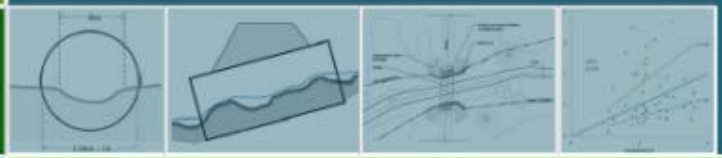
2013



Water Crossing Design Guidelines

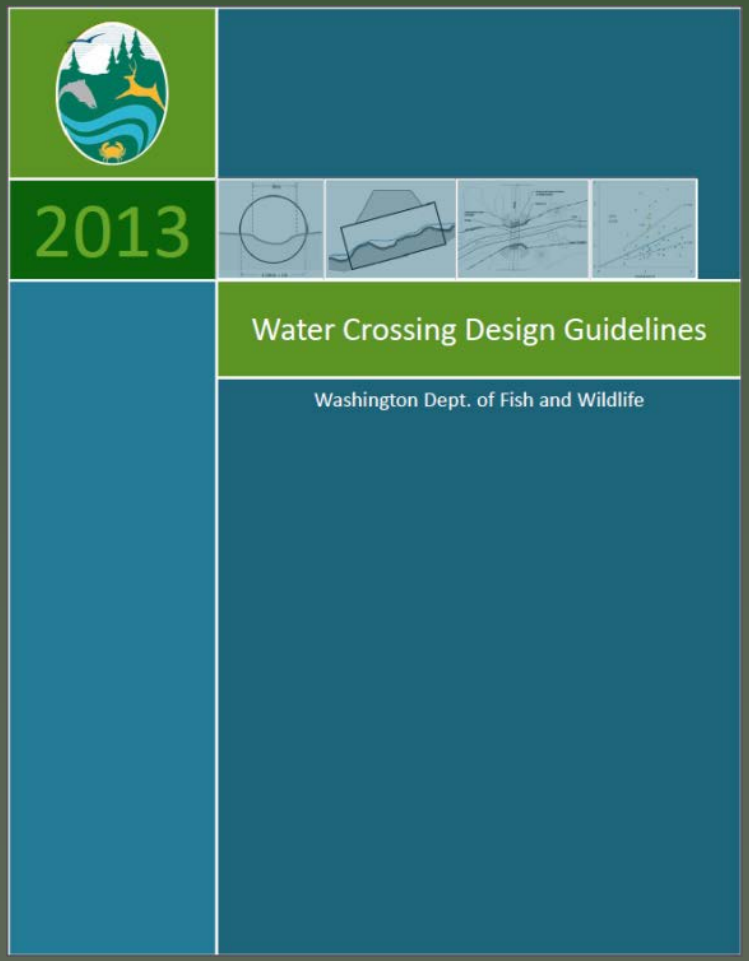
Washington Dept. of Fish and Wildlife

Price, D. M., T. Quinn, et al. (2010). **Fish Passage Effectiveness of Recently Constructed Road-Crossing Culverts in the Puget Sound Region of Washington State**. North American Journal of Fisheries Management

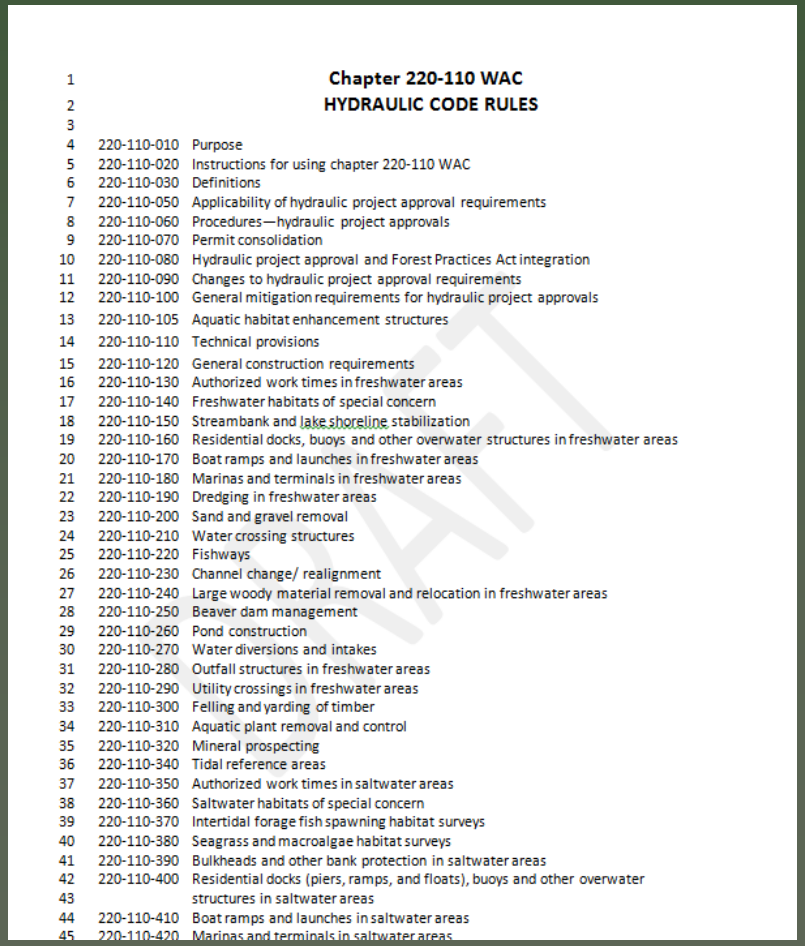
Crossings in 6 steps

Crossings in 6 steps

1. Rules & Guidelines



New WACs (June 2014)



Chapter 220-110 WAC
HYDRAULIC CODE RULES

220-110-010	Purpose
220-110-020	Instructions for using chapter 220-110 WAC
220-110-030	Definitions
220-110-050	Applicability of hydraulic project approval requirements
220-110-060	Procedures—hydraulic project approvals
220-110-070	Permit consolidation
220-110-080	Hydraulic project approval and Forest Practices Act integration
220-110-090	Changes to hydraulic project approval requirements
220-110-100	General mitigation requirements for hydraulic project approvals
220-110-105	Aquatic habitat enhancement structures
220-110-110	Technical provisions
220-110-120	General construction requirements
220-110-130	Authorized work times in freshwater areas
220-110-140	Freshwater habitats of special concern
220-110-150	Streambank and lake shoreline stabilization
220-110-160	Residential docks, buoys and other overwater structures in freshwater areas
220-110-170	Boat ramps and launches in freshwater areas
220-110-180	Marinas and terminals in freshwater areas
220-110-190	Dredging in freshwater areas
220-110-200	Sand and gravel removal
220-110-210	Water crossing structures
220-110-220	Fishways
220-110-230	Channel change/ realignment
220-110-240	Large woody material removal and relocation in freshwater areas
220-110-250	Beaver dam management
220-110-260	Pond construction
220-110-270	Water diversions and intakes
220-110-280	Outfall structures in freshwater areas
220-110-290	Utility crossings in freshwater areas
220-110-300	Felling and yarding of timber
220-110-310	Aquatic plant removal and control
220-110-320	Mineral prospecting
220-110-340	Tidal reference areas
220-110-350	Authorized work times in saltwater areas
220-110-360	Saltwater habitats of special concern
220-110-370	Intertidal forage fish spawning habitat surveys
220-110-380	Seagrass and macroalgae habitat surveys
220-110-390	Bulkheads and other bank protection in saltwater areas
220-110-400	Residential docks (piers, ramps, and floats), buoys and other overwater structures in saltwater areas
220-110-410	Boat ramps and launches in saltwater areas
220-110-420	Marinas and terminals in saltwater areas

DRAFT

Crossings in 6 steps

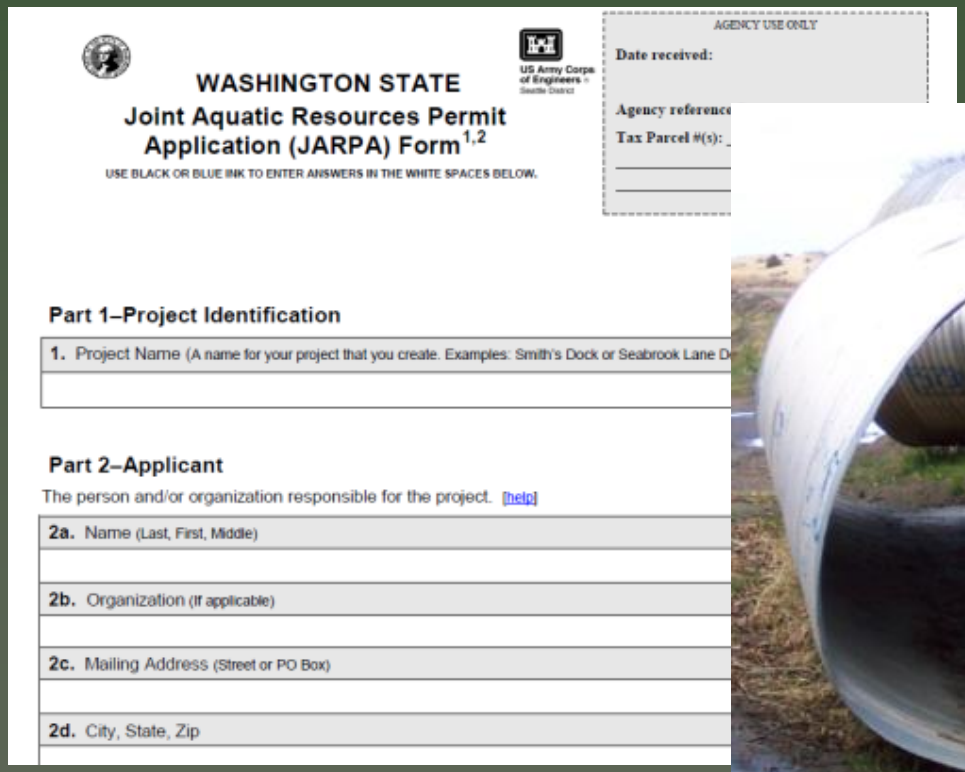
2. Designers

Apply rules
Assess site
ROW/other landowners
Balance costs/benefits

Crossings in 6 steps

3. Regulators

Protect natural resources



US Army Corps of Engineers
Seattle District

WASHINGTON STATE
Joint Aquatic Resources Permit Application (JARPA) Form[1,2]

USE BLACK OR BLUE INK TO ENTER ANSWERS IN THE WHITE SPACES BELOW.

AGENCY USE ONLY
Date received:
Agency reference
Tax Parcel #(s):

Part 1–Project Identification

1. Project Name (A name for your project that you create. Examples: Smith's Dock or Seabrook Lane D

Part 2–Applicant

The person and/or organization responsible for the project. [help]

2a. Name (Last, First, Middle)

2b. Organization (If applicable)

2c. Mailing Address (Street or PO Box)

2d. City, State, Zip

Crossings in 6 steps

4. Contractors

Need good plans
Site complications

Crossings in 6 steps

5. Monitor

You have to look to know if you're successful

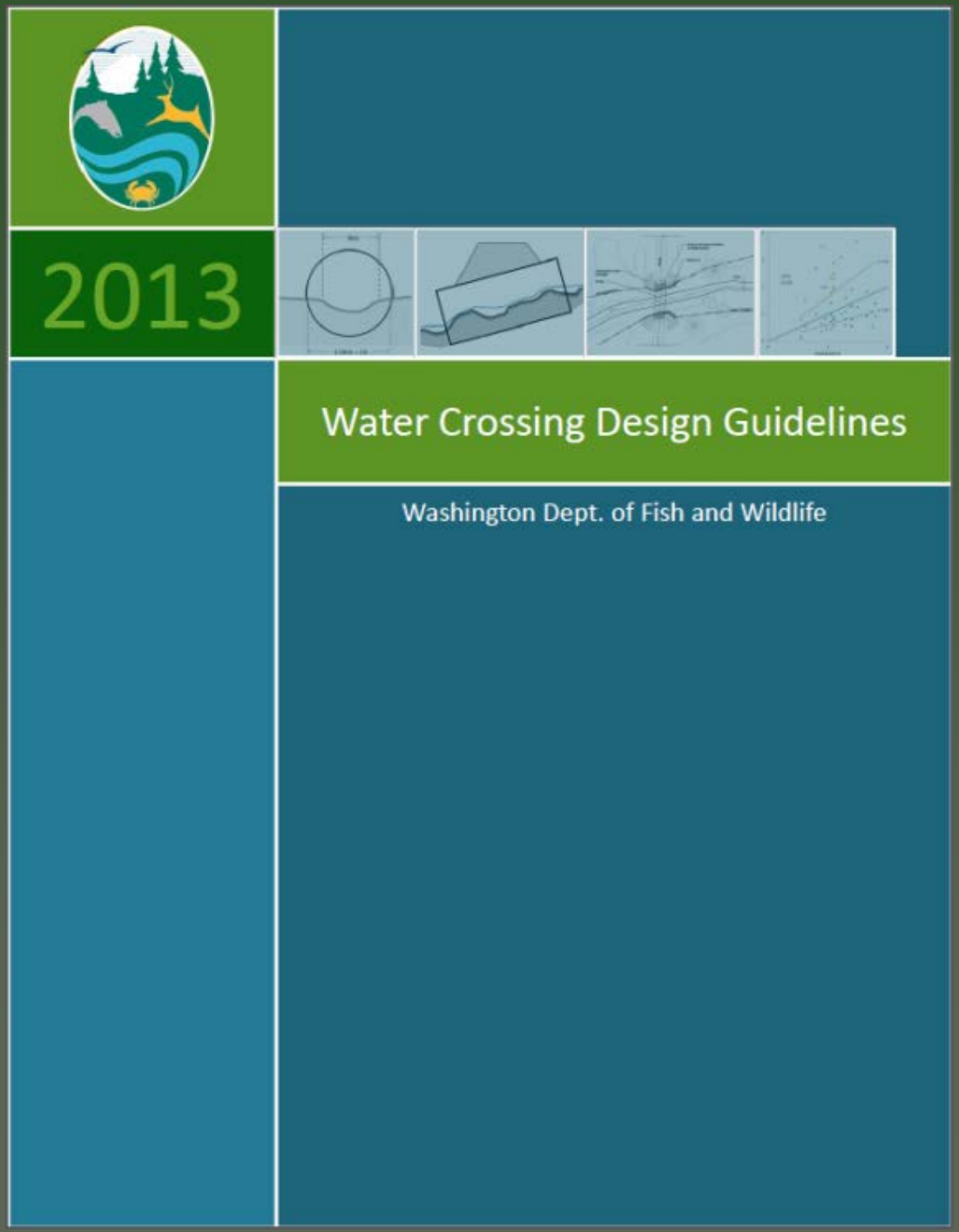
Crossings in 6 steps

6. Maintain

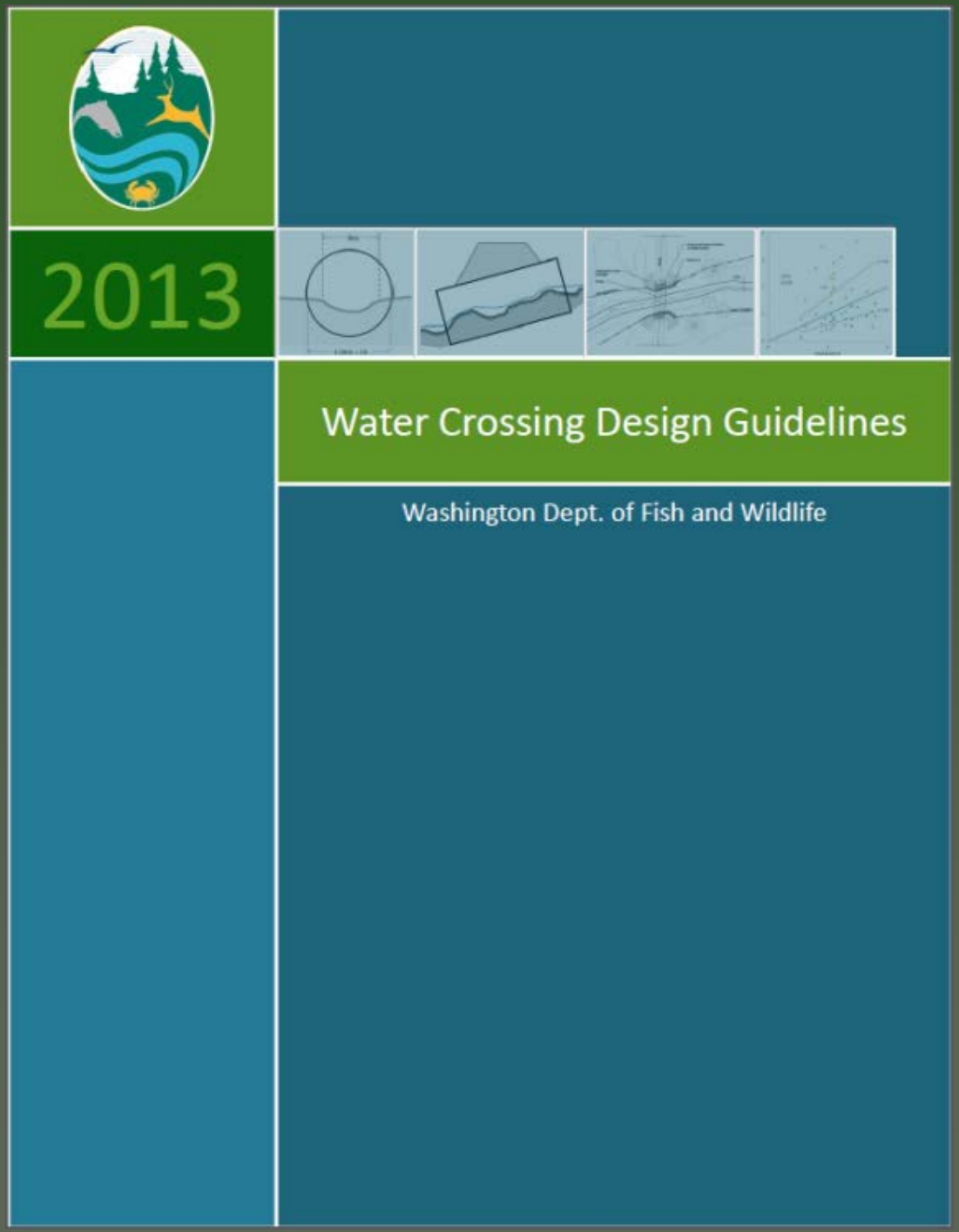
If it doesn’t work, fix it.

WASHINGTON'S AQUATIC HABITAT GUIDELINES (AHG) PROGRAM

An Integrated Approach to Marine, Freshwater, and Riparian Habitat Protection and Restoration



- 4 years
- 5 drafts
- Wide review
  - WDOT
  - WADNR
  - Ecology
  - RCO
  - WSACE
  - WFPA
  - FHWA
  - NOAA/NMFS
  - Tribes
- > 1000 comments
- SEPA



- 300 pages
- Digital only
- Draft form for now

- Google : “WDFW Fish Passage”

WCDG 2013

We ‘re NOT going to talk about:

- Hydraulic design of culverts and fishways
- Crossing abandonment
- Temporary crossings
- Tide and flood gates
- Project development (3 chapters)
- Monitoring
- Road Impounded Wetlands
- Measuring channel width (detailed)
- Crossing Impacts and mitigation
- Design flows (FP and peak)

WCDG 2013

Chapter 1 – Geomorphic approach to design

Chapter 2 – No-slope culvert design

Chapter 3 – Stream simulation culvert design

Lunch (12-1)

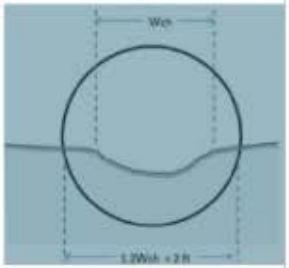
Chapter 4 – Bridge design for habitat protection

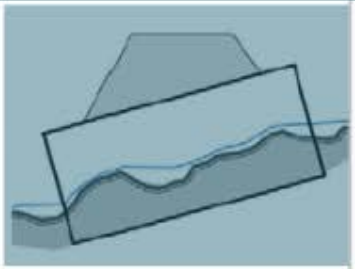
Chapter 7 – Channel profile adjustment

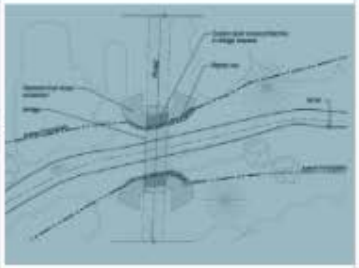
Crossing selection and good plans

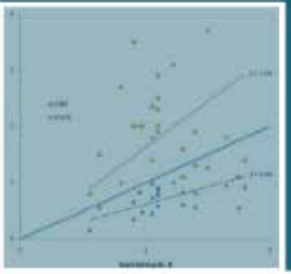
Q & A after each major section (1 Q/person, please, only relevant topics)

2013









Water Crossing Design Guidelines

Washington Dept. of Fish and Wildlife

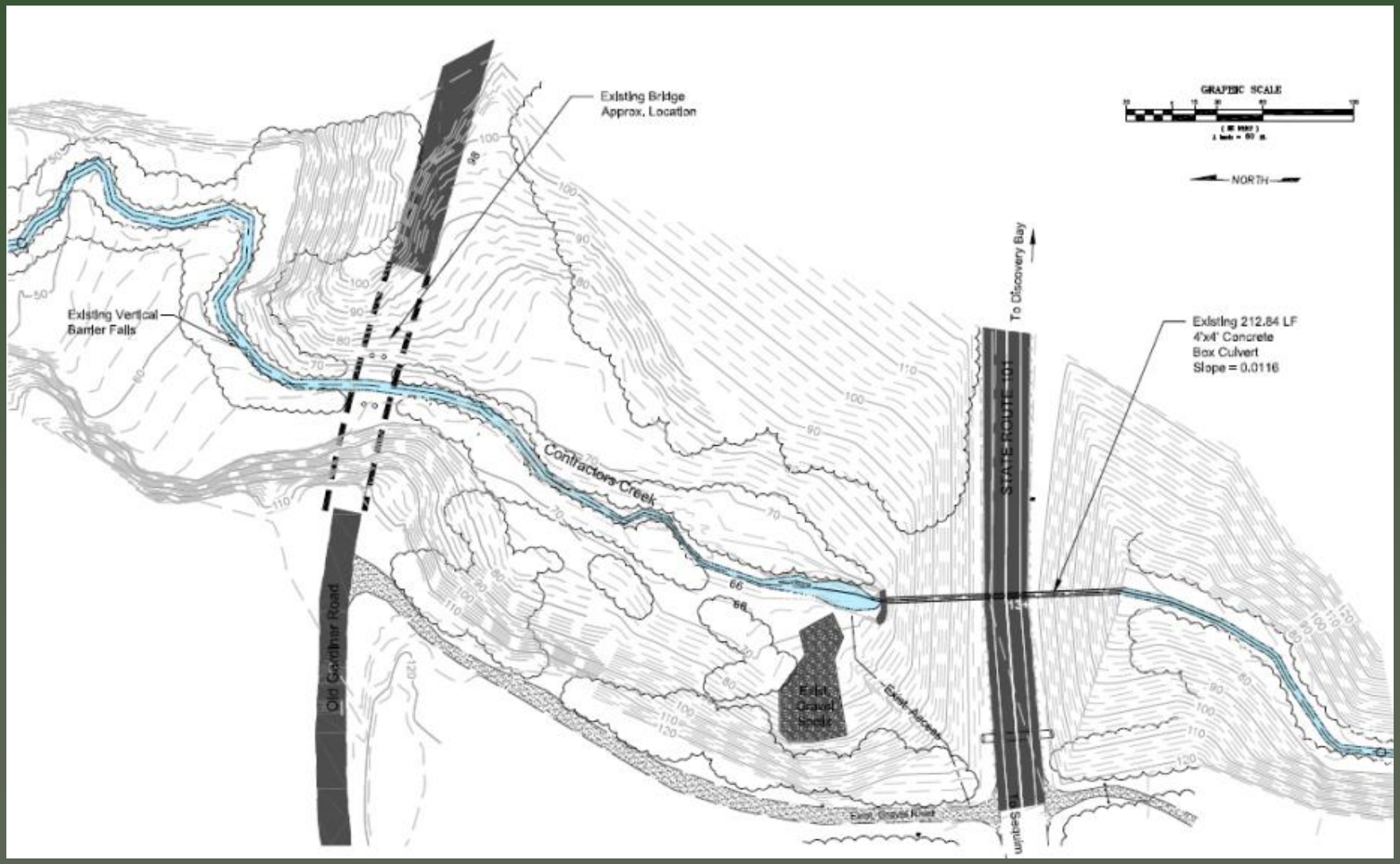
Chapter 1: Geomorphic Approach to Design

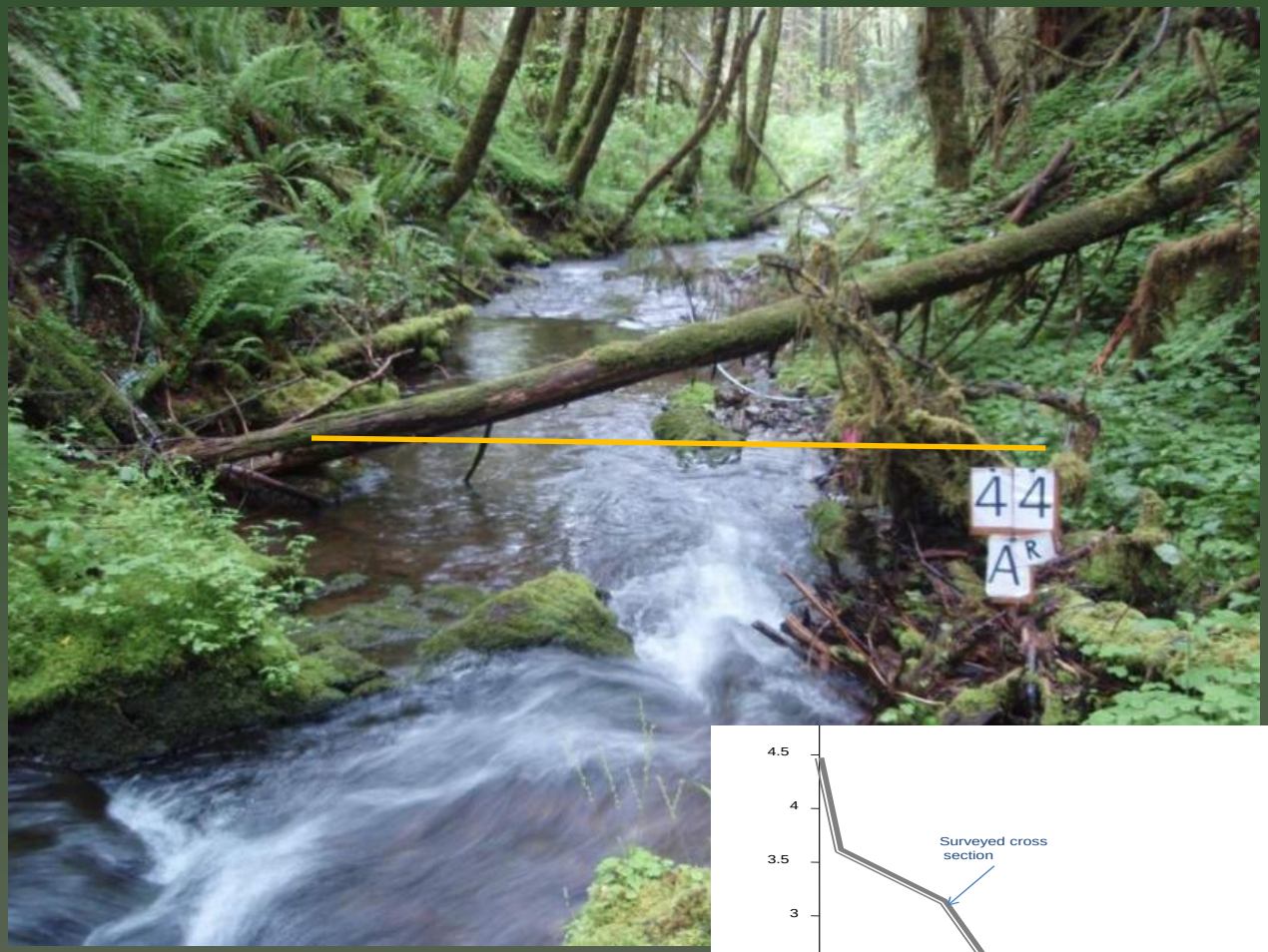
- Introduction
- Bank Full Width
- Longitudinal Profile
- Streambed Sediment
- Vertical Clearance & Debris Passage
- Floodplain Utilization Ratio
- Channel Stability
- Constraints

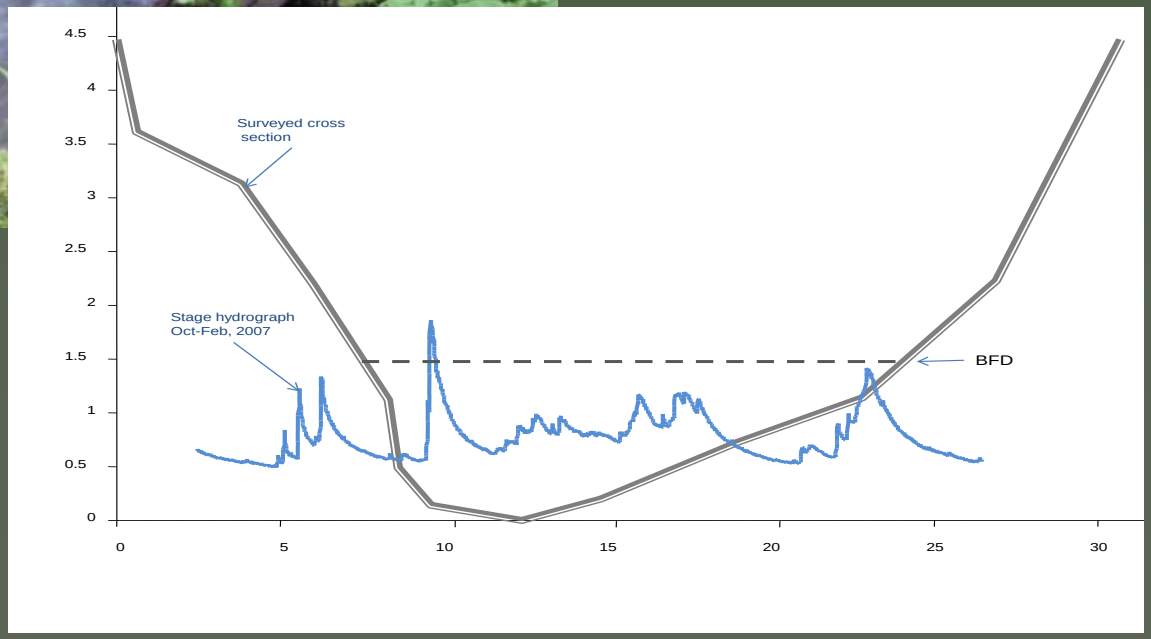
What is Geomorphic Approach?

- A crossing selection and design process intended to have the least effect on the natural processes that create and support the stream structure in which fish live and migrate.
- Emphasis on continuity of the stream processes.
- Based on assessment of the adjacent channel.
- Channel assessment is necessary for No Slope and Stream Simulations culverts; reach analysis may be needed for larger, more complex projects.

Geomorphic Approach to Design

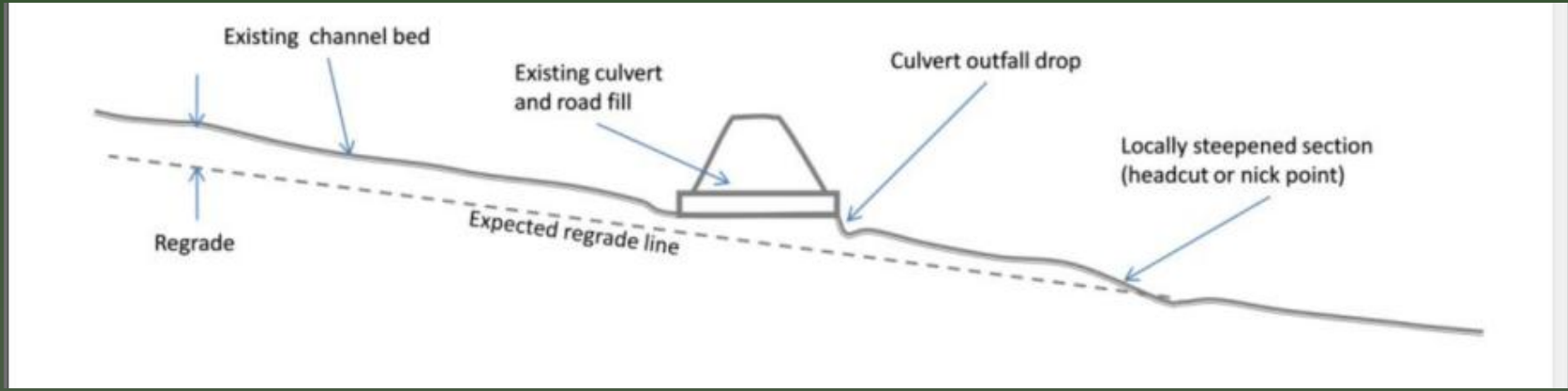






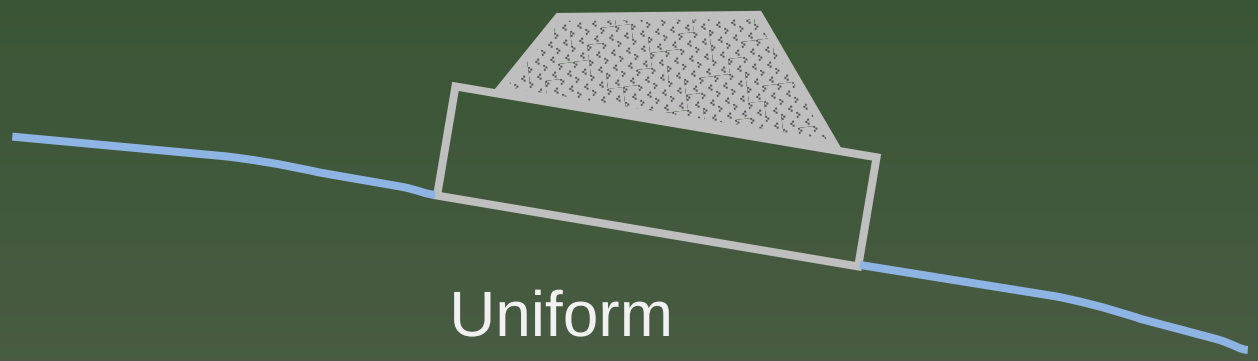
Bankfull width

Long Profile

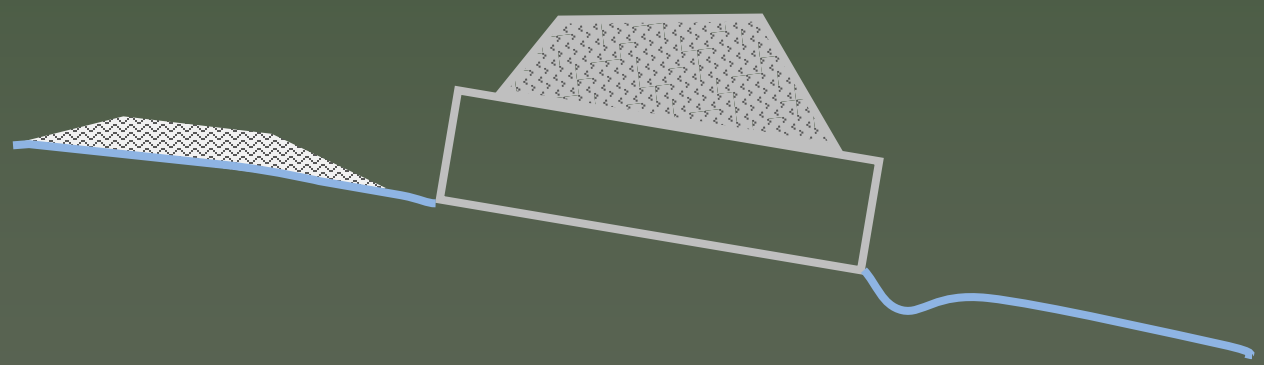


- Long Profile: 20 channel widths or 200’ minimum upstream <u>and</u> downstream
- Essential for determining characteristics of the channel and appropriate degree of countersink for a new culvert
- Reveals true channel slope and expected extent of scour

Longitudinal profile shapes*



Uniform



Uniform, with sediment wedge at inlet of undersized culvert

* Adapted from: *USFS Stream Simulation AOP*

Under-sized culvert halts sediment and debris transport, induces u/s channel widening and d/s channel scour.
Upstream channel width = 9ft
North Fork Secret Ck.

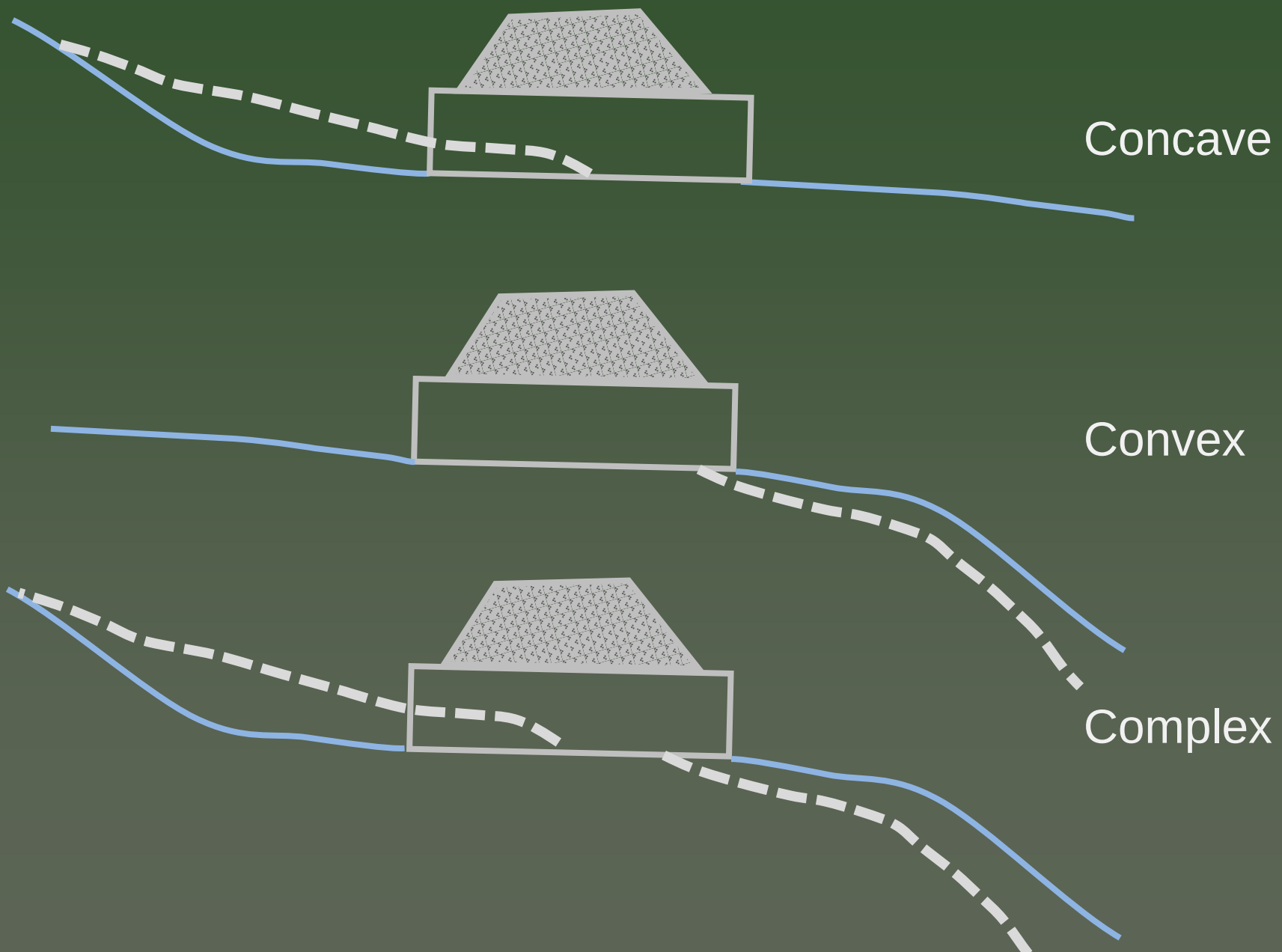
Longitudinal profile shapes

Concave (e.g., outlet of a canyon)

Convex (e.g., transition from alluvial to bedrock-controlled)

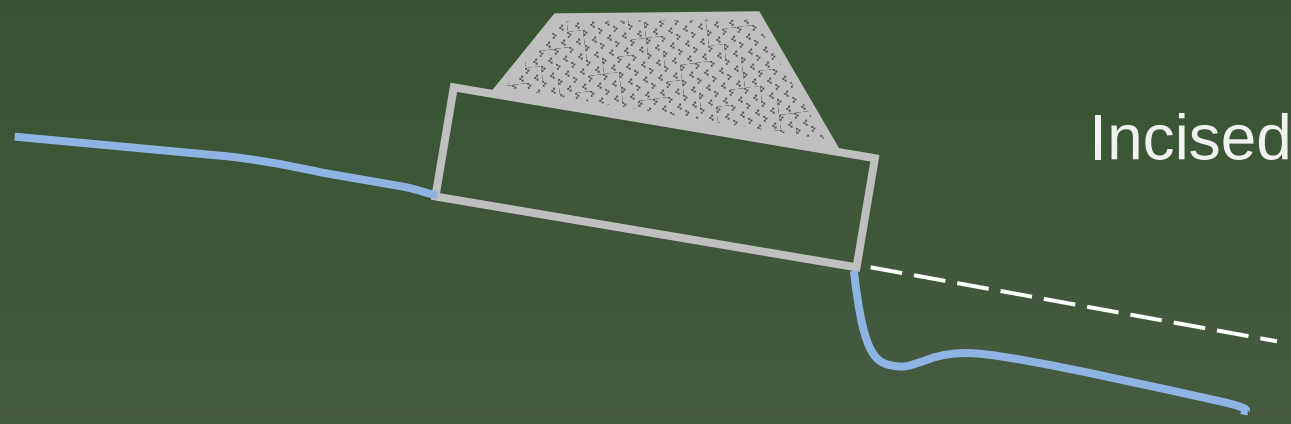
Complex (e.g., mid-slope bench

Longitudinal profile shapes

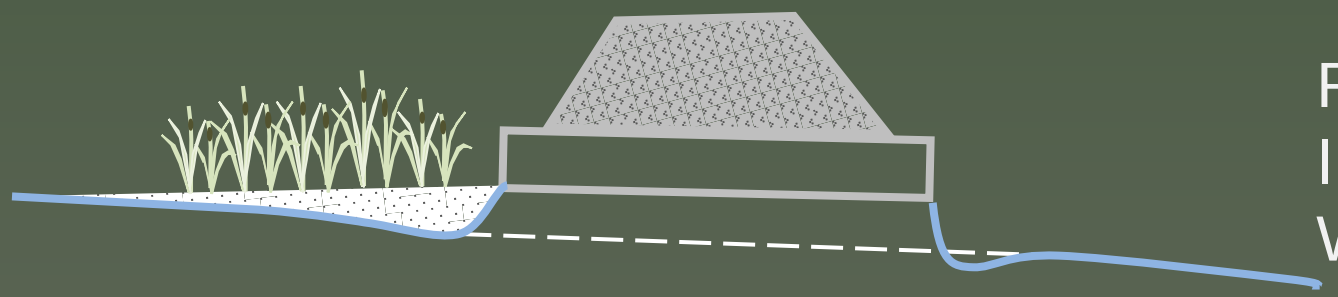


Concave profile with sediment issues

Altered longitudinal profile shapes

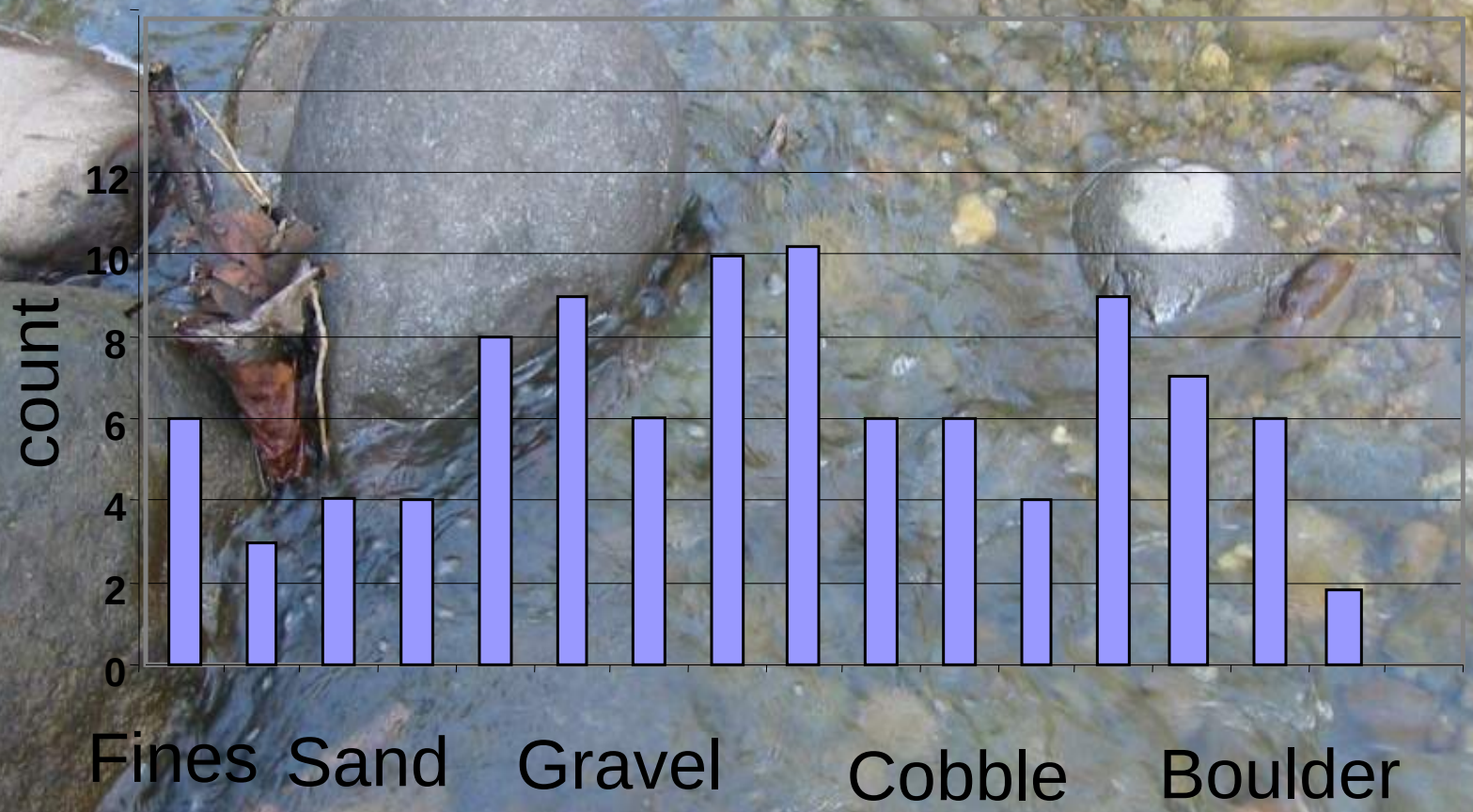


Incised downstream



Road
Impounded
Wetland

Well-graded Bed Material

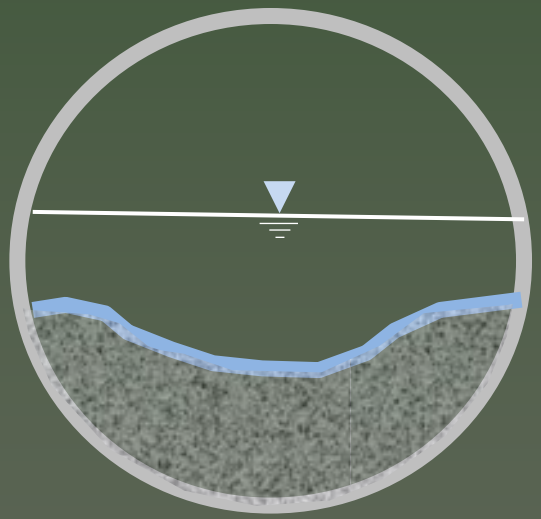


Clearance

To allow for passing floating debris at high flow

Suggested minimum clearance for culverts above the 100 year water surface:

- 1 ft - BFW < 8 ft
- 2 ft - BFW 8 – 15 ft
- 3 ft - BFW > 15 ft



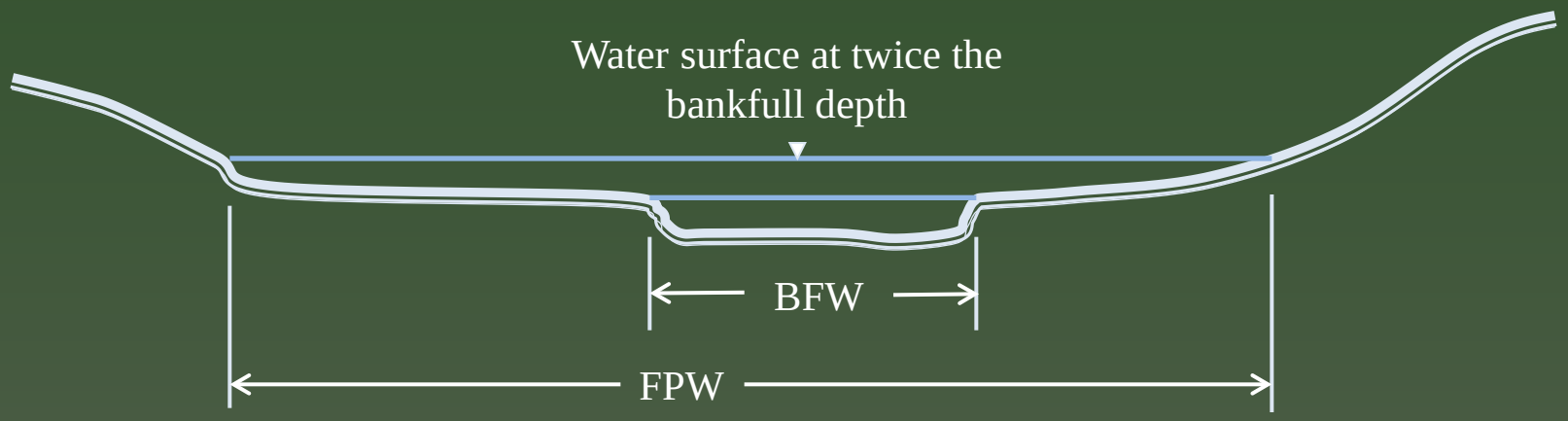
Hydraulic Engineering Circular No. 9, DEBRIS CONTROL STRUCTURES EVALUATION AND COUNTERMEASURES

Larger clearances needed for special cases

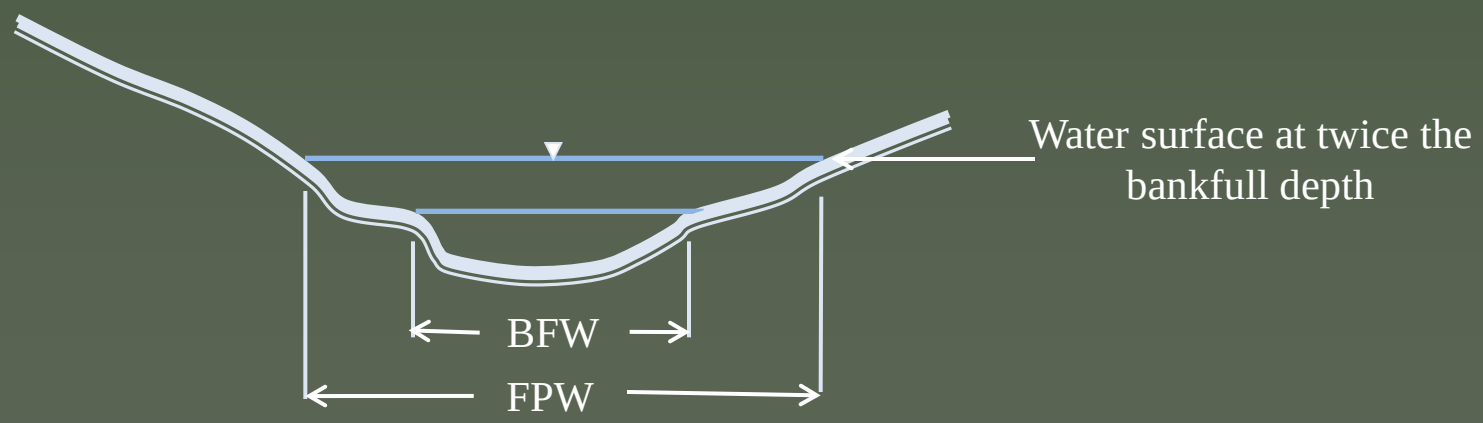
Ice

Heavy debris load

Floodplain Utilization Ratio



FUR= FPW/BFW ~ 3.5



FUR = FPW/BFW ~ 1.8

11 23 2004

Channel banks

Aggraded Channel

Constraints

Culvert retrofits

Homes or other structures

Shallow pipeline crossing upstream

Uncooperative partner

Habitat considerations

Rattlesnakes

Geomorphic Design Summary:

- Mimic the natural channel
- Provide continuity of channel slope, stream bed material, bank full width, channel shape
- Constraints may prevent us from achieving full geomorphic approach in some instances

No Slope Option

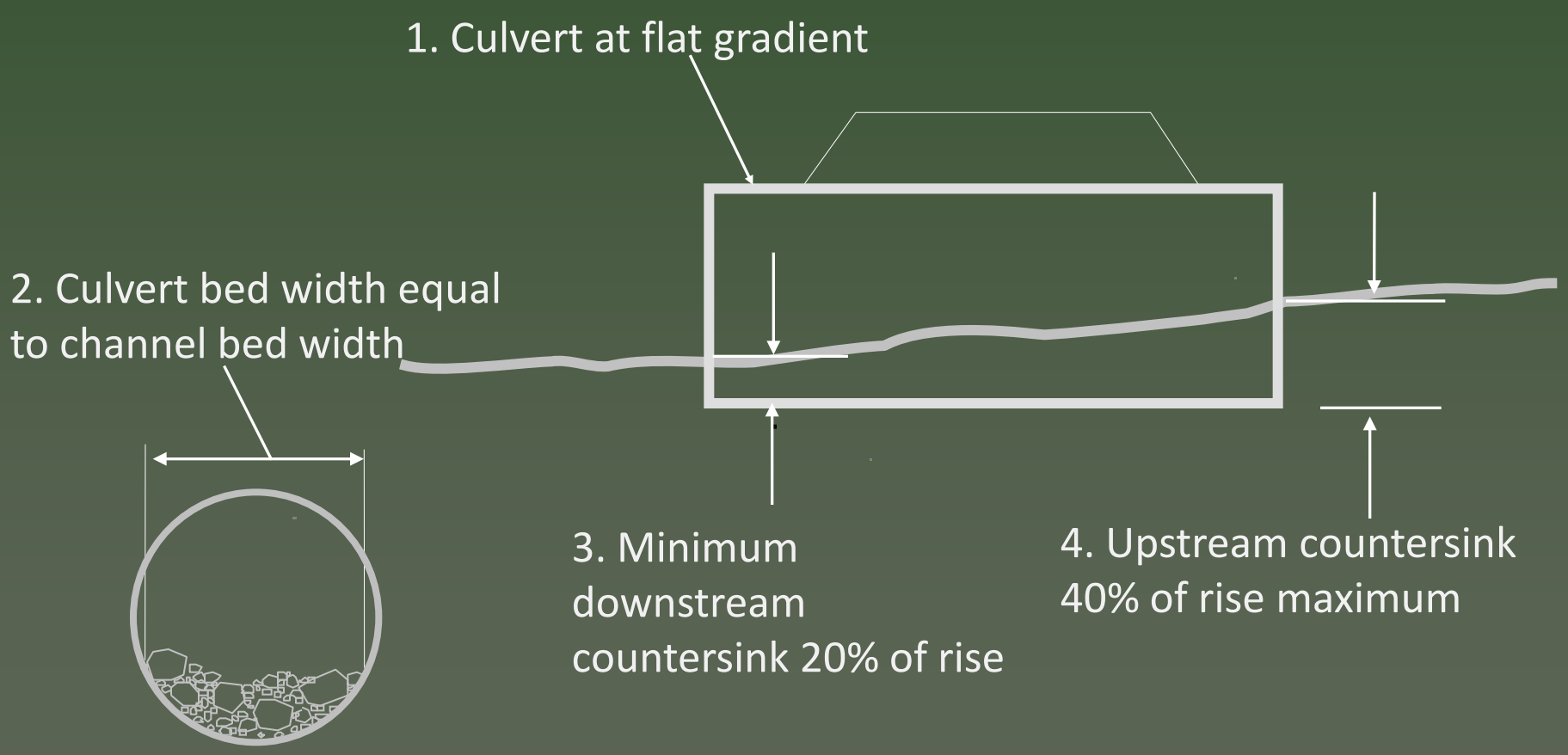
Intent of No Slope Option

- Simplify design

- For use in low-risk situations
  - Low velocity channels with relatively easy fish passage
  - Low fill height, short length, low traffic volume crossings

No Slope Sites

No Slope Option Criteria



No-slope option

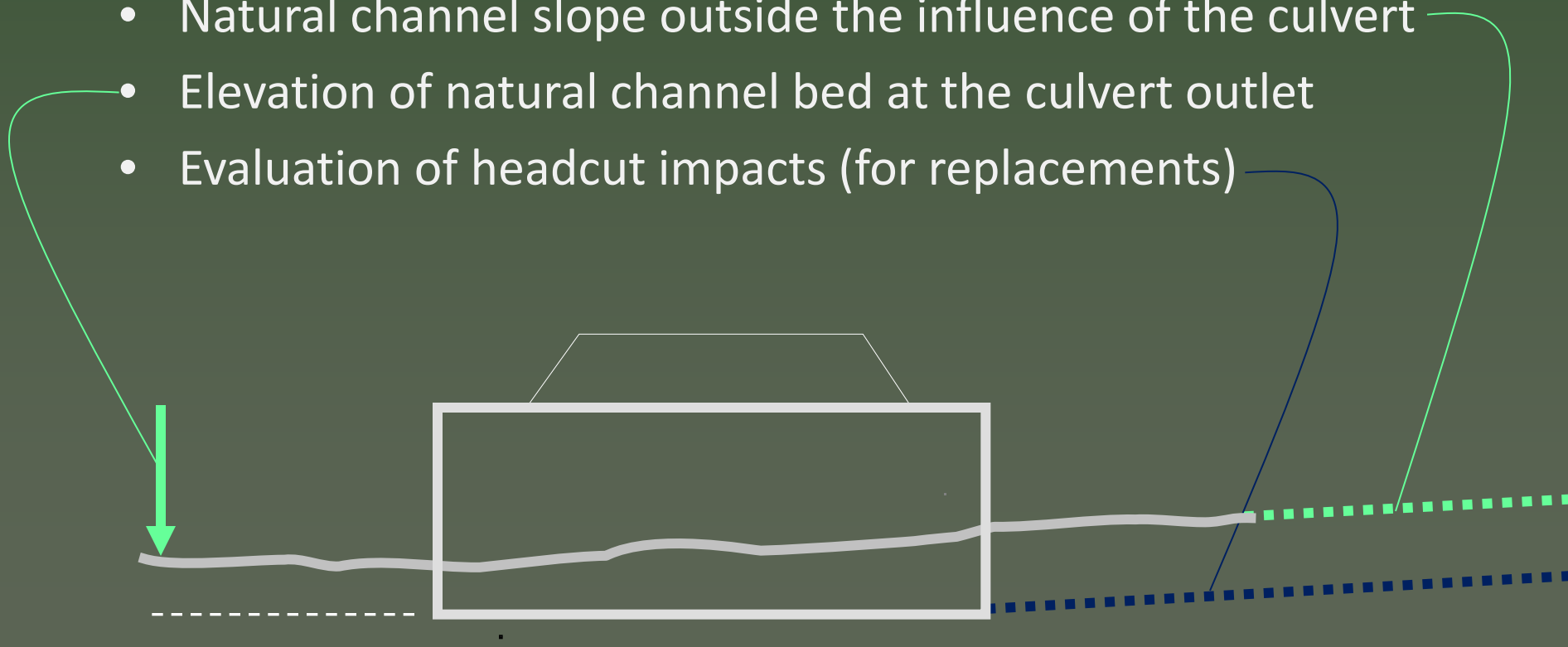
General application

- New and replacement culverts
- Simple installations;
  - Small stream (generally, <8 ft width)
  - low to moderate natural channel slope (generally, <3%) and
  - short culvert length (generally, <75 ft.)

No-slope option; Information needed

- Bankfull channel width

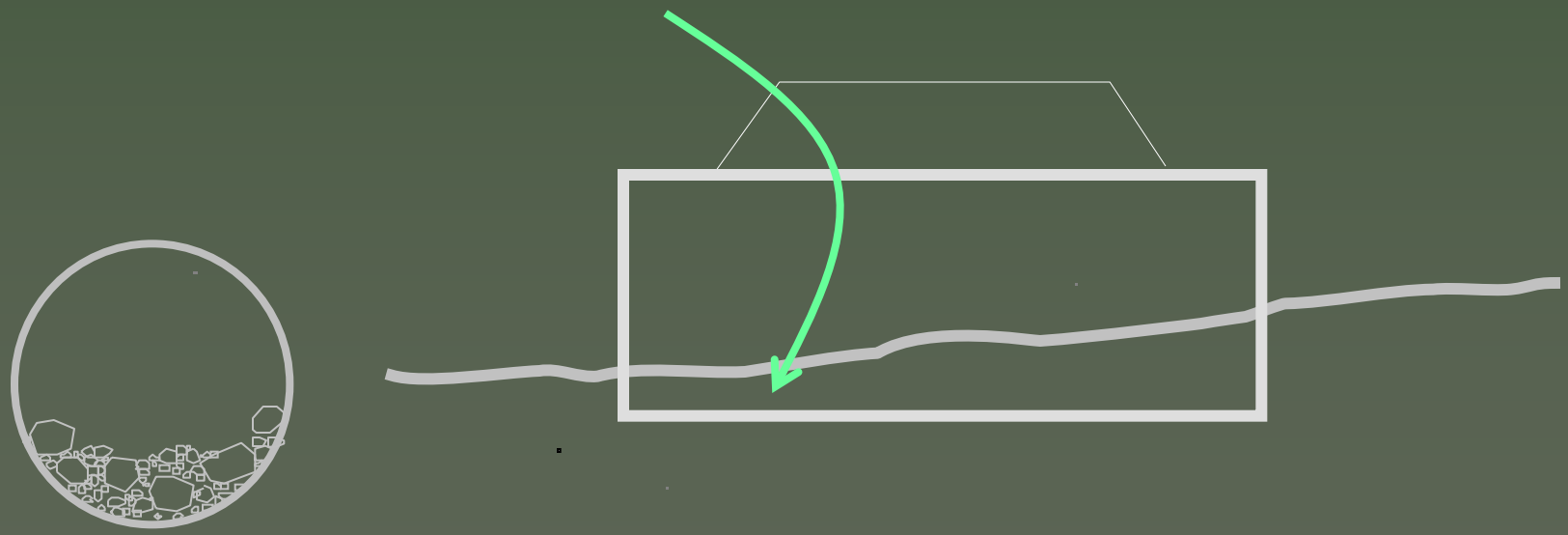
- Natural channel slope outside the influence of the culvert
- Elevation of natural channel bed at the culvert outlet
- Evaluation of headcut impacts (for replacements)



General streambed material specification

Culvert fills should be:

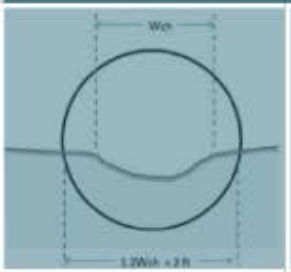
- Appropriate for the slope and discharge of the stream
- Well-graded, with all size classes represented below the maximum size (fines, sands, gravel … larger sizes as needed)
- Include at least 5% but less than 10% fines
- Replicate the upstream channel bed, if applicable
- Rounded, stream-like, material

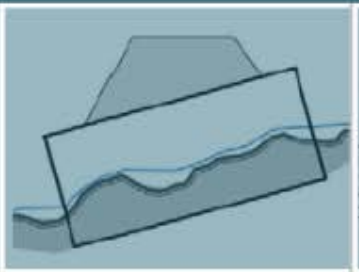


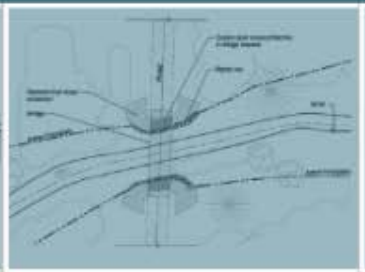
Flood Analysis

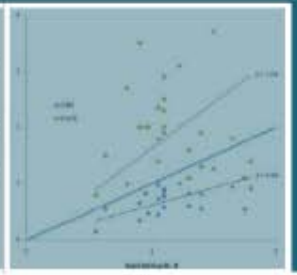
- No slope design does not eliminate the requirement for the culvert and road fill to be stable during a 100-year recurrence flood

2013









Water Crossing Design Guidelines

Washington Dept. of Fish and Wildlife

Chapter 3: Stream Simulation Culvert Design

- Description and Application of Stream Simulation
- Suitability of the Site
- Assessment of Adjacent Channel Reach
- Culvert and Bed Design

Culvert Design: Stream simulation option

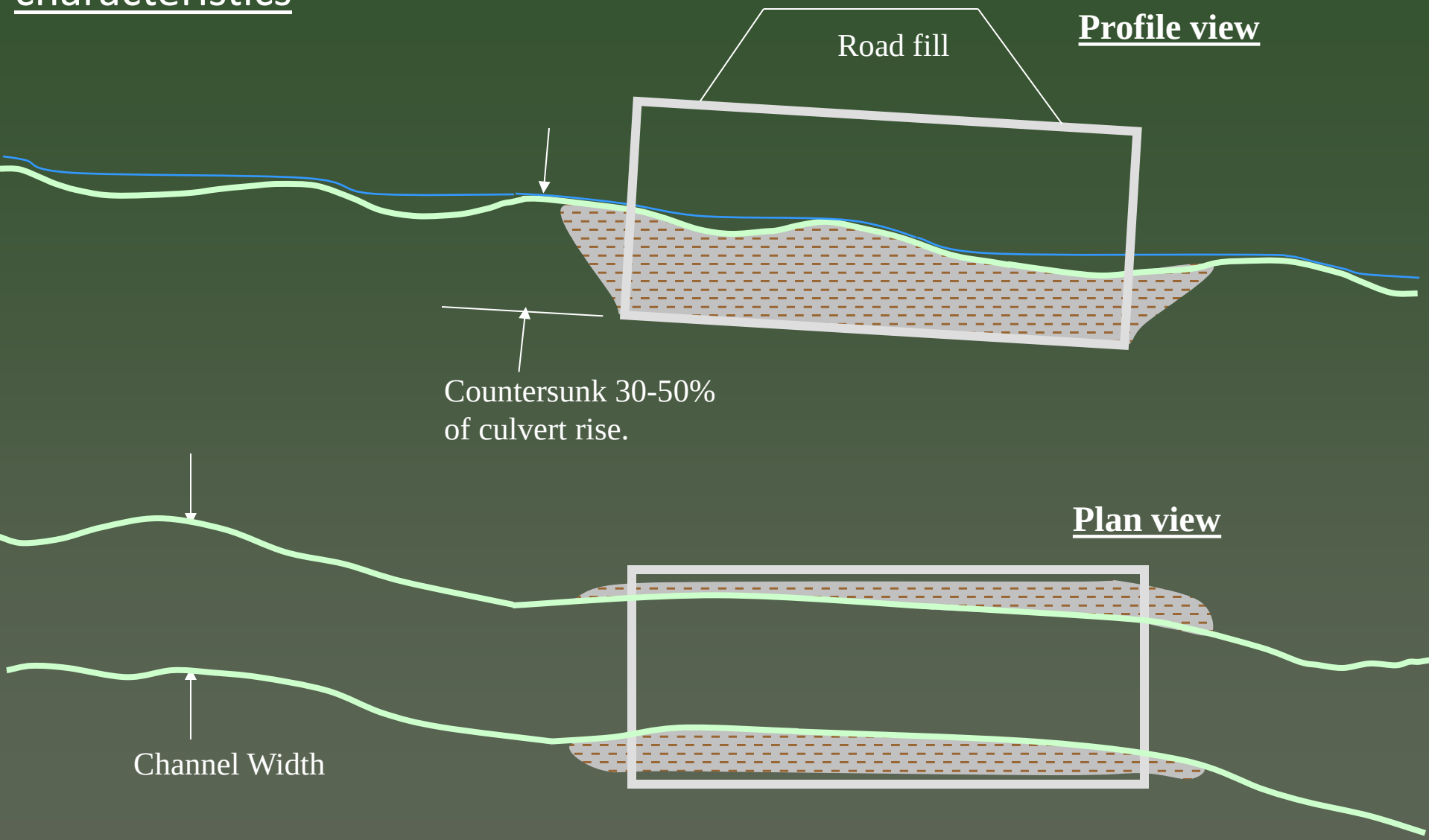
Design approach is to “Simulate” adjacent natural channel

Premise: If fish can move through natural channel they can move through simulated channel in a culvert.

For success, these must be designed & implemented by those familiar with stream geomorphology

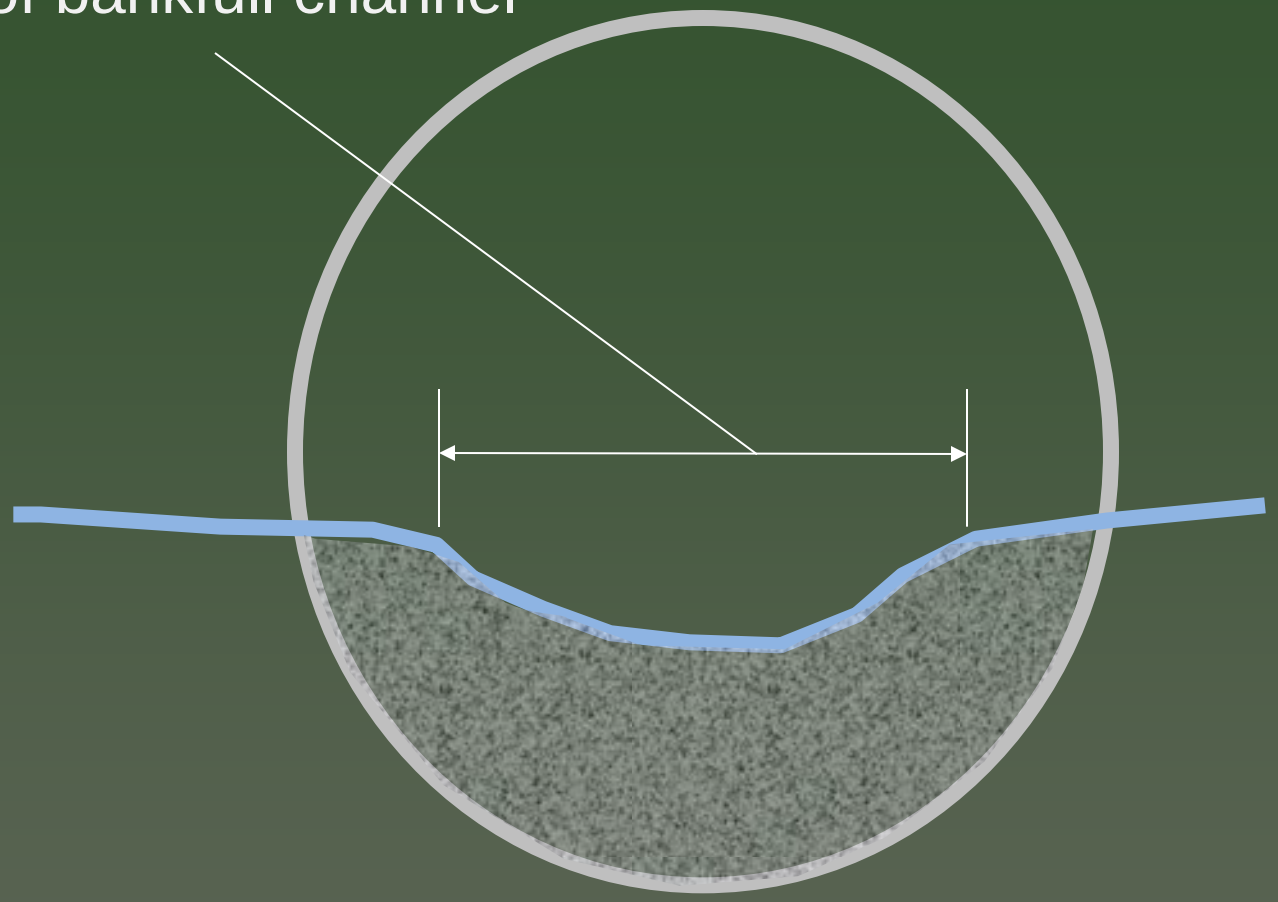
- Passage for all species & life stages
- Broadly applicable
- Eliminates depth & velocity design considerations
- Requires detailed engineering

Stream Simulation Culvert Design is consistent with natural channel characteristics



Slope, bedform, channel width & bed material

Width of bankfull channel



Cross-Section View

Flow isolated from hydraulically smooth culvert wall
Club Ck.
Width = 1.2Wch+2 ft
Slope = 6.8%
← Good — flood — width →
Natural streambed
Dry bank at most flows
Low velocity margin

Stream Simulation Design Procedure

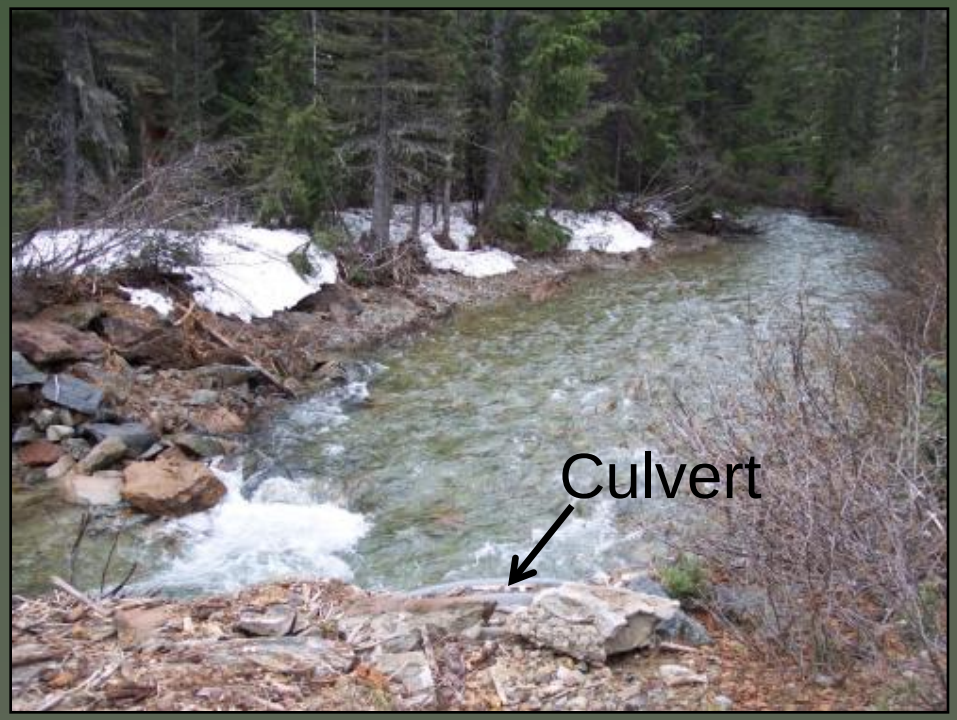
1. Determine suitability of the site for a design approach .
2. Determine major characteristics of natural channel; width, slope, floodplain utilization, bed form and bed composition
3. Plan any needed stream profile adjustment (replacement culverts).
4. Design the culvert; dimensions, slope, burial.
5. Design the streambed through the culvert and project area (materials and configuration)

Determining Site Suitability:

small, stable, moderately confined channels with limited need for profile adjustment

Guidance:
“Small”:
Bankfull width < 15 ft

“small” (BFW ~ 10 ft)



“not small” (BFW ~ 60 ft)
Note the stream has cut around the culvert

“Moderately confined”:
Flood utilization ratio < 3)

Confined
(FUR ~ 1)

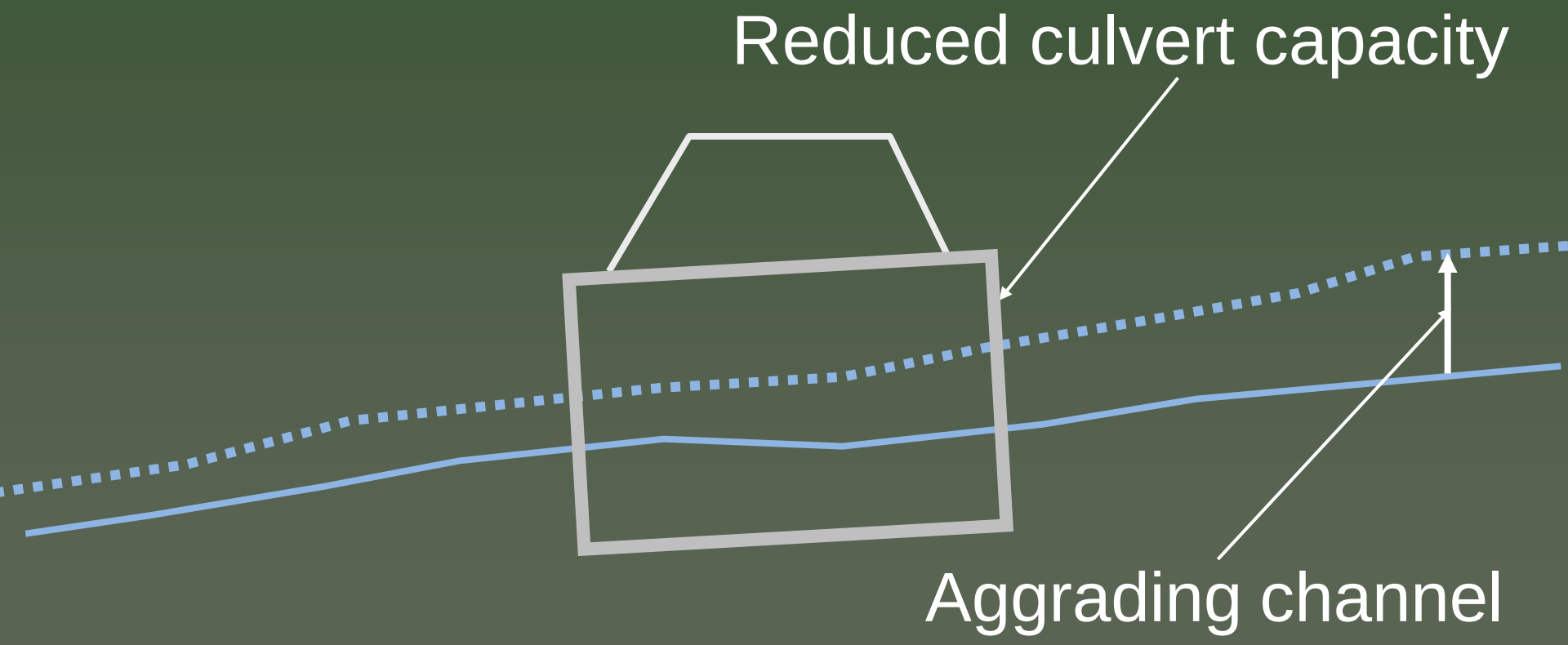
Unconfined
(FUR = ‘huge’)

Moderately confined

(FUR ~ 2)

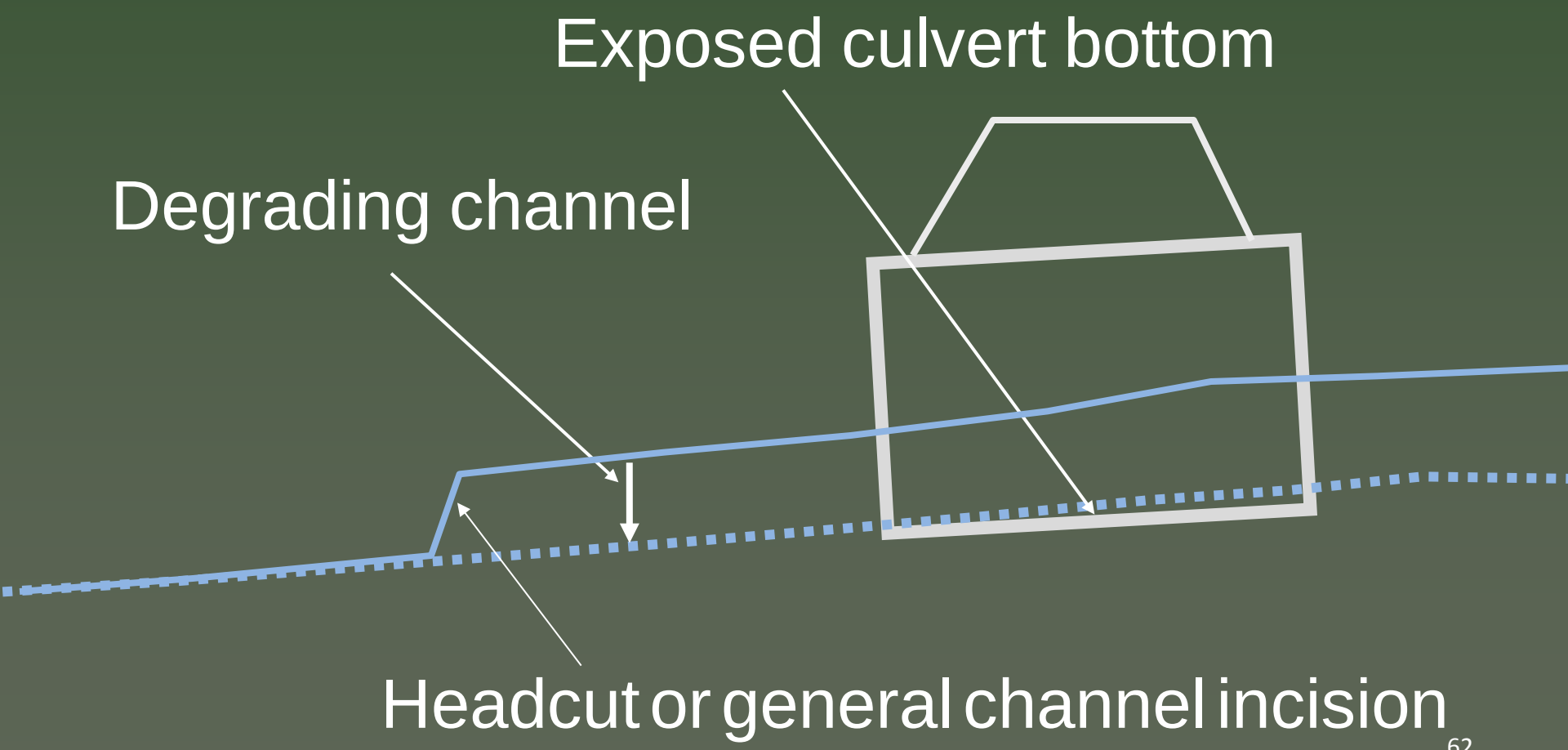
Channel must be in equilibrium

within the culvert's capacity to accommodate change



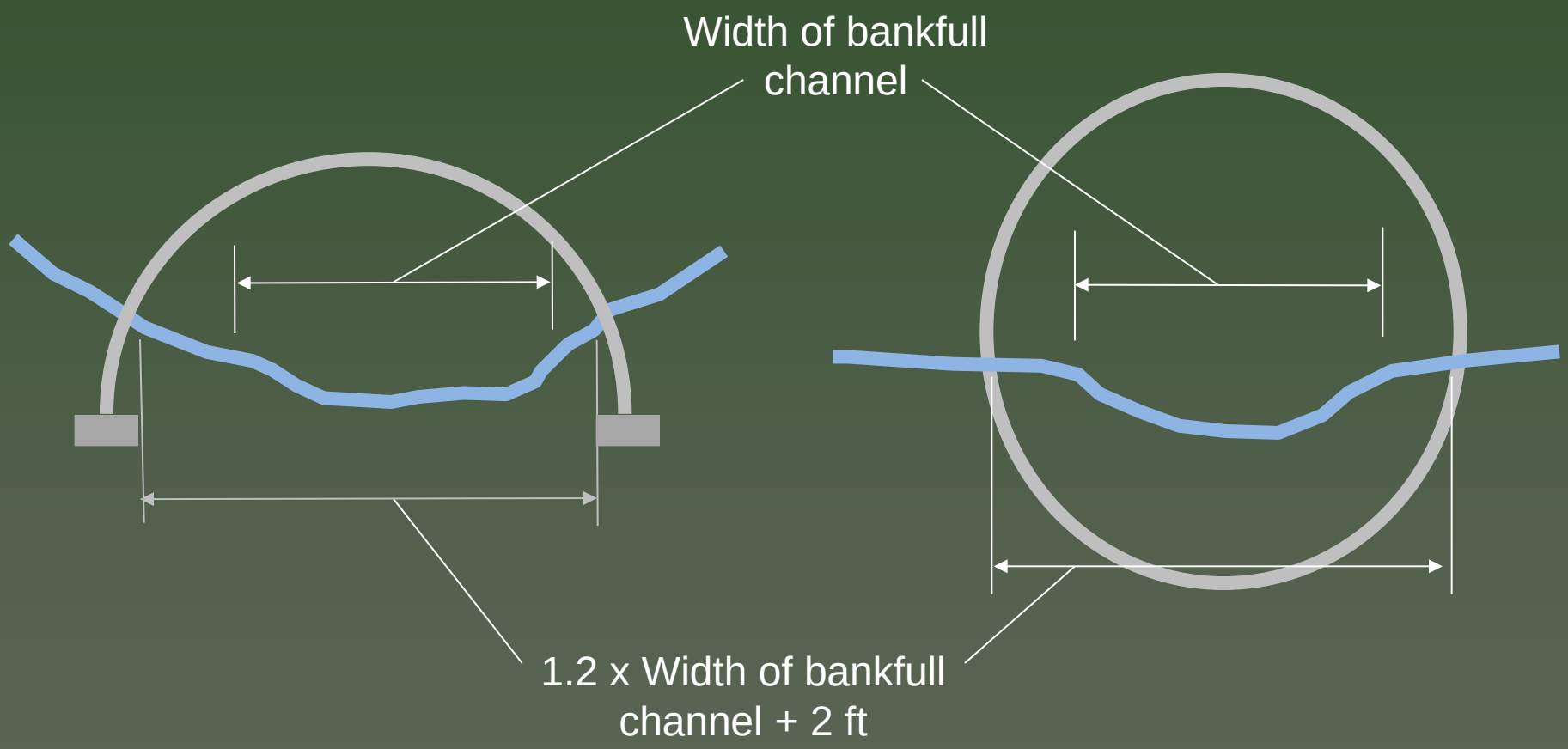
Channel must be in equilibrium

within the culvert's capacity to accommodate change

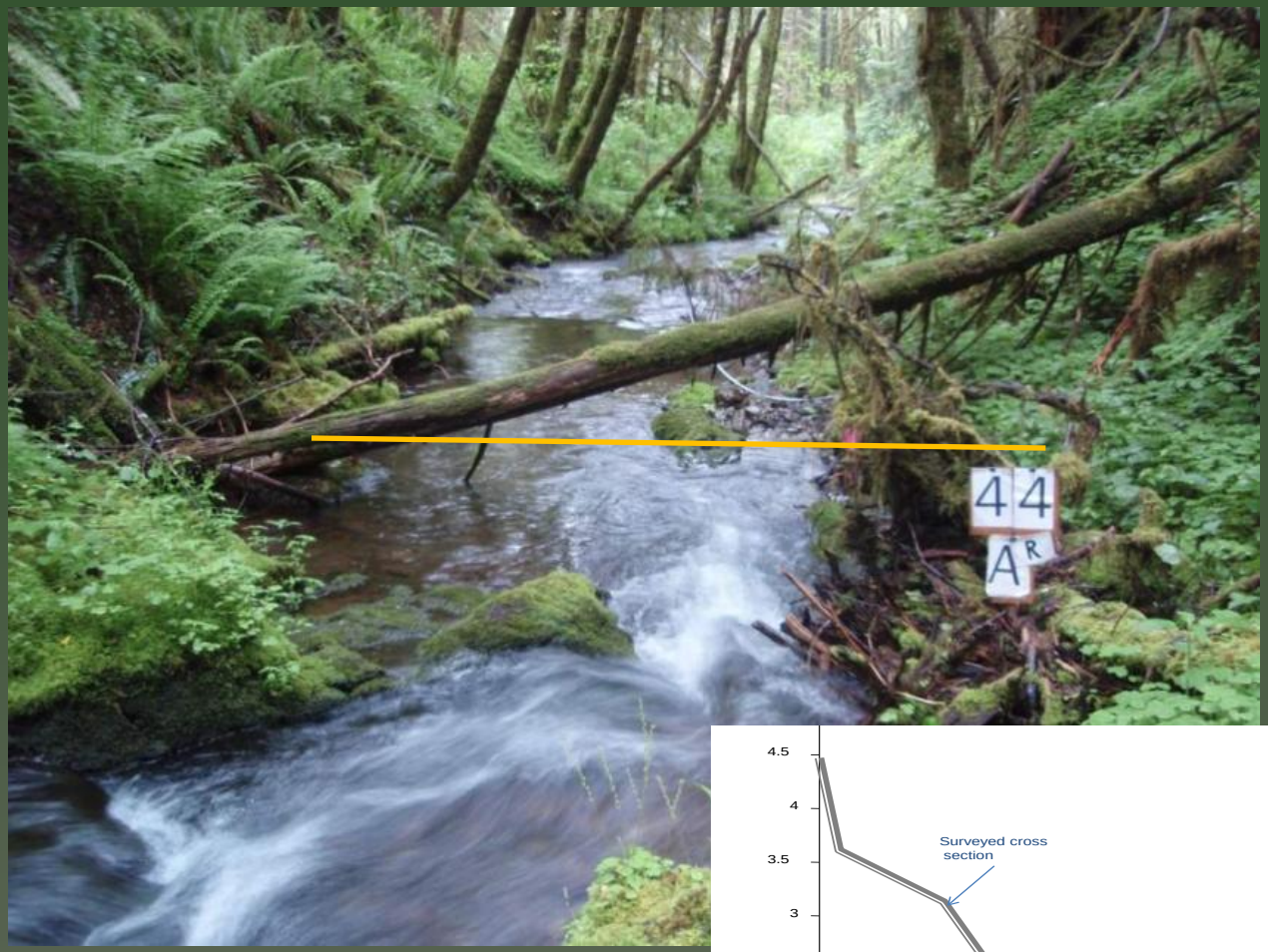


Headcut

Stream Simulation Width Criteria



Significant inlet contraction or long culvert may require a larger pipe size.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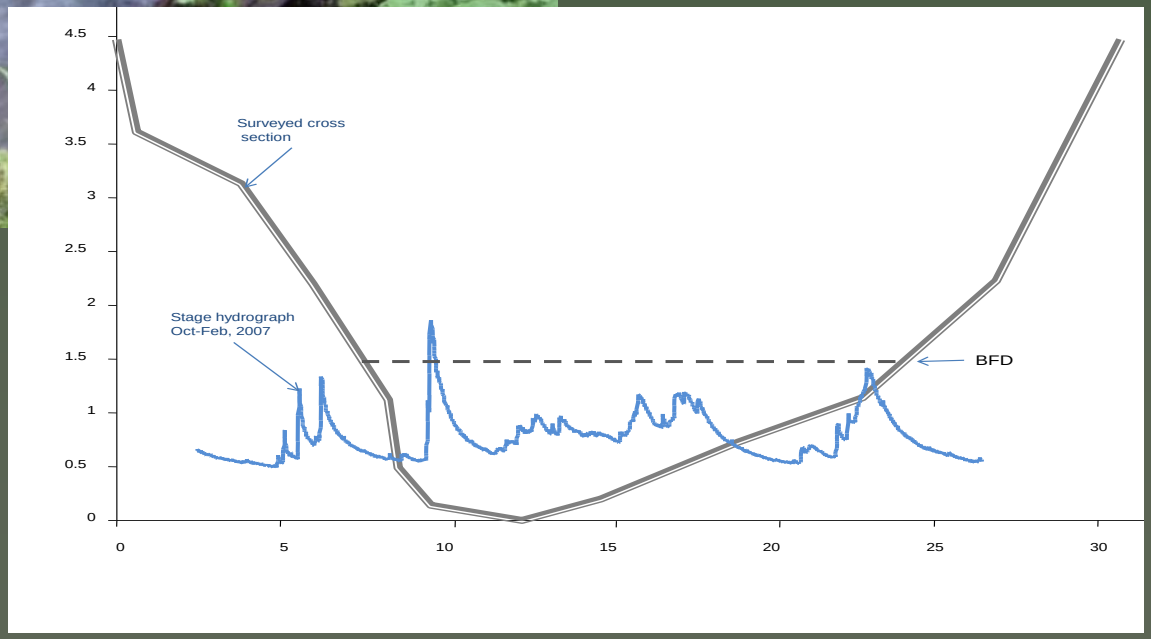
AR


4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
Surveyed cross section
Stage hydrograph Oct-Feb, 2007
BFD

Lake Creek at bankfull flow

Identifying cross-sections:

Representative

Stable

Naturally formed by fluvial processes

Free-flowing (not backwatered)

Sharp bends & unusually shaped cross-sections

Debris accumulations

Beaver activity

Depositional features

Infrastructure or channel manipulation

Bankfull Indicators:

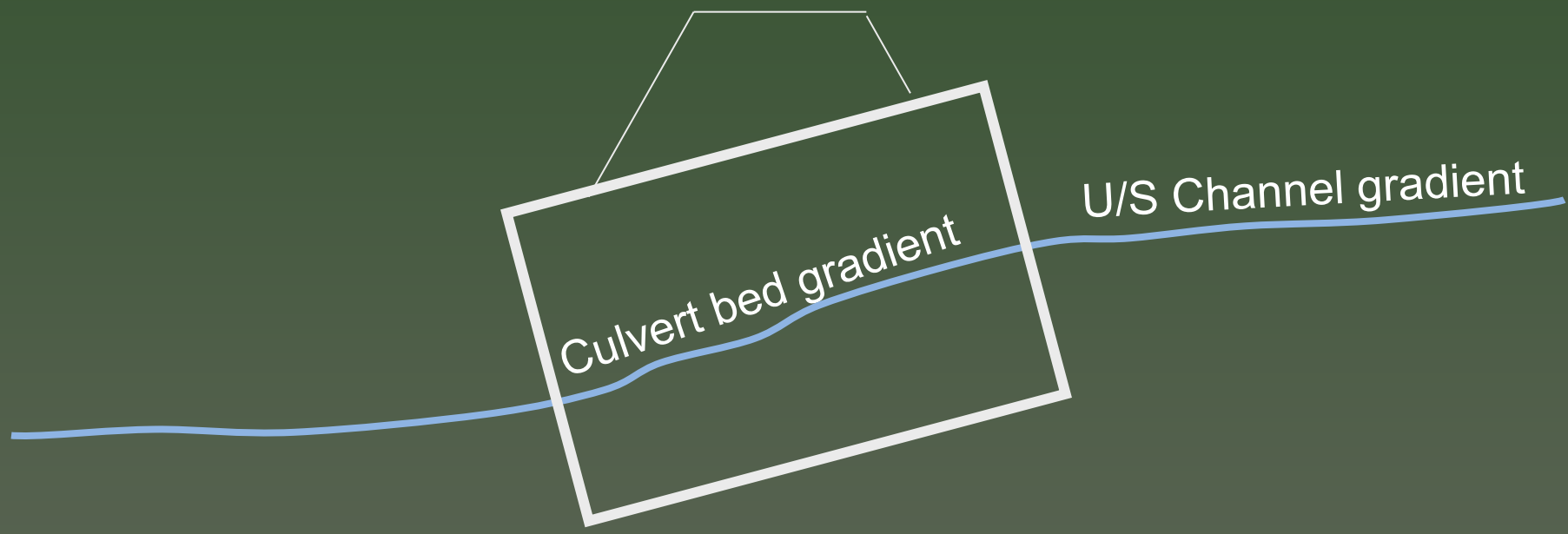
- Perennial vegetation
- Bank geometry
- Bank texture

Bankfull indicators: vegetation and bank geometry

Bankfull indicator: bank texture

Slope Ratio

$$\text{Slope ratio} = \frac{\text{Culvert bed gradient}}{\text{U/S Channel gradient}}$$



Slope ratio must be less than or equal to 1.25.

