Science, Service, Stewardship

Fish Passage Design for Roughened Channels

Aaron Beavers

Hydraulic Engineer

Northwest Region

E.I.T.
M.S.C.E.

NOAA

NOAA FISHERIES SERVICE

Pre-Presentation Note

NOAA FISHERIES SERVICE

- The majority of material in this presentation is design concepts, techniques, and methods.
- Concepts, techniques, and methods ARE NOT NMFS CRITERIA.
- Please do not disseminate this presentation as NMFS criteria.

NOAA FISHERIES SERVICE

Background

What Are Roughened Channels?

NOAA FISHERIES SERVICE

Roughened Channels

- “Rocky” stream channel
- The main structure component is large rock.
- Used to…
  - Control stream grade
  - Increase stream slope
- Other generic terms
  - Rock ramps
  - Roughened chutes

Roughened Channels

NOAA
FISHERIES
SERVICE

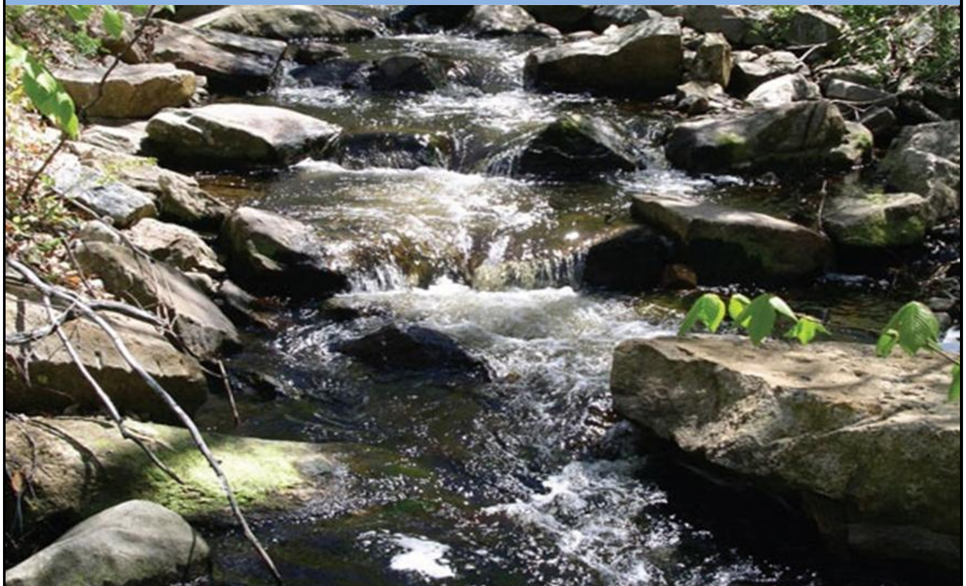


Image: NOAA

Roughened Channels

NOAA
FISHERIES
SERVICE

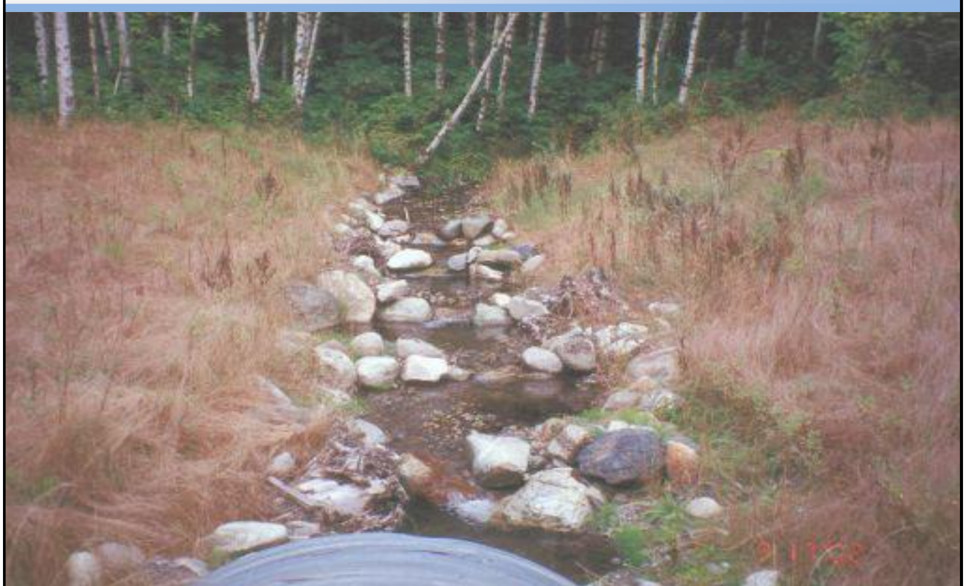


Image: WDFW

Roughened Channels

NOAA
FISHERIES
SERVICE

Image: USFS

Roughened Channels

NOAA
FISHERIES
SERVICE

- Structure slope is > natural slope.
- Rock or roughness elements > natural channel.
- Higher velocities than natural channel.
- More turbulent than natural channel.

Roughened Channels

NOAA FISHERIES SERVICE

Image: WDFW

Roughened Channels

NOAA FISHERIES SERVICE

- Structure provides…
  - Debris transport
  - Sediment transport
  - Fish passage
- Elements provide…
  - Structure stability
  - Fish refuge
  - Hydraulic diversity

NOAA
FISHERIES
SERVICE

Background

Design Guidance

NOAA
FISHERIES
SERVICE

Design Guidance

- WDFW 2003
- 1st design literature
- Appendix E
- Rock ramp approach
- **Little experience**
- **Experimental**

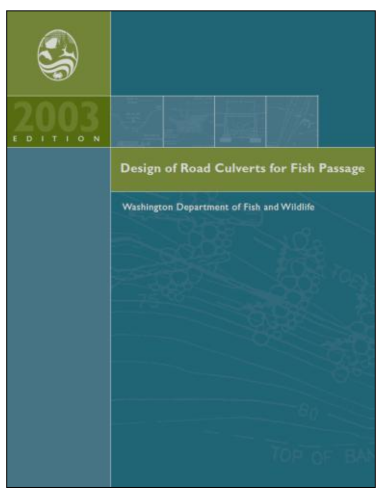
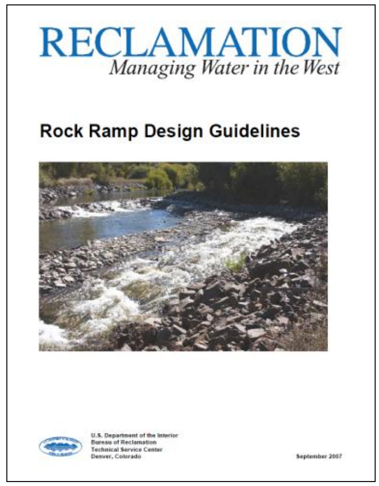


Image: WDFW

Design Guidance

NOAA FISHERIES SERVICE

- USBR 2007
- 1st comprehensive design guidance for rock ramps.
- Focus on large system application.
- **Little experience**
- **Still experimental**


RECLAMATION
Managing Water in the West

Rock Ramp Design Guidelines

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

September 2007

Image: USBR

Design Guidance

NOAA FISHERIES SERVICE

- CDFG 2009
- Introduces morphologic design approach.
- Better understanding of failure mechanisms.
- **Moderate experience**
  - Small systems.
- **Still experimental**
  - But more confidence in small system design.

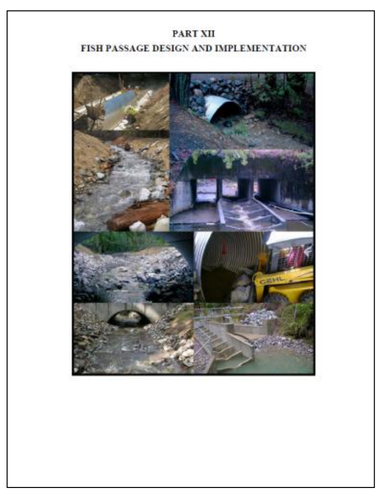

PART XII
FISH PASSAGE DESIGN AND IMPLEMENTATION

Image: CDFG

Recommendations

NOAA FISHERIES SERVICE

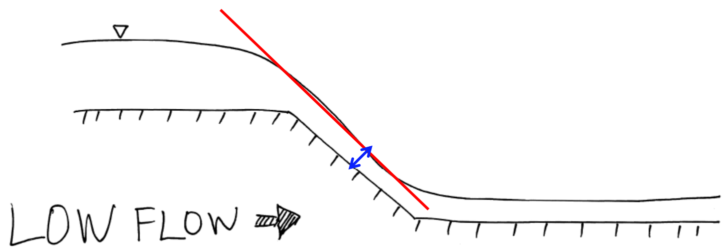
- Manuals **ARE NOT** NMFS criteria.
- Manuals **ARE** an excellent source of information for designers.
- BPA project managers become familiar with these documents.
- Provide as design references to BPA contractors and consultants.
- **THESE DESIGNS ARE STILL CONSIDERED EXPERIMENTAL.**

