River Meandering and Braiding

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River Mechanics and Sediment Transport
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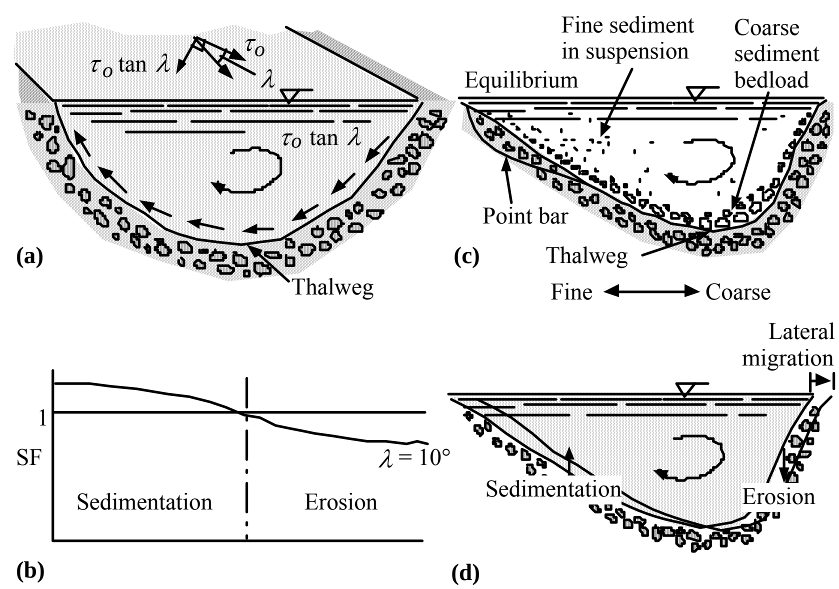
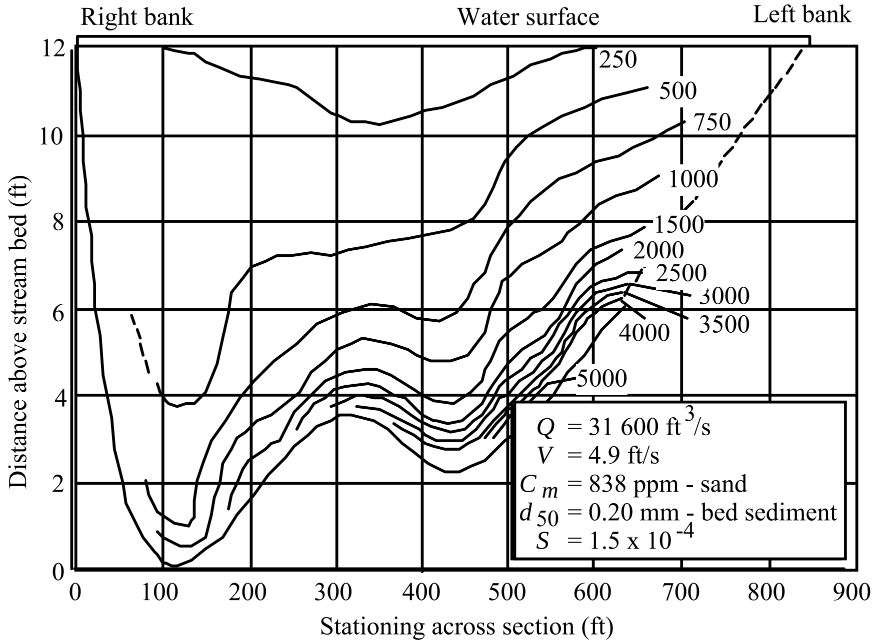
Objectives

