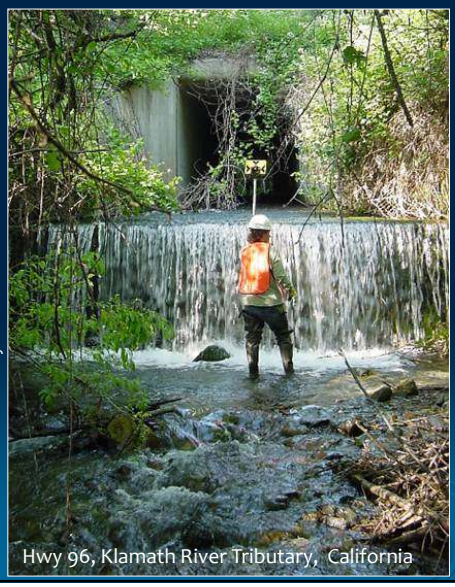
Assessing Geomorphic Risk for Stream Crossing Projects

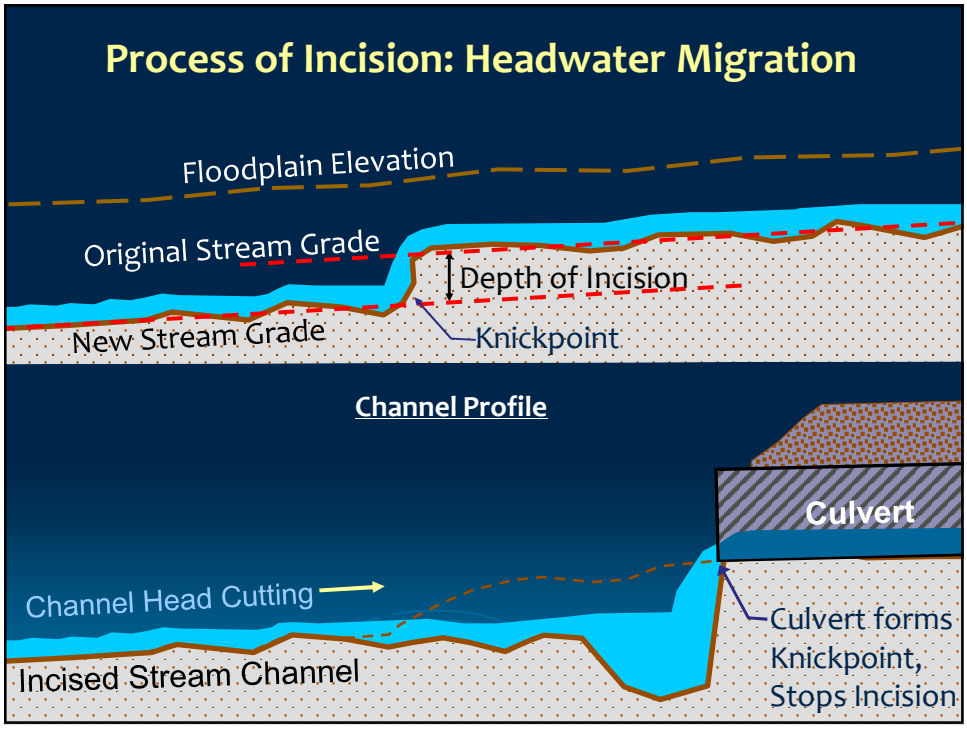


Hwy 96, Klamath River Tributary, California

Michael Love P.E.
Arcata, California
mlove@h2odesigns.com

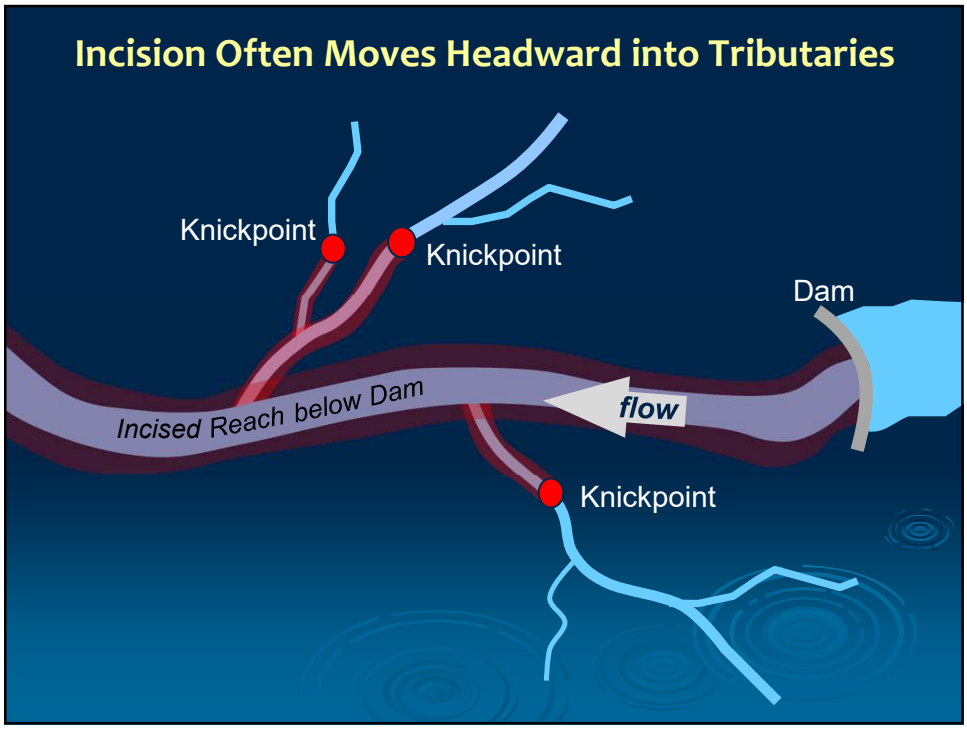
Michael Love & Associates
Hydrologic Solutions