NOAA FISHERIES SERVICE

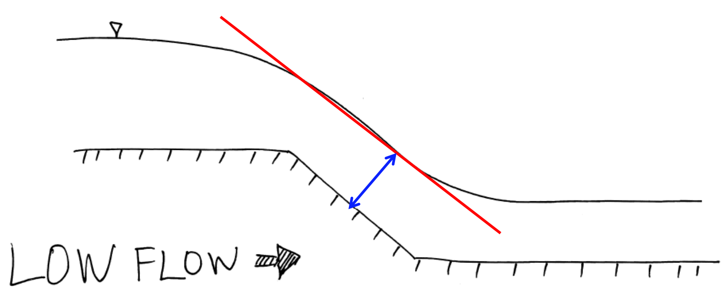
Background

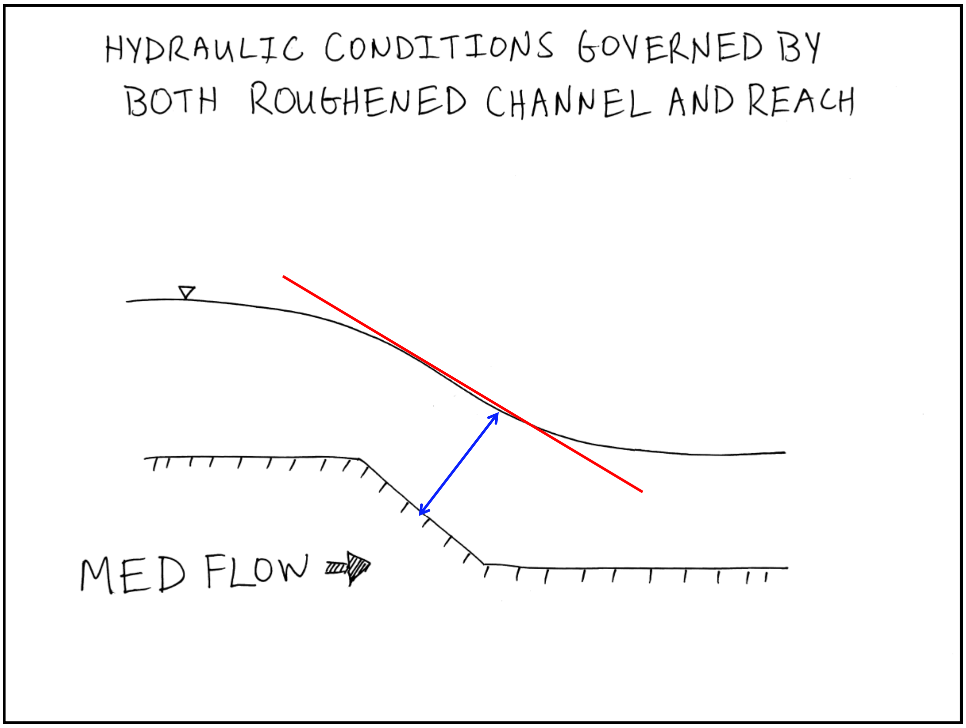
A Simple Model of Flow Effects of Roughened Channels

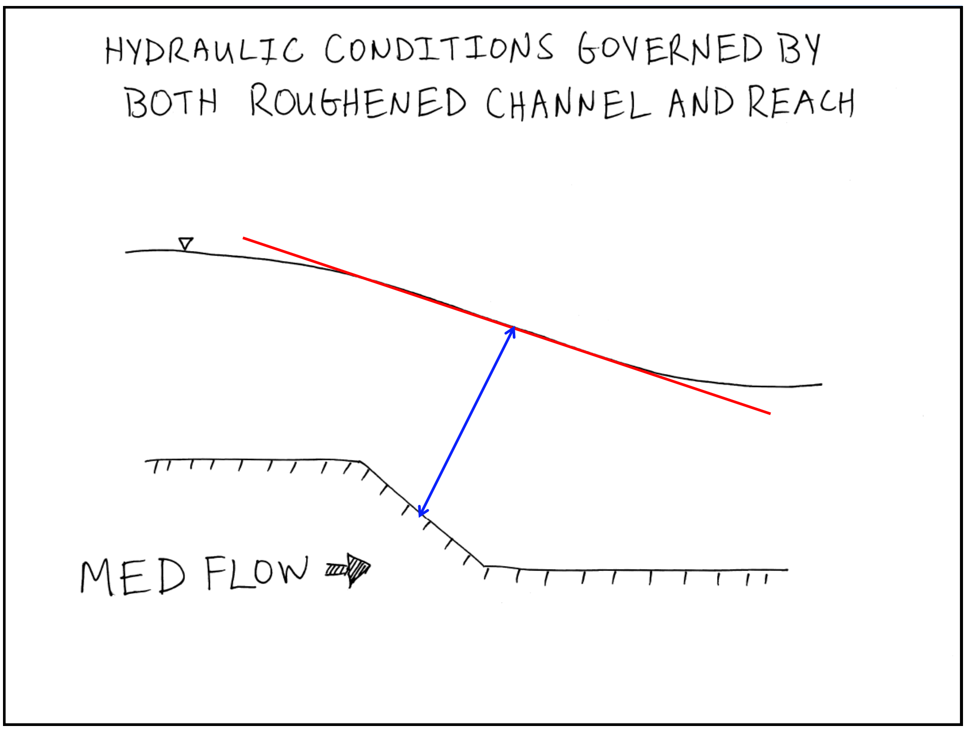
HYDRAULIC CONDITIONS GOVERNED BY ROUGHENED CHANNEL



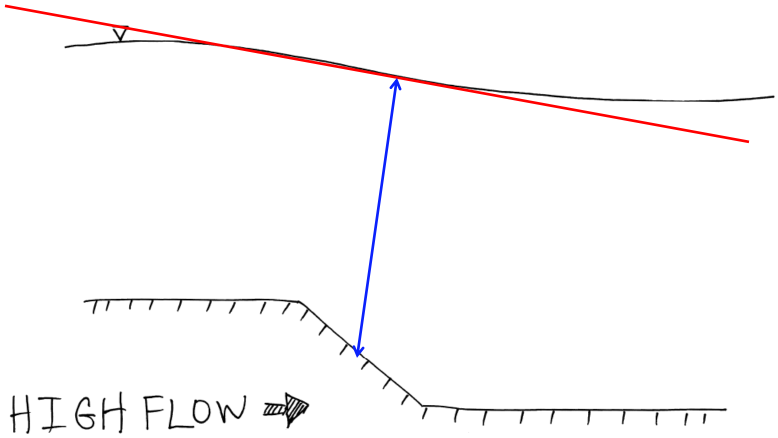
HYDRAULIC CONDITIONS GOVERNED BY ROUGHENED CHANNEL



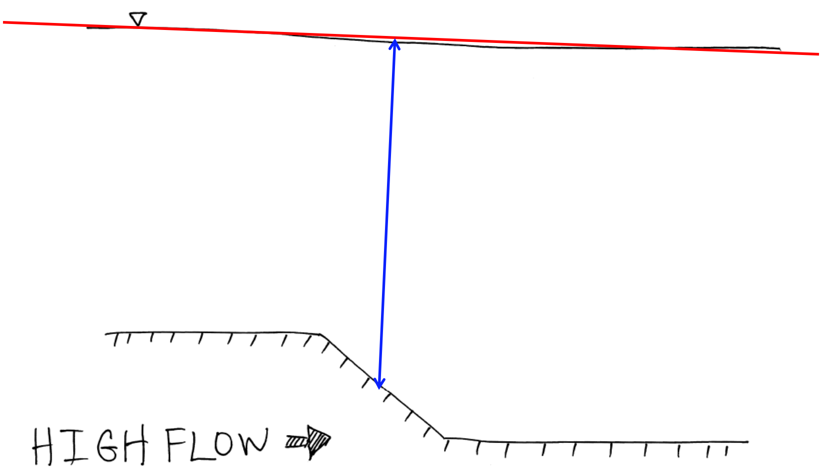

HYDRAULIC CONDITIONS GOVERNED BY
BOTH ROUGHENED CHANNEL AND REACH
MED FLOW


HYDRAULIC CONDITIONS GOVERNED BY
BOTH ROUGHENED CHANNEL AND REACH
MED FLOW

HYDRAULIC CONDITIONS GOVERNED BY REACH



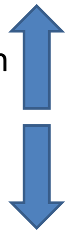
HYDRAULIC CONDITIONS GOVERNED BY REACH



Discussion

NOAA FISHERIES SERVICE

- As flows increase…
  - Stream depth
  - Stream slope



- Equations to calculate scour, velocity, and turbulence ALL depend on depth and slope!

Discussion

NOAA FISHERIES SERVICE

- Highest velocity MAY occur at lower flows rather than at higher flows.
- Greatest turbulence MAY occur at lower flows rather than at higher flows.
- Greatest scour forces MAY occur at lower flows rather than at higher flows.

Fish Passage Implication

NOAA FISHERIES SERVICE

- High fish passage flow (5% exceedence) MAY NOT produce the highest velocities OR greatest turbulence across the roughened channel!
- Designers must evaluate several flows between the low and high fish passage flows to correctly evaluate fish passage!

