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"The Yellow River Comes from Our Hands ":

Silt, Hydroelectricity, and the Sanmenxia Dam, 1929–1973

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Abstract: Focusing on the planning and construction of the Sanmenxia hydropower project, this article analyzes the dynamics and tensions between energy demand and the nature of the Yellow River in the twentieth century. Since the late 1920s, Japanese engineers aimed to develop hydroelectric power by building dams on the Yellow River. They viewed the Yellow River as an important source of hydroelectric power for building the Greater East Asian Co-Prosperity Sphere. When the Chinese Communists took control, they claimed that the primary function of the Sanmenxia project was flood control. Yet, with the influences from the Soviet Union and the Chinese Communist state's industrialization efforts, the engineers also emphasized the generation of electrical power, which resulted in a high dam design. The silting of the reservoir, however, frustrated the ambition of the Chinese leaders and engineers and resulted in the production of much lower and unstable power output upon the dam's completion.

Key words: Yellow River, Sanmenxia Dam, silt, hydroelectricity

Introduction

In the winter of 1866, on his way from Kaifeng to Qufu, William A.P. Martin, an American Presbyterian missionary, crossed the Yellow River for the first time. The fierce and turbid stream carried his thoughts irresistibly into the future: "spurning the feeble efforts of the natives, it waits to be subdued by the science of Western engineers."[1] Since the late nineteenth century, with modern nation-state building, the Yellow River basin was recognized as the cradle of Chinese civilization. Therefore, the Yellow River was appraised as "China's mother river." Yet, for inhabitants of the North China Plain—in particular, for people along the lower stream of the Yellow River—their evaluation of the river was much more complicated, and some even criticized that the river brought nothing but disasters. The rising riverbed and frequent dike breakings earned the river another name: "China's Sorrow." As William Martin suggested, during the twentieth century, a number of European, American, Japanese, and Soviet hydraulic engineers visited China to investigate and study the Yellow River, and some Chinese students who had studied hydraulic engineering abroad returned and devoted themselves to the Yellow River conservancy enterprise.[2] In the twentieth century, however, the history of the river was not only the triumph and prevalence of modern engineering and technology but also included various social and political processes, such as socialist state building, the industrialization of the river, and involuntary reservoir displacement.

In his study of rivers in the American West, Donald Worster stated, "To write history without putting any water in it is to leave out a large part of the story. Human

[1] W. A. P. Martin, *A Cycle of Cathy* (New York: The Caxton Press, 1896), p. 280.
[2] For instance, American engineer John Ripley Freeman and German hydraulic engineer Hubert Engels. American Oliver J. Todd served as the United Nations Relief and Rehabilitation chief advisory Yellow River project engineer. See Jonathan D. Spence, *To Change China: Western Advisors in China, 1620–1960* (Boston: Little, Brown and Company, 1969), Chapter 8.

experience has not been so dry as that."[3] Indeed, rivers were the confluence of nature and human societies and have become one of the most appealing research subjects for environmental historians.[4] Existing studies of river history have shown that economic incentives and political circumstances were the two major clusters of driving forces in the remaking of the hydrosphere in recent human history.[5] In the process of the "industrializing of rivers," hydroelectric technology using concrete dams fundamentally altered riverine ecology and integrated all major rivers into the modern industrial system.[6] Large hydropower projects were dense with politics. Usually, they were directly sponsored by state powers and ecologically more disruptive. Richard White argues that technologies such as dams can actually link humans with nature. Therefore, he suggests that we ought to consider a dammed river as an organic machine—an energy system that still retains some of its original nature.[7] In contrast, based on his study of large concrete dams in the Soviet Union and the United States, Paul Josephson underlines the irreversible environmental degradation and social disruption caused by these large projects and refers to large concrete dams as "brute force technology".[8] Moreover, environmentalist Patrick McCully points out the various negative environmental and social impacts of the construction of large dams. He calls for an end to the building of large dams worldwide and for planning the decommissioning of existing dams.[9] As does Chinese political and environmental activist Dai Qing.[10] Rather than assessing the losses and gains created by the Sanmenxia hydropower project, this article aspires to unveil the agency of the Yellow River by examining both the dynamics and tensions between energy demand and the nature of the Yellow River throughout the twentieth century.

Democratic politics and public participation would impact the design—and even halt the construction of—hydropower projects.[11] The assumption of inherent connection between autocratic regimes and megalomania is dubious, at least in the

[3] Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West* (Oxford: Oxford University Press, 1985), p. 5.
[4] For comprehensive overviews of river historiography, see Paula Schonach, "River Histories: A Thematic Review" *Water History* 9 (2017): 233–257; Matthew Evenden, "Beyond the Organic Machine? New Approaches in River Historiography," *Environmental History* 23 (2018): 698–720.
[5] See Marc Cioc, *The Rhine: An Eco-Biography, 1815–2000* (Seattle: University of Washington Press, 2002); Christof Mauch, Thomas Zeller eds., *Rivers in History: Perspectives on Waterways in Europe and North America* (Pittsburgh: University of Pittsburgh Press, 2008) suggests that economic incentive was more decisive than political structures in the damming of large rivers and the digging of canals. David Blackbourn illustrates the connection between river management and the making of German national identity. See David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: W.W. Norton & Company, 2006).
Terje Tvedt, Eva Jakobsson eds., *A History of Water: Water Control and River Biographies* (London: I.B. Tauris, 2006). On the river history of the non-Western world, see Allen F. Isaacman & Barbara S. Isaacman, *Dams, Displacement, and the Delusion of Development: Cahora Bassa and Its Legacies in Mozambique, 1965–2006* (Athens: Ohio University Press, 2013); Heather J. Hoag, *Developing the Rivers of East and West Africa: An Environmental History* (New York: Bloomsbury Press, 2013).
[6] Sarah Pritchard, *Confluence: The Nature of Technology and the Remaking of the Rhone* (Cambridge: Harvard University Press, 2011).
[7] Richard White, *The Organic Machine: The Remaking of the Columbia River* (New York: Hill and Wang, 1995).
[8] Paul R. Josephson, *Industrialized Nature: Brute Force Technology and the Transformation of the Natural World* (Washington: Island Press, 2002).
[9] Patrick McCully, *Silenced Rivers: The Ecology and Politics of Large Dams* (New York: Zed Books, 2001).
[10] Dai Qing eds., *The River Dragon Has Come!: Three Gorges Dam and the Fate of China's Yangtze River and Its People* (New York: Routledge, 1998).
[11] Particularly in the Pacific Northwest, the concern over salmon resources demanded hydro-technological adaption and dam-free rivers. See Karl B. Brooks, *Public Power, Private Dams: The Hells Canyon High Dam Controversy* (Seattle: University of Washington Press, 2006); Paul W. Hirt, *The Wired Northwest: The History of Electric Power, 1870s–1970s* (Lawrence: University Press of Kansas, 2012).

field of hydropower engineering.[12] The scale of hydropower projects was less determined by political regimes and more by the magnitude of the natural flows. Moreover, unlike our perception of the Sanmenxia project as "Mao's war against nature," the project's hydro and social engineering process was far more complicated.[13] The worldwide pursuit of economic benefits, especially electricity, was a major incentive for high dam construction on the Yellow River. Meanwhile, political factors, such as World War II, the Cold War, the Sino–Soviet alliance, and Mao's Great Leap Forward, also circumscribed the design and construction of the concrete dam.

The history of the Yellow River is a highly developed field. Within Chinese language scholarship, most studies are about imperial state efforts of flood control before the twentieth century.[14] Inspired by Donald Worster's three modes of water control in human history, Ling Zhang criticizes the "hydraulic mode of production" logic behind previous scholarship.[15] By examining the costs, losses, and suffering caused by maintaining the Yellow River–Hebei environmental complex from 1048–1128, Zhang proposes a theory of the "hydraulic mode of consumption" that underlines the high cost of maintaining a particular water management system in order to understand the human–water relationship in North China. She also believes that this mode continues to be in place today.[16] This article extends the discussion to the twentieth century, after the arrival of hydroelectric technology, and examines how this new technological system, particularly the Sanmenxia project, reshaped that mechanism.

Some studies have covered the Yellow River in the twentieth century, in particular, the first concrete dam-Sanmenxia hydropower project on the river.[17] Yet,

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[12] Martin Reuss, "Seeing Like an Engineer: Water Projects and the Mediation of the Incommensurable" *Technology and Culture* 49 (2008): 531–546. Similar logic could be traced to Karl A. Wittfogel, *Oriental Despotism: A Comparative Study of Total Power* (New Haven: Yale University Press, 1957).

[13] Judith Shapiro, *Mao's War Against Nature: Politics and the Environment in Revolutionary China* (Cambridge: Cambridge University Press, 2001).

[14] See Cen Zhongmian, *Huanghe bianqianshi* (*The Changes of the Yellow River in History*) (Beijing: Zhonghuashuju, 2004); Tan Qixiang ed., *Huangheshi luncong* (*On the Yellow River*) (Shanghai: Fudandaxue chubanshe, 1986); Yao Hanyuan, *Huanghe shuilishi yanjiu (Historical Research of the Yellow River Conservancy)* (Zhengzhou: Huanghe shuili chubanshe, 2003); Shuilibu Huangheshuiliweiyuanhuieds, *Huanghe shuilishi shuyao* (*A Brief History the Yellow River Conservancy*) (Zhengzhou: Huanghe shuili chubanshe, 1982); Ma Junya, *Beixisheng de jubu: Huaibei shehui shengtai bianqian yanjiu, 1680–1949* (*The Sacrificed Part: A Study of the Social and Ecological Changes of Huaibei, 1680–1949*) (Beijing: Beijingdaxue chubanshe, 2011); Mark Elvin, *The Retreat of the Elephant: An Environmental History of China* (New Haven: Yale University Press, 2004), pp. 128–140. Jane K. Leonard, *Controlling from Afar: The Daoguang Emperor's Management of the Grand Canal Crisis, 1824–1826* (Ann Arbor: Center for Chinese Studies, University of Michigan, 1996); Randall A. Dodgen, *Controlling the Dragon: Confucian Engineers and the Yellow River in Late Imperial China* (Honolulu: University of Hawai'i Press, 2001).