Photos: Ross Taylor


Process of Incision: Headwater Migration
Floodplain Elevation
Original Stream Grade
Depth of Incision
New Stream Grade
Knickpoint
Channel Profile
Culvert
Channel Head Cutting
Culvert forms Knickpoint, Stops Incision
Incised Stream Channel

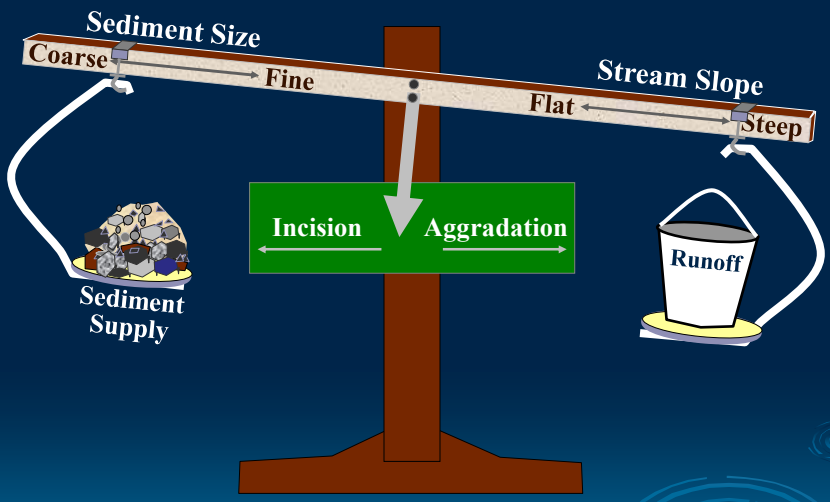
Channel Incision is a Natural Process, but…

We Initiate of the Incision More often then Not


Incision Often Moves Headward into Tributaries
Knickpoint
Knickpoint
Dam
Incised Reach below Dam
flow
Knickpoint


Knickpoints that Stop Incision but Create Fish Barriers
Harrison Grade Creek, Calif.
Perched Culverts
Alameda Creek, Calif.
Photo: Jon Stead
Armored Utility Crossings
Napa River, Calif.
Perched Bridge Aprons
San Pedro Creek, Calif.
Perched Fishway Entrances
8

Dynamic Equilibrium and Causes of Incision



The Lane Relationship (from Lane, 1955)

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Causes of Channel Incision

- ✓ Decrease in sediment supply (dams, gravel extraction, urbanization)
- ✓ Channel encroachment (Increase depth of flow, bed & bank shear)
- ✓ Channelization (shortening/steepening the channel)
- ✓ Increase in runoff (urbanization, agriculture, road density)
- ✓ Loss of wood in streams (removal of large wood, beaver dams)
- ✓ Climate change/extreme weather

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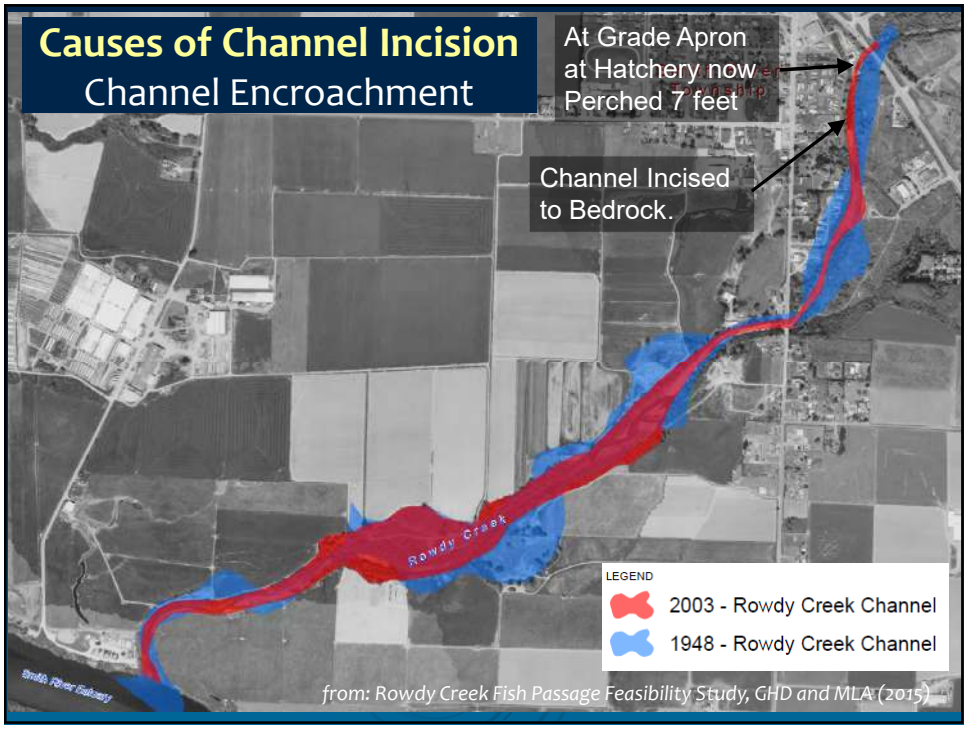
Causes of Channel Incision

