Smart River Engineering

Chapter 2. River Morphology

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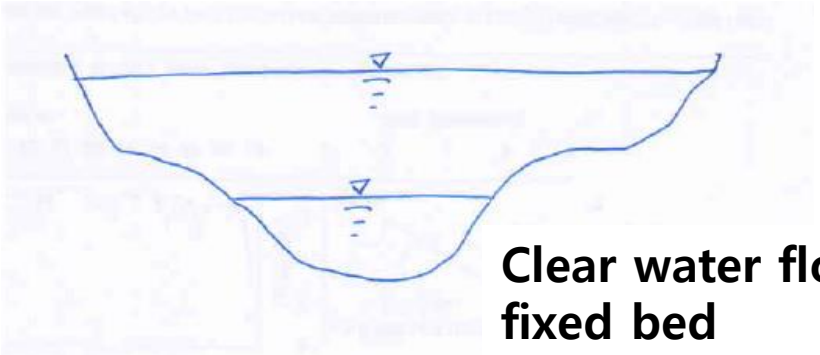
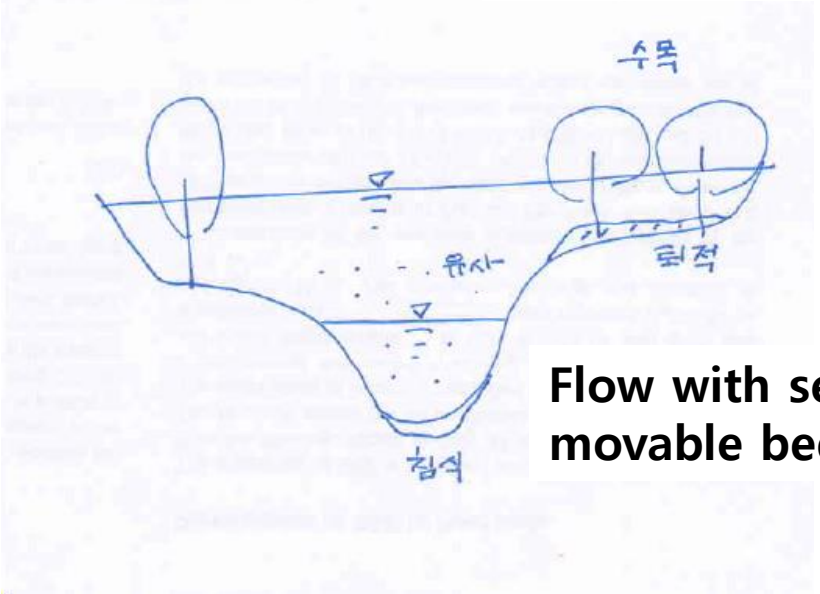
0. What is River Morphology (河川形態學)?

• The term **river morphology** is used to describe the shapes of river channels and how they change over time.