Structural Implication

NOAA FISHERIES SERVICE

- High design flow MAY NOT BE the most unstable flow across the roughened channel!
- Designers must determine what flow will cause the most structural instability…and then design the framework elements based on that flow!

Designs & Methods

Roughened Channels

Designs & Methods Outline

1. Three degrees of design difficulty
2. Types
3. Design

Three Degrees of Difficulty

NOAA
FISHERIES
SERVICE

1. Design variables
2. Morphologic considerations
3. Modeling

Design Variables

NOAA
FISHERIES
SERVICE

- Design variables (what you can change).
  - Slope
  - Cross section area
  - Bed roughness
- Constraint (what you can't change).
  - Discharge

Design Variables

NOAA FISHERIES SERVICE

- Designer changes variables to develop appropriate depths, velocity, turbulence, and scour.
- Variables must produces a design that is BOTH structurally stable and passes fish.
- REMEMBER: These components must be evaluated over a range of flows!

Three Degrees of Difficulty

NOAA FISHERIES SERVICE

1. Design variables
2. Morphologic considerations
3. Modeling

Morphologic Considerations

NOAA FISHERIES SERVICE

- When you deviate too far from the natural stream template…
  - The stream will impose its natural pattern on the structure (failure).
  - The structure may resist changes to such a degree that adverse hydraulic conditions are created.

Morphologic Considerations

NOAA FISHERIES SERVICE

- The design should be as morphologically “transparent” as possible.
- Transitions between the structure and the natural channel must be as smooth and seamless as all constraints allow.
- Use of natural “templates” to facilitate better transitions.

Morphologic Considerations

NOAA FISHERIES SERVICE

- Transitions
  - Slope
  - Channel width
  - Cross section area
  - Roughness
  - Planform

OK

NOAA FISHERIES SERVICE

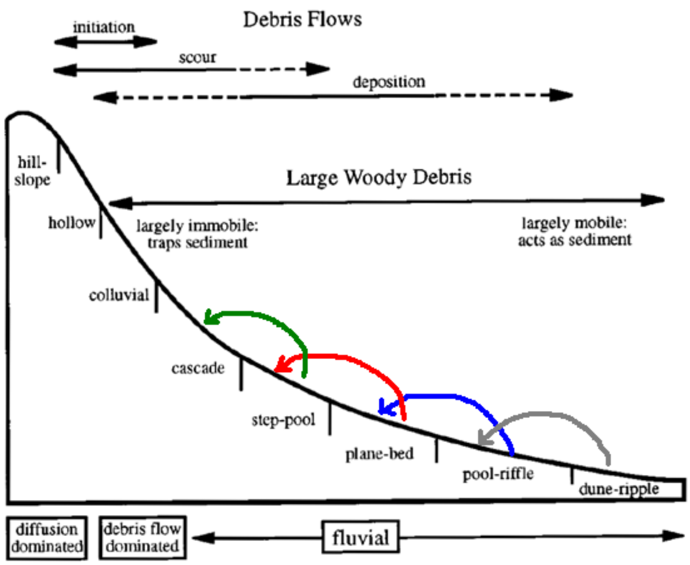


Image: Montgomery & Buffington (1997)

Probably Not OK

NOAA FISHERIES SERVICE

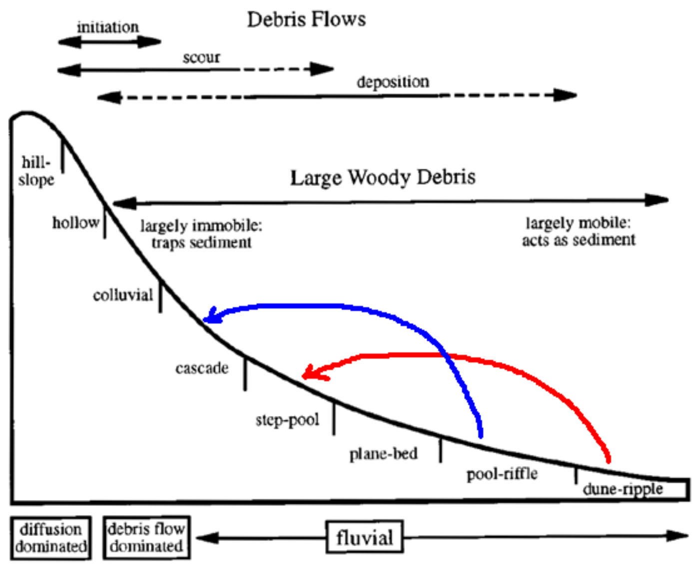


Image: Montgomery & Buffington (1997)

General Stability Issues

NOAA FISHERIES SERVICE

- Steep rough engineered structures are inherently unstable.
- Stability of roughened channels rely heavily on large rock as ballast.
- Increasing rock size may increases turbulence which may lead to a porous design…or a passage barrier.

Sediment Transport

NOAA FISHERIES SERVICE

- Discontinuities in stream slope and roughness create dissimilar sediment transport conditions.
- Dissimilar conditions induce changes in bed material size and composition.

Relationships

NOAA FISHERIES SERVICE

- For steeper slopes (relative to the natural channel) material continues move when transport has ceased in the natural channel.
- Net loss of fines to gravel size material occurs.
- This condition effects structure porosity AND turbulence.
- Sub-surface flow or increased turbulence may create a passage barrier.

Turbulence

NOAA FISHERIES SERVICE

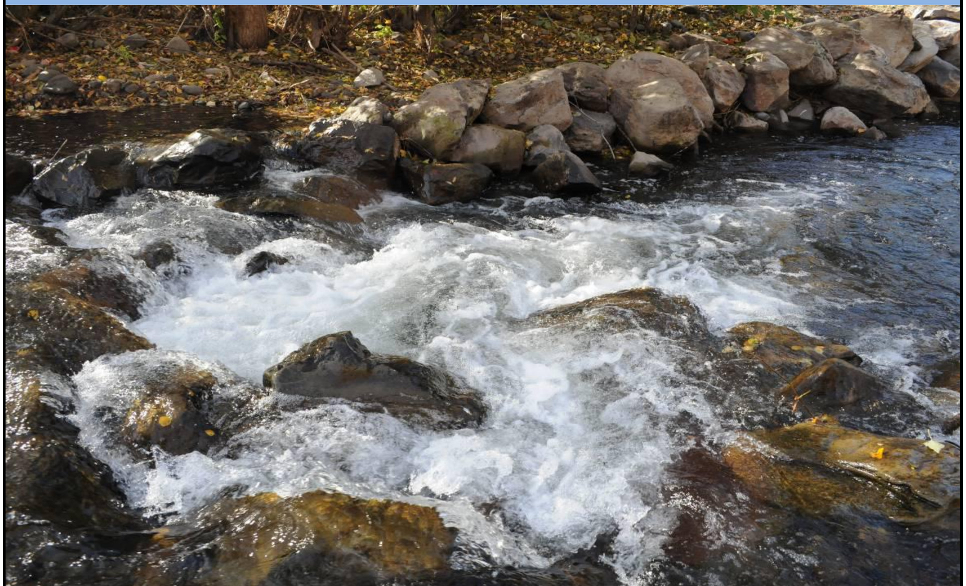
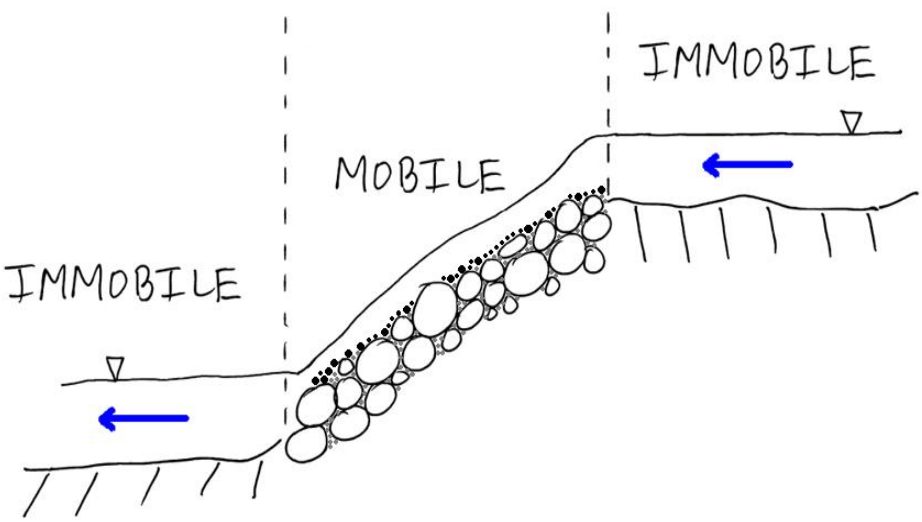