Dams and Debris Basins

Causes of Channel Incision

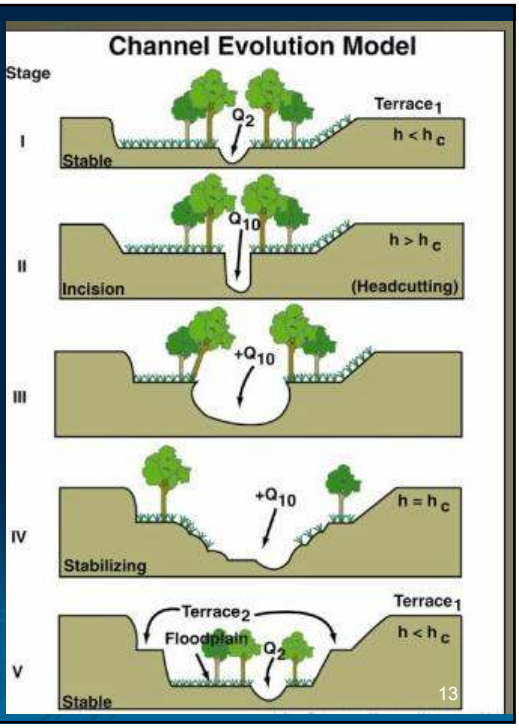
Channel Encroachment



Channel Evolution Model (CEM)

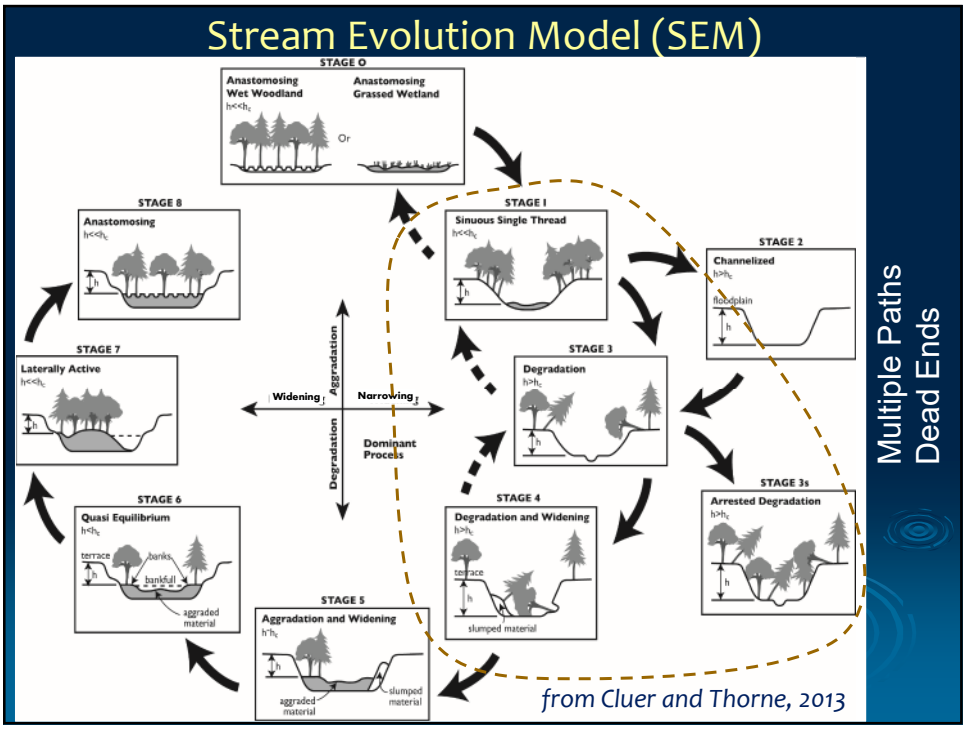
Stage II Incision

from Schumm, Harvey, and Watson. 1984.

