Channel Morphology - Stream Crossing Interactions

An Overview

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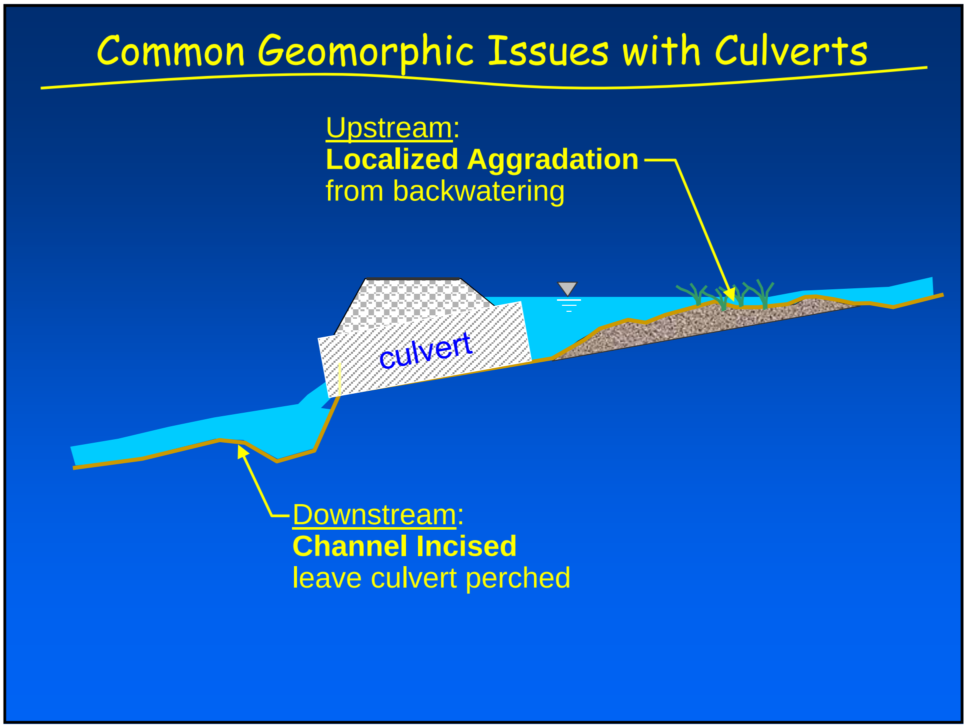
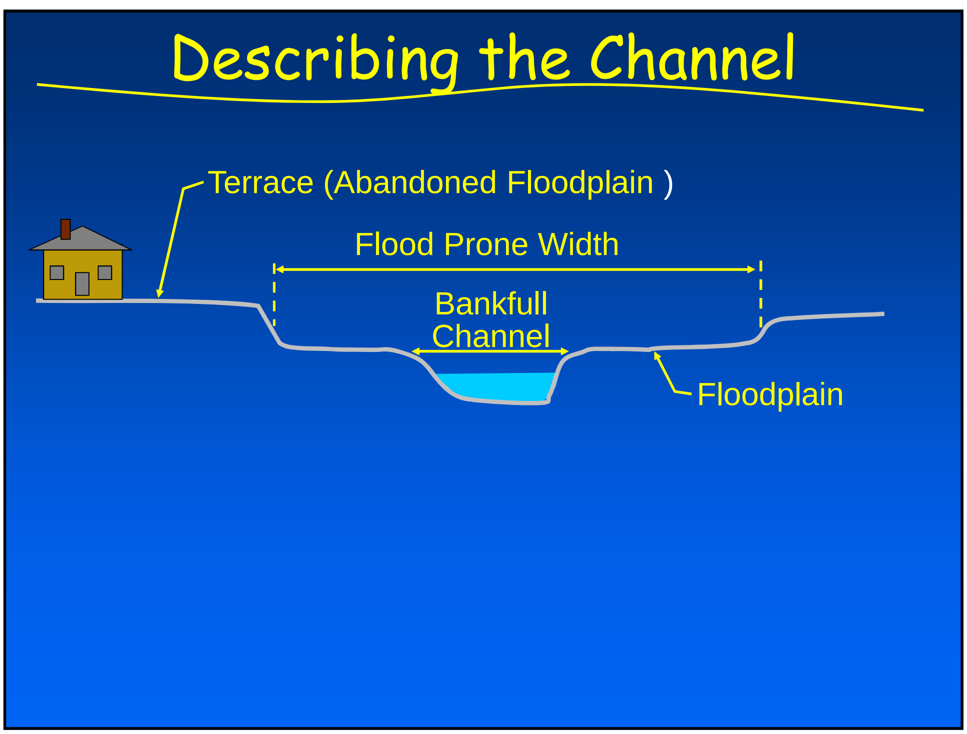
Why Geomorphology for Fish Passage

