REGULATION OF THE RIVER HUANG:

A Study of the Chinese Concept of River Basin Development

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"Water is a dragon
From its head start to restrain
If you only cure the bottom
All will be in vain"
(Shanxi peasant saying)

水是一条龙
先从顶上行
治下不治上
万事一场空

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Preamble

1) Abstract and Declarations.

Abstract.

This thesis is about the Chinese approach to the joint problems of flood control and regional development in the River Huang basin, and the major influences from which that approach has resulted. Throughout Chinese history, the River Huang has been notorious for the suffering it has brought in devastating floods two years out of three. In these floods thousands have died, crops have been ruined and whole villages buried up to the eaves. Meanwhile, the surrounding land usually suffered severe drought but, largely owing to the danger of initiating further flooding, use of the River Huang for irrigation was extemely limited.

The root of the River Huang problem is its extreme sediment load, unrivalled amongst the large rivers of the world. About one quarter of the 1.6 milliard tonnes which enter the lower reaches each year is deposited there, continuously raising the bed level between its protective dykes. Thus, the river is raised by several metres above the densely populated North China Plain across which it flows like a giant aquaduct. Any breach in the dykes during one of the large and transient Summer flood peaks, therefore, would cause extensive damage to property and a terrible loss of life. Meanwhile, the severe erosion of the loess plateau in the river's middle reaches, which gives rise to this extraordinary silt load, also has rendered the locality one of the poorest in China. In the past thousand, or so, years, the loess plateau has lost much of its vegetation cover, the climatic constraints, in any case severe, have worsened and the terrain has become dissected to an extreme degree.

Work since the end of the civil war has made remarkable progress in the face of these severe natural conditions. There has been no largescale Summer flood along the lower reaches, much work on the techniques and application of soil and water conservation has been undertaken, and many specific advances have been made. It has not all been plain sailing and a considerable proportion of this experience has been gained by way of expensive lessons. The Chinese experience, therefore, has much of value to offer the rest of the world.

This thesis goes some way towards furthering the communication of that experience. Technical detail is given where possible, especially with regard to the effects of the Sanmenxia reservoir on the delicate fluvial and alluvial balance of the River Huang, the comprehensive use of soil and water control measures as adapted to the various regions of the loess plateau, and the techniques which have been developed to put the silt and water of various sizes of flood peak to good use. Social, political and economic questions are also addressed, particularly with regard to questions of technological scale, technology transfer and the balance between industry and agriculture in development.

Declarations.

I declare that this thesis has been composed by me and that the work contained therein is my own.

I further declare that except where specifically indicated to the contrary all opinion expressed herein is my own and in particular may not be taken necessarily as representing that of any Chinese organisation, group or individual.

Paul Mosely 27 August 1982

2) Acknowledgments.

A great deal of help has been given by various people in the preparation of this thesis. I am sincerely grateful for all of it. In addition, I should like to pay special tribute to the following, who have each expended considerable amounts of time and effort on my behalf. They are mentioned in chronological order.

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3) Contents.

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6) Note on Units.

The following basic units are used throughout this thesis:

m	metre	^{o}C	degree Celsius
ha	hectare	%	per cent
l	litre	ppm	parts per million
g	gramme	人 (ren)	person
t	tonne	头 (tou)	head (of cattle)
s	second	只 (zhi)	head (of rabbit)
h	hour	羊 (yang)	sheep
d	day	¥ (Yuan)	Chinese currency unit
yr	year	£	Pound Sterling
W	Watt		

Powers are indicated using indices, multiple factors of ten are shown using the following, complementary, systems:

Factor	10^{12}	10^{9}	10^{6}	10^{3}	10^{2}	10
Prefix	tera	giga	mega	kilo	hecto	deca
Symbol	T	G	M	k	h	da

Factor	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}
Prefix	deci	centi	milli	micro	nano	pico
Symbol	d	c	m	μ	n	p

The following combinations of the above units appear in the text:

$m\ s^{-1}$	metres per second
$m\ yr^{-1}$	metres per year
m^{2} 人$^{-1}$	square metres per person
ha 人$^{-1}$	hectares per person
$ha\ yr^{-1}$	hectares per year
$km^{2}\ yr^{-1}$	square kilometres per year
$m^{3}\ s^{-1}$	cubic metres per second
$m^{3}\ yr^{-1}$	cubic metres per year
$m^{3}\ ha^{-1}$	cubic metres per hectare
$mg\ l^{-1}$	milligrammes per litre
kg 人$^{-1}$	kilogrammes per person
$kg\ ha^{-1}$	kilogrammes per hectare
$kg\ m^{-3}$	kilogrammes per cubic metre
t 人$^{-1}$	tonnes per person
$t\ d^{-1}$	tonnes per day

Note on Units (Continued)

t yr^{-1}	tonnes per year
t ha^{-1}	tonnes per hectare
t ha^{-1} 人$^{-1}$	tonnes per hectare per person
t ha^{-1} yr^{-1}	tonnes per hectare per year
t km^{-2}	tonnes per square kilometre
t km^{-2} yr^{-1}	tonnes per square kilometre per year
t m^{-3}	tonnes per cubic metre
GW h	gigawatt hours
TW h yr^{-1}	terawatt hours per year
人 d	man days
人 d ha^{-1}	man days per hectare
人 km^{-2}	people per square kilometre
羊 ha^{-1}	sheep per hectare
羊 km^{-2}	sheep per square kilometre
¥ 人$^{-1}$	Yuan per person
¥ 人$^{-1}$ yr^{-1}	Yuan per person per year
¥ kg^{-1}	Yuan per kilogramme
£ 人$^{-1}$	Pounds Sterling per person

7) List of Abbreviations.

CB	Current Background, US Consulate, Hong Kong.
CSHE	Chinese Society of Hydraulic Engineering.
ECMM	Extracts from China Mainland Magazines, US Consulate, Hong Kong.
GLF	Great Leap Forward.
JPRS	Joint Publications Research Service, US Department of Commerce, Washington, DC, USA.
QUSRL	Qinghua University Sediment Research Laboratory.
RHHI	River Huang Hydrotechnical Institute.
RHMRSWCCSG	River Huang Middle Reaches Soil and Water Conservation Comprehensive Surveying Group.
RHSRCG	River Huang Sediment Research Coordinating Group.
RHWCC	River Huang Water Conservancy Commission.
SCMP	Survey of China Mainland Press, US Consulate, Hong Kong.
SECPWC	Supreme Economic Council Public Works Commission.
SPCO	Sanmenxia Project Conference Office.
SPRCM	Survey of People's Republic of China Magazines, US Consulate, Hong Kong.
SRIHEWL	Shaanxi Research Institute of Hydraulic Engineering Waterways Laboratory.
USA	United States of America.
USSR	Union of Soviet Socialist Republics.
WCHPRI	Water Conservation and Hydroelectric Power Research Institute.
WDPLCMBRC	Weinan District People's Luohui Canal Management Bureau Revolutionary Committee.
WDSRMB	Weinan District Sanmenxia Reservoir Management Bureau.
WIHEE	Wuhan Institute of Hydraulic and Electrical Engineering.
XINHUA	Xinhua (New China) News Agency.

8) List of Dynasties.

Dynasty	Sub-period	Dates (AD except where shown)
Xia		c. 21st Century BC to c. 16th Century BC
Shang		c. 16th Century BC to c. 11th Century BC
Zhou	Western Zhou	c. 11th Century BC to 771 BC
	Eastern Zhou	770 BC to 256 BC
	Spring and Autumn	770 BC to 476 BC
	Warring States	475 BC to 207 BC
Qin		221 BC to 207 BC
Han	Western Han	206 BC to 24
	Eastern Han	25 to 220
Three Kingdoms	Wei	220 to 265
	Shu Han	221 to 263
	Wu	222 to 280
Early Jin	Western Jin	265 to 316
	Eastern Jin	317 to 420
Southern	Song	420 to 479
	Qi	479 to 502
	Liang	502 to 557
	Chen	557 to 589
Northern	Northern Wei	386 to 534
	Eastern Wei	534 to 550
	Northern Qi	550 to 577
	Western Wei	535 to 556
	Northern Zhou	557 to 581
Sui		581 to 618
Tang		618 to 907
The Five	Later Liang	907 to 923
	Later Tang	923 to 936
	Later Jin	936 to 946
	Later Han	947 to 950
	Later Zhou	951 to 960
Song	Northern Song	960 to 1127
	Southern Song	1127 to 1279
Liao		916 to 1125
Jin		1115 to 1234
Yuan		1271 to 1368
Ming		1368 to 1644
Qing		1644 to 1911
Republic of China		1911
People's Republic of China		Established 1949

Source: Beijing Foriegn Languages Institute, A Chinese English Dictionary, Shangwu Press, Beijing, 1980, p. 972.

9) Introduction.

i) The Subject Matter and the Scope of the Study.

This thesis is about the Chinese approach to the joint problems of flood control and regional development in the River Huang basin, and the major influences from which that approach has resulted. In the correct amount, water not only holds the potential for new benefits, but is the very lifeline upon which man depends. Yet, too little water continues to be a major problem in many parts of the world, and, likewise, too much frequently brings extensive suffering. Thus, the control and use of water resources is of the utmost importance to mankind. How, though, is this to be realised? Identifiable constraints exist of technical, political, social and economic kinds; and the combined effect of their respective influences is sufficiently varied, under the many different circumstances obtaining throughout the world, not just to allow, but to require, a multitude of different approaches. The study of which this thesis is the synthesis, sought to investigate the example of one such problem; one which is particularly noteworthy for the extreme nature of the many constraints encountered. It is also an attempt to discover the extent to which the various approaches, which have been tried so far, have succeeded or have themselves been modified in the process.

China's River Huang is extreme in several ways. It is the world's most heavily silted large river, both in terms of the sediment load, and of the sediment concentration. Its basin suffers a lack of water most of the year but, in the Summer months, the lower reaches are threatened by transient flood peaks. Throughout history, the precious water contained in these flood peaks, has either flowed to the sea unused, or has spread over large areas of the flat North China Plain, laying crops to ruin and causing the deaths of thousands of people, by drowning or in consequent famines. It is for this havoc that the River Huang is notorious throughout history and the world, and for which it has earned itself the epithet "China's Sorrow" (中国的忧患).

The River Huang's importance in history is not limited, however, to its propensity for the joint disasters of flood and drought. It is within its drainage area that the earliest human remains from China have been found, and where the Capital of China has been situated for the major part of history. Moreover, the North China Plain, although not part of the river's drainage area, nevertheless, has close links with the river in Chinese culture. For these reasons, amongst others, the River Huang basin is also known as the "Cradle of Chinese Culture" (中华民族的摇篮).

If the technical problem is both extremé and important, so, in recent years, have been many other factors. After a long feudal history, China, in any case a poor country, was wracked by half a Century of civil war and a number of floods of the R. Huang. This has been followed, after about ten years of recovery, by nearly twenty years of internal political chaos and external ostracism. Meanwhile, the pressures of a rapidly increasing population have lain emphasis on the need to control and exploit the R. Huang. Furthermore, for reasons which the following seeks, in part, to elucidate, some more extreme aspects of the general approach to these problems proved to be expensively in error.

In this thesis the pertinent facts are first set out in a clear and concise way. It is important to understand fully both the problem under discussion and the various events which have taken place. Technical details are supplied where possible, so that the reader may make his or her own judgement. Answers are sought to the question; what are the problems of the R. Huang and what has been tried to overcome them? Secondly, the reader's attention is drawn to a number of general questions, of which the R. Huang and its regulation may provide an example, or upon which they may bear relation. What can happen when a large dam is built across a river? What are the particular constraints imposed by heavily silted rivers? How readily may technology be transfered from one country to another? How important to a developing country is agriculture, in comparison to industry? How important is indigenous experience in comparison with that gained abroad? On what scale should solutions be sought?

Thirdly, a number of the above questions have a political content, and this thesis gives an account of how various decisions were taken and what influences on the decision makers there might have been. The value of the technical considerations is enhanced when it is recognised that river basin development has a political aspect, and the juxtaposition of this, with technical considerations provides a more complete picture of what took place, and why.

Fourthly, current opinion on the problem, and the approaches made to understand and resolve it, are described. What advances have been made, what lessons learnt? In particular, what has the Chinese experience, in tackling this extreme example of river basin development, to offer those tackling similar problems elsewhere?

Thus, the scope of this thesis is broad and, as demanded by the nature of river basins, cuts across the traditional academic boundaries. The technical questions will be of interest to engineers in general and to civil and hydraulic engineers in particular. The account of the problems caused by reservoir sedimentation will be of interest not only to sedimentologists, but to anyone concerned with reservoir design, construction or maintenance in arid areas where river silt loads are high.

It rapidly becomes apparent that the root of the R. Huang problem is its silt, and a major part of this thesis is concerned with the problems involved in trying to reduce the silt load of the river at source. Soil and water conservation measures, though, are important not only to the regulation of the river but, to an even greater extent, they are important to the development of the locality. As with river control along the lower reaches, the questions raised are not limited to technical ones.

Therefore, whilst the specific approaches to soil and water conservation will be of interest to agriculturalists and engineers alike, the discussion needs to be much broader, and economists and planners, for example, should be able to find matter of interest therein. Politicians, too, will find much here which falls within their field of concern. The questions range from how conflicts of interest between upstream and downstream water users are tackled, through policies for evacuees from an area to be flooded by a new reservoir, to the unique struggle of China to determine its own political identity. This is illustrated both by the split with the Soviet Union and the anarchy of the Cultural Revolution. In all these matters, sinologists, too, will find that this thesis has relevance to their field of study. Finally, the example of the Chinese experience, should be of general interest to anyone concerned with development problems in the third world, for it provides an example of one approach to a fundamental problem, from which both good and bad lessons may be drawn.

The two main topics covered by this study, the regulation of the lower R. Huang and the development of the loess plateau, from where the river's heavy silt load comes, are, by their nature, open ended. Certain policies have been tried and subsequently modified but, since the work is far from complete, assessment of their future, overall, success is somewhat speculative. This thesis does, however, attempt to provide the basis for such a speculative prognosis. Furthermore, specific questions are dealt with in depth. In particular, the numerous effects, extending both upstream and downstream, of the Sanmenxia reservoir, upon the delicate fluvial and alluvial balance of the R. Huang, are dealt with at length and with some technical detail. The uniquely Chinese mix of natural, social, political, economic and technical factors which have led to slow progress in soil and water conservation, are also a major point of attention, as are the reasons behind certain cruxial decisions affecting the past and future approaches to the many problems of the R. Huang basin. Detailed descriptions of certain advances, both technical and administrative, are also given.

Nevertheless, to go into all of these questions fully would require a study several fold larger than the present, and limitations to its scope have had to be imposed. Irrigation and hydroelectric power within the basin are described, but are not dealt with in a comprehensive manner. Similarly, it is acknowledged that reservoir sedimentation affects all the structures so far built across the mainstream and tributaries, but detailed discussion is restricted to Sanmenxia reservoir, the most notorious and serious example. The much debated schemes for interbasin transfers of water are discussed at slightly greater length than those topics just mentioned, but what could be sufficient material for a thesis on that subject alone, has necessarily had to be reduced to the proportion fitting its minor role within the whole question of the R. Huang basin development. Where discussion of certain topics is limited, they are, however, mentioned, and it is intended that this thesis should provide sufficiently detailed accounts, on a firm technical basis, to stimulate and facilitate their further research by others.

ii) Previous Related Studies.

Very little has been published, with a sound technical basis, or of comprehensive scope, in fields related to the R. Huang, and hardly any of that is in English. In the English speaking world, therefore, the problems of the world's most heavily silted large river constitute an important gap in our knowledge, one which this thesis goes some way towards filling. One reason for the lack of our knowledge has been the corresponding lack of published information in China itself. Comprehensive studies began only in the last Century and, whereas, prior to the end of the Civil War they were necessarily limited, thereafter, for many years, they were unnecessarily secret.

A number of papers on various specific aspects of the R. Huang basin are to be found, dating from the end of the last Century onwards. Their interest, though, lies more in their historical, than their technical, content, the latter being either insufficient or no longer so relevant. Their individual scope is very limited, but together they do make informative background reading. The proposals of Freeman, 1922, for the regulation of the lower R. Huang, for example, may be taken with the report of Lowdermilk, 1930, on the denudation of the loess plateau, and of Todd, 1935 and 1936, on the subjects of the Salachi irrigation scheme and the repair of the

R. Huang dykes after a breach, respectively, to form a general view of the state of hydraulic affairs in China during the Civil War years. Similarly, in Chinese, the collected works of Li Yizhi, 1956, provides a view of contemporary thinking.

There is only one early work, however, which presents any comprehensive appraisal, in English, of the various problems of the R. Huang basin. Furthermore, only eight of the twelve planned reports by the Supreme Economic Council Public Works Commission, ever reached publication (SECPWC, Eds., 1947). These reports describe and discuss in detail the problems and some of the solutions proposed at that time. Although they are comprehensive, their big shortcoming is that they are based largely on insufficient data. This is because of the relatively new and small nature of the collecting network at that time. Records generally went back only a few years, and only two full-size hydrological stations, at Shanzhou and Luokou, respectively, had been in operation between 1919 and 1933. In any case, whilst these reports provide a good review of the R. Huang's problems and the approaches under consideration at that time, there is, of course, no way in which they could be expected to bear close relation to the discussion of, for example, the later political events which form a part of the present thesis.

Since the end of the Civil War a number of books have been published, in Chinese, concerning specific problems which bear relation to the R. Huang. This thesis makes use of them along with the technical papers mentioned in the next section of this introduction. It is more apposite to mention here, however, that they are almost wholly concerned with narrow technical aspects, and not with an overall view. Furthermore, they differ in nature from this study in the important respect that this is an outsider's view and, therefore, the terms of reference will be different. The one exception is, perhaps, Deng Zihui, 1955, published in both Chinese and English, which is an overall report on the river's problems and the approach about to be embarked upon, at that time. Even this, though, is relevant mainly as a historical account of what was thought possible and desirable then, and lacks the experience gained in the twenty seven, or so, years since elapsed.

Foreign studies on this subject are very few. Generally, where the R. Huang has been studied, it has been as part of a thesis which concentrates on some other matter. Erisman, 1967, for example, makes a cursury study of the problems of the lower R. Huang, as part of his project to determine the optimum level of investment for the diversion of river flow to irrigation on the North China Plain. Nickum, 1974, likewise, is not dealing with the problems of the R. Huang as such, in his extremely thorough thesis on the Commune system, although much of his work is in the related field of water resource development.

Two studies do deal specifically with the problems of the R. Huang. Mitchell, 1961, though, deals mainly with irrigation and the prospective benefits to that which the Sanmenxia reservoir and interbasin transfer schemes might bring. In addition to being limited in scope, therefore, it is now also out of date, since, as the present thesis describes, the Sanmenxia reservoir has undergone a significant reconstruction, severely curtailing its usage, and the interbasin transfer schemes have been shelved.

The study by Greer, 1975, should be considered at a little greater length, since it is the only other study to deal comprehensively with the question, and to describe the reconstruction of the Sanmenxia project. The first four Chapters of his thesis address very much the same questions as are dealt with in the present thesis. Greer's point of emphasis, though, is more towards the philosophical basis of river basin management and, consequently, his discussion of the basic problems, centres more on organisational matters, whilst not being as detailed on technical ones. Likewise, whereas in the present study, the review of historical responses to the R. Huang's problems is more or less confined to technical considerations, Greer expands into the analogous and contemporary debates between legalism and confucianism. Yet, it is the latter halves of the two works where the divergence of approach is most marked. Greer, writing about eight years ago, was unable to obtain access to much information concerning the period after 1960, and was therefore constrained to rely upon news reports. China, at that time was in the throws of the

Cultural Revolution, and these circumstances are, together, reflected somewhat in Greer's concentration on the relative merits of technological or socialogical solutions to problems, and of centralised or decentralised organisational units. The present study, on the other hand, continues, with technical detail, the description of the problems encountered in the sixties and seventies, and then goes on to discuss the advances also made in that period, the status of the work, and its prospects for the future.

iii) The Sources used.

This thesis uses predominantly Chinese sources. They may be divided into three broad categories, namely; articles and books of general interest, written for the layman; technical books, journals and papers; and the notes made during nearly two years of study in China. Chinese newspaper articles also fall roughly into the first two categories, above, since news items tend to be quite general in nature, whereas articles making a specific technical argument tend to be written by those actually involved in the work.

There would appear to be no practical purpose, for the British side, of the inter-library loan agreements between Britain and China. Requests such as the author of this study made, through that system, for technical papers mentioned in the Chinese press, were met with no response; not even the courtesy of a refusal. Similar problems face scholars who wish to subscribe to Chinese journals. Subscriptions are available to a number of journals, for example, Zhongguo Shuili (Chinese Water Conservancy), but for a full-ranging discussion one really has to consult a wider selection. Regrettably, these are subject to all sorts of restriction. The journal Nisha Yanjiu (Sediment Research), for example, is freely available in China, and may be taken or sent out of the Country but, owing to difficulties with printing, will not be available for foreign subscription for about two more years. As an attempt to overcome this setback, some foreign experts, selected by the editors, receive complementary copies as and when available. The magazine, Renmin Huanghe (People's R. Huang), however, is marked 'For Internal Circulation only' and, although foreigners may, on occasion, succeed in subscribing to it inside China, it is likely to be impounded by the customs should one try to take or send it abroad. Similarly, the book Reservoir Sedimentation, written jointly by the Shaanxi Research Institute of Hydraulic Engineering Waterways Laboratory (SRIHEWL) and the Qinghua University Sediment Research Laboratory (QUSRL) was made available to the author only as QUSRL teaching material and may not normally be taken out of China. Other reports, for example, Selected Reports on R. Huang Sediment Research, published by the R. Huang Sediment Research Coordinating Group (RHSRCG, Eds., 1975), are marked 'Internal Document' and are available only inside China, and with special permission. Much of the material in these articles has been re-written and published openly by the Chinese Society of Hydraulic Engineering (CSHE, Eds., 1980), but the originals contain much more technical detail, and also provide a historical perspective, since they were written nearer the time of the events to which they relate. Finally, there is the systematic data collated and published annually by the RHWCC, which remains firmly closed to foreign eyes.

It is the technical books, journals and papers consulted in this way, which are the backbone of the present thesis. Nevertheless, there are three shortcomings which should be mentioned. The papers themselves were drawn up by different organisations, and are, therefore, sometimes inconsistant; the information is not always as complete as one would like; and they often claim an unrealistic degree of accuracy. Generally speaking, though, they are taken to be sufficiently reliable for the purpose to which they are put here. The book Reservoir Sedimentation and the magazine Renmin Huanghe were the most useful sources of this category.

The news items and books of general interest contain much useful information, but it is wrapped up in rhetoric, does not give its basis, and is often incomplete. Considerable effort is required to sift out the useful facts from the rest. The reliability of these sources is also much more variable. Statistics issued during the periods of the Great Leap Forward (1958) and the Cultural Revolution (1966 to 1976) are particularly dubious. Those from other periods, however, seem more consistent, and the book Ten Thousand Li Course of the R. Huang, by the R. Huang Water Conservancy Commission (RHWCC, Eds., 1979), is the major source of this category.

Similar arguments apply to the books and news releases in English or American. In this case further care is needed to weed out errors of translation. Examples include the unit, mu (0.067 ha) being given directly as hectares, and one milliard (10^9) being given as one billion (10^{12}). The only major source in English to have been used here, is SECPWC, Eds., 1947, and that is subject to the limitations mentioned in the previous section of this introduction.

iv) The Structure of the Thesis.

This thesis has six Chapters. The first Chapter, divided into ten Sections, describes the R. Huang basin and sets out, in some detail, the various problems to be found there, and their importance to the rest of China. The technical constraints imposed by nature upon the basin are given first, and they are then considered in a wider, historical context, so as to include their influence on Chinese culture and the Chinese people.

The second and third Chapters take a chronological look at man's attempts to change some of the natural characteristics of the basin, in particular, to stop flood damage. Chapter Two juxtaposes the various proposals throughout history, ending with the 1955 Multiple Purpose Plan, and the various arguments which surrounded some of its details. The first two Chapters together, then, describe the problem and the approach to be taken in dealing with it, and point out the ways in which the chosen approach was seen in its historical context.

The third Chapter, whilst continuing with the chronological account of Chapter Two, expands the timescale significantly, to look at the period since the announcement of the Multiple Purpose Plan. Its point of emphasis is also concentrated on the key project within that plan, the Sanmenxia reservoir. An assessment is made of the assumptions upon which it was based, and the reasons for its construction, when so many questions were still unanswered, are discussed. The effects of the construction of the reservoir upon the river, the surrounding land, and the people who lived there, are described and reasons are given to explain why it was thought necessary to abandon the original design and operational regime, and subsequently, to re-build the dam to allow the reservoir to be operated in a different way. The various effects of these changes are also assessed. The discussion of the assumptions upon which the original design has been based, includes a lengthy section on the factors which gave rise to slow progress in soil and water conservation on the loess plateau. Chapter Three ends with a discussion on the adoption of the original, erronious design, in juxtaposition with the design and operational regime which subsequently replaced it. An attempt is made to draw lessons from the debacle.

Not everything that took place in that period was a failure, however, and Chapter Four looks at the advances which have come about as a direct consequence of work on the R. Huang. Many of these advances are empirical, and the description therefore takes the form of examples.

The fifth Chapter presents an overall assessment of the work done in the R. Huang basin since the end of the civil war, not confined to the regulation of the lower reaches. It then describes the two major issues concerning the R. Huang which are currently under debate. This, in effect, is a description of the various Chinese view points on how the work of regulation and development of the R. Huang should proceed in the light of the experiences, both positive and negative, of the past thirty odd years.

In the sixth Chapter, the material presented in this thesis is summarised and discussed. The lessons of the Chinese experience are assessed and a prognosis is made about the future direction of the work, with particular regard to the debates outlined in Chapter Five.

Chapter One

General Description of the River Huang Basin.

1) Position and Course of the River Huang.

The River Huang rises over 4800 m above sea level, as the Yueguconglie stream, East of Mt. Yaladaze, in Qinghai Province in the Bayan Kala mountains of the Central Asian Plateau. It flows some 5460 km through Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, He'nan, and Shandong, before discharging into the Bo sea, at a point East of Ji'nan, Shandong.(1) Although its annual runoff of $43{,}200 \times 10^6\ m^3$ is only one twentieth that of the R. Changjiang, or 1.9 % that of the whole country, it is China's second largest river. Its drainage area is 752,400 km^2, which includes some 40 tributaries with catchments over 3000 km^2 and which contains 20×10^6 ha of arable land and supports a population of over 110×10^6 人.(2) (Figures 1-1 and 1-2, Table 1-1).

i) The Upper Reaches.

The upper reaches are taken to be the 3470 km stretch above Hekouzhen in Inner Mongolia, where the river drops 3840 m and drains about 400,000 km^2.(3) Of this some 265,000 km^2 of the Qinghai-Gansu highlands above Longyang Gorge near Guide, Qinghai, form the river's headwaters. This region is generally above 4000 m, and even in the river valleys, is nowhere below 2000 m.(4)

From Longyang Gorge to Qingtong Gorge, in Ningxia, the river drops 1300 m through a series of twenty gorges, which occupy over 40 % of the 918 km stretch and which account for half the estimated 26.5 GW power generation potential of the whole river.(5) Just within the loess covered area, this region has many small basins and plains between the gorges and situated in one of them is Lanzhou, Capital of Gansu Province.

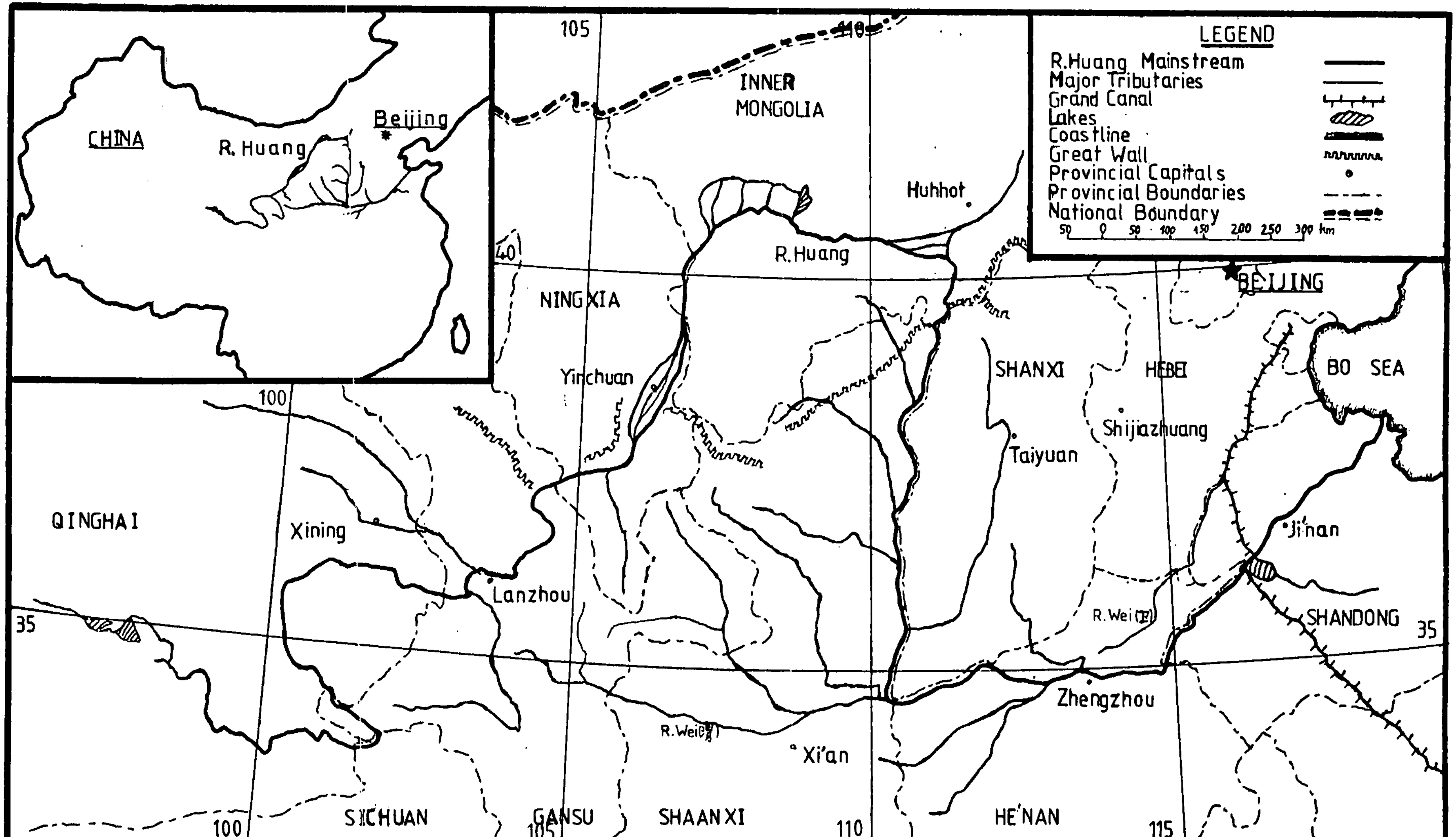


Figure 1-1 POSITION AND COURSE OF THE RIVER HUANG

TABLE 1-1 THE SLOPE OF THE R.HUANG

River Section	Length (km)	Change in Height (m)	Ave. Slope (%)
Source to Lake Eling	150	205	0.136
Lake Eling to Lake Zhaling	249	130	0.052
Lake Zhaling to Guide	960	1,680	0.175
Guide to Lanzhou	382	850	0.226
Lanzhou to Yinchuan	348	524	0.151
Yinchuan to Baotou	560	71	0.0127
Baotou to Longmen	829	630	0.076
Longmen to Tongguan	133	59	0.044
Tongguan to Shanzhou	86	16	0.0186
Shanzhou to Mengjin	195	171	0.088
Mengjin to Dongbatou	222	49	0.022
Dongbatou to Luokou	341	45	0.013
Luokou to Mouth	245	20	0.008

Source: LIU Dongsheng, et al., 1964, page 2.

Note: These figures differ from those given in the text, which are drawn from other sources. The differences are small, and this table is included to give a consistent general view of the changes in the slope of the river along its course. Shanzhou is situated some 20 km upstream of the dam of the Sanmenxia reservoir.

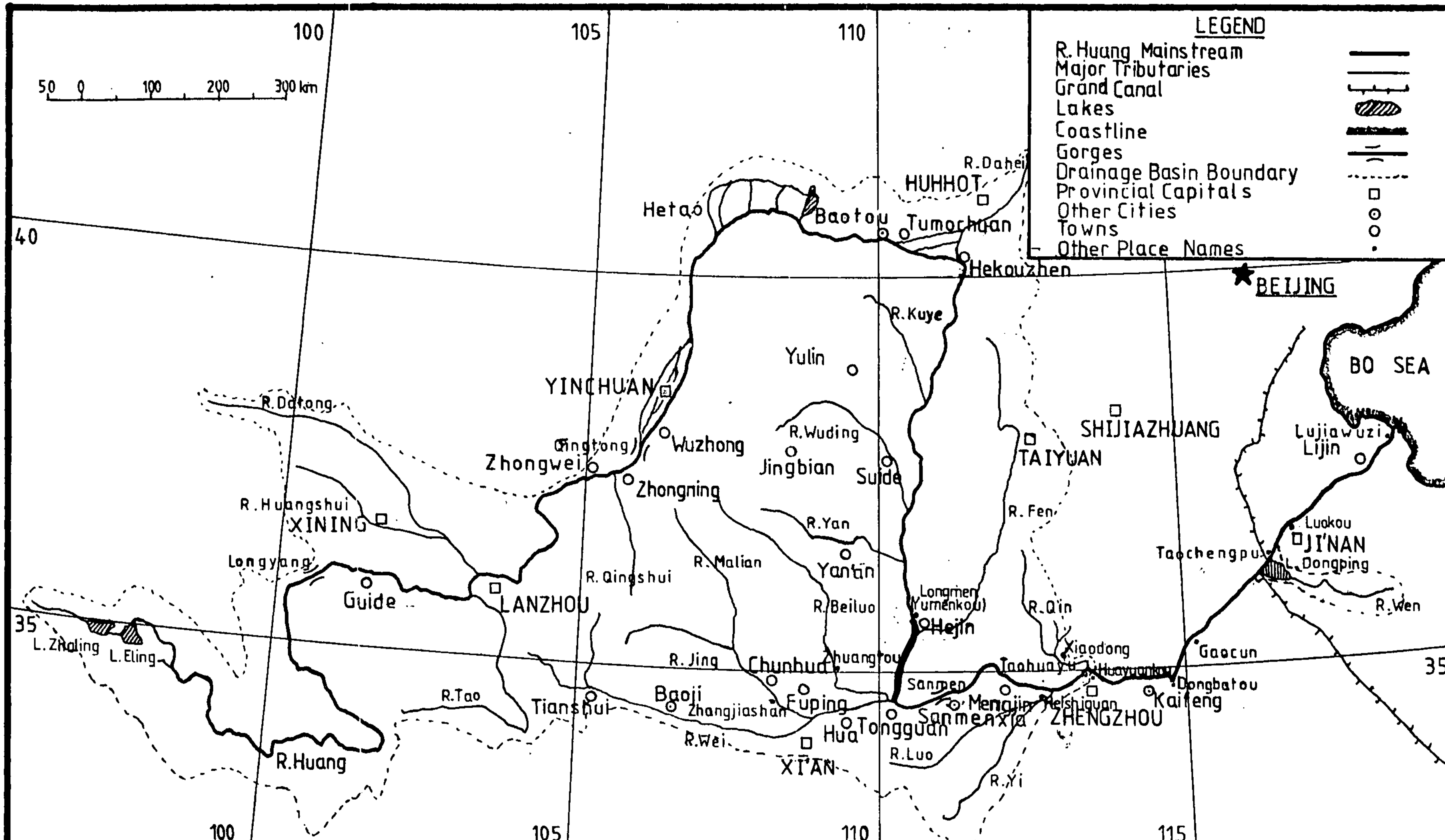


FIGURE 1-2 MAJOR TRIBUTARIES AND IMPORTANT PLACES

The River Huang then makes a diversion in a great loop Northwards through Ningxia to Hekouzhen, in Inner Mongolia, forming as it does so the Eastern and Northern boundaries of the E'erdousi (Ordos) Plateau. This is a very flat plateau about 1000 m above sea level, covering 130,000 km^2, though not all of it is drained by the River Huang, whose catchment in this 867 km stretch is 107,000 km^2.(6) The river has a very gentle slope here (total drop about 120 m) and silt may be deposited and some flooding may occur similar in nature to, but far less serious than, that of the lower reaches.

ii) The Middle Reaches:

iia) Hekouzhen to Tongguan:

The 1210 km stretch from Hekouzhen to Taohuayü, near Zhengzhou, Capital of He'nan Province, comprises the R. Huang's middle reach. About 27 km downstream of Hekouzhen the river turns Southwards and enters a series of deep rocky gorges which form also the border between Shanxi and Shaanxi.

In the 725 km stretch from Hekouzhen to Longmen (otherwise called Yumenkou) the river drops 610 m and receives many silt-laden tributaries from the loess region either side; on average, one every kilometre along the mainstream.

Below Longmen the river widens, to as much as 15 km in places and in the next 130 km stretch to Tongguan, it drops about 50 m and is joined by three major tributaries, the rivers Fen, Beiluo and Wei (渭).(7)

iib) The Tongguan Confluence.

Just above Tongguan is the confluence of the Huang, Wei and Beiluo rivers. This confluence, where the river Huang makes a sharp Eastward turn, is worthy of being singled out for extra attention, since it plays a special role in the problems to be discussed in Chapter 3. (Figures 1-3 and 1-4).

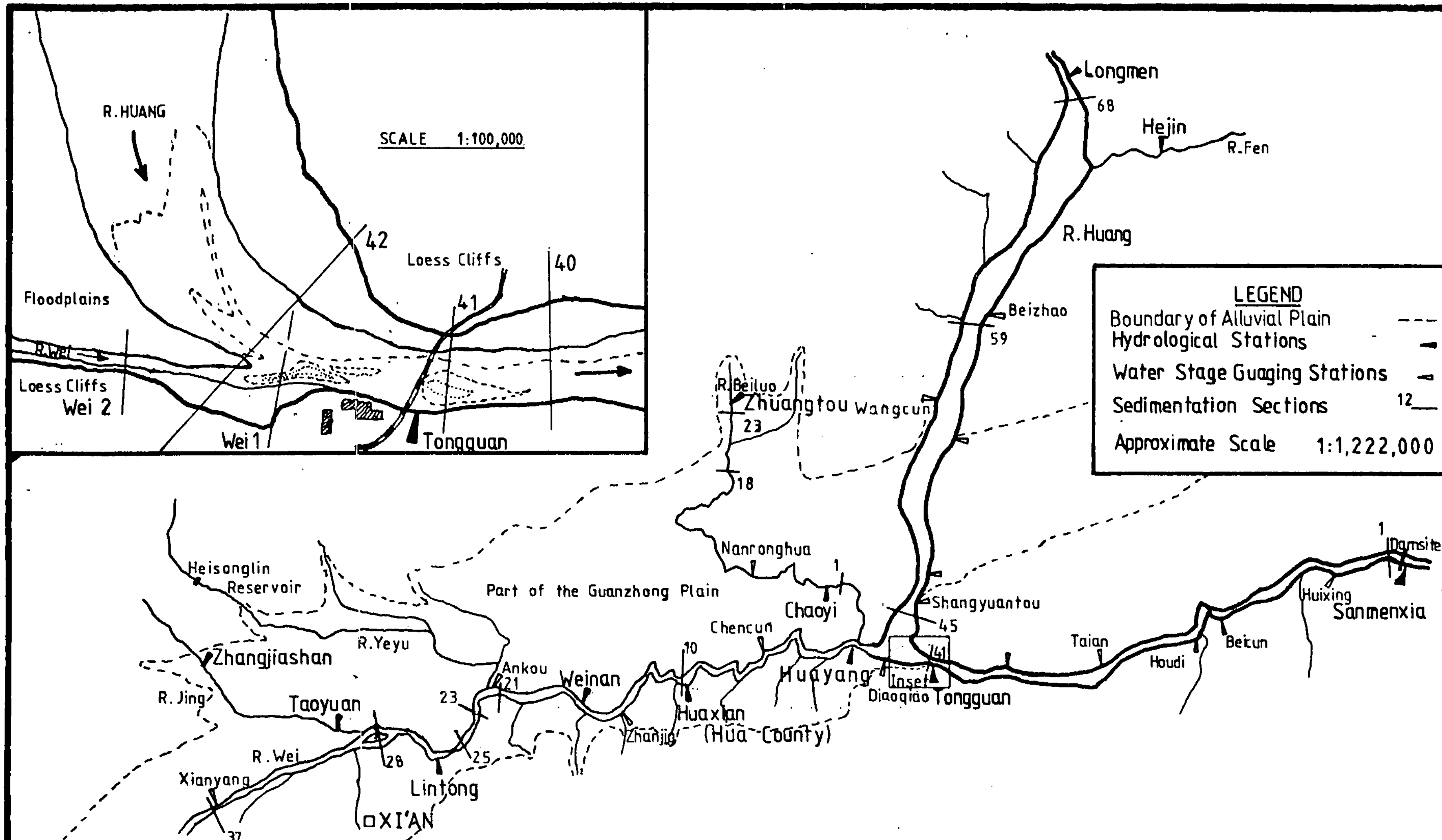


FIGURE 1-3 THE TONGGUAN CONFLUENCE

SOURCES: Note 8

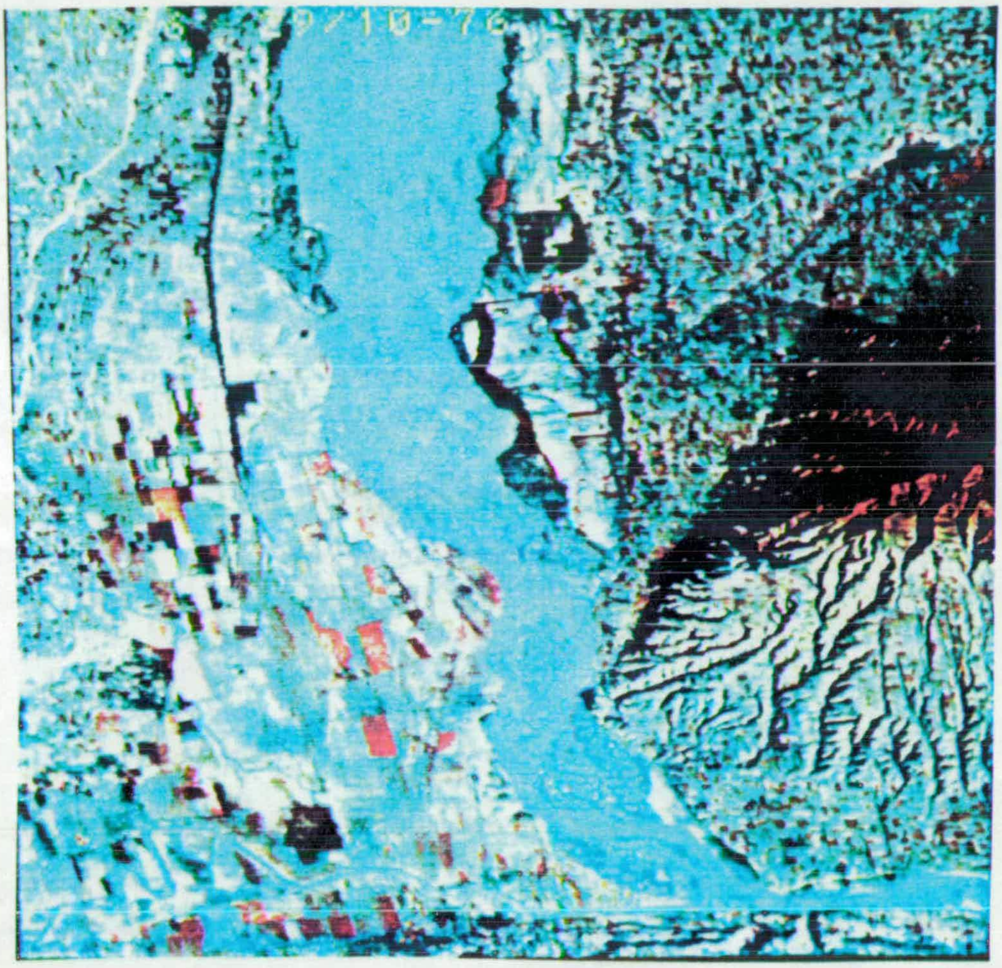


FIGURE 1-4 SATELLITE FALSE COLOUR IMAGE OF THE TONGGUAN CONFLUENCE

SOURCE: Note 9

The R. Huang just above the confluence is some 10 km wide, but its Eastern outlet is less than one kilometre wide.(10) Thus whenever one or more of the rivers is in spate the flooded area increases. It is marshy here and the river channels are liable to change their position. Indeed, the Beiluo river at one time flowed into the River Huang directly, rather than via the River Wei as at present, a 10 km Eastward shift of the River Huang in the past 30 years.(11)

The gradients of the three rivers, Huang, Wei and Beiluo, just above the confluence are 0.035 %, 0.01 % and 0.022 % respectively.(12) When the R. Huang is in spate, it is not uncommon for its waters to sweep Westwards, flooding the mouths of the Wei and Beiluo rivers. Under such circumstances silt may be deposited there which would change the slope of the tributaries' lowest reaches, hindering or even blocking the flow until such time as a flood should occur in them to wash out the deposits. In any case, it should be noted that the bed level at Tongguan is the local datum for the fluvial and alluvial processes in the lower Wei and Beiluo rivers and plays an important role in determining such factors as their flood carrying capacity and whether their beds are scoured, deposited upon, or remain in equilibrium.(13)

iic) Tongguan to Taohuayu:

Below Tongguan the R. Huang flows for the next 113 km between loess bluffs 20 m to 60 m high, and varying in separation between 1 km and 6 km, to the site of the famous Sanmenxia, or Three Gates Gorge. This stretch drops about 45 m and now forms the main part of the Sanmenxia Reservoir, which has the shape of a deep main channel between floodplains, within the original loess bluffs.(14) The bed at present can be divided into upper and lower sections. The upper section exhibits a delta deposition pattern with a top slope of between 0.014 % and 0.015 % during the low water season, whilst in the flood season scouring is restored and the bed slope is between 0.022% and 0.023%. The lower section, for about 62 km to the dam, is more or less in equilibrium, with a bedslope of between 0.016 % and 0.018 %. The slope of the floodplains will vary with the discharge of the most recent overbank flood; at present it is 0.012 %, after the flood of 1967.(15)

Below the dam there is first a 160 m drop through 150 km of rocky gorges up to 600 m high and generally about 250 m apart, interspersed with small alluvial floodplains, until, at Mengjin in He'nan the loess bluffs on the Northern bank suddenly recede, become discontinuous and low (10 m to 40 m). The Southern bank continues to be formed by loess bluffs about 125 m high, but the Northern bank is formed by levees. The drop in the last 92 km to Taohuayu is 25 m. The river itself is usually about 3 km broad and the floodplains are not high. In this section the R. Huang is joined by three tributaries, the Yi, Luo and Qin rivers.(16)

iii) The Lower Reaches:

The lower reaches comprise the 700 km to 800 km stretch across the North China Plain from Taohuayu to the mouth. It is wide in the upper part and narrow lower down. For all but about 100 km in Shandong province, where the Southern bank is formed by hills, both banks are continuously lined by a total of 1340 km of main flood protection dykes and the river flows across the plain, raised by deposition within the dykes to about 4 m (10 m in places) above the surrounding land, like a giant aqueduct. The total drop is 95 m. There are three distinct sections of the lower reaches.(17) (Figure 1-5).

iiia) Taohuayu to Gaocun.

The first section of the lower reaches has the appearance of a broad braided stream. The dykes are between 5 km and 20 km apart and the river consists of a main channel 1 km to 3 km wide between extensive floodplains. In places, smaller 'production dykes' have been built within the main dykes to protect cultivation on the floodplains. The main channel is choked with sand bars and is divided into many interwoven streams. The main watercourse is forever shifting and sometimes can move from one bank to the other within a few days.

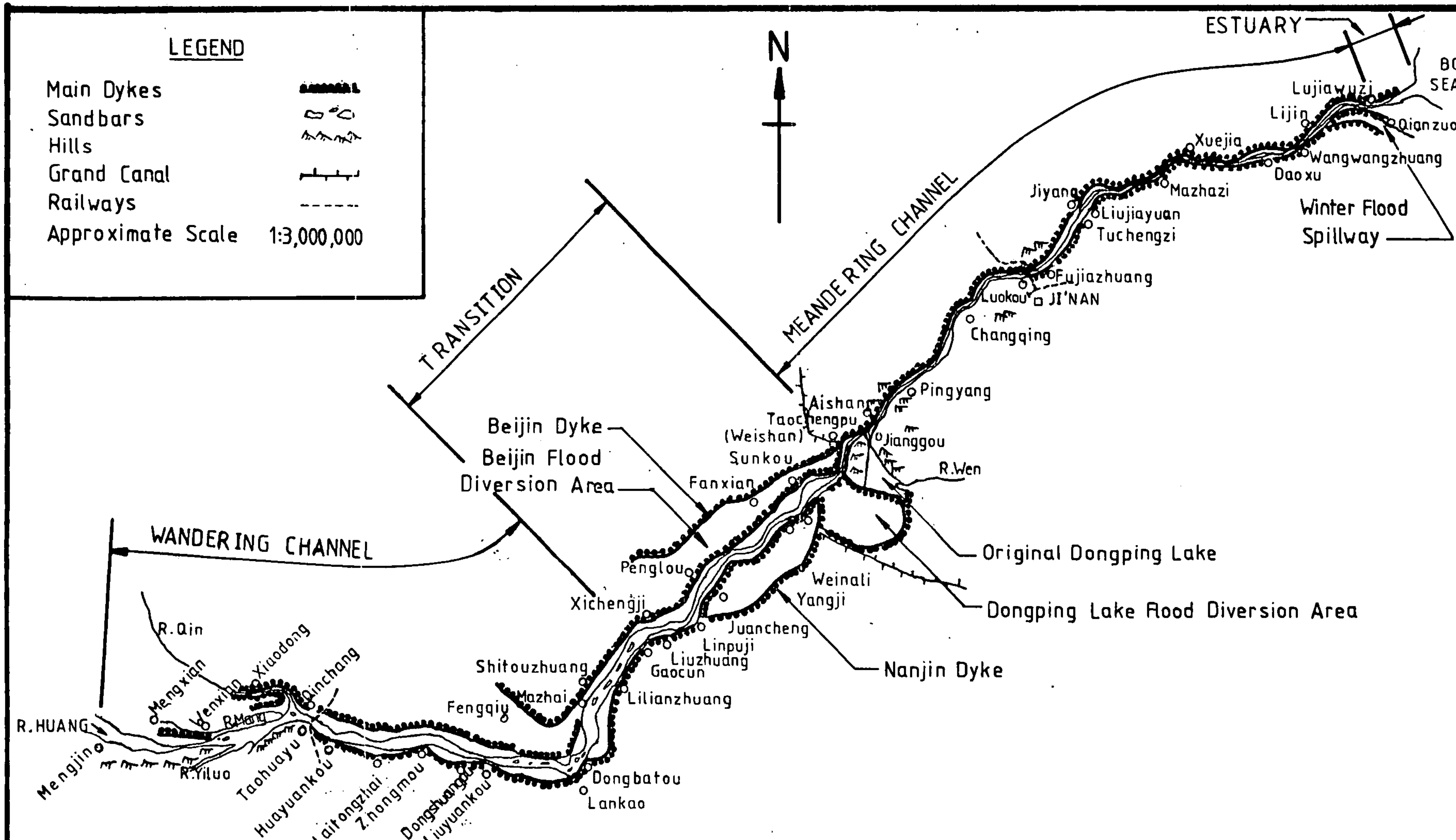


FIGURE 1-5 SOME FEATURES OF THE LOWER RIVER HUANG SOURCE: Note 18

For this reason the term 'wandering stream' has been adopted to denote both its braided and shifting characteristics. The constant wandering of the water course poses a threat to the dykes. The river has alternate zones of divergence and convergence. In the former, the main channel can migrate freely, but in the latter it is confined by protruding cliffs, erosion-resistant shorelines or bank protection works.(19)

iiib) Gaocun to Taochengpu.

This 146 km stretch forms a transitional reach from a wandering to a meandering pattern. The main dykes are about 5 km apart and the water course is fairly stable. Apart from the main dykes, there is a secondary set, whose total separation is about 35 km and parts of the area between the two sets along the Northern bank have been designated as flood detention areas. Similar use has been made of the Dongping lake on the Southern bank in the region of Taochengpu. It is through this lake that the lower reaches' only significant tributary, the R. Wen, makes its entry.

iiic) Taochengpu to the Estuary.

In the lower section, to Lujiawuzi the channel contracts to between 0.5 km and 2.0 km and systematic bends develop. No loops form, however, as the bends are too closely controlled by bank protection works. The meandering coefficient is 1.2.(20)

The last 50 km to the sea is considered to be the Estuary region. Some 1200 $\times 10^6$ t of sediment enter the estuary each year, of which two thirds are deposited in the delta area and along the coastlines. At present the estuary delta is about 2220 km^2 and this is increasing at a rate of about 50 $km^2\ yr^{-1}$, whilst the coastline is extending by 1.4 $km\ yr^{-1}$. The upper parts of the estuary have been stabilised, but in the lower 25 km, the river is allowed to wander freely over its delta, in an attempt to slow down the rate at which the lower reaches' slope is decreasing.(21)

2) The Climate of the River Huang Basin.

For the most part the R. Huang basin lies in arid and semi-arid territory whose climate is controlled by the Mongolian and Pacific anticyclones. Winter is dominated by its Mongolian anticyclones and is characterised by several cold Northerly waves in which the temperature may drop by 10° C in 24 hours and there may be dust storms accompanied by slight rain or snowfall. The frequency of storms, and their intensity, increase in the Spring as the influence of the Pacific anticyclones develops and cold fronts sweep from West to East. In Summer the warm maritime airmass surges in and the whole basin falls within the scope of the continental depression, with pressure down to 752 mm. Winds are Southerly and moist and when they meet cold Northerly air flows, precipitation results. In the middle reaches this often occurs as very violent rain or hail storms. In the Autumn, as the low pressure troughs recede, more moderate rainfall occurs as the cold Northerly fronts are obstructed by high ground.

The general climatological features are shown in Table 1-2, and of particular note is the uneven distribution and large variation. Annual temperature variation for example, is about 30° C, and in 1934 at Xi'an it was 57.7° C (-12.5° C to 45.2° C). Precipitation varies from about 150 mm in the Great Loop region to 750 mm in the Southeast (Figure 1-6) but its seasonal variation is even more extreme. Of the total precipitation, 70 % falls in June, July and August, and less than 5 % between December and February. The storms which frequent the middle reaches in Summer may be so violent that, in extreme cases, between 160 mm and 300 mm can fall in a single day. The annual variability is between 100 % and 125 % at the Southern margin, rising to over 150 % in the Northwest, which renders the rainfall of the area unpredictable and this is a major factor in the difficulties faced by the inhabitants of the region. Evaporation is very high, being greater than rainfall in the middle and lower reaches. In recent years the frost-free period has also become unstable.(23)

TABLE 1-2 CLIMATIC FEATURES

PLACE	AVERAGE TEMPERATURES (°C) Annual	January	July	ANNUAL PRECIPITATION (mm)	ANNUAL EVAPORATION (mm)
Headwaters *		-16.0	-8.0	250.0	
Xining *		-6.4	18.3	376	
Lanzhou	9.5	-6.5	22.8	337.6	1883.9
Yinchuan	8.7	-9.1	23.8	182.7	1432.8
Baotou *		-14.1	22.2	409.5	1409.0
Huhhot	6.6	-12.8	23.4	392.2	1631.7
Taiyuan	10.1	-7.7	25.2	382.2	1770.6
Suide	10.0	-8.6	24.8	441.9	1816.0
Yan'an	9.3	-6.2	22.9	597.1	1513.2
Tianshui	11.0	-3.5	22.4	481.2	1479.3
Baoji	13.0	-0.6	25.1	754.0	1398.1
Xi'an	14.0	-0.5	27.1	330.1	1420.0
Tongguan *		-2.4	26.9	471.1	1423.4
Shanzhou *		0.5	28.2	545.2	1249.4
Lijin *		-3.2	27.6	487.5	1410.3

Sources: LIU Dongsheng, et al., 1964, page 4. *GREER Charles E, 1975, page 25.

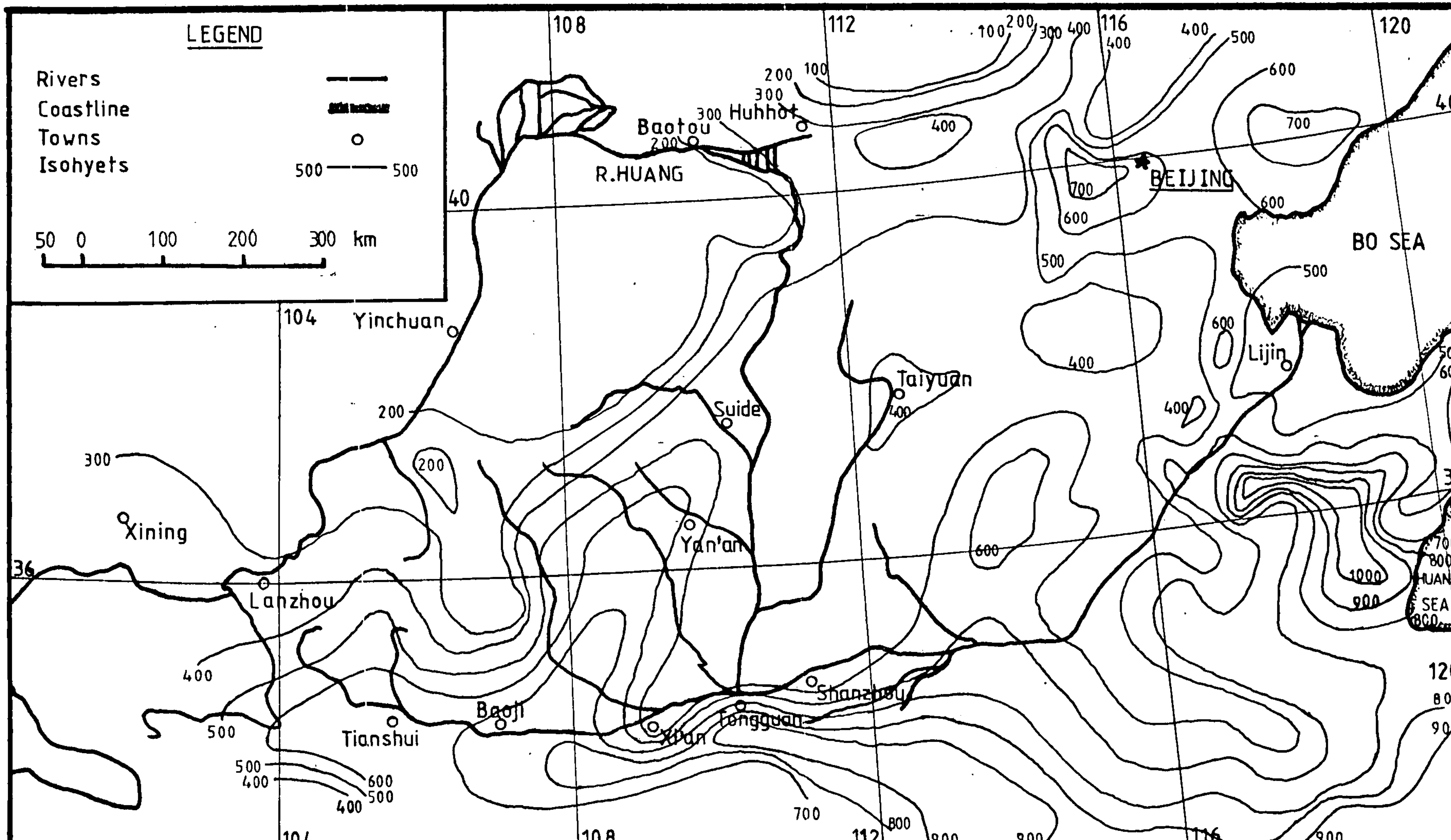


FIGURE 1-6 AVERAGE ANNUAL PRECIPITATION SOURCE: Note 22

3) Hydrology of River Huang Basin.

i) Runoff.

Owing to high evaporation rates and the extreme permeability of the loess which covers most of the region, runoff in the middle reaches of the R. Huang and its tributaries is very low (Table 1-3). In the lower reaches the reason is different, namely that for the main part the river runs above the level of the surrounding land and receives little water as runoff therefrom.

ii) Discharge.

The mean discharge at selected stations along the R. Huang is shown in Figure 1-7. It may be seen that over 50 % comes from the area above Lanzhou, which accounts for less than 30 % of the drainage area. This is very important during the Winter and early Spring, when hardly any rainfall occurs in the lower and middle reaches, since there the discharge follows very closely the rainfall, and varies in the same seasonal way. By the same token, whilst the upper reaches contribute a not insignificant flow during the Summer months, it is from the tributaries of the middle reaches that the large and transient flood peaks come which so trouble the lower reaches. (Chapter 5).

iii) Sources of River Huang Flood Peaks and Silt.

Above Hekouzhen in Inner Mongolia there is a little over 100×10^6 t of silt in a little over 20×10^9 m^3 of water, thus it is basically clear. Yet by Mengjin these figures are increased by about 1.5×10^9 t and 20×10^9 m^3 respectively. Thus, in general terms it can be seen that the source of R. Huang silt is the loess plateau of the middle reaches. A more detailed presentation of the data for the source of R. Huang silt is given in Table 1-4, and with reference to Figure 1-13, will demonstrate that the sediment of the rivers Wei, Fen and Jing (except its tributary, the Malian) will be predominately fine, whilst that of the tributaries between Hekouzhen and Longmen, and the rivers Beiluo and Malian, will be coarser.

TABLE 1-3 MAINSTREAM AND TRIBUTARY RUNOFF COEFFICIENTS

River	Station	Runoff (mm)	Precipitation (mm)	Effective* Evaporation (mm)	Runoff Coefficient (%)
Huang	Lanzhou	161	340	179	47.35
"	Baotou	65	280	215	23.21
"	Shanzhou	58	405	347	14.32
"	Luokou	63	415	352	15.18
Wei	Huaxian	91	430	339	21.16
Beiluo	Zhuangtou	21	380	359	5.53
Jing	Zhangjiashan	43	410	367	10.49
Fen	Hejin	58	410	352	14.15
Yiluo	Heishiguan	170	550	380	30.91

Source: LIU Dongsheng, et al., 1964, page 2.
*Evaporation and percolation losses expressed as the equivalent rainfall.

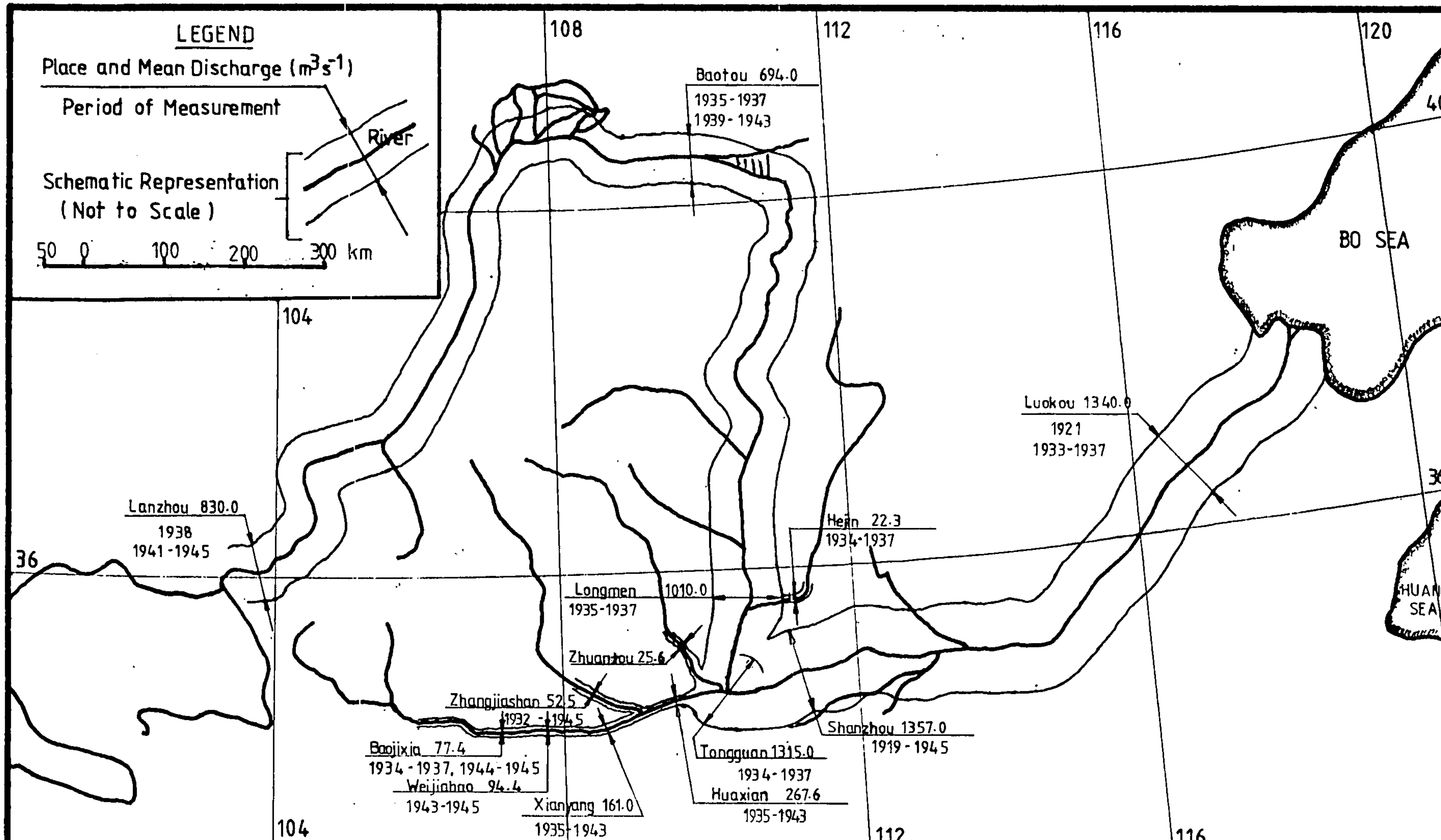


FIGURE 1-7 MEAN DISCHARGE AT SELECTED PLACES

SOURCE: Note 24

TABLE 1-4 SOURCE OF RIVER HUANG SILT, BY REGION (1965-1974)

REGION		AREA (km^2)	ALL SIZES		DIA. d<0,025mm		DIA. d>0,05mm	
PROVINCE	CATCHMENT		AMOUNT ($t \times 10^6$)	PROPORTION OF TOTAL (%)	AMOUNT ($t \times 10^6$)	PROPORTION OF TOTAL (%)	AMOUNT ($t \times 10^6$)	PROPORTION OF TOTAL (%)
Inner Mongolia	Below Hekouzhen	15600	134	8.10	29	5.52	91	13.30
Shanxi	N. W. Shanxi	30500	259	15.60	83	15.90	115	15.60
"	R. Fen Basin	38700	26	1.56	11	2.10	8	1.13
"	Sub-total	69200	285	17.30	94	18.00	123	16.70
Shaanxi	Yulin District	47400	419	25.30	95	18.20	252	34.40
"	Yan'an District	35400	232	14.00	64	13.20	104	14.20
"	Guanzhong	35500	40	2.40	9	1.67	20	2.79
"	Sub-total	118300	691	41.70	168	32.00	376	51.60
Gansu	Within R. Jing Basin	37100	240	14.50	94	18.00	64	8.80
"	Within R. Wei Basin	26200	180	10.90	86	16.50	37	5.08
"	Sub-total	63300	420	25.40	180	34.50	101	13.80
Hekouzhen to Tongguan (Sum of above)		266400	1531	92.50	470	90.00	693	94.67
River Huang Basin Above Hekouzhen		386000	124	7.50	52	10.00	39	5.33
Grand Total		652400	1655	100	522	100	732	100
'Long, Hua, He, Zhuan'* Total		667900	1613		528		665	
Difference		15500	-42		6		-67	

Source: GONG Shiyang, XIONG Guishu, 1980, page 44.

*The sediment yield of the upper and middle reaches is generally taken as the sum of the sediment loads at the Longmen, Huaxian, Hejin, and Zhuantou stations (abbreviated as shown), and is given for reference.

Waters from the areas above Hekouzhen or below Sanmenxia (notably the Rivers Yi, Luo and Qin) will be relatively clear. It may further be seen that 80 % of the sediment from these regions (74 % of the sediment from all regions) comes from a smaller area, 130,000 km^2, and 50 % (46.5 % of sediment from all regions) comes from just 58,000 km^2. For coarse silts (Diameter >0.05 mm), the corresponding areas are 110,000 km^2 and 43,000 km^2, respectively.

An analysis of rainfall and R. Huang discharge and sedimentation data has been made and has shown that there are six main different circumstances which give rise to flood peaks in the lower R. Huang.(26) They are :

i) Light rain over the whole middle reaches area.
ii) Fairly large floods from the coarse sediment area, little or no floods from the clear water source areas.
iii) Medium floods from the coarse sediment source area supplemented from the clear water source areas.
iv) Simultaneous large floods from the coarse sediment area, the fine sediment source area and the clear water areas.
v) Principally from the clear water areas, with some from the coarse sediment source areas.
vi) Mainly from the fine sediment source areas.

The results of the analysis are presented in Table 1-5. These were analysed in conjunction with flood data for the lower R. Huang and the following observations were made :

i) Floods from groups i) and vi) (above) give rise to only slight deposition in the lower R. Huang.
ii) Floods from group ii) are created by concentrated storms and though their hydrograph has a high peak, the amount of water brought down is small. In the lower R. Huang the hydrograph becomes flatter, because of channel storage, and the flood plains are not inundated. Very serious channel deposition results from these floods, 60 % of the total recorded; this can even extend to

TABLE 1-5 MAIN FLOODPEAK SOURCE AREAS AND THEIR INFLUENCE ON DEPOSITION AND SCOURING (1952-1960 AND 1969-1978)

FLOODPEAK SOURCE AREA(S) — Numbers (i) to (vi) refer to floodpeak source area groups identified in the text	No. of Occurr-ences	Proportion of Total (%)	Floodpeak Characteristics at Huayuankou: Qm (m^3s^{-1})	Floodpeak Characteristics at Huayuankou: $\bar{S}/\bar{Q}$ ($kg\ s\ m^{-6}$)	Proportion of 'San, Hei, Xiao'* Water Discharge From Various Tributaries** (%): I	II	III	IV	Proportion of 'San, Hei, Xiao' Silt Discharge From Various Tributaries (%): I	II	III	IV	Rate of Deposition or Scouring (-) in the Lower Reaches ($t \times 10^3\ d^{-1}$): Above Gaocun	Gaocun to Aishan	Below Aishan	Whole of Lower Reaches	Proportion of Deposn. or Scourg. Attributable to Source Area (%)
(i) Light Rain Over the Whole Middle Reaches Area	7	6·8	3680	0·0216	29·9	22·3	26·8	17·1	3·7	59·6	34·2	5·6	3790	64	-441	3413	4·0
(ii) Fairly Large From Coarse Areas	13	12·6	6830	0·0516	26·8	60·8	18·1	6·3	1·2	122·5	15·9	0·3	26200	3490	1310	31000	59·8
(iii) Medium From Course Areas Supplemented From Clear Areas	22	21·4	4280	0·0360	46·0	33·3	14·8	8·5	5·6	97·0	17·7	0·9	5150	670	-370	5450	13·6
(iv) Large From Coarse, Fine, and Clear Areas Simultaneously	10	9·7	11742	00131	23·7	24·2	26·1	22·8	3·0	72·2	30·2	5·2	13130	8560	-2710	1899	28·2
(v) Mainly From Clear Areas Some From Course Areas	47	45·6															·9·0
(v) All Three Clear Areas Simultaneously	6	5·8	4750	0·0110	56·8	9·9	21·6	11·3	10·2	40·0	23·2	1·6	-1480	256	-4420	-1666	-1·9
Two Areas: Above Hekouzhen, and From Mountains South of R.Wei	4	3·9	4620	0·0093	64·6	10·8	26·7	4·5	13·1	52·5	42·4	2·8	2503	-674	-1078	751	0·4
Two Areas: Above Hekouzhen, and From the Rivers Yi, Luo, and Qin	3	2·9	3520	0·0094	57·2	4·6	18·6	15·0	15·9	35·4	14·1	3·4	1253	-976	- 874	- 597	-0·1
Two Areas: Mountains South of R.Wei, and From the Rivers Yi, Luo, and Qin	15	14·6	5150	0·0102	30·1	10·2	40·7	17·2	8·1	26·0	44·4	6·1	-381	−301	-1115	- 1797	-4·6
One Area: Above Hekouzhen	13	12·6	3830	0·0113	75·8	9·9	10·2	3·5	19·2	56·0	8·3	0·3	615	-130	-464	21	-1·2
One Area: Mountains South of R.Wei	1	1·0	4920	0·0074	41·7	1·3	63·5	5·8	7·0	9·4	39·2	0·2	2050	860	-2880	20	0·0
One Area: Rivers Yi, Luo, and Qin	5	4·9	5400	0·0119	33·5	11·2	7·8	38·5	7·3	49·0	9·2	15·5	- 2144	387	-570	-2327	-1·6
(vi) Mainly From Fine Areas	4	3·9	5730	0·0210	34·0	8·8	46·0	9·0	4·6	21·5	72·3	1·0	5720	2450	1150	9320	3·4
Average			5500	0·0226	42·3	23·4	22·6	12·5	7·7	66·8	25·6	3·1	6150	1441	-535	7056	

Source: QIAN Ning, WANG Keqin, YAN Linde, FU Renshou, 1980, page 58.