Slope ratios > 1.25 represent a change in channel type,
not simulation of the adjoining channel.

Culverts sloped > 1.25 x channel slope fail to simulate the adjacent channel

Gradient = 0.5%

Gradient = 3%

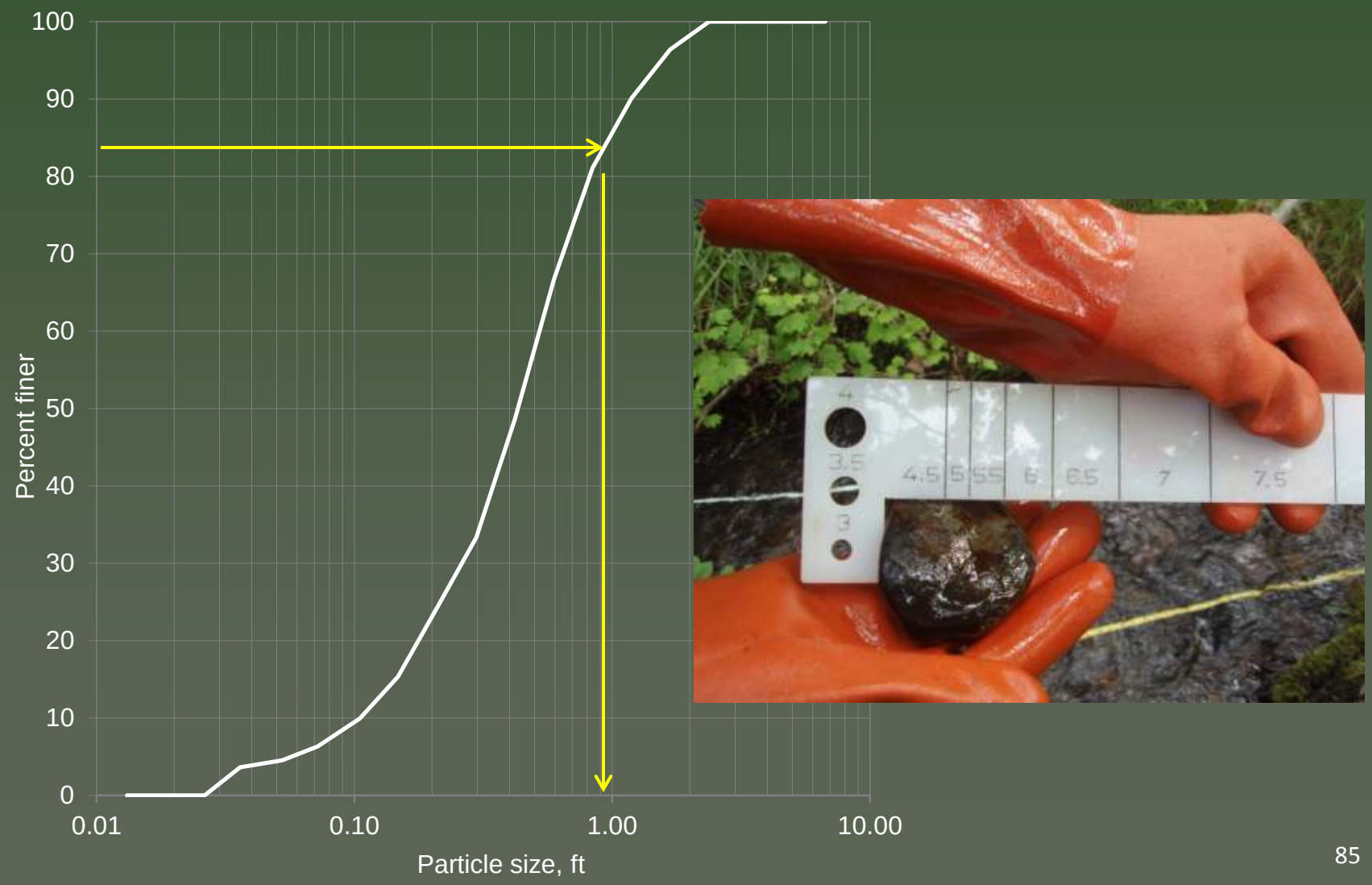
Stream Simulation Bed Design

- If the channel is in equilibrium and slope is maintained by sediment, use natural channel gradation to duplicate in culvert.
  - Pebble count of natural channel to determine $D_{84.}$
  - Use D_{84} to size designed bed.
  - Increase size distribution for
    - Inlet contraction
    - Increased slope
    - If the channel is controlled by debris

Inlet Contraction

Wood Controlled

Sediment assessment



Bed Material Size

Recommended size ratios:

$D_{84}/D_{100} = 0.4$

$D_{84}/D_{50} = 2.5$

$D_{84}/D_{16} = 8.0$

5 to 10% fines

For example,

if D_{84} = 1.0 feet then:

D_{16} = 0.13 ft
D_{50} = 0.4
D_{84} = 1.0
D_{100} = 2.5

Or

16% small gravel and fines
34% gravel
50% cobble and boulder

DOT 9-03.11Streambed Aggregates

(1) Streambed Sediment – 2.5” minus

(2) Streambed Cobbles

A. 1.5 – 4”

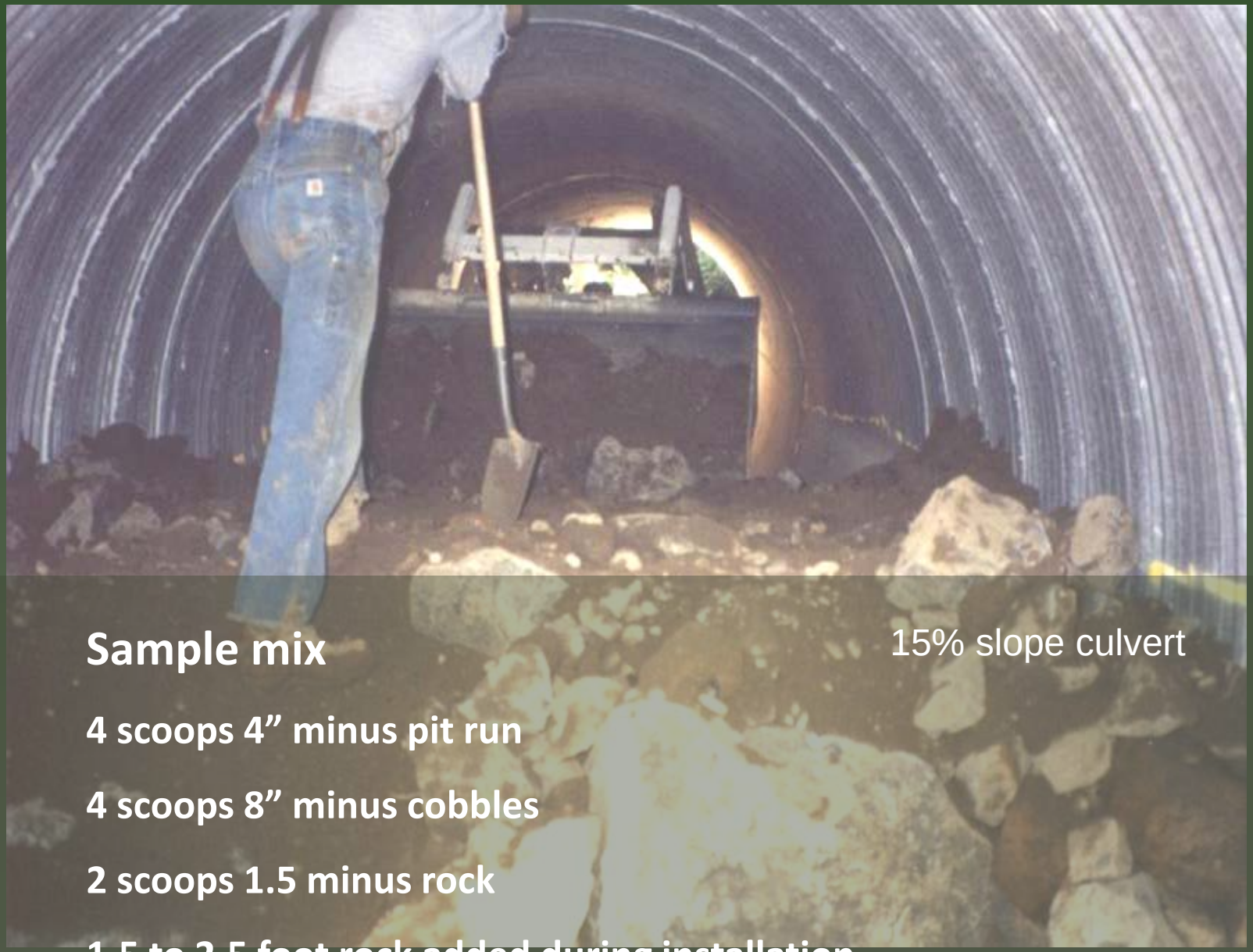
B. 2 – 6”

C. 3 – 8”

D. 4 – 10”

E. 5 – 12”

(3) Habitat Boulders; 1 – 5 ft (one to six man)



15% slope culvert

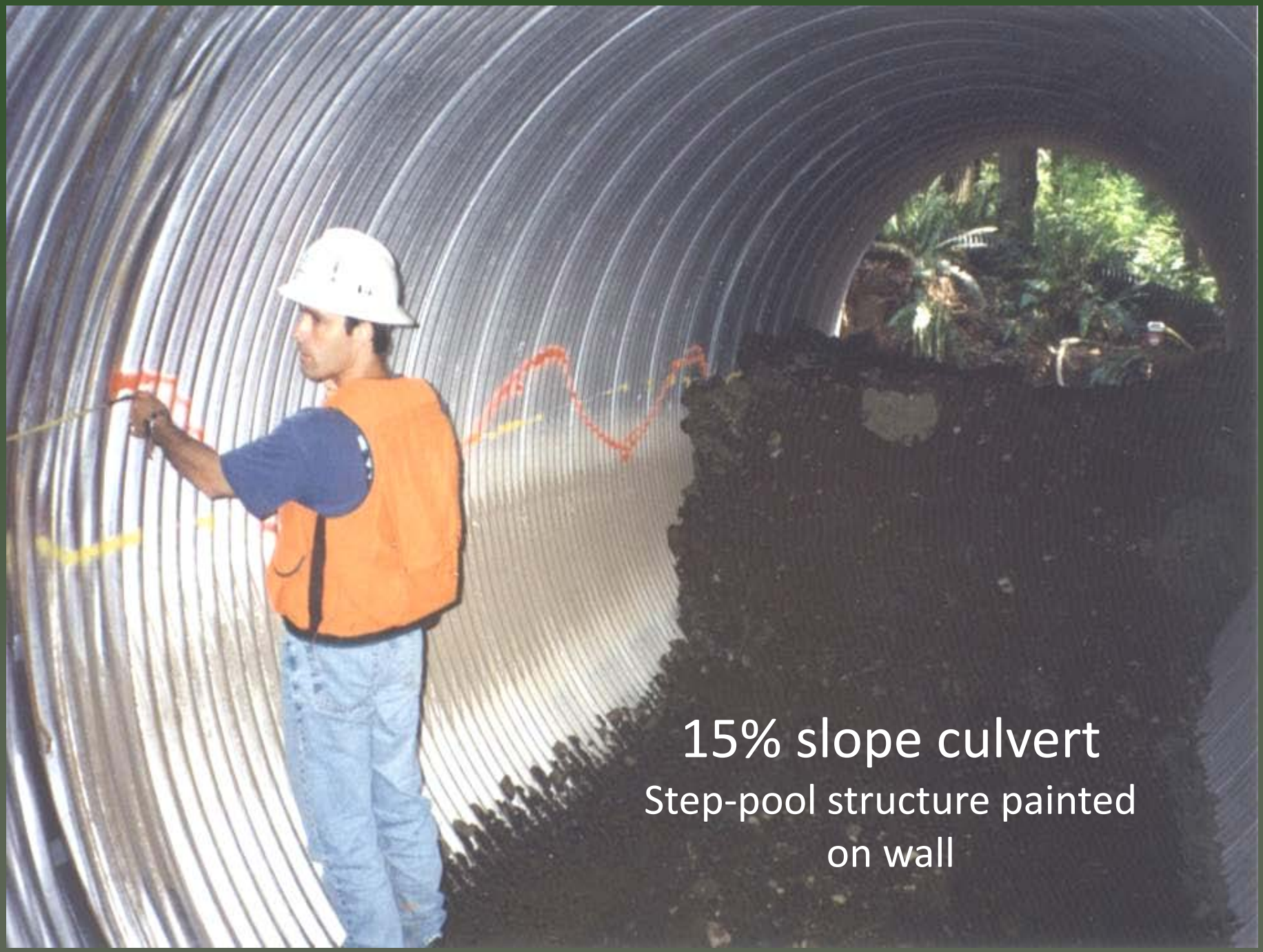
Sample mix

4 scoops 4” minus pit run

4 scoops 8” minus cobbles

2 scoops 1.5 minus rock

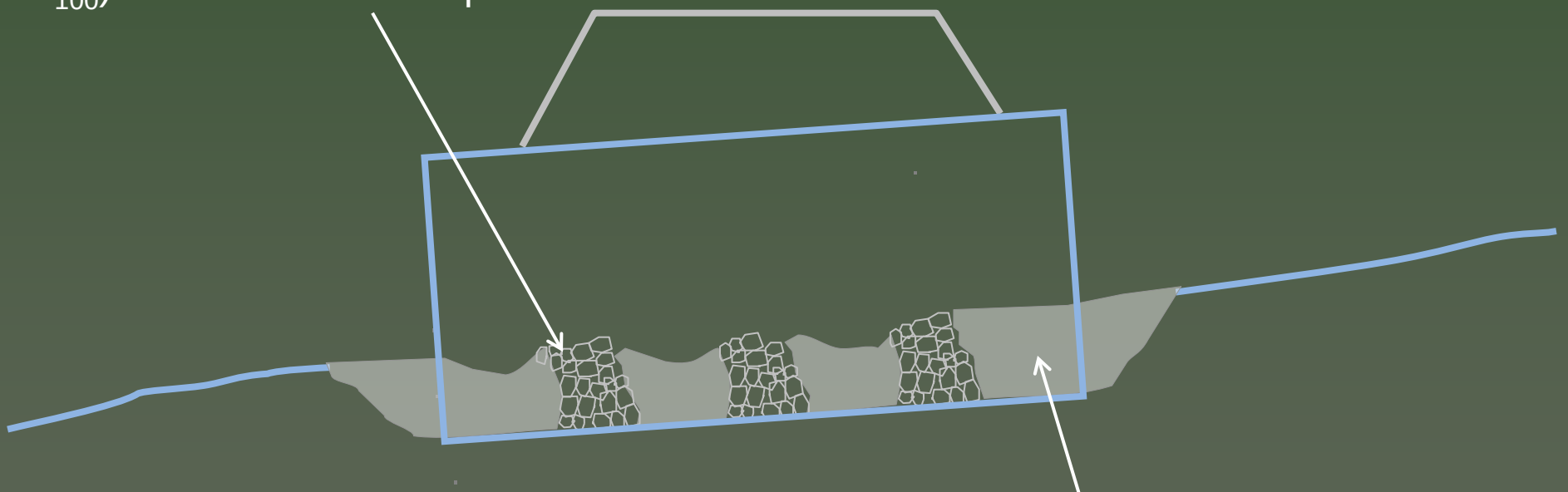
1.5 to 2.5 foot rock added during installation


15% slope culvert
Step-pool structure painted
on wall

Low Slope Stream Simulation

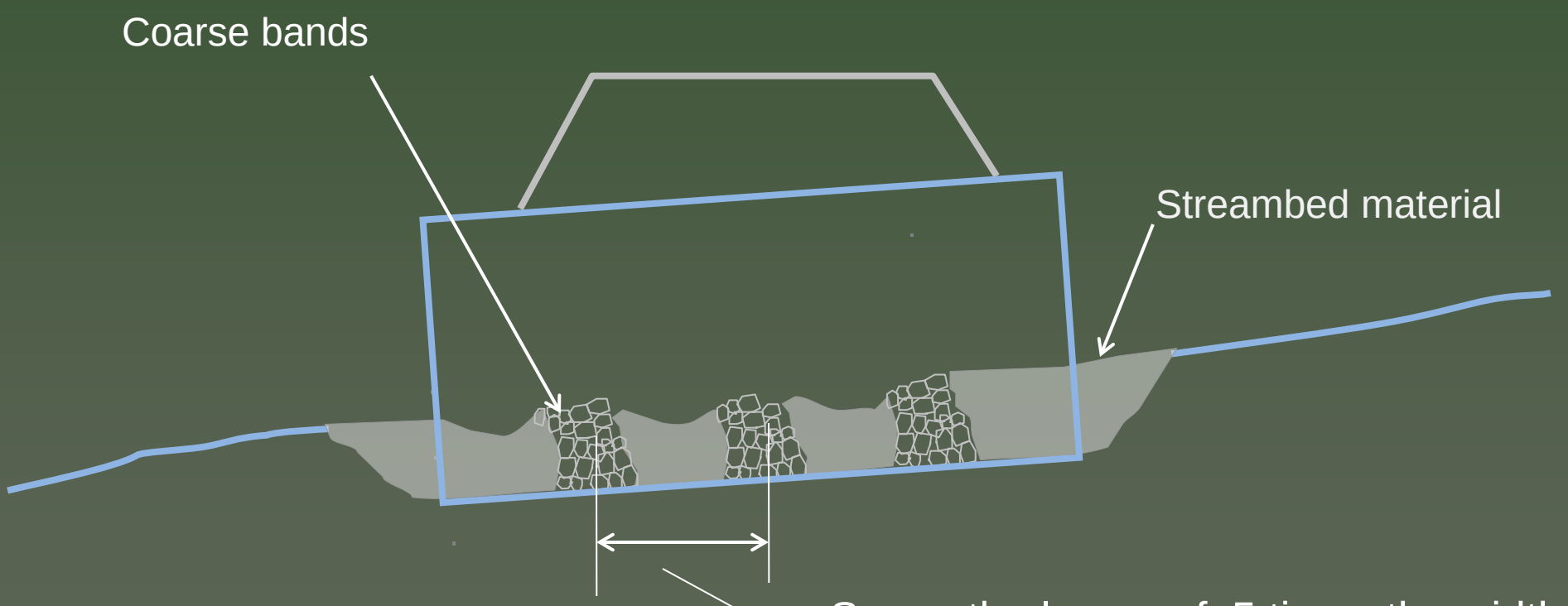
Bed Slope < 4.0%

Well-graded coarse bands (D_{100} = up to 2+ times bed D_{100}) to control initial shape



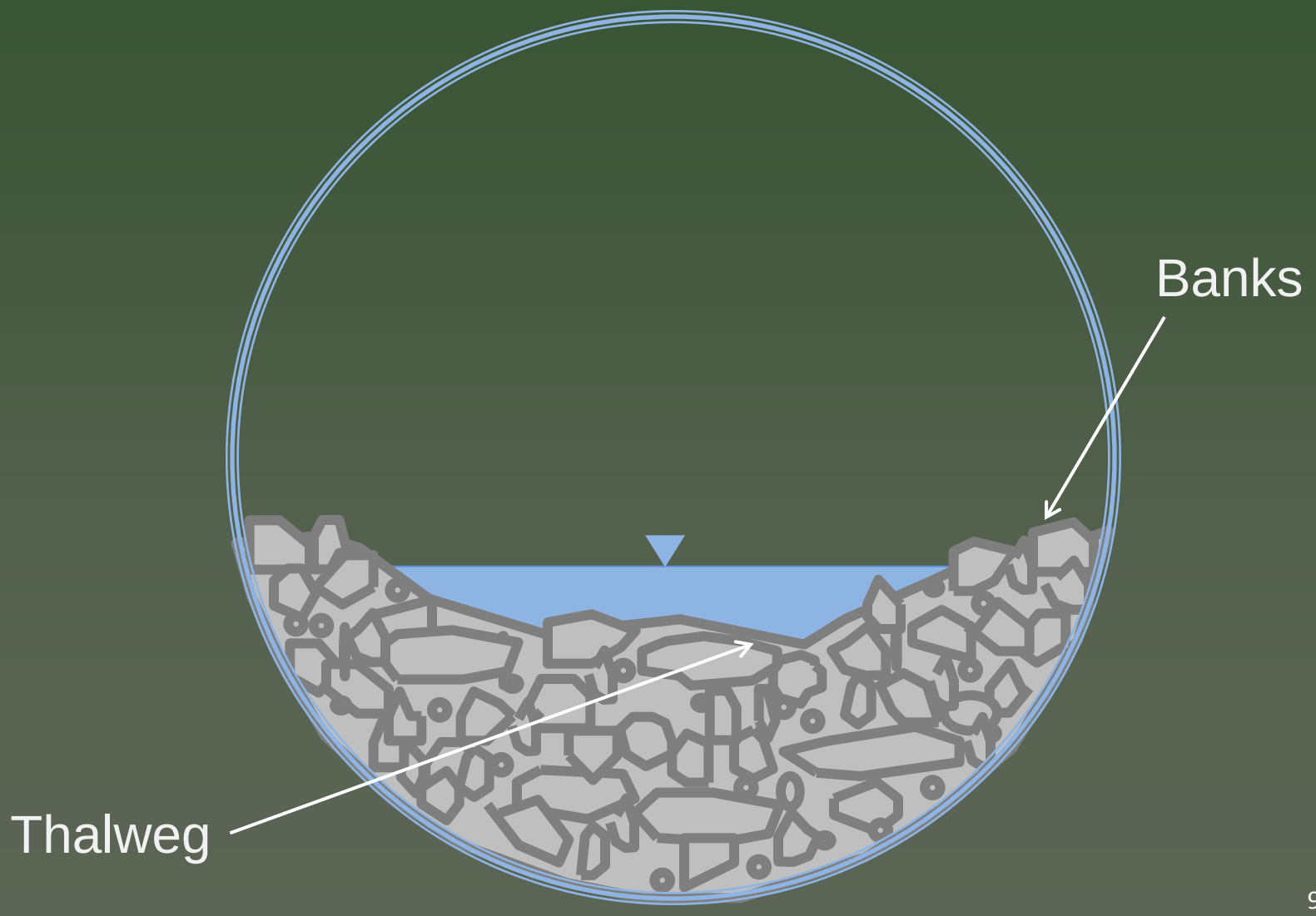
Well-graded, not stratified, native streambed sediment mix

Coarse Bands



Space the lesser of: 5 times the width of channel or max. vertical difference between crests < 0.8 feet

Crest of coarse bands have a streambed shape



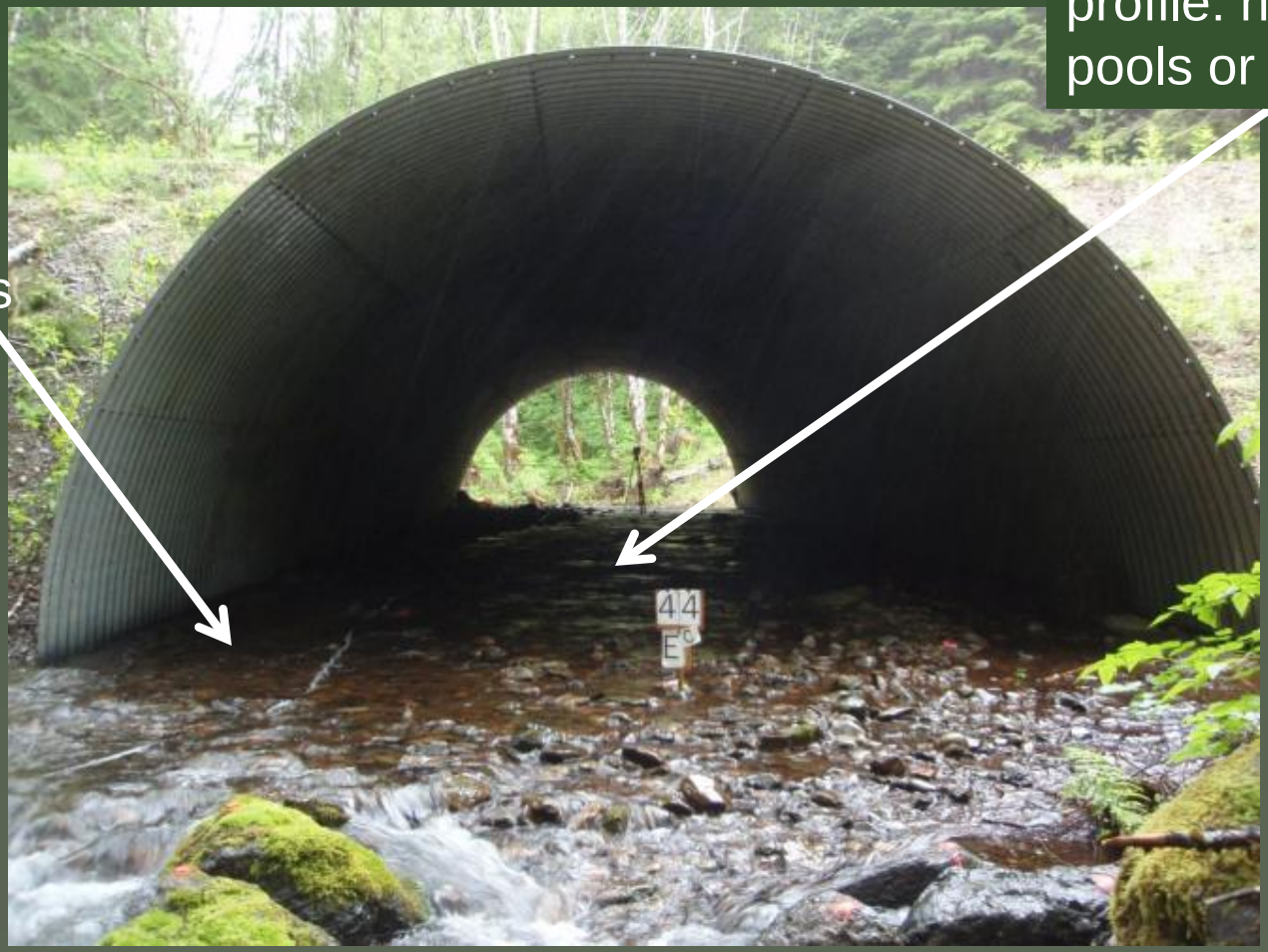
Low slope without bands

44
AR

Channel structure doesn't form on its own inside a culvert: you have to build it in.

Flat cross section and profile: no thalweg or pools or riffles

No banks

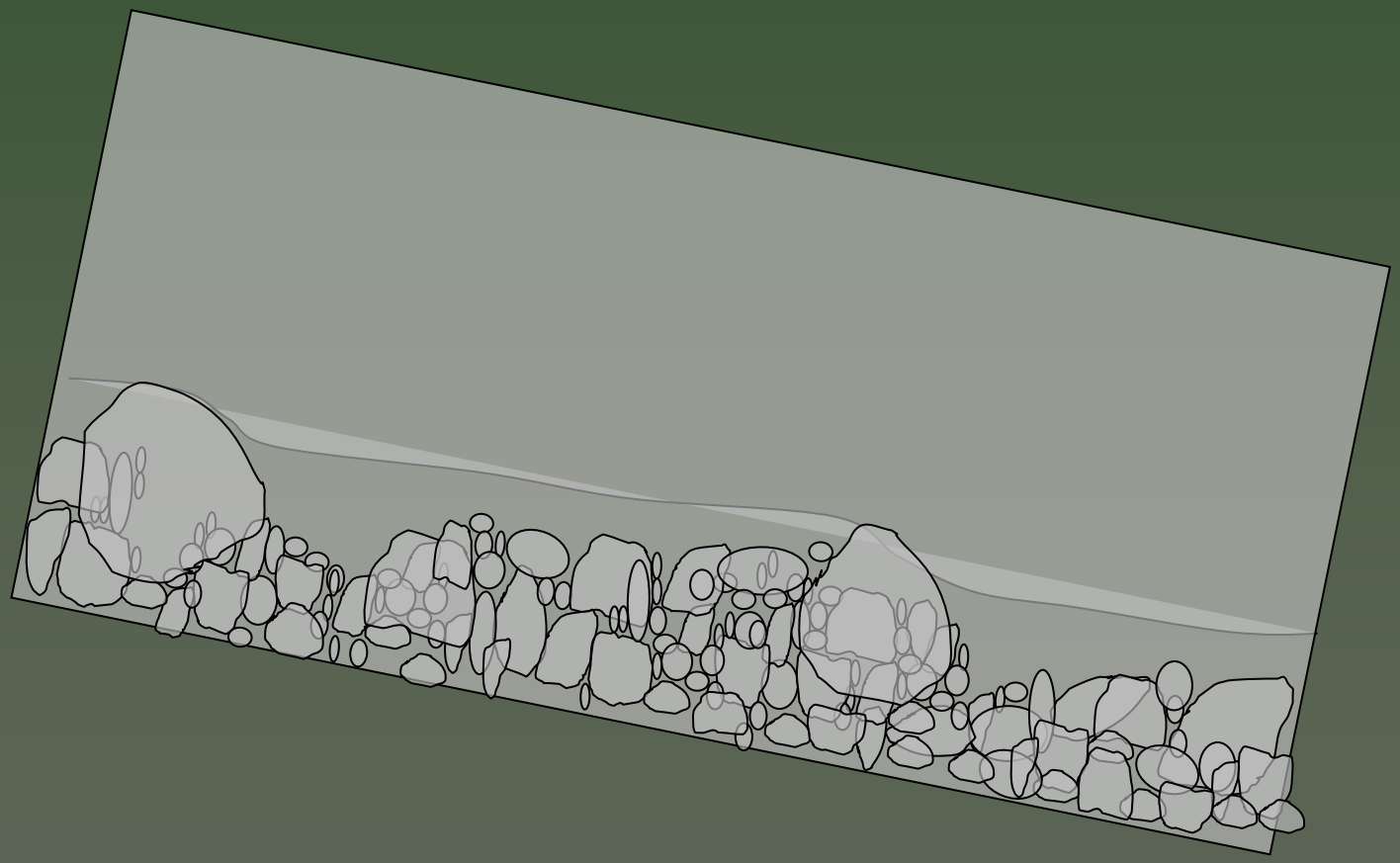


Darby Ck. rock bands just after construction

Darby Ck. rock band during first flood. Band has altered but flow is centered and a pool has formed downstream of it.

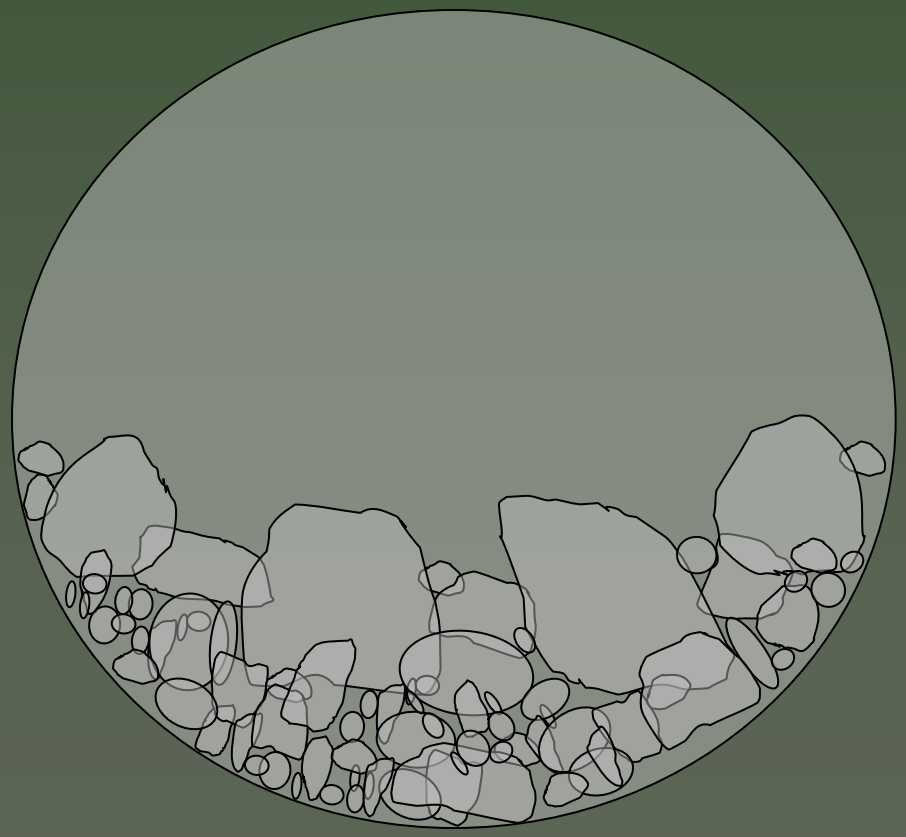
High Slope Stream Simulation

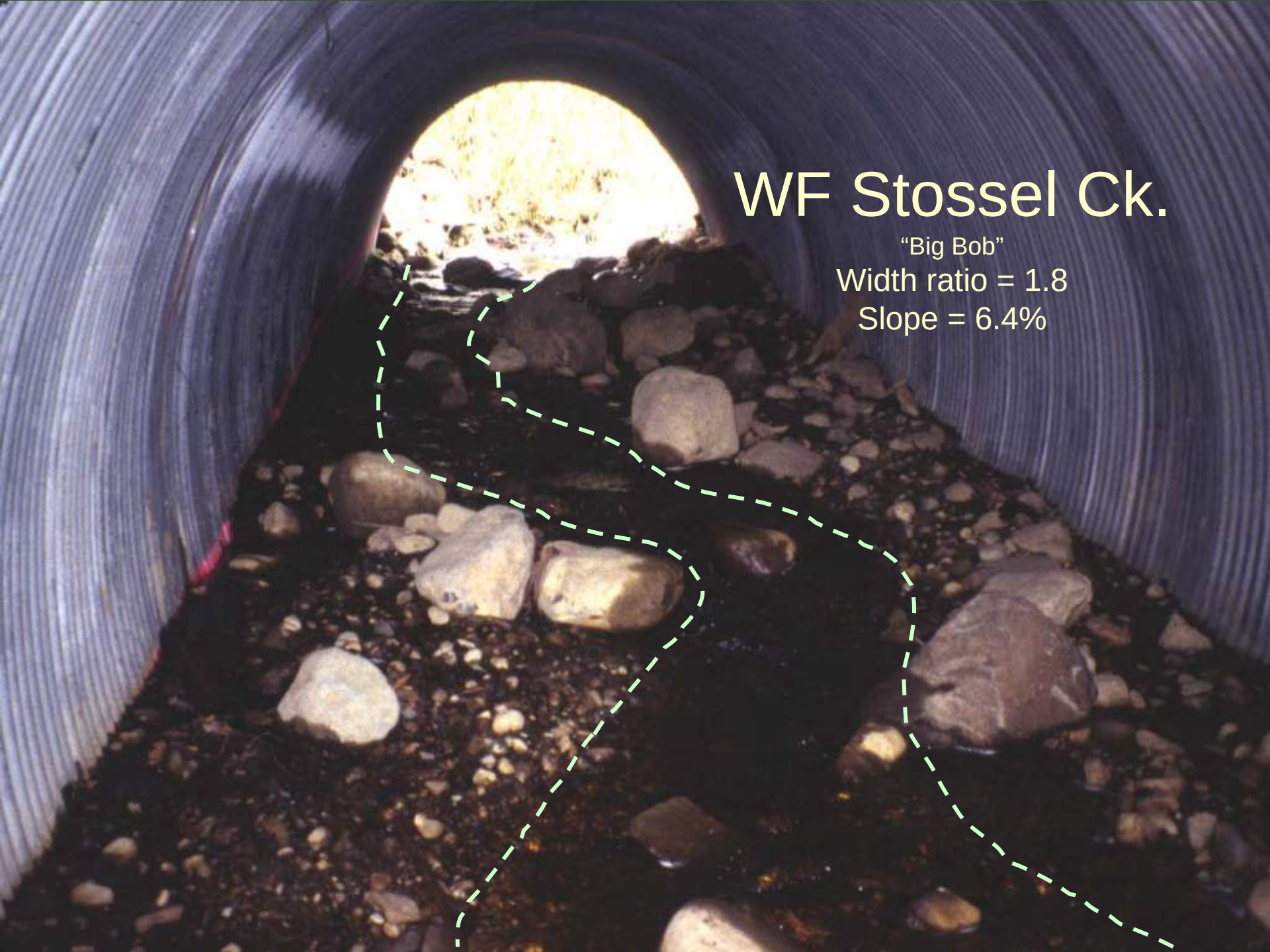
Bed Slope > 4.0%



High Slope Stream Simulation

Bed Slope > 4.0%



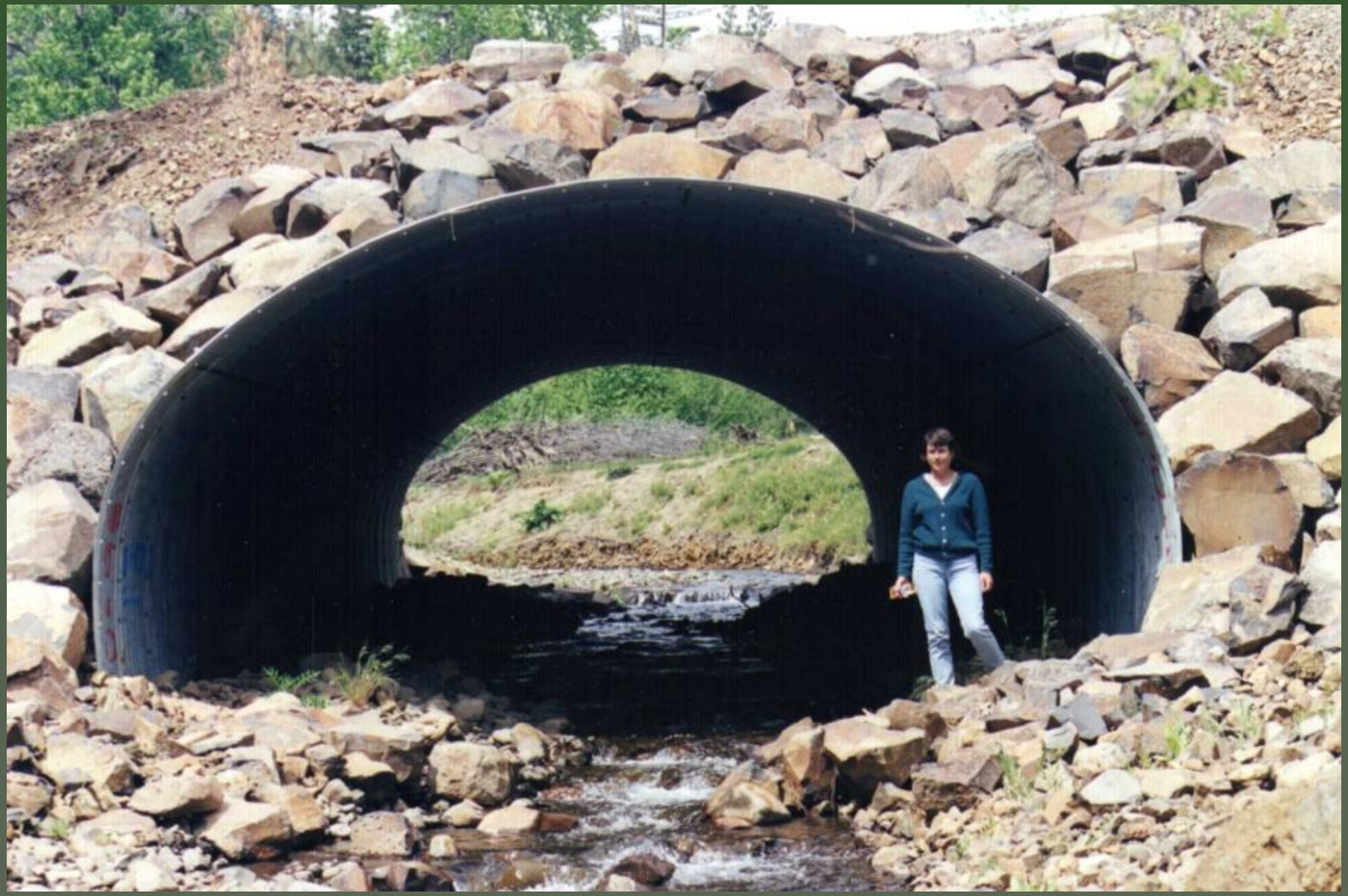

WF Stossel Ck.
"Big Bob"
Width ratio = 1.8
Slope = 6.4%

No channel features built into bed.
Slope = 7%

10 Mile Ck.

Xtrib. Sherman Ck.
Culvert bed slope 14%
10 feet diameter
Elevated flood flow

Xtrib Sherman Ck.
Culvert bed slope 11%
13 ft diameter
At flood flow



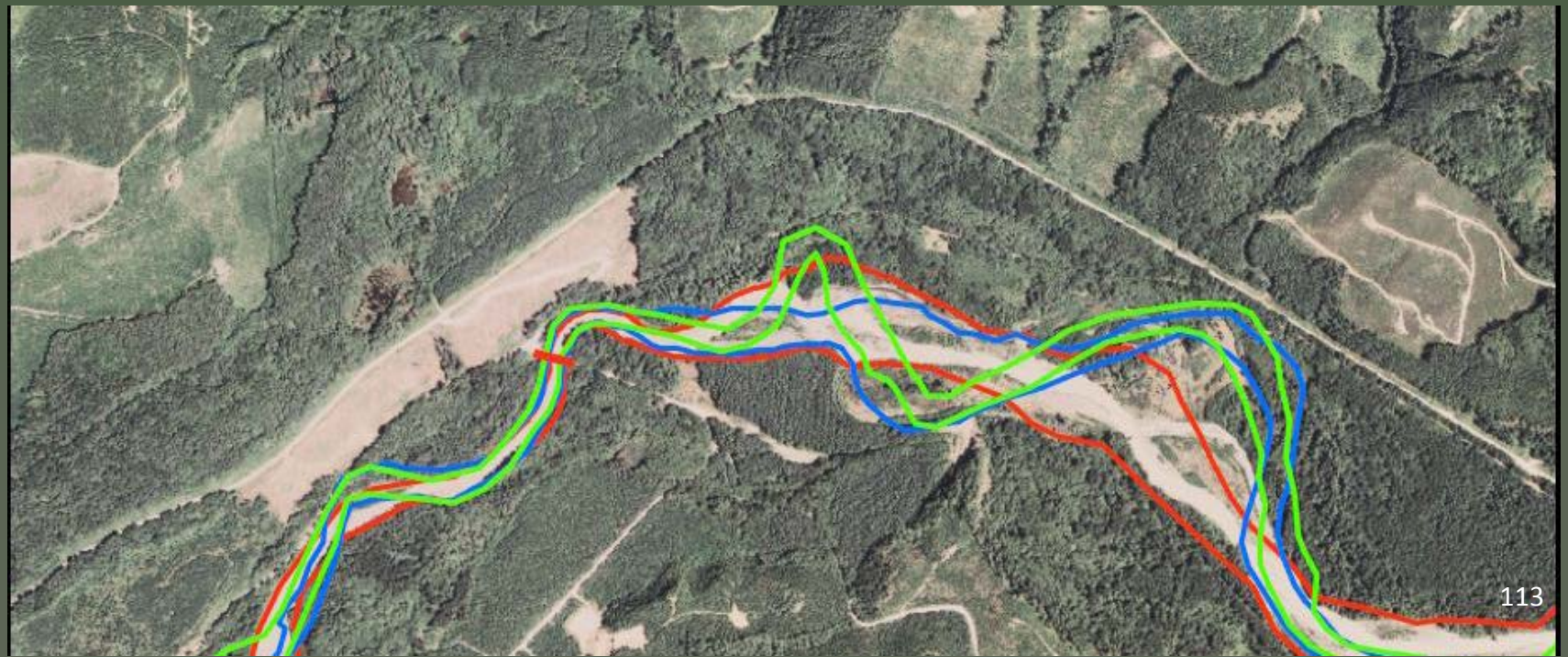
Bridge design for habitat protection

Bridge design goals:

1. Prevent excessive backwater rise during floods.
2. Prevent or limit local scour and coarsening of the stream substrate.
3. Allow free passage of expected woody debris.
4. Allow natural evolution of the channel planform and longitudinal profile
5. Allow continued down-valley flow of water on the floodplain
6. Reduce the risk from catastrophic floods

Reach analysis for bridges

- Describes the geomorphic setting; stream geometry and processes
- Provides the basis for proper bridge design to meet biological performance standards and avoid impacts to fish life
- **Scalable** from none required to major analysis
- **Phased** to match funding and design cycles



Recommended level for reach analysis

Level	Analysis Type	Bankfull Width, ft	Floodplain Utilization Ratio	Stream Type	*Bridge Performance	Meander Migration
1	Limited local assessment	<15	<3	Transport	Excellent	Stable
2	Qualitative reach assessment	<15	<3	Transport	Good	Stable
3	Quantitative reach assessment	>15	>3	Response	Good to Poor	Migrating

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Larger river with a deteriorated but well-functioning bridge

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Small stream at a grade break with chronic sediment problems

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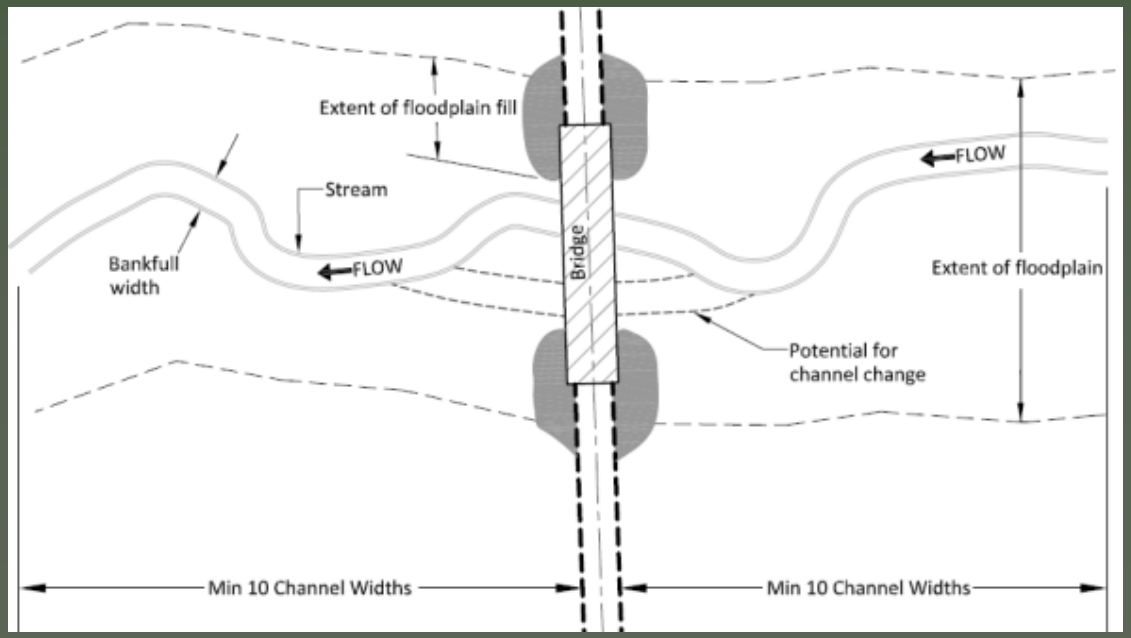
Level 1: **Limited local assessment**

- Minimum for planning, design and permitting
- Drawings that show existing and proposed bridge components
- Description of relevant natural and infrastructure features.