1. Understand the Scale of the Barrier
(local or related to watershed scale changes)
2. Base Design on Channel Morphology
3. Anticipate Channel Response to Project
4. Conduct Geomorphic Risk Assessments


Common Geomorphic Issues with Culverts
Upstream:
Localized Aggradation
from backwatering
culvert
Downstream:
Channel Incised
leave culvert perched


Describing the Channel
Terrace (Abandoned Floodplain)
Flood Prone Width
Bankfull
Channel
Floodplain

Definitions

Bankfull Discharge - For streams with adjustable banks, flow associated with water surface at edge of lowest depositional bank.

Average return period of 1.2 – 1.7 years (regional).

Video Guide to Field Identification of Bankfull Stage in Western US

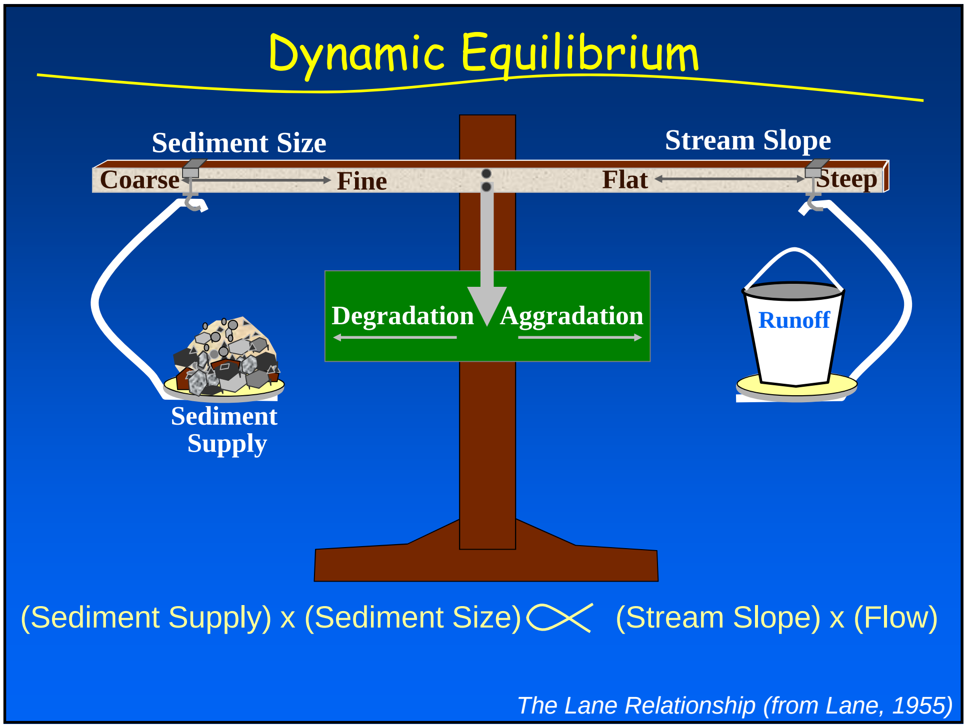
http://www.stream.fs.fed.us/publications/bankfull_west.html

