UNESCO - IHP International Sedimentation Initiative

ISI

Summary Report –

International Sediment Initiative (ISI) Case Study on Yellow River Basin Sedimentation

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River Basin:

The Yellow River is located between $32^{0}02^{'}$ - $40^{0}28^{'}$ of North latitude and $95^{0}58^{'}$ - $116^{0}45^{'}$ of East longitude. It originates from the Yaoguzenglie piedmont basin on the northern slope of Bayankala Mountains in Qinghai Province. It passes through the Qinghai-Tibet Plateau, Loess Plateau and North China Alluvial Plain and empties itself into the Bohai Sea, descending in three steps from west to east.

Main Features of the River:

The total length of the Yellow River is 5,464 km and the drainage area is 753,000 km2. According as the geomorphology the Yellow River is usually divided into three reaches. From the river source to Hekouzhen in Inner Mongolia Autonomous Region is known as the upper reaches. The middle reaches are designated from Hekouzhen to Taohuayu in Henan Province, and the lower reaches are from Taohuayu to the Bohai Sea. Table 1 shows the characteristic of different courses of the Yellow River.

Table 1 Characteristic of different courses of Yellow River.

Reach	Start to end	Basin area (km2)	River length (km)	Numbers of tributaries
Upper reaches	River source to Hekouzhen	385966	3471.6	43
	1.River source to Madou	20930	369.7	3
	2.Madou to Longyangxia	110490	1417.5	22
	3.Longyangxia to Xiaheyan	122722	793.9	8
	4.Xiaheyan to Hekouzhen	131824	990.5	10
Middle reaches	Hekouzhen to Taohuayu	343751	1206.4	30
	1.Hekouzhen to Longmen	111591	725.1	21
	2.Longmen to Sanmenxia	190842	240.4	5
	3.Sanmenxia to Taohuayu	41318	240.9	4
Loweres reaches	Taohuayu to estuary	22726	785.6	3
	1.Taohuayu to Gaocun	4429	206.5	1
	2.Gaocun to Aishan	14990	193.6	2
	3.Aishan to Lijin	2733	281.9	0
	4.Lijin to estuary	574	103.6	0

The upper reaches of the Yellow River has a length of 3,472 km, a basin area of 386,000km2 and a total drop of 3,496m, accounting for 63.5%, 53.8% and 78% of the whole river, respectively. There are 43 tributaries, flowing into the reach. Each catchment area of these tributaries is bigger than 1000 km2. The first course of the upper reaches originates from the river source and ends at Madou, flowing through a series of swamps and grassland and across the Zaling and Eling lakes, and is called as the river source course. It is located on the first step of the Yellow River Basin. There are lush pastures and vast expanse of open landscape along both banks, the average ground elevation of which is above 4000m. There are less human activities due to high ground elevation. The second course from Madou to Longyangxia extends through valleys, ancient lakes and gorges, surrounded by high mountains between Bayankala Mountains and Jishi Mountains. There are also less human activities. The third course of upper reaches from Longyangxia to Qingtongxia roars swiftly through 10 long gorges and 17 wide valleys alternatively. In the gorges many good dam sites are available for exploitation of hydropower resources. Up to now, there are 8 commissioned hydro-projects in this course, two of which, Longyangxia and Liujiaxia hydro-projects are

multipurpose projects and the others are mainly for power generation or irrigation. Longyangxia and Liujiaxia hydro-projects play main role in runoff regulation in the upper reach of the Yellow River due to their large storage capacity. The fourth course of the upper reach from Qingtongxia to Hekouzhen stretches through the wide alluvial plain and the deserts of Ningxia and Inner Mongolia loess plateau. Two tributaries, the Qingshui and Zuli Rivers, bring some sediment into the reach. As early as in Qin Dynasty, from 245 to 206 B.C, ancient irrigation canals were built in this area. Nowadays, Qingtongxia and Sanshenggong irrigation canals systems have been greatly developed, diverting water from the Yellow River through Qingtongxia and Sanshenggong Hydro-projects and become one of largest water consumers in the Yellow River Basin. In addition, the four course of the upper reach flows from low latitude to high latitude. During spring, when the ice bound river of the upper stream breaks up of ice due to the low latitude, but the river of downstream is still bound by ice. The floating ice would form icejam in the downstream channel, which is the water level and occurres the so-called “ice flooding”.