[15] On the three modes of water control, see Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West* (Oxford: Oxford University Press, 1985).

[16] Ling Zhang, *The River, the Plain, and the State: An Environmental Drama in Northern Song China, 1048–1128* (Cambridge: Cambridge University Press, 2016), p. 178–179; pp. 288–290.

[17] See Charles Greer, *Water Management in the Yellow River Basin of China* (Austin: University of Texas Press, 1979); Shang Wei, "A Lamentation for the Yellow River: The Three Gate Gorge Dam," in Dai Qing (ed.), *The River Dragon Has Come! The Three Gorges Dam and the Fate of China's Yangtze River and Its People* (London: M.E. Sharpe, 1998), pp.143–159; Judith Shapiro, *Mao's War Against Nature*, Chapter 1; Bao Heping, *Gongchengde Shehuiyanjiu: Sanmenxia Gongchengzhongde Zhenglunyu Jiejue* (Social Study of Engineering: Debates and Solution of the Sanmenxia Project) (Huhehaote: Neimenggu jiaoyu Chubanshe, 2007); Hu Yingze, *Liudong de Tudi: Ming Qing yilai Huanghe Xiaobeiganliu Quyu Shehui Yanjiu* (*Floating Lands: Regional Social Study of Xiaobeiganliu Since the Ming and Qing Dynasties*) (Beijing: Beijing Daxue Chubanshe,2012), Chapter 8; Wang Ruifang, *Dangdai Zhongguo shuilishi, 1949–2011* (*The History of Water Conservancy in Modern China, 1949–2011*) (Beijing: Zhongguo shehuikexue chubanshe, 2014), Chapter 4. On other hydropower projects on the

these studies either conform to the official narrative by defending the overall benefits created by the project or are in need of thorough and critical analysis from the perspective of environmental history. David Pietz has shown that the Chinese state was committed to transforming the Yellow River from being flood prone as "China's Sorrow" to being a potential source of China's agricultural and industrial growth. Unlike studies on conventional water conservancy, he underlines the internationalization and the rise of the "multipurpose exploitation" idea in Yellow River management.[18] Focusing on the Sanmenxia hydropower project, I will deepen the inquiry from energy and state-making perspectives, especially the role of hydroelectricity in twentieth-century China. During the late 1920s and early 1940s, Japanese engineers aimed to develop hydroelectric power by building dams on the Yellow River. In 1949, when the Chinese Communists took control, they claimed that the primary function of the Sanmenxia project was flood control, but with the influences from the Soviet Union and the Electric Power Ministry, they also emphasized the generation of electrical power, aiming to install infrastructure with 1,000,000-kW electrical capacity. Unfortunately, the nature of the river frustrated the ambition of the Chinese leaders and engineers. This resulted, as of 1969, in the installation of only 250,000-kW capacity and unstable power output. In this paper, I argue that unlike previous water conservancy efforts, the pursuit of hydroelectricity dominated the design and construction of the Sanmenxia project, thus resulting in serious reservoir silting and unnecessary social disruption.

Japanese Planning of the Sanmenxia Project

Although the Sanmenxia Dam was not built until the late 1950s, the project proposal first appeared years prior. In 1929, in *The Yellow River Conservancy*, Japanese explorer Ogashi Heiriku proposed to build hydroelectric projects at Hukou and Sanmenxia. Although he was not a hydraulic specialist, Heiriku traveled along the Yellow River to explore the reason it brought so many disasters to the Chinese people. Under the influence of pan-Asianism—in particular, the unification of the yellow race against the white race—he called for Japanese assistance for the Chinese people to remake the Yellow River basin, which was seen as the cradle of East Asian civilization.[19]

A few years later, in 1933, Li Yizhi, the director of the Yellow River Conservancy Commission of the Nationalist-party-run Republic of China, who had studied hydraulic engineering in Germany, proposed to build a dam between Hukou and Mengjin in Henan province to manage the flow of the Yellow River. In 1935, through field investigation, S. Elisson, a Norwegian engineer, working as consultant for the Nationalist government, proposed to build a dam at Sanmenxia, rather than at two possible alternative sites: Baili Hutong and Xiaolangdi, located at the lower stream of Sanmenxia.[20] Due to the 1933 flood of the Yellow River and its frequent dike breakings in history, all of the proposals above aimed to protect the central plain from devastating floods.

Yellow River, see Zhang Zhihui, "Liujiaxia shuidianzhan gongchengjianshe de ruogan lishifansi (Historical Reflections on the Construction of the Liujiaxia Hydropower Project)" *Gongcheng Yanjiu* 05.01 (2013): 58–70.

[18] David Pietz, *The Yellow River: The Problem of Water in Modern China* (Cambridge: Harvard University Press, 2015).

[19] Ogashi Heriku: *Koga chisui* (Tokyo: Seikyosha, 1929), p. 160.

[20] Zhao Zhilin, "Jianguoqian Sanmenxia gongcheng yanjiu (Studies of Sanmenxia Project Before 1949)," *Zhongguo Shuili Fadian Shiliao* 3 (1991): 13.

In October 1940, when most of North China was under the military domination of Japan and its Chinese collaborators, a group of Japanese engineers commenced an investigation of the Yellow River. They exclaimed,

> The ancestors of the Chinese people have been credited with the miraculous accomplishment of building up the Great Wall in the North and the Grand Canal running across its lowlands in the East. But, despite the most strenuous efforts made by Emperor Da Yu and other national leaders in past history, they had not succeeded in finding an effective means of control of the Yellow River, which had been a constant threat to the people in North China from time immemorial.[21]

In other words, this report claimed that it was time for the Japanese to regulate the river and make it serve the interests of the Chinese people and the Japanese empire.

The Japanese survey team was composed of 26 specialists, among whom, 10 were hydroelectric experts.[22] Therefore, despite lip service paid to the welfare of the Chinese people, it was clear that the major purpose of this investigation was to prepare for the production of hydroelectric power to serve the interests of the Japanese empire. Through the investigation, the team worked out a cascade development plan for the river, extending from the upper stream in Inner Asia to the lower stream of the North China Plain. The Japanese estimated that 8,000,000 kW of hydroelectric capacity could be exploited by building dams on the Yellow River. In the twentieth century, particularly during World War II, Japanese engineers believed that the strength of a nation was positively related to the quantity of energy it had at its command. By the early 1940s, almost all of the major rivers in the Japanese home islands had been developed. It was expected that hydroelectric power would be fully developed in Korea and Manchuria within the next decade. The contemporary focus was on building dams at Fengman on the Songhua River and at Sup'ung on the Yalu River.[23] The next step, the Japanese believed, should be the development of the Yellow River, which possessed tremendous resources that were valuable for the building of the Greater East Asia Co-Prosperity Sphere.[24]

[21] *A Brief for the Control of the Yellow River and Construction of San Meng Shar Dam,* Percy Othus Collection on Chinese Hydrology, Special Collection Library, Pennsylvania State University, p. 3.

[22] Toa Kenkyujo dai 2 chosa linkai hokushi linkai dai 4 bukai, Koga suiryoku hatsuden keikaku hokokusho (January 1941), p. 2.

[23] See Aaron S. Moore, *Constructing East Asia: Technology, Ideology, and Empire in Japan's Wartime Era, 1931–1945* (Stanford: Stanford University Press, 2013), Chapter 4. Mobilizing rivers for hydroelectric development during wartime could be seen in other parts of the world as well. One example would be Canada's rapid growth of hydroelectricity during WWII. See Matthew Evenden, *Allied Power: Mobilizing Hydro-Electricity During Canada's Second World War* (Toronto: University of Toronto Press, 2015).

[24] Toa Kenkyujo dai 2 chosa linkai hokushi linkai dai 4 bukai, Koga suiryoku hatsuden keikaku hokokusho, gou (May 1941), p. 2.

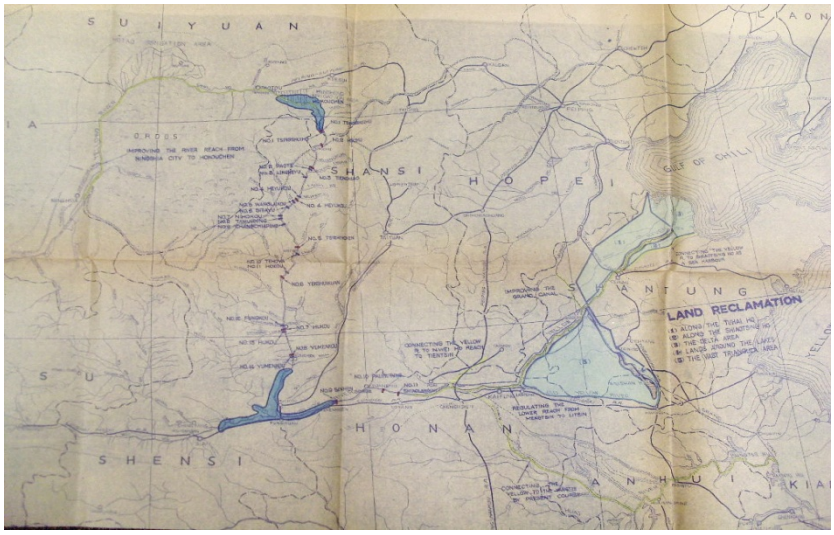

Figure 1. General Layout of the Preliminary Planning by the Japanese (Percy Othus Collection on Chinese Hydrology, Special Collection Library, Pennsylvania State University)

As part of the Japanese plan, more than 11 sites for dams were identified in the middle part of the Yellow River, among which, Sanmenxia was selected as the first and foremost project.[25] In the words of the Japanese engineers, it was a case of "one stone killing five birds."[26] Building a dam at Sanmenxia would bring not only hydroelectricity but also flood control, irrigation for agriculture, navigation, and water for industries in the region. Moreover, with hydroelectricity from the Yellow River, mineral resources in the North China region—in particular, coal in Shanxi—could be excavated much more efficiently than before. With sufficient energy, the Japanese thought they would be able to stabilize the political and economic situation in North China.