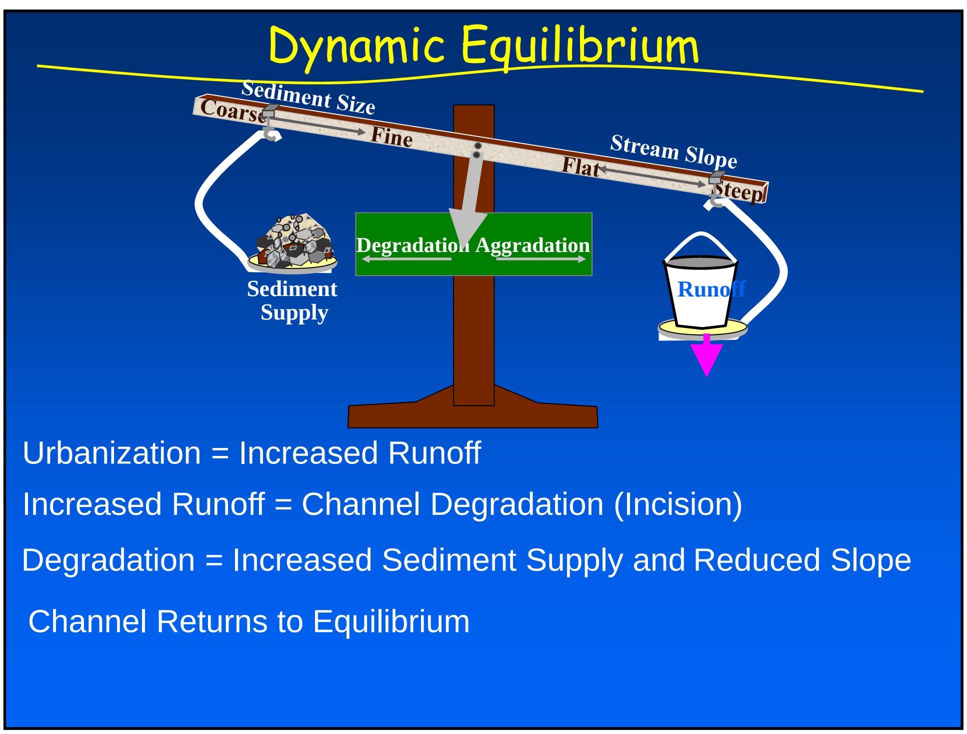
Active Channel - Line on the shore established by the annual fluctuations of water.

Physical Characteristics:

- Scour line along bank
- Destruction of terrestrial vegetation.

Channel Indicators


Dynamic Equilibrium
Sediment Size
Coarse
Fine
Stream Slope
Flat
Steep
Degradation
Aggradation
Runoff
Sediment Supply
(Sediment Supply) x (Sediment Size) ∝ (Stream Slope) x (Flow)
The Lane Relationship (from Lane, 1955)


Dynamic Equilibrium
Sediment Size
Coarse
Fine
Stream Slope
Flat
Steep
Degradation
Aggradation
Runoff
Sediment Supply
Urbanization = Increased Runoff
Increased Runoff = Channel Degradation (Incision)
Degradation = Increased Sediment Supply and Reduced Slope
Channel Returns to Equilibrium

Channel Incision

Channel Incision – Lowering of the channel bed (a.k.a. degradation or downcutting).

Causes of Channel Incision:

- Channelization
  - Shortens channel length (increasing slope)
  - Reduces overbank storage, increasing peak flows.
  - Increases stream power (velocities and bed scour).

Example of Channelization

Little Browns Creek, Trinity County, CA

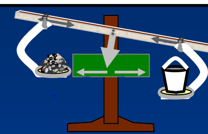
Original Disturbance:

- Channel moved during historical placer mining
- Downstream channel straightened for 5,000 feet for Highway 3

Result:

- Channel downstream of County culvert incised 9 feet.
- Unstable channel banks, numerous bank failures, continuing incising of channel bed, loss of riparian trees.

