5 Managing the Yellow River: Continuity and Change

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Introduction

In 1997, the Yellow River dried up, 750 km from its mouth in the Bohai Sea, triggering significant comment and concern both within and beyond China. In China, this drying-up elicited a broad response in print and broadcast media about the environmental consequences of rapid economic development. At the same time, the state directed a range of scientific and technical organizations to focus research on the causes of water depletion in the Yellow River basin. Internationally, the general issue of water scarcity in north China prompted speculation about China's future ability to feed itself and the consequent impact on global grain markets (Brown and Halweil, 1998).

As suggested by the dramatic photographs of the desiccated river bed, the protagonist in this contemporary drama was indeed the Yellow River. One explanation for the vigorous domestic and international response to the drying-up lies in the tangible economic importance of the Yellow River to the North China Plain – the 'breadbasket' of China. The problems with the Yellow River suggested the profound impact that resource scarcity could have on China's continuing transformation to a global economic power. An additional explanation for the outcry generated by the drying up of the Yellow River was cultural. In the historical memory of past and contemporary Chinese, the Yellow River is the 'mother river' – the river that sustained the growth of Chinese civilization. To witness this river fail to reach the sea was to conjure up a host of negative images about the Chinese and China.

The goal of this chapter is to elucidate the contemporary relevance and importance of the Yellow River by exploring the trajectory of its historical development. This historical trajectory includes the trends over time in the physical development of the river's water resources, including traditional river-control practices. Just as importantly, it also includes the evolution of traditional values and symbols related to water and the river. As a result, this chapter, perhaps to a greater degree than any other in this volume, devotes substantial space to understanding the relevance of historic cultural antecedents to current issues. The physical and cultural aspects together help explain contemporary approaches to hydraulic management of the Yellow River basin and the options that Chinese society and basin managers have for the future.

Physical Geography of the Yellow River Basin

Most descriptions of the Yellow River's geography commence with a recitation of facts. For example, the Yellow River begins in the Qinghai–Tibetan Plateau of Qinghai province, from where it flows across eight other provinces and autonomous regions, before emptying into the Yellow Sea north of the Shandong peninsula (Fig. 5.1). With a length of over 5400 km, the Yellow River is the second longest in China and the tenth longest in the world, and drains an area larger than France. The basin contains approximately 9% of China's population and 17% of its agricultural area. While such static figures may be of passing interest, it is a deeper understanding of variation in the Yellow River basin's physical geography that is necessary if one wishes to understand the issues which both the Chinese government and basin residents face in their daily efforts to use, manage and protect the river. For accomplishing this formidable task, and for analysis, the river is often divided into its three main reaches.

Upper reach

The upper reach of the Yellow River drains just over half of the total basin area and extends from the river's origin in the Bayenkela mountains to the Hekouzhen gauging station downstream from the city of Baotou. On the Qinghai–Tibetan Plateau, where the Yellow River begins, steep rock slopes, low evaporation and high moisture retention produce runoff coefficients estimated to range from 30 to 50% (Greer, 1979; World Bank, 1993). This, combined with relatively high precipitation levels, results in this westernmost region of the upper reach contributing 56% of the entire river's total runoff by the point of the Lanzhou gauging station (YRCC, 2002b). As the river moves northward from there into the Ningxia/Inner Mongolian plains and the Gobi desert, potential evaporation rises to levels several times that of precipitation. The spatial variation in flow contribution within the upper reach is further exacerbated by human usage patterns. In the most western regions of the upper reach, relatively low population densities, agricultural development and industrializa-

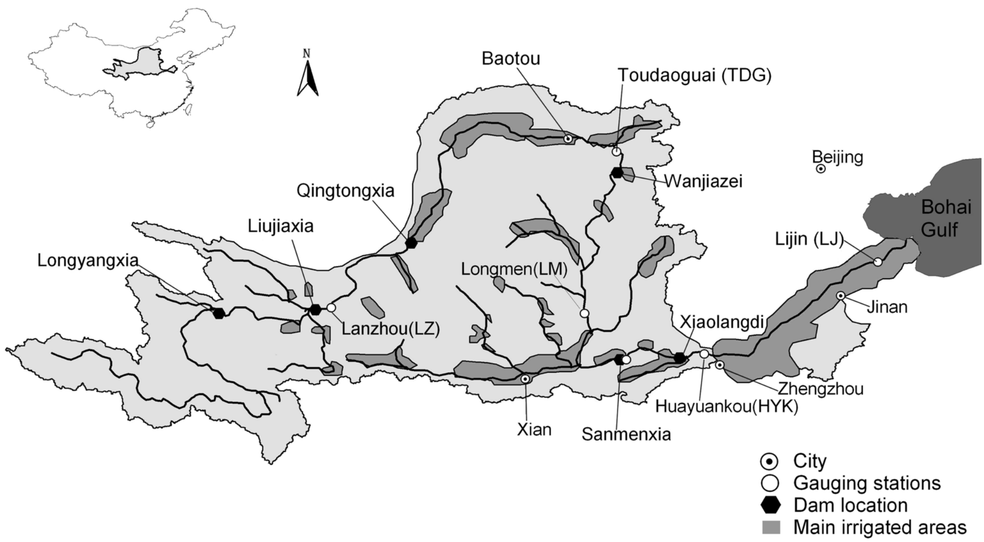

Fig. 5.1. The Yellow River basin.

tion limit *in situ* usage. As the river moves northward from Lanzhou, the agricultural population, with its long history of irrigation, and a growing industrial base substantially increase water withdrawals.

Middle reach

The middle reach, covering 46% of the basin area and providing virtually all of the remaining runoff, begins at the Hekouzhen gauging station (YRCC, 2002a). The middle reach of the Yellow River plays a significant role in basin water balances and availability for human use for two reasons. First, the reach includes some of the Yellow River's major tributaries, such as the Fen and the Wei, which contribute substantially to the total flow. Second, as the river begins its 'great bend' to the south, it cuts through the Loess Plateau and its potentially fertile but highly erodible loess soils. These soils enter the main stem and its tributaries as massive quantities of silt, resulting in average sediment concentrations unprecedented among major waterways and giving both the river and the sea into which it flows, their common 'Yellow' names (Milliman and Meade, 1983).

Sediment levels in the Yellow River are caused, in part, by such natural factors as the erodibility of the loess soils already mentioned, low average precipitation (which retards the growth of soil-stabilizing vegetation); and an increase in the gradient and power of the Yellow River as it passes through the most erodible zone. However, these levels are clearly exacerbated by anthropogenic factors, many of which have been in place for centuries or millennia (Ronan, 1995). While there is debate on the degree to which the Loess Plateau was 'naturally' forested, it seems clear that as early as the Qin and Han dynasties, large areas of land had been deforested for fuelwood and agricultural expansion, a factor believed to have contributed to increased erosion and, perhaps, regional desiccation (Menzies, 1995). Whatever the cause, the long-standing nature of the sedimentation phenomenon can be seen in the Chinese use of the phrase 'when the [Yellow] river runs clear' to mean 'never'. As will be described later, control of the potentially devastating Yellow River floods, which are greatly exacerbated by the high sediment loads generated in the middle reach, has formed a central theme in Chinese water management and politics for at least 3000 years. In addition, control of sedimentation to reduce the severity and frequency of flooding, accomplished through flushing, is now estimated to require about 25% of the total Yellow River flow and so is a major factor in current utilization of basin water.

Lower reach

The lower reach of the Yellow River commences at the apex of the natural basin in Taohuayu near the city of Zhengzhou and forms one of the most unique river segments in the world. Here, the sediment transported from the middle reach begins to settle as the river spills onto the flat North China Plain, producing a consistent aggradation of the bed and a naturally meandering and unstable channel (Ren and Walker, 1998). This instability has, in fact, been so severe that the Yellow River has had six major channel changes over the past 3500 years, in which the outlet to the sea has shifted 400 km from one side of the Shandong peninsula to the other (Greer, 1979). These massive shifts in the river channel, as well as more frequent smaller movements, have clearly caused problems for the millions of people who have attempted to farm the fertile alluvial soils of the lower reach. In response, successive river managers down the millennia have constructed levees along the banks of the Yellow River in an attempt to stabilize the main channel. While such structures may hold the channel in the short term, their success depends on consistently raising levee walls as sediment elevates the level of the channel constrained within.

