Countermeasure Calculations and Design

- Summarized from “Bridge Scour and Stream Instability Countermeasures, Experience, Selection, and Design Guidance”, Second Edition, Publication No. FHWA NHI 01-003, Hydraulic Engineering Circular No. 23, FHA
- Author’s experience

Selecting a Countermeasure

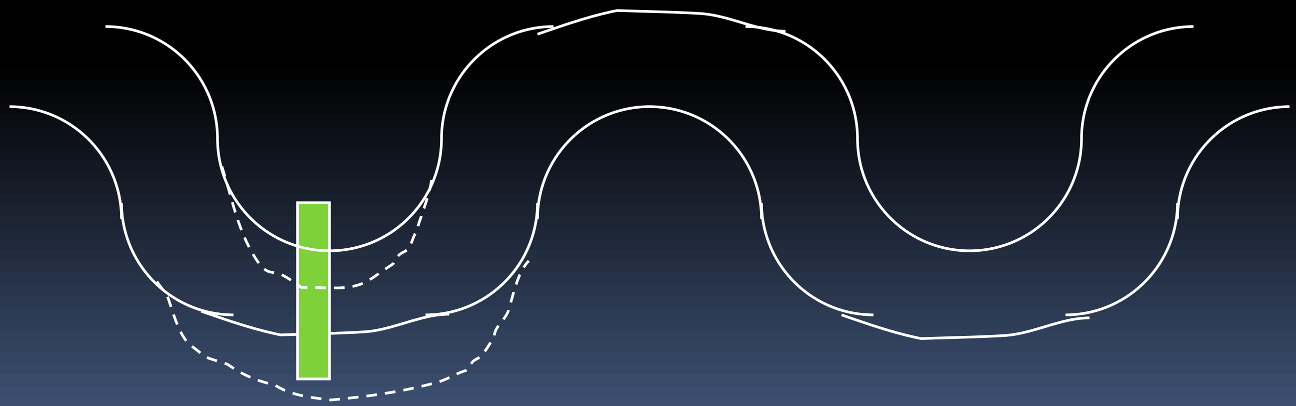
- depends on
  - Erosion Mechanism,
  - Stream Characteristics,
  - Construction and Maintenance Requirements,
  - Vandalism, and
  - Costs

Countermeasures for Meander Migration

- bank revetments,
- spurs,
- retardance structures,
- longitudinal dikes,
- vane dikes,
- bulkheads,
- channel relocations, and
- a carefully planned cutoff

River Out-Flanking Bridge Opening

- Some rivers continue to meander and migrate in plan view.
- River may go around (out-flank) the bridge opening, or attack abutment.



Example of River Meander

FHA (1978) “Countermeasures for Hydraulic Problems at Bridges”

Countermeasures For Channel Braiding And Anabranching

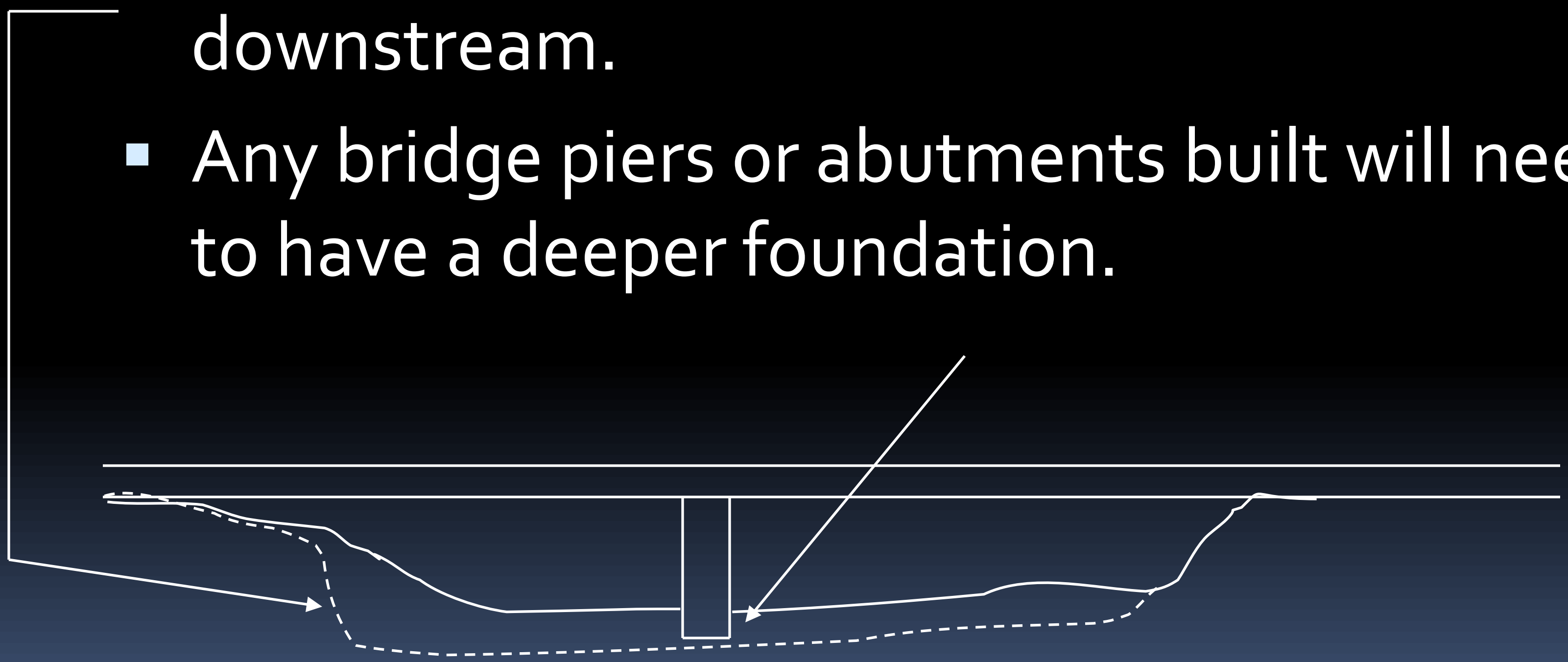
- dikes constructed from the margins of the braided zone to the channel over which the bridge is constructed,
- guide banks at bridge abutments (Design Guideline 10) in combination with revetment on highway fill slopes (Design Guideline 12),
- riprap on highway fill slopes only, and
- spurs (Design Guideline 9) arranged in the stream channels to constrict flow.