Hydroelectric projects in Japan usually required fossil fuel power plants as supplements due to the limited capacity of the reservoirs. The Japanese were excited to find the capacity of the planned Sanmenxia reservoir would be three times larger than that of Biwa Lake, the largest reservoir in Japan. However, large capacity reservoirs could also lead to tremendous inundation of residential areas. In the case of the Sanmenxia project, areas designed to become reservoirs were heavily populated. Nonetheless, in the view of the Japanese engineers, the benefits from hydroelectricity and flood control greatly outweighed the costs of inundations. Therefore, these engineers suggested sticking to the standard height of the dam, making no exceptions out of concern for inundation. The height of the dam, from dead water level to full water level, should be no less than 70 meters. Anything less would seriously diminish the hydroelectric production capacity of the dam.[27]

According to the Japanese estimation, the expense of constructing the Sanmenxia Dam would be approximately US $174,000,000, with an additional amount of

[25] Toa Kenkyujo dai 2 chosa linkai hokushi linkai dai 4 bukai, Koga suiryoku hatsuden keikaku hokokusho, san (May 1941), p. 9.
[26] Koga chisui- hatsuden, file no. 5-1645, Second Historical Archives of China, Nanjing.

[27] Koga suiryoku hatsuden notokucho, file no. 5-685, Second Historical Archives of China, Nanjing.

$176,000,000 for the land price and property compensation for residents of submerged areas. The Japanese engineers were so optimistic about the potential benefits of the dam that they claimed that all the expenses could be written off in less than a year's time. "When hydroelectric power plants are erected," they wrote, "we can start productive enterprises on a large scale, and turn the quiet countryside into booming industrial districts."[28]

According to the Japanese designs, the dam would be constructed to 70 m above water level, with the assumed effective water head at maximum load to be roughly 64 m. Thus, the maximum installed capacity was calculated as 1,123,000 kW, and maximum power output could achieve 5,000,000,000 kW per year. The cost of power generation would be 0.73 cents per kW, including compensation for submerged areas, which was much cheaper than fossil fuel electricity. Building such a massive concrete dam and hydropower plant required reliable materials supply. Being seen as an important project for the building of the Greater East Asian Co-Prosperity Sphere, it was promised that all construction materials would be obtained from ready stocks held in Japan, Korea, Manchuria, and North China, whenever available. So far, it seemed that everything was ready for putting the grand plan into practice. However, the eruption of the Pacific War and Japanese defeats on the battlefields eventually led to the collapse of the Japanese empire. Despite their enthusiasm regarding the Yellow River, in 1945, the Japanese engineers finally had no choice but to retreat, leaving their investigations and planning in the hands of the Chinese and their allies.

Like its counterparts in Europe and North America, the Yellow River was subjugated to World War II as well.[29] While the Chinese Nationalist government decided to break the Yellow River dike to halt the advance of the Japanese army, the Japanese planning of the Sanmenxia project was closely related to the agenda of warfare and the building of the Japanese empire in East Asia.[30] Although the Japanese did not have a chance to put their planning into practice due to their defeat on the battlefield, their investigation and planning were taken over by the Nationalists and their American consultants. According to the Yellow River consultant board for the Nationalist government, the Japanese plan "contains many excellent proposals and shows evidence of careful, intelligent study."[31] However, the cost of the reservoir was too high. In addition, the Japanese underestimated the serious problem of silting in the reservoir, which would significantly shorten its lifespan. Therefore, John Cotton, a member of the American consulting board of the Nationalist government, suggested that no dam should be built at Sanmenxia before effective soil conservation could be achieved across the entire region.[32]

Table 1. Main Stages of the Sanmenxia Project

[28] *A Brief for the Control of the Yellow River and Construction of San Meng Shar Dam*, Percy Othus Collection on Chinese Hydrology, Special Collection Library, Pennsylvania State University, p. 6. After the end of World War II, the Yellow River Conservancy Commission of the Nationalist government translated part of Japanese materials into English for their American consultants. Therefore, this document uses US dollars as its monetary unit.
[29] See David Blackbourn, *The Conquest of Nature*, 2006; Matthew Evenden, *Allied Power*; Giacomo Parrinello, "Systems of Power: A Spatial Envirotechnical Approach to Water Power and Industrialization in the Po Valley of Italy, ca. 1880–1970," *Technology and Culture* 59 (2018): 652–688.
[30] Micah Muscolino, *The Ecology of War in China*.
[31] The Yellow River Consultant Board, *Preliminary Report on Yellow River Project.* (January 17,1947), Percy Othus Collection on Chinese Hydrology, Special Collection Library, Pennsylvania State University, pp. 19–20.
[32]In Wang Huayun's memoir, he referred to Japanese planning during one of his meetings with Mao Zedong. See Wang Huayun, *Wode Zhihe Shijian (My Practice on River Management)* (Zhengzhou: Henan Kexuejishu Chubanshe, 1989), p. 145.

Year/Context	1940/ Japanese Invasion	1949/ Communist China led by Mao	1956/ Sino–Soviet Alliance	1969/Project Reconstruction
Engineers	Japanese	Chinese Communists	Soviets and Chinese	Chinese
Claimed Major Function	Electricity Generation	Flood Control	Multi-Purpose	Multi-Purpose
Electrical Capacity(kW)	1,123,000 (design)	N/A	1,100,000 (design)	250,000

Early Soil and Water Conservation Efforts

The problem of the Yellow River is caused by serious soil erosion on the Loess Plateau.[33] In 1923, American soil conservationist Walter C. Lowdermilk visited northwest China for the first time. He mediated on the cause of the struggle of Chinese farmers along the Yellow River and concluded that "silt was the great enemy causing this endless, hopeless struggle! Silt had defeated the courageous toiling farmers, valiant as they were!"[34] To find an effective way to control the silt and the river, in 1925, Lowdermilk and his colleagues set up three runoff plots in Shanxi to measure erosion on the Loess Plateau. Although there were no quantitative results, Lowdermilk observed that:

> when the runoff from the rain of an inch an hour rushed down off the slopes, there was a roar because the runoff was full of soil and debris and boulders. One could hear the boulders striking each other, sort of a muffled sound like cannonading. The smaller gravel hitting against the boulders sounded like machine-gun fire. In other words, these were torrential flows—we called the mud flows, they were so powerful.[35]

People had to reduce the erosion wherever it took place:

> But the situation which makes it so difficult is that demands of the people to grow food on the land area now so high they can't permit trees to grow. If they need fuel, they'll go out and pull up the trees they have planted for fuel, and to cook their food. So fuel have become a part of their food supply, and as I have said many times, we have to be in possession of a certain amount of abundance to act in an intelligent way in the conservation of our resources, for a starving farmer will eat his seed grain.

Considering the economic and environmental conditions of this region, Lowdermilk concluded that "it is a tremendous problem for which there isn't any

[33] On Loess erosion, see Vaclav Smil, *The Bad Earth: Environmental Degradation in China* (Armonk: M.E. Sharpe Inc., 1984), pp. 38–57.
[34] Walter C. Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States,* vol. 1 (University of California Berkeley, Regional Oral History Office, 1969), p. 62.
[35] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 1, p. 86.

ready and rapid solution. It would require a consistent and continuing program based on measures that will work." [36]

Meanwhile, Li Yizhi admitted that silting was the most challenging problem of Yellow River conservancy and proposed to build check dams and dig ditches along the Loess Plateau to prevent soil from flowing to the river.[37] In 1942, as a consultant of the Nationalist government, Lowdermilk and his Chinese colleagues established erosion prevention demonstration projects in the vicinity of Tianshui, southern Gansu, in the upper Wei River valley. They put in experimental strip crops of alfalfa, rye grass, and sweet clover mixture so as to absorb rains on sloping lands. This prevented any runoff on slopes by up to 24%.[38] Yet, this did not work well on steep walls of gullies. They proposed to use airplanes to drop clay pellets containing seeds of grasses, shrubs, and trees, together with fertilizer. In addition, it was necessary to build thousands of soil-saving dams to collect silt in flat stretches of great gullies to build up alluvial areas for farming and to reduce the silt load of streams.[39]

After establishing demonstration projects in the northwest area, Lowdermilk attempted to obtain aid from the American government so as to establish nurseries and conduct thorough research on the Loess Plateau. Unfortunately, his proposal was denied by the US government. The American agricultural attaché said: "The United States government is not interested in doing this sort of thing for Chinese farmers. All we are interested in is getting from China tung oil, raw silk, tea and hog bristles."[40] Disappointed by the attitude of the American government, Lowdermilk lost the opportunity to expand his soil erosion prevention project to a larger scale in northwest China.