Fixed bed vs. Mobile bed



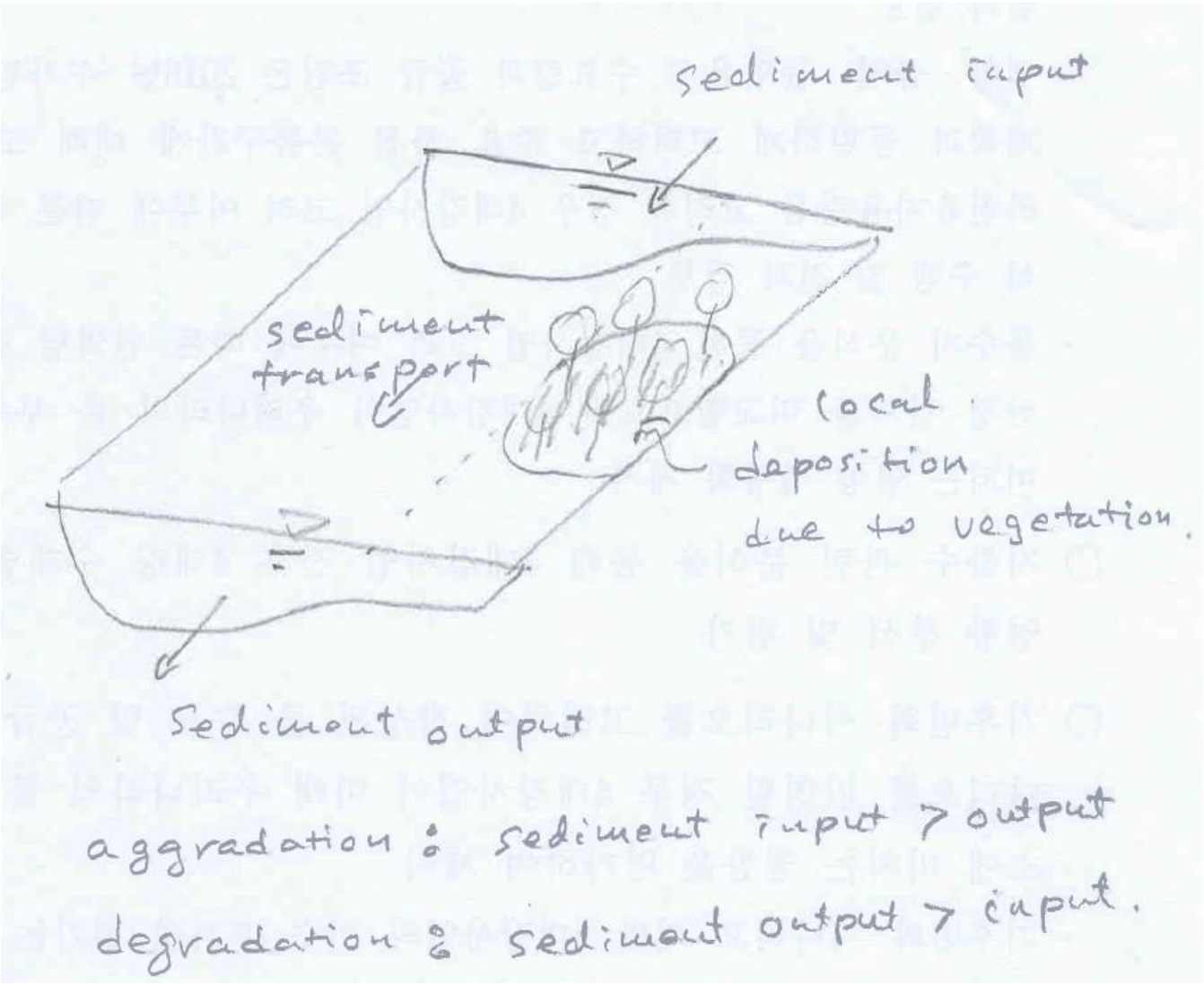
Clear water flow over a fixed bed



Flow with sediment over a movable bed

vegetation, eco-hydraulics

Morphological Change of River



River Morphology

• The morphology of a river channel is a function of many processes and environmental conditions, including

(1) sediment input;

(2) the composition of the bed and bank sediment;

(3) vegetation and the rate of plant growth;

(4) the rate of sediment transport;

(5) and aggradation and degradation

The sediment out of reach is computed automatically.

A Relevant Issue

Change from White River to Green River

엄마야 누나야
김소월

엄마야 누나야 강변 살자
뜰에는 반짝이는 금모래빛
뒷문 밖에는 갈잎의 노래
엄마야 누나야 강변 살자

1. Physical Characteristics of Rivers

- Important hydraulic parameters of a river
  - discharge Q
  - slope S
  - sediment discharge Qs
  - roughness n
  - vegetation
  - sediment size D

Lane's law (1955)

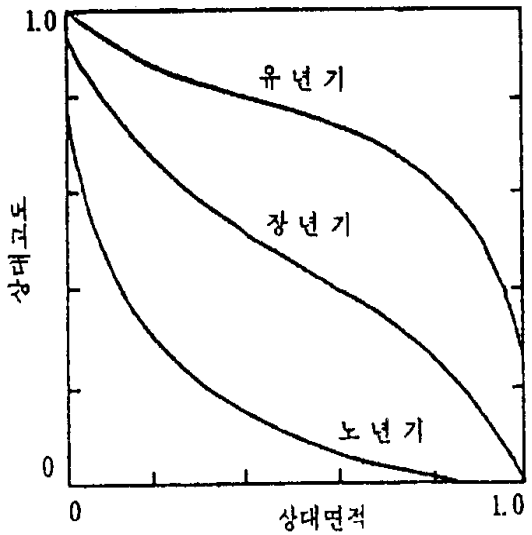
$$\frac{Q_s}{Q} \propto \frac{S}{D_{50}}$$

- Lane's law looks conceptually true, but cannot be used in quantitative predictions.

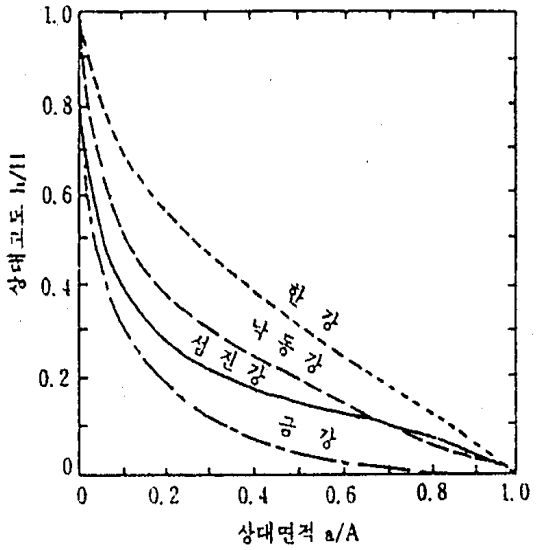
1. Physical Characteristics of Rivers

- **Classification of rivers**
  - young rivers
  - mature rivers
  - old rivers

relative height



relative area



2. Channel Configuration

- Straight channels (直流路)
- Meandering channels (蛇行流路)
- Braided channels (網狀流路)