The middle reaches of the Yellow River from Hekouzhen to Taohuayu has a river length of 1,206 km, a basin area of 344,000 km2 and a drop of 890m, accounting for 22.1%, 43.3% and 19.7% of the totals, respectively. The course of the middle reaches from Hekouzhen to Longmen, turning southward abruptly in front of Luliang Mountains, extends through the gorges, separating Shannxi and Shanxi Provinces. The course is about 725 km long, with a steep bed slope. In its basin of 113×103km2, there are 21 tributaries, flowing through the largest loess plateau in the world and emptying into the course. These tributaries cut the loess plateau into deep gullies, long and narrow weirs and sharp mounds, bringing huge amount of sediment into the Yellow River, and making it the muddiest river in the world. Getting out of the gorge at Longmen, the middle reaches enter into a wide alluvial plain, where two of largest tributaries, the Weihe and Fenhe, converge. The upper reaches of the Weihe River and its tributaries, the Jinghe and Beiluo Rivers also flow through the loess plateau and transfer a large amount of sediment into the Yellow River. The basins of middle and lower reaches of the Weihe River were the cradles of ancient Chinese civilization, with developed ancient irrigation canals, and nowadays, become the agricultural and industrial base in West China. After confluence with the Weihe River, the Yellow River turns sharply to the east in front of the Qinling Mountains and flows through Sanmenxia and Xiaolangdi gorges to Taohuayu, the outlet of last series of gorges in Henan Province. The basin of middle reaches is not only the source region of extraordinary floods, but also the source region of heavy sediment load and harmful coarse. 90% of total sediment load of the Yellow River come from the basin of middle reaches.

The lower reaches of the Yellow River from Taohuayu to the Bohai Sea has a river length of 786km, a basin area of 2,3000 km2, and a drop of 94m with an average bed slope of 0.016 %. The lower reaches is confined by the levee system along both banks and become a well-known” perched river” due to the unceasing aggradation of sediment. The surface level of the floodplain is 3-10 m higher than that of riverain ground surface outside the levees. This has rendered the arduousness of flood control in the Yellow River. The upstream of the lower reaches has wide floodplains and a main channel, while the downstream has narrow ones, which makes flood passing not fluently. The main channel in the reach from Taohuayu to Gaochun, having a river length of 194 km is a wide and shallow wandering channel, which is the most dangerous stretch for flood control. The reach from Aishan to Lijin, having river length of 282 km is a meandering river with stable narrow main channel. It is also a dangerous stretch for flood control and icejam due to its narrow channel and floodplains. The reach from Gaochun to Aishan is the transitional reach from wandering to meandering channel. The reach

downstream Lijin is the river mouth stretch, the main channel of which frequently migrates on the mouth delta in company with its aggradation. In 1976 a new outlet channel was artificially diverted into the Bohai Sea. Since then about one billion tons of sediment has been deposited in this region, forming annually new ground of 25-30 km2 in average. In addition, the reach from Tongwaxiang to Lijin has the same icejam danger just like in the course from Qintongxia to Hekouzhen, because the river flows also from low latitude to high latitude.

Temperature and Rainfall: Temperature in the Yellow River Basin varies very remarkably. The average temperatures are 1-8 $^{\circ}$C, 8 $^{\circ}$-14 $^{\circ}$C and 12 $^{\circ}$-14 $^{\circ}$C in the upper, middle and lower basins, respectively. The weather in river source area is under the control of Tibet Plateau monsoon and the others are under the control of the temperate and subtropical monsoons. In winter usually the northern wind prevails, which brings a little moisture, so it is very cold and dry. But in summer usually the southeastern wind blows from Pacific Ocean. During this season the moisture is continually transferred into the basin and rainy days become more frequently. Sometime appear heavy storms, when the warm moisture meets with the cold airflow from the north. Average annual precipitation in the Yellow River Basin is 467mm, while the average annual rainfall volume is about 370×10^{9} m^{3}, which accounts for only 6% of the total volume in China. The Yellow River Basin is deficient in rainfall. In addition, the distribution of rainfall is very uneven in space, decreasing from southeast to northwest. Northern slope of the Qinling Mountains in Shanxi Province is a rich rainfall region, where the mean annual precipitation reaches 800mm. But the mean annual precipitation in the region of Hetao plain in Inner Mongolia Autonomous Region is less than 200mm.The distribution of the average annual precipitation from 1950 to 1988 is listed in Table 2.