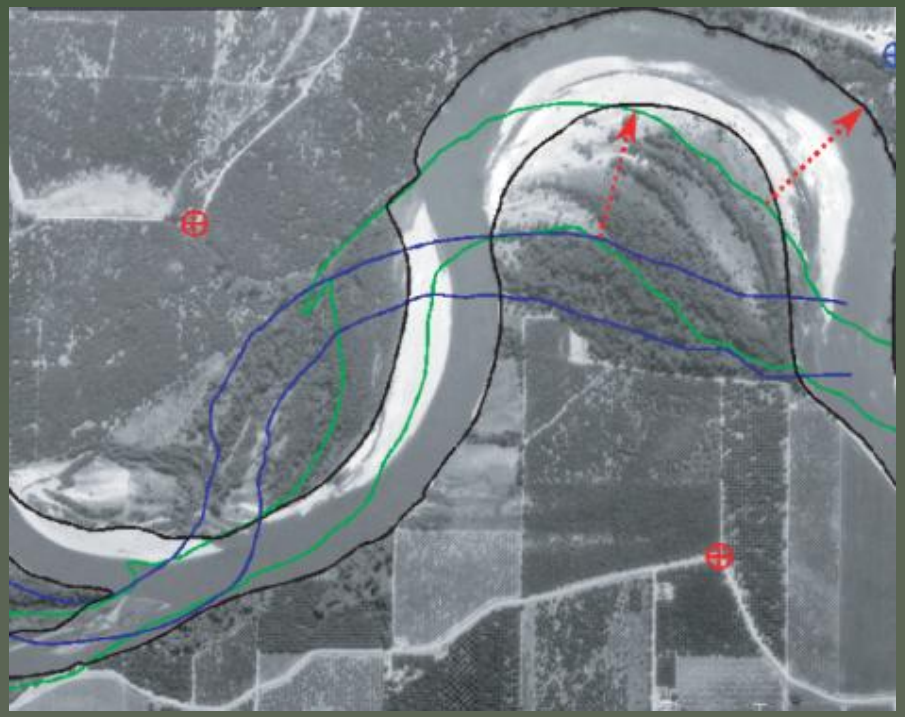
Level 1: **Limited local assessment**

Level 2: Qualitative reach assessment

- Low risk
- Reach easily understood
- Uses technical expertise and judgment of the design team
- Consists of basic description of the reach and
- Identifies and minimizes impacts to habitat

Level 3, Quantitative reach assessment

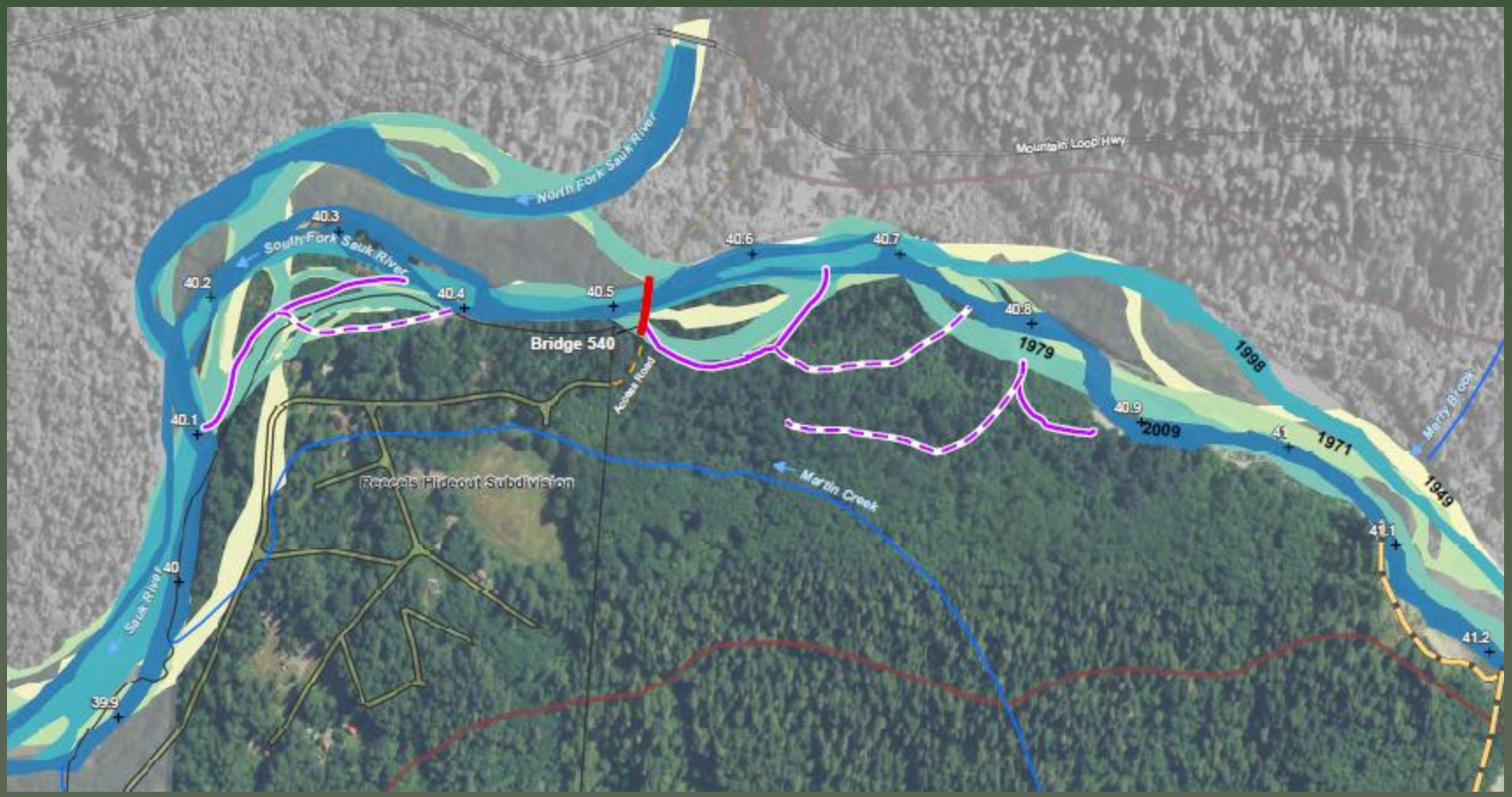
- High risk
- Detailed data collection
- Uses numerical analysis to model performance
- Results in design report



Lagasse, P. F., W. J. Spitz, et al. (2004). Handbook for predicting stream meander migration

Snohomish Co. Bridge 540, SF Sauk R.

Channel migration zone analysis
Alternative analysis



Anchor QEA, Bridge 540 Channel Migration Study

Bridge span sizing design sequence

This design method minimizes impacts to fish habitat, it is not a substitute for a thorough engineering evaluation to satisfy concerns about safety and to properly design bridge elements.

The method suggested here provides a starting point for hydraulic analysis and a basis for evaluating bridge designs.

Bridge span sizing design sequence

Stepwise approach to bridge design

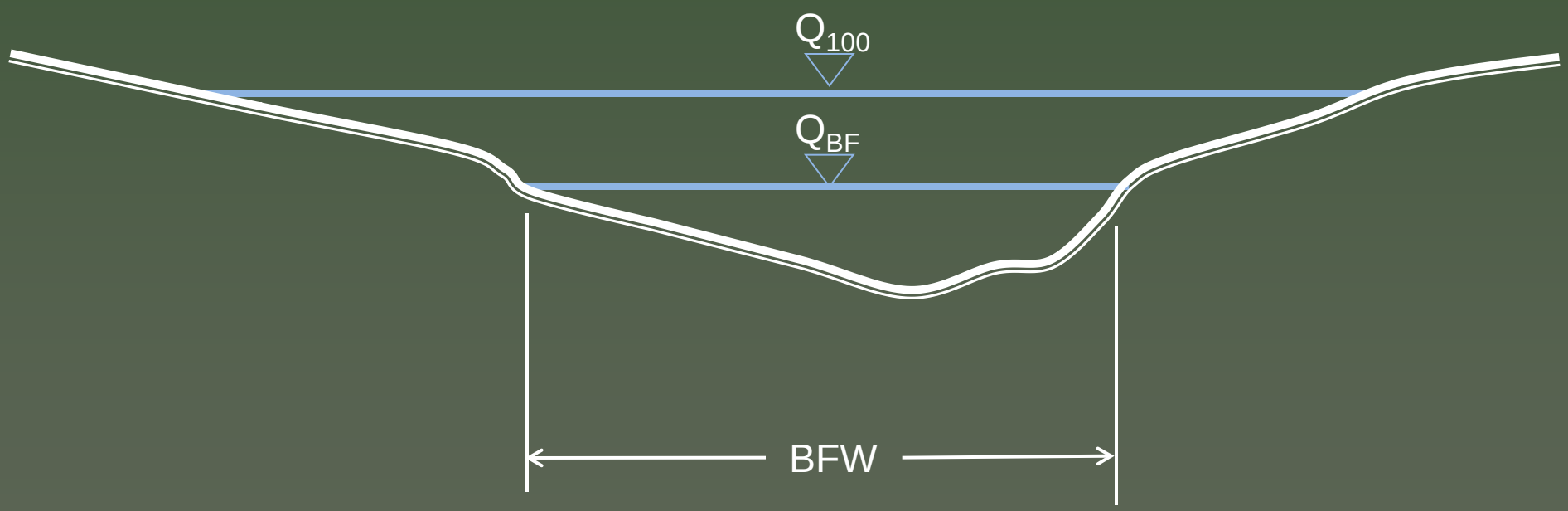
1. **Existing Bridge Condition,** if the old one was good enough, replace in kind
2. **Confined channels**, apply factor of safety for bank-to-bank span
3. **Floodplain and Overbank Areas**, use velocity ratio as a guide
4. **Lateral Channel Movement**, allow for meander migration
5. **Floodplain Management Regulations,** follow the rules
6. **Flood Control Features,** dikes define floodplain, mostly
7. **Other Infrastructure,** if you don't own it, you can't control it
8. **Height of Bridge, Approach Roads and Intermediate Piers**

Existing Bridge Condition, if the old one was good enough, replace in kind

1. The bridge has not received regular or annual maintenance for debris removal, ice removal, or sediment accumulation.
2. Countermeasures have not been required for approach, abutment or pier scour.
3. The channel in the vicinity of the bridge has not scoured below prevailing pool depth or the sediment coarsened relative to undisturbed natural conditions.
4. Channel migration has not been interrupted as identified in a time series of aerial photographs.

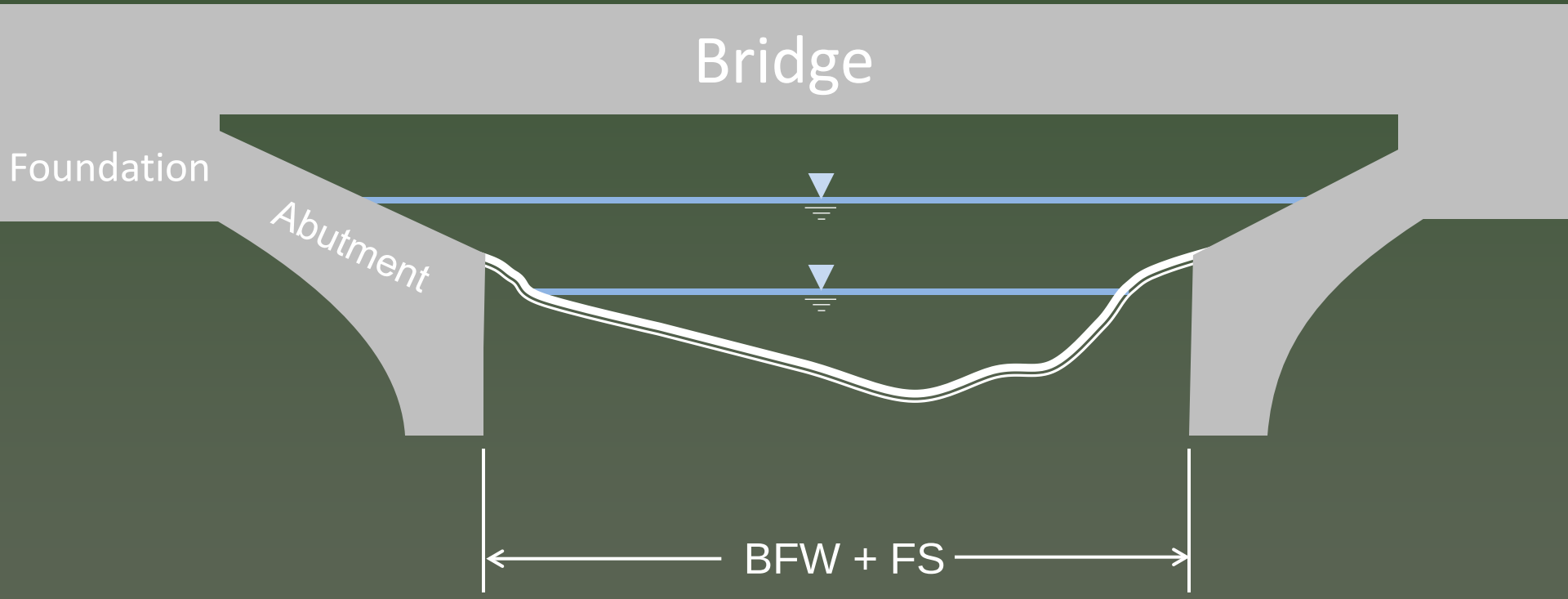
Confined channels

Bridges over confined channels can be based on BFW



FUR = 1.9

Bridges over confined channels can be based on BFW, but with a factor of safety.



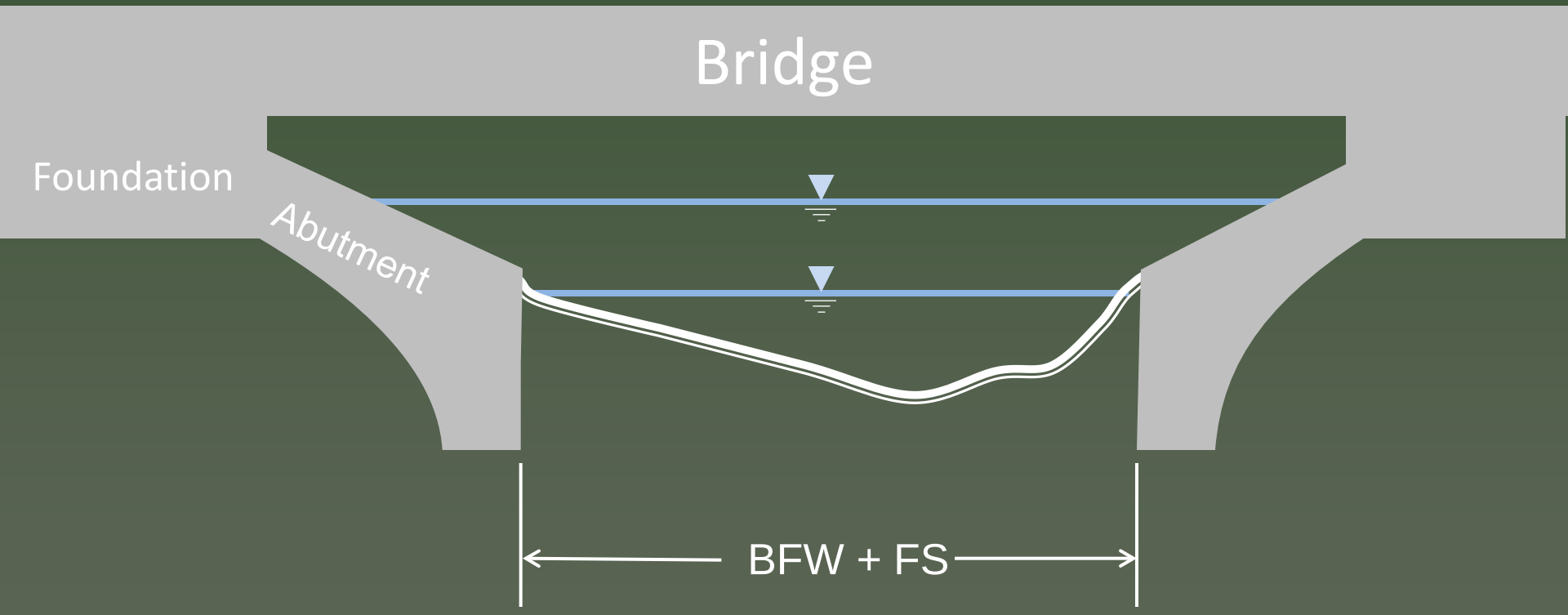
BFW as a bridge design parameter

- Condenses watershed conditions in one number
- Easily measured
- Has been used for 20 years to design WA culverts

Factor of safety as applied to crossings:

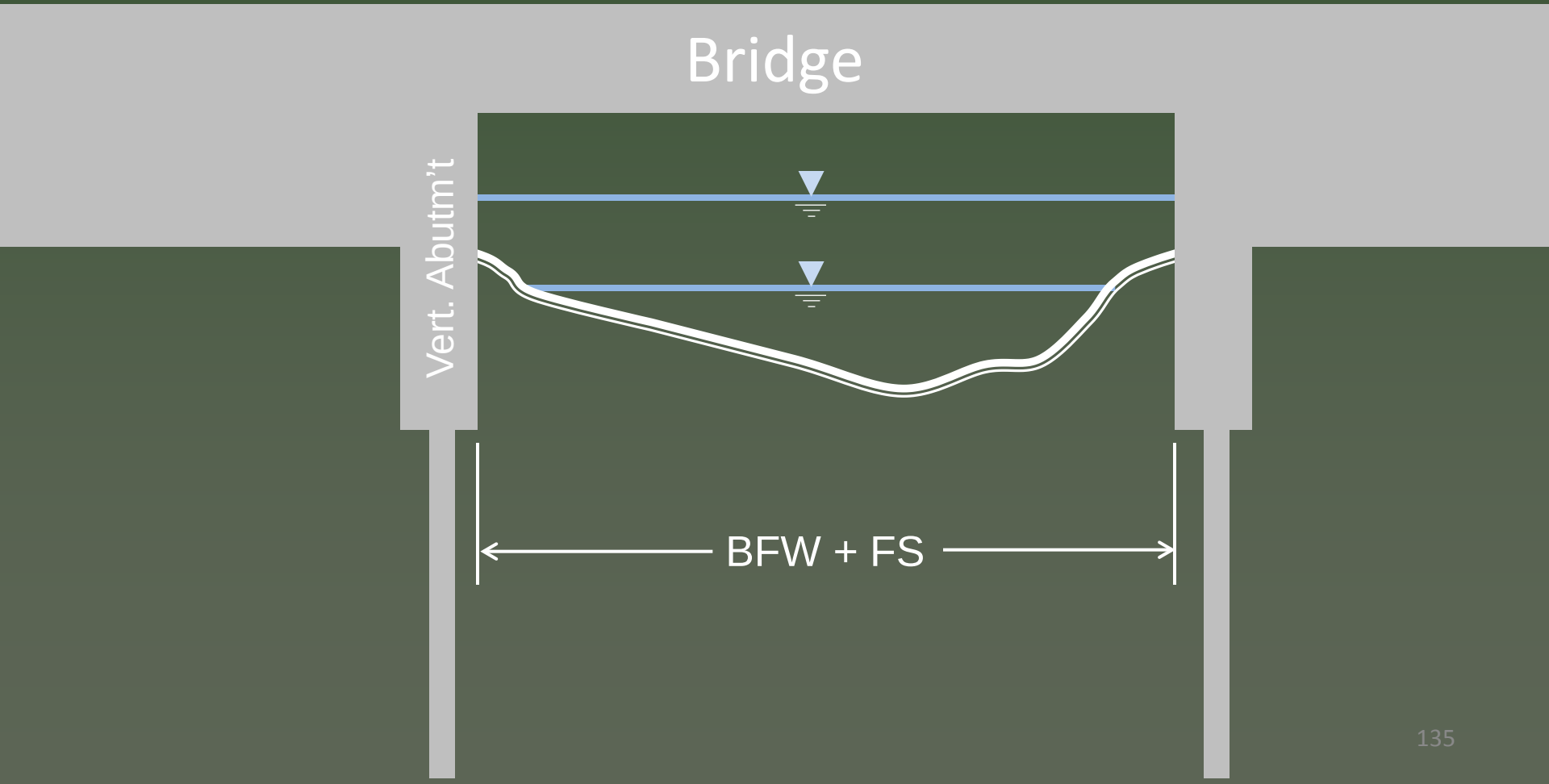
- FS accounts for
  - Changing geomorphology
  - Error in measurements
  - Errors in modeling H&H
- All eng. calculations use FS because of:
  - Uncertainty about forces and materials
  - Risk
- FS ranges from 1.2 to 10 in engineering

Flow through abutments with low FUR can minimize factor of safety.

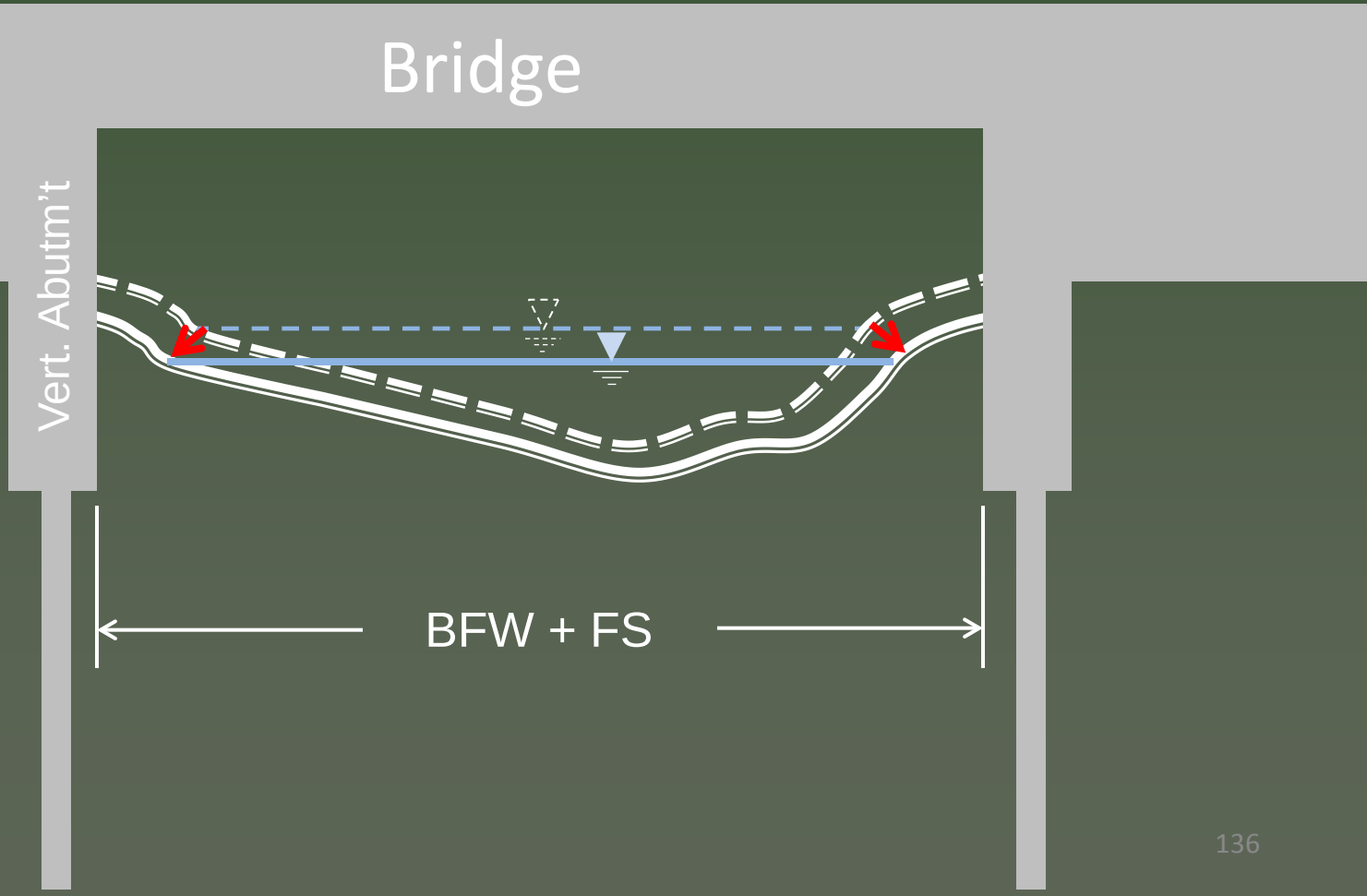


FUR = 1.9

Vertical abutments need a larger factor of safety.



Uncertainty about channel widening or regrade may suggest a larger FS.



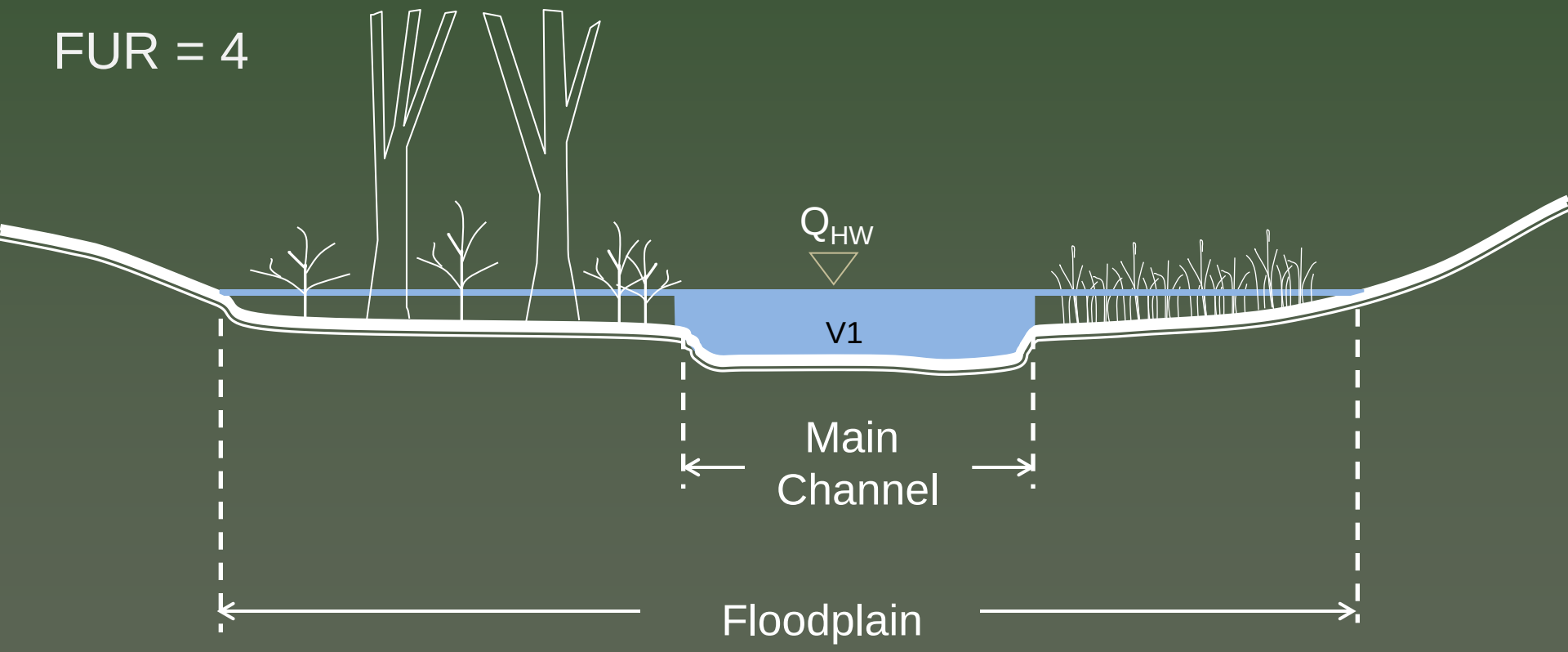
High gradient, coarse-bedded channels may need a smaller factor of safety.

Floodplain and Overbank Areas

Determining acceptable encroachment

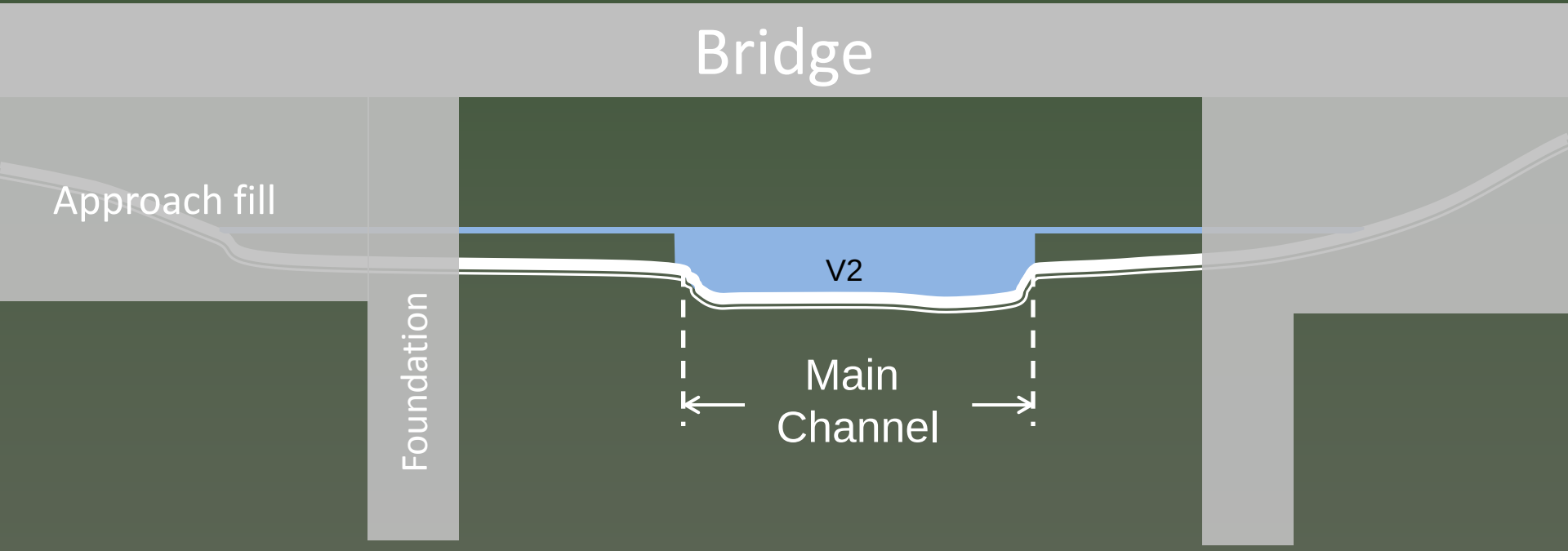
Bridges over unconfined channels can be based on the main channel velocity ratio.

FUR = 4



Bridges over unconfined channels can be based the main channel velocity ratio.

$$\frac{V2}{V1} \sim 1$$



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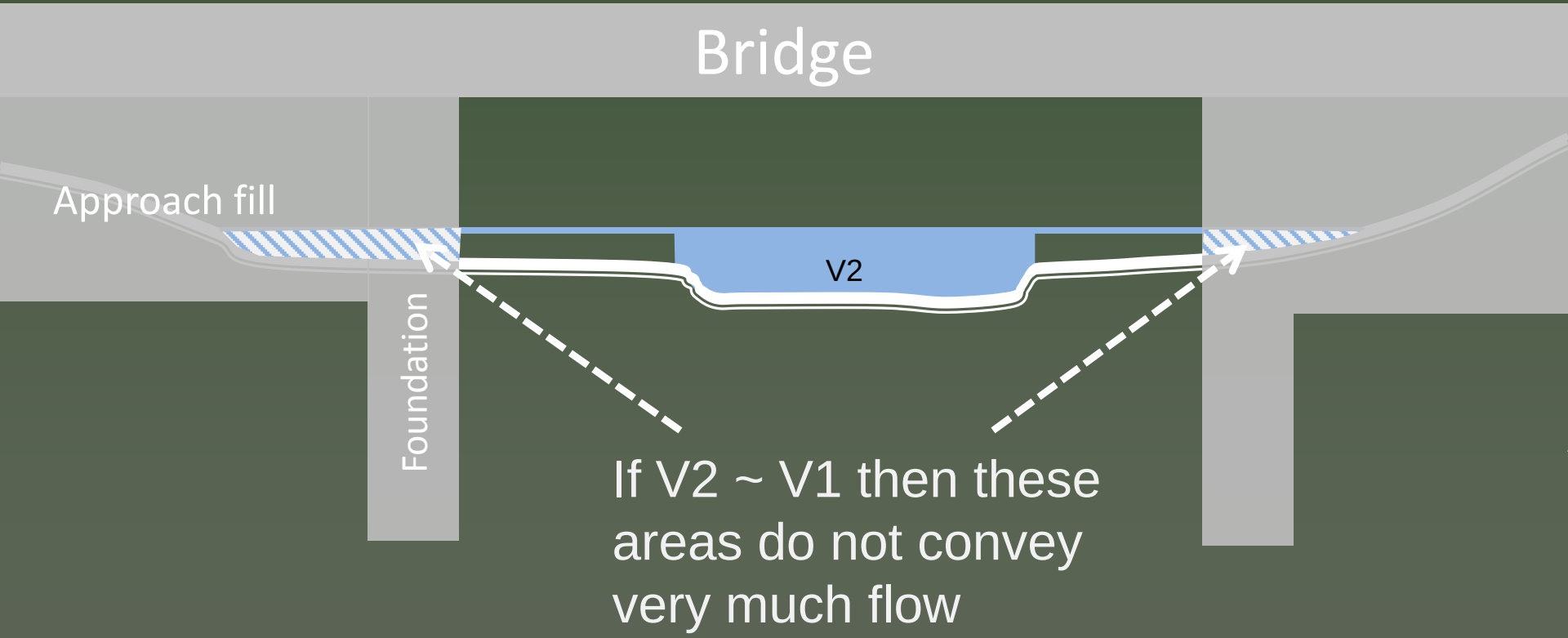
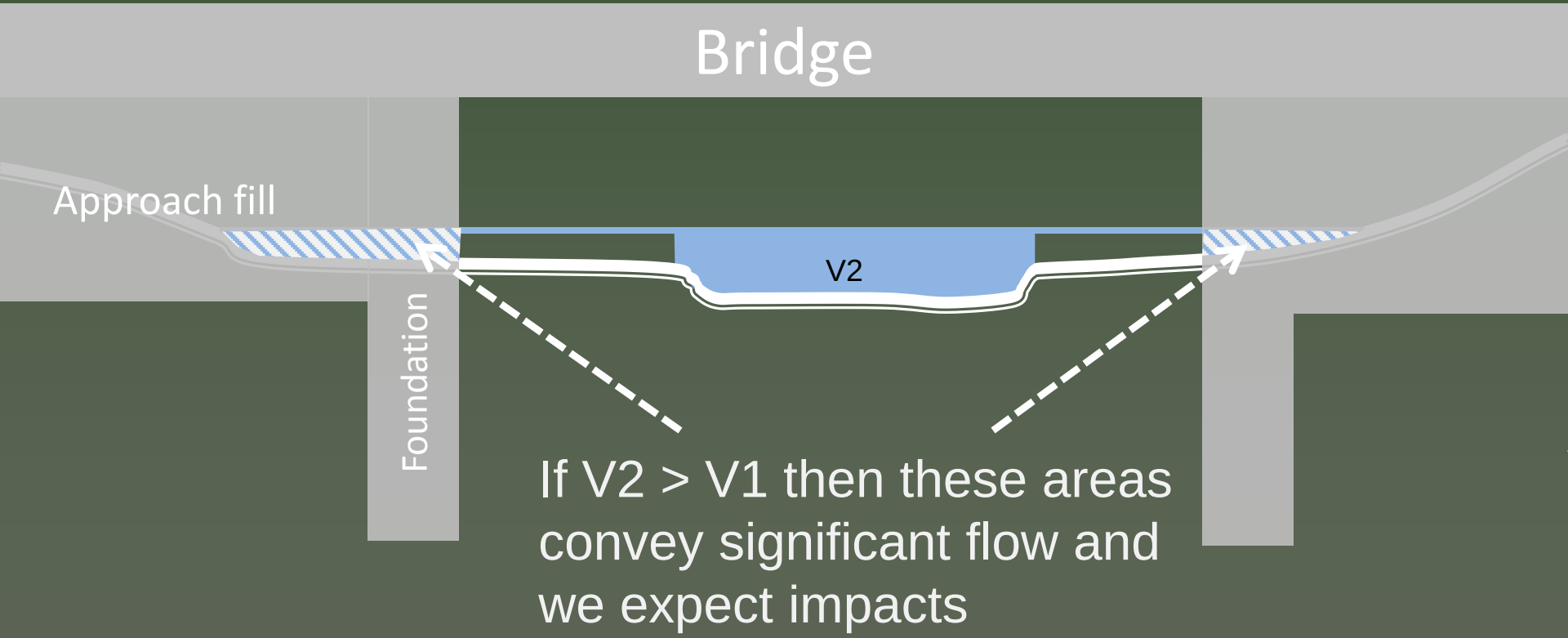
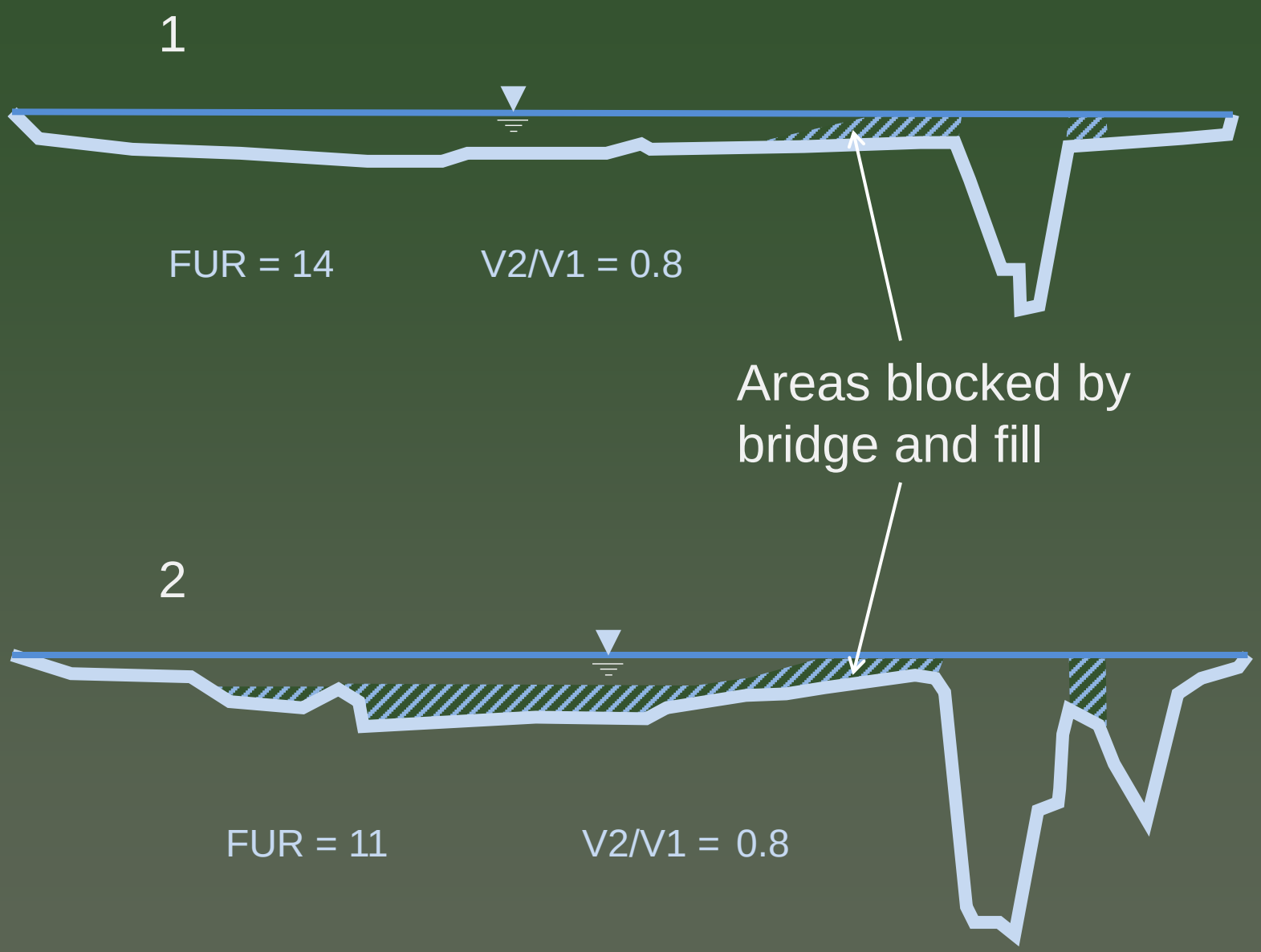
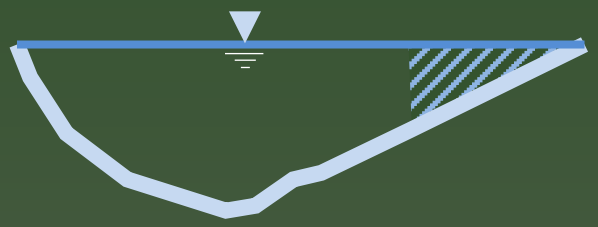


$$\frac{V2}{V1} > 1$$


Bridge
Approach fill
V2
Foundation
If V2 > V1 then these areas convey significant flow and we expect impacts

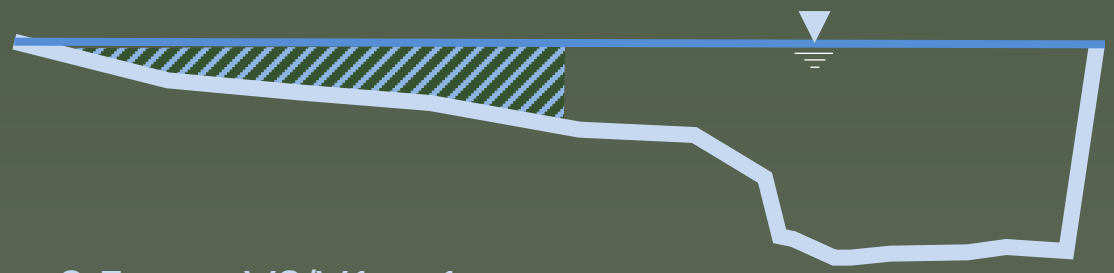

1
FUR = 14
V2/V1 = 0.8
Areas blocked by bridge and fill
2
FUR = 11
V2/V1 = 0.8

3



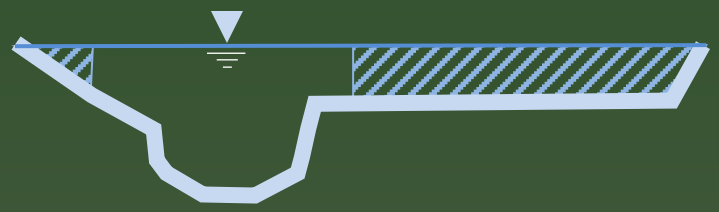
FUR = 5 V2/V1 = 1

4



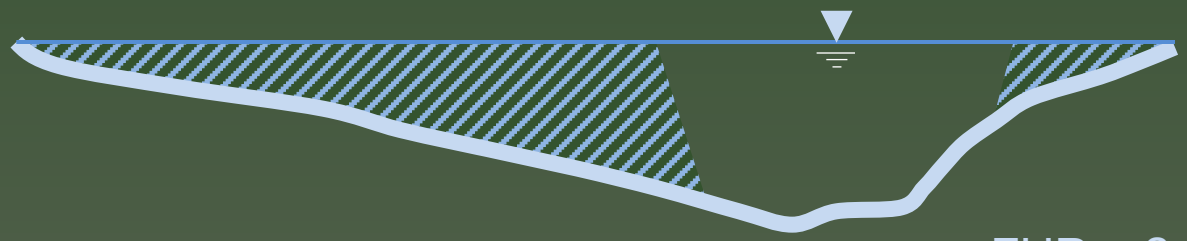
FUR = 3.5 V2/V1 = 1

5



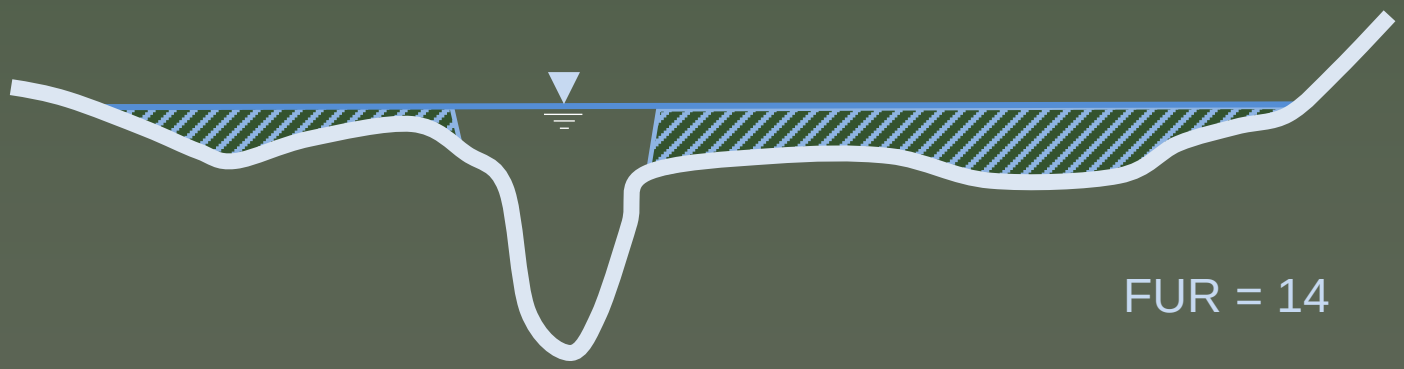
FUR = 4 V2/V1 = 1.32

6



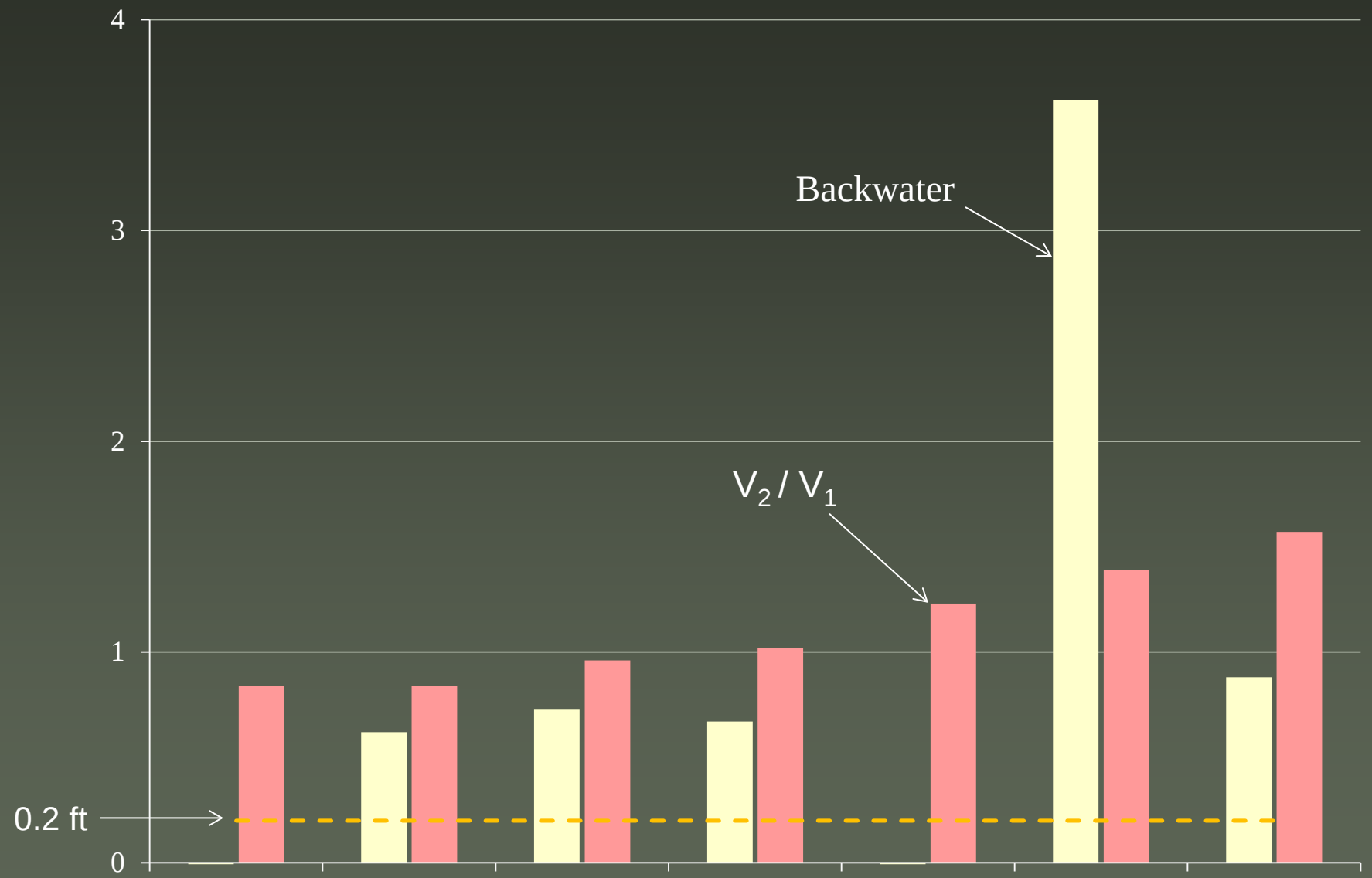
FUR = 2 V2/V1 = 1.39

7



FUR = 14 V2/V1 = 1.6

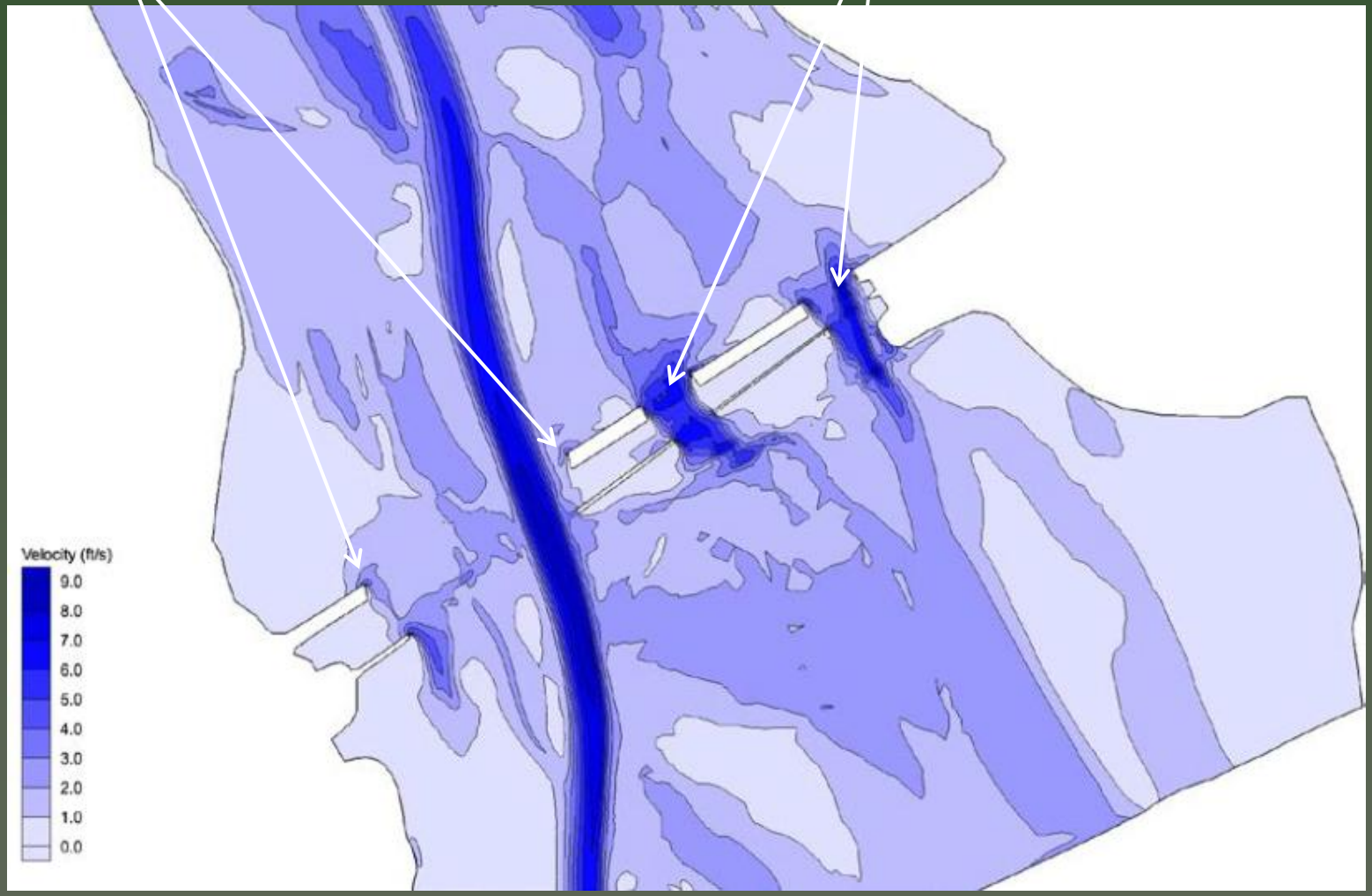
Comparison of 7 recent bridge projects (Jeff Johnson & Peter Brooks, NHC)