사행하천: Meandering stream

사행하천: Meandering stream

망상하천: Braided stream

망상하천: Braided stream

3. River Meandering

- **An experiment in WES**

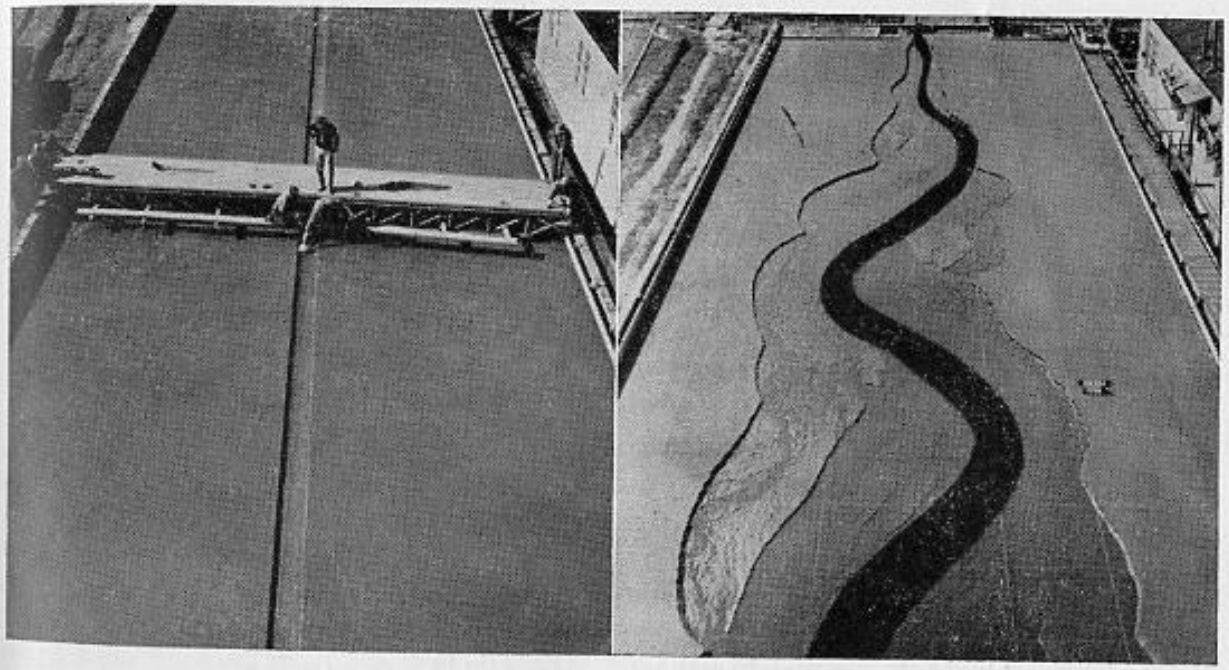


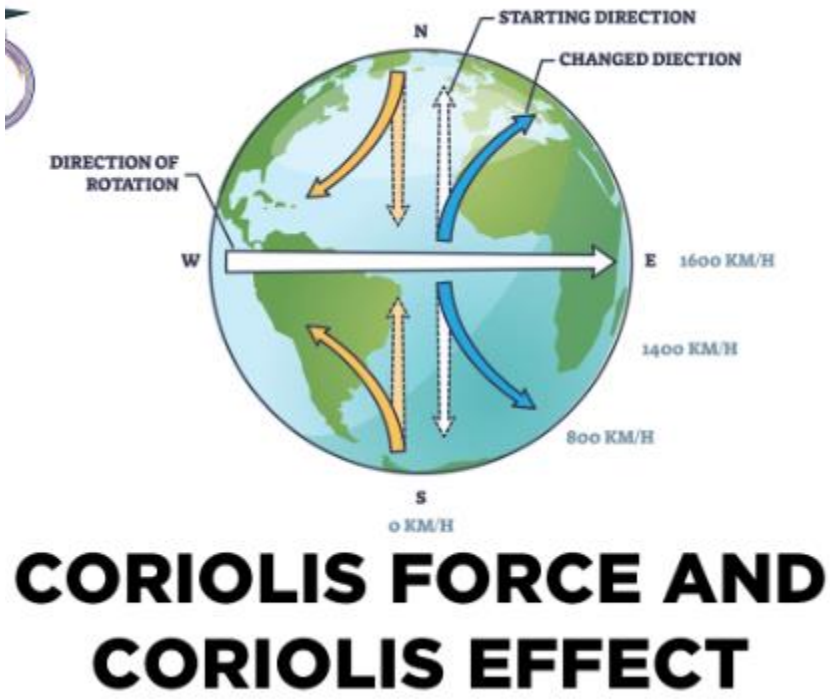
Figure 12-17. Left: *Molding a straight channel in Mississippi River sand at the U. S. Waterways Experiment Station, Vicksburg, Mississippi.* Right: *Sinuous course produced after 72 hours of flow in an initially straight channel. (Photos from J. F. Friedkin; courtesy of the U. S. Waterways Experiment Station.)*

Why Does River Meander?

- Up to date, a clear mechanism that causes river meandering has not been revealed. It is supposed that the following components contribute river meandering:

- Coriolis Force*
- Excessive slope and excessive energy
- non-uniform bed elevation
- oscillations of water surface

Coriolis Force



- The effect of Coriolis force is a deflection of the path of a moving object.
- This effect is most obvious in the path of an object moving longitudinally.

The old watercourse may not be seen.

〈그림 7〉 동림 구하도

광주시 북구 동림동과 광산구 신가동 경계에 위치하며, 시가지 개발과 고수부지 정비과정에서 구하도의 흔적이 사라짐(좌측). 그러나 북구와 광산구의 경계선(검정색 일점쇄선)이 구하도의 위치 및 형상과 일치하여 옛 모습 복원이 가능함(우측).

〔자료 : 구글 위성지도, 생태자연도〕

- **Why has the river straightening been done?**

4. Components of Channel Meandering

Meandering can be considered a part of the overall process by which a stream adjusts to the slope of the valley in which it flows.