*Oncoming water and silt for the lower reaches are taken as the sum of those measured at Sanmenxia, Heishiguan, and Xiaodong stations, abbreviated as shown.

**Tributaries arranged in groups: I, above Hekouzhen; II, between Hekouzhen and Longmen, R. Malian, and R. Beiluo (course sediment areas); III, R. Fen, upper R. Wei, R. Jing mainstream and tributaries except R. Malian (fine sediment areas), and mountain tributaries South of R. Wei; IV, R. Yi, R. Luo, and R. Qin.

Shandong province.

iii) Floods of group iii) cause moderate channel deposition.

iv) The floods of the fourth group have the highest discharge and generally cause the floodplains to be inundated. However, although deposition resulting from these floods is second only to those of group ii), accounting for 28.2 % of the deposition recorded, most of it occurs on the flood plains of the upper two stretches, which, in effect, deepens the main channel there and improves its flood carrying capacity, whilst in the lower stretch in Shandong, scouring occurs, which is also beneficial.

v) Floods of group v) are the most common and generally lead to scouring of the bed, sometimes over the entire stretch to Shandong. However, this is slight and exerts only a restraining effect on the general accretion of the lower R. Huang.

The study of the source of R. Huang silt has shown that there is a very close correlation indeed between soil erosion and R. Huang sediment. The amount of silt entering small tributaries was found to equal the amount of soil lost from the catchment area, and the larger tributaries and R. Huang mainstream were found to be in long term equilibrium. Thus it is concluded that the delivery ratio of sediment to the R. Huang is close to unity.

The sediment content of the R. Huang, as is the case for its water discharge, thus follows closely the seasonal variation in rainfall over the loess plateau. In the Summer months July to October, 58.5 % of the annual discharge carries 83.8 % of the annual sediment load.(27)

iv) Fluvial Processes of the Lower River Huang.

The lower R. Huang is aggrading at a rate of about 0.07 m yr^{-1}, with the main channel and floodplains essentially rising in parallel.(28) The deposition is caused mainly by particles coarser than 0.05 mm., over 350 x 10^6 t of which enter the lower reaches each year and between 50 % and 60 % of which are deposited. (Table 1-6, Figure 1-8). Furthermore, although 87.6 % of the fine particles which enter the lower reaches are subsequently discharged into the sea, they can still have a marked effect upon the balance of deposition and scouring therein, as will now be explained.(29)

In rivers with fairly clear water, the sediment discharge rate, Q_s is uniquely determined by the water discharge, Q, according to the relation, $Q_s = KQ^a$ where K is a constant, and for the lower R. Huang in times of clear water flow, the exponent, a, is about 2. Yet when heavily silted waters come down, the relationship between the sediment and water discharge becomes more complicated. The sediment discharge can vary by an order of magnitude for the same flow conditions, and only by introducing the oncoming silt concentration can a more definite relation be found. It is $Q_s = KQ^a Su^b$, where Su is the oncoming concentration and, for the lower R. Huang, $a + b = 2$ and $1.1<a<1.2$; $0.8<b<0.9$. Thus, the greater the oncoming sediment load, the greater the sediment discharge. This is the so-called "more come - more go" law of the lower R. Huang. There is a point, as the sediment concentration increases, at which deposition abruptly gives way to high intensity erosion. This point, and the degree of erosion, depend upon the proportion of very fine particles in the sediment (<0.01 mm) but for the lower R. Huang it usually occurs at around 400 kg m^{-3}. Hyperconcentrations of this type do not occur very often and this type of main channel erosion is frequently limited to the upper part of the lower reaches. At Mengjin the R. Huang slope is about 0.035 %, at Gaocun it is between 0.015 % and 0.02 %, and at the mouth it is about 0.01 %, and even where hyperconcentrations do occur, there is often deposition in the lower stretch, owing to the more gentle slope.

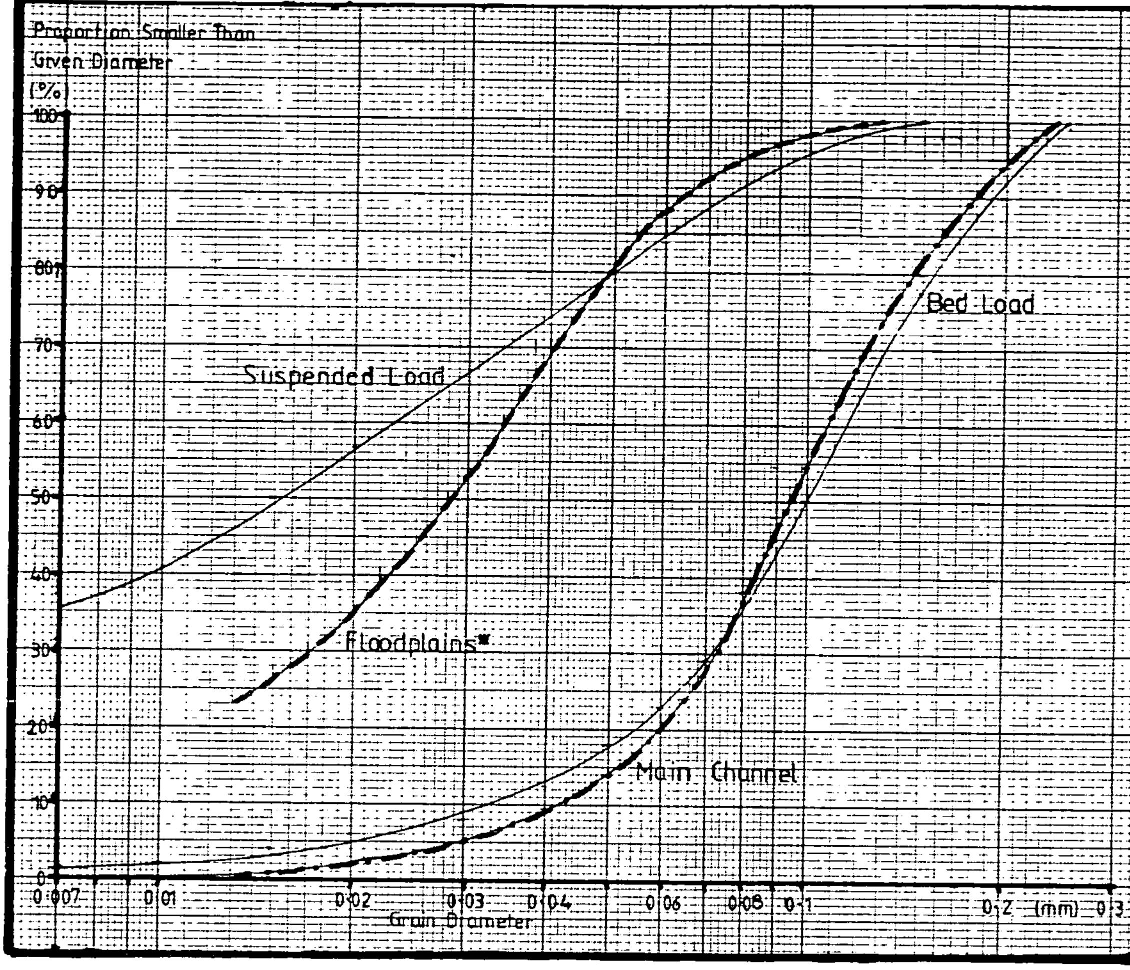
Owing to cultivation, the roughness of the floodplains is considerably higher than that of the main channel, and whilst the flow velocity over both is highly variable, the former is usually only between 25 % and 50 % that of the latter. A typical value for the main channel velocity at Huayuankou would be 2 m s^{-1} to 3 m s^{-1} for a discharge of about 5000 $m^3 s^{-1}$ to 7000 $m^3 s^{-1}$.(30) Thus, when the

TABLE 1-6 AVERAGE ANNUAL ONCOMING WATER AND SEDIMENT LOADS, AND SEDIMENT DISCHARGE, JULY 1950 TO JUNE 1960

Water Volume ($m^3 \times 10^6$)		Sediment Grain Diameter	Oncoming Sediment Load		Sediment Drawn Into Irrigation Canals	Sediment Discharged Beyond Lijin		Sediment Deposited on Riverbed		Sediment Discharge Ratio
San, Hei, Xiao	Lijin	(mm)	($t \times 10^6$)	(%)	($t \times 10^6$)	($t \times 10^6$)	(%)	($t \times 10^6$)	(%)	(%)
48000	46300	< 0.025	970	54.0	51	850	64.3	69	17.8	87.6
		0.025 to 0.05	461	25.7	21	312	23.6	128	33.1	67.7
		> 0.05	364	20.3	14	160	12.1	190	49.1	44.0
		Total	1795	100	86	1322	100	387	100	73.7

Source: QUSRL, 1981, p. 2.
San, Hei, Xiao, refers to oncoming conditions for the lower reaches, see note to Table 1-5.

FIGURE 1-8 GRAIN SIZE DISTRIBUTION CURVES AT HUAYUANKOU



Sources: QUSRL, Eds., undated mimio, page 56. *MAI Qiaowei, ZHAO Yean, PAN Xiandi, 1980, page 4.
Note: QUSRL curves for 29 July, 1959. MAI, et al. curve date not specified.

TABLE 1-7 RELATIVE AREAS OF MAIN CHANNEL AND FLOODPLAINS (km^2)

Location	Tiexie to Huayuankou	Huayuankou to Gaocun	Gaocun to Aishan	Aishan to Lijin	Total
Floodplains	183	867	457	541	2048
Main Channel	606	857	360	173	1996
Whole River Channel	789	1724	817	714	4044

Source: QIAN Ning, and ZHANG Ren, 1982, table 2.

floodplains are inundated, deposition may occur on them simultaneously with scouring of the main channel. This, and the variations in deposition and scouring according to the oncoming water and silt conditions, in the long term ensures an even distribution of sediment over the floodplain and in the main channel. Since they occupy roughly equal areas, (Table 1-7), they are rising in parallel.

Apart from straightforward scouring of the lower reaches by large volume floods, particularly clear floods, or hyperconcentrated floods, moderate floods, provided that they cover the floodplains, can also do much to remove silt from the main channel above Gaocun. As mentioned above, there are alternative divergent and convergent stretches here. In the divergent parts the waters spread over the floodplains and will deposit some of their silt load. Clearer, they return to the main channel in a convergent zone and proceed to pick up silt therefrom. At the next divergent zone, part of this will be deposited upon the floodplains, as before. Thus, by repetition, main channel flow sediment concentration will diminish and erosion may extend over long distances.

4) The Loess of the Middle Reaches.

The debate on the development policy of the middle reaches (Chapter 5) has been complicated by ambiguity over what constitutes the area in question. For many years, the whole of the great loop, from Longyang Gorge to Taohuayu was considered to be the middle reach,[(31)] and, indeed, it makes a very convenient geographical region, bounded as it is by the Yin mountains to the North, the Qin mountains to the South, the Taihang mountains to the East and the Helan mountains and Qinghai-Xizang plateau to the West (Figure 1-9). Whilst for hydrological reasons it is usual to consider the middle reaches to comprise the stretch from Hekouzhen to Taohuayu, for other purposes the geographical region as a whole is still often referred to as the "Middle Reaches" or the "Loess Plateau", though the latter actually only occupies about half of the area and some of it is drained by the upper reaches.

This larger region is 607,000 km^2 in area and has many different land forms, which suffer varying degrees of erosion (Table 1-8). Whilst each part has its problems, we are concerned here only with the loess-covered regions, since it is these which contribute the major part of the silt to the R. Huang. The term 'loess plateau' will therefore be used hereafter to denote those loess-covered parts whose sediment yield modulus exceeds 5000 t km^{-2} yr^{-1}, an area of approximately 280,000 km^2, distributed in a broad band running Southwest to Northeast, from Eastern Gansu to Northern Shaanxi and Northwestern Shanxi.

i) Topography.

Seventy per cent of the loess plateau lies between 1000 m and 2000 m above sea level and the whole region is still rising very slowly. It has two main land forms. In the Southern part there is a region of 52,000 km^2 which resembles a plateau, its surface being flat, but cut up by many steep-sided gullies. The loess is thick, gully erosion is serious, and the gullies, which are well defined, occupy between 40 % and 60 % of the surface area (Figure 1-10). In the

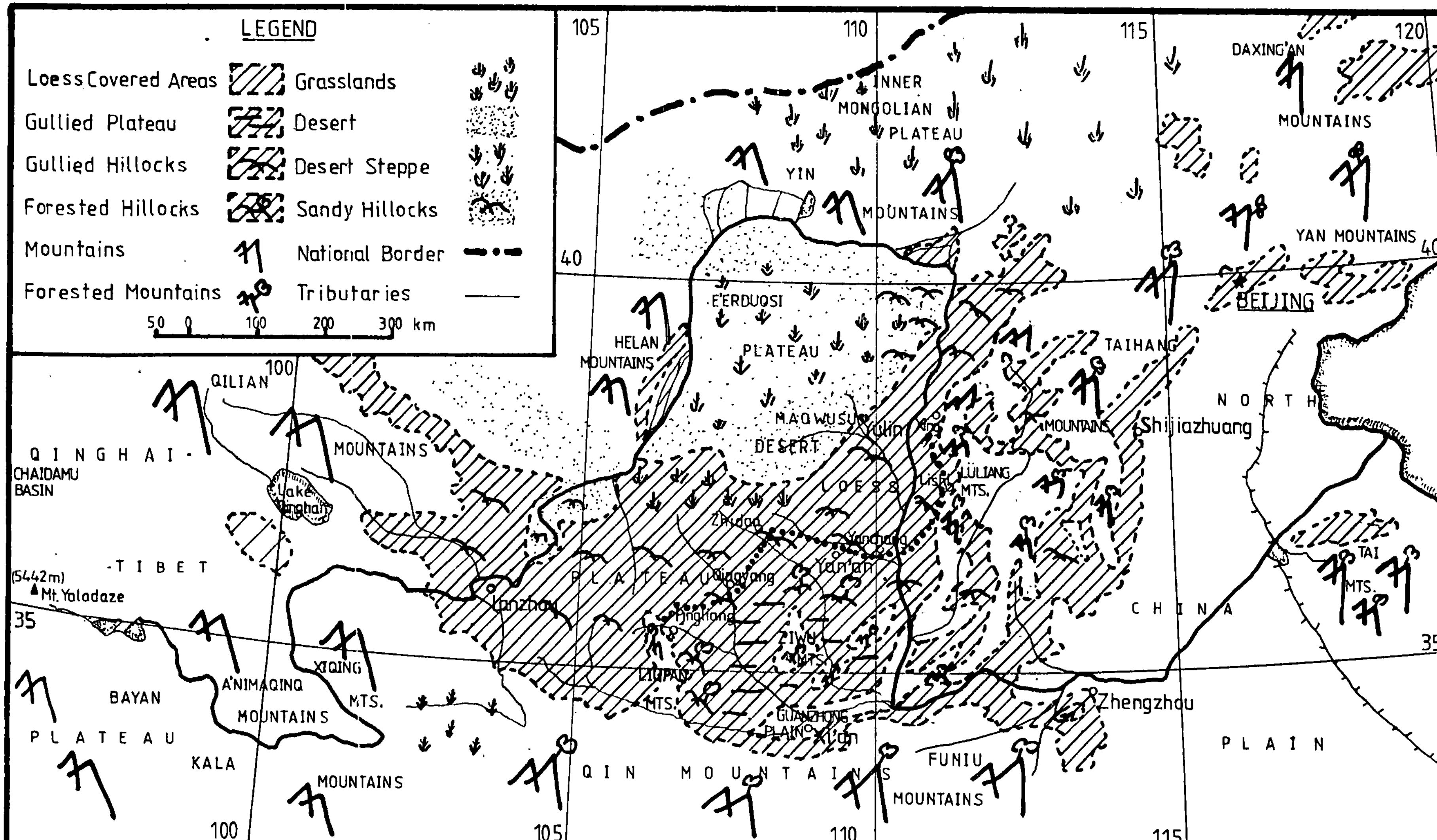


FIGURE 1-9 GEOGRAPHICAL FEATURES

SOURCES: Note 32

TABLE 1-8 SOIL AND WATER LOSSES IN THE CENTRAL* R.HUANG AREA

(units: km^2)	GULLIED HILLOCK REGION	GULLIED PLATEAU REGION	STONY MOUNT-AINS	LOESS BORD-ERLAND	ARID GRASS-LANDS	DESERT	MOUN-TAIN GRASS-LANDS	ALLUV-IAL PLAINS	TOTAL
LAND AREA	247	52	116	19	18	38	26	91	607
AREA OF SOIL AND WATER LOSSES	238	49	86	17	13	9	17	0	429

Source: RHWCC, Eds., 1959, page 200.
*The area described in the text, often loosely referred to as the middle reaches, but strictly much larger.

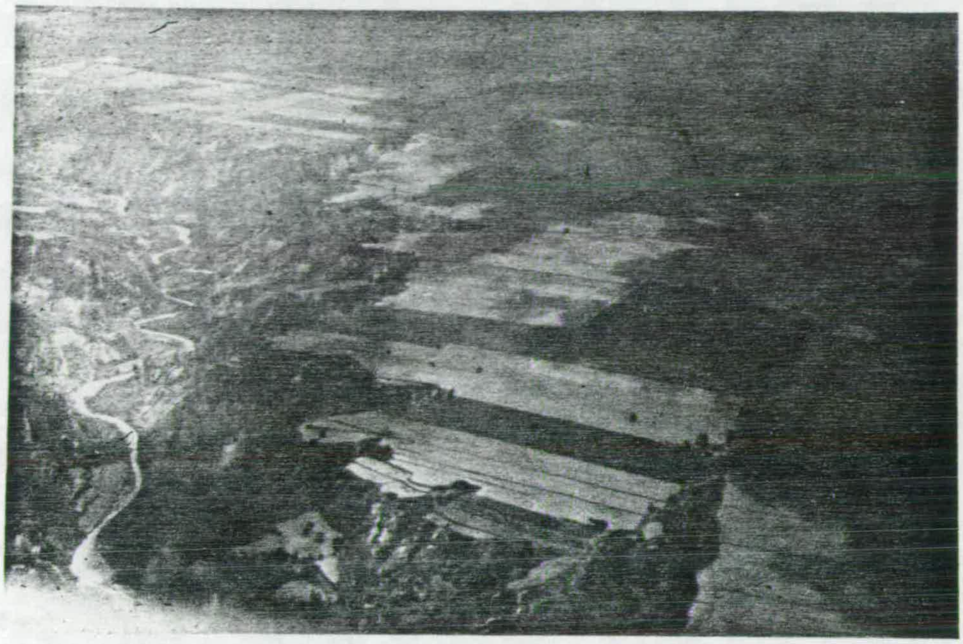


FIGURE 1-10 THE GULLIED PLATEAU REGION

Photo: About 100 km North of Xi'an, 30 July 1980. (PM)

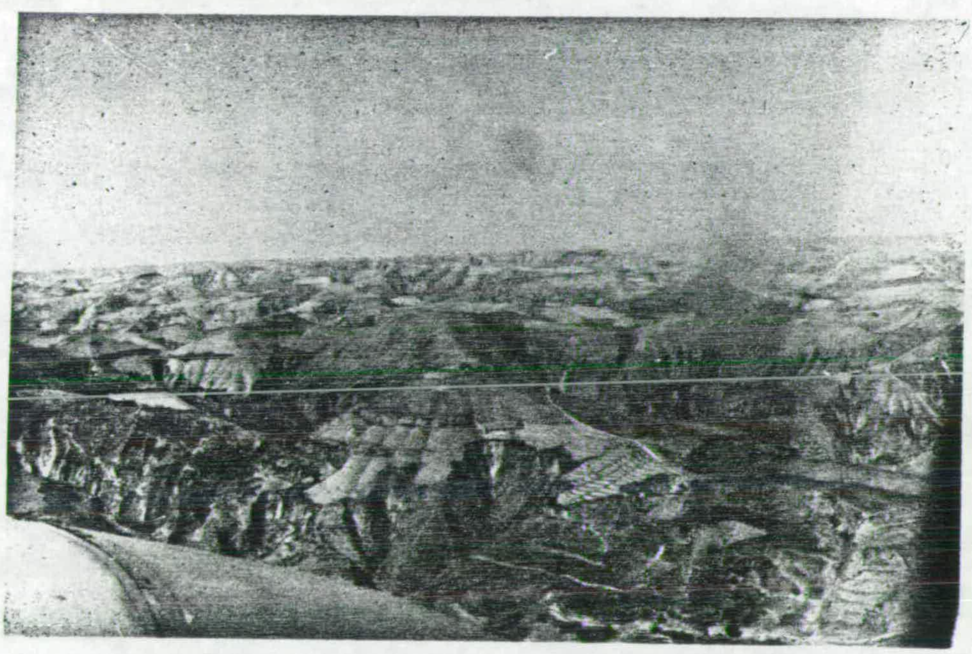


FIGURE 1-11 THE GULLIED HILLOCK REGION

Photo: About 5 km from Yan'an, 25 July 1980. (PM)

Northern part, 247,000 km^2 in area, both gully and sheet erosion have been so serious that the land has become criss-crossed by gullies and cut up into an array of small round hillocks, resembling tray upon tray of bread rolls (Figure 1-11). On average, gullies occupy about four kilometres per square kilometre. The above two regions are known as the 'gullied plateau' and 'gullied hillock' regions, respectively.

ii) Plant Cover.

Natural vegetation throughout the region has suffered, over a long period, very severe destruction owing to such factors as ill-suited land use, overgrazing, and wanton felling of trees for fuel or for war. After the revolution, extant natural vegetation fell roughly into two districts, with a boundary line running through Xing and Lishi counties in Shanxi, Yanchang and Zhidan counties in Shaanxi and Qingyang and Pingliang counties in Gansu, as in Figure 1-9. To the South and East of this line, dense coniferous forests grew on mountains and mixed forests grew on isolated hills, but one estimate gives this area as only "2 % of the loess plateau".(33) On the loess plateau itself, though, most hilltops had been opened up to agriculture and, apart from isolated instances of man-made forest, the only natural vegetation was semi-arid type grasses to be found along gully floors. Most of the gullied hillock region to the North and West of the boundary lay bare, natural vegetation was very scattered and what little existed comprised those drought and cold resistant plants with strong propagation properties which were to be found on wasteland on or gully edges.

iii) Loess Soil.

Loess is a fine, loose, wind-deposited yellow soil, rich in minerals. Usually unstratified and lacking granual structure, it relies for cohesion upon calcium carbonate which, however, disperses readily in water, rendering the loess highly susceptible to (water) erosion.(34) On a larger scale, it is riddled with holes left by the roots of previous vegetation and underground cleavages have created large columnar voids (Figure 1-12).

Loess has a porosity of about 50 % and, owing to capillary action, can hold about 250 mm to 300 mm of effective moisture (the equivalent rainfall) in the top two metres. It is very fertile, containing 0.8 kg to 1.5 kg of nitrates, 1.5 kg of phosphates and 20 kg of potassium per tonne.[35]

FIGURE 1-12 SINK HOLE AND CAVERN IN LOESS

Photo: Chunhua County, Shaanxi, 19 July 1980. (PM)

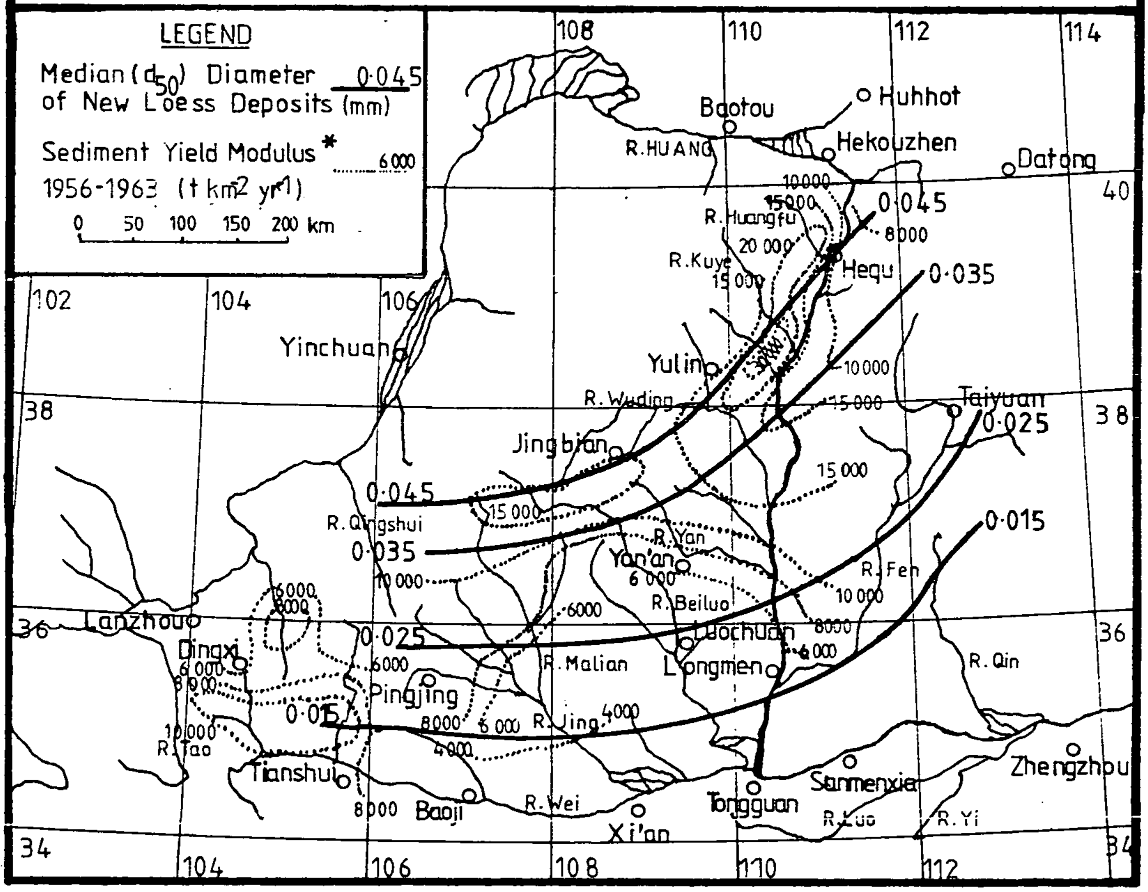
5) Soil Erosion.

Over the region as a whole, an average of 3700 t km^{-2} of loess are lost each year, rising to as much as 25,000 t km^{-2} (Figure 1-13), which has been described as the loss of "more rich earth than all the fertilizer that the whole country could produce or import".(36)

Some erosion is by wind, notably along the Southern edge of the E'erduosi plateau, where Northerly winds blow away the finer particles, leaving sand dunes. The Maowusu desert, for example, is expanding Southwards into Yulin county at a rate of about 13 km^2 yr^{-1}.(37) As another result, the loess soil becomes finer in the Southern areas. The distribution of average grain size is also shown in Figure 1-13.

However, erosion is mainly caused by the action of water, occuring as sheet erosion, gully extension, sink holes (Figure 1-12), soil creep and riverbank carving. It follows closely the variations in rainfall and the resultant silt is carried immediately into the R. Huang, from whose silt load it can be concluded that some 80 % of soil loss occurs in the three months July, August and September, when 50 % of the annual rainfall occurs. In August, 40 % of the annual silt flow occurs in 20 % of the annual runoff.(38)

FIGURE 1-13 VARIATION OF PARTICLE SIZE AND SEDIMENT YIELD MODULUS



Sources: LIU Dongsheng, 1964, p. 183. *RHWCC Hydrotechnical Inst., et al., 1975, p. 165.

6) Problems of the Development of the Loess Plateau.

Quite apart from the problems created by silt in the R. Huang and its tributaries (Section 7), many years of erosion have rendered this one of the poorest regions of China. A report from 1958 contains figures for 1955 over an area of 432,000 km^2 comprising those parts of Shanxi, Shaanxi, Gansu and Ningxia within the R. Huang catchment, which may be taken to demonstrate the size of the problem.(39)

In the report, the total population of 29,010,000人 gives an average density of 67 人 km^{-2}. The national average density is 62.5 人 km^{-2}, about the same, but if the population is compared to cultivated land, then the figures are 215 人 km^{-2} and 543 人 km^{-2}, respectively. 22.8 % of the land has been opened to cultivation, compared with 11.5 % for the country as a whole. On average, each agricultural worker is responsible for 0.4 ha, compared to 0.21 ha nationally. The region's production of wheat, miscellaneous grains, and cotton account for 13.9 %, 6.8 % and 10.1 %, respectively, of the national output. The average food provision (268.2 kg 人$^{-1}$) approaches that of the national average (284.4 kg 人$^{-1}$), but whereas the cultivated land accounts for 8.9 % of the national total, staple foodstuffs yield is only 4.5 % of the national yield. The national average unit yield is 1500 kg ha^{-1} but in this region it is 885 kg ha^{-1}. Of the region's 983,000 km^2 of cultivated land, only 7.5 % is irrigated, the rest depends on the unpredictable rainfall. There is an average of 123.6 羊 km^{-2} (the national average is 76.5 羊 km^{-2}) and each labouring animal has to deal with 2.2 ha. Forests account for only 2.8 % of the area, and are mainly scattered.

However, these figures include such populous and fertile regions as the Guanzhong Plain, which, in the report, has a population density of 335 人 km^{-2}, where 74 % of the land is opened to cultivation and each agricultural worker has an average of 0.15 ha. On the loess plateau, the conditions are far more stringent. Between 1950 and 1955, in North Shaanxi for instance, where the population density is 29 人 km^{-2}, the average unit grain yield is 546 kg ha^{-1} in Yan'an district and 285 kg ha^{-1} in Suide and Yulin districts, In extreme cases in some parts of Shanxi, each labouring animal has to work 6.7 ha. Sheep rearing is important. In Suide and Yulin districts in 1954 there were 250 羊 km^{-2}.

The gradual impoverishment of conditions as one goes Northwards is illustrated in the report by a comparison between Yan'an and Yulin districts in Shaanxi. Although Yulin has a greater population density than Yan'an (35 人 km^{-2} and 23 人 km^{-2} respectively) a greater proportion of the available land has been opened up (17.8 % and 10.5 % respectively) resulting in almost identical ratios of agricultural workers per unit of tilled land (0.57 ha $人^{-1}$ and 0.6 ha $人^{-1}$ respectively). The number of domestic animals is about the same in both districts, but in Yulin there is a higher proportion of sheep. Yet, in the period in question (1950-1955) Yan'an has been able, each year, to export foodgrain. In 1954 this amounted to 11 % of the district's total yield, and export continued even in the severe drought year of 1955. Meanwhile, in Suide (Yulin) the total yield halved between 1951 and 1953, and had fallen again, by a third of the 1953 amount, by 1955, during which year 100 x 10^6 kg of foodgrain had to be imported to North Shaanxi and Northwest Shanxi.

The loss of vegetation has long been recognized as the main reason for the lack of fuel, fodder and fertilizer and it is also held responsible for the instability of the climate which is the ultimate cause of the region's poverty. Spring droughts and Autumn torrents have become common features, the droughts being especially severe. As the report puts it,

> "Take Shanxi for example, during the period of the first five-year plan, it suffered two droughts and one deluge. Adding together the areas affected over the five-year period gives a total of 47,000 km^{-2}, which is equal to the present day cultivated area of Shanxi. Thus out of five year's bitter toil by the masses, one can be reckoned to have been wasted."(39)

The principal contradiction manifests itself as the practice of shifting cultivation. The potency of land that has been opened to cultivation diminishes as fertilizer is insufficient and as the upper layers, which contain organic matter, are washed away by storms. When hilltop forests in the region are first opened up to tilling, yields of 1875 kg ha^{-1} are obtained, but this falls to less than 750 kg ha^{-1} in a few years.(40) The peasants are forced to open up an even larger area of land in order to maintain their total yield. Then, as more land is opened, so the climate becomes less stable and yields fall even more rapidly. Furthermore, with a larger area to look after, the peasant cannot pay such full attention to all his crops, and poor management further reduces yields and increases the severity of soil and water losses. Eventually, some areas are left to fall into total neglect, creating the vast area of barren hilltops which characterises the greater part of the loess plateau. Meanwhile the peasants' livelihood cannot be guaranteed; the climate becomes forever less stable and fertilizer, fodder and fuel ever more scarce. There is no option for the peasant but to close the vicious circle by opening up more land.

7) Sedimentation Problems in the River Huang Basin.

The highest recorded silt content of a Huang river tributary is 1500 kg m^{-3} and those above 1000 kg m^{-3} are quite common.(41) This is unmatched by any river of the world. From Table 1-9 it can be seen that there are 13 large rivers in the world whose annual suspended load exceeds 100 x 10^6 t. The R. Huang has the highest, followed by the Ganges and the Brahmaputra. Yet, in terms of drainage area and water discharge, the R. Huang is of very moderate proportions. Furthermore, of the ten tributaries shown in Table 1-10, there are eight whose annual suspended load exceeds 100 x 10^6 t. In terms of sediment concentration, only the Colorado River (USA) approaches either the R. Huang or its tributaries. Moreover, like precipitation, sediment concentrations vary greatly both seasonally and year by year. For example, the maximum annual silt load in the R. Huang was 3910 x 10^6 t (1933) whilst the minimum was 488 x 10^6 t (1928). The maximum recorded mainstream concentration is 919 kg m^{-3}. The sediment load in five to ten days can be between 50 % and 90 % of the total annual load, whilst in the Winter months January to March, the average concentration is only some 2 kg m^{-3} to 4 kg m^{-3}.(42)

i) Loss of reservoir capacity.

Chinese engineers view the problem of silted-up reservoirs with great seriousness and the problem in the R. Huang valley is indeed serious. In Shaanxi, for example, 31.4 % of the 1500 x 10^6 m^3 capacity of 192 reservoirs each over 1 x 10^6 m^3 had been lost by the end of 1973. On average, 30 x 10^6 m^3 are being lost annually and 43 reservoirs have already been completely filled. Most of these reservoirs have been in operation for less than 20 years. In recent years there has been an increase in the storage capacity of reservoirs over 1 x 10^6 m^3 of 260 x 10^6 m^3 yr^{-1}, but about a third of this amount, 80 x 10^6 m^3 yr^{-1}, has been lost from existing reservoirs. In Shanxi 700 x 10^6 m^3 of the 43 large and medium sized reservoirs built before 1958 (total capacity 2230 x 10^6 m^3) had been lost by the end of 1974. It is estimated that the annual loss of 50 x 10^6 m^3 is equivalent to ¥ 7 x 10^6 (£ 2 x 10^6 at 1981 exchange

TABLE 1-9 HEAVILY SILTED LARGE RIVERS OF THE WORLD

RIVER	COUNTRY	DRAINAGE AREA (km^2×10^3)	RUNOFF (m^3 yr^{-1}×10^9)	SILT LOAD (t yr^{-1}×10^6)	AVERAGE SILT CONCENTRATION (kg m^{-3})
Huang	China	752	43	1640	37.60
Colorado	USA	637	5	135	27.50
Liao	China	166	6	41	6.86
Ganges	India, Bangladesh	955	371	1451	3.92
Missouri	USA	1370	616	218	3.54
Indus	Pakistan	969	175	435	2.49
Brahmaputra	India, Bangladesh	666	384	726	1.89
Nile	Egypt, Sudan	2978	89	111	1.25
Red	Vietnam	119	123	130	1.06
Irrawaddy	Burma	430	427	299	0.70
Mississippi	USA	3220	561	312	0.56
Changjiang	China	1807	921	478	0.54
Mekong	Laos, Tailand, Kampuchea, Vietnam	795	348	170	0.49
Xijiang	China	355	253	69	0.35
Don	USSR	422	28	6	0.23
Niger	Nigeria	1112	180	40	0.22
Danube	W.Germany, Austria, Czechoslovakia, Hungary, Yugoslavia, Bulgaria, Romania	1165	200	28	0.14
Volga	USSR	1500	250	25	0.11
Amazon	Brasil	5770	5710	363	0.06
Congo	Zaire	3700	1400	70	0.05
Rhine	W.Germany, Netherlands, France, Switzerland	362	800	3	0.04

Sources: QIAN Ning, DAI Dingzhong, 1980, page 20. SRIHEWL, et al., Eds., 1979, p. 2.

TABLE 1-10 TRIBUTARY SEDIMENT LOADS

RIVER	STATION	RUNOFF (m^3 yr^{-1} $\times 10^6$)	ANNUAL SILT LOAD ($t \times 10^6$)	AVERAGE CONCENTRATION (kg m^{-3})	MAXIMUM CONCENTRATION (kg m^{-3})	CATCHMENT SEDIMENT YIELD MODULUS (t km^{-2} yr^{-1})
Huang	Shanzhou	42640	1600	38	590	2330
Zuli	Qingyuan	169	83	493		5600
Huangfu	Huangfu	197	61	312	1480	19200
Kuye	Wenjiachuan	795	138	174	1500	11800
Wuding	Chuankou	1555	210	135	1290	7700
Qingjian	Yanchuan	163	51	313	1150	14700
Yan	Ganyuyi	251	65	258	1210	11000
Fen	Hejin	1831	41	22	286	1100
Beiluo	Zhuantou	965	106	110	1190	4200
Jing	Zhangjiashan	1738	271	156	1040	6400
Wei	Xianyang	6012	201	33		4000

Source: SRIHEWL, et al., Eds., 1979, p. 1.

TABLE 1-11 SEDIMENTATION OF THE MAINSTREAM RESERVOIRS

RESERVOIR	DRAINAGE AREA (km^2)	DAM HEIGHT (m)	DESIGN CAPACITY ($m^3 \times 10^6$)	PERIOD SURVEYED	TOTAL SEDIMENTATION ($m^3 \times 10^6$)	PROPORTION OF CAPACITY LOST (%)
Liujiaxia	181700	147	5720	1968–1978	580	10.1
Yanguoxia	182800	57	220	1961–1978	160	72.7
Bapanxia	204700	43	49	1975–1977	18	35.7
Qingtongxia	285000	42.7	620	1966–1977	485	78.2
Sanshenggong	314000	Intake Gate Type	80	1961–1977	40	50.0
Tianqiao	388000	42	68	1976–1978	7.5	11.0
Sanmenxia	688421	106	9640	1960–1978	3760*	39.0

Source: QIAN Ning, DAI Dingzhong, 1980, page 24.
*At water level of 335m.

rate) of their construction costs alone. Similar examples can be found from Gansu, Inner Mongolia, Qinghai, Ningxia and Shandong.(43) The case for the seven mainstream dams along the R. Huang is shown in Table 1-11. The case of Sanmenxia is discussed in more detail in Chapter 3.

ii) Backwater deposition.

The most notorious case of danger resulting from reservoir backwater deposition is that which followed the alteration of the fluvial conditions of the lower R. Wei during the period immediately after impounding at Sanmenxia (Chapter 3). Another example may be given from Zhenziliang reservoir in the Yanbei district of Shanxi, where, in ten years, the backwater deposition extended 3 km and compensation payments made, after repeated upstream inundations so caused, amount so far to 1.8 times the original capital investment.(44)

iii) Wear and Tear.

Before Liujiaxia reservoir, just upstream, began impounding, inspection and repair work lasting between 30 and 40 days had to be made annually at Yanguoxia power station on the R. Huang, 80 % of which dealt with mechanical erosion. In 1964, the trash racks collapsed under water pressure as a consequence of blocking. Repairs and other losses amounted to ¥ 30×10^6 (£ 8.6×10^6). 90 % of the mineral content of R. Huang silt is quartz, both hard and abrasive, and Figure 1-14 shows the pumps out for repair at the Mangshan irrigation scheme on the lower R. Huang near Huayuankou.(45)

iv) Lower River Huang Dyke Protection Problems.

The North China Plain is the vast (250,000 km^2) alluvial wedge of the R. Huang, which flows across its apex at Mengjin, to the sea, with the land on either side of the dykes sloping gently away (gradient = 0.02 %).(46) It is an extraordinarily flat plain, and one tenth (100×10^6 人) of China's population and 15.8 % (170,000 km^2) of its cultivated land are on it. Thus, should the

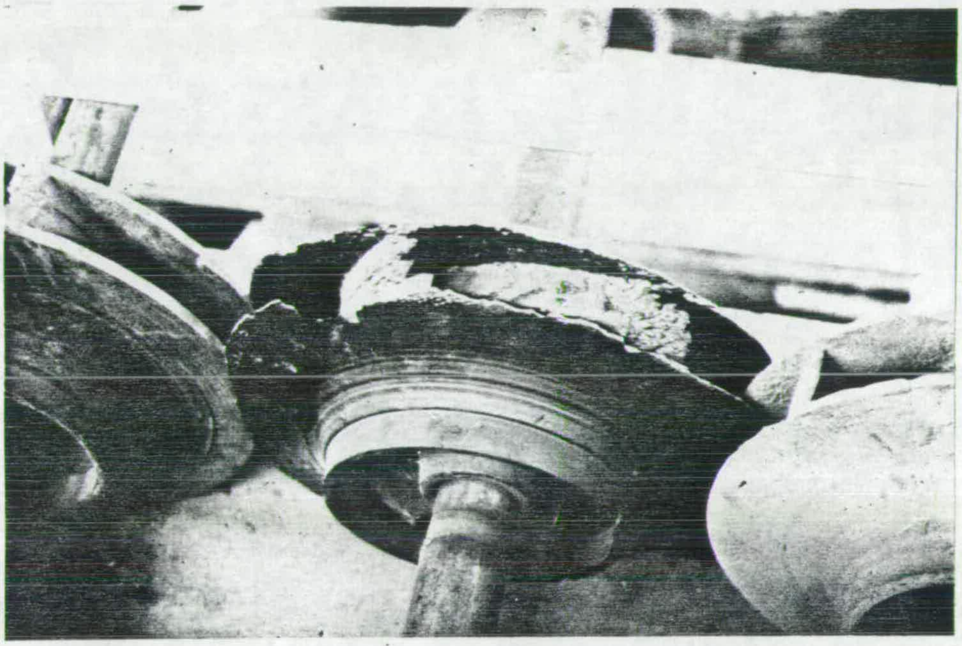


FIGURE 1-14 PUMP ROTORS WORN BY SILT

Photo: Mangshan Pumping Station, near Huayuankou, on the lower (PM) R. Huang, 9 August 1980. After about 1000 hr the pump radius (about 500 mm) is reduced by 10 mm. After 3500 hr the rotor may be worn right through.

river break its dykes, a very large area would be flooded and the loss of life and property would be enormous. Flood prevention is seen as the first priority of R. Huang control work.

There are three types of dyke breaching which may occur on the lower R. Huang. Firstly, overtopping the dykes when the flood discharge capacity is insufficient. Heavy deposition has necessitated constant maintenance of the dyke system and, three times since the Civil War, the raising of its height; furthermore, whilst the flood carrying capacity varies with time and position along the river course, dangerous reductions may occur. For example, the water level at Huayuankou for a discharge of 5000 $m^3 s^{-1}$ in 1973 was higher than that for 22,300 $m^3 s^{-1}$ in 1958. The narrow reaches in Shandong are where this type of breach is most likely.(47)

The second type of breach is by bursting, when the dykes give way owing to seepage or piping under the pressure of a persistant high water level. Attention also has to be paid to prevent animals from weakening the structure of the dykes by burrowing therein.

The third and most common type of danger is that which occurs during the receding stage of the flood, when the flow suddenly takes a different path and attacks the dyke at a sharp angle. This is very critical in the reach above Gaocun, which has long been the point of emphasis in R. Huang flood prevention work.

v) Ice-jam Floods in the Lower Reaches.

Mention of this phenomenon is made here, despite its not being a consequence of the sediment of the R. Huang, because it would seem appropriate to discuss it alongside the other sources of dyke breach. The problem also occurs, but to a lesser extent, in the North-bound part of the Great Loop, in the vicinity of Ningxia. The details below refer only to its effects in the Lower Reaches.

From Gaocun, where it crosses the 35^{o} N. parallel of latitude, the lower R. Huang proceeds steadily Northeastwards to the mouth, which is at the 38th degree. Generally, between 50 km and 700 km of the lower reach is covered by ice from mid January to the last week of February, but the upstream, Southerly, part tends to freeze later and thaw earlier, by a factor of about 10 days. The ice cover above Gaocun is about 0.1 m thick, but at the mouth, its thickness is usually about 0.35 m. When the river freezes over, only a limited amount of water may flow beneath the ice cover and the excess water collects and freezes in the wider channel upstream of Gaocun. When the upper section thaws, this water may suddenly be released, causing a small flood peak which cannot pass through the section below and thus may overflow the dykes. The more serious cause of danger, though, is the successive jamming of ice floes set free as the upper section begins to thaw, which restrict further the flow of water. It may be noted that flood peaks arising from ice jams appear to travel back upstream from the point of constriction. Ice floes also present the threat of mechanical damage to the dykes.(48)

8) History of Drought and Flood in the River Huang Basin.

i) Drought.

Owing to the generally arid nature of the basin and the seasonal rainfall characteristics, a shortage of water is the rule rather than the exception. Any prolonged drought is very serious but, unfortunately, quite common. In the 3710 years from 1766 BC to 1944 AD, recorded instances of drought number 1070. During the 267 years of the Qing dynasty there were 201 such instances. Drought may occur over a very large area and affect several provinces, thereby making the migration to other provinces of those affected, largely futile. From 1877 AD to 1879 AD three consecutive years of drought occurred, extending over Shanxi, Hebei, He'nan and Shandong, during which 13 x 10^6 人 died of starvation. Similar phenomena have continued to occur well into the twentieth century.(49)

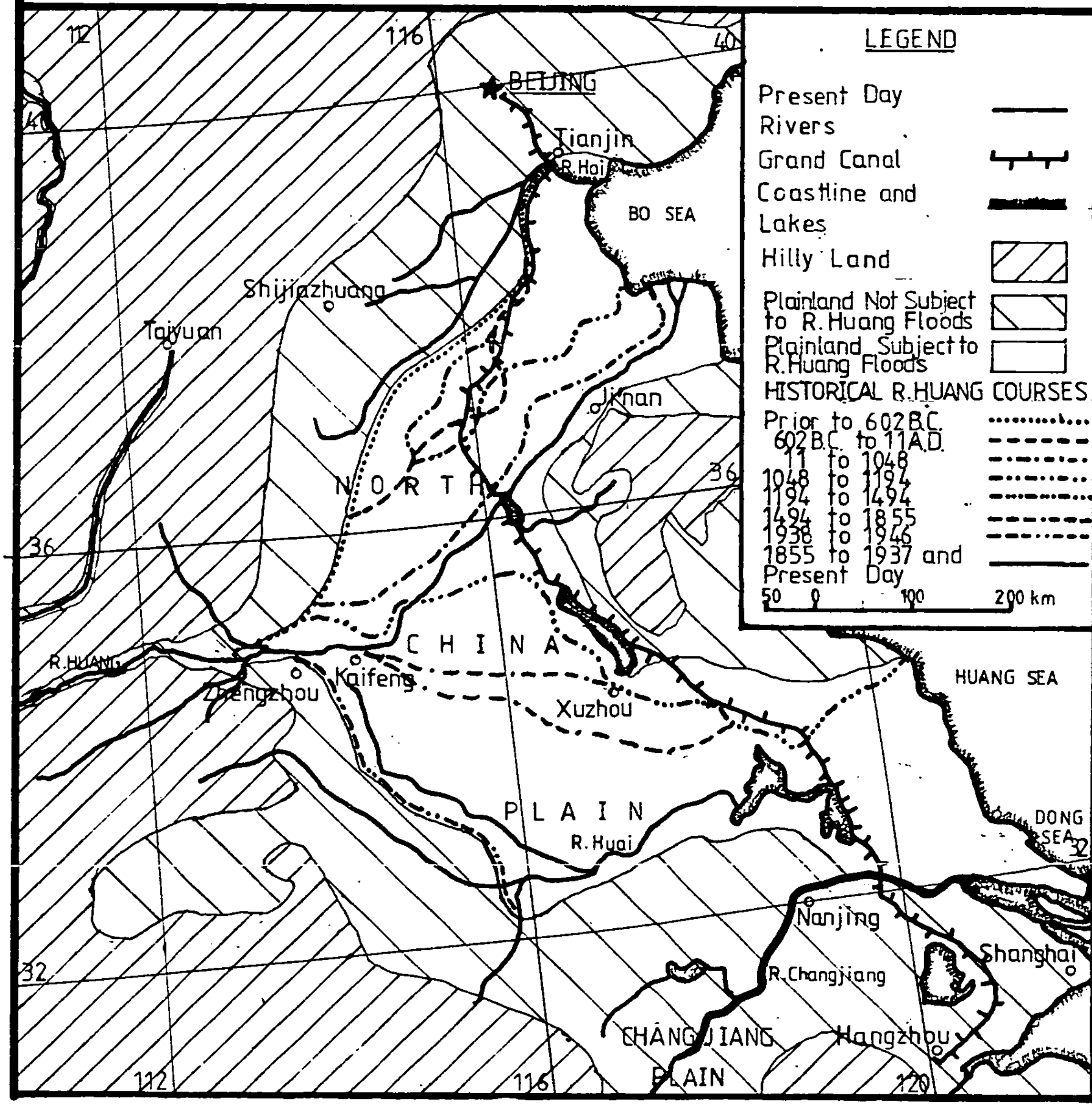
ii) Natural Floods.

The floods of the R. Huang are a common feature of over 4000 years of recorded Chinese history. Incomplete records mention over 1500 instances of dyke breaching or overtopping, including 27 changes of course in the 2500, or so, years since the Spring and Autumn period (770 BC to 475 AD). These would be equivalent to two breaches every three years and a change of course once a century.(50)

Whilst most parts of the North China Plain have borne the course of the R. Huang at some time, there have been but four general routes to the sea (Figure 1-15) and four major estuary points :

- i) Along the extreme Northern edge of the alluvial cone to join the R. Hai at Tianjin.
- ii) More or less along its present course following the Northern edge of the Tai hills in Shandong.
- iii) Southwards, following parts of some R. Huai tributaries, and on to the Huang Sea.
- iv) Joining both the R. Huai and the Changjiang, flowing into the Dong Sea near Shanghai.

FIGURE 1-15 HISTORICAL COURSES OF THE LOWER RIVER HUANG



Sources: RHWCC, Eds., 1979, page 249. Shanghai Shifan University, Eds., 1974, page 114.

It may be noted that after a change in course, the mouth might be situated up to 1000 km from its original position.

Virtually the whole of the North China Plain is susceptible to R. Huang floods and one characteristic of such inundations is the large area covered and the shallow depth of the floodwaters. Contemporary reports say that the flood of 1887 AD inundated a strip between 30 km and 80 km wide and 25,000 km^2 in area; about half the size of Scotland. At the breach which caused this flood, the riverbed was 1.2 m above the surrounding countryside and the average flood depth was 0.75 m, though in the region of the break, a gully had been cut 20 m, or so, deep. On this occasion, 3000 large villages were flooded or destroyed and the loss of life was estimated at 7×10^6 人.(51) Owing to this shallow and extensive characteristic, the seriousness of a given flood can also depend upon its timing, for should it occur just before harvesting, a crop is lain to ruin, whereas should it occur just after harvest, then a useful layer of most fertile silt is deposited ready for the next crop.

iii) Man-made Floods.

The use of floodwaters in battle is another occurance common throughout Chinese history, especially on the North China Plain, there being records of such use dating back to the Spring and Autumn period.(52)

There were several ways in which floods were so used :

i) By taking advantage of naturally occuring floods.
ii) By building reservoirs sited where they would block communications.
iii) By breaching the dykes of elevated rivers (Most examples of this type concern the R. Huang during the Warring States period, 475 BC to 221 BC).
iv) By building weirs to raise the water level, and then releasing it to flood prescribed areas below.
v) By building weirs below cities so that the backwaters

would extend to encroach thereupon.

One example of the ingenuity employed by these methods comes from 480 AD, when Yuan Chongzu built a dyke which caused the R. Feishui to rise and surround three sides of the city of Shouchun, which he hoped to protect. On the far side of the dyke he built a small city-like battlement and sent several thousand people there to guard it. Around this battlement he dug a deep and narrow trench. When the enemy, Wei, troops arrived, they attacked the small battlement, whereupon Yuan Chongzu ordered the dyke to be breached, which flooded the trench and all the troops within. Thus was Shouchun saved.

Although the period of most frequent use of water for waging battle was in the Wei, Jin and Northern and Southern dynastic periods (220 AD to 581 AD), there is no record of the deliberate breaching of the R. Huang at that time, nor are there very many accounts of other rivers being used then in that manner. This has been taken to suggest that the dyke systems at that time were fragmentary and were seldom called upon actually to hold flood waters in check.

Yet, it is, indeed, the use of this method along the R. Huang which is most notorious. For example, during the Warring States period, it was used by Chu to attack Wei in 359 BC, by Qi and Wei to attack Zhou in 322 BC, by Zhou to attack Wei in 281 BC, and by Qin to attack Wei in 225 BC. In 1234 AD the Mongols broke the dyke near Kaifeng, as in 1642 AD, in the Ming dynasty, did the governor of He'nan in order to put down a peasant army which held the city in siege. It has been claimed that 340,000 of its 370,000 inhabitants died in that flood. It has been rumoured that the last change in course (Beginning in 1851 AD) was made either by the Taipings as their rebellion approached Beijing, or by the Imperialists who opposed them.(53) Finally, in 1938, Nationalist Generalissimo Jiang Jieshi (Chiang Kai-Shek) ordered the blasting of the Southern R. Huang dyke at Huayuankou to cover his flight from the Japanese invaders. An area of 53,000 km^2 was affected and 890,000 人 died. It has been claimed that his subsequent purpose in returning the river to its original course in 1947 was to drown the liberated areas therein.(54)

9) Irrigation in the River Huang Basin.

A comprehensive review of the development of irrigation throughout the R. Huang basin is beyond the scope of this study. Nevertheless, inasmuch as on the loess plateau, irrigation promotes the development of soil and water conservation work, whilst along the lower R. Huang and on the Guanzhong Plain, its own development is restricted by silt which results from the limited efficiency of soil and water conservation work, a general review may be helpful to give a perspective where irrigation is mentioned in Chapters 3 and 4.

Large scale irrigation works were in existence in China as early as the Warring States period. Subsequently, there have been alternate periods of activity and neglect, the most active periods being the Han, Tang, Qing and Mao dynasties. The methods used in the R. Huang basin before 1949 generally relied upon favourable topographical conditions, for no reservoir of appreciable capacity was built for irrigation, and the principal construction was a single headgate for river diversion, sometimes coupled with a low weir.(55) With the exception of the larger-scale schemes mentioned below, irrigation was very poorly developed; in the whole of N. Shaanxi, for example, only 1120 ha were irrigated, by small-scale means. Wells were to be found scattered in different localities in river valleys, where the water table was high, but until recent times, there was no high-lift pumped irrigation, as is needed on the loess plateau, though along rivers and canals, various devices were used to raise water a few metres. Wooden waterwheels, for example, were common in Gansu, in 1947, where a total of 6700 ha were served by 360 such wheels, whose maximum lift was 18 m.

The most significant irrigation schemes, though, were the ancient ones to be found on alluvial plains and desert areas along the mainstream, and in the Wei, Jing and Beiluo river valleys on the Guanzhong Plain though, by the end of the Civil War, they had fallen into disrepair. There was no large scale irrigation using the water of the lower R. Huang, because it was feared that any small error in constructing a diversion work would result in disasterous accidents.

At Hegangkou, near Kaifeng, diversion gates were built in the Southern dyke, but were abandoned. In Shandong, some syphon projects had been tried near Ji'nan, but found to be of limited capacity and the silt deposits were not as uniform as had been hoped.

In recent years many advances have been made in small scale irrigation, not only on the loess plateau, (Chapter 4), but also on the North China Plain, though the latter is not considered strictly to be part of the R. Huang basin. Reparations, improved maintenance and new techniques have enabled the major irrigation areas, not only to be brought back into full use after having degenerated during the Civil War years, but also to be extended or made more effective. These schemes are as follow:

i) Ningxia Plain.

Irrigation on the alluvial plain along the R. Huang in Ningxia has a history of over 2000 years. Its total area is over 17,000 km^2, and is divided into two districts by the Qingtong gorge multipurpose project. To the South (Upstream) are the Zhongning and Zhongwei Plains, whose collective irrigated area of 39,000 ha is known as the Ningwei Plain. To the North is the Yinwu Plain, made up of the Yinchuan and Wuzhong irrigation districts, whose total irrigated area is 151,000 ha.(56)

ii) Hetao.

Also known as Houtao, this plain in Inner Mongolia just at the Northernmost point of the R. Huang's Great Loop, as it turns Eastwards, is made up alternately of cultivated land, grassland and barren beachlands, covered with R. Huang alluvial deposits, but it is very susceptible to alkalisation. Its irrigated area is at present 387,000 ha.(57)

iii) Tumochuan.

At the site of the failed Salachi irrigation scheme of the Nationalists, just upstream of the Southward turn of the R. Huang at Hekouzhen, some 113,000 ha of the originally planned 130,000 ha irrigated area is now in operation.(58)

iv) Guanzhong Plain.

The Guanzhong Plain, 52,990 km^2 in area, as a whole is drained by the R. Wei, of which the rivers Jing and Beiluo are two large tributaries. This plain has throughout history been renowned for its fertility and it is the site of many ancient schemes, such as the Zhaolaoyu system, in Fuping county, where flood waters have been drawn for over 2300 years from the R. Shunyang for irrigation and warping. The three major schemes at present in operation are all based upon ancient schemes at the same sites. They are the Jinghui (R. Jing), the Luohui (R. Beiluo) and the Baojixia (R. Wei) schemes, and their respective areas of irrigation are 86,000 ha, 49,300 ha and 200,000 ha. The latter is really the sum of two R. Wei schemes of 129,300 ha and 70,700 ha, above and below Baoji Gorge, respectively.

The regional importance of the Guanzhong Plain should be emphasised. The centre of Chinese culture over many centuries (Section 10), this region today retains a position of utmost agricultural and strategic importance. Not only is it the site of Xi'an, the Capital of Shaanxi province and an important industrial centre, but the plain, itself only accounting for 28 % of the area of Shaanxi province, contains 53 % of its arable land and produces 70 % and 90 % of its cereals and cotton, respectively.(59)

v) Others.

Various other tributary schemes have also been developed, such as the R. Fen reservoir, which irrigates 66,700 ha in Shanxi, but the more interesting recent development is along the lower reaches, where the People's Victory Canal now irrigates 40,000 ha and where other, similar, schemes and the use of such methods as syphoning (Chapter 4) are now claimed to irrigate a total of 10^6 ha (including the People's Victory Canal). In the whole R. Huang basin, it is claimed that the total irrigated area has increased from 8000 km^2 just after the Civil War, to 44,700 km^2 in 1979.(60)

10) Historical Ecology of the River Huang Basin.

i) The Cradle of Chinese Culture.

The R. Huang is known as the Cradle of Chinese Culture because it was within the confines of its drainage area that the earliest records of Neolithic settlement have been found. Yet, it was not on the vast and troubled alluvial plains that Chinese culture began, but on the loess plateau above the various tributaries of the R. Huang's middle reaches and along the R. Wei, on the Guanzhong Plain. So the birth of China owes relatively little to the R. Huang, as it was only much later that people began farming alongside the lower reaches, and the earliest agricultural system was characterised by its freedom from the influence of the flood plain.(61)

ii) Early Environment.

Although the environment of the prehistoric loess highland was generally harsh, there were also many favourable characteristics. Loess is unusually homogenous and the grass cover then was not as dense as in other steppe regions. Wooden digging implements could be more easily used here than on the alluvial wedge where patches of pebbles, gravels and conglomerates were to be found. Furthermore, being little weathered, this soil retained much of its fertility despite the lack of moisture. The natural vegetation was of steppe-type grasslands with forests limited to the hilltops.

iii) History of Man.

The earliest records of Human activity are the fossils unearthed at Lantian County in Shaanxi which date back some 500,000 to 600,000 years. Little is known, though, of any culture before the Yang-Shao of some 5000 to 6000 years ago, which exhibited weaving, livestock breeding, pottery and the use of cellars to store grain. Historic times in China begin with the Shang dynasty (16th to 11th Century BC) during which, settlement of the alluvial plains began.

When China was unified for the first time by Emperor Qin Shi in 221 BC it was on the Guanzhong Plain that he established his Capital, near the site of present day Xi'an, called Xianyang. Over the next thousand or so years, to the end of the Tang, this has been the approximate sit of the Capital of China for eleven dynasties.(62)

iv) Ancient Crops.

The main crop in ancient times was millet, which was indigenous to China and has been cultivated since the fifth millenium BC. Sorghum was also indigenous but, apparently, the varieties which occurred naturally were not suitable for cultivation, since only after the Mongol conquest did sorghum begin to be grown extensively in China. Of all the cereal plants, these two are the best suited to arid conditions. Wheat and barley were latecomers to Chinese agriculture; wheat arrived first, in about 1300 BC and barley somewhat later. These two plants are not naturally suited to semi-arid conditions, coming as they do from areas of winter rains in Southwest Asia, and they, therefore, proved hard to grow. Nevertheless, they were still grown, even without irrigation, which was not introduced until about 600 BC. Soybean, whilst indigenous in the lowlands, was not used by ancient societies on the loess plateau. It was probably first domesticated in about the eleventh Century BC, towards the end of the Shang dynasty. It may be noted that soybean requires three times as much water as millet (S.Italica) to produce the same amount of solid material, excluding the roots.

Surprisingly, rice dates back to at least 3000 BC in Shaanxi. In ancient times it was not irrigated and the seeds were broadcast, not sown. Transplanting did not begin until the second Century AD.(63)

v) Population.

By 1850 AD China was the most productive agricultural area in the world, but its population was also rising rapidly. For many years it had remained fairly constant, being 60×10^6 人 in 2 AD and 52×10^6 人 in 742 AD, but by 1661 AD it had reached 108×10^6 人

and had begun to rise more rapidly, so that by 1743 AD it was 150×10^6 人. Although these figures are not directly comparable, owing to marked changes in the political size of China from dynasty to dynasty, the trend is nevertheless clear; for by 1851 AD, in the same dynastic period (Qing dynasty) as the figure of 150×10^6 人 for 1743 AD, there were nearly two and a half times as many people, 423×10^6 人. In 1953 AD the population was 602×10^6 人, in 1975 AD it was 800×10^6 人, and the present day population is estimated at over 1000×10^6 人.(64)

Since the Civil War, China's population policy has had three main stages. In the first stage, from 1949 to 1957, population control was advocated on the grounds that the birthrate was increasing and the death rate declining, and the increase in population was more rapid than the development of the national economy, which could lead to unemployment. From the late fifties the policy was reversed, on the grounds that a higher population is equivalent to a larger workforce, and therefore would stimulate production, and the accumulation of investment capital. The third stage, since the mid-seventies, consists of a return to the advocacy of population control.(65) Some strict measures have been adopted, but the rapid growth of the last thirty years has led to renewed pressure being placed on the productivity of the land, especially on the North China Plain, where cultivation of the floodplains of the R. Huang to the detriment of flood prevention had anyway long been carried out.(66) In earlier times the construction of inner dykes to protect these crops against lesser floods, would contribute to the neglect of the outer dykes, such that no proper defence was left against the rarer large floods. Even now, this practice, though discouraged, cannot successfully be stopped (Chapter 5). The pressures of population also contributed to the denudation of the loess plateau, as shown below.

vi) Denudation of the Loess Plateau.

The destruction of the plant cover of the loess plateau is a relatively recent event. According to Wang Huandou, 1978, historical records state that in the Qin dynasty (221 BC to 207 BC), General

Meng Tian commanded 300,000 troops garrisoned in what is now one of the most severely eroded regions of N. Shaanxi and S. Inner Mongolia, centred around Yulin County, and that they got their provisions locally.(67) This is taken as evidence of the abundance of the region at that time. Records from the Western Han dynasty (206 BC to 24 AD), for the same region, state that there, 'livestock is the most abundant on earth'. It is also the site of one of the six most famous horse-rearing centres of the time, Tianfengyuan, situated in present-day Shenmu County, Shaanxi.

In 413 AD the Huns built the city of Tongwan at what is now Jingbian County in N. Shaanxi, and are reported to have chosen it for its rich vegetation, clear streams and natural beauty. In August, 1977, a warehouse built at that time was found to contain Pine, Cypress, _Thuja orientalis_ and Cedar, presumably grown locally. The existence of primordial sand beneath the ruins of Tongwan is taken as evidence that sand was there before the town was built, but that originally it was protected by rich vegetation, whereas the removal of this cover led to the impoverishment seen today. Even in the Tang dynasty (618 AD to 907 AD) it was an agricultural region, but by 994 AD, in the Song dynasty, Tongwan was annulled, and was already 'deeply in the desert'.

Many lakes which were formerly to be found in N. Shaanxi have since dried up, mainly since the Tang dynasty. Similarly, before that time, the R. Wuding, one of the major sources of the coarse silts of the R. Huang today, is reported to have been a clear stream. Furthermore, historical records show the elimination of several species of animal from the region, such as Tiger, Bear and Monkey.

The ability of the local climate to support forestry was demonstrated at the turn of the century by the survival of temple forests dotted all over the region, and was given as evidence that the loss of vegetation was due to factors other than some general meteorological change. This would be borne out by recent experience, where forests and grasslands, once re-established, have again become self-sustaining, though in the early stages problems are posed by the lack of water.

Such climatic changes as have taken place, are seen as one of the consequences of denudation, rather than one of the causes.(68)

Food production is the main reason, but not the only one, why man has cleared the vegetation. Forests have been burned annually in all parts of China to scare away wild animals, wood has been cut for building materials, especially for reconstruction after rebellions, and crop litter or shrubs on the gully slopes, which might otherwise have slowed erosion, have carefully been collected for fuel.

In addition to the practice of shifting cultivation, the ancient custom of dividing lands amongst successive heirs also contributed to the neglect of large areas of land. The point would be reached where an individual's share was too small to be delineated on the ground, and the heirs would then become joint owners; but, their individual interest would not be sufficient to cover conservation. Since these problems do not end with local impoverishment, but extend to the far-away alluvial plains as well, the need for community rather than private concern is well illustrated here. As Lowdermilk put it as long ago as 1930,

> "The free play of individual interest is a cherished privilege of many peoples; but China has demonstrated that the unwise exercise of that privilege decreases the aggregate productivity of a land, as the needs are augumented by an increasing population".(69)

Notes to Chapter One

1. HUANG Wei, 1978, p. 1.

2. The figure for the annual runoff is taken from QIAN Ning, DAI Dingzhong, 1980, p. 4. Other sources give higher values, for example, LIU Shanjian, 1979, gives 56,000 x 10^6 m^3. Other figures are from HUANG Wei, 1978, p. 1.

3. RHWCC, Eds., 1979, p. 100.

4. ZHANG Ruijin, 1947, pp. 2 to 7.

5. RHWCC, Eds., 1979, pp. 39, 40.

6. RHWCC, Eds., 1959, p. 11.

7. RHWCC, Eds., 1979, pp. 105 to 115. There are two rivers Wei which bear relation to the R. Huang. Unless otherwise indicated, the R. Wei in question is the major tributary from Shaanxi Province (渭). The other R. Wei, (卫), is a river on the North China Plain, which flows into the Grand Canal. Both rivers are shown in Figure 1-1.

8. QUSRL, unpublished map, personal communication, 1981. Further detail added from Map Publishing House, Eds., 1975, pp. 94, 95. Inset from Tongguan Hydrology Station, Eds., 1975, p. 135.

9. T. Lindell. Water Quality Laboratory, Swedish Space Corporation. The image is dated 29 October 1976.

10. ZHANG Qishun, LONG Yuqian, 1980, p. 707.

11. GREER Charles E, 1975, p. 14.

12. ZHAO Wenlin, et al., 1975, p. 103.

13. ZHANG Qishun, et al., 1975, p. 132.

14. RHWCC, Eds., 1979, p. 215. RHWCC, Eds., 1959, p. 13.

15. ZHANG Qishun, LONG Yuqian, 1980, p. 707.

16. RHWCC, Eds., 1979, p. 234. QIAN Ning, ZHOU Wenhao, 1965, p. 58.

17. RHWCC, Eds., 1979, p. 253. QIAN Ning, ZHOU Wenhao, 1965, p. 59.

18. Qinghua University Department of Hydraulic Engineering, RHWCC, Eds., 1979, p. 44.

19. QIAN Ning, ZHANG Ren, 1982 p. 3. According to p. 2 of QIAN Ning, ZHOU Wenhao, 1965, the term 'Wandering Stream' (游荡) was used even over 2000 years ago, by JIA Rang, whose work on the R. Huang is described here in Chapter two.

20. QIAN Ning, ZHANG Ren, 1982, p. 4. QIAN Ning, ZHOU Wenhao, 1965, p. 45. The meandering coefficient is the ratio of the actual length of the river course, to the length it would be if it did not meander.

21. RHWCC, Eds., 1979, p. 339.

22. XIE Jiaze, et al., 1947, plate 19.

23. The figures for this section are taken from LIU Dongsheng, et al., 1964, pp. 1 to 5. XIE Jiaze, et al., 1947, pp. 18 to 32. RHWCC, Eds., 1959, pp. 18 to 25. TONG Dalin, BAO Tong, SHI Shan, 1978.

24. XIE Jiaze, et al., 1947, plate 5.

25. WANG Huayun, 1979, p. 3.

26. The data on the sources of R. Huang flood peaks and silt are taken from GONG Shiyang, XIONG Guishu, 1980 and QIAN Ning, et al., 1980. A more readily available summary is to be found in QUSRL, 1981.

27. SHEN Chonggang, 1957, p. 14.

28. QUSRL, Personal communication, 1982. This figure is for the years 1950 to 1970. QIAN Ning, ZHANG Ren, 1982, give 0.02 m yr^{-1}, for an unspecified period.

