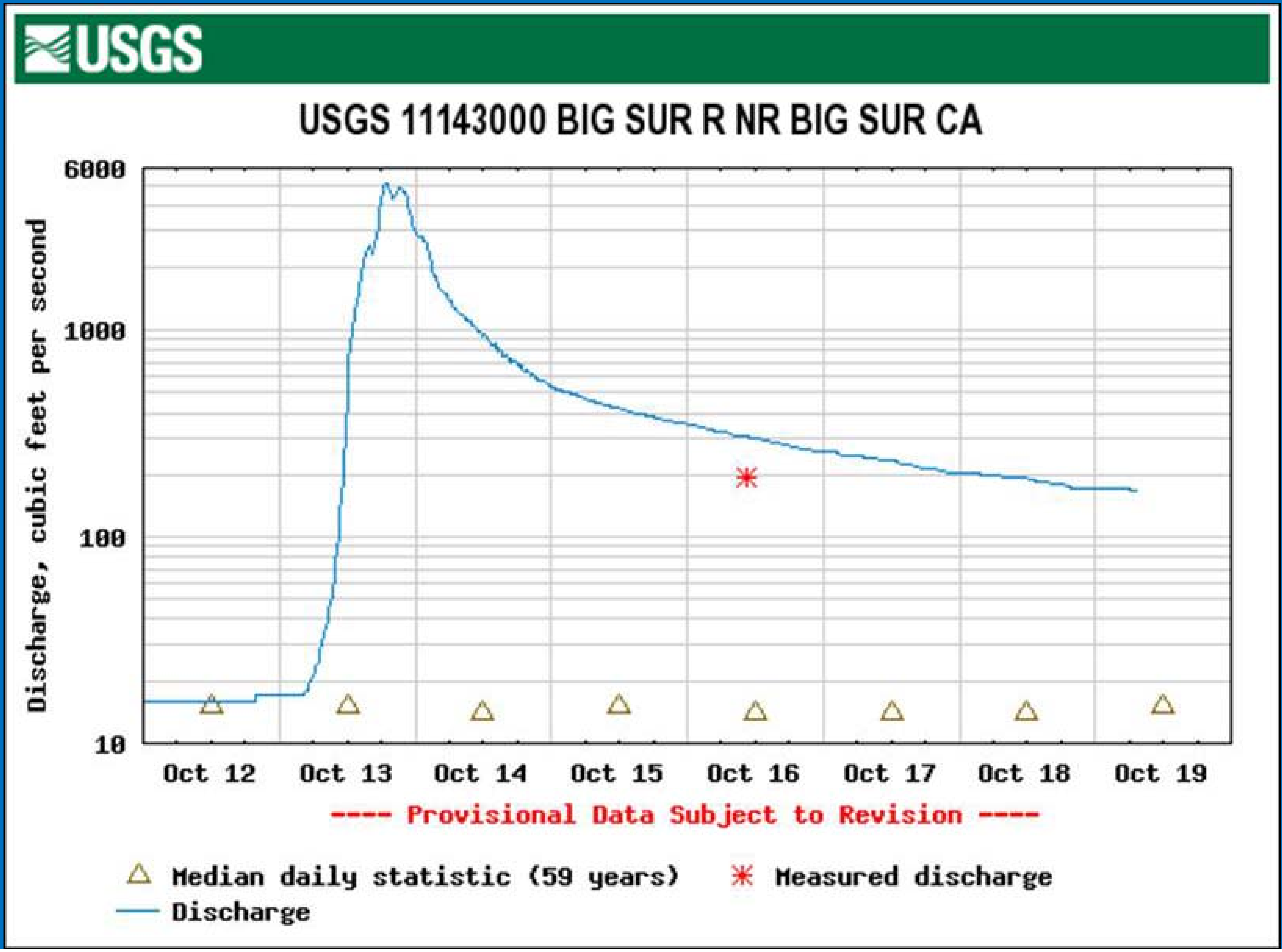
Central Sierra Nevada in the Rain-on-Snow Zone

Example of a High Intensity/Long Duration Frontal Rain Storm:
October 13, 2009 -- Mining Ridge, Monterey County
21.2 inches in 24 hours. 1000 yr RI rainfall event

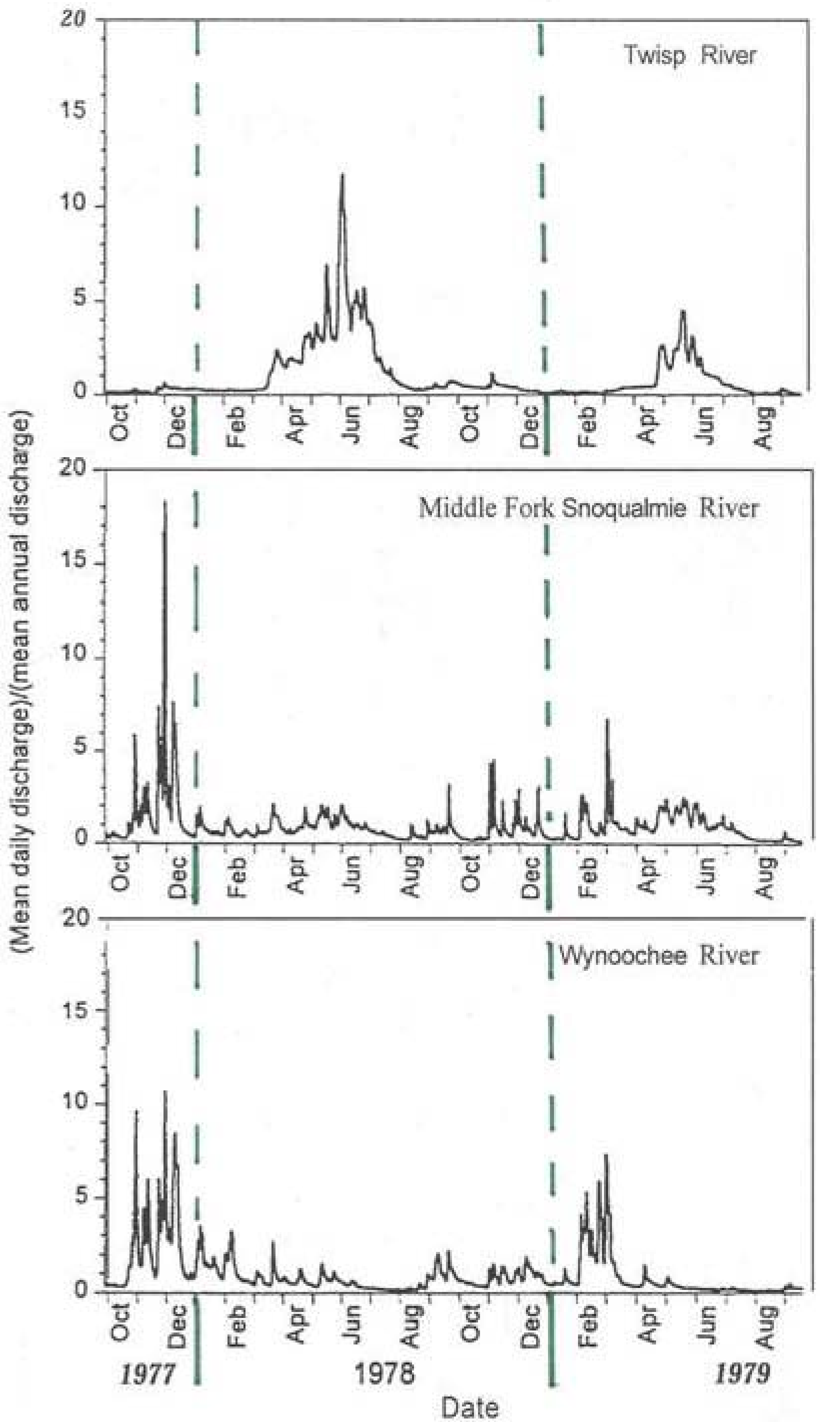


Big Sur River: 17 cfs to 4,830 cfs in 17 hrs!

(approximately 7.5 yr Return Interval stream flow event—dry soils in October!)



Biggest Peaks!



Snow

Rain-on-Snow

Rainfall

Hydrology Dominated by 3 Different Precipitation Types

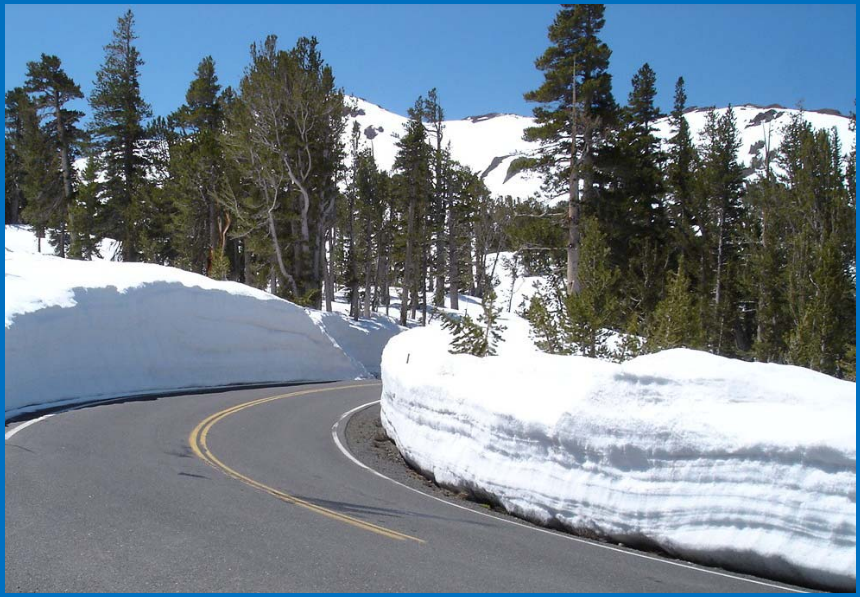
Image: Ziemer and Lisle (1998)

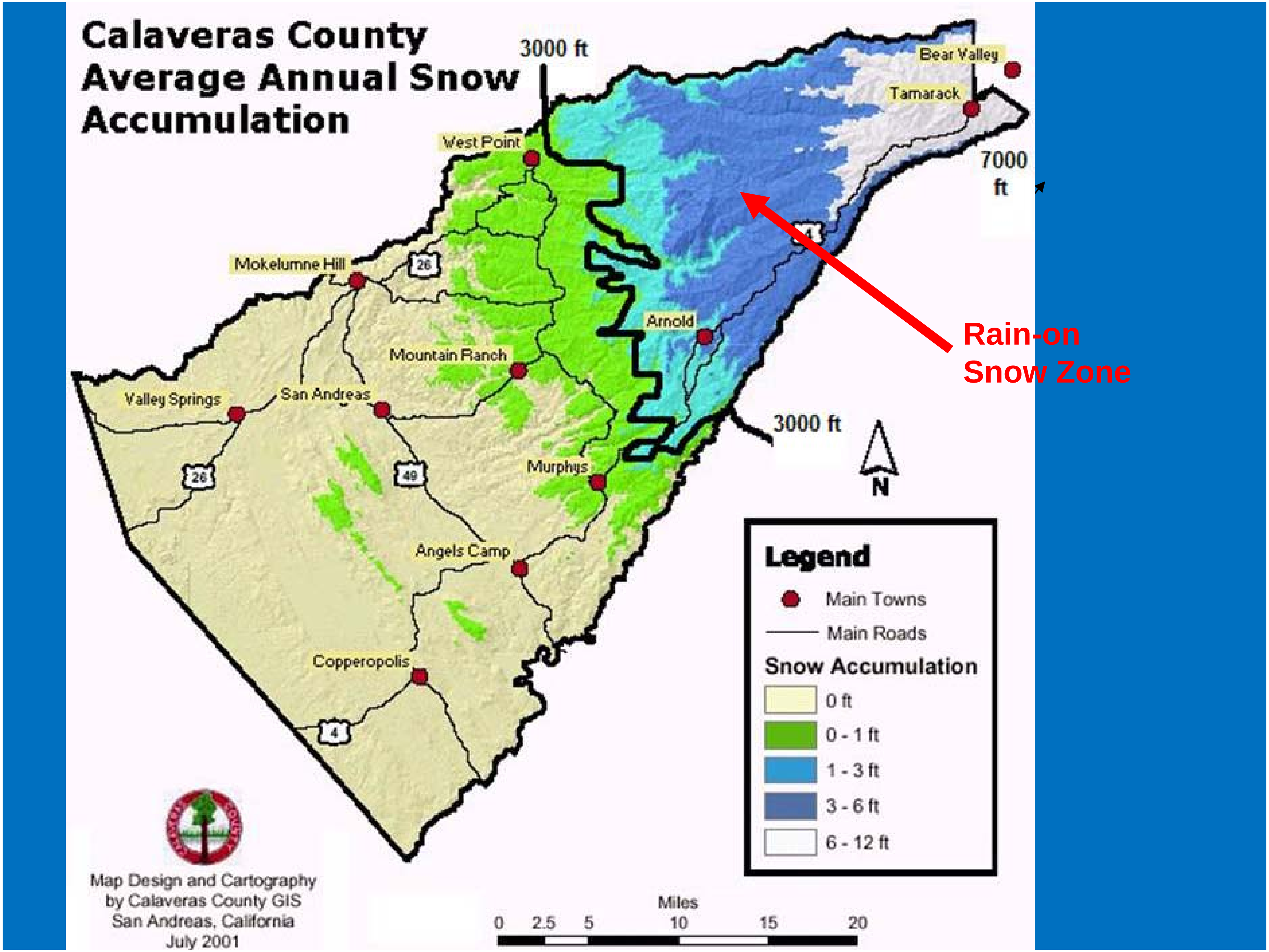
Hydrology Basics

- **Rain-on-Snow Zone – Area on a mountain range where a snow pack forms that may or may not last through the winter. Rain occurs in this zone several times a year and may melt all the snow, depending on total snowpack depth (McGurk and Cafferata 1991).**

- **95% of the major floods in California have involved rain and melting snow!**

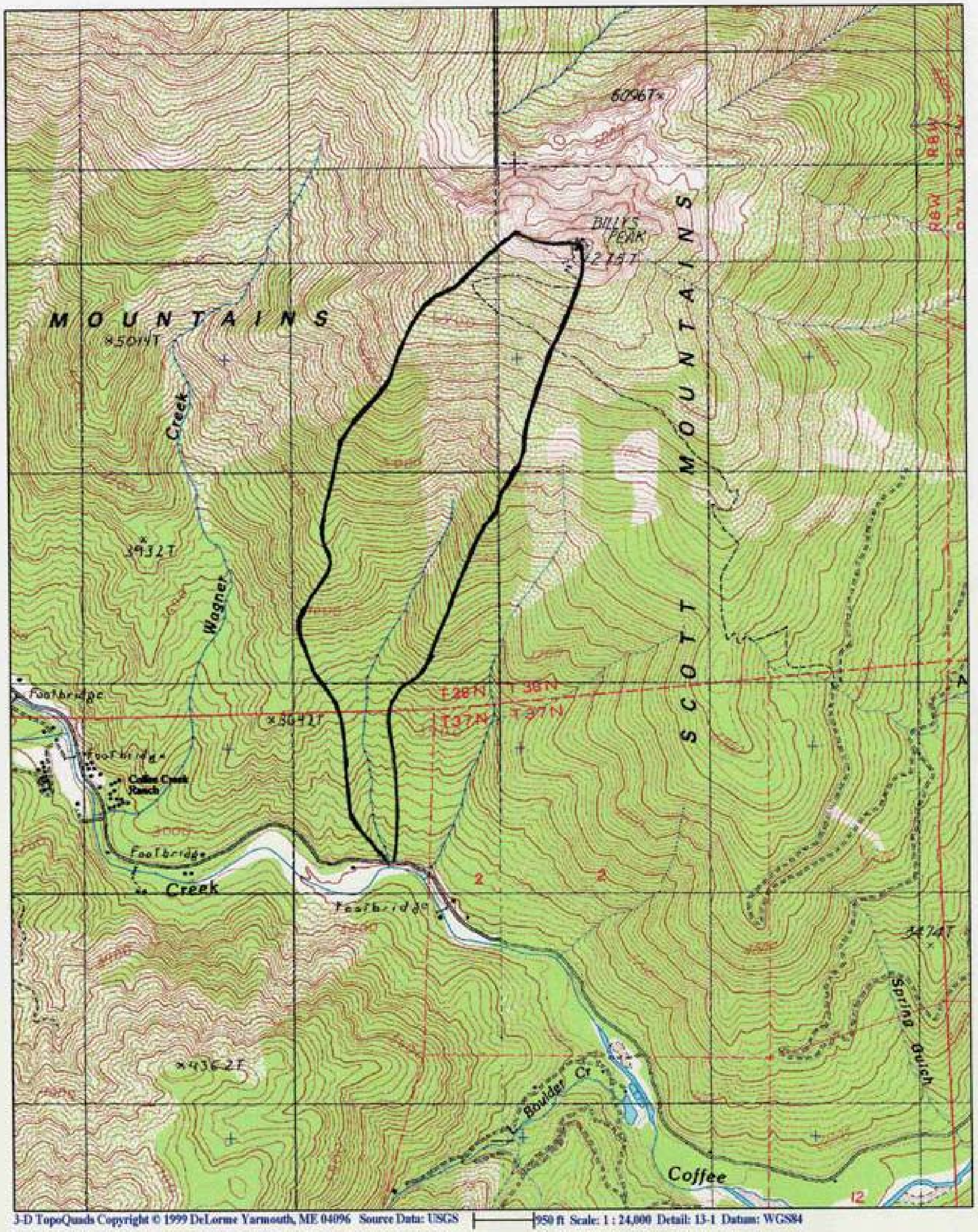
- **Rain-on-Snow Zone for Central Sierra Nevada**
  - **3000 to 7200 feet**