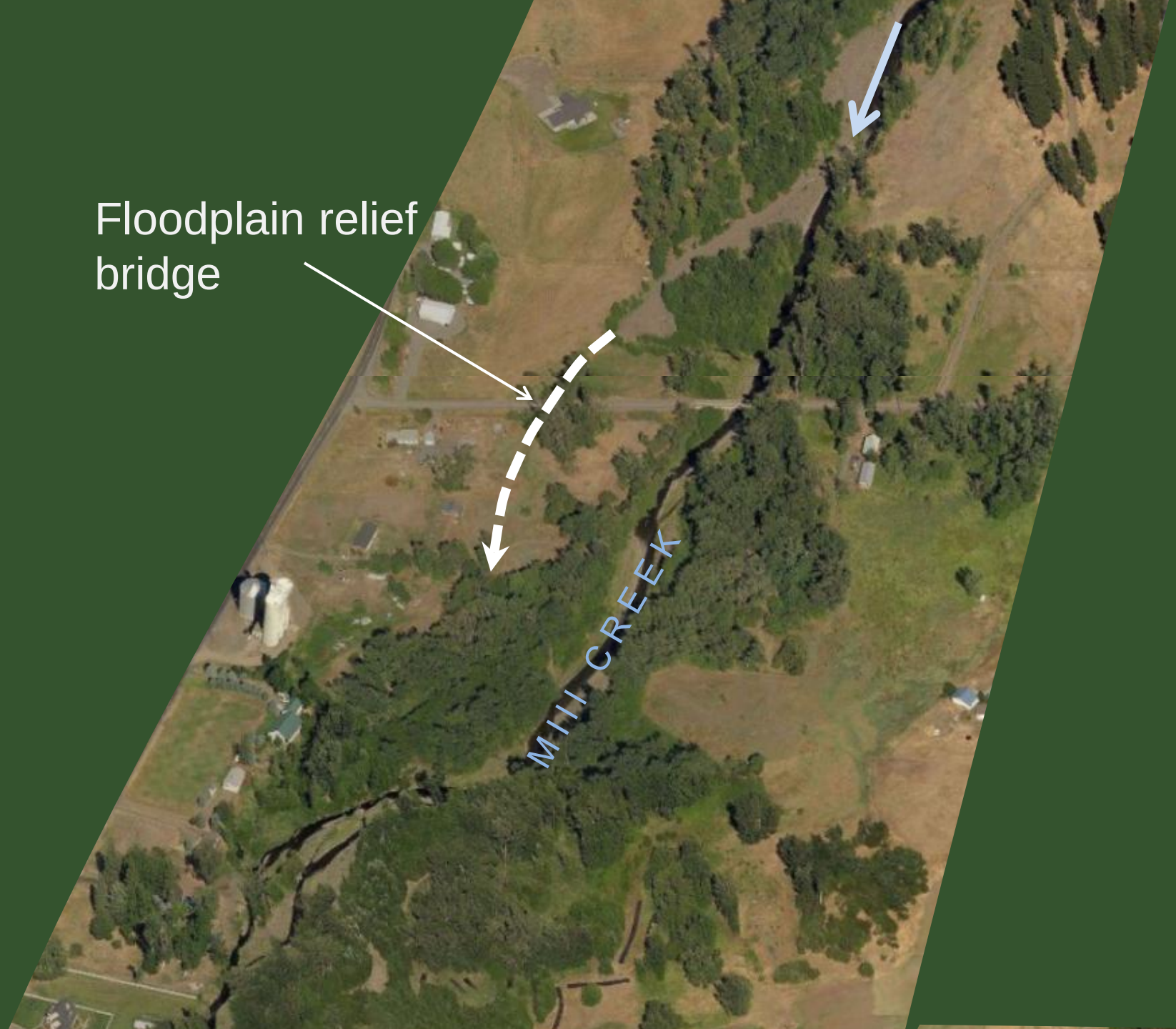
River Sta	Vel Chnl (ft/s)	Vel Ratio V2/V1	Q Perc Chan	Prop. TW Twbridge/TW
3118	10	1.0	89%	37%
2834	10	1.0	81%	34%
2600	10		99%	100%
1744	11	0.9	85%	36%
829	9	1.1	89%	39%
mean	10	1.0	86%	36%

Main channel bridge

Floodplain relief bridges

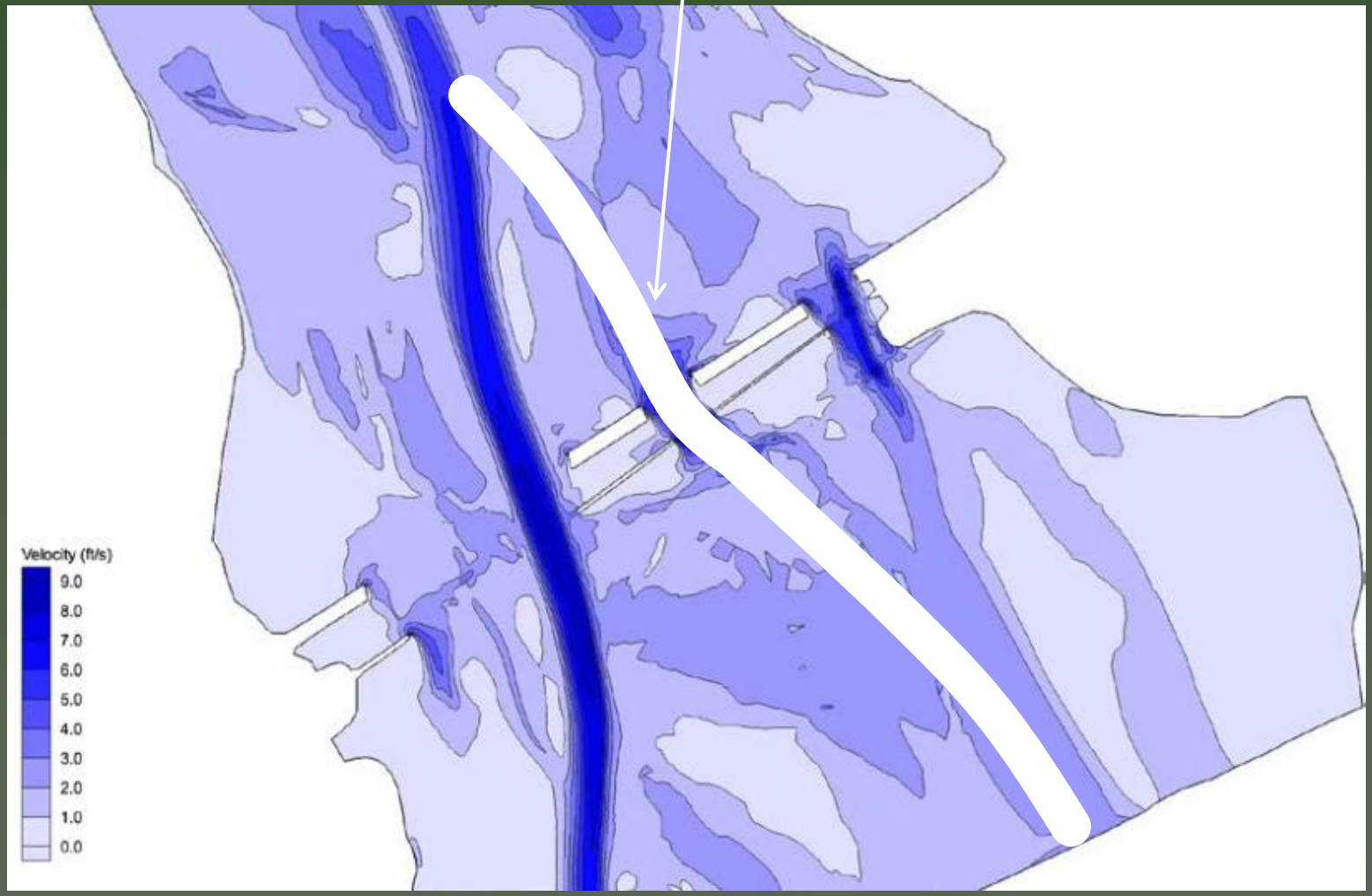


FHWA HDS 7


Floodplain relief bridge
MILL CREEK

Scour
Stranding

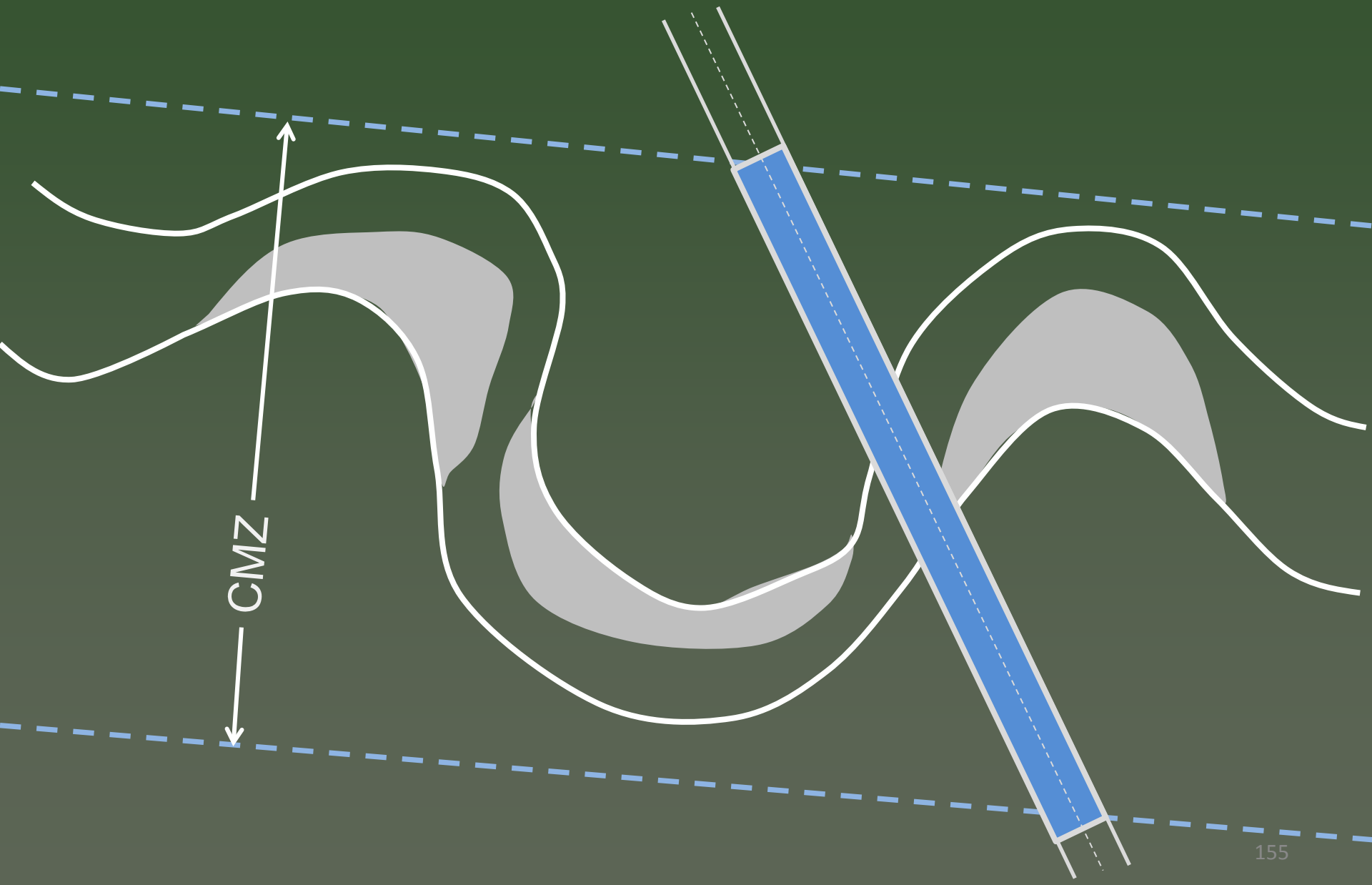
Align floodplain crossings with existing side channels



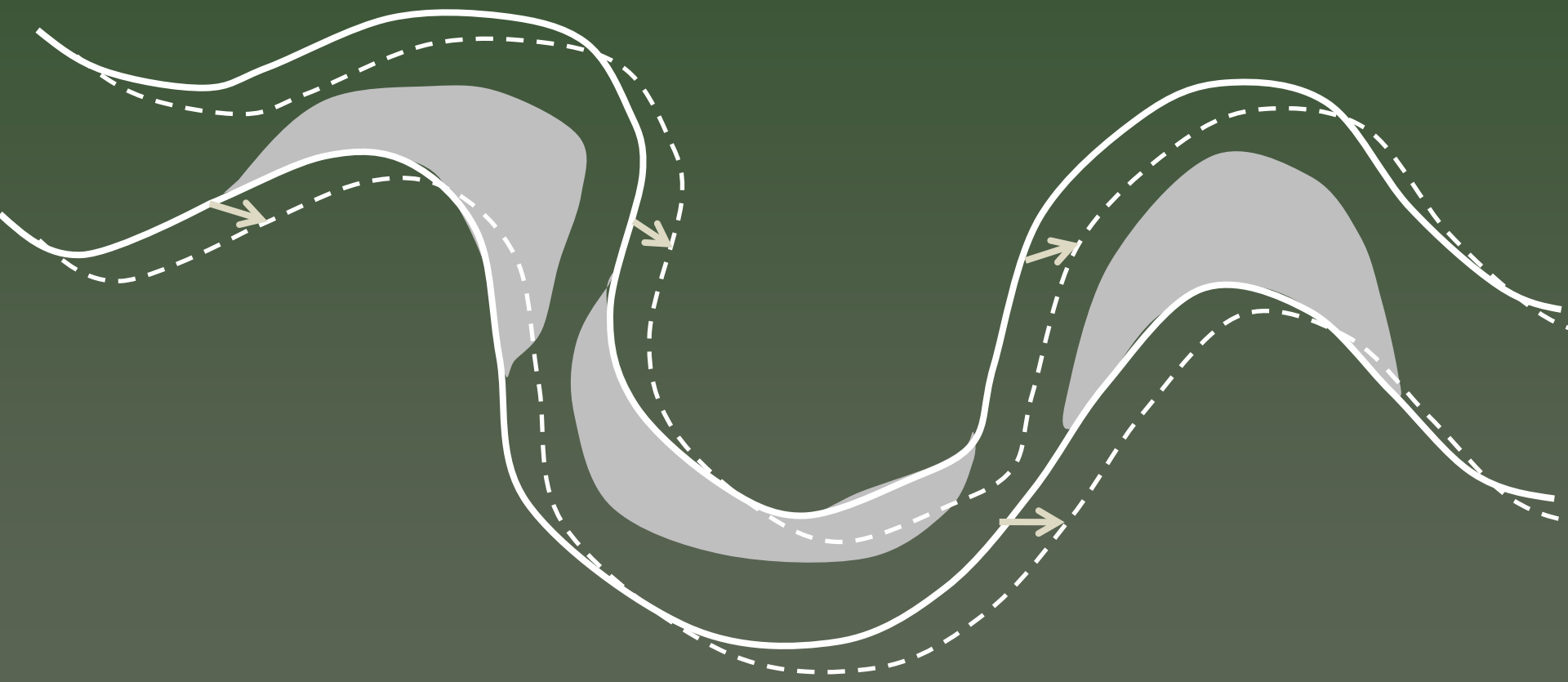
FHWA HDS 7

© Rex Features

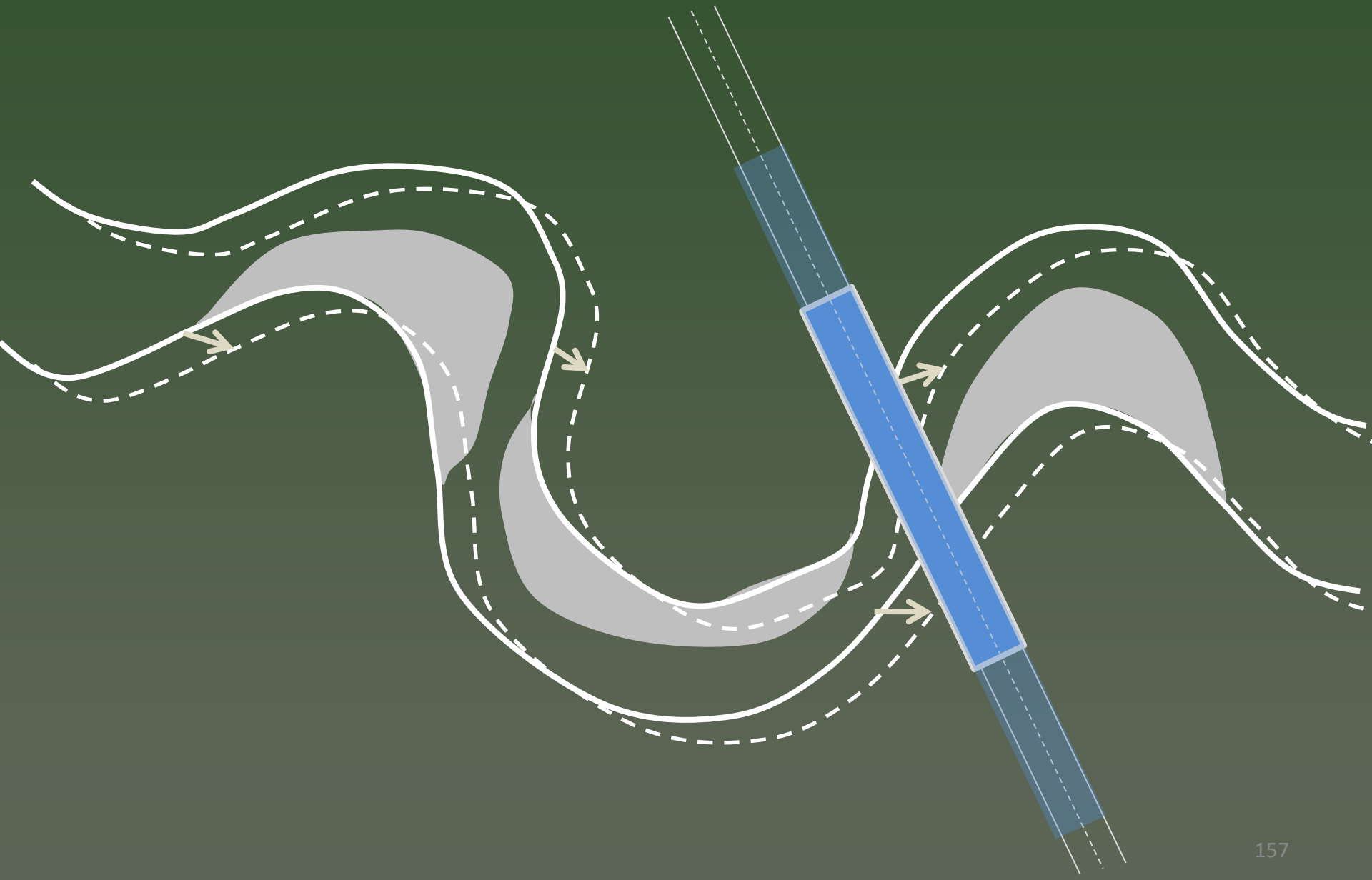
Lateral Channel Movement

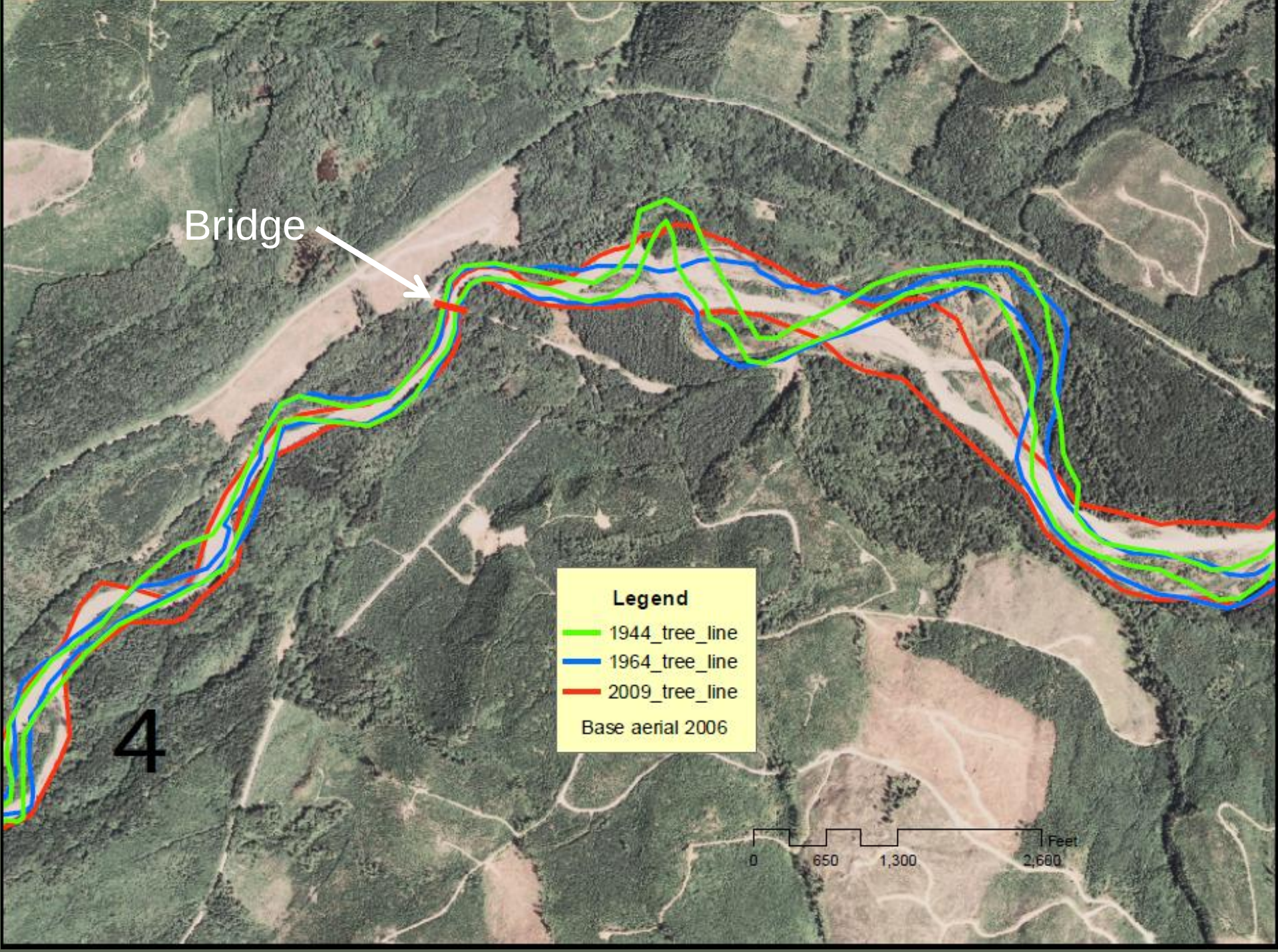


Lateral Channel Movement, allow for meander migration



Lateral Channel Movement, allow for meander migration



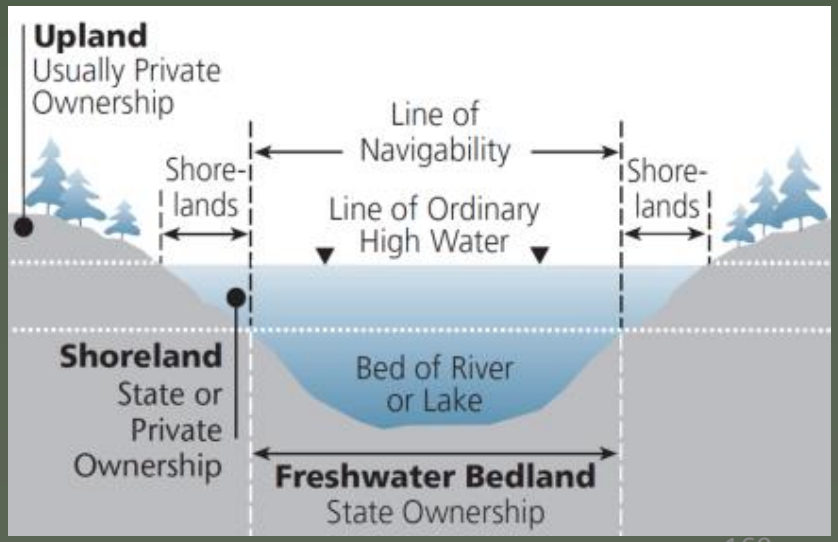

Bridge
Legend
1944_tree_line
1964_tree_line
2009_tree_line
Base aerial 2006
4
0
650
1,300
2,600
Feet

Floodplain Management Regulations

- FEMA Flood Insurance Program
- Shoreline Management Act
- Growth Management Act
- Shoreline master programs
- Critical areas ordinances

State-owned aquatic lands

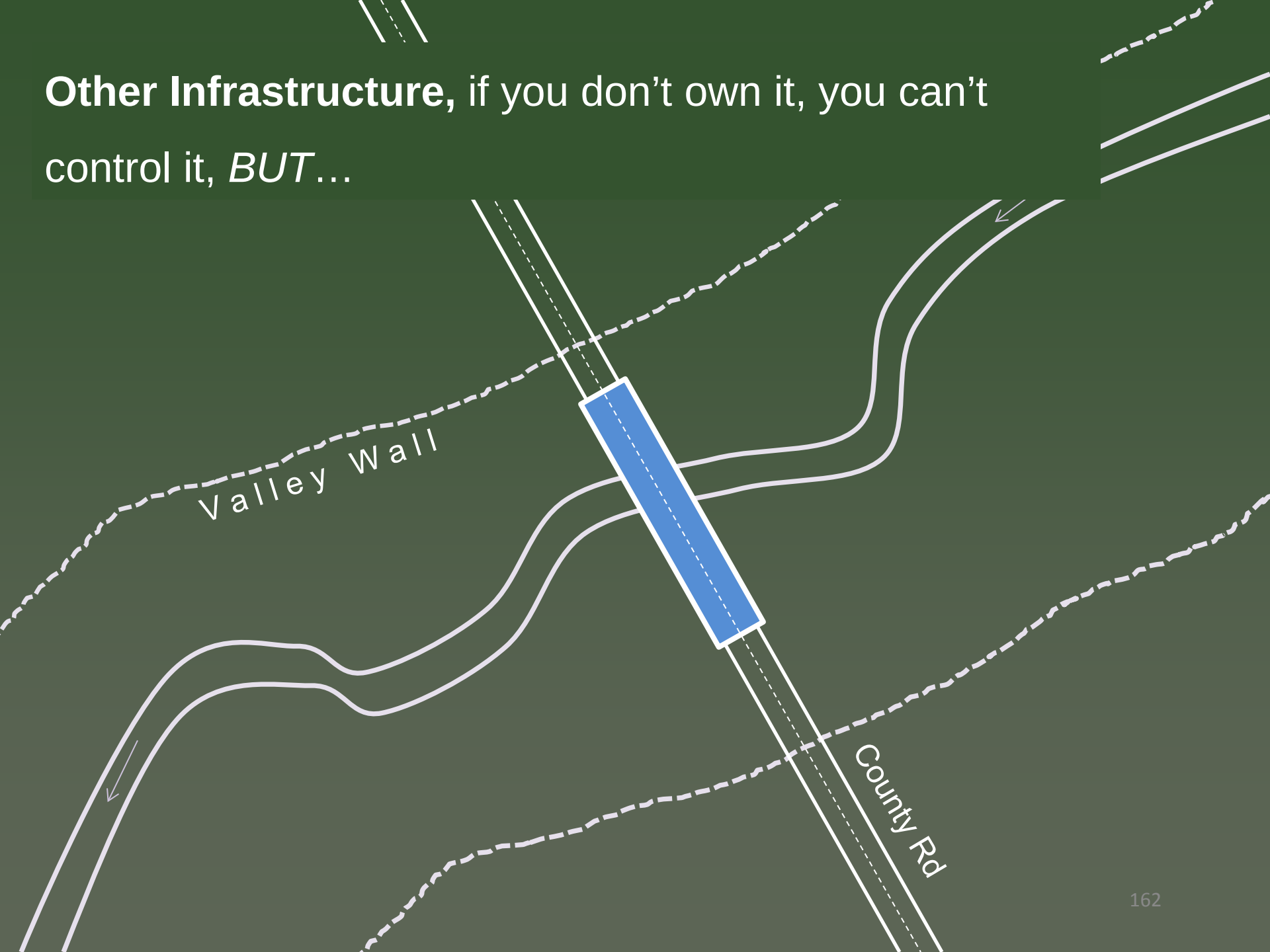
- All projects on state-owned aquatic lands require consultation with DNR and possible land use authorization
- Call DNR before you design (Google: dnr aquatic districts)
- All marine waters are navigable.
- Some fresh water rivers and lakes are navigable (BFW < 15, probably not, but could be)



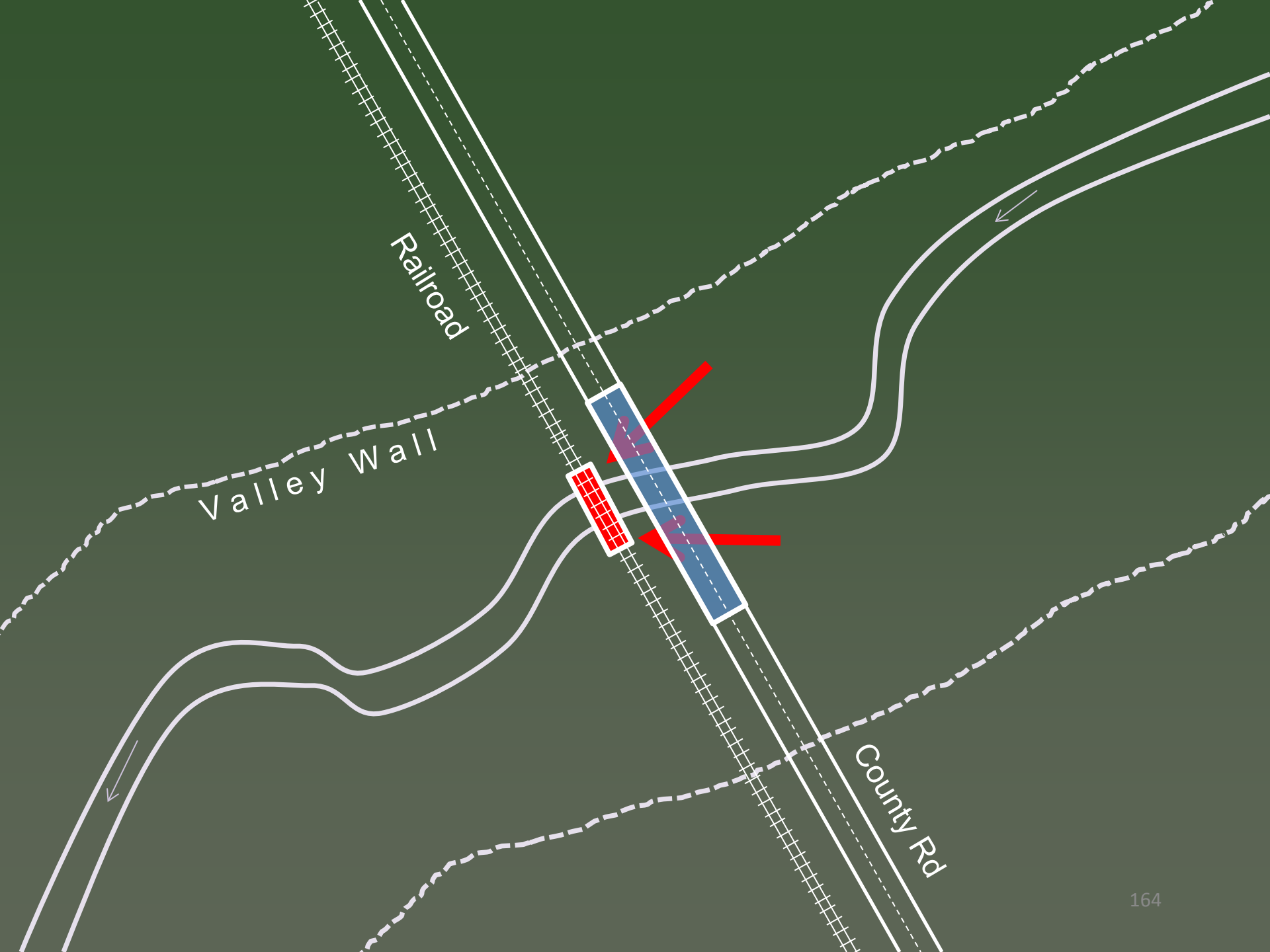
Flood Control Features: levees define floodplain, mostly

Levees

Other Infrastructure, if you don't own it, you can't control it, *BUT*…

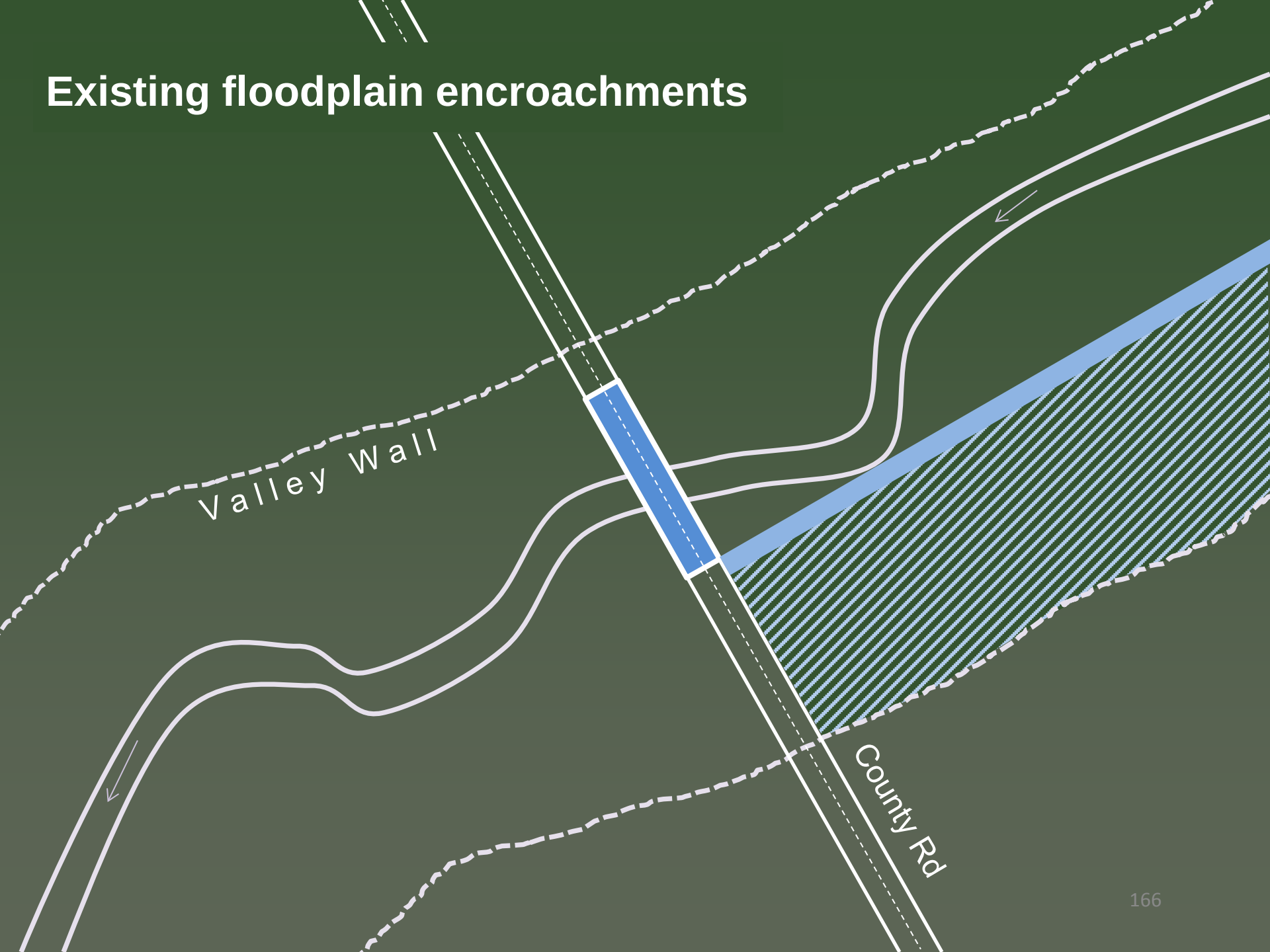


Adjacent crossings

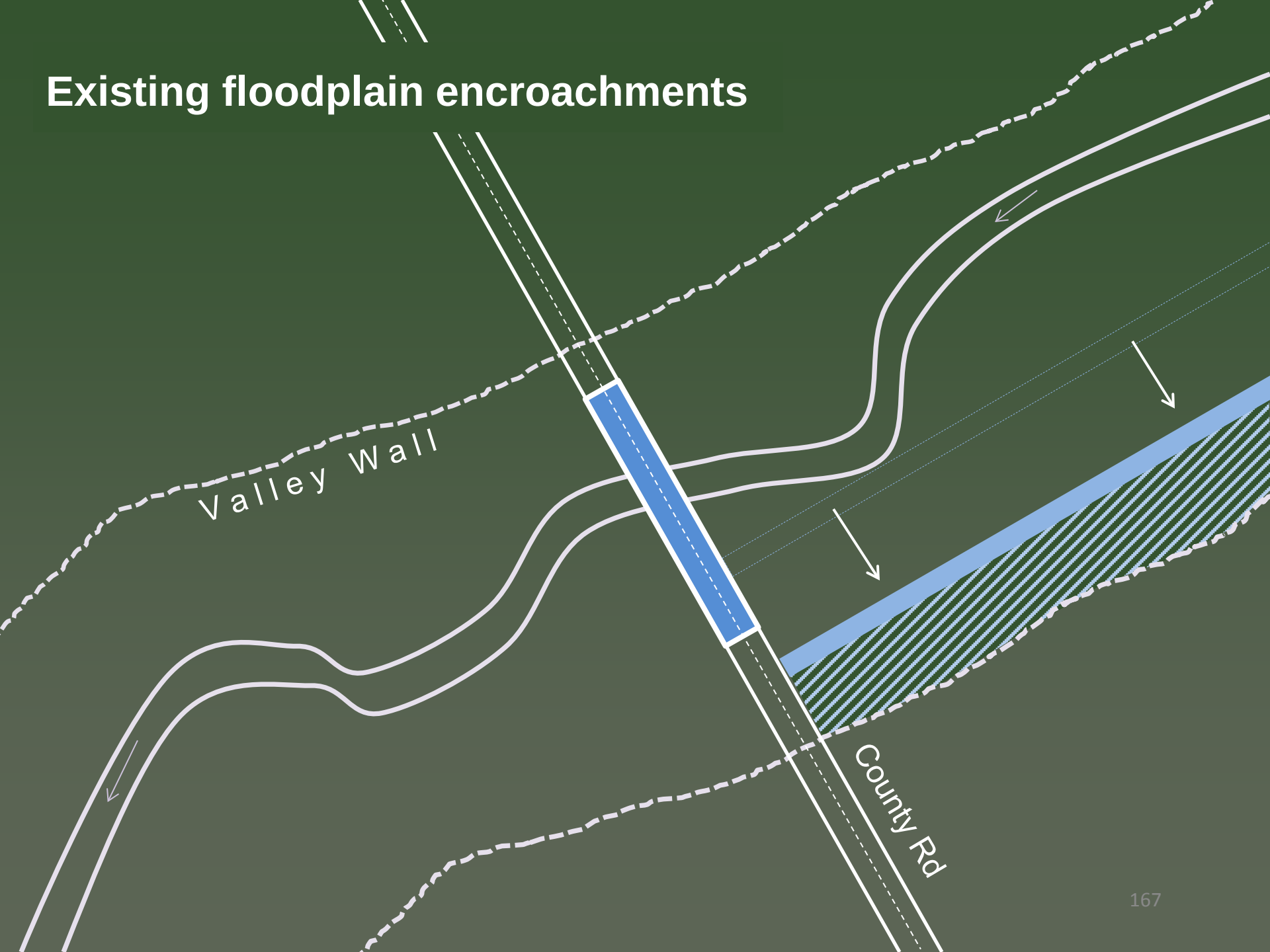

Railroad
Valley Wall
County Rd

Existing floodplain encroachments

Existing floodplain encroachments



Existing floodplain encroachments



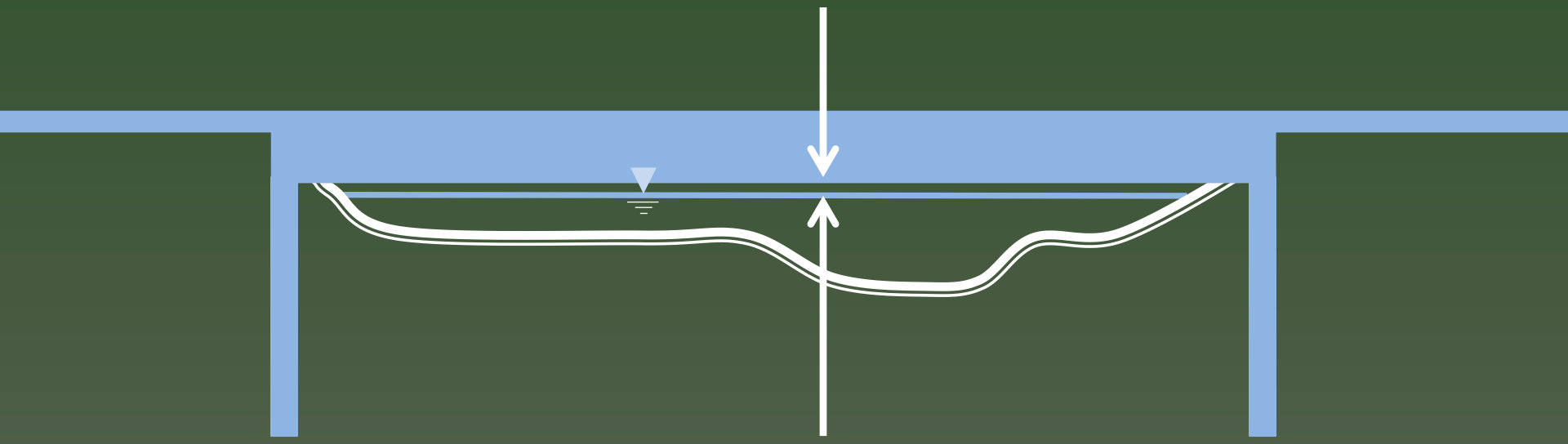
Intermediate Piers

Good example: outside OHW, doesn’t rack up wood, economically increases span.