Image: USBR

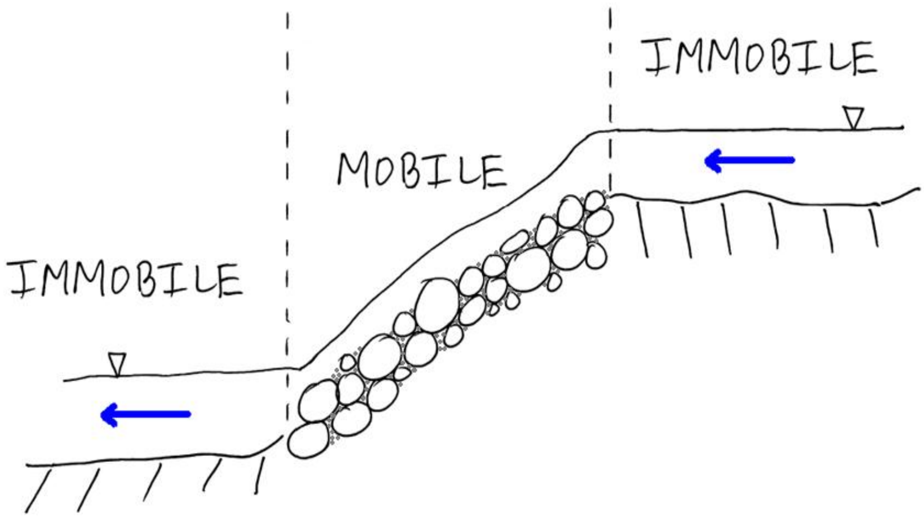
Net Loss of Smaller Material

NOAA FISHERIES SERVICE



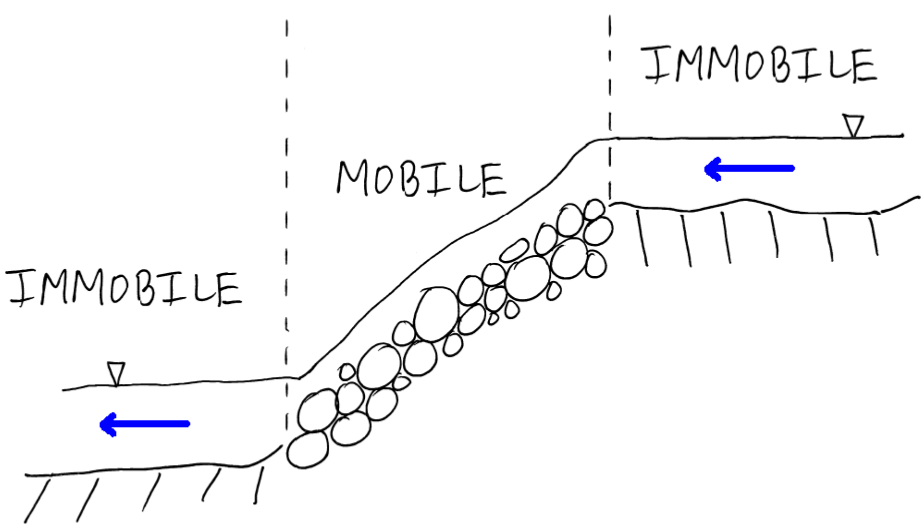
Net Loss of Smaller Material

NOAA
FISHERIES
SERVICE



Net Loss of Smaller Material

NOAA
FISHERIES
SERVICE

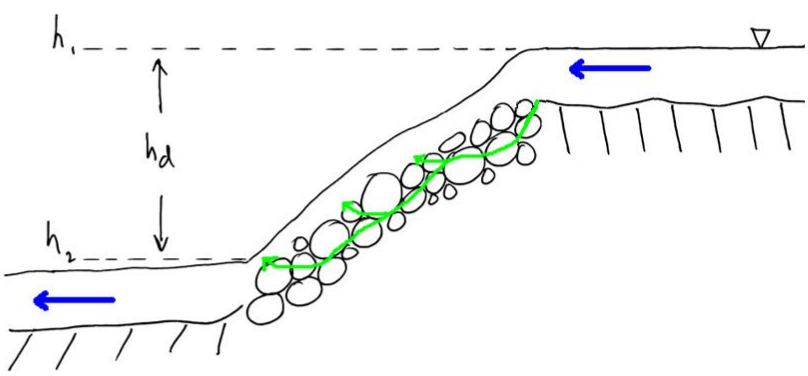


Results

- Net loss of material increases roughness and turbulence.
- Net loss of material due to scour facilitates "piping".
- Piping can also be the "stand alone" mechanism for removal of material.

Piping

NOAA FISHERIES SERVICE



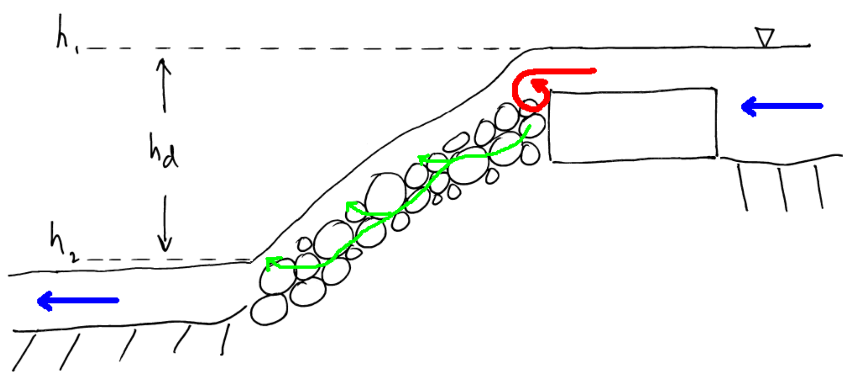
NOAA FISHERIES SERVICE

Problematic Applications

- Many roughened channels are built to retrofit lost stream grade at diversion dams and bridge aprons.
- Some designs have tried to incorporate material retention weirs.
- These applications bring their own set of problems to the design.

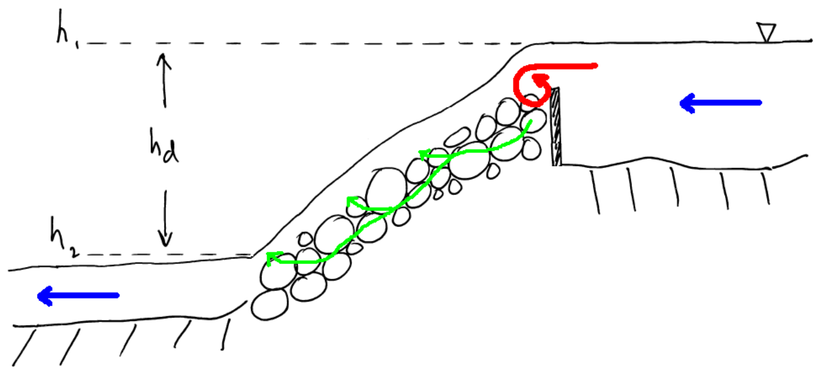
NOAA FISHERIES SERVICE

Piping/Scour



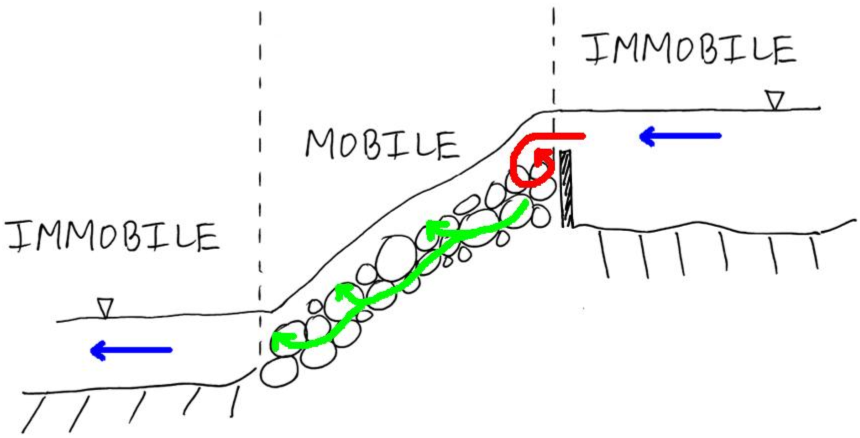
Piping/Scour

NOAA FISHERIES SERVICE



Piping/Scour/Transport

NOAA FISHERIES SERVICE



General Design Difficulties

NOAA FISHERIES SERVICE

- If we assume the framework of structure is stable (a big IF) we have three major design obstacles…
  - **Creating low velocity** migration paths.
  - **Stabilizing fines and gravels.**
  - **Providing non-turbulent** conditions.