Over time, the process of raising levees has contributed to a 'suspended' river, in which the channel bottom is above ground level, sometimes by more than 10 m (Leung, 1996). This raising of the channel above the level of the neighbouring countryside has clear implications for the severity of flooding when the levees inevitability fail in their function. In addition, the elevated bed alters the meaning of the Yellow River basin concept. With the channel above ground level, the surrounding landscape cannot drain into the river nor can tributaries enter it. This essentially means that the river 'basin' becomes a narrow corridor no wider than the few kilometres' breadth of the embanked channel. With almost no inflow, the contribution of the lower reach is limited to only 3% of the total runoff. While much of the sediment is deposited in the lower reach, approximately half has historically reached the river's outlet to the sea. These large deposits have, until recently at least, caused the river's delta to expand outward, creating substantial new farmlands (Ren and Walker, 1998).

Extra-basin issues including the south–north transfer

While the above discussion focused on the current geographical boundaries of the Yellow River basin, it is important to note that these boundaries, particularly in the lower reach, have changed, and may again change, over time. As mentioned, the high sediment load of the Yellow River makes the channel very unstable in the lower reach, where the topography is extremely flat. When the Yellow River's channel shifts, typically after a flood event or through human intervention, it connects hydrologically with either the Hai River system to the north or the Huai River system to the south, resulting in an expansion of basin boundaries across various portions of the North China Plain. The last time such a change occurred was in 1938, when the Yellow River's south dyke was purposefully breached at Huayuankou to block an advance of the Japanese army. The river was returned to its present course by engineering means in 1947 (Todd, 1949). The imposition of the Grand Canal, which runs perpendicular to the generally east-to-west-flowing rivers of eastern China, and which essentially links all basins from Hangzhou north to Tianjin, further complicates the strict definition of basin boundaries in the lower reach.

Another problem confusing the understanding of the Yellow River basin boundaries is the lack of congruence between the geographical extent of the basin as commonly delineated and the relevant hydrological units. For example, in the lower reach of the basin, seepage from the suspended main stem of the river recharges groundwater aquifers in both the Hai and Huai basins, where it is extracted for crop production. Additional water is also transferred out of the basin for industrial and domestic use, especially to the cities of Jinan, Qingdao and Tianjin. Of potentially greater significance for the future is the planned construction of the 'south waters north' engineering schemes, which may eventually transfer large amounts of water from the Yangtze River basin into the Yellow River, further marring the relevance of the geographical definition of the Yellow River basin (Biswas *et al.*, 1983).

Water and Governance in Chinese History

This and the following section explore how the state, during the late Imperial, early Republican, Nationalist and People's Republic periods sought to manage the Yellow River in central China. They identify multiple meanings of water in general and the Yellow River in particular during the *longue durée* (an approach to the study of history, giving priority to long-term structures over events) of Chinese history and examine how these meanings shaped 20th-century efforts to control the Yellow River. Despite fundamental differences in political form among the various Chinese state-building projects of the 20th century, each state was fundamentally driven by similar modernizing assumptions, and each sought to selectively draw upon multiple historical meanings of the Yellow River and water in similar ways.

As reflected in the official histories written during the Imperial period, the origin of Chinese civilization is directly connected to water. One of the first renderings of this creation myth comes from the *Annals of History* (Shiji), written by Sima Qian (circa 145–90 BC) during the Han dynasty. Yü the Great, reputed to be the founder of China's first dynasty, is credited with draining the great north-central plain by digging discrete channels to lead the water of the Huai, Yellow, Yangtze and Wei rivers to the sea. The ordering of these waterways, collectively known as the 'four great rivers' (*sidu*), was attributed to Yü by most of the great historical writers of Imperial China

(Wang, 1987). The work of Yü the Great led to the development of sedentary agriculture and gave rise to a state that promoted agricultural pursuits and was sustained by appropriating a portion of the agricultural surplus. In sum, Yü the Great was responsible for the development of the cradle of Chinese civilization. The creation tale not only helped to legitimize the veneration of agriculture by later Confucian states, but also continued to inspire Chinese water-control endeavours throughout the Imperial period and beyond (Levenson and Schurman, 1969).

Complementing the connection of the birth of Chinese civilization with water were other systems of early Chinese thought that arose during the period of the 'Hundred Schools' in the late Zhou, early Warring States period (circa 500 BC). Adherents of the Naturalist school of thought, which developed during this period, sought to explain nature on the basis of the complementary cosmic principles of *yin* and *yang* (Fairbank *et al.*, 1989). *Yang* represents the male, light, hot and active qualities, while *yin* represents the forces of femaleness, darkness, coldness and passivity. These opposing elements, however, represent complementary forces that comprise nature.

The Naturalists also stressed the basic concept of the 'five elements' to explain the composition of nature. The five elements – fire, earth, metal, water and wood – came to represent a pre-science, which was used in combination with other cosmic correlations, including numerology and astrology, to formulate calendars and to form the foundation of geomancy (*fengshui*). The point here is that the view of water as articulated by the Naturalists (female, dark, passive) complemented the creation myth surrounding Yü the Great. The connection centred on the qualities of femaleness as giver of life, or that which was responsible for the birth of a civilization. At the same time, we can see an affinity between the passive, dark qualities of water as described by the Naturalists and the historical sanction that manipulating water gave to Yü the Great.

Taoism was another major Chinese philosophical movement with direct connection to water. The meaning of water in philosophical Taoism represents an alternative to the creation myth surrounding Yü the Great and the concepts of the Naturalists. Water is perhaps the supreme moral example of the stricture to find harmony with 'the way' (*tao*) through the principle of *wu-wei*, or do-nothingness. Left to its own accord, water finds its harmony with the way by effortlessly following the contours of the land. Water as an object of contemplation intending to reveal moral truths informed much of China's cultural production during the Imperial period. Viewed by Taoists as something to be admired rather than controlled, mountains and other features of the natural landscape were rendered in poetry, painting and gardens as places of contemplation, where it was possible to connect with the ultimate realities of nature and to escape worldly concerns. The quietude of unaltered landscapes was a recurring poetic and philosophical theme during the Imperial period (Murphey, 1967; Greer, 1979).

Certainly, this sort of cultural expression was produced by, and for the benefit of, the literati, and it is precisely these people who were the face of the predominant socio-political system in imperial China – Confucianism. Indeed, Confucianism and Taoism share a fundamental similarity in their respective view of the unity of heaven, earth and man. There is a long tradition of Confucian-trained members of the bureaucratic class absenting themselves on occasion from their administrative duties and seeking a more contemplative life in nature.

Despite the strength of the Taoist traditions regarding nature, and the expression that this was often given in cultural production, it is equally true that nature in Imperial China was altered in a massive way. Deforestation of upstream regions supported, expanded and intensified agricultural pursuits necessary to support expanding populations. Farmers viewed water as a means of supporting these pursuits, and as something which needed solutions for managing both dry (irrigation) and wet (flood control) periods. Imperial states, in turn, through the medium of the administrative bureaucracy, viewed water as a means of promoting agriculture, thereby increasing expropriation of the agricultural surplus to expand and sustain the empire.

Development and Management of the Yellow River Basin

For most of the Imperial period, the Imperial Chinese state expended considerable resources in controlling the water of the Yellow River. One focus was the early development of irrigation. An additional focus was the construction of an extensive canal system connecting the Huai with the Yellow and Yangtze river valleys to facilitate the transport of the agricultural surplus to capital regions. The building of these canals created a complex matrix of waterways involving the lower Yellow plains. Complicating water controls were the periodic shifts of the Yellow River. Throughout the Imperial period, state priorities remained centred on maintaining the system of canals that provided the artery of grain tribute transport to northern capitals.

Canal transport and irrigation became intimately tied to the growth of Imperial power. Canal transport, developed within the context of warfare, served the formation of political power. Irrigation sustained agricultural development, which, in turn, expanded revenue for the political centre. Thus, the importance of water spawned a need to create an administrative organization to develop and maintain large canal and irrigation systems. Although the degree to which the central government was involved in local irrigation projects was in fact limited, 20th-century sinologists such as Wittfogel (1957) correctly identified the importance of effective water management to maintaining the state and the empire during the Imperial period. The pattern for subsequent water administration was established during the Han dynasty (206BC–220AD). In the Imperial capital, *dushui* (the office of the Director of Water Conservancy), under the Ministry of Public Works, was created as a planning and coordinating organization for the management of all river basins in China. At the same time, responsibility for labour recruitment and construction was delegated to local administrative units (Greer, 1979). The central challenge to successful water management during the Han dynasty, and later, was the ability to coordinate the efforts of the centre and the locality.