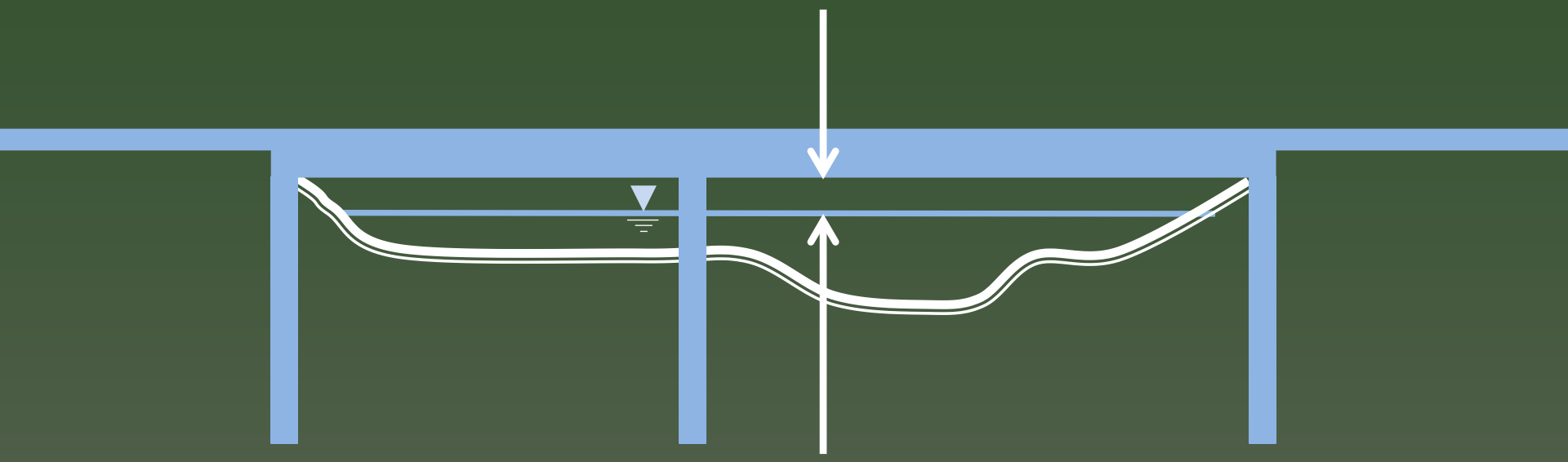
Acceptable: piers slender, rounded shape
Long, economical span.

Bad example:
massive, numerous piers,
debris catcher,
hydraulic constriction.

Low elevation road crossing



Inadequate clearance



Adequate clearance

Pier allows reduced girder depth, increases clearance.

Hierarchy of benefits

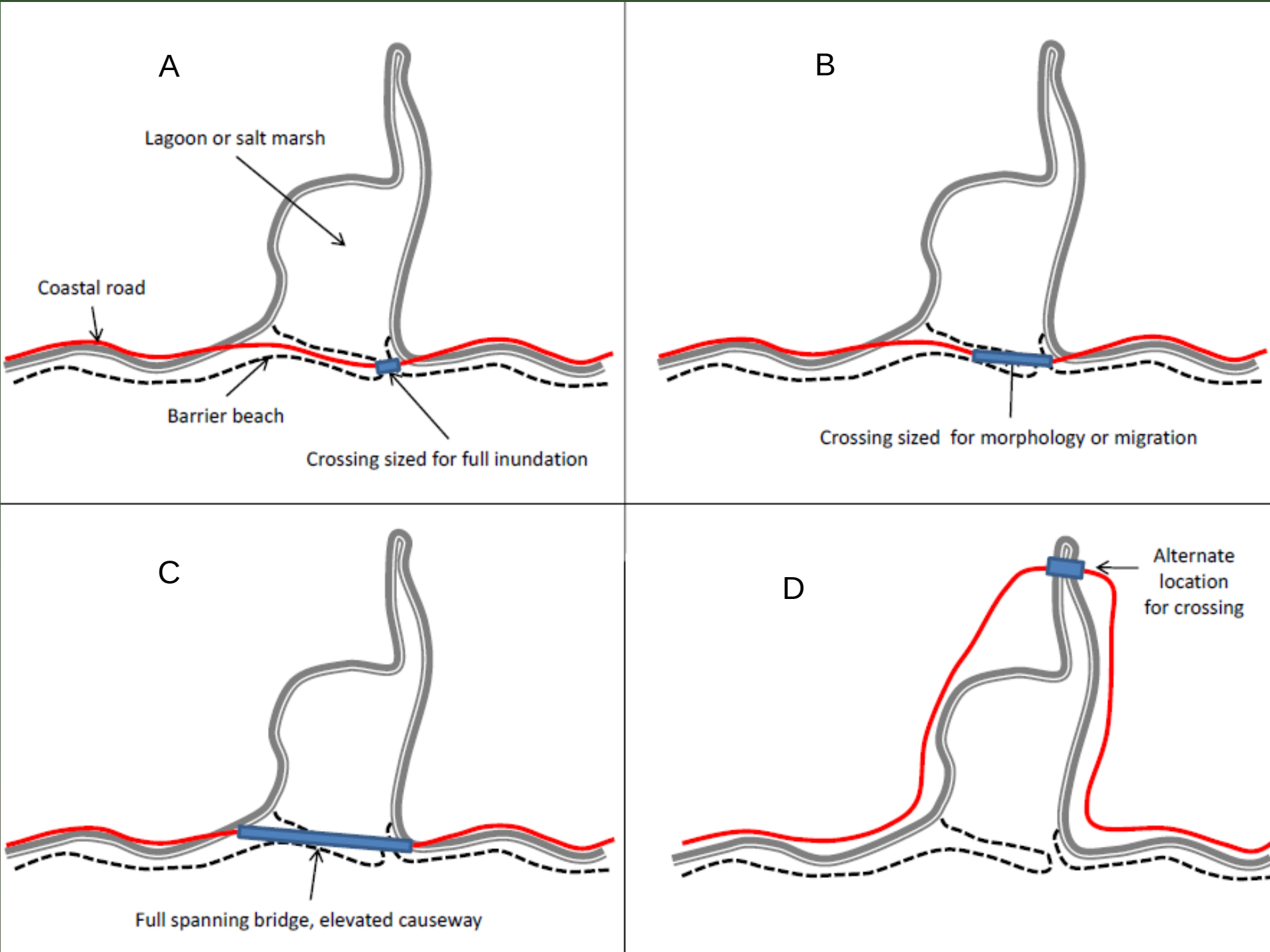
Appendix D: Tidally Influenced Crossings

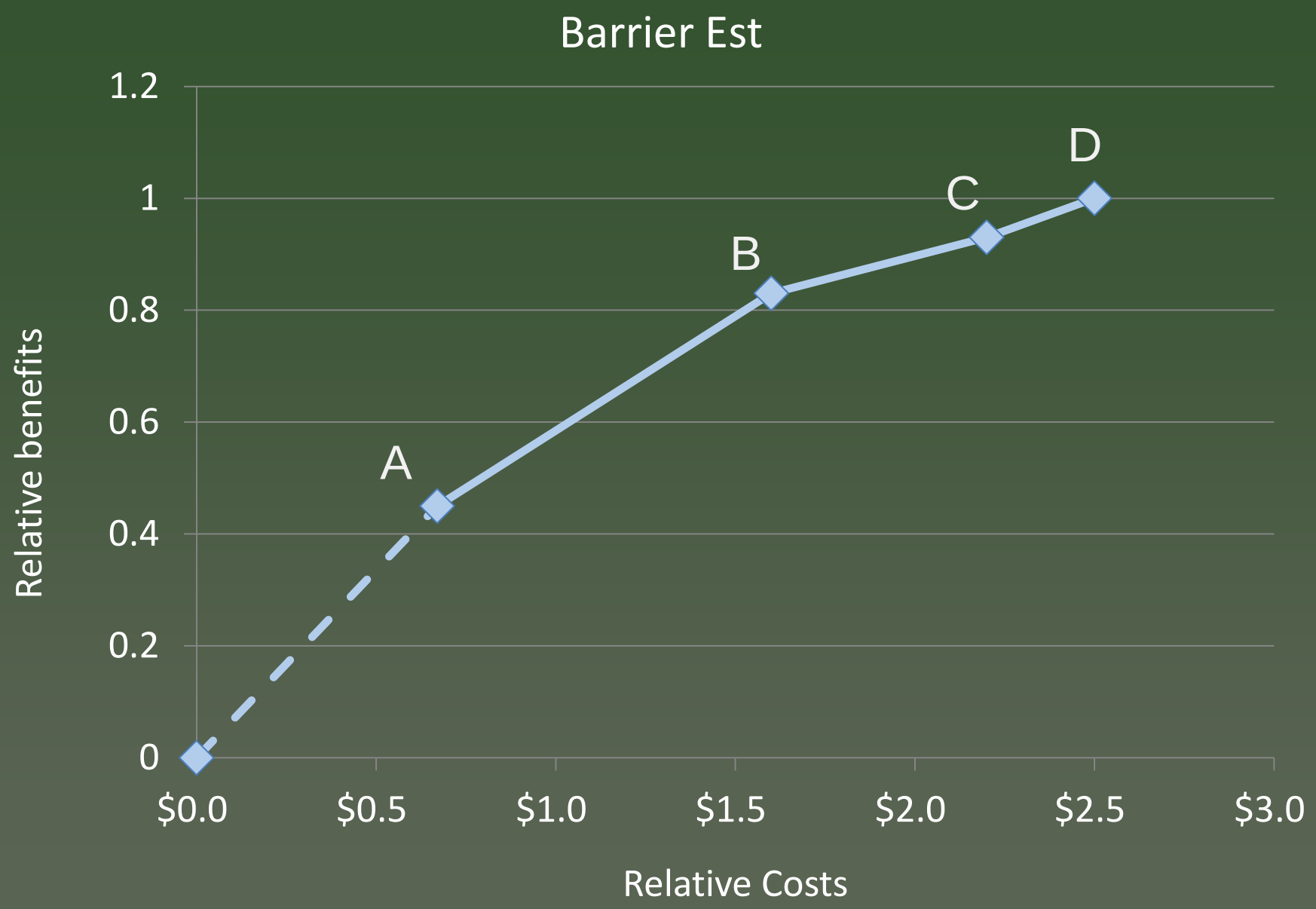
Alternative analysis using a hierarchy of benefits

Increasing Benefits

- Hydraulic processes
- Sedimentary processes
- Geomorphic processes

Increasing Costs


A
Lagoon or salt marsh
Coastal road
Barrier beach
Crossing sized for full inundation
B
Crossing sized for morphology or migration
C
Full spanning bridge, elevated causeway
D
Alternate location for crossing


Barrier Est
1.2
1
0.8
0.6
0.4
0.2
0
Relative benefits
A
B
C
D
$0.0
$0.5
$1.0
$1.5
$2.0
$2.5
$3.0
Relative Costs

Bridge clearance

- Generally, 3 ft above 100-year WSE
- Less for small streams
- More for big rivers

Bridge Rehabilitation

Alternative analysis (rehab vs. replace) considering:

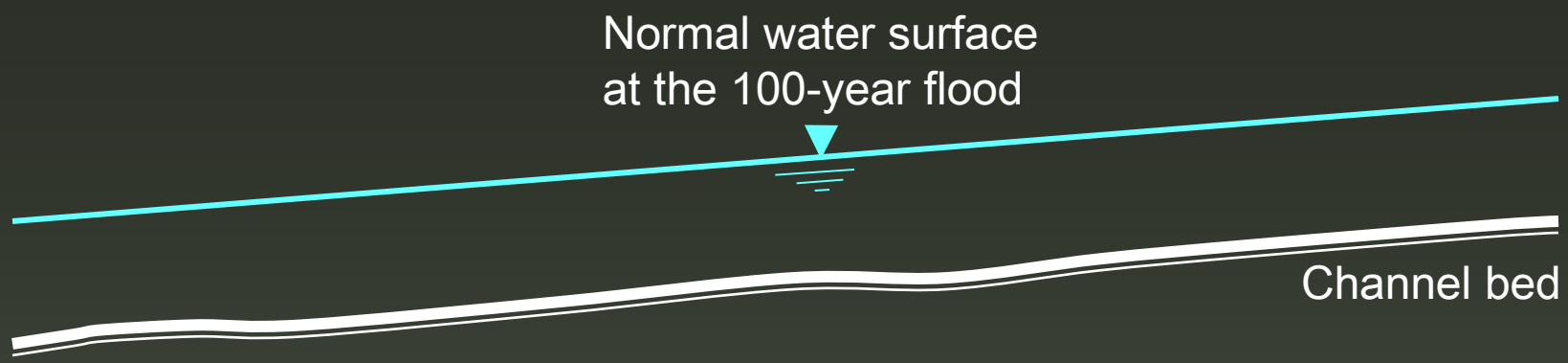
1. Safety
2. Traffic flow and road geometry
3. Expected bridge life considering structural deficiencies and channel dynamics
4. One-time maintenance activities
5. Chronic maintenance activities over remaining life
6. Environmental impacts
7. Annualized cost of replacement versus rehabilitation

WAC 220-110-070(1) Bridge construction

(h) Abutments, piers, piling, sills, approach fills, etc., shall not constrict the flow so as to cause any appreciable increase (not to exceed .2 feet) in backwater elevation (calculated at the 100-year flood) or channel wide scour and shall be aligned to cause the least effect on the hydraulics of the watercourse.

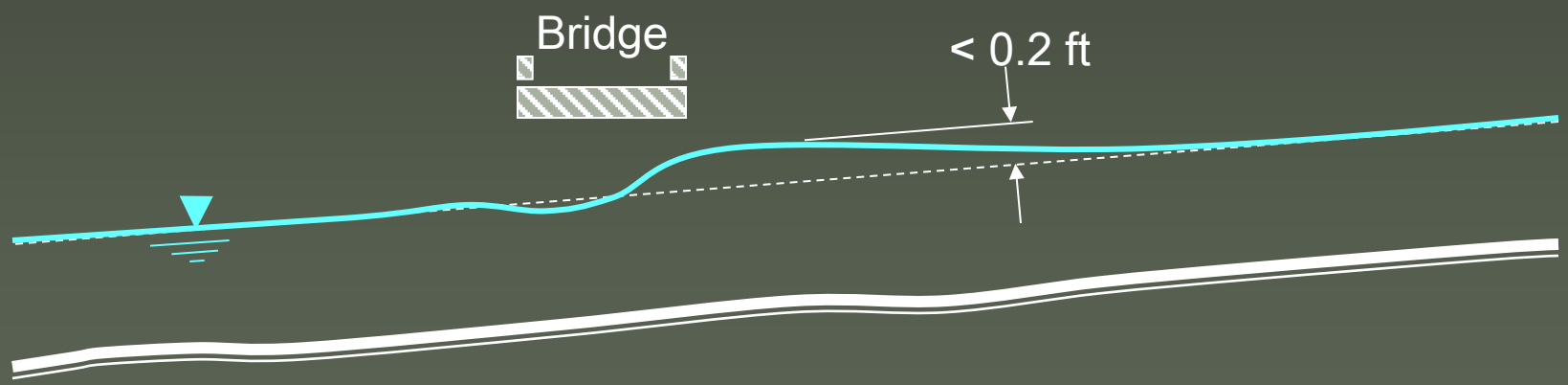
USDOT FHWA : “Backwater: the increase in water surface elevation *relative to the elevation occurring under natural channel and floodplain conditions*, induced by a bridge or other structure that obstructs or constricts the channel.”

“Natural” includes manmade features in floodplain that are out of control of the owner and unlikely to change.



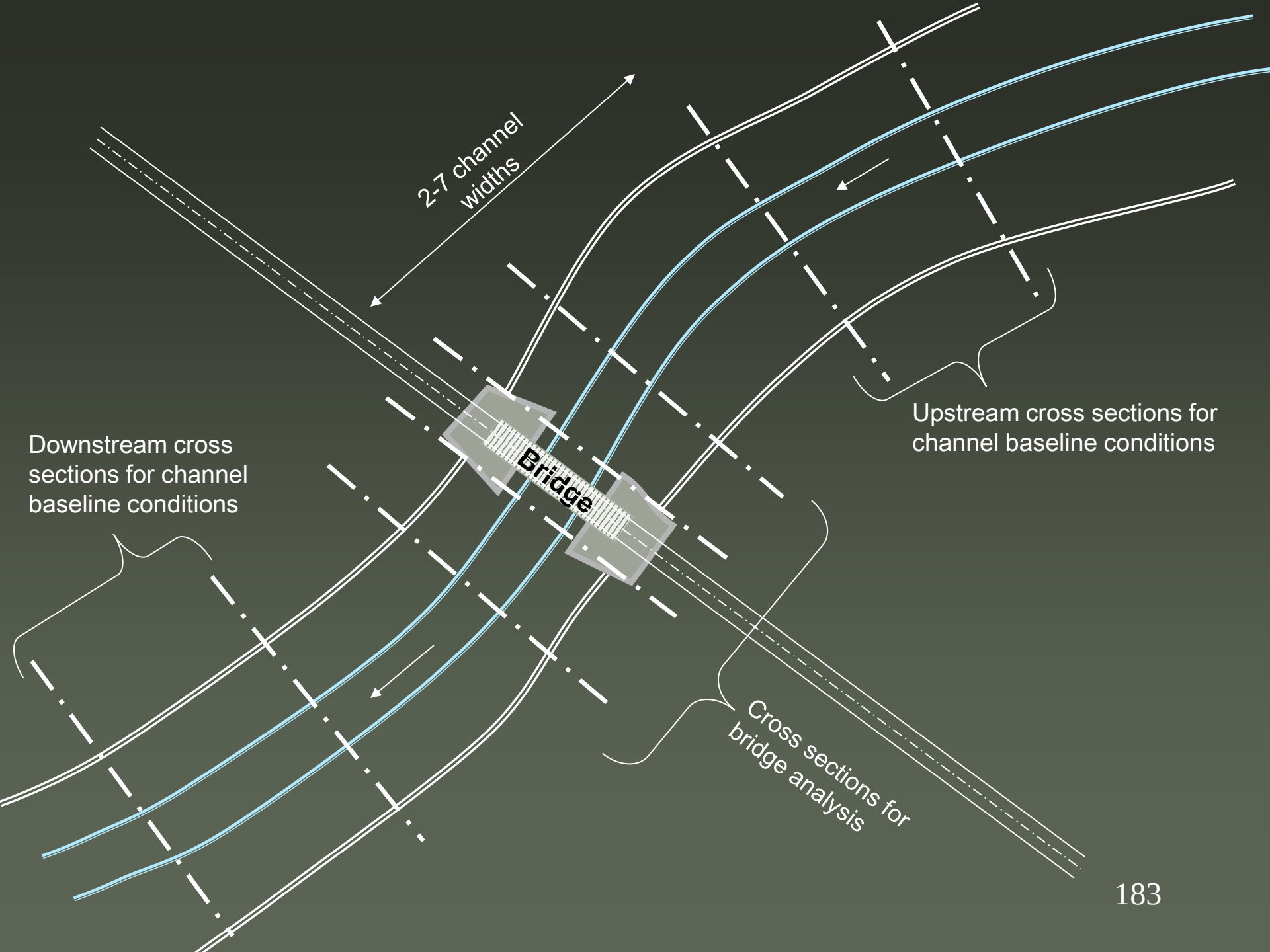
Longitudinal profile without bridge structure

Without existing “abutments, piers, piling, sills, approach fills, etc.”



Longitudinal profile with proposed bridge structure

With proposed “abutments, piers, piling, sills, approach fills, etc.”


2-7 channel widths
Bridge
Upstream cross sections for channel baseline conditions
Downstream cross sections for channel baseline conditions
Cross sections for bridge analysis

Profile Adjustment

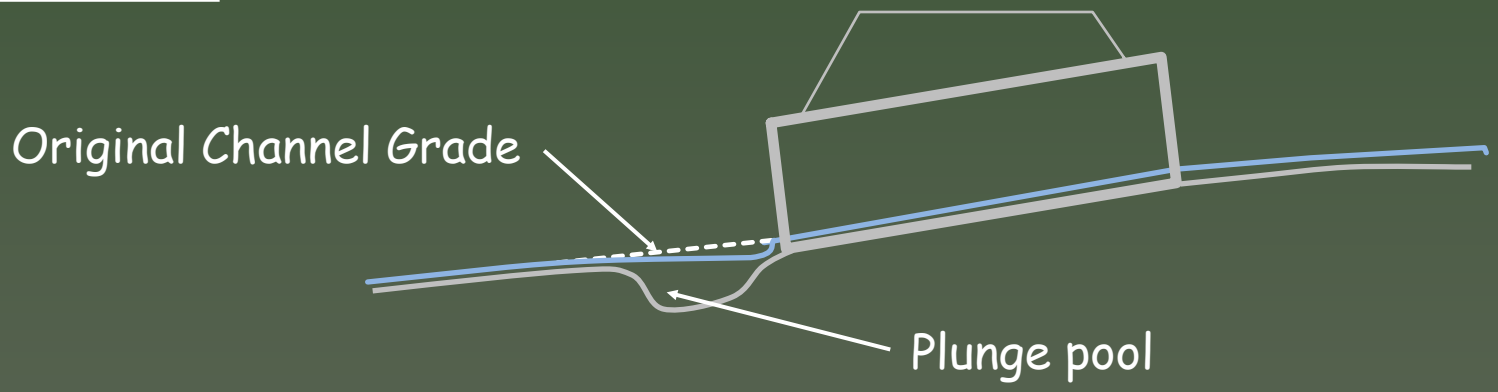
Channel profile adjustment occurs when a culvert is removed or replaced and there is an abrupt change in the channel slope or elevation at the water crossing.

Source of Hydraulic drop at Crossing

- Outlet Scour
- Downstream channel incision
- Slope of existing culvert

Source of Hydraulic Drop

Outlet Scour



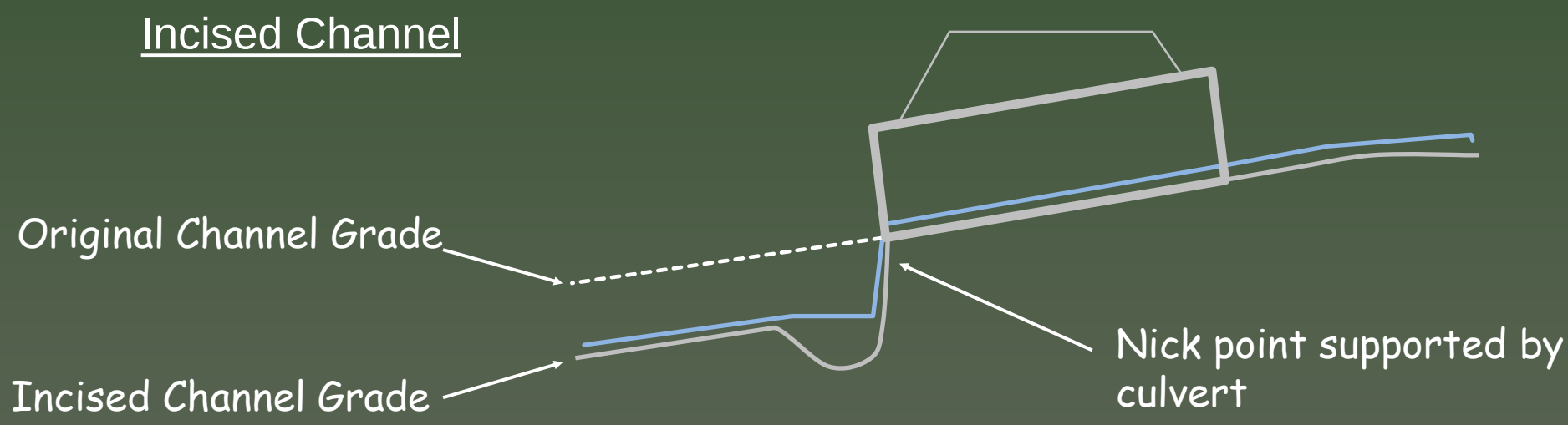
Small plunge caused by concentrated energy in undersized culvert

←

Characteristic gravel bar upstream of same undersized culvert

→

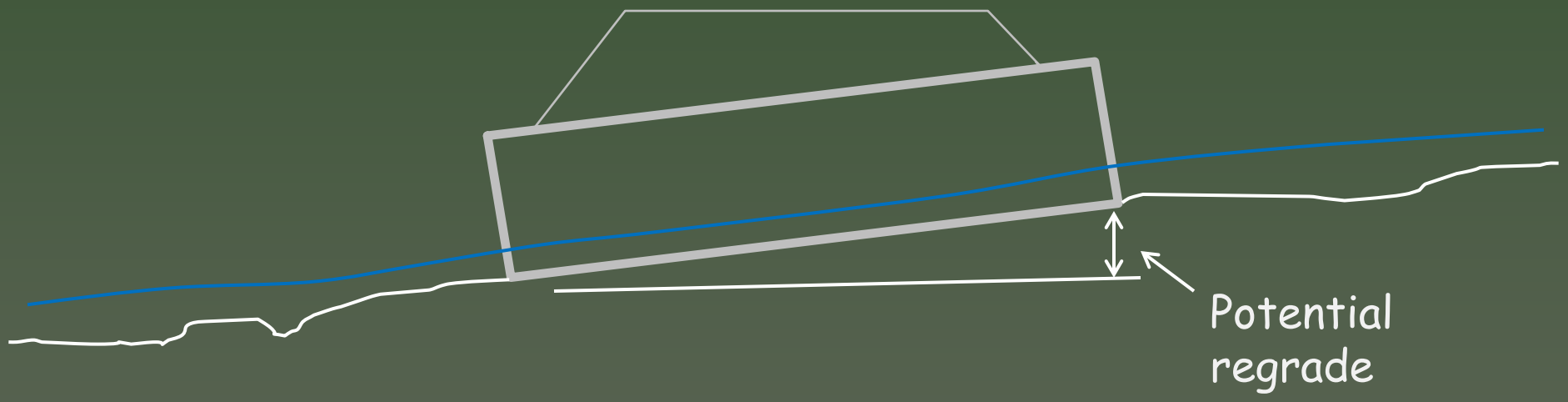
Source of Hydraulic Drop



4 ft

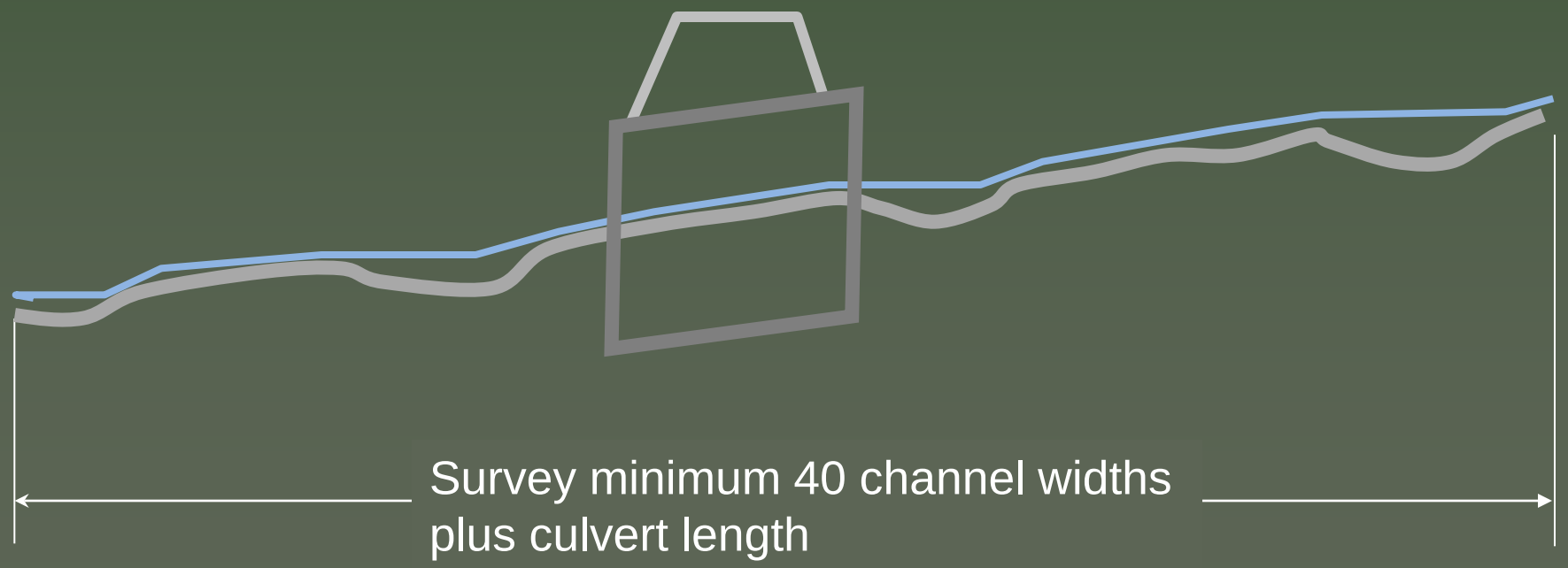
Source of Hydraulic Drop

Drop through existing culvert



Long profile is necessary to understand reach-level behavior of the channel

- identify grade breaks
- assess regrade potential and effects
- average scour depth of pools
- determine channel incision
- channel characteristics for stream simulation



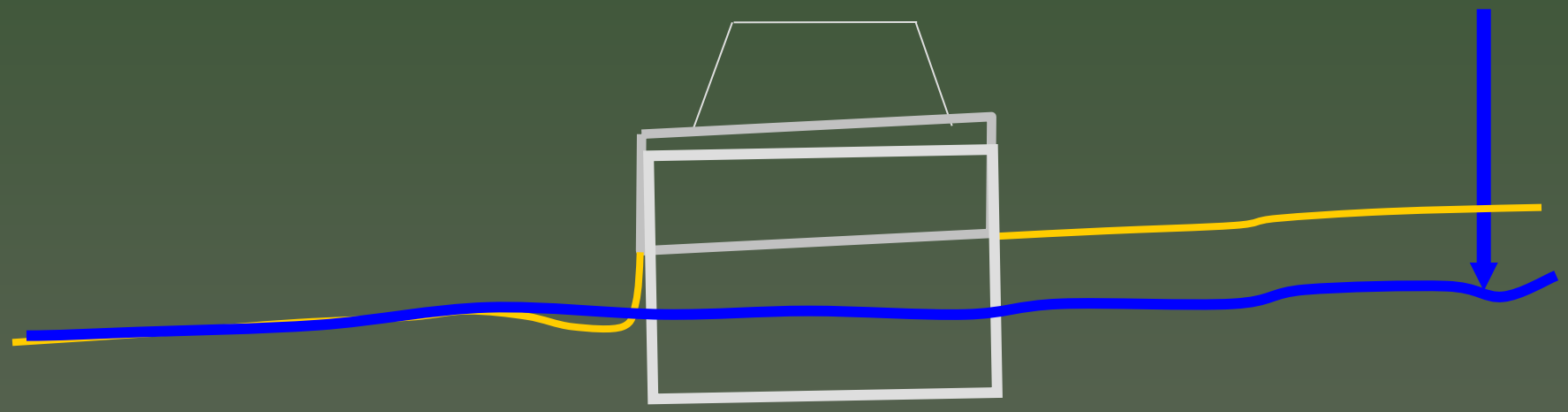
Profile Adjustment Options

- Allow regrade
- Control all or part of regrade

Channel Grade Options

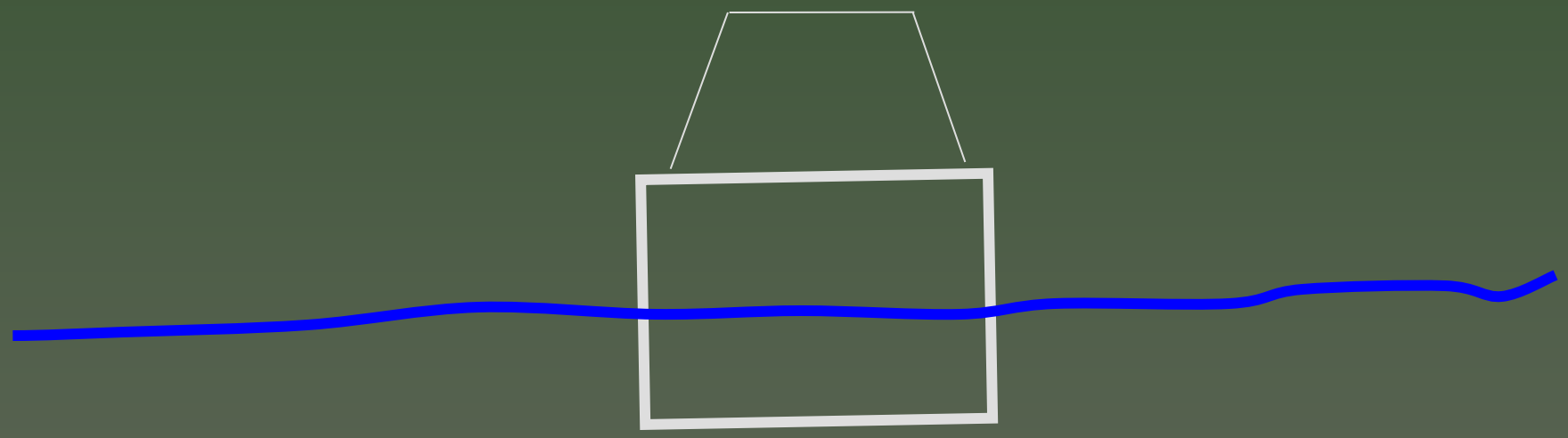
Regrade

Allow upstream
bed elevation to lower
and establish a new profile.

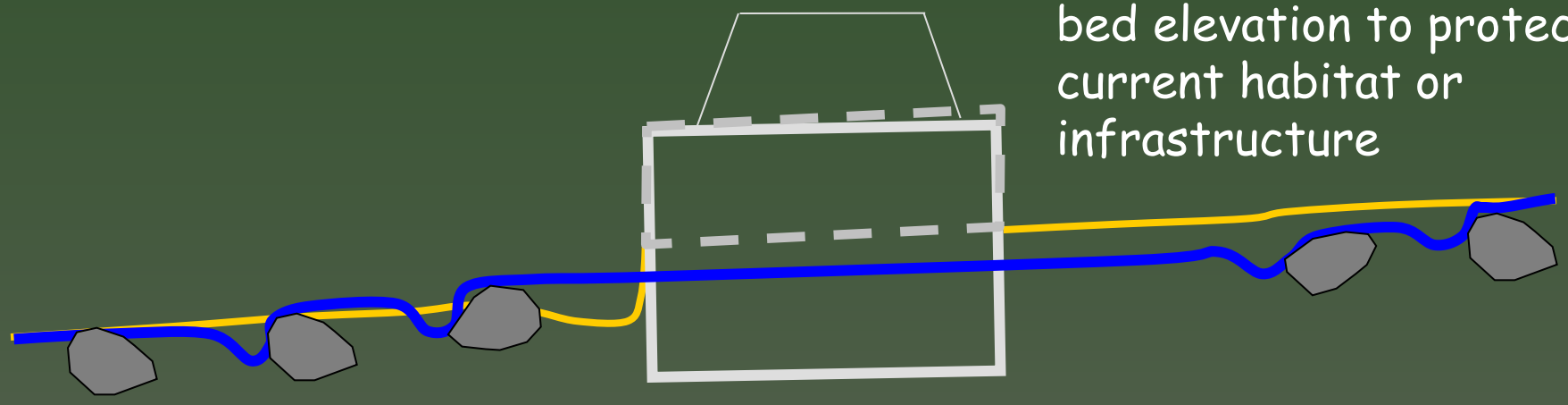


Channel Grade Options

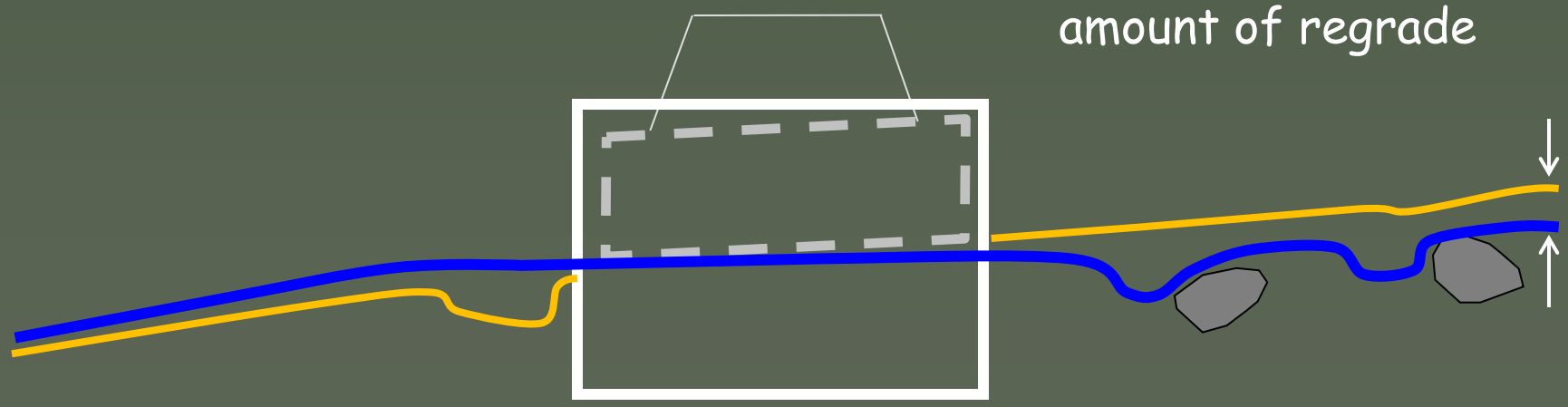
Regrade



Controlling Channel Grade

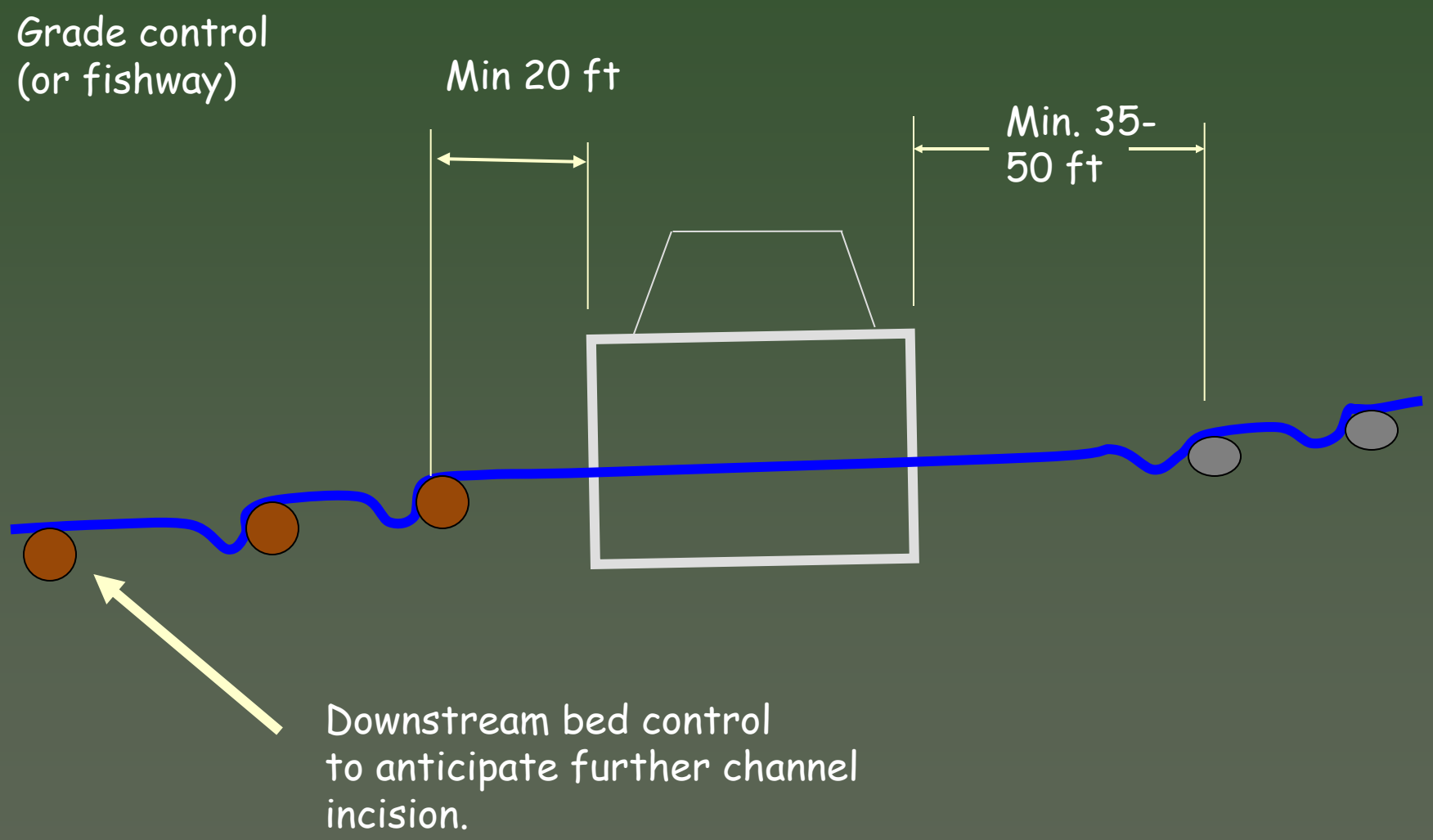


Maintain upstream bed elevation to protect current habitat or infrastructure



Allow a limited amount of regrade

Grade Control Location



These are <u>recommendations</u> in the water crossing guidelines.

Channel regrade considerations

- Extent of regrade expected.
  - Low channel slopes (fine bed materials) are sensitive.
  - High channel slopes less so.
- Condition of upstream channel and banks
  - Are they susceptible to bank collapse, riparian dewatering?
- Bedload benefits to downstream channel

Channel regrade considerations

- Habitat impacts by upstream incision
  - Is there value of culvert as nick point, preventing further incision?
  - Is there hard pan or bedrock near the surface?
  - Potential passage barriers created upstream by further incision?

1983 – Culvert replaced

looking upstream of culvert

2002 - Channel regraded to bedrock

looking downstream at culvert inlet

Wynoochee tributary

Channel regrade considerations

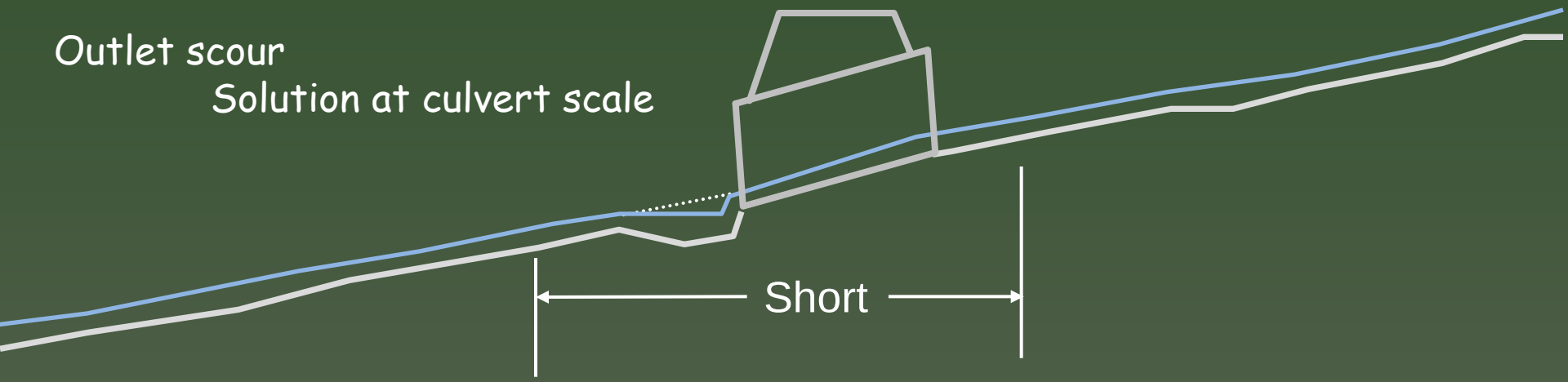
- Culvert and channel capacity reduced by sediment slug released from upstream incision.

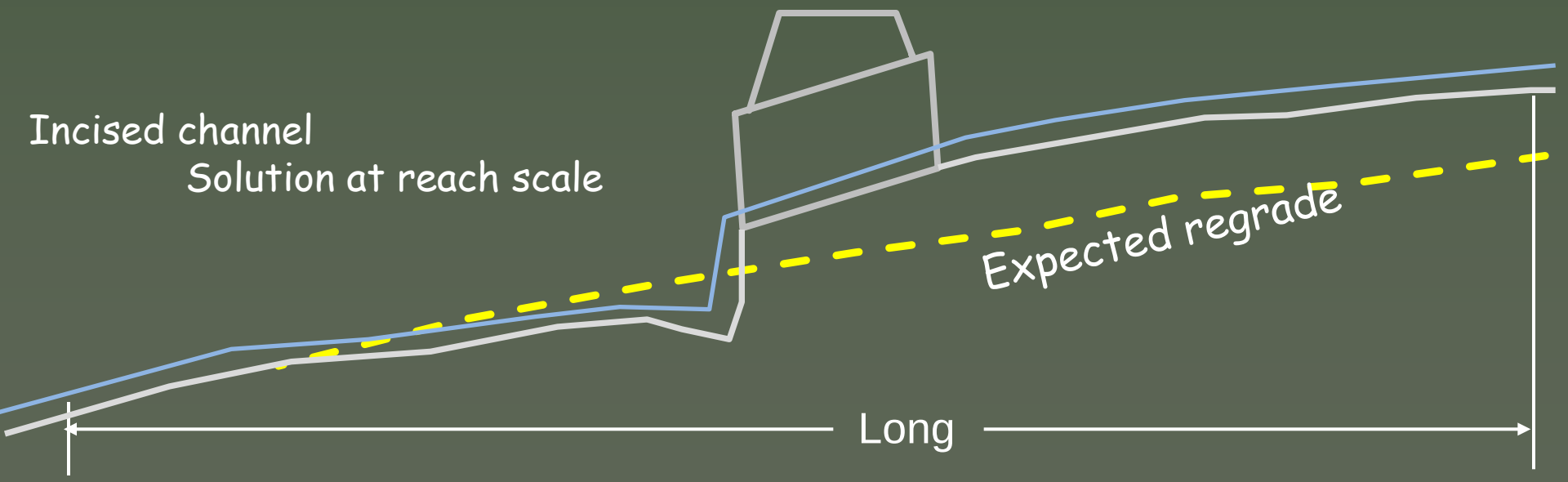
Channel regrade considerations

- Risk to utilities and structures.
- Construction access to dig regrade.