29. This account is taken from QIAN Ning, ZHANG Ren, 1982.

30. QUSRL, Personal communication, 1982.

31. For example, RHWCC, Eds., 1979, p. 116. LIU Dongsheng, et al., 1964, p. 1.

32. LIU Dongsheng, et al., 1964, appended map. WANG Yongyan, et al., 1980, map preceding preface. GONG Shiyang, XIONG Guishu, 1980, p. 45. Shanghai Shifan University, Eds., 1974, map inside front cover.

33. SONG Chaoshu, in MA Xingmian, et al., 1979. The rest of this section (Plant Cover) is taken from LIU Dongsheng, et al., 1964, p. 5.

34. SRIHEWL, et al., Eds., 1979, p. 2.

35. FANG Zhengsan, 1964. DENG Zihui, 1955, p. 18.

36. China News Analysis, No. 190, 26 July 1957, p. 7.

37. WANG Huandou, 1978.

38. DING Su, et al., 1947, p. 111. XIE Jiaze, et al., 1947, p. 111.

39. Except where otherwise indicated, this section is drawn from Academia Sinica, RHMRSWCCSG, Eds., 1958, pp. 51 to 54.

40. LUO Laixing, 1957.

41. SRIHEWL, et al., Eds., 1979, p. 2.

42. QIAN Ning, DAI Dingzhong, 1980, p. 21. WU Zhiyao, XI Jiazhi, 1979, p. 10.

43. SRIHEWL, et al., Eds., 1979, pp. 4 to 7. QIAN Ning, DAI Dingzhong, 1980, p. 24. DAI Dingzhong, WANG Guiyin, 1979.

44. SRIHEWL, et al., Eds., 1979, p. 8.

45. ibid. QIAN Ning, DAI Dingzhong, 1980, p. 26. MAI Qiaowei, et al., 1979, p. 5.

46. ZHANG Hanying, 1952, p. 14. Shanghai Shifan University, Eds., 1974, p. 55, gives the area of the North China Plain as 130,000 km^2.

47. QIAN Ning, ZHANG Ren, 1982, pp. 14, 15. QIAN Ning DAI Dingzhong, 1980, p. 25.

48. CHEN Zanting, et al., 1980.

49. HUANG Wei, 1978, p. 14. A table of the dynasties appears in the preface.

50. ZHANG Ruijin, 1947, pp. 33, 76.

51. FREEMAN John, 1922, pp. 1428 to 1430. GIBB Alexander, 1929, writes, "The outstanding failure in the history of river engineering ...... is perhaps the avulsion of the Hwang-Ho in 1851."

52. These are taken from WIHEE, WCHPRI, Eds., 1979, pp. 58, 262, unless otherwise indicated.

53. HUANG Wei, 1978, pp. 13, 14. BICKMORE Albert S., 1869, p. 213.

54. HUANG Jun, in HUANG Jun, et al., 1972, p. 6.

55. ZHANG Ruijin, 1947, pp. 53, 73. A notable exception is the 2200 year old Dujiangyan scheme on the Minjiang river in Guan County, Sichuan, which uses a complicated combination of weirs to separate the sediment so that clearer water only may enter the irrigation system. However, this is not typical.

56. ZHANG Ruijin, 1947, p. 57. RHWCC, Eds., 1979, p. 62.

57. ZHANG Ruijin, 1947, p. 61. RHWCC, Eds., 1979, p. 79.

58. RHWCC, Eds., 1979, p. 93. ZHANG Ruijin, 1947, p. 65. The scope of the original project is discussed in TODD O.J., 1935, where

it is reported that although the plain is some 130,000 ha in area, it is thought convenient first to irrigate only about 100,000 ha. Furthermore, it was thought possible to irrigate only 53,000 ha without a weir. The present scheme does not use a weir.

59. RHWCC, Eds., 1979, pp. 170 to 173. Northwest Research Inst. of Soil and Water Conservation, Biology, and Pedology, et al., 1976, p. 54. Map Publishing House, Eds., 1975, p. 185.

60. RHWCC, Eds., 1979, p. 260. WANG Huayun, 1980, p. 3. LIU Shanjian, 1979, p. 43.

61. HE Bingdi, 1969, p. 2.

62. HUANG Wei, 1978, pp. 6 to 11. RHWCC, Eds., 1979, p. 185.

63. HE Bingdi, 1969, pp. 16 to 20.

64. MURPHEY Rhodes, 1967, p. 315. The Sunday Times China Time Chart, 1973. LOWDERMILK W.C., 1930, p. 129. SU Zhong, 1958. Map Publishing House, Eds., 1975, p. 151. XUE Yuan, 1980.

65. Xue Yuan, 1980.

66. For example, FREEMAN John, 1922, p. 1433.

67. These three paragraphs are all taken from WANG Huandou, 1978.

68. LOWDERMILK W.C., 1935, pp. 416, 417. Fieldtrip notes, Yan'an, 1980.

69. LOWDERMILK W.C., 1930, p. 133.

Chapter Two

The Evolution of River Huang Development Concepts.

1) Historical Flood Control Tactics.

The first stories of attempts to control the R. Huang are intermingled even with the creation myth; Da Yu made land and river out of the great confusion. The story goes that after the first legendary flood, in 2297 BC, the mythological emperor Yao sent one Comrade Gun to control the waters. He built "walls" nine ren high around settlements, as flood protection, but failed in nine years to accomplish his task. He was executed, yet was held in great esteem, and his son, Da Yu was ordered to succeed him. Da Yu spent four years surveying, and then set about controlling the whole of the lower reaches. He "directed" the flow as far as Julu County, Hebei, then led it into nine other contemporary rivers on the North China Plain before rejoining to enter the Bo sea. Thus his principal method was by dividing the stream, but this, supposedly, was supplemented by dykes. It is said that thereafter there was no change in the course until 602 BC, though there was often serious flooding.(1)

By the Qin (221 BC to 207 BC) and Han (206 BC to 220 AD) dynasties, protection from the floods of the river Huang had already begun to move to the river itself. There is some uncertainty as to the exact date for the first flood protection levees along the lower R. Huang, but the consensus of opinion indicates that they began to be used widely during the Warring States period (475 BC to 221 BC), and did not become unified until China itself was unified under the first Qin emperor.

Towards the end of the Western Han dynasty (about the time of Christ) there existed three main schools of thought, which debate shows that the causes of R. Huang disasters were being sought in an attempt to find the correct policy.

The first school of thought, represented by Feng Qun, considered that before the river Tunshi, a branch of the lower R. Huang, became blocked with R. Huang deposits, it had served to take excess waters to the sea and had prevented R. Huang disasters. Thus, he advocated dredging the river Tunshi to restore its flood discharge capacity.(2)

The second school of thought is represented by Jia Rang, who, in 8 BC, put forward three alternative proposals.(3) The first proposal was to remove the people who inhabited the wide floodplains within the main dykes which, in those days, were about 25 km apart. These people had constructed smaller inner dykes to protect their new land and Jia Rang considered that this unnatural constriction was the cause of so many dyke breaches. He wanted, therefore, to return this land to the river. Should this be unattainable, his second alternative was to divide the lower R. Huang into a number of smaller streams. Although this might not be so effective a flood-prevention measure as his first proposal, it had the advantage of making R. Huang water and silt available for irrigation and warping over a wide area. The third alternative, which he considered a waste of effort and money, was to continue to repair the dykes and to increase their height and width when necessary. This was the method adopted by the powers that were. In 11 AD the lower R. Huang changed its course again.

The third main school of thought may be represented by Zhang Rong. He considered that there was too much silt in the lower R. Huang, but that a deep channel could be cut and the silt washed out to sea, were it not for irrigation upstream taking all the water. He therefore proposed putting an end to upstream water use.

In 69 AD, Wang Jing and Wang Wu organised several hundred thousand people to control the river and repair an irrigation canal.(4) One record says that over 500 km of dykes were constructed, and that sluice gates were placed "at a distance of 5 km". The next major change of river course was in 955 AD and Wang Jing became famous as the man responsible for over 800 years of hydraulic peace along the lower R. Huang. In recent years this story has been brought into question.(5) Firstly, although there was no change of course, there were many instances of dyke breaches and inundations which became more frequent in later years; secondly, "sluice gates at a distance of 5 km" and "Wang Jing's river control method", which had been taken to indicate some elaborate means of directing floodwaters on to the floodplains and back again, have also been interpreted more simply as the use of two intakes to the Bian Irrigation Canal (no longer in existence), separated by 5 km in order to overcome the problems of drawing water from an ever-shifting channel such as the lower R. Huang. Some Comrades go so far as to suggest that Wang Jing was really mainly concerned with this irrigation scheme and that only the Southern bank of the R. Huang was properly protected by levees; Thirdly, many additional factors have been proposed to explain the relative stability of the R. Huang at that time, namely that the river had taken the shortest possible route to the sea, and had a steeper slope than before, that dyke repair work was done better than previously, that there were fewer storms or droughts in the middle reaches during that period and that agriculture was secondary to animal husbandry on the loess plateau. This last factor has been vigorously advocated by proponents of a return to husbandry in the recent debate on development policy for the loess plateau. (Chapter 5).

Whilst Wang Jing undoubtedly made a contribution by putting R. Huang water and silt resources to good use on the North China Plain, it is unclear what sort of contribution he made to river control. Furthermore, his efforts, like those before him, were confined to the lower reaches.

In the Ming dynasty (1368 to 1644) one Pan Jixun devoted most of his life (1521 to 1595) to the regulation of the R. Huang.(6) His principle was radically different from those before, in that he would build narrow inner dykes to confine the flow, scour the bed and thus increase the flood discharge capacity. In case of accidents, which he thought could not be avoided, owing to the increased erosive power of the confined stream and the frailty of earthen dykes, he called for a set of outer dykes to contain floodwaters. Between the two sets of dykes, transverse dykes were to be built to hinder the flow and cause deposition, thus stabilising the area which we would now regard as the floodplains. In case an extraordinarily large flood should occur, he proposed stone spillways at intervals along the outer dykes, to lead the waters into specially designated areas.

2) Early 20th Century Proposals for the River Huang Basin.

The proposals of the first half of the twentieth Century fall mainly into three categories.(7) Firstly, there were those who continued to concentrate mainly upon flood control by engineering works along the lower reaches to conduct the silt to the sea. John Freeman, former president of the American Society of Civil Engineers, suggested, in 1922, that the lower reach be confined into a straighter and narrower channel, about 0.55 km wide, maintained by spur dykes 0.8 km apart, within the old dykes.(8) In this he was supported by the German engineer, Otto Franzius, who further advocated that the land between the two sets of dykes be built up and consolidated by warping. In 1923, Freeman requested another German engineer, Dr. Hubert Engels, to carry out hydraulic model tests on the arrangements of the proposed spur dykes, after which Engels put forward his own, differing view, namely that better main channel stability and deeper scouring could be brought about by maintaining wide flood-plains and distant dykes. Following further tests requested by the Chinese government in 1932 and 1934, respectively, Engels made the following proposals:

i) That the original dykes be raised to guard against extraordinary floods.

ii) That the mean water channel be stabilised by proper engineering works.

iii) That spur dykes be built at designated positions.

iv) That measures be taken to prevent erosion of the flood-plains.(9)

The second category of proposal, was for those which emphasised control of the middle and upper reaches. Again there were two schools of thought, the first of which can be represented by Wan Jin, who advocated forestry as the solution to the problem of the lower R. Huang. He held that forestry would improve soil structure and increase the plant cover index, both of which would retain soil and water upstream and thus eliminate disasters further down. Amongst the proposals emphasising first controlling the loess plateau there is even a spurious reference to a suggestion to cover the whole of the loess area in concrete, although it is anonymous.(10)

The second school of thought can be represented by Cheng Fulong, who was opposed to forestry, but advocated instead, the building of precipitation dams on the loess plateau, and collectivisation of the land to end the practice of shifting cultivation. He claimed that his proposals were unique in that they used nature instead of opposing it. Furthermore, he claimed that his measures were simple, cheap and effective.

The third category of proposal was for comprehensive development of the whole of the R. Huang Basin. The first exponent of a whole-basin approach was former Chairman of the R. Huang Commission, Li Yizhi (otherwise known as Li Xie), who, like his colleagues Shen Yi and Zhang Hanying, studied engineering in the West and went on to a distinguished career in China.(11) Li thought that between five and ten years' investigation would be needed before a comprehensive plan could be formulated. Meanwhile the lower reaches were to be protected by maintenance work on the dykes. The investigation would include:

i) More hydrological observation stations and improved equipment therein.
ii) A survey of the whole drainage basin.
iii) An investigation of soil and silts throughout the basin.
iv) The establishment of a large-scale hydraulic laboratory at Ji'nan and full scale tests on a suitable portion of the river near Ji'nan or Kaifeng.
v) Erosion control experiments at selected sites in Shanxi and Shaanxi.

Li regarded flood control to be most important, but advocated the development of navigation, irrigation and water power where compatible. His proposals of 1934 emphasised silt precipitation dams in gullies, and large flood detention reservoirs in the various tributaries of the middle reaches. He did not make an appraisal of biological control measures. As for damming the mainstream, at Sanmenxia or elsewhere, he reserved judgement until further data were at hand. His proposals for engineering works downstream were to provide, in accordance with Engels' findings, a stabilised channel (of the same design capacity as the combined outlets of the various proposed detention reservoirs) and broad floodplains. Li died in 1938, before any of these plans could be enacted.

From 1934 to 1944, the Oriental Research Institute of Japan made comprehensive studies of R. Huang basin development, but these differed from Chinese efforts in that their point of emphasis was lain upon hydroelectric power and navigation rather than flood control.(12) Two alternative plans were drawn up for a series of hydroelectric power stations in the middle reaches, one of which included an 86 m high dam at Sanmenxia, in He'nan, some 113 km downstream of Tongguan, which would have a capacity of about $40,000 \times 10^6$ m^3, generate a maximum of 1.123×10^6 kW, and reduce the design flood of 30,000 m^3 s^{-1} by a third. Navigation was planned on a larger scale than other contemporary proposals; the river was to be made navigable for small steamboats between Mengjin and Ji'nan. The Grand Canal was to be improved, the stretch of the R. Huang from the Grand Canal (at Lake Dongping) to Mengjin was to be canalised, a canal was to be constructed connecting the R. Huang to the R. Xiaoqing and then to a new sea harbour in Laizhou Bay, and a new canal was to join the R. Wei (卫) in He'nan to the R. Huang, making the whole stretch from Huayuankou to Tianjin navigable. A total of 25,050 km^2 was to be irrigated. Flood control depended, after the effects of the Sanmenxia retention reservoir, upon channel storage, a detention area between the two Northern sets of dykes from Gaocun to Taochengpu, and, below Ji'nan, the diversion of some 5000 m^3 s^{-1} into the R. Tuhai. Dyke maintenance was proposed for the whole of the lower reaches.

In May 1946, the R. Huang Water Conservancy Commission (RHWCC) completed its "Project for Regulation of the Lower River Huang."(13) Although the R. Huang had changed course in 1938, planning work proceeded on the assumption that it would be returned to its old course, as was indeed done in 1947. The Commission's plan was based, it was claimed, upon the work of Li and Engels. Whilst soil conservation and afforestation were to be encouraged, both for local benefits and their action in reducing the silt load of the lower R. Huang, it was thought that a very long period would be needed before any signficant improvement would be seen.(14) Furthermore, flood detention reservoirs such as those proposed by Li, received only qualified approval, since it was held that deposition usually occurs as the flood peak falls and that such dams would increase the silt concentrations in that, latter, part of the flood, with the net result of increasing downstream deposition. Thus, the plan of 1946 emphasised broad floodplains as suggested by Engels, and the regulation of the lower R. Huang such that floodpeaks and silt could be reduced by channel storage and safely conducted to the sea. The lower R. Huang would then be seen to be in equilibrium. Extraordinary floods would be reduced by a spillway and flood detention basin beside the South bank of the R. Huang at Huayuankou, constructed from part of the area flooded when the dyke was blasted there in 1938.

In addition to the specific proposals outlined above, the RHWCC expressed its opinion on other, more general proposals. Silt precipitation water storage dams were thought worthwhile, especially in the larger tributaries where they were expected to have very long lives, but particular attention was drawn to the criticism levelled by the National Conservancy Board's American adviser, a Mr. Barrett, of the Japanese plan for a storage dam at Sanmenxia or anywhere in the various gorges below Shanzhou, which might, he warned, impede navigation, waste a lot of money and cause the loss of a damsite, unless proper experiments and design work were done first. Nevertheless, a design for a detention reservoir at Shanzhou was discussed as a possible alternative to the proposed detention basin at Huayuankou. Irrigation and warping were advocated strongly, in general terms, and the Japanese proposals for the development of navigation were supported. However, power generation was confined to the middle and upper reaches of both the mainstream and tributaries. No site below the Hekou Falls (near Longmen) on the mainstream was discussed with regard to hydroelectric power generation.

The opinion of several other American Engineers was sought.(15) They were given the title of River Huang Consulting Board, were furnished with the data so far available to the RHWCC and made a one-month inspection tour to various parts of the R. Huang basin in December

1946. The ensuing report, submitted by Messrs. Reybold, Growden and Savage presented a definite plan for flood control, some very general remarks on irrigation, hydropower and navigation, and more specific comments upon the Japanese plan, and soil and water conservation. With regard to flood control, the Americans suggested a reservoir above Mengjin, and a stable channel to conduct silt and water to the sea.

They strongly criticised the Japanese plan for a reservoir at Sanmenxia because a large area of arable land would be flooded and, not being a gorge-type reservoir, it would be difficult to desilt and would have, therefore, a short life. As an alternative, they proposed a 170 m high dam with large capacity outlets at the bottom, about 110 km downstream from Sanmenxia, at Balihutong, which would create a gorge-type reservoir extending to Tongguan. Such a dam would have ample capacity to control the maximum flood, would control the storing and release of silt and could generate a large amount of power. Since it would be desilted each year, it would have an indefinite lifespan.(16) Similarly, the lower reaches would remain stable until the coastline had extended so far as to render the riverbed slope inadequate to prevent siltation. This would be "a very long time." In acknowledgement that the choice of damsite had been based on but a brief aerial inspection, (a fact over which propagandists had a field-day in later years), it was suggested that the performance of both the proposed dam and the lower river channel, which was to be that already designed by the R. Huang Commission, should be subjected to model testing at the Experimental Laboratory of the Mississippi River Commission, in the USA. In the meantime, the dykes were to be raised and the channel stabilised. Geological surveys were to be carried out and it was recommended that several types of dam be designed for each of the three most promising damsites, and comparative studies made. Soil and water conservation should, suggested the Americans, be carried out with the utmost vigour, though despite the "moderate" success of several small-scale experiments, their impression was that hundreds of years would be required to treat the area completely, and that, whilst all such work is beneficial, it could not be relied upon as a solution to the

R. Huang silt problem.(17) On the other hand they were of the opinion that complete control of the silt could be acheived by the construction of high dams, with large capacity bed sluices on the R. Huang mainstream and tributaries, in conjunction with a deep channel across the alluvial delta. Furthermore, once controlled the silt could be used for warping inland and land reclamation along the coastline.

Another American to partake of the one-month inspection tour, was Mr. John S. Cotton, Adviser to the Public Works Commission and Chief Engineer of the Chinese National Hydroelectric Engineering Bureau. He was asked to draw up a report on the investigation and planning work for the development of the R. Huang basin, and, when completed, he attached his own comments on the R. Huang problem.(18) He placed flood control above all else, then came irrigation and reclamation, then power, and lastly navigation. Flood control by some means or other should be achieved at once, but, whereas, control by detention or retardation reservoirs would be desirable, Cotton had grave doubts as to their performance, especially on the equilibrium of the river channel downstream, owing to the unusually high silt concentrations involved. He believed that the only permanent solution to the R. Huang problem lay in soil and water conservation, and he emphasised this by calling for an immediate start to such work on a large scale.

To discharge the silt and water into the sea would be a waste of natural resources, he thought, and whilst a duplication of effort should also be avoided, a scheme to ensure flood protection by a combination of the existing dykes and some new reservoirs or silt-traps was not to be ruled out. He differed with his colleagues over the difficulty of soil and water conservation work, in that he thought that complete control was attainable by changing farming practices and relying on nature to heal its wounds. However, he visualised that over 50 years would be required. Specifically his plan had two stages.

The first stage comprised large scale soil and water conservation work on the loess plateau, combined with widespread warping of alkaline lands on the North China Plain, whilst relying on dyke maintenance for flood control. This would take over 50 years, which time would be used for investigation and planning. As an aid to flood control, large scale silt-trapping dams would be provided near the mouths of the various R. Wei tributaries, and at Longmen and one other place along the mainstream. In the upper reaches large reservoirs would be built for power generation and to regulate the river discharge for flood control. In the second stage, the silt-trapping reservoirs would cease their role in flood prevention, being full, but would provide large areas of fertile land and runoff power generation, whilst soil and water conservation work would have taken care of the silt problem. Thereafter - and Cotton emphasises that it is "absolutely essential" that it be done last(19) - a regulating reservoir could be built at Sanmenxia, for flood control and irrigation.

3) Policy in the Immediate Post-War Period.

During the Civil War no large-scale programme could be drawn up, but local efforts were made in the liberated areas. The R. Huang dykes were repaired for the return of the mainstream to its original course in 1947, during each flood season they were manned in order to prevent breaches, and in 1949 they held firm during a flood crest which exceeded 10,000 $m^3 s^{-1}$ for 90 hours (maximum 16,300 $m^3 s^{-1}$ at Shanzhou) despite the 430 leaks which had to be repaired.(20) However, in the rest of China there was widespread flooding and thus, the need for repairs to the existing dykes, both of other rivers and the R. Huang, and the absence of sufficient hydrological data, compelled the first year of the new order, to be spent on flood protection in general and dyke repairs in particular. Nevertheless, outline plans for the R. Huang were drawn up, and the policy was first to prevent floods by defensive measures along the lower reaches whilst carrying out surveying and research work, and then to formulate a comprehensive solution to the joint problems of flood control and the development of the R. Huang's natural resources.(21)

The basic needs of flood control were met in two ways. Firstly, engineering works; The area between the old Northern dykes and the present main dykes along parts of the reach from Gaocun to Taochengpu was designated a flood diversion area known as the Beijin flood diversion area, and a 1500 m spillway capable of diverting 5400 $m^3 s^{-1}$ was constructed for it at Shitouzhuang in the Summer of 1951. In the Autumn of the same year a 200 m spillway was constructed along the Southern bank at Lijin, just above the estuary region, to allow 1000 $m^3 s^{-1}$ to be diverted in case of flood during the Spring thaw. The Dongping Lake also served as a natural detention basin and this was extended to be capable of absorbing 3000 $m^3 s^{-1}$. Together with a policy of broad floodplains as suggested by Engels, channel storage and dyke reparations these measures were claimed, by 1952, to be able to protect against a flood peak of 23,000 $m^3 s^{-1}$ at Shanzhou. The second method was through mass organisations, to prepare emergency materials and to man the dykes during the passage of flood crests. For example, in the Spring of 1954, 8000 peasants in He'nan and 58,000 in Shandong carried out preparatory work, and over 250,000 m^3 of stone, 700,000 wooden poles and "large quantities" of rope, sacks and wire were made ready beside the dykes there.(22)

In much the same way that basic flood prevention work was begun immediately, so the first steps towards exploiting the river were also taken without waiting for the completion of the surveying and planning work. In March, 1951 work began on a 50 km main canal which was to irrigate 15,000 ha as the first stage of the People's Victory Canal project. It began operation on 12th April 1952 and subsequently was extended to join the River Wei (卫), in 1953, thus making R. Huang water and navigation available, via the R. Wei and the Grand Canal, to Tianjin, and, by 1955, to irrigate 37,000 ha. Renovation work on existing irrigation schemes was begun at once; in the Houtao Irrigation District of Inner Mongolia, for example, a new headgate was begun in May 1950 and completed in May 1952. The irrigated area was gradually increased from 96,000 ha to 133,000 ha as canals were restored. Local soil and water conservation efforts were made, but these were very small, pending planning by the results of the surveys. In Shaanxi and Gansu, by the end of 1954, for example, 1000 km^2 of farmland had been treated, 2300 km^2 had been afforested and over 9000 check dams had been built.(23)

Surveying work was indeed on a large scale. In 1950, there were 33 hydrological stations and 66 rainfall stations, and these increased in number by averages of 40 and 76, respectively, each year in the first decade (Chapter 4). Meanwhile, between 1950 and 1954, 1000 人, in 30 teams reconnoitred 420,000 km^2 of the basin, and 21,000 km of river courses. A further 1000 人 geological surveying contingent carried out topographical surveys of 33,000 km^2 including 5200 km^2 of precision levelling and triangulation-controlled surveys. Several dozen damsites underwent geological survey.(24)

The general approach to more comprehensive basin development can be inferred from an article by Zhang Hanying, Vice-Minister of Water Conservancy, published in September 1952, in which he writes, "During the last three years, the People's Government has been making surveys of the main river and its tributaries in order to draw up a comprehensive project for the regulation of the whole R. Huang water system. It is thought that the key to the problem lies in building dams and reservoirs on the middle reaches of the river ...."(25)

In 1952, China asked the Government of the Soviet Union for a group of Soviet experts to help draw up an overall plan for the R. Huang. In April, Comrades Waguolinge and Geluogeluoweiqi paid a visit to Sanmenxia and recommended that detailed surveys be carried out there. In June 1953, a R. Huang research group was set up including representatives of the Ministries of Water Conservancy and Fuel Industry with over 100 technical personnel, to analyse data and to work with the Soviet experts.(26) In January 1954, a team of seven Soviet experts led by Comrade A.A. Koroliev arrived. They considered that enough data had been gathered and recommended that a whole basin plan be drawn up as soon as possible. The R. Huang research group was expanded to become the R. Huang Planning Commission and work on the report was begun. Meanwhile a team of Soviet and Chinese experts set off on a four month inspection of the R. Huang basin from the estuary to Liujiaxia, spending a whole day at Sanmenxia. At the end of the inspection tour, Sanmenxia was recommended as the site for the key reservoir, and alternative sites at Mangshan and Zhichuan were rejected as being poor geologically, expensive, and unable to be used comprehensively. In helping to draw up the whole basin plan (China's first ever), the Soviet team answered over two hundred questions, corrected the first draft, and wrote the conclusions. In October, 1954, the "River Huang Technical and Economic Report" was completed and, based on this, after gaining the approval of the State Planning Commission, the State Council and the Party Central Committee, the Multiple Purpose Plan for Permanently Controlling the River Huang and Exploiting its Resources was officially adopted by the First National People's Congress at its Second Session, on 30 July, 1955.

4) The Multiple-Purpose Plan of 1955.

This plan comprised two parts; a long term Comprehensive Plan to bring about complete control of the whole basin and the development of its resources, and a more specific First Phase Plan for those items requiring immediate attention.(27)

The Comprehensive Plan, was in outline only. It gave the general principles which subsequent planning and works would follow, but the sites and number of engineering works were to be decided later. Furthermore, whereas a good precis of contemporary methods of soil and water conservation was given and much was made of their role within the plan, no detail was given on how they were to be applied, nor by whom, other than several calls for the support of all sections of society. Nevertheless, it was asserted that the overall plan was "sound on basic content and principle."(28)

The stated aims were to control floods permanently, to check soil and water loss, eliminate drought, and to make full use of the river's water resources for irrigation, power generation and navigation, thus to promote the development of agriculture, industry and transport.

The method was to be to control and use water and silt in the middle reaches rather than to shift them. This was to be done in two ways; firstly, a series of dams and reservoirs on the mainstream and tributaries, the purpose of which was stated to be, to,

> "Conserve soil and water, prevent flooding, regulate the volume of water, develop irrigation and navigation, and, what's more important .... to give us plenty of cheap power."(29)

Secondly, by soil and water conservation, principally in Gansu, Shaanxi and Shanxi. Reporting on this plan to the second session of the First People's Congress, Vice Premier Deng Zihui said,

> "It goes without saying that reservoirs and hydroelectric power stations cannot be built along the main river tributaries by depending upon handicraft technique, nor can soil and water conservation work be done on a large scale by depending upon the efforts of individual peasants. What is needed here is modern scientific technology, large state investments, the support of the masses, and all-round co-operation between government and people, workers and peasants."(30)

The Comprehensive Plan divided the river mainstream into five sections, to be dealt with according to their respective characteristics. The section of many gorges, between Longyang Gorge and Qingtong Gorge, was to emphasise the production of hydroelectric power and irrigation. The gentle stretch between Qingtong Gorge and Hekouzhen would be provided with reservoirs to further irrigation and navigation. From Hekouzhen to Longmen, the many gorges would be used for runoff electrical generation, but only once regulation of the river discharge had been acheived by the completion of the large reservoirs further upstream. The gorges in the stretch from Shanzhou to Taohuayu were seen as the key to flood control, and another source of electrical power. In the gentle lower reach, structures would be built to aid irrigation and navigation. Altogether a "staircase" of 19 reservoirs in the upper reach, 25 in the middle reach and 2 in the lower reach was envisaged. (Figure 2-1). Subsequently more sites were added (Chapter 3, Section 4, vii).

Beside the mainstream, the tributaries would also receive attention. Reservoirs would be built, mainly as silt-traps, but with a few (unspecified) having multiple functions. These silt-traps were seen as temporary measures to protect the mainstream dams and to reduce the silt of the lower reaches whilst awaiting the sufficient effects of soil and water conservation. Meanwhile, though, it was pointed out that the tributary reservoirs themselves would require that soil and water conservation work should make a rapid start if they were not to fill up too quickly.(32)

Although no more than an outline, the Comprehensive Plan went as far as deciding the key to the whole project, which would be a $36{,}000 \times 10^6$ m^3 reservoir at Sanmenxia, and its attendant tributary projects immediately above and below. The dam at Sanmenxia would be 90 m high and the water level behind it would be 350 m above a datum, approximately at sea level. The lake so formed would cover an area of 1500 km^2 and extend beyond the Tongguan confluence along all three rivers but not confined to their former banks. Some 600,000 人 would have to be moved and resettled.(33)

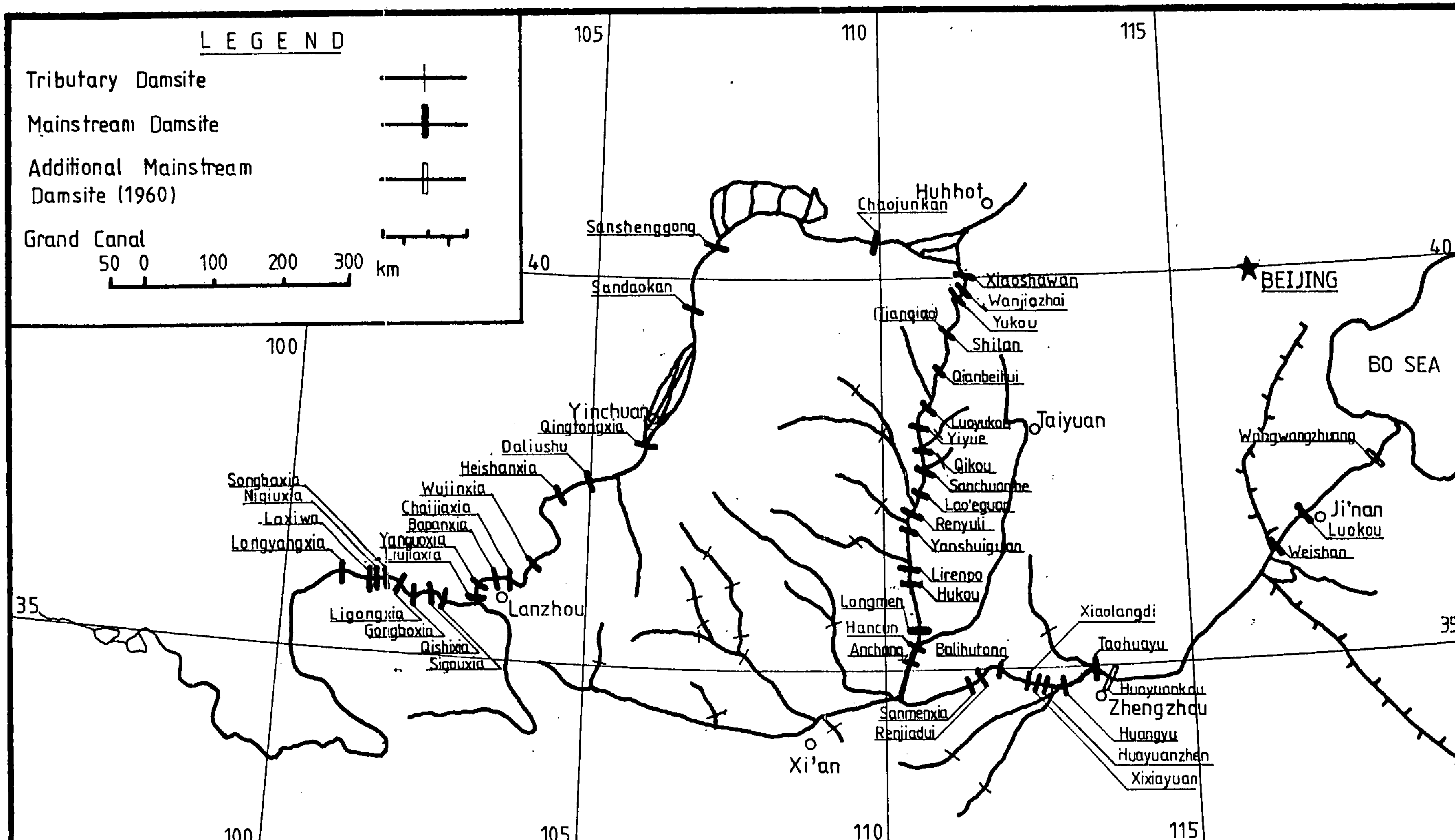


FIGURE 2-1 DAMSITES IDENTIFIED IN THE 1955 PLAN SOURCES: Note 31

The Comprehensive Plan would, in about 50 years, achieve its stated aims thus: The Sanmenxia reservoir and reservoirs along the Yi, Luo and Qin tributaries could together reduce the maximum discharge borne by the lower reaches to 8000 $m^3 s^{-1}$, which could safely be dealt with. Similarly, of the various reservoirs in the upper reaches, one at Liujiaxia could reduce the discharge of the gentle part of the upper reaches to 5000 $m^3 s^{-1}$. The Sanmenxia reservoir would be protected by upstream tributary reservoirs, which would themselves be protected by soil and water conservation work in their respective catchments. All of these reservoirs would gradually silt up and the period envisaged for this to happen would be about fifty years. Nevertheless, by that time soil and water conservation work would be complete, as would the other mainstream reservoirs, the lower reaches would, carrying clean water, cut a stable channel, and the water and silt system of the entire basin would be under control. The Economic and Technical Report had estimated that the R. Huang's silt load would be reduced by 50 % in 1967, and 75 % within about fifty years. Deng Zihui confidently predicted,

> "As for difficulties that may arise in power generation, irrigation and navigation as a result of the silting up of the reservoir, they will be comparatively easy to deal with". (34)

Meanwhile, the 46 mainstream dams could produce 23 x 10^6 kW of electrical power, to be supplemented by smaller tributary hydropower stations; the multiple purpose projects in the gorge sections and the special reservoirs on the gentle sections would together increase the irrigated area to 77,000 km^2, which was estimated to be 65 % of the basin's needs; navigation requirements would be met by making the whole stretch from the mouth to Lanzhou navigable by 500 t barges. There would also be a substantial increase in the outputs of agriculture, silviculture and animal husbandry on the loess plateau. A passing reference was made to the possibility later of supplementing the water resources of the R. Huang basin by transfers from others, but no detail was included in the plan.

The First Phase Plan, announced simultaneously with the Comprehensive Plan, comprised those proposals to be carried out within twelve years, before 1967. They included entrusting Chief Design Engineer Comrade

Koroliev, of the Leningrad Hydropower Design Annex of the Soviet Ministry of Power Stations, with the design of the Sanmenxia reservoir and power station. The proposed water head of 70 m would have an installed generation capacity of 1 GW, the water level in the first period would be 335.5 m and 215,000人 would have to be resettled. The low water season flow could be supplemented to 500 m^3 s^{-1} for irrigation and navigation. Work would begin in 1957 and be completed in 1961. Another multipurpose project at Liujiaxia, above Lanzhou, would be constructed which would have a 107 m head, an installed capacity of 1 GW, and would be capable of increasing low season flow to 465 m^3 s^{-1}. 27,000人 would have to be moved. For flood control below Sanmenxia, one or more reservoirs on each of the Rivers Yi, Luo and Qin would be completed before 1964. The river was to be made navigable in two sections, 703 km from the mouth to Taohuayu, and 843 km from Qingshuihe to Yinchuan. For irrigation, reservoirs would be built at Qingtongxia Sanshenggong and Taohuayu. In all 20,000 km^2 of land would be newly irrigated in various parts of the basin and 8000 km^2 would benefit from the improvement of existing works. As for tributary dams, it was proposed,

> "...to build first of all five reservoirs at suitable sites along the Rivers Jing, Hulu, Beiluo, Wuding and Yan, and another five smaller reservoirs on suitable smaller tributaries."(35)

It was also proposed to build two multiple purpose tributary projects, on the rivers Fen and Ba, respectively. Soil and water conservation work to be completed in the First Phase Plan included,

> " i) Improved cultivation methods on 85,000 km^2 of orchards, and the enclosure and withdrawal of farming from 7300 km^2 of steep slopes;
>
> ii) New terraces on 18,700 km^2 of slopes, ditch terrace 9300 km^2, build banks around 9800 km^2 of fields, bank along contours on 11,300 km^2 and dig dust-pan storage ponds on 240 km^2 of slopes;
>
> iii) Afforest 14,000 km^2, have 470 km^2 of nurseries, and enclose 24,400 km^2 for natural afforestation;
>
> iv) Dig 37,000 small water sumps, build storage ponds totalling 20 x 10^6 m^3 , 16,000 small dams across ditches by roads, 215,000 gully head protection works, 638,000 check dams, 79,000 silt-precipitation dams, irrigate 3173 km^2 by small projects, warp 667 km^2, build 300 earthen gully dams and repair 4300 km of roads."(36)

Adding up the various areas given accounts, almost exactly, for every square kilometre of the loess plateau!

5) Preliminary Design of the Sanmenxia Project.

The R. Huang Technical and Economic Report formed, and, it is claimed still forms, the conceptual basis for the development of the R. Huang basin.(37) The Soviet team returned in February 1955, to examine geological data pertaining to Sanmenxia, in order to draw up the preliminary design. They also suggested the next stage of surveying work and gained an understanding of damsites on tributaries having a large influence of the R. Huang; the Rivers Jing, Beiluo, Wei, Yi, Luo and Qin. In the Summer of 1956 they came a third time and proposed the main points of the preliminary design, gained an understanding of the position and geology of the worksite, the present circumstances and future prospects of Zhengzhou, Luoyang and Xi'an with respect to electricity supply, and surveyed typical measures for soil and water conservation on the loess plateau. It was on their fourth visit, beginning in February 1957, that the preliminary design was formally proposed, although the plans had been handed over the previous December, and the Leningrad Hydroelectric Design Annex of the Soviet Ministry of Power Stations undertook to design the Sanmenxia project, with Korolïev as Chief Engineer in charge, and a team of 1000 人 .(38)

In the course of drawing up the Preliminary Design, some changes had been made to the specifications of the Sanmenxia Project. Yet, it remained a storage reservoir, and other aspects of the planned "staircase" were not involved, so the changes, though significant, do not represent an alternative proposal. These changes had been debated and agreed by the Chinese State Council in April 1956. The twenty one Soviet experts who came in 1957, were asked to give details of their calculations under four headings: Water resources, Water Conservancy, Electrical Engineering and Civil Engineering. The Chinese experts were to discuss them in four groups and the Soviet experts were to answer questions at the concluding session of their meetings.(39)

The Preliminary Design differed from that envisaged in the R. Huang Technical and Economic Report, in the points shown in Table 2-1.

TABLE 2-1 CHANGES TO THE SPECIFICATIONS FOR THE SANMENXIA RESERVOIR

	Technical and Economic Report	Preliminary Design
Normal High Water Level (m above datum)	350	360
Total Reservoir Capacity (Mm^3)	36000	64700
Area to be Flooded (km^2)	1500	2300
Number of Evacuees	584000	890000
Maximum Water Discharge ($m^3\ s^{-1}$)	8000	6000
Irrigated Area in the First Period (km^2)	13000	26000
Installed Generation Capacity (MW)	1000	1100
Annual Energy Output (GW h)	4600	6000
Investment (¥ x 10^6 [£ x 10^6])	1220 [349]	1600 [457]

Sources: CHENG Xuemin, 1957. SHEN Chonggang, 1957.

Much debate ensued over the design details and was still going on when work officially began, on 13 April 1957.(40) Indeed, evacuation had begun the year before, and heavy machinery from the Soviet Union, Eastern Europe and Japan, had, along with over 600 engineers and technicians, been gathering at the site in preparation. Details of the Soviet design and the thinking behind it are given below, and those of alternative proposals in section 6.

The requirements of the Sanmenxia Project, according to the R. Huang Technical and Economic Report, were:

i) Regulate floods, lower the volume of water discharged to the lower reaches such that the dykes are never again breached.

ii) Satisfy the expanding needs of irrigation along the lower reaches.

iii) Satisfy the expanding Industrial, Agricultural and Residential needs for electricity.

iv) Provide for navigation by regulating the water stage above and below the dam.

v) Guarantee Industrial and Residential water supplies.(41)

As the Soviet advisers saw it, a reservoir at Sanmenxia would control 684,000 km^2 of the R. Huang Basin, but below it 43,000 km^2 would still not be controlled and would require reservoirs on the Rivers Yi, Luo and Qin, to be designed by the RHWCC. The original specification allowing 8000 $m^3 s^{-1}$ to be discharged into the lower reaches was based on a flood peak of that size which had been safely conducted to the sea in 1949. For the Preliminary Design, though, this was believed to be too risky in the Shandong reach, and, so, was reduced to 6000 $m^3 s^{-1}$. To provide the storage necessary to reduce a 1000 year flood of 35,000 $m^3 s^{-1}$, to 6000 $m^3 s^{-1}$, would require reservoir capacity of 7200 x 10^6 m^3. Furthermore, if large floods were simultaneously to occur on the Rivers Yi, Luo, Qin and Huang, this 6000 $m^3 s^{-1}$ would, when combined with the waters from the other three tributaries, be excessive, and it would be desired to close the discharge gates at Sanmenxia for seven days. This would require another 2800 x 10^6 m^3 of reservoir capacity. Thus basic flood control would require a total retention capacity of $10,000 \times 10^6 m^3$.

The following new assumptions were made:

i) As soil and water conservation progressed, so the silt load of the R. Huang would be reduced by 20 % by 1967 and 50 % in 50 years' time.

ii) 20 % of the silt entering the reservoir would be discharged to the lower reaches.

It was then calculated that $35,000 \times 10^6 m^3$ of reservoir capacity would have to be provided to store silt over 50 years. Together, flood prevention and silt detention would require $45,000 \times 10^6 m^3$, which corresponds to a normal water level of about 354 m above datum.(42)

In addition, calculations on power generation gave the most efficient water level as between 364 m and 368 m, but this would require flooding an area in excess of 2700 km^2, the evacuation of over a million 人 , and the possible encroachment of a raised water table at Xi'an. Therefore, it was agreed with the Chinese, to fix the normal high water level at 360 m, giving a total capacity of $64,000 \times 10^6 m^3$ (R. Huang above Tongguan, $21,000 \times 10^6 m^3$, R. Wei $22,000 \times 10^6 m^3$, and reservoir area below Tongguan, $22,000 \times 10^6 m^3$.), flooding an area of 2300 km^2 and necessitating the evacuation of 890,000 人 . With this additional reservoir capacity, it was claimed that comprehensive use of the reservoir could be guaranteed for 50 years and flood control for 80 years.(43)

In order to alleviate the problem of moving so many people, it was suggested that:

i) The construction time be extended by one or two years.

ii) The generator sets be gradually installed according to the requirements of industry etc..

iii) The normal high water level start at 345 m and be raised according to the rate of deposition, the requirements of generation and irrigation, and the practicality of moving the evacuees. (It may be noticed that a similar provision, to begin with a water level of 335.5 m, had been included in the First Phase Plan).

As for the design of the dam itself, the Soviet advisers proposed that the left hand side should comprise a 124 m long sluicing section with 12 deep sluices 3.5 m x 6.0 m, at a height of 320 m (40 m above the base of the dam), capable of discharging 4500 $m^3 s^{-1}$ under a water level of 350 m and 6000 $m^3 s^{-1}$ under 360 m. Reserve discharge capacity of 2000 $m^3 s^{-1}$ would be provided by two 11 m x 13 m spillways near the top of the dam. Another 1500 $m^3 s^{-1}$ could pass through the turbines. During construction, sixteen 3.5 m x 6.3 m bottom sluices would be provided at 280 m to allow the river to pass unhindered, but they would be sealed thereafter.(44)

6) Alternative Proposals.

After these proposals had been discussed in the meetings of February 1957, some Chinese were not satisfied, principally about the enormous cost of the project and the large area of prime agricultural land to be lost. A number of opinions were discussed at a special meeting of over 50 Chinese specialists from government, universities and colleges, held by the Ministry of Water Conservancy.(45) Amongst these opinions, one type can be said to differ in concept from the Soviet plan, since it proposed not to have a storage reservoir at all, but instead to build a smaller, flood attenuation reservoir, designed to avoid, as far as possible, a loss of capacity through deposition. The main proponents of this alternative type of scheme were Comrades Ye Yongyi and Wen Shanzhong. Comrade Ye's arguments were as follow :(46)

To reduce a thousand-year flood (35,000 m^3 s^{-1}) to 6000 m^3 s^{-1} and to be able to close off the flow at Sanmenxia should a simultaneous flood occur in the lower tributaries would require a reservoir capacity of 10,000 x 10^6 m^3. Assuming that bottom sluices be provided at 280 m, of sufficient capacity to discharge 6000 m^3 s^{-1} under a water stage of 310 m, and noticing that at Tongguan, the water level which corresponds to a discharge of 6000 m^3 s^{-1} is 325 m, it should be expected that for a discharge of 6000 m^3 s^{-1} the whole silt load of the river would enter the gorge section of the reservoir area below Tongguan and all but the coarsest grains, which would be deposited in the reservoir backwater at the 310 m level, would be carried beyond the dam to the lower reaches. For flows above 6000 m^3 s^{-1}, the dam would interfere with the flow and cause the water level to rise. At the 320 m level, all the silt would still enter the gorge section, but since the water in the reservoir would be comparatively deep, deposition would occur in the backwaters just below Tongguan. For water stages in excess of 320 m, the backwaters would extend beyond Tongguan and 75 % (an assumption based on the distribution of the grain size of R. Huang silt) of silt would be deposited there and 25 % would be carried into the gorge section. As high flood peaks recede, a main channel would be scoured, but the capacity lost to the formation of floodplains would be irrecoverable.

Future flood peaks not exceeding 6000 $m^3\ s^{-1}$ (and therefore not covering the floodplains) would, if not at once, then successively, scour the main channel back to its original level, thus conserving the main channel reservoir capacity. The original reservoir capacity between the water levels 310 m and 320 m was $1800 \times 10^6\ m^3$, and assuming that half of this would be lost in the formation of floodplains, only $900 \times 10^6\ m^3$ would be left as regulation capacity.

Using 38 years' records, it was found that 6000 $m^3\ s^{-1}$ was exceeded on only 86 days, and the main channel regulation capacity could have been exceeded only in the extra large floods of 1933, 1943 and 1944. Calculations based on the above assumptions show that 26×10^6 t yr^{-1} would accumulate on the floodplains, on average. To be on the safe side, it was postulated, hypothetically, that one 100 yr and one 1000 yr flood had also occured. Thus 110×10^6 t yr^{-1} could be expected to accumulate during the flood season. To this must be added 220×10^6 t yr^{-1} which would be deposited when the reservoir is being used in a water storage mode during the rest of the year. Together this is equivalent to 25 % of the annual silt load.

Accepting the Soviet predictions for the efficiency of soil and water conservation, and assuming a density of 1.2 t m^{-3}, the above calculations predict that after 50 years $9400 \times 10^6\ m^3$ would be deposited. In order at that time still to be able to protect against a 1000 yr flood, an original capacity of $(10,000 \times 10^6 + 9400 \times 10^6)$ $19,400 \times 10^6\ m^3$ would be required. This is equivalent to a water level of 342 m, (348 m for 10,000 yr flood). Therefore the dam should be built to a height of 350 m and the sluices placed at 280 m.

Comrade Wen suggested several schemes similar to that of Comrade Ye. In one, for example, he would set the water level at about 336 m to 337 m and make the corresponding original capacity of $11,000 \times 10^6\ m^3$ to $12,000 \times 10^6\ m^3$ last 20 years, by doing without water storage (and the consequent deposition) in the Winter. In an earlier scheme, he had suggested that all Winter deposits could in Spring be successfully flushed away.(47)

These schemes satisfied the needs of flood control, whilst obviating the loss of so much arable land, and saving on construction and other costs. Comrade Ye calculated that his scheme would save ¥ 40 x 10^6 (£ 11.4 x 10^6) on concrete alone, whilst Comrade Wen claimed more specifically that under his scheme 70,000 人 fewer would have to be evacuated, and 1700 km^2 of land and ¥ 750 x 10^6 (£ 214 x 10^6) would be saved in all.

Yet, both schemes forsook many of the potential benefits of the proposed storage reservoir. Under Comrade Wen's scheme, between 10,000 km^2 and 13,000 km^2 could be irrigated in Shandong, but North and East He'nan would have to rely more upon underground water sources. Under Comrade Ye's scheme, 27,500 km^2 could be irrigated between November and June whilst Summer irrigation would have to depend upon rainfall and wells. Navigation would not be provided in either scheme, other than on the irrigation canals. Power generation capacity would be restricted to between 150 MW and 300 MW by way of runoff generation at Sanmenxia, which would have to be subordinate to silt discharging, and, therefore, would also be intermittent during the Summer months. It was suggested that this could be supplemented by hydropower stations, such as at Balihutong, or by thermal power stations, the region being rich in coal.

Critics of these schemes outnumbered their supporters considerably. Amongst them, the Soviets denied that deposits substantially could be flushed out and therefore insisted that a large storage reservoir was needed, or it would fill up in 16 years under normal conditions or one year if there be a large flood.(48) They also claimed that silty waters could not be used for irrigation, so there could be no Summer irrigation, and that the cost of thermal power stations would be excessive by comparison. Furthermore, the silt flushed out from the reservoir would cause the lower reaches to continue to rise, again harming flood prevention.

Comrades Ye and Wen answered by contesting the need for large scale benefits. As Comrade Wen put it, there were four alternatives for achieving the aims of comprehensive use:

i) Co-ordinated projects at Heishanxia, Sanmenxia and Balihutong.

ii) Co-ordinated projects at Heishanxia and Balihutong.

iii) One multipurpose project at Sanmenxia, but gradually raising the water level.

iv) A project at Sanmenxia, in which the level would be raised according to the deposition, followed by the construction of a hydropower station at Balihutong.(49)

Comrade Wen said that as far as flood control and irrigation of 15,000 km^2 was concerned, there was no difference amongst the four schemes, but that there were obvious differences when it came to evacuation and electricity generation. Owing to alkalisation problems, irrigation would not be able to expand to the predicted 27,000 km^2 by 1967. The Soviet comrades' complaint that silty water cannot be drawn for irrigation would apply equally to their own scheme, he said, because beyond a few hundred metres below the dam, the clear waters will have picked up silt in concentrations of several tens of kilogrammes per cubic metre. Similarly there would be no need before 1967 for all the generating capacity proposed at Sanmenxia, and thereafter hydropower stations would be built at Balihutong and Renjiadui, so really much of the capacity of Sanmenxia would have been built just to act as a standby.

Comrade Ye pointed out that 75 % of silt at present entering the lower reaches was safely carried to the sea. Even with silt discharging, only about 75 % of the silt entering the reservoir could enter the lower reaches, therefore it should all be safely carried to the sea, or at least, deposition would be very slow. Irrigation canal intakes could use such methods as settling ponds, built on the floodplains, to derive clear water. Anyway, between July and October, only a few hundred cubic metresper second of water would be needed for irrigation, whereas natural flow was 2000 $m^3 s^{-1}$ to 3000 $m^3 s^{-1}$. To store all the silt in this quantity of water, just to get a few hundred cubic metres per second of clear water, would be unreasonable.

Even though, because of the high silt content, the People's Victory Canal irrigation scheme can only use water for nine days during August, yields do not drop because in August over 60 mm of rain falls. The canal system for the proposed 27,000 km^2 of irrigation could not be prepared within those ten years, and even if it were, only those few hundred cubic metres per second would be taken from the R. Huang. Rather than fill up Sanmenxia to provide that much clear water, why not put the silt to use by warping outside the R. Huang dykes? The 150 MW to 200 MW generating capacity at Sanmenxia which he (Comrade Ye) proposed, would, he said, be quite enough for the short term. Thereafter another 300 MW could be got in the periods of the third and fourth five year plans, by building a dam at Balihutong. After 1972, it would be possible, depending on the effectiveness of soil and water conservation, either to increase the generation capacity at Sanmenxia, or to build other new stations at sites such as Xiaolangdi.(50)

Professor Huang Wanli of Qinghua University brought into question the postulate that a reduction in soil erosion on the loess plateau would give rise to a corresponding reduction in the silt content of the R. Huang.(51) If clear water were to collect in the tributaries on the loess plateau, he suggested, then it would pick up silt from the various tributary and mainstream beds. By the time the waters reached Sanmenxia, they would be as muddy as ever. Now everybody was opposed to allowing silt to accumulate in the lower reaches, so why let it do so in a reservoir? Professor Huang went on to deplore the attitude, "A dam solves 10,000 problems, no silt , a clear river," and feared that silt accumulating in the backwaters of the reservoir would eventually cause flooding upstream and that clear water discharged from Sanmenxia might attack the floodplains or dykes as had happened previously below the Guanting Reservoir (R. Yongding), hampering flood prevention work. In conclusion, Professor Huang advocated that the bottom sluices be left after construction so that silt could pass unhindered through the dam. From July to September, the whole reservoir capacity should be used uniquely for flood prevention. In the other months it should be used for irrigation.

All the above points, and more, were discussed repeatedly in the late fifties. Eventually it was decided to build the dam to the Soviet design, but modified to have an initial height of 350 m, to have an initial high water level of 340 m, and to lower the twelve deep sluices by 20 m, to a level of 300 m. It is said that the Soviet engineers so vehemently opposed these changes, that a compromise had to be found whereby the official blueprints would still show the original heights, despite the changes.(52) The Soviets were not going to be held responsible for what they saw as errors on the part of their Chinese counterparts.

Notes to Chapter Two

1. ZHANG Ruijin, 1947, pp. 33 to 51. RHWCC, Eds., 1959, pp. 64 to 117. ZHANG Shunong, 1953, pp. 479 to 486. WIHEE, WCHPRI, Eds., 1979, p. 39. One ren is about 2.5 m.

2. RHWCC, Eds., 1959, pp. 70 to 72. WIHEE, WCHPRI, Eds., 1979, pp. 172 to 196.

3. WIHEE, WCHPRI, Eds., 1979, pp. 196 to 211.

4. RHWCC, Eds., 1959, p. 75.

5. For example, see WIHEE, WCHPRI, Eds., 1979, pp. 189 to 196. WANG Yongquan, XU Fuling, 1979.

6. ZHANG Ruijin, 1947, pp. 36 to 40.

7. RHWCC, Eds., 1959, pp. 113 to 117.

8. FREEMAN John, 1922.

9. ZHANG Ruijin, 1947, p. 42.

10. Letter from John S Cotton to Dr. Shen Yi, 20 February 1947, appended to COTTON J.S., 1947.

11. GREER Charles E, 1975, p. 67, gives the information that Li Yizhi studied civil and hydraulic engineering at Berlin, Shen Yi studied hydraulic engineering at Dresden, and Zhang Hanying studied civil engineering at Cornell.

12. ZHANG Ruijin, 1947, pp. 45 to 50.

13. ZHANG Shunong, 1953, p. 484. RHWCC, Eds., 1947, introduction.

14. RHWCC, Eds., 1947, pp. 73 to 101. The 'very long period' is not defined in the report.

15. REYBOLD Eugene, et al., 1947. Lit. Gen. Eugene Reybold, formerly Chief Engineer in the US Army; Dr. John L.Savage, Chief Design Engineer, US Bureau of Reclamation; James P Growden, Chief Hydraulic Engineer, Aluminium Company of America; Percy M Othus, Executive Engineer; John S Cotton, Chief Engineer, National Hydroelectric Engineering Bureau of the National Resources Commission. (SHEN Yi, 1947, p. 7).

16. REYBOLD Eugene, et al., 1947, pp. 17, 18.

17. ibid., p. 26.

18. COTTON J.S., 1947, Addendum, 10 pp.

19. ibid., p. 9 of addendum.

20. FU Zuoyi, 1950.

21. ZHANG Hanying, 1952. XINHUA, Beijing, 13 Sept. 1952.

22. ZHANG Hanying, 1952. XINHUA, Beijing, 9 April 1954. XINHUA, Kaifeng, 23 August 1954.

23. XINHUA, Beijing, 25 October 1952. ZHANG Zilin, 1953. XINHUA, Zhengzhou, 31 March 1955. WANG Huayun, 1955. XINHUA, Zhengzhou, 4 October 1955. ZHANG Hanying, 1952. XINHUA, Huhhot, 20 June 1952. RHWCC, Eds., 1979, p. 79. XINHUA, Zhengzhou, 15 Dec 1954.

24. WANG Huayun, 1980, p. 5. LONG Yuqian, XIONG Guishu, 1981, p. 16. However, DENG Zihui, 1955, p. 29, gives the following: 16,000 km of mainstream and tributaries reconnoitred, 85,000 km^2 surveyed, 100 tentative damsites selected along the mainstream, and 344 borings made at 27 damsites.

25. ZHANG Hanying, 1952, p. 19.

26. DENG Zihui, 1955, p. 29. JUN Qian, 1957. ZHANG Diezheng, 1954.

27. DENG Zihui, 1955.

28. ibid., p. 30.

29. ibid., p. 27.

30. ibid., p. 28.

31. KOROLIEV A.A., 1957. RHWCC, 1959, p. 240.

32. DENG Zihui, 1955, pp. 34, 35.

33. ibid., p. 40. SHEN Chonggang, 1957, p. 11.

34. DENG Zihui, 1955, p. 39. The reservoir mentioned is the one planned for Sanmenxia.

35. ibid., p. 41.

36. ibid., p. 43. Some alteration is made to the translation after study of p. 127 of the Chinese original.

37. Fieldtrip notes. Meeting on 10 August 1980 with three representatives of the RHWCC; Comrades TENG Guozhu, Planning Bureau of the Design Inst., CAI Lin, Engineering Bureau, QING Xianya, Science Institute.

38. JUN Qian, 1957.

39. SHEN Chonggang, 1957, p. 13. GUANGMING RIBAO, 10 February 1957.

40. ZHONGGUO SHUILI, Eds., 1957, part 1. XINHUA, Zhengzhou, 2 April 1957. XINHUA, Sanmenxia, 13 April 1957.

41. SHEN Chonggang, 1957, p. 11.

42. Interpolated from WANG Huzhen, 1957, p. 2.

43. SHEN Chonggang, 1957. GUOERHUANGFU K.C., et al., 1957.

44. CHEN Yikun, 1957, p. 21.

45. ZHONGUO SHUILI, Eds., 1957, gives a summary of the various opinions. More detailed presentations of some of these opinions are to be found in the 1957 issues of the two magazines, SHUILI FADIAN and ZHONGGUO SHUILI.

46. YE Yongyi, 1957. ZHONGGUO SHUILI, Eds., 1957.

47. GUOERHUANGFU K.C., et al., 1957. ZHONGGUO SHUILI, Eds., 1957.

48. GUOERHUANGFU K.C., et al., 1957, p. 7.

49. ZHONGGUO SHUILI, Eds., 1957, part 2, p. 33.

50. ibid., part 1, p. 21.

51. ibid., part 1, p. 19, part 2, p. 31. HUANG Wanli, 1957.

52. Fieldtrip notes, 1981.

Chapter Three

Walking a Tortuous Route 走一个弯路

The Sanmenxia reservoir project turned out to be so greatly in error that it had to undergo extensive reconstruction even before it was fully commissioned. The prevalent view is as follows:

> "Owing to insufficient knowledge of the natural laws of the R. Huang and the laws of China's socialist construction, over optimistic estimates, of the speed and efficiency of soil and water conservation, and in particular, insufficient appraisal of the objective situation in China, where the population is large and land is scarce, and where it is impermissible to exchange large areas of plain-land for greater reservoir capacity, the Sanmenxia project failed to attain the expected goals."(1)

Other writers refer to inadequate attention being paid to the sedimentation problem and to the goals for multipurpose development being set too high. Others still, like to emphasise the positive aspects, saying that they had taken a tortuous route for which Sanmenxia had exacted 'study fees', but that a great deal had been learned in the process.(2)

This chapter is intended to show the reasons for the failure of the project, and the process by which new experience was gained, and the present solutions, or attempts thereat, developed.

1) Estimates and Unknowns.

The description in Chapter 2 of some of the opinions held in 1957 by engineers concerned with R. Huang control, contains several references to estimates, sometimes disputed, on the basis of which the various proposals were based. These estimates were, in many cases, based upon assumptions, and often alternative estimates were put forward, based upon different assumptions. The purpose of an assumption is to substitute for an unknown quantity, and it is illuminating to consider the limitations of the knowledge at the disposal of those faced with the task of deciding how best to bring the R. Huang under control, in the late fifties. This section, therefore, comprises a list of some of the unknown quantities and estimates used in deciding to adopt the modified Soviet design. Subsequent sections will show how accurate or otherwise the estimates were.

i) Estimates concerning the future silt content of the River Huang.

Several different estimates were put forward for the reduction likely to occur in the silt content of the R. Huang, consequent upon the development of soil and water conservation on the loess plateau.(3) The RHWCC made estimates, based upon extrapolations from the data obtained from several soil and water conservation testing stations, that the silt content would fall by 40 % by 1967 and by 78 % after 50 years. However, figures put forward by the Soviet experts from the Leningrad Hydropower Design Annex, that the silt content would fall by 20 % by 1967 and 50 % after 50 years, were adopted so as to provide a safety margin. It should be mentioned though, that apart from the assumptions on which the various estimates of the efficiency of soil and water conservation work were based, there is also the implied assumption that the silt picked up by the clear water from tributary beds would be of negligable amount in the long run.

Soil and water conservation work should also give rise to a reduction in surface runoff, and hence, river discharge. The Soviet National Hydrologic Institute claimed that no appreciable reduction would occur, whereas the Soviet Geographical Research Institute estimated a reduction of 5000 x 10^6 m^3 yr^{-1} by 1967 and 10,000 x 10^6 m^3 yr^{-1} after 50 years. This question, in June 1957, was left open to await research.(4)

Although the distribution of grain size in the silt of the R. Huang was studied carefully in order to estimate the amount and distribution of silts within the proposed reservoir area, no detailed analysis had been done, by 1957, of the source of the various sized silt grains. It was assumed therefore, that for soil and water conservation to have any marked effect upon the R. Huang, it must be carried out all over the loess plateau, there being little distinction between the various regions other than the severity of erosion.

ii) Estimates concerning deposition within the reservoir area.

A very significant assumption made in adopting the Soviet design was that the Soviet engineers were correct in their assertion that,

> "As is confirmed by the experience of various nations worldwide in reservoir usage, it is impossible in practice to flush out silt already deposited in the reservoir area...all that you get is a narrow channel accompanied near the sluices by a funnel-shaped hole.... the amount thus dischargeable is tiny compared to the amount deposited..... so only suspended matter can be discharged."(5)

How much of that suspended load could be discharged was another much disputed estimate. It was assumed that a delta would form in Summer in the R. Huang mainstream above Tongguan, and a density current would occur in the R. Huang mainstream above and below Tongguan. This density current would be capable of reaching the dam and then rising to the deep sluices (20 m above the bed according to the modified design) and discharging 20 % of the total annual silt load. This assumes that a density current would be capable of turning sharply and passing through the sudden restriction of the Tongguan confluence. It was acknowledged that the density current might flow the other way, and cause deposition in the lower R. Wei, but the only comment on this was that it would be "complicated". Similarly, deposition in the R. Wei for other reasons, and deposition below Tongguan are recognised but not assessed.(6)

As for the volume occupied by the deposits, to 1957, silts from the floodplains of the R. Huang or from the Guanting reservoir on the R. Yongding had not been available to the Soviet experts, and so the assumption was used that deposits of fine silts (<0.01 mm) would weigh 0.9 t m^{-3}, and coarse silts would weigh 1.2 t m^{-3}.(7)

iii) Upstream effects.

Retrogressive backwater deposition is mentioned by some opponents of the Soviet design. But their point is not answered, so it may be concluded that, in adopting the modified Soviet design, the assumption was that it would not give rise to any serious effect.(8)

iv) Downstream effects.

It was assumed that to discharge clear water from Sanmenxia to the lower reaches could only have good effects on the channel, and that irrigation depended upon it, since silty water would not be useable. It was further assumed that to discharge silty water would lead to channel deposition such that eventually flood protection would fail. These assumptions were all challenged, but apparently upheld.(9)

In addition it was assumed that there were suitable reservoir sites to be found on the rivers Yi, Luo and Qin, since flood prevention would depend on their water retention.

v) The Need of a Multipurpose Project.

It is of particular interest to note the assumptions made concerning the desirability, or otherwise, of having one large project to solve a whole series of present and future problems, as opposed to tackling immediate, and local, problems first and future, and distant, problems in a step by step fashion. Quite apart from the conclusion, based upon the above technical assumptions, that only a large storage reservoir would be capable of controlling R. Huang floods, it was assumed to be desirable to provide for the maximisation of the other multipurpose benefits as an end in itself. Indeed, multipurpose use was included in the original terms of reference for the project. One of the major objections to the alternative proposals, for a flood-retardation reservoir at Sanmenxia, was their apparent failure to provide multipurpose benefits on a comparable scale.(10) It was assumed to be desirable to provide for such benefits, even though they would not be needed for some time, as can be seen, for example, by the plan to reduce the burden of moving and resettling so many people, by gradually raising the water level of the reservoir according to the evolving needs of the region for power and irrigation.

Perhaps the more significant assumption here is that the provision of these multipurpose benefits would, in the future, be of greater relevance to China's development than the land which would have to be lost. That is, it is worthwhile to lose land to pay for water and electricity, and that China's development strategy must give a high proportionate emphasis to industry rather than to agriculture.

2) Acceptance of the Modified Soviet Design and the Beginning of Doubt.

With so much in dispute or left to assumption, it may seem a little imprudent to have begun work strictly according to the original plan, on 13 April 1957. There are two issues to be considered here. Firstly, there is the giving in 1957 of instructions to proceed with the modified Soviet design and, secondly, there is the failure to make any other change until after the dam had been completed and severe problems encountered. In subsequent sections, it is intended to demonstrate that the failure of the Sanmenxia project was more a failure to relinquish a dream than a failure to predict technical problems. To begin, the factors likely to have influenced those decisions must be considered.

i) Desirability of the Project.

The Sanmenxia Project held out the promise of removing a scourge, notorious throughout history and, at the same time, of transforming the region into the industrial and agricultural base of the New China. Furthermore, the successful completion, albeit with Soviet assistance, of such a project, would provide a much needed boost to the national pride of a China politically isolated from much of the rest of the world. To quote from Vice Premier Deng Zihui's 1955 report,

> "Ever since ancient times the Chinese people have longed to harness the R. Huang and turn it to good use..... Only now, under the People's Democracy in the era of Mao Zedong, can their dreams - and much more than their dreams - come true. Three Americans... whom the Guomindang government invited to China as advisers in 1946...... still believed that 'hundreds of years will be required to treat the entire area.' This reminds one of a saying current in the Zhou dynasty: 'Life is too short to see the river run clear.' Yet we need only a few decades, not several centuries, until we see results from water and soil conservation work in the entire loess region. Furthermore, in six years, when the Sanmenxia reservoir is completed, we shall be seeing practically clear water in the lower R. Huang. It will not be long before all the deputies here and the people of the whole country see the day when the age-old dream comes true - when the R. Huang runs clear."(11)

Since its conception in the early fifties, this scheme had repeatedly been held to be capable of realising that dream. It would not seem unreasonable to suggest that having lived in hope and belief in that currently unchallenged ability for several years, those charged with this decision might be predisposed towards confusing the desired outcome, with the possible outcomes.

ii) Relations with the Soviet Union and its Experts.

In view of China's political isolation in the fifties and its concurrent overt friendship with the Soviet Union, it is not unnatural to wonder how this close relationship was likely to have influenced the choice of reservoir design. Similarly, in view of the subsequent rift which appeared openly between the two powers from 1960 onwards, the motives of the USSR in helping China in this way are open to question.

Dealing with the latter point first, the evidence would seem to indicate that Soviet aid, though granted for political motives, was carried out conscientiously and to the best abilities of the Soviet experts concerned. Similarly, although the services of these experts were unilaterally and permanently withdrawn by the Soviet Government in July and August 1960 in order (unsuccessfully) to exert political pressure on the Chinese Government to toe the Soviet line, there is no suggestion whatever that they were used by the Soviets in any other way to exert pressure. To all appearances, the Soviet experts were allowed to work without political interference from their own government, and their way of working was regarded as satisfactory by the Chinese. For example, in 1964, four years after the withdrawal of the experts, the Chinese said of them,

> "The overwhelming majority of them was hard working and helpful to China's socialist construction. We have always highly appreciated their conscientious work, and still miss them to this day."(12)

More specifically, Chinese engineers, concerned today with R. Huang control, are at pains to emphasise that the members of the Leningrad Hydropower Design Annex assigned to this project gave "genuine, friendly help." Problems only arose because they did not have highly silted rivers in the USSR, and both sides lacked experience.(13)

In assessing the possible influence of China's friendship with the Soviet Union on the choice of reservoir design, a change in attitude, in the late fifties and early sixties on behalf of the Chinese towards the Soviet experience, is discernable.

However, it is not easy to discover the extent to which this change was politically motivated. The changes of attitude which took place would have had their effects after 1957, after the decision to continue had been taken, and are, therefore, more suited for discussion in section iv. Here, consideration is restricted to the earlier period.

Following the Declaration of the People's Republic on 1 October 1949, and the signing of the 30-year "Sino-Soviet Treaty of Friendship, Alliance and Mutual Assistance" early the following year, China set about the establishment of new industries and the organisation of science, along Soviet lines. Meanwhile, although in absolute financial terms, Soviet aid was modest, it must have been of great value in the first five years. The major capital projects built with Soviet assistance, by the admission of both the Soviet Union and China, laid "the primary foundations of modern industry and technology."(14) Thus the great and positive impact of Soviet assistance is not in question.

What is important though, is the question of the relevance of Soviet and Chinese experience, respectively, with respect to Chinese needs, and the degree of reliability of the former, in the Chinese context, as seen by the Chinese decision-makers. There is little doubt that in the early fifties, Soviet engineering and technology was well in advance of that of the Chinese in many respects. It would seem reasonable that this be acknowledged, but it is also very possible that its constant repetition gave the illusion that it was infallible. What is the evidence to support such a suggestion?