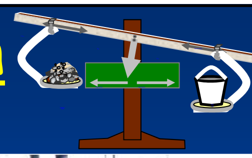
Channel Incision



Causes of Channel Incision (cont.):

- Deceased Sediment Supply
  - Gravel Mining
  - Dams

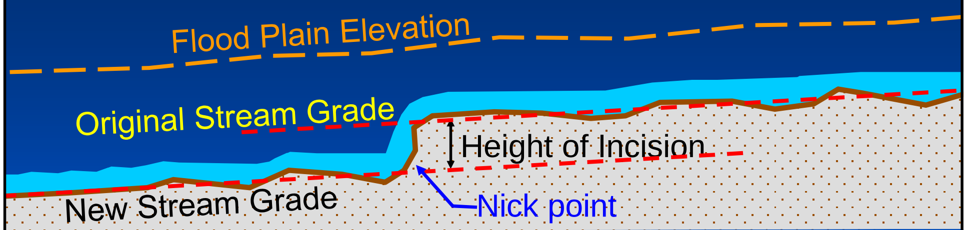
Channel Incision



Causes of Channel Incision (cont.):

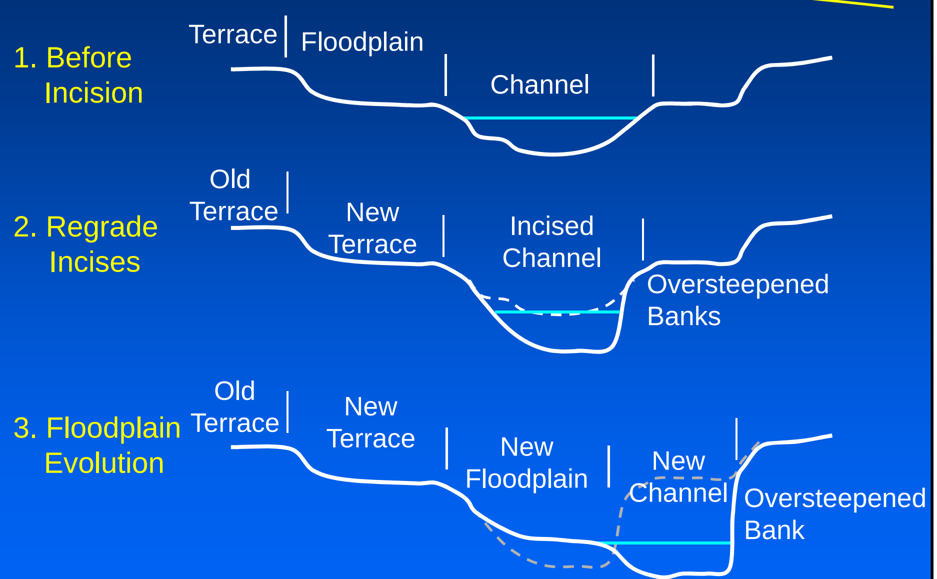
- “Steam Cleaning” – Removal of Large Wood which controls the channel grade
- Increase in Peak Flows through changes in landscape
  - Urbanization
  - Wildfire
  - Grazing
  - Timber Harvesting

Head Cutting and Channel Incision



Headward retreat of a Nick Point, an interruption in a stream's longitudinal profile.

Evolution of Channel Regrade



Channelization - Case Example

Carmen Valley Watershed – Plumas NF

A head-cut has formed as the channel regrades, causing the bed to lower as it moves upstream

Channelization - Case Example

Carmen Valley Watershed – Plumas NF

Incised channel beginning to develop a new lower floodplain. The former wetland has dried with the lowering of the water table.