Calaveras County
Average Annual Snow
Accumulation
3000 ft
Bear Valley
Tamarack
7000
ft
West Point
Mokelumne Hill
26
Arnold
Mountain Ranch
Valley Springs
San Andreas
Rain-on
Snow Zone
3000 ft
Murphys
26
49
N
Angels Camp
Legend
Main Towns
Main Roads
Snow Accumulation
0 ft
0 - 1 ft
1 - 3 ft
3 - 6 ft
6 - 12 ft
Copperopolis
4
Map Design and Cartography
by Calaveras County GIS
San Andreas, California
July 2001
Miles
0 2.5 5 10 15 20

Key Factors for Predicting Peak Flows <u>for Stream Crossings</u>

- Drainage area above the stream crossing site (acres or mi^2).
- Watershed elevation data (ft).
- <u>Precipitation Data.</u>
  - <u>Average annual precipitation</u> (inches)
  - <u>Rainfall intensity in inches/hour</u> for the 100-yr storm event



Example for Computing Watershed Area:

Coffee Creek Tributary

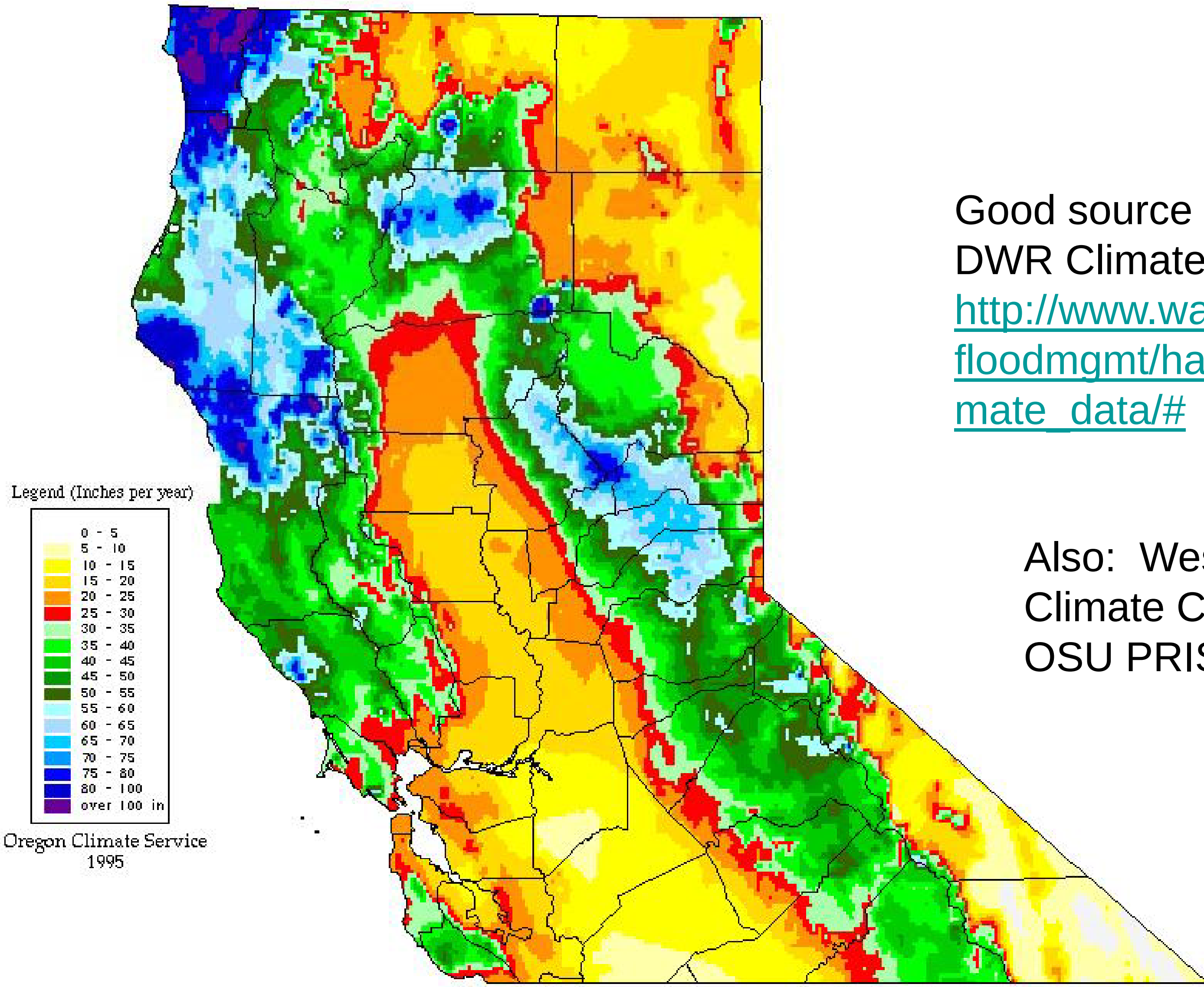
Trinity River Watershed

Basin area = 412.5 acres or 0.645 mi^2

Image: Wopat, CGS

Good source for data:
DWR Climate webpage:
http://www.water.ca.gov/floodmgmt/hafoo/csc/climate_data/#

Also: Western Regional Climate Center webpage; OSU PRISM webpage

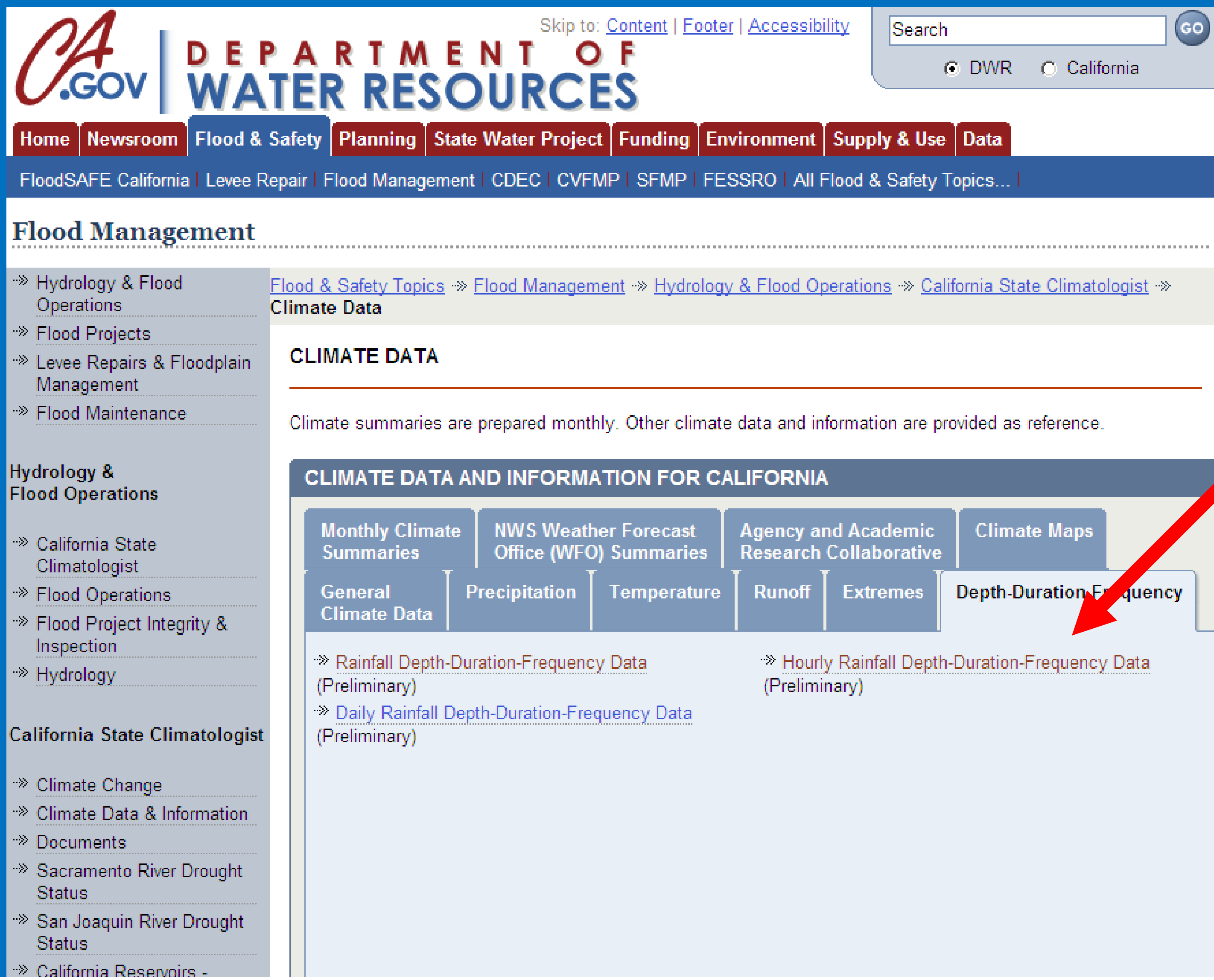


Annual Average Precipitation (Inches),
Northern California

Period: 1961-1990

Rainfall Intensity Data Source

http://www.water.ca.gov/floodmgmt/hafoo/csc/climate_data/#



100 Year RI Rainfall Intensity Data

Example: Georgetown

Duration	15 Minute	30 Minute	1 Hour
Return Period: 100 Year	0.68 inches	0.91 inches	1.29 inches
Intensity in Inches per Hour	2.72	1.82	1.29

Shorter Duration = Higher Intensity

Source: DWR Climate webpage

California Forest Practice Rule
Requirements for Stream Crossings

[Non-Federal Timberlands with Commercial Timber Harvesting]

All permanent watercourse crossings that are constructed or reconstructed shall accommodate the estimated 100-year flood flow, including sediment and debris.

All permanent crossings must allow for upstream and downstream fish passage.

Forest Practice Rule Requirements for Stream Crossings

<u>**100-Year Flood Flow**</u>

A flood flow that has a 1% annual chance of occurrence in any given year.

Yosemite - Merced River

January 1997

Eel River December 1964

Photo: PALCO

Forest Practice Rule Requirements for Stream Crossings

Simple methods to determine 100-yr flood flows based on rainfall and drainage area above crossing site:

1. Rational Method
2. Regional Regression Equations
3. Flow Adjustment by Drainage Area

Complicated Methods: NRCS TR-55, USACE HEC-HMS

1. Rational Method

$$Q_{100} = CIA$$

Where:

Q = Discharge in cfs (cubic feet per second)

C = Runoff coefficient (proportion of rainfall that runs off)

I = Rainfall intensity in inches/hour for 100 yr storm event

A = Basin drainage area in acres

Best used for basins ≤ 200 acres

Rational Method

- **Advantages**
  - Easy to use
  - Widely used and understood
  - Accounts for local conditions

- **Disadvantages**
  - Hourly rainfall data may be difficult to obtain
  - Many assumptions not met
  - Uses only rainfall; does not address rain-on-snow events
  - For small watersheds only, better for urban areas

2. Regional Regression Equations

Sierra Region Example:

$$Q_{100} = 15.7\ (A)^{0.77}\ (P)^{1.02}\ (H)^{-0.43}$$

- **Developed by USGS** ***(Waananen and Crippen 1977. USGS WRI 77-21)***
- **Empirical - based on regression of gaged stream discharge versus (>700 stations):**
  - **basin area (A)**
  - **average annual rainfall (P)**
  - **average basin elevation (H)**
- **State subdivided into 6 areas (flood frequency regions)**

Best Used for Basins >100 acres

Regional Regression Equations

Map of Flood Frequency Regions

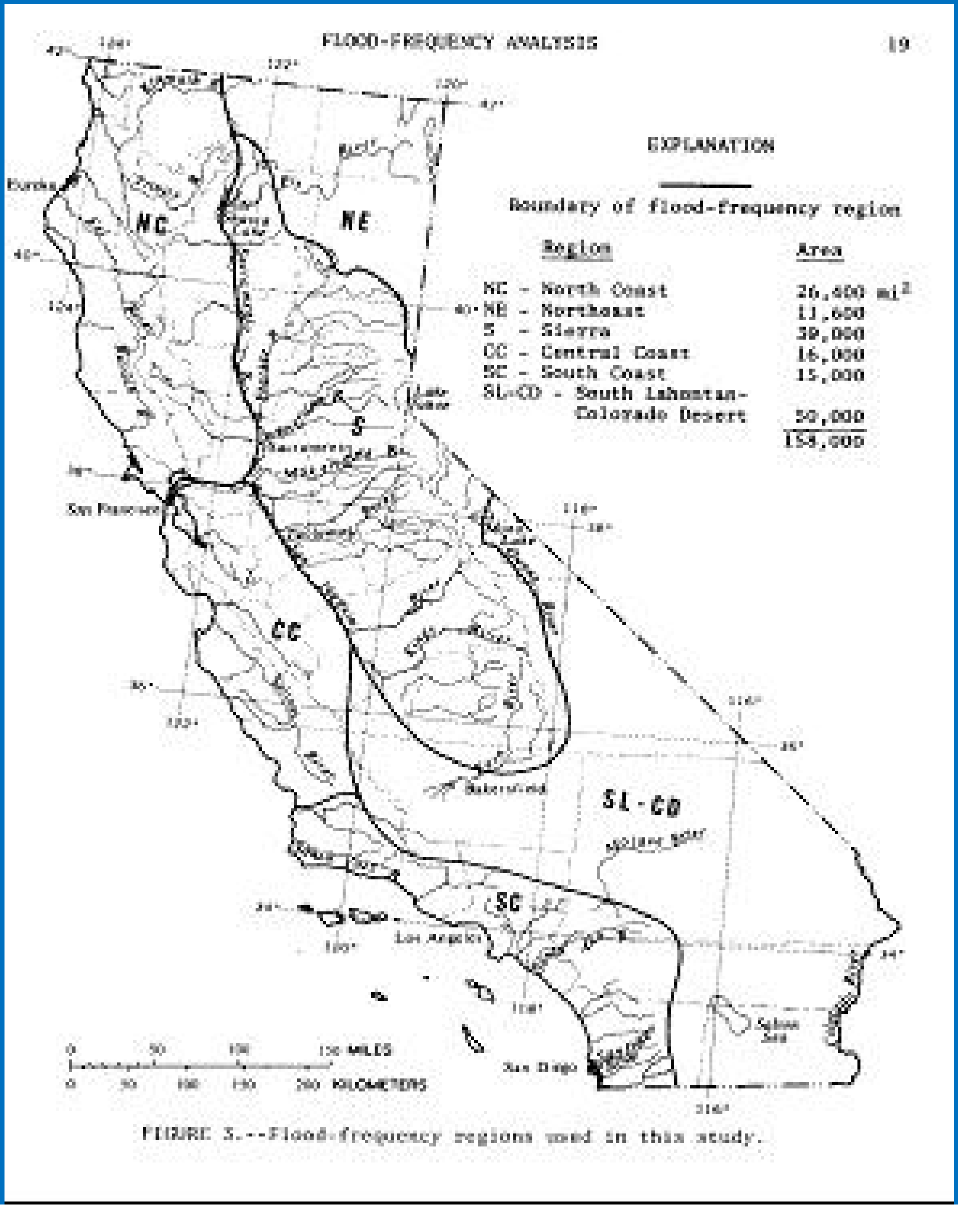


FIGURE 3.--Flood-frequency regions used in this study.

Regional Regression Equation Method

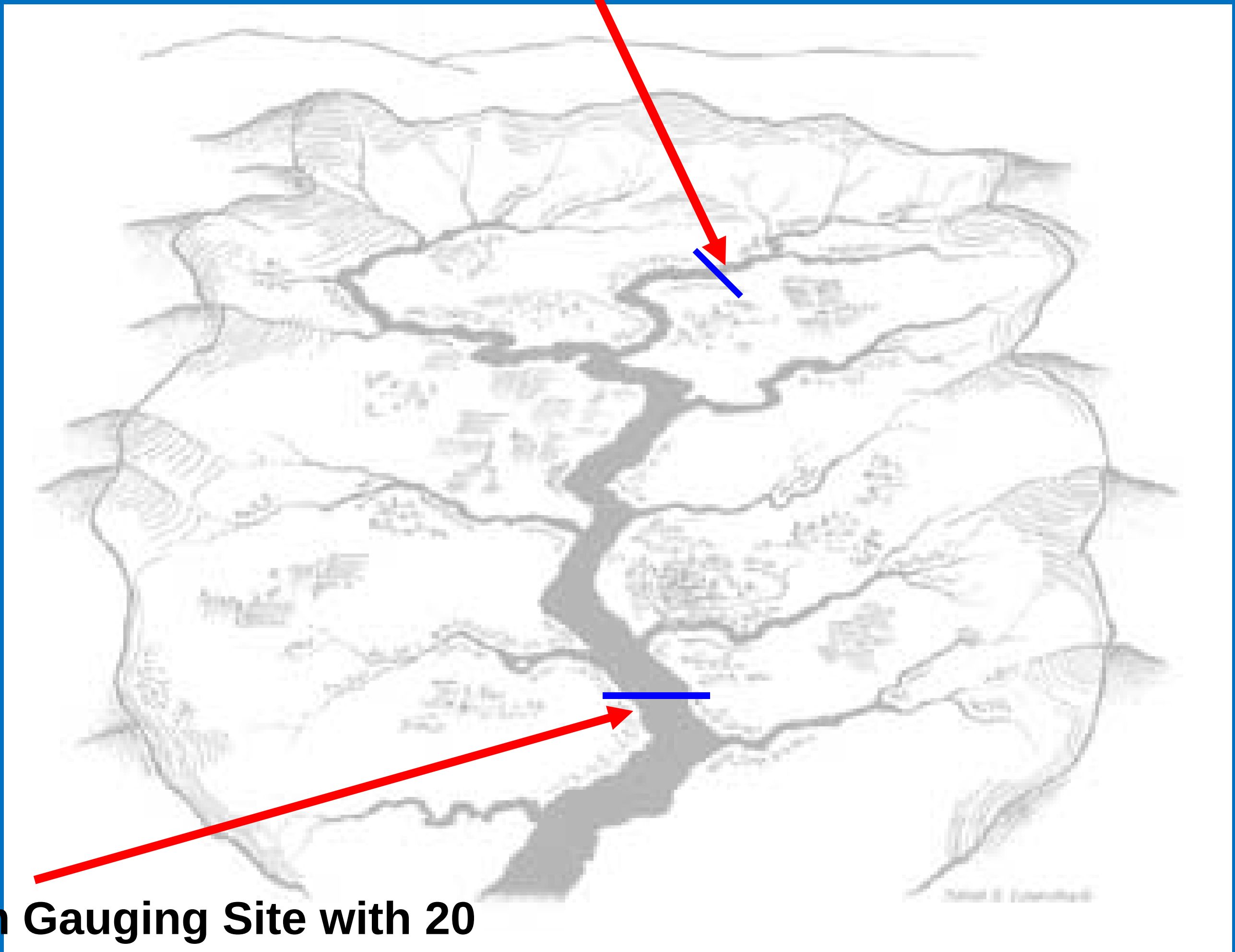
- **Advantages**
  - Easy to use
  - Uses average annual rainfall data
  - Based on measured flood flows from widely distributed, numerous locations
  - Includes rain-on-snow flood data
- **Disadvantages**
  - Broad-brush method (entire state covered by only 6 regions)
  - Tends to overestimate in some areas, underestimate in others
  - Based on old (1977) data

3. Flow Adjustment by Drainage Area Method

- Used for an <u>un</u>gaged basin when discharge data from a downstream station or nearby gaged (hydrologically similar) site is available.