Countermeasures For Degradation

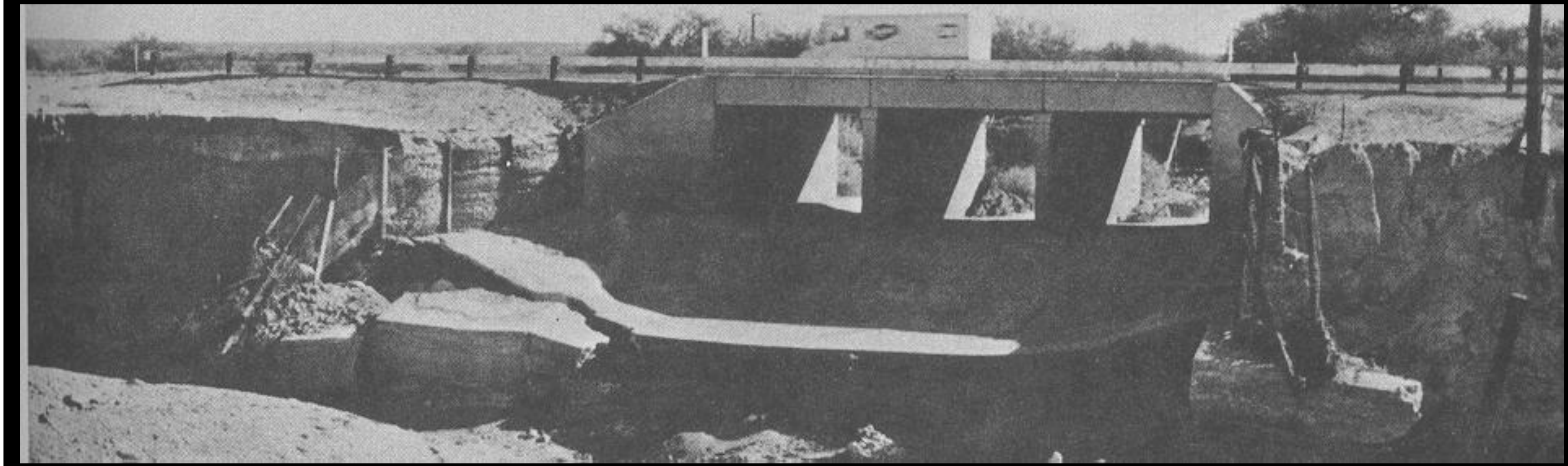
- Check-dams or drop structures,
- Combinations of bulkheads and riprap revetment,
- deeper foundations at piers and pile bents,
- Jacketing piers with steel casings or sheet piles,
- adequate setback of abutments from slumping banks,
- Rock-and-wire mattresses,
- Longitudinal stone dikes placed at the toe of channel banks,
- tiebacks to the banks to prevent outflanking.

Riverbed Degradation

- Some rivers have beds that are naturally degrading due to conditions upstream or downstream.
- Any bridge piers or abutments built will need to have a deeper foundation.



Degradation Failure,Ariz.



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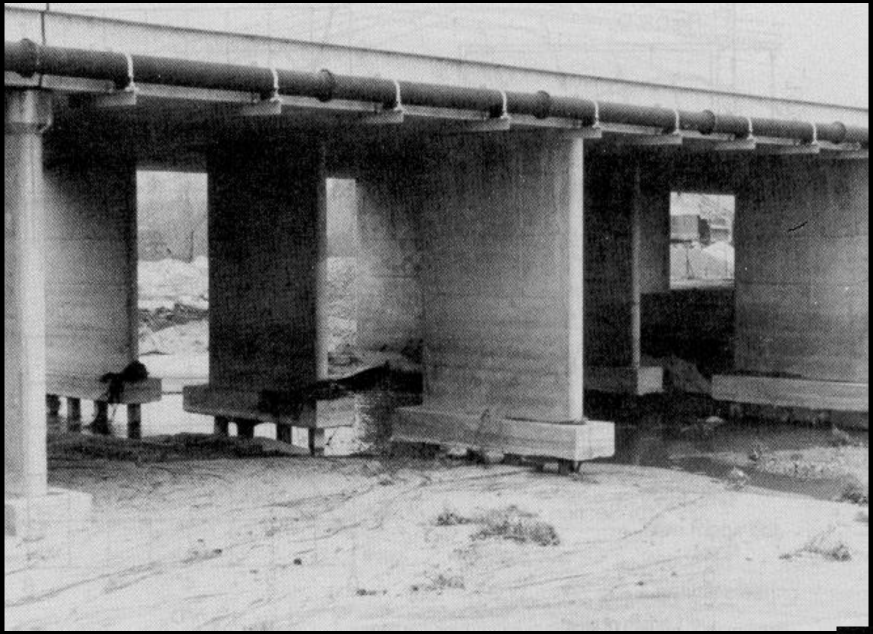
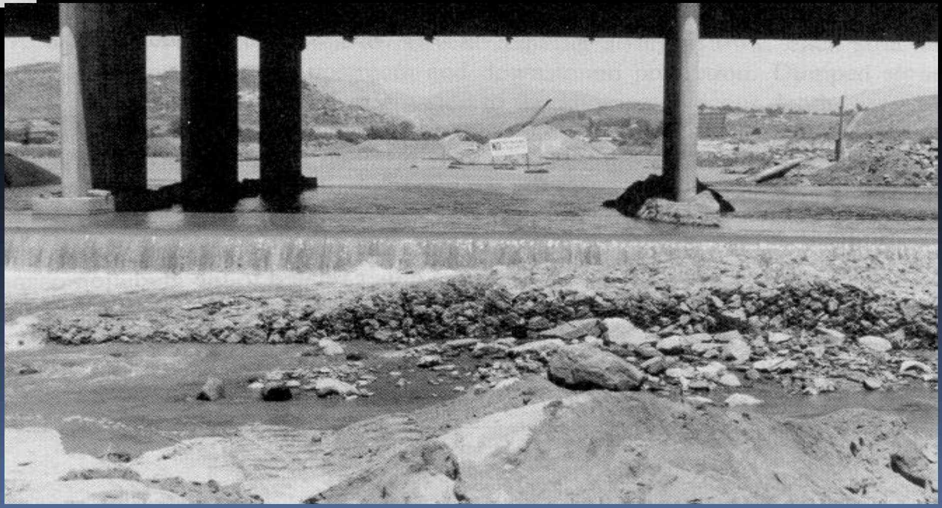
Grade-Control Structure