Before the arrival of Lowdermilk, the Chinese farmers had long developed the practice of bench terracing on the land to safeguard it from erosion. In the view of Lowdermilk, however, this measure lacked " scientific exactness, has not been sufficient to prevent serious erosion damage in many places."[41] Upon learning the effect of soil conservation produced by Lowdermilk's demonstration projects, some local farmers asked Lowdermilk and his colleagues to do the same thing on their sloping lands. After 1949, despite his return to the United States, Lowdermilk was delighted to learn that their method of soil erosion prevention was still practiced by Chinese farmers under the Communist rule.[42] However, the construction of the Sanmenxia hydropower project would bring unprecedented challenges to water and soil conservation efforts on the Loess Plateau.

Soviet Assistance and the Sanmenxia Project

[36] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 1, p. 95.
[37] Li Yizhi, *Huanghe gaikuang ji zhibentantao* (*Overview of the Yellow River and Exploration of its Management*) (Huanghe shuiliweiyuanhui, 1935).
[38] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 2, p. 395.
[39] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 2, p. 396.
[40] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 2, p. 404.
[41] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 2 p. 398.
[42] Walter Lowdermilk, *Soil, Forest, and Water Conservation and Reclamation in China, Israel, Africa, and the United States*, vol. 2, p. 410.

In 1895, on the American side of Niagara Falls, the Fourneyron turbine was installed to turn generators to produce electricity. For the first time in history, waterpower was converted into electricity on a large scale, thus making long distance transmission possible and opening a new era of hydroelectricity.[43] By the beginning of the twentieth century, three major scientific and technical advancements made possible the large scale exploitation of hydroelectricity. The first was hydrology, new techniques of dam and canal construction, which had the effect of stabilizing and maximizing the energy capacity of the water. The second was the innovation of the turbine, which transformed falling water into a mechanical driving force in a more efficient way. The third was alternating current, which made long distance transmission of electricity feasible.[44] In the 1930s, to solve high rates of unemployment caused by the Great Depression, countries such as Nazi Germany and the United States began to build large concrete dams to generate electricity.[45] The United States pioneered the development of river-basin management and multipurpose dams, represented by the Tennessee Valley Authority (TVA) and the Boulder Dam on the Colorado River. The so-called multipurpose exploitation included flood control, irrigation, navigation, and electricity generation. Letting rivers run freely to the sea without any use was seen as a huge waste by many state leaders. Compared to other benefits, hydroelectricity was something new that appealed to the engineers and political leaders of many other countries, including the Republic of China and the Soviet Union.[46] Lenin claimed that Soviet polity plus electrification equal communism. In the twentieth century, electrical capacity had become one of the most important indexes of a nation's industrial strength. Christopher Sneddon introduces a civil engineer of the U.S. Bureau of Reclamation, John Savage, and his survey of the Yangtze Gorge project in the context of wartime geopolitics.[47] Meanwhile, supported by the Lend-Lease Act, the TVA accepted personnel from the Soviet Union and Nationalist China as trainees in the early 1940s.[48] After signing the Sino–Soviet Treaty of Alliance, Friendship, and Mutual Assistance in February 1950, the Chinese Communist party officially turned to the Soviet model for industrial development. In 1952, the Water Conservancy and the Fuel Industry Ministries jointly asked the central government to invite Soviet experts to come assist the country in making plans for the Yellow River. Considering the scientific and technical achievements of the Soviet Union—and particularly its success in developing hydroelectric power—the State Council of China decided to include the Yellow River control and exploitation in their requests for Soviet assistance.

Before the arrival of the Soviet experts, the State Planning Commission established a Yellow River research group, mainly consisting of people from the

[43] Actually, the first hydroelectric plant on the Niagara Falls was built in the 1880s, but it produced direct current electricity, which had a very short transmission distance. Until the development of a poly-phase alternating current system of generator, motor, and transformer by Nikola Tesla in the late 1880s, long distance transmission of electricity was impossible.

[44] See Louis C. Hunter and Lynwood Bryant, *A History of Industrial Power in the United States, 1780–1930, Volume 3: The Transmission of Power* (Cambridge: The MIT Press, 1991).

[45] David Blackbourn, *The Conquest of Nature*; Richard White, *The Organic Machine*.

[46] John R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth-Century World* (New York: W. W. Norton & Company, 2000), p. 157.

[47] Christopher Sneddon, *Concrete Revolution: Large Dams, Cold War Geopolitics, and the US Bureau of Reclamation* (Chicago: The University of Chicago Press, 2015). Also see Richard Tucker, "Containing Communism by Impounding Rivers: American Strategic Interests and the Global Spread of High Dams in the Early Cold War" in John R. McNeill & Corinna R. Unger eds. *Environmental Histories of the Cold War* (Cambridge University Press, 2010), pp. 139–166.

[48] *Ziyuanweiyuanhui jishurenyuan fumei shishi shiliao (Archives on the National Resources Commission Technicians' Training in the United States)* (Taipei: Academia Historica, 1988), pp. 277–278.

Water Conservancy and the Fuel Industry Ministries. The group was responsible for collecting and translating materials and data on the Yellow River for the Soviet experts. The Soviet group of experts arrived in Beijing on January 2, 1954.[49] After reading basic materials on the Yellow River, they suggested that they could begin to make comprehensive planning for the river while field surveys were being conducted. In April 1954, based on the Yellow River Research Group, the state council established the Yellow River Planning Commission, recruiting technocrats from the Geology, Forestry, Transportation, Railway, and Agriculture Ministries. Now the Yellow River was no longer an issue merely for the Water Conservancy Ministry. Many other state departments became involved as well in the name of river valley comprehensive development. Indeed, the Yellow River was a complicated problem and could only be thoroughly solved through collective efforts of multiple functional institutions. However, different departments had different orientations. The Water Conservancy Ministry would make flood control its priority. In the meantime, the Fuel Industry Ministry saw exploiting hydroelectric power as its responsibility. The Yellow River, which contains much more silt than other rivers, made it a challenge to fully exploit the water's uses. It was not impossible to make the Sanmenxia Dam a multipurpose project, but the design needed to strike a reasonable balance among flood control, reservoir inundation cost and hydroelectricity output. To achieve the ideal balance, it was necessary to master the temperament of the entire Yellow River. Moreover, this balance did not mean equality among different functions, and it required clear distinctions between primary and secondary goals. However, to some extent, the Soviet experts and their hydroelectric achievements broke the balance, although not permanently. Along with the political movements in China, this would lead to the greatest setback in Chinese efforts to control the river in the twentieth century and the displacement of hundreds of thousands of residents living along the upper reaches of the river above the dam.[50]

In the Yellow River planning group, all Soviet experts were assigned from the Soviet Electrification Ministry, in particular, the Hydroelectric Designing Academy. After field surveys along the Yellow River, all Soviet experts highly recommended Sanmenxia as the ideal dam site. "None of other sites could bring comprehensive benefits to the river valley like the Sanmenxia. Unfortunately, it would also submerge more lands than other options," said one Soviet expert leader, "in order to eliminate flood threat, we must have reservoirs. It is impossible to build a reservoir without population displacement."[51] Nonetheless, the state decided to divide the entire project into several steps, so as to give local governments enough time to prepare for massive population displacement and to win over local bureaucrats who opposed the project.

In October 1954, the planning commission completed the *Comprehensive Development Planning of the Yellow River Report.* According to the report, 46 dams would be built across the main stream and tributaries of the Yellow River. Sanmenxia was highlighted as the priority project of the first period, and the reason was made clear: "When we select the first period project, it must be capable to solve flood

[49] The group leader was the vice chief engineer of Leningrad Hydropower Designing Institute of Soviet Union Electricity Ministry, and group members included hydro-technical specialists, hydrology and hydropower calculation specialists, construction specialists, project geologists, irrigation specialists and navigation specialists. There was no silting, water, and soil conservation and reservoir inundation expert.

[50] See Leng Meng, "The Battle for Sanmenxia," *Chinese Sociology and Anthropology* 31.03 (1999): 4–98.
[51] *Huanghe Sanmenxia Shuilishuniuzhi (Annals of the Yellow River Sanmenxia Hydro Station)* (Beijing: Zhongguo dabaikequanshu chubanshe, 1993), p. 30.

control, detain sediments from flowing to downstream, and provide irrigation, electricity generation and navigation at the same time. In the middle reaches of the river, only Sanmenxia is eligible for multipurpose development."[52] Moreover, the Soviet Union agreed to design the dam and supply related equipment. Soon, the report was submitted to the state council and the Central Political Bureau for discussion. Most leaders of the party and the state thought that the plan was feasible with Soviet assistance. Hence, they decided to submit it to the National People's Congress for discussion. Without any public opposition, the plan was passed by the Congress.