The followings are related with the meandering channel:

- Point bar
- Alternate bar
- Cutoffs (oxbow lake)
- Bend hydraulics

Point Bar: 점사주 1

photo: S. Hillebrand. U.S. Fish & Wildlife Service
Digital Library System http://images.fws.gov/

Point Bar: 점사주 2

photo: M. LeFever. U.S. Fish & Wildlife Service
Digital Library System http://images.fws.gov/

Alternate Bar: 대응사주

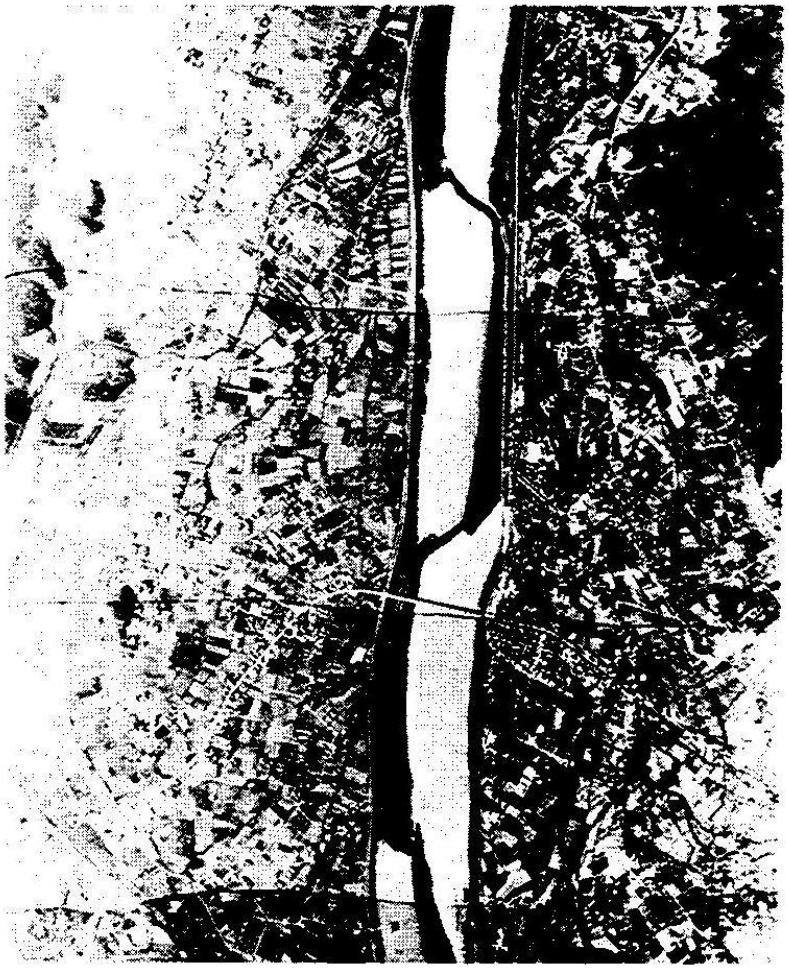


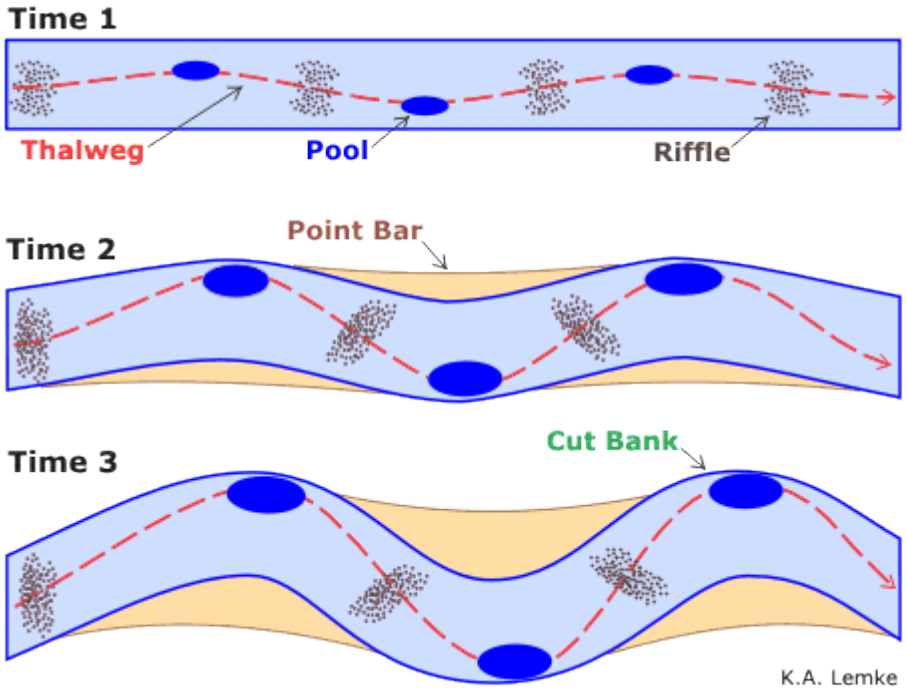
Figure 1. Alternate bars in the Naka River, Tokushima Prefecture, Japan (courtesy Tokushima Construction Office, Ministry of Construction, Japan).