Before

FHA (1978)
"Countermeasures for Hydraulic Problems at Bridges"

After

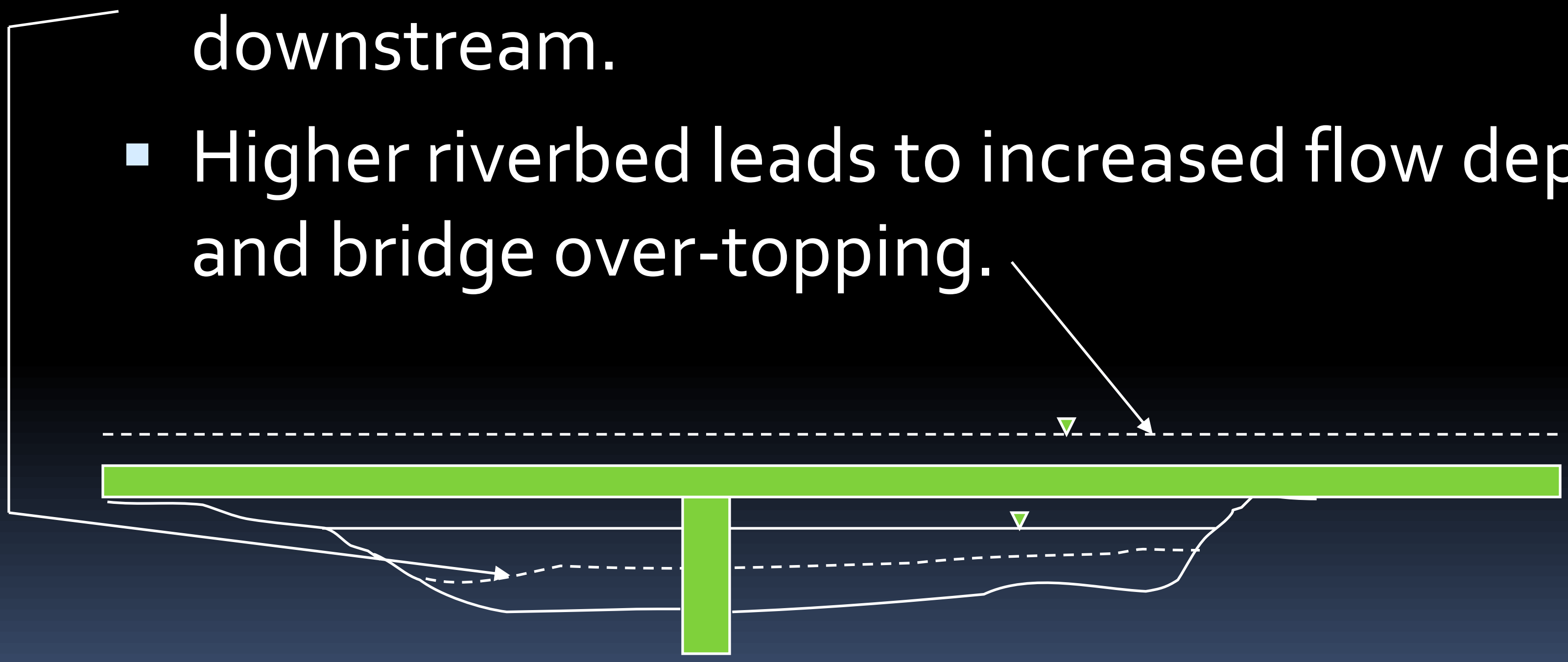


Countermeasures to Control Aggradation

- Alteration or replacement of a bridge,
- Maintenance programs,
- spurs or dikes with flexible revetment have,
- A debris basin and controlled sand and gravel mining

Riverbed Aggradation

- Some rivers have beds that are naturally aggrading due to conditions upstream or downstream.
- Higher riverbed leads to increased flow depth and bridge over-topping.



Countermeasure to Control Contraction Scour

- longer bridges,
- relief bridges on the floodplain,
- superstructures at elevations above flood stages of extreme events, and
- a crest vertical profile on approach roadways to provide for overtopping during floods exceeding the design flood event

Contraction Scour

- For some bridges the width of the river has been narrowed to reduce span length.
- This smaller flow cross-sectional area leads to higher velocity ($V=Q/A$)
- If increased velocity is high enough, then the sediment will start to erode.

Contraction Scour Schematic

- Original riverbanks
- Reduced flow area
- Bridge Abutments

Scour Monitoring

- very important to catch problems before they get dangerous

Bendway Wiers/ Stream Barbs

- Flow goes over to redirect flow
- Made of stones, grout bags, or logs
- Must design
  - height,
  - angle,
  - length,
  - location,
  - spacing,
  - key length,
  - top width,
  - # of wiers

Rock Riprap at Piers and Abutments

- Does help, but must be monitored
- Must design
  - rock size,
  - extent of mattress, and
  - underlying Geotextile filter size

Bank-Hardening: Riprap

- Use round stones; flat ones can be lifted and washed away.
- Use well-graded stones so small ones fill void spaces. Largest size =2D_{50}; smallest size is gravel.
- Use geotextile filter fabric between bank material and riprap stones to prevent winnowing of fines. Place stones carefully. Seal sides of fabric to prevent undermining.
- Riprap blanket thickness should be at least 12 in. or 1.5D_{50}.
- Difficult to place in flowing water. Can add additional thickness at toe to settle into place after initial settling.