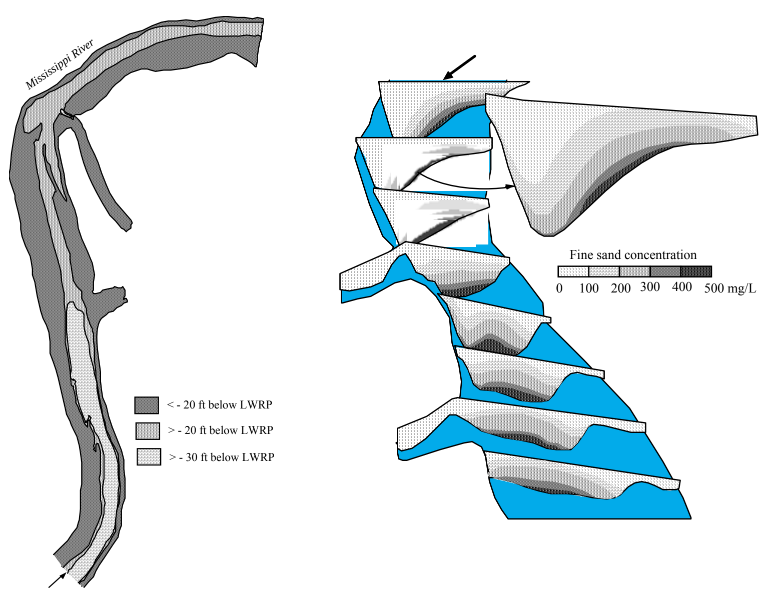
Brief overview of river and meandering characteristics, and riprap design:

1. River Meandering and Braiding;
2. Riprap Design;
3. Case Study; Gupo Bridge, South Korea.

1. River Meandering and Braiding




Right bank
Water surface
Left bank
Distance above stream bed (ft)
Stationing across section (ft)
0
2
4
6
8
10
12
0
100
200
300
400
500
600
700
800
900
250
500
750
1000
1500
2000
2500
3000
3500
4000
5000
Q = 31 600 ft^3/s
V = 4.9 ft/s
C_m = 838 ppm - sand
d_50 = 0.20 mm - bed sediment
S = 1.5 x 10^-4


Mississippi River
< - 20 ft below LWRP
> - 20 ft below LWRP
> - 30 ft below LWRP
Fine sand concentration
0 100 200 300 400 500 mg/L

Old River Control Complex

Meandering Evolution of Natural River

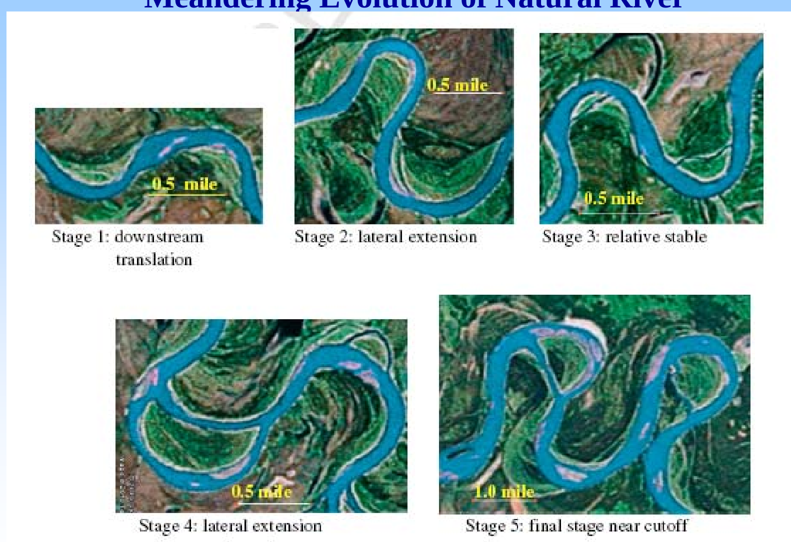


Fig.6. Free meandering patterns of Tanana River in Alaska

Slide 9

PGC1 Numerical model evaluated the hydrodynamics of the location and recommendations were made to construct 4 dikes on the right bank. After construction, the problem was immediately converted from unmanageable to a manageable situation. It is anticipated that proposed numerical stdies will similarly identify a manageable solution.