A Bad Case of Stream Restoration

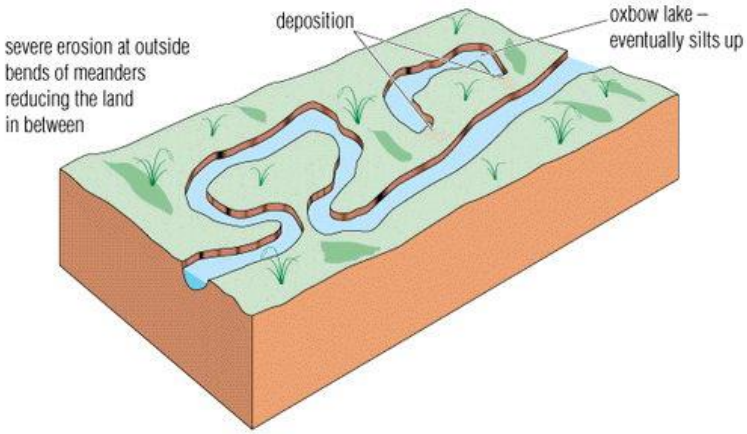
restored stream

after flood

Meander Growth and Downstream Migration



Oxbow Lake: 牛角湖



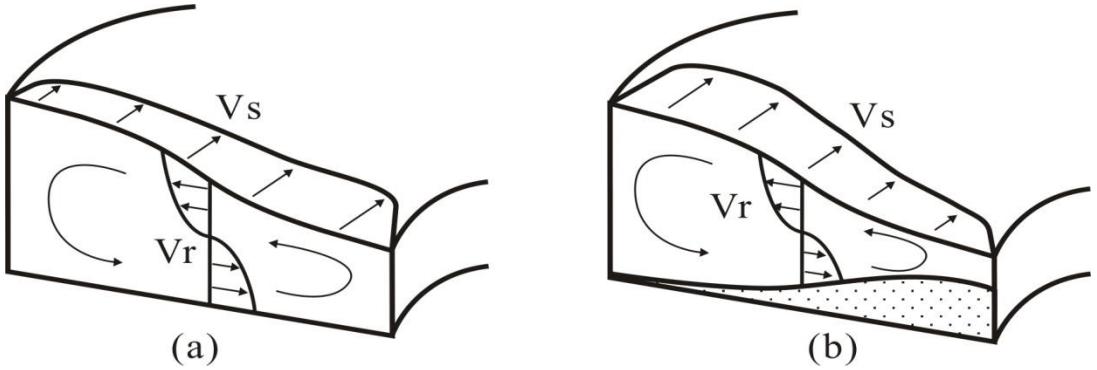
Rio Madre de Dios

5. Bend Hydraulics

- Understand the flow and channel deformation in the bend
-
- Understand the flows in the flat bed
- Understand the resulting bed deformation
- Understand the flow in the deformed bed

- Protection (revetment) of the outer side of the bend against the flow force during floods
- Protection of the bank by lowering the level of the toe
- Shift the thalweg using the vanes
- Maintaining the navigable water depth

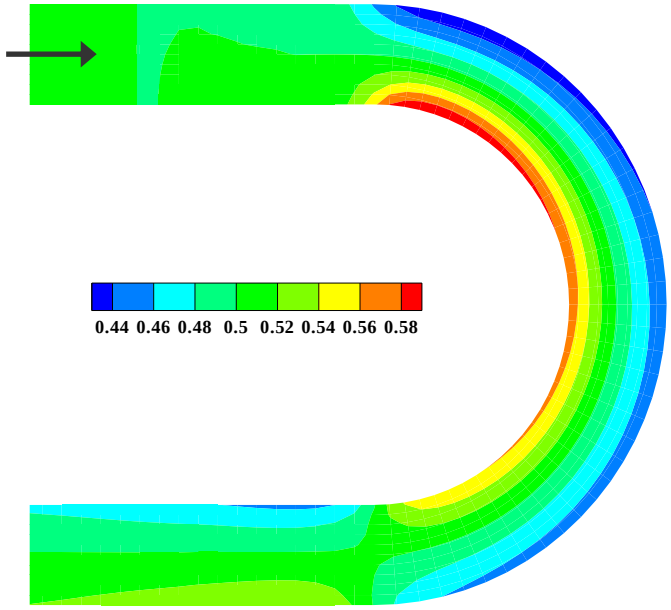
Flow in the Bend



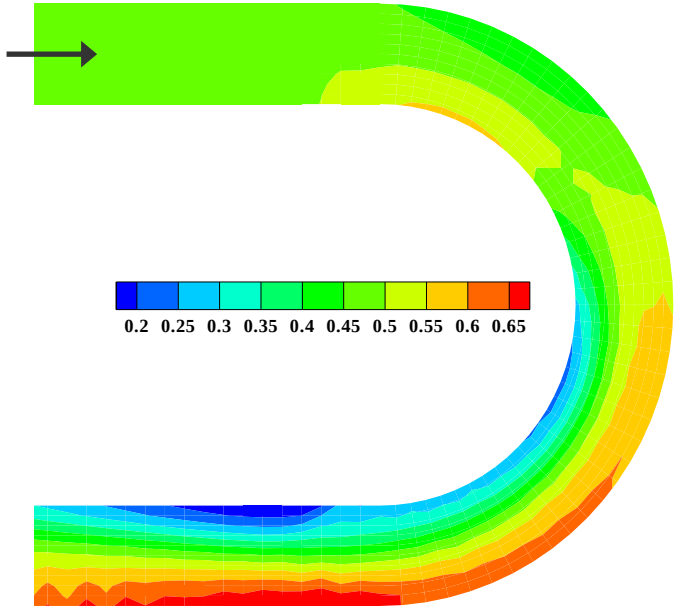
- For a bend with the flat bed
  - Velocity at the inner bank is larger.
  - Secondary currents rotating counter-clockwise are made.
  - This moves sediment towards the inner bank.