Sizing Riprap

$D_{50}=(\tau_c)_s/4$; d_{50} in ft, τ_{cs} in psf

$(\tau_c)_b=1.6\gamma RS$

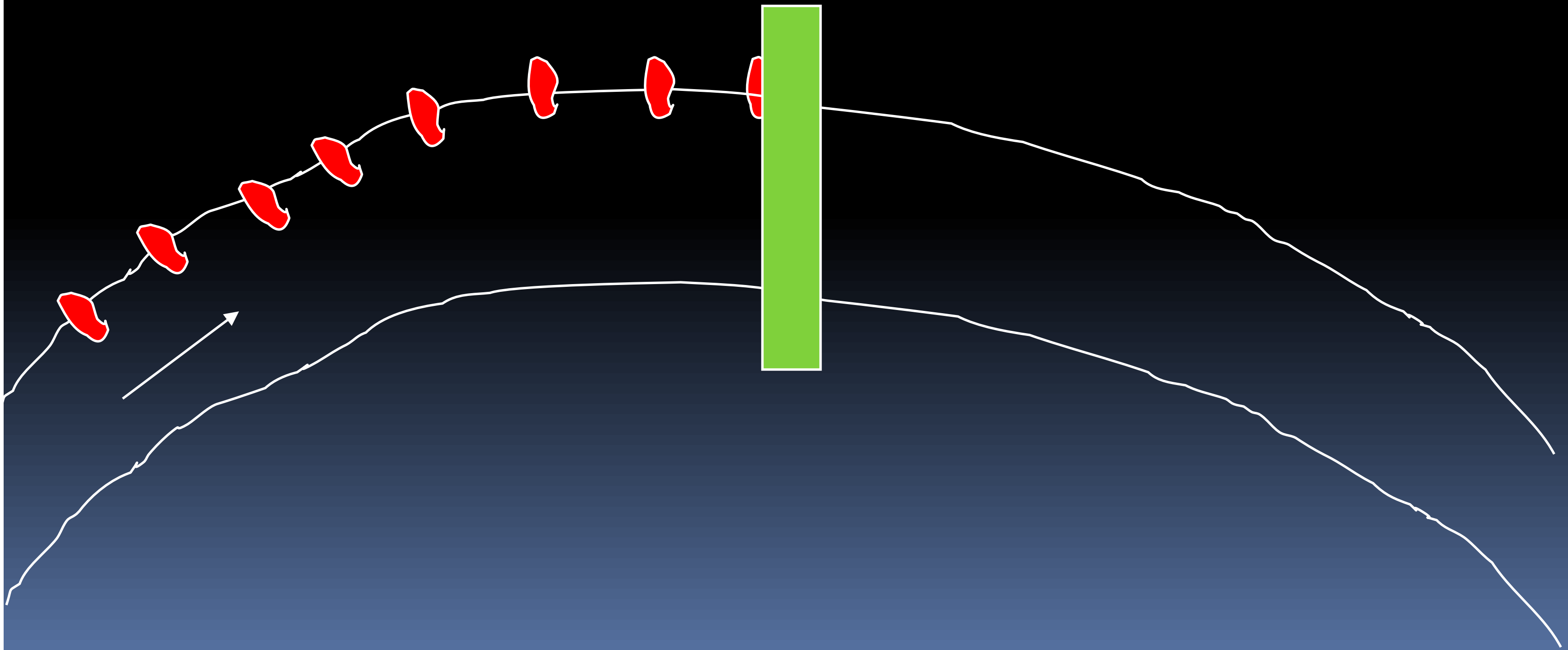
θ=angle of repose;R=hydraulic radius;S=bed slope

Spurs

- Flow goes around to re-direct flow
- Must design
  - type of spur,
  - extent of spur field,
  - length,
  - orientation,
  - permeability,