Phil Combs, 8/29/2002

Migration of the Mississippi River

Examples of Natural Cutoffs

Chute Cutoff

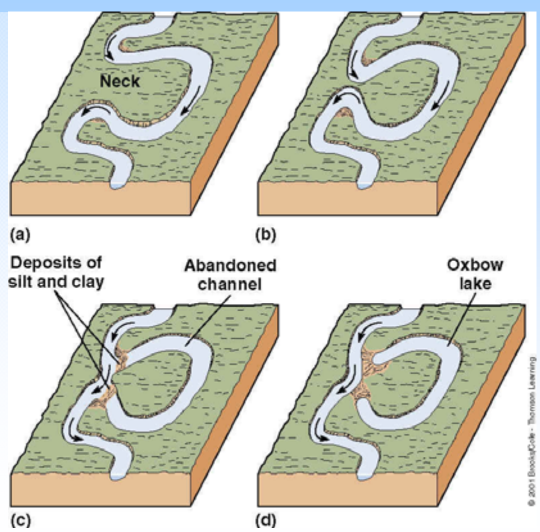
Williams River, AK
(Photo by N.D. Smith)

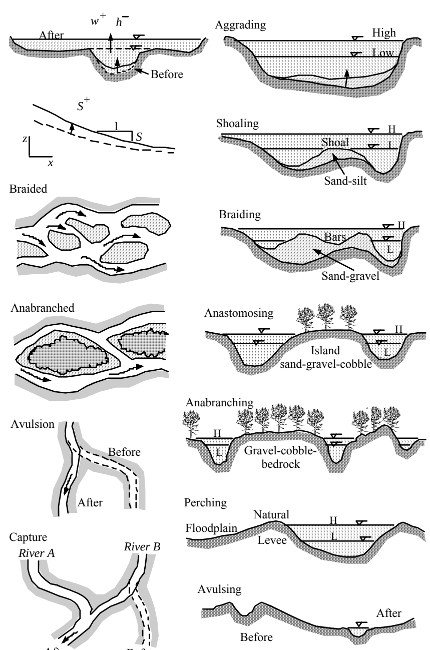
Neck Cutoff

Owens River, CA
(Photo by Marli Bryant Miller

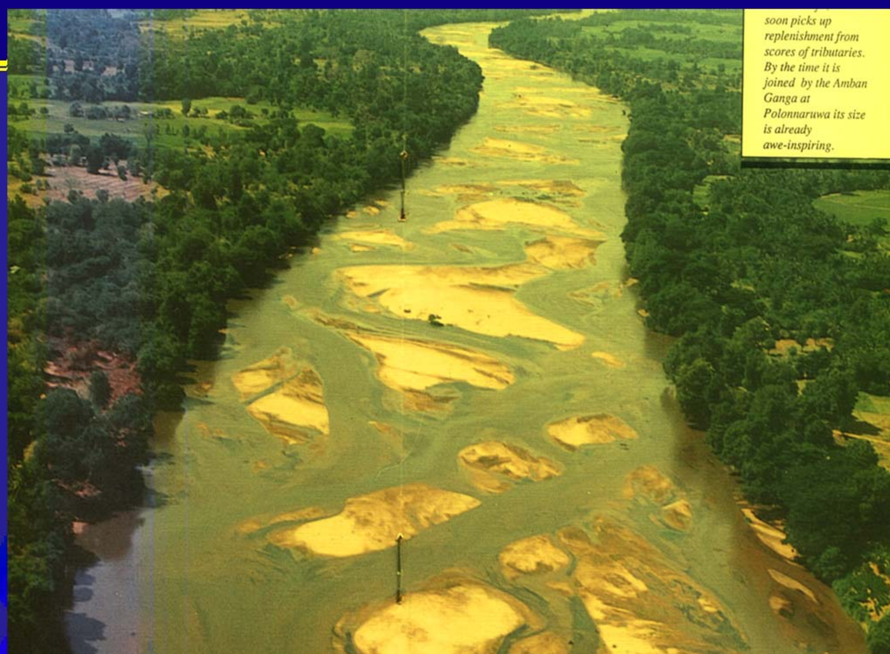
Natural Meander Cutoffs

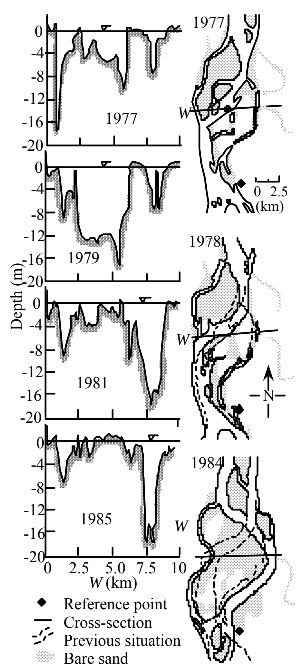
- Lateral migration increases sinuosity of the channel until two bends connect
- Sedimentation occurs where the bends connect
  - Neck cutoff
  - Abandoned channel