The imperial period

Governments in the early Imperial period persistently faced a cycle of water management issues: heavy dependence on water development for irrigation and grain transport led to a breakdown of hydraulic conditions when central authority waned, which in turn mandated large expenditures to restore stability. Managing this cycle required central capacity to undertake large-scale engineering projects. Indeed, throughout the Imperial era, rulers repeatedly viewed the regulation of water as providing legitimacy to rule. The historical precedent was Yü the Great, who claimed the right to rule based on his success in regulating water during the prehistorical period. Indeed, official dynastic histories esteemed the rule of individual rulers or their dynastic houses by claiming the legitimate historical mantle of Yü the Great. Such was the legitimizing rhetoric of Ming (1368–1644), who administered Yellow-conservancy projects in the mid-15th century.

Throughout the Ming and Qing (1368–1911) dynasties, Yellow River policy was guided by two differing principles: (i) diverting the flow of the Yellow River to the sea through different channels; and (ii) increasing the scouring capacity of the Yellow River by *shu shui gong sha* (confining the river between high dykes). Although these schemes were alternately adopted, they were guided by the singular goal of protecting grain transport (Huang, 1986). The debate between those advocating each of the two main engineering approaches was couched in moral terms. This debate was between a 'Confucian approach', which sought to regulate the behaviour of waterways through human action (i.e. digging channels to divert flows), and a 'Taoist approach', which sought benefit through the natural quality of water (i.e. allowing the natural forces of water to wash away silt) (Wu and Fan, 1993).

The struggle waged by the Ming court to regulate the Yellow River reveals several points. With overall management premised on safeguarding canal transport, the options available to management officials were limited. The two alternatives within this context, 'dividing the flow of the Yellow River' and 'utilizing a single flow to scour', remained the normative approaches to the management of the Yellow River well into the 20th century. In 1578, important additions to these fundamental approaches were proposed, including the construction of retention basins in upstream segments of the Yellow River to regulate flows in periods of heavy runoff. However, these plans were abandoned. One potential explanation is the fractured nature of administrative authority over waterways in central China. Competing bureaucratic units during the Ming dynasty, such as the Grand Canal Commission, Board of Public Works and provincial organizations, exerted pressures not always complementary to one another. The Qing dynasty, however, established the view that complete centralized control over the Yellow River was critical. The creation of the Yellow River Administration (YRA) in the early Qing dynasty (circa 1700) was the institutional expression of this sentiment.

The YRA was created in the early Qing period and headed by a director general appointed by the central government. With offices in Jining (Shandong province), the YRA served as a planning and coordinating organization for the lower Yellow River basin, the Grand Canal, and the lower Huai River valley. The functional goal of the YRA was to maintain grain transport from the south. As such, the YRA was essentially an adjunct of the Grain Transport Administration, as its primary function was to prevent flooding in the lower Yellow and Huai rivers, which would endanger the smooth functioning of the Grand Canal (Pietz, 2002). The historical importance of the YRA was that it was the first administrative organization in China to consider basin-wide issues, even though its actual operation was restricted to the lower Yellow River basin. Thus, when basin-wide river management gained currency in the early and mid-20th century in North America and Europe, China already had institutional experience with basin governance concepts.

In 1855, the Yellow River yet again changed course. The river breached its banks in Henan and adopted a northerly course, running through Shandong province to the sea. By this time, much of the grain tribute to the capital Beijing was transported by ocean. But the shift of the Yellow River rendered any transport via the Grand Canal hopelessly inefficient and expensive. Thus the immediate rationale for central control of the Yellow River, namely maintenance of the canal system, was lost. As a consequence, the YRA was abolished in 1856. The removal of central management of Yellow River control ultimately left local and provincial institutions responsible for water management in their immediate locales. The general collapse of Qing provincial and local government institutions, mirroring the deterioration of central capacity, meant that Yellow River management languished. By the end of the dynasty in 1911, water-control structures along the Yellow River, particularly in the lower reaches, were collapsing.

Basin development and management during the early 20th century

The period between 1855 and 1927 represented an important transformation in Yellow River management. The shift of the Yellow River in 1855 triggered the withdrawal of state patronage over water management, although there were attempts during the last years of the Qing and the early years of the Republican period to reconstitute centralized control. By the so-called Warlord period (1915–1926) the fundamental collapse of central political authority in China precluded any functioning of centralized water administration. Still, reformers among China's political elites retained the ideal of centralized control – realizing the reformulation of centralized management during the 1930s, in the Nationalist period.

With the nominal reunification of the country by the Nationalist Party after 1927, the new government embarked on an ambitious 'reconstruction' campaign to promote national strength. Consistent with Imperial patterns, Chiang Kai-shek and the Nationalist government immediately sought sanction to rule by 'ordering the waters' of the empire.

Coupled with this traditional concern of stabilizing the agricultural economy, the Nationalist government's state-building efforts were heavily influenced by the trend toward growing state capacity in many countries during the mid-20th century. The Nationalists re-established centralized institutions to manage the water on the North China Plain. The national government established *Huanghe shuili weiyuanhui* (the Yellow River Water Conservation Commission, or YRWCC) having in 1932, organized the National Economic Commission (NEC), whose purpose was to promote modern industrial growth by improvements in agricultural production and marketing. The formation of the NEC and its goals were familiar patterns engendered by the worldwide economic depression. As a supra-bureaucratic economic planning and coordinating body, the NEC had a number of analogues in different countries suffering from the worldwide depression, as state intervention in the economy was deemed necessary to optimize allocation and utilization of resources. The NEC underwent a series of reorganizations in mid-1933, which gave it broad jurisdiction over water conservancy and other reconstruction activities aimed at reviving the agricultural infrastructure (Tongyi, n.d.).

Another significant change in water management during the late 19th and early 20th centuries was the potential of water to serve modern industrial development. Although the specific goal was indeed industrial development, the more instrumentalist view of water serving state-sponsored economic growth (i.e. agricultural growth) during the Imperial period provided the basic assumption. Although small, China's modern economic sector experienced sustained growth in the late 19th and early 20th centuries. Several prominent Chinese industrialists in the early 20th century advocated active water management policies to promote cotton production and effective water transport to and from industrial enterprises centred in the Yangtze River delta region.

A third important development during the early Republican period, which established a pattern that would largely be consistent throughout 20th-century Yellow River management, was the introduction of modern hydraulic science into China. Initially introduced by foreign technical experts, a strong nationalistic tendency soon served to impel the development of native talent. Based on European and American models, engineering training institutes were founded that trained Chinese students in fundamental engineering practices, such as surveying. One example is the Hehai Engineering Institute (presently HeHai University) in Nanjing, founded by Zhang Jian, whose students would come to provide a cadre of well-trained technicians in the years to come.

The development of a cadre of hydraulic engineering and technical professionals during the first several decades of Republican China reflected increasing levels of technical education during this period (Strauss, n.d.). Technical personnel in positions of policy planning included members of the commission itself, as well as directors of the Engineering Office and senior engineers. These individuals all received advanced training in engineering in the USA or Europe. Most of the engineering personnel at both the low and mid-levels received training in their specialties from the growing number of engineering departments at colleges and universities in China. In 1935, there were a total of 37 institutions of higher education offering degrees in civil and other fields of engineering (Huang, 1986). Included in this number were institutions such as the Qinghua University and *Shuili gongcheng zhuanmen xuexiao* (the former Water Conservancy Training Institution) in Nanjing, which became part of *Guoli zhongyang daxue* (National Central University).

The last broad development of Yellow River management during the early to mid-20th century was the pattern of developing foreign partners in water management. This development, however, reflected the troubled relationship that China had with the USA and European powers. In some ways, the power of the traditional role of water and the cultural significance of the Yellow River in China also mitigated the success of international cooperation. An early effort was led in 1914 by the American Red Cross, which attempted to secure an agreement for a loan to pursue an aggressive water management scheme on the North China Plain. Ultimately, the plan failed because of problems related to leadership of the project and over differing conceptions about the technical approaches to water management in China. The Chinese leader of the project, Zhang Jian, suggested that the American chief engineer simply did not understand the special nature of China's water and traditional methods of dealing with it. This sensitivity to the special nature of China's water and a certain reverence to past Chinese accomplishments in managing water continued to be an undercurrent even as China intensified these sorts of transnational cooperative efforts over the next decades (Pietz, 2006).