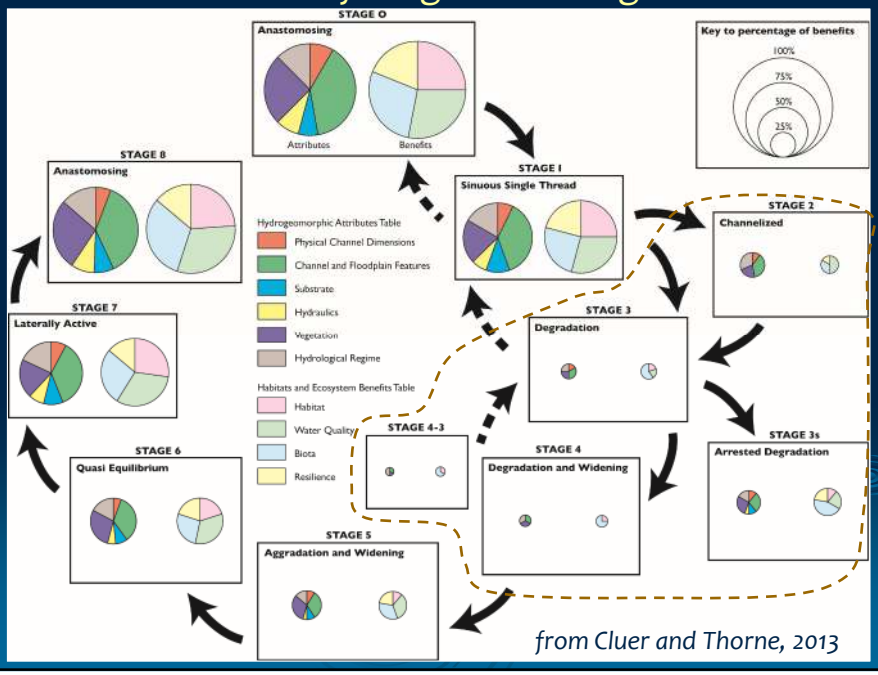


Incising Channel, Toby Tubby Creek Watershed, Mississippi

Stream Evolution Model (SEM)



Stream Evolutionary Stage vs. Ecological Benefits

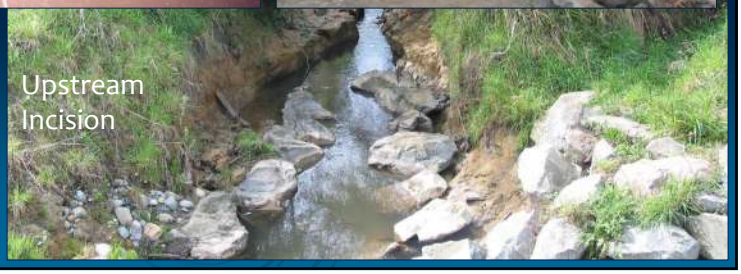


The Stream Channel Incision Syndrome
Loss of Habitat and Ecosystem Benefits

"We conclude channel incision presents a syndrome that is characterized by perturbed hydrology, degraded physical habitat, elevated nonpoint source pollution, and depleted fish species richness and that is extremely deleterious to instream ecosystem services."

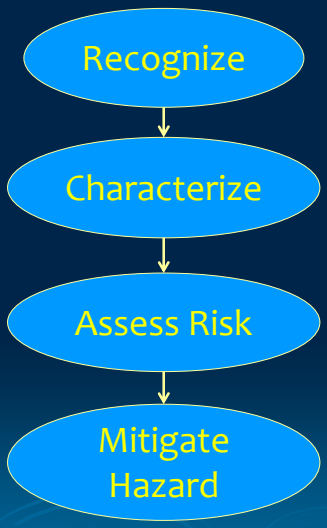
Shields et al. 2010. *The stream channel incision syndrome and water quality.* Journal of Ecological Engineering

Allowing Incision to Migrate Upstream without Considering Risk



Jordan Creek at Parkway Drive

Incorporating Incision Risk Assessments into Passage Projects



Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

Step 1 - Recognition: Incision or Local Scour?