River-Training: Groynes/Spur Dikes

- Rock structures tied into bank
- Directs flow away from bank



River-Training: Groynes/Spur Dikes

o courtesy of Roger Kuhnle

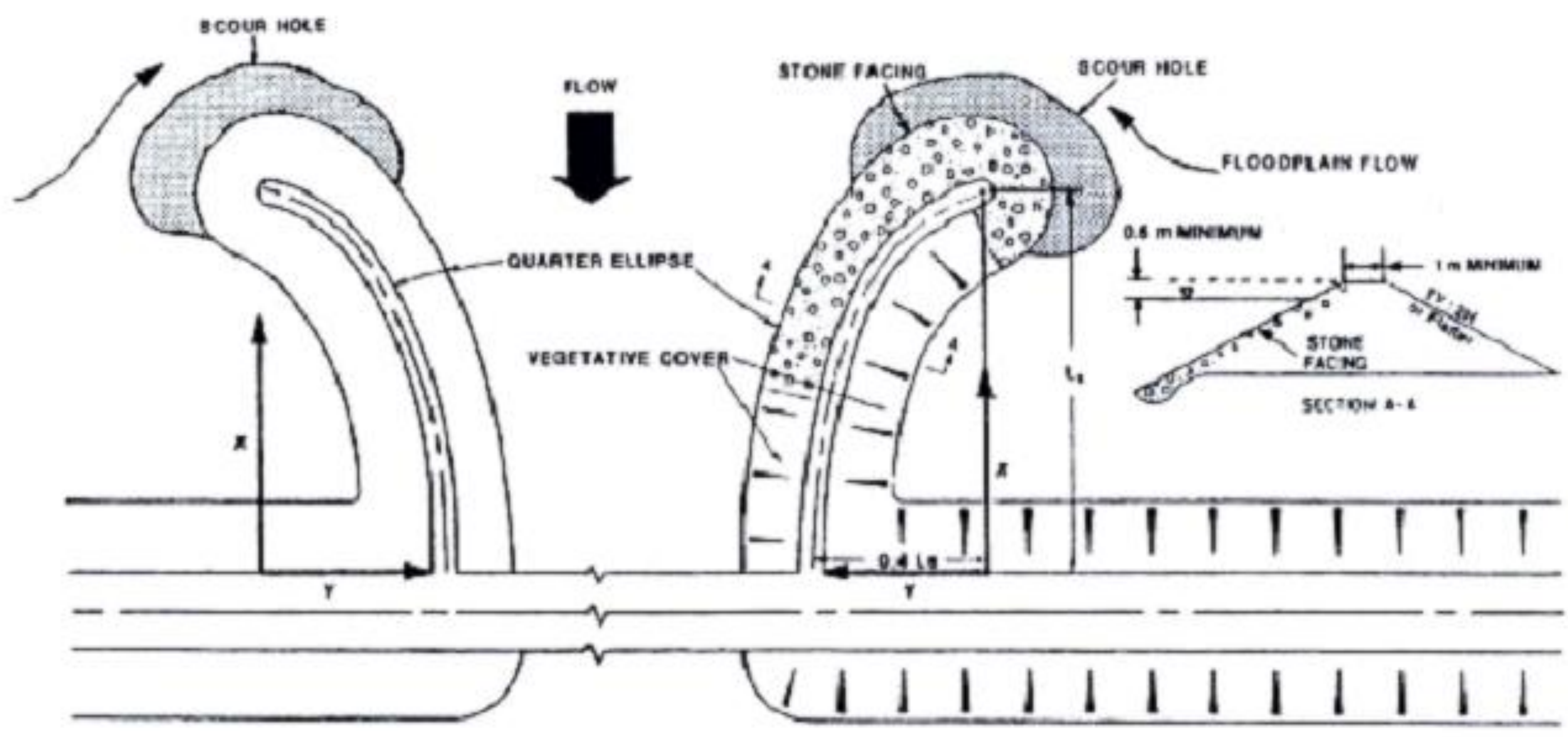
Additional Design Parameters for Spurs

- height,
- depth of keying into bank,
- spacing,
- shape, and
- protection with riprap

Guidebanks

- For use when embankments encroach on floodplain
- Must design
  - orientation,
  - length,
  - height,
  - shape,
  - size,
  - riprap protection, and
  - downstream extent

River-Training: Guidebanks
Guide flow through opening



gasse, P. F., Zevenbergen, L. W., Schall, J. D., Clopper, P. E. (2001). Bridge Scour and
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neering Circular No. 23, U. S. Department of Transportation, Federal Highway

Guidebank

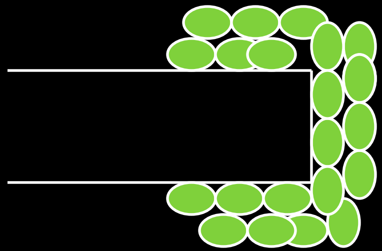
FHA (1978) "Countermeasures for Hydraulic Problems at Bridges"

Additional Countermeasures

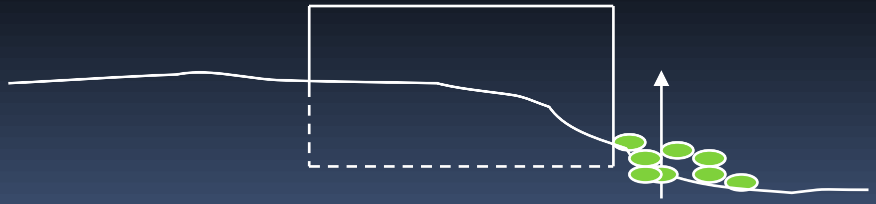
- Soil cement (where rock not available)
- Wire-enclosed riprap mattress (Gabions)
- Articulated concrete blocks
- Grout-filled mattress
- Concrete Armor Units
- Grout-filled bags
- Check dams for grade control
- Revetments for bank stabilization

Geobags-Pervious Bags Filled with Gravel

- PLAN



- SECTION
- Vertical water seepage
- No winnowing of fines



New Version of HEC 23

- coming out this summer
- new material on biotechnology as countermeasures

NCHRP Reports Published on Bridge Scour

- Expert System for Stream Stability and Scour Evaluation
- Scour at Contracted Bridge Sites
- Complex Pier Scour and Contraction Scour in Cohesive Soils
- Abutment Scour in Cohesive Soils
- Methodology for Predicting Channel Migration
- Prediction of Scour at Bridge Abutments
- Criteria for Selecting Numeric Hydraulic Modeling Software

More NCHRP Reports

- Guidelines for Risk-Based Management of Bridges with Unknown Foundations
- Effects of Debris on Bridge-Pier Scour
- Handbook for Predicting Stream Meander Migration and Supporting Software
- Debris Forces on Highway Bridges
- Riprap Design Criteria, Recommended Specifications, and Quality Control

More NCHRP Reports

- Countermeasures to Protect Bridge Piers from Scour
- Countermeasures to Protect Bridge Abutments from Scour
- Instrumentation for measuring scour at bridge piers and abutments
- Magnetic Sliding Collar Scour Monitor: Installation, Operation, and Fabrication Manual
- Pier And Contraction Scour in Cohesive Soils
- Portable Scour Monitoring Equipment

Bank-Hardening: Toskanes

- Kind of jacks that interlock (Tetrapods)
- Won’t wash away as easily as riprap
- Placement similar to riprap