Transnational cooperation continued to develop during the Nationalist period. In early 1931, the government invited the directors of the League of Nations' Economic and Financial Section and its Communications and Transit Section to visit China to advise on reconstruction projects (National Economic Council, 1934). In addition, the Board of Trustees of the Returned British Boxer Indemnity Commission designated that 66% of the money from the British Boxer Indemnity be returned to China to assist water conservancy projects. Finally, the United Nations Relief and Rehabilitation Administration sponsored Yellow River management operations following the end of World War II. In all, the record of international cooperation in Yellow River management during the 20th century was spotty. But China's pattern of seeking these partnerships suggests a general trend in the internationalization of China's water management.

The ability of the Nationalist government to realize its Yellow River conservancy plans during the 1930s was conditioned by difficulty in controlling resources at the local level. In other words, it could organize and plan but it struggled to build. Several projects were completed but on a smaller scale and beyond schedules originally envisioned. This was primarily due to inadequate labour conscription and the inability to enforce work discipline. The government tried campaigns of moral suasion and the dispatch of Nationalist troops to ensure compliance with its goals, but projects were persistently obstructed by the inability to mobilize conscripted labour.

Basin development since 1949

Yellow River management was in a shambles by the time of the Communist victory in 1949. In large measure, difficult conditions in the lower portions of the valley were severely aggravated by Chiang Kai-shek's order to destroy the southern dykes of the Yellow River near Huayuankou in 1937. This decision was intended to slow the advance of Japanese troops from the north. The massive flood towards the lower Huai River valley indeed brought a pause to the Japanese invasion, but the longer-term consequences were to destroy much of the conservancy works that the Nationalist government had managed to build during the prior decade. Although there were some projects initiated after the end of the Pacific War in 1945, the state of the Yellow River was indeed precarious when Mao Zedong led the communists to power in 1949.

The developments described above during the Nationalist period, namely centralization, modern industrial development, introduction of modern science and technology, and international cooperation in water management, suggest that hydraulic engineering during this period was increasingly reflective of standards and practices that prevailed in the industrialized countries of the time. One need only look to the institutional model of river management in China during the Nationalist period (the Tennessee Valley Authority) to get an understanding of the types of 'mega-project' that China was moving towards. Does the history of Yellow River conservancy under the Chinese Communist Party after 1949 suggest continuities with these trends? The answer is yes for much of the post-1949 period. Beginning in 1958, however, with the onset of the Great Leap Forward, China modified this orientation towards the grand project by introducing small-scale projects that emphasized local administration, mass mobilization, a celebration of traditional notions of water conservancy (i.e. a certain anti-modernism) and self-reliance. Thus, after 1958 there was a dual character to Yellow River engineering: mega-projects combined with small-scale installations.

Looking back at such diverse approaches to Yellow River engineering, one is certainly tempted to come to some conclusion as to which paradigm best served the goals of river management. The problem, of course, is defining these goals. There were multiple goals, and respective goals, it was argued, could be best achieved by different approaches. The purpose of the following examination of Yellow River engineering after 1949 is not to evaluate differing approaches to river management but is, instead, intended to delineate areas of continuity and change. One significant difference in Yellow River management effort after 1949 was the degree of local political control attained by the new government, and hence the ability to sufficiently mobilize labour for conservancy projects. In other important respects, however, the decade after 1949 reflected broad continuities and discontinuities with earlier Yellow River management efforts. Institutional structure, modern technology and international cooperation were all issues that would be at the centre of fierce debates over the Yellow River.

Institutional structure: centralization and decentralization

One of the key policy debates after 1949 was over the institutional structure of the Yellow River control. In its most distilled manner, the debate was over whether water management could best be pursued with a centralized structure. Immediately after 1949, the government of the People's Republic of China (PRC) had, by and large, assumed the institutional structure of the Yellow River Conservancy Commission (YRCC), as established during the Nationalist era.

The first large-scale water management plan adopted by the government after 1949 was focused on the Huai, not the Yellow, River. This plan clearly signalled the degree to which water management immediately after 1949 would be centrally planned and financed. Begun in 1950, the plan called for the creation of nine upstream reservoirs, strengthening dykes in the middle and lower reaches, and improving the storage (Hongze Lake) and drainage capacity in the lower portions of the river. State expenditures for the Huai River project during the 1950s were high. Between 1949 and 1952, state spending on the Huai River scheme was 64% of all government expenditures on river management in China (Vermeer, 1977). Water officials felt that immediately rectifying the Huai River was critical to addressing long-term social and political disruption in the valley.

The Huai River plan provided the basic blueprint for the Yellow River plan adopted by the government. In 1955, the Technical and Economic Plan for Yellow River Comprehensive Utilization was submitted to the state council by the YRCC. This was probably the first ever comprehensive development plan for the basin, and focused on power generation in the upper reach, flood control in the middle reach and irrigation downstream. The ambitious plan, approved by the First People's Assembly in July 1955, envisioned, among other items, the construction of an astounding 46 large dams on the Yellow River's main stem (Greer, 1979). It is interesting to note that, probably because of Soviet influence and aid, the water-engineering efforts in the early 1950s were *relatively* capital intensive rather than labour intensive, as had traditionally been the case in Chinese water development (Chi, 1965). At the basin level, the YRCC was responsible to the Ministry of Water Conservancy and was the representative of centralized control over the breadth of the basin. Although labour mobilization remained the responsibility of provincial and sub-provincial institutions, the Yellow River Commission held overall coordinating functions over technical elements of the engineering plans.

Beginning in 1958, however, water management administration experienced a strong trend toward decentralization. Corresponding with the communalization push, administration and spending on Yellow River projects increasingly became the responsibility of provincial and local governments or the communes. This shift from central to local control was influenced by several factors: incorporation of small projects alongside large ones, the increasing labour element of overall project design and execution, and the primacy given to local irrigation projects that were more suited to local control (Wu and Fan, 1993).

Science and technology: modern hydraulic engineering and mass mobilization

Behind the plans of the early People's Republic of China for the development of the Yellow River basin was a strong belief in the ability of human ingenuity to overcome nature. This belief emanated from the tremendous pride and euphoria following the defeat of Japan, victory in the Chinese Civil War and the establishment of 'New China', and the success in stopping the advance of US and UN forces in the Korean peninsula. If the Chinese people could defeat feudalism and imperialism, why would not it also be possible to conquer the Yellow River? Why would it not be possible to use the will of the people to make the river 'run clear' for the first time in history? The then commissioner of the YRCC, the successor agency to the Nationalist-era Yellow River Water Conservation Commission, Yang Huayun, presented such visions during a field trip to the Yellow River by Chairman Mao through a promise: the Yellow River would be made peaceful for at least 300 years through the construction of the planned large dams. While Mao is attributed to have made a somewhat more realistic assessment of the potential to control the river in his suggestion that the Yellow River problems could be 'well handled' although not necessarily fully resolved; in this respect, the actions of the government were to follow the ambitious plans.

An example of the resolve to develop the river is seen in the name of the first major irrigation project under the new development plans, the People's Victory Canal, located in Henan province. This project, which still provides the name to a brand of cigarettes, was designed to divert Yellow River water by gravity to irrigate almost 100,000 ha of farmland (Zhang and Shangshi, 1987). Signalling the symbolic and real significance of such undertakings, Chairmen Mao visited the project in October 1952, when he officially opened its diversion gates. Irrigation and dam construction continued through the late 1950s under the slogan 'big diversion, big irrigation'. However, the primary means to complete projects shifted from capital to labour, probably in large part due to the withdrawal of Soviet aid. In fact, the decision made in 1957 to 'depend on the masses' and rely more on local capital in water construction projects can be seen in some ways as the beginning of the nationally disastrous Great Leap Forward, which began in 1958.

Although voluntarism was a critical element of the regime's ruling psychology, science and technology were still valorized during the decade of the 1950s. During the first period, the ambitious Yellow River engineering plans were, in part, predicated on data and plans gathered and formulated by the technical staff of the Nationalist government's YRCC. Although the number of technical specialists throughout China was limited, large numbers of such experts were heavily recruited by the new government's YRCC after 1949 to participate in some of the nation's premier projects (Vermeer, 1977). So, by the mid-1950s, newly minted technical experts from a growing number of technical institutions in China joined with experts who had received their training and work experience during the Nationalist period and were, together, vital participants in the conceptualization of the Yellow River engineering scheme.

The orientation towards technical expertise and notions of modern hydraulic practices came under attack with the onset of the Great Leap Forward policies in 1958. As an auxiliary to the rectification campaigns such as the Anti-Rightist Movement, which saw the discrediting of many water conservancy technical experts and the move towards greater local administration of water control projects, these projects themselves increasingly became conceptualized and executed by subunits of the People's Communes (usually the production brigade). The mantra became cheaper, quicker, better, etc., as Yellow River conservancy projects were the result of local initiative designed to meet local problems. The ideal was indeed not to conform to the abstract notions of modern hydraulic practices, but projects were designed to fill practical needs and were to be executed through the sheer power of the human will, that is to say by a massive mobilization of labour.