Impacts of Channel Incision

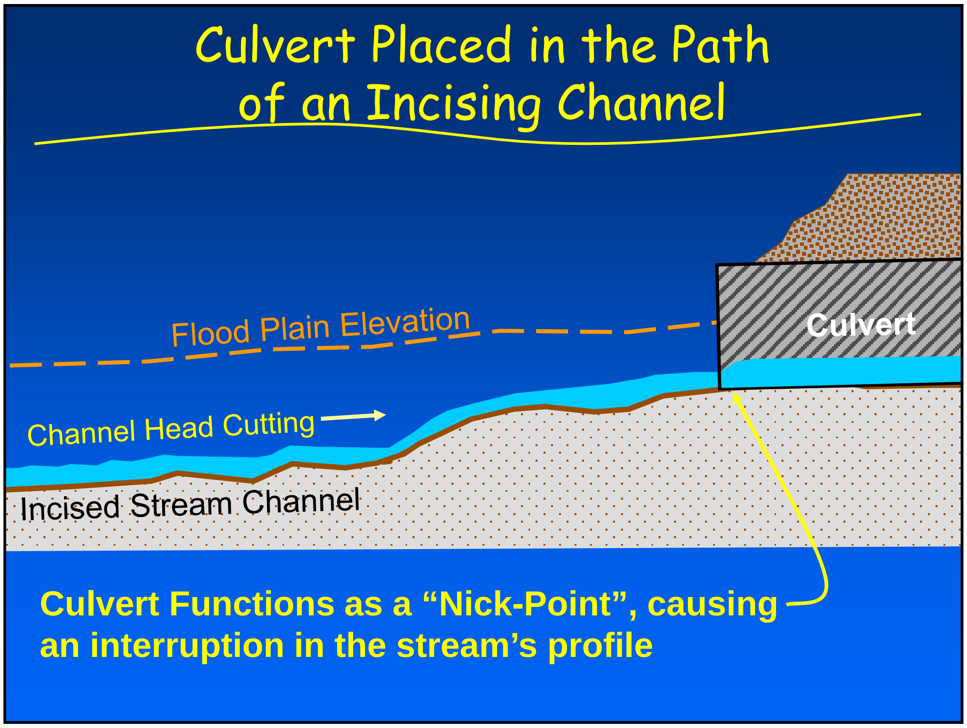
Degradation places a stream in great danger of dramatic change.

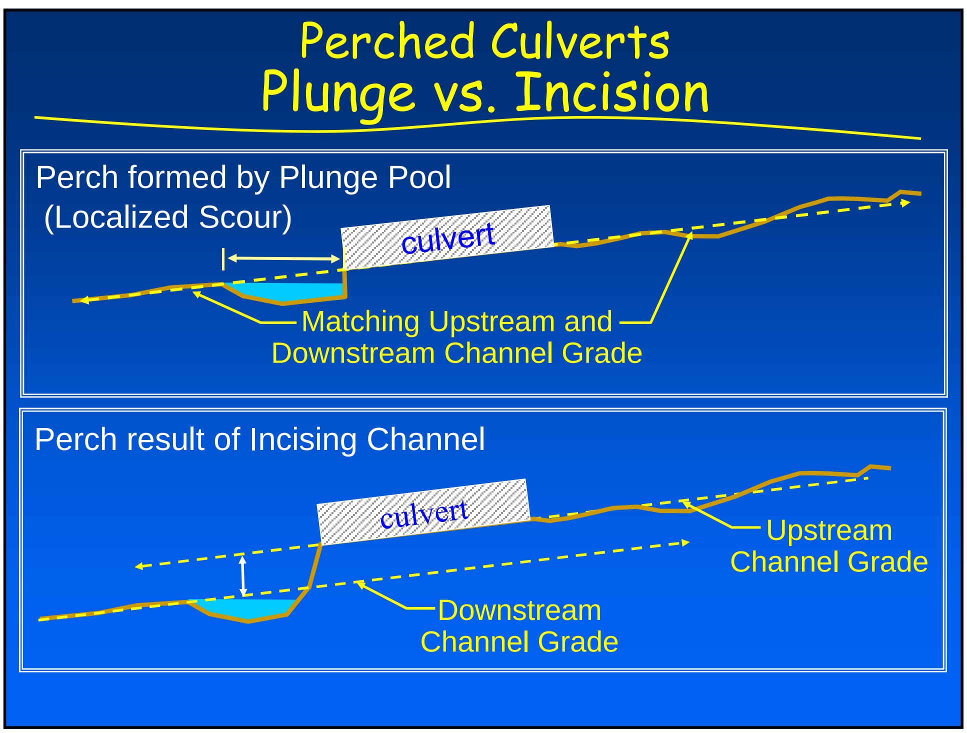
- Disconnection with flood plain.
- Lowered water table and loss of riparian vegetation.
- Oversteepened banks and bank failures.
- Large episodic and chronic releases of fine grain sediment.