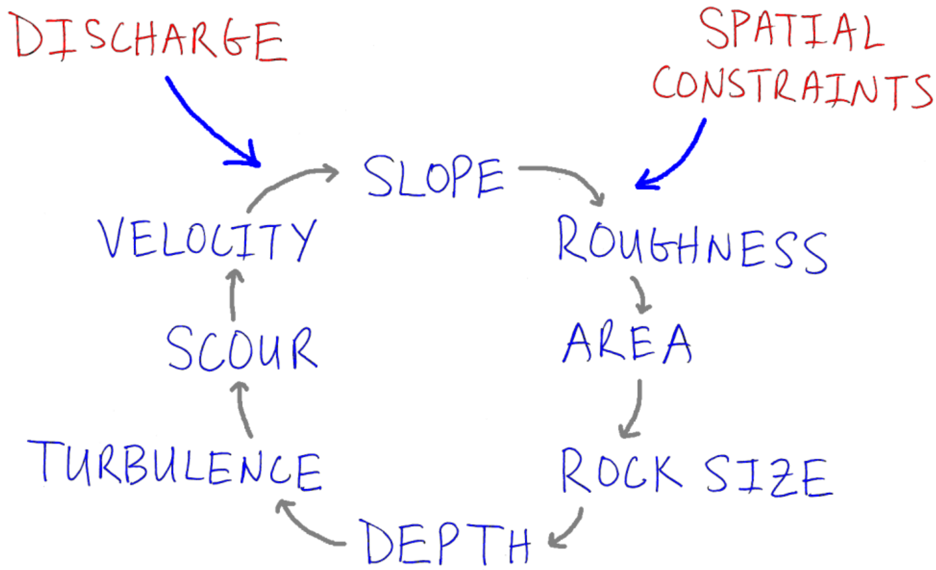
Design Process

NOAA FISHERIES SERVICE

- The design process is extremely iterative.
- Change in one stream condition or variable affects several other stream conditions or variables.

Design Process

NOAA FISHERIES SERVICE



Three Degrees of Difficulty

NOAA FISHERIES SERVICE

1. Design variables
2. Morphologic considerations
3. Modeling

Modeling

NOAA FISHERIES SERVICE

- Designers use equations to model fish passage conditions in their channel design.
- Certain hydraulic conditions are assumed in these equations.
- When the hydraulic condition is violated the equation no longer produces valid results.

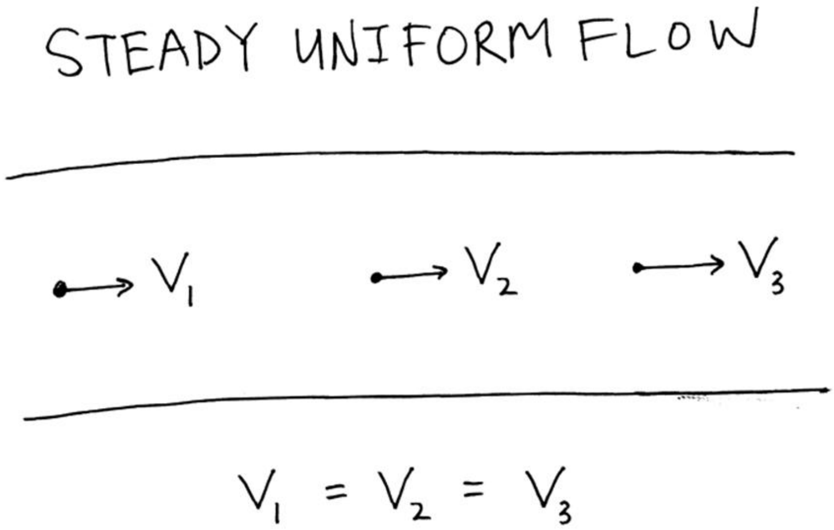
Hydraulic Assumptions

NOAA FISHERIES SERVICE

- For most equations in open channel hydraulics the equations assume “steady uniform flow”.
  - Velocity does not change with position in the stream or with time.
  - Example: Constant discharge (flow) in a pipe with a constant diameter.

Hydraulic Assumptions

NOAA FISHERIES SERVICE



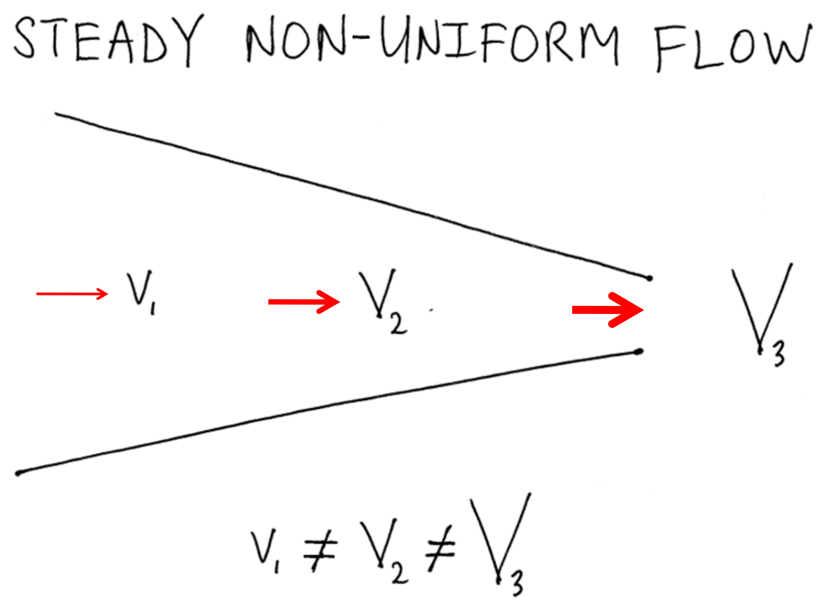
Hydraulic Assumptions

NOAA FISHERIES SERVICE

- However velocity across a roughened channel is “steady NON-uniform”.
  - Velocity changes from point to point in the stream but do not change with time.
  - Example: Constant discharge (flow) in a pipe with a tapered diameter.

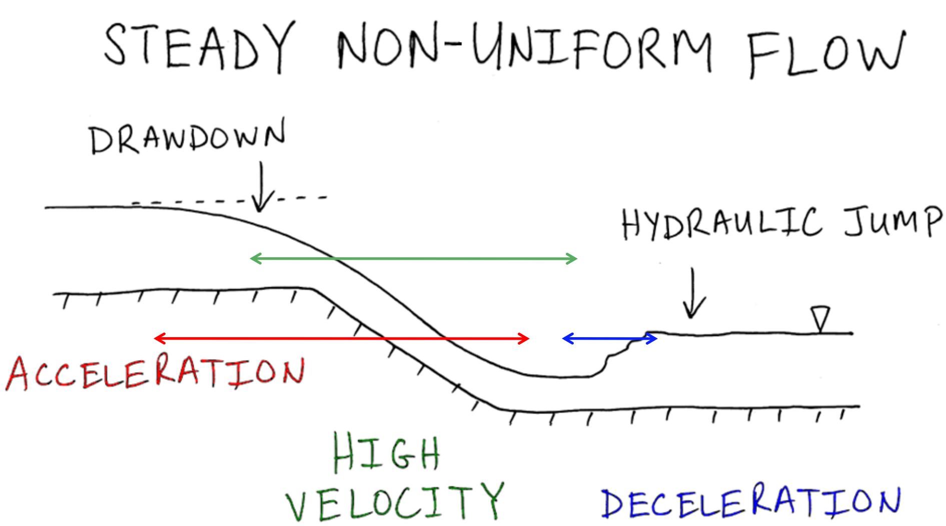
Hydraulic Assumptions

NOAA FISHERIES SERVICE



Hydraulic Conditions

NOAA FISHERIES SERVICE



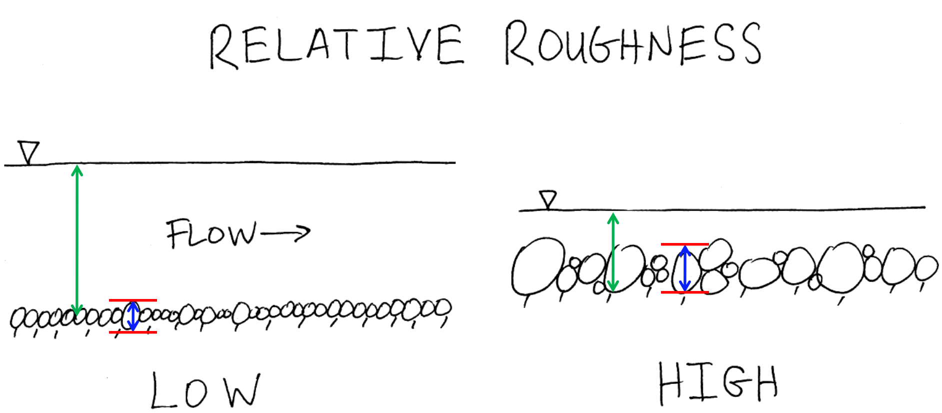
Hydraulic Assumptions

NOAA FISHERIES SERVICE

- Most equations assume a low relative roughness.
- However relative roughness in roughened channels is HIGH.

Hydraulic Conditions

NOAA FISHERIES SERVICE



Invalid Assumptions

NOAA FISHERIES SERVICE

- Equations are ill-suited to accurately predict the fish passage conditions of the design.
- Only experience can bridge the “unknown” between model results and actual function.
- Little experience with roughened channels so… designers are at a severe disadvantage.