Disregarding Japanese experience and American caveats before 1949, the Chinese Communists finally decided to undertake the ambitious project. The specific designing task was assigned to Leningrad Designing Academy of the Soviet Union. In 1956, in order to train Chinese engineers' designing capability, Wang Huayun proposed to invite the Soviet design team to work in China so that Chinese technical cadres could observe and learn how to design a massive scale hydropower project. Yet, Wang's proposal was rejected by the Soviets. Rather than coming to China, the Leningrad Designing Academy invited Chinese delegates to visit the Soviet Union.[53]

On the Sanmenxia project, the Yellow River report suggested the regular water level of the reservoir should be 350 m above sea level. Later, engineers of the Leningrad Designing Academy suggested the regular water level should not be lower than 360 m if the Chinese wanted to keep the dam functional for at least 100 years. The initial Soviet design of the Sanmenxia hydropower project aimed for multipurpose development. First, by building a reservoir with 65 billion cubic meters capacity, it would be able to handle a flood as large as 35,000 cubic meters per second and would protect the lower stream plain from flooding. Second, the project could balance the flow of the river and thus provide water to 40,000,000 mu of farmland on the North China Plain for irrigation through the seasons. Third, a large-scale hydroelectric plant would be built, with a capacity of over 1,100,000 kW. Its annual output of electricity would reach 6 billion kWh. Centered on this plant, China would build more thermal electric plants and form a large electric grid in central China, which would cover the Shaanxi, Shanxi, Hebei, and Henan provinces. It would power the development of heavy industries and thus contribute to Chinese national industrialization.[54]

There was no doubt that the Soviet experts, from professional and personal perspectives, sincerely devoted themselves to the enterprise of managing the Yellow River. Fu Zuoyi, the former Nationalist commander who played a key role in the civil war, now served as secretary of the Water Conservancy Ministry of the People's Republic of China, exalted the Soviet experts. In his words, "they love China as much as they love their native country."[55] They worked hard, not only contributing to the survey and design of the hydraulic projects but also sacrificing their leisure time for lectures and writing textbooks for their Chinese comrades. They had no intention to

[52] Huanghe zongheliyong guihua jishu jingji baogao (Technical and economic report of the multipurpose development planning of the Yellow River).
[53] Wang Huyun zhuren zai Sanemnxia gongchengju qicaide bufen wenjiandigao (Parts of Manuscripts of Director Wang Huayun at the Sanmenxia Project Bureau) (1956) file no. 1-3-1956-0052Y, the Yellow River Conservancy Commission Archives, Zhengzhou.

[54] A.A. Kololev, "Huanghe Sanmenxia shuilishuniu (Sanmenxia Hydropower Project on the Yellow River)," *Zhongguo Shuili* (1957.07), p. 5.
[55] Fu Zuoyi, "Sulian dui Zhongguo Shuilishiye de Bangzhu (Soviet Assistance to Chinese Hydraulic Enterprise)," *Renmin Ribao*, Oct. 22, 1957.

keep their knowledge secret, at least not from hydraulic experts, and they attempted to help Chinese technicians learn more and learn faster. One of the experts said, "We are extremely delighted that our work would contribute to the socialist enterprise of our Chinese brothers."[56]

However, in the words of Zhang Hanying, who served as the vice minister of the Water Conservancy Ministry, they were also "people sent by Stalin."[57] Their activities were inseparable from international geopolitics. Once the fraternal relationship between the Soviet Union and the People's Republic broke down, their scientific internationalism would be submerged by ideological disputes between the two Communist parties.[58] In July 1960, when the Soviet experts were recalled by their home country, most of them felt astonished, without any clue as to what was going on between the two fraternal countries.[59] Upon the departure of the Soviet experts, Chinese technicians felt disappointed but still expressed their gratitude for the selfless assistance from the Soviet experts. Yet, many projects, including the Sanmenxia Dam, had not been completed. The Soviet experts' departure left the Chinese engineers alone to complete the megaproject. In particular, the Soviets delivered the hydro turbine assemblage to China without any instruction or data. This stimulated the national pride of the Chinese people, who vowed to complete the project on their own.[60]

Silting Challenge and the Debates Over the Soviet Design

When the Yellow River planning project emerged in the state agenda in the early 1950s, effective water and soil conservation on the Loess Plateau had been widely recognized by hydraulic specialists as the precondition for creating a durable reservoir on the river. To find effective methods of water and soil conservation, as aforementioned, in the early 1950s, the Yellow River Conservancy Commission of the Communist state inherited the legacy of Lowdermilk and set up three experimental stations at Tianshui, Xifeng, and Suide. In 1955, Wang Huayun visited Shanxi and Shaanxi to investigate the local practice of water and soil conservation. In his report, Wang introduced the experience of Daquanshan of Yanggao county, Jiajiayuan of Liulin county of Shanxi province, and Jiuyuangou of Suide county of Shannxi province. According to Wang, these three locations represented both biological and engineering methods to prevent water and soil erosion, which mainly included paving terrace, building soil-saving dams, digging wells, building small and mid-size reservoirs, and cultivating trees and grasses. Through these specific methods and the strong leadership of the Communist party, Wang was optimistic to meet the goals of the water and soil conservation project on the Loess Plateau by 1967.[61]

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[56] Shuili Fadian Jianshe Zongju Zhuanjiagognzuoshi, Sulian Zhuanjiadui woguo Shuidian Jianshede Bangzhu (Soviet Experts' Aid on Our Country's Hydroelectric Construction), *Shuili Fadian* 04.07 (1954).

[57] Zhang Hanying, "Sidalin pailaideren zenyang zai Zhongguode Heliushang gongzuozhe (How people being sent by Stalin work on Chinese rivers),' *Renmin Ribao*, Nov. 25 1952.

[58] Regarding the Sino–Soviet split, see Odd Arne Westad ed. *Brothers in Arms: The Rise and Fall of the Sino–Soviet Alliance, 1945–1963* (Washington D.C.: Woodrow Wilson Center Press, 1998).
[59] Zhang Peiji, "Sanmenxia jianshezhongde Sulianzhuanjia (Soviet Experts at Sanmenxia Project)," *Wanli Huanghe Diyiba*, (Zhengzhou: He'nan renmin chubanshe, 1992), p .309.
[60] Qu Zhide and Bai Wenying, "Hanhao wolunji, weiguozhengguang (Welding well the water turbine, honoring motherland)" *Wanli Huanghe Diyiba* (Zhengzhou: Henan renmin chubanshe, 1992), p. 462.

[61] Wang Huayun, "Huangtu qiuling gouhequ shuitubaochi kaochabaogao (Investigation report of water and soil

At Jiuyuangou, as an experiment, the commission built a silt trap reservoir, estimating that it would be fully silted in 10 years. Yet, the silting process was much faster than people expected, and it took only three years for the reservoir to be fully silted. This experiment was a caveat for the prospective Sanmenxia reservoir. On May 27, 1957, in a state council meeting, Zhou Enlai said: "According to the Jiuyuangou experience, it is possible that the Sanmenxia reservoir would be clogged quickly as well. Despite the fact that the project has been started, I feel uneasy about it."[62]

According to the Yellow River conservancy plan, which was made in 1954, it required finishing 165,000,000 mu of field engineering (terracing and building ridges), improving 220,000,000 mu, cultivating 20,000,000 mu of forest, constructing 720,000 check dams and silt trap dams, and developing 4,900,000 mu of irrigated lands on the Loess Plateau, particularly in the provinces of Shaanxi, Shanxi, and Gansu, so as to reduce soil erosion and silt flowing into the Yellow River by at least one-third.[63] Later, with rural collectivization and the rise of the Great Leap Forward, thousands of rural construction teams, which consisted of laborers from local communes, were organized to take charge of the water and soil conservation effort. In a short period, hundreds of thousands of terracing lands were paved, and thousands of soil-saving dams were built. However, due to the lack of professional instruction and comprehensive planning, many silt trap dams collapsed when subjected to rainstorms in the following years.[64]

The Soviet engineers also realized the silting problem. They estimated that roughly 80% of silt would remain in the reservoir, while 20% would flow down to the lower stream of the river. They believed that the water and soil conservation efforts on the Loess Plateau would reduce the amount of sediment flowing to the reservoir by half. Based on these conditions, 34 billion cubic meters—a little more than half of the total capacity of the reservoir—would be silted in 50 years.[65] Considering the multipurpose benefits that the project promised, the Soviet engineers were confident that this slow pace of silting was acceptable.

In the debate over the Soviet design of the Sanmenxia Dam in 1957, Huang Wanli, a hydraulic professor at Tsinghua University, agreed that water and soil conservation was necessary and good for the region. However, he insisted that it should not be considered as the final solution of the Yellow River problem. Huang argued that a high percentage of silt was the reality and nature of the river and that its flowing down to the lower stream was a natural principle. Hence, containing sediment in the reservoir was against this natural principle would cause ecological problems in the upper stream region of the dam.[66] Although Huang initially opposed building a dam at Sanmenxia, he was not able to stop the project. In order to reduce the negative effect of silting that the dam could cause to the upper stream, he suggested that the

conservation on the loess plateau)," *Xin Huanghe*, (Dec. 1955): 26–31.

[62] *Zhou Enlai nianpu* vol. 2 (1949–1976) (Beijing: Zhongyang wenxian chubanshe,1997), p. 45.

[63] "Huanghe shuiliweiyuanhui 1954 nian shuitubaochi gongzuo huiyi jielun (Conclusion of the Yellow River Conservancy Commission water and soil conservation working meeting in 1954)," *Kexuetongbao* (March 1954): 19–21.

[64] Hao Ping, "A Study of the Construction of Terraced Fields in Liulin County, Shaanxi Province in the Era of Collectivization," in Thomas DuBois and Huaiyin Li (eds.) *Agricultural Reform and Rural Transformation in China Since 1949* (Leiden: Brill, 2016).

[65] A.A. Kololev, "Huanghe Sanmenxia shuilishuniu," *Zhongguo Shuili* (1957.07), p. 6.