- Adjusts 100-year discharge from the gaged basin for the difference in drainage area between the ungauged basin and the gauged basin by using a simple equation.

Crossing Site: Drainage Area = 10 sq miles



Stream Gauging Site with 20 years of Record: Drainage Area = 100 sq miles

Flow Adjustment by Drainage Area Method

$$Q_{100u} = Q_{100g} \, (A_u/A_g)^b$$

where:

- Q_{100u} = 100-year discharge at ungaged site
- Q_{100g} = 100-year discharge at gaged site
- A_u = drainage area of ungaged site
- A_g = drainage area of gaged site
- b = exponent for drainage area from the appropriate USGS Regional Regression Equation
  (= 0.77 for 100-yr equation for Sierra Region)

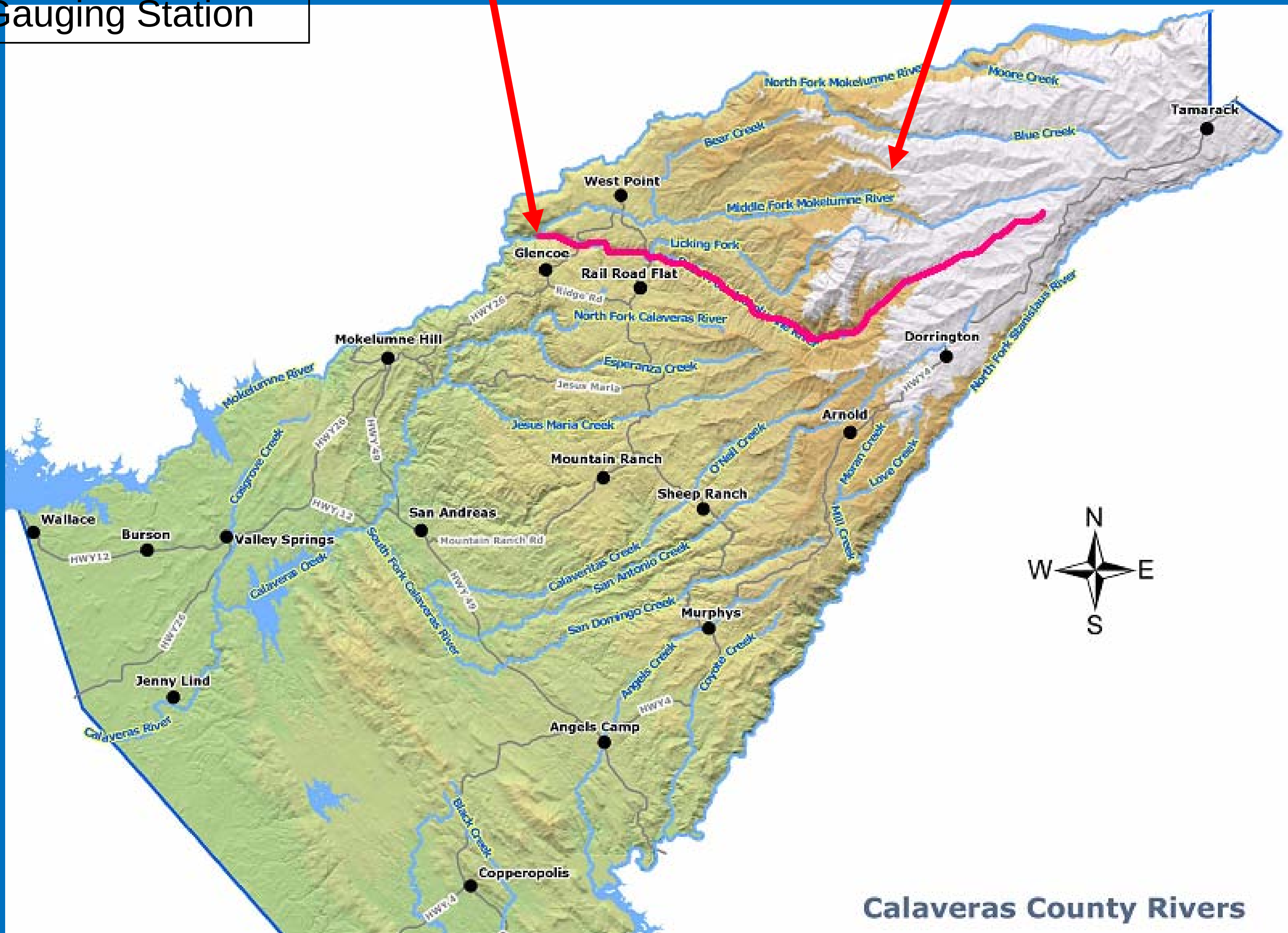
Flow Adjustment by Drainage Area Method

- **Advantages**
  - Easy to use
  - Highest confidence, since local data is used

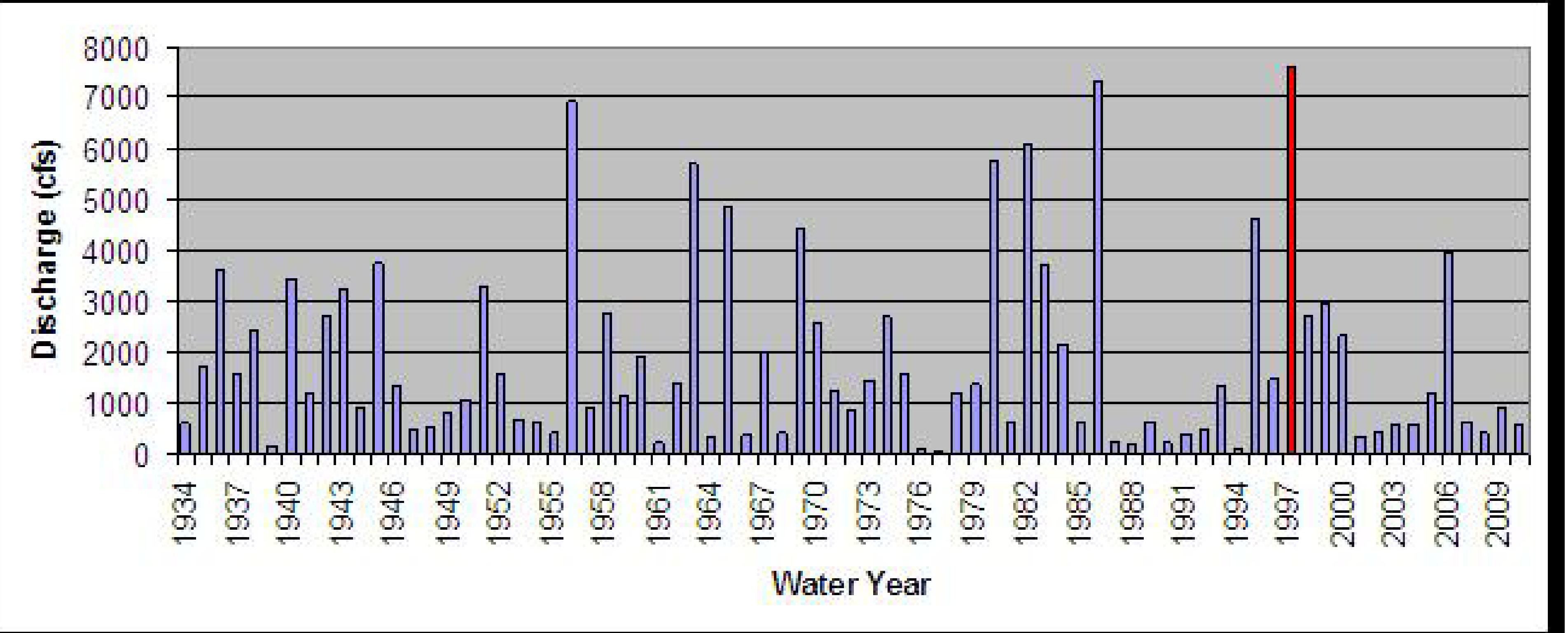
  Disadvantages
  - Nearby unregulated gauging station data ($\geq$ 20 yrs) required.
  - Must determine 100-yr flood flow for gauged station.
  - Difference in drainage areas should not exceed one order of magnitude.

Location of SF Mokelumne USGS Gauging Station

Location of Forest Creek Bridge Site



South Fork Mokelumne River: Peak Discharges: 1934 to 2010



Flood of Record: January 1997– 7,610 cfs

South Fork Mokelumne River:
Estimated Peak Discharges (1934-2010)

RETURN PERIOD (yr)	STREAMFLOW (cfs)
2	1,427
5	2,851
10	4,428
25	6,966
50	9,251
100	11,870
200	14,840
500	19,330

Use USGS PEAKFQ computer program

Example in the South Fork Mokelumne River Watershed

For a new bridge site on Forest Creek, the 100-year discharge can be estimated as:

$Q_{100u} = Q_{100g} (A_u/A_g)^b$

= **11,870** cfs (8.0 mi^2/75.1 mi^2)$^{0.77}$

= <u>2,116 cfs</u>

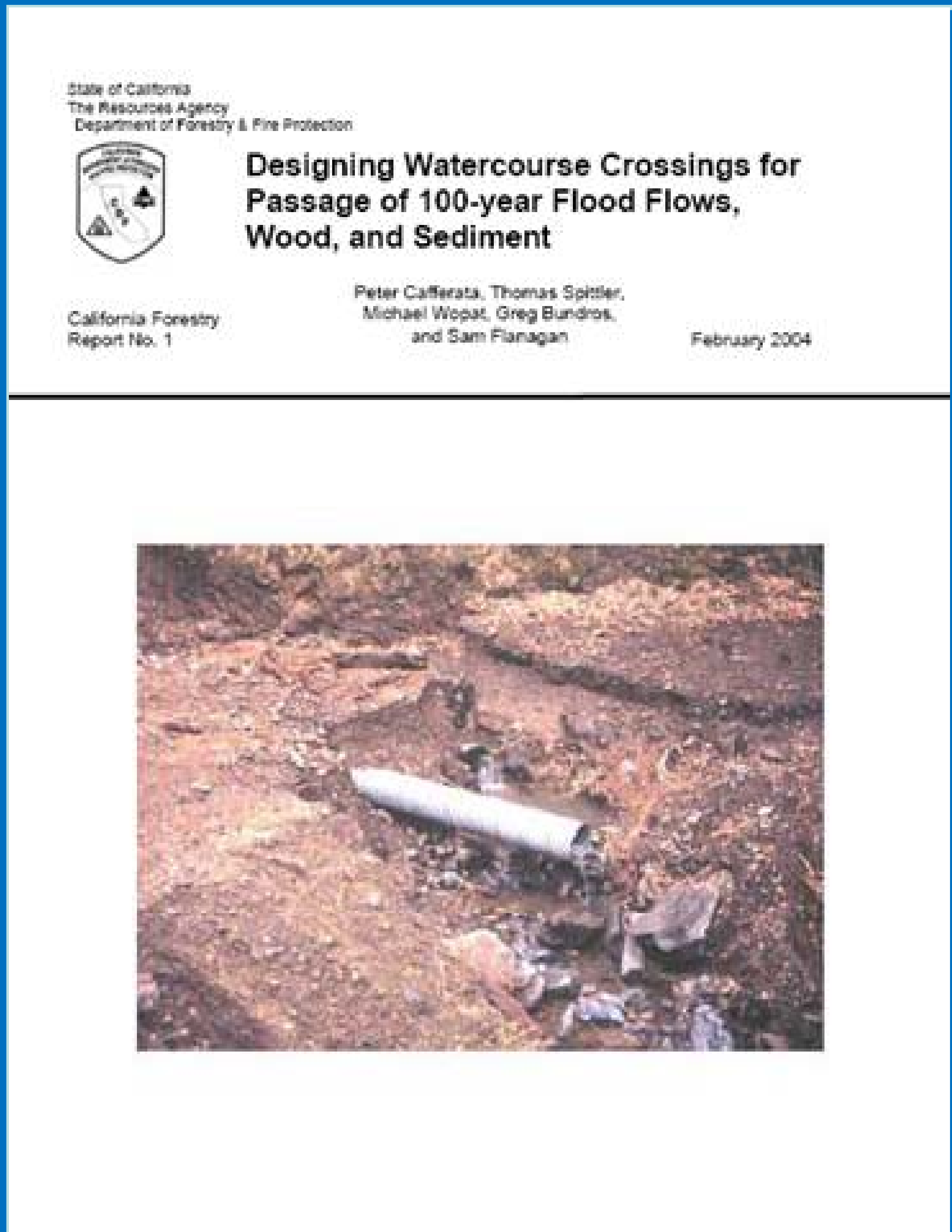
Estimating 100-Yr Flood Flow and Sizing Pipes

- **100-yr flood flow is estimated by relationships between precipitation and watershed characteristics and runoff *(use <u>multiple</u> predictive, <u>office</u> methods).***

- **Use a simple nomograph or chart to convert 100-yr discharge to <u>pipe size</u>.**

- **Check result by making a direct stream channel cross- section <u>field measurement</u> <u>[area of pipe should be at least 3x the bankfull cross sectional area].</u>**

Recommend: Minimum of 24 inch pipe for a <u>stream</u> crossing


State of California
The Resources Agency
Department of Forestry & Fire Protection

Designing Watercourse Crossings for Passage of 100-year Flood Flows, Wood, and Sediment

California Forestry Report No. 1

Peter Cafferata, Thomas Spittler, Michael Wopat, Greg Bundros, and Sam Flanagan

February 2004

Guidebook produced in 2004 to assist foresters in designing watercourse crossings and predicting flood flows

Available online at:

http://www.fire.ca.gov/resource_mgt/downloads/100yr32links.pdf

III. Types of Crossings Available

Types of Crossings

A. Culverts
B. Open Bottom Arches
C. Bridges
D. Fords
E. Temporary Crossings
   - Temporary Fords [e.g., Spittler log fill, rock fill, etc.]
   - Temporary Culverts
   - Temporary Bridges

No Permanent Humboldt Log Crossings

Which One Should I Use?

Depends on…

- Watercourse class (e.g., fish present?).
- Watershed drainage area and expected size of 100 yr flood flow.
- Channel slope; landslide susceptibility.
- Maintenance expected.
- Amount and type of traffic expected.
- Road type (permanent, seasonal, temporary).
- Amount of wood and sediment expected to reach the crossing location.
- Topography at the crossing site (incised or flat?).

A. Culverts

- Culverts in forest settings very common (~70% of crossings)--mainly steel or plastic.
- Aluminum <u>not</u> used as much since the mid-1980's—too expensive. At that time, plastic pipes became available.
- Plastic now used heavily (particularly up to 36 inches—especially in the Coastal Mountains).

A. Culverts

- **Pro's**
  - **Good for small, non-fish headwater streams where winter maintenance is possible and will occur.**
- **Con's**
  - **Require lots of maintenance!**
  - **Steel--expected life often only ~25 yrs (range 10-100 yrs).**
  - **Relatively high probability of failure, especially from sediment and woody debris.**
  - **Bad for fish passage.**


Steel 48 inch Culvert—
Mendocino County;
projecting inlet
JUN 20 2002

Plastic 18 inch Culvert—
(single wall); Humboldt County


Double Wall
Smooth-Invert
Plastic Pipe-
High Density
Polyethylene
(HDPE);
Western Oregon

Plastic Pipe Pro's and Con's

- **Caltrans expects a minimum life of 50 years for HDPE pipes exposed to sunlight. UV damage is generally not a concern.**

- **Benefits that HDPE pipe have over CMP include: (1) light weight, (2) ability to be cut with hand tools (saws, chainsaws, etc.) that don't pose a large fire hazard, (3) abrasion resistant, and (4) resistant to corrosion due to low pH soils.**

- **Double-walled pipes are very common now and provide:**
  - **more rigidity to accommodate higher static (overburden) and dynamic traffic loads.**
  - **a lower roughness (n) value to increase the conveyance capacity of the pipe (about the same as a concrete pipe).**

- **Problems: (1) increased flow velocities on inclined culverts; and (2) significant energy dissipation structures are often needed below HDPE pipes.**

- **Biggest problem: Fire Damage.**

Holes left where plastic culvert burned in small drainages

Roca/Rosa 2007 Fires

San Diego County

Photo: R. Eliot, CAL FIRE (retired)


Lockheed Fire 2009
Santa Cruz County

Steel 84 inch Culvert with Mitered Inlet—Mendocino Co.