Impacts of Channel Incision

- Degradation of fish habitat:
  - Redds highly susceptible to scour.
  - No escape from high velocities
  - Loss of pool habitat
  - Increased turbidity and sedimentation
  - Lower summer base flows, causing dry-up prematurely.
  - **Knickpoints (fish barriers)**

Incised channel upstream of culvert replacement


Culvert Placed in the Path
of an Incising Channel
Flood Plain Elevation
Culvert
Channel Head Cutting
Incised Stream Channel
Culvert Functions as a "Nick-Point", causing
an interruption in the stream's profile


Perched Culverts
Plunge vs. Incision
Perch formed by Plunge Pool
(Localized Scour)
culvert
Matching Upstream and
Downstream Channel Grade
Perch result of Incising Channel
culvert
Upstream
Channel Grade
Downstream
Channel Grade

Other Channel Degradation Indicators

- **Visible Nick Point or Head Cut**
- **Lack of Sediment Deposition** – Erosion of channel bed down to bedrock or other resistant soil layers.
- **Toe of Bank is Vertical** – lack of sediment layering at streambed-banks interface, exposed roots
- **Lack of Pools** – Long reaches of riffle or run with no pools
- **Cultural Features Exposed** – Perched culverts or exposed bridge footings, aprons, and pipelines

(List adapted from J. Castro, 2003)

Extent of Natural Regrade

McCready Gulch

Upstream of perched culvert, prior to removal

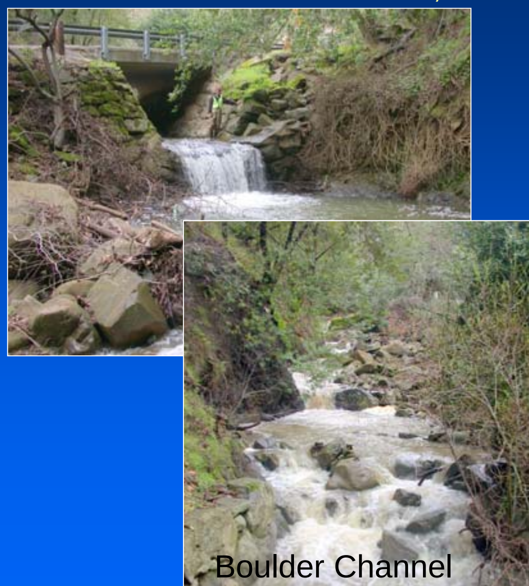
Morrison Gulch

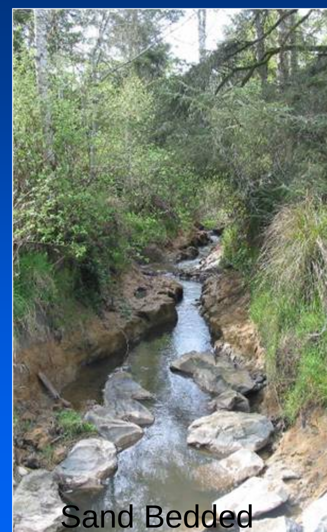
Channel upstream of culvert replaced and regrade

Box Culvert Outlet Perched 2 feet

Rate of Natural Regrade

More mobile the bed material, more rapid the channel regrades





Considerations for Culvert Replacements Downstream Channel has Incised

- **Grade Control at Project Site**
  - Log or Boulder Weirs
  - Roughened Channels
  - Fishways, Baffles
- **Uncontrolled Regrade (no grade control)**
  - Let it Rip!
- **Restoration of Downstream Channel Profile**
  - Raise channel bed and reconnect/construct floodplain
  - Reestablish grade controlling features
  - Stabilize streambanks
  - Reestablish riparian vegetation