- For a bend with the mobile bed
  - Velocity at the outer bank is larger.
  - Sediment deposition occurs at the inner part.

Velocity in a Bend

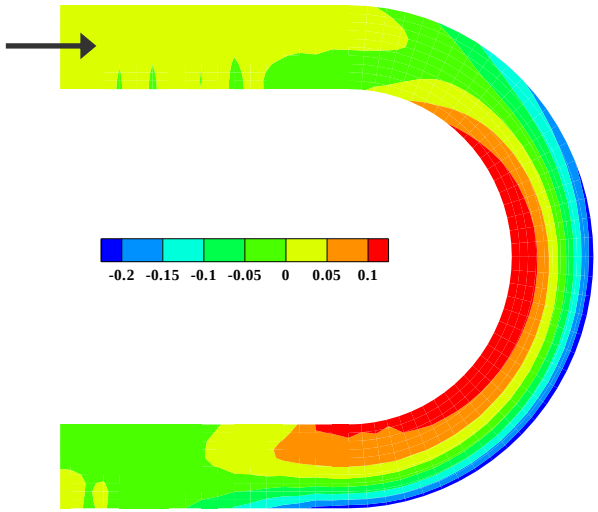


Initial velocity distribution

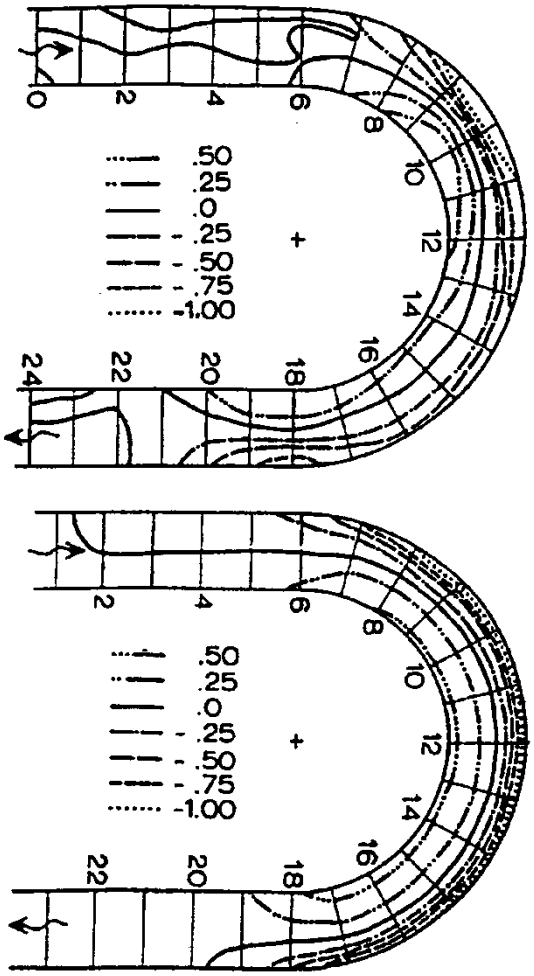


Velocity change due to the morphological change at equilibrium

Morphological Change in a Bend



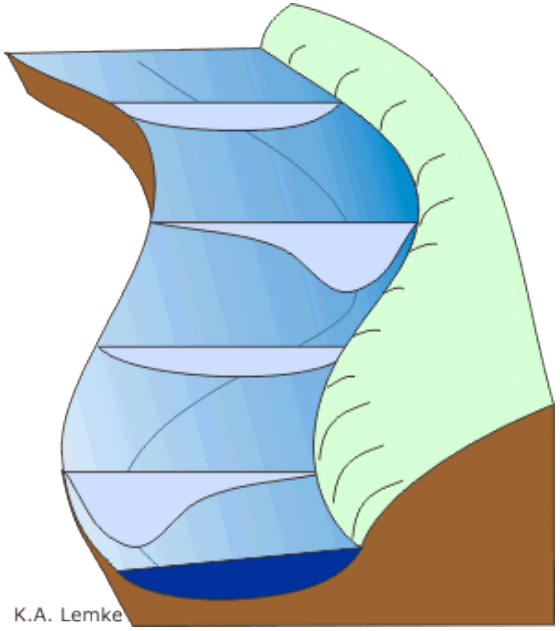
Total load from Engelund & Hansen's (1972) formula



Measured by Sutmuller and Glerum (1980)

Computed by Koch and Flokstra (1981)