Selecting Roughness Value

NOAA FISHERIES SERVICE

- Paramount in modeling roughened channel designs is the selection of a roughness value.
- Simply defined, the roughness value models the rock size and the distance it protrudes above the streambed.
- Its really not that simple…there other conditions which effect roughness.

Manning's "n"

NOAA FISHERIES SERVICE

- Typically the roughness value used is the Manning's "n" value.
- The value of "n" effects model output for ALL the other design variables.
- "n" is the only value we don't know or can solve for in the design.

Overestimate "n"

NOAA FISHERIES SERVICE

- If we overestimate "n" velocities are higher and depth is shallower
  - Is real world velocity and turbulence acceptable for fish passage?

Underestimate "n"

NOAA FISHERIES SERVICE

- If we underestimate "n" velocities are lower and depth is higher
  - Is the design going to affect upstream landowners or infrastructure?

Manning's "n"

NOAA FISHERIES SERVICE

- "n" values have been determined for a myriad of materials and conditions.
- **Not for roughened channels**…the selection of a "n" value is there for a non-trivial matter.

Calculating "n"

NOAA FISHERIES SERVICE

- Where can we go to get a defendable "n" value?
  - Experience (as before…limited)
  - Equations (assumptions are strained)
- Lets take a look at experience and equations anyway!

Calculating "n"

NOAA FISHERIES SERVICE

- Several equations exist to model "n".
- Highly technical procedure to select and use them.
- Each equation has a limited range of application.

Empirical Methods

NOAA FISHERIES SERVICE

Author	Slopes	Sediment Sizes (D_{50}) (feet)	Relative Submergence R/D_{84} or d/D_{84}	Data Origin
Mussetter (1989)	0.54-16.8%	0.1-2.1	0.2-3.7	CO mountain streams
Bathurst (1985)	0.2-4% (tested for slopes up to 9%)	0.2 - 1.1	0.4-11	gravel and boulder bedded rivers
Rice, et al. (1998)	1-33%	0.1-0.9	0.3-1.9	riprap on steep slopes in flume
Bathurst (1978)[1]	0.8-1.7%	0.6-0.8	0.4-1.3	Regulated river in Great Britain
Hey (1979)[1]	0.09-3.1%	0.1-0.7	0.7-17.2	Straight gravel bedded rivers
Limerinos (1970)	Not provided	0.02-0.8	0.9-69	CA rivers with coarse beds
Jarrett (1984)	0.2-4%	0.2-1.4	0.4-10.8	cobble & boulder streams
Bathurst (2002)	0.2-4%	0.4-2.5	0.4-11	compilation of stream data sets

Image: CDFG

Calculating “n”

NOAA FISHERIES SERVICE

- This method DEMANDS significant engineering experience…which we’ve already described as being limited due to the experimental nature of the design and a general lack of design specific data and research

Calibrated "n"

NOAA FISHERIES SERVICE

- Where ELSE can we go to get a defendable "n" value?
  - Developed data (non-available)
  - Calibrate from "reference reach" (?)

Calibrated "n"

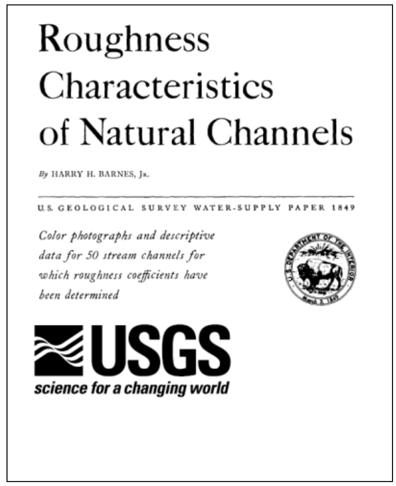
NOAA FISHERIES SERVICE

- USGS has some "pretty picture" data...but this method also has its drawbacks.
  - Many designers are unaware of what they are.

Field Survey "n"

NOAA FISHERIES SERVICE

- Engineers often reference photos and associated data to ESTIMATE "n".


Roughness Characteristics of Natural Channels

By HARRY H. BARNES, Jr.

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1849

Color photographs and descriptive data for 50 stream channels for which roughness coefficients have been determined

USGS
science for a changing world

Image: USGS

USGS Reach Average

NOAA FISHERIES SERVICE

- Length
  - 126 ft
- Width
  - 50 ft
- Slope
  - 4.5%
- **Manning's "n"**
  - **0.75**

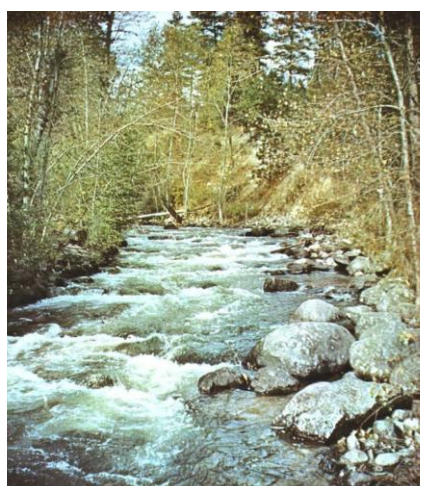


Image: USGS

Drawback #1

NOAA FISHERIES SERVICE

- Photo doesn't represent the surveyed discharge!
- Actual discharge is A LOT higher than shown in the picture.
  - Surveyed condition is 5ft higher.
  - Measured flow was > 1000 cfs.

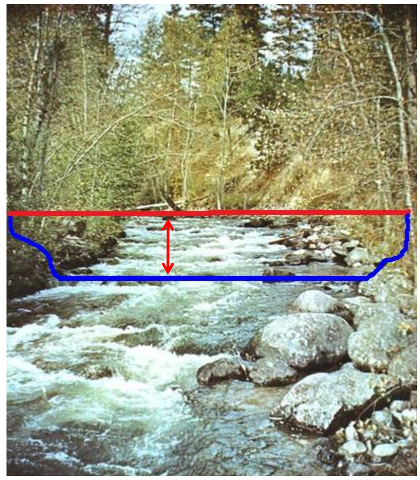


Image: USGS

Drawback #1

NOAA FISHERIES SERVICE

- "n" is lower for higher discharge.
- Basing roughness on picture is very misleading.
- Actual "n" value for conditions in picture could be higher or lower!

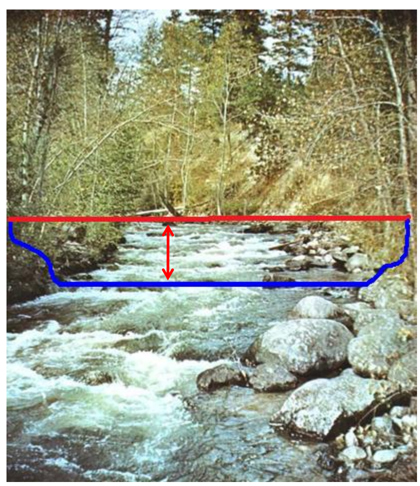


Image: USGS

Drawback #2:

NOAA FISHERIES SERVICE

- Reach conditions are not constant.
- Width
  - 43 ft to 54 ft
- Slope
  - 3.5% - 7.5%
- **Manning's "n"**
  - **0.50 to 0.85**
  - **Reach specific values vary!**

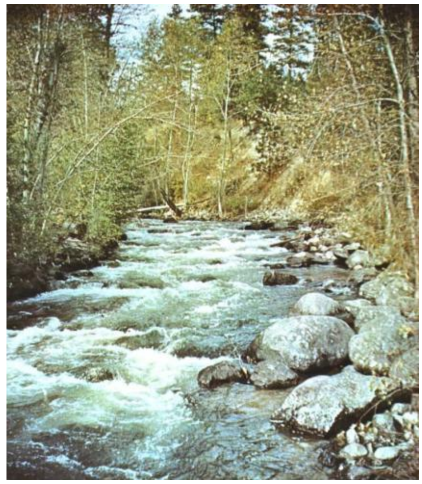


Image: USGS

Effects of Variation on Design

NOAA FISHERIES SERVICE

- Width
  - 30 ft
  - Rectangular channel
- **n = 0.50**
  - Depth = 5.0 ft
  - Velocity (ave) = 10 ft/s
- **n = 0.85**
  - Depth = 7.0 ft
  - Velocity (ave) = 7 ft/s

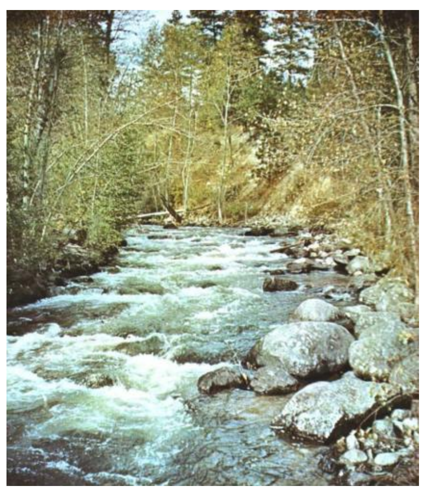


Image: USGS

Calibrated "n"

NOAA FISHERIES SERVICE

- The best method may be to go out and collect your own data (measure discharge).
- Before we can go out and collect some good "n" data.
- Lets look at some of its characteristics.