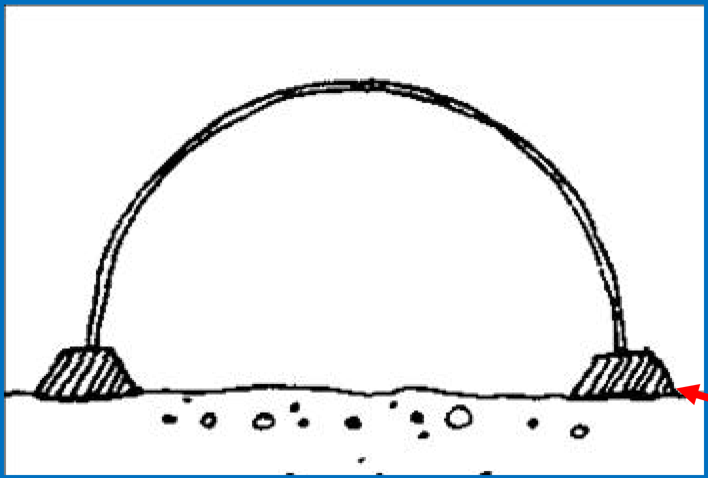
Steel Culvert with Flared Metal End Section, Tahoe National Forest

Steel Culvert with Concrete Headwall—Santa Cruz County


Pipe Arch Culvert Crossing—Tehama County—Deer Creek Watershed.
Note Rock Headwall/ Wing Walls

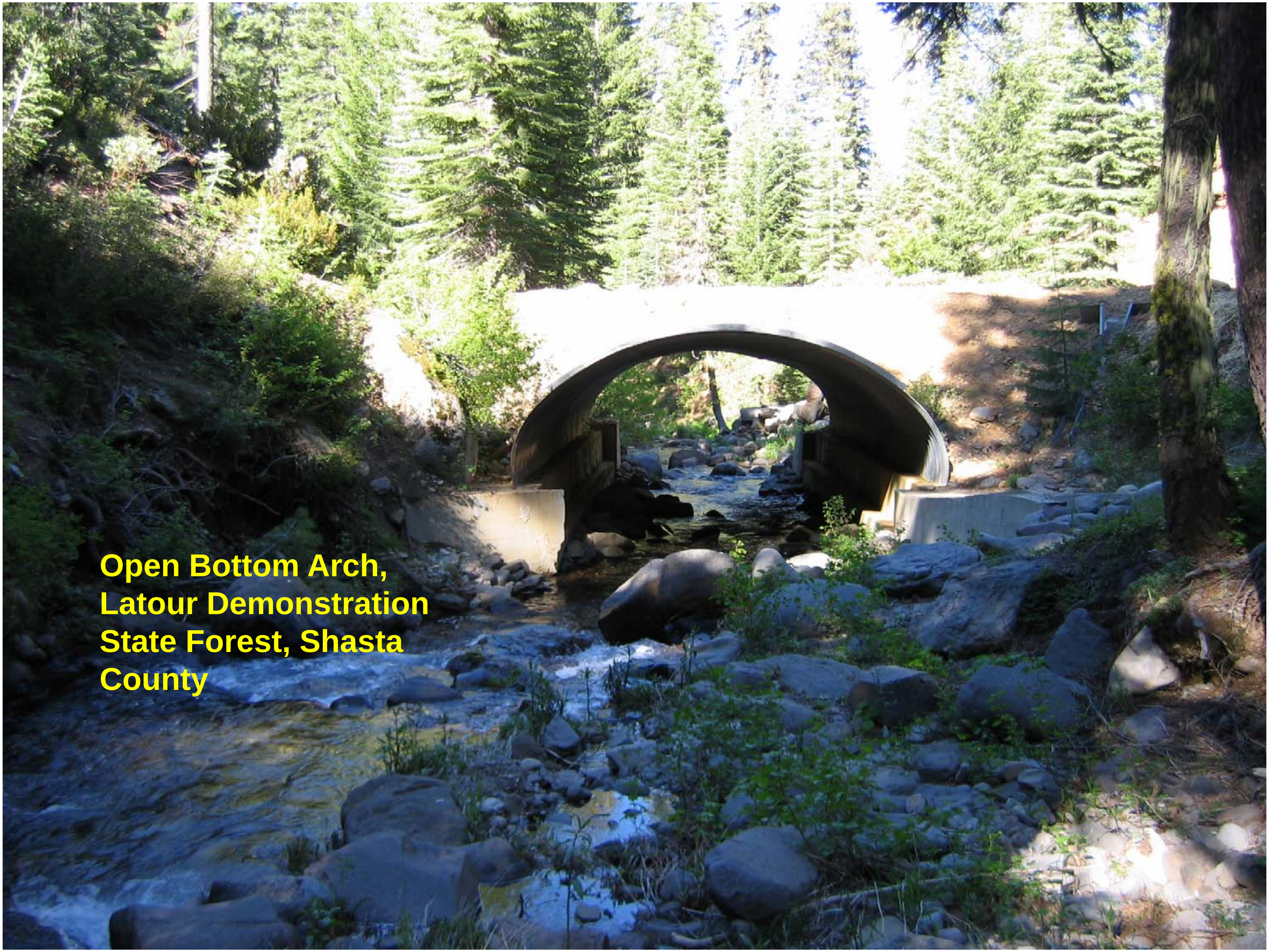
B. Open Bottom Arch

- **Pro's**
  - Excellent for fish passage.
  - May be cheaper than a bridge.
- **Con's**
  - Expensive.
  - Will require a professional engineer design.
  - Can fail by undermining if concrete footings not on solid rock base.



Concrete footing

Image: Weaver and Hagans 1994


Open Bottom Arch,
Latour Demonstration
State Forest, Shasta
County


Open Bottom Arch—
Freshwater Creek Watershed,
Humboldt County
Replaced a 10 ft Round CMP
10.18.2006

C. Bridges

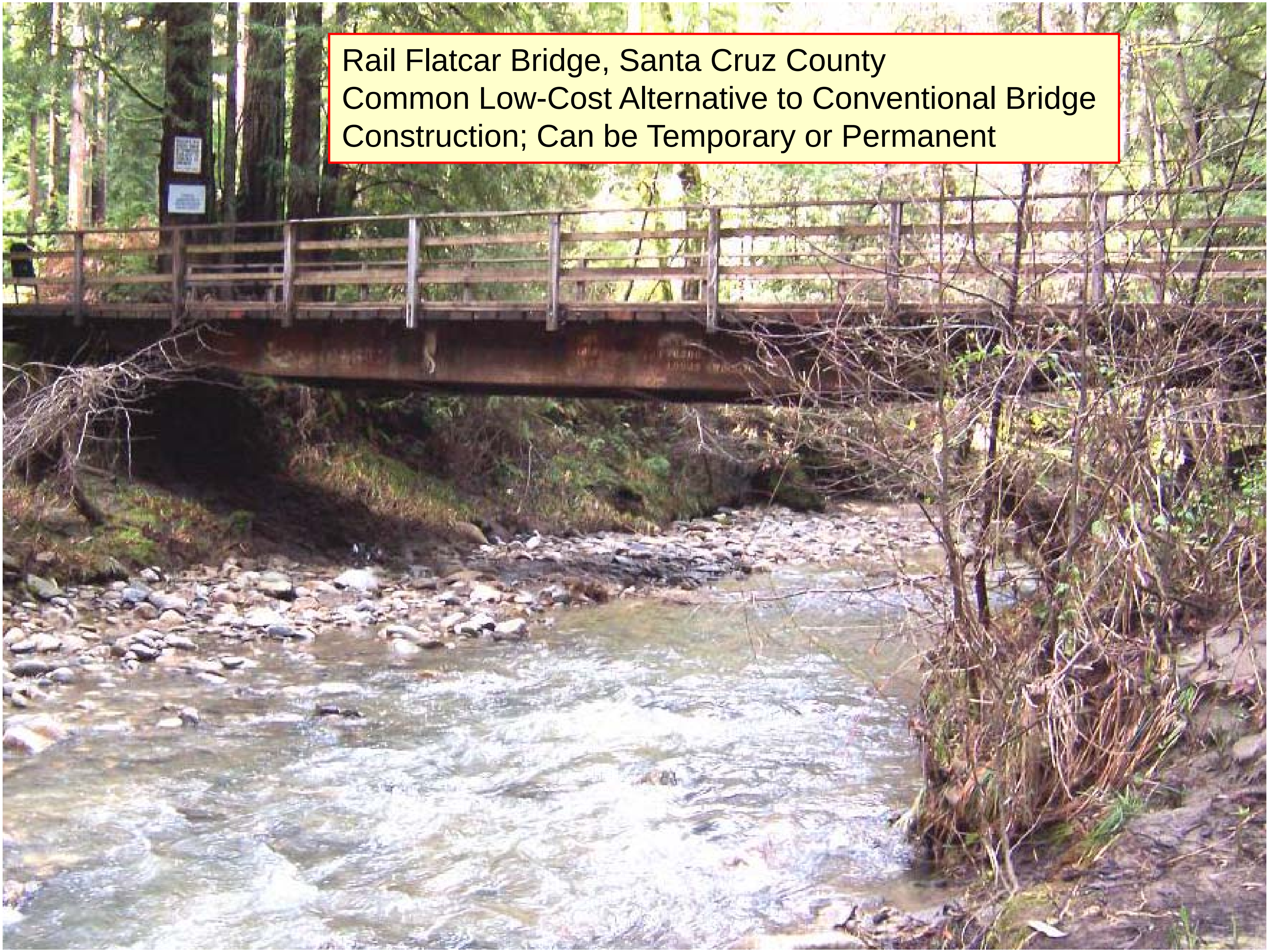
- **Pro's**
  - Excellent for fish passage.
  - If built correctly, long expected life (low chance of failure).
  - Little impact to the stream channel.
  - Little sediment entry.
  - Low overall environmental impact.
  - Good for incised stream channels/larger watercourses.
- **Con's**
  - Expensive.
  - Railroad flatcar bridges are $20,000 to $50,000, depending on length (55 ft or 90 ft) + $10,000 or more to install).
  - May require Professional Engineer design.


"Legacy Crossings":
Log Stringer Bridge
Mendocino County


Big River Steel Bridge
Mendocino County

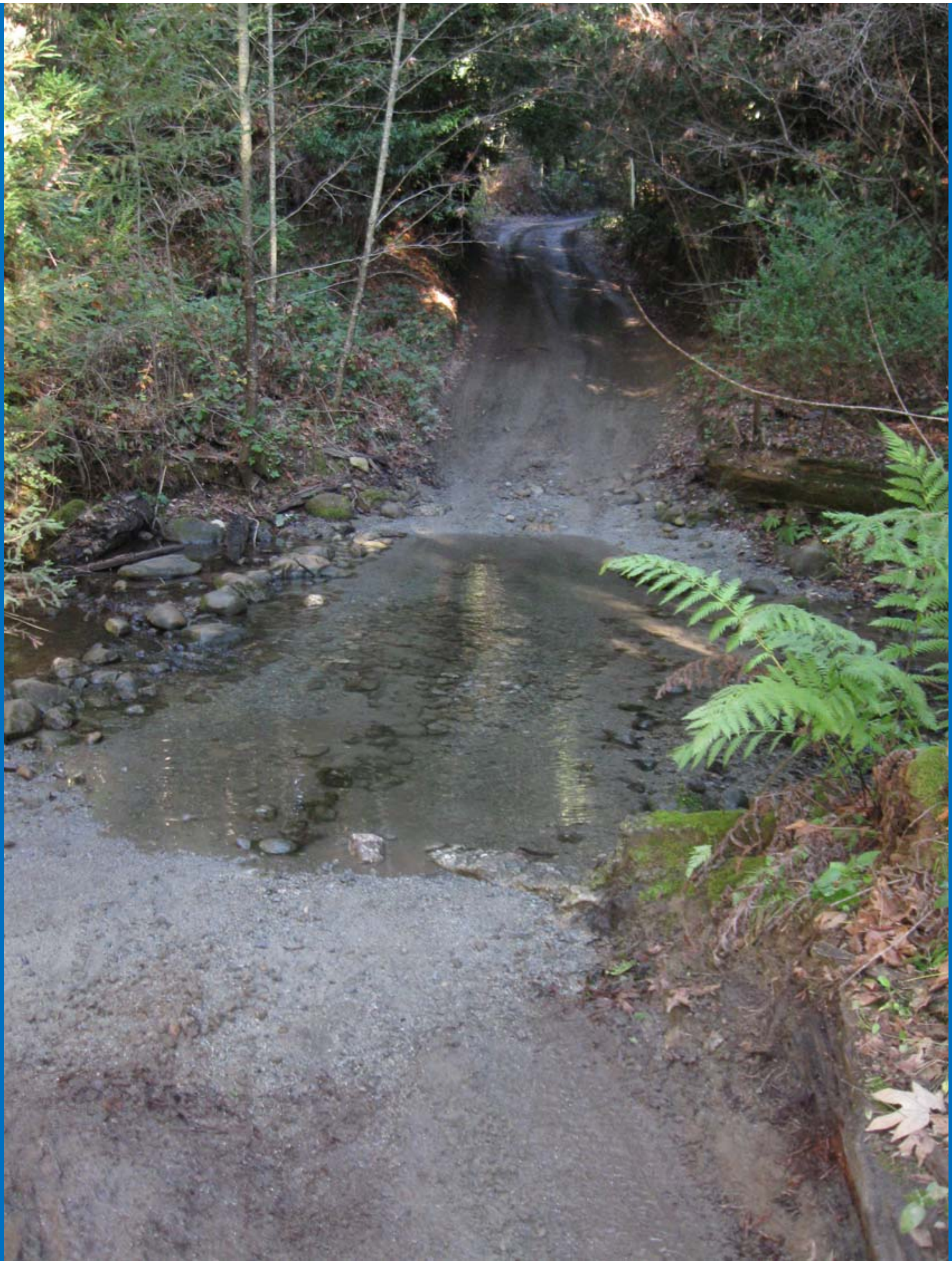
Steel Bridge, Forest Creek, Calaveras County
Note Pre-Cast Concrete Supports for Bridge Abutments

Photo:
M. Hartzell,
CVRWQCB


Rail Flatcar Bridge, Santa Cruz County
Common Low-Cost Alternative to Conventional Bridge
Construction; Can be Temporary or Permanent

D. Ford Crossings

- **Pro's**
  - Often relatively inexpensive alternative for small to medium sized streams w/stable bottoms.
  - Low maintenance.
  - Low chance of failure if designed correctly.
  - Better than a pipe where winter maintenance will not occur (no plugging).
  - Not very sensitive to specific flow volumes ("forgiving").
  - Good for channels susceptible to landslides/debris flows.
- **Con's**
  - Can have high sediment entry, high impact to stream channel, especially with lots of traffic.
  - Rock ford crossings can fail easily if not designed correctly.
  - Not passable during flood flows!
  - Improved ford crossings (concrete slabs) bad for fish passage—prone to scour around edges.



Unimproved Wet Ford Crossing with Chronic Sediment Entry into Hinckley Creek

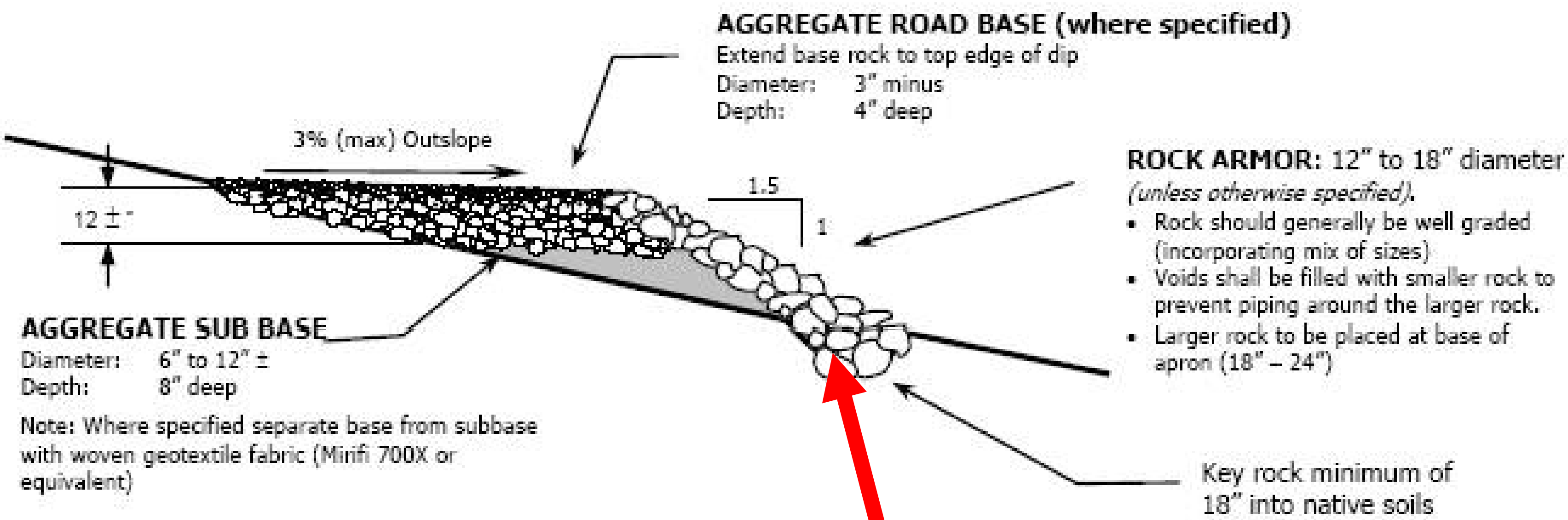
Santa Cruz County

NOT DESIRABLE

Rock Ford Crossing—Mendocino County. Rock must be large enough to resist movement in winter storms

Rock Ford Design Specifications

Tim Best, CEG



Large rock (18-24 in) needed at base of crossing

Concrete Slab Ford—Tehama County—Ponderosa Road.