6. Pool & Riffle Sequence: 여울과 소 연속구조



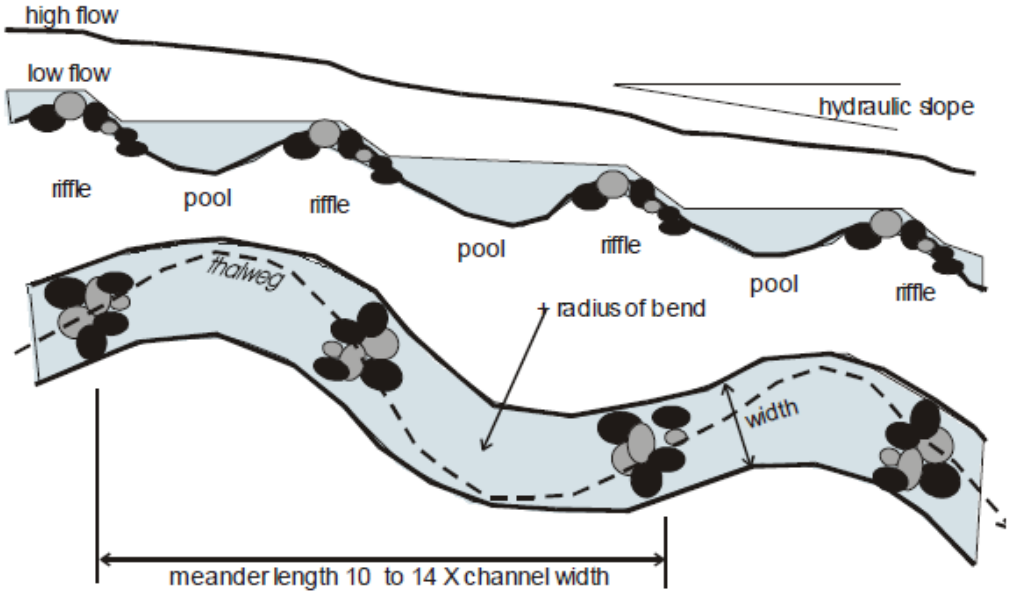
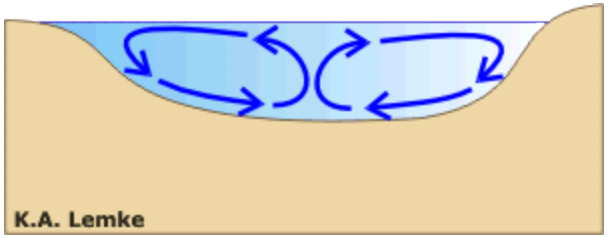


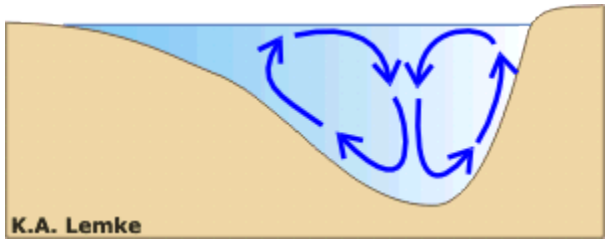
Figure 2: average pool, riffle and meander dimensions observed in some mobile bed streams.

- The pool and riffle sequence is closely related with increasing the biodiversity of the river.

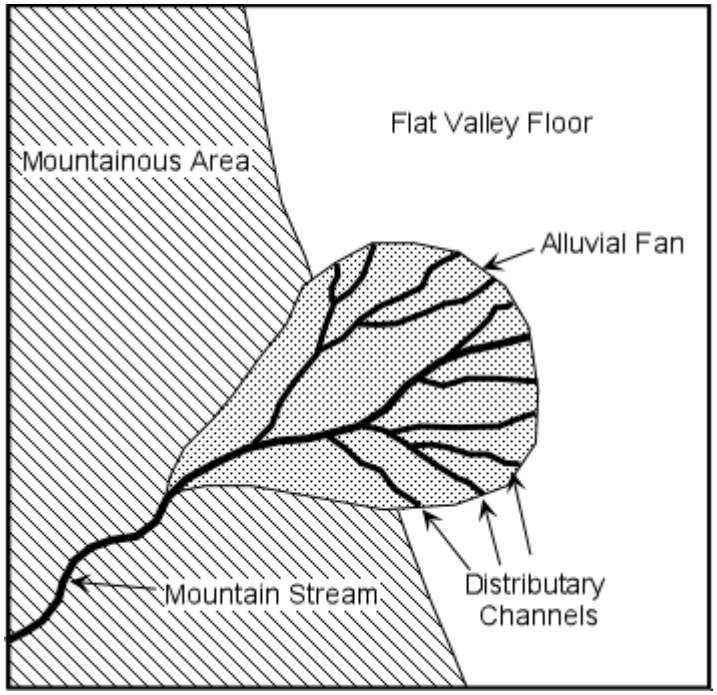
Pools and Riffles: 소와 여울

Riffle	Pools
shallow (& wide)	deep (& narrow)
high velocity	low velocity
coarse grained bed material 모래하천의 경우도 여울 부분은 조립화되어 자갈이 보이기도 함	fine grained bed material
divergent flow (facilitates erosion during the flood)	convergent flow (facilitate deposition during the flood)





7. Alluvial Fan (扇狀地)

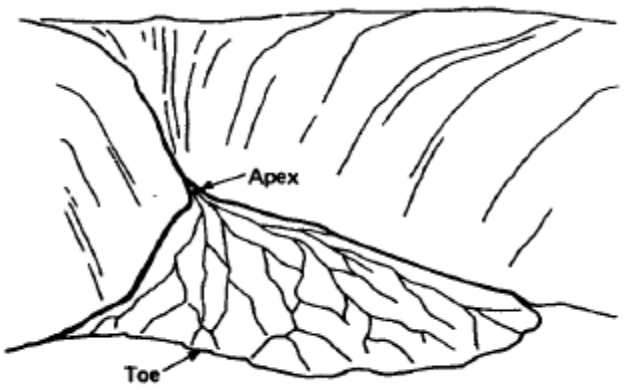


- Alluvial fans are fan-shaped deposit of sediment transported by the river.