[66] Huang Wanli, "Duiyu Huanghe Sanmenxia shuiku xianxing guihua fangfa de yijian (Comments on the current operation principles of the Sanmenxia reservoir on the Yellow River)," *Zhongguo Shuili* 08 (1957): 26–29.

regular water level of the reservoir be lower than 360 m, and in case of serious silting in the future, the diverting conduit at the base of the dam used during its construction should not be blocked permanently.[67] Unfortunately, in 1957, Huang was criticized by Mao and his followers as a rightist. Therefore, as a "fish already in the net,"[68] his professional contributions were also downplayed by the government and other engineers.[69]

As the top leader of the Communist state, Mao had long been skeptical of Chinese intelligentsia. He considered many of them as "small Nagys in China."[70] During the Great Leap Forward, he claimed that the

> part of the Chinese intelligentsia in industrial plants and universities is an intelligentsia of the bourgeois heritage… these people were allowed to say their views. They took advantage of this in order to viciously attack the Party. In reality, they did not want socialism, but a restoration of capitalism. This was a harsh struggle. One can say that we also had a civil war, but not by means of rifles, but by tongues.[71]

According to Huang's allegorical tale "The Road Turns Over," which was published in *Xin Qinghua* and later in the *People's Daily*, with reprobation from Mao on June 8, 1957, we know that Huang's rightist identity was given based more on his criticism of the Chinese Communist Party than on his opposition to the Soviet high dam design.[72] Nonetheless, after Huang was criticized as a rightist by Mao, no other hydraulic engineers dared to publically support Huang's technological advice at that time.

To the Shaanxi province, every inch raise of the water level of the reservoir would submerge more of the most fertile lands in the province. If the water level was raised from 350 to 360 m, submerged lands would extend from 2 to 3.25 million mu; the displaced population would also increase from 584,000 to 870,000. Officials of Shaanxi wished to fix the regular water level of the reservoir as low as possible. Provincial party secretary Zhang Desheng, along with other local officials, was worried about what would happen to the area when the reservoir would become fully silted in 50 or 100 years, if not sooner. For centuries, people living along the lower stream complained about the rising riverbed of the Yellow River on the central plain. According to the Soviet design, however, containing silt in the reservoir was actually transferring the threat of a rising riverbed to the Guanzhong plain and the Wei River valley.

Upon hearing complaints from the Shannxi officials and residents, Premier Zhou Enlai immediately asked the Water Conservancy Ministry to convoke experts to

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[67] Huang Wanli, "Duiyu Huanghe Sanmenxia shuiku xianxing guihuagangfa de yijian," *Zhongguo Shuili* (1957. 08); Also see Zhao Cheng, *Huang Wanli de Changhegulv (Huang Wanli's Long River Lonely Journey)* (Xi'an: Shaanxi Renmin chubanshe, 2013), pp. 68–82.

[68] From the Diary of P. A. Abrasimov, Memorandum of Conversation with the General Secretary of the CCP, Deng Xiaoping, July 3, 1957. Wilson Center Digital Archives.

[69] Zhao, *Huang Wanli de Changhegulv*, 94–101. Also see Judith Shaprio, *Mao's War Against Nature*.

[70] Imre Nagy was a Hungarian communist politician who became leader of the 1956 revolution in Hungary against the Soviet Union and the communist political system. He was executed following the Soviet invasion of Hungary.

[71] Record of Conversation Between Polish Delegation and PRC Leader Mao Zedong, Beijing, Oct. 14, 1959. Wilson Center Digital Archives.

[72] See Judith Shapiro, *Mao's War Against Nature*, pp. 53–54; Huang Wanli, "Huacong xiaoyu," *Huang Wanli Wenji* (2001).

discuss the Soviet design of the Sanmenxia project. In the meeting, Wen Shanzhang, a technician of the Hydroelectric Development Bureau, proposed that all sediments be flushed down to the lower stream and not detained in the reservoir. He also suggested that the regular water level be between 336–337 m.[73] Wen argued that lowering the regular water level would significantly reduce the cost of submerging land and population in the valley, even if at the cost of reducing hydroelectric output. However, fascinated with the benefits that the high dam design promised, most of the experts supported the Soviet design, taking 360 m as the regular water level, and believed in the principle of keeping sediments in the reservoir. They argued that the principle of flushing sediment out of the reservoir was wrong because it would not alleviate the rising riverbed of the lower stream.[74] Moreover, Wen's proposal would tremendously reduce the comprehensive benefit of the project and would weaken the significance of the project's political and economic value. Once it was decided to build a large project like Sanmenxia, they argued, it was incumbent on it to boost the agricultural and industrial development for the nation.

By early 1958, quite a large part of the project had been constructed. Due to the controversy over the anticipated water level, the design was falling behind construction. To work out an acceptable design for all related parties, Zhou Enlai and other state leaders visited the Sanmenxia project site in person in April 1958. Zhou summoned all related parties for a meeting. Delegates from Shaanxi wished to reduce the planned height of the dam and to lower the anticipated water level accordingly, thereby saving arable land in their province. In contrast, the Water Conservancy and Electricity Ministry, the Yellow River Conservancy Commission, and the project Bureau all supported the initial design to ensure maximal hydroelectric power and the largest possible reservoir to absorb silt. Peng Dehuai and Xi Zhongxun, two of the senior leaders of the Communist party, also underlined the importance of the comprehensive benefits of the initial design. Peng said that transforming the Yellow River into a beneficial river was positive for promoting socialist China's international status. He argued that a successful large dam was necessary for China's industrialization and its ambition to catch up to Great Britain in 15 years. It would be a huge waste of resources if China used the dam only for flood control.[75] In contrast, Zhou appeared to be more pragmatic than others. He admitted that human research on nature was still preliminary, and people's knowledge of technology was not mature enough to turn the harmful river into a beneficial river through a single project. It was already a great contribution if it could protect the people from suffering from floods. According to Zhou, a successful design required an appropriate combination of politics and technology. Politically, the Communist government was devoted to conquering the river, but technologically, not every natural factor was subject to the

[73] *Huanghe Sanmenxia Shuilishuniuzhi (Annals of the Yellow River Sanmenxia Hydro Station)*, (Beijing: Zhongguo Dabaikequanshu Chubanshe, 1993), p. 48.

[74] Sanmenxia shuilishuniu taolunhui (Discussion meeting on the Sanmenxia hydropower project) *Zhongguo Shuili* (1957.07). Judith Shapiro argues that the idea of "Shengrenchu, Huangheqing" (when a great man emerges, the Yellow River will run clear was influential in the design of the project (so as to please Mao). However, there is no direct evidence to approve that this idea determined the design of the dam. From the engineering and flood control in the North China plain perspective, the rising riverbed had long been a concern of hydraulic engineers and officials before the Mao era.

[75] Peng Dehuai fuzongli zai 1958 nian Sanmenxia shuilishuniu shuiku huiyi shangde jianghua (Vice Premier Peng Dehuai's talk in the Sanmenxia project meeting in 1958); Xi Zhongxiong mishuzhang fayan (Secretary Xi Zhongxiong's talk in the meeting), April 24, 1958. Sanmenxia Municipal Gazetteer Office. Although later, Peng was seen as a major opponent of Mao's Great Leap Forward movement, he showed an optimistic attitude toward the Sanmenxia project in 1958.

command of human beings, and more exploration was needed. Hence, considering the debate over the regular water level and the uncertain prospect of soil conservation in the steppe and along the river, Zhou was inclined to "leave some spaces," which was relatively conservative compared to supporters of the initial Soviet design.[76]

In the end, Zhou affirmed that the primary function of the project was flood control and preventing dike breakage in the lower stream. To address the concern of Shaanxi province, Zhou ensured that Xi'an, the capital of Shannxi province, would not be sacrificed for the hydropower project. Under Zhou's leadership, all parties finally achieved a compromise: the project was still designed to ultimately attain and maintain the anticipated water level at 360 m, but before 1967, the water level should not be higher than 340 m. The dead water level (the height of the inlet of penstocks above sea level) was reduced to 325 m. To avoid excessive population displacement, the 335-m line was chosen as the most desirable.

We can see that the principle of containing silt in the reservoir was dominant among hydraulic engineers at that time. A sustainable hydropower project on the Yellow River required massive water and soil conservation efforts on the Loess Plateau, where most of the Yellow River sediments came from. According to the calculation of the American consultant group hired by the Nationalist government in 1946, effective soil conservation application could reduce erosion at the rate of 0.3% annually, which would take 300 years to eliminate the serious sediment problem of the Yellow River.[77] Under the pressure of the Great Leap Forward, however, the officials in Shaanxi province anticipated reducing soil erosion by 20% before 1967 and 50% by 2010 through masses mobilization.[78] Many engineers estimated that the silting process would achieve a tipping point that silt would no longer pose a threat after years' worth of conservation efforts. Yet, the quick silting of the Sanmenxia reservoir after the completion of the dam construction in the early 1960s suggested that those water and soil conservation efforts had failed to meet expectations from the very beginning. [79]

Constructing Sanmenxia with Propaganda

At the opening ceremony of the project on April 13, 1957, Fu Zuoyi, minister of the Water Conservancy Ministry, gave a speech, saying that the project was possible only under the leadership of the Chinese Communist Party. Additionally, the decorations at the site of the opening ceremony reflected the transition of Chinese attitudes toward nature. Since the Ming dynasty, a cliff in the gorge had been inscribed with the characters "Qiaobixiongliu, guifushengong," which described the

[76]Zhou Enlai zongli zai Huanghe Sanmenxia shuilishuniu shuiku huiyi shangde zongjiefayan (Premier Zhou Enlai's talk in the Sanmenxia Project meeting), April 24, 1958. Sanmenxia Municipal Gazetteer Office.