Bank Hardening: Cable-Tied Blocks

- Large concrete block tied together with cable. Acts as a mattress

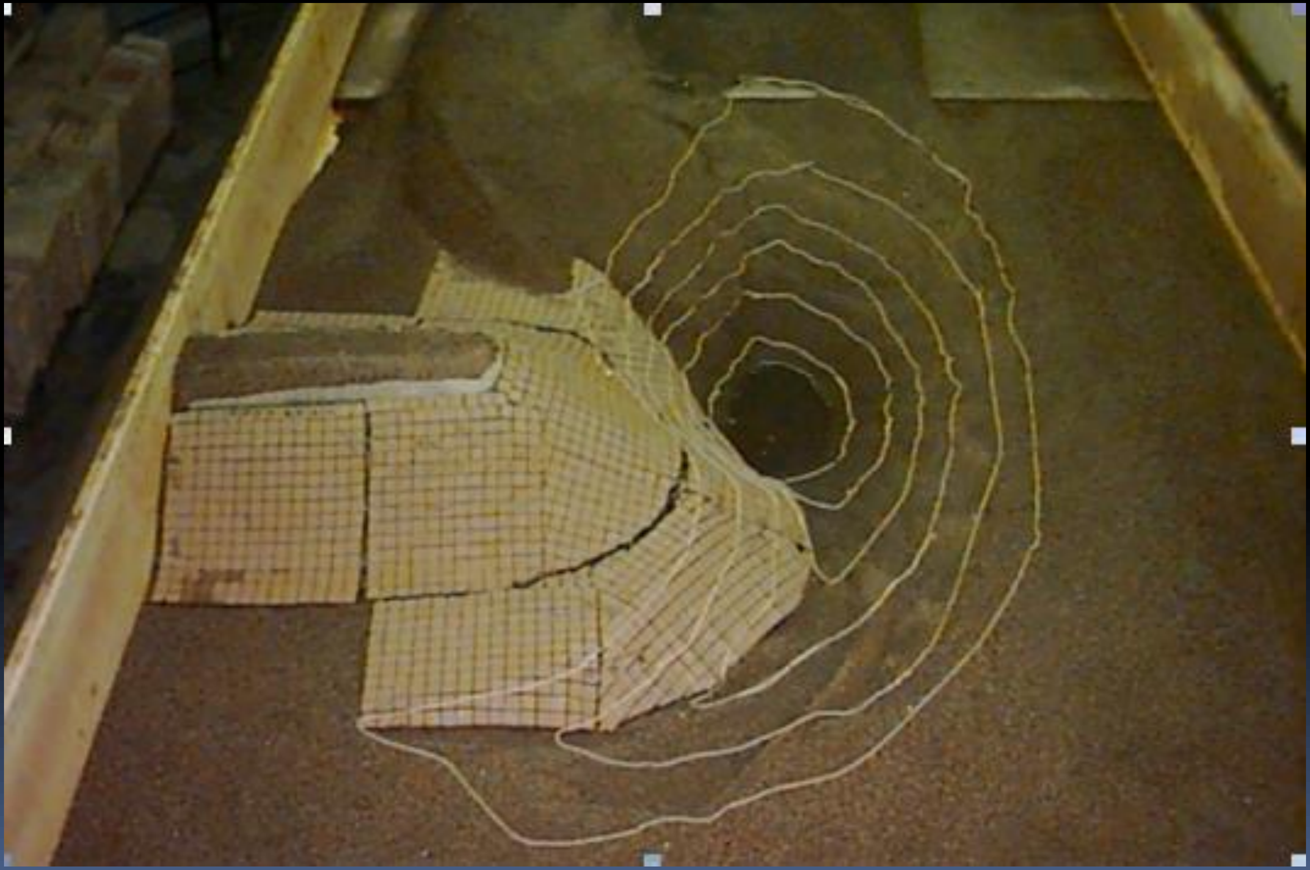
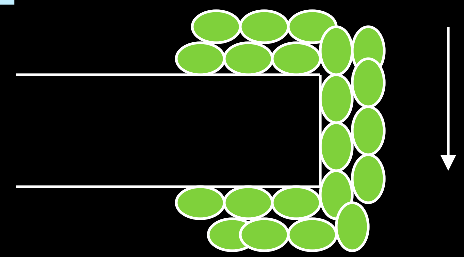


Photo courtesy of Bruce Melville

Bank-Hardening: Geobags- Pervious Bags Filled with Gravel

- PLAN



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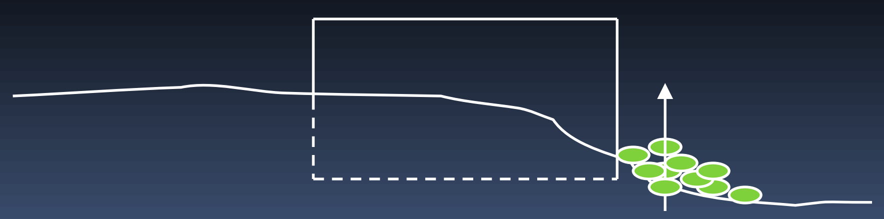
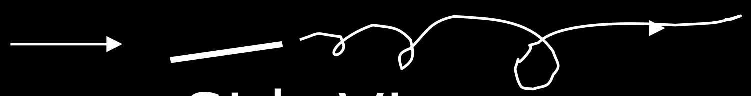
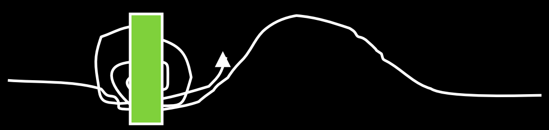


