Chapter 2

River Morphology

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River morphology concerns the structure and form of rivers, including channel configuration (plan form), channel geometry (cross-sectional shape), bed form, and profile characteristics.

1. Physical Characteristics of Rivers

Rivers can be characterized by the following hydraulic (physical; not geometric) properties:

\[
\begin{align*}
Q &= \text{stream discharge} \\
S &= \text{slope} \\
Q_s &= \text{sediment discharge (load)} \\
n &= \text{resistance of bed and banks} \\
n_v &= \text{resistance due to vegetation} \\
d &= \text{sediment size}
\end{align*}
\]

These factors are not all independent but they are inter-related. For example, according to Lane’s (1955) law, the sediment load is proposed to be estimated by the following empirical formula:

\[
\frac{Q_s}{Q} \propto \frac{S}{D_{50}} \tag{1}
\]

which always disagrees with the sediment transport observations and theory.

Classifications of River

Geologically, rivers are classified as young, mature, and old.

- Young river: mountain streams in V-shaped valley. Irregular and degrading.
- Mature river: river in a widened and flat valley. Stable and capable of transporting sediment load coming into the reach.
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- Old river: very wide river with very flat slopes. Wide flood plain areas and lakes where old meanders have been cut off from the river.

(Q) Can you classify rivers in Korea?

2. Channel Configuration

River alignment can be categorized in three basic types and combinations of these basic types.

- Straight channels: relatively short and transitory. Very minor irregularities in channel shape or alignment or a temporary obstruction can cause a transverse flow leading to meandering.
- Meandering channels: consisting of a series of bends of alternate curvature in a flat area. Meandering channels are unstable with banks carving. There are deep pools (pools are deep, usually roughly triangular-shaped channel reaches in river bends) in the bends and high velocities along the outer concave bank.
- Braided channels: very wide stream with poorly defined banks. Unstable. At low flow rates, two or more channels exist

3. Meandering

3.1 Meandering process

The term “meandering” comes from a river in Turkey, following winding crooked course. Meandering increases stream length and decreases slope. 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 configuration and geometry of a meandering channel are formed by erosion and deposition.

At high flow, the outer concave bank in bends erodes, and the bed scours and deepens. The
eroded sediment from the bank is deposited through the next downstream crossing. At low flow, the bends erode, and the crossings tend to scour and deepen.

Figure 2.1 Meandering channels

The figures below show multispectral false color infrared images of a portion of the floodplain along the Missouri River north of Boonville, Missouri. The 1992 data were acquired on September 24 and shows levees and agricultural fields. The 1997 data were acquired on August 23, approximately 4 years after the floods of 1993. The 1997 data show a chute cutting through Lisbon Bottoms, erosion of a northeastern section of Jameson Island, and development of wetlands vegetation on both bottoms. These bottoms are now the core of the Big Muddy Fish and Wildlife Refuge. Images cover approximately 7 km in width. North is toward the top. EOS (Nov. 17, 1998), 79(46).
3.2 Components of meandering river

(1) Bends

A feature of typical meandering river is the bend. Predicting the bed level in the bend is important because it provides information on (1) the available depth and width for navigation; and (2) the level of the toe of the bank for the design of bank protection. In the prediction of the variation in bed level across the width of the river, both deterministic and stochastic approaches are available. The former is restricted in practical applications because of too much simplifications. The stochastic method seems to be more suitable because of too many parameters that are involved in the coupled process of flow and the sediment motion (Jansen
et al., 1979).

(2) Crossings
Crossings are located between bends of reverse curvature or where the flow changes from flowing along one concave bank to the opposite bank. Crossing sections in alluvial rivers are approximately rectangular in contrast to the triangular sections in bends.

(3) Cutoffs
As meandering continues with time, and as the concave bank continues to recede, old bends become elongated and a narrow neck of land develops. A large flood exceeding channel capacity breaks the narrow neck, and eventually makes a new short channel called cutoff. Then the old bendway becomes separated from the river by deposition.

![Figure 2.3 Formation of natural cutoffs](image)

**3.3 Hydraulics of channel bend**
The figure below show flows in bends of (a) a flat bed and (b) a mobile bed. Both distribution of streamwise velocity and secondary flows are shown. First, for the bend of a flat bed, it can be seen that the velocity at the inner bank is larger than that at the outer bank. The centrifugal
force makes the water surface higher at the outer bank. In addition, the secondary flows rotate in the counter-clockwise direction, which will move sediment particles towards the inner bank if any.

However, for the bend of a mobile bed, the cross section is not rectangular any more, deeper flow depth at the outer bank. Sediment particles are deposited at the inner bank, forming a point bar there. The flow accelerates along the outer bank with higher water surface.

![Figure 2.4 flows in bends](image)

**Figure 2.4 flows in bends**

### 3.4 Pool and riffle sequence

Flows in bends interact with bed sediment and form pool in the bend and riffle in the crossing. In natural rivers, pools and riffles are formed in series, and they are called pool and riffle sequence. The pool is characterized by low velocity with deep water depth. The flows are convergent because the cross section of the pool is triangular, in general. The bed sediment particles in the pool are fine. However, in the riffle, the water depth is shallow, with high velocity. Since the cross section of the riffle is widely-flat, the flows therein are divergent. The bed sediment in the riffle is rather coarse.
The presence of the pool and riffle sequence in the river is known to affect the biodiversity of aquatic organisms. That is, for example, the lentic fish prefer the pool and the lotic fish do the riffle. Therefore, the various configurations of river reach may increase the number of fish species.

Figure 2.5 Pool and riffle sequence

4. Alluvial Fans

Alluvial fans are deposits of sediment with surface of a cone, fan-shaped in plan. They occur at the point where a stream emerges from a confined valley and can spread laterally or where the slope abruptly flattens. At the apex of the fan where velocity suddenly decreases, the stream deposits large quantities of sediment that is reworked by subsequent floods.
Figure 2.6 Typical alluvial fan

Figure 2.7 Bed elevation change with time
5. Stream-Bank Erosion

The stream bank changes with flow variables ($Q$ and $y$), sediment load, and characteristics of the bed materials. Stream-bank stability depends on these interrelated stream variables as well as on channel geometry. Annual damages from bank erosion in the U.S. is about $340,000,000, which may exceed benefits from a cost-benefit standpoint.

**Surficial bank deterioration mechanism**

(1) Flow: Soil particle removal by overbank flows. Quantity of flow, transport capacity, turbulence, secondary currents, and wave action are related to bank erosion.

(2) Human actions: Destruction of protective tools such as vegetation; Dredging and sand or gravel mining

(3) Gravity: For steeper slopes, surface particles roll downslope

It has been identified that the most common cause of bank failure is the attack by streamflow at the toe of a bank. As the toe erodes and the eroded material is carried away by the flow, the bank progressively steepens, become unstable and fails. As other causes, there are bank sloughing and flow slides. Bank sloughing occurs when cohesive banks are saturated by a flood of long duration, followed by a fairly rapid fall in water surface and bank failure. Flow slides occur when a massive deposit of silty and sandy (non-cohesive) soils becomes saturated. When forces exceed the friction resistance of the individual soil particles, liquidation of the mass occurs.
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References

EOS (Nov. 17, 1998), 79(46).