The distribution of precipitation is also uneven in seasons around a year and from year to year. The rainy season occurs in 4 months from June to September in most areas of the Yellow River basin. The precipitation in rainy season accounted for 58-77% of the annual total. The precipitation in winter accounts for only 1-5% of the annual total.

Table 2 Distribution of average annual precipitation in various basins from 1950 to1988

Basin	Precipitation (mm)	Basin	Precipitation (mm)
Upstream of Lanzhou	484.5	Jinghe	506.7
Lanzhou-Hekouzhen	263.8	Beiluo	553.1
Hekouzhen-Longmen	450.8	Weihe (except Jinghe and Beiluo)	627.1
Longmen-Sanmenjia (except Jinghe, Beiluo and Weihe)	552.7		

Note: This table is selected from" the foundamental data of changes of runoff and sediment in the Yellow River'' Research Institute of Water Resource Protection, YRCC.

Soil Erosion:

Soil erosion in the Yellow River Basin is mainly concentrated on the Loess Plateau which covers 8 latitudes from 35^0 N to 42^0 N and 13 longitudes from 102^0 E to 114^0 E with an area of more than 530,000 km^2. It locates in the Middle Yellow River basin and borders by the Great Wall in the north, extending southward to the Qinling Mountains, and by the Qilian mountains in the west, stretching eastward to the Taihang Mountains. Loess in this region has been transported by wind for about three million years. During deposition of loess in different history periods the neotectonic rising movement was still going on. Hence, its deposition was often accompanied by erosion, forming a series of strange geomorphologies.

Table 3 Erosion types on loess plateau of china

Group	Type	Distribution
Water erosion	1.Splash erosion	Barren slope of loess mound and loess weir
	2.Sheet erosion	Cultivated land
	3.Gully erosion(rill erosion, shallow gully erosion, hanging gully, blind gully, vertical hollow)	Cultivated land, gully wall, convergence of rills and gullies
	4.Debris flow erosion	Gully or surface of slope land, composed of loose materials
Gravitational erosion	1.Landslide	Slope steeper than 35°
	2.Breakdown erosion	Slope steeper than 60°
	3.Slumping erosion	Slope steeper than30°
Concealed erosion	Funnel erosion Hole erosion	Flat slope, brook bed of thick loess deposit, where runoff is concentrated.
Wind erosion	1.Blowing erosion 2. Rubbing erosion	Desertification land and malan loess covered by sand
Ice-melt erosion	1. Ice-melt erosion 2. Ice-melting wriggling erosion	Slope composed of loose moisture-laden material
Animal erosion	1. Holes dug by mice and rats 2.Ground stamped down by animals	Waste slope, composed of loose soil on north part of Loess Plateau
Artificial erosion	1.Waste dregs and abandoned soil, from mining, construction works and houses 2.Destruction of natural forestry, pasture and land	Mineral regions, inhabitant points and communication lines

Note: Gan zhimao.(Gan zhimao " Research on Morphology and Soil Erosion on Loess Plateau" Xian, Shannxi People Publishing House,1989)

The Loess Plateau in China is a region of heaviest soil erosion in the world, which make the Yellow River as one of heaviest sediment-laden rivers. Soil and water loss is a complicated natural phenomenon. The thick loess, covering this region has been the material base for forming the various types of landscape, and the erosion types and erosion intensity are different due to different natural environments and human being activities. In addition, the delivery of eroded materials would be restrained by the characteristics of basin,

geomorphology and runoff in gullies and tributaries. Differentiation of erosion types and zoning of their distribution in a macroscopic scale have great significance for their management. But differentiation of erosion types is various by various branches of learning, such as hydrology, soil and water conservation, etc.

According to the exogenous effecting forces it can be divided into water erosion, wind erosion, gravitational erosion, freeze-thaw erosion, concealed erosion and erosion by human being activities. Table 3 shows the erosion types on the Loess Plateau of China, made by Mr.Gan Zhimao.

It can be seen that an erosion group under the effect of an exogenous force can be divided into several erosion types in accordance with the eroded objects. Water erosion is a natural phenomenon, which can be further divided into splash erosion, sheet erosion, gully erosion and debris flow erosion. Splash erosion appears on a surface ground with less plant cover and soil particles are splashed away by raindrops. It can be further developed into layer erosion, fish-scale erosion and rill erosion etc, according to the forms of erosion. Gully erosion appears when runoff on ground surface converges in rills and scoures their bed into a small brook with its depth and width of more 20cm, which would develop into a ditch, as shown on Photo 1 and Photo 2.