Pave across live streams to maintain water quality with regular traffic (get scour at edge).

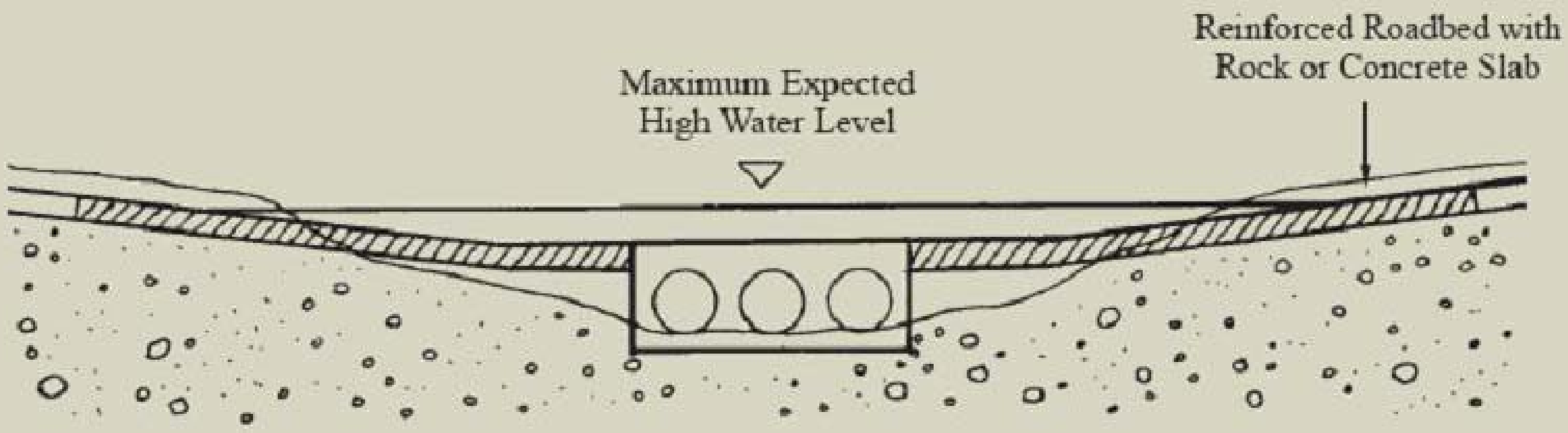
Concrete Slab Ford—Tehama County—Crane Mills

Thomes Creek "The Slab."

Brett Rohrer DFG


Vented Ford—Butte County

Diagram of a Vented Ford Crossing (Keller and Sherar 2003)



b. Improved (Vented) Ford with Culvert Pipes in a Broad Channel

Note that armoring must extend to the 100 yr High Water Level on either side of the pipes.

Comparison of Crossing Types Impacts on Water Quality

– Culverts: higher catastrophic failure risk; lower chronic sediment input.

– Fords: lower catastrophic failure risk; higher chronic sediment input.

– Chronic Water Quality Effects from sediment entry:
  - Highest: fords and culverts
  - Lowest: bridges

E. Temporary Crossings

- **Pro's**
  - Little impact to stream channel if designed and implemented correctly.
  - Almost no chance for failure.
  - Complete fish passage.
  - Relatively inexpensive.
  - Required for temporary roads (pulled by October 15th).
- **Con's**
  - Higher sediment input, especially if built incorrectly.
  - High sediment input if removed incorrectly.

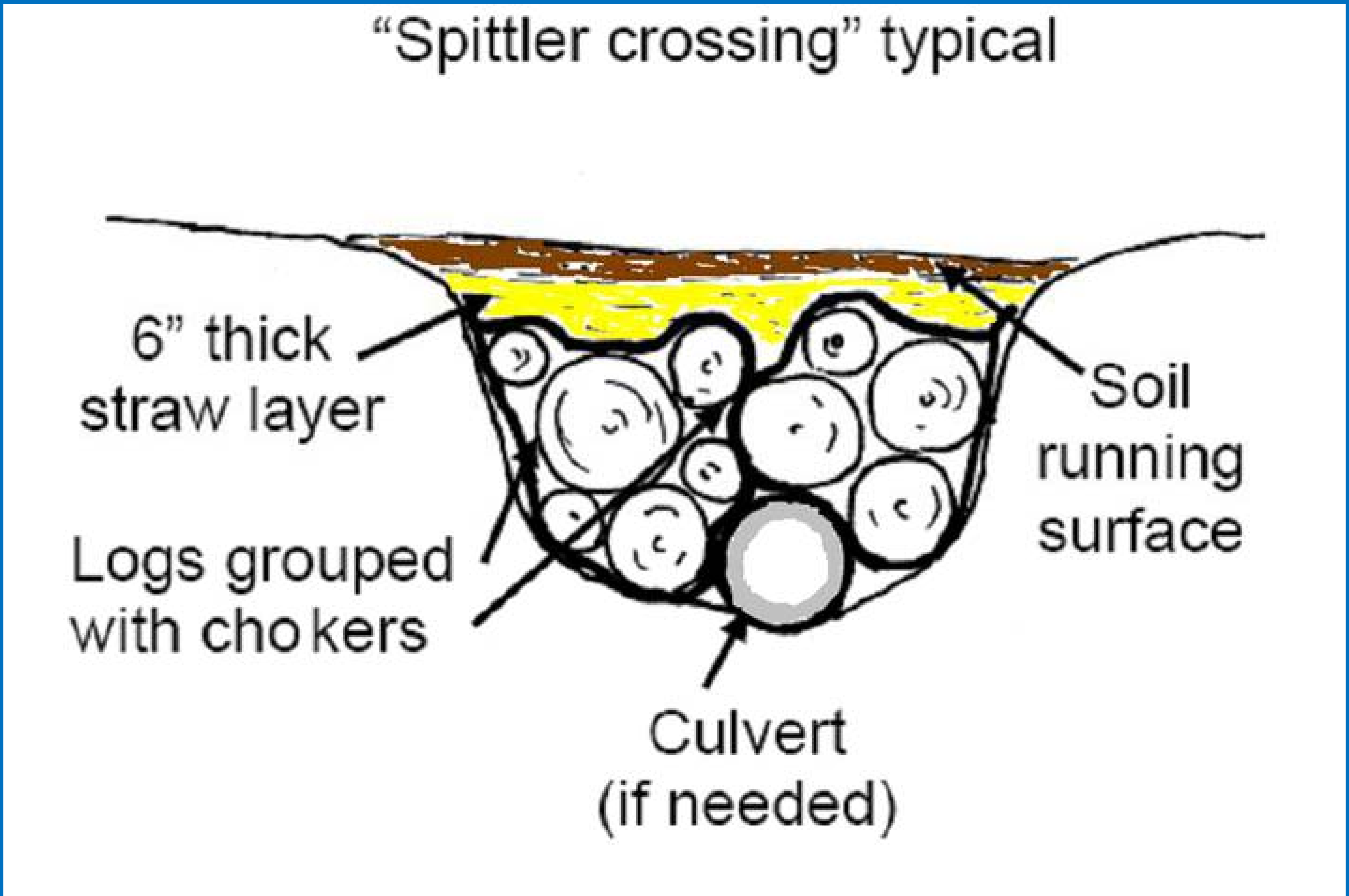


Image: T. Spittler, CGS (retired)


Temporary Spittler
Crossing—Tehama
County

Temporary 12 inch plastic pipe

Santa Cruz County

Photo: Stacy Stanish, DFG


Temporary Culverts with
Rock Fill (Clean Gravels)
Shasta County


Temporary Bridge Crossing—SF
Stanislaus River, Tuolumne County—SPI
and PG&E. Cost effective; quick
installation and removal; little disturbance
Image: Hartzell, CVRWQCB

Crossing Crosswalk

Watercourse Type	Crossing Alternatives
Class I fish-bearing	1. Temporary crossing; 2. Bridge; 3. Open-bottom arch; 4. Pipe arch culvert
Class II non-fish bearing perennial	Culvert or Temporary Crossing
Class II non-fish bearing intermittent (headwater)	Culvert or Rock ford (or Temporary crossing)
Class III ephemeral	Rock ford or Culvert (or Temporary crossing)

PREFERRED ALTERNATIVES FOR FISH-BEARING CROSSINGS

The following alternatives and structure types should be considered in order of preference (NMFS 2001):

1. ***Nothing*** - Road realignment to avoid crossing the stream.

2. ***Bridge*** - spanning the stream to allow for long term dynamic channel stability.

3. **Bottomless arch, embedded culvert design, or ford**.

4. ***Non-embedded culvert*** - this is often referred to as a hydraulic design, associated with more traditional culvert design approaches limited to low slopes for fish passage.

IV. What Can Go Wrong at a Crossing?

(short answer—LOTS!)


Plugging of the pipe
inlet with sediment

Terrace Development

Crossings with terraces or sediment wedges above the inlet often have insufficient capacity to pass flood flows.

Terraces upstream of the culvert inlet indicate past ponded conditions.

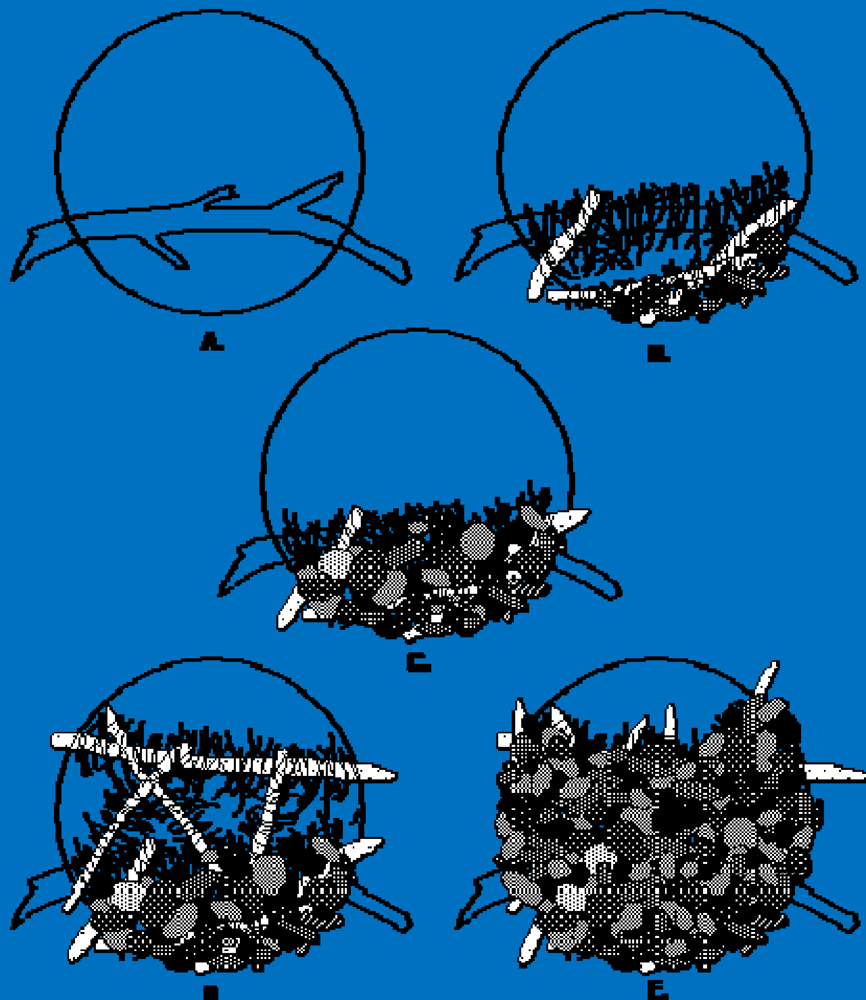
Culverts Blocked by Woody Debris

Photo: Wopat, CGS

Photo: Wilson, CVRWQCB

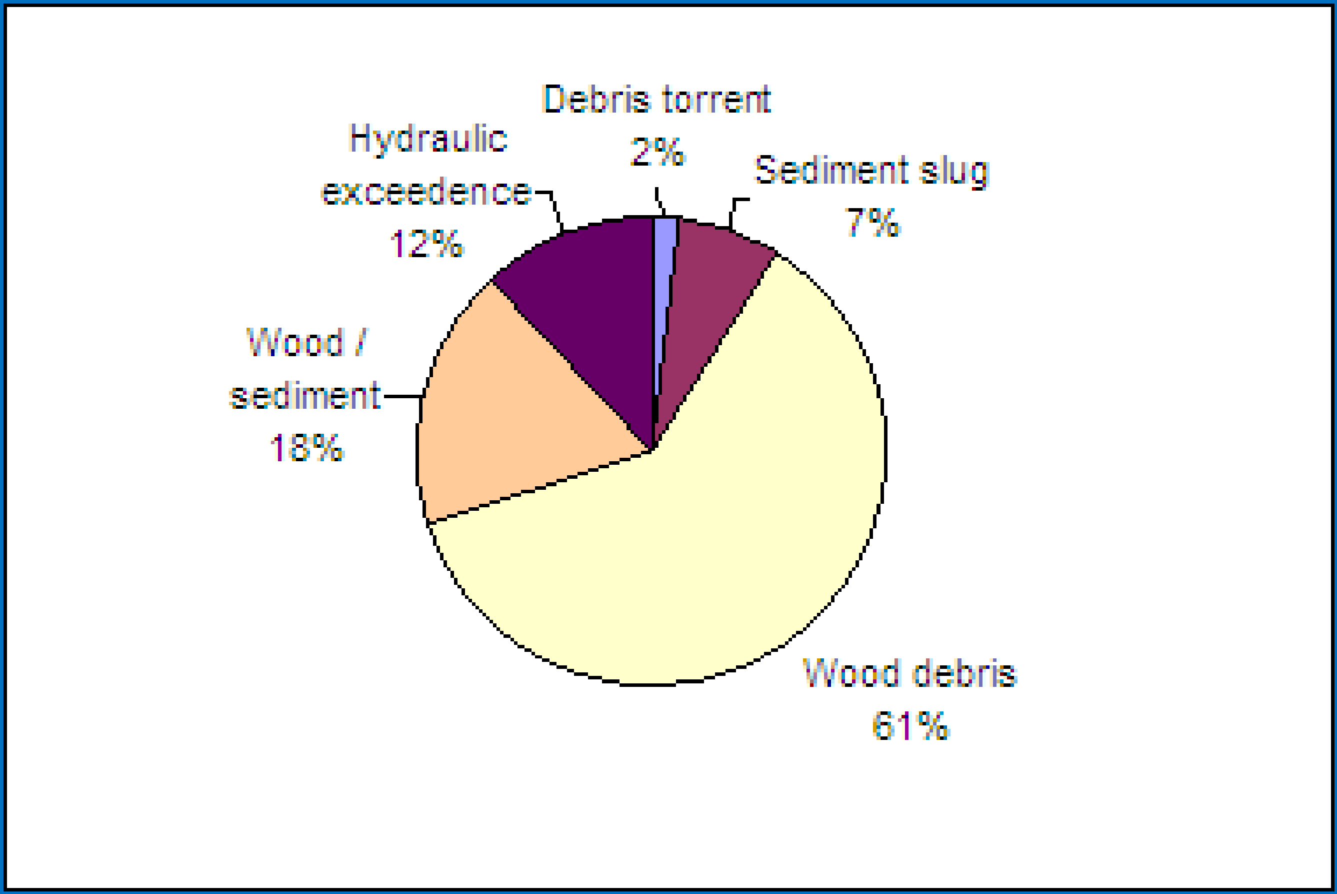

Upper
Sacramento River
Basin 2009
Photo: M. Boone,
CVRWQCB

Typical Woody Debris Lodging at the Culvert Inlet (Flanagan 2004)