Quirky "n"

NOAA FISHERIES SERVICE

- "n" changes relative to channel depth.
- "n" changes relative to rock size.
- "n" changes relative to stream slope.
- Other conditions effect "n" as well.

Calibration Method

NOAA
FISHERIES
SERVICE

Image: USGS

Calibration Method

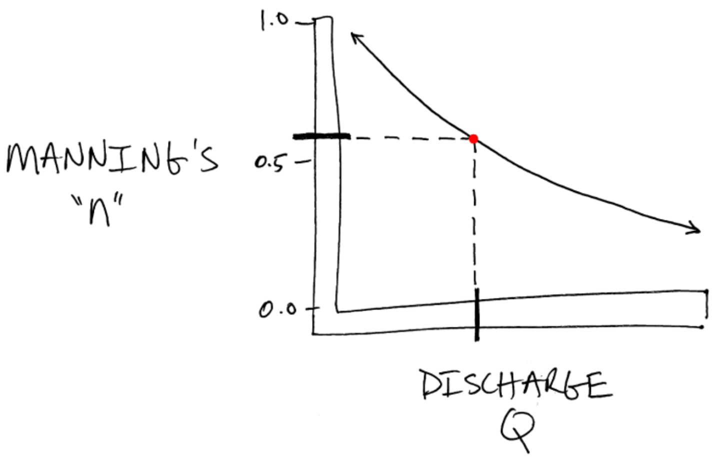
NOAA
FISHERIES
SERVICE

$$Q = \frac{1.49}{\text{"}n\text{"}} A R^{2/3} S^{1/2}$$

$$\text{"}n\text{"} = \frac{1.49}{Q} A R^{2/3} S^{1/2}$$

BUT…Only Provides a Snapshot

NOAA FISHERIES SERVICE



Final Thoughts on "n"

NOAA FISHERIES SERVICE

- Since flow depth effects "n" designers should develop a relationship between "n" and stream depth when collecting field data for design.
- Several discharges (preferably within the expected fish passage window) should be measured and the "n" value back-calculated.

Final Thoughts on “n”

NOAA FISHERIES SERVICE

- Once you have a defendable method for selecting a suite of “n” values you can move to the design phase.

TAKE HOME

NOAA FISHERIES SERVICE

- It’s not a trivial task!
- It’s not an easy task!
- Requires significant experience!
- Designers are reduced to extrapolation and guest-imation.
- Selected roughness has a SIGNIFICANT effect on hydraulics of the design.

TAKE HOME

NOAA
FISHERIES
SERVICE

- BPA should select designers which have a proven track record of designing roughened channels.
- BPA should contact NMFS engineering as soon as a roughened chute design has been established as an alternative or conceptual design.

Designs & Methods Outline

NOAA
FISHERIES
SERVICE

1. Three degrees of design difficulty
2. Types
3. Design

Rock Ramp

NOAA
FISHERIES
SERVICE

- Rock ramp and pool (Bates & Love 2009)
  - Contain no bedform (uniform size material).
  - Continuous slope and material .
  - Limited to slopes < 4% and drops of 5ft or less.
  - Design with an energy dissipation pool at the downstream end.

Rock Ramp

NOAA
FISHERIES
SERVICE

Image: USBR

Chutes and Pools

NOAA FISHERIES SERVICE

- Chutes and Pools: Subunit ramp and pool (Bates & Love 2009)
  - Rock ramp/pool is a discrete subunit
  - Armored pool dissipates energy and protects from scour
  - Over all structure slope <4%
  - Pools at 0% and chutes >4%
  - Drop across the subunit is 2 ft or less

Chutes and Pools

NOAA FISHERIES SERVICE

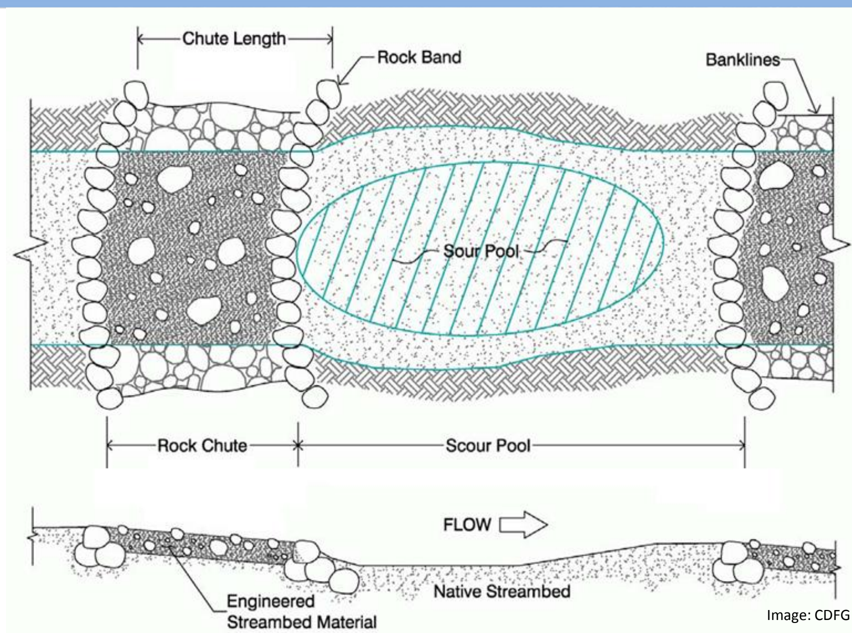


Image: CDFG

Morphologic

NOAA FISHERIES SERVICE

- Morphology based (Bates & Love 2009)
  - Based on the morphology and composition of natural channels.
  - May be used where natural slopes > 4%
  - **May be used for design slope > 4%**
  - **CAUTION:** The greater the structure slope deviates from natural conditions the greater the risk of failure.

Morphologic

NOAA FISHERIES SERVICE

- Considerations
  - Bedform morphology changes with stream slope.
  - Natural morphology, slope, spacing, and rock size should be considered when selecting an appropriate design template.

Morphologic

NOAA FISHERIES SERVICE

- Considerations
  - Design “template” should be as close to natural channel as possible.
  - Will require significant data collection (burden of proof is on the designer).

OK

NOAA FISHERIES SERVICE

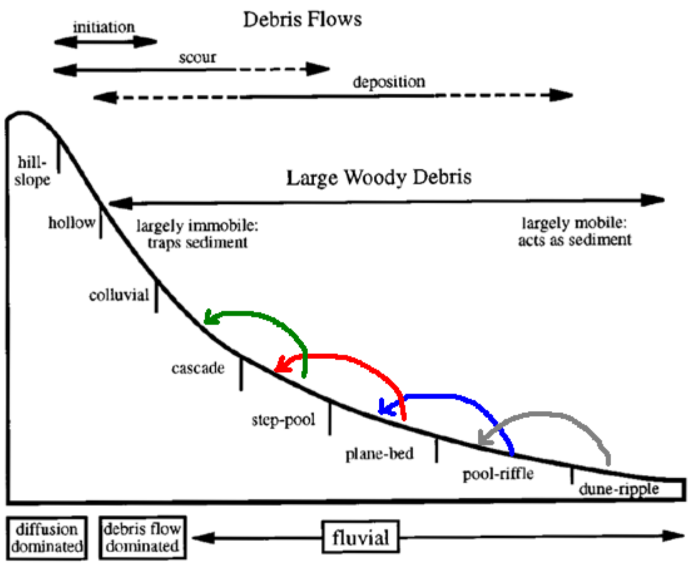


Image: Montgomery & Buffington (1997)

NOAA FISHERIES SERVICE

Probably Not OK

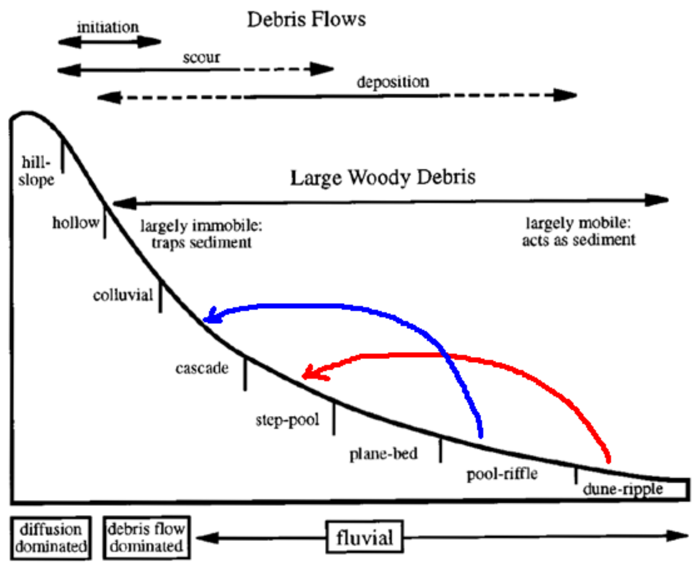


Image: Montgomery & Buffington (1997)

NOAA FISHERIES SERVICE

Designs & Methods Outline

1. Three degrees of design difficulty
2. Types
3. Design

General Fish Passage Design

NOAA FISHERIES SERVICE

- With so many design constraints the application of this type of fish passage structure is very narrow.
- Structure must be shown to pass fish between the low and high fish passage flows.
  - Low flow (95% exceedence)
  - High flow (5% exceedence)

General Fish Passage Design

NOAA FISHERIES SERVICE

- The shorter the ramp the more controlled the hydraulics.
- Issue with longer ramps (flow acceleration)
  - Exhaustion barrier
  - Less stable due to increasing velocities the further the ramp extends
  - Retaining fines
  - Shallower depths

Slope and Roughness

NOAA FISHERIES SERVICE

- Slope > adjacent stream slope
  - Slope should be as close to natural slope as possible.
  - Not to exceed 6% (NMFS criteria)
- Roughness > adjacent stream channel
  - Roughness should be as close to natural stream roughness as possible.