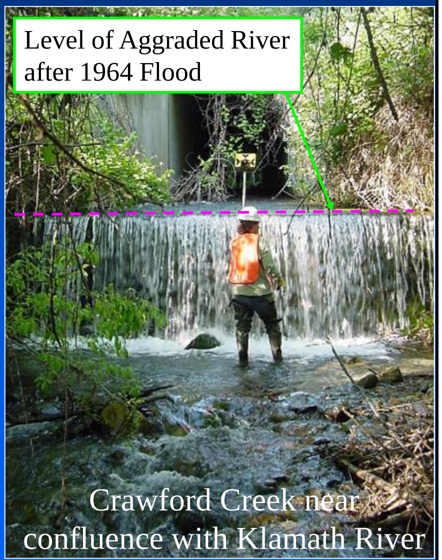
Channel Aggradation

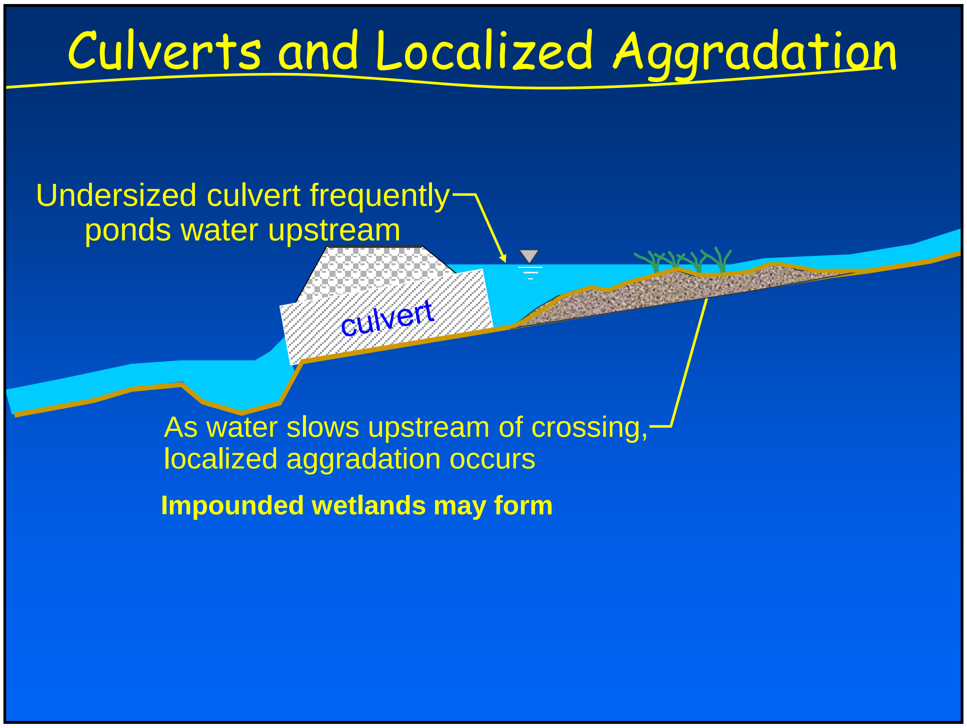
Increased sediment loads combined with large flood can cause entire streams and rivers to aggrade.