[77] Zhao Zhilin, "Jianguoqian Sanmenxia gongcheng yanjiu," *Zhongguo Shuili Fadian Shiliao* 03. (1991), p. 18.
[78] Huanghe Sanmenxia Shuilishuniuzhi, p. 49.
[79] Martin Reuss, "Seeing Like an Engineer: Water Projects and the Mediation of the Incommensurable," *Technology and Culture*, vol. 49, July 2008, pp. 531–546. On the role of negotiation in public works, in this case, negotiation over the dam design involved Soviet engineers, Chinese engineers, Chinese central government, and local government. Yet, people who were impacted the most, reservoir residents, were not directly involved in the negotiation process. This negotiation was not merely a top-down gesture led by the central government. Instead, it was initiated by engineers and local officials, who had practical concerns. Despite the fact that modification was made on the construction process, the original Soviet high dam design persisted. Therefore, we can claim that this negotiation process ended with the triumph of high-modernists. Years later, with the emergence of a serious silting problem and the reverse tide of reservoir displacement, the hydropower project had to reconcile with the river and the indigenous population.

magnificent power of the natural river. On the occasion of the opening ceremony of the major project, those eight characters were replaced by 12 new ones, "genzhi shuihai youri, Huanghe bianqing youqi," promising the imminent elimination of floods and the flowing of a clear river. Although the ideal of the Yellow River running clear had a long history and persisted in the People's Republic, the revision reflected the shift from admiring nature to subordinating nature that characterized much of twentieth-century world history.

Similar to the Soviet Union and the United States, the Communist China leaders also hold a utilitarian view of the natural world, not only economically but also politically.[80] People were mesmerized by the benefit promised by the hydropower project and the indispensable leadership of the Communist Party. Unlike river conservancy in previous polities, when hydraulic projects were mainly limited geographically to certain river valleys, mega hydropower projects in the twentieth century were hyped in propaganda media and affected the daily lives of millions of ordinary people who lived far from rivers. Through official media, the population of the People's Republic of China were made aware of this unprecedented plan. Thereafter, not only engineers and state cadres but also millions of ordinary people of the country, hundreds of thousands of neighbors of the river, and many others would inevitably get involved in the building of the dam. In the case of the Sanmenxia project, state propaganda institutions used this hydropower project to exhibit the strength of the new regime and win the support of the people.

Immediately following the passage of the comprehensive plan for the Yellow River by the state council, an editorial appeared prominently in the *People's Daily* entitled "A Great Plan to Change the Yellow River has been Declared." The article first describes the history and current situation of Sanmenxia. It then underlines the promising future that the project could bring. With the completion of the project, the dam would create a reservoir even larger than that of Tai Lake, the third largest freshwater lake in China. In other words, the new reservoir would be equal to around 16 Guantings, a reservoir near Beijing. This reservoir would be used for flood control to tame the river that had caused the most serious floods in Chinese history. The reservoir would be used to irrigate more than 200 million mu of land in North China. It would generate electricity for industrial development in Shaanxi, Shanxi, and Henan. It would spur navigation transport in surrounding provinces. It could reduce the sediment in the river, allowing the lower reaches to run clear, a metaphor of a saint ruler in power.[81] All discussions, regardless of whether they were oral or written, predicted a bright future for the river and its basin. Under state censorship, there was no mention of any possible social stress or technological challenges that might also come out of the project.

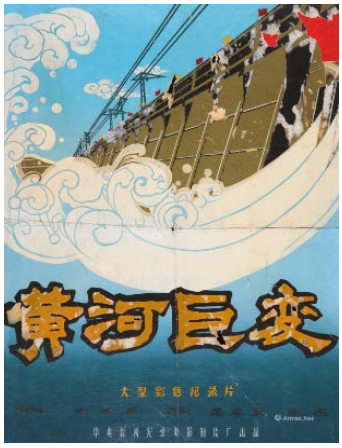
Another report in *People's Daily* portrayed the future of Sanmenxia envisioned by engineers and cadres who worked on the project. "Our country has 540,000,000 kW hydropower in reserve," a junior engineer said, "What a huge number! If all of the reserves are exploited, every person in our country would get thousands of kilowatt hours of electricity. We are fully devoted to exploiting those resources,

[80] Dorothy Zeisler-Vralsted, *Rivers, Memory and Nation-Building: A History of the Volga and Mississippi Rivers* (New York: Berghahn Books, 2015); David Pietz, *The Yellow River*.
[81] Hua Shan, "Sanmenxia: yige gaibian Huanghe ziranmianmao de weida jihua xuanbule!（Sanmenxia: A Great Plan to Change the Yellow River has been Announced)," *Renmin ribao*, July 21, 1955.

Sanmenxia is just the first step!"[82] Wang Huayun, the vice director of the project bureau, told a journalist, "The Sanmenxia project will generate 6,000,000,000 kWh electricity annually. Hydroelectricity is the most affordable source of power, costing less than one tenth of electricity produced with fossil fuels. It would save more than 3,600,000 tons of coal for the country annually."[83] According to these words, the megaproject's contribution to the production of energy was pretty impressive.

Moreover, on the day following the opening ceremony of the Sanmenxia project, *People's Daily* published an editorial entitled "Come to Support Sanmenxia, Everybody!" Unlike the excessively optimistic previous reports, this editorial unveiled the tremendous amount of work required to make the project a success. As a megaproject in a state-planned economy, the Sanmenxia project required cooperation from various state departments and local governments. In the socialist system, all supporting facilities of the project had to be initiated by the state, including railway and road transport, staff dormitory, food supply, and even barber service for workers.[84] Thus, the editorial called upon all state institutions and ordinary people to support the project. Henan province, where the project was located, assumed most of the supporting duties. Under the local government's demand, agricultural cooperatives nearby expanded their vegetable cultivation area from 1500 to 4000 mu. The area's social and economic activities unfolded revolving around the hydropower project.[85]

Journalists from the Xinhua press, *People's Daily*, and *Henan Daily* stationed in the construction site to observe and report the latest progress. Many other national media also sent journalists to visit the site frequently. The National Writers' Association organized writers to visit the site, urging them to write poetry and prose about the project, taking advantage of their prestige to create a supportive social atmosphere. The central and local radio and television broadcasting stations periodically touted the significance of the project. Moreover, as part of the Great Leap Forward, the Central News Documentary Film Factory produced color documentaries entitled *Sanmenxia* and *Great Changes on the Yellow River* in 1958 and 1961, respectively, and screened them across the country.



[82] Ye Jianyun, "Sanmenxia de mingtian（The future of Sanmenxia）," *Renmin Ribao*, Nov. 26, 1956.
[83] Ibid.
[84] Editorial, "Dajia lai zhiyuan Sanmenxia a! (Come to Support Sanmenxia, Everyone!)," *Renmin Ribao*, April 14, 1957.
[85] "Zhiyuan Sanmenxia (Support Sanmexia)," *Renmin Ribao*, April 18, 1957.

Figure 3. Film Poster of *Great Changes on the Yellow River*

Such overwhelming official propaganda successfully inscribed the significance of the megaproject in the minds of the majority of the people. In the months prior to and after the beginning of the project, the project bureau office and union received more than 3,000 letters from people who were workers, farmers, cadres, soldiers, and even young pioneers all over the country. In these letters, they all wished that the dam could be completed as soon as possible in order to "conquer the Yellow River and turn people's dream of a calm and clear Yellow River into reality." For instance, one letter from pupils of Shiyan elementary school of Chongming county, Shanghai, included the lines:

> From our geography textbook, we have learned that our country is building the Sanmenxia project and everyone of us wants to do something for it. Therefore, during wheat harvest time, on our way to school and back home, we picked up ears of wheat left on the roads. Totally we gathered 77 jin wheat and sold it for 5.33 yuan. Now we want to donate the money to the project, hoping you can complete the dam quickly and turn the Yellow River into a beneficial river.[86]

This letter suggested that the state had integrated the megaproject into elementary education. From school children to elders, the entire society was mobilized to participate in the conquering of the Yellow River.

State propaganda made Sanmenxia a household name. The project was said to promise a prosperous future for industrial workers and farmers in the region. Those reports and works of literature were not "objective" introductions to the grand dam, if such were even possible. Rather, they aimed to build up the people's confidence in the socialist state and the Chinese Communist Party. From this perspective, the Sanmenxia project not only posed a landmark of the professional hydraulic engineering but also the party's social engineering ambition. Through the public project, the Communist state successfully fitted its legitimacy and authority into the envirotechnical regime building.[87]

Reconstructions

After the completion of the dam, from September 1960 to March 1962, the reservoir began to store water. Unfortunately, the silting process was much more serious than expected.[88] During those three years, 1.53 billion tons of sediment had been deposited into the reservoir. Moreover, these sediments began to block the estuary of the Wei River, the largest tributary of the Yellow River. As a result, unexpected backup water flooded lands along the Wei River. With the rising of ground water, more than 670,860 mu farmlands on the Guanzhong plain suffered salinization.[89] To relieve reservoir silting and floods in the Wei River valley, the project authority had to reorient the operating principle and the structure of the dam. In February 1962, the Water Conservancy and Electricity Ministry held a meeting in Zhengzhou. Through discussion, it was decided to change the way the reservoir

[86] Ji Wenxuan, "Quanguo zhiyuan Sanmenxia (The Whole Country Supports Sanmenxia)," *Wanli Huanghe Diyiba* (Zhengzhou: Henan renmin chubanshe, 1992), pp. 431–432.