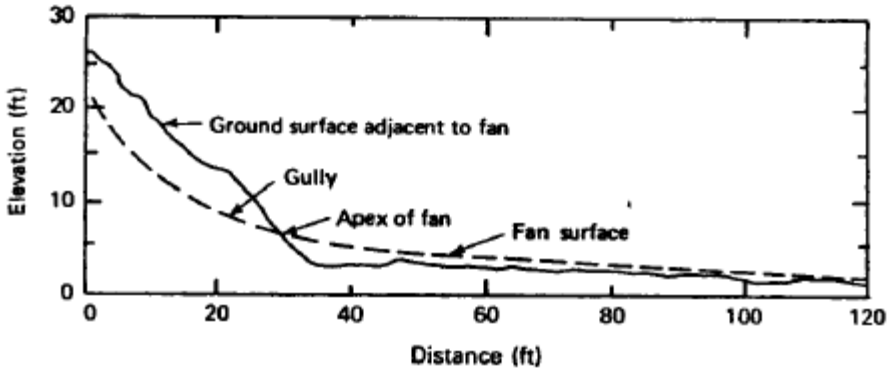
Alluvial Fan

This simulated natural-color image of southeastern Fars province in southern Iran shows a dry river channel carving through arid mountains toward the northeast. A broad belt of lush agricultural land follows the curve of the alluvial fan and stretches out along a road that runs parallel to the ridgeline. The valley-ward margin of the intensely green agricultural belt fades to dull green along streams (or irrigation canals). The image was captured by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite on October 12, 2004. (NASA/Jesse Allen, NASA/GSFC/METI/ERSDAC/JAROS, U.S./Japan ASTER Science Team)

Alluvial Fan

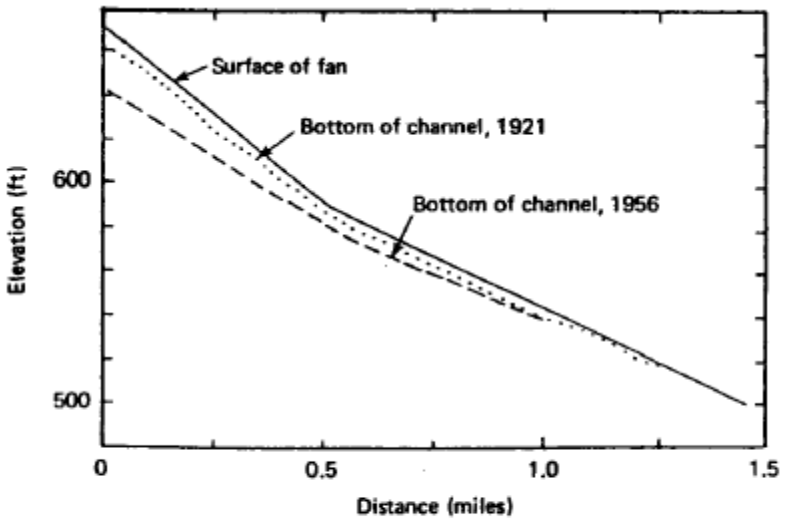


(a) Fan at valley wall



- They occur at a point where a stream emerges from a confined valley.
- At the apex where the velocity suddenly decreases, a stream deposits a large amount of sediment that is reworked by subsequent floods.
- Note that the fan surface is higher than ground surface adjacent to the fan after the apex.

Alluvial Fan



Typical Alluvial Fans

- Morphology of the fan and stream within it are changed by subsequent floods.

8. Stream-Bank Erosion 1

- Factors affecting stream-bank erosion
  - Flow variables (Q & h)
  - Channel geometry
  - Human actions: vegetation, dredging, and sand or gravel mining (골재채취)
  - Gravity

- Annual damages from bank erosion in the US is about $340,000,000, which may exceed benefits from a cost-benefit standpoint. (3,400억원)

- Hungry river

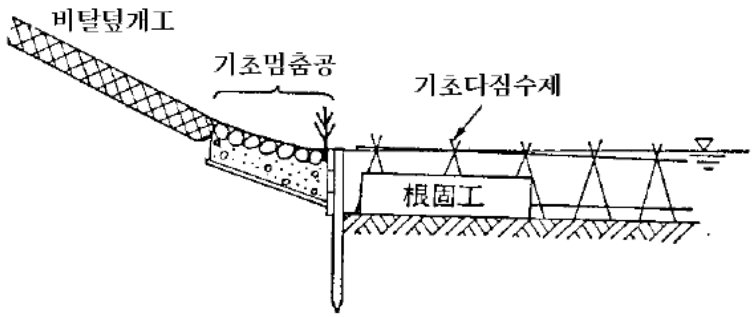
Stream-Bank Erosion 2

- **Causes of Bank Failure**

(1) Streamflow attack at the toe of a bank

(2) Bank Sloughing (for cohesive soils)

(3) Flow slide (for non-cohesive soils) 액화현상



호안의 구성

Bank Sloughing

Riverbanks along the LaSueur show clear signs of erosion. Researchers are trying to understand the erosion process (MPR photo/Mark Steil)

The effort to clean up the Minnesota River is running into some unpleasant realities. Some of the river's problems may be unfixable. Take the high bluffs that flank parts of the Minnesota and its tributaries. They routinely send tons of soil sliding into the water. Engineers could stabilize the banks, but there's not enough money available. Muddy water affects a river's health. It harms both plant and fish life.

Flow Slide

The failure of a sloped bank of soil in which the soil movement does not take place along a well-defined surface of sliding.