Gravitational erosion is a natural phenomenon that a rocky or soil body on a steep slope loses its equilibrium and falls down at the slope foot. It can be divided into landslide, breakdown and slumping erosion. Landslide erosion appears where a slope land with a watertight layer lays under a rocky or soil body, which would slide down as a whole along the slope land under the effect of gravitational force and infiltrated water. Breakdown erosion usually occurred on a steep bank slope of a valley, where the foundation of the slope loses support due to degradation of valley bed and soil body loses its equilibrium and falls down to the valley bed. Some valley slopes are composed of weathering rocks or sticky red clay, which become as loose blocks under the effect of earthquake and alternative weather changes and falls down at slope foot. This phenomenon is named as slumping erosion. Gravitational erosion can be seen on Photo 3 and Photo 4. Concealed erosion is a micro-landscape on the Loess Plateau. Some funneled holes and vertical wells appear in loess body. It is because that there are a series of vertical structural cracks in loess deposits, into which runoff on ground surface infiltrates, gradually forms converged flow and scoures loess body, forming funneled holes, etc. (refer Photo 5 and Photo 6) In this way the geomorphic landscape of loess gully and weir network on Loess Plateau has been formed.

In general, wind erosion occurs when the wind speed exceeded 4-5m/s. There are two types of wind erosion, one of which is named as blowing erosion, that is, soil particles on ground surface are blown away and transported with wind to some distance. Another is named as rubbing erosion, which breaks down the rocky or loess mound due to the friction by wind and conveyed sand. It is widely distributed around desert (refer Photo 7 and Photo 8.)

Artificial destruction leads to serious increase of soil loss, and cultivation on steep slope land is one of the most serious destruction. It destroys natural plant cover and changes physical and chemical features of loess soil, leading to serious soil erosion. Cultivation on steep slope land on the Loess Plateau began in Song Dynasty, 1000 years ago. With the increase of local population cultivated area increased simultaneously. In addition, extreme grassing is another artificial destruction, particularly for sheep grassing. In recent 50 years industry, mining and communication have had quickly developed, which brought up new destruction on the weak

ecological environment of Loess Plateau.

Runoff and Sediment Load:

Generally speaking, the Yellow River is deficient in runoff and abundant in sediment load. The annual natural runoff and sediment load are 47.38 $\times 10^9$ m3 and 1.63 $\times 10^9$ t at Huayuangkou gauge station from 1919 to1960.

The Yellow River basin is a widely dimensional area with distinctly different geographies. And more distinguishingly, the source regions of the natural runoff and sediment yield are inconsistent and divided in the Yellow River basin. The runoff is mainly from the upper Yellow River, while the sediment load is mainly from the area between Hekouzhen to Tongguan, possessing character of different source areas. As shown in Table 4, the runoff and sediment load, which enter into the lower Yellow River, mainly come from four districts. The first district is located in Hekouzhen gauging station catchment, which accounts for 52.2% of Huayuankou station catchment, with characteristic of rich in runoff and little in sediment. The annual runoff of this district is 25 billion m3 in the proportion of 52.8% of the total, while the annual sediment load is only 0.14 billion t, equal to 8.6% of the total basin sediment load. The second district is in the catchment between two gauging stations of Hekouzhen and Longmen in the middle reaches, which only accounts for 18.4% of Huayuankou station catchment, but is abundant in sediment and short in runoff. The annual runoff is 7.08 billion m3 in this area, in the proportion only of 14.9%, while the annual sediment load is 0.91 billion t equal to 55.8% of the total basin. So this district is regarded as the main sources of sediment yield. The third district is in the catchment between Longmen and Sanmenxia reservoir including three distributary basins (Weihe, Beiluohe and Fenhe rivers), which accounts for 24.8% of Huayuankou station catchment. The annual runoff is 10.3 billion m3 in the proportion of 21.7% and the annual sediment load is 0.55 billion t equal to 33.7% of the total. The fourth district is the area downstream of Sanmenxia, including Yiluo and Qinhe river basins with low sediment load. The annual runoff in this district accounts for 10.6% and the annual sediment load accounts for 1.9% of the whole basin yield. In summary, the runoff of the Yellow River mainly comes from Hekouzhen upstream watershed, while the sediment mainly comes from Hekouzhen downstream basin, focusing on the catchment of Hekouzhen – Longmen - Sanmenxia.