International cooperation and self-reliance

The pattern of seeking international technical and financial assistance established during the Nationalist period was continued during the first decade of the PRC. After 1949, however, American, Dutch and German engineers were replaced by technical experts from the Soviet Union. Indeed, up to the onset of the Great Leap Forward, all water conservancy projects in China were advised by Soviet engineers.

Perhaps the best-known example of Soviet technical cooperation was the construction of the Sanmenxia dam (1958–1960). The

Sanmenxia reservoir was created behind the first significant dam in history to be built on the main stem of the Yellow River. However, because of the failure of the Soviet engineers to appreciate the nature of the sediment load in the river and the Chinese enthusiasm of the period to carry the project forward, the dam was woefully unsuited and the reservoir was silted within only a few years of construction. This, in turn, caused the waters of the Yellow River to back up into the Wei River basin, where they inundated land and threatened the ancient city of Xian with flooding. The failure of Sanmenxia, the similar failure of early irrigation projects and the famine which occurred in the aftermath of the Great Leap Forward were shocks to the leadership of the People's Republic in Beijing as well as to the YRCC (Greer, 1979; Becker, 1998). Together, these events caused a new sense of realism in policy and dampened the enthusiasm for pure engineering solutions to development problems and programmes. Better effort was made to understand the role of sediment in reservoir operations; dam construction plans were modified; and the number of new reservoirs to be constructed was reduced. Drainage development and irrigation system rehabilitation were also begun, and farmers were slowly re-convinced of the potential value of irrigation construction.

Soviet advisors packed up and returned to the Soviet Union by 1960. Beneath the mantra of self-sufficiency after 1960, Yellow River management was to be guided by the inspiration of the masses. The Cultural Revolution, which lasted from 1966 to 1976, brought political chaos to China, including the Yellow River basin. Somewhat surprisingly, the moderately revised development plans of the 1950s, and heavy government investment in the basin, continued despite the chaos, without substantial debate (Stone, 1998). Giant power-generating reservoirs were constructed in the upper basin; a soil-conservation campaign created new terraced fields on the Loess Plateau of the middle reach; and irrigation diversions were substantially expanded in the lower reach, especially in Shandong and Henan provinces. Meanwhile, village-based water management systems, including canal maintenance and water allocation between neighbouring villages, were shaped in the basin, although they were structured based on the political overtones of the time.

The Contemporary Setting: Change and Response

With the death of Mao Zedong in 1976, Deng Xiaoping came to power and helped to introduce a wide-ranging set of reforms that swept through China in the 1980s (Meisner, 1999; Naughton, 2003). The commune system that had been established in villages was abolished and a rural household responsibility system moved production decisions and power towards individual farmers (Ash, 1988). Government planning and control became more decentralized and, as also occurred in the agriculture sector, public investment in the water sector declined. Environmental awareness later started to grow and a more politically liberal atmosphere allowed people to review past basin strategies and lessons. In 1984, the state council approved the Second Yellow River Basin Plan, which listed soil-erosion control in the middle reach as the most important policy objective, as opposed to power generation and flood control, as had been emphasized in the 1954 plan.

Changing political economy

Following these changes, the late 1980s and early 1990s saw the arrival of a new water era for China. In the Yellow River, this was reflected in two ways. First, the rule of law was given added relevance. Second, economic growth placed increasing demand on water resources, in both quantitative and qualitative terms. Together, these and other factors caused fundamental changes in both perceptions of appropriate water policy and management, and, increasingly, in water management practice.

The major legal landmark for water policy was the 1988 Water Law, which provided the basic framework and principles for water management in the 1990s. This was followed by related legislation, including the Water Pollution Prevention and Control Law, the Soil and Water Conservation Law, and the Flood Control Law. A large body of additional administrative rules and ministerial regulations related to water were also passed, along with a number of other laws at least indirectly related to water.

This move towards legalism took place at a time of dynamic economic growth and structural change, which began in the early 1980s. Increasing liberalization of markets and foreign investment helped to sustain rapid economic growth. Industrial output increased dramatically. Increasing agricultural labour productivity and de facto and de jure changes in residency rules freed people from the farms and allowed rapid urbanization. While population growth has slowed, expansion continues and, importantly, rising affluence has caused dietary changes which favour meats and contribute to massive growth in feed grain use, with concomitant increases in crop water demand.

New challenges for the river

The key factors driving Yellow River management in the new era are thus not water itself but rather the larger economic and social environment, which has shifted pressure and focus. While flood control is still important, water stress is now probably the number one issue for most basin authorities and residents. How water stress rose in prominence can be seen by looking at three factors: a decline in water supplies, an increase in demand and a growing awareness of environmental water needs.

On the supply side, runoff substantially decreased in the 1990s, as shown in Fig. 5.2. One question is whether the decline is caused by secular declines in long-term precipitation levels brought about, perhaps, by global climatic change. As a similar, but apparently less severe, dry spell to that which occurred in the 1990s also occurred from 1922 to 1932, it is suspected by some that the Yellow River is now at the tail-end of a 70-year cycle, and that rainfall levels and river flows will therefore begin climbing in the near future. However, the figure graphically shows that the runoff decline is not a phenomenon of only the 1990s, but that other factors must also be at work. Possibilities include changes in land use, which have altered rainfall/runoff ratios (Zhu *et al.*, 2004), and increased irrigation (Yang *et al.*, 2004), including groundwater irrigation, perhaps in part as a response to declining surface supplies. Although a slowing of the problem is evident in the early 21st century, consistent with near average rainfall (YRCC, 2007), it is debatable whether this is evidence of a turnaround. There is no question, however, that the reduced runoff has contributed to supply constraints.

Even if runoff levels do increase, they might well be offset by decreases in effective supply due to pollution. Water pollution, in general, has been called the number one environmental issue in China (Jun, 2004). For the Yellow River, the declining state of water quality is exemplified in Fig. 5.3, which shows changes

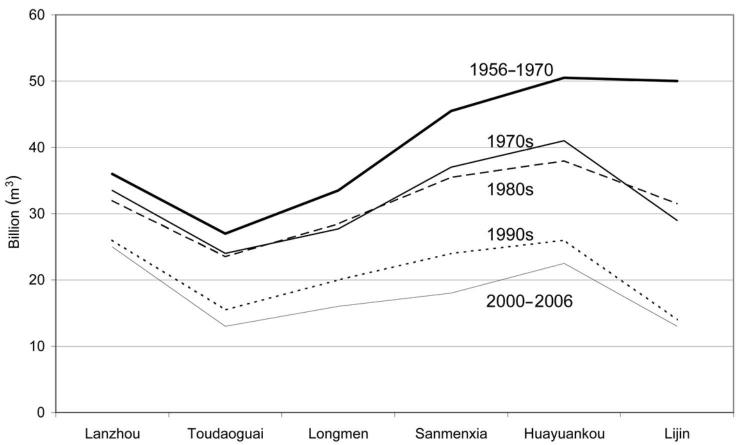

Fig. 5.2. Yellow River runoff, 1956–2006. Source: YRCC 2002b, 2007.

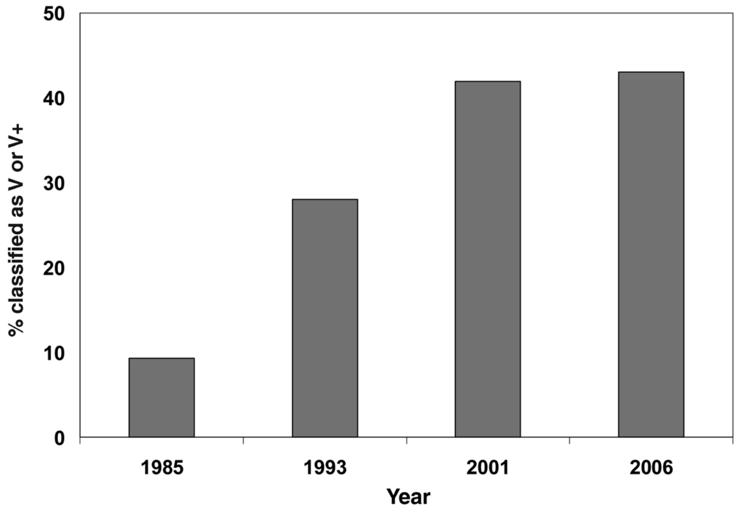

Fig. 5.3. Severely polluted length of the Yellow River (% classified as class V or V+). Source: Yellow River Water Resources Bulletin, YRCC. www.yellowriver.gov.cn/other/hhgb/

in percentages of the river's length classified under the Chinese system to be in the lowest-quality grade (V) or even worse (V+) – levels unsuitable for most direct human use. Nearly half the river now falls into one of these categories, and the Yellow River is now perhaps the second most polluted river in China.