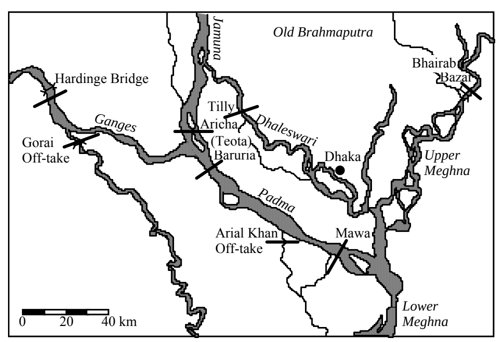




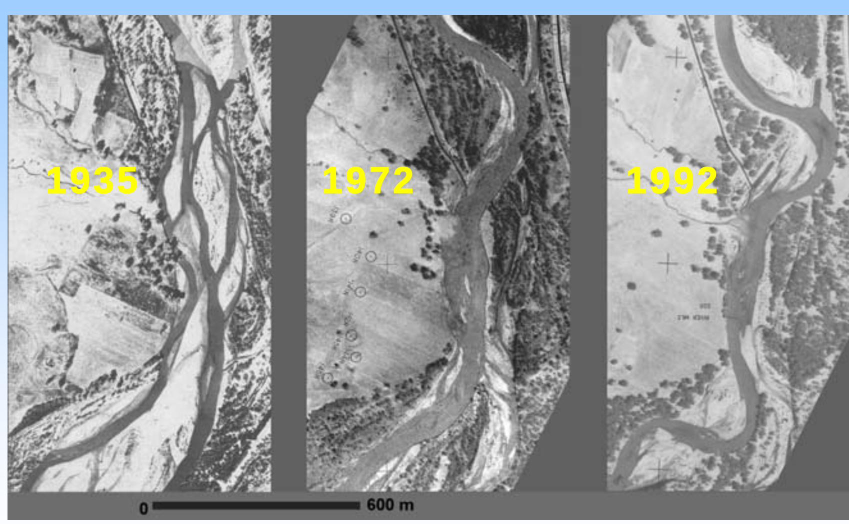
After
w^+ h^-
Before
Aggrading
High
Low
S^+
1
S
z
x
Shoaling
H
Shoal
L
Sand-silt
Braided
Braiding
H
Bars
L
Sand-gravel
Anabranched
Anastomosing
H
Island
sand-gravel-cobble
L
Anabranching
H
L
Gravel-cobble-
bedrock
Avulsion
Before
After
Perching
Natural
H
Floodplain
Levee
L
Capture
River A
River B
After
Before
Avulsing
After
Before


soon picks up replenishment from scores of tributaries. By the time it is joined by the Amban Ganga at Polonnaruwa its size is already awe-inspiring.


1977
1979
1981
1985
1978
1984
Depth (m)
W (km)
0 2.5
(km)
N
Reference point
Cross-section
Previous situation
Bare sand

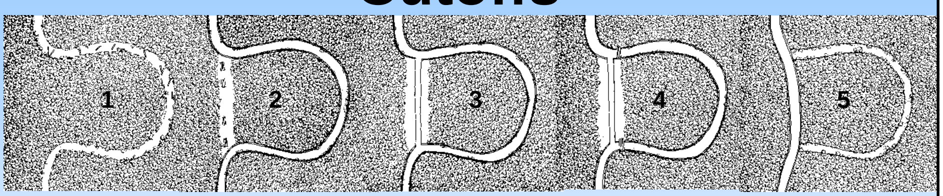

Jamuna
Old Brahmaputra
Bhairab Bazar
Hardinge Bridge
Tilly
Aricha
(Teota)
Baruria
Ganges
Dhaleswari
Gorai Off-take
Dhaka
Upper Meghna
Padma
Arial Khan Off-take
Mawa
0 20 40 km
Lower Meghna