Channel profile

Scale of Problem = Scale of Solution

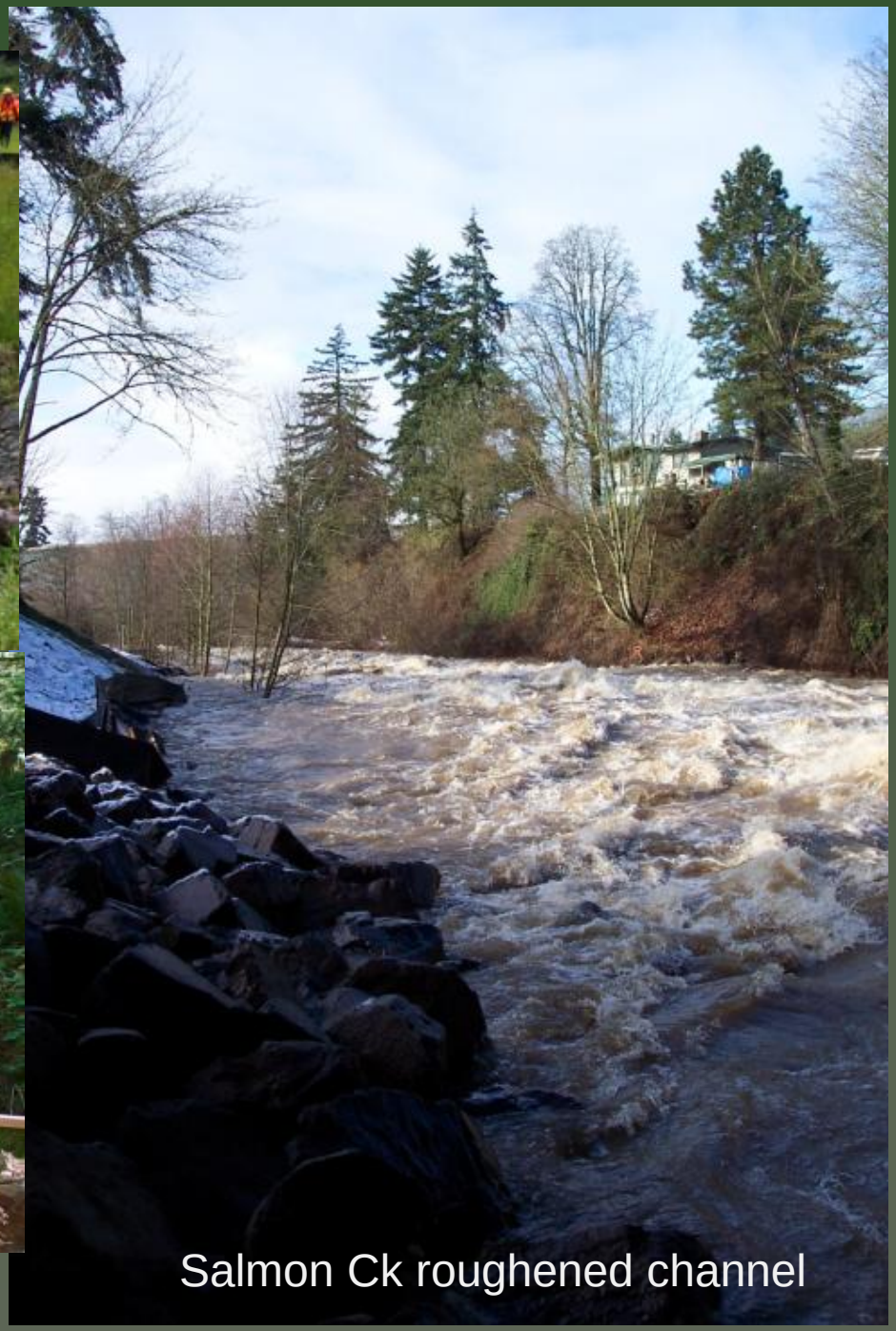




Grade control options

Taylor Ck log weirs

Outlet Creek large wood roughness



Salmon Ck roughened channel

Roughened channel used for grade control below an existing culvert.

Boulder controls

Goldsborough Creek concrete weirs

Pool and chute fishway
Fish passage design flow

Roughened Channels

What is a Roughened Channel?

- A hydraulic design method creating an artificial channel constructed to increase prevailing stream gradient .

Characteristics of Roughened Channels

- Provides sufficient roughness to provide upstream fish passage, generally for adult salmonids
- Generally constructed out of rock
- Often expected to maintain a set streambed elevation (grade control)
- Typically made of larger bed material than found locally in the channel.

Design Objectives

1. Meet average velocity criteria at flows up to the high fish passage flow.
2. Maintain structural bed stability up to a design flow (typically 100-yr flood).
3. Limit turbulence which is a potential passage barrier, particularly to small fish.
4. Control bed porosity to maintain surface flow.

Guidelines present a 6-step design process that requires familiarity with open channel hydraulic design methods.

Scale of analysis should be commensurate with fish passage and structural risk

Rock ramp spanning Yakima River at Union Gap (3480 sq. mi. drainage, multiple anadromous and resident species)

vs.

Brook trout dominated tributary with ½ mi. of useable habitat upstream.

Roughened Channels

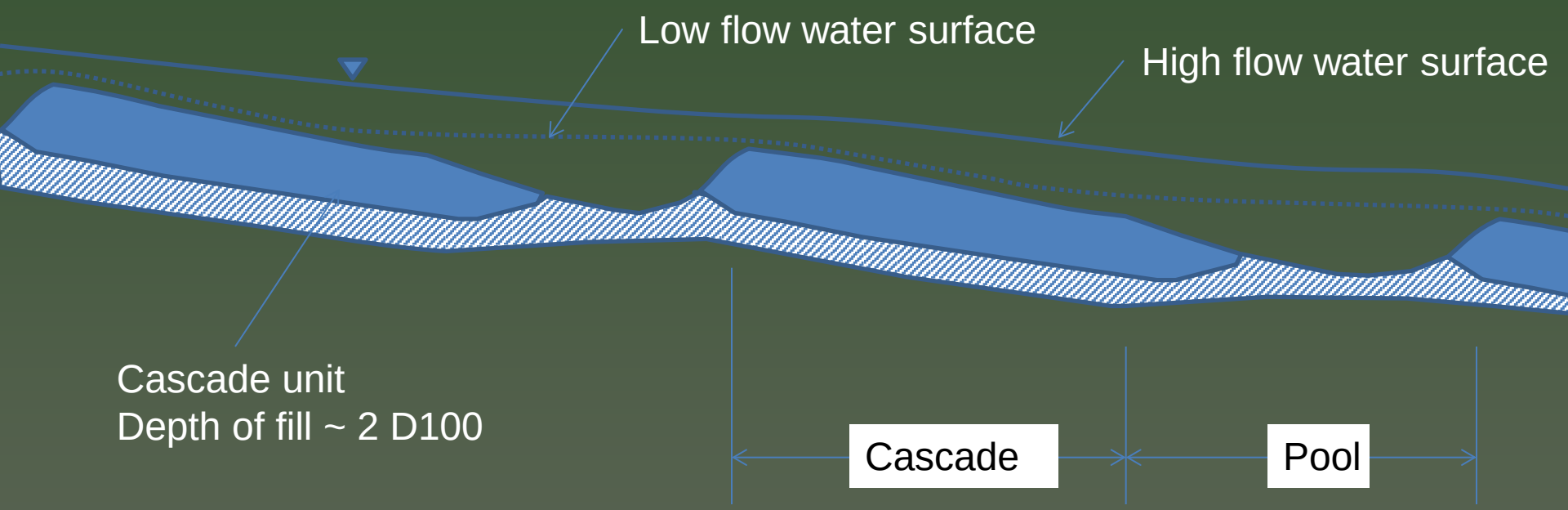
- There is a general lack of robust evaluations of fish passage at roughened channels in WA.
- Claims of success or failure generally based on judgement or anecdotal information.

Application of roughened channel design should be based on local channel reference conditions

Consider:

- Total length of RC units
- Total drop though RC units
- Maximum slope of RC

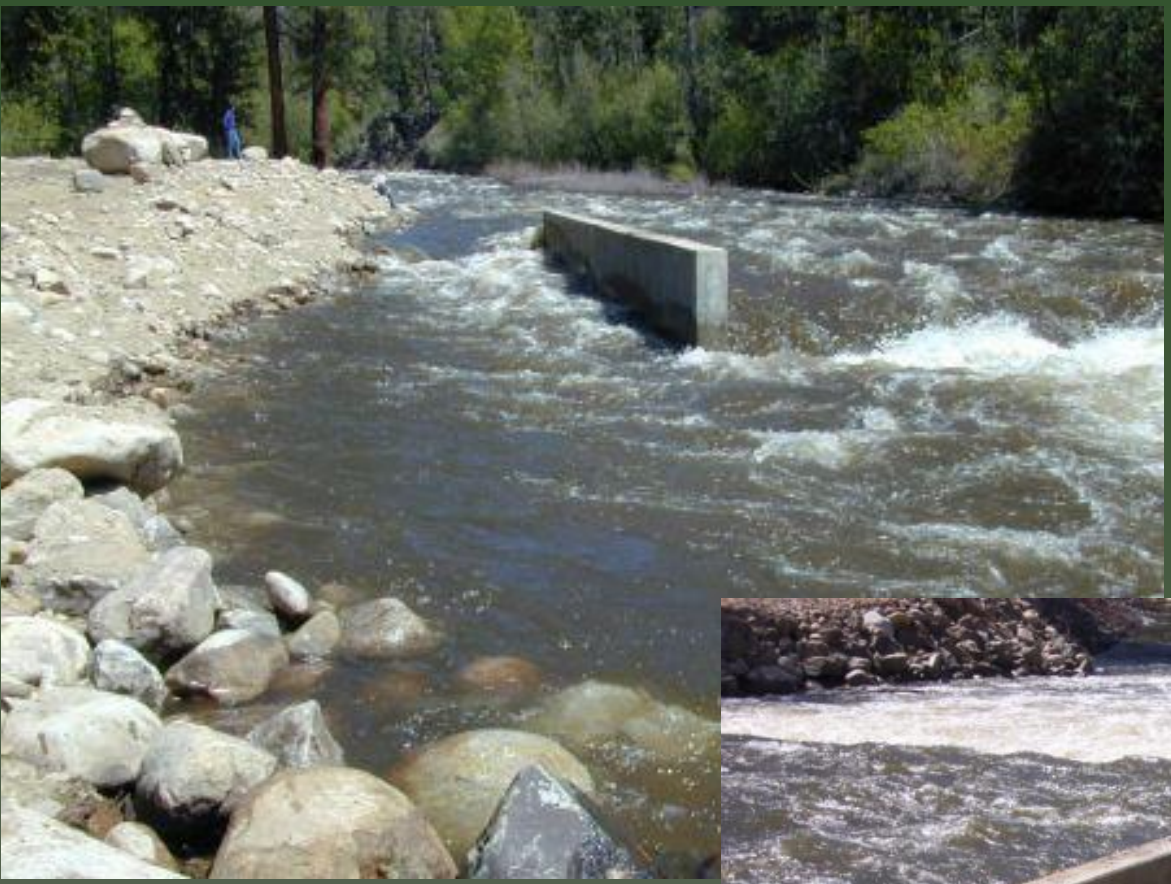
Roughened channel: cascade-pool concept drawing



Overall channel gradient = S
Cascade gradient = 1.5-2S
Cascade length = L
Pool length = 0.5 – 1.0L

Old Chewuch Diversion @ 45 cfs

New Chewuch diversion roughened channel



2400 cfs

←

1650 cfs

→

5500 cfs

Selecting a method

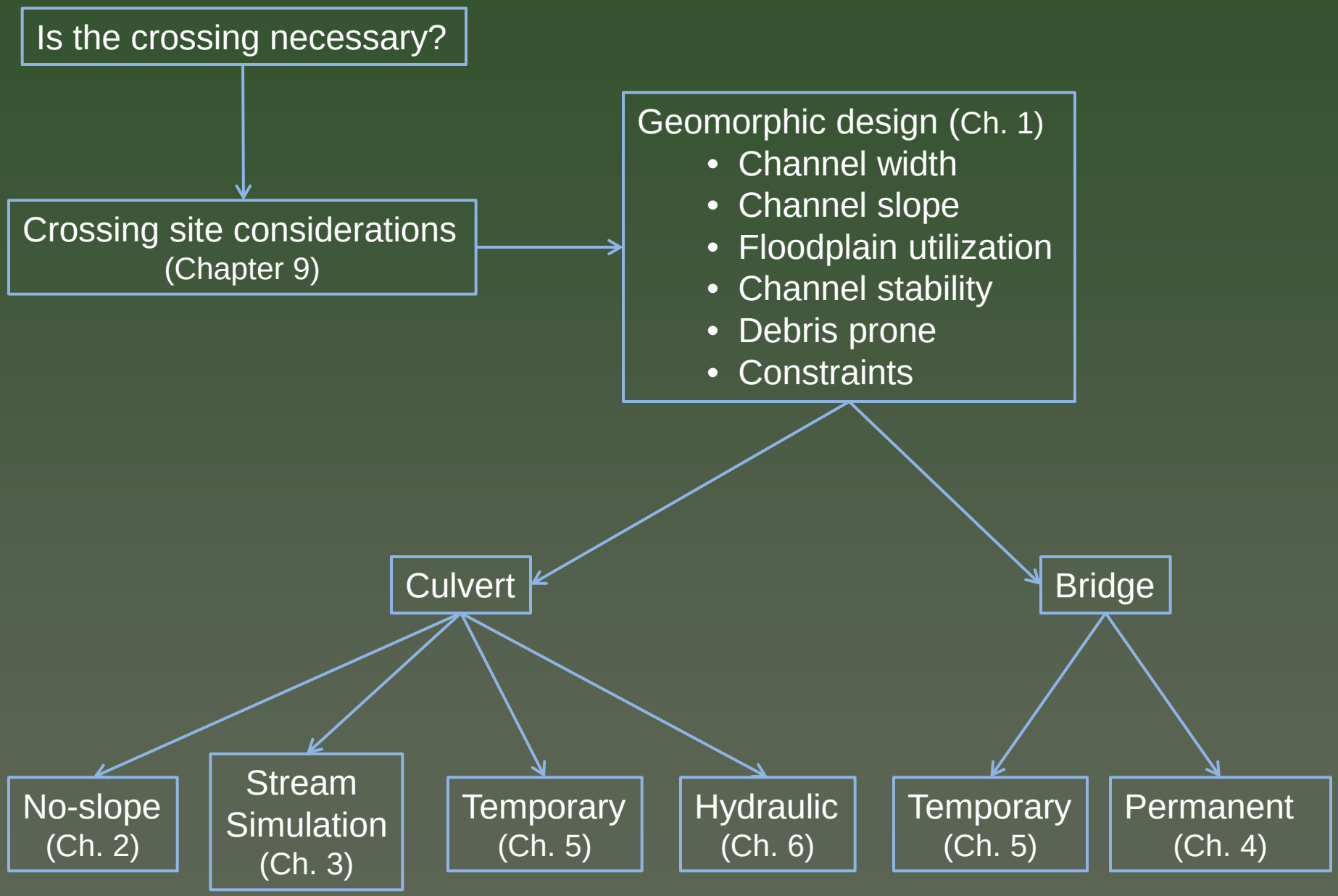
Bridge

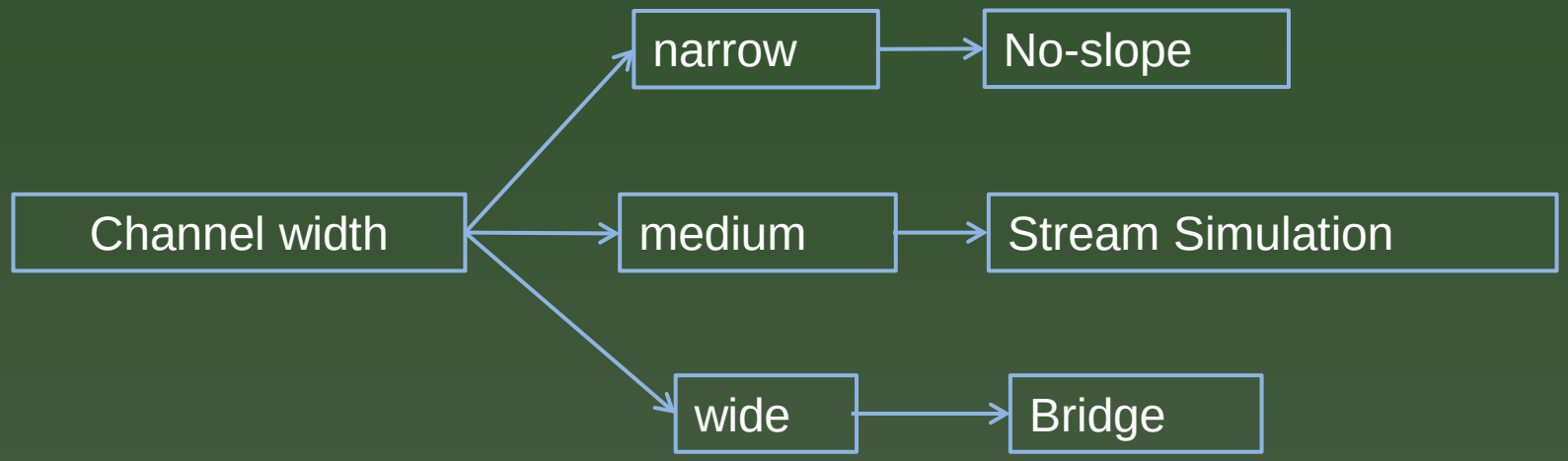
Stream simulation

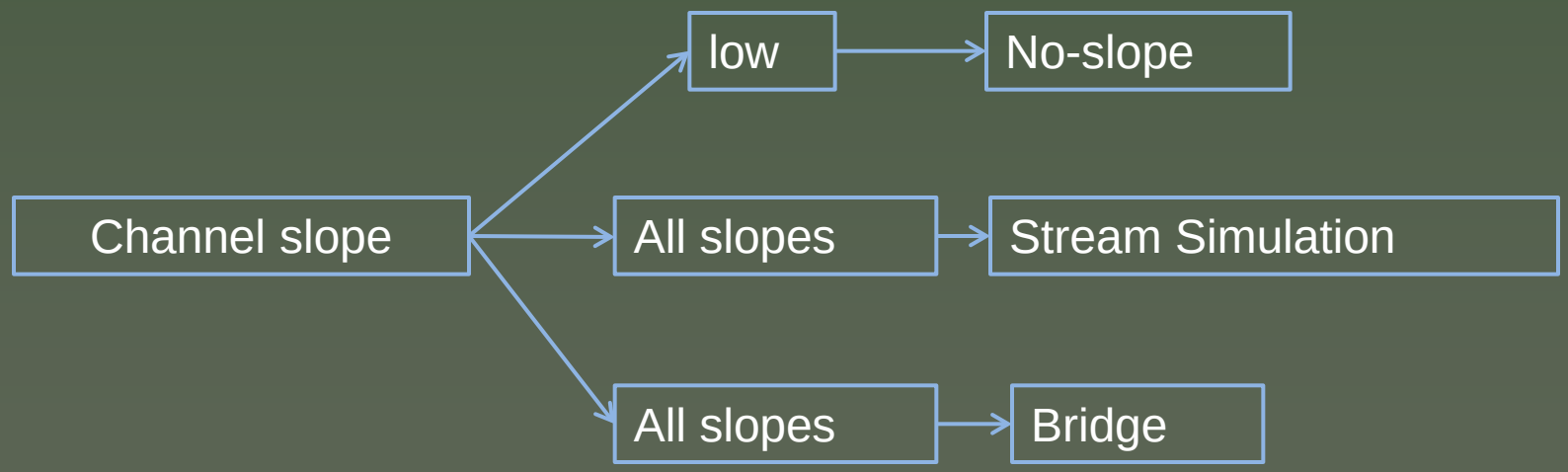
Temporary

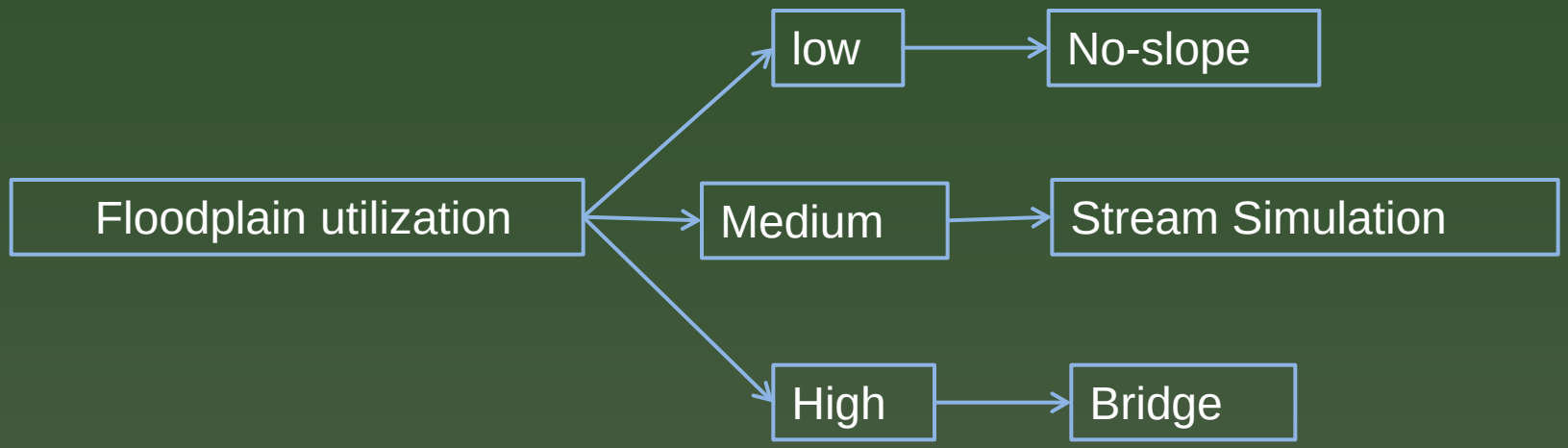
No-slope

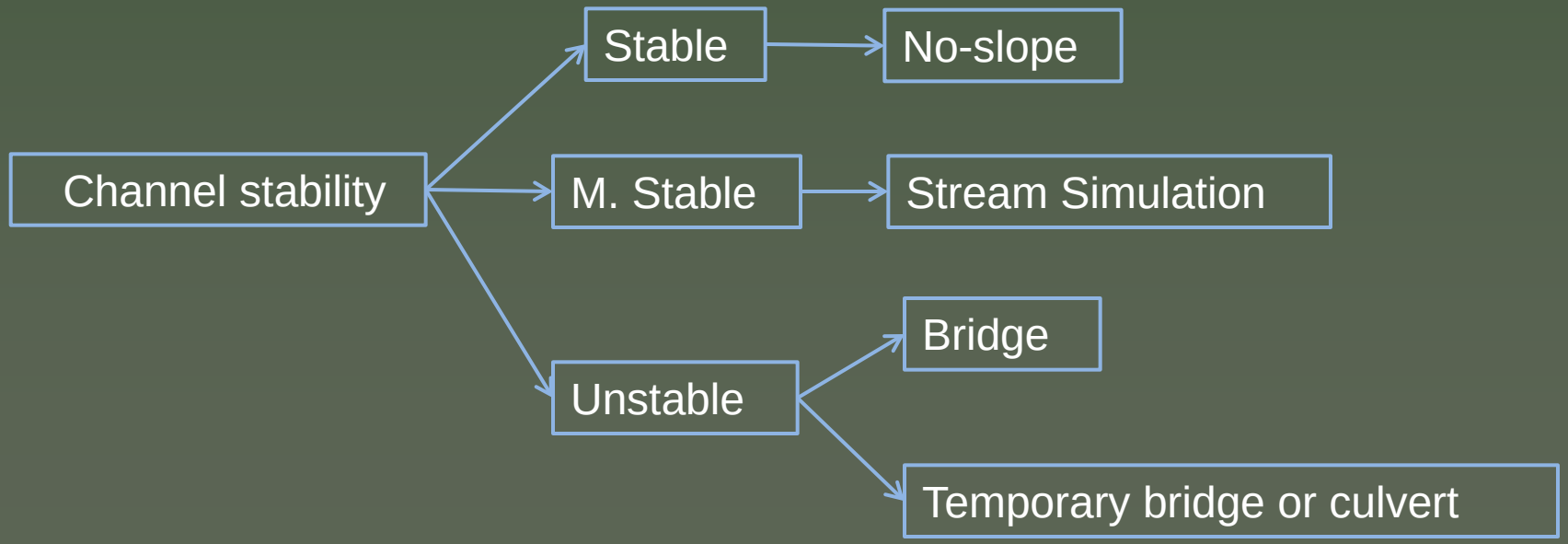
Hydraulic (RC)

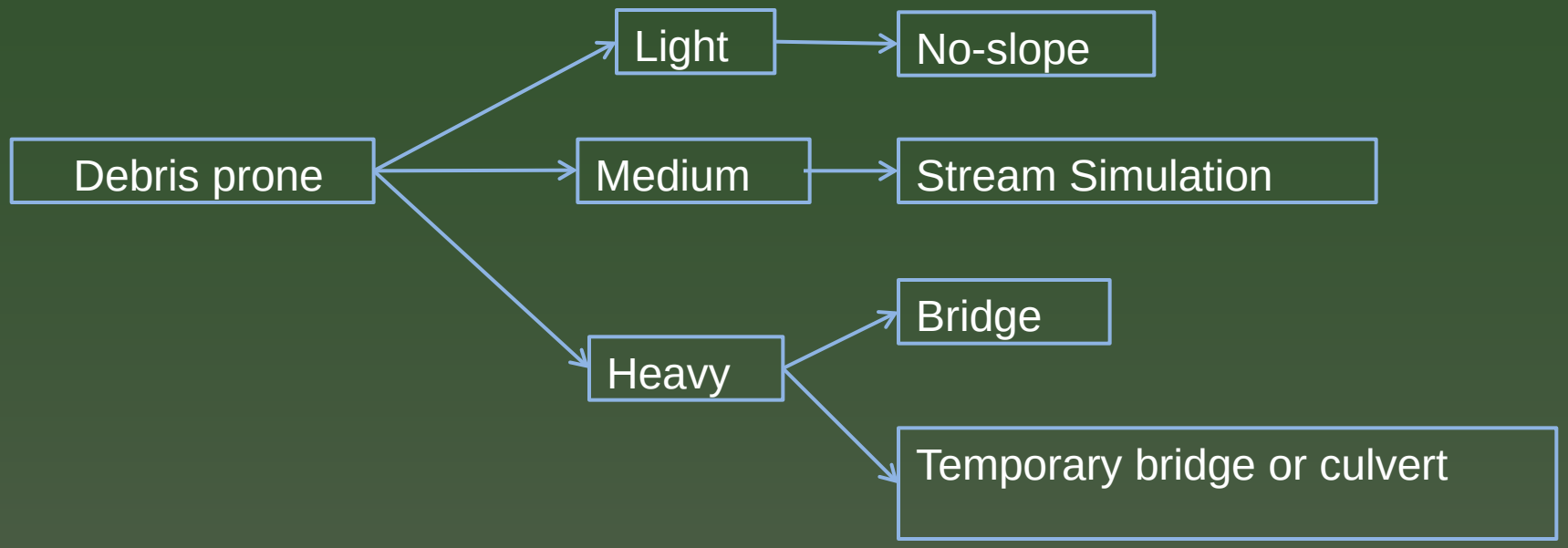

Is the crossing necessary?
Crossing site considerations
(Chapter 9)
Geomorphic design (Ch. 1)
• Channel width
• Channel slope
• Floodplain utilization
• Channel stability
• Debris prone
• Constraints
Culvert
Bridge
No-slope
(Ch. 2)
Stream
Simulation
(Ch. 3)
Temporary
(Ch. 5)
Hydraulic
(Ch. 6)
Temporary
(Ch. 5)
Permanent
(Ch. 4)

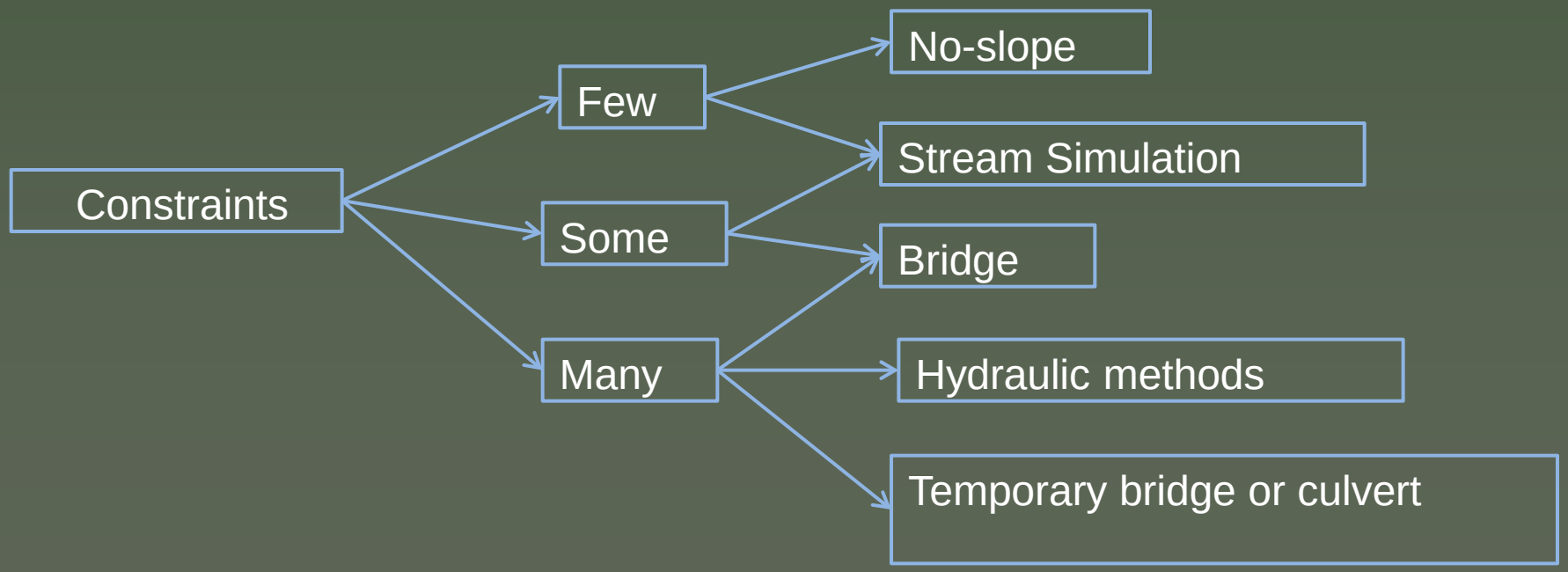

Channel width
narrow
No-slope
medium
Stream Simulation
wide
Bridge

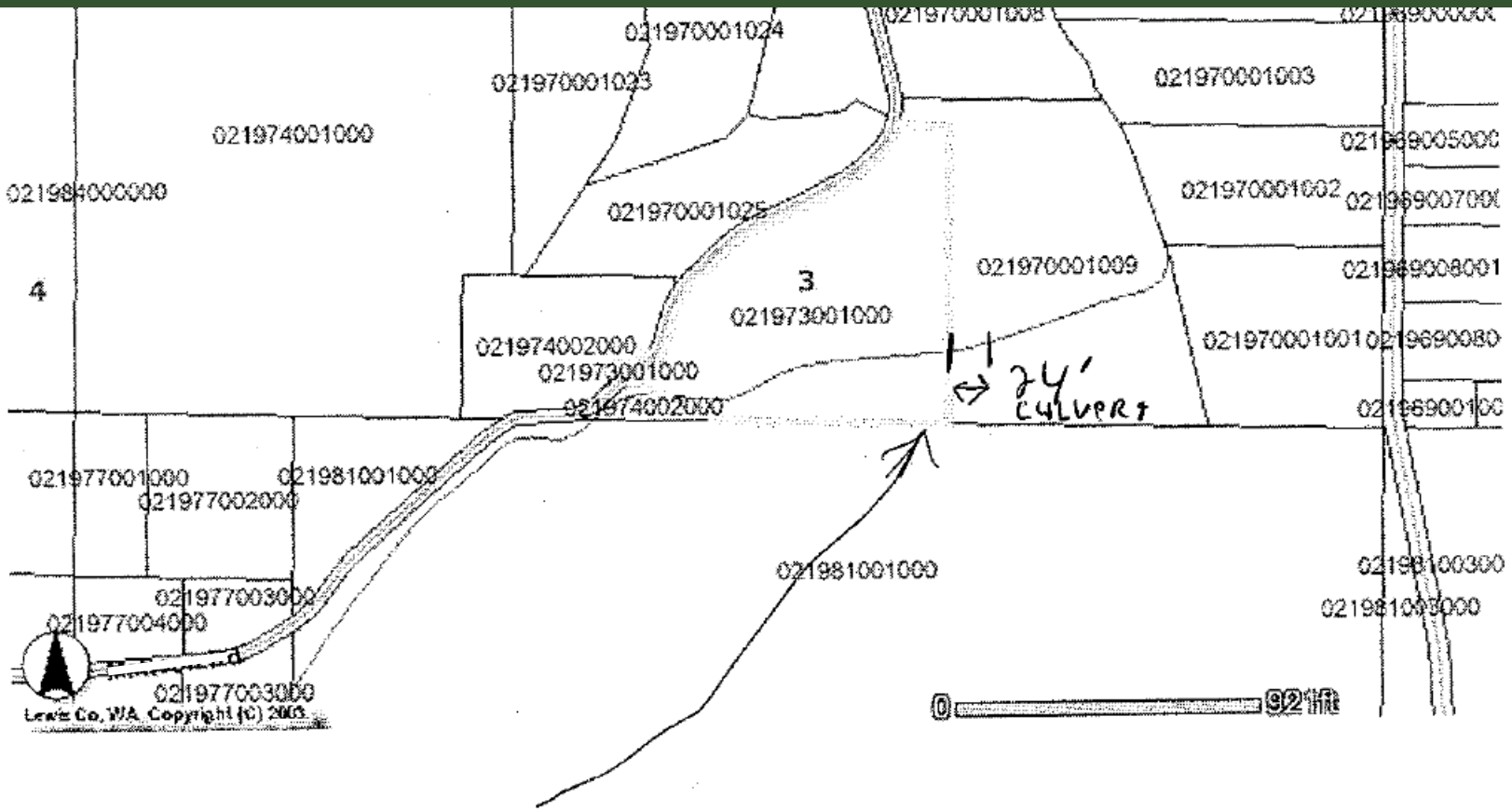

Channel slope
low
No-slope
All slopes
Stream Simulation
All slopes
Bridge


Floodplain utilization
low
No-slope
Medium
Stream Simulation
High
Bridge


Channel stability
Stable
No-slope
M. Stable
Stream Simulation
Unstable
Bridge
Temporary bridge or culvert


Debris prone
Light
No-slope
Medium
Stream Simulation
Heavy
Bridge
Temporary bridge or culvert


Constraints
Few
No-slope
Stream Simulation
Some
Bridge
Many
Hydraulic methods
Temporary bridge or culvert

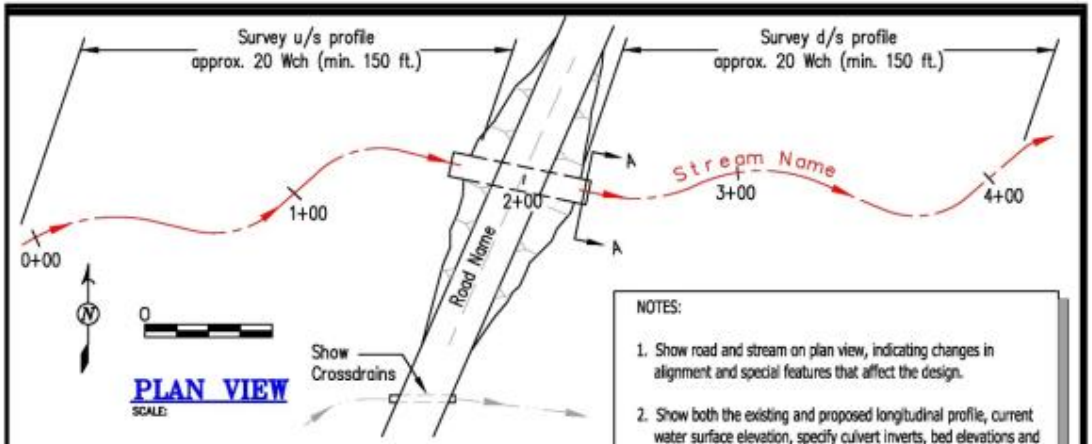


Install Culvert at This Location.

Culvert size 8' Tall

10.5 wide

24' Long

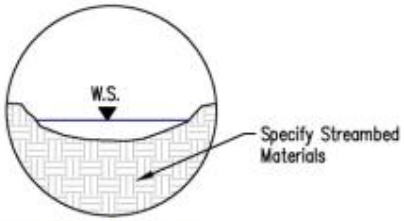


PLAN VIEW

SCALE:

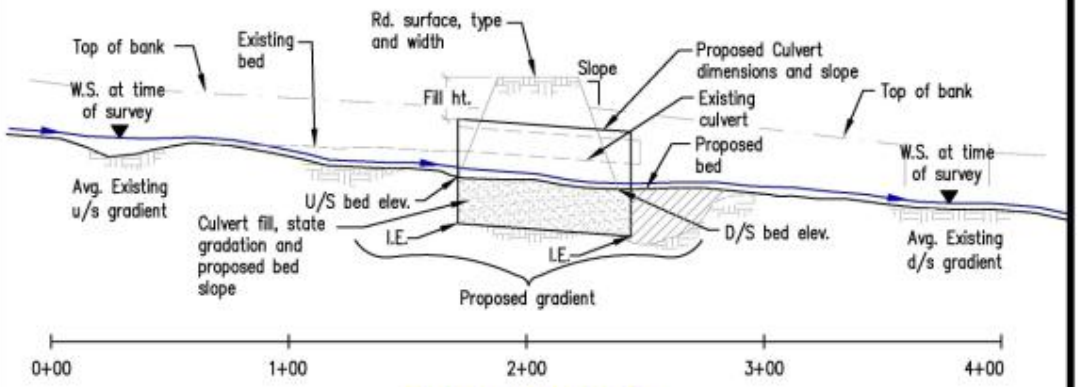
NOTES:

1. Show road and stream on plan view, indicating changes in alignment and special features that affect the design.
2. Show both the existing and proposed longitudinal profile, current water surface elevation, specify culvert inverts, bed elevations and degree of regrade expected. Length of profile should be at least 40 times the bankfull width plus the length of the culvert.
3. Show proposed culvert cross section with streambed shape. Specify culvert bed materials.
4. Show road drainage plan, including cross culverts, ditch lining, sediment ponds, etc.
5. Optional: show 100-year flood water surface, and top of bank on profile.
6. Optional: add details concerning stream channel characteristics, for instance pool-riffle geometry, size and placement of large wood.
7. Optional: a site map with contours and stream layout details.



SECTION A–A

Culvert Cross Section



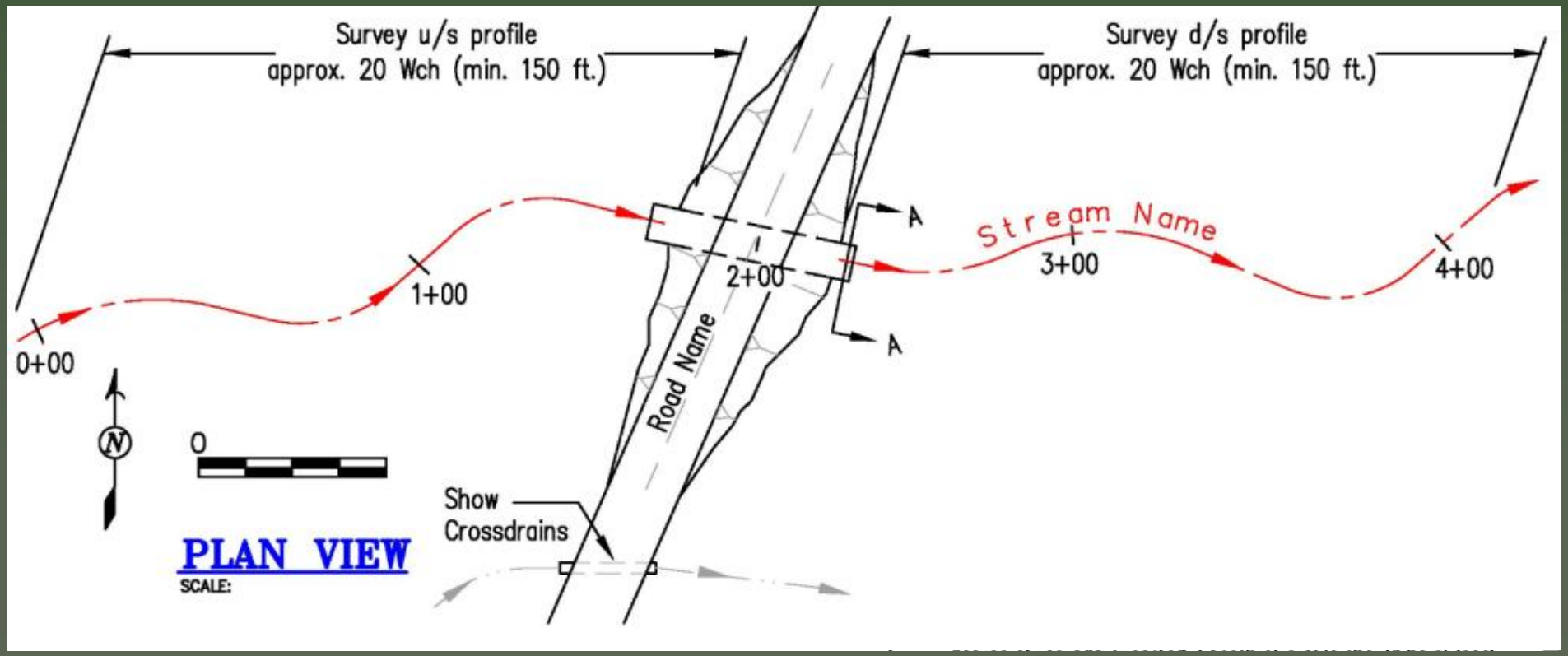
STREAM PROFILE

SCALE: 0

PURPOSE: *EXAMPLE CULVERT REPLACMENT* *N.T.S.* DWG. Name: clvrt1 SHEET OF DATE	Applicants name: Address & phone:	Stream Name:_____ WRIA:_____ Date: _____ Sec. _____ T _____ R _____ County of: _____

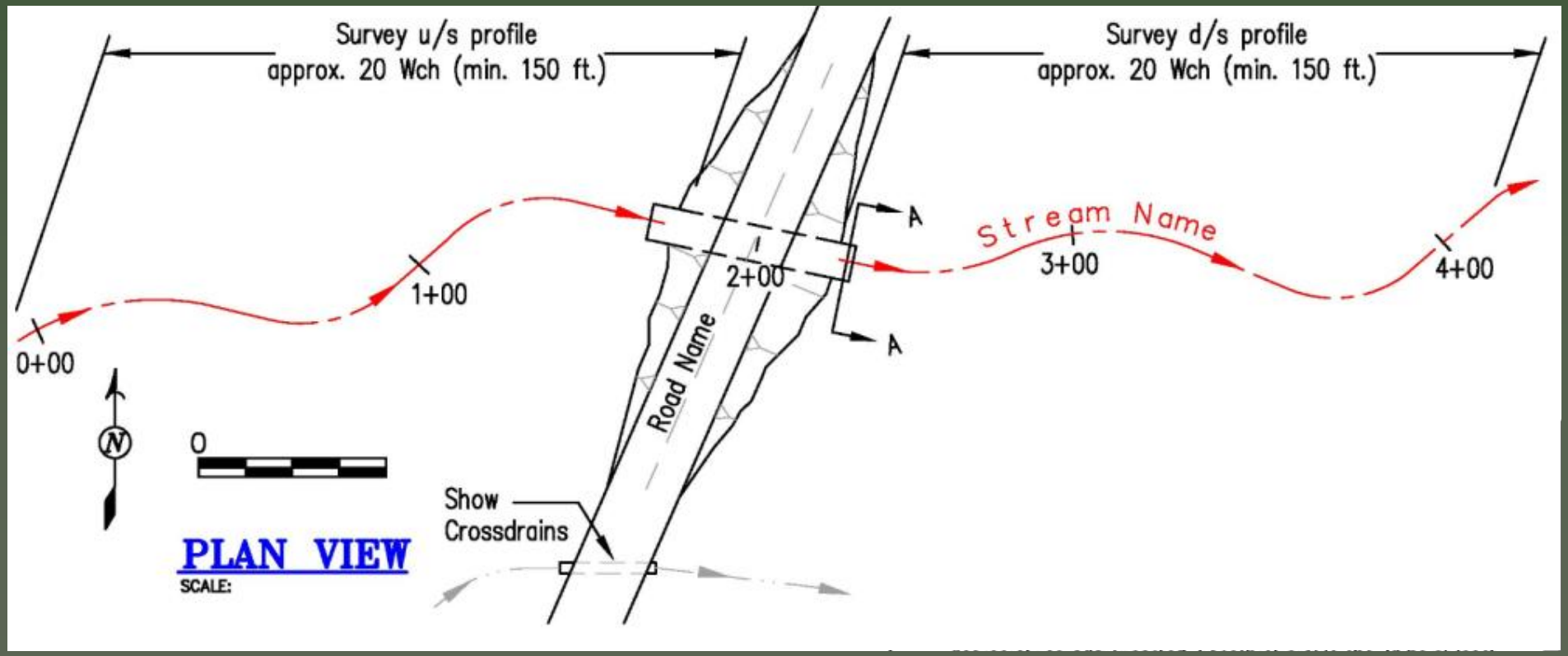
Show road and stream on plan view, indicating

- changes in alignment and
- special features that affect the design.



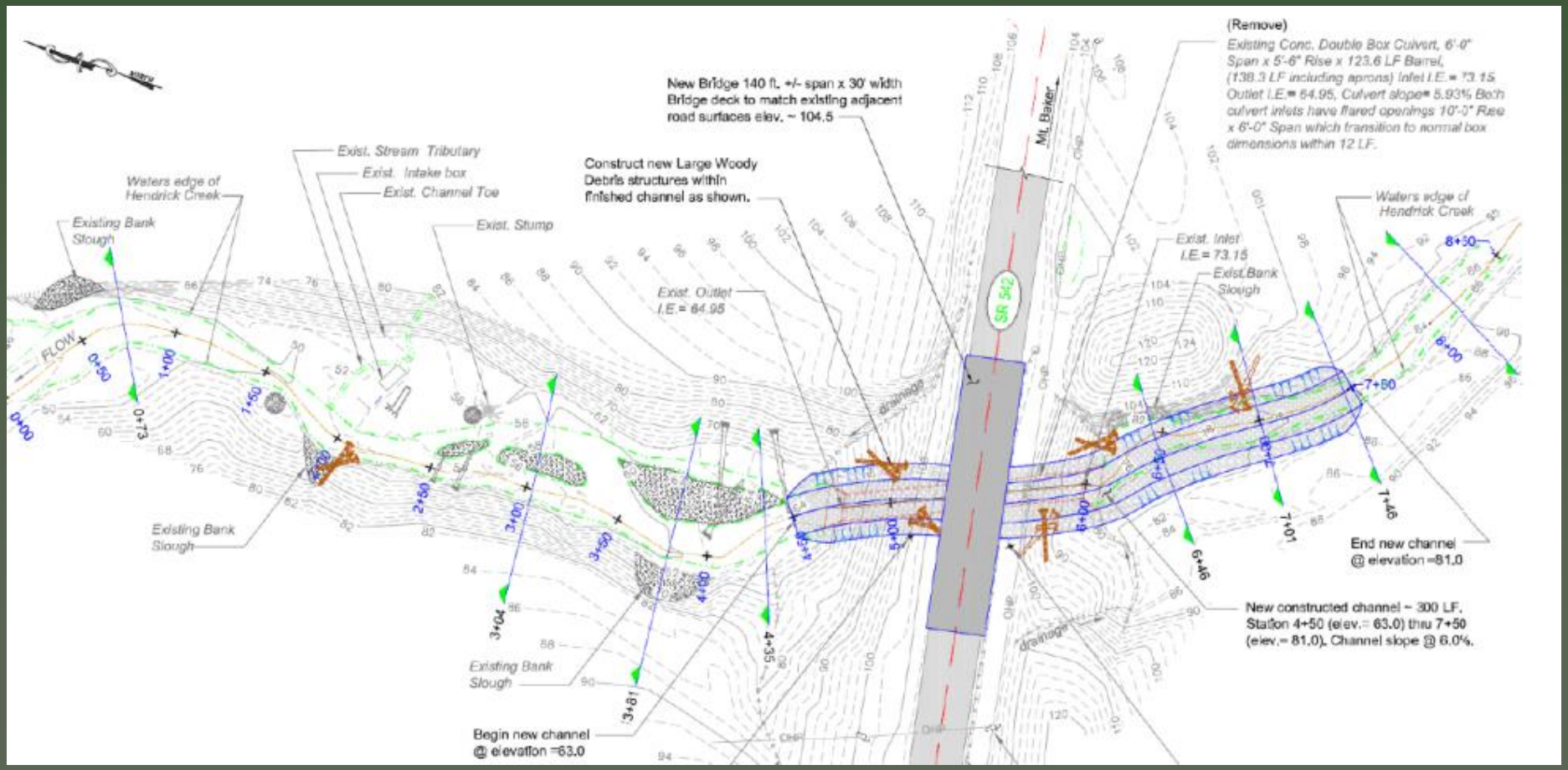
Show road drainage plan, including

- cross culverts,
- ditch lining,
- sediment ponds, etc.