One major pollutant source is industrial and domestic waste discharged into the Yellow River's main stem and tributaries. While there is substantial discharge from all provinces, Shaanxi contributes over one-quarter of the total, and the Wei River tributary contributes the largest share, almost 30% of the basin total. Two other important pollution sources are the unmeasured discharge from rural township and village enterprises (TVEs) and non-point pollution sources from agriculture. Beginning in the 1980s, TVEs developed rapidly throughout China and have often been allowed to remain out of compliance from wastewater laws and regulations because of their limited technology and financial levels, difficulty in monitoring their discharge, and the general trend in decentralization of economic control and management. From the early 1980s to the mid-1990s, farmers substantially increased their use of fertilizers and pesticides, with the result that a considerable fraction of residues now enters the river with return flow from irrigation.

On the demand side, total use (depletion) has increased only somewhat over the past one and a half decades (Table 5.1), in large part because there is little additional water to develop. However, there has been substantial change in the geography of use, with upstream regions consuming more and downstream regions less. Sectorally, there have also been moderate reductions in agricultural use, more than offset by dramatic growth in industrial and domestic depletion. Partially in response to declining surface supplies and increasing demand, groundwater pumping has also increased dramatically since the late 1980s. Available data from 1980 to 2002 show that groundwater abstraction increased by 5.1 billion m^3 billion, or 61%, reaching 13.5 m^3. However, since groundwater data are notoriously difficult to collect, especially for agriculture, where most use occurs, it is possible that actual use is even higher than the figures suggest (Wang *et al.*, 2007a). In fact, the lower Yellow River basin is part of a now-infamous groundwater drawdown problem in the North China Plain, which has been suggested to be a threat to a substantial part of China's future food supply (Foster and Chilton, 2003). Even using formally collected statistics for the most recent period available (Table 5.2), combined surface water and groundwater depletion is now equal to nearly 80% of total withdrawals, which are themselves equal to nearly 90% of annually renewable water resources.

The outcome of declining supplies and increasing demand has already been the seasonal desiccation of portions of the Yellow River, discussed at the beginning of this chapter. From 1995 to 1998, there was no flow in the lower reach for some 120 days each year, and in some cases flow ended over 700 km from the sea, failing even to reach Shandong province. This cut-off inflow has important repercussions to basin function for three reasons. First, it obviously limits the availability of surface water for human use in downstream provinces and, less obviously, reduces groundwater recharge in the lower reach (because of the raised channel, discussed further below, this impact may be outside formal basin boundaries). Second, it negates the competence of the river to carry its heavy sediment load to the sea, potentially resulting in a more rapidly aggrading and flood-prone channel than would otherwise exist (although low flows also tend to be associated with lower sediment loads). Third, it has clear consequences for the ecology of the downstream areas and, in particular, for the Yellow River delta and coastal fisheries. The reduction in flow, coupled with success in flood control in the past five decades, has caused a retreat of the delta shoreline, intrusion of salt water, and increased salinity and lowering sea water temperature in the Bohai estuary. Further complicating matters, the Shengli petroleum field, the second largest petroleum oil source in China, is located in the delta and competes with the trickling river flow for environmental needs.

Table 5.1. Yellow River water depletion (billion m^3) by sector and reach, 1988–1992 and 2002–2004. Source: Cai, 2006.

Years	Reach	Total	Agriculture	Industrial	Domestic
1988–1992	Upper	13.11	12.38	0.51	0.22
	Middle	5.44	4.77	0.38	0.28
	Lower	12.18	11.24	0.55	0.38
	Basin	30.72	28.39	1.45	0.89
2002–2004	Upper	17.54	15.71	1.42	0.41
	Middle	5.71	4.16	0.97	0.58
	Lower	8.44	7.04	0.82	0.58
	Basin	31.69	26.91	3.21	1.57
Difference	Upper	34%	27%	179%	84%
	Middle	5%	–13%	155%	108%
	Lower	–31%	–37%	49%	54%
	Basin	3%	–5%	121%	77%

Table 5.2. Yellow River resources, withdrawal and depletion (billion m^3), 2004–2006.

Annual water resources		55.5
Withdrawal		
	Total	48.9
	Surface water	35.3
	Groundwater	13.5
Depletion		
	Total	38.2
	Surface water	28.6
	Groundwater	9.5

Since the 1998 strengthening of the 1987 Water Allocation Scheme and the operationalization of the Xiaolangdi dam, discussed below, the YRCC has managed to nominally end absolute flow cut-off, an important accomplishment. Even so, it is now clearly established that environmental water demands have not been adequately included in existing allocation schemes. According to basin managers, the primary environmental water use in the Yellow River is for sediment flushing to control potentially devastating floods, and it has been estimated that this would require about one-quarter of the Yellow River's flow (Zhu *et al.*, 2004). The special challenge of flood control in the lower reach is caused when sediment transported from the middle reach begins to settle as the river spills on to the flat North China plain, producing a naturally meandering and unstable channel (Ren and Walker, 1998). It is calculated that roughly 1 trillion t of sediment enter the Yellow River each year. Of these, 400 million t are calculated to be captured by two large reservoirs and various irrigation diversions, 100 million t are believed to settle within the lower reach, and an additional 100 million t are flushed to the sea through dry-season minimum flow. To flush the remaining 400 million t, an environmental water requirement of 14 billion m^3 (3.5 billion m^3 of water per 100 million t of sand), which is more than one-quarter of the recent flow, is currently estimated to be necessary (Giordano *et al.*, 2004).

To control the impact of that sediment which is not flushed, successive river managers over millennia have constructed levees to contain the Yellow River. While such structures may hold the channel in the short term, their success depends on continually raising the levee walls as new sediment elevates the level of the channel constrained within. Over time, the process of levee raising has contributed to a 'suspended' river, in which the channel bottom is above ground level, sometimes by more than 10 m (see Fig. 5.4). Since the founding of the People's Republic, the levees have held, but obviously the levee-raising solution cannot continue indefinitely. The current comprehensive flood management plan comprises a range of inter-related strategies. These include extensive soil and water conservation programmes in the upper and middle river reaches (particularly in the Loess Plateau); the construction of multi-purpose reservoirs; adjustment and strengthening of levees in the lower river reach; the development and improvement of flood-retention basins; the implementation of development and building controls in flood-prone areas; and planning measures, such as the relocation of families presently living in areas of high flood risk, such as the inner flood plain (Giordano *et al.*, 2004).

In the more 'traditional' sense of ecological use, Chinese scientists, and the Chinese in general, increasingly recognize the environmental services that high-quality water flow brings. In the case of the Yellow River, these are largely discussed in terms of flow maintenance for biodiversity protection and sustenance of wetlands and fisheries at the mouth of the river, and for dilution and degradation of human-introduced pollutants. That concepts of environmental flows and values have changed is evident in the water-utilization accounts provided by the YRCC. The environment as a user of water was first included in basin water accounts as recently as 2004. While the most recent figures place environmental use at only 2% of total depletion, a more realistic figure would be likely to approach one-third of annual flow (Zhu *et al.*, 2004).

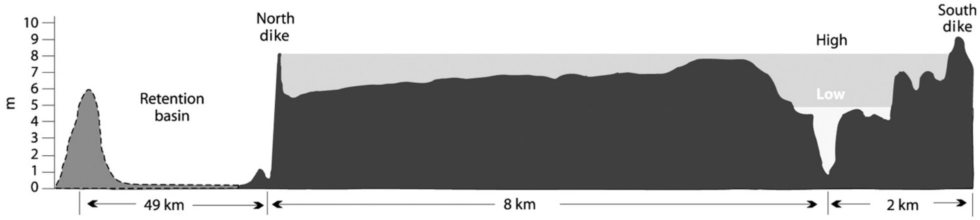

Fig. 5.4. Schematic representation of a cross-section of the Yellow River.[1] Source: after Ronan, 1995.