Hydraulic geometry of the Rio Grande, NM



Braiding **Transition** **Meandering**

Historic Artificial Meander Cutoffs

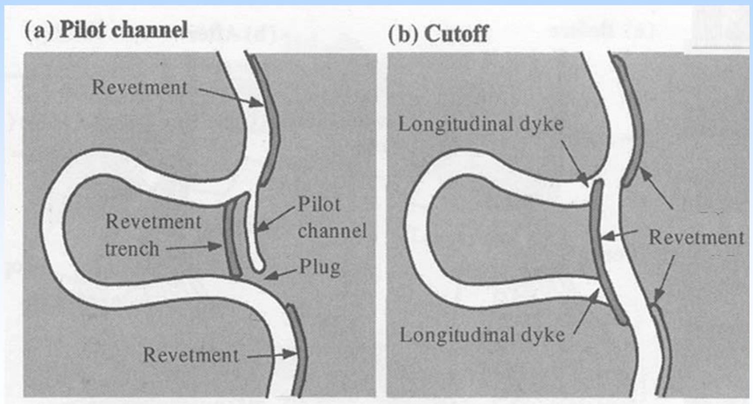


- Stages of meander cut-off construction for navigation on Wood Creek, NY in 18th century are similar to design methods today
  1. Clear natural channel
  2. Clear cut channel and stockpile logs
  3. Excavate ditch across meander neck
  4. Dam old channel
  5. New channel filled by stream flow

(Sketches from New York State Museum)

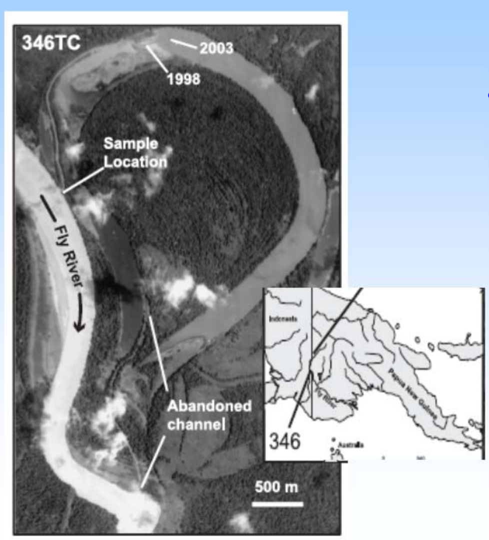
Engineered Cutoffs

- Illustration of artificial cutoff construction



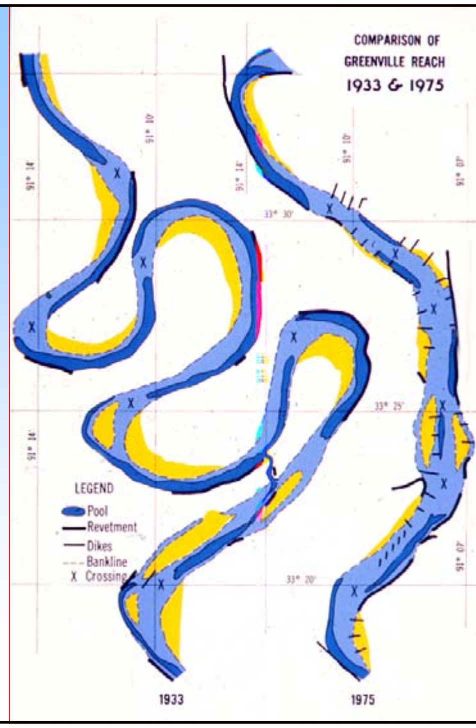
(Figure 9.21 from Julien, 2002)

Engineered Meander Cutoffs



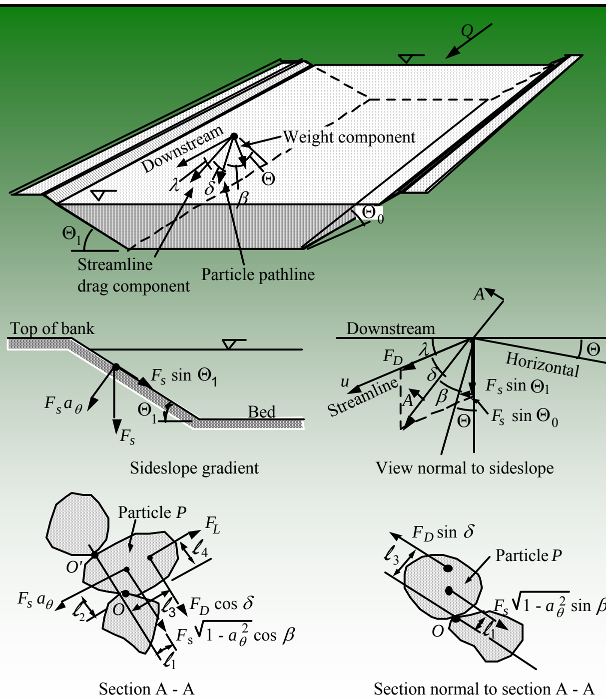
(Rowland et al. 2005)