In the first instance there is the repetition itself. "Learn from the Soviet Union" was a common slogan in the early fifties.(15) Almost every reference to the Soviet Union included the adjective "advanced", and nearly every progress report made reference to its beneficial influence. For example, in forestry,

> "The Socialist Soviet Union is the only country in the world where a shelter-belt afforestation programme of similar magnitude has been successfully carried out. Nothing of the sort is possible in any capitalist country."(16)

in irrigation,

> "The adoption of advanced Soviet experience and economy in the use of water have already had the most beneficial effects."(17)

in farming technique,

> "Many farms and more advanced peasants have improved their farming technique and adopted the advanced experience of the Soviet Union."(18)

in water conservancy,

> "The use of advanced experience accumulated in China and from the Soviet Union, given by Soviet experts, has greatly improved working efficiency and increased the speed at which these projects have been carried out."(19)

and on the R. Huang itself,

> "... and with the aid of Soviet experience, we are confident that we shall wipe out once and for all the last remnants of the river's threat."(20)

The official view of Soviet aid was that it was very useful, but not the be all and end all,

> "We advocate the study of the scientific and technical experiences of the Soviet Union, because Soviet water conservancy science and technique are amongst the most advanced in the world, whilst Soviet aid to us is impartial, unselfish and without reservation. During the past few years, our gigantic achievements in water conservancy construction have practically been inseparable from Soviet Aid. At the same time it must also be pointed out that there are also many good things in the science and technique of the capitalist countries; they are worthy of our study, because technique is devoid of class nature, and will serve whichever party controls it".(21)

Yet, perhaps inevitably, Soviet experience did come to carry with it the image of the man in the white coat, he who is right because he is "scientific". In some instances, the Soviet expert was used to build up the image of greatness or of competance as required,

> "The new scheme which has now been published is the result of six years' work by surveyors, geologists, architects, hydrologists and experts of many kinds, including a group of top-level engineers from the Soviet Union".(22)

In one case this was extended, by inference, to give the Soviet Union credit where it was not strictly due,

> "The way we propose to take is the way the Soviet Union took to harness and exploit its rivers - that is, to adopt a comprehensive, multiple-purpose plan".(23)

Similarly, mistakes could be blamed on a failure fully to grasp the said Soviet experience,

> "We did not learn the advanced experience of the Soviet Union systematically and penetratingly, and some technical cadres were still inclined to a subjective style of work divorced from actual conditions".(24)

Thus it was not surprising to find, in the late fifties, complaints and warnings concerning the acceptance of this imagery. As one Soviet press agency later complained, the Chinese leadership had proclaimed the slogan,

> "Struggle against blind faith in established technical standards and regulations and in foreign experience", which "In view of the ...... large number of Soviet specialists in China", they concluded to be, "in essence directed against the Soviet specialists and against Soviet scientific and technical experience".(25)

Finally, the extent to which this image influenced the acceptance of Soviet ideas can be judged from an article which appeared in November 1957, just after the decision to proceed at Sanmenxia had been reached,

> "The Soviet experts gave us great enlightenment on the concept of designing. They pointed out the purpose of multi-purpose use of rivers, that is, to use the minimum funds to satisfy the maximum needs of the national economic development. They told us that we must not confine our view to the interests of a given department or a given target, but should consider how to meet the maximum interests of all departments from the political, economic and technical points of view.(26)

The inference from this is that their advice was taken.

iii) Timing and Decision-making Process.

In December 1956, when the blueprints of the Preliminary Design were handed over, the starting date had already been fixed for April 1957 and certain preliminary steps had already been made, in that some people had been evacuated and some heavy machinery had been ordered. It is not unreasonable, therefore, to suggest that it was generally assumed that the Chinese State Council would approve the plans and work would proceed. It was in no way expected that there would be any serious challenge to them. Furthermore, although the number of questions raised was indeed sufficient for the State Council to order special meetings of Chinese technical experts to furnish advice, it would seem that, in the view of the State Council, the basic idea of having a reservoir at Sanmenxia was not in question, and that, hopefully, these outstanding questions could soon be resolved. Given that a dam of some sort or other was to be built at Sanmenxia, then it was not such a sign of imprudence that work should begin on time. After all, it may have been argued that the first stage of the work, blasting away rocks and laying foundations, would take some time and would not seriously be affected by any modification to the reservoir silt discharging criteria. Yet, as we shall see, this feeling that there would always be time for modification, was an important influence upon the decision to proceed.

At the special meetings of June 1957, opening the debate on the design of the Sanmenxia reservoir, Vice Minister Zhang Hanying, of the Ministry of Water Conservancy, asked the collected assembly to consider three points:

i) Should the plan for a reservoir at Sanmenxia be based upon considerations of comprehensive use, or simply upon flood control?

ii) If comprehensive use be considered, should the power output be appropriately reduced?

iii) If the original design outline be bascially agreed, but with a lower water level in the first stage, should the structural design further be changed (such as by lowering the silt discharge sluices)? (27)

The decision reached has already been described in Chapter 2, but the reasoning behind it remains to be given.

The official summary of the meetings begins by pointing out that of the three aspects of R. Huang control, that is, soil and water conservation, channel regulation in the lower reaches and the building of a reservoir, only the latter would provide rapid results. It was recognised that, owing to sedimentation, the safe flood capacity of the river's lower reaches was falling and flood prevention was seen as a requirement of the utmost urgency. Meanwhile, under the conditions of rapid industrial and agricultural development current in China, the use of the R. Huang's water resources, using a reservoir, was asserted to be another important need.

At the meeting, "The overwhelming majority of the Comrades present consider Sanmenxia to be the most suitable site to satisfy these requirements, and should be chosen as the first period project." (28) It is worthwhile to quote extensively the argument as put, since it reveals more than technical points,

> "It possesses the following outstanding conditions:
>
> 1) The position of Sanmenxia is suitable, it can control a fairly large catchment area (93 % of the whole basin). Simultaneously, it has a fairly large reservoir capacity which can undertake the requirements of flood regulation;
>
> 2) The Sanmenxia reservoir capacity is large and can guarantee the requirements raised by the various departments in developing the national economy, such as farmland irrigation, hydroelectric power, and improving the river channel;
>
> 3) The geology of the Sanmenxia valley is excellent and has the conditions for building a high dam. Also, the valley is narrow and so construction costs will be low;
>
> 4) The reservoir capacity is large and, whilst at present we need to trap silt which is harmful to the lower reaches, it can maintain a fairly long life and provide upstream soil and water conservation work an abundant and reliable time.

"However, the conference recognised that to build the Sanmenxia project would at the present time also have disadvantages:

1) Since the reservoir capacity is large, the area inundated will be large, and many people will have to move. In particular, at the present in China, where arable land is lacking, it is even more problematic to flood such land and move people;

2) Problems may arise during the period when soil and water conservation upstream is in the process of gradually taking effect and regulation of the channel downstream has still to be completed. Silt deposition could occur in the reservoir backwaters such that the floodwater level of the R. Wei would rise, possibly causing flooding or saturation of the backwater district. This needs more detailed research to be done. Meanwhile, owing to floodwater regulation, fairly clear water will be discharged and the time taken by floods to pass will be extended. Rapid erosion could thus occur in the lower reaches and, in the period just following completion of the reservoir, when clear water will first be released, the bed will be unstable and flood prevention could deteriorate or encounter new problems. Strict attention and suitable measures will be needed.

"At present it is still difficult to estimate the life of Sanmenxia reservoir, because the reduction in oncoming silt and water, following conservation upstream, and the time required for conservation to show effect, have still not been calculated, and the density of the sediment etc., is still being researched. Thus, from a purely technical point of view, it would seem somewhat better to wait until fairly clear results have been received from scientific research, and then to build the Sanmenxia reservoir; Yet, from the viewpoint of flood control, it is a requirement of the utmost urgency to use the reservoir first to regulate floods. Whilst the flood discharge from 1951 to 1956 was not so large and no breach occurred, there was nevertheless severe deposition which will continue hereafter and raise daily the threat of a change in the river's course. Meanwhile, soil and water conservation cannot completely come into play in a short time, so the threat of inundation must be reduced by sacrificing a part of the reservoir's storage capacity in exchange for the necessary time. Therefore, even if the above few problems in regulating the R. Huang continue to require further research and analysis, before reliable and accurate figures may be achieved, the Sanmenxia project should still be built at once to fulfill the present urgent flood control task.

"Requirements exist with regard to developing water conservancy and meeting the needs of various parts of the national economy, be they irrigation, hydroelectricity, or navigation. The Sanmenxia reservoir can attain the above goal of comprehensive use whilst still satisying flood prevention. This should be borne in mind.

"A reservoir would stop the breaches of the R. Huang's lower reaches, eliminate the threat of inundation from the 80 million residents along its two banks, and develop its water resources. Owing to the factors mentioned above, it would be very difficult to attain similar results, in a short time, by any other means. The losses due to reservoir flooding cannot be avoided, but they may be balanced against the benefits to the great majority of the people, and to carry out evacuation from a few places upstream is a measure we are obliged to adopt. Nevertheless, the number of evacuees and the flooded area should be reduced, as far as is possible, whilst ensuring that the reservoir can resolve the flood problem without shortening its own life, and can still achieve comprehensive benefits. Meanwhile, in the first period of use, the problems should be reduced, by raising the stored water level gradually, so as to extend the period for evacuation. Mobilisation work to evacuate the reservoir residents should be well prepared and, as far as possible, should respect the local residents' wishes and provide suitable arrangements.

"Thus, the overwhelming majority of Comrades all along considered that to build the Sanmenxia reservoir now is an urgent requirement. As for the problems of soil and water conservation, reservoir deposition and regulation of the channel downstream, etc., the State Council is requested to instruct the relevant departments to organise their strength and get moving to solve them quickly."(29)

The picture which emerges from the above is clear. On being faced with alternative proposals, the State Council asked for technical advice. The experts, in debating the various alternatives, acknowledged large areas of uncertainty, for which the protagonists of each scheme substituted their respective assumptions. These assumptions concerned not only the occurence of given phenomena, but also their extent and their relative importance. The acceptance, or otherwise, of a given assumption is an act of belief, albeit possibly based upon experience. In this case the experts had to accept or reject whole sets of assumptions involving many different disciplines, so the element of belief played a greater role. Under these circumstances it is not difficult to understand how it was that, despite the very accurate predictions of disaster from some Comrades, the modified Soviet plan was sanctioned.

iv) Whilst Under Construction.

As the dam construction proceeded towards completion, China was roused into its first post-war frenzy of activity and political chaos, known as the Great Leap Forward (GLF). This began in 1957, reached its climax in 1958, and would have had two, noticeably contradictory, types of effect on the Sanmenxia project: to strengthen the hold of the dream, upon which its selection had depended, and to undermine some of the illusions which contributed to that dream.

In the rush of enthusiasm which typified this period, noted for its slogan, "More, Better, Faster, Cheaper", there would have been a tendency to display little patience for careful research and little tolerance of dissenting voices. Meanwhile, a propaganda campaign was under way to assure the people of their great progress. Therefore, to call a halt to one of the greatest projects, would really have been a politically risky business. To plod on carefully even, would not have shown the correct "revolutionary spirit" and, indeed, it was announced on 13 March 1958, that the dam at Sanmenxia was to be completed by 1960, a year ahead of schedule, and that electricity would begin to be generated on 1 April 1961, six months early.(30)

In the meantime, there were other problems which demanded attention. In 1958 there occurred the most critical flood peaks on the lower R. Huang since the disastrous floods of 1933, during which over 18,000 人 had perished and which had been caused by a flood discharge of 22,000 $m^3 s^{-1}$. In 1958, the maximum discharge was 22,300 $m^3 s^{-1}$ and although there was no reported dyke breach, two large leaks and 32 cases of piping had to be dealt with. In addition, supplementary dykes between 1 m and 1.5 m high had to be added on top of the main dykes and around Lake Dongping, into which a total of 700 x 10^6 m^3 of water was diverted. In places the water rose above the original dyke tops, and part of the trunk line railway bridge at Mangshan collapsed.(31) An official statement said that the R. Huang,

> "was brought to its knees in the face of political leadership and the masses' redoubled efforts in the Great Leap Forward".(32)

The fact remains, though, that it was a very dangerous situation which must have increased pressure for something to be done at Sanmenxia. A special meeting to sum up the experiences of these flood peaks held in August 1958, noted that,

> ".... by next year, the dam of the multipurpose Sanmenxia Project .... would begin to hold back water. When completed the project would be big enough to contain the total average annual flow from its upper reaches."(33)

The first part of this optimistic statement actually referred to the coffer dam which would divert the river during construction. The extent to which this could retard the flow during flood peaks is not known. Nevertheless, it is reasonable to believe that in the prevailing psychological climate, there would have had to have been some very strong arguments indeed for any change to be made in the chosen course of action.

Another factor likely to have prevented early recognition of the extent of the problems to be encountered, was the fragmented nature of the distribution of work amongst the various research or administrative organs concerned. As one engineer put it,

> "Premier Zhou Enlai was very concerned about it. Upon his return from India, he suggested that model tests be carried out. Consequently, in 1958, a model 1 km long of the proposed reservoir, was constructed at Wugong, and another model was made, at Zhengzhou, of the Huayuankou reach. At Wugong we discovered the backwater deposition and the density current failure, but still we did not discover the seriousness of the reservoir sedimentation. Why? Because we were using previous estimates for the efficiency of soil and water conservation and considered that there would not be too great a problem. We failed to take fully enough into account the overall situation, partly because the divison of labour was too fine; for example, I had never seen the loess plateau and had no reason to question the figures for sediment yield given to me by the R. Huang Conservancy Commission."(34)

Yet, although this and other such pieces of evidence may have been too scattered for their meaning to have been recognised quickly, it is nonetheless true that a body of evidence was coming into being which, when brought together, would be able to contribute to a reappraisal of the whole project. Furthermore, political and other changes would have caused some changes in the way in which large technical projects and foreign experience were regarded, in relation to China and its needs. Examples are the 'Two Legs' policy, the split with the Soviet Union, and the 'Three Hard Years'.

The policy of 'Walking on Two Legs' was, in effect, a call for a more comprehensive economic development. It was first mentioned in the communique issued, in December 1958, by the 6th Plenary Session of the Party Central Committee, which stated,

> "The development of our national economy by leaps and bounds in 1958 has proven the correctness of the whole group of policies laid down by the Party; the policy of simultaneous development of industry and agriculture.....; the policy of simultaneous development of heavy and light industries;.....; the policy of simultaneous development of national and local industries; the policy of simultaneous development of large enterprises and medium and small enterprises, the policy of simultaneously employed modern and indigenous methods of production, and the policy of combining centralised leadership with a full-scale mass movement in industry - in a word, the policy of walking on two legs rather than dragging along on one or one and a half legs......."(35)

On the one leg, the government took upon itself the large, the heavy, the national and the centralised and, it is assumed, performed its tasks to its own satisfaction whilst, on the other leg, the small, light, local, indigenous and mass were encouraged by a worthy press campaign. Thus, intentionally or otherwise, people's thoughts would have been directed away from grandiose schemes and they would perhaps have been a little more ready to accept making the Sanmenxia project more modest, by relying, for example, on local schemes for well irrigation.

After such a vicious split as subsequently occurred between the Soviet Union and China, the latter would not have had to consider whether or not it would give offence to challenge the Soviet design. It could be said that the split might have influenced the decision to rebuild the Sanmenxia reservoir, but it was not important in comparison with the occurrences preceding it. The way the Chinese Government wished to encourage independent assessment of technical standards and foreign experience has already been noted and, indeed, as early as 1957 an article appeared in the Renmin Ribao entitled "Several Questions Needing Attention in Commissioning Abroad for the Design of Water Conservancy Projects" which, in essence, contained five complaints about having asked the Soviets to design the Sanmenxia project,

> "i) Foreigners should not be asked to design what could be designed by Chinese. China had sufficient experience, gained from earlier projects, to design large-scale water conservancy projects.
>
> ii) Where possible, foreign experts should be invited to China. Many more people would benefit from doing design work in China, led by a foreign specialist, than could be sent to watch the design procedure abroad. Only two Chinese had participated in the design of the Sanmenxia reservoir at the Leningrad Institute.
>
> iii) In commissioning design work abroad, it is necessary first to establish clearly the basis of foreign experience. Chinese experience in designing water conservancy projects was unique, whilst foreign experience often was inapplicable to China. The Sanmenxia project had many unique features and only experience gained from practice within China could acheive good, fast and cheap objectives.
>
> iv) Planning should be well done before commissioning designs abroad. The Technical and Economic Report had been too broad to act as a basis for designing the Sanmenxia reservoir, yet a contradiction had arisen, because the various departments' requests, for benefits from Sanmenxia, had only been brought up once the design work was already underway abroad, and to meet these requests would require a higher water level than had been envisaged in the Technical and Economic Report. To propose design criteria in such a scattered and biased way, without an overall plan which unified contradictions, was bound to lead to chaos. The lesson that good preparation is vital, should be learnt for the future.
>
> v) When design work is carried out abroad, it should be done simultaneously in China. The effect of this would be to raise the general standard of design work within China".(36)

Thus, eventually, was the illusion of Soviet infallibility challenged on technical grounds. As is well known, it was also challenged on ideological grounds, but that is beyond the scope of this study.

Owing to poor harvests brought about principally by successive years of drought, the three years 1960 to 1962 have become known as the 'Three Hard Years'. It is reasonable to suggest that the value of good arable land such as that being made unavailable by the Sanmenxia reservoir, would thereby have been brought home to people's minds sufficiently vividly to influence their assessment of the contending reservoir designs.

Thus we can see that, under the various influences of the times, the conditions were slowly developing for the acceptance of different design concepts for the Sanmenxia project. Perhaps, by 1960, when the reservoir came into operation, only a precipitating agent was needed to bring together the evidence, which could make a different design acceptable. Of course, by then, the dam had already been built and any change would amount to the admission of a very costly error. These themes will be addressed again but, first, what actually happened will be considered.

3) The Slow Progress of Soil and Water Conservation Work and Loess Plateau Development.

The most conservative estimate of the effectiveness of soil and water conservation work, the Soviet estimate, predicted a 20 % reduction in sediment yield by 1967 and a 50 % reduction in fifty years. Yet, although it was claimed in 1980, that over 60,000 km^2 (21 %) of the area of soil and water loss had been "brought under control", there has still been no noticeable reduction at all in the silt content of the R. Huang.(37) Some explanation of this can be drawn from the extreme variability of the figures themeselves (Table 3-1). The extent of erosion is highly dependent on the rainfall, not only on how much rain falls in any year, which is highly variable, but where it falls and with what intensity. Light rainfall over the fairly flat and well covered southern edge of the gullied plateau region, for example, would probably give rise to less silt in the R. Huang, than would an equivalent volume of rain falling in violent storms over the gullied hillock region of N. Shaanxi and N.W. Shanxi. Thus a reduction of 10 % or even 20 %, in the average silt content of the R. Huang would be hardly discernable for many years from the figures and, in any case, it would be very difficult to attribute such changes solely to soil and water conservation work rather than climatic peculiarities.

To have brought 21 % of the area "under control" could not be expected to mean a 21 % reduction in R. Huang silt load, despite the unity delivery ratio (all silt washed from the loess plateau enters the R. Huang), because of the ambiguity of the expression "under control". Leaving aside the exaggerated claims of the late fifties and sixties, it should still be mentioned that in some instances to "bring under control" simply meant that the said area of land had been treated in one way or other, and paid no attention to whether or not the treatment had been successful. More recently, the expression is taken to mean that somewhere between 60 % and 70 % of the area in question has successfully been treated, or that there has been a similar reduction in sediment yield from that area.(38) Local estimates refer, however, to bringing 30 % of those catchment

TABLE 3-1 SILT LOAD OF THE RIVER HUANG OVER 19 YEARS ($t \times 10^6$)

Year	Toudaoguai (Hekouzhen)	Tongguan	Difference
1954	146	(2610)*	2514
1955	260	(1290)	960
1956	81	(1670)	1589
1957	78	(1030)	952
1958	210	(2990)	2780
1959	209	2600	2391
1960	124	935	811
1961	273	1200	927
1962	110	938	828
1963	162	1230	1068
1964	299	2450	2151
1965	80	454	374
1966	184	2110	1926
1967	316	2180	1864
1968	219	1520	1301
1969	22	1210	1188
1970	72	1900	1828
1971	106	1340	1234
1972	77	600	523
1973	101		
1974	60		
1975	190		
Average 1954-72	159	1592	1432

Source: QUSRL, personal communication, 1981.
*Bracketed figures are from Shanzhou station, not Tongguan.

areas being treated under control within the next ten years, though with the addition of dams at the gully mouths it is hoped that silt will cease to be washed from them. Meanwhile, one recent estimate of the area of soil and water loss which has successfully been brought under 'comprehensive' control, was put at less than 1 %.(40)

Whatever the extent of the work done successfully, even if it be on 21 % of the loess plateau, there would have had to have been no deterioration on the rest of the loess plateau if it were to have resulted in a significant reduction of the R. Huang silt load. Thus, the whole region must be taken into account. When this is done, we find that, for technical, social and political reasons, there has been very little improvement, and in some cases there has even been some retrogression. This has been seen as an apparent failure of soil and water conservation work. The most basic economic development in this region would be the stabilisation and increase of agricultural production. In turn, this would mean finding solutions to the joint problems of soil erosion and the practice of shifting cultivation. Thus, it has been recognised that economic development and soil and water conservation are so closely related that they must be considered together. Indeed, the terms are often used interchangeably in reports on the loess plateau.

i) Basic Approach.

The approach adopted to tackle the development of the loess plateau was based upon the principle that the major part of the work would be done by the local peasants themselves, supported by mainly technical aid from the State. Substantially, this has remained unchanged.

In the period immediately after the Civil War, a 'Northwest R. Huang Engineering Office' and a total of over thirty local soil and water conservation experimentation stations and popularisation stations were established.(41) These were run by the government, through the RHWCC and were staffed by technicans headed by administrative officers under party groups. Their job was to create model areas where experiments could be carried out as examples which, with the aid of propaganda teams, the masses could copy on their own land.

In Yan'an District, for example, seven teams of ten were sent out to guide work at county level and, in 1955, two one-month courses were held to explain the methods of conservation. Thus, in practice the methods were to be copied without awaiting the results of the experiments, which would require about ten years to complete. After 1956, every county in Yan'an District had at least one model area. Meanwhile, large-scale preliminary surveys were organised by the Academy of Sciences, once in 1953 and again from 1955 to 1957.(42) This first period is referred to as the 'Experimental Period'.

Following the establishment of agricultural co-operatives, in 1956, the second period extended from the fifties to the mid seventies. It was characterised by political chaos, and the use of the mass campaign in an attempt to increase the rate at which soil and water losses were being brought under control. In December 1956, the first Middle Reaches Soil and Water Conservation Conference was held. In 1957, a Central Soil and Water Conservation Committee was established, followed by another meeting later that year. In 1958 and 1959, on the spot meetings were also organised. In 1959, the People's Communes were established and in Yan'an District, mentioned above, the seven propaganda teams were replaced, as each County set up its own Water Conservancy Office.

The largest of the mass campaigns occured in 1958, during the period of the Great Leap Forward. Meanwhile, in 1957, a team from the Soviet Academy of Sciences had come to investigate the conditions obtaining on the loess plateau. This team included experts on Comprehensive Natural Geography, Soil and Water Conservancy, Pedology, Forestry, Sand Fixing, Hydrology, Geomorphology and Geology. The use of mass campaigns for conservation measures continued, on and off, throughout the Cultural Revolution, though their points of emphasis varied.

The most recent period, since about 1973, has been one of drawing lessons from the past, making economic and political changes, and drawing up new plans for development. These are discussed in Chapter 5. Many of the organs of soil and water conservation work destroyed in the Cultural Revolution have been restored; the three experimentation stations of Xifeng, Suide and Tianshui, respectively, have once again been brought under RHWCC control, and other parts of the organisation have been upgraded. For example, 'Hydrology Points' have become 'Hydrology Bureaux'.(43) Yet, progress has been slow. A central 'R. Huang Middle Reaches Bureau' has been set up but had not commenced work in July 1980. An impression of the pace of restoration is obtained from an article in the Guangming Ribao of 19 December 1978,

> "There were 48 key soil and water loss counties in Shaanxi, but only 29 local and County soil and water conservation stations have been restored and most of those are on the Guanzhong Plain. Shanxi has four regions of serious soil and water loss, but only two regions have soil and water conservation institutes. Since 1976 the Ningxia Moslem Autonomous Region has established six water and soil conservation stations, but they are all mere skeletons. The one in Tongxin County has an authorised strength of 15 人, but at present it only has two, and one of those is the accountant...."(44)

In the next two sections consideration is given to the development of the technical and political imbalances which together account for the slow progress of soil and water conservation work. This will be followed by a further analysis of the effects of that slow progress upon the Sanmenxia project.

ii) Technical Imbalance.

The first emphasis was on biological control. That is, the need for an increase in the plant cover index was to be satisfied by large-scale tree planting and grass sowing. However, in many cases tree-planting was poorly done; the commensurate water preservation measures (such as fishscale pits and reverse-slope terraces) were not undertaken, trees were neglected once they had been planted or were eaten by sheep before they could grow. Even where the work was done well, the survival rate for saplings was low, as it was hard to find suitably resilient species. The most common species used was, and still is, the Locust tree (Robinia pseudo-acacia), but its growth rate tends to slow down or stop after several years; by way of example, some thirty year old trees at the soil and water conservation station in Suide have trunk perimeters of only 400 mm.(45)

In view of the large amount of manpower required and the slow returns, there was also popular resistance to afforestation campaigns. The masses called it a case of "Distant water cannot assuage nearby thirst".(46) As Liu Wanquan remarks, in the Renmin Ribao of 13 February 1979,

> "Some places coerced the masses into withdrawing tillage from slopes and planting grass and trees. Yet since the unit grain yield was not raised, after withdrawing from tillage, the masses' food provision fell and, of their own volition, they reopened the forest and grassland to sow cereals, even to the extent that in some places trees were planted each year but the forest was never seen".(47)

The idea of having special shock brigades for afforestation also got off to a bad start when resistance was met to the assumption that the shock brigades' food provision would be provided by the regional production brigades.(48)

Seeding to grass met similar problems. Before the late seventies, only two types of grass were popular, the biennial Caomuxi (Sweet Clover) and the perennial Muxu (Lucerne). Caomuxi is fast-growing and resistant to drought, alkali and cold, but for the best results, has to be used in grass-arable rotation. Muxu is difficult to grow, cannot form pastureland on its own, declines after five or six years and, after three years, its roots exhaust the soil moisture down to about three metres below the surface. In the mid seventies a new strain became popular, Shadawang, which is available in biennial and triennial forms. However, it cannot bear seeds in N. Shaanxi, and for many years seed had to be brought from Jiangsu province. Recently, however, it has been bred successfully on the fertile floodplains of the lower R. Huang.

In sparcely populated areas where it was acknowledged that there is not the manpower to nurture trees and grass, aerial seed broadcasting was tried but, in the fifties, the survival rate was only 3 % or 4 % and it was abandoned until the late seventies, when new species were available for experimentation, and the survival rate was increased to 45 %.(50)

Thus, although by emphasising biological control the plant cover index would have increased in places, it proved incapable of facilitating the withdrawal of tillage from slopes.

Meanwhile large-scale dams were built as silt traps in preparation to meet the requirements of the Sanmenxia reservoir, originally due for completion in 1961. For example, in the late fifties large tributary dams were built at Xinqiao (R. Hongliu), Dancheng (R. Lu), Bajiazui (R. Pu) and on the R. Fen, amonst other places. However, they were found to be too big, rather expensive and difficult to connect to the needs of productive labour. They also had a tendency to fill up with silt; the above mentioned four, for example, had lost 75 %, 100 %, 61.4 % and 34.2 % of their capacities by 1973, 1973, 1972 and 1976 respectively.(51) As Luo Laixing commented in the Renmin Ribao as early as 1957,

> "There are also those who hold that building large dams can reduce gully floor erosion, hold back floods and, moreover, facilitate pisciculture, irrigation and electricity generation. It cannot be denied that large dams have such potential, but it can be realised only subject to avoiding damage to the dams by floodwaters or their being clogged up with silt. Taking a look at the large dams already in existence on the loess plateau and seeing how many of them rear fish or can generate electricity or can irrigate, and how much fish is being raised, or electricity produced, or fields irrigated in practice, etc., one would find it hard to be satisfied by the situation...."(52)

In the late fifties, the emphasis shifted to terraces and small silt precipitation dams. To build terraces well, however, is very laborious and consumes, for example, between 750 人 d ha^{-1} and 1650 人 d ha^{-1} to construct level, 10 m wide terraces on slopes of about 20 %, conserving the topsoil. In many cases, narrower terraces were built to save labour, but were then harder to maintain and were ill suited to mechanisation. Often the terracing work was shoddily done, with insufficient attention being paid to keeping them level, conserving the topsoil, or making proper provision for drainage and access paths.(53) When this happens, even the usually excellent conservation properties of terraces can be lost, as the Renmin Ribao comments,

> "Some peasants dig holes in the border ridges in order to walk through. However ..... water can then flow out through this gap and give rise to concentrated erosion."(54)

The "level terraces" which were popularised in the early sixties as a new type of terrace, in fact just meant taking care to make a good job of it.

Terraces do hold more water, it is true, but the border walls are prone to evaporation losses and percolation is severe on the loess plateau. Therefore, without irrigation, they could not provide stable yields throughout successive years of drought. Moreover, terraces alone do not necessarily provide a sufficiently substantial increase in crop yields for the peasants to consider them worthwhile. With appropriate and carefully applied agricultural measures, yields above 1125 kg ha^{-1} can be obtained from tilled slopes, which is only slightly less than the 1500 kg ha^{-1} usually obtained from terraces. If terraces are built on land whose organic content has already been depleted by years of erosion, then large amounts of manure or several years of leguminous crops will be needed before yields can be raised. Thus, much of the terracing work of the great campaigns subsequently fell into disuse.(55)

Small precipitation dams, on the other hand, gained the immediate acceptance of the masses. They were cheap, easy to build, and easy to work. They were good at retaining moisture and, since the precipitated soil originated from topsoil, rich in the organic matter lost from the tilled slopes, they also showed very quick returns and produced high crop yields. Instances of yields exceeding 7500 kg ha^{-1} are not uncommon, though the average is probably about half this amount. At first a small dam would be built, which might well silt up in one Summer and provide its first crop the following year. The dam would then be raised annually, gradually increasing the area available for cropping. Adequate yields could also be guaranteed in drought years and there is a report of a popular ditty, "With three _mu_ of dam about, no need to fear a drought."(58)

There were problems though. The first, larger, dams had been designed with drainage systems and flood spillways capable of coping with a storm of intensity whose annual probability was 5 %, i.e. one which would be expected to occur once in twenty years. Small earth dams were supposed to have a 10 % criterion but, as their popularity spread, many were built without proper technical aid and these criteria were not observed. Either the construction work would not follow the design, or the design work was poor or not done at all.(57)

Owing to poor drainage, the use rate was low and the high yields of which this type of land is capable, often failed to materialise or were erratic. In 1963, for example, it was estimated that only one third of the total area of precipitated land was being used.(58) As for meeting the flood resistance criteria, even where an attempt was made to observe them, it was very difficult because in the fifties, with incomplete records, nobody knew just how big a once in twenty or ten year flood would be. In any case, those criteria are now considered to have been too low.(59)

There are numerous reports of the large-scale damage done to these dams, each year, throughout the past 25 years and continuing today. To quote the Renmin Ribao of 10 January 1957,

> "According to incomplete statistics, during the flood season of 1956 a total of 3500 check dams and over 1000 other dams were damaged in Gansu. Of the 36 dams built by Qingyang County, Gansu, in the Spring of 1956, only one remained at the end of July which had not been ruined by the waters..."(60)

The same newspaper, this time of 28 March 1979,

> "Then again, Yangjia Gully in Mizhi County has concentrated large amounts of manpower for several years on building precipitated land to grow grain ..... in the two years 1977 and 1978 the great majority of their precipitated land was destroyed by storms and torrents."(61)

Of course, the phenomenon of damage to dams also diminished their role in reducing the silt load of the R. Huang. The 1957 article continues,

> "Of the total number of 84 small earthen dams built in the Jiuyuan Gully (Suide, N. Shaanxi), 40 had been filled up by accumulated silt before 1956 and, in one violent storm which it encountered on 8 August 1956 and in which 40.7 mm fell in the gully catchment in 275 minutes, 48 earthen dams were filled up ..... eleven suffered partial loss of silt originally deposited in the dam, reckoned to

amount to 14,667 m^3 and seven suffered its complete loss, reckoned at 28,000 m^2, whilst losing also the dams themselves. Thus, even the efficiency of the earthen dams in holding back floods, accumulating silt and preventing gully bed erosion was completely lost ... It is a pity that at a time when construction of the Sanmenxia reservoir has not yet started, of the large numbers of earthen dams built on the loess plateau before 1956, some have been damaged by erosion, some clogged up, and the storage capacity of others has been reduced. Soon their silt-checking function will be lost."

Jiuyuan Gully, furthermore, was one of the special control points set up by the Government.

Despite these losses, precipitation dams took an even greater precedence over the other measures. Whatever the reasons for this, which will be summarised in section iv, it was not that the need for a more balanced approach was not recognised. At least as early as 1957, the adoption of the two most fundamental principles advocated today as being necessary for the development of the region, and for the control of soil and water losses, was already being urged.

The first principle is that the withdrawal of tillage from slopes, generally accepted as the aim of soil and water conservation work, should depend upon the provision of an equivalent, stable, productive capacity elsewhere (on terraces or precipitated land) in order to guarantee the peasant's livelihood. The following statement was made in an authoritative report of 1958,

> "A contradiction has arisen between agriculture and conservation work: One side needs to withdraw tillage from ill-suited land to conserve water and soil, and to obtain rational use of the land, whilst the other side, in order to guarantee the resident's food provision, cannot permit the large-scale withdrawal of tillage. In order to resolve this contradiction, we will adopt the following pathway:
> 1) First of all, stabilise foodgrain production and furthermore raise per unit yields on land suited to cultivation, thus guaranteeing the resident's self-sufficiency in foodgrains.
> 2) On land from which tillage is to be withdrawn, plant trees and sow grass, develop animal husbandry .... thus to raise the residents' income."(62)

In order to create the stable and high-yielding land, referred to above, the constant threat of water damage had to be alleviated, and this could be done by increasing slope protection measures (either by terracing or by increasing the plant cover index) so that the sudden Summer storms would not give rise to sudden floods, but the surface runoff would be reduced to a level with which the dam system could safely cope. Thus was born the second principle, that a whole small catchment area should be taken as the basic unit for control measures, and that gully and slope control should proceed simultaneously,

> "Some people consider that the carrying out of all types of conservation work will create a contradictory lack of manpower. In reality it is a question of how to distribute it. If large amounts of manpower are expended uniquely on building dams, of course there will be none left to pursue other measures ..... There are also those who reckon that the cause of damage to earthen dams is the absence of a carefully considered choice of damsite or a correct design for the dam itself or observation of the quality of work, etc. Although there is some truth in this, a more important cause is that without the conservation measures in the large catchment area above the dams, it is impossible to retard the speed of, or reduce the amount of, runoff and its silt from the slopes .... To set biological and engineering methods against each other is incorrect. Each type of conservation measure has its own function and the building of dams in gully floors is no exception. However, if you emphasise any one kind of measure ...... you are doomed to failure .... This is not completely to negate the conservancy efficiency of dams, since they are one of the intergrated measures of soil and water conservation. What should be opposed are policies which do not consider the locality or ..... which take conservation work simply to be the building of dams."(63)

Yet these warnings went unheeded. The reasons are complicated, but as we have seen, in addition to technical problems, the principal factor in determining the extent to which a given measure was applied, turned out to be its appeal to the peasants, who had to apply it, maintain it and lose or gain by it, themselves. Proper comprehensive control, as represented by the above two principles, is capable of providing considerable benefit to the peasants, but owing to its long term and unfamiliar nature, it required good planning and organisation in order to gain their acceptance. Regrettably these were lacking, as this complaint in the Guangming Ribao of 11 January 1957 points out,

> "It seemed that the water conservancy department was fighting single-handedly; the agricultural and forestry departments helped little, if at all. The forestry department seemed to

be only concerned with large-scale afforestation and lost sight of the fact that for soil conservation, small patches of trees were needed. The agricultural department was behind in the co-ordination work on soil conservation and increasing production. Thus, the water conservancy department, unable to do what properly was the onus of the agricultural department in the comprehensive policy, unleashed its energy on the aspect of water conservancy and built as many dams as it could. Peasants in the R. Huang region were right in saying, the Ministry of Water Conservancy works hard, the Ministry of Foresty works lukewarmly and the Ministry of Agriculture hardly works."(64)

The same article goes on to report that, at the 1956 Soil and Water Conservation Conference, the matter of poor co-ordination amongst the various departments was not gone into deeply enough and no summary was made. Another conference was held in January 1957, and an investigation was conducted by the RHWCC. In June it reported,

> "Soil and Water conservation work in various provinces along the upper and middle reaches of the R. Huang has slowed down in many areas .... As Spring is the best season for the development of the soil and water conservation work and, while the task for this year is only half that of last year, the incomplete statistical survey prepared by April 20 shows that only 20 % of the year's task .... has been achieved and, in some areas, it was below 10 %. If this rate of progress is maintained the plan for the year will hardly be materialised."(65)

In September 1957, it was reported,

> "Up to the present, water and soil conservation work in some areas has not been placed in an important position. More often than not, the task is put aside when some other tasks become imminent."(66)

At the same time (September 1957) the State Council approved the Provisional Programme of soil and water conservation, which established new organs, called upon all levels of administration to draw up the conservation plans, and laid down various laws: Slopes exceeding 42% might not be reclaimed; destruction of forests for land reclamation was prohibited; where slopes had already been reclaimed and could not be afforested because of the pressures of population, a limit was set by which time the land should be terraced, and others.(67) However, such laws were both impracticable and unenforceable under the conditions obtaining on the loess plateau and were ignored, or at least soon forgotton.

So, the trend towards building small precipitation dams to the neglect of other conservation measures continued to develop and although statistics from the time cannot be relied upon to show what was done, they do show at least what was hoped. The shift in emphasis is clear. The "1,707,621 check dams, earth dams and small reservoirs"(68) claimed to have been built by 1958, represent a 2.38 fold increase over the total number of "check dams, silt precipitation dams and gully earth dams" proposed in the 1955 plan.(69) In the 1959 plan, 683,000 silt precipitation dams replace the 79,000 of the 1955 plan, a 6.8 fold increase. By the time of the beginning of the Great Proletarian Cultural Revolution the emphasis on dams had become well established and to quote Li Fudu, Vice-Chairman of the RHWCC,

> "We propose a policy of checking silt and accumulating water in the middle reaches whilst preventing floods and discharging silt in the lower reaches, with emphasis on the checking of silt. The method to be adopted .... apart from the active promotion of soil and water conservation in the serious loss areas ..... is vigorously to develop gully control work here, with the emphasis on the building of silt precipitation dams".(70)

The same article goes on to praise silt precipitation dams, but does not mention their susceptibility to water damage when unaccompanied by other conservation measures, and even singles out Jiuyuan Gully as being exemplary,

> "Between 1953 and 1957, the RHWCC constructed five large-scale precipitation dams in Jiuyuan Gully .... After several years of successively raising their height, these dams by 1964 had accumulated over 5×10^6 m^3 of silt and had created over 40 hectares of fertile precipitated land. The masses have grown crops there since 1959 and under the extraordinarily dry circumstances of 1962 and 1965 the crops still flourished, which shows the outstanding superiority of precipitated land."

iii) Political Imbalance.

By all accounts, in the anarchy of the Cultural Revolution and the subsequent period known as the time of the Gang of Four, matters became much worse. Yet inasmuch as these events are very complicated and still the subject of much debate, only three aspects bearing a direct influence on conservation work will be presented here. They can be summarised by three slogans of the time:

'Put Politics in Command'.

'In Agriculture Learn from Dazhai'.

'Make Grain the Key Link'.

'Put Politics in Command' meant, in practice, that party cadres gave orders and everyone else had to do as they were told. There was factional in-fighting and, as the Chinese people were blown hither and thither by shifting gusts of policy, 'Bigger' or 'More' were taken to mean 'Better'. Statistics, such as the number of dams or terraces built, or the area of land newly opened to cultivation, took on disproportionate importance as arbitary orders were issued by people who did not understand the problem. As it was described, with hindsight, in the Renmin Ribao,

> "For a number of years we have done agriculture by relying on campaigns and 'Going all out'. Now we can see very clearly that the endless political campaigns seriously wounded the enthusiasm of the broad masses and basic level cadres, with such results as 'You check up on me, I check up on you, check here, check there, we all get a scolding; You're boss, I'm boss, change boss, no one's boss.' This kind of stupidity must not be repeated. As for 'Going all out' .... the problem is, 'all out' to do what? In recent years it has been 'all out for farmland capital construction, all out for small man-made plains, all out for water conservancy.' Of course .... some were done well ...... suited to practice and deriving large benefit from small investment, but on the other hand, a very large part was done badly, even to the extent that they should never have been done at all."(71)

An example, of what the last remark might indicate, may be taken from that part of Shanxi where several tens of hills have all been terraced, but remain unused because they are just too far from the villages for peasants to commute, let alone to carry water and manure there.(72)

The corollary to such experiences was that experts of all kinds were discredited (or worse), their opinions were ignored and their units were disbanded. Jiuyuan Gully, for example, had been a small catchment experimental gully of the RHWCC since 1954 and, up to the beginning of the Cultural Revolution, had received ¥ 460,000 (£ 131,000) and built 161 precipitation dams of various sizes, which controlled 57 % of the catchment area and had created about 130 ha of precipitated land whose average yield was 4500 kg ha^{-1}. During the Cultural Revolution it was singled out as a bad example, as representing, "the State forks out money whilst the peasants till the land."(73)

In Shaanxi there used to be a central conservation office employing 290 人, four experimental stations, one research institute and a subordinate organisation at the 'control point' of each County. In all, there was a technical staff of 2000 人. All but the central office and the Suide testing station were closed down and the technical workforce fell to 100 人. Thus, when it came to building dams, facilities such as spillways for the prevention of flood damage, for example, were considered expensive and anyway unnecessary, as the original capacity of the reservoir would be sufficient to absorb the flood. Technicans' objections were overruled, and it is said that when, a few years later, the reservoir having silted full, the dam would succumb to flood, it would be the technicans would get the blame.(74)

The Learn from Dazhai campaign began in 1964, when Chairman Mao Zedong called upon the nation to adopt the attitude of self-reliant hard struggle by which it was claimed the Dazhai brigade had acheived outstanding agricultural yields despite harsh conditions.(75) Dazhai falls within the R. Hai catchment on a hilly part of the loess plateau in Xiyang County, Southeast Shanxi.

What is not in dispute is that the Dazhai brigade claimed vigorously to oppose what at that time was called the 'Counter-revolutionary Revisionist Line' of 'the renegade, traitor and scab', Comrade Liu Shaoqi and especially those policies attributed to him and known as 'San Zi Yi Bao' (Plots for private use, free markets, small enterprises with sole responsibility for their own profit or loss, and the fixing of output quotas based on individual households).(76) Later, with the downfall of the Gang of Four, the 'Learn from Dazhai' movement was held to have had 'ultra-leftist errors' such that,

> "In the past, Dazhai was elevated to an inappropriate status and the specific experience of Dazhai became an insurpassable oracle, and a lot of stupid things were done".(77)

Since then, the first three of the San Zi Yi Bao policies have been restored, the fourth has been declared justified 'under the particular circumstances and on the limited scale of the time' and responsibility for these policies has been reassumed by the Party Central Committee. Comrade Liu Shaoqi has been reinstated posthumously and the blame for his downfall has been put with Comrades Lin Biao and the Gang of Four who, it is claimed,

> "In order to push the ultra-leftist line, repeatedly critised San Zi Yi Bao, meddled with party policy, messed up people's ideology and seriously obstructed or ruined rural economic development".(78)

The main outcome of all this was that the masses lost their enthusiasm. In order to 'cut off the tail of capitalism', private plots and private trees were collectivised and free markets were banned (although they continued secretly). Dazhai's egalitarian workpoints system was widely adopted (though in some cases it was just a pretence to avoid being criticised for 'opposing Dazhai') as was its grain ration distribution by 'self assessment and public discussion'. This was later criticised as being 'self assessment and no discussion' giving rise to,

> "the same results whether or not you work .... no matter how good other brigades' production was, they refused to exceed Dazhai with respect to the levels of payment in kind or in cash, so in quite a few brigades more work could not earn more remuneration".(79)

The same article reports that there was also a discincentive against comprehensive development, in that doing better than Dazhai at anything was as likely to bring criticism as would failing to learn from Dazhai,

> "'Capitalism within the collective economy' was criticised. This exerted a heavy influence on all

> production and basically strangled to death domestic sidelines. In Xiyang there was also the unwritten law that whatever the work, it must not outstrip Dazhai. Some brigades from Chengguan Commune originally had quite good material and technical preconditions for the development of industrial sidelines but, since they were afraid of 'crushing Dazhai', they did not dare to get moving with such development .... We could only say, 'learn from Dazhai', 'catch up with Dazhai', but never dared say 'surpass Dazhai' ..... to 'grow maize and nothing else' was in fact a 'suicide policy' and had it continued, the .... collective economy of the communes would have collapsed".

During the course of the Cultural Revolution, Chairman Mao's call to "Make grain the key link and ensure comprehensive development" was popularised with great vigour. On the same theme, he had also called for China to develop with one third arable farmland, one third pasture and one third forest.(80) As can be inferred from the above quotation, what actually happened was that grain production was over-emphasised at the expense of comprehensive development. As Yu Zheng, Vice-President of Shaanxi Sciences Commission, put it,

> "'Make grain the key link' became 'Make grain the whole net' and pushed out the other links, namely forestry, husbandry and sidelines."(81)

This happened in two ways, by the setting of unrealistically high state grain purchasing quotas and by direct opposition to other activities.

Of the first trend, Chen Guoliang, Vice-Principal of the Research Office of the North West Institute of Soil and Water Conservation, Biology and Pedology writes,

> "Recently, owing to a lopsided understanding of making grain the key link, in several places in N. Shaanxi, the cadres resorted to coercion and commandism, issued arbitrary and confused orders and set indiscriminate planting and state purchasing targets. In order to fulfil the task stipulated by higher ranks, the peasants had no alternative but blindly to open up wasteland, have extensive sowing but meagre harvests, and open up for grain all the land suited to forestry or husbandry".(82)

In an earlier part of the same article, Shan Lun, Vice-President and Assistant Researcher at the Institute, is more specific,

> "In Yan'an they were asked, in 1977 to increase grain yields from the original 450×10^6 kg to 1500×10^6 kg

and in order so to do, step by step to complete the task, they promiscuously opened up wasteland to grow more grain".

The outcome is described bleakly in both cases; by Chen,

> "Grain didn't rise, forestry and husbandry were both lost, the peasants' income fell and their livelihood became even poorer."

and Shan,

> "..... resulted in the destruction of forests and grassland and the intensification of soil and water losses."

To this it may be added that the total grain yield acheived, in 1979, in Yen'an was 458 x 10^6 kg, but the area of wasteland newly opened, between 1977 and 1979, was 1200 km^2, which prompted a letter to the Renmin Ribao, complaining,

> "Some cadres ..... do not cherish natural resources, they lopsidedly reckon, 'When grain yields reach the goal, then the party secretary's a good old soul'".(83)

Opposition to activities, other than growing grain, ranged from general fears that afforestation would use up too much land and that husbandry would waste fodder, to direct incitement to "use the methods of dictatorship in agriculture" to chop down trees and build grain silos.(84) More specifically, the idea that the demands made on forestry and stockrearing regions for grain production should be limited to self-sufficiency was dubbed the, "Enought to eat theory" and criticised as being insufficient.(85) According to the Renmin Ribao of 22 December 1978,

> "It was advocated quite absurdly that forest and pasture areas should make grain the key link. As a result, in forest areas, forests were destroyed, wasteland was opened up .... and the phenomenon of grain squeezing out forests occurred continuously; in pastural areas some places eliminated investment in husbandry and cancelled its leading organs and the various grassland administrative and veterinary units, etc., Under such false slogans as 'Shepherds shouldn't eat ill-gotten grain' and 'Battle to turn the tables in agriculture', pastural areas were urged to become self-sufficient in foodgrains, seeds and fodder; then they were burdened with the responsibility of compulsory grain sales to the state".(86)

Thus, the picture emerges of a generally apathetic or war-weary peasantry continuing in the traditional way to crop hilltops and, when obliged so to do, opening up forests and pastures for grain, or building precipitation dams. These latter, being built without due technical competence and without other conservation measures to reduce runoff from above, were prone to collapse. The example of the luckless Jiuyuan Gully can be taken to show how these factors might combine to create disaster. The following is drawn from a report in the Renmin Huanghe magazine of January 1979.(67) (Figure 3-1).

Jiuyuan Gully catchment is 70.1 km^2 in area and the main Gully is about 11 km long. Notwithstanding the difficulties described in previous sections, by 1977 it contained in all 333 precipitation dams and reservoirs. Ten of them were in the main gully, and of these three were clear water reservoirs. Tributary gullies included, four kilometres from the main gully mouth, Linjiaxian Gully. At the mouth of Linjiaxian Gully was the Qingnian reservoir and, 500 m upstream, a precipitation dam where silt would be allowed to settle so that only clear water would enter the reservoir.

On 6 July 1977, 109.9 mm of rain fell and the Liujiawan reservoir dam suffered piping, and collapsed. This reservoir had been added just downstream of the Jiuyuan Gully main dam, a precipitation dam, and was meant to receive clear water from it. However, owing to poor siting, its backwaters immersed two thirds of the Jiuyuan Gully main dam and, as the level suddenly dropped, a large portion of the main dam slumped. Meanwhile, a landslip in Linjiaxian Gully blocked that precipitation dam's flood spillway.

During the night of 4/5 August, 117.4 mm of rain fell and the Linjiaxian precipitation dam, its spillway still uncleared, overflowed and collapsed, taking with it the Qingnian dam, the Malian front dam and the Jiuyuan main dam, which had not been repaired. A little later, the Hongqi reservoir, which had an insufficient spillway, overflowed and gave way, causing the successive collapse of all eight reservoirs and dams beneath it. In the gully catchment as a whole, 234 tributary dams and 9 main gully dams were destroyed and 51.5 ha

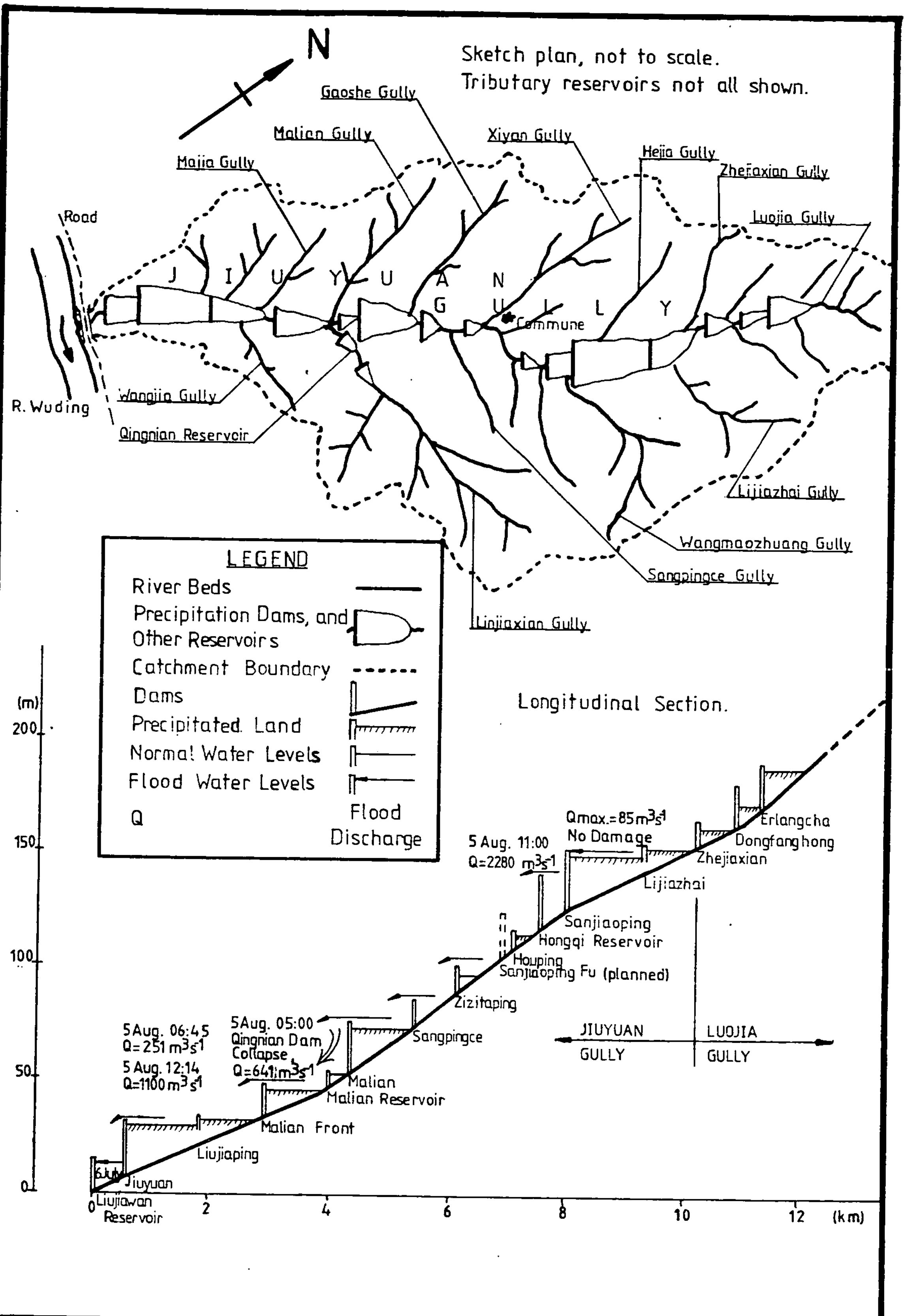


FIGURE 3-1 FLOOD DAMAGE IN JIUYUAN GULLY IN 1977 SOURCES: Note 87

of precipitated land (27 % of the total) were lost. The official verdict was that, "the main reasons .... were inferior work quality, poor siting and slack managment." We have seen that there were general causes both for this, and for the slow development or actual decline, of the region as a whole.

iv) Relevance to the Sanmenxia Project.

Even if the conservation work had proceeded according to plan, and had fulfilled the hopes expressed in the Soviet estimates of the reduction in R. Huang silt load, it would not have been discernable, because of natural variation, from measurements of the silt load made in the late fifties and early sixties. Therefore, it cannot be said that the failure to reduce the silt load of the R. Huang noticeably, by 1962, was a new factor in the decision to reconstruct the Sanmenxia reservoir. The silt content of the river would have been, within the limits of accuracy of the measurements, as predicted. It must be concluded that, despite the exaggerated claims of the Great Leap Forward, the inaccuracy of the previous estimates was realised, or the significance of such a heavy silt load was reassessed, or the decision had little to do with the oncoming silt load.

There is evidence to suggest that all three factors played their part. The latter two, combined, are inferred from the discussion of so many other factors (Section 4). As for the need for a general reassessment of the pace of conservation work, it would have become obvious, at least to those working on the loess plateau, that no quick solution had been found. Since their fears were publicised from time to time, it is reasonable to assume that, as with other aspects of the Sanmenxia project, there was a gradual accumulation of evidence which would eventually have given rise to change. Furthermore, when it was realised that the loess plateau was to develop more slowly than had at first been assumed, and that this region was to remain poor for longer, then the relative importance of the Guanzhong Plain, which for so long had supported it, would correspondingly have had to have been raised.

Thus, interestingly, one of the more important ways in which the slow pace, of both conservation and economic development, on the loess plateau, would have influenced the Sanmenxia project, was its effect in placing emphasis on the loss of prime agricultural land from the Guangzhong Plain. It should be emphasised though, that, whereas the failure for there to have been a significant decrease in R. Huang silt might not be so significant to the original design of the Sanmenxia reservoir, it is, nonetheless, still of importance to the long-term control of the river. (Chapter 5).

4) Sedimentation Problems Exposed.

Impounding began at Sanmenxia on 15 September 1960 and, in accordance with the modified Soviet design, the top of the dam was at 353 m and the operational regime was a high head reservoir for the storage of water and silt. Under the modified plan, the maximum permissible water level in the first period would be 340 m. Actually it was above 330 m for a total of 200 days and the highest level, which occurred on 21 October 1961, was 332.58 m. At this point the reservoir backwater, along the R. Wei, extended 55 km beyond Tongguan to Chishuizhen in Hua county, 178 km from the dam, and the confluence of the rivers Wei, Beiluo and Huang was flooded. This regime was continued until 19 March 1962, when the normal maximum water level was lowered by 10 m to 330 m as the first stage in its conversion to operate as a flood retardation and silt discharge reservoir.(88) The sedimentation problems exposed in this first period, were a major factor in the decision to change the operational regime and, subsequently, to reconstruct the dam. They will be presented in two groups; those contributing to what was seen as rapid loss of reservoir capacity, and those seen as posing a threat to the Guanzhong Plain.

i) Failure of Density Current and Loss of Reservoir Capacity.

It was the design intention that silt, especially the coarser grains, should settle within the reservoir area to obviate turbine erosion and downstream aggradation. About 20 % of the finer particles, though, were expected to be discharged by a density current which would establish itself in Summer. In fact, of the 1646 x 10^6 t of silt which entered the reservoir area before March 1962, only 112 x 10^6 t (6.8 %) were discharged and 1534 x 10^6 t were deposited in the reservoir area, 1266 x 10^6 t below Tongguan.(89)

In the clear water period, before the first flood of 1961, the bed was far from flat. This, and the submerged bar caused by bank collapses in the stretch just before the dam, increased flow resistance such that the density current could not reach the dam and, so, silt was deposited.(90)

In the flood months July to October, 1310 x 10^6 t of silt entered the reservoir from which 780 x 10^6 m^3 was deposited in a fairly typical delta morphology (Figure 3-2) subsequently extending both upstream and downstream. Since deposition had by then levelled out the bed to the top of the submerged bar, the density current was capable, on occassion, of reaching the dam, but it was still too weak to discharge a substantial quantity of silt. It deposited a further 140 x 10^6 m^3 in the antedam area and only 88 x 10^6 m^3 were discharged downstream. The dry bulk weight of the deposits was found to be 1.3 t m^{-3}.(91)

How significant was the total deposition is a relative question. Much attention has been drawn, in recent years, to the fact that in this first period of eighteen months, which included only one flood season, the reservoir lost about 12 % of the capacity under a water level of 335 m.(92) However, under the modified Soviet plan, this would have been expected; the 1646 x 10^6 t which entered the reservoir in this period, would have been reduced, at best, by 10 % by soil and water conservation work. Of the 1481 x 10^6 t thus entering the reservoir, 20 % would have been expected to have been discharged. The expected volume of the remaining 1184 x 10^6 t would have been 987 x 10^6 m^3 (Dry bulk weight assumed to be 1.2 t m^{-3}), or about 10 % of the capacity under 335 m. The extra 2 % found in practice is hardly an unreasonable degree of error and, when it is remembered that under the modified plan the total reservoir capacity was gradually to have been increased to about 64,000 x 10^6 m^3, it really does not appear significant. However, if for any reason the reservoir water level was not to be permitted to rise, or, indeed, was to be lowered, then even the predicted loss of 10 % in just eighteen months would seem very serious indeed, for its significance would be that the reservoir would have a life of only 12 to 15 years.

ii) Retrogressive Deposition and other R. Wei Problems.

In the flood of 1961 the backwaters extended 7 km upstream from Tongguan along the R. Huang mainstream, and 178 km from the dam along the R. Wei, and covered much of the surrounding land; this was

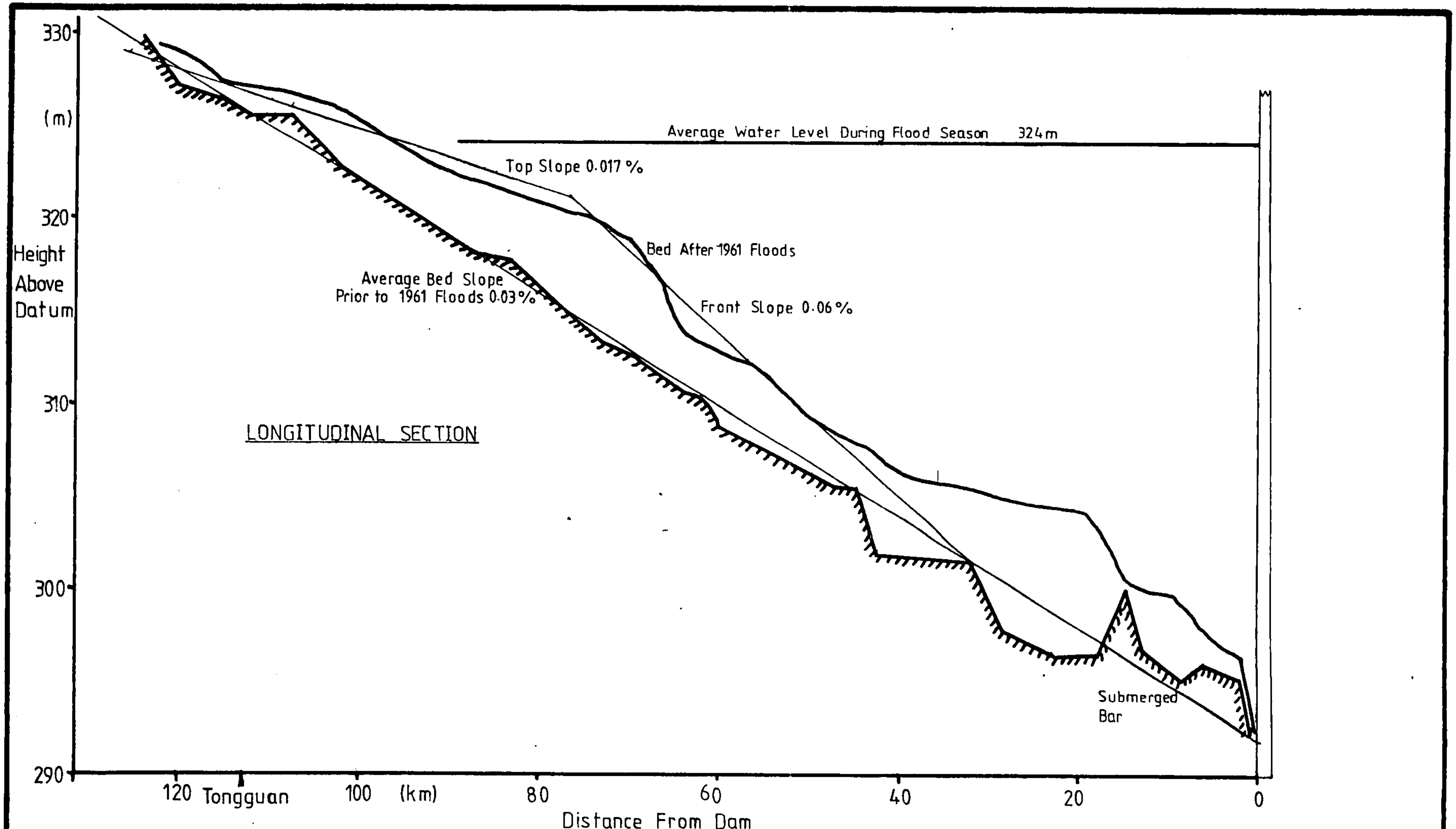


FIGURE 3-2 SANMENXIA RESERVOIR SEDIMENTATION IN 1961 SOURCE: Note 91

in keeping with the design intention. However, deposition within this area raised the bed level at Tongguan by 1.7 m, and a sandbar appeared across both the main channel and floodplains at the mouth of the R. Wei. In the past, such sandbars had been known to occur when the confluence was flooded, but they had been confined to the main channel and had been easily washed away by the first R. Wei flood after the recession of the R. Huang water. Now, whilst the reservoir level remained high, these obstructions would stay and, together, they had the effect of reducing the slope of the lower R. Wei from 0.021 % to 0.0181 %.(93)

The effects of the reduced slope of the lower R. Wei were extensive. In the first period, to March 1962, 9.8 % of the total deposition at Sanmenxia occurred above the highest water level, that is, retrogressive deposition had begun and, by November 1961, it extended 223 km from the dam, along the R.Wei, and showed no sign of stopping. Both the normal and flood water levels of the R. Wei were thus raised by about 2 m. (Figure 3-3).(94)

The rise in the normal water level brought about a corresponding rise in the ground water level alongside and caused difficulties for the riparian farmers of the great Guanzhong Plain, especially in the two counties, Hua and Huayin, of Weinan district. In this region, between the R. Wei and the Qin mountains to the South, lies the dry bed of a Western Han dynasty canal, called Caoqu ("Transport Canal"), which had been built to enable goods to be shipped from the R. Huang at Tongguan to the then Capital, Chang'an (present day Xi'an), because the R. Wei meandered too much and was too shallow, except in the flood season. This lowland has for many years suffered alkalisation problems, but the increase in the water level of the R. Wei raised the local underground water table and both extended and intensified them. One estimate gives the area spoilt above Tongguan as 330 km^2.(96)

The rise in the flood water level made flood prevention work all the more critical. Although in the first eighteen months Xi'an was not endangered, voices were raised to the effect that if the backward

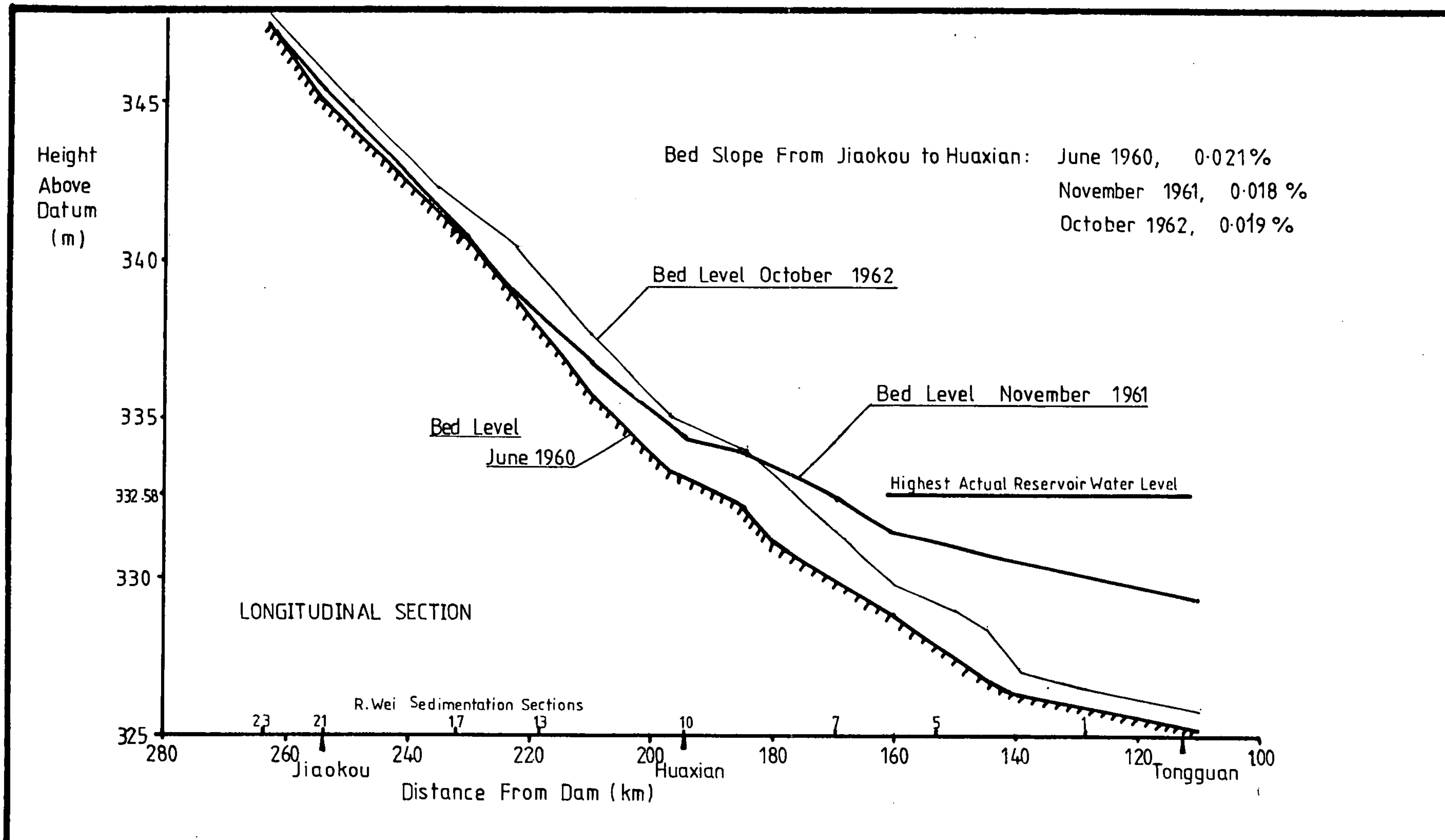


FIGURE 3-3 SEDIMENTATION IN THE LOWER R.WEI IN 1961/2

SOURCE: Note 95

extension of the R. Wei deposition, and subsequent rise in water level were not halted, then soon it would be.

iii) The Decision to Abandon Sanmenxia as a High Head Storage Reservoir.

On 19 March 1962, the reservoir water level was lowered and a new operational regime adopted. The new regime was that which had been proposed earlier, by such people as Comrades Ye and Wen, and covered using the reservoir to store only clear, Winter, water, and to hinder the Summer flood peaks as little as possible, using them, at the same time, to scour out such sediment as had already been deposited. No detail of the process by which this decision was made was published outside China; indeed, it was not even acknowledged until 1971, after the completion of a two-stage reconstruction. It is interesting to note, however, that a conference of the Chinese Hydraulic Engineering Society was reported, in January 1962, to have been held 'recently', in order to discuss the effects of the release of clear water from the Sanmenxia reservoir, upon the lower reaches of the R. Huang, which would assume no change in the reservoir's operational regime.(97) Whilst in this instance it is not possible to go into how the decision was reached, it is nonetheless instructive to summarise the reasons why it was reached and, furthermore, why in 1962.

In the course of operating the Sanmenxia reservoir, even at the reduced maximum water level of 340 m, many of the assumptions upon which the design had been based were tested. Some were found to have been correct, some were found to have been in error, and others were quantified for the first time. Some of the effects of the reservoir were largely beneficial; for example, although the erosive action of clear water destroyed some engineering structures for river training in the lower reaches, in general it brought about an improvement in channel morphology and flood carrying capacity (Section 6).(98) Furthermore, as we have seen in Sections 3,iv, and 4,i, the increase in reservoir deposition occasioned by the slow progress of soil and water conservation work and the failure of the density current, would not, of itself, have made a significant change to the original design intentions, whilst the effects in the

R. Wei valley gave genuine cause for deep concern which might well have been sufficient alone to bring about a change in policy.

It was suggested at the end of Section 2,iv, that, owing to various political, social and economic changes, the conditions prevailing by the early sixties in China would have been conducive to the abandonment of the dream that had favoured the adoption of those assumptions upon which the Soviet design had been based, in favour of alternative assumptions leading to an approach more closely linked to the short term needs of a developing China. The dangerous situation developing in the lower R. Wei valley would have been the required catalyst and there, then, would have been an interrelated set of reasons for change. Firstly, the spoilage of so much land beyond the reservoir backwaters and the threat to Xi'an would have precluded the proposed increase in reservoir capacity to $64,000 \times 10^6$ m^3. This would be true not only for its own sake, but also because the relative value of such prime land as is to be found on the Guanzhong Plain, would have been placed much higher in view of the strictures occasioned by the 'Three Hard Years' and of the failure of soil and water conservation work substantially to improve agricultural yields on the loess plateau. Since it had been found to be undesirable to raise the water level further, or even to allow it to remain at its current level, the extent of deposition within the reservoir area took on alarming new proportions, for 10 % of the new, lower, maximum reservoir capacity had been lost in the first eighteen months.

Not all the points of contention had been tested here though. The most notable amongst those which had not, were the questions of whether sediment already deposited in the reservoir, could be flushed out subsequently and whether or not the bed level at Tongguan, base level for the R. Wei, could be lowered successfully. Recent experiences elsewhere in China, and abroad, suggested that it would be possible, but, as will be seen, the lessons of over-optimism had been well learnt and subsequent changes were to be made with great caution.