Institutional response

With effective supply decrease, increases in demand from traditional users and growing recognition of environmental needs, the Yellow River Basin is now effectively closed in most senses of the term. As a result, there is a clear need for water policy to shift away from a singular emphasis on flood control and resource development, and towards comprehensive basin management strategies. Such a new direction in thinking was, in fact, reflected in Article 1 of the 1988 Water Law, which stated that the document was 'formulated for the rational development, utilization, economization and protection of water resources, for the prevention and control of water disasters and for the realization of sustainable utilization of water resources in order to meet the needs in national economic and social development'. In other words, water management in China in the 1990s, harkening back to the Tang dynasty edicts, was officially going to take a more comprehensive approach, which would include concepts of economic value and trade-offs, resource protection and sustainable development, among others.

To carry out such changes in management, however, would require a movement in institutional structures. While the YRCC was already ostensibly serving as the river basin authority, in practice its powers for basin management and planning were limited and unclear. However, the changes in thinking brought about in part by the 1988 Water Law slowly began to be reflected in the management mandate of the YRCC. For example, in 1997, the state council approved the 'Outline of Yellow River Harnessing and Development', which, though still calling for the construction of 36 additional large dams, began addressing the issues of comprehensive utilization of the basin water resources. In 1998, the state council, the Ministry of Water Resources and the National Planning Committee issued the 'Yellow River Available Water Annual Allocation and Main Course Regulating Scheme' and the 'Management Details of Yellow River Water Regulating', leading the way to the first basin-wide, main-course flow regulation, which began the following year.

Perhaps more fundamentally, the Ministry of Water Resources brought forward ideas for the conceptual transformation of water resource development and management in China, from engineering-dominated approaches to approaches based on demand management and the value of water resources (a shift from emphasis on *gondchengshuili,* engineering water benefits, to *ziranshuli,* broader water resources benefits) (Boxer, 2001). Following this shift, concepts such as water pricing, water rights and water markets were further discussed and tested, and are now beginning to have an impact on water management across China, including the Yellow River basin.

Changing mechanisms and adaptation

The overarching changes in institutional structures and approaches brought new mechanisms through which water users have to, or choose to, use the resource. Following from the water-resource-based approach and the overarching change in political economy, calls for the use of water pricing as a mechanism to regulate use have now become almost universal in official discussions of water policy change. While the meaning and impact of water pricing in China, and elsewhere, are contested, the use of water pricing as a policy tool is at least premised on the assumption that it will provide incentives for farmers, the largest water user group, or, in practice, their direct water suppliers, to reduce water use and increase efficiency (Lohmar *et al.*, 2007). A confounding issue, however, is that it is farmers who have benefitted least from China's economic growth, and increasing rural incomes is now also a major policy goal. Thus the government is struggling with ways in which pricing can be used as a tool for water savings and investment, while at the same time protecting or improving farmer welfare. As a result, water price increases are being discussed in terms of broader agricultural reform policies, which include reductions in rural taxation rates and new rural investments.

Often connected to water pricing reform is the establishment of water user associations (WUAs). As with pricing, devolution of at least some irrigation management control to local levels fits in with the overall push in China towards market principles, as well as with 'global' trends in water management paradigms. This is evidenced in the large involvement of international organizations in the funding of Chinese projects to create and support WUAs in the Yellow River and elsewhere. In theory, WUAs place management closer to the actual uses and therefore improve service and provide a mechanism for both fee collection and, therefore, sustained investment in operations and maintenance (Lohmar *et al.*, 2007). This is expected to result in better long-term use of water, as well as improved farmer outcomes.

In practice, the utility of water pricing and WUAs as efficiency- and livelihood-enhancing tools is still the subject of debate. For example, it has been suggested that, given the low level of current prices, the level of increase needed to induce demand response may not be politically feasible, and the initial result of pricing may thus simply be one of a welfare transfer away from farmers without associated changes in water-use levels or practices (Yang *et al.*, 2003; Barnett *et al.*, 2006). Some empirical analyses have shown that this is not necessarily the case (Huang *et al.*, 2006; Liao *et al.*, 2007); however, even these analyses highlighted the incompatibility of agricultural water prices with rural poverty-alleviation goals. A second issue, perhaps especially important in the Yellow River's lower reach and the associated basins of the North China Plain, is that direct water pricing can, at present, only be applied to state-controlled surface water supplies, not to privately accessed groundwater. Some of the implications as related to water use are discussed further below.

In addition to direct effects on water-use decisions, increased prices and irrigation management reform are also hoped to provide indirect incentives for the adoption of water-saving technologies. There is, in fact, evidence since the 1980s of increasing use of such technologies, including field levelling, plastic sheeting, canal lining and sprinkler irrigation (Blanke *et al.*, 2007). However, adoption still seems to be confined mostly to low-cost options appropriate for individual household use only. It has also been suggested that, even in the face of increasing scarcity, the water-related incentives for water users and managers to adopt most technologies are still simply too low.

To address this issue, new approaches are being sought. For example, there is at least one ongoing experiment with large-scale 'water trading', in which industry invests in agricultural water-savings technology, and other farmer benefits, in exchange for access to the water saved. This experiment is taking place between farmers in the Hetao irrigation district in Inner Mongolia (the largest in the Yellow River basin), and in the downstream industry near Baotou city.

There is also evidence that, even without sufficient incentives to adopt water-saving technologies, farmers are adapting to changing water and market circumstances in other ways. For example, as formal surface water allocations have declined, farmers have switched from low- to high-value crops, a phenomenon made profitable by the rising demand for vegetables, fruits and meat in growing cities, or by changing farming practices (as highlighted by Moya *et al.*, 2004, in the Yangtze basin).

There is, however, a question on the extent to which these responses to planned (e.g. pricing) and unplanned (e.g. declining surface deliveries) actions result in real water savings. For example, reduction in the agricultural application of surface irrigation can, in some cases, simply reduce groundwater recharge, recharge that would later have been pumped and used again elsewhere. Kendy (2003) and Kendy *et al.* (2003) have highlighted this outcome for an area of the North China Plain, where virtually all annually renewable water is used (depleted) and groundwater tables are falling with agricultural and urban expansion. As Kendy *et al.* (2003) show, while water might be used and reused more wisely, bringing a balance between water supply and demand can only come from reduced use. With almost no water reaching the sea, it could be argued that the same holds true for the Yellow River in general.

Engineering not forgotten

Changing institutional structures and options for individual response to the new water challenges in the Yellow River have been closely connected with China's evolving political economy over the past quarter century. But China has, of course, long been famous for the use of large-scale engineering as a tool for water management. Thus it should come as no surprise that engineering solutions still form a large part of official efforts to manage the Yellow River, even in the new environment. These continuing engineering efforts can be put into three general categories – landscape change, water control and water mobilization.

In terms of landscape change, perhaps the most important is related to the Loess Plateau in the Yellow River's middle reach. Large-scale engineering efforts to transform the landscape of the Loess Plateau began in the 1950s and have included sediment-retention dams, revegetation and strip farming. Perhaps the most visually stunning means, which highlights the true magnitude of the input and the impact on the land surface, has been the creation of terraces on the steeply sloping gullies, easily visible with the naked eye even from commercial flights. While the early efforts at transformation of the plateau were couched in terms of agricultural output increases, they are now promoted on the basis of sediment reduction and poverty alleviation. By the turn of the 21st century, somewhat more than one-third of the farmland in the most erodible areas was considered to have been brought basically under control.

Related at least in part to engineering efforts at sediment control has been the continued construction of large-scale dams for water control. Most prominent of these is the recently completed Xiaolangdi dam, located in the lower middle reach, the largest dam on the Yellow River and second in China only to the Three Gorges. While a multi-purpose project, the dam's most heralded feature is its possibly unique system of tunnels and underground powerhouses, which make it possible to flush sediment through the creation of controlled floods. While the dam has been financed in part with foreign funds and constructed with the involvement of foreign engineers, it was built with a thoroughly Chinese understanding of the Yellow River's problems, showing that, since Sanmenxia, much has been learned in terms of both engineering skill and the management of international relations. In fact, the dam has been considered a major success and has even managed to avoid the criticism by international NGOs levelled against many other large-scale water-engineering projects in China. This may, in part, be because an international environmental expert panel was included in the project, perhaps a first for such a significant project in China (Gunaratnam *et al.*, 2002).