- Fly River in Papua New Guinea: meander cutoff showing abandoned channel and new straight river flow path



2. Riprap Design


Crush



Particle Stability

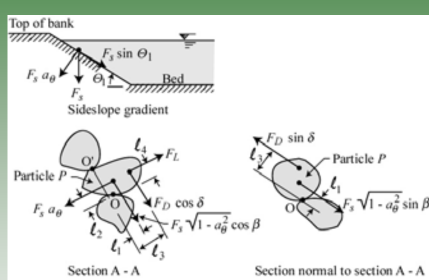


Figure 7.14. Moment stability analysis of a particle

$$SF_0 = \frac{l_2 F_s a_\theta}{l_1 F_s \sqrt{1-a_\theta^2}\cos\beta + l_3 F_D \cos\delta + l_4 F_L}$$

$$SF_{0'} = \frac{l_2 F_s a_\theta + l_1 F_s \sqrt{1-a_\theta^2}\cos\beta}{l_3 F_D \cos\delta + l_4 F_L}$$

- $SF_0<1$
  - Particles in Motion
- $SF_0=1$
  - Incipient Motion
- $SF_0>1$
  - Particles are Stable

Simplified Stability

- Ratio of $\tau_{\theta c}$ (shear on embankment) to τ_c (shear on horizontal surface)

$$\frac{\tau_{\theta c}}{\tau_c} = -\frac{\sin\theta_1 \sin\lambda + \sin\theta_0 \cos\lambda}{\sqrt{1+\Pi_{ld}^2}\,\tan\phi} + \sqrt{\frac{(\sin\theta_1 \sin\lambda + \sin\theta_0 \cos\lambda)^2}{\sqrt{1+\Pi_{ld}^2}\,\tan\phi} + 1 - \frac{(\sin^2\theta_0 + \sin^2\theta_1)}{\sin^2\phi}}$$

- Brooks' relationship: $\theta_0 = 0°$ and $\Pi_{ld} = 0$

$$\frac{\tau_{\theta c}}{\tau_c} = -\frac{\sin\theta_1 \sin\lambda}{\tan\phi} + \sqrt{\frac{(\sin\theta_1 \sin\lambda)^2}{\tan\phi} + 1 - \frac{(\sin^2\theta_1)}{\sin^2\phi}}$$

- Lane's relationship: $\Pi_{ld} = \infty$ or $\lambda = 0$ and $x = 0$

$$x = \frac{\cos\phi(\sin\theta_1 \sin\lambda + \sin\theta_0 \cos\lambda)}{\sqrt{1+\Pi_{ld}^2}\,\sqrt{\sin^2\phi - \sin^2\theta_1 - \sin^2\theta_0}} \qquad \frac{\tau_{\theta c}}{\tau_c} = -+\sqrt{1 - \frac{\sin^2\theta_1}{\sin^2\phi}}$$