5) The Reconstructions.

In December 1964, a meeting was called by Comrade Zhou Enlai and held under the auspices of the State Council to discuss the regulation of the R. Huang. The point of emphasis was the proposed reconstruction of the Sanmenxia reservoir. Those attending the meeting included representatives of the Ministry of Hydroelectric Power, the Ministry of Forestry, the RHWCC and the Local Authorities of some of the regions through which the R. Huang flows. Also represented were various colleges and research bodies.(99)

Although the reservoir water level had been lowered in March 1962, siltation had continued both within the reservoir area and as retrogressive deposition along the R. Wei, extending to 268 km above the dam by October 1962. Furthermore, it had become apparent that, despite the new mode of operation, in its present form the reservoir was still unable to discharge the greater part of its incoming silt load and even less to purge that already accumulated. When an exceptionally large flood was encountered in the Summer of 1964, $1294 \times 10^6 t$ of sediment were deposited in the reservoir area as the waters were slowed by the retarding effect of insufficiently large sluices. In this way, in just over four years, the reservoir capacity corresponding to a water level of 335 m had been reduced from $9600 \times 10^6\ m^3$ to $5700 \times 10^6\ m^3$.(100)

The shades of opinion expressed at the meeting ranged from the advocacy of no change, to the proposal that the dam be demolished. The majority, however, believed that some form of reconstruction should be carried out, and with urgency too, lest Xi'an be further endangered.

Two main proposals were considered. Firstly, to construct two tunnels in the Northern (left) bank and to convert four of the eight generator penstocks into sediment discharge sluices, a plan which became known as the Two Tunnels and Four Tubes plan. Secondly, to re-open some or all of the twelve bottom sluices used for diversion during construction (Figure 3-4). In choosing an appropriate scheme,

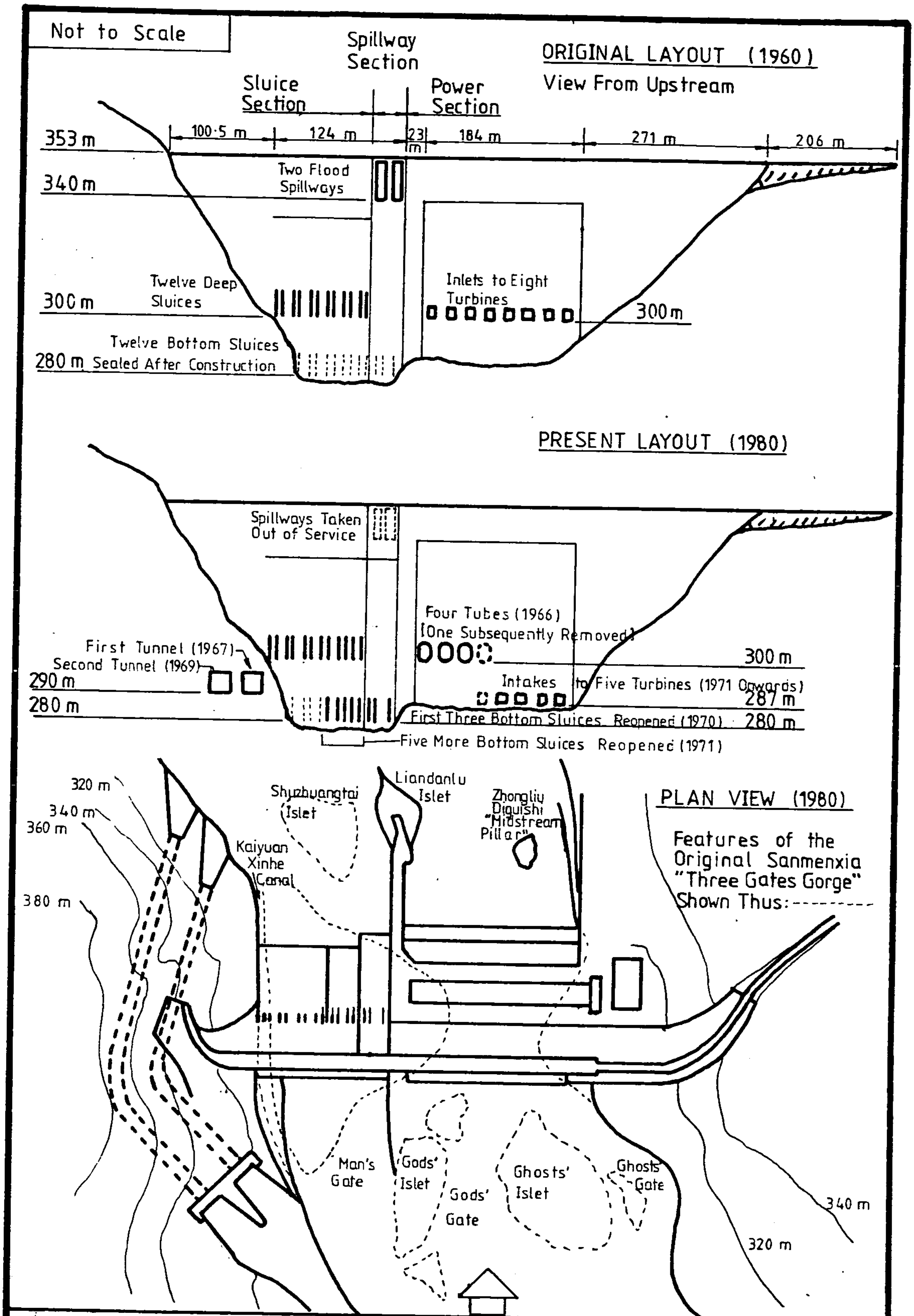


FIGURE 3-4 THE RECONSTRUCTIONS OF THE SANMENXIA DAM

SOURCES: Note 101

the desire for increased sediment discharge capacity was the key point, but it had to be weighed against considerations of the structural integrity of the dam. The capacity to generate electricity had already been lost and, in any case, would have had to take second place to safety, be it of the dam itself, of the Guanzhong Plain, or of the reservoir's role in flood prevention downstream.

The total existing discharge capacity provided by the twelve deep sluices was 3080 $m^3\ s^{-1}$, corresponding to a water level of 315 m. For the same water level each additional bottom sluice, if re-opened, could provide about 440 $m^3\ s^{-1}$ additional discharge capacity, each tunnel 1040 $m^3\ s^{-1}$ and each tube 225 $m^3\ s^{-1}$. Thus, opening all twelve bottom sluices could increase the discharge capacity by 170 % and the Two Tunnels and Four Tubes plan would roughly double it, to 6060 $m^3\ s^{-1}$.

The Two Tunnels and Four Tubes plan was considered insufficient to allow the reservoir to be operated without retarding floods and, thereby, becoming further silted, and so the additional re-opening of some of the bottom sluices was proposed. However, several comrades expressed fears for the structural integrity of the dam. The chief concern was that the tensile stress in the concrete surrounding the sluices might be too great and lead to cracking around the sluicing structures. A second concern was that since all but three of the bottom sluices are directly beneath the deep sluices and their outlets converge, cavitation might occur when both sets are used simultaneously, (Figure 3-5). These proposals were, therefore, shelved.

In his closing address to the conference, Comrade Zhou Enlai noted that most comrades were in favour of at least the Two Tunnels and Four Tubes proposals and, accordingly, gave permission for that part of the work to proceed. However, it should be done with 'caution and conscientiousness', he said. It was acknowledged that the scope of this reconstruction would be insufficient to solve the problems, and indeed this was the case (Section 6), but it should be able to ameliorate them somewhat whilst further studies were carried out in

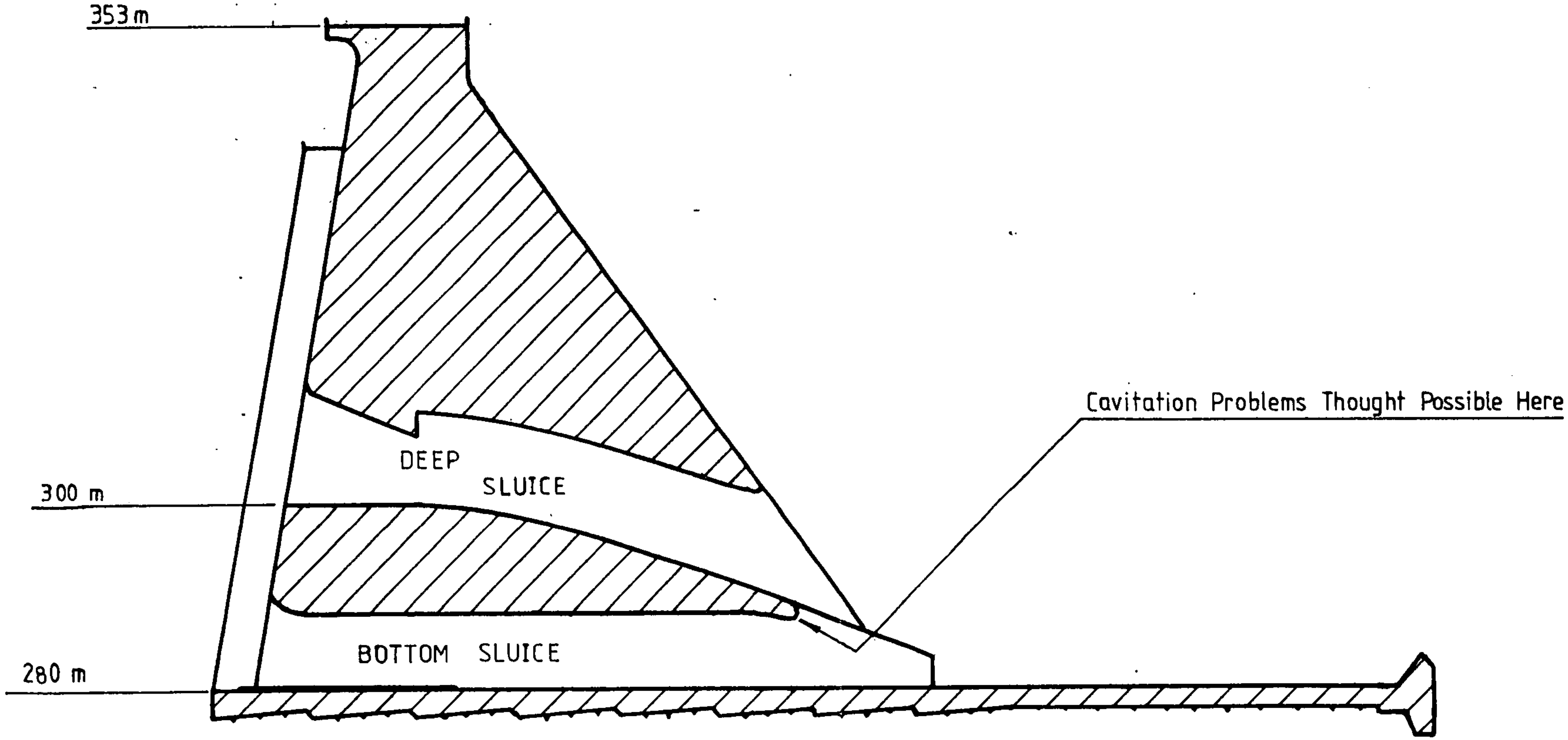


FIGURE 3-5 — SECTION THROUGH SLUICE SECTION OF THE SANMENXIA DAM

SOURCE: QUSRL, Unpublished Drawings.

order to determine a suitable advanced reconstruction plan, he thought. He remarked that the sedimentation problem had 'The urgency of singed eyebrows' and could not wait. Determination was needed to guarantee the safety of Xi'an, and he rejected, as undialectical, any suggestion that the Guanzhong Plain might become flooded in order to save the lower reaches.

The terms of reference for research into an advanced reconstruction were also given at the conference,

> "For ordinary floods the greatest possible use is to be made of the flood carrying and silt discharging capacities of the lower reaches, so as to reduce deposition above Tongguan and to guarantee the safety of Xi'an. Only thus can the life of the reservoir be conserved so that when the lower reaches definitely require that it hold back the flood, it can be brought into action. Once the flood discharge capacity has been increased, then the rationality and possibility of low head electricity generation may also be considered."(102)

In the meantime, calls were made for the strengthening of soil and water conservation work in the middle reaches and for improvements in flood prevention works in the lower reaches. The four tubes were completed in time for the flood season of 1966 and the tunnels were completed for the 1967 and 1969 floods respectively. Their dimensions and discharge capacities are given in Table 3-2 and Figure 3-6.

The cautious approach seen here was again apparent in 1969, when another such meeting was held, this time to discuss an advanced reconstruction. Represented at this second meeting were the leaders of the four provinces He'nan, Shaanxi, Shanxi and Shandong and also various scientific and research organisations and colleges. It was decided, this time, to reopen a total of eight of the bottom sluices, but to do so in two stages, beginning with the three bottom sluices in the spillway section (Figure 3-3) of the dam and only later to move on to do five in the sluice section. This allowed the reconstruction design to be checked first on part of the dam which served no other purpose (the changes in mode of operation had rendered the spillways vestigial) and without disturbing the deep sluices or bringing up the problem of cavitation. The first three bottom sluices were brought into operation in 1970, followed by the other five in 1971. The dimensions and discharge capacities are

TABLE 3-2 DETAILS OF SANMENXIA DAM DISCHARGE FACILITIES

Type	Level of Lowest Part (m)	Dimentions (m)	Discharge of Single Sluice Under Various Water Levels ($m^3 s^{-1}$)			
			310m	305m	300m	295m
Deep Sluice	300	3 Wide x 8 High	150	45		
Tunnel	290	Upstream Section 11 Dia., Open Section 9 Wide x 12 High Arch, Radial Intake Gates 8 x 8.	910	655	360	100
Tube	300	7.5 Dia., Outlet 2.6 Wide x 3.4 High	910			
Bottom Sluice	280	3 Wide x 8 High	420	370	310	240

Source: CHEN Shangqun, et al., Eds., 1972, p. 124.

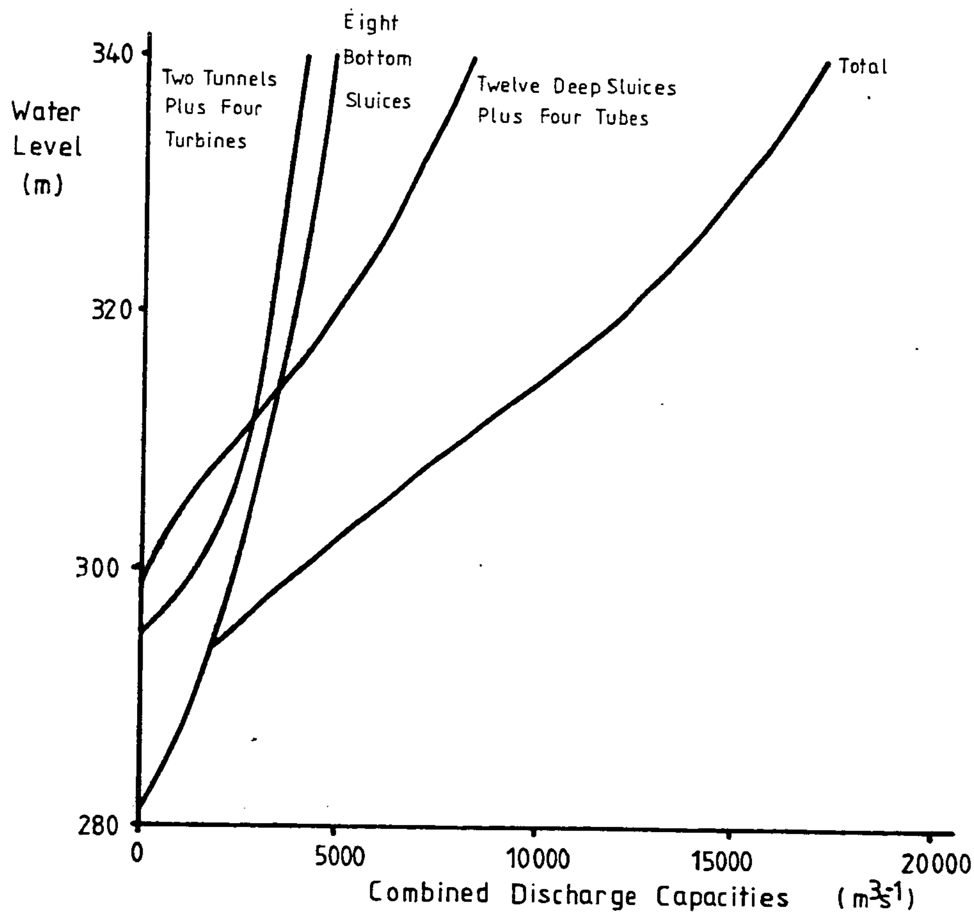


FIGURE 3-6 DISCHARGE CURVES SOURCE: Note 103

shown in Table 3-2 and Figure 3-6.

The overall reconstruction principal decided at the 1969 meeting was summarised thus,

> "Under the precondition of the two guarantees, there shall be rational flood prevention, silt discharge and purging, and run-of-river electricity generation."(104)

The two guarantees referred to the safety of the lower reaches and of Xi'an respectively. Rational flood prevention meant that the reservoir would only be used to retard floods in emergencies and that its influence on the passage of ordinary floods would be minimised.

The specific scope of the reconstruction was as follows: In order that deposition during ordinary floods should not extend beyond Tongguan, a discharge capacity of 10,000 $m^3 s^{-1}$ for a water level of 315 m would be provided (this corresponds to a flood of the size expected once every three years). In the flood season the normal water level would be kept below 305 m and during the rest of the year it would not normally exceed 315 m, except for the prevention of ice-jam floods, when it might rise to about 328 m. Four 50 MW generating sets would be installed, which could be used whenever the water level exceeded 300 m. The four generator inlets were to be lowered to 287 m. Electricity so produced would be sent to Shaanxi and Shanxi so as to distribute more fairly, between upstream and downstream, the benefits as well as the burdens of the reservoir.

The first new generating set was installed in 1971 and, with the installation of the second one in 1973, the reconstruction period is considered to be completed. The one high head set to have been installed under the original scheme was dismantled and was subsequently used in the Danjiang hydropower station on the R. Hanshui in Hubei, the others did not arrive from the USSR.(105) Although no further major reconstruction has taken place at Sanmenxia, the dam has been modified so that one of the four tubes was lowered to 287 m and reassumed its original role as penstock, for the addition of a fifth generator set (Figure 3-7).

FIGURE 3-7 THE SANMENXIA DAM 1979-80

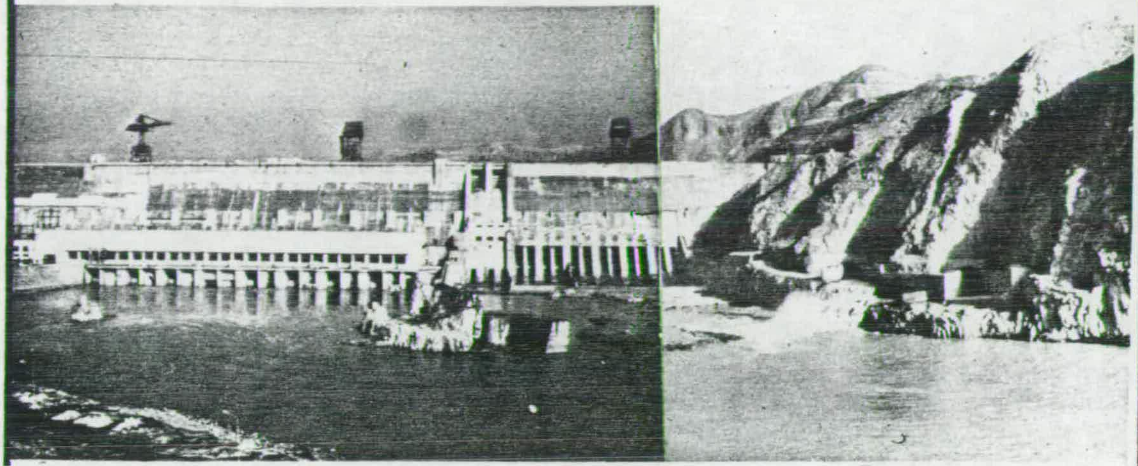


Figure 3-7 (a) Downstream overall view (PM)

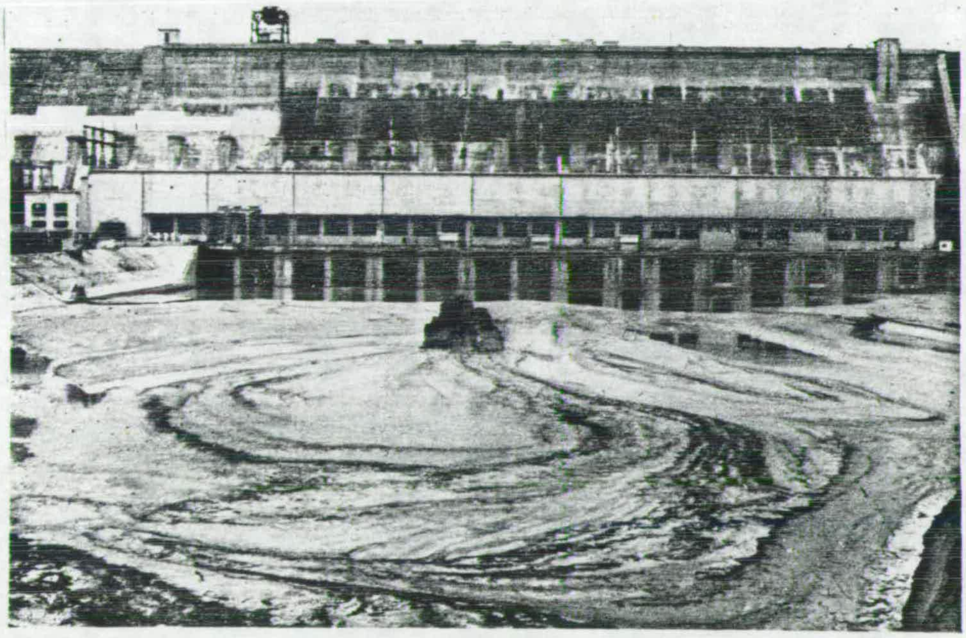


Figure 3-7 (b) Downstream view of the original power station showing, from left to right, four turbine outlets, one silt discharge tube reconverted to turbine outlet, and the three remaining discharge tube outlets. Also, the remains of Zhongliu Diguishi, the 'Midstream Pillar' (PM)

Continued

FIGURE 3-7 Continued

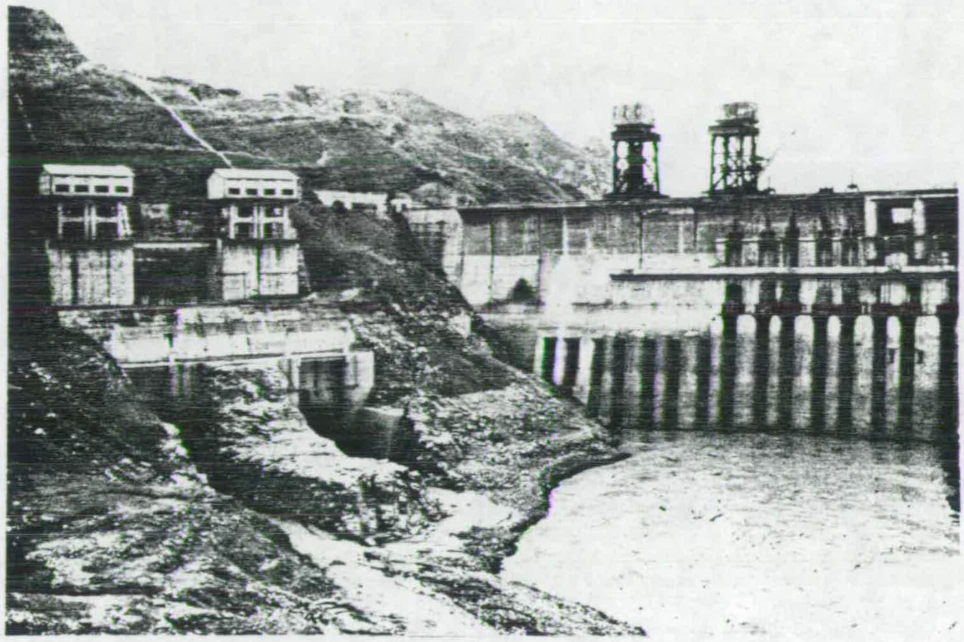


Figure 3-7 (c) Upstream view of the two tunnels (PM)

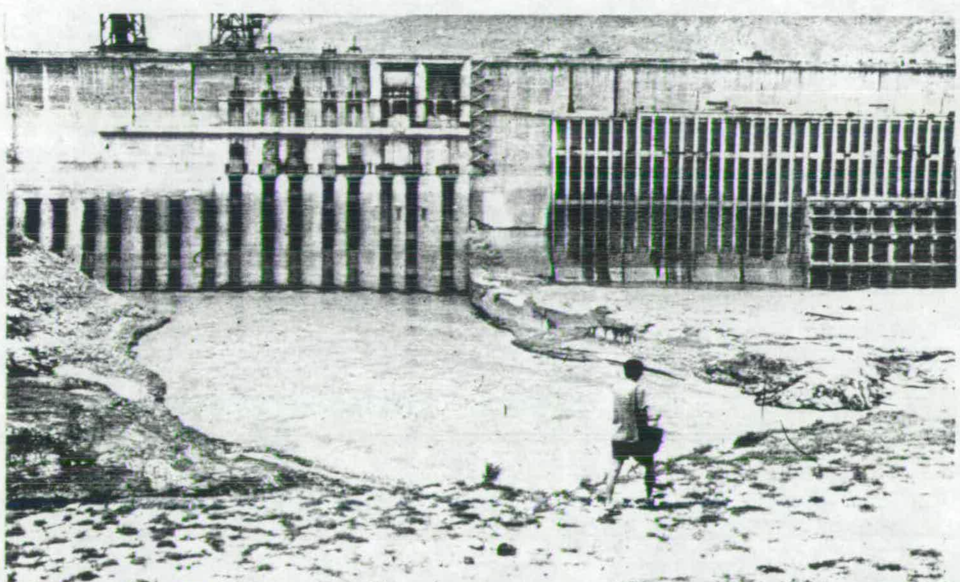


Figure 3-7 (d) Upstream view of the two vestigial flood (PM)
spillways, the twelve deep sluices, the twelve bottom sluices, of which the four left-hand ones remain sealed, the inlets to three silt discharging tubes, and the trash racks for two of the turbine intakes

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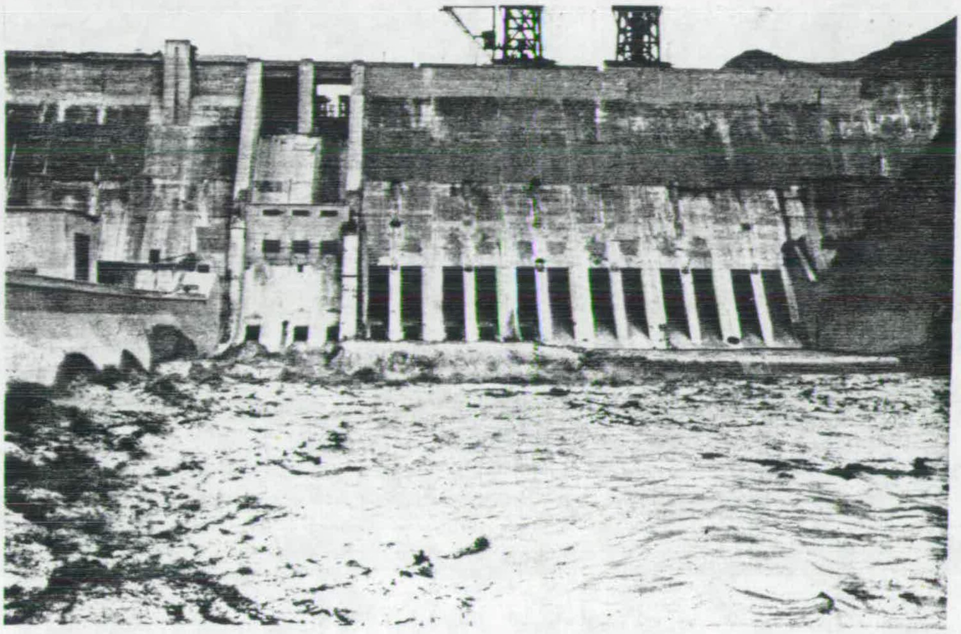


Figure 3-7 (e) Downstream view of the two vestigial flood spillways, the twelve deep sluice outlets, and the eight reopened bottom sluice outlets (PM)

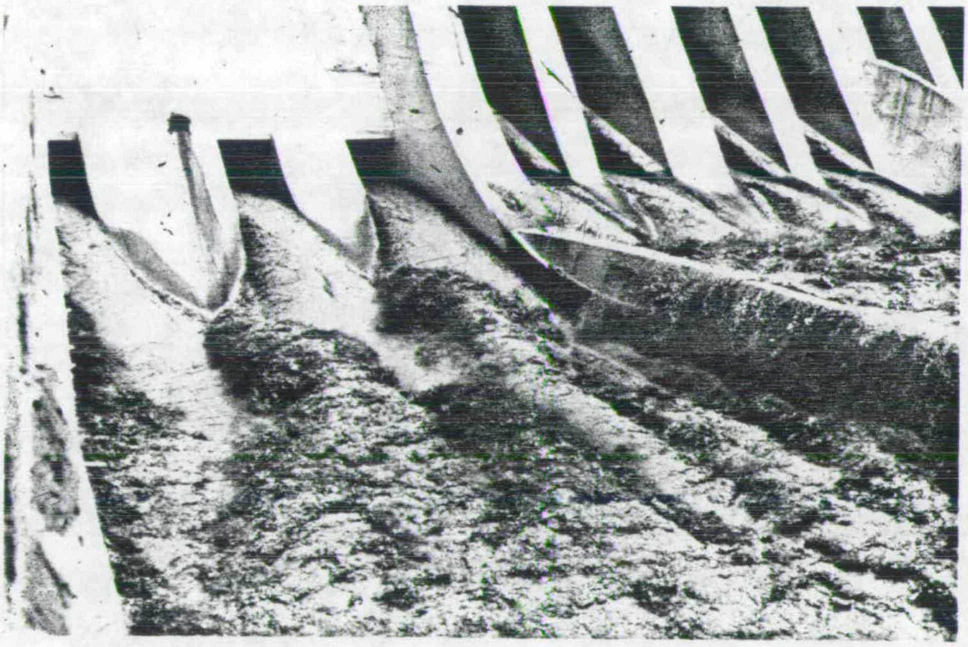


Figure 3-7 (f) Close-up downstream view of seven of the reopened bottom sluice outlets, discharging silt (PM)

Photos: Figure 3-7 (a), Sanmenxia, 29 December 1979. Figures 3-7 (b) to 3-7 (f), Sanmenxia, 3 August 1980.

6) The Effects of the Reconstructions and Some Wider Implications.

The reservoir mode of operation was changed in 1962 to silt discharging and flood retardation, which meant that, except when the lower reaches so required for flood prevention, the reservoir discharged as much as possible of both incoming water and silt. Flood retardation was an unavoidable consequence of the inadequate discharge capacity, especially at low water levels. The reconstructions, which were aimed at resolving that shortcoming, brought into play as they proceeded, one by one, a total of six different discharge regimes, whose effects on the reservoir area and the river stretches above and below are discussed later in this section.

First of all, it is necessary to consider the consequences of the grandiose scheme and its abandonment, on some of the problems of evacuation and relocation of the population. In order so to do, it will be necessary first to consider the arrangements which existed before the changes took place.

i) Relocation of Peasants.

As mentioned previously, it was not expected to be easy to relocate the 890,000 人 displaced as a result of building the Sanmenxia reservoir and this was one factor in the decision to operate it, in the first period, with a maximum water level of 340 m, which would necessitate the relocation of some 300,000 人 only. The official viewpoint was given by Deng Zihui in his 1955 report,

> "The Sanmenxia reservoir ...... will inundate over 1330 km^2 of arable land when the water in it reaches a height of 350 m. Therefore, 600,000 people will have to be resettled, Of course, there is no comparison between this and the damage brought about by floods or breaches of the dykes. The latter causes incalculable loss of life and property, whereas resettlement will be carried out in a well-planned way under the leadership and with the help of the People's Government, which will see to it that, when they reach the places of resettlement, the evacuees are given whatever assistance they need to resume work and earn a living. That has always been our policy and, in the past, when building of reservoirs began or water detention basins or flood-retarding areas were created, the local people gladly fell in with public

needs and the Government's measures. As a result, plans for resettlement or temporary resettlement, went without a hitch ...... These resettlers will assuredly earn the deepest gratitude of the 80 million people living under constant menace of the R. Huang, while the Government will play its part in seeing to it that they suffer no loss in the course of resettlement, and by helping them attain a secure and happy life as soon as possible after they reach their destination."(106)

The area to be affected included parts of Shan and Lingbao Counties in He'nan; Pinglu, Ruicheng and Yongji Counties in Shanxi; and Tongguan, Huayin, Hua, Weinan and Dali Counties in Shaanxi. In all 970 villages would be covered, as would Shanzhou, the County Town of Shan County (Figure 3-8).(108)

The work both of persuading people in the reservoir area to move out and of persuading people in the resettlement area to accept the newcomers was organised by special Party committees at County and, later, at Commune levels. For example, in the region including Shan County, an "Evacuation Committee" was set up in 1956, and comprised about ten people. Evacuation from rural areas began the same year in Shan County and the majority moved in 1958 and 1959. Work proceeded away from the damsite such that the furthest areas, those in Shaanxi, were not evacuated until 1959.(109)

The arrangements made for the evacuees in 1956 and 1957 are reported to have been as follows: The people and all their movable belongings, including farm animals, were transported at the Governement's expense, and what could not be moved was paid for at agreed prices. In the resettlement districts, special 'Immigration Committees' were established to greet them and to organise the preparation of new houses for them. Groups of 'Pioneers', usually youths, went several months in advance to carry out the work, and their food, fuel and construction materials were provided free by the Government. Since all these evacuees were peasants, they were considered not to need work, which therefore was not provided, but land was made available _gratis_. All of them moved voluntarily, and the average budget was ¥ 800 $人^{-1}$ to ¥ 900 $人^{-1}$, equivalent then to about £ 130 $人^{-1}$, which was paid to collectives, not individuals.(110)

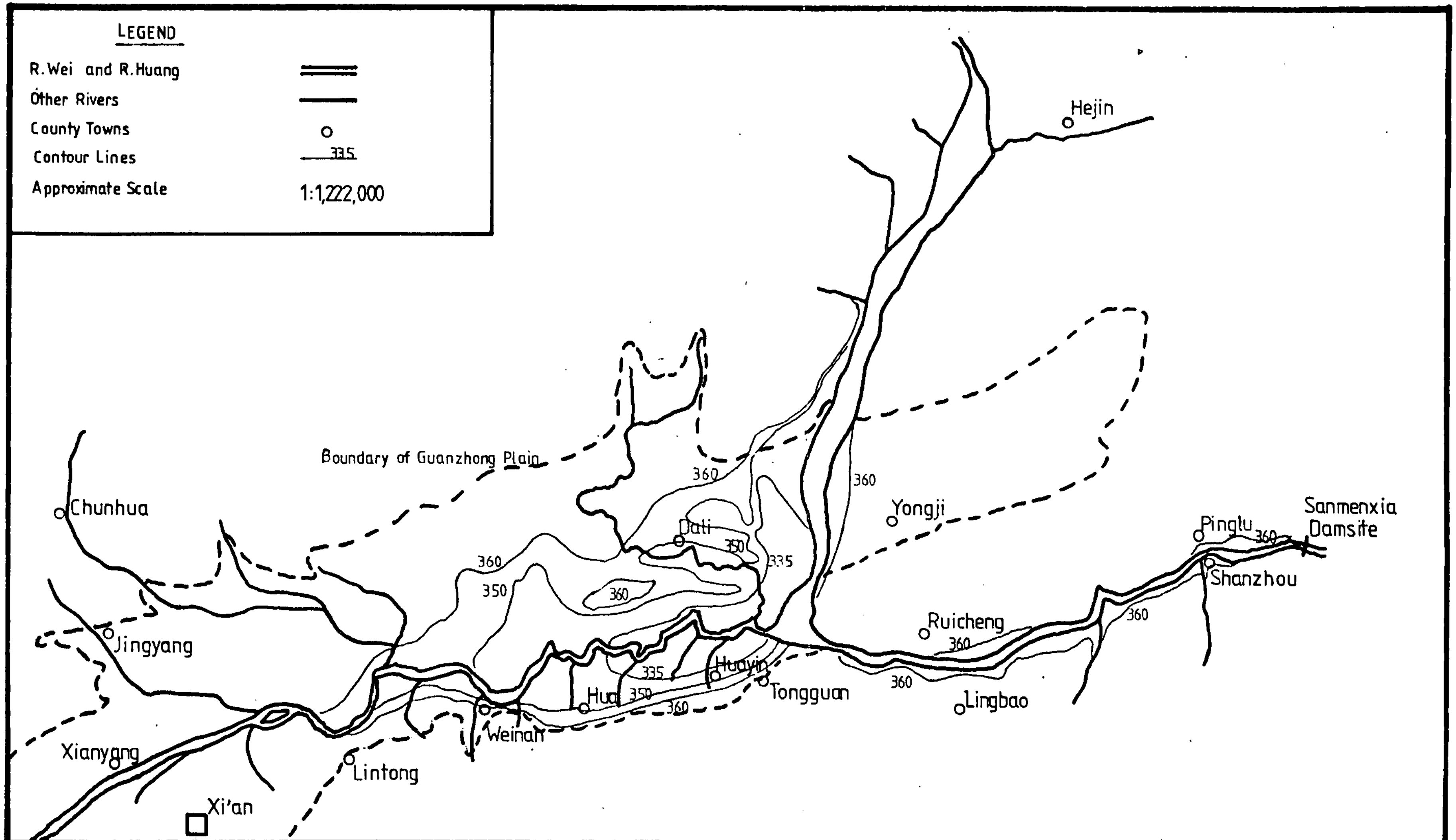


FIGURE 3-8 AREAS TO BE FLOODED UNDER VARIOUS WATER LEVELS SOURCE: Note 107

According to various reports, the first group to move, 2000 人, went to Dunhuang in Western Gansu and by the end of 1956 over 7000 人 had left Shan and Lingbao Counties, and had gone to Zhangye, also in Western Gansu, and Yinchuan, Capital of Ningxia. By April 1957, over 12,000 人 are reported to have left for the Northwest.(111)

Despite these efforts, many evacuees subsequently returned, mainly in 1957 and 1958, complaining that they could not become used to the dry Northwestern climate. After some altercation they were allowed to stay and were relocated, along with those moving for the first time, as close as possible to their places of origin, just beyond the reservoir area. They are reported to have suffered no loss for this circumnavigation, being treated equally with those yet to move.(112)

Reports of the evacuation work in 1959, as the dam neared completion, give an insight into the problems which occurred as the rate of resettlement reached its peak. Some 78,000 人 from Dali County and 69,000 人 from Weinan County were to be moved between November 1959 and the next Summer flood season. One reason for the delay was to reduce the effects on agricultural production before flooding began. The Chairman of an Agricultural Co-operative, of whose 280 members 29 had left to be 'Pioneers', claimed, for example, in 1957, that the Government had promised to provide tractors to make up for subsequent loss of manpower. Similarly, whilst the majority of the above were to move before December 1959, 25,000 人 would remain to gather the harvest on 267 km^2 of wheat and cereal crops the following Summer. In accordance with the new policy of disturbing people as little as possible, all were to remain within Shaanxi, and village communities were to remain intact. Some 60,000 人 would be settled in Pucheng County and at Caotan in Xi'an Municipal District, and some 80,000 人 still within Dali and Weinan Counties.(113)

Emphasis was placed on ideological preparation. In October 1959, a special conference was convened in Weinan by the secretary of the Shaanxi Provincial Party Committee of County Party Committee First Secretaries, and others, and this was followed by an enlarged conference of the Weinan County Party Committee at which it was decided that responsibility for emigration or immigration work should be borne by one Commune Manager or Commune Party Committee Secretary at each Commune. Similar conferences were held subsequently at Commune level. Examples were reported of two Communes, Gushi and Guandao in Weinan which each assigned 12 cadres full time to take charge of the work and one, Huayang Commune, which trained 250 propagandists for the purpose. Evacuees' representatives were also organised to make inspection tours of the resettlement areas.

Nevertheless, a project of such large proportions would be expected to raise problems and, although their extent was not reported their nature can be inferred. Building materials for the evacuees' new houses were in short supply, and so were supplemented by the prompt demolition of the houses they had just left. 'Incomplete' statistics, quoted in the Shaanxi Ribao for the period preceding October 1957, report that 17,000 labourers had been assigned to demolish some 20,000 houses, so far, and over 22,000 t of timber, bricks and tiles had been moved. In addition to building new houses, existing property was requisitioned for the newcomers. This was reported to have been done in the spirit of attaching equal importance to construction and requisition. The statistics quoted above refer, however, to 3300 new houses having been built and 6800 requisitioned in Weinan County, and 13,000 built and 30,000 requisitioned in Pucheng County.

As for the acceptability of these houses to the evacuees, whereas officials are not slow to point out that,

> "... their design was the same as the originals, their quality was better and they were provided for all, even the 10 % who originally had none,"(114)

it should be remembered that cave dwellings such as those inhabited by this 10 % "homeless" are very popular throughout the loess plateau region, and the people had been living in them from preference for centuries. For example, one contemporary report states,

> "Peasants hate to leave their land, even if it is poor. And some ..... were not too sure that the brick houses they will have on the nearby Communes would be as warm in Winter as the snug caves they were used to."(115)

It may be added that Yaodong, as these caves are known, are also renowned for being pleasantly cool in Summer. In deference, perhaps, to these fears, the local Party and Government leadership are reported to have required that all requisitioned property should have doors, windows, the traditional warmed brick beds and the necessary fuel. As previously, all costs were borne by the state, including extra medical workers and veterinaries; in the end the budget came to about ¥ 400 人$^{-1}$.

It is regrettable that no report has been found which gives more detail of the problems of evacuation, and their solution. It can be seen that considerable effort was made to satisfy all concerned, but it would be naive to accept without reservation the official conclusion,

> "Emphasis was placed on carrying out eduction in class fraternity and in taking the nation as a co-ordinated chess game amongst the masses. By virtue of such progaganda and education, and on the basis of raising everybody's ideological consciousness, people in the emigration area were happy to move out and the people in the area of resettlement were happy to accept the new settlers."(116)

It is reported, however, that the policy emphasising ideological preparation and the relocation of evacuees within the locality was a consequence of the problems encountered in moving the first groups from the Sanmenxia reservoir area to the Northwest. It would appear that this new policy acheived general acceptance in the leadership and, in 1962, a theoretical article in the magazine Jingji Yanjiu (Economic Research), concerning the problem of compensation for losses due to reservoir flooding, stated,

> "The regional scope of planning is limited to pertinent areas outside the reservoir, principally not beyond 100-150 km and generally within 30-50 km. It is only for a few mammoth reservoirs where the migrants are numerous and it is difficult to accomodate them in nearby areas that migration will involve more distant areas."(117)

ii) Relocation of Workers: Shanzhou and Sanmenxia City.

Shanzhou, the County Town of Shan County and the nearest town to the Sanmenxia damsite, just 22 km upstream, was situated within the proposed reservoir area and would have to be annulled. Meanwhile, despite a high degree of mechanisation, the scale of the reservoir project would require a full-time construction force of some 10,000 人 for six or seven years, with others to run peripheral services such as banking, postal services and administration. Even more people would be needed during periods of peak activity. Accommodation would have to be found, therefore, both for those displaced from Shanzhou and for those arriving to work on the reservoir project.(118)

The problem was aggravated by the local topography, in that the damsite was situated in a narrow gorge surrounded by severely dissected loess terrain. No suitable site for the proposed lodgings and support workshops could be found within 20 km and communications were difficult. Furthermore, a major source of aggregate had been found in Lingbao County, some 54 km upstream, and this site would also have to be serviced.

Most of the workforce would leave the area once the project had been completed. Some would remain to run and maintain the reservoir's various functions and, ideally, live close to the damsite. Meanwhile, it was estimated that accommodation at the main site would have to support 30,000 人 , including dependants, and suddenly to remove many of them at the end of the construction period would create new problems.

The solution adopted is shown in Figure 3-9. Some 20 km upstream of the damsite was the small town of Huixingzhen, which was situated only 1 km from the nearest railway station, on the main Longhai line, and on the Luoyang - Tongguan road. At that time it had a population of about 4000 人 , mainly peasants. The buildings were very simple adobe or brick and wood structures, some dilapidated, and it was considered that very few could be used in the new scheme. To the South-West of Huixingzhen there was, however, an area of fairly level cotton fields at 370 m to 410 m above sea level, of which 7 km^2 to 8 km^2 were thought to be useable. It was, therefore, decided to make it the site of the engineering offices, the main support

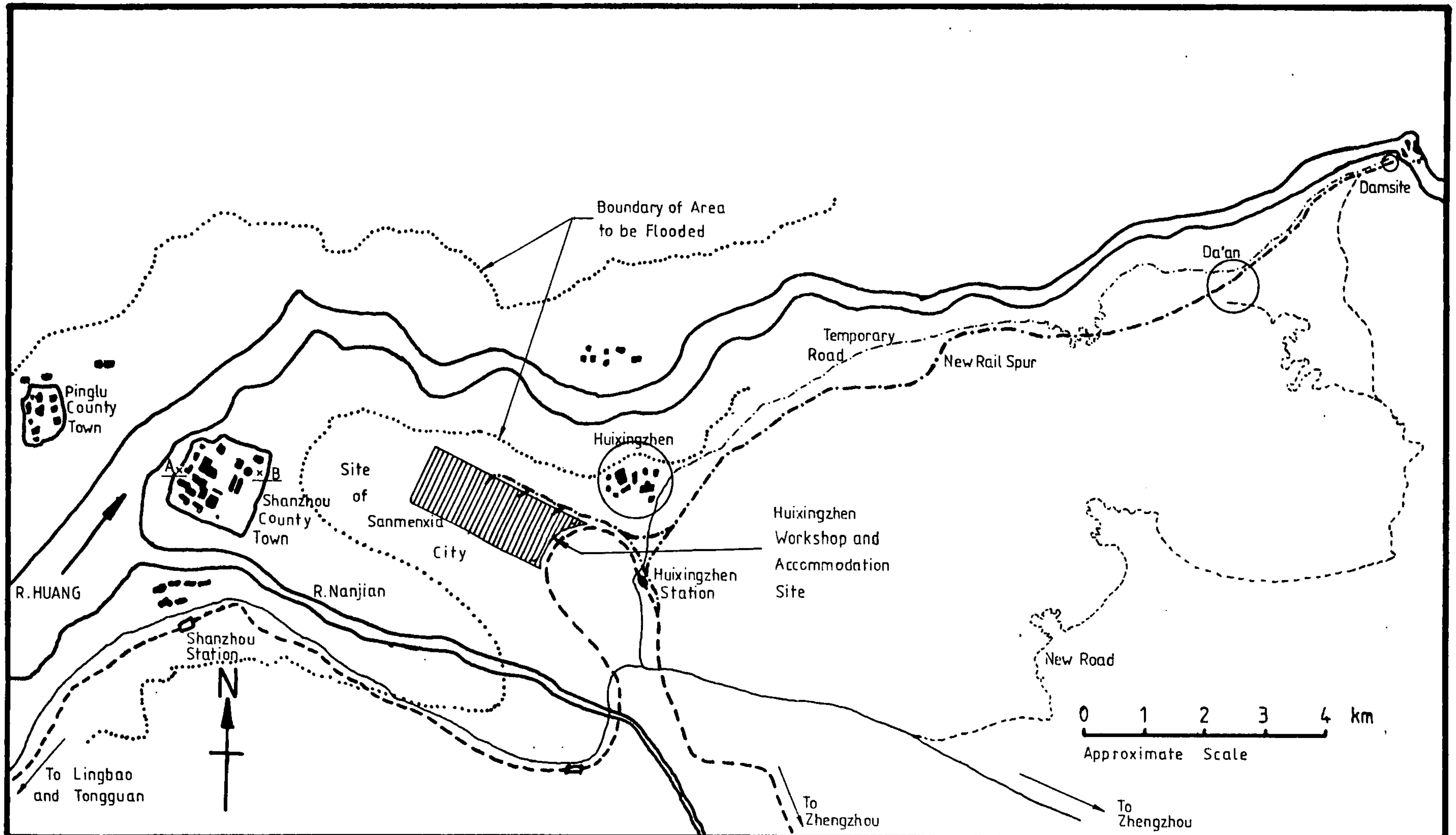


FIGURE 3-9 WORKSITES, SHANZHOU, AND SANMENXIA CITY SOURCE: Note 118

workshops and various grades of living quarters. The six support workshops planned are reported to have included a central repair and maintenance depot, a vehicle servicing shop, a timber processing shop, a concrete prefabrication shop, a reinforcing materials processing shop, and base workshops for the assembly of hydromechanical equipment, and for drilling, grouting, and blasting. Facilities for the residents, such as a comprehensive hospital, a club, a nursery, a kindergarten, a school and a canteen would also be provided.

The local topography was such that when the reservoir water level rose, to its planned height, this site would lie along one side of a large peninsula and it was thought that such a scenic spot would make an excellent place for a small new town covering the whole peninsula. In this way, facilities of a more permanent nature could be provided for the construction workers and their families and, after the completion of the reservoir project, some could stay to run the industries of the developing new town. Furthermore, the town could adopt the function of County Town, to replace Shanzhou, and absorb some of its population. As expansion developed, new industries could move to the area, which would then have abundant power supplies from the Sanmenxia hydropower station. This neat plan to "kill two birds with one stone", when first drawn up by the River Huang Sanmenxia Engineering Office and the He'nan Provincial City Construction Office, envisaged a small town not exceeding 60,000 人 . In 1956, the State Council sanctioned the establishment of Sanmenxia City. This occured in June, and by July it was reported that the main streets had already been lain out. Whilst it should be mentioned that the usual definition of 'City' in China requires the population to exceed 100,000 人 , it is not clear whether at that stage a city meeting that criterion was planned.(119)

The problem of transition was to be solved by providing less living space per capita during the construction period than in the long term. In this way, during the construction, people would be crowded together at a density of 2.5 m^2 人 $^{-1}$, which would decrease, to the levels expected for permanent residence, later. Two types of building, typical of Chinese architecture, were provided for residence; threestorey blocks and the more traditional one-storey type (Figure 3-10), which would provide, in the long term, 5 m^2人$^{-1}$ and 9 m^2人$^{-1}$, respectively.

Since the new Sanmenxia City is distant from the damsite it was decided to provide permanent accommodation, offices, shops, a clinic, college and kindergarten, for the 450 人 who would run the dam facilities after construction, and their families, at the nearest permanent site to the dam, some 1.5 km from it. However, this site was only 7.5 ha in area, whilst, during construction, it was thought necessary to lodge some 8000 人 to 10,000 人 near to the damsite. It was decided, therefore, to erect temporary accommodation and services including clubs, shops, execerise grounds, canteens, an open-air stage, and washrooms, on the terraced fields around the village of Da'an, some 4 km West of the damsite. The land here was on deep and porous loess, at about 400 m above sea level. Since there would be a considerable risk that the whole area might collapse into the reservoir after impounding, the maximum life of those buildings and Da'an village was not expected to exceed eight years.

Thus, the work was spread over four sites. Excavation at Lingbao, where only temporary accommodation would be provided, the main living and support area at Huixingzhen, which was to develop into Sanmenxia City and was therefore provided with permanent structures, the damsite itself where some permanent facilities would be provided, and a small, temporary, residential area at Da'an. Whilst road and rail links already existed between Lingbao and Huixingzhen, there was only a temporary road, due to be flooded during impounding, between Huixingzhen, Da'an and the damsite. So, a permanent road and rail spur, 30 km and 17 km long, respectively, were to be built.

These plans were subsequently put into effect and, by April 1957, it was reported that 8 km of the rail spur and all but 4 km of the new road had been completed, as had a whole hospital, from Luda City in Liaoning, 100 shops, a club and a 100-seat theatre where regular performances were already being held, at Huixingzhen.(120) The six workshops, however, were still 'under preparation' and the 40,000 m^2 of warehouse space was full and piles of machinery were collecting

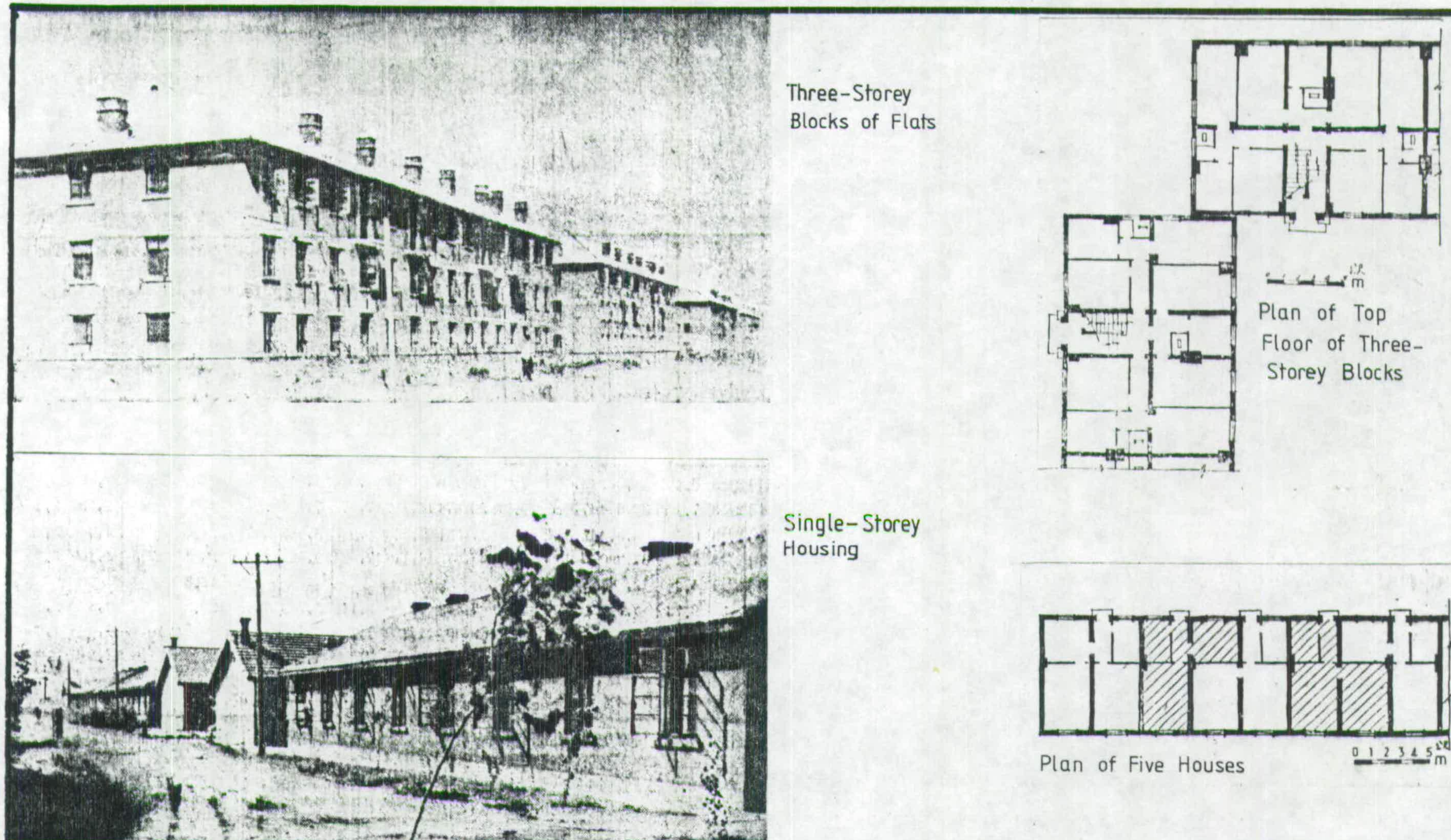


FIGURE 3-10 SANMENXIA CITY BUILDINGS

SOURCE: Note 118

in the railway sidings. By 1958, the city population had risen to 88,000 人, including construction workers, but not including the peasants in the surrounding area. In October 1959, Shanzhou was annulled, Shan County was officially merged with Sanmenxia City and the city population at that time exceeded 100,000 人. Shanzhou was duly demolished and the materials carefully taken away for use elsewhere.(121)

iii) Some Social, Demographic and Heritary Effects of the Changes in Reservoir Design and Use.

All the effects to be described here stem from two aspects of changes in the planning of the Sanmenxia scheme. These are, that the proposed gradual expansion of the scope of the scheme was cancelled, and that much of the area inundated in the first instance was subsequently uncovered.

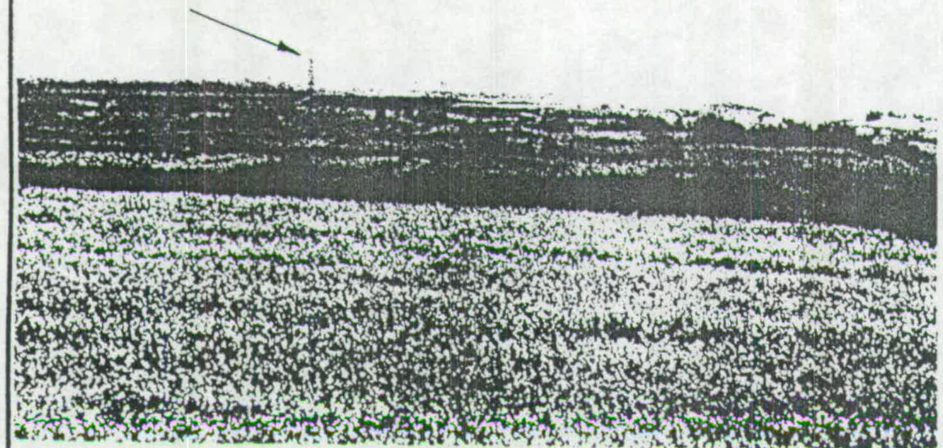
With regard to the relocation of peasants, these events would have meant that the problem was greatly reduced, for many people would no longer have had to move and, in some cases, others could reoccupy land previously evacuated. Whilst it should be pointed out that not all the land designated to be flooded in the first period actually was covered, yet, as we have seen, much land had been spoilt and many villages had been demolished. On the other hand, once the waters had receded, land which had become saline often could be recovered.

In one instance, however, a new problem arose. In the area surrounding the Tongguan confluence much land had, indeed, been inundated and was so severely damaged that it was beyond the scope of ordinary peasants to undertake its recovery. Moreover, although under the new reservoir operational regime, the backwaters would not, as far as possible, extend beyond Tongguan, should an extraordinarily large flood peak occur some flooding would be inevitable. This region had adopted, therefore, a role similar to that of a flood retardation basin, and was not suitable for rehabitation. The solution adopted was to establish a large state farm where army units could undertake the work of farming and reclaiming the land, whilst remaining mobile enough to evacuate at short notice if need be.(122)

Lamentable, indeed, is the fact that the new design and operational regime rendered much of the former destruction vain. The ruins of Shanzhou, for example, with just its pagoda and parts of the town walls still standing (Figure 3-11), were never flooded and lie as a testament to the lost reservoir scheme. On the other hand, the village of Da'an still stands and is occupied, and the fertile floodplains of the new reservoir in certain areas may be farmed for their high yields, though officially the practice is discouraged owing to the danger from transient floods.

Another loss which turned out to have been in vain was that of many architectural relics. In over 70 places along the cliffs, on both sides of the Sanmen Gorge, and on the famour "midstream pillar" just below (Figure 3-12) were famous historical graffitti carved in large characters, some dating back to the Han dynasty. For example, the words "Come by me" (照我來), written on the midstream pillar to remind boatsmen of how to survive the passage through the Three Gates, had been there so long that their true origin had been lost amongst the myths of Da Yu. These writings, some by famous historical figures, were all lost during construction of the dam. Also lost were the remnants of a Tang dynasty attempt to bypass the dangerous gorges by cutting a canal through "Man's Gate Peninsula", which nonetheless had failed, reportedly partly because the rock was too hard to be cut by hand, and partly because the flow of the river could not be controlled enough for the canal to be used.(123) Not least regrettable is the loss of such a historic and scenic set of gorges. (Figures 3-4, 3-12).

Not only has the Sanmen Gorge been famous throughout Chinese history, but the region as a whole has always been important; this is reflected in abundant discoveries made during site preparations for Sanmenxia City. Relics were found from various times from the New Stone Age to the present, including 450 graves and pits in an area of 83,000 m^2, dating from Guoguo of the Warring States period (770 BC to 665 BC). Of particular interest is a pit 29 m x 4 m of which 8 m were opened up to reveal four chariots and eight horses. Shanzhou itself had been the Capital of various States in Chinese History.(124)



Above: View from the remains of the city wall, point A in Figure 3-9, across the ruins, with the Frog Pagoda in the distance.

Below: The Frog Pagoda, position as point B in Figure 3-9.

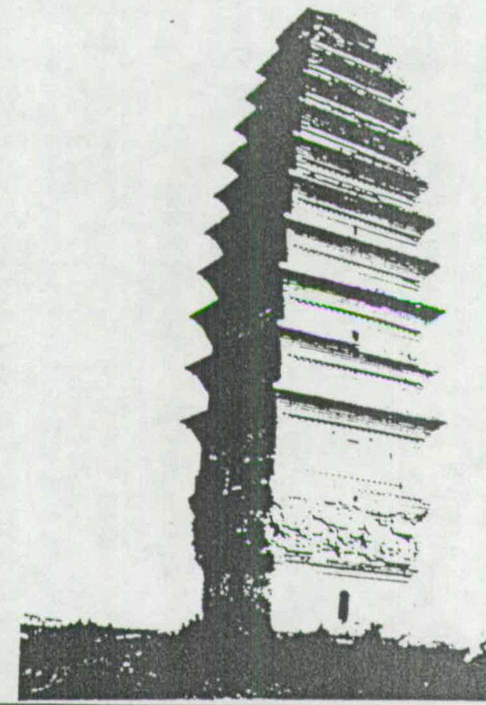
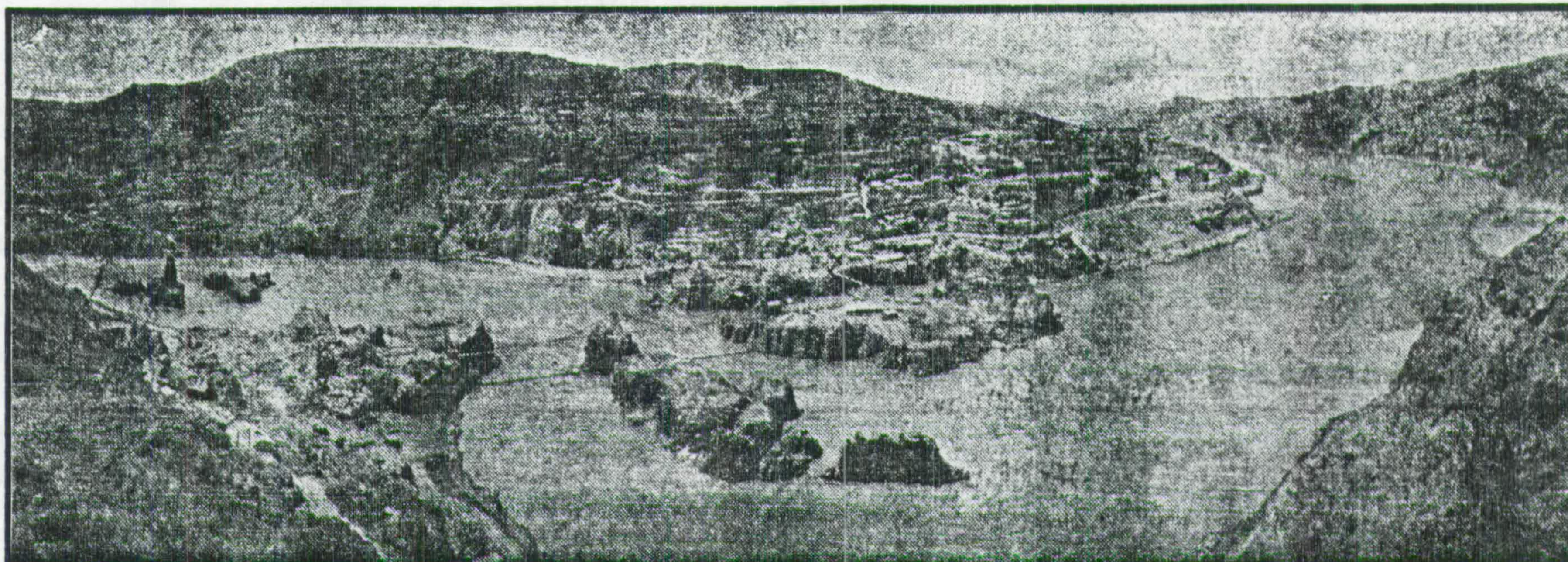


FIGURE 3-11 THE RUINS OF SHANZHOU AND THE FROG PAGODA

Photo: Shanzhou, near Sanmenxia City, He'nan, 4 August 1980. (PM)



Above: Upstream view

Left: The 'Midstream Pillar'

Right: Downstream view

FIGURE 3-12 THE ORIGINAL SANMEN GORGE

SOURCES: RHWCC, Eds., 1979, pp. 221, 224.
RENMIN RIBAO, 13 April 1957, p. 2.

Inasmuch as these discoveries were occasioned by the construction of the Sanmenxia reservoir project, it could be claimed that archeology had gained from it all. However, only the 900 year-old 'Frog Pagoda', named after the characteristic sound of its echo, was left in Shanzhou, and that by chance since it was to have been flooded. The only evidence on display of the ancient graves is about 40 m^2 of the 'Horse and Chariot Pit' mentioned above, in Sanmenxia City, much of which, sadly, was damaged during the Cultural Revolution. It is not known whether the rest of these graves are intact beneath the city. Despite repetition of these points, no word of regret is to be heard within China. The question appears simply not to have been considered important in relation to the assumed benefits of the proposed reservoir, with one exception, which is the Daoist monastery called Yonglegong, from the Yuan dynasty (1271 - 1368). This was moved, in 1959, from the reservoir area and rebuilt, in 1966, on higher ground in Ruicheng County, in order to preserve its famous mural paintings.(125) It is not known whether the original site of Yonglegong was actually flooded but, perhaps, that removal, too, was in vain. Nevertheless, in view of the much reduced scale of the project, it would seem reasonable to suggest that had the tortuous route not been taken, many of these features, perhaps even the Three Gates, could have been saved.

It is natural to suppose that the proposed development of Sanmenxia City was also affected by the unexpected curtailment of the reservoir project. Whilst this is indeed the case, the full story is more complicated. The expected abundance of electrical power, the lake, its fishing, and the scenic formation of a peninsular, all failed to materialise. Many construction workers left the city after the initial completion of the project and, although a workforce had to be found for the reconstructions of the late sixties, it could be expected that the scale of development of Sanmenxia City would have been less than planned. In fact, in the early sixties the city's economy was mainly built around handicraft industries. However, after 1965, some factories moved to Sanmenxia City from other parts of the country, notably Shanghai. In 1980, the area of the city was given as 19 km^2 and its population, only 65,000 人 . Unless the rest of

Shan County, 185 km^2 in all, is included, thereby bringing the population to 133,560 人 , Sanmenxia City should not qualify for its title. It remains the smallest city in China.(126)

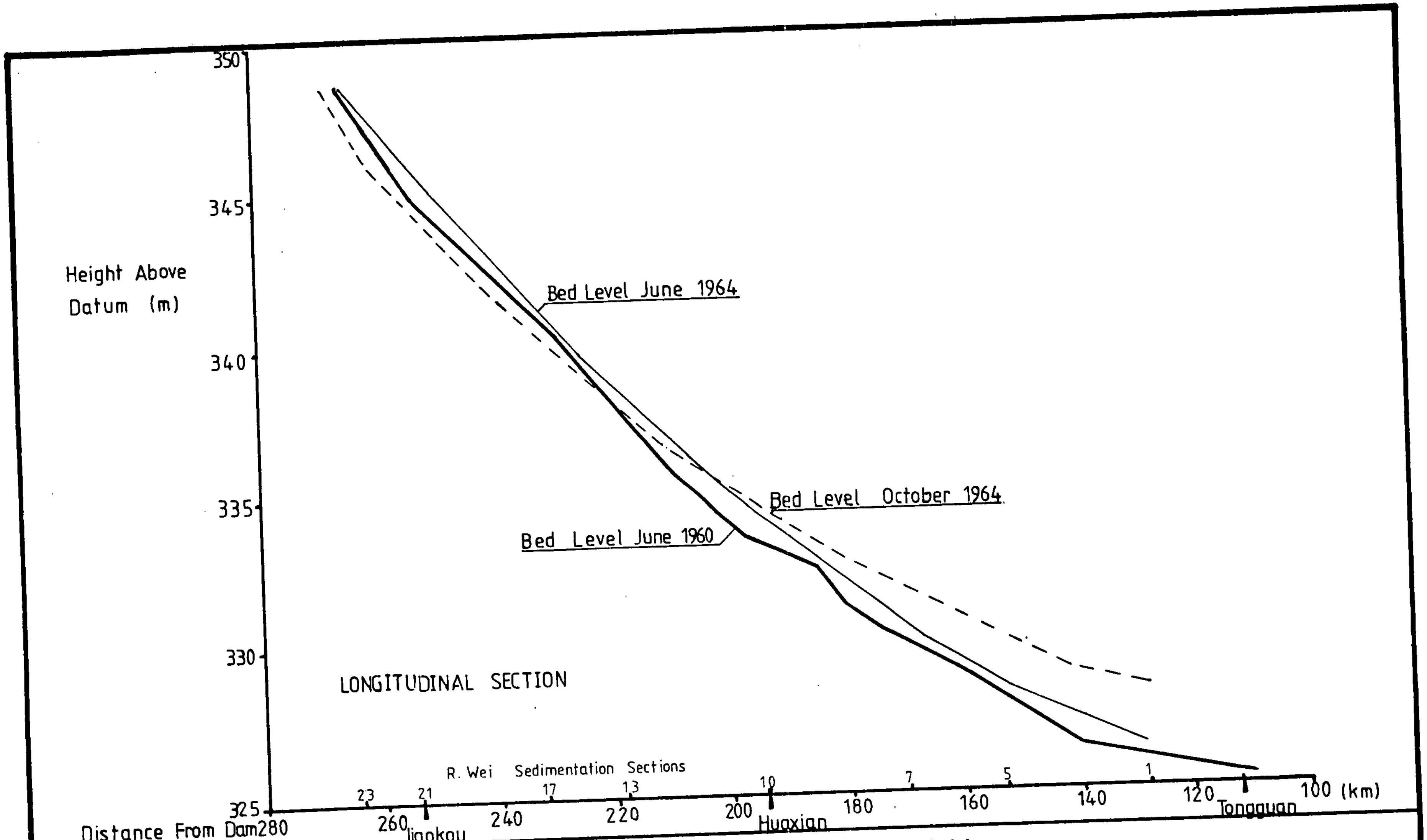
Some idea of the size of Sanmenxia City and the scale of its activities can be gained from the following figures. There is an industrial workforce of 35,000 人 including 18,300 人 who work in the 46 main factories. These are: nine large, provincially controlled, state owned factories each employing over 1000 人 ; eight locally controlled, state owned light engineering factories; eleven collectively owned and run handicraft workshops, each employing less than 100 人 ; and the two Commune run industries, coal and bauxite. In Shan County there are five Communes, divided into 31 Brigades and 310 Production Teams. The average per capita annual income in the town is ¥ 691; in the countryside it is ¥ 205. There are 149 schools and colleges including 5 Higher Middle Schools and 40 kindergartens. These employ 1766 teachers and 434 administrators, and there are 41,000 students. In four large hospitals and 59 clinics there is a total of 624 beds. Cultural facilities include 31 clubs, cinemas and roving cinema teams, one theatre group and three swimming pools.(127)

iv) Result of the Reconstructions in Solving R. Wei Problems.