Flow Altering: Submerged Vanes

- Creates vortex to direct bed sediment
- Plan View

Downstream View

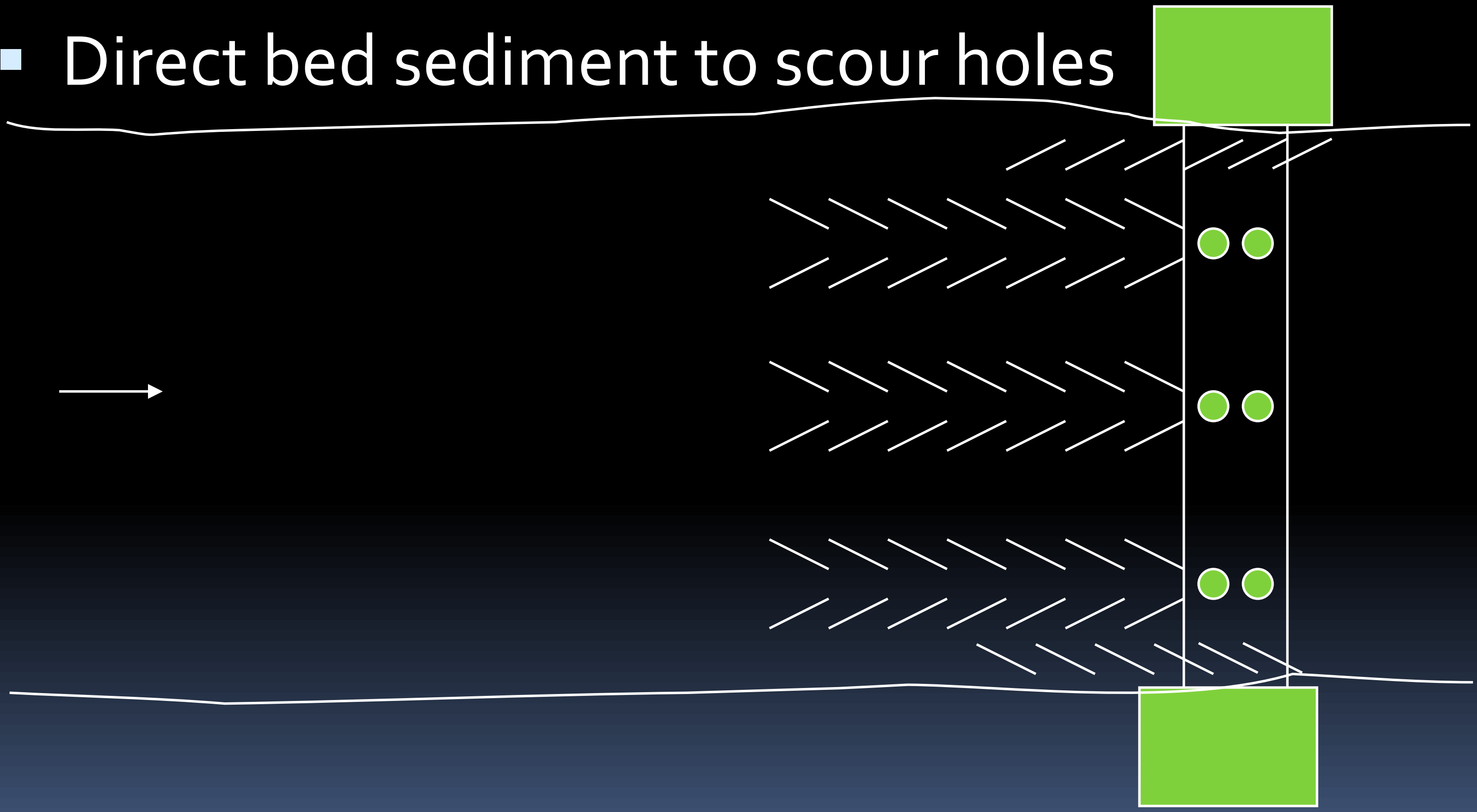




- Side View

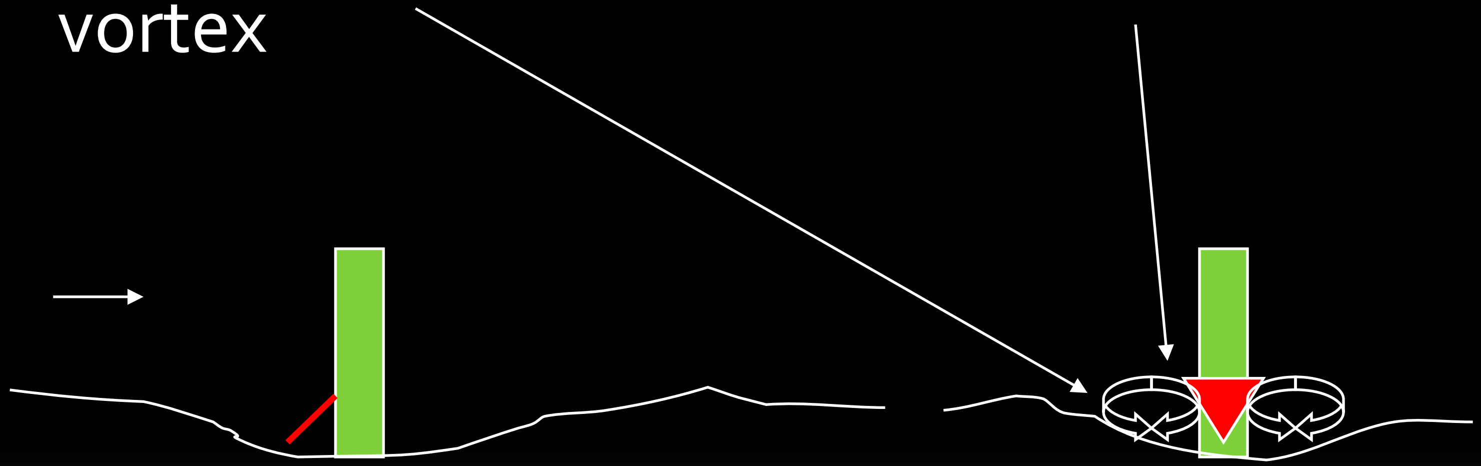
Flow Altering: Submerged Vanes

- Direct bed sediment to scour holes



Flow Altering: Delta Wings

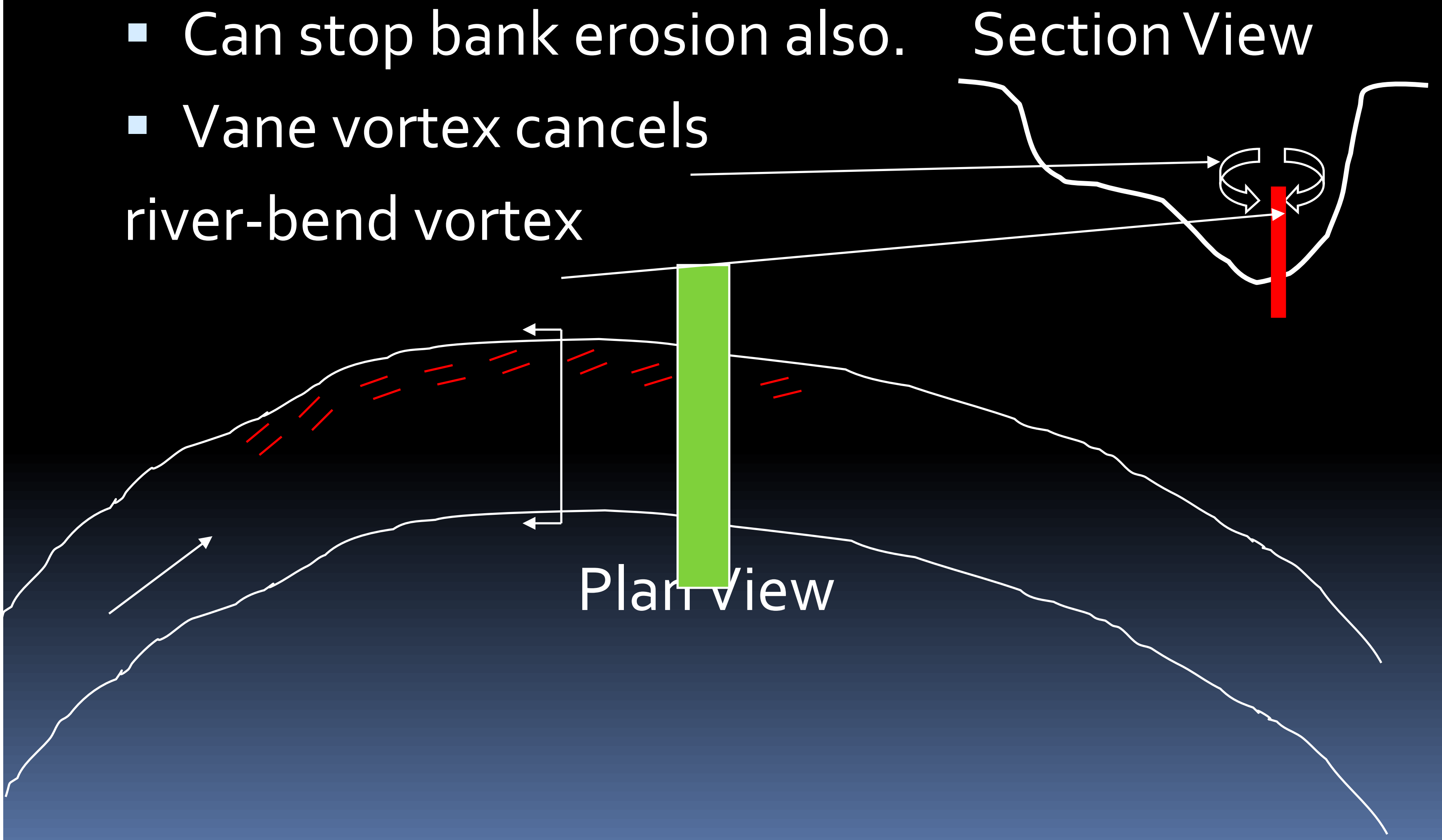
- Creates vortex to counter pier's horseshoe vortex