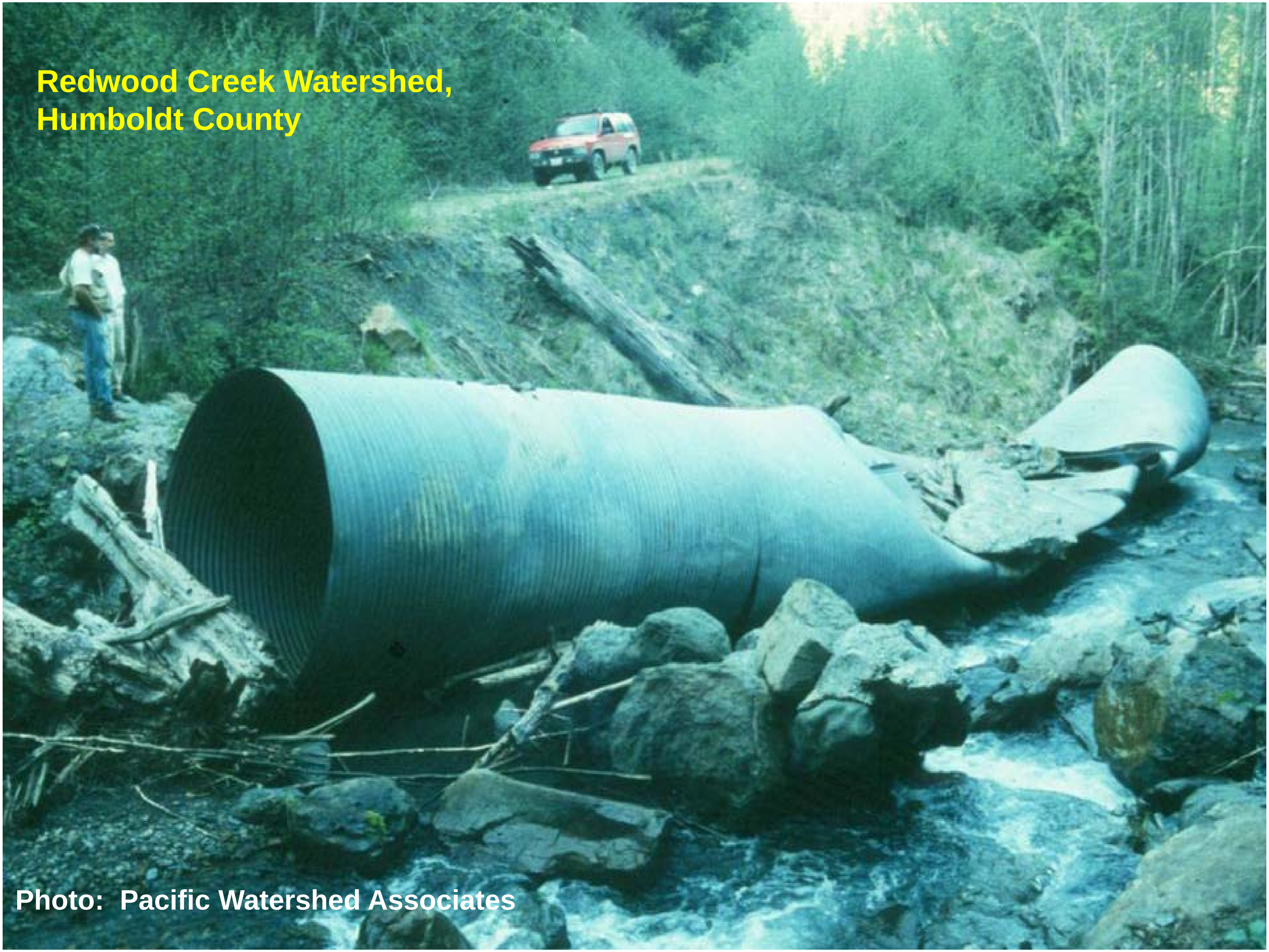



JUN 5 2002

Failure Mechanisms for Culverts Along Forest Roads in Northwest CA Associated with Storms < 12 RI (Flanagan 2004)



n = 57


Redwood Creek Watershed,
Humboldt County
Photo: Pacific Watershed Associates

Humboldt County Crossing—Inlet Blocked

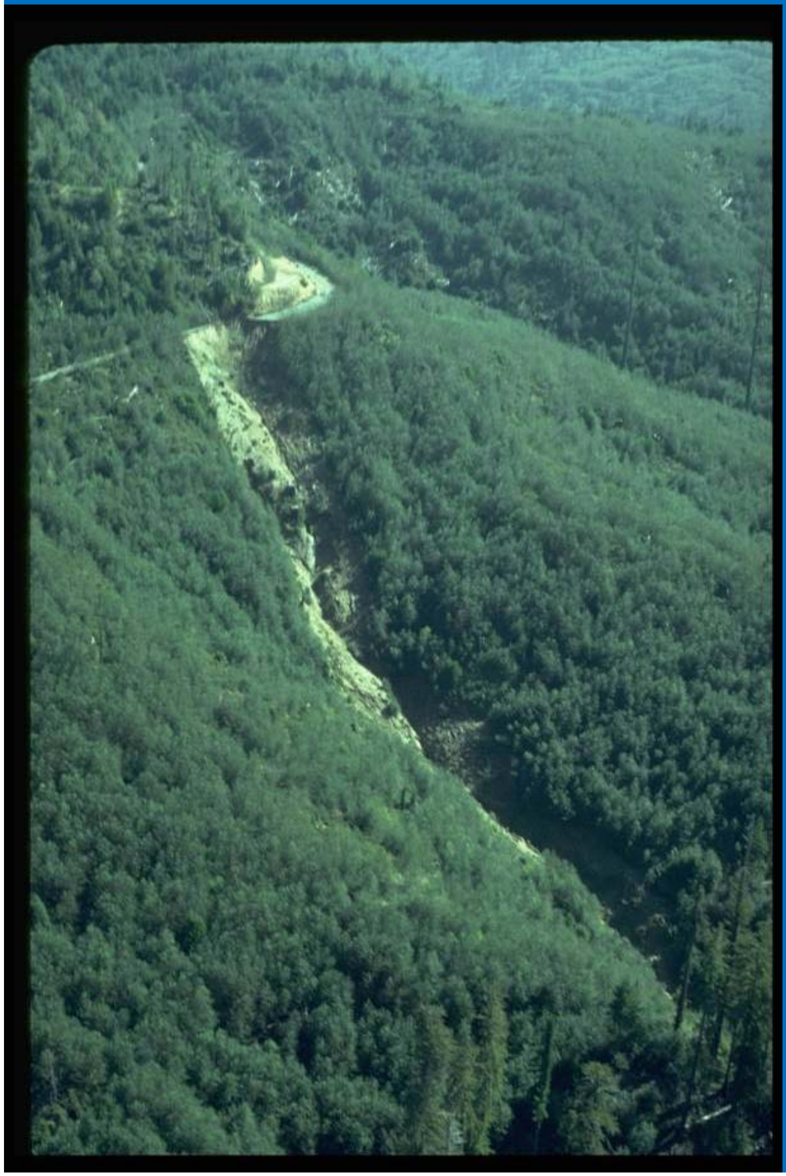
Photo: Scanlon, CAL FIRE


Lassen National Forest
Photo: Derrig, USFS

Stream Diversion from Blocked Culvert Inlet

Photo: Pacific Watershed Associates

Example of Stream Diversion Gullies — Redwood Creek Watershed

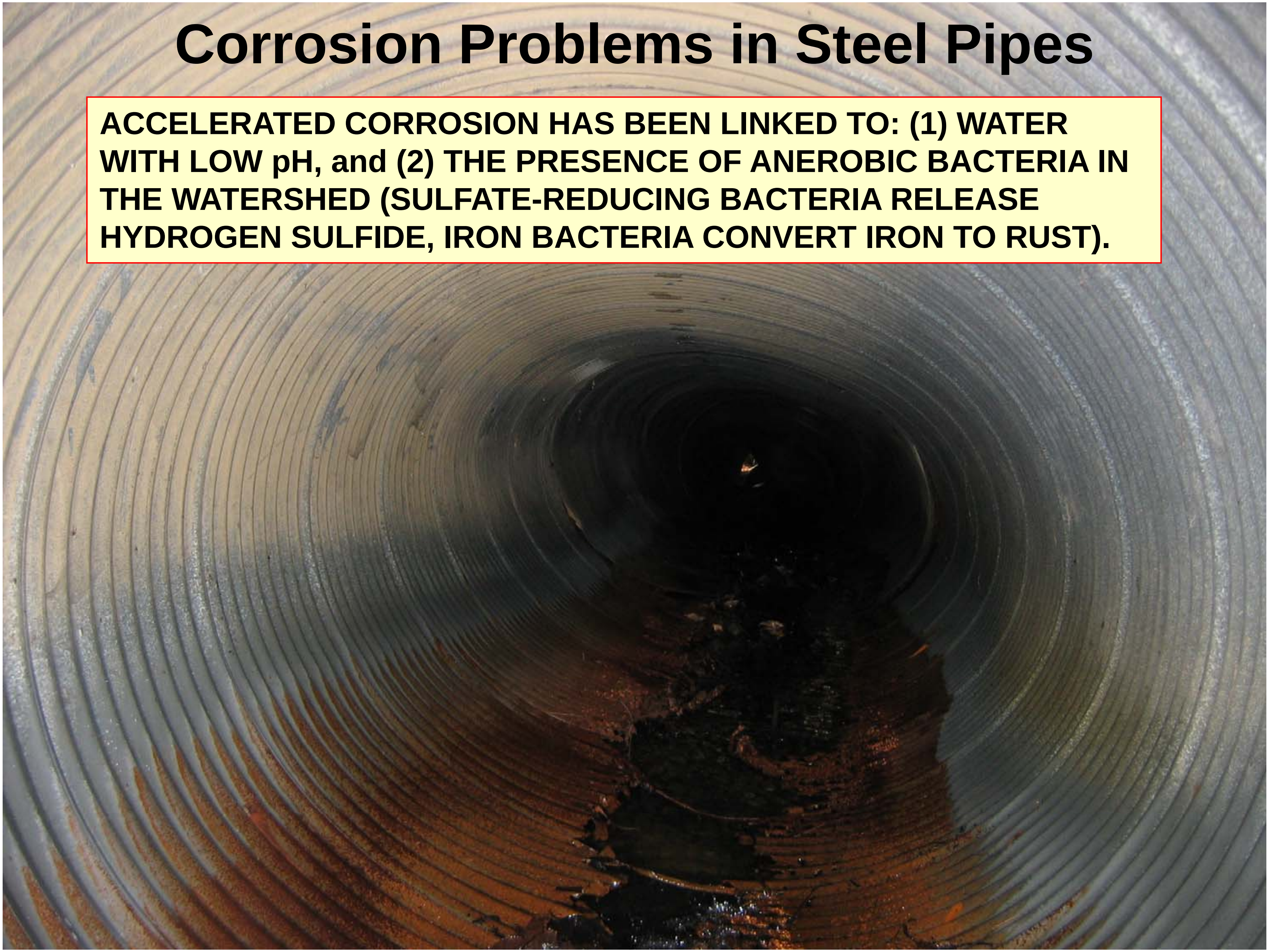


Photos: Bundros, RNSP (retired)


Installation Problems!
Lassen County Steel Culvert--culvert bands were probably not attached correctly

Corrosion Problems in Steel Pipes

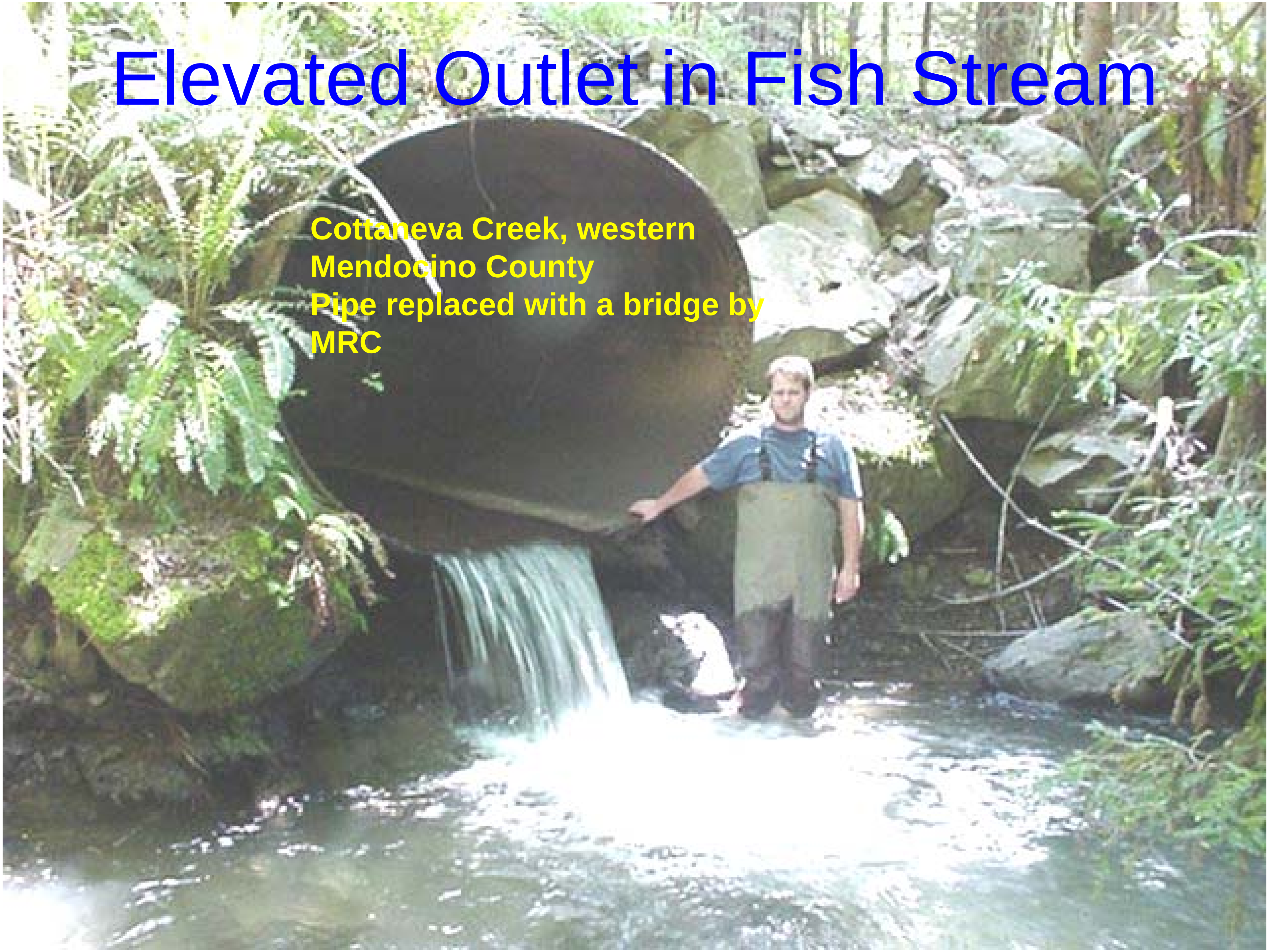
ACCELERATED CORROSION HAS BEEN LINKED TO: (1) WATER WITH LOW pH, and (2) THE PRESENCE OF ANEROBIC BACTERIA IN THE WATERSHED (SULFATE-REDUCING BACTERIA RELEASE HYDROGEN SULFIDE, IRON BACTERIA CONVERT IRON TO RUST).




Pipe Installed in western Mendocino
County 20-30 yrs ago

Culvert Crushing and Plugging

Elevated Outlet in Fish Stream



Cottaneva Creek, western Mendocino County
Pipe replaced with a bridge by MRC


Failed Open Bottom Arch Crossing—Tehama County
After first winter, 5 feet of scour at inlet, undermining footings by 2 feet

Failed Rock Ford Crossing—Undersized Rock


Soquel Creek Bridge
January 1982
Photo: Swanson, NRCS

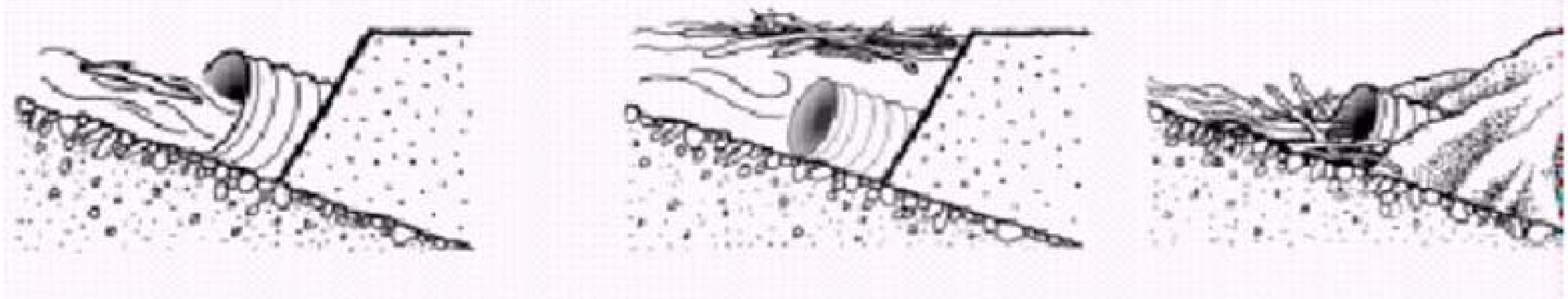
V. Proper Design and Construction for New or Reconstructed Culverted Stream Crossings*

[In addition to Proper Design for 100 yr Flood Flow]

***If you Modify a Stream's Bed or Banks, you must First Notify the California Department of Fish and Game and Obtain a Streambed Alteration Agreement (or 1600 Agreement)**

1. Culverts Should Not Pond Water

(Furniss and Others 1998)



HW/D < 1.0
(suggest 0.67)