Velocity Method

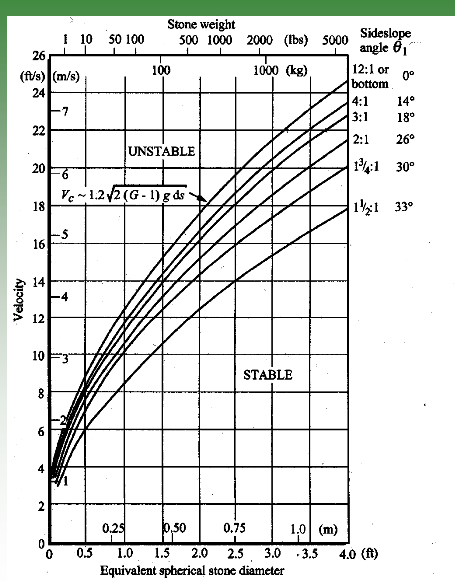
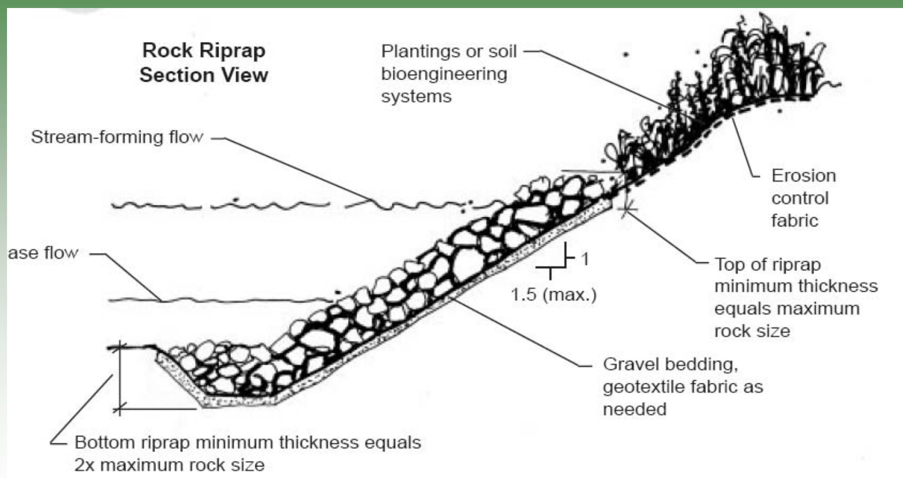


Figure 8.4. Particle-stability diagram.

$$V_c = K_c\sqrt{2(G-1)gd_s}$$

$$K_c = \log\left(\frac{4h}{d_s}\right)\sqrt{\tan\phi}$$

Riprap Design



Riprap Thickness US Army Corp of Engineers

- 30 cm for practical placement
- At least the diameter of the upper limit of d_{100} stone
- At least than 1.5 times the diameter of upper limit d_{50} stone, whichever is greater.
- If riprap is placed under water, the thickness should be increased by 50%.
- If it is subject to attack by large floating debris or wave action it should be increased 15 to 30 cm.

Riprap Failure

- There are four main types of riprap failure: particle erosion, transitional slide, riprap slump, and sideslope failure.
- The four types of riprap failure are shown in the figure to the right.
- The most common failure type is particle erosion from flow

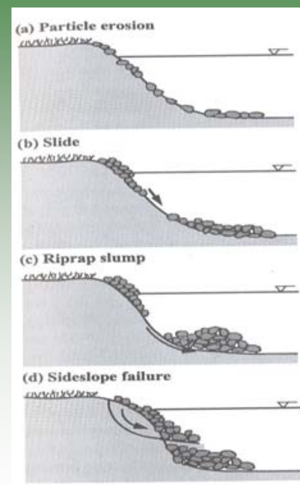


Figure 8.6. Riprap-failure types.

Gradation of Riprap

- Well graded riprap scours less than uniform size riprap due to the process of armoring
- Suggested Riprap gradation from USACE is shown to the right
- Riprap with poor gradation may be used, but a “filter” layer is required

Table 8.2. *Suggested riprap size gradation*

Percent finer by weight	Sieve diameter ($\times d_{50}$)	Stone diameter ($\times d_{50}$)
0	0.25	—
10	0.35	0.28
20	0.50	0.43
30	0.65	0.57
40	0.80	0.72
50	1.00	0.90
60	1.20	1.10
70	1.60	1.50
90	1.80	1.70
100	2.00	1.90

Gravel Filters

- Gravel filters should not be less than 15 to 23 cm
- ½ thickness of Riprap layer is a good guideline
- Suggested gravel filter gradation equations are shown to the right

$$\frac{d_{50}(filter)}{d_{50}(bank)} < 40$$

$$5 < \frac{d_{15}(filter)}{d_{15}(bank)} < 40$$

$$\frac{d_{15}(filter)}{d_{85}(bank)} < 5$$