Prior to March 1962 deposition in the lower R. Wei had taken the form of retrogressive extension of the reservoir deposits. Thereafter, when the reservoir water level was lowered, vigorous scouring took place in the reservoir area. It did not affect the R. Wei, where bed adjustments continued according to the reduced slope occasioned by the deposits remaining near the mouth, and caused deposition to continue upstream. By October 1962 it had extended a further 43 km, to 268 km above the dam. (Figure 3-3). When fluvial conditions within the R. Wei are suitable, and provided that the bed level of the R. Huang at Tongguan happened to be sufficiently low, scouring once again could take place. This scouring lowered the R. Wei main channel and brought back the deposition end point towards Tongguan. For example, in 1964, when hyperconcentrated flow from the R. Jing gave rise to very severe erosion (a phenomenon common to hyperconcentrated flows and known as bed-ripping) in the R. Wei, the deposition endpoint withdrew by 44 km. (Figure 3-13).(128)

Yet it should be stressed that in the years between the change of reservoir operational regime, and the completion of the reconstructions at the commencement of the 'controlled operation' regime in 1973, there was still insufficient control over these events. Much depended upon the weather, for should a large floodpeak occur in the R. Huang, or in both the R. Huang and R. Wei, then the Tongguan confluence would be flooded, its bed level would be raised by deposition, and its attendant problems could recur in the lower R. Wei. By contrast, should a large floodpeak occur in the R. Wei only, then scouring would lower the Tongguan bed level and a general improvement of conditions would occur. The problems of the lower R. Wei were, in effect, a consequence of the failure as yet to bring the R. Huang bed level at Tongguan under control. Its variations are shown in Table 3-3. An example of the serious consequences of this lack of control occured in 1967 when a large floodpeak in the R. Huang flowed up the R. Wei and a serious mouth bar occured across the lower R. Wei, so that an 8.8 km stretch of the R. Wei was blocked and a new channel had to be dug by hand to prevent inundation upstream. This incident caused the deposition endpoint to move from 250 km above the dam in 1967 to 264 km by 1969.(130) (Figure 3-14).

In common with the reservoir area below Tongguan and the lower R. Huang, deposition takes place uniformly on both floodplains and main channel, whilst erosion takes place uniquely in the main channel. In the cases of the lower R. Huang and the lower R. Wei this is beneficial as long as the net main channel effect is zero or controlled scouring. In the case of the lower R. Wei, this was acheived once the bed level at Tongguan had been brought under control, but the haphazard changes which occured during the reconstruction period were worthy of respect. The consequent changes in the position of the deposition endpoint during that period are given in Figure 3-15.



SOURCE: Note 129

FIGURE 3-13 RIVER WEI BED ADJUSTMENTS, 1964

TABLE 3-3 TONGGUAN BED LEVEL, 1960-1978

Period	Before Construction	Water Storage			Awaiting Reconstruction					Preliminary Reconstruction					Advanced Reconstruction		Controlled Operation
Month and Year	Jul. 1960	Nov. 1960	Oct. 1961	Mar* 1962	Oct. 1962	Nov. 1963	Oct. 1964	Oct. 1965	Jun* 1966	Oct. 1966	Oct. 1967	Oct. 1968	Oct. 1969	Jun* 1970	Oct. 1970	Oct* 1973	Oct* 1978
Level of Bed at Deepest Point (m)	320.5	322.8	322.2		321.5	320.5	327.0	326.0		321.6	323.1	320.4	325.4		324.1		
Change From July 1960 Level (m)		+2.3	+1.7	+4.5	+1.0	-0.2	+6.5	+5.5	+4.4	+1.1	+2.6	-0.1	+4.9	+5.0	+3.6	+3.1	+3.0

Sources: Academia Sinica, Geographical Institute, Geomorphology Lab., R. Wei Group, Eds., 1975, page 52. *ZHANG Qishun, LONG Yuqian, 1980, page 2. These two sets of data do not necessarily refer to the same datum.

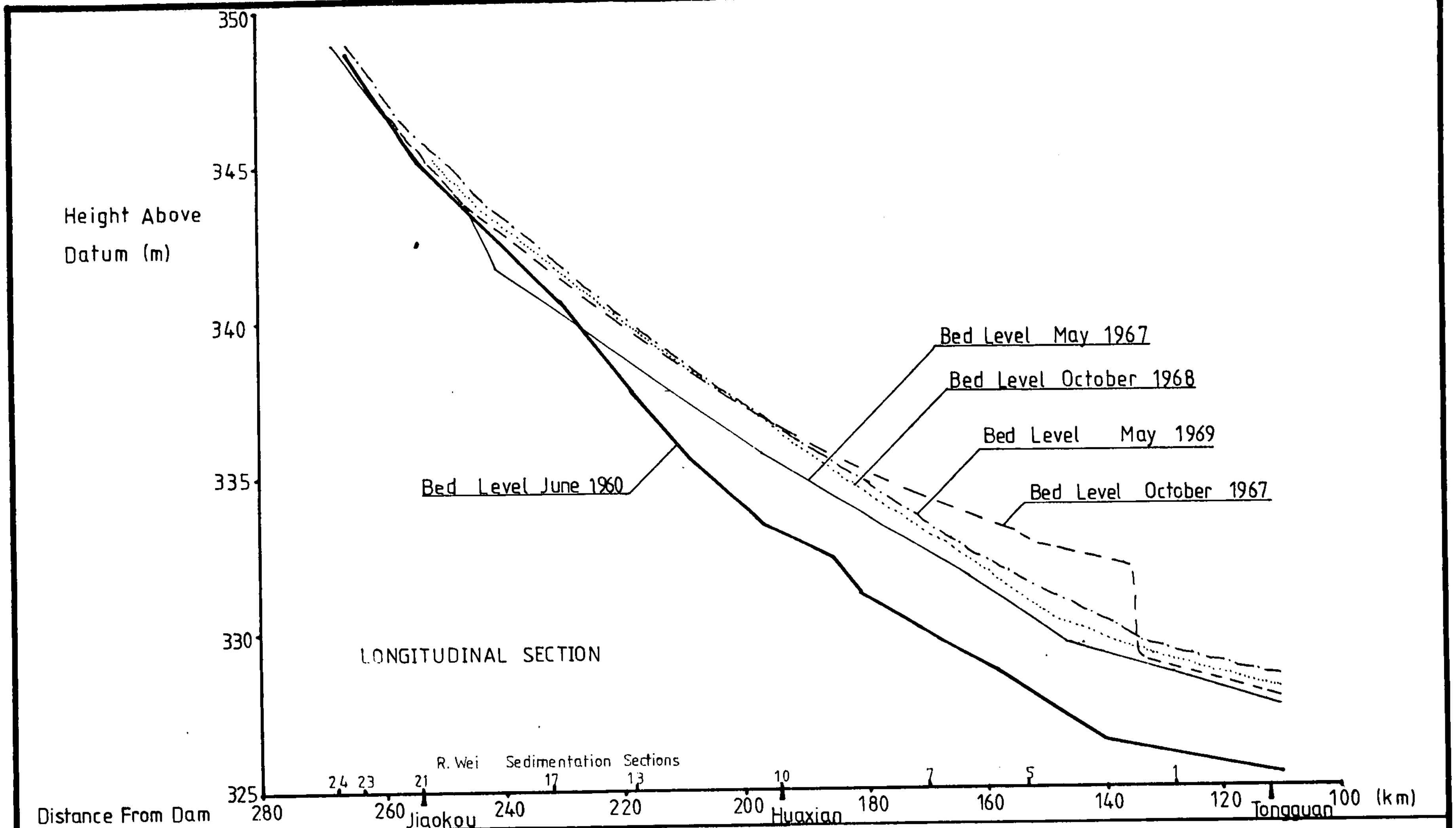


FIGURE 3-14 RIVER WEI BED ADJUSTMENTS, 1967-9

SOURCE: Note 131

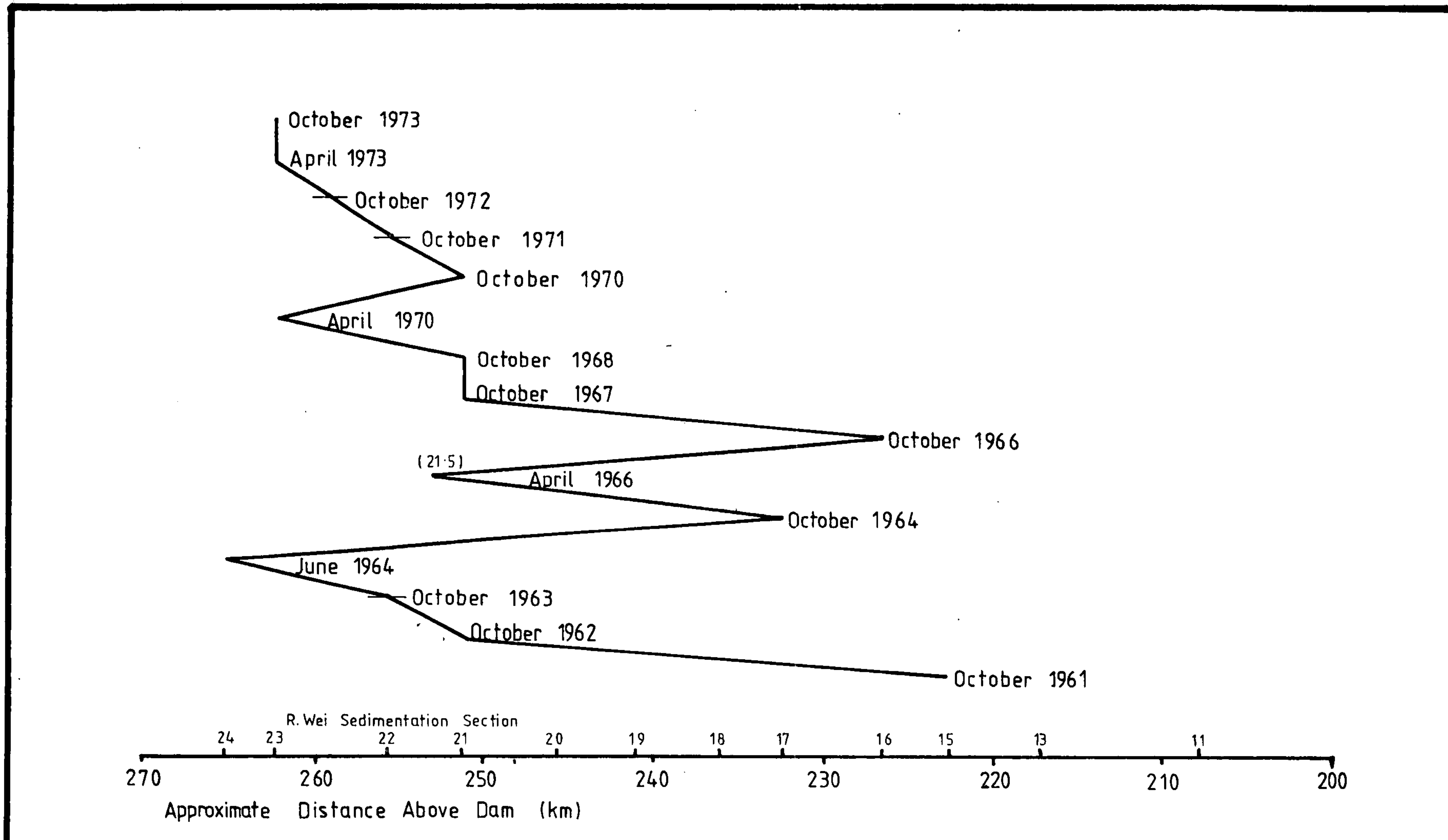


FIGURE 3-15 POSITION OF R. WEI DEPOSITION END POINT, 1961-73

SOURCE : Note 132

v) Effects in the Reservoir Area Below Tongguan.

The predominating changes to occur as the reservoir was drawn down, in March 1962 and thereafter, concerned the morphology of the deposits. The delta morphology typical of deposits in deep reservoirs was rapidly eroded in the middle section whilst simultaneous deposition occured in the upper and lower sections. What happened may be thought of as a process in which backwater deposition continued as before, whilst the delta body was washed down to the antedam area.(133) This process was soon accomplished, for, by October 1963, a new reservoir morphology, comprising a simple wedge of sediment stretching back from the dam, had become established. Thereafter, deposition under deep water conditions, such as would occur in Winter in small amounts, still had a delta morphology, but this would similarly revert to a wedge shape whenever the reservoir was drawn down to the Summer level.

Subsequently, a clear main channel developed which wholly contained the flow during low water seasons. Indeed, it was only during the two large floods of 1964 and 1967 respectively, details of which are given in Table 3-4, that the floodplains so formed unavoidably became covered and thereby raised further. It is worth mentioning that owing to the different relative depths and flow velocities which occur over the main channel and floodplains during silt-laden overbank floods, simultaneous erosion of the main channel and deposition on the floodplains may occur. The longitudinal slope of the floodplains is the equilibrium slope for deposition and the longitudinal slope of the main channel is the equilibrium slope for erosion. The morphologies of different times are shown in Figure 3-16a, and the present main channel and floodplains are shown in Figures 3-16b and 3-16c. Since deposition upon floodplains is irreversible, it is to be avoided as far as possible in reservoirs, where it represents an irrecoverable loss of capacity. In the case of the Sanmenxia reservoir, it was also desirable to limit main channel deposition to the area below Tongguan, so as to stabilise the bed level there. This was achieved in the long term but there remains some seasonal variation.

TABLE 3-4 DATA FROM TONGGUAN FOR 1964 AND 1967 FLOODPEAKS

Year	Maximum Discharge (m^3 s^{-1})	Date	Silt Load For Year (t x 10^6)	Silt Load Jul/Aug. (t x 10^6)
1964	12400	14 Aug.	2450	1548
1967	9530	11 Aug.	2180	1318

Source: QUSRL, Personal Communication, 1981.

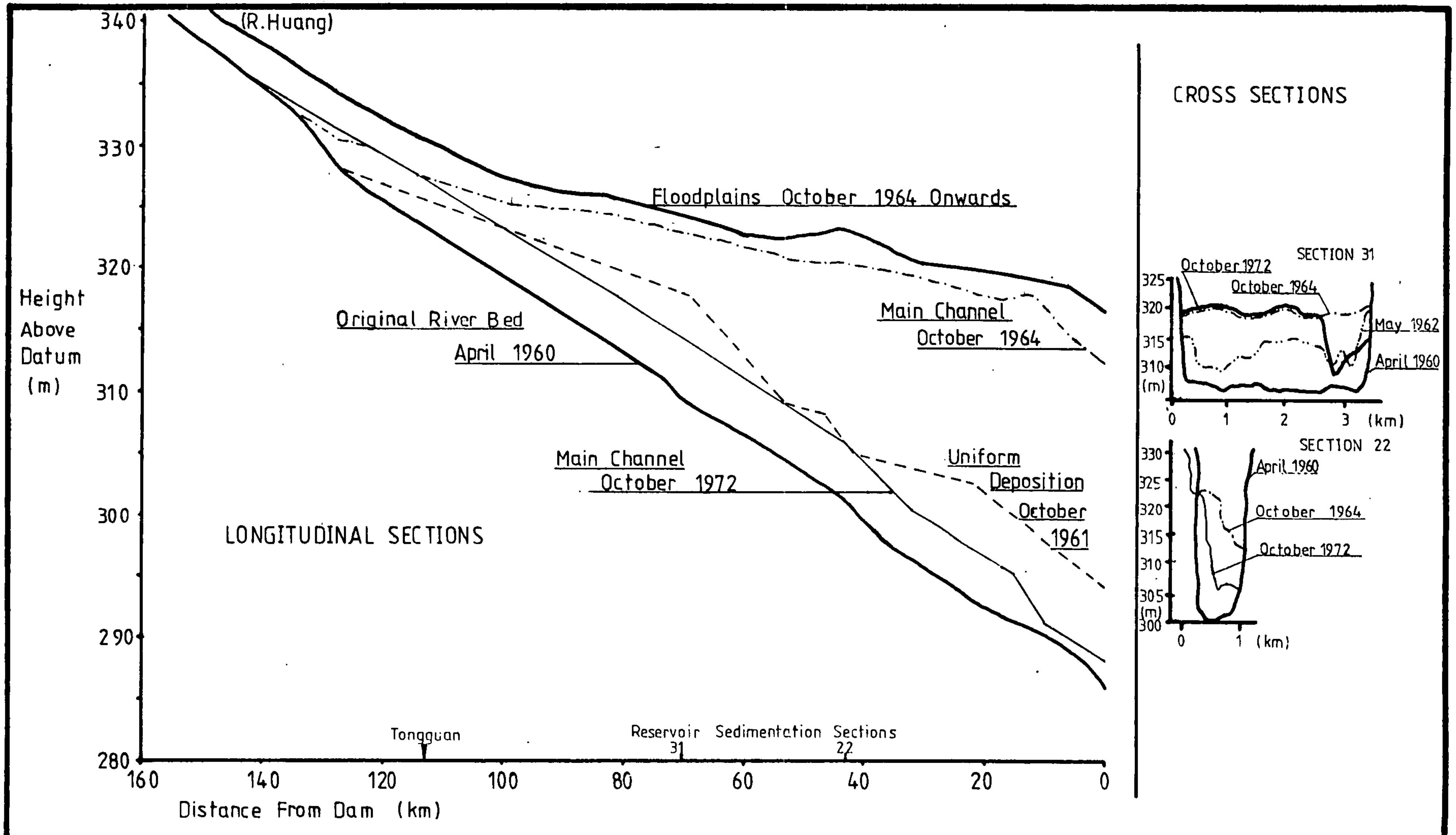
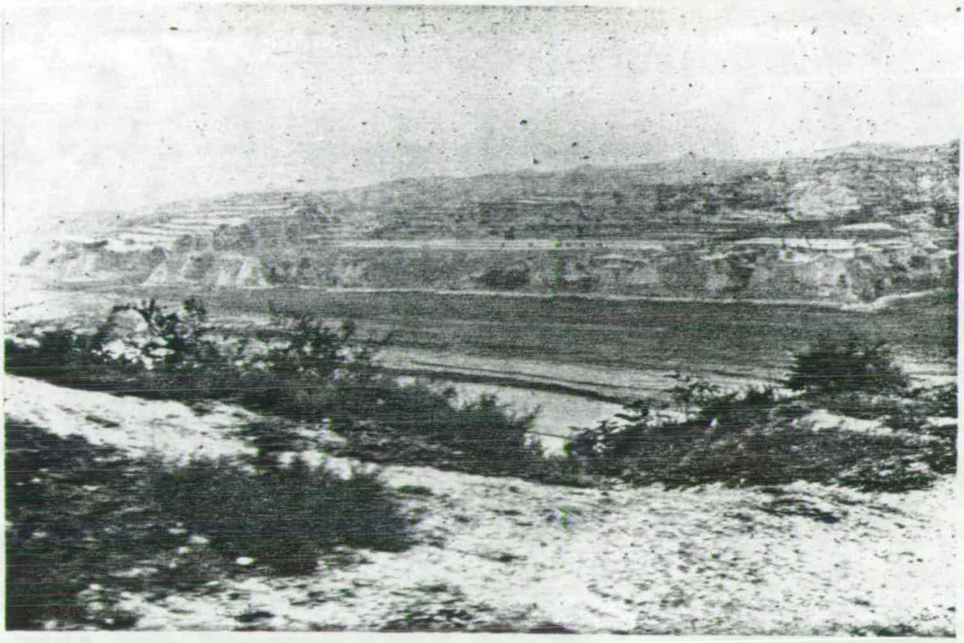


FIGURE 3-16 (a)DEPOSITION MORPHOLOGIES, SANMENXIA 1960-1972 SOURCE: Note 134

(b) Photo: Shanzhou, near Sanmenxia City, He'nan, 4 August (PM) 1980, point A in Figure 3-9. The deposition occupies the whole area infront of the distant hills, with the exception of the reservoir main channel, which may also be seen.



(c) Photo: Just upstream of the Sanmenxia Dam, 3 August 1980. (PM)

FIGURE 3-16 (b) and (c) DEPOSITION MORPHOLOGY, SANMENXIA 1980

The respective effects upon reservoir deposition of the six different discharge regimes, which came into play as the reconstructions proceeded, may be seen in Table 3-5. Apart from 1965, when unusually little water or silt entered the reservoir and erosion took place, it can be seen that in the reservoir area as a whole deposition continued until the second tunnel came into use in 1969. Figure 3-17 shows the changes in reservoir capacity, below Tongguan only, from 1960 to 1975, and clearly illustrates the restoration there of the main channel capacity, and the simultaneous loss of capacity above the floodplains. Figure 3-18 shows the present variation of main channel and floodplain reservoir capacities, respectively, with water level.

vi) Direct Effects in the Lower Reaches of the R. Huang.

The effects of the reservoir and its reconstructions in the lower reaches of the R. Huang arose for two reasons. Firstly, there was a sudden reduction in the silt concentration of the waters entering the lower reach, followed by a return to former levels, or higher, a few years later. Secondly, because flood peaks were attenuated whilst their duration was extended.

In the first period, to March 1962, only 6.8 % of the silt entering the reservoir was passed through the dam to the lower reaches and the relatively clear water discharged eroded a total of about 1×10^9 t of silt from the lower reaches. Of this, 91.3 % was eroded from the reach above Aishan, a reach notable previously for silt deposition, where 104 % of the net deposition of the lower R. Huang between 1956 and 1960 occurred (137) With the passage of successive floods, the extent of scouring downstream of Sanmenxia, for a given discharge, lengthened as the upper sections developed an armoured bed. Scouring would extend to the estuary whenever $Q \geq 2500\ m^3\ s^{-1}$ and $Q^2\ \Delta t = 90 \times 10^6$, where Q is the discharge ($m^3\ s^{-1}$) and Δt is the duration (days). Thus, the smallest discharge, $Q = 2500\ m^3\ s^{-1}$ would have to be maintained for about 14 days, requiring some $300 \times 10^6\ m^3$ of water. Throughout the whole lower reach a hydraulic exchange took place, between bed and suspended loads,

TABLE 3-5 EFFECT OF RECONSTRUCTIONS ON SEDIMENT ACCUMULATION AND DISCHARGE, SANMENXIA 1961-1974

Year		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Average Water Level (m)		324·05	310·15	312·31	320·27	308·54	311·38	314·51	311·37	302·82	299·37	297·54	297·23	296·96	303·58
Average Discharge (m^3s^{-1})		2990	1910	2390	4120	1310	2750	3800	2730	1010	1610	1260	1158	1710	1147
Sediment Entering Reservoir ($t \times 10^6$)		1084	693	906	2125	302	1967	1837	1253	983	162	1081	395	1396	551·6
Sediment Leaving Reservoir ($t \times 10^6$)		111	230	427	831	381	1851	1752	1206	1092	1794	1195	545	1610	653·6
Sediment Deposited or (-) Eroded ($t \times 10^6$)		973	463	479	1294	-79	116	85	47	-109	-174	-114	-150	-214	-102
Sediment Discharge Ratio (%)		10·2	33·4	47	39	126	94	95	96	111	111	110	138	115	118
Bed Slope at Reservoir Entrance (%)		0·0062	0·0165	0·0130	0·0188	0·0210	0·0202	0·0140	0·0191	0·0256	0·0300	0·0350	0·0267	0·0270	0·0205
Discharge Facilities	Deep Sluices (300 m)	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	Tubes (300 m)						4	4	4	4	4	4	4	4	4
	Tunnels (290 m)						1	1	2	2	2	2	2	2	2
	Bottom Sluices (280 m)										3	8	8	8	8
	Turbines (287 m)											1	1	2	2
Operational Regime		Storage	Flood Attenuation											Controlled Operation	
Discharge Capacity Under Given Water Level (m^3s^{-1})	300 m		0	0	0	0	0	356	356	712	1522	3244	3244	3644	3644
	315 m		3080	3080	3080	3080	3980	5020	5020	6060	7275	9260	9260	9660	9660

SOURCE: SRIHEWL, et al., Eds., 1979, p. 300.

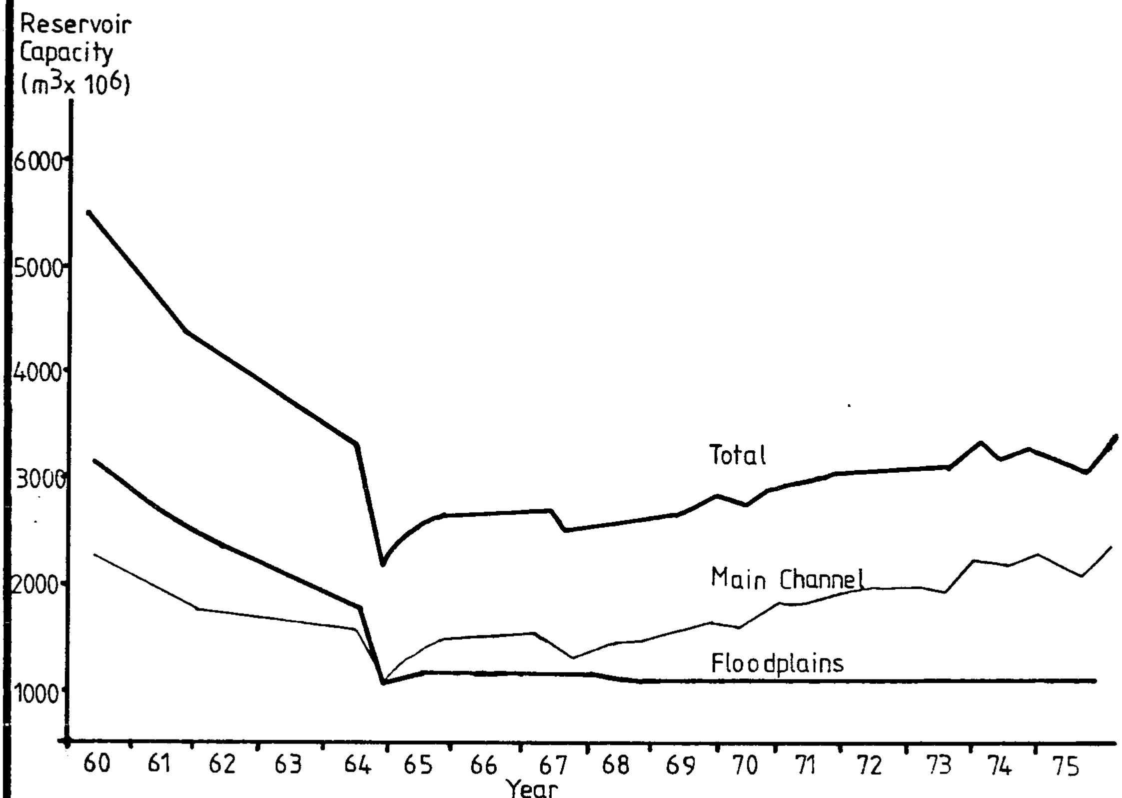


FIGURE 3-17 LOSS AND RECOVERY OF SANMENXIA RESERVOIR CAPACITY SOURCE: Note 135

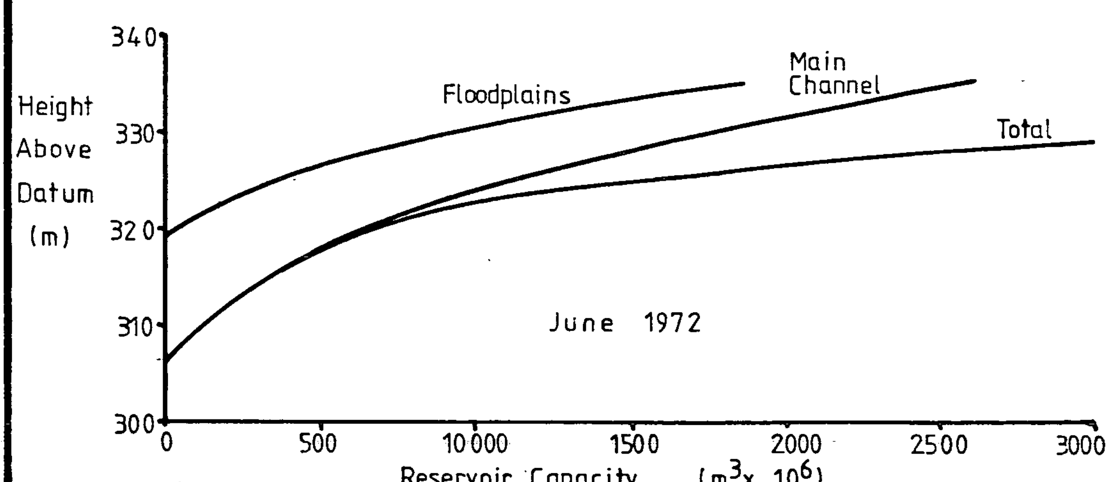


FIGURE 3-18 SANMENXIA RESERVOIR CAPACITY vs. LEVEL SOURCE: Note 136

whereby the coarser grains of the latter were replaced with finer material from the former (Figure 3-19). Particles of diameter of less than 0.025 mm continued to be eroded over the whole of the lower reach. The armouring process at Huayuankou is shown in Figure 3-20, whence the proportion of coarse material (diameter 0.1 mm to 0.5 mm) in the bed is found to have increased after a year of erosion and the suspended load is found to comprise coarser material than before, principally of diameter 0.025 mm to 0.1 mm. After armouring, d_{50} at Huayuankou, Aishan and Luokou corresponded to what had been d_{75}-d_{90} a year earlier.(138)

The effects of changes in channel morphology consequent upon these new processes depended upon the reach in question. In the wandering, upper stretch, it tended both to become deeper, and towards stability, with a single, broader, channel (Figure 3-21). Further downstream, though, in the absence of sufficient control works, the broadening of the stream caused serious collapse of the floodplains and the loss of some engineering structures thereupon.(140) Lower still, control works exerted a strong restraint on the river and the basic meandering pattern was little affected.

Without going into detail about local changes in slope, or the formation or otherwise of sand waves and their consequent effects upon the flow resistance of the lower R. Huang, it may, nevertheless, be noted that the flood-carrying capacity there increased markedly with the deepening and widening of the channel subsequent to erosion. (Table 3-6).

Despite the water level having been lowered, in 1962, and the floods thereafter being allowed to pass through the reservoir with as little hinderance as possible, until the big flood of 1964, the proportion of incoming silt subsequently discharged in a given year remained at about 40 %. The ability of the dam to discharge silt still depended principally on the flow conditions inside the reservoir. Thus relatively clear water continued to be discharged and in all some 2311 x 10^6 t of silt were eroded from the lower reaches between September 1960 and October 1964.(141) Owing to

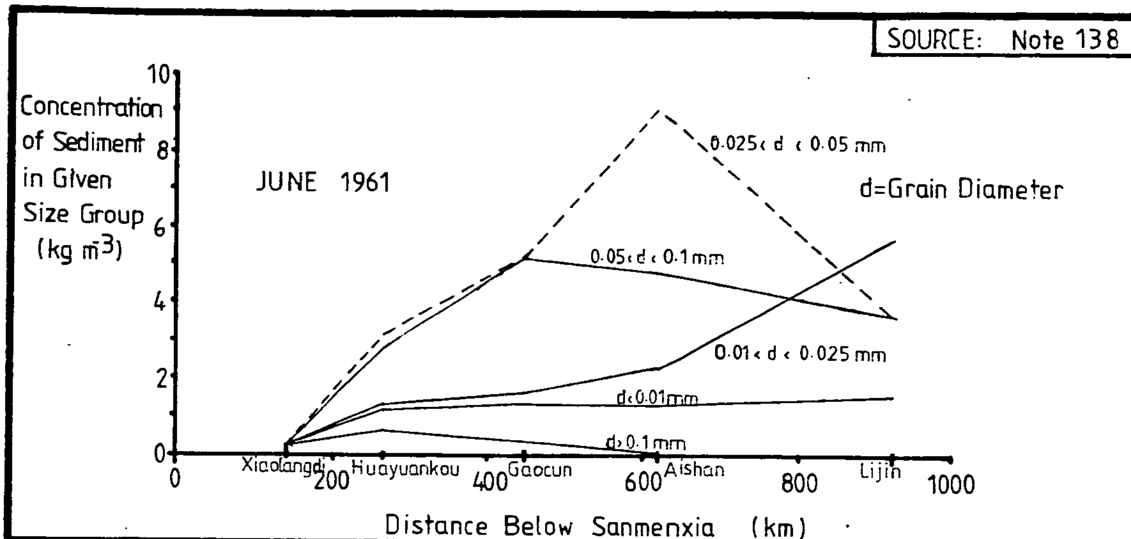


FIGURE 3-19 EFFECT OF HYDRAULIC EXCHANGE ON SUSPENDED LOAD COMPOSITION

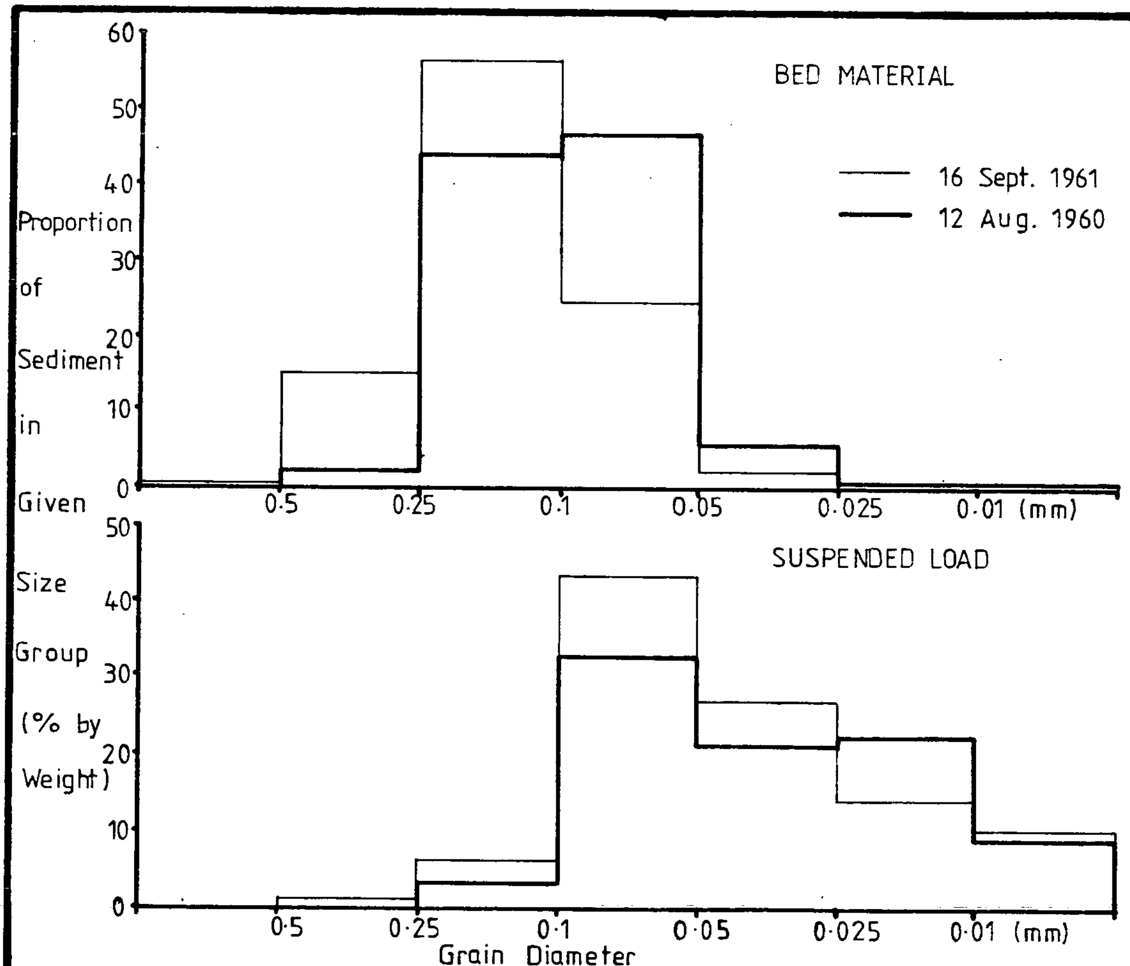


FIGURE 3-20 SEDIMENT COMPOSITION AT HUAYUANKOU, 1960 AND 1961

SOURCE: Note 139

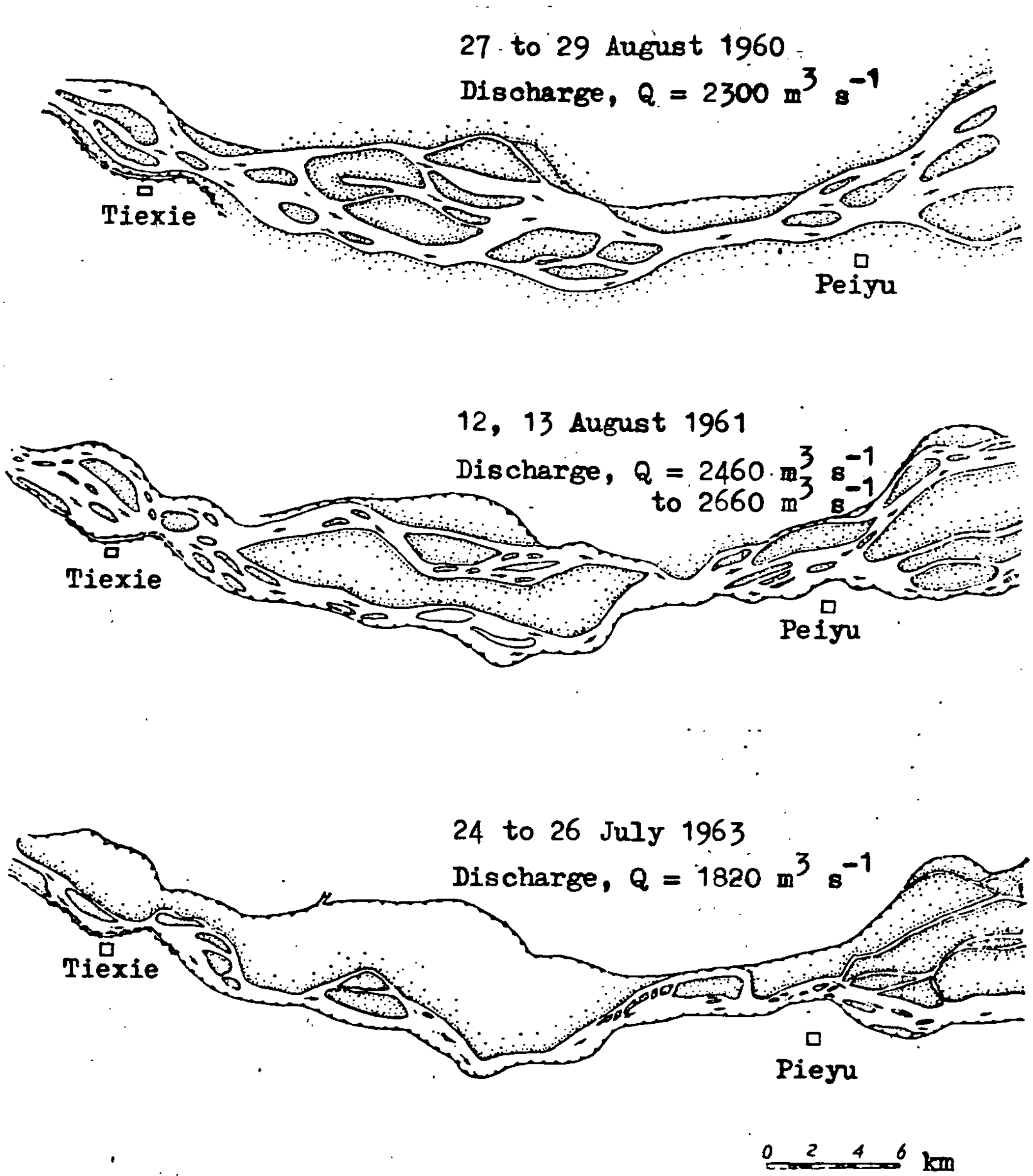


FIGURE 3-21 CHANGES IN CHANNEL MORPHOLOGY IN THE UPPER SECTION OF THE LOWER R. HUANG, 1960-1963

Source: LI Baoru, et al., 1980, p. 409.
Tiexie is situated some 100 km upstream of Huayuankou.

TABLE 3-6 CHANGES IN LOWER REACHES' FLOOD CARRYING CAPACITY, 1960-4

Station		Huayuankou	Jiahetan	Gaocun	Aishan	Luokou
Water Level (m)		92.30	72.95	60.70	37.15	26.30
Discharge ($m^3 s^{-1}$)	1960	1000	1000	1000	1000	1000
	1964	7800	9000	7285	2250	2300
Difference in Discharge ($m^3 s^{-1}$)		6800	8000	6285	1250	1300

Source: LI Baoru, et al., 1980, p. 411.

unusual conditions in 1965, when only 302 x 10^6 t of silt entered the reservoir, and, thereafter to the gradual increase in the silt discharge capacity at the dam, deposition resumed in the lower reaches. A total of 3709 x 10^6 t were deposited between November 1964, and December 1973, when 'controlled operation' began at the reservoir. Thus, accumulation resumed its original pattern (Figure 3-22) and the flood carrying capacity of the lower reaches, which had improved up to 1964, was again seriously reduced. By 1973, a water level slightly higher than that which in 1958 had carried 22,300 $m^3 s^{-1}$ (Table 3-7) at Huayuankou could only carry 5000 $m^3 s^{-1}$.(142)

The effects of the reconstructions upon sedimentation in the reservoir area and the lower reaches may be summarised as in Table 3-8. As the reconstructions proceeded, though, lower reach deposition took on seasonal characteristics (Table 3-9). The reason was that whereas in Summer the change in dam operation resulted in more silt being discharged, insufficient water accompanied it to carry it beyond Aishan or to raise the level to cover the floodplains. Thus, deposition took place within the main channel and led to its deterioration. In Winter the relatively clear water would pick up these deposits and carry them beyond Aishan but would have insufficient energy to carry them to the sea. The bed material also took on seasonal characteristics, being fine after Summer deposition and gradually becoming coarser in Winter as the clearer water took away the finer particles. In the long term, however, the bed material gradually returned to its original composition. (Figure 3-23)

vii) Indirect Effects - The Expunction of Irrigation Projects.

The Comprehensive Plan of 1955 identified nine sites for mainstream dams below Sanmenxia, of which six were in the gorges above Taohuayu, one at Taohuayu just between the Beijing-Guangzhou rail bridges and the confluence of the rivers Huang and Qin, and two were in the lower reaches in Shandong at Weishan, by Lake Dongping and at Luokou near Ji'nan. The plan was subsequently revised and expanded such that by 1959, it included six sites below Taohuayu, all of which were principally diversion weirs for irrigation, but including some

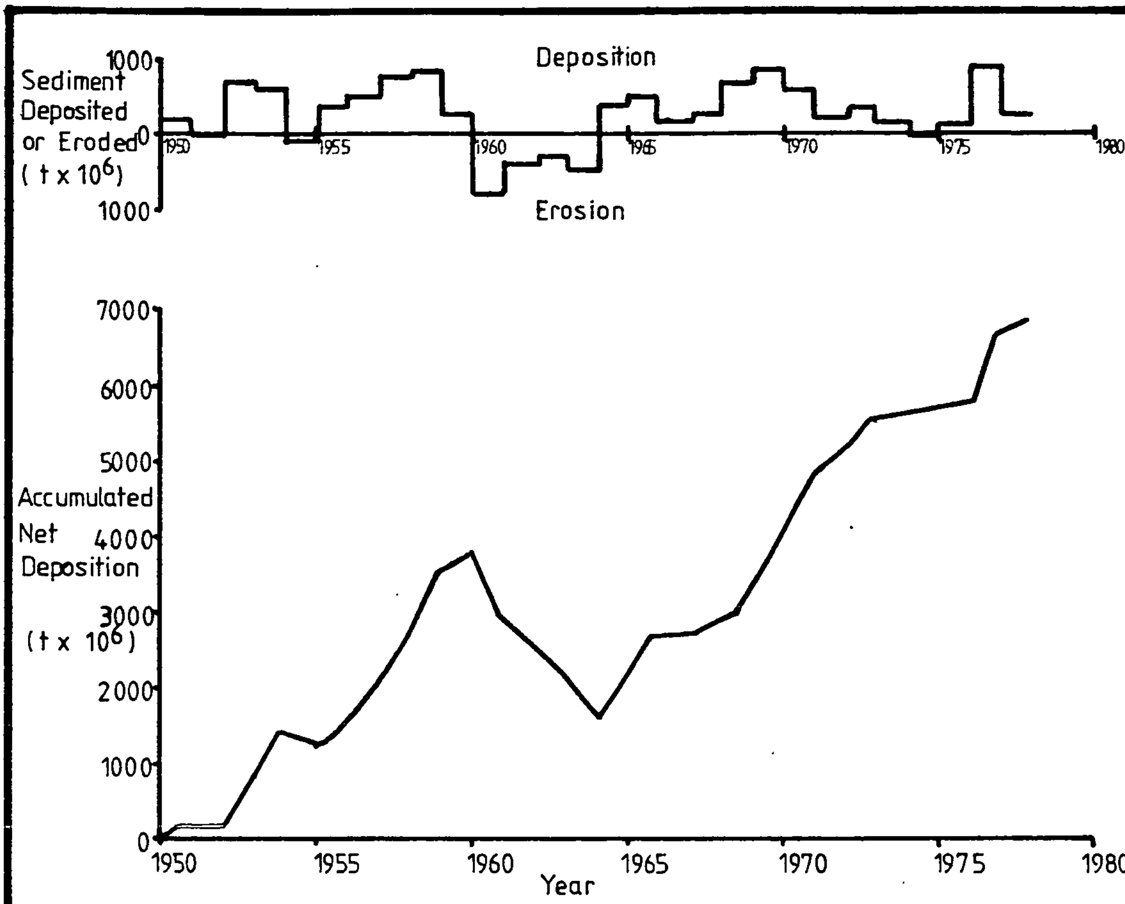


FIGURE 3-22 DEPOSITION AND EROSION IN THE LOWER R. HUANG

SOURCE: Note 161

TABLE 3-7 LOSS OF FLOOD CARRYING CAPACITY

Station	1973 Flood		1958 Flood		Difference Between 1973 and 1958 Water Levels (m)	Water Level for Discharge (Q)=3000 m^3s^{-1} (m)			Increase in Q=3000 m^3s^{-1} Water Levels (m)	
	Max. Water Level (m)	Corresponding Discharge (m^3s^{-1})	Max. Water Level (m)	Corresponding Discharge (m^3s^{-1})		1973	1958	1972	1973 -1958	1973 -1972
Huayuankou	94.63	5000	94.42	22300	0.21	93.88	92.54	93.28	1.34	0.60
Jiahetan	74.89	4900	74.52	20500	0.37	74.17	72.78	73.78	1.39	0.39
Shitouzhuang	67.94	4030	67.61	20000	0.33	67.40	65.89		1.51	
Gaocun	62.29	4030	62.96	17900	-0.67	61.82	60.80	61.55	1.02	0.27
Sunkou	47.00	3940	48.85	15900	-1.85	46.52	44.99	46.22	1.53	0.30
Aishan	40.17	3600	43.13	12600	-2.96	39.85	38.27	39.70	1.62	0.15
Luokou	29.76	3360	32.09	11900	-2.33	29.48	27.22	29.07	2.26	0.41
Lijin	13.32	3650	13.76	10400	-0.44	13.08	11.06	12.80	2.02	0.28

Source: LIU Yuelan, ZHANG Yongchang, HAN Jianmin, LIN Xuxian, 1975, page 195.

TABLE 3-8 DEPOSITION AND EROSION IN THE SANMENXIA RESERVOIR AND THE LOWER RIVER HUANG, 1960-1972

Reservoir Use Stage	Period	Long, Hua, He, Zhuang Silt Load ($t \times 10^6$)	Reservoir Area Deposition and (-) Erosion ($t \times 10^6$)			Reservoir Sediment Discharge		San, Hei, Xiao, Silt Load ($t \times 10^6$)	Lower Reaches Deposition and (-) Erosion ($t \times 10^6$)			Lower Reaches Sediment Discharge	
			Above Tong-guan	Below Tong-guan	Total	at Dam ($t \times 10^6$)	Ratio (%)		Above Aishan	Aishan to Lijin	Total	Lijin Silt Load ($t \times 10^6$)	Ratio (%)
Storage	15-9-60 to 19-3-62	1646	268	1266	1534	112	6·8	136	-890·2	- 85·4	-975·6	971	716
Flood Attenuation	20-3-62 to Oct.64	5118	652	2405	3057	2061	40·2	2194	-1052·6	-283	-13356	3527	161
	Nov.64 to Jun.66	720	88	-693	-605	1325	184	1342	558	132	690	638	47·6
Preliminary Reconstruction	Jul.66 to Jun.70	8948	1796	-228	1568	7380	82·5	7448	1079	345	1424	5639	75·8
Advanced Reconstruction	Jul.70 to Oct.72	3917	353	-554	- 201	4118	105	4152	1290	174	1464	2279	54·8
Total	15-9-60 to Oct.72	20349	3157	2196	5353	14996	73·8	15272	984	283	1267	13054	85·5

Source: RHHI, Eds., 1972, p. 138.
Long, Hua, He, Zhuang, and San, Hei, Xiao, refer to oncoming conditions for the Sanmenxia reservoir and the Lower Reaches, respectively. See note to Tables 1-4, 1-5.

TABLE 3-9 SEASONAL VARIATION IN THE WATER, SILT, DEPOSITION AND EROSION OF THE LOWER RIVER HUANG, JUL. 1966-JUN.'72

Season	San, Hei, Xiao Water Volume ($m^3 \times 10^6$)	Sediment Load ($t \times 10^6$)			Deposition or (-) Erosion ($t \times 10^6$)			Discharge Ratio (%)		
		San, Hei, Xiao	Aishan	Lijin	Sanmen-xia to Aishan	Aishan to Lijin	Sanmen-xia to Lijin	Aishan/ San, Hei, Xiao	Lijin/ Aishan	Lijin/ San, Hei, Xiao
Flood	25500	1495	1080	1038	349	24	373	72·3	96·0	69·4
Not Flood	21100	346	306	237	18	59	77	88·5	77·4	68·5
Whole Year	46600	1841	1386	1275	367	83	450	75·1	92·0	69·2

Source: RHHI, Eds., 1972, p. 139.
San, Hei, Xiao, refers to oncoming conditions for the Lower Reaches. See note to Table 1-5.

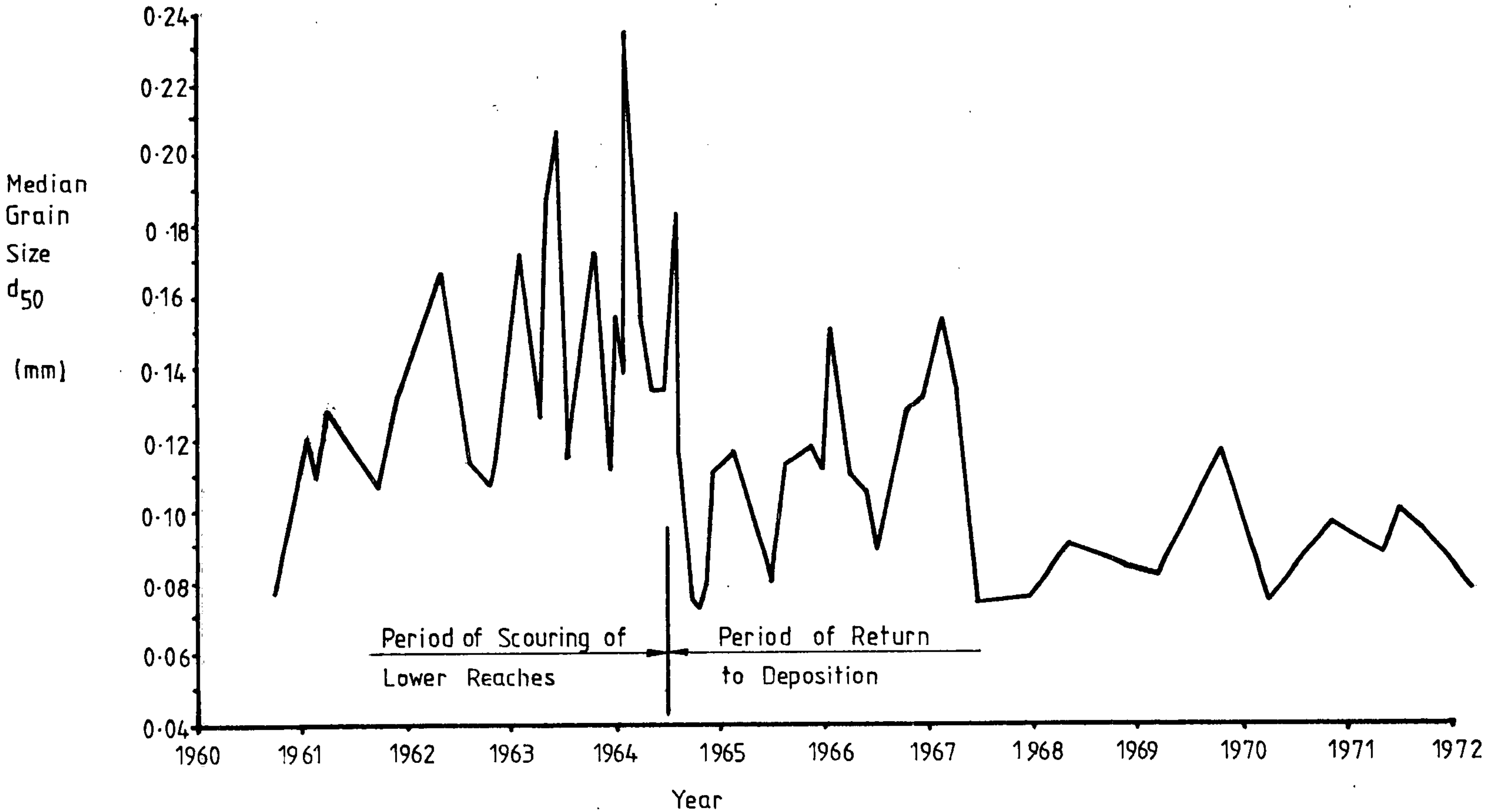


FIGURE 3-23 CHANGES IN THE COARSENESS OF THE BED MATERIAL AT HUAYUANKOU

SOURCE: Note 143

additional power generation and, in the case of the largest project, at Weishan, a flood-prevention role.(144)

By 1960, following further revision, four schemes were underway in the lower reaches:
i) At Huayuankou, just below the two Beijing-Guangzhou Railway bridges, a weir was being built to control fluvial conditions around the bridge supports to prevent them being undermined by erosion consequent upon clear water being released from Sanmenxia, to divert water for the irrigation of some 2.5×10^6 ha and to generate 100 MW of electrical power. Work had begun in 1959.(145)
ii) At Weishan, a complicated multipurpose project was being built. Firstly, in the Northern bank of the R. Huang, a set of 10 sluice gates each 10 m wide had been built, in 1956, for irrigation purposes. The main canal of the irrigation system later would form part of the Grand Canal, in a scheme to provide a permanent crossing of canal and river, which included the construction of a new Southern canal route to the West of Lake Dongping. In order to regulate the water level of the R. Huang for this purpose, and to store both Summer and Winter water for irrigation and flood control, especially the prevention of ice-jam floods, a perimeter dyke was built around Dongping Lake and some of the surrounding land. This work provided two linked reservoirs with a total capacity of 4000×10^6 m^3, and was provided with a diversion weir across the R. Huang made of earth and stalks, capable of handling 6000 m^3 s^{-1} and an exit sluice, lower down with a capacity of between 1500 m^3 s^{-1} and 3000 m^3 s^{-1} (Figure 3-24). Basic construction began in 1958 and was completed by 1960 but, at that date, did not include all the planned irrigation canals for 3.5×10^6 ha nor the 8 MW hydropower station. It is reported that villages within the new, outer, lake district were rebuilt on earthen platforms one metre above the highest expected water level. Thus, the area could be farmed by the local peasants without endangering their lives.(146)
iii) At a point 10 km downstream of Luokou (previously called Lekou) work began in 1960 on 4 sluices, a diversion weir, locks and a hydropower station, in a project to join Jiaozhou Bay (better known as the site of Qingdao, famous for beer), S. Shandong, and Dezhou, N. Shandong, by a new canal, which would cross the R. Huang at that

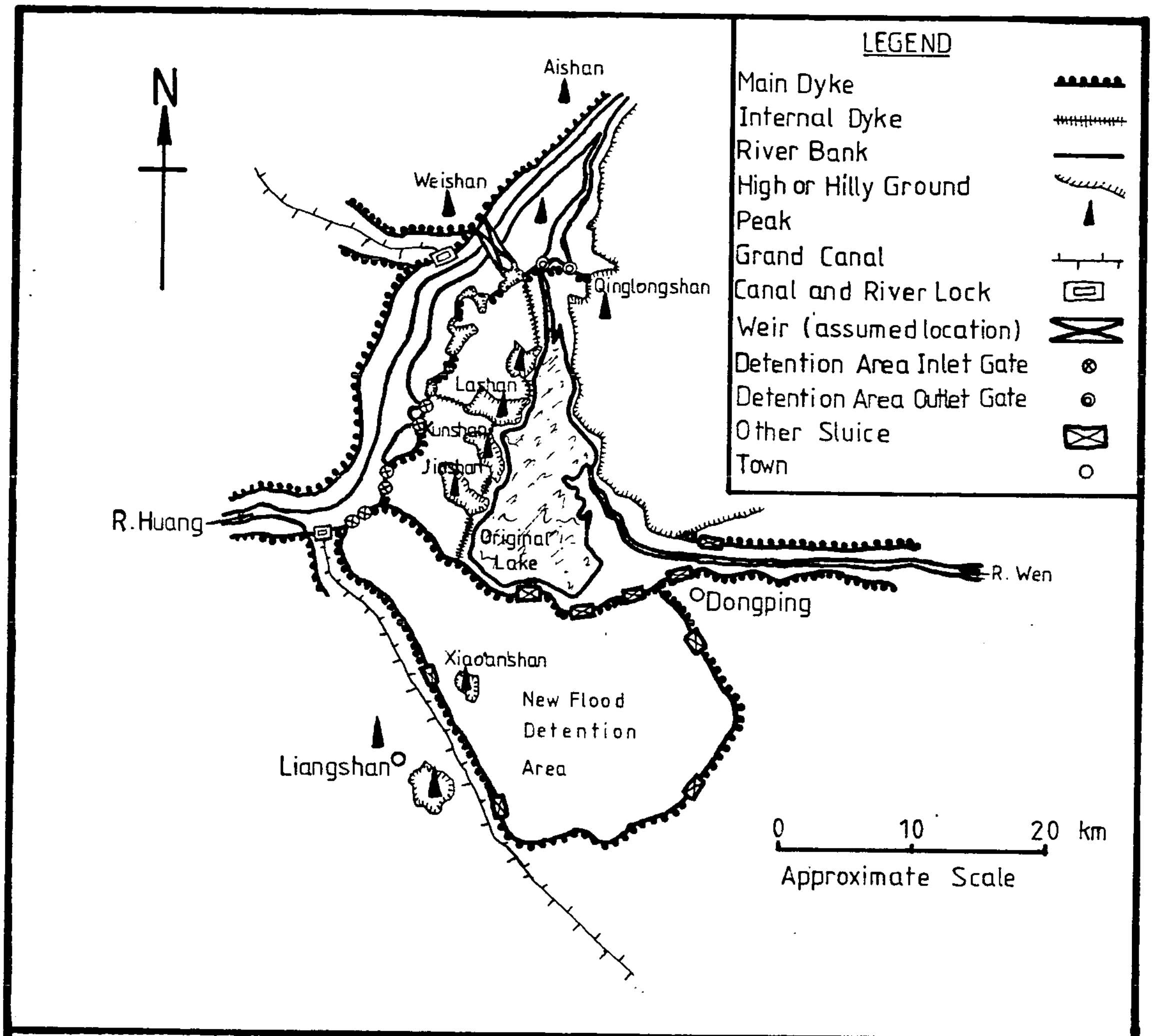


FIGURE 3-24 THE PLANNED WEISHAN PROJECT FOR DONGPING LAKE, c.1960

Source: RHWCC, Eds., 1979, p. 309. Position of weir and Northern section of the Grand Canal drawn according to the description in the text.

point, whilst providing 1.92 x 10^6 ha with irrigation and 8 MW of electrical power.(147)

iv) At a point called Wangwangzhuang, just upstream of Lijin, 120 km from the mouth, a small reservoir project involving a dam, four sluice gates, two ship locks and a 2 MW hydropower station was begun, to guarantee water supplies to the estuary region and to irrigate some 700 ha.(148)

These four schemes (Figure 2-1) all made use of low weirs across the river to raise the water level and, therefore, had in common their dependance upon, or allowance of, the expected reduction in the silt load of the lower R. Huang and the limitation of the maximum flood discharge to 6000 m^3 s^{-1} consequent upon the completion of the Sanmenxia reservoir. Furthermore, they shared, with the arguments for the original design at Sanmenxia, the assumption that large scale irrigation would be practical on the North China Plain. It should be noted that responsibiltiy for controlling Winter floods lay with the Weishan project, not Sanmenxia.

Although, as mentioned previously, the silt load of the lower R. Huang prior to 1964, rose only moderately after the change of operational regime at Sanmenxia in 1962, it had sufficient effect to confirm that these projects would not be compatable with the new, restored, fluvial conditions. To take the Weishan project as an example, silt accummulation behind the weir was so serious that the intake gates to the lake became blocked so that they could no longer handle large floods. Meanwhile the river itself could not pass more than 6000 m^3 s^{-1} since that was the maximum capacity of the diversion weir. Obviously this posed a serious threat to local flood prevention work. Reluctant to destroy the project completely, it was decided to divert the river around the weir so that should conditions again change, it could be resurrected. The lake intake sluices were also rebuilt to handle 8000 m^3 s^{-1} to 9000 m^3 s^{-1} and this part of the work alone cost ¥ 15. x 10^6 (£ 43 x 10^6). The work was done in 1964 and 1965.(149)

In the rest of the lower reaches, it was also decided to restore the original fluvial conditions. In 1963, work began on large scale dyke raising and reparations, the demolition of the Huayuankou diversion weir, and the curtailment of works still in progress at Luokou and Wangwangzhuang.(150)

The losses occasioned were not inconsiderable, but were offset by two new facts. Firstly, without any intervening structure along the lower reaches, Winter flood control could be undertaken directly from the Sanmenxia reservoir, so this important activity was not lost. Secondly, it began to become apparant, at about that time, that the planned area of irrigation was impracticable.(151)

Owing to the wandering characteristic of the lower R. Huang and fears of inducing floods, very little experience of irrigation was gained prior to the Great Leap Forward, about 1958, and the large scale schemes proposed then, in order to justify the costs of special river training works at the intakes, subsequently gave rise to serious and widespread alkalisation of the soil, which rendered much of the work useless. The reasons for this are as follow:

i) Whilst it was relatively easy to dig the proposed canals to service a wide area, it involved a far greater expenditure of work to level off the land. Therefore, instead of the intricately balanced schemes seen in other parts of China, large areas were simply irrigated by flooding and this contributed to a rise in the underground water table.(152)

ii) The natural river drainage system on the North China Plain was very poor. This was due to frequent changes in course of the R. Huang which had blocked up many previous outlets. The investment needed to provide drainage was, therefore, very high and, partly for that reason, adequate drainage systems were not provided either locally or regionally.

iii) When irrigation is carried out over such a large area, there is always somewhere which needs water, so the main canals have to be kept full. Leakage from these main canals further aggrevated alkalisation problems by raising the local water table.

In view of the above problems, the use of the water of the lower R. Huang for irrigation was temporarily forbidden, many irrigation projects were abandoned, and some canals were filled in whilst others just fell into disuse. Irrigation schemes on the North China Plain are now generally limited in scope to an area less than 200 km^2.

7) Discussion.

The suggestion has been made, by Wang Huayuan, 1979, and was reported at the beginning of this chapter, that the tortuous route taken had exacted 'study fees' in order that the correct role for a reservoir at Sanmenxia within the scheme to control and develop the lower R. Huang could be established. This section presents the new role of the Sanmenxia reservoir, compares it to that originally planned, and seeks to summarise the lessons learnt in the process of change, and to discuss the validity of the above suggestion.

i) The Present Role of the Sanmenxia Reservoir.

The present mode of operation at Sanmenxia is termed 'controlled operation'. During the reconstruction period the original channel improvements downstream had been lost, some of the reservoir capacity had been regained. Some factors, such as deposition morphology and the relative coarseness of the lower reaches' bedload, had taken on largely seasonal characteristics. Other factors, such as the retrogressive extension of sedimentation up the R. Wei, the bed level at Tongguan, the depletion of floodplain reservoir capacity and the extent of deposition in the lower reaches, had all depended upon the oncoming water and silt conditions. From 1973 onwards, after the reconstructions had freed the latter group of factors somewhat from their dependance upon the oncoming flood and silt conditions, an attempt was made to find the best compromise to satisfy the needs of the various reaches affected by the dam. This is what is meant by controlled operation and, in the following description, it is apparent that all other factors depend upon the successful disposal of the reservoir silt load.

In Winter, the R. Huang silt content is small and comprises coarse material, so the water level may be raised safely so as to cover the floodplains and most of the deposition to arise therefrom will occur upstream of the part of the reservoir where the floodplains have been covered.(153) Thus, floodplain losses will be extremely small. Spring freshets and the first small floods of the Summer can then be used to relower the bed at Tongguan and to purge out deposits from the main channel, in readiness for the big floods, although, as explained below, in deference to conditions in the lower reaches, floods smaller than 2500 $m^3 s^{-1}$ will be stored, not used.

Water storage begins in early December in preparation for the ice-jam season. The role of Winter flood protection has been taken over from the Weishan project and, as the temperature falls later in December, the water previously stored is released. This increases the discharge in the lower reaches and delays the formation of an ice cover. Once such a cover has formed, however, the discharge from Sanmenxia is greatly reduced to ensure that in the lower reaches it does not exceed that which can safely pass beneath the ice, taking into account the water supplied when the ice itself begins to melt. (Figure 3-25).(154)

Water so stored, for Winter flood protection, can be released during the Spring to supplement the supplies to irrigation areas along the lower R. Huang.(155)

Under normal Winter conditions, about a quarter of the silt entering the lower reaches would be deposited there but, since the reservoir now catches this silt and clear water is discharged, the main channel above Aishan is eroded instead. At the same time the reaches further down receive its silt as deposition. Therefore, after the ice control period, the reservoir may be drawn down quickly to produce an artificial floodpeak, exceeding 2500 $m^3 s^{-1}$, so that the whole of the lower reaches may be eroded and a good channel prepared to carry the forthcoming Summer floods.

In the Summer, whenever a peak of the order of 3000 $m^3 s^{-1}$ to 4000 $m^3 s^{-1}$ occurs, the lower reaches are eroded. If a flood larger than 6000 $m^3 s^{-1}$ should occur, the level above Aishan rises above the floodplains. If the sediment coefficient (ρ/Q) is greater than 0.03, both the main channel and the floodplains will receive deposition; if it is less than 0.03, then the main channel will be scoured whilst the floodplains are accreted. In both cases the silt content below Aishan will fall and erosion will take place. In ordinary years, floods smaller that 2500 $m^3 s^{-1}$ will not be used for reservoir flushing and

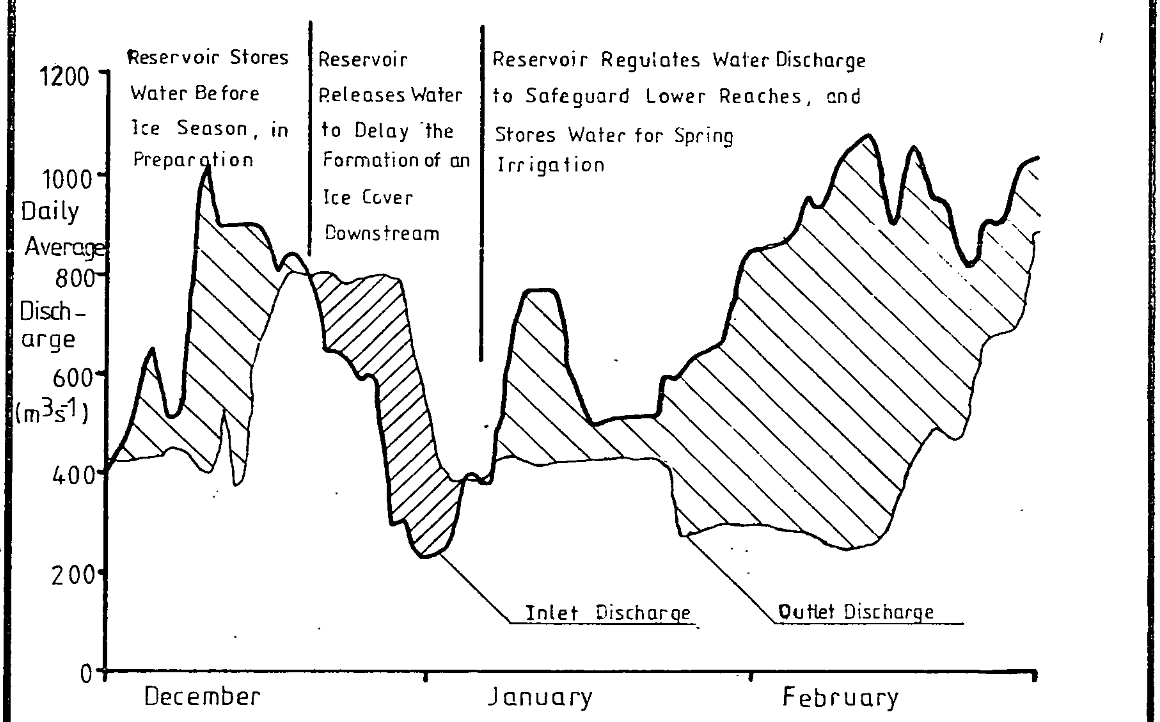


FIGURE 3-25 SANMENXIA RESERVOIR REGULATION, WINTER 1976-7

SOURCE: Note 154

heavily silted small floods will be stored so that their silt may not affect the lower reaches. It would be discharged as part of some larger flood later in the season.

Summer flood protection using the larger capacity above the reservoir flooplains is held as a reserve for floods greater than 12,000 m^3 s^{-1}, which are expected to occur, on average, once in ten years, (Figure 3-26). The large discharge capacity at low water levels provided by the reconstructions (Figure 3-6) allows ordinary Summer floods below that level to be discharged without causing the reservoir floodplains to be covered. Should floodpeaks in the lower reaches in excess of 22,000 m^3 s^{-1} be predicted, it is generally agreed that the sluices at Sanmenxia be closed or partially closed so that the flood crest from the R. Huang does not coincide with that from the rivers Yi, Luo and Qin; although this would give rise to deposition within the reservoir which may, or may not, be reversible, depending upon whether the reservoir floodplains were covered. Deposits in the main channel may be flushed out by subsequent floods of less than 12,000 m^3 s^{-1}.

Except when a particularly large flood is predicted, or in October, which is put aside for inspection and repair, electricity is produced the year round by five 50 MW generating sets. The opportunity may be taken in October to draw down the reservoir for a purge under free flow conditions, as this enhances the silt discharging capacity. (Figure 3-27). In October 1974 for example, 35 x 10^6 m^3 capacity were recovered in just ten days by such means.

Of the above reservoir uses, some have complementary requirements for silt regulation, whilst others are in mutual contradiction. For example, the control of retrogressive deposition is complementary with preserving the reservoir flood control capacity, whilst, at the same time it places restrictions on regulation of the lower reaches and is in contradiction with raising the water level in Spring, as storage for irrigation.