photo: Kozmo Bates

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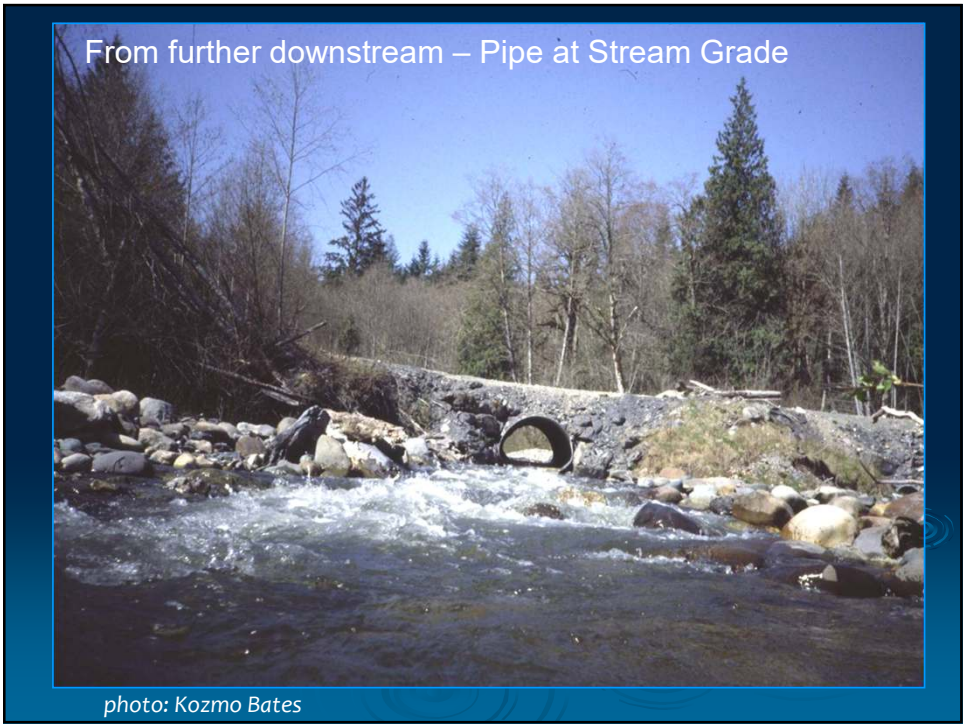
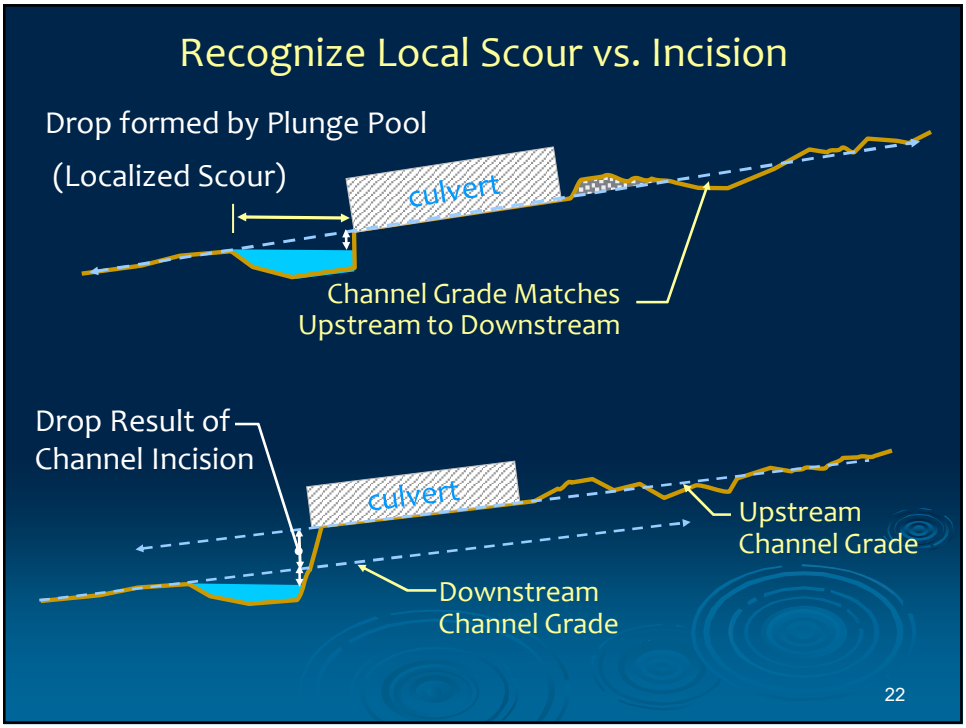
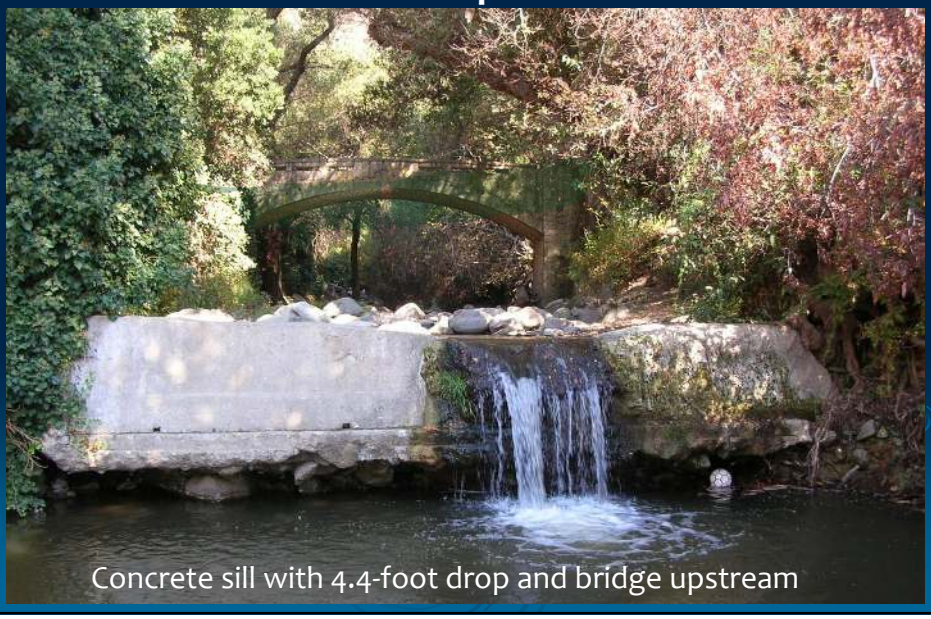