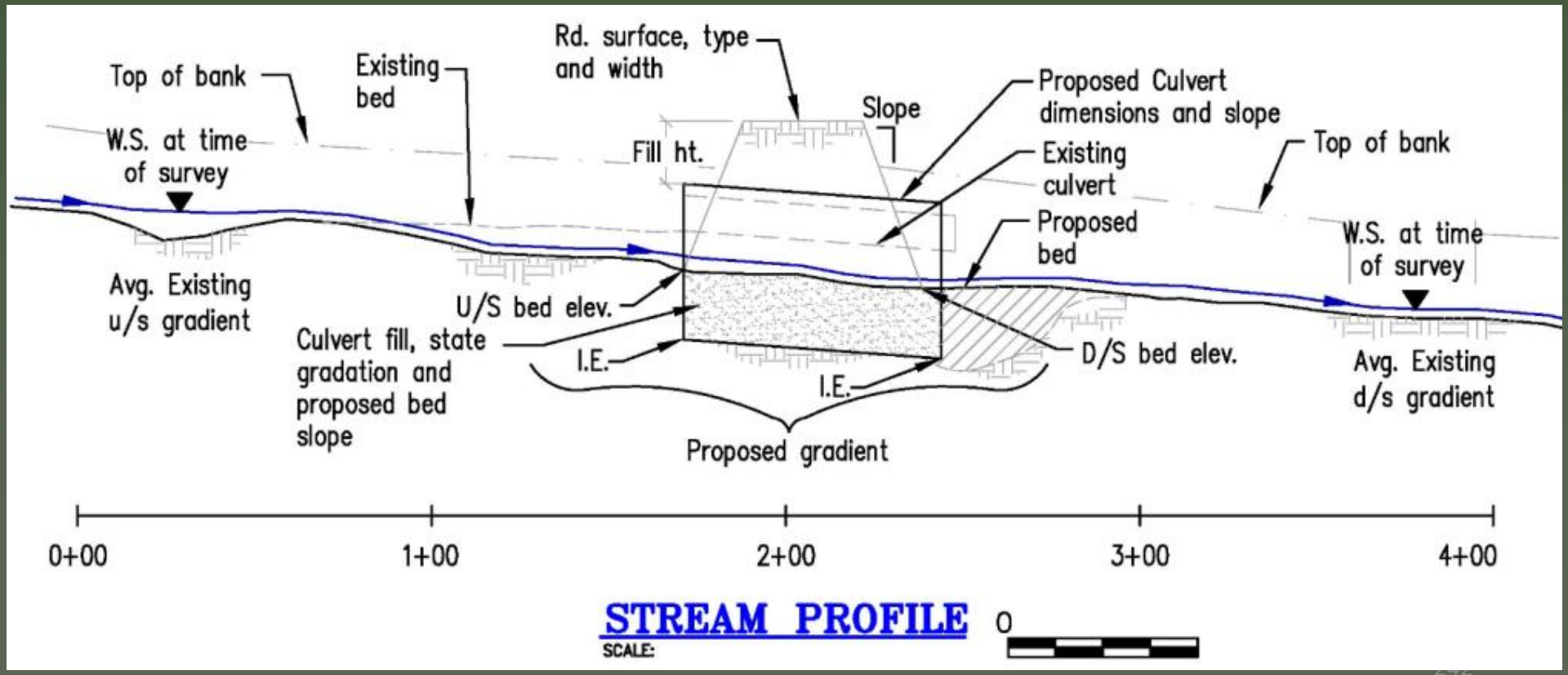
Optional:

- a site map with contours
- stream layout details.



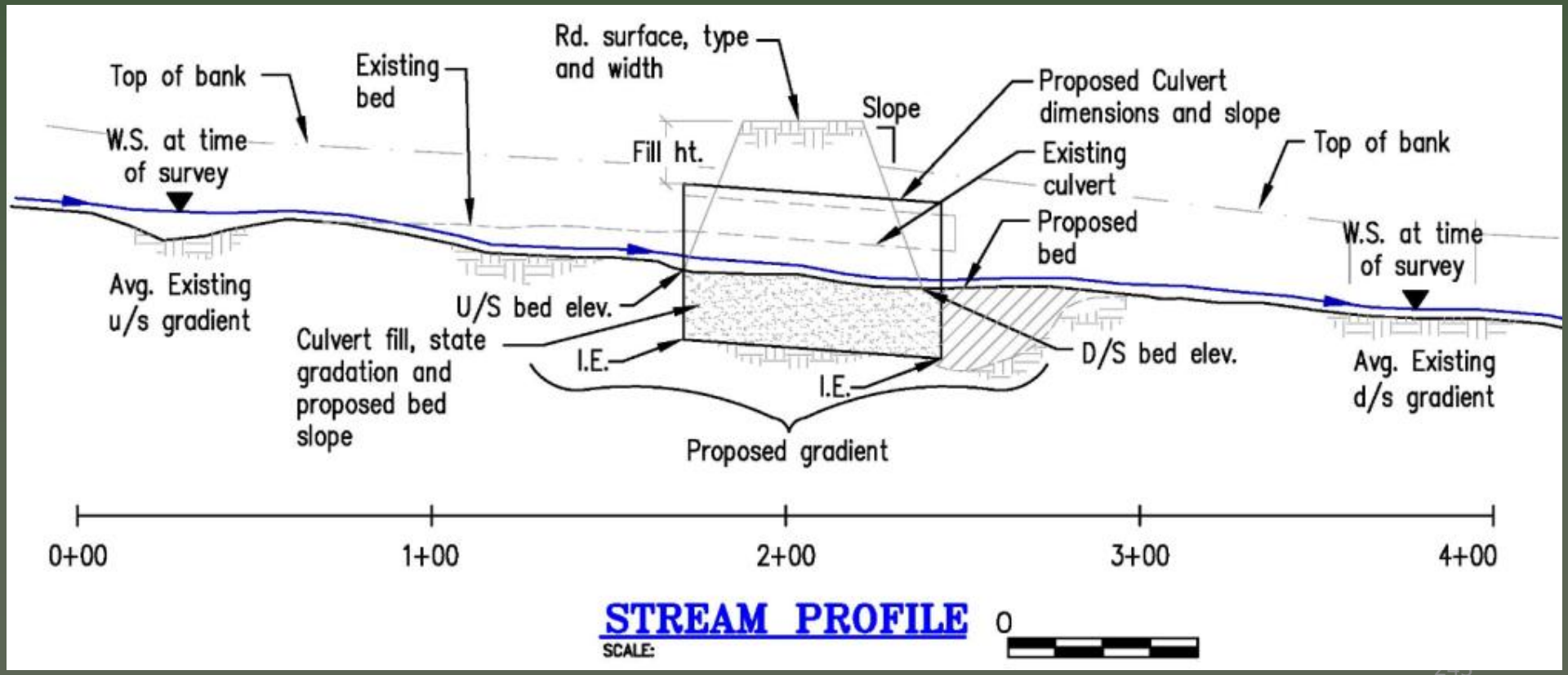
Length of profile at least 40 times the bankfull width plus the length of the culvert

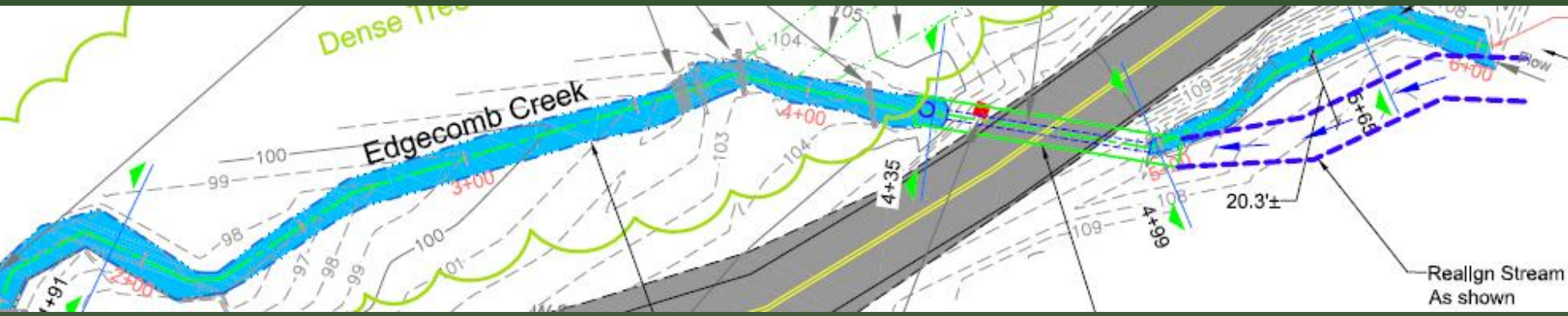
- both the existing and proposed longitudinal profile,
- current water surface elevation,
- specify culvert invert, bed elevations (BM required)
- TOB and regrade expected.



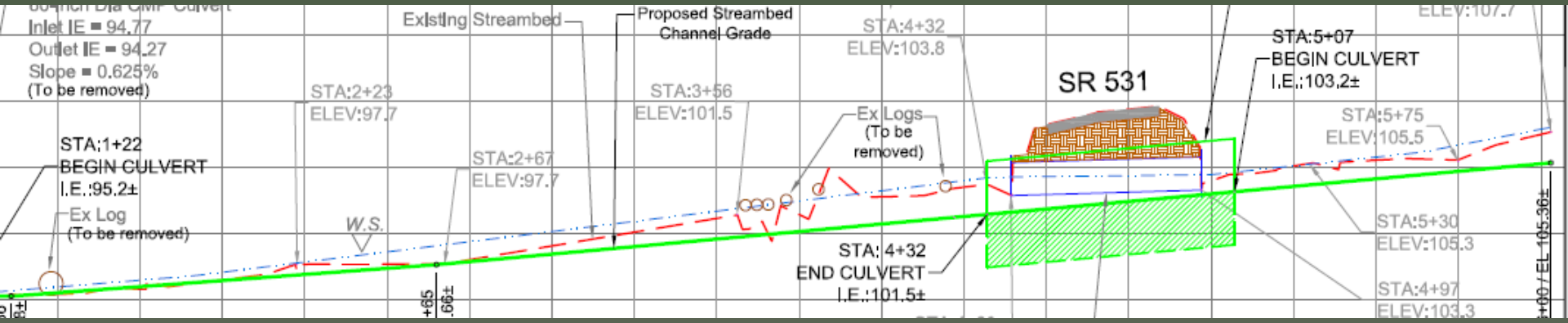
Optional:

- stream channel characteristics, for instance pool-riffle geometry,
- size and placement of large wood.

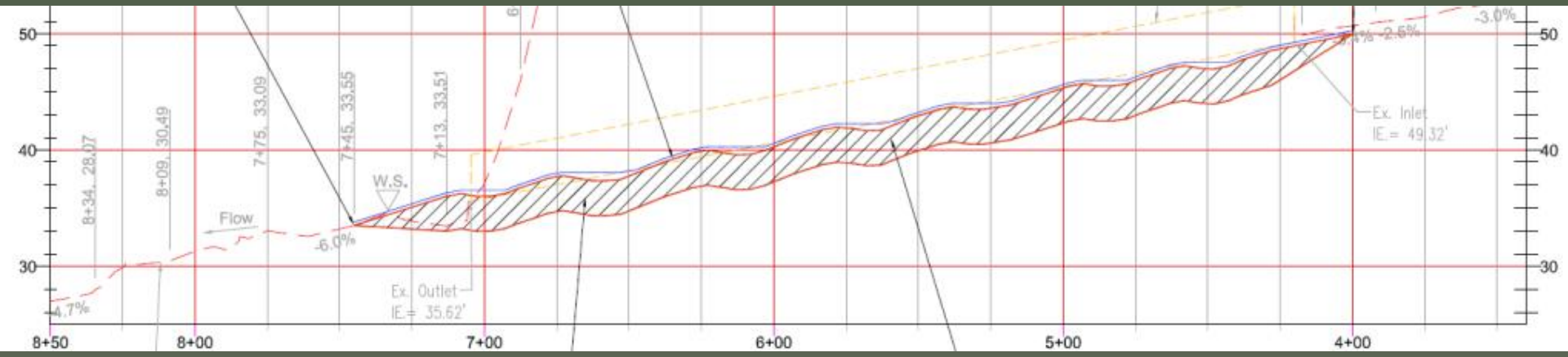




Realignment

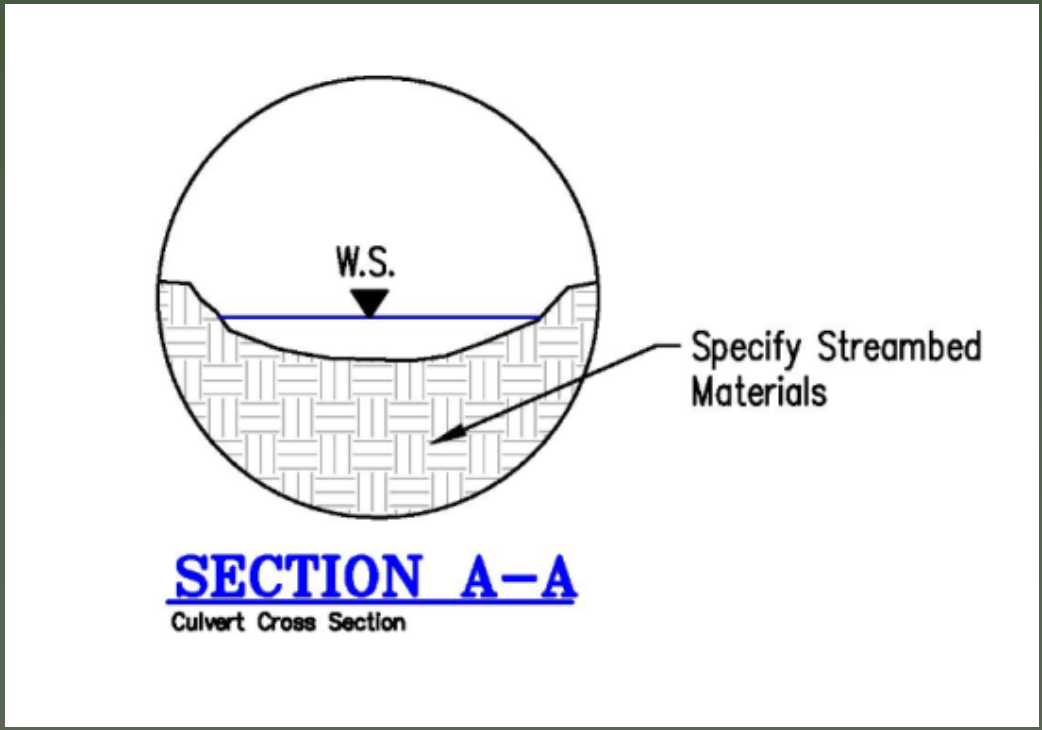


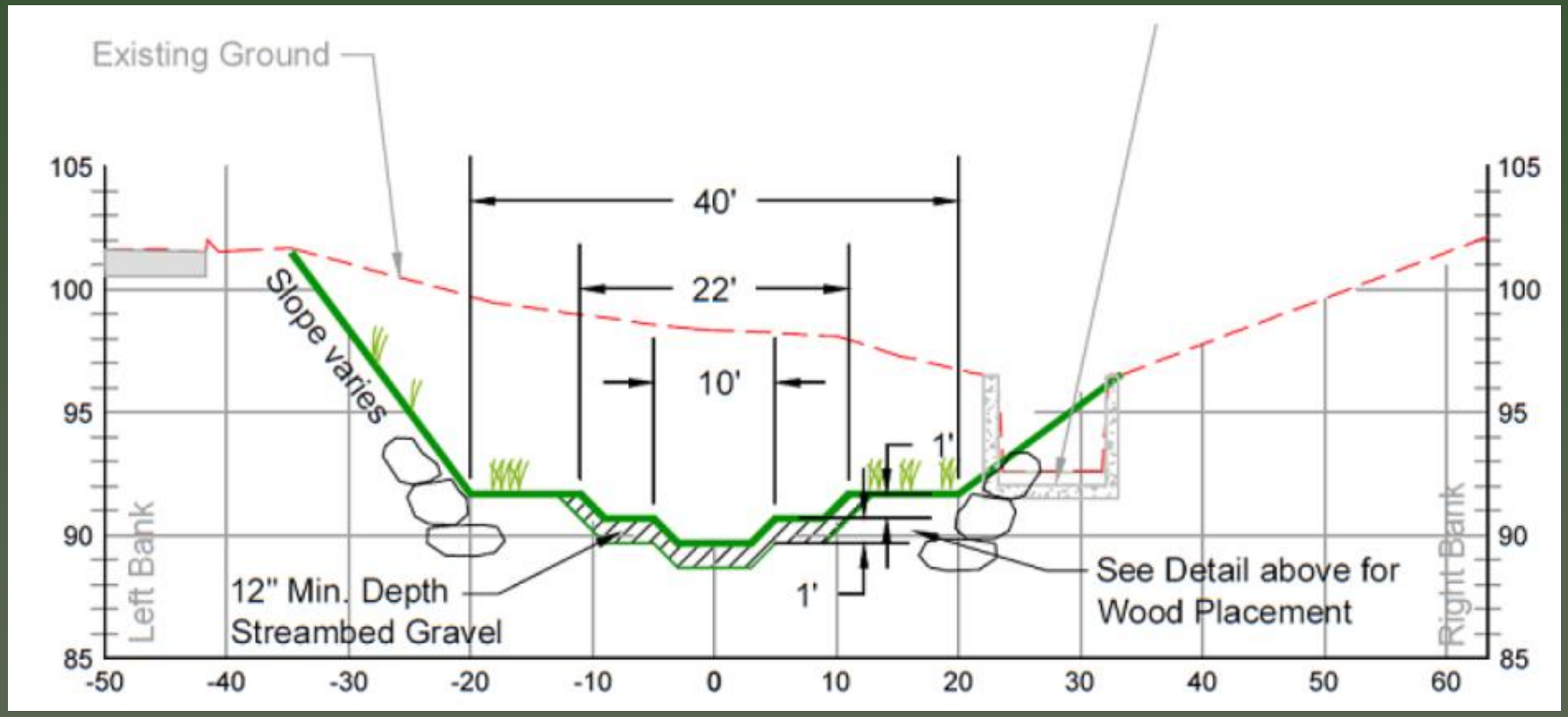
Regrade

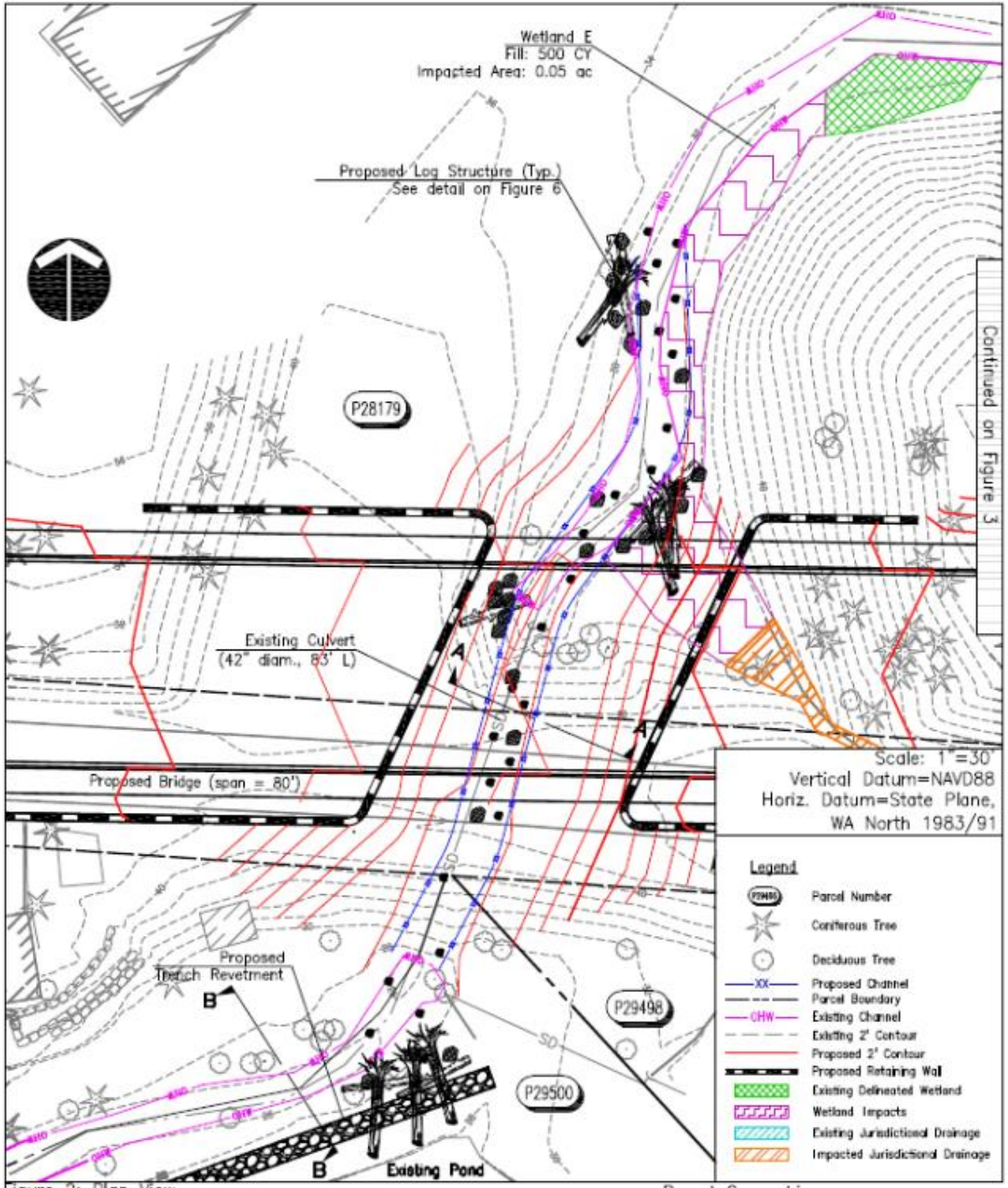


Detailed profile (Trafton Ck concept drawing)

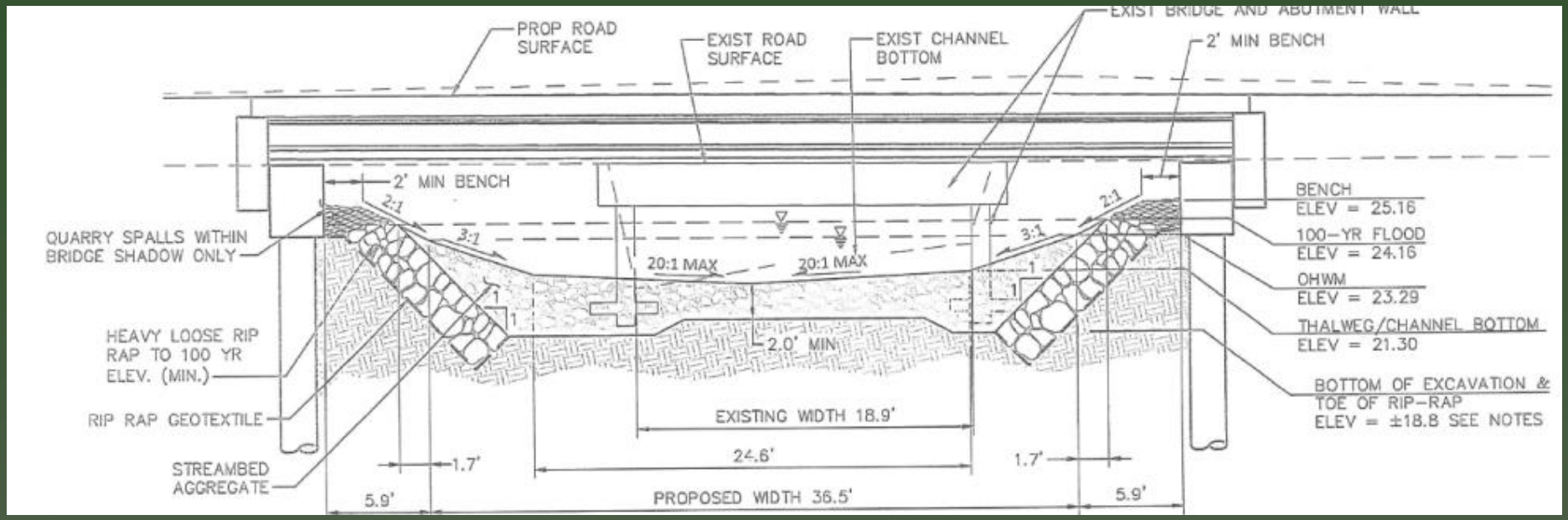
- Show proposed culvert cross section with streambed shape.
- Specify culvert bed materials.

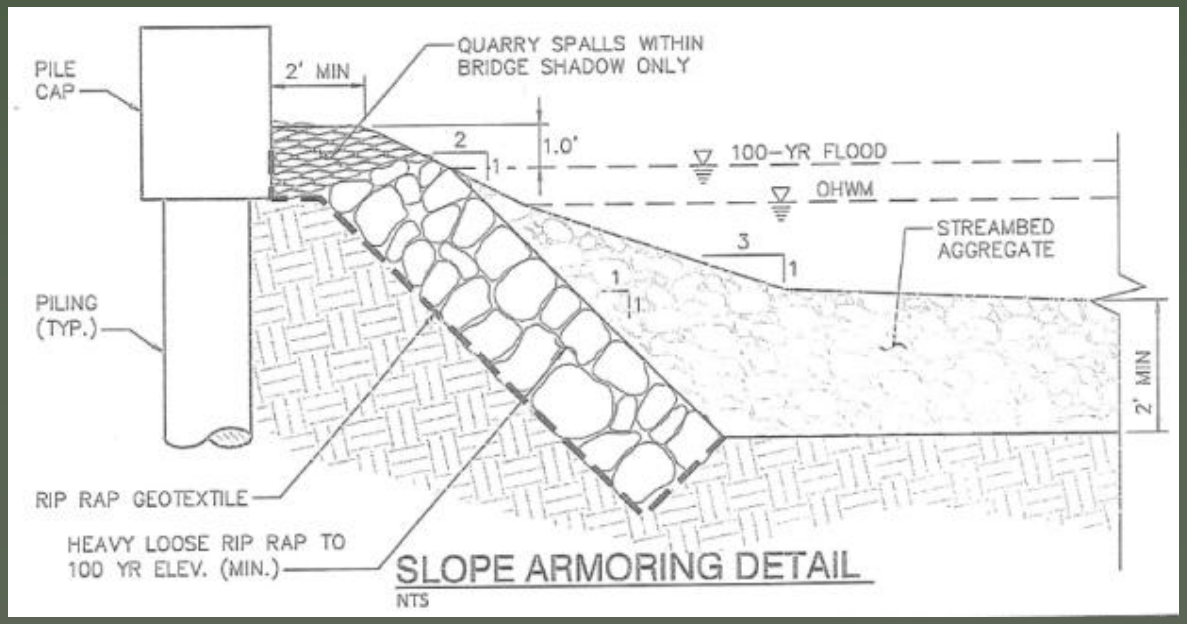



Existing Ground
40'
22'
10'
1'
1'
Slope varies
12" Min. Depth
Streambed Gravel
See Detail above for
Wood Placement
Left Bank
Right Bank
105
100
95
90
85
-50
-40
-30
-20
-10
0
10
20
30
40
50
60

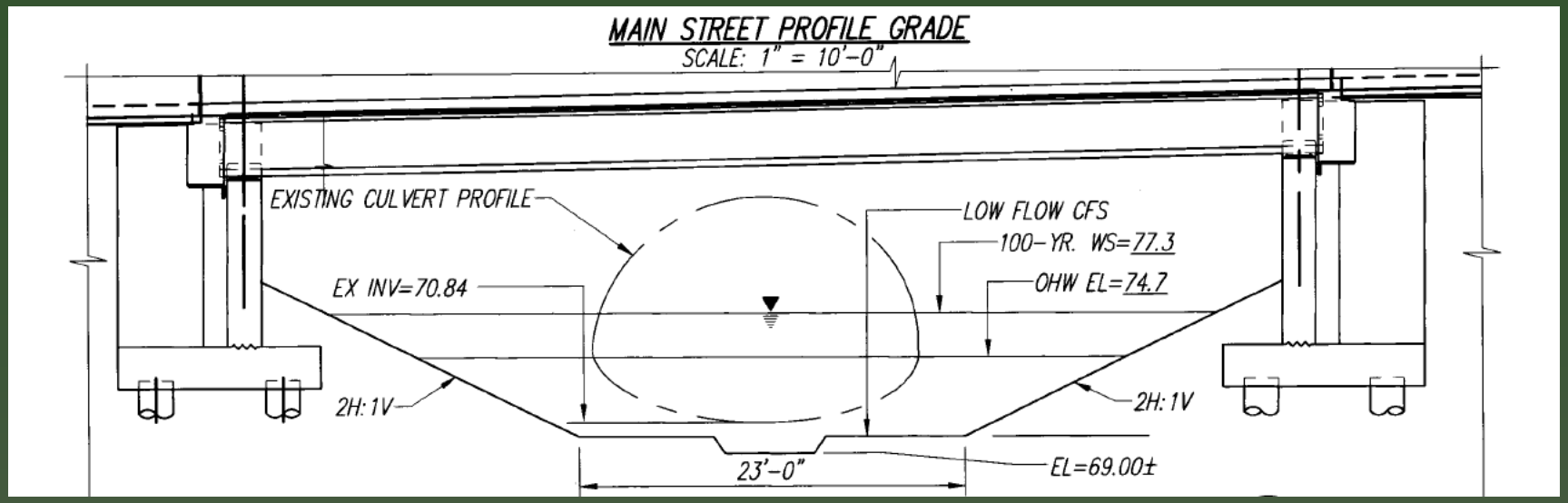


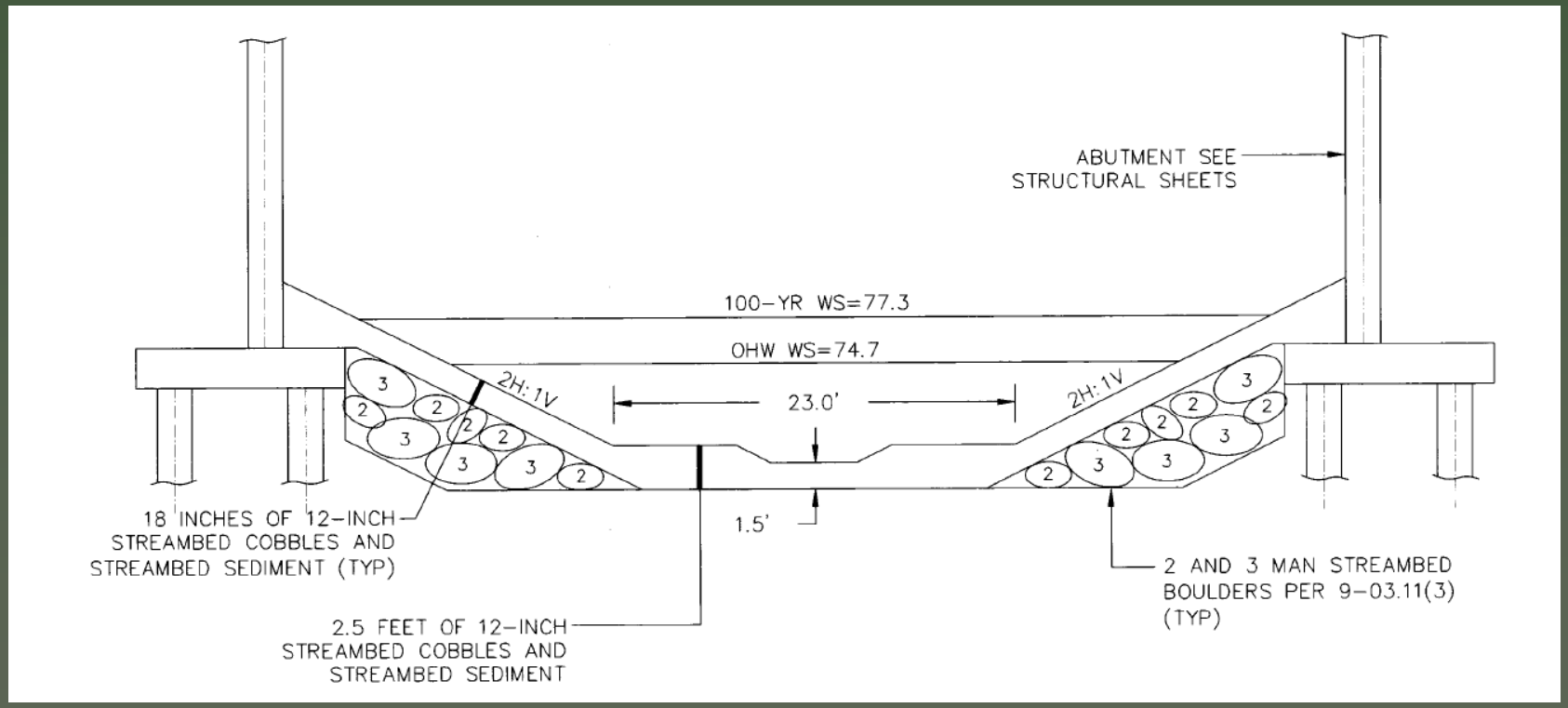
Skagit Co.
Anderson Ck.
Laventure Rd.



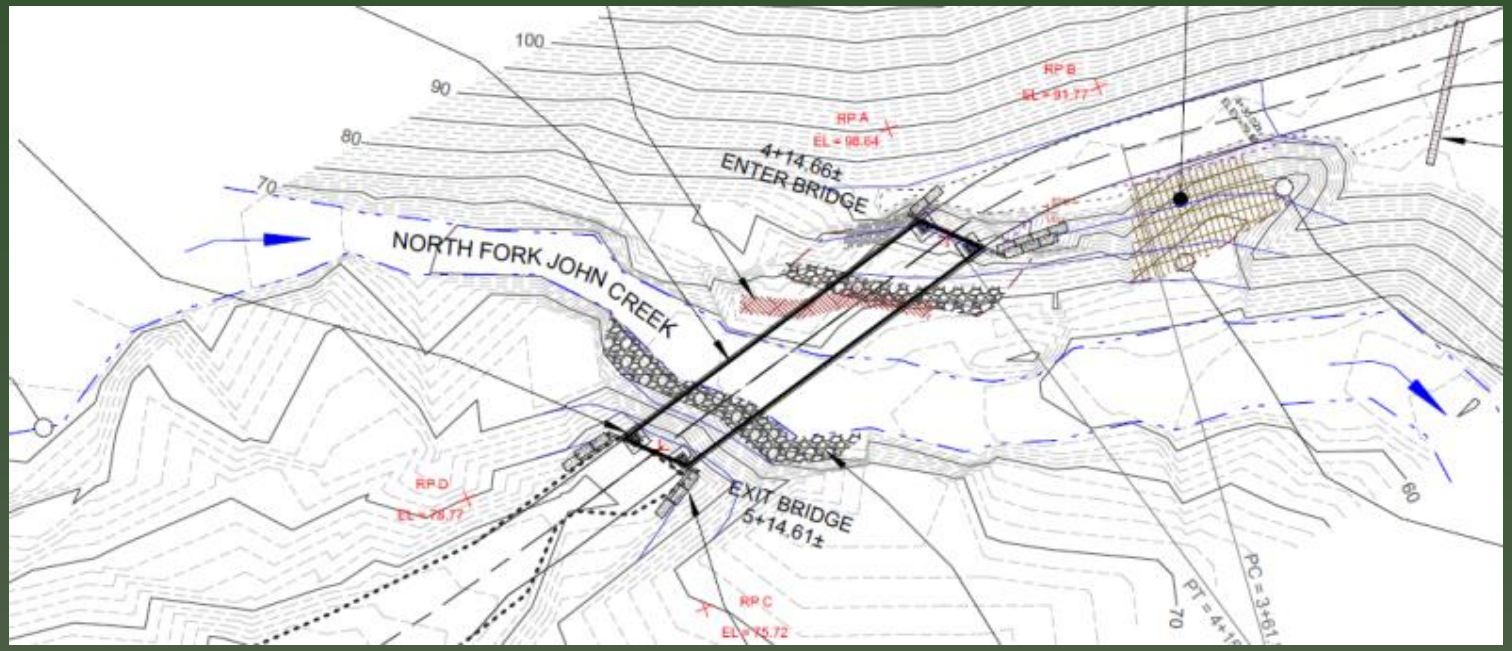


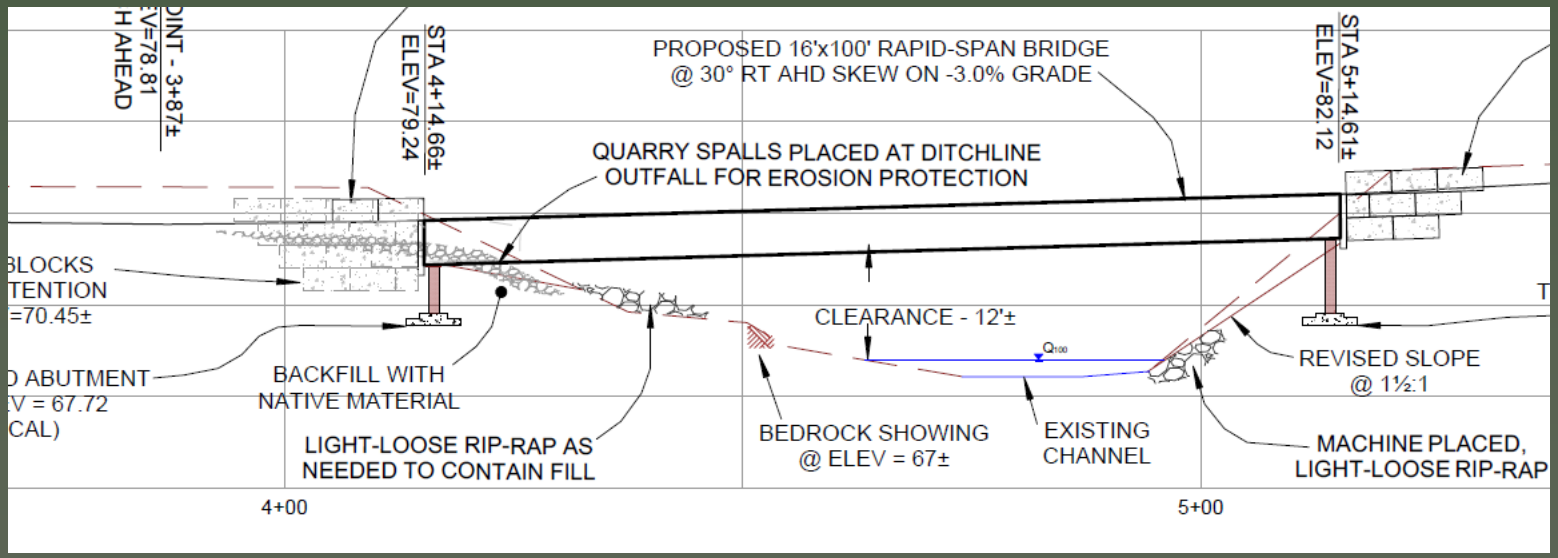
Kitsap Co. (BergerABAM) Miami Beach Rd. Seabeck Ck.

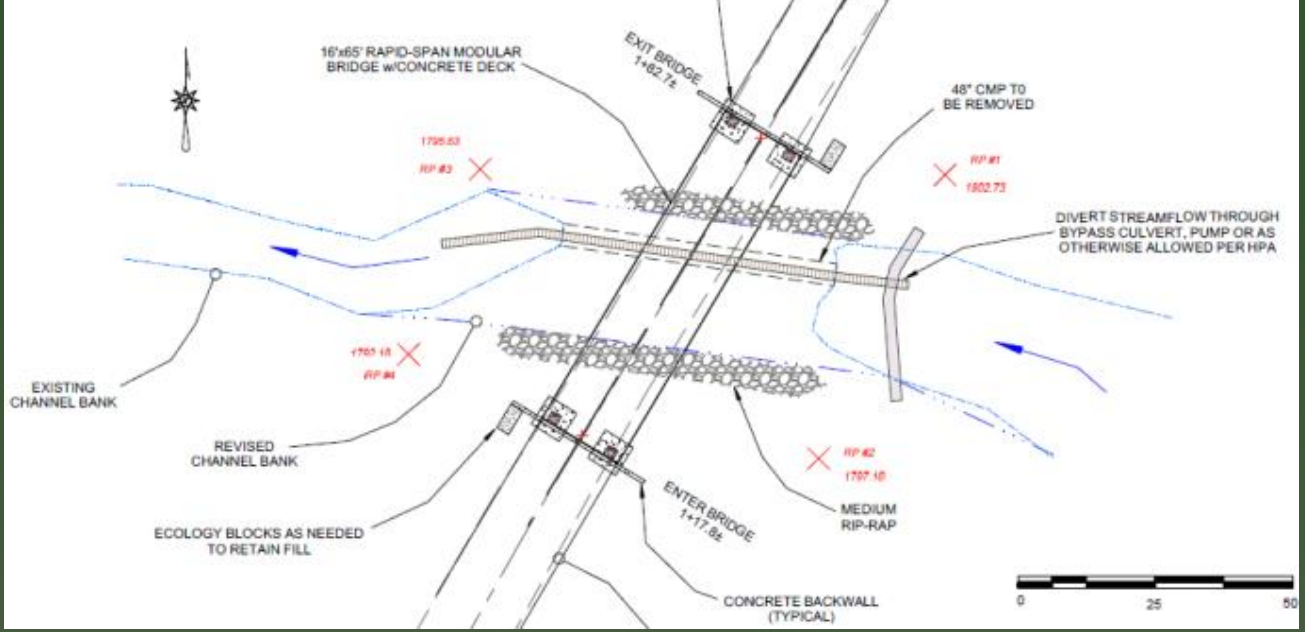


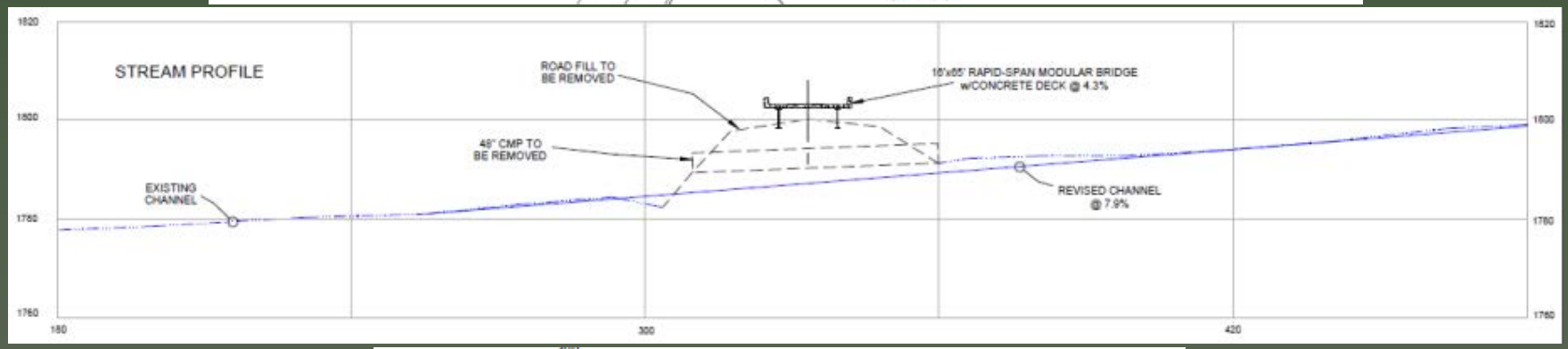


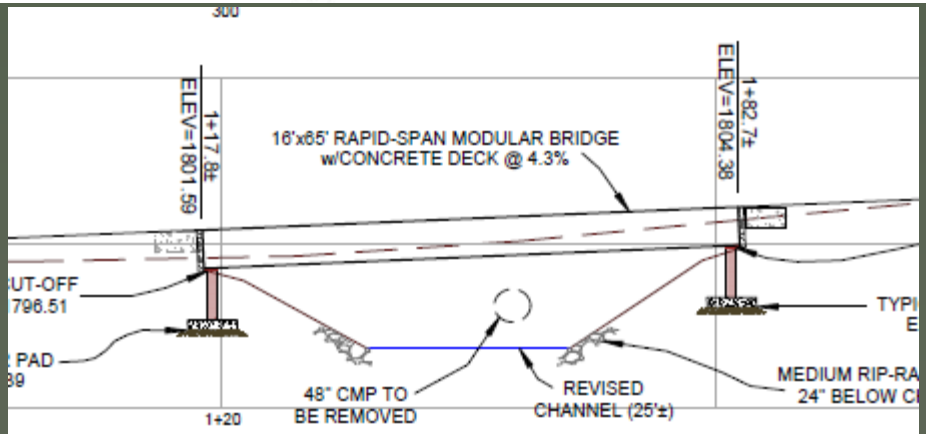
City of Lynden, Main St., Fishtrap Ck.


100
90
80
70
60
RP A
EL = 98.64
RP B
EL = 91.77
RP C
EL = 75.72
RP D
EL = 78.77
4+14.66±
ENTER BRIDGE
NORTH FORK JOHN CREEK
EXIT BRIDGE
5+14.61±
PC = 3+61
PT = 4+1


DINT - 3+87±
EV=78.81
H AHEAD
STA 4+14.66±
ELEV=79.24
PROPOSED 16'x100' RAPID-SPAN BRIDGE
@ 30° RT AHD SKEW ON -3.0% GRADE
STA 5+14.61±
ELEV=82.12
QUARRY SPALLS PLACED AT DITCHLINE
OUTFALL FOR EROSION PROTECTION
BLOCKS
TENTION
=70.45±
CLEARANCE - 12'±
Q100
REVISED SLOPE
@ 1½:1
D ABUTMENT
V = 67.72
CAL)
BACKFILL WITH
NATIVE MATERIAL
LIGHT-LOOSE RIP-RAP AS
NEEDED TO CONTAIN FILL
BEDROCK SHOWING
@ ELEV = 67±
EXISTING
CHANNEL
MACHINE PLACED,
LIGHT-LOOSE RIP-RAP
4+00
5+00


16'x65' RAPID-SPAN MODULAR BRIDGE w/CONCRETE DECK
EXIT BRIDGE 1+82.7±
48" CMP TO BE REMOVED
DIVERT STREAMFLOW THROUGH BYPASS CULVERT, PUMP OR AS OTHERWISE ALLOWED PER HPA
EXISTING CHANNEL BANK
REVISED CHANNEL BANK
ECOLOGY BLOCKS AS NEEDED TO RETAIN FILL
ENTER BRIDGE 1+17.8±
MEDIUM RIP-RAP
CONCRETE BACKWALL (TYPICAL)
0
25
50


STREAM PROFILE
ROAD FILL TO BE REMOVED
16'x65' RAPID-SPAN MODULAR BRIDGE w/CONCRETE DECK @ 4.3%
48" CMP TO BE REMOVED
EXISTING CHANNEL
REVISED CHANNEL @ 7.9%
1820
1800
1780
1760
180
300
420


300
1+17.8±
ELEV=1801.59
1+82.7±
ELEV=1804.38
16'x65' RAPID-SPAN MODULAR BRIDGE w/CONCRETE DECK @ 4.3%
48" CMP TO BE REMOVED
REVISED CHANNEL (25'±)
1+20

Things to remember:

1. Fish passage and water crossing design is all about the channel (geomorphic approach to design). If you don’t get that right, then limited success.

2. Determining the future profile and setting the culvert elevation is harder than it looks.

3. Good drawings (and specifications) are one of the keys to good projects.