The area that the Yellow River flowing though in the loess plateau is 580 103km2, accounting for 77% of the total basin area and 91% of the total loess plateau area. Among that the most serious soil erosion area is 212 103km2 (mainly gullied-hilly zone) and being the main sediment resources of the Yellow River, which can contribute 90% of the sediment load to the Yellow River.

Table 4 Mean annual runoff and sediment load distribution in the Yellow River

Districts	**Area**		**Runoff**		**Sediment Load**		Annual sediment concentration (kg/m^3)
	Watershed (km^2)	% to Huayuankou	Annual ($10^9 m^3$)	% to Huayuankou	Annual ($10^9 m^3$)	% to Huayuankou	
Upstream of Hekouzhen	367900	52.2	25.00	5.28	1.4	8.6	5.6
Hekouzhen~Longmen	129700	18.4	7.08	1.49	9.1	55.8	128.5
Longmen~Sanmenxia	174300	24.8	10.30	2.17	5.5	33.7	53.4
Sanmenxia~Huayuankou	32400	4.6	5.00	1.06	0.3	1.9	6
Sub Total	704 300	100	47.38	10.00	16.3	100	

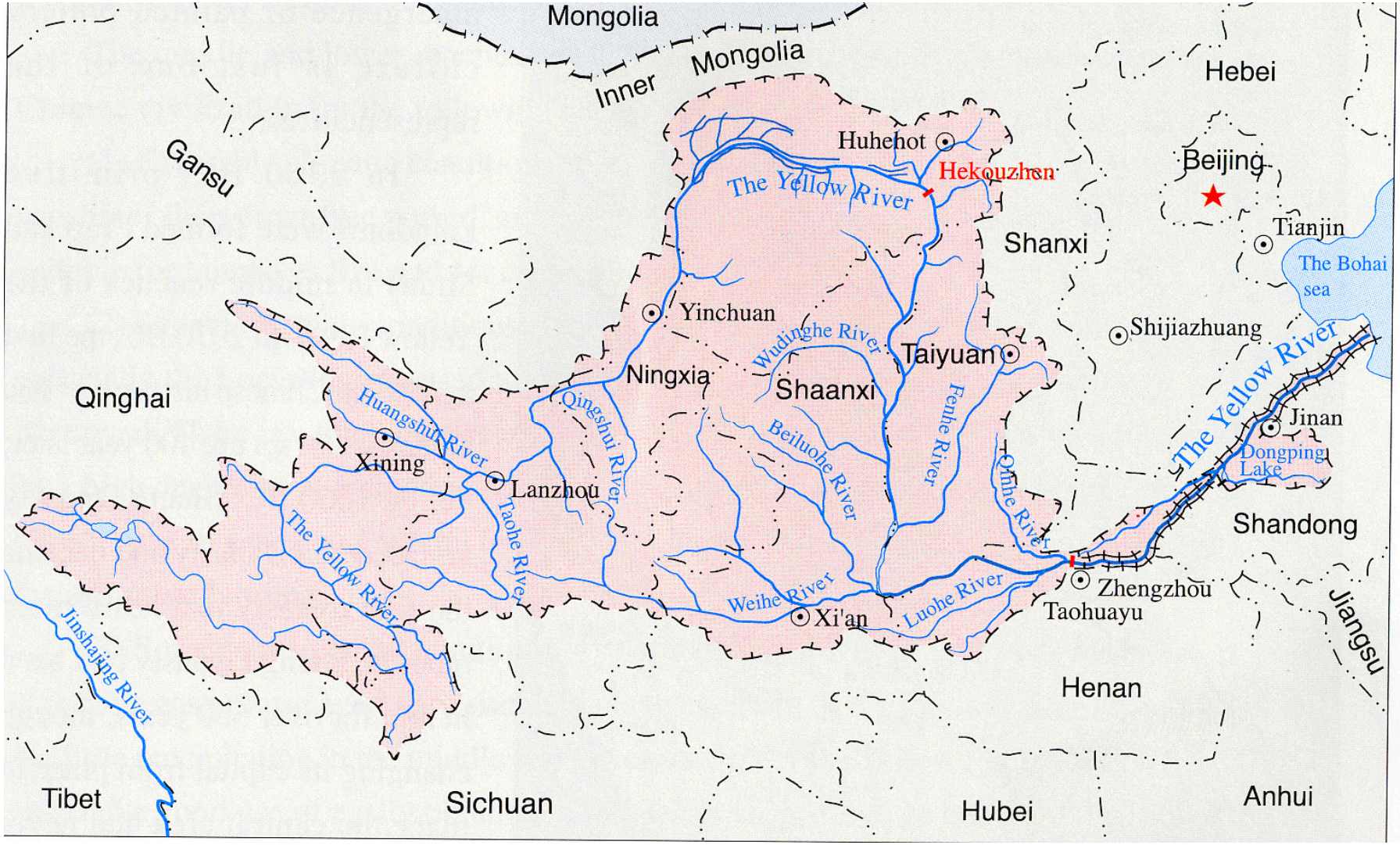

Fig.1. Sketch map of the Yellow River Basin

Photo 1 Splash Erosion

Photo 2 Gully Erosion

Photo.3 Landslide Erosion

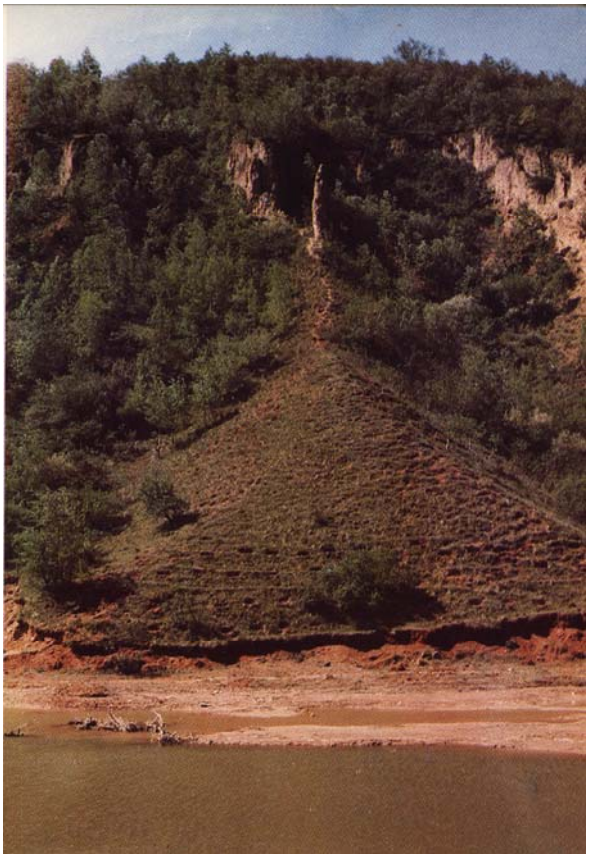

Photo 4 Slumping Erosion

Photo5 Concealed Erosion - Funnel Erosion

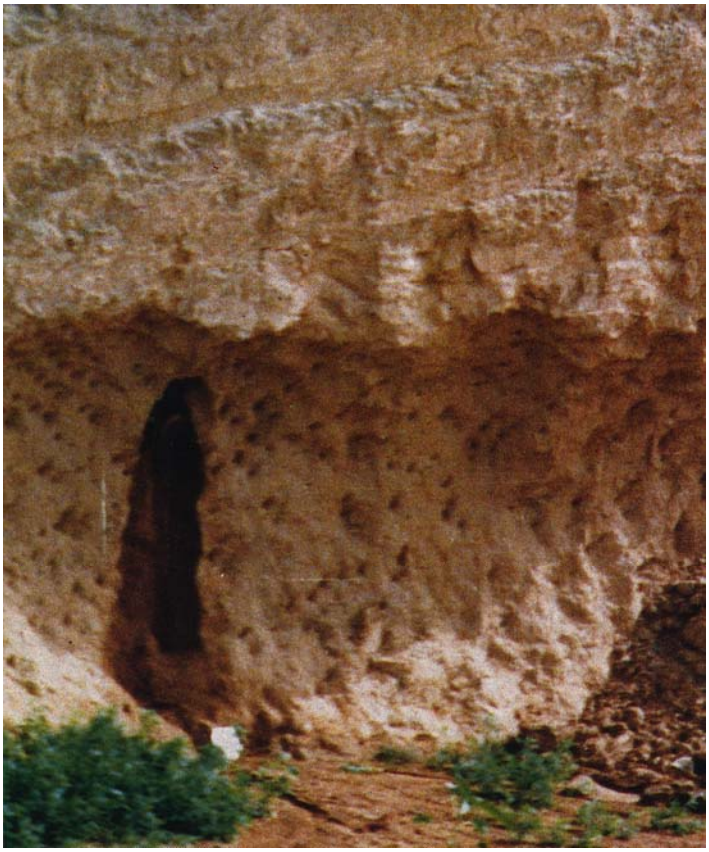

Photo 6 Concealed Erosion Hole Erosion (Outlet of Funnel, Vertical Well Erosion)

Photo 7 Wind Erosion ---- Blowing Erosion

Photo 8 Wind Erosion - Rubbing Erosion

Management Aspects of Yellow River Basin:

The Ministry of Water Resources of the People's Republic of China is a department of the State council that is responsible for water administration. Seven basin organs under the ministry take charge of major river systems in China.

Basin organization (YRCC)

The Yellow River Conservancy Commission (YRCC) as an agency under the Ministry of Water Resources takes, on behalf of the Ministry of Water Resources, the responsibilities of water administration in the Yellow River basin and the inland river basins in several provinces of Xinjiang, Qinghai, Gansu and Inner Mongolia. Its main duties are as follows:

(1) Taking charge of the implementation, supervision and inspection of Water Law and other regulations concerned; drawing up regulations and policies concerning water administration in the basin;

(2) Taking charge of mapping a comprehensive professional plan for the whole basin; answering for the supervision and implementation of the plan; undertaking the preparatory works of key projects and inter-provincial water projects;

(3) Carrying out an integrated management of water resources (including surface water and ground water) in the basin; organizing and coordinating the hydrological work of the principal rivers or river sectors in the basin; issuing information on water resources in the basin;

(4) Answering for the protection of water resources;

(5) Drawing up and implementing the plan for flood control in the basin; regulating water in flood and drought according to the rules and authorization; organizing research of the flood control of important projects;

(6) Guiding the harnessing and development of the rivers, lakes, beaches and coasts; undertaking the management and protection of rivers, dikes and water projects; checking and approving the construction of water projects;

(7) Taking up and directing soil and water conservation and ecological construction and carrying out dynamic monitoring;

(8) Managing and operating the state-owned assets of key projects and inter-provincial projects;

Professional Departments under the YRCC

Hydrology Bureau

This department takes charge of hydrological measurement and monitoring of the main rivers, tributaries, reservoirs and coastal zones in the basin; provides hydrological information and forecast on flood control and ice jam control; carries out documentation and management of

hydrological data, draws up the plan of hydrological stations networks; implements regulations and rules of hydrology of the Yellow River based on the related state regulations and standards; and carries out investigation and evaluation of water resources and edits the Water Resources Gazette and Annual Sedimentation Gazette, etc.