Beyond Xiaolangdi, at least two dozen additional dam projects on the Yellow River and its tributaries are still planned. However, swamping any of these projects in terms of scale and impact, and certainly in controversy, is the effort to mobilize water in the south–north water-transfer scheme. While formally started late in 2002, the scheme was initially conceptualized in the 1950s (Greer, 1979) to move 50 billion m^3 of water, approximately the annual flow of the Yellow River, from the Yangtze basin in the south to the Yellow River and the North China Plain. If completed as in present plans, the south–north transfer will involve three routes, known by their relative geographic position – eastern, middle and western. The eastern and middle routes cross the Yellow River, before delivering most of their planned water further north. The western route would transfer water directly into the Yellow River. Because of the costs per unit of water moved, the diversion can only be justified on the basis of domestic and industrial demand. None the less, it can still be argued that agriculture is an indirect beneficiary, since the new water availability would reduce pressure on diversions from agriculture (Berkoff, 2003). In terms of direct impact on the Yellow River itself, the outcomes are not clear. Most of the planned transfers through the eastern and middle routes will be used outside the basin. The transfers from the western route would increase Yellow River flows directly, with the greatest benefit to provinces in the middle reach. However, as this route is the most costly and difficult to build, it is not clear whether it will ever be constructed.

While the south–north transfer is in many senses a classic engineering project of the hydraulic mission era, it is being justified on economic grounds. In fact, firms are expected to buy and market the water. Thus, even what might in the past have been thought of as a pure engineering endeavour now also has the flavour of the new economic environment.

Old tensions revisited and continuing transformation

The closure of the Yellow River basin has come at a time of, and in large part because of, larger economic and political change within China. The resulting management challenge brings to light again an age-old governance tension in China on the balance between central and local power. In essence, the necessary shift toward basin-scale management considerations implies a role for central authority, even if with a broader range of social input in decision making. At the same time, economic liberalization, even with 'Chinese characteristics', implies decentralized authority and the use of individual-oriented market incentives to drive resource use and conservation.

The potential conflict this can cause for water management is evidenced in the dichotomy in the authority and decisions between surface water and groundwater use. Allocation of surface water in the Yellow River remains the mandate of the YRCC and, with recent improvements in bureaucratic operation, monitoring ability and engineering control, it has been able to manage allocations between provinces reasonably well, even in the face of growing scarcity.[2] The end of Yellow River flow cuts is partial evidence. However, rapid growth in groundwater use over the last one or two decades (Wang *et al.*, 2007b), along with the growth of private tube-well ownership (Wang *et al.*, 2005) since 1979, has weakened the meaning of that control. For example, Molden *et al.* (2007) have shown that farmers in the Zhanghe irrigation district of the Yellow River's lower reach responded to declining surface water allotments by switching to self-supplied groundwater. The overall water result was not so much a change in the volume of water used, as was intended by the allocation reduction, but rather a change in the source of that use. The options and choices of individuals in effect nullified the ability of the YRCC. This is a conflict likely to surface in other areas as well. While it is not yet clear where the final balance of power will lie or how legal and regulatory change, and enforcement, will help to take the best from each approach, the history of adaption in the Yellow River to date suggests that solutions will be found.

Conclusions and Implications

To many an observer, the events reflected in the post-1949 history of Yellow River management may indeed suggest much that was novel, and much that was unprecedented, in Chinese history. It is our argument, however, that to look at this period in such a discrete manner is to neglect important historical continuities that can be viewed as an entire 20th-century effort to devise some type of political and social system to replace the Imperial system that fell in 1911. Much of this 20th-century effort was informed by the values and images of water and the Yellow River, as these evolved during the Imperial period. Although an examination of Yellow River conservancy certainly reflects broad and often bitter disagreement about institutional arrangements, China's role in the world and state–society relations, from the perspective of the post-Mao period there remain important continuities with patterns that were initiated and developed during the past. Despite fundamental differences in political form among the various Chinese state-building projects of the 20th century, each state was fundamentally driven by similar modernizing assumptions, and each sought to draw selectively upon multiple historical meanings of the Yellow River and water in similar ways.

Since the fall of the Imperial system in 1911, China has sought to reconstruct a state system able to ensure national survival and to pursue the goals of renewed wealth and power. Lasting for much of the last century, China's search for political form has expressed itself in experiments from one end of the 20th-century political spectrum to the other: representative democracy, warlordism (decentralization), quasi-fascism, communism and, most recently, capitalism with, what the government calls, Chinese characteristics. Transcending all these political–economic boundaries was water. More to the point, a major consideration of each successive state-building effort in the 20th century was how to effectively manage water to serve the goals of nation building and modernization. During the 20th century, every Chinese state sought to address the hydraulic breakdown on the North China Plain that had occurred during the late Qing period. The

Republican government after 1911, the Nationalist state after 1927, and the communist government after 1949 all sought to assume the historical legitimacy conferred by effectively regulating the Yellow River water. Although there were fundamental differences in political ideologies and organization during each political experiment during the 20th century, there were historical themes that transcended these boundaries. For example, the quest to establish a vigorous modern national identity among the peoples of the empire was a goal, transcending political–economic divides, of virtually every Chinese elite.

Water management in the 20th century was also informed by fundamental assumptions and goals that cut across the traditional political boundaries. Several pan-20th-century developments included faith in: (i) administrative centralization; (ii) modern industrial development; (iii) modern science and technology; and (iv) transnational cooperation. In turn, many of these assumptions and goals were informed, or promoted, by selective views of water that existed in the Imperial period. Traditional views of water, such as the politically legitimizing role of 'ordering the waters', centralized water management and the entire Confucian notion of active manipulation of water to serve the broader goals of statecraft, were never far below the surface, and infuse contemporary China's predilection for an activist government role in managing water on the North China Plain. The Confucian traditions that premise good government on the ability to 'control the waters' continue to animate the tendency within the YRCC to promote engineering solutions to water-scarcity issues. One need only offer the South to North Water Diversion Project as the latest supporting evidence of this bias. In contrast, a growing sensibility in China of environmental degradation has spawned a nascent environmental movement, which has promoted non-engineering approaches (e.g. conservation) to water issues. In the rhetoric of this movement, one clearly sees an implicit, and occasionally explicit, re-emergence of an aesthetic that is informed by traditional Taoist sensibilities. The continuing existence of these sensibilities is likely to mean that China has the capacity to be flexible in its management policies – able to execute shifts from engineering and non-engineering approaches by selectively calling upon historical and philosophical sanction.

The historical tension between centralized control and local autonomy continues to define the challenge of managing water in contemporary China. The imperatives of economic reform have entailed a significant devolution of central administrative power in China since 1978. Water planners recognize the historical lesson of effective central presence in managing the Yellow River, but efforts to successfully mediate local and regional interests have been difficult. Negotiating and enforcing water allocation compacts between provinces continues to be a major challenge. Below the provincial level, local governments are caught between serving central mandates and local constituents. By and large, pollution and groundwater exploitation continue to increase under the pressures of local economic development. This historical and contemporary tension between centre and locality will continue to define China's attempt to implement a national water strategy well into the future.

Since 1978, the YRCC has deepened commitments to internationalization that emerged during the 20th century. Although periods like the Great Leap Forward have witnessed water management premised on local initiative and local technical knowledge, the current patterns of internationalization are the consequence of the state's promotion of modern science and technology. Indeed, much of the content of international technical exchange and capital was embedded in the context of engineering solutions adopted by the state, and state involvement in scientific, technical and financial networks has also introduced the range of experiences, engineering and otherwise, that nations and regions have undergone in water management.[3] Similarly, the emphasis on market justifications for both water investment and management is largely premised on international practices. Indeed, one might suggest that with the historical emphasis on 'ordering the waters' in China, coupled with China's current commitment to international experience, we may see a certain synthesis of tradition and contemporary approaches to Yellow River management, which may well represent models for other regions of the world.

In the more immediate realm, the entire context of the Yellow River basin's closure has intensified the competing interests over water resources since the well-publicized 'shock' of the basin drying up in 1997. At the very centre of China's attempt to formulate institutional arrangements and responses lie the fundamental tensions arising from expanding urban populations, burgeoning industrial production and consumer demands for greater food resources. The trajectory for the Yellow River basin in the context of water scarcity will include adjustments in utilization, allocation and institutional responses, all shaped by the historical context of river and water management outlined above.

Notes

1 Just above the railway bridge linking modern Zhengzhou with Ximxiang, i.e. just west of the old Bian canal.

2 Under the system, the YRCC controls all key surface water reservoirs and surface water abstraction points and assigns use quotas on behalf of the central government to each basin province and autonomous region, plus Hebei and Tianjin. The quotas are adjusted proportionally each year, based on expected water availability. However, the system is more nuanced than this simple explanation suggests and provides opportunities for negotiation and adjustment, based on immediate conditions. See Zhu (2006) for additional details.

3 For an example of such commitments note the series of International Yellow River Symposiums held since 2000.

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