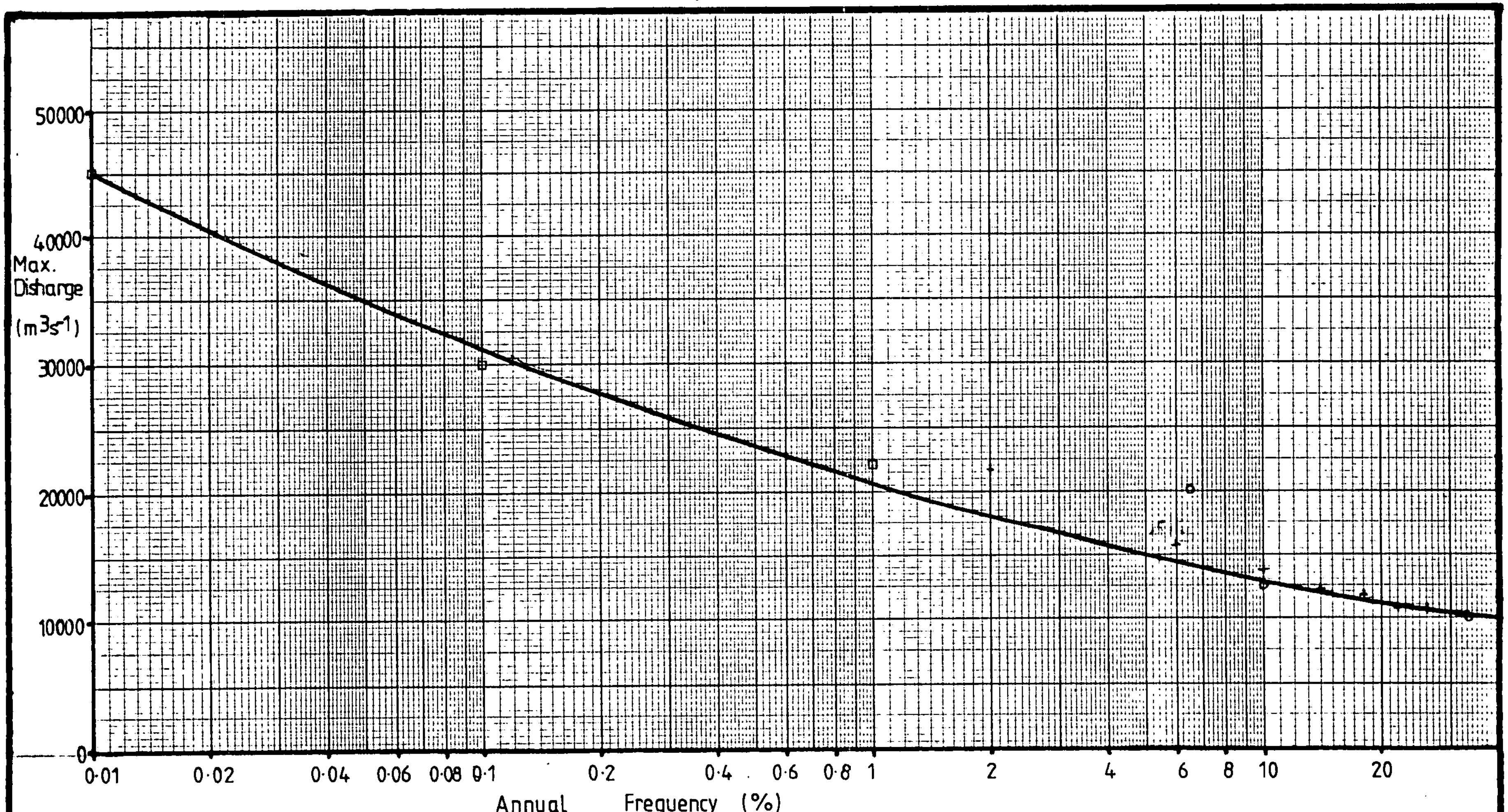


FIGURE 3-26 FLOOD FREQUENCIES AT SHANZHOU

SOURCES: Note 156

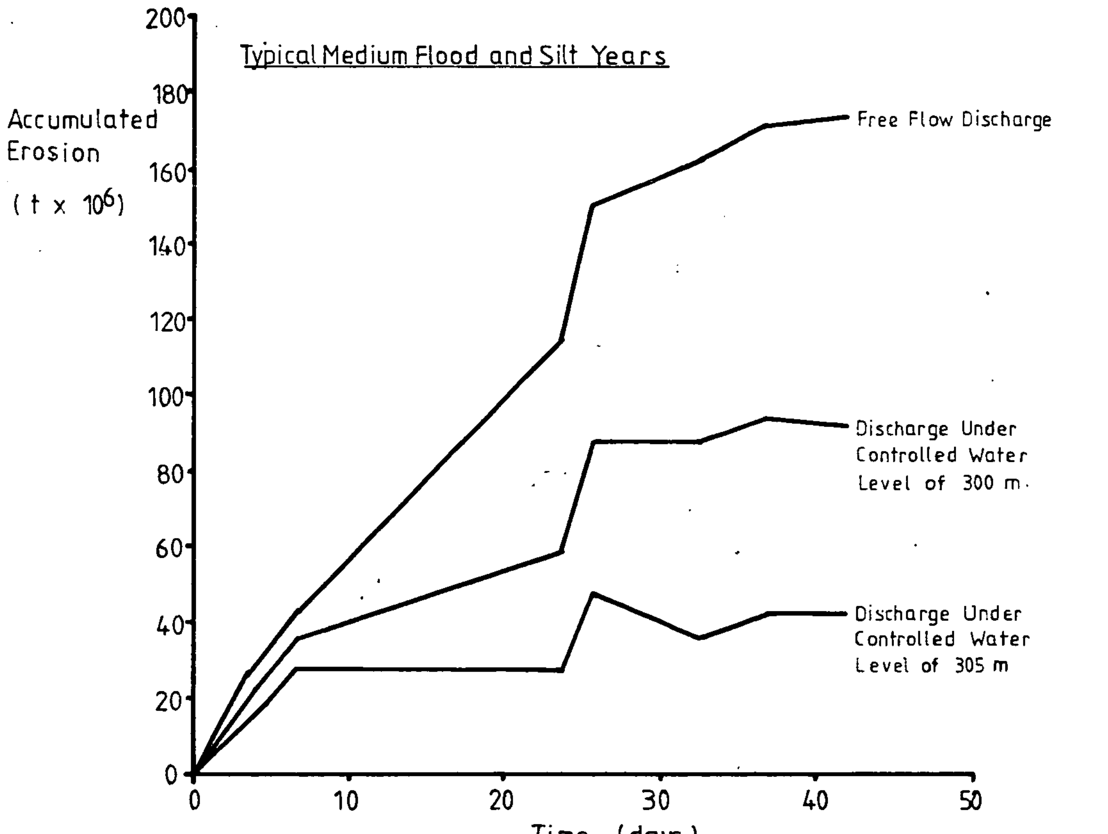


FIGURE 3-27 SCOURING OF SANMENXIA RESERVOIR DEPOSITS UNDER DIFFERENT DISCHARGE CONDITIONS

Source: SRIHEWL, et al., Eds., 1979, p. 338.

To summarise the present reservoir operations, variations in water level, discharge, sedimentation, bed level at Tongguan and the volume of water stored, for 1974-5 are shown in Figure 3-28. A 'use year' is taken as from November to the following October. November to February or March is the period for ice-jam prevention; from then on until June the reservoir is used for Spring irrigation, regulation of the lower R. Wei, the bed level at Tongguan and preparation of the main channel of the lower reaches of the R. Huang; from July to October its use is silt discharge and flood prevention. In October electricity generation ceases, for inspection and repair, and the reservoir may be drawn down for silt discharging or channel improvement in the lower reaches.

ii) Comparison with the Original Aims.

The role of the Sanmenxia reservoir was to provide flood control for the lower R. Huang for a period adequate to allow soil and water conservation, and further engineering works, together to bring the whole river under control. Meanwhile, it was to provide various multipurpose benefits including clear water for the irrigation of 27,000 km^2, a head of water for an installed power generation capacity of 1.16 GW, supplementary water for perennial navigation of the lower reaches, and the conditions for various multiple purpose projects to be built in the lower reaches.

Flood prevention is limited at present, and it is not certain how long it will last. It is certain, however, that without the aid of some other measure it cannot be seen as a long term solution to the R. Huang flood problem. The reasons for this are threefold. Firstly, whereas since the initiation of controlled operation, the bed level at Tongguan has been stabilised (at an average of 3 m above the 1960 level), some 900 x 10^6 m^3 of reservoir main channel capacity below Tongguan have been recovered and only 20 x 10^6 m^3 are now lost annually, the reservoir's lifespan still cannot be guaranteed, or even accurately estimated. For example, it has been estimated that should a flood discharge of 30,000 m^3 s^{-1} occur over 12 days and deposit 16 % of its total silt load (i.e. 2250 x 10^6 t), then between 50 % and 60% of the reservoir capacity would be lost and the discharge

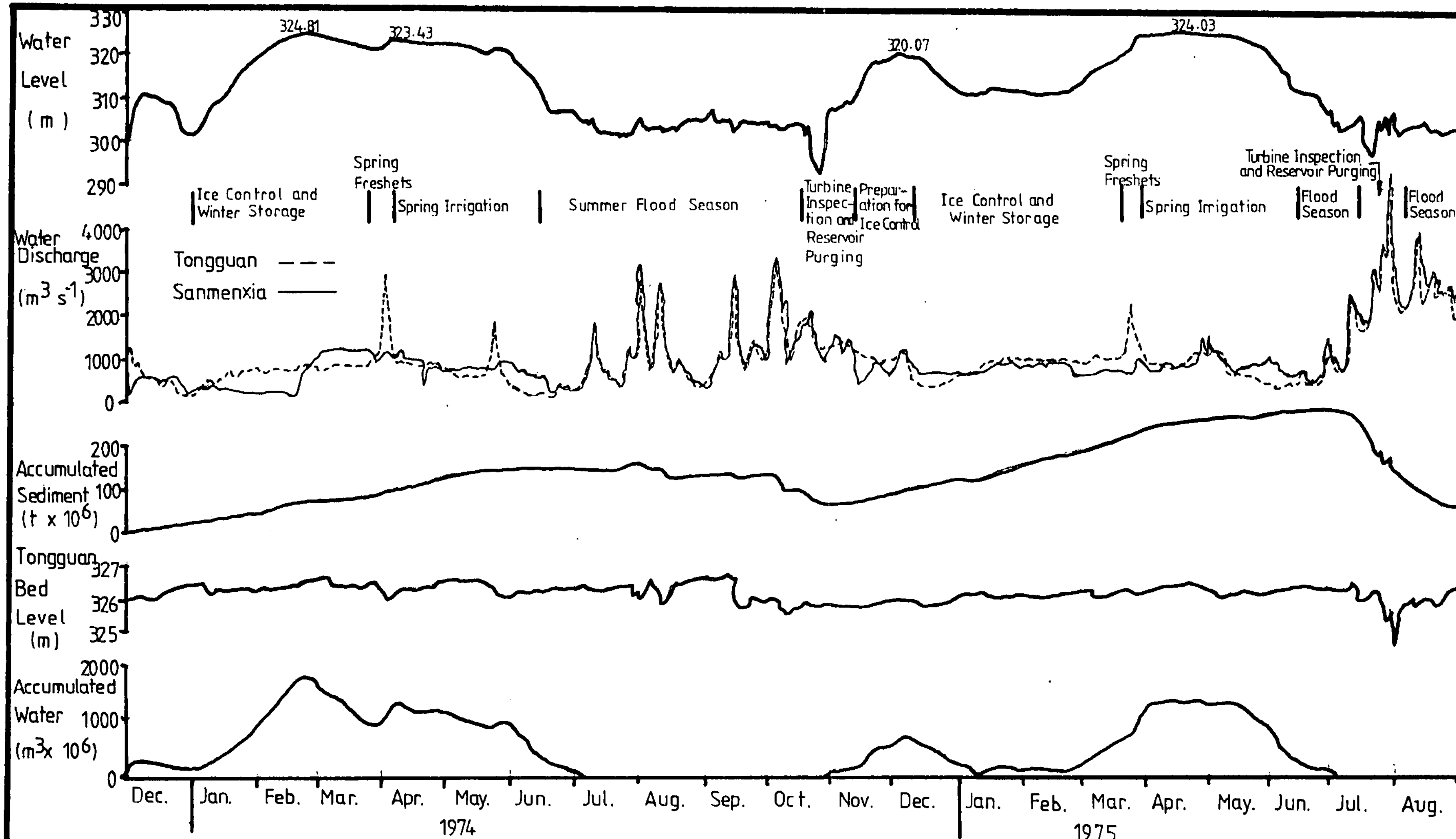


FIGURE 3-28 DATA FOR THE USES OF SANMENXIA RESERVOIR SOURCE: Note 157

and flood carrying characteristics of the reservoir would be altered whilst the passage of the flood peak was still in progress. Thereafter it would take a year before the channel capacity could be regained and even longer before the effect on the lower R. Wei could be overcome. Within the reservoir some 400 x 10^6 m^3 of floodplain capacity (30 %) would permanently be lost.(158) Secondly, although there is no record of simultaneous floods originating from above and below Sanmenxia, even without such an event it has been estimated that the flood discharge could reach about 45,000 m^3 s^{-1} at Huayuankou, and this could not necessarily be reduced to the safe carrying capacity of the lower reaches (22,000 m^3 s^{-1}) by the Sanmenxia reservoir. Thirdly, there still remains a net annual accretion of some 0.07 m over the whole of the lower reaches. The various proposals for future flood control are discussed in chapter 5.

Irrigation has been provided for 10,000 km^2 along the lower reaches, but the failure to develop it further has not been so much a consequence of a failure to provide clear water in the Summer, indeed remarkable progress has been made in the technique of using silty water (Chapter 4), as a failure, in the first instance, to cater for the problem of alkalisation. It may be said, therefore, that if more clear water had been provided, it would have been wasted, and the present reservoir is adequate in this respect for present needs.

The present installed electrical power generation capacity is 250 MW and its use is subordinated to flood control. One example of the shortage of electricity, which causes an underuse of industrial capacity in China, and which may have been helped by a larger installed capacity at Sanmenxia, existed in July 1979, when visitors were told that the tractor and ball-bearing factories could not with certainty be run at the same time.(159) The failure to make special provision for navigation, though undoubtedly regrettable, may be seen as the loss of a small bonus, and not particularly important. Again, such a suggestion may be supported from the discussions of the fifties, where the proposals of Comrades Ye and Wen left out navigation, but failed to draw serious comment on the ommission, from their opponents.

Though it is true to say that many of the benefits expected from the Sanmenxia reservoir failed fully to be forthcoming, it should also be pointed out that some 2000 km^2 of precious land has been saved which, even when it is acknowledged that a part of it might have been ruined in the process, and some may still be subject to periodic flooding, is considerable. Similarly, some 600,000 人 fewer were evacuated than under the original plan, and some of those who did have to move, have been able to return.

iii) Lessons.

In their description of the current status and problems of river sedimentation in China, given as an introduction to the technical section of the Proceedings of the International Symposium on River Sedimentation, Beijing, 1980, Professor Qian Ning of Qinghua University and Comrade Dai Dingzhong of the Ministry of Water Conservancy echo the official view quoted from other sources at the beginning of this chapter and add their consideration of the consequences,

> "Lack of experience in the early days when the Sanmenxia reservoir was planned, resulted in inadequate attention being paid to the sediment problem and the goals for multipurpose development being much too high....... Accordingly the normal high water level was set at 360 m...... Even under the lower level of 350 m, reservoir deposition was so serious that 1500 x 10^6 t of sediment had accumulated by March 1962, one and a half years after the dam had been put into operation. By 1964 the amount of material deposited in the reservoir had increased to 4400 x 10^6 t and the backwater effect extended rapidly to the upstream direction, endangering the industrial and agricultural development of the Guanzhong plain and the city of Xi'an. Thereafter, we were forced to give up the impounding of the resevoir, dismantle the generating set just installed, and start a renovation programme. As a result, the original development goals had to be reduced greatly and the construction time extended by 10 years. This is indeed a lesson not lightly to be forgotten".(160)

Although, as we have seen, this represents only part of the story and, it may be suggested, fails fully to point out which are the lessons to be drawn, it is arguably the most succinctly telling comment to have been published on the affair; for it implies not that the knowledge had not been available, but that it had not been heeded. It also indicates that the goals for regional development being set to high had led to the adoption of an inappropriate scale of project, rather than that the reservoir simply had failed to fulfil real needs. Herein lie the most important lessons and it is worthwhile to consider them further.

One lesson is the importance of assessing accurately the conditions obtaining in China at the time, which falls into two categories. Firstly, there is the extraordinary silt load of the R. Huang, unrivalled in quantity amongst the large rivers of the world, except the Ganges, and occurring in average concentrations over ten times those of all but the Colorado. In particular, there is no comparable river in the Soviet Union, whilst in Northern China there are very many heavily silted smaller rivers. In view of this, it would seem appropriate to lay emphasis on both domestic and foreign experience of heavily silted rivers in designing for the R. Huang, and then to make special allowance for its extreme conditions.

Yet, whereas in his submission to the special meetings of 1957, Comrade Ye, for example, drew upon two examples from Northern China and one from each of Egypt, India and Algeria to refute the Soviet claim that silt already deposited in a reservoir substantially could not be flushed out, the adopted design made no provision so to do. Even lowering the deep sluices by 20 m was done with reference only to the suspended load of the river.(161) Similar arguments apply to the failure to account for retrogressive backwater deposition; to quote from Comrade Ye's submission,

> "Since the R. Huang mainstream is heavily silted and deposition occurs quickly, a sand bar could occur across the R. Wei, render its storage capacity useless and affect its drainage. This kind of phenomenon has already occurred at the mouth of the Guishui river in the Guanting reservoir and is worth attention...... Since the water level will be very high and the backwaters will extend far up the R. Wei, local deposition will be

> detrimental to flood discharge in the R. Wei. It should be noted that the loess soil base will collapse due to the raised water table. The phenomenon of cave-ins and houses tumbling has already occurred beyond the evacuated areas around the Guanting reservoir".(162)

Another comment made at the meeting was,

> "It has been pointed out that the scope of backwater deposition can be several times that of the reservoir itself. If that is so, then there is a danger that Xi'an will become surrounded by desert."(163)

Even the official summary of the meetings, already quoted extensively, went as far as to point out that owing to backwater deposition,

> "The R. Wei would rise, possibly causing flooding or the saturation of the backwater district. This needs more detailed research to be done".(164)

Since these most serious phenomena were all predicted and debated in the 1950's, yet were not particularly heeded and, since the R. Huang's silt load is almost unique in the world, should have warrented attention, it would seem that the fault did not lie so much with a failure to take technical advice as with the failure to give sufficient emphasis to Chinese conditions, and experience, as opposed to foreign expertise based upon different conditions. As we have seen, the choice was essentially between accepting sets of assumptions based upon local or distant conditions, respectively; that is, deciding which advice was appropriate.

The second aspect in assessing China's particular characteristics concerns the speed and direction of future development. We have seen that in the first instance it was thought reasonable to exchange large amounts of fertile land upstream for electrical power (flood control was thought to be possible without flooding so much land, under the alternative scheme) and downstream irrigation. Perhaps this would not have been so unreasonable had the rate of development been as predicted but, as we have seen, the failure of the loess plateau region so to develop exaggerated the upstream losses of agricultural production, whilst downstream the increases expected to substitute for it also failed to materialise. The crux of the matter lies, then, with the speed of agricultural progress, and there we have found that insufficient attention was paid to assessing the real needs of a given area. Thus, on the loess plateau soil and water conservation work failed to achieve widespread success because the approach was not suited to local conditions and the peasants could not adopt the measures suggested without threatening their own meagre food supply. At the same time, on the North China Plain, irrigation works failed to achieve the expected returns, partly because the scale was inappropriately large and the commensurate drainage and management work could not keep up. Given that agricultural development had yet to be assured, was it not inappropriate to exchange prime land such as the Guanzhong Plain, for electricity?

The lesson from various localities, that local conditions were not sufficiently taken into account, applies equally well to the scheme as a whole. From its inception it was assumed to be a largescale multipurpose project and that this one pivotal construction would be capable of solving present and future, near and distant problems, and that this was desirable. Yet, the only real need was for some way to be found to attenuate floods exceeding 22,000 $m^3 s^{-1}$ at Huayuankou, which might be expected to occur once in 50 years, (The lower reaches could handle, or quite easily be made to handle, smaller floods) with sufficient longevity to allow soil and water conservation work to bring the runoff of the middle reaches under control. The rest may be seen as much desired but secondary benefits. A more appropriate scheme would have contrived to meet these criteria first and, with the infallibility of hindsight, it may be said that stalling for time in this way would have enabled a more appropriate scheme to have been developed simply because the special characteristics of the problem could have been better understood. For example, an analysis of the sources of different grain sizes of the R. Huang silt has revealed that 74 % of the larger grains (>0.05 mm), which are the ones that settle in the lower reaches, come from an area of 110,000 km^2, and 46.5 % from only 43,000 km^2, (Chapter 1, Section 3 iii) which greatly simplifies the problem. Meanwhile, had a more appropriately scaled scheme for flood control been devised, not only would much wastage have been saved, but, perhaps, more effort and resources would have been spent on finding more appropriate schemes for the other benefits. As it is, acceptance of the unrealistic demands for the various other benefits, led to a construction inappropriate to them and inappropriate to flood control on the world's most heavily silted river.

It may be remembered that a number of points of contention were to have been tested, in the late fifties, simultaneously with the construction, but that, despite the discovery of various adverse phenomena, nothing was done until they were proven in practice. It was suggested that one reason was that the division of labour was too finely drawn. The lesson may, therefore, be taken of the extreme importance of good communications amongst scientists, engineers, politicians and others involved. The way in which work began whilst so much was in dispute, and continued despite the confirmation, by experimentation of many fears, right until disaster struck, illustrates that decisions should be open to review in the light of new evidence, and also the lesson best summed up by the old proverb common to English and Chinese, "More haste, less speed", (欲速则不达).

The above are some of the lessons to be drawn from the experience of 'walking a tortuous route'. Whether they have been drawn is another matter, which is addressed in Chapters 5 and 6.

Notes to Chapter Three

1. WANG Huayun, 1980, p. 6.

2. QIAN Ning, DAI Dingzhong, 1980, p. 25. WANG Huayun, 1979, p. 5.

3. SPCO, Eds., 1957, p. 9.

4. SHEN Chonggang, 1957, p. 15. SPCO, Eds., 1957, p. 9.

5. GUOERHUANGFU K.C., et al., 1957, p. 7.

6. SHEN Chonggang, 1957, p. 14. SPCO, Eds., 1957, pp. 6, 10, A density current: When a heavily silted flow enters an accumulation of clearer water, under certain circumstances it may not disperse, but continue as a distinct flow. Since the density of the silted water is greater than that of the clearer water, this flow is termed a 'density current'. Generally speaking, density currents affect the distribution of sediment within a reservoir inasmuch as they carry suspended material a certain distance before dispersing. When they disperse, the material is deposited locally. Under the rarer circumstance that the density current may reach the dam intact, a higher proportion than othewise of the oncoming sediment load may be discharged from the reservoir.

7. SHEN Chonggang, 1957, p. 14. According to QUSRL, all such data certainly were made available and the bulk weight was not a point of controversy anyway. SHEN actually just writes that the samples hadn't yet arrived, so these estimates were made instead.

8. ZHONGGUO SHUILI, Eds., 1957. SPCO, Eds., 1957.

9. ibid.

10. For example, SPCO, Eds., 1957, p. 4. " A serious shortcoming of the silt purging scheme, is that it both cannot satisfy the need to eliminate water disasters downstream, and excludes the possibility of developing fully comprehenisve use of the reservoir. Therefore, most opinions considered the use of this scheme inappropriate".

11. DENG Zihui, 1955, p. 46.

12. GITTINGS John, 1968, p. 14, quoting a letter of 29 February 1964, from the Central Committee of the Chinese Communist Party, to their Soviet counterparts.

13. Fieldtrip notes, 28 August 1980.

14. SUSLOV Mikhail, 1964, quoting GU Zhexin (KU Cho-hsin). This question is discussed in more detail in MOSELY Paul, 1977.

15. GITTINGS John, 1968, p. 19. An example of the extent to which the establishment of Chinese institutions followed the Soviet

pattern is given in KLOCHKO M.A., 1964, p. 19, "Following the Soviet example, the Chinese based their scientific research in specialised institutes rather than at the universities. This proved a great mistake, for there were simply not enough trained and educated technicans to make the system work ...... These scientists would have been more usefully employed in teaching, where they could have trained future technicians and researchers. .... Assuming that each scientist could have trained ten new men capable of taking over his research in ten years, the Chinese could have produced enough scientists of their own. At present .... the professors and instructors have time for neither teaching nor research .... nor for advancing their own work. .... /This/ neglect .... was a consequence of China's blind copying of the Soviet system. The provincial branches of the Acadamy of Sciences ...... consist entirely of bureaucrats".

16. GAO Gang, 1952, p. 11.

17. FU Zuoyi, 1952, p. 28.

18. XINHUA, Beijing, 22 September 1952.

19. ZHANG Zilin, 1953, p. 15.

20. ZHANG Hanying, 1952, p. 19.

21. FU Zuoyi, 1957.

22. LI Fudu, 1955, p. 4. The 'new scheme' is the 1955 multiple purpose plan for the R. Huang.

23. LI Rui, 1955, p. 11. The inference is that the whole-basin approach to control of the R. Huang was a Soviet idea. As is shown in Chapter 2, this is not the case.

24. FU Zuoyi, 1955.

25. GITTINGS John, 1968, p. 55, quoting the Novosti Press Agency, 14 August 1964.

26. TANG Shi, 1957.

27. ZHONGGUO SHUILI, Eds., 1957, p. 17.

28. SPCO, Eds., 1957, pp. 1, 2.

29. ibid.

30. XINHUA, Beijing, 13 March 1958.

31. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2. Certain Xinhua reports give the number of leaks as 6. XINHUA Beijing, 27 July 1958. XINHUA, Zhengzhou, 6 August 1958, XINHUA, Ji'nan, 22 July 1958. XINHUA, Beijing, 25 July, 1958.

32. XINHUA, Beijing, 27 July 1958.

33. XINHUA, Zhengzhou, 5 August 1958.

34. Fieldtrip notes, 28 August 1980.

35. BEIJING ZHOUBAO, 1959, p. 3.

36. WANG Huzhen, 1957a.

37. WANG Huayun, 1980, p. 2. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2.

38. Fieldtrip notes, 22 July 1980, conversation with representative of the Shaanxi Hydropower Bureau, 18 July 1980, meeting with representatives of the Shaanxi Soil and Water Conservation Bureau.

39. Fieldtrip notes, 30 July 1980, meeting with representatives of the Yan'an District Soil and water conservation Bureau.

40. Fieldtrip notes, 18 July 1980, as in note 38,

41. RHWCC, Eds., 1959, p. 203. Except where specified, the rest of this section is drawn from fieldtrip notes of 18 July 1980 and 30 July 1980, as in notes 38 and 39.

42. Academia Sinica, RHMRSWCCSG, Eds., 1958. p. 1.

43. WANG Huayun, 1980, p. 7.

44. ZHANG Xiuping, 1978.

45. Fieldtrip notes, 30 July 1980, as in note 39. 30 August 1980, meeting with Prof. QIAN Ning, head of QUSRL. LI Erzhong, 1979. YANG Wenzhi, in YU Zheng, et al., 1978.

46. ZHANG Sen, 1963.

47. LIU Wanquan, 1979.

48. LI Erzhong, 1979.

49. ibid. FANG Zhengsan, 1964.

50. Fieldtrip notes, 18 July 1980, as for note 38.

51. RHWCC, Scientific and Technical Information Station, 1977, p. 19. SRIHEWL, et al., Eds., 1979, p. 5.

52. LUO Laixing, 1957.

53. FANG Zhengsan, 1964, ZHANG Sen, 1963.

54. ZHANG Sen, 1963.

55. FANG Zhengsan, 1964. Fieldtrip notes, 20 January 1981, meeting at Academia Sinica. SHI Shan, ZHANG Tianceng, LI Kaiming, Academia Sinica, GAO Bowen, Soil and Water Conservation Engineer, YANG Tingxiu, Research Commission for Agricultural Modernisation, CHEN Yongzong, Geographical Institute.

56. ZHANG Sen, 1963. The term 'precipitated land' hereafter refers to land formed by precipitation of silt from rivers or reservoirs, and has nothing to do with local water precipitation. One mu is approximately equal to 0.067 ha.

57. Fieldtrip notes, 18 July 1980, as for note 38.

58. ZHANG Sen, 1963.

59. Fieldtrip notes, 20 January 1981, as for note 55.

60. LUO Laixing, 1957.

61. LI Erzhong, 1979. Other examples may be found in YU Zheng, et al., 1978, TONG Dalin, et al., 1978.

62. Academia Sinica, RHMRSWCCSG, Eds., 1958, p. 83.

63. LUO Laixing, 1957.

64. XIAO Enyuan, 1957.

65. ZHOU Junqian, 1957.

66. RENMIN RIBAO, 8 September 1957.

67. XINHUA, Beijing, 6 September 1957.

68. RHWCC, Eds., 1959, p. 249.

69. DENG Zihui, 1955, p. 43.

70. LI Fudu, 1966. A wider discussion of the imbalances which occurred during this period is contained in GUSTAFFSON Jan-Eric, 1981.

71. RENMIN RIBAO, 15 June 1980, p. 1.

72. Fieldtrip notes, 20 January 1981, as for note 55.

73. WANG Huayun, 1980, p. 7.

74. Fieldtrip notes, 18 July 1980, as for note 38. 20 January 1981, as for note 55.

75. WEN Yin, LIANG Hua, 1977, p. 1.

76. ibid., pp. 23, 34. HUANG Jun, et al., 1972, p. 4.

77. XINHUA, Taiyuan, 2 October 1979.

78. JIN Guang, XIONG Yan, 1980.

79. XINHUA, Taiyuan, 2 October 1979.

80. REN Zhanbiao, QIN Dongcheng, 1979.

81. YU Zheng, et al., 1978.

82. ibid.

83. Yan'an Water Conservancy Bureau, personal communication, 31 August 1980. WANG Zhengqiu, et al., 1980.

84. REN Zhanbiao, QIN Dongcheng, 1979. RENMIN RIBAO, 1 November 1978.

85. LI Erzhong, 1979.

86. RENMIN RIBAO, 22 December 1978.

87. LI Baoru, et al., 1979, pp. 24, 25. Shaanxi Soil and Water Conservation Bureau, Eds., 1973, p. 29.

88. LIU Yuelan, et al., 1975, p. 182. WDSRMB, et al., 1975, p. 36. ZHANG Qishun, LONG Yuqian, 1980.

89. RHHI, Eds., 1972, p. 138.

90. SRIHEWL, et al., Eds., 1979, p. 101.

91. ibid., p. 84.

92. QIAN Ning, DAI Dingzhong, 1980, p. 24.

93. Acadamia Sinica Geographical Inst., Geomorphology Lab., R. Wei Group, Eds., 1975, p. 52. Shaanxi Research Inst. of Hydraulic Engineering, et al., Eds., 1975, p. 122, SRIHEWL, et al., Eds., 1979, p. 186.

94. SRIHEWL, et al., Eds., 1979, p. 181.

95. ibid., p.186.

96. Fieldtrip notes, 21 April 1980, WIHEE, WCHPRI, Eds., 1979, p. 159.

97. XINHUA, Beijing, 5 January 1962.

98. GUO Tiying, 1980, p. 38.

99. QUSRL, Personal communication, 1980.

100. SRIHEWL, et al., Eds., 1979, pp. 185, 300.

101. RHWCC, Eds., 1979, p 221, SRIHEWL, et al., Eds., 1979, p.317. Fieldtrip photographs, 29 December 1979, 3 August 1980. ZHANG

Qishun, LONG Yuqian, 1980, p. 708. WU Zuoren, 1956, p. 43. CAO Bingquan, ZHANG Jinsheng, 1957, p. 13. CHEN Yikun, 1957, p. 19.

102. Copied from personal notes of Prof. Qian Ning. This is not an official quotation from Comrade Zhou Enlai, but Prof. Qian's own paraphrase.

103. SRIHEWL, et al., Eds., 1979, p. 338.

104. As for note 102.

105. Fieldtrip notes, 7 August 1980, visit to the RHWCC Exhibition at Zhengzhou.

106. DENG Zihui, 1955, p. 41.

107. ZHANG Qishun, LONG Yuqian, 1980, p. 707.

108. CAMERON Nigel, 1960, p. 35. CHEN Xuejian, CHEN Shitong, 1957, p. 22.

109. WANG Huayun, 1959. SHAANXI RIBAO, 26 November 1959. Fieldtrip notes, 4 August 1980, meeting with member of former 'Evacuation Committee' for Shanzhou (Sanmenxia) district.

110. XINHUA, Xi'an, 20 April 1957.

111. Fieldtrip notes, 4 August 1980, as for note 109. XINHUA, Zhengzhou, 2 April 1957. XINHUA, Lanzhou, 20 August 1956.

112. Fieldtrip notes, 4 August 1980, as for note 109. 21 April 1980.

113. SHAANXI RIBAO, 26 November 1959. XINHUA, Xi'an, 20 April 1957.

114. Fieldtrip notes, 4 August 1980, as for note 109.

115. CAMERON Nigel, 1960, p. 35.

116. SHAANXI RIBAO, 26 November 1959.

117. FENG Huade, 1962.

118. Except where otherwise indicated, this section is taken from CHEN Xuejian, CHEN Shitong, 1957.

119. XINHUA, Zhengzhou, 22 July 1956. Fieldtrip notes, 4 August 1980, as for note 109.

120. XINHUA, Sanmenxia, 4 April 1957, XINHUA, Sanmenxia, 7 April 1957.

121, Fieldtip notes, 4 August 1980, as for note 109.

122. Fieldtrip notes, 15 July 1980.

123. RENMIN RIBAO, 14 April 1957. RHWCC, Eds., 1979, pp. 215 to 225.

XINHUA, Sanmenxia, 9 April 1957. According to QUSRL the characters on the midstream pillar were 朝我來.

124. CHEN Xuejian, CHEN Shitong, 1957. RENMIN RIBAO, 14 April 1957,

125. CHINA PICTORIAL, 1980.

126. Fieldtrip notes, 4 August 1980, as for note 109.

127. ibid.

128. SRIHEWL, et al., Eds., 1979, p. 185.

129. ibid., p. 187.

130. ibid., pp. 185 to 187. Shaanxi Research Inst. of Hydraulic Engineering, et al., Eds., 1975, p. 122.

131. SRIHEWL, et al., Eds., 1979, p. 186.

132. RHSRCG, Eds., 1975, Selection 1, Vol. 2, p. 61.

133. Shaanxi Research Inst. of Hydraulic Engineering, et al., Eds., 1975, p. 121. Antedam area: the area immediately in front of the dam, within the reservoir. In reservoirs on lightly silted rivers this area is usually free from deposition.

134. SRIHEWL, et al., Eds., 1979, p. 366.

135. ibid., p. 256.

136. ibid., p. 337.

137. RHHI, Eds., 1972, p. 138. MAI Qiaowei, et al., 1980, p. 339. Former deposition above Aishan is greater than the net deposition in the whole lower reaches, because scouring took place elsewhere.

138. LI Baoru, et al., 1980, p. 408.

139. ibid., p. 413.

140. GUO Tiying, 1980, p. 38.

141. Table 3-5. MAI Qiaowei, et al., 1980, p. 4.

142. LIU Yuelan, et al., 1975, p. 183. According to QUSRL (personal communication, 1982), this was mainly due to the fact that during the large 1958 flood the bed was severely, and beneficially, eroded whereas, thereafter, deposition occurred with the dispersal of hyperconcentrated flows carrying sediment eroded from elsewhere. By 1976, the flood carrying capacity had returned almost to the 1958 level.

143. SRIHEWL, et al., Eds., 1979, p. 197.

144. KOROLIEV A.A., 1957. RHWCC, Eds., 1959, p. 240.

145. XINHUA, Zhengzhou, 2 December 1959.

146. RHWCC, Eds., 1959, pp. 226, 240. XINHUA, Zhengzhou, 30 May 1958. XINHUA, Ji'nan, 2 October 1958. XINHUA, Ji'nan, 4 November 1959. XINHUA, Ji'nan, 1 December 1959. XINHUA, Ji'nan, 3 January 1960. RHWCC, Eds., 1979, p. 311.

147. RHWCC, Eds., 1959, p. 240, 245. XINHUA, Ji'nan, 27 February 1960.

148, RHWCC, Eds., 1959, p. 240. XINHUA, Ji'nan, 23 January 1960.

149. Fieldtrip notes, 30 August 1980, as for note 45. RHWCC, Eds., 1979, p. 310. WANG Huayun, 1980, p. 4.

150. WANG Huayun, 1980, p. 4.

151. Fieldtrip notes, 30 August 1980, as for note 45. Except where otherwise indicated, the rest of this section is from the same source.

152. XINHUA, Beijing, 24 June 1971. RENMIN RIBAO, 28 May 1971.

153. SRIHEWL, et al., Eds., 1979, p. 326.

154. CHEN Zanting, et al., 1980.

155. Except where otherwise indicated, this description of the reservoir's present operational mode is taken from SRIHEWL, et al., Eds., 1979, pp. 336 to 340.

156. Points marked + are from XIE Jiaze, et al., 1947, p. 81. Points marked o are from SRIHEWL, et al., Eds., 1979, pp. 338, 339. Points marked □ are from the original Soviet data, made available by QUSRL, personal communication, 1980.

157. Survey, Design and Research Inst. of the No. 11 Engineering Office of the Ministry of Electrical Power, Eds., 1975, p. 146a.

158. SRIHEWL, et al., Eds., 1979, p. 339.

159. H. Dickinson, School of Engineering, Edinburgh University, personal communication, 1982.

160. QIAN Ning, DAI Dingzhong, 1980, pp. 5, 6.

161. See also DUQUENNOIS H, 1956, p. 174.

162. YE Yongyi, 1957, p. 11.

163. MEI Changhua, in ZHONGGUO SHUILI, Eds., 1957, part 2, p. 35.

164. SPCO, Eds., 1957, p. 1.

165. The frequency of floods of 22,000 $m^3 s^{-1}$ at Shanzhou is 100 years. The frequency of floods of 22,000 $m^3 s^{-1}$ arising between Sanmenxia (Shanzhou) and Taohuayu is also 100 years. Therefore, the frequency of floods of 22,000 $m^3 s^{-1}$ at Huayuankou is 50 years.

166. MAI Qiaowei, et al., 1980, p. 399.

Chapter Four

Direct Advances.

In the previous chapter an attempt was made to describe some of the difficulties encountered in the last thirty-odd years of R. Huang control and to point out the more important lessons offered by the experience. It concentrated on what could be learnt from having made mistakes, and is noteworthy for its mainly social, political or economic, rather than purely technical, lessons. Yet, as might be expected of an undertaking on the scale of the whole of the R. Huang basin, many advances have been made as the result of deliberate scientific research and it is to these that attention is directed in this chapter.

1) Scope of Research Related to the River Huang.

The R. Huang shares with all the rivers across a large part of North China, other than those in the far North-east and North-west, the characteristic heavy silt load and seasonal water flow. It plays, therefore, a pivotal role in research, and what applies to the R. Huang is important over the larger area, and vice-versa. It is useful to consider separately the general, permanent data collection organisation, as it applies to the R. Huang, and the advances which have arisen out of such work and from the various related special projects within the R. Huang basin.

i) General Surveying and Organisation.

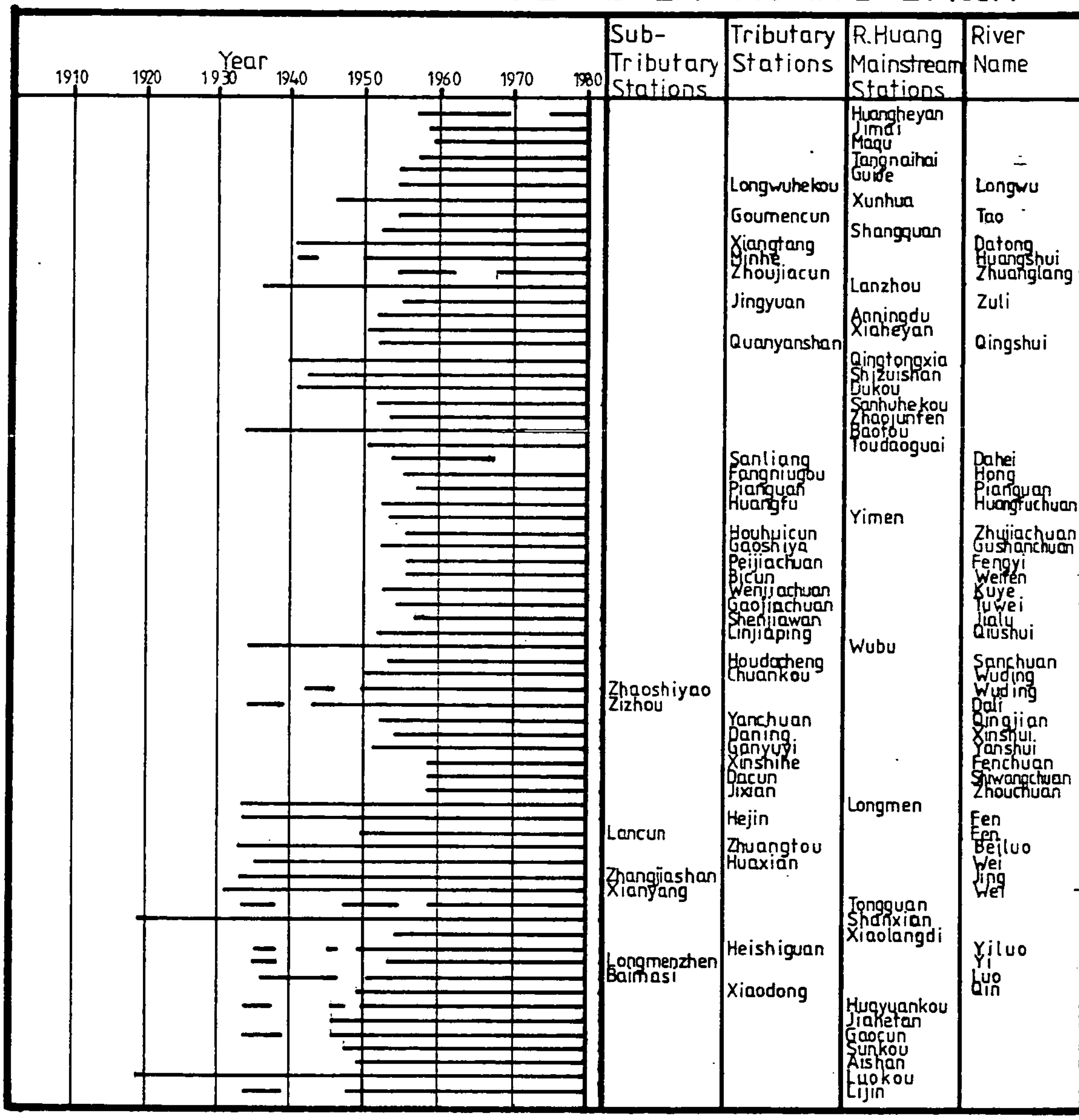
There are over 2910 hydrological gauging stations on the rivers of China of which 1230 carry out sediment measurement.(1) In the R. Huang basin there are 485 such stations, all of which include sediment measurement, and 2211 rainfall stations. Of these, 137 hydrological stations, 795 rainfall stations and an additional 51 water level stations are under the control of the RHWCC. The others come under various local authorities, depending upon their position.(2) The data which all collect are later collated and published together in bound volumes, although, regrettably, under conditions of strictly restricted circulation.(3) The development of this comprehensive network of gauging stations is shown in Figures 4-1, 4-2.

Gauging began with the establishment in 1919 of the Shanzhou and Luokou hydrological stations. Three tributary stations were added, between 1931 and 1933, on the rivers Wei, Jing and Beiluo respectively. In 1933, the RHWCC was established and in that Summer a disastrous flood occurred in the R. Huang. In the following year 15 new stations were added and by 1949 there were 33 hydrological and 66 rainfall stations. In the fifties both types of station increased rapidly in number but, thereafter, whilst the number of rainfall stations has continued to increase rapidly, the number of hydrological stations has remained in the 400s. Meanwhile the distribution of both types of station reflects the relative importance of the various conditions in different parts of the basin; in the middle reaches there are about 6 hydrological and 52 rainfall stations per 10,000 km^2, but in the upper reaches there are 3 and 10 stations per 10,000 km^2 respectively.(4)

Under normal conditions the hydrological gauging stations measure water level, water temperature, water discharge, total silt load, silt transportation rates, bed and suspended loads, particle size distribution and chemical composition. These are supplemented where necessary as the following examples reveal.(5)

A special testing station and gauging team has been set up at each of six reservoirs, where measurements are made of the sedimentation morphology, at least twice a year, before and after the flood season. From these stations, extra measurements are made, for special purposes, into such phenomena as density currents, bank collapses, underground water, the dry bulk weight of the deposits, the backwater effect, and the passage of sediment through the turbines in power stations. In the case of the Sanmenxia reservoir, for example, the reservoir area has been divided into 131 sedimentation sections of which 61 are on the R. Huang mainstream, 48 are along the R. Wei and 22 are up the R. Beiluo. (Figure 1-3). In addition to the special station at the damsite, there are 11 hydrological and

FIGURE 4-1 MAJOR TRIBUTARY AND MAINSTREAM STATIONS IN THE RUNOFF AND SEDIMENT GAUGING NETWORK FOR THE WHOLE RIVER HUANG BASIN



Source: LONG Yuqian, XIONG Guishu, 1981, page 17.

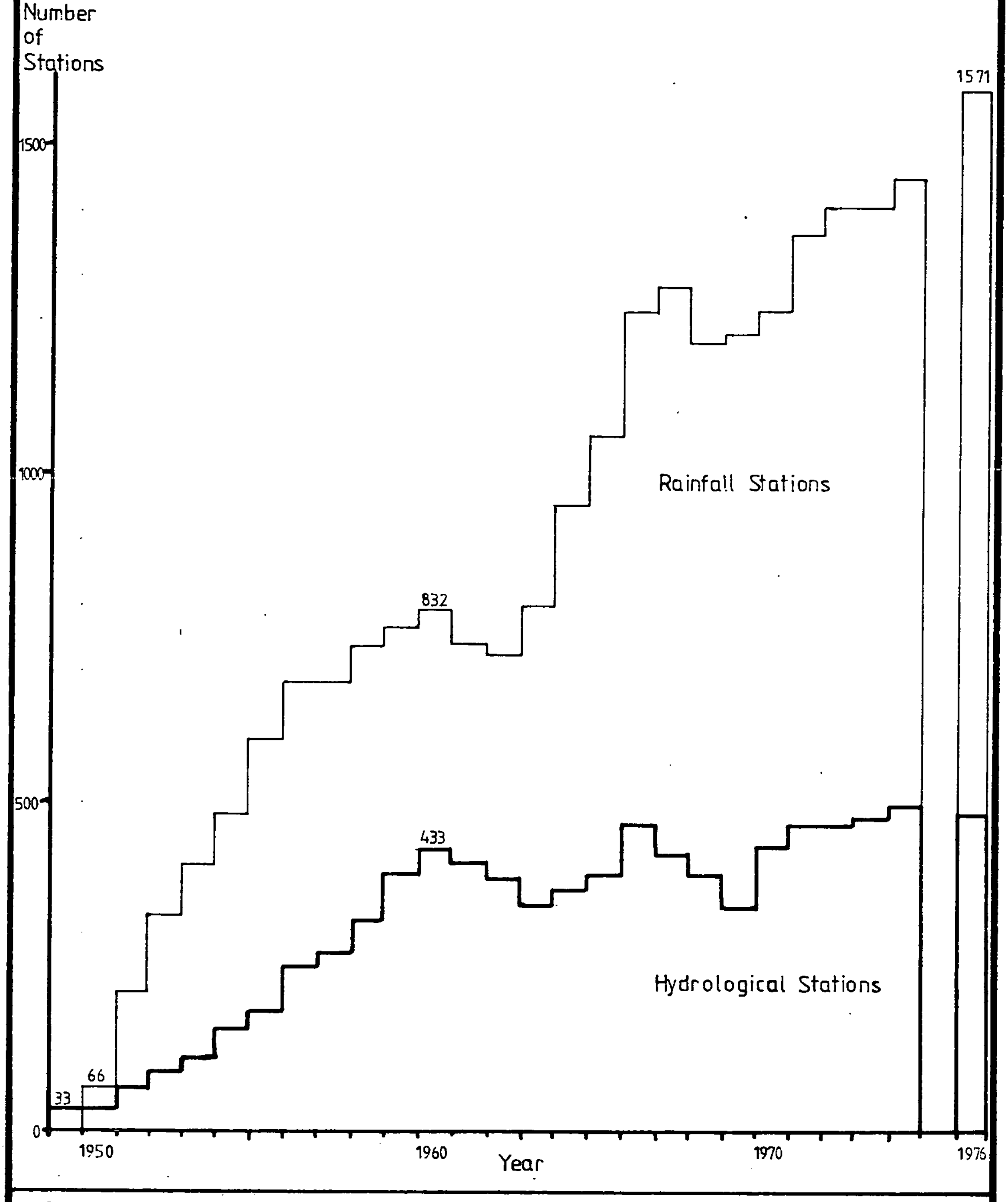


FIGURE 4-2 GAUGING STATIONS IN THE RIVER HUANG BASIN, 1949-76

Source: LONG Yuqian, XIONG Guishu, 1981, page 16.

14 water level gauging stations. Meteorological data are also gathered. It is usual for the normal range of measurements to be taken about five times a year but, in 1960, they were made eleven times and special density current tests in 1961 and 1962 numbered sixteen. Other extraordinary tests have also been carried out from time to time.

A similar sub-system of stations has been set up to investigate other important questions. For example, in 1959, an experimentation station was set up in Chaba Gully, in Zizhou County, Shanxi, to investigate soil loss phenomena. This small gully catchment, of 187 km^2 in area now has 9 hydrological stations. One of its tributary gullies, Tuanshan gully, includes 14 runoff fields, in its 18 ha area, and an observation station at the mouth. Attention is also paid here to such phenomena as soil moisture and evaporation. Ten special silt particle analysis stations were set up under the Wubu main hydrological station (Shaanxi) following Professor Qian Ning's suggestion, of 1965, that the source of the coarse grains within the R. Huang silt load be investigated.

The lower reaches of the R. Huang have been divided into 101 sections relative to which normal and extraordinary measurements are made. Supplementary facilities, at Huayuankou in the fifties and sixties, included special teams to investigate the laws of riverbed changes in the upper, wandering, section. At Tuchengzi, below Luokou, in the fifties, special teams were set up to investigate the silt discharge capacity of the lower, meandering section.

The above examples are not exhaustive, but they serve to illustrate the scale and the comprehensive nature of general field data collection throughout the R. Huang basin, which extends even to the coastline and sea beyond the estuary. The collection of series of such data provided the basis for organised research.(6)

Sedimentation research in China is now carried out under three types of agency; Central Government, university and college; and local research units. The central co-ordinating body is the Bureau of Science and Technology of the Ministry of Water Conservancy, and the main forum of academic exchange is the Chinese Society of Hydraulic Engineering. There are over 1000 college and technical school graduates working in this field. Table 4-1 gives the fifteen institutions whose work now bears a more direct relation to the R. Huang. It is taken from a list of 38 for all China appearing in the proceedings of the 1980 Beijing International Symposium on River Sedimentation.(7)

The co-ordinating body for all work on the R. Huang is the RHWCC, and under them a "River Huang Sediment Research Co-ordinating Group" has been established in which eight provincial bureaux and universities or colleges participate. They have drawn up joint research programmes and have held various symposia from which four volumes of "Collected Works on R. Huang Sediment Research" have been published. Regrettably, these, too, like the volumes of basic hydrologic and meteorologic data of the R. Huang, are subject to very severe circulation restrictions.(8)

ii) Advances Made Through Academic Research.

Perhaps the discoveries with the most direct application are the two which concern the source of R. Huang sediment. Firstly, 74 % of the coarse grains which give rise to the deposition in the lower reaches were found to come from one particular part of the loess plateau, only 110,000 km^2 in area (Chapter 1, Section 3(iii)). Secondly, it was discovered that, unlike the situation common in other countries, soil lost from the loess plateau is not stored permanently in the gullies, tributaries, or R. Huang middle reaches, but practically all enters the lower R. Huang.

These two discoveries indicated that conservation work could benefit R. Huang control directly and the scale of the task was to be less daunting, since effort could be concentrated in the area from which coarse grains mostly come. On a more academic level, formulae have been developed and tested to predict the sediment yield of various types of gully.

TABLE 4-1 SELECTED SEDIMENTATION RESEARCH ORGANISATIONS OF CHINA

Name		Location	Main Research Topics	Main Facilities
Agencies Under the Leadership of the Central Government	Sediment Research Division, Water Conservancy and Hydroelectric Power Research Inst.	Beijing	Basic research and important sediment problems arising from practice. (Awaiting reestablishment. To be the centre of Chinese sediment research).	Three experimental halls with dimensions 18 x 60, 18 x 66, and 7 x 42 m, respectively. 0.5 x 0.5 x 32 and 0.5 x 0.5 x 14 m flumes with adjustable slopes.
	Sediment Research Division, Inst.of Hydraulic Research, RHWCC.	Zhengzhou	R.Huang sediment problems including putting sediment to use as a natural resource.	25 x 88 and 10 x 107 m experimental halls. Two sediment mixing basins to concentrations of 800 kg m^{-3}. Two large flumes, one with adjustable slope.
	River and Canal Division, Northwest Inst. of Hydrotechnical Research.	Wugong	Sediment problems relating to N.W. China, including canals, intakes, hyperconcentrated flow, siltation of small to medium sized reservoirs.	24 x 60 and 21 x 75 m experimental halls. 1000 m^2 outdoor experimental area.
	Division of Hydrology and Hydraulic Structures, Chinese Academy of Railway Science	Beijing	Scour around bridge piers. Local river regulation.	Experimental areas of 1160 m^2 indoors and 1500 m^2 outdoors. Three fixed and one tilting flume.
	Division of Geomorphology, Inst. of Geography, Academia Sinica.	Beijing	Fluvial processes in geomorphology.	Experimental area of 600 m^2. Part of the floor may be raised or lowered to simulate tectonic movement.

Continued

TABLE 4-1 Continued

Name		Location	Main Research Topics	Main Facilities
	Northwest Inst. of Soil and Water Conservation, Academia Sinica.	Wugong	R.Huang soil and water conservation problems.	
	Division of Debris flow, Lanzhou Inst. of Glacial and Frozen Soil Research, Academia Sinica.	Lanzhou	Debris flow in Northwest China.	Experimental area of 500 m^2. 0.5 x 0.78 x 14 m adjustable flume with maximum slope of 17%.
	Inst. of Desert Research, Academia Sinica.	Lanzhou	Movement of wind blown sand. Desert regulation.	700 m^2 experimental area. Wind tunnel with maximum cross-sectional area of 3 m^2
Colleges and Universities	Sediment Research Lab., Dept. of Hydraulic Engineering, Qinghua University.	Beijing	Basic research and important sediment problems arising from practice. Emphasis on rivers of North China.	24 x 90 m experimental hall. 1 x 1 x 60 m flume with adjustable slope. (under construction).
	Xi'an Experimental Station in Hydraulics, N.W. College of Agriculture.	Xi'an	N.W. China's sedimentation problems including the exclusion of sediment from turbines and canal intakes.	250 m^2 experimental hall. 350 m^2 outdoor model basin. 0.4 x 0.6 x 22 m flume with adjustable slope.
Provincial Agencies	Division of Sediment Research, Shanxi Provincial Inst. of Hydraulic Research.	Taiyuan	Shanxi province's reservoir and canal sedimentation.	18 x 60 m experimental hall. 0.5 x 0.6 x 26 m flume with adjustable slope.

Continued

TABLE 4-1 Continued

Name	Location	Main Research Topics	Main Facilities
Shanxi Provincial Research Inst. of Soil Conservation.	Lishi	Shanxi province's soil and water conservation.	
Shandong Provincial Inst. of Hydraulic Research.	Ji'nan	Sediment problems arising from the diversion of R. Huang for irrigation and reclamation purposes.	
Gansu Provincial Research Inst. of the Electric Power Centre.	Lanzhou	Turbine erosion and the exclusion of sediment from turbine intakes.	
Soil and Water Conservation Experimentation Stations.	Various, Nation-wide	Effects of collective soil and water conservation methods.	

Source: QIAN Ning, DAI Dingzhong, 1980, pages 28 to 31.

Extremely high silt loads common to the rivers of such a large area have necessitated extensive research into reservoir sedimentation problems and this has not been restricted to large-scale projects such as at Sanmenxia. Much work has been directed to the investigation of the laws governing deposition morphology and backwater extension, and preliminary methods to predict them have been developed. Methods have been found to reduce or discharge deposition and these are adapted to the locality, the determining factors often being situated downstream. For example, the main concern of the Sanmenxia reservoir is for flood control downstream. In arid regions, however, to divert even the water discharged for reservoir purging to productive use is the overriding factor, and so special operational regimes are needed which are united with warping. There are now more than ten reservoirs where silt discharging through syphons is being tried to reduce water loss. In the case of medium and small reservoirs it has been found that near the dam, under the clean water layer, a very deep layer of muddy water remains unconsolidated for a long time. This is due to the reduced settling velocities within a structure comprising many flocculated particles, and can be used to enhance density current purges.(9) The use of heavily silted water is discussed separately in Section 4-2(i).

The fluvial processes found in heavily silted streams are in many respects different from those of ordinary ones. The channel morphology of the upper part of the lower R. Huang, for example, is sufficiently unusual to have warranted a special name, 'wandering stream'. The main difference would appear to be related to the discovery that, for heavily silted streams, the sediment carrying capacity varies with the oncoming sediment load. The channel may rapidly undergo large changes in section and bed composition, and is in an unstable state. When hyperconcentrated flows occur with a sufficient proportion of fine particles severe erosion (bed-ripping) occurs and this, together with other characteristics of such flows, has been studied with a view to bringing greater accuracy to river control.

The above three aspects involve several different academic disciplines and both theoretical and empirical work. The methodology itself also forms an interesting branch of study where, for example, advances have been made with modelling and instrumentation. Other complementary fields of study must be covered in order to solve the problems of engineering in a silty environment. Here methods have been sought to prevent the more heavily silted parts of the flow from entering turbines, and special erosion resistant coatings have been found for turbine blades. The special problems of erosion around bridge piers is another example which has been studied.

2) Silt and Water Resources Put to Use.

It has long been realised that to allow the soil of the loess plateau to be washed away, eventually to the sea, is a huge waste of a valuable resource, as is also the case with water. Yet the early concept of putting these resources to use had dealt more with preventing them from leaving the hilltops, than with their recovery and use further downstream. Whilst it would seem very desirable to stop all soil and water loss in one go, that is not practicable, and consequently ways have been sought to promote the latter aspect. This section seeks to describe the advances that have been made in drawing off heavily silted water for use, both in spite of, and because of, its high sediment content.

i) Irrigation Projects Along Heavily Silted Tributaries.

For many years the heavy silt load of the rivers of Northern China was a nuisance which was capable at times of putting irrigation schemes out of action. Taking as an example the three major irrigation schemes on the Guangzhong plain, the Jinghui, Luohui and Weihui (rivers Jing, Beiluo and Wei, respectively) schemes, it is possible to illustrate how this inhibiting attitude was abandoned and replaced by the view that, properly treated, sediment can be a blessing.

All three schemes have been renovated and extended in recent times. The Jinghui scheme for example now serves 2.65 times the area it served in the early fifties, although it is still about a third smaller than it was in ancient times (Qin dynasty) because the R. Jing has cut into its sandstone bed by several metres.[10] There are now a number of sets of intake and return gates, for returning water to the river because it is too silty to be allowed to enter the canal system, from various historic times, which were abandoned as the river level fell too low to be used. The present scheme uses a diversion weir across the stream to overcome this problem. Total yields still exceed those of the Qin dynasty. This is because although the area is smaller the per unit yields are five times higher, owing to better management.

The basic situation of the three schemes is given in Table 4-2. The Summer floods of these rivers contain very high concentrations of silt (Table 4-3), and it had long been the practice to prohibit the use of water whose silt concentration exceeded 15 % (166 kg m^{-3}), even though, in the Zhaolaoyu area of Fuping County, Shaanxi, water with higher concentrations has been drawn on and off without trouble for over 2300 years. Nobody is very sure whence came the interdiction, but it has been suggested that it might have originated when the Jinghui canal was reconstructed in 1938 and suffered serious deposition.(11)

Nevertheless, the restriction has had severe consequences. It has meant that during the sixty or so days of crop ripening and swelling, when water needs are greatest and, unfortunately, local droughts are most common, there would be between 360 and 480 hours when the limit was surpassed. Furthermore, owing to the scattered nature of local storms and the difficulties of handling the consequent transient changes of river water level and silt content, about 40 days' supply would be affected. Whereas the total requirement of the three regions was 2540×10^6 m^3 yr^{-1}, only some 1330×10^6 m^3 yr^{-1} could be provided. If, in any extreme case, the greatest part of the rainfall occurred in one big storm and gave rise to high silt concentrations, the major part of the annual water supply would have had to have been allowed to flow away unused.(12)

Beginning in 1954, the trunk canal of the Luohui scheme (Figure 4-3) was used to transport heavily silted water, reaching 59.8 % (959 kg m^{-3}), for filling in a gully by deposition, and it was found that there was no sediment deposited in the canal itself. Throughout the fifties, the problem of alkalisation became more widespread within the region and, in 1964, water of concentration 47.7 % (682 kg m^{-3}) was led to some fields to counter this problem by warping, and again there was no deposition in the trunk canal. From 1969 onwards, this was extended to the whole irrigation district, but it then ran into trouble. In 1973, when the silt peak lasted an unusually long time, serious and widespread silting occurred. Some 1000人 had to be organised to jump about in the water so as to stir

TABLE 4-2 BASIC DATA FOR THREE IRRIGATION DISTRICTS ON THE GUANZHONG PLAIN

Irrigation District		Headworks	Intake Capacity (m^3s^{-1})	Irrigated Area (km^2)	Topography	Land Surface Slope (%)	Soil	Groundwater
Jinghui		Zhangjiashan	50	880	Northwest high, Southeast low	0·17 to 0·3	Clay loam rather plentiful	Water table high, water quality good, suited to well irrigation
Luohui		Zhuangtou	18·5	493	North high, South low	0·2 to 0·5	Sand loam, loam	High mineral content, not suited to well irrigation
Weihui	Upper	Linjiacun	50	1293	Northwest high, Southeast low	0·2 to 2·0	Medium loam light loam	Water table at depth of 15 to 80 m
	Lower	Guijiabu	50	707	Northwest high, Southeast low	0·2 to 2·0	Medium loam, light loam	Water table at depth of 3 to 80 m, water quality good, suited to well irrigation

Source: YANG Tingrui, et al., 1980, page 93.

TABLE 4-3 ONCOMING WATER AND SEDIMENT CONDITIONS FOR THE THREE SCHEMES

River		Station	Maximum Flood Discharge (m^3s^{-1})	Minimum Discharge (m^3s^{-1})	Annual Runoff ($m^3 \times 10^6$)	Oncoming Silt Load: Annual Total ($t \times 10^6$)	Oncoming Silt Load: Flood Season (%)	Maximum Concentration ($kg\ m^{-3}$)	Flood Season Average Concentration ($kg\ m^{-3}$)	Silt Median Grain Diameter (mm)	Composition
Jing		Zhangjiashan	9200	3·44	1910	265	92·8 July to October	1012	312	0·038	Fairly even
Beiluo		Zhuangtou	4420	1·20	840	95	90 July to Sept.	1093	345	0·035 to 0·042	Fairly even
Wei	Upper	Linjiacun	5030	3·70	3074	207	76·3 June to August	855	189	0·02 to 0·026	Some uneven coarse particles
	Lower	Guijiabu	5970			216		732		0·025	

Source: YANG Tingrui, et al., 1980, page 95.

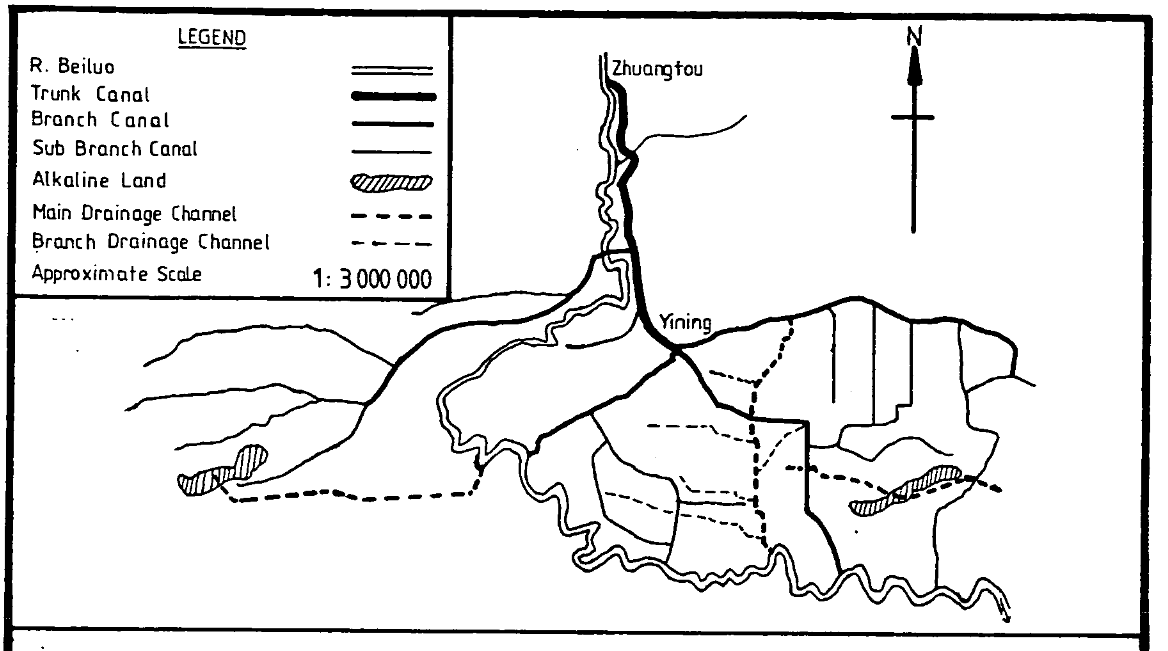


FIGURE 4-3 SKETCH OF THE LUOHUI SCHEME

Source: YANG Tingrui, et al., 1980, page 94.

TABLE 4-4 THE THREE DISTRICTS' TRANSPORTATION AND USE OF HEAVILY SILTED WATER

		Jinghui	Luohui	Lower Weihui	Upper Weihui
Normal maximum concentration to be drawn	(kg m^{-3})	542	964	498	466
	(%)	40·4	60·0	37·9	36·0
Volume of water drawn, in the flood season, whose concentration exceeds 166 kg m^{-3} (15%)	($m^3 \times 10^6$)	15·00	24·93	32·43	
Sediment drawn in flood season	($t \times 10^6$)	8·80	15·05	22·55	
Sediment Transportation	Distance (km)	67	50	200	
	Maximum concentration (kg m^{-3})	542	818	466	
	Maximum concentration (%)	40·4	54·0	36·0	
Maximum concentration ever drawn	(kg m^{-3})	565	964	562	578
	(%)	41·7	60·0	41·5	42·37
	(year)	1978	1977	1974	1979

Source: YANG Tingrui, et al., 1980, page 94.

up the silt and thus facilitate the purging of the system. In 1974 part of the system was in danger of becoming choked up again. The banks had to be raised and the flow concentrated by raking in order to restore the original discharge capacity. Therefore, between 1974 and 1976 the canals were lined, broadened and straightened, using 2,687,000 人 d, ¥ 1,985,000 (£ 567,000) state investment and a contribution of ¥ 710 (£ 203) from the masses.(13)

Meanwhile, research into the characteristics of hyperconcentrated flow had been promoted and empirical formulae had been derived. With the aid of this increased understanding, it became possible to transport silt over long distances without deposition.(14) (Table 4-4). The principles of canal design and use which have been developed in this way all seek to maintain the hydraulic intensity of the flow; the channel design, for example, should include a sufficiently large slope and a deep and narrow section is preferred. Channels should be lined, and straightened, yet whilst bridge piers should be avoided, it has been found that inverted syphons may be used without loss. The modes of operation have to maintain a large continuous discharge to prevent deposition, whilst the needs of various parts of the irrigation district at different times are very variable. This apparant contradiction is resolved in the Luohui scheme by the adoption of the fairly complicated regime described below.(15)

Before the flood season, or between flood peaks, water is supplied to those parts of the system lacking the facilities to cope with very silty flows. This is because the flood peaks have much higher silt concentrations than the basic flow. As successive flood peaks arrive each one is led to one part only of the system, so as to maintain discharge in the trunk canal. Different parts of the system are served on a rotation basis. Silt peaks rise sharply and fall gently and deposition is less likely as the silt content is declining. So, as a given silt peak approaches, it is used for irrigation until the concentration reaches 25 % (297 kg m^{-3}) and then it is used for warping; whereas, as the silt peak recedes, it is used for warping only at concentrations exceeding 35 % (449 kg m^{-3}), below which point it is once more used for irrigation. Furthermore, once the silt content has dropped below 25 %, the area irrigated is increased so as to increase the discharge of relatively clear water in the main canals and flush out any previous deposition. Small branch ditches still suffer deposition, but this is not serious and can be cleared by jumping around in the water, or by digging.

The combined effects of enlarging the capacity of the system as a whole by 84 % and of making use of water with a silt content in excess of 166 $kg\ m^{-3}$ are, together, claimed to have resolved the water shortage problem of the Luohui irrigation district. Furthermore, soil structure can be improved by choosing to draw water from small flood peaks, which contain fine grain silt, or large flood peaks, which contain coarser grains, respectively. Figures for the three irrigation districts show that alkalinity in the top 300 mm of soil can be suppressed by 48.6 % on average, reaching 75.9 % in some places. Topsoil fertility is also improved, there being 71.4 %, 19.7 % and 40 % increases in the content of Nitrogen, Phosphorus and Organic Matter, respectively. Crops grown on land after warping in the irrigation district show 22.8 % to 39 % increases over the yields of unirrigated land in the same region.(16)

The Jinghui and Luohui schemes successfully adopted these measures only in the mid-seventies. In the case of the Jinghui scheme, good conditions for well irrigation had meant that there had not been the urgency to manage the silt discharge as in the Luohui district, and this would explain the late adoption there of these new techniques. In the case of the Weihui scheme, where the trunk canal is some 200 km long, it was thought unlikely for many years that the principles used on the Luohui scheme could successfully be transferred. However, they were found, in practice, indeed to be transferrable, and have in recent times been popularised all over the loess plateau.

These techniques are notable for their joint use of theoretical and empirical advances. With respect to the latter it is also notable that although the first steps were taken previously, the extension of the technique to the whole area occurred primarily in the periods of the Cultural Revolution and shortly thereafter. Therefore, it may be surmised that the general mistrust of experts and established rules, which characterised that period, would have been instrumental in the overthrow of the 166 kg m^{-3} upper limit.(17) These improvements have brought about, in addition to technical and agricultural advances, a reduction of some 46 x 10^6 t (9.5 %) of these three irrigation districts' contribution to the silt of the R. Huang in the flood season, probably amounting to over 10 % for the whole year. Although useful, this is not very significant to R. Huang control, being a reduction of only about 3 % in its annual silt load, and predominantly of the less troublesome fine particles. But, in terms of regional development, it would be very important.

ii) Drawing River Huang Silt for Land Reclamation and Dyke Consolidation.