From further downstream – Pipe at Stream Grade
photo: Kozmo Bates

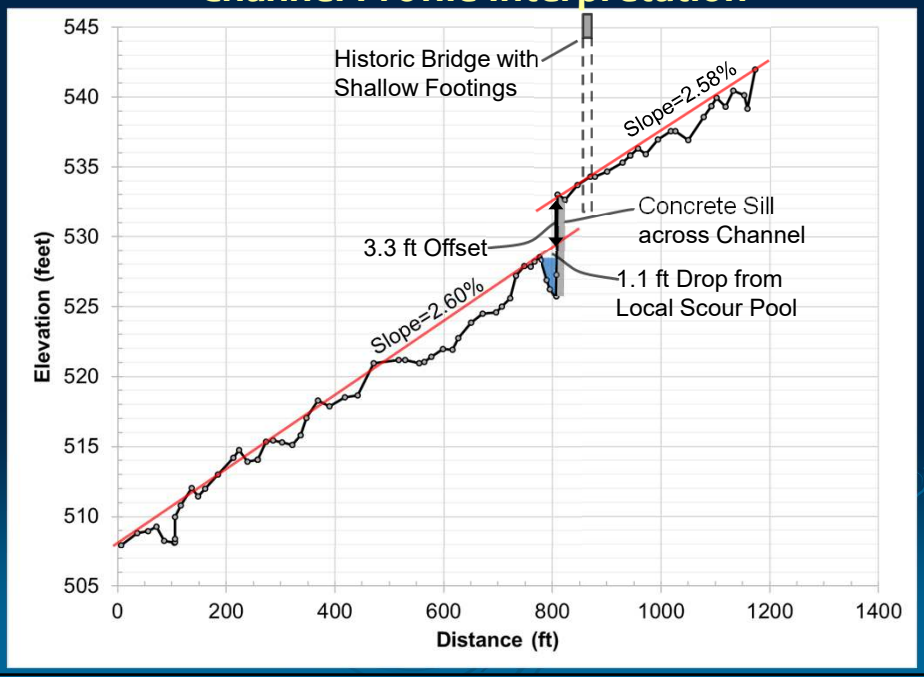

Recognize Local Scour vs. Incision
Drop formed by Plunge Pool
(Localized Scour)
culvert
Channel Grade Matches
Upstream to Downstream
Drop Result of
Channel Incision
culvert
Upstream
Channel Grade
Downstream
Channel Grade
22

Channel Profile Interpretation
Incision Knickpoint or Not?