Channel Design

NOAA FISHERIES SERVICE

- Bates & Love 2009
  - Triangular and trapezoidal cross sections
  - Hydraulic diversity
  - Design width => adjacent stream width
  - Active channel should become fully wetted at the low fish passage flow.

Channel Design

NOAA FISHERIES SERVICE

- Transition: Bates & Love 2009
  - Transition should take into consideration flow acceleration due to constriction of the active channel AND the adjacent floodplain.
  - Steep side slopes can destabilize the channel by constricting flow in the structure.

Channel Design

NOAA FISHERIES SERVICE

- Bates & Love 2009
  - Should fully contain the bankfull or 2 yr flood event.
  - Require a downstream armored pool to dissipate energy and protect from scour.

Channel Design

NOAA FISHERIES SERVICE

- Bates & Love 2009
- General guidance…when a roughened channel extends more than 5 channel widths the structure should be…
  - Broken up with a large pool, adequately sized, to dissipate energy before the next section.

Bank Design

NOAA FISHERIES SERVICE

- Bates & Love 2009
  - Streambank is designed as an armored bank.
  - Largest rock at toe to protect bank from scour.
  - Generally composed of smaller material than channel bed.
  - Height of bank should extend sufficient to protect from scour, flanking, and channel avulsion.

General Design

NOAA
FISHERIES
SERVICE

- The bed and banks should be made of a stable framework at the structural design flow.
  - 50%-70% of the structure should be immobile
- The bed and bank material should be well graded (NMFS criteria).

General Design

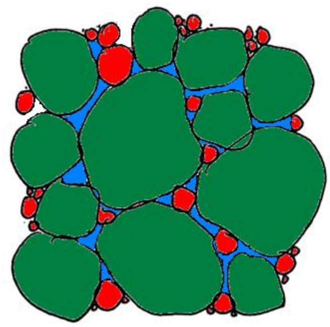
NOAA
FISHERIES
SERVICE

- Bed and banks should be framework supported not matrix supported.
  - Larger roughness/stability elements should be in contact with each other.
  - Bed should contain 5%-10% fines.

Design Bed Components

NOAA FISHERIES SERVICE

- Framework rock
  - Immobile component of design (structural design flood)
- Void material
  - Provides seal
  - Small cobbles & gravels
  - Fines (< 2mm)

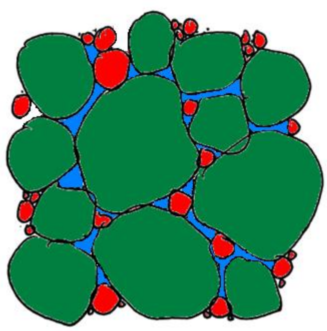


Streambed Types

NOAA FISHERIES SERVICE

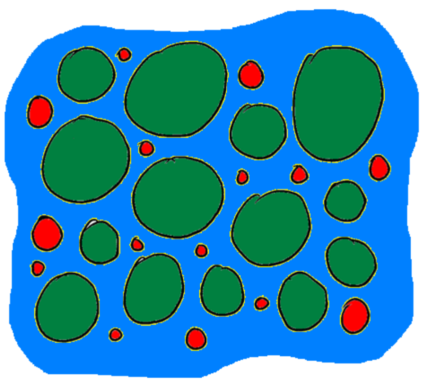
Framework-supported

Fines <25%



Matrix-supported

Fines >40%



General Design

NOAA FISHERIES SERVICE

- Bed and banks should contain sufficient fines to seal sufficiently (NMFS criteria).
  - Subsurface flows are the typical mechanism for failure.
- Due to these constraints roughened channel designs are ONLY to be used in systems with sufficient bedload (NMFS criteria).

General Design

NOAA FISHERIES SERVICE

- The design should therefore include collecting and quantifying both the sediment load and size.
- Typical methods to evaluate energy dissipation in fishways can be used to quantify turbulence in roughened channel designs.

General Design

NOAA FISHERIES SERVICE

- Although no studies have been performed to definitely correlate fish passage with turbulence levels, a common maximum turbulence (energy dissipation value) used in design is…
  - 7 ft-lb/s over the range of flows expected to pass fish.

NOAA FISHERIES SERVICE

Fish Passage Criteria

Roughened Channel

Fish Passage Criteria

NOAA FISHERIES SERVICE

- Channel must be designed around stream simulation techniques.
- Channel slope < 6%.
- Total channel length is < 150 ft.
- Bed material must be uniformly graded.
- No subsurface flow.
- Minimum flow depth of 1 ft for adult salmonids.

Fish Passage Criteria

NOAA FISHERIES SERVICE

- Bed materials and rock placement mimic channel complexity of the adjacent stream reaches.
- NO hydraulic drops across the entire width of the roughened channel.
- Design must demonstrate that any scouring of fines from the engineered channel will be refilled by subsequent bedload transport.

Fish Passage Criteria

NOAA FISHERIES SERVICE

- It is noted that if the channel roughness of adjacent stream reaches is heavily influenced by woody debris, it may be difficult to mimic this condition with any sort of constructed roughened channel.

Fish Passage Criteria

NOAA FISHERIES SERVICE

- Guidance on the mixture of bed material is still evolving, but general guidance is provided in…
  1. WDFW (2003)
  2. CDFG (2009)

NOAA
FISHERIES
SERVICE

Project Review & Assessment

Roughened Channel

NOAA
FISHERIES
SERVICE

Project Review & Assessment

- NMFS engineering support should be anticipated and sought after, for review and approval of roughened channel projects.

NOAA FISHERIES SERVICE

Data for Review

Roughened Channel

Data for Review

NOAA FISHERIES SERVICE

- Selection of roughness values (Manning's "n") and accompanying justification.
- Hydraulic model assumptions and output.
- Target species, life stages and migration timing at project site.

Data for Review

NOAA
FISHERIES
SERVICE

- Calculation of lower and upper fish passage stream flows for each life stage and species and 100-year flow.
- Water surface profiles at existing conditions for upper and lower fish passage stream flows and 100-year flow.

Data for Review

NOAA
FISHERIES
SERVICE

- Water surface profiles with proposed roughened channel for upper and lower fish passage stream flows and 100-year flow.
- Rock and engineered streambed material sizing and thickness calculations.

Data for Review

NOAA
FISHERIES
SERVICE

- Geotechnical information may be necessary to ensure project design is structurally appropriate.
- Calculations of depths and velocities along length of roughened channel.
- Calculation of overall drop and slope along roughened channel.

Data for Review

NOAA
FISHERIES
SERVICE

- If at a water diversion, ditch/pump hydraulic calculations showing roughened channel provides sufficient head to divert maximum diversion flow + bypass flow at minimum stream flow considering head losses at flow measurement devices, fish screens, pipes, open ditches, headgates, etc.

NOAA FISHERIES SERVICE

Data for Review

- Design drawings showing structural dimensions in plan, elevation, longitudinal profile, and cross-sectional views along with important component details including construction notes on placement of bed material and boulders.
- Post construction evaluation and monitoring plan.

NOAA FISHERIES SERVICE

Monitoring

Roughened Channel

Monitoring

NOAA FISHERIES SERVICE

- Contingency plan (what are you going to do if it fails?)
- Study plan (collect data to further develop design concept!)
- Monitoring plan
- Adaptive management record (what did you modify and why?)
- Provide a report for presentation/peer review.

NOAA FISHERIES SERVICE

- Evaluated until the 50 year return flood.
- Monitoring must include an assessment of passage conditions and/or maintenance of original design conditions, and repaired as necessary to accomplish design passage conditions.

NOAA FISHERIES SERVICE

Maintenance

Roughened Channel

NOAA FISHERIES SERVICE

Maintenance

- May require seasonal or annual maintenance.
- Monitoring plan should include specific maintenance measures to ensure the upstream passage of salmonids in the event that…
  - flow goes subsurface.
  - the structure becomes a turbulent barrier.
  - the structure becomes a velocity barrier.
  - passage is in any other way impeded.

NOAA
FISHERIES
SERVICE

END

Thank you!

NOAA
FISHERIES
SERVICE

Contact Info

Contact INFO:

aaron.beavers@noaa.gov

503-231-2177