River-Training: Submerged Vanes

- Can stop bank erosion also.
- Vane vortex cancels

river-bend vortex



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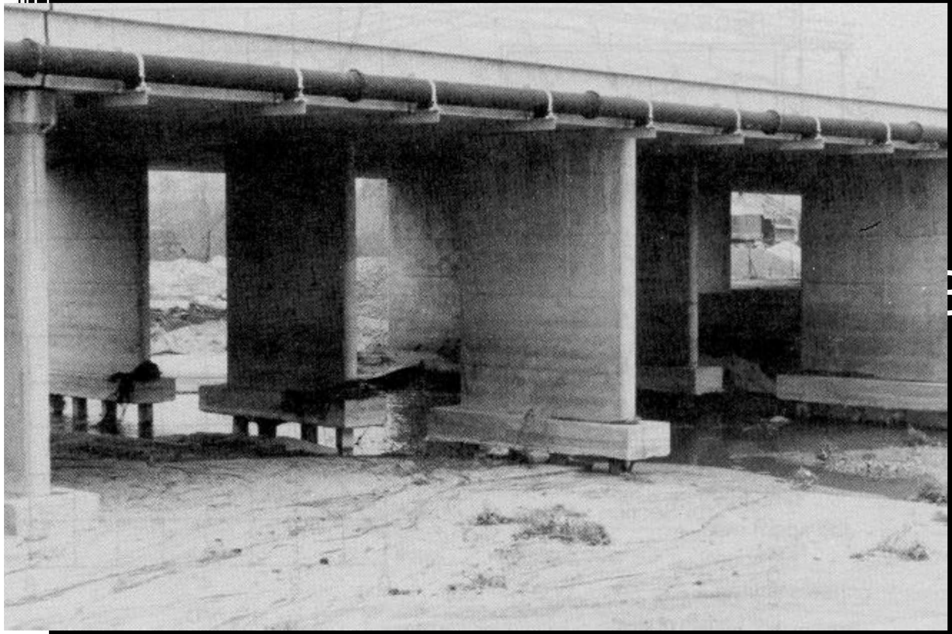
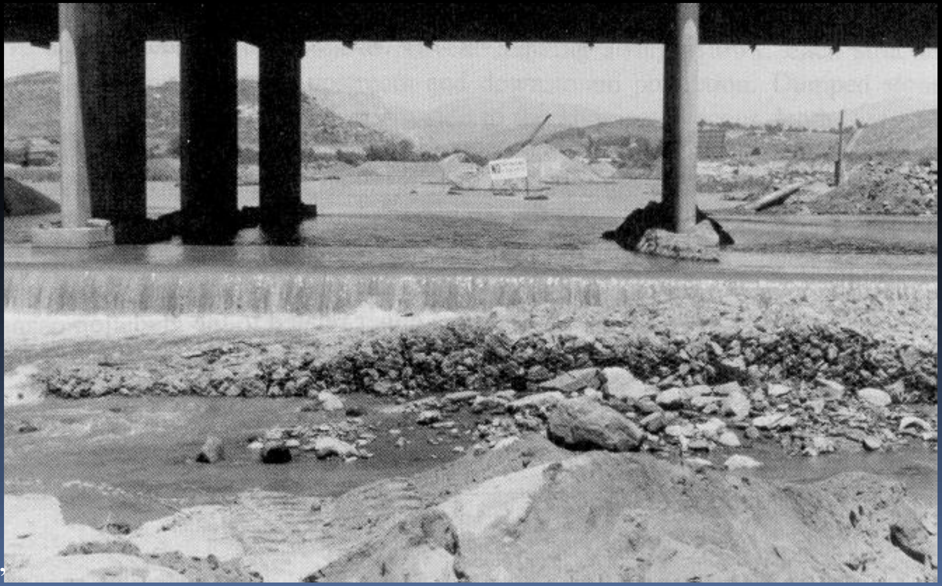


Small dam to fix bed elevation

Before

After



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