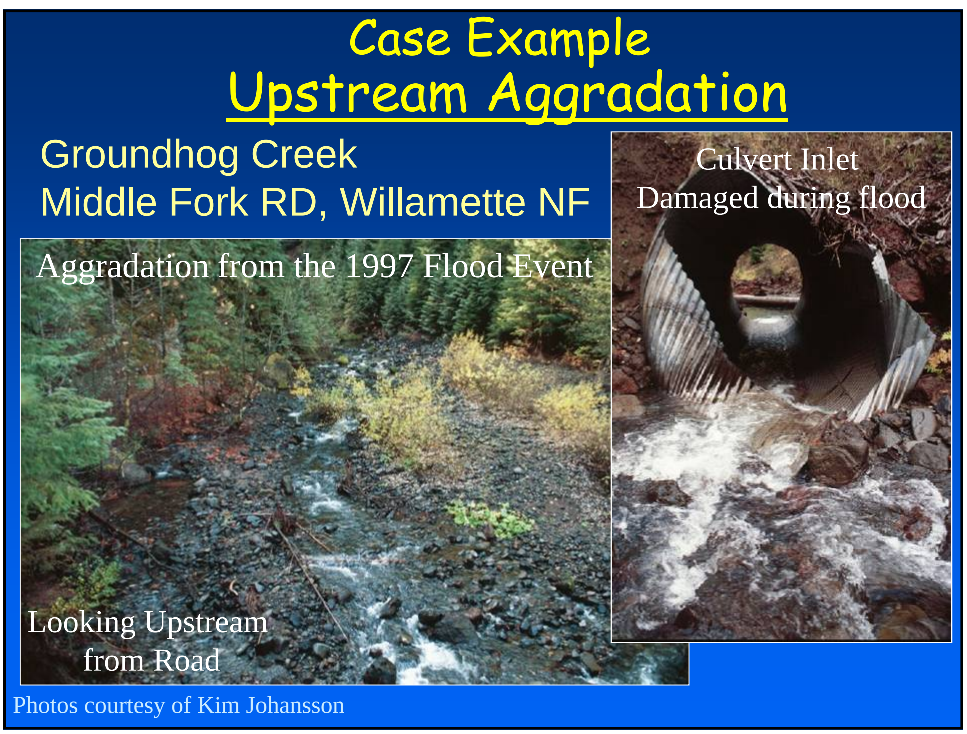
Channel Aggradation and Culverts

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.

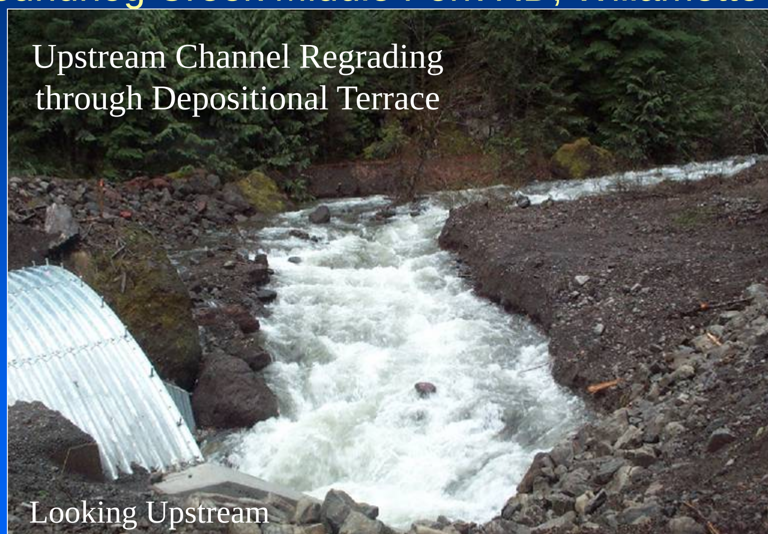



Culverts and Localized Aggradation
Undersized culvert frequently ponds water upstream
culvert
As water slows upstream of crossing, localized aggradation occurs
Impounded wetlands may form


Case Example
Upstream Aggradation
Groundhog Creek
Middle Fork RD, Willamette NF
Culvert Inlet
Damaged during flood
Aggradation from the 1997 Flood Event
Looking Upstream
from Road
Photos courtesy of Kim Johansson

Case Example
Upstream Aggradation

Groundhog Creek Middle Fork RD, Willamette NF



Photos courtesy of Kim Johansson

Conclusions

- Perched culverts often result from larger-scale channel incision, and not site-scale channel changes.
- Incision is not caused by culverts
- Potential consequences associated with removing a culvert nick-point requires careful consider.
- When replacing culverts after large floods, consider channel instability.
- Issues of upstream aggradation are usually at the site-scale.
- Design for anticipated variability in channel elevation over the life of project

Conclusions

Consider the scale of channel restoration and protection needed when beginning a culvert replacement project.