Concrete sill with 4.4-foot drop and bridge upstream

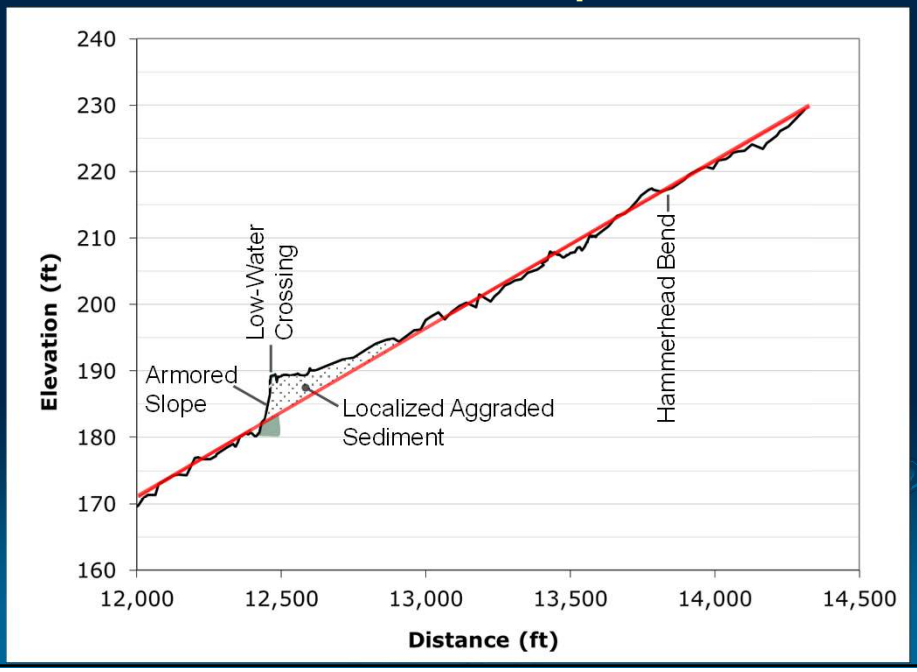
Channel Profile Interpretation



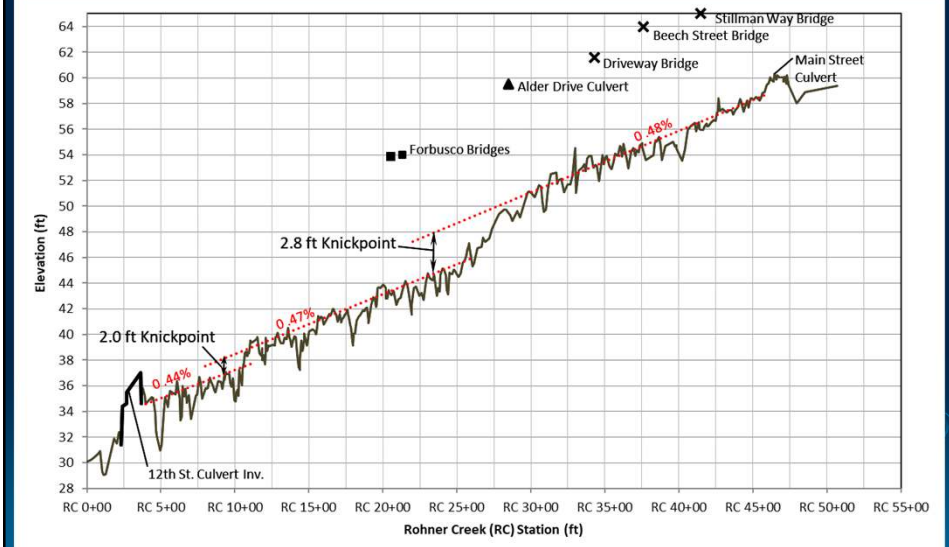
Channel Profile Interpretation
Incision Knickpoint or Not?

Vented low-water crossing (ford) with 8.7 feet of drop.

Channel Profile Interpretation

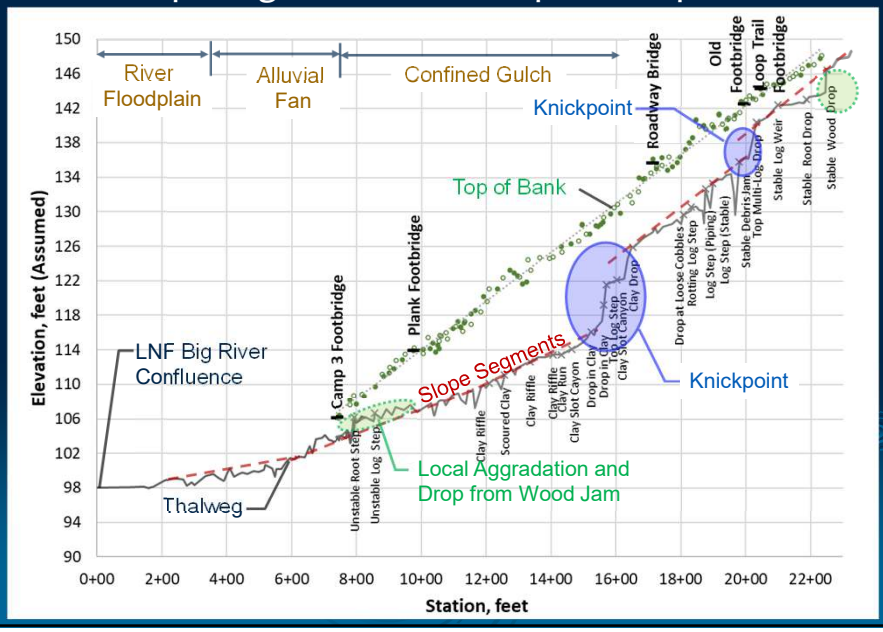


Channel Profile Interpretation



Channel Profile Interpretation

Slope Segments and Multiple Knickpoints



Other Channel Incision Indicators

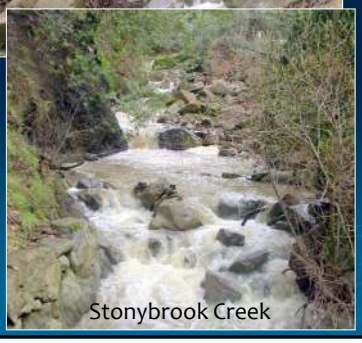
- **Toe of Bank is Vertical**
  Exposed roots, lack of sediment layering at streambed-banks interface
- **Actively Widening (Stage III)**
  Active bank failures, low depositional bars
- **Cultural Features Exposed**
  Perched culverts or exposed bridge footings, aprons, and pipelines
- **Lack of Sediment Deposition**
  Erosion of channel bed down to bedrock or other resistant soil layers
- **Lack of Pools**
  Long reaches of riffles/runs without pools

List adapted from J. Castro, 2003

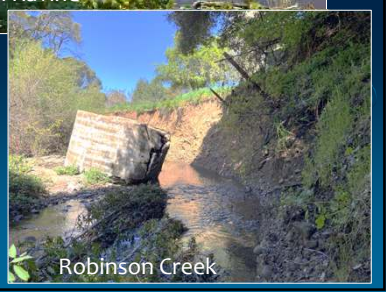
Risk Assessment - Rate of Headward Incision

More mobile the bed material, more rapid the channel regrades.