GOOD

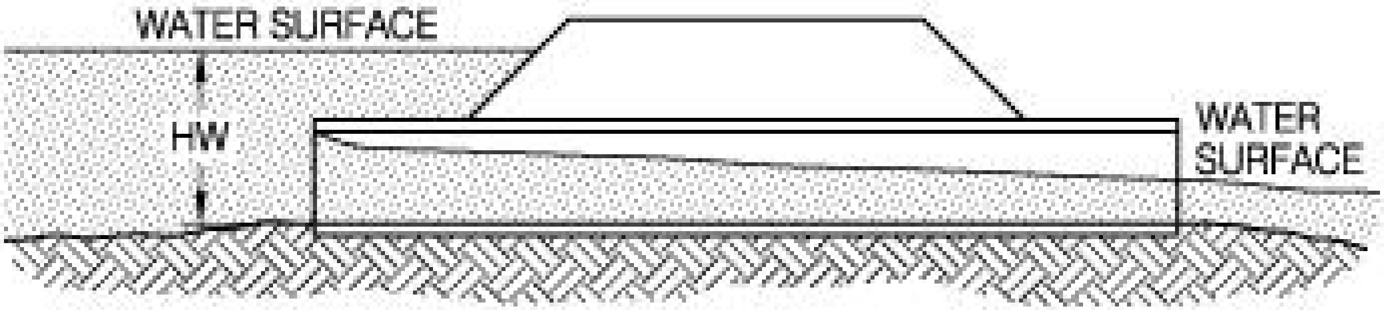
Reduced Plugging Hazard

HW/D > 1.0

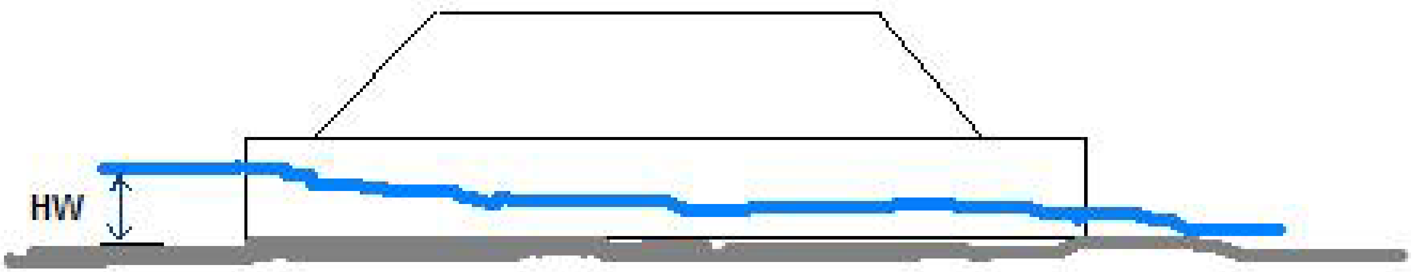
HW/D > 1.0

BAD

Culverts Should Not Pond Water



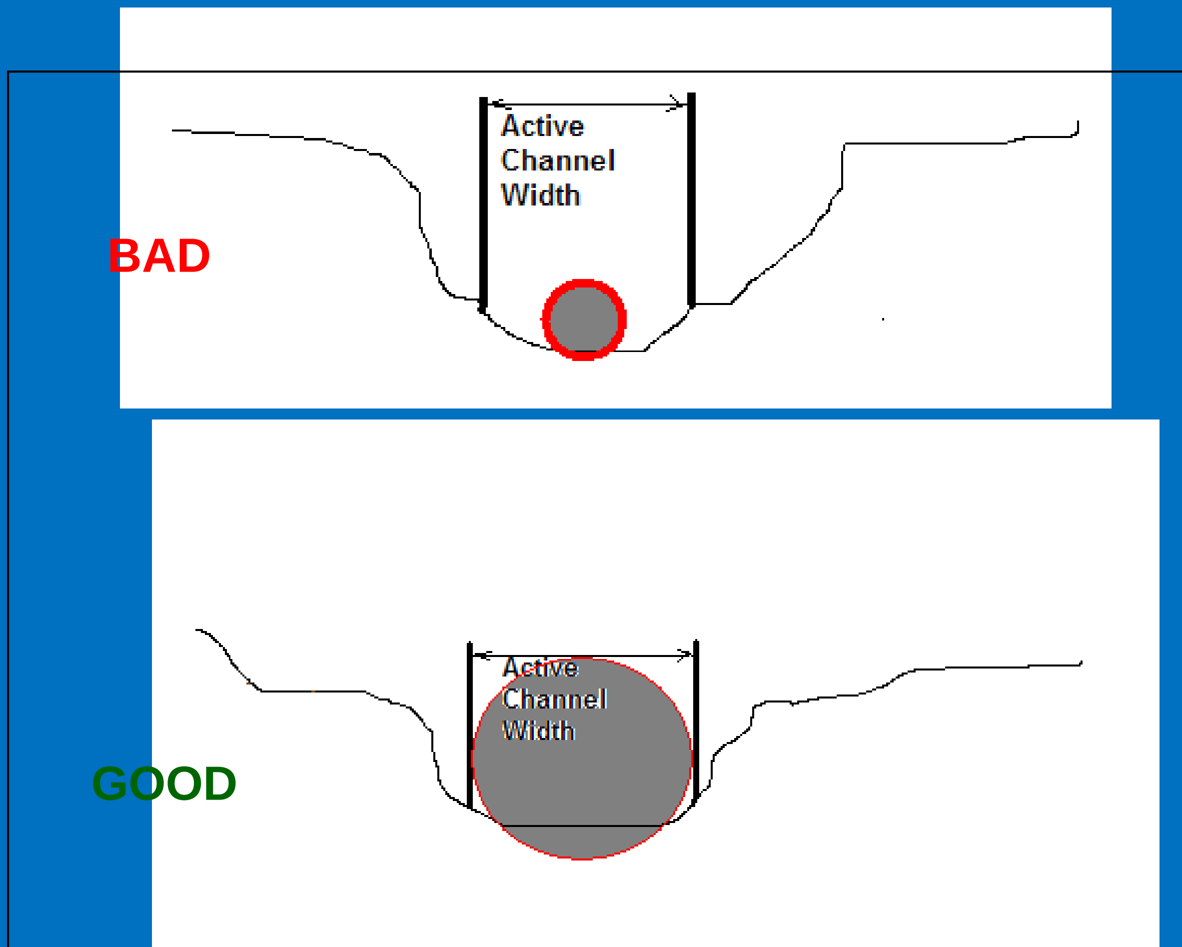
BAD



GOOD

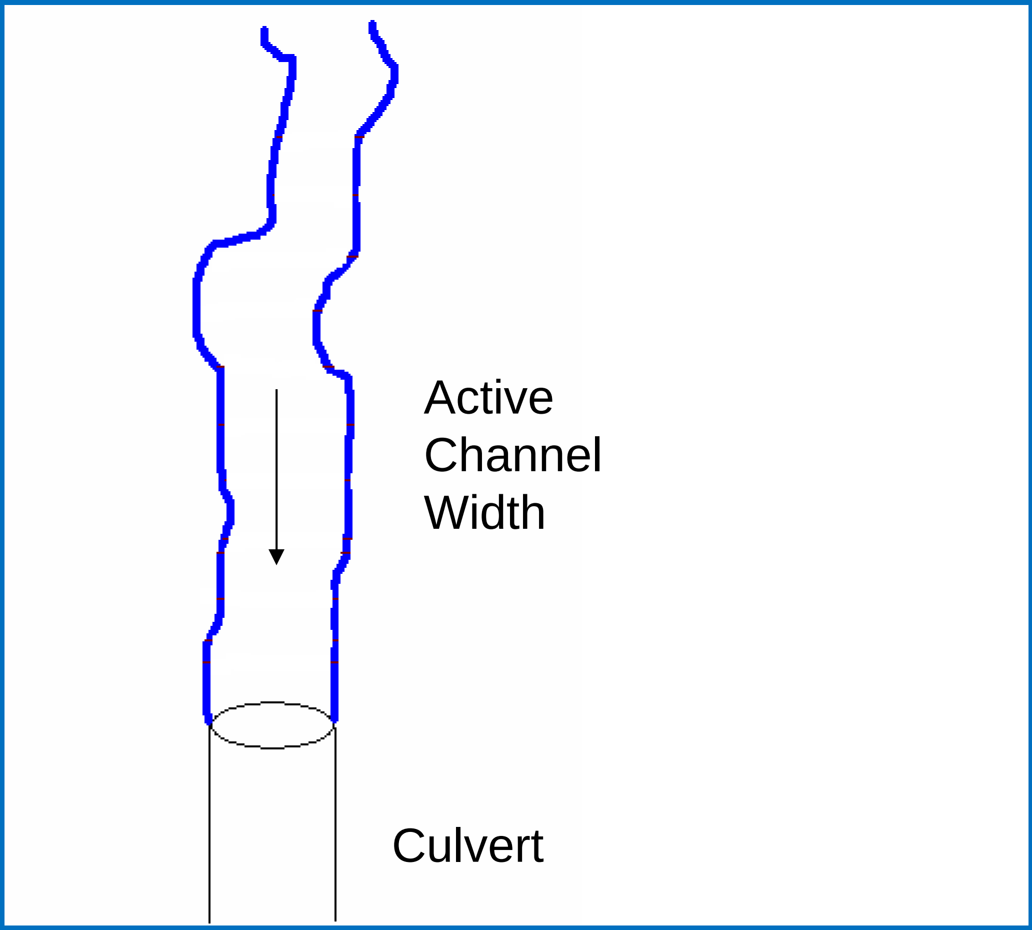
2. Utilize Culverts as Wide or Nearly as Wide as the Active Channel Width

Channel Width vs. Culvert Inlet Diameter

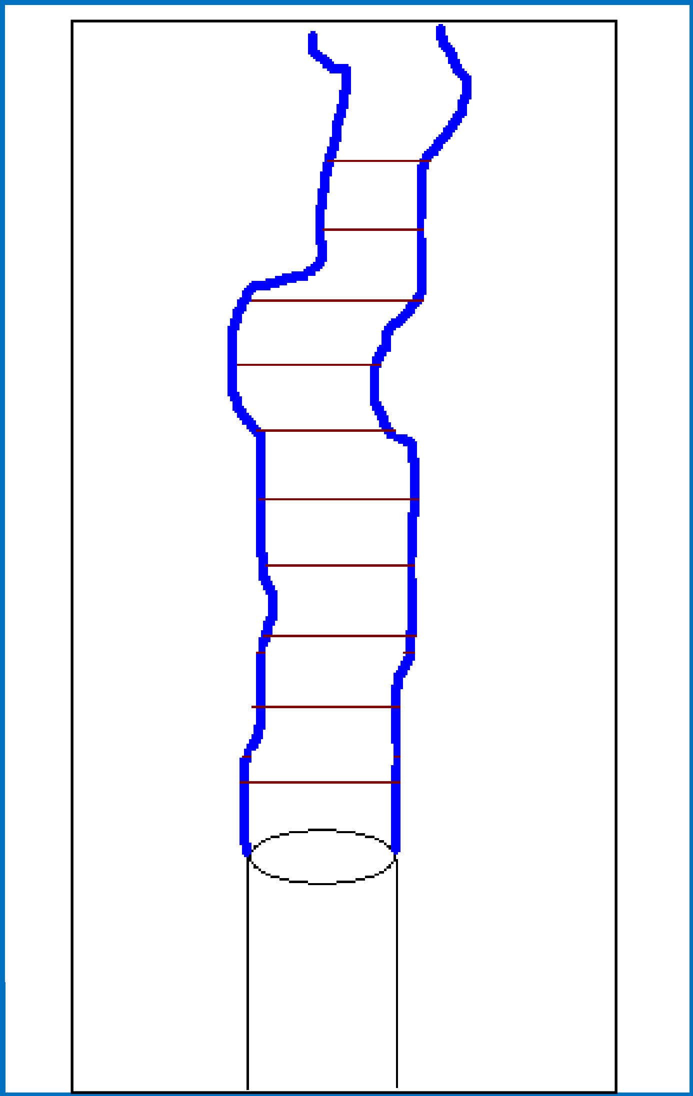


Small pipe in a wide channel = high risk of plugging by woody debris

Channel Width vs. Culvert Inlet Diameter



Determining Active Channel Width



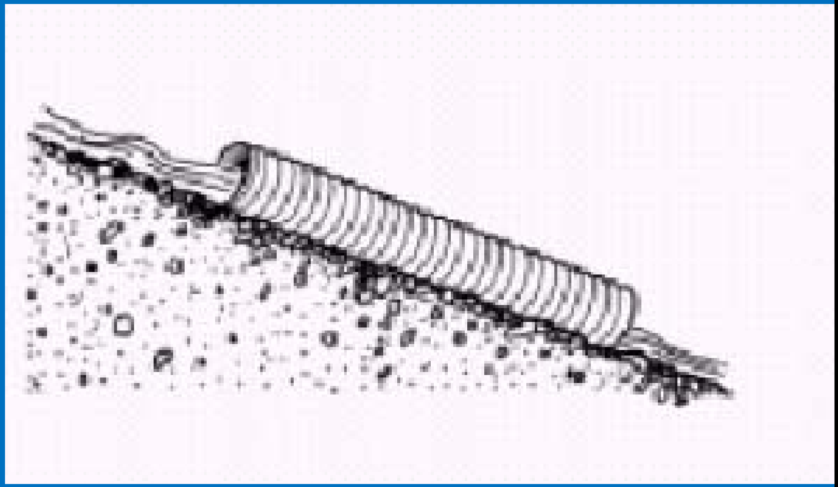
Make 10 systematic measurements of active channel width.

20 ft intervals, beginning 20 ft above the pipe inlet.

Calculate average width.

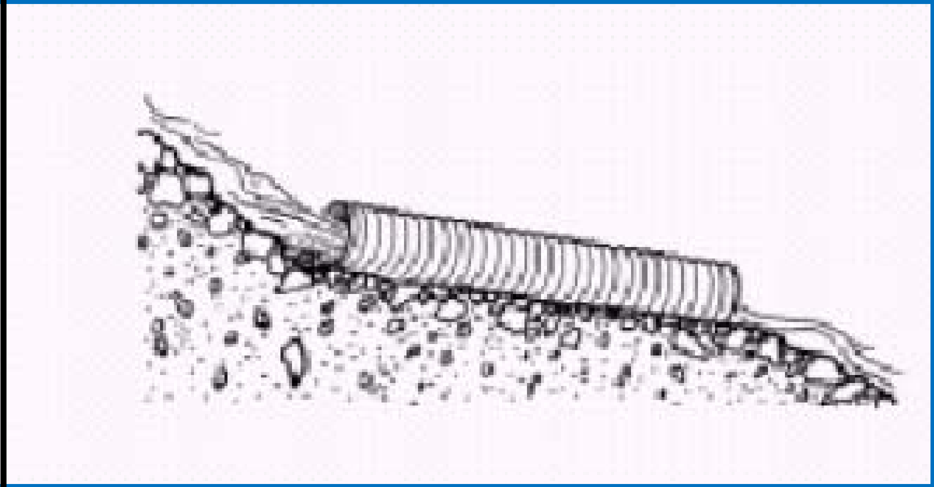
3. Culvert Should Maintain Channel Grade to Avoid Bedload Accumulation

(Furniss and Others 1998)



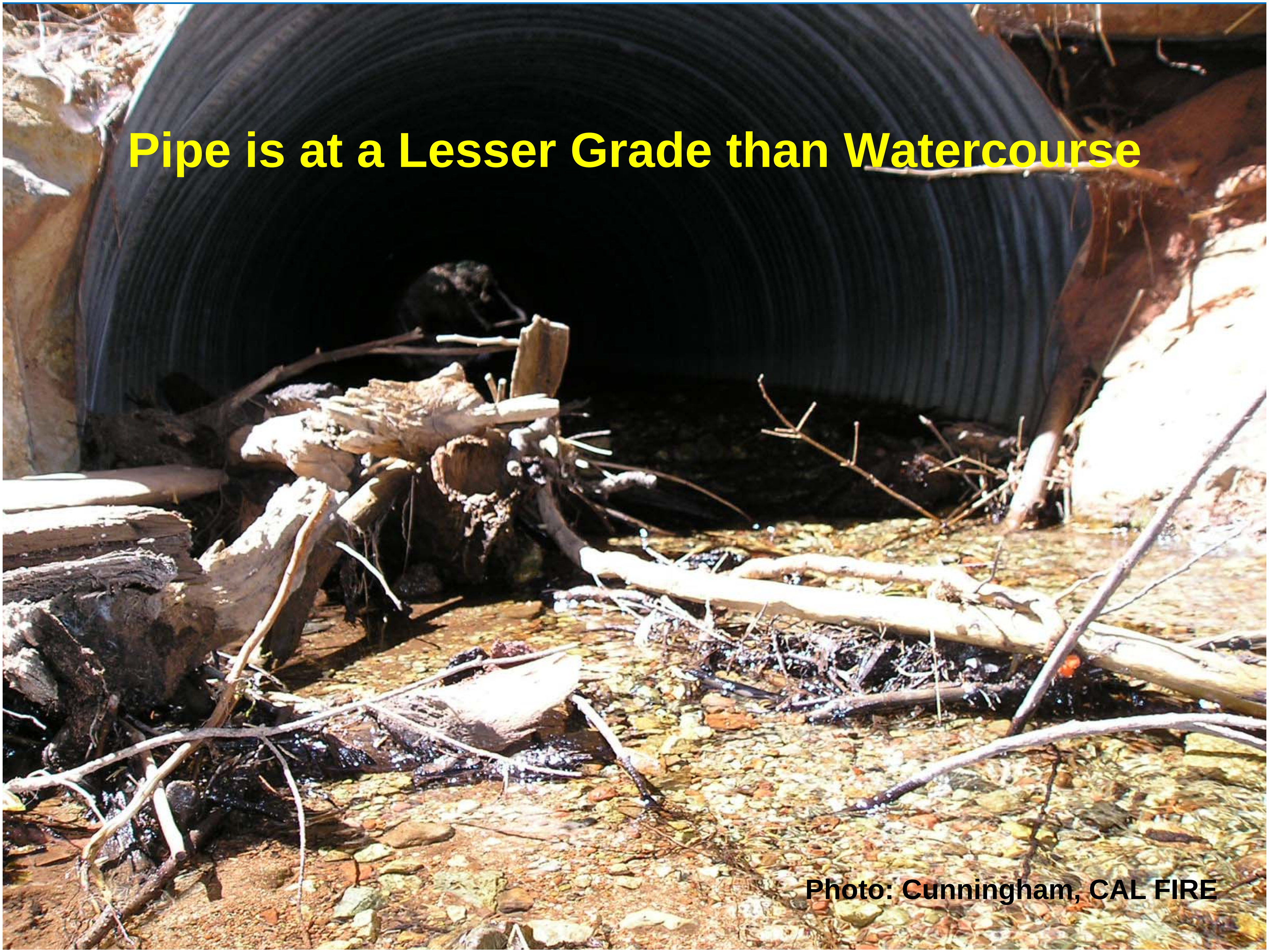
GOOD

Reduced Plugging Hazard

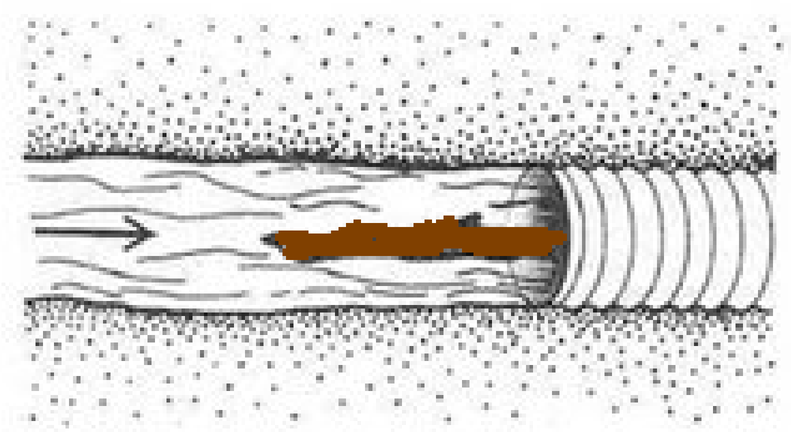


BAD

Pipe slopes of <3% may be prone to bedload sediment accumulation.


