IMPACTS OF WATER AND SEDIMENT LOAD CHANGE ON DEVELOPMENT OF MEANDERS IN LOWER YELLOW RIVER

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The Yellow River, with a drainage area of 795,000 km^2 and a length of 5,464 km, is the second longest river in China. The most important characteristic of the river is "insufficient water and heavy sediment load". The total annual runoff is 58 billion m^3, and annual sediment load is 1.6 billion tons at Sanmenxia Hydrological Station (control station), ranking first among the world's rivers. The average sediment concentration is 35kg/m^3. The river flows through the vast Loess Plateau in the middle reaches with many of its tributaries originating from the plateau. The lower Yellow River is from the Xiaolangdi dam to the river mouth, which can be divided into a wandering river section from Mengjin to Gaocun, a transition river section from Gaocun to Taochengpu, and a meandering river section from Taochengpu to Ninghai. The grain size of sediment ranges from 0.02 mm to 0.04 mm, mainly with mineral components of quartz and feldspar, which are cohesionless. Therefore, the sediment is very erodible and is associated with strongly movement of the river channel. There are many river meanders in the wandering, transitional and meandering river sections. According to the minimum stream power theory, the morphology of fluvial rivers develops until it reaches the minimum stream power. So meanders develop until reach the minimum stream power. The channel sinuosity and sediment transporting capacity will reach equilibrium after experienced a long period of fluvial process. However, this balance will be broken by change of water and sediment load, which will result in a new circle of fluvial process. According to continuous years' river morphologic map and hydrological data from 1960-2002 at the hydrological stations of Sanmenxia, Xiaolangdi, Huayuankou, Jiahetan, Gaocun, Sunkou, Aishan, Lekou and Lijin in the lower Yellow River, this paper analyses the impacts of changes of water and sediment load on the meander process.

The sediment load is closely related to the operation of Sanmenxia Reservoir. This reservoir is the first large-scale hydraulic project on the mainstream of the Yellow River for purpose of power generation and flood defense. The operation mode of this reservoir experienced three periods with different management strategies: "store water and trap sediment (1960-1963)", "detention floods and discharge sediment (1964-1973)", and "store clear water and discharge turbid flood (1974-present)". Annual sediment load at Sanmenxia Hydrological Station decreased sharply during the period of "store water and

trap sediment", but increased during the period of "detention floods and discharge turbid flood", and varied with water in its capacity during the period of "store clear water and discharge muddy flood". These changed artificially water and sediment condition in the lower reaches, and caused change in the lower river channel.

Water and sediment load in the Lower Yellow River has been changing due to climate change and human activities in the past decades. Development of meanders in the Lower Yellow River is closely related to the change of water and sediment load. To consider the effects of both water and sediment, we introduce the following parameter, which is the ratio of discharge to sediment concentration:

$$r_{ws} = \frac{Q}{S} \tag{1}$$

in which, r_{ws} is calculated with the unit of $m^6/(kg.s)$; Q is annual average discharge with unit of m^3/s and S is the annual average sediment concentration with unit of kg/m^3. Obviously, small r_{ws} stands for less water and more sediment, and big r_{ws} for high discharge and low sediment concentration.

Generally speaking, the river channel was eroded in continuous years with high discharge and low sediment load. As a result the number of meanders decreased, the radius of meanders increased and the sinuosity of the river channel decreased. On the contrary, in a period of continuous years of low water and high sediment load, siltation occurred and the number and radius of meanders increased, and the sinuosity goes up. The meanders become larger if erosion occurred in the river channel, and become smaller if deposition occurred. Because the development of meanders is induced by the change of water flow and sediment load and the development need a period of time, the variation of meanders lags behind the change of water and sediment load, and time-lag is about 3-4 years. The operation mode of the Sanmenxia reservoir affects the meander process greatly. If the reservoir changed water and sediment condition abruptly, complicated changes will occur in meander process.