Boulder Channel

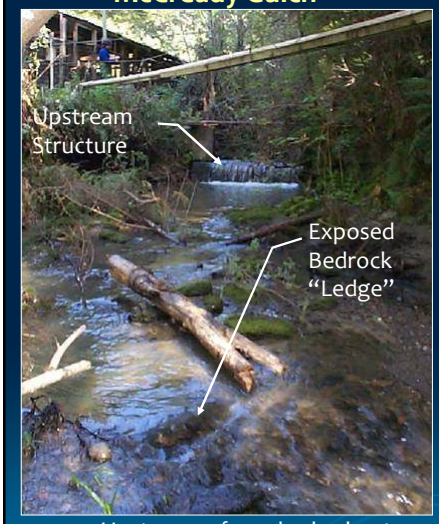


Fine Grain Bed and Banks



Risk Assessment - Extend of Regrade

McCready Gulch



Upstream of perched culvert, prior to removal

Morrison Gulch

Channel upstream of culvert replacement and regrade

Risk Assessment for Removing Knickpoints in Incised Channels

- Anticipated magnitude and extent
  Depth of incision and length of channel at risk
- Risk to upstream property and infrastructure
- Impact to existing riparian/wetland vegetation
  Will water table lower with incision and rootzone become dry?
- Change in connectivity to side-channels and floodplain
- Rate of incision, bank widening, and sediment release
  Mobility of bed, erosivity if banks, wood controls, bedrock
- Ability of channel to recover
  Will bank material and land-use permit channel evolution (widening)?

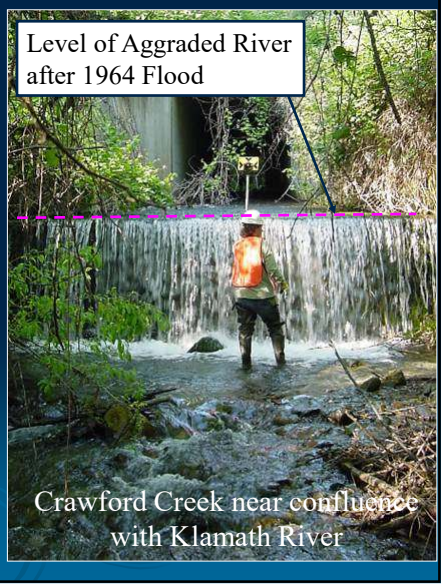
Channel Aggradation

Increased sediment loads combined with large flood can cause entire streams and rivers to aggrade.

Channel Aggradation and Culverts

Culvert replacements after flood events have added complexity and risk:

- Anticipating future regrade.
- Determining vertical placement of culvert invert or arch-footings.
- Providing enough flood capacity in aggraded state.



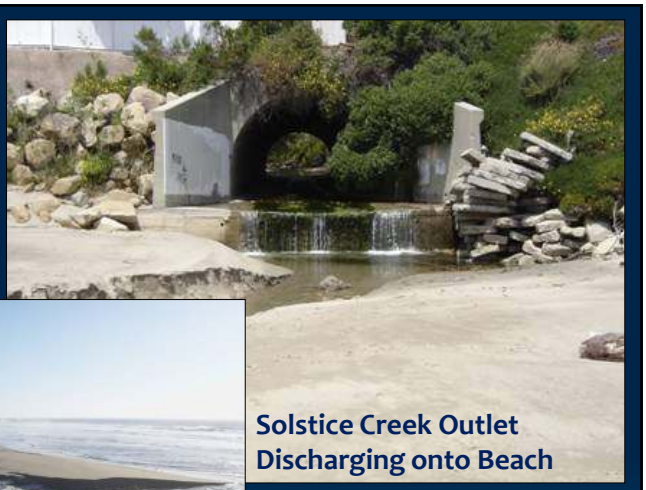
Crawford Creek near confluence with Klamath River

Backwater Influences

Sultan Creek Bridge
Influenced by Debris Jamming from High Flow Backwatering by Smith River – inadequate capacity

Little Mill Creek Bridge
Depositional Bar from River Backwatering – adequate capacity

Fluctuating Levels of Beaches and Coastal Lagoons



Solstice Creek Outlet Discharging onto Beach

Arroyo Hondo Lagoon Breaching