Pipe is at a Lesser Grade than Watercourse
Photo: Cunningham, CAL FIRE

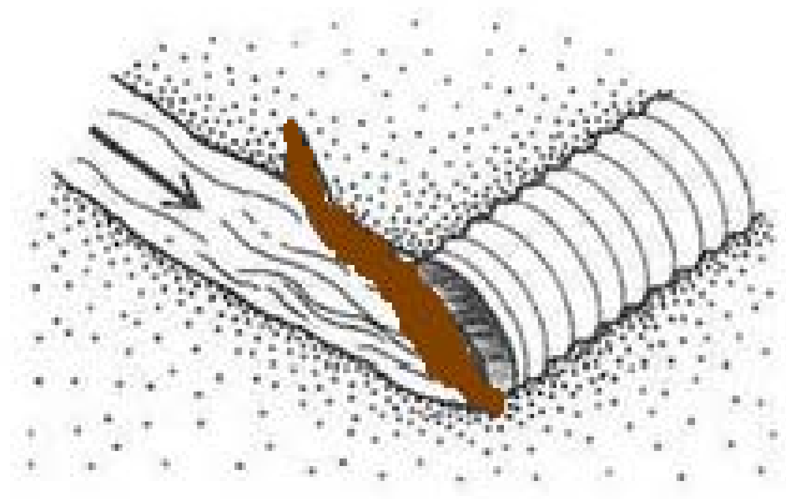
4. Culverts Should be Placed on the Same Alignment as Natural Stream Channel (Furniss and Others 1998)



GOOD

Reduced Plugging Hazard

BAD



Misaligned Crossing

After Construction

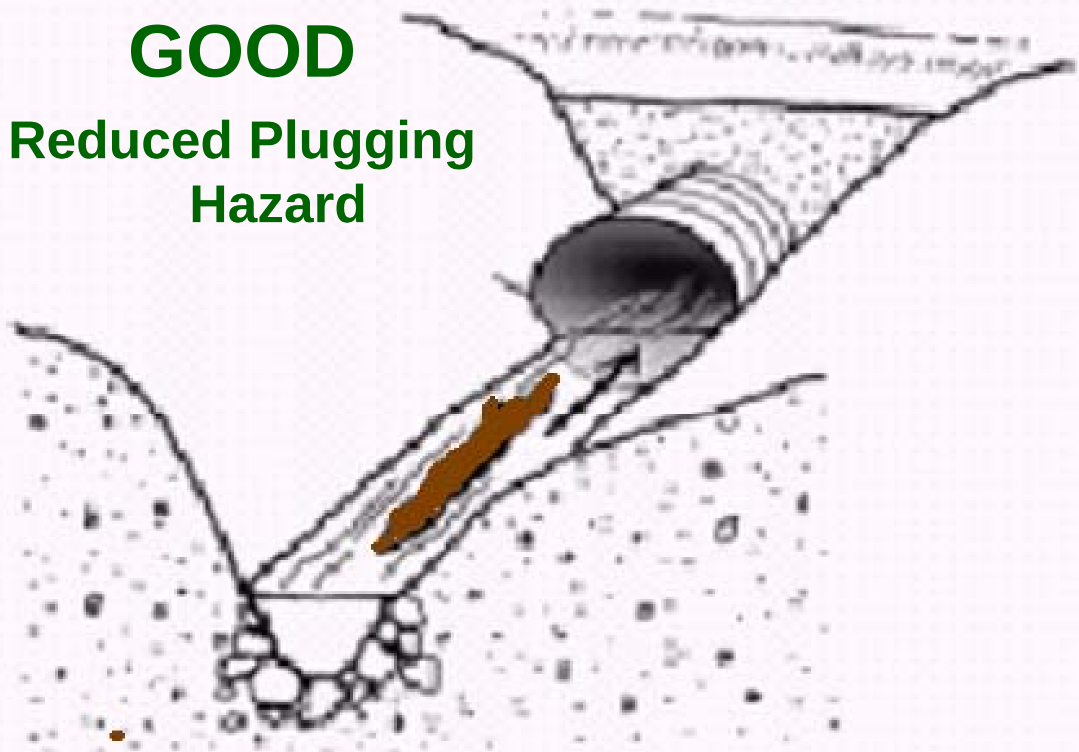
After One Winter

Misalignment can result in Road Fill/ Bank Erosion!

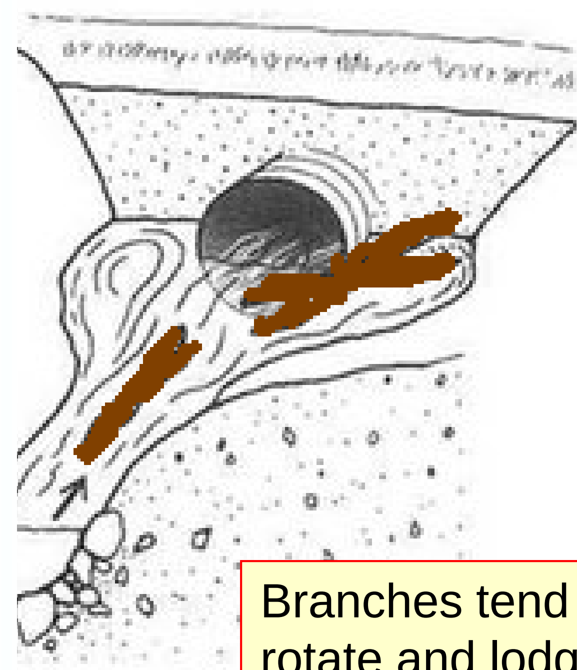
Photos: Harris, UCB (retired)

5. Culverts Should Not Create Wide Areas Near the Pipe Inlet

(Furniss and Others 1998)



BAD




Lassen National Forest

6. Single Large Pipe—Not Multiple Pipe Barrels

- **Installing multiple pipes is a bad strategy for passing woody debris.**

Use Single Large Pipe to Minimize Plugging Potential!

7. Critical Dip Installed to Prevent Diversion Potential—Required BOF Rule since 1990

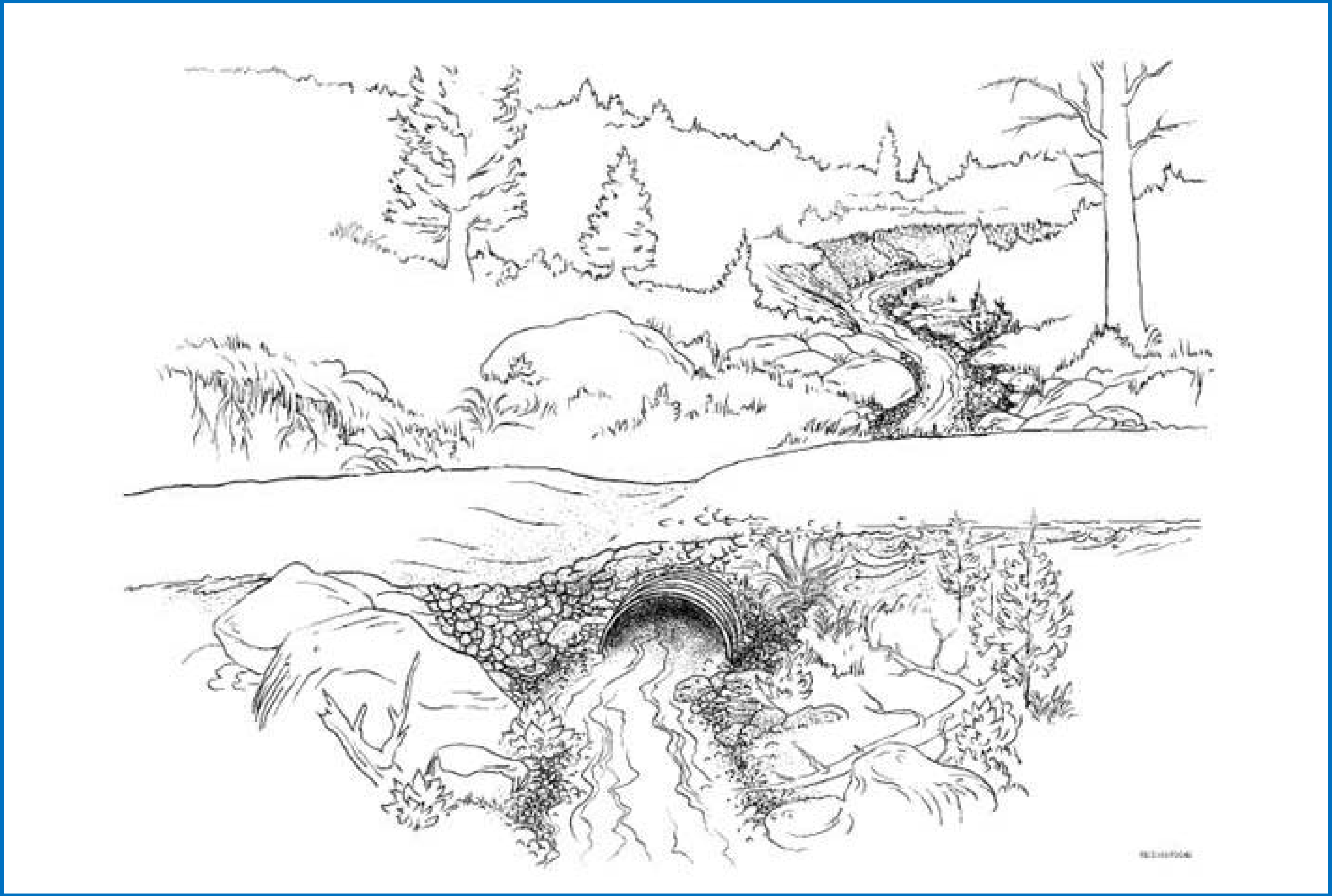


Image: Furniss et al. 1997

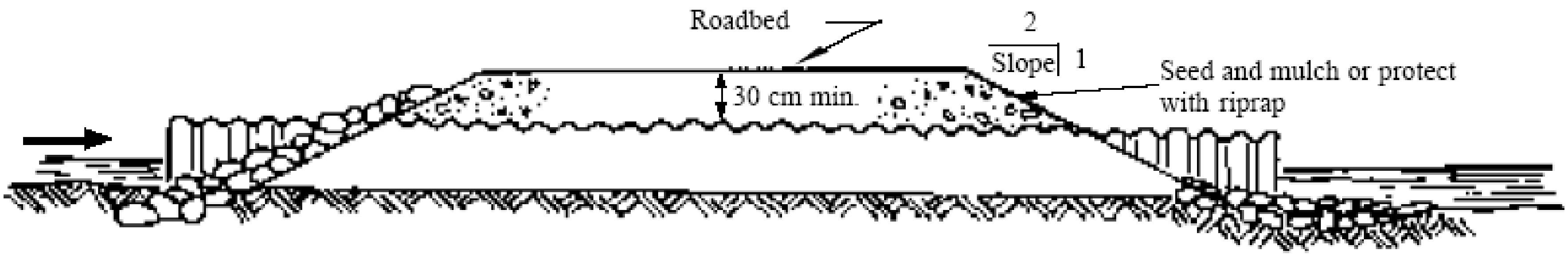
Goal: Keep water in its natural drainage!

8. Culvert Installation-- Depth of Fill Over Culvert

- Cover the top of metal pipes with fill to a depth of at least 12 inches to prevent pipe crushing by log trucks (or at least 1/3 of pipe diameter for larger pipes).
- Minimum cover of 24 inches for concrete pipes.

Typical Culvert Installation with a Projecting Inlet

(Keller and Sherar 2003)



- At least 12 inches of fill over pipe
- Rock armored inlet and outlet to prevent erosion of the fill

8. Culvert Installation (cont’d)

- Both ends should extend at least one foot beyond the edge of the fill material.
- Backfill material around the pipe should be moist, well-graded soil with up to 10% fines and free of rocks (avoid non-cohesive uniform fine sand).
- Backfill material should be well compacted (compacted in 6 inch lifts or layers).
- Both the culvert inlet and outlet should be armored with rock to protect against erosion.


6. 2. 2004


FSM
6. 2. 2004

48 inch Steel Culvert with Mitered Inlet, Rock Armoring

Lassen County


Napa County Culvert --
Rock Riprap Outlet to
Prevent Erosion
2007/05/23 12:31

8. Additional Techniques to Reduce Crossing Problems


Flared Metal End Section
Lassen National Forest
Photo: Derrig, USFS


Mitered Pipe Inlet
Tehama County
NOV 8 2004

Mitered Inlets

- A mitered culvert is formed when the culvert is cut to conform with the plane of the embankment slope.

- Beveled inlets reduce wood blockage and plugging.

- Bevel the inlet edge to increase flow efficiency and reduce pipe size by <10%.

- "Mitered ends are much less likely to be plugged by ice, debris, or beaver" (*Wisconsin Transportation Bulletin).*


Simple Fence Post
Trash Rack
Santa Cruz County
APR 27 200


Caltrans Welded Metal
Trash Rack for 12 ft CMP,
Highway 299 Trinity
County
Photo: Wopat, CGS

Costs of Additional Techniques

- Simple Trash Rack (Fence Posts)
  - <$50 (but requires abundant maintenance!)
- Bevel (Mitered) End Section
  - ~$50 - $100
- Flared Metal End Section
  - 36 inch pipe -- ~$500
  - 48 inch pipe -- ~$1,100
  - 60 inch pipe -- ~$2,000

VI. Summary (Take Home Messages)

- Stream crossings are high risk locations for sediment entry and road travel limitations (20% have problems).
- In the Sierra Nevada, most large floods are the result of rain-on-snow events (big—once ~ every 10 yrs).
- Crossings need to be built correctly for large flood flows (100-yr return interval), as well as sediment and wood passage.
- Numerous types of crossings are available (no one “right answer”)—pick the type that fits the features of the landscape, the maintenance that will be possible, and the legal requirements (e.g., fish passage).

VI. Summary (Take Home Messages)

- Numerous problems can occur at all types of crossings, indicating that frequent monitoring observations are needed, with upgrading performed as required.
- Simple guidelines are available for culverted crossings to ensure that new or reconstructed crossings have reduced risk of failure and WQ impact.
- Crossings must be maintained over time—you cannot install them and expect them to function properly without proper upkeep—clean/maintain on a regular basis and during/after large storm events.

VII. Stream Crossing References

- Cafferata and others 2004 -- Designing Watercourse Crossings for Passage of 100-year Flood Flows, Wood, and Sediment
- Clarkin and others 2006 -- Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations
- Flanagan 2004 – Woody Debris transport Through Low-Order Stream Channels of northwest California—Implications for Road-Stream Crossing Failure
- Flanagan and others 1998 -- Methods for Inventory and Environmental Risk Assessment of Road Drainage Crossings
- Flanagan and Furniss 1997 -- Field Indicators of Inlet Controlled Road Stream Crossing Capacity
- Furniss and others 1998 -- Response of Road Stream Crossings to Large Flood Events in Washington, Oregon, and Northern California
- Furniss et al. 1997– Diversion Potential at Road-Stream Crossings
- Keller and Sherar 2003, Chapter 8 -- Culvert Use, Installation, and Sizing
- Merrill and Casaday 2001—BMPs for Culvert Replacement
- Weaver and Hagans 1994—Forest and Ranch Roads (Chapter V-Drainage, VI-Construction)
- ODF 2002 -- Determining the 50-year Peak Flow and Stream Crossing Structure Size for New and Replacement Crossings