Water and Soil Conservation Bureau

This department takes charge of management of soil and water conservation works in the basin, guides and coordinates preservation and supervision of soil and water conservation and ecological management, organizes establishment of modern soil and water conservation supervision system, supervises implementation of related laws and regulations of soil and water conservations and carries out key projects of soil and water conservations, etc.

Yellow River Institute of Hydraulic Research

The institute is a multi-subjects and comprehensive research institution with focus on study of river sedimentation and fluvial processes in the Yellow River. As one of the national key scientific institutions in China, it consists of five non-profit professional sub-institutes which are orientated towards research on sedimentation, soil and water conservation, water resources, construction and structure, techniques for flood control and disaster mitigation; six profit-orientated R & D centers, which are experimental center for river training and development, center for Yellow River irrigation engineering, Hi-tech engineering center and center for YRCC infrastructure quality survey, Yellow River calibration center for hydraulic engineering measurement, and center for service management.

International Exchange Forum

The International Yellow River Forum (IYRF) provides a forum to all people interested the Yellow River in the world with an opportunity to discuss and exchange some key issues and information. The first IYRF with the topic on “Let Yellow River flow up to the world and let the world know Yellow River” and the second IYRF with topic on “Keeping the healthy life of the river and modern river basin management” were held in Zhengzhou, China in October 2003 and in October 2005 respectively.

The Yellow River Estuary from Space