[87] On the definition of "envirotechnical regime," see Sarah Pritchard, *Confluence* , pp. 18–23.
[88] See Vaclav Smil, *The Bad Earth*, pp. 45–47.
[89] Sanmenxia kuzhou yanjianhua qingkuang (The situation of salinization around the Sanmenxia reservoir), 1963. A12-1(1)-31, the Yellow River Conservancy Commission Archives, Zhengzhou.

worked. The policy changed from "detaining water and sediments" to "detaining water but flushing sediments," as proposed earlier by Wen Shanzhang. Additionally, it was decided to open the sluice gates during the rainy season, unless there was a clear and present danger of flooding to the lower stream. With these changes, silting of the reservoir was, to some extent, relieved, but the Yellow riverbed near Tongguan, at the confluence with the Wei River, did not drop. Due to the high altitude of water outlets of the dam at 325 m, more than 60% of the sediment in the Yellow River above the dam entered and remained in the reservoir. The reservoir capacity (set by the water level at 335 m) shrank from 9.84 billion cubic meters of water in 1960 to 5.74 billion cubic meters of water (about two-thirds of the original capacity) in 1964. Silting of the Wei River persisted. In December 1964, Premier Zhou hosted a meeting in Beijing. After a discussion, the majority of experts agreed on the need to open two tunnels through the north bank of the dam and to repurpose four steel tubes, which were initially designed to generate hydroelectric power, to serve simply as outlet tubes to facilitate, enlarge, and accelerate the drainage of water and sediment through the reservoir.[90] Without any better options, the officials sacrificed the generation of electricity to mitigate persistent salinization and floods.

By 1969, the outlet velocity of the dam had doubled. Yet, due to the sediments, which had been accumulating over the past eight years, the reservoir had lost half its capacity. In particular, serious silting persisted in the Wei River and in the reservoir above Tongguan. In 1968, the dikes of the Wei River in Hua county broke, causing serious flooding, which put Xi'an directly under threat. This proved that the previous reconstruction work was far from enough. To relieve riverbed silting above Tongguan, it required 10,000 cubic meters per second outlet velocity when the water level was 315 m. Therefore, eight diversion bottom outlets, which were blocked after completion, were reopened, as had been suggested earlier by Huang Wanli. Moreover, five penstock inlets were lowered from 300 to 287 m. Rather than running, it as a planned conventional hydropower plant. All generators applied the run of the river pattern without impounding water behind the dam during flood season. This resulted in a total capacity of 250,000 kW. Compared to the original design of 1,000,000 kW capacity, the electricity generation capacity of the project had shrunk radically.

Through these remodeling efforts, silting in the reservoir above Tongguan and in the Wei River was gradually diminished. Based on these years of experiments, from November 1973, the reservoir began to store clear water during non-flood seasons and to discharge turbid water during flood seasons so as to improve the efficiency of electricity generation. Finally, the first mega dam on the Yellow River found its suitable pattern of operation 15 years after its opening ceremony, which posed less of a threat to the upper reaches of communities in Shaanxi and Henan.

[90] *Huanghe Sanmenxia shuilishuniuzhi*.

Figure 4. Sanmenxia Dam Today (photo taken by the author in December 2014)

Conclusion

In *Silenced Rivers*, McCully incisively concludes that "the failure of dams to perform as promised is generally because the promises were based on highly overoptimistic assumptions made during project planning."[91] This study exactly corroborates this statement. In the 1950s, an overoptimistic soil and water conservation plan led to the underestimation of the silting challenge in the Sanmenxia reservoir, thus resulting in a high dam design that promised tremendous hydro-electrical capacity. As early as 1964, a conference was held by the Water Conservancy and Electricity Ministry at Beidaihe to draw lessons from the Sanmenxia project. As the conference concluded, one of the major lessons was to avoid overemphasizing the function of generating hydroelectric power. Indeed, the Soviet model, the demand of industrialization for electricity, and the Great Leap Forward movement had together shaped Chinese technocracts' expectations of the project. Although officials from Shannxi and engineers such as Huang Wanli and Wen Shanzhang had offered alternatives, the compromise supported by Zhou Enlai was not sufficient to turn the tide against favoring hydroelectric power production. From the beginning, serious silting broke the multipurpose development illusion that high output of electricity could be attained along with protection from flooding. Considering the degradation of riparian ecology and the social disruption caused by reservoir displacement, many people began to doubt the value of the first mega-dam on the Yellow River. Nonetheless, in the official narrative, the state continues to hail the manifold achievements of the dam, thus maintaining and burnishing its image as "an energetic, determined state capable of taming rivers for the social good."[92] Therefore, the Sanmenxia project continues to be politically, as well as technologically, constructed.

Today, on the downstream of the Sanmenxia Dam, a sight-viewing deck has been built near the old site of Shuzhuangtai, a small rock island in the middle of the

[91] Patrick McCully, *Silenced Rivers*, p. 101.

[92] John McNeill, *Something New Under the Sun*, p. 157.

river that had been removed for dam construction. On the deck, a poem written in 1958 by He Jingzhi, a well-known modern revolutionary poet, has been posted. It reads:

> …Pangu [one of China's few and uncharacteristic creator gods] gave birth to our new generation! Raising the red flag, opening the earth and heaven, trampling history underneath our feet, we are writing a new chapter of history. Socialism—here we come! Here we come, here we come, Shocking Mang Mountain and Kunlun; showing our river control blueprint, bundling waist of the Yellow River—God gate gone, Ghost gate gone, Human gate turning to ashes!
>
> The three gates are not there anymore, tomorrow the sluice gate will open. Li Bai should revise his poem: the Yellow River comes from our hands!"[93]

It is known that Li Bai's original poem included the line "Can't you see that the Yellow River comes from heaven!" He Jingzhi replaced "heaven" with "our hands" as a declaration of human domination. Chinese poems before the twentieth century usually expressed admiration and respect for the power of nature.[94] In contrast, poems written in the twentieth century—in particular, in the Mao era—generally praised people's triumph over nature. Filled with revolutionary romanticism, He Jingzhi's poem reflected the dominant ideology of the Great Leap Forward. As David Pietz suggests, Mao and his followers targeted the Yellow River as a major obstacle to the success of the Communist revolution.[95] However, the connection between politics and nature was nothing new. In the context of long Chinese history, the myth of the Great Yu's successful flood control was closely related to the founding of the early Chinese state. The Yellow River "running clear" had been seen as an auspicious omen in late imperial China.[96] Indeed, as He Jingzhi claimed, the water of the Yellow River in 1958 appeared to be increasingly coming from "our hands." Since the completion of the concrete dam in the 1960s, the water of the Yellow River has had to flow through the dam to drive turbines and irrigate arable lands of the central plain.

While focusing on the design and construction of the concrete dam, this article leaves out the experience of more than 200,000 displaced people in the Sanmenxia reservoir region. Based on the examination of the sites of energy production and the transmission of electricity in America, Christopher Jones argues that transport infrastructure systems deprived most consumers of knowledge of the environmental harms caused by their energy use.[97] This resonates with geographer Darrin Magee's inspiring idea of a spatial configuration-powershed, which he calls a "powershed" and uses to explain large hydropower projects built in western, rural China but oriented to provide electricity to eastern, urban China.[98] In the case of the Sanmenxia hydropower project, the resulting social inequality and environmental injustice created by the hydropower project had long been overshadowed by the sublimity of the concrete dam in state propaganda. C.W Lewis reminds us that "what we call man's power over nature turns out to be a power exercised by some men over other men with nature as

[93] For the whole poem, see *He Jingzhi Wenji* Vol.1 (Beijing: Zuojia chubanshe, 2005).
[94] See Mark Elvin, *The Retreat of the Elephants*.
[95] David Pietz, *The Yellow River*.
[96] Mark Elvin, "Who Was Responsible for the Weather? Moral Meteorology in Late Imperial China." *Osiris* 13(1998):213-237.

[97]Christopher Jones, *Routes of Power*, p. 12.
[98] Darrin Magee, "Powershed Politics: Yunnan Hydropower under Great Western Development," *The China Quarterly* 185 (2006): 23–41.

its instrument."[99] The Sanmenxia hydropower project was not so much a trophy wrested from the conquest of the Yellow River. Rather, through involuntary displacement and official propaganda, the river was turned into a theater, and the project became an instrument for the Chinese Communist Party to exercise and consolidate its power.

Regardless of calling it the inappropriate human "hands" or the brute force technology, the dam, in turn, had to be remodeled to be more in accord with the nature of the river. Of course, the high sediment concentration of the Yellow River is not completely "natural." Unlike the Columbia River, the Yellow River has long lost its "unmade" qualities.[100] The history of the Yellow River is a human history, despite that the river has a much longer history on the Earth than human beings do. The Europeans had turned the Rhine into an industrial faucet for navigation. To mitigate flood threats, the Chinese had built thousands of miles of dikes to regulate its flow on the North China Plain. The twentieth-century technological hubris had to compromise with the silting "nature" of the river. Both the river and the dam were modified to deliver a sustainable instrumental use of the river. We might say that the Yellow River returned, but only shortly, more dams would be built on the river in the following decades.[101]

In Matthew Evenden's and Paula Schonach's recent review articles of river historiography, both call for more comparative and global narratives of river history.[102] Unfortunately, this study focuses on a single hydropower project on the Yellow River. Yet, the transnational activities of hydropower engineers from Japan, the United States, and the Soviet Union had globalized the history of the Yellow River, as David Pietz lays out in his comprehensive study of the river.[103] Through analyzing the tangled entity of river, technology, and politics, I hope this study will enrich our understanding of the evolution of human–river interactions in the field of environmental history.

[99] C. S. Lewis, "The Abolition of Man," in *The Complete C. S. Lewis Signature Classics* (Grand Rapids: Zondervan, 2007), p. 719.
[100] Richard White, *The Organic Machine*.
[101] Marc Cioc, *The Rhine: An Eco-Biography, 1815–2000*. Christopher Armstrong, H.V. Nelles, and Matthew Evenden, *The River Returns: An Environmental History of the Bow* (Montreal: McGuill-Queen's University Press, 2009).
[102] Paula Schonach, "River Histories: A Thematic Review," *Water History* (2017) 9: 233–257; Matthew Evenden, "Beyond the Organic Machine? New Approaches in River Historiography," *Environmental History* 23 (2018): 698–720.
[103] David Pietz, *The Yellow River.*