The rapid expansion of irrigation along the lower R. Huang, which was attempted in the late fifties and was subsequently curtailed owing to alkalisation problems, as described in Chapter 3, Section 6, vii, gave rise to some interesting developments, which benefitted from the silt, in flood control and in agricultural production. A fairly complete picture may be drawn by bringing together what information is available.

It may be remembered that, in the first instance, the emphasis was on drawing water for irrigation. Nevertheless, in some areas large-scale works, requiring headgates and diversion weirs, were being built. In several parts of Shandong, use was made instead of the river's elevation, by drawing off water through syphons. These were easy to construct, as each system would comprise only a few 0.9 m diameter steel pipes to a total length of 100 m to 150 m, well within the financial means of the Production Brigades.(18) It was here too, that syphons had been tried before the revolution, for warping.

Syphoning was as susceptible as any other irrigation method to the problems of alkalisation, whilst being more sensitive to changes in river water level or channel position. For example, in 1958, an early experiment was undertaken in Licheng County, near Ji'nan, to use the crude flood irrigation from the syphon projects built, since 1955, in a better way. This involved changing from the usual dry cultivation of wheat, to rice paddies, as had been done successfully in Linyi County, South-East Shandong. Yet the experimental crop failed when the R. Huang water receded just at the time for transplantation of the seedlings.(19) For all these reasons their use was suspended in the early sixties along with other irrigation measures which used R. Huang water.

Yet the higher per unit yield obtained on the smaller area where rice crops had succeeded, and the consistently good wheat yields from land previously dressed with silt from the syphons, led to further experimentation, especially important in the light of the failure of the Sanmenxia reservoir permanently to reduce the river's downstream silt content. In 1965, it was reported that by supplementing the syphons with pumps and by complementing the system with proper drainage ditches, yields of 2.25 t ha^{-1} had been obtained the previous year on 1200 ha at Licheng. A conference was held, under the auspices of the Shandong provincial authorities, and it was decided that other Counties along the R. Huang should continue the experiment on a small scale, of 700 ha to 1400 ha each, to a total of 13,000 ha for the whole province.(20)

Owing to seepage from the elevated river and to the previous use of much soil for dyke building, the strip of land just outside the dykes was low and the most prone to alkalisation. It was here that conversions to rice paddies proved most beneficial. Rice has a relatively strong tolerance of alkali and the flooding, provided that there was adequate drainage, tended to wash out the salts. Furthermore, with successive deposition the low land was gradually built higher, which assisted drainage.

These developments were undertaken independently of the dry cultivation which continued further from the river and care was taken to prevent the spread of alkalisation by separating the different cultures with drainage ditches. Furthermore, water drawn for wet cultivation was not necessarily done through syphons, but special culverts were also built. By 1972, there was a total of over 50 culverts and 100 syphon tubes along the lower R. Huang, which were reported to have been treating 267,000 ha of productive land.(21)

The practices adopted led to the land immediately beyond the dykes being raised. It was realised that therein lay a good method for consolidating them and, accordingly, the use of settling ponds for this purpose, and to provide clear water for both wet and dry cultivation, became popular. It was found that this method effectively prevented seepage from the R. Huang. From about 1970 it has been popularised, along the whole of the lower river, in its own right as a method of strengthening the defences against flood.(22) (Figure 4-4)

At about the same time the Ji'nan Dyke Maintenance Office began to use simple sediment suction boats to provide the silt for dyke strengthening and consolidation. Owing to the unreliable supply of materials, there was much variation in the detail of the design of such boats. They were made from wood, steel or cement, used a variety of pumps and motors or engines, and not all of them were self-propelled, but the principle upon which they worked was constant. Each boat had a captain and three crews of four, who would use water cannon to agitate the river bed, and when the concentration of the mixture so created was sufficiently high (over 200 kg m^{-3}), it would be sucked up and pumped over the dykes to the settling ponds.(23)

This method is difficult to use where the main channel is a long way from the dykes, but at the perilous section where the flow acts directly against them, it is particularly effective. It has been estimated to use only one tenth of the labour needed to reinforce the dykes by hand and, despite the cost of some ¥ 100,000 to ¥ 150,000 (£ 35,000) per boat, to save 60 % of the cost. Although not suited to the type of rapid mass campaign, by which the whole length of the dykes may be worked in a few years, the use of such boats provides advantages with respect to agriculture; in particular it conserves the topsoil outside the dykes, and provides clear water for irrigation.

FIGURE 4-4 DYKE BUILDING METHODS OLD AND NEW

(a)

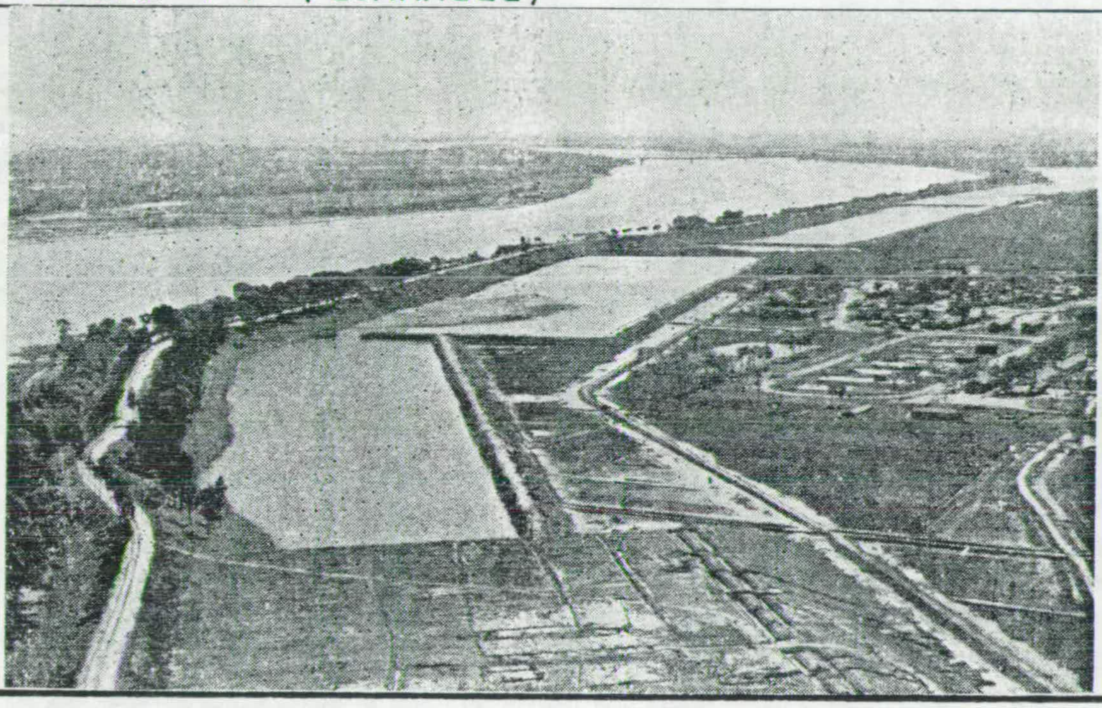
Photo: R. Huang Exhibition, RHWCC, Zhengzhou, 7 July 1980. The first large scale dyke raising effort of the fifties. (PM)

(b)

Photo: View from the main dykes near Huayuankou, looking away from the river. In the left foreground a pipe delivers R. Huang silt and water over the dyke. In the background is a small embankment, and the area in between is where the silt is allowed to settle for dyke consolidation. An impromtu wheat crop is grown during the process. (PM)

Continued

FIGURE 4-4 (Continued)



(c) Settling ponds for dyke consolidation by warping.
Source: RHWCC, Eds., 1979, p. 255.

By careful use of silty water deposited when the river discharge is high or low, respectively, and by good management of the settling process, silts of various sizes may be drawn selectively either for engineering reasons (such as lining the dykes with clays to prevent seepage, whilst filling the centres with coarser silts), or for agricultural reasons (such as drawing the fertile Summer silts for the top metre of the consolidation, so that it might be cropped, which in turn protects it from wind erosion). Meanwhile, the silt load of the river is reduced thereby.(24) Since the mid seventies about 50×10^6 m^3 yr^{-1} of sediment has been deposited, principally by using boats, of which there are now 240. Along ordinary sections of the dykes, the consolidation is some 50 m wide, whilst at the danger points it is made 100 m wide. In both cases it is brought up to the level of the dyke tops. Since, during construction, the settling ponds are usually 4 m to 5 m above the level of the surrounding plain, extra drainage has to be provided to obviate their spoiling agricultural land.(25)

These methods have proven to be very effective in stopping the kind of small seepage which historically has been the usual cause of dyke breaches, as opposed to overflowing or erosion. At Huayuankou, for example, traditional methods which had been used to repair the large breach of 1938, gave rise to constant leakages as the materials (mainly willow stalks) rotted. In 1975, this section was consolidated by deposition and no leak has been found since. Also, in the stretches in Shandong where leakages occurred during the flood of 1958, the water level has twice exceeded that level since consolidation, once in Summer and once in Winter, both without incident. As for reduction in main channel deposition of the lower R. Huang, although the silt drawn off is only some 3 % of the river's annual load, it is about 15 % of the annual deposition in the whole of the lower reaches. Furthermore, in the Shandong stretch, deposition usually occurs during Winter, whilst in the Summer floods scouring takes place. Whilst this method may not be able to make any significant impact above Aishan (i.e. in the He'nan stretch) where, on average, some 400×10^6 t are deposited annually, in Shandong the average deposition of 39×10^6 t yr^{-1} could be completely removed by fewer than 150 boats.(26) However, as the following quotation shows, there has already been some financial restriction,

> "Consolidation by warping is an effective method to eliminate hidden dangers from the dykes and prevent them bursting. It should be vigorously carried out. At present the two Provinces have only 200 or so boats and can deposit only 40 x 10^6 m^3 yr^{-1} or 50 x 10^6 m^3 yr^{-1}. Yet, owing to 'serious financial shortages forcing many boats to cease to work', the pace of consolidation is very slow. Calculating for the planned required water level for 1983, there is still a task of 400 x 10 m^3 to be done, so this work needs greatly to be strengthened."(27)

iii) Improvements in Dam Building Methods.

A similar use of sediment is made in the gullies of the loess plateau where silty water is used in the construction of earthen dams. The basic method came from the Soviet Union, and involves leading silt laden water to the top of the dam, where deposition takes place, and then draining off the clear water. The resulting dam is termed a 'Hydraulic Fill Dam'. In China new techniques were developed, in the late sixties, which make use of the natural conditions on the loess plateau. The gullies are deep and the surrounding soil is loose and often uncovered. Conditions are good for transporting silt by the use of water. In the new technique, soil is first loosened, sometimes by hand or explosives, but more usually by water cannon. These are used in the next stage, which is to create a dense mix and to transport it by gravity to the dam surface for settlement and subsequent drainage. It is the use of water cannon to mix and transport the silts which enables a stronger dam to be built with a smaller section and a more homogenous texture. In comparison with earthen dams made by ramming or rolling, it is quicker, requires fewer people and less equipment. This can reduce the total cost by 60 %. (28)

This type of construction has been widely popularised, and in Shanxi and Shaanxi, for example, applications number over 8000, of which over 5000 are more than 35 m high and the largest reservoir so formed has a capacity of 69 x 10^6 m^3.(29) Yet, it should be emphasised that, as with any dam construction on the loess plateau, there has to be the proper complement of spillways, drainage system and gully side conservation measures if the dams are not to be washed away in storms. They are most successful as part of comprehensive whole catchment control and development schemes, such as are described below.

3) Comprehensive Control and Development.

This section is concerned with the technical aspects of the methods by which soil and water conservation measures have been applied successfully on various parts of the loess plateau. The reasons for failure of less well balanced approaches and the delay in applying over a wide area the present techniques, which were first suggested in the fifties, have been discussed in Chapter 3. The new policies, proposed to redress the balance, are discussed in Chapter 5. Three examples are given here, and it is hoped both to illustrate the methods available, and to emphasise the necessity of adapting them to the particular local circumstances.

i) Gullied Plateau Region.

In the smaller, Southern part of the loess plateau, where the topography comprises a level plateau surface cut by deep gullies whose steep sides are not usually cultivated, there is little need to withdraw tillage. Thus, the apparent contradiction between soil conservation and local farming methods does not arise. The two are complementary, and the principal aims of conservation work are to prevent the formation of new gullies or the extension or widening of existing ones, whilst doing as much as possible to reduce runoff and promote agriculture.(30)

Chunhua County, an administrative area of 965 km^2 on the Southern edge of the gullied plateau region in Shaanxi, is one such area. The 19 Communes of this County have 219 Brigades, divided into 981 Production Teams, and the total population is 145,000人 . In the Southern part is a small hilly region, but the rest is mainly level land cut by six large, clearly defined, steep sided gullies, several kilometres in length; and 228 smaller ones, each still over 1 km long. Precipitation is about 550 mm yr^{-1} and the sediment yield modulus is about 2500 t km^{-2} yr^{-1}, principally from gully sides and from where runoff collects on the gently sloping plateau surface, whose average slope is 8 % to 14 %, becomes concentrated and gives rise to sink holes or gully extension.

Work began relatively late, in 1970, with improvement works on the plateau surface. From 1974, afforestation was also undertaken. Mass campaigns and the sharing of the demands for manpower amongst various Brigades are used extensively here, especially in the agricultural slack season, of about 100 days, when 50 % to 60 % of the county's workforce may be brought together for conservation work, including some ten days devoted to afforestation. For example, in 1974, four Communes together pooled 10,000 人 and planted 1.3 km^2 of trees in 1½ days. Emphasis is placed on planning, and a whole catchment or water system is taken as the planning unit. In order, it is said, to safeguard the masses' enthusiasm, 70 % of any benefit to accrue from this work may be kept by the Communes and Brigades.

Plateau Surface Protection: The plateau surface is the county's agricultural production base. Its management and use relies on land levelling and soil amelioration. Cultivated land which has a surface slope of less than 12 % is made up into broad levelled bands 50 m to 70 m wide, and attention is paid to keep the original top soil layers uppermost during the levelling process, so as to keep the organic matter where it is needed. This is called 'Niandi' (埝地), or Bench Terracing (Figure 4-5). On uncultivated plateau land above gully heads, a series of large, low, earthen embankments may be built across the contour lines to collect the Summer storm water, which may reach 58 mm d^{-1}, and its silt. The depressions behind these barriers gradually silt flat, whereupon the new land can be used for agriculture. The gully below is thus fixed and prior to completion of the entire works the land above may be used for grazing. Attention is also paid to the prevention of new gullies forming from roads; they are widened, straightened, metalled, lined with trees and, wherever possible, built up proud of the plateau surface. Runoff from roads is led back to the fields.

Gully Edge Protection: Along gully edges, where the land slope is greater than 12 %, terraces are constructed. Where the slope exceeds 26 %, narrow, reverse-slope terraces are built and consolidated by being planted with shrubs and trees (Figure 4-6).

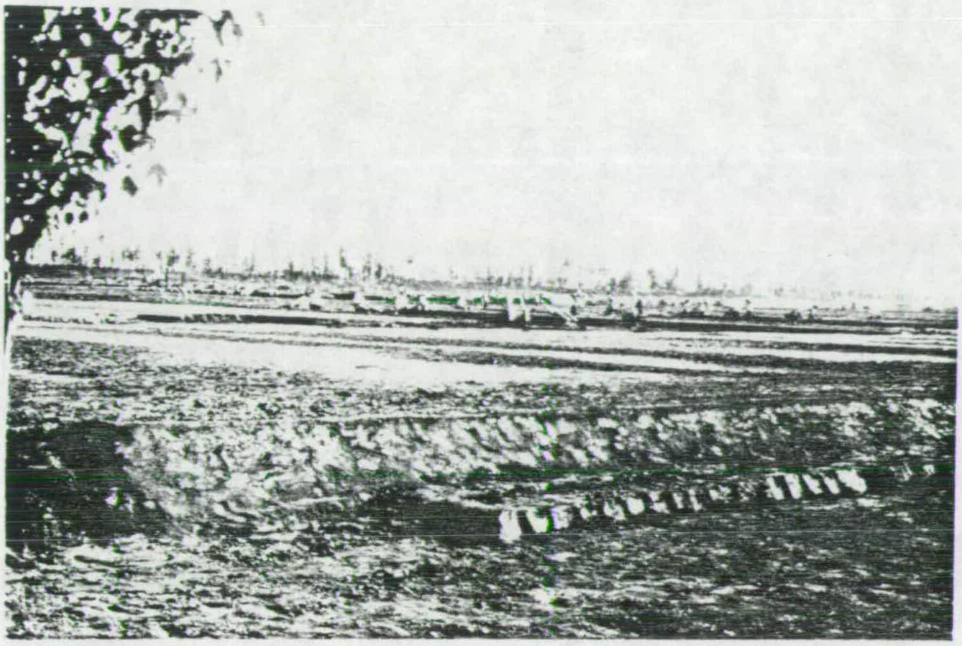


Photo: Chunhua County, Shaanxi, 20 July 1980. (PM)

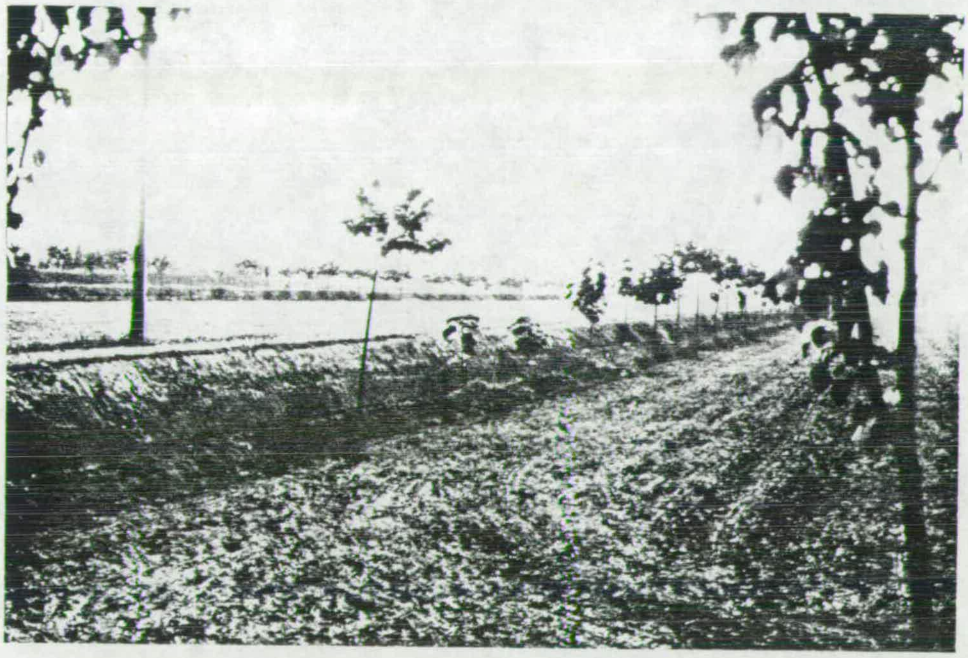


Photo: Chunhua County, Shaanxi, 20 July 1980. (PM)

FIGURE 4-5 BENCH TERRACES UNDER CONSTRUCTION AND COMPLETED

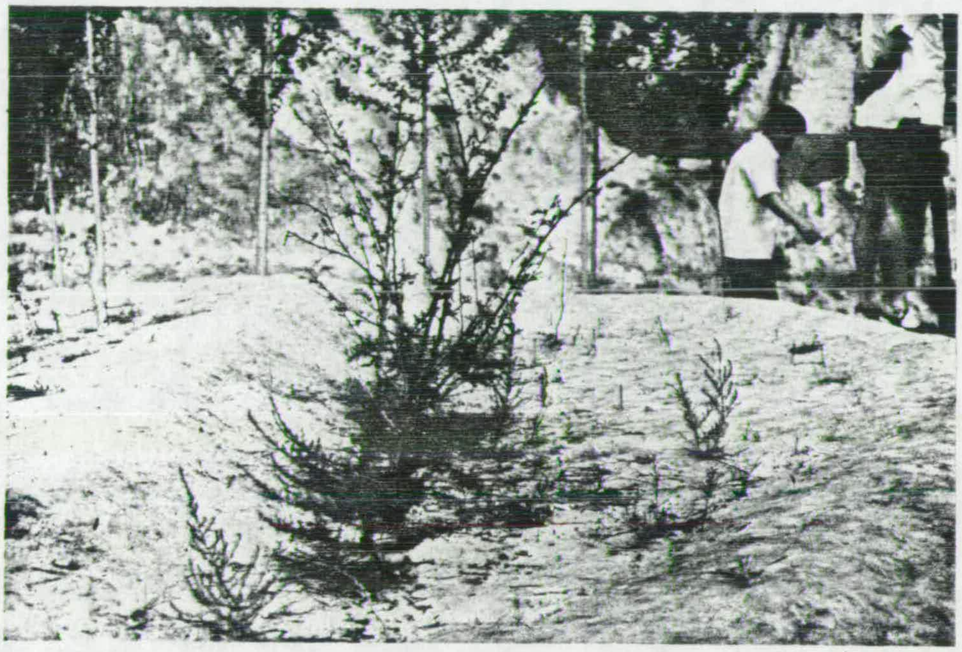


Photo: Chunhua County, Shaanxi, 19 July 1980 (PM)

FIGURE 4-6 REVERSE-SLOPE TERRACES

Gully Floor Control: Larger gullies rely on reservoirs as a means of trapping silt and storing water. The small alluvial plains at bends in the rivers are often cultivated. As an experiment one smaller tributary gully floor has been completely forested. It now holds back all the silt and 60 % of the water.

Extent of the Work: Since work began and up to the end of 1979, some 228 km^2 have been afforested, including 6.7 km^2 in reverse-slope terraces, 182 km^2 on what had been barren land and 64 km^2 of economic forest, mainly orchards, of which one third already bears fruit. There are 16 km^2 put aside as nurseries, 85 % of saplings and seeds are self supplied, and transplanted saplings have a survival rate of 50 %. 116 km^2 of plateau surface have been levelled, 160 km^2 of reverse-slope terraces have been built and 32 km^2 of grass has been sown. This work means that in the County as a whole, there are now 387 km^2 of tilled land, 229 km^2 of forest, 105 km^2 of grass and 233 km^2 of barren land. There are 24 small reservoirs and 35 silt precipitation dams which together collect the silt from catchments totalling 375 km^2. In a total reservoir capacity of 28.3 x 10^6 m^3, with an effective capacity of 14 x 10^6 m^3, 12.7 x 10^6 t of silt have already been deposited. Only one of the small reservoirs uses a silt-purging operational regime. There are also 94 pumping stations and 109 wells. The total irrigated area is 68.7 km^2.

It is interesting to look at the types of problem to have been encountered in the course of undertaking this silt-control work. In one of the six large gullies, Qingzhuang Gully, a reservoir was built in 1958 to control 76 km^2 of the catchment. However, commensurate soil conservation works were not done adequately and the sediment yield modulus did not fall below 3020 t km^{-2} yr^{-1}, and by 1970, 2.1 x 10^6 m^3 of its 2.9 x 10^6 m^3 capacity had been filled with silt. Thereafter, another reservoir was built upstream, which controlled some 20 km^2 of the catchment and the following conservation measures were taken: 120 ha of plainland were levelled, ten small precipitation dams were built in tributary gullies, and 533 ha of slopes were afforested. The sediment yield modulus fell to 1860 t km^{-2} yr^{-1} and in nine years only 0.22 x 10^6 m^3 of its original 2.84 x 10^6 m^3 capacity were lost. Silt purging is not carried out there. In the course of afforestation several unsuccessful attempts were made to use new species of tree, but only locust species were found to be suitable. The other major problem, still not satisfactorily resolved, is that of retaining the plateau's soil moisture.

Effects of the Work: Estimates for the reduction in soil loss were available only for levelled land, where it was claimed that water and silt runoff had both been eliminated. For the whole County, 4120×10^3 t yr^{-1} of silt were estimated to have been lost between 1972 and 1977, compared with 7010×10^3 t yr^{-1} for the previous ten years. However, it is not indicated as to what extent this has been due to agricultural conservation measures as compared with the retarding effect of reservoirs. One brigade reported a four-fold increase in the organic content of the soil of levelled fields between 1973 and 1978. The average unit grain yields for the whole County between 1971 and 1978 were 68.4 % higher than for 1970. However, the average yield in 1980 was only 1.35 t ha^{-1} to 1.5 t ha^{-1}, a figure comparable to yields on unirrigated land in the poorer gullied hillock region to the North. Despite the many successes made in Chunhua County, essentially in the short space of ten years, the relatively slow development of water conservancy, and especially the small area irrigated, still do not permit agricultural production there to be free from the threat of drought.

ii) Gullied Hillock Region.

The greater part, some 250,000 km^2, of the loess plateau is so severely eroded that it no longer has any level surface, but is cut into many small, rounded, barren hillocks, criss-crossed by gullies. The general topography is shown in Figure 1-11. Most of the hilltops are barren, some are cultivated and very few have been terraced. It is throughout this region that the apparent contradiction arises between withdrawing tillage from the hilltops, so that it may be replaced with grass or trees to reduce soil and water losses, and providing sufficient food to support the local population. One solution, which has been developed successfully in small catchment areas, is to make the catchment area the basic unit. The first task is to provide an area of stable and high yields on precipitated or other "basic land" along the gully floor, or elsewhere, suitably protected against the Summer torrent; This is followed by the withdrawal of tillage from a larger area of hilltops, equivalent in total yield to the new land, and then, gradually, to extend the process until the whole catchment has been treated. Not only should runoff be greatly reduced, whilst guaranteeing the supply of staple foods, but extra income should also accrue from economic activities on the new forest or pasture land.(31)

The above process is slow and needs careful planning with special attention being paid to local conditions. Nianzhuang Gully, a small tributary of the Yan river, 14 km Northeast of Yan'an City, in the gullied hillock region, is a good example of one of the few such catchments where these principles have been adopted continually since their inception in the early fifties and, therefore, may be used to illustrate the available techniques.

The Nianzhuang Commune comprises 52 km^2 of the gully's 54.2 km^2 catchment area (the former figure is used in all subsequent data). The main gully is 14.6 km long, running Northwest to Southeast with a slope of 0.2 ‰. There are 203 tributary gullies of which only nine are longer than 2 km and 139 are between 0.3 km and 1 km long. The total population is 3446 人 (66 人 km^{-2}) and the original area of tilled slopes was 8.76 km^2 (Table 4-5). The most serious type of erosion is caused here by water, the next is by gravity (landslips), wind erosion is slight. The long term runoff coefficient is 33,000 $m^3\ km^{-2}\ yr^{-1}$ and the sediment yield modulus was 6000 $t\ km^{-2}\ yr^{-1}$. Thus, before control, $312 \times 10^3\ t\ yr^{-1}$ of silt were contributed, through the R. Yan, to the R. Huang. Originally this region was one of broad-leaved deciduous forest but now agriculture leans heavily towards cereals and even after 25 years of erosion control, vegetables, oil crops and medicinal herbs together account for only 10 % of the agricultural production. Production is usually from one crop per year as the area has not proved suitable for multicropping.

Provision of "Basic Land": Work began in 1955 and, by the end of 1979, 189 earthen dams had been built, mainly as silt precipitation dams, ten of which were in the main gully. The area of land so far created behind these dams is 107.3 ha, and this is expected to increase to 132.6 ha. In 1980, a stone dam was added to store clear water. In addition, 4.3 ha have been reclaimed by straightening the river course, irrigation has been provided elsewhere on 70.2 ha, 167.9 ha has been terraced and 1.2 ha of broad level fields (Niandi) have been created. Thus 376.2 ha have been made into basic fields by the engineering measures taken so far (using 132.6 ha as the area of precipitated land), which is about 0.1 ha 人$^{-1}$.

New Plant Cover: Between 1965 and 1979, two tree belts, totalling 617 ha have been planted, one along each side of the main gully. Timber trees are grown along the shadier side, and along the sunnier side there is 120 ha of fruit trees, one third of which have begun to bear fruit. These trees are grown in bands on reverse-slope terraces interspaced with bands of shrubs, notably cannabis (Figure 4-7c). A further 7.3 ha has been put aside as a nursery for saplings, and 167 ha has been sown to grass.

Thus, excluding the nursery land, 11,6 km^2, or 22.31 % of the catchment has been treated in one way or another. Including other works, such as road improvement and a 22 km electric main, a total ¥ 550,000 (£ 157,000) has been expended. That is investments of ¥ 10,600 km^{-2} for virgin land and ¥ 47,000 km^{-2} for controlled land.

The Effects of the Work: The effectiveness of the work so far in reducing runoff and soil erosion, and the contribution of each respective method, may be judged from Table 4-5. The plan for 1985 provides for the gradual withdrawal of all tillage from slopes and the creation of three mu 人$^{-1}$ of grass, five mu 人$^{-1}$ of forest and two mu 人$^{-1}$ of basic fields. One mu 人$^{-1}$ of this will be precipitated land, (0.2 ha 人$^{-1}$. 0.33 ha 人$^{-1}$, 0.13 ha 人$^{-1}$ and 0.07 ha 人$^{-1}$, respectively). The criterion used in the plan for the withdrawal of tillage from slopes is that, elsewhere, there should be 0.07 ha 人$^{-1}$ of land which has a stable annual yield of 7.5 t ha^{-1}人$^{-1}$. The sediment yield modulus is expected to be reduced to

TABLE 4-5 EFFECTS OF VARIOUS CONSERVATION MEASURES IN NIANZHUANG GULLY

	General Characteristics			Original Condition Prior to 1955				Condition in 1979				Planned Condition for 1985			
	Specific Runoff ($m^3 km^{-2}$)	Specific Erosion ($t\ km^{-2}$)	Specific Yield ($kg\ ha^{-1}$)	Area (km^2)	Runoff ($m^3 \times 10^6$)	Erosion ($t \times 10^6$)	Estimated Total Yield (t)	Area (km^2)	Runoff ($m^3 \times 10^6$)	Erosion ($t \times 10^6$)	Estimated Total Yield (t)	Area (km^2)	Runoff ($m^3 \times 10^6$)	Erosion ($t \times 10^6$)	Estimated Total Yield (t)
Natural Wasteland	31470	4170	0	43·24	1·36	0·18	0	35·97	1·13	0·15	0	28·70	0·90	0·12	0
Tilled Slopes	40350	15000	750	8·76	0·35	0·13	657	4·43	0·18	0·07	332	0	0	0	0
Irrigated Land (Damland and River Berms)	0	0	4500	0	0	0	0	2·07	0	0	931	2·33	0	0	1048
Level Terraces and Bench Terraces	2780	620	1125	0	0	0	0	1·69	0·005	0·001	190	2·33	0·006	0·001	262
Afforested Land	9280	62	0	0	0	0	0	6·17	0·06	0	0	11·67	0·12	0·001	0
Grassland	31470	7350	0	0	0	0	0	1·67	0·05	0·01	0	6·97	0·22	0·05	0
Total	32800	5900	'Yield' refers to grain crops only	52	1·71	0·31	657	52	1·425	0·231	1453	52	1·246	0·172	1310
	Long term average														

Source: Fieldtrip notes made at Nianzhuang Gully on 28 July, 1980.
Note: Economic benefit accruing from forests and grasslands is not shown.

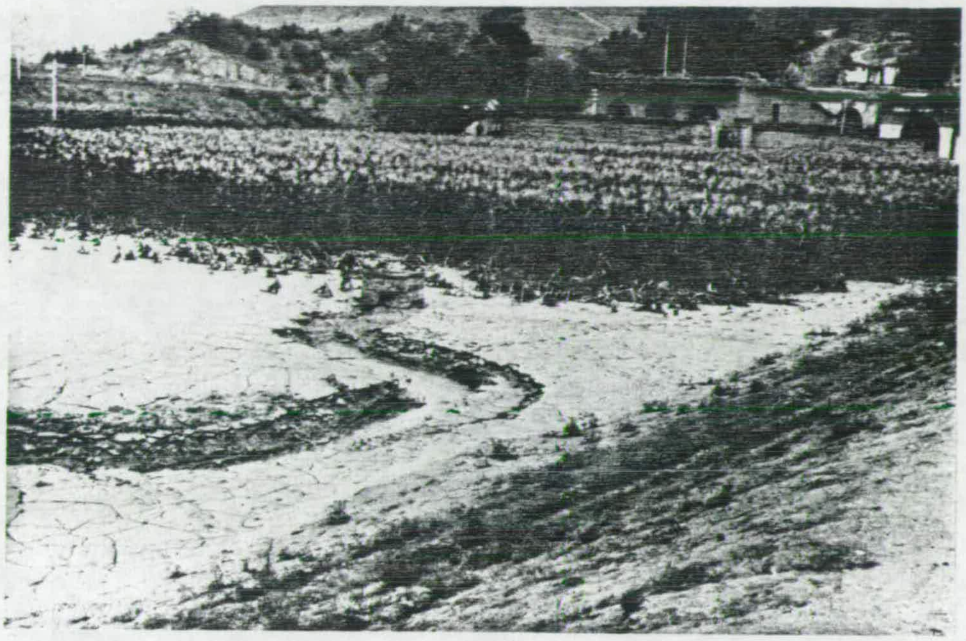
3332 t km^{-2} yr^{-1}. Since 1974, all silt not held by the slope control measures has been trapped by the dam system. However, in 1979, its unused retention capacity was only 1×10^6 m^3 (1.3×10^6 t) and, even using the estimated 1985 erosion coefficient, it would last but seven years. Thereafter, the gully will resume the supply of silt to the R. Yan at about half its previous rate.

The average unit grain yield for tilled slopes is 0.750 t ha^{-1}, for terraced land 1.125 t ha^{-1}, and for irrigated land 4.5 t ha^{-1}. Calculating from the 1979 figures of Table 4-5, these figures would give an annual grain yield of some 1450 t and the official figure is 1200 t, or about 0.350 t 人$^{-1}$. To this must be added the income from fruit and sideline production and together they would constitute a considerable improvement in yield over the simple 657 t yr^{-1} (0.191 t 人$^{-1}$) estimated from the original 876 ha of tilled slopes.

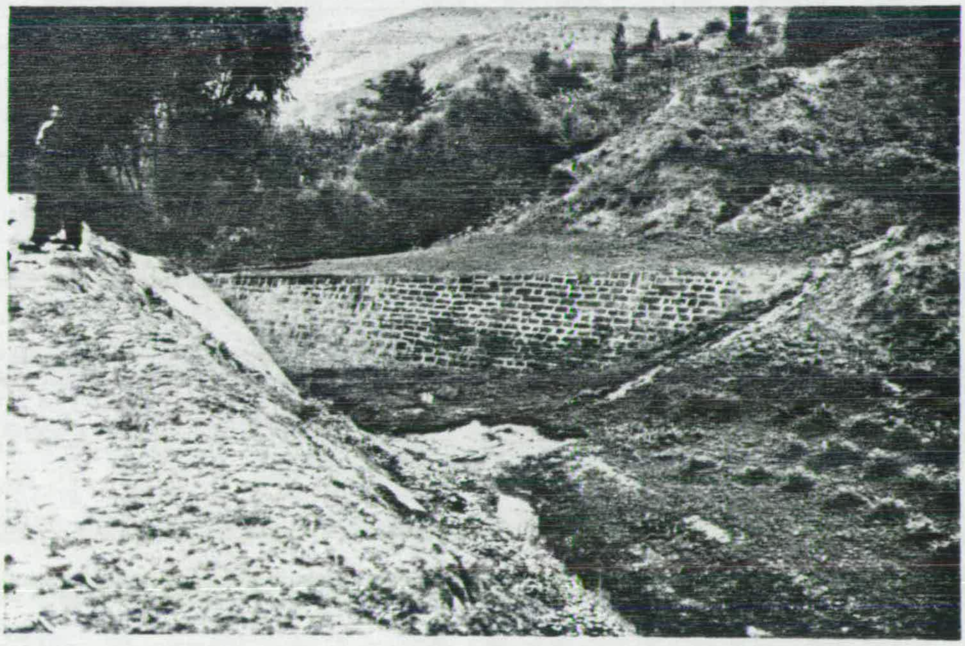
Thus, it may be seen that whilst there are excellant prospects for regional development, those for reducing the silt content of the R. Huang are somewhat more distant, since the dam system is nearly full and many years will be needed to reduce significantly further slope losses. It should be emphasised that this prognosis applies only to the gully in question and that its predicted erosion coefficient is really quite low in comparison to other parts of the loess plateau. If this kind of result could be acheived on the 110,000 km^2 which contribute 74 % of the R. Huang's silt load and where the average sediment yield modulus is nearly 14000t km^{-2} yr^{-1}. it would constitute a very significant improvement.

The types of problem encountered at Nianzhuang Gully include alkalisation where poor dam layout and drainage has caused 4.7 ha to be affected, two ha of which are incapable of growing any crop (Figure 4-7d). Some of this land had extra drainage facilities added in 1980 and the results are awaited before proceeding further. Although the main gully dam system has proper drainage facilities and flood spillways, (Figures 4-7a, 4-7b), it was designed to resist a storm of the intensity expected once in twenty years (5 % criterion), and it is now thought that this is too low. It is hoped that in future, terraces will yield 1.5 t ha^{-1} and irrigated land at least 6 t ha^{-1}. Only then,

FIGURE 4-7 NIANZHUANG GULLY 1980



(a) Photo: View from the top of No. 4 precipitation dam, (PM) Nianzhuang Gully, Yan'an, Shaanxi, 28 July 1980, showing the proper drainage facility, the newly precipitated silt, and an impromptu crop of maize.



(b) Photo: The flood spillway provided for No. 5 precipitation (PM) dam, Nianzhuang Gully, Yan'an, Shaanxi, 28 July 1980.

Continued

FIGURE 4-7 Continued

(c) Photo: Slope control measures on the sunny side of Nianzhuang Gully, Yan'an, Shaanxi, 28 July 1980, showing apple trees in reverse-slope terraces interspaced with cannabis. The terrace edges are further protected with melon plants. Below, No. 5 precipitation dam is visible. (PM)

(d) Photo: View across the back of No. 5 precipitation dam, Nianzhuang Gully, Yan'an, Shaanxi, 28 July 1980, showing crop damage owing to alkalisation. A tributary gully which has been treated in a similar way may also be seen. The predominant continued use of tilled slopes in the catchment is visible. (PM) when the average per capita grain income will be 0.5 t yr^{-1}, can economic sideline production be developed. A guaging station and experimental station are also planned.

iii) Desert Border Region.

The most severe erosion from the loess plateau occurs in N. Shaanxi and N.W. Shanxi, and the coarsest soil is to be found along the Western border of N. Shaanxi where, to the Northwest of a line drawn approximately along the Great Wall, d_{50} is greater than 0.1 mm (Figure 1-13). The Maowusu desert has encroached upon much of this area and has covered the loess hills with sand dunes. The basic principles used in control of the gullied hillock region may still be applied here. It is interesting to observe how they are adapted so that emphasis might be placed upon protection against the wind and sand from the desert.(32)

The work done by the Longzhou Brigade of Jingbian County, N. Shaanxi is notable for the application of a variety of techniques in a new combination which suits the stringent local circumstances. This brigade has a population of 3600 人, a labour force of 1100 人 divided into 19 production teams, and is situated in the upper reaches of a tributary of the R. Wuding. Its total area of 90 km^2 includes the catchments of three large gullies, in all 88.7 km^2, whose confluence is known as Guimenguan (Figure 4-8). There are three types of topography in this region; 59 km^2 of gullied hillocks, 13.3 km^2 of low, level land, between hillocks, and 17.7 km^2 of gullied remnants of such level land. The sediment yield modulus is 20,000 t km^{-2} yr^{-1}, although the annual rainfall, concentrated in Summer storms, is only 400 mm. Some 733 ha of the 1330 ha level land is covered with windblown sand.

The work so far may be divided into three stages. From 1955 to 1965, 34 silt precipitation dams were built, creating 20 ha of land, and a canal was dug to lead flood waters on to the low level land. The work was begun in the branch tributaries of the Tuqiao Gully, where the first dam of six, interconnected by the flood canal, was

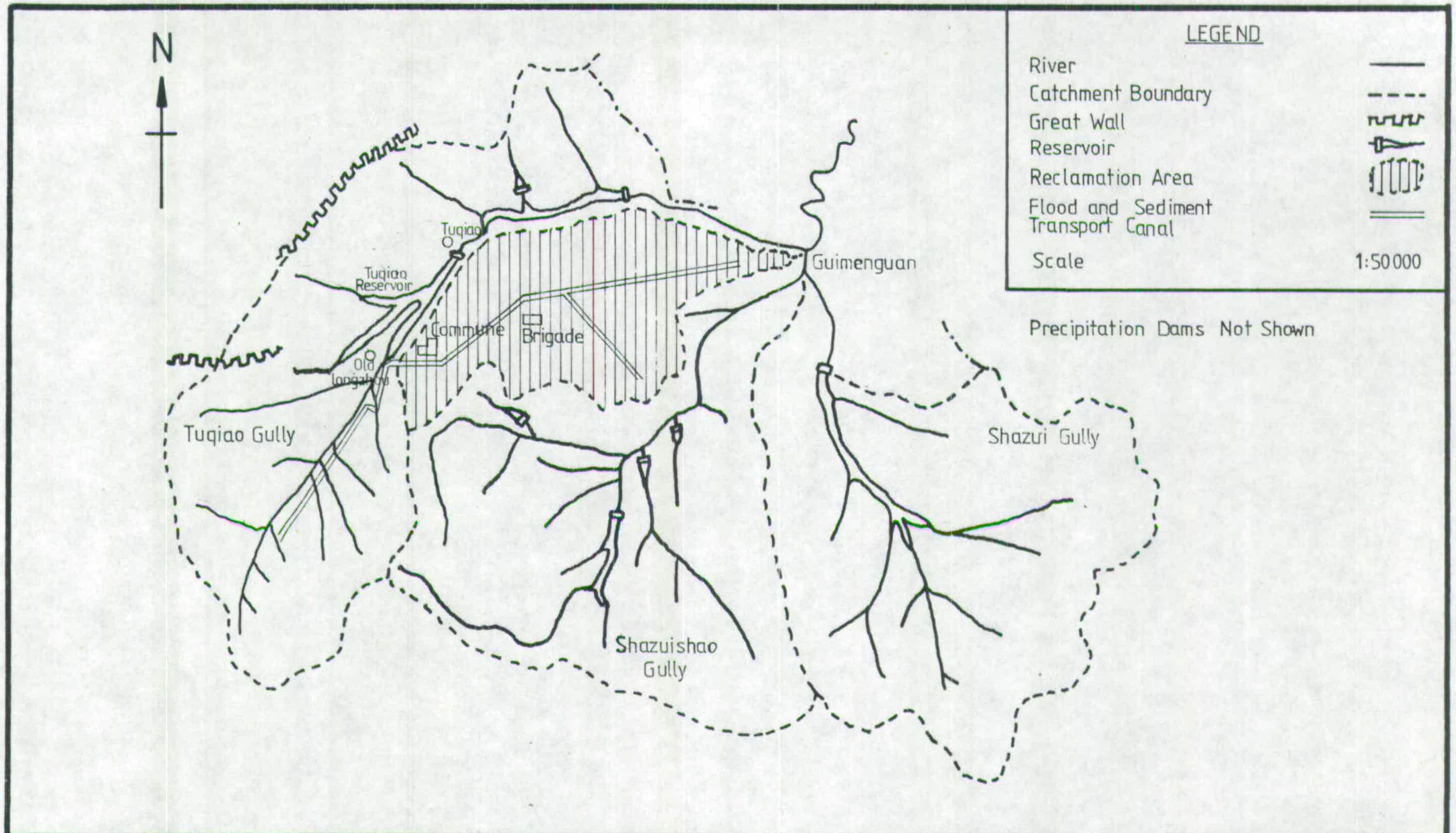


FIGURE 4-8 LONGZHOU BRIGADE COMPREHENSIVE CONTROL SCHEME SOURCE: Note 33

built in 1956. Five more were added above the point where underground water issued into the gully, and the remaining 23 were in various branch tributaries to the other gullies.

These first precipitation dams rapidly became silted and, in 1965, as the second stage, the canal was extended by 7 km and became the trunk canal of a warping scheme, on part of 560 ha of sandy level land, which was undergoing silvicultural measures for protection against the further encroachment of windblown sands. Trees were planted four deep in rows, running East to West, separated by 200 m, and two deep in rows running North and South, separated by 400 m. Some 200 ha was in need of treatment with the finer and more fertile silts brought from the hills by the canal, and where this was to be done, each 200 m x 400 m field formed by the trees was further divided into eight 50 m x 200 m deposition units, and filled according to the available floods. On average, 13 ha yr^{-1} could be treated, and with this scheme to absorb the silt laden flood peaks, the second stage was complemented by a clear water reservoir built in Tuqiao Gully, without any serious sedimentation problem. This reservoir was the first in N. Shaanxi to be built to such a height, (52 m), using the new method described in Section 2, iii, and had a total capacity of $20 \times 10^6 m^3$.

Yet, although the muddy floodwaters had been put to use, the programme so far had been a little lacking in balance and in the rest of the catchment there were still unstable yields and a general lack of water. Therefore, in the third stage, since 1970, four more reservoirs with a total capacity of $15 \times 10^6 m^3$, and four more precipitation dams, have been built. In addition 12 pumping stations have been added, to raise the stored water for irrigation.

The Effects of the Work: By 1975 there was a total of 733 ha of tilled land, which comprised 28 ha of precipitation dam land, 67 ha of warped sandy land, 440 ha of irrigated land and 137 ha of tilled slopes. There were also 1337 ha of forest. Since 1965, all silt lost from the slopes has been intercepted either by the precipitation dams or by the warping scheme. This has reduced the silt content of the R. Huang by some 1.8×10^6 t yr^{-1}, whilst guaranteeing water supplies by ensuring that sedimentation of the reservoirs is very slow. In the Tuqiao reservoir, for example, only 5×10^6 m^3 had accumulated in ten years, and this was mainly due to bank collapses in the early period. It is particularly interesting to note that no drainage facility is provided for the floodwaters after warping. They are left to soak into the ground, which usually takes about a month. This is reported to be beneficial in conserving the soil moisture during the extemely hot Summer and in preventing the problem of land becoming stiff when too dry. No mention is made of any alkalisation problem and it is to be assumed that the water table is low enough in the sandy soil for waterlogging not to occur. A special team has been charged with the duty of building 'basic fields' and it is they who have the responsibility for warping and for management and maintenance of the engineering structures.

Warping has been used for improvement of the soil structure and for increasing the fertility of existing cultivable land, as well as for creating new such land in sandy areas. Fresh water irrigation has also improved yields on the land further upstream. Earlier unit yields of 0.3 t ha^{-1} have increased on irrigated land to about 2.6 t ha^{-1} and on precipitated land to about 6.7 t ha^{-1}. Double cropping has also become possible for the first time. Whereas between 1956 and 1970 total yields varied between 300 t yr^{-1} and 600 t yr^{-1} (av. 0.15 t 人$^{-1}$), and grain often had to be bought from the state, by 1975 the yield had reached 1500 t (0.42 t 人$^{-1}$), had stabilised, and 320 t was sold to the state. In addition the necessary conditions were achieved for biological erosion control measures to be taken on the hills, although 75 % of the catchment is still untreated. It is interesting to note, however, that in order that the silt washed from the hillsides, and thus made available for warping, should not diminish too drastically, it has been decided to built fewer tributary precipitation dams than originally planned. Some 80 agricultural machines have been bought, and willow weaving, brick and tile manufacture, pig rearing, medicinal herb growing and beekeeping activities have begun. The brigade's income in 1975 was ¥ 150,000 (£ 43,000), or ¥ 42 人$^{-1}$ (£ 12 人$^{-1}$).

The latter two examples both depend upon sediment deposition in the gully floor, to provide the necessary 'basic land'. Another, similar, method, is to straighten rivers. The land regained in this way is built up each year by allowing the Summer floods to cover it and to dress it with fertile silts. 'Basic land' is not, however, confined to the gully floors. Terraces, for example, may be used, as long as an adequate water supply can be provided. Figure 4-9 shows a model of a scheme where 'basic land' is provided by both river straightening and terracing measures. The important point about comprehensive control, is that the general principles should be adapted to the particular circumstances of each locality.

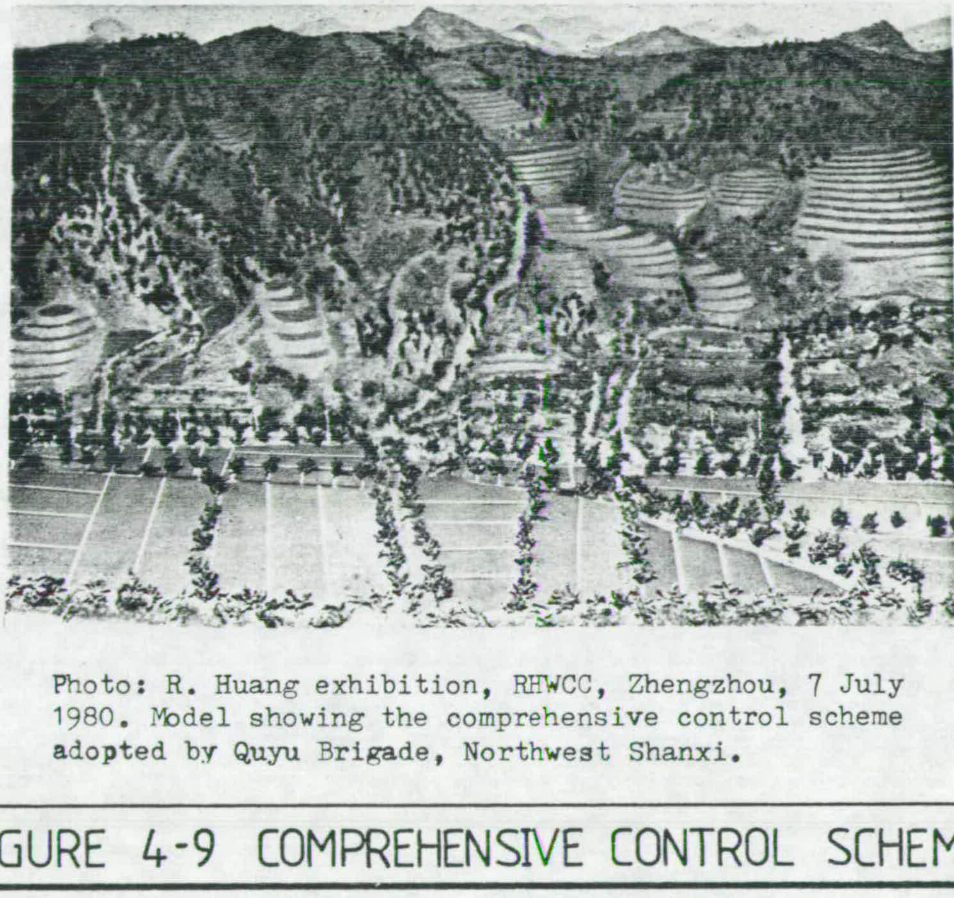


Photo: R. Huang exhibition, RHWCC, Zhengzhou, 7 July 1980. Model showing the comprehensive control scheme adopted by Quyu Brigade, Northwest Shanxi. (PM)

FIGURE 4-9 COMPREHENSIVE CONTROL SCHEME

Notes to Chapter Four

1. QIAN Ning, DAI Dingzhong, 1980, p. 20.

2. LONG Yuqian, XIONG Guishu, 1981, p. 16. WANG Huayun, 1980, p. 3. QUSRL, Personal communication, 1980.

3. These very comprehensive volumes are on display at the RHWCC exhibition in Zhengzhou. However, my request to the Ministry of Water Conservancy, to be allowed to use the copies held by QUSRL, was met with the reply that I may be given hydrological data from one or two stations. Consquently, I was given the data which appears here as Tables 3-1, 3-4, only.

4. LONG Yuqian, XIONG Guishu, 1981, p. 17.

5. This description is compiled from the sources given in note 2, unless otherwise indicated.

6. The following two paragraphs are from QIAN Ning, DAI Dingzhong, 1980, pp. 26 to 27.

7. ibid., pp. 28 to 31.

8. Despite being quoted in CSHE, Eds., 1980, which is published internationally, these reports (RHSRCG, Eds., 1975, 1976) are not allowed out of China.

9. This is compiled from QIAN Ning, DAI Dingzhong, 1980, pp. 32 to 39. LONG Yuqian, XIONG Guishu, 1981.

10. Fieldtrip notes, 20 July 1980, visit to the Jinghui Irrigation District. In Qin times the irrigated area was 1300 km^2, in 1932 it was 300 km^2, and at present it is 900 km^2.

11. YANG Tingrui, et al., 1980. Northwest Research Inst. of Soil and Water Conservation, Biology and Pedology, et al., 1976, p. 1. Fieldtrip notes, 20 July 1980, as for note 10.

12. WDPLCMBRC, 1976, p. 24. Bureau No. 11 of the Ministry of Electrical Power, et al., 1976, p. 29. Fieldtrip notes, 20 July 1980, as for note 10.

13. WDPLCMBRC, 1976, p. 25.

14. YANG Tingrui, et al., p. 94.

15. WDPLCMBRC, 1976, p. 26.

16. YANG Tingrui, et al., 1980, p. 100.

17. WDPLCMBRC, 1976, p. 24.

18. BEIJING ZHOUBAO, 1965. XINHUA, Ji'nan, 23 May 1965.

19. RENMIN RIBAO, 26 May 1971.

20. FU Hongde, 1965.

21. HUANG Wen, 1972, p. 26.

22. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2.

23. RHWCC, Eds., 1979, p.254. Shandong R. Huang Bureau Public Works Team, 1975.

24. XU Qihua, LI Shiying, 1980, p. 10.

25. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2. XU Qihua, LI Shiying, 1980, p. 10.

26. Figures for deposition for the nine years 1969 to 1978 are taken from MAI Qiaowei, et al., 1980, p. 399. These give average figures of 389 x 10^6 t yr^{-1} above Aishan and 39 x 10^6 t yr^{-1} below. Thus the 50 x 10^6 t yr^{-1} drawn each year is about 15 % of the total. Each boat can remove about 0.31 x 10^6 t yr^{-1} (BAO Xicheng, 1980) so slightly more than 125 boats are needed to remove 39 x 10^6 t yr^{-1}.

27. RENMIN HUANGHE, Eds., 1979, p. 58.

28. This description is from Shaanxi Soil and Water Conservation Bureau Revolutionary Committe, 1976. Gansu Province Pingliang District Soil and Water Conservation Testing Station, 1976.

29. TONG Yungao, et al., 1979, p. 26.

30. Except where otherwise indicated, this sub-section is taken from fieldtrip notes made at Chunhua County on 19, 20 July 1980.

31. Except where otherwise indicated, this sub-section is taken from fieldtrip notes made at Nianzhuang Gully on 28 July 1980.

32. This sub-section is all taken from SRIHEWL, et al., Eds., 1979, pp. 270, 271. Yulin District Hydroelectric Bureau, 1976.

33. Yulin District Hydroelectric Bureau, 1976, p. 53.

Chapter Five

Present Situation and Future Plans.

The descriptions presented in the previous two chapters, concerning both the lessons and the experiences which have come from the past thirty years of R. Huang control and development, contain a number of examples of the work done so far in various parts of the basin. It is the intention to use this chapter to take an overall view of the state of the basin to-day and the prospects for its future control and development and, in doing so, it is necessary first to bring together, complement, and summarise the accounts of these aspects.

1) Extent and Outcome of Work to Date.

The work of regulating the R. Huang has cost China an estimated ¥ 5.6×10^9 (£ 1.6×10^9) in the last thirty years. Let us see what it has bought.(1)

i) Organisation, Planning and Research.

The RHWCC co-ordinates many different specialisations, all related, in one way or another, to the R. Huang basin. These include dyke maintenance, surveying, planning and design, soil and water conservation, research, water quality control, hydrology and communications. It is estimated that the corps of specialists so created is now over 20,000 人 strong.

The RHWCC employs over 1700 人 in the gauging stations under its control and over 2000 人 in a special planning and surveying staff. In the period in question these have completed 289,000 m of drilling, made geological maps to various scales of 20,800 km^2, carried out triangulation on 500,000 km^2 and level surveying on 36,000 km^2. Maps to various scales, including many aerial maps, have been drawn up to cover 90,000 km^2. Plant surveys and socio-economic investigations have also been carried out. Like the work, described in the previous Chapter, of China's 1000 sediment researchers, these must be seen as ongoing, regular tasks.

The R. Huang Technical and Economic Report of 1954 still forms the conceptual basis of the work of the R. Huang basin. However, the details are subject to further research and some debate (Section 3), whilst modifications are to be expected to have arisen as the consequence of the Sanmenxia reservoir failure, and as a result of new knowledge gained through research.

ii) Flood Control.

The most important flood control undertakings occur in the lower reaches of the river. The main method of control lies in the application of the concept, "Broad river and strong dykes", which requires the dykes to be supplemented by the Beijin and Dongping retardation works (Chapter 2). Two widening schemes, for the R. Huang, but known as the R. Wen and Kenli schemes respectively, have been carried out in Shandong and the dykes have been raised three times; once just after the Civil War, 1950 to 1954, again from 1963 to 1965, when the failure of the Sanmenxia reservoir was realised, and again, beginning in 1973 and continuing at present. In all, work on the dykes to 1979 had involved 480 x 10^6 m^3 of earthworks, 280 x 10^6 m^3 of consolidation by warping and over 10 x 10^6 m^3 of stonework. Some 5300 spur dykes at dangerous points along the dykes were built, as were over 3000 buttresses for main channel training at 172 places. Dyke maintenance has included the drilling of 70 x 10^6 exploratory holes and the discovery and elimination of 240,000 hidden faults. Control of the oncoming flood waters mainly comprises the Sanmenxia reservoir (Chapter 3) and the Luhun reservoir on the R. Yi, although some adjustment of the basic flow would result from the various reservoirs in the upper reaches (Section iii).(2) Their overall effect will now be considered.

Whilst the upper reaches provide a basic flow of some 2000 m^3 s^{-1} to 3000 m^3 s^{-1}, the large transient flood peaks come either from the tributaries of the loess plateau, between Hekouzhen and

Sanmenxia, or from those, principally the Yi, Luo and Qin, between Sanmenxia and Huayuankou.(3) They have never been known to arise in both regions simultaneously, and are called 'Upper Big' (上大) and 'Lower Big' (下大), respectively. The criterion for future flood control work, is to protect the lower reaches against the combination of a flood peak of 0.1 % annual probability (a 1000 yr flood), from one of the above regions, together with an 'ordinary' flood from the other. At present this criterion is not being met. Flood frequencies for Shanzhou, from the fifties, are shown in Figure 3-26, but the value of a 1000 yr 'Upper Big' flood peak is now thought to be somewhat higher than is shown. When combined with an ordinary flood from below Sanmenxia, the total peak discharge at Huayuankou is estimated to be of the order of 46,000 $m^3 s^{-1}$. The same peak flood discharge at Huayuankou is estimated for the combination of a 1000 yr flood arising below Sanmenxia, together with an ordinary flood from above.(4) Neither of these estimates takes into account possible attenuation of flood peaks by the Sanmenxia reservoir.

The total flood volume of the 'Upper Big' type of extraordinary flood is greater than that of the 'Lower Big' type, and the 'Upper Big' type carries a heavy silt load, whereas the 'Lower Big' type is comparatively clear. Less severe flood peaks of the 'Upper Big' type occur more frequently than corresponding 'Lower Big' types. There were 17 instances of large flood peaks in the lower reaches between 1950 and 1977. Of these there were 10 occasions during which water from above Sanmenxia accounted for over 80 % of the total volume of five days' flood, 14 occasions during which it accounted for over 60 %. During the big flood of 1958, moreover, whilst 71 % of the flood peak originated below Sanmenxia, 57 % of the five day flood volume still came from above. Flood peaks lasting more than five days are reported to be even more predominantly originated upstream of Sanmenxia. It would appear therefore, that whilst the control of the more rare, especially large floods might be concentrated upon the tributaries below Sanmenxia, a more immediately important role would be played in channel regulation and the proper disposal of silt, by control of the more frequent, less severe, but nevertheless potentially catastrophic floods which originate above Sanmenxia.(5)

The criterion achieved in the lower reaches at present is that floods which do not exceed 22,000 $m^3 s^{-1}$ at Huayuankou may be conducted safely to the sea. In the narrower section below Aishan, the corresponding safe carrying capacity is 10,000 $m^3 s^{-1}$, the difference being made up by the upstream channel and floodplain storage capacities.

The Sanmenxia resevoir has brought Winter ice-jam floods successfully under control, but has a very limited role in controlling Summer floods. The Luhun reservoir offers no regulation of the rivers Luo and Qin, and the Sanmenxia reservoir has no direct influence upon floods originating in any of the rivers below, although it may help by reducing any contribution from the R. Huang upstream. Furthermore, any part it plays in regulating large floods from above is either at the cost of some of its own capacity, or is subject to restrictions necessary to safeguard the future flood carrying capacity downstream. (Chapter 3).

Under low flow conditions, in the lower R. Huang, deposition will occur in the main channel. Even in Winter when it is clean water that is discharged, at between 600 $m^3 s^{-1}$ and 800 $m^3 s^{-1}$, from the Sanmenxia hydropower station, the effect is to move silt from the wide, He'nan, stretch and deposit it in the narrow, Shandong, stretch downstream.(6)

Moderate and large flood peaks from about 4000 $m^3 s^{-1}$ to near the safe limit for the lower reaches (22,000 $m^3 s^{-1}$ at Huayuankou) generally scour the bed in the Shandong stretch, and often in the upper part as well (Chapter 3, Section 7, i), whilst those which cover the floodplains (over 6000 $m^3 s^{-1}$ at Huayuankou) cause beneficial deposition thereupon. However, the net outcome is still a rise of about 0.07 m yr^{-1} of the whole lower reach, including both the main channel and the floodplains, which makes dyke maintenance more difficult, increases through seepage the alkalisation problems outwith the dykes, and reduces the slope of the stream, thereby facilitating a further increase in the rate of deposition. Furthermore, any part of these flood peaks, from above Sanmenxia, which exceeds 12,000 $m^3 s^{-1}$, will cause the reservoir water level to rise and deposition to take place there which would be detrimental.

The very large flood peaks which could arise from above Sanmenxia pose a double problem. Firstly, there would be the threat to the Guanzhong Plain and Xi'an (Chapter 3, Section 7, ii), as a result of the hindrance caused by the restricted discharge capacity of the dam. Secondly, when the silts deposited in the resevoir during the course of the flood are subsequently worked out of the reservoir by smaller floods, they would pose another problem in the lower reaches.

Even together, therefore, the Sanmenxia and Luhun reservoirs are at present incapable of ensuring that the flood discharge at Huayuankou shall not exceed 22,000 $m^3 s^{-1}$. Meanwhile, the problem of deposition in the lower reaches continues. As a result of the three dyke raising efforts since the Civil War, the dykes along both sides of the river have been raised by between 2 m and 3 m in the upstream part between 4 m and 5 m in the lower part. Above Aishan they are some 2.5 m to 3 m above the water level corresponding to 22,000 $m^3 s^{-1}$, and below Aishan they are some 2.1 m higher than the level corresponding to 10,000 $m^3 s^{-1}$.(7) In the upper stretch this is the same safe carrying capacity as after the first major dyke overhaul in the early fifties, whilst in the lower stretch, it has fallen to its present level from 13,000 $m^3 s^{-1}$. Thus, it may be seen that although several advantages have come from careful use of the Sanmenxia reservoir in maintaining a good channel morphology, (Chapter 3), and despite the effectiveness of the silt-suction boat in Shandong, the silt problem really has not been solved, and the extensive dyke works have been necessary just to maintain the status quo. Whilst the estuary continues to extend and the bed continues to rise, it is arguable, furthermore, that the status quo is not being maintained. Figure 5-1 gives the example of the change in water level corresponding to a discharge of 1000 $m^3 s^{-1}$ at Luokou, Shandong. Silt is the fundamental problem of the lower R. Huang, and whilst it remains present in unchanged quantities, the flood menace has not been and can not be eliminated.

There is one further line of defence, namely the Beijin flood detention area (the use of the Dongping Lake flood diversion reservoir is assumed in the 22,000 $m^3 s^{-1}$ criterion). Yet there is

FIGURE 5-1 CHANGES IN THE FLOOD SEASON WATER LEVEL FOR DISCHARGE $Q=1000\ m^3s^{-1}$ AT LUOKOU

Source: FANG Chongdai, 1980, page 62.

considerable opposition to the use of such areas. Firstly, there would be considerable losses within the area, and it is arguable that the problem is only being moved, not solved. At present the 2500 km^2 area contains nearly 1500 km^2 of cultivated land and houses 1.3×10^6人. It is estimated that to flood it once would incur losses amounting to ¥ 570 x 10^6 (£ 163 x 10^6).(8) Secondly, the perimeter dykes of such areas on plain land would be subject to the same maintenance problems as the R. Huang main dykes, which would put extreme pressure upon repair and maintenance staff who at that time would be needed on the main dykes. In the thirty years since its construction, the Beijin detention area, for those reasons, has never been used and, under the present arrangements for flood control, would not be used for a flood smaller than 22,000 $m^3 s^{-1}$; that is, a once in 50 years flood. Meanwhile, the people who live in the area still have to make preparations every year and clearly this disturbance to their lives would not be welcome. Work is in progress to construct the Guxian (Gu County) reservoir on the R. Luo, and design work has begun for the Hekoucun reservoir on the R. Qin. These are attempts to bring a measure of control to these tributaries, but it will be some time before they are complete and, even then, their contribution to flood control between Sanmenxia and Huayuankou will be limited.(9)

None of the above is intended to deny the generally good flood prevention record since the Civil War. Floods of less than 22,000 $m^3 s^{-1}$ at Huayuankou have been brought under control and there is provision, albeit provided with reluctance, for greater floods, by way of the Beijin diversion area or, under certain circumstances, the use of the Sanmenxia reservoir. Winter floods have now been eliminated, although two such events did occur in the early fifties, and no Summer inundation has occurred for over thirty years.(10) Advances have been made in the attempts to dispose of the silt and maintain the present flood carrying capacity. Whilst it must be said that this good record also owes a debt to good luck, in that no extraordinarily large flood peak has arisen in this period, it should also be pointed out that the shortcomings have been recognised and work is in progress to rectify them (Section 3).

There remains one further problem in controlling the lower R. Huang, which is the ancient practice of tilling the river's floodplains within the main dykes. The main channel is often controlled by special river course training embankments built on the floodplains and usually following a wandering or meandering pattern. The training embankments are an attempt to stabilise the channel so as to reduce the instances of floodplain collapse, which not only increase the silt content of the river, but also reduce the main channel flood carrying capacity. These works are kept to a minimum so as to reduce their influence on the flow conditions on the floodplains on the occasions that overbank floods occur. However, quite contrarily to this principle, the local peasantry build villages on the floodplains, till the land, and protect these activities by the construction of 'production dykes' along large stretches of the edge of the main channel, so as to reduce the instances of overbank flooding. (Figure 5-2).(11)

These practices increase deposition within the main channel, whilst reducing it on the floodplains and are clearly detrimental to flood control work, as the following quotation shows,

> "At present, small and medium sized floods (5000 $m^3 s^{-1}$ to 15,000 $m^3 s^{-1}$) cause tension in flood prevention, mainly below Dongbatou. In this stretch, because of the construction of production dykes, the main channel is higher than the floodplains, creating a second level suspended river. If the production dykes should burst, a flood peak could travel along the main dykes, causing a danger."(12)

Despite such considerations, there are now some 2000 km^2 of tilled floodplains and a population of over a million there, and finding a suitable alternative would be difficult. According to the RHWCC, early attempts to remove these people met stubborn refusal, despite various offers of money. Now, although the practice is not encouraged, it is tolerated. These people's production is not taxed, and when they suffer losses due to overbank floods, they receive State aid.

iii) The Use of Water Resources.

Seven reservoirs have been completed on the R. Huang mainstream, as have 136 large and medium-sized ones on the various tributaries.

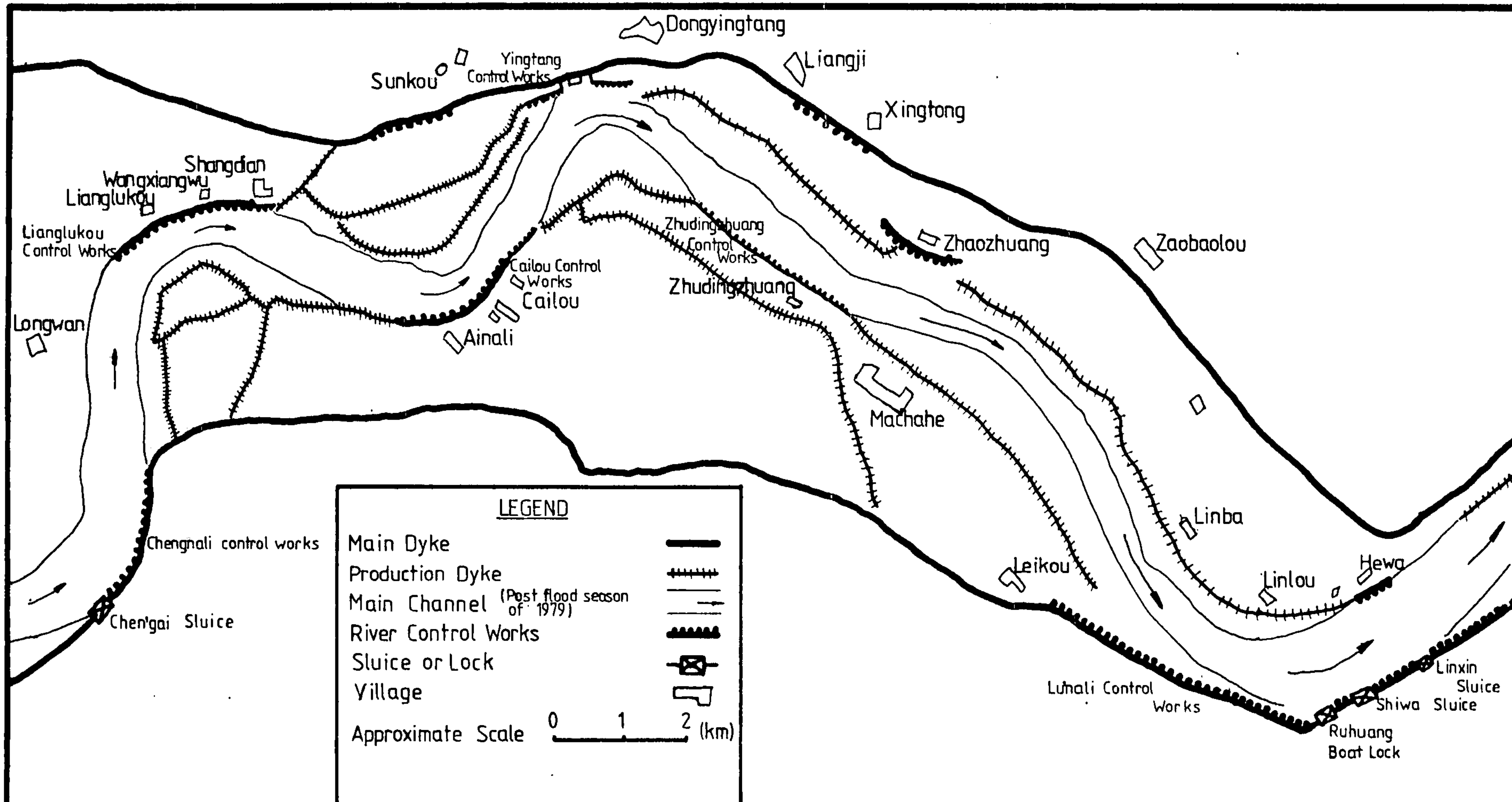


FIGURE 5-2 PRODUCTION DYKES, VILLAGES, AND RIVER CONTROL WORKS ON THE R. HUANG FLOODPLAINS NEAR SUNKOU SOURCE: BIN Guangmei, 1980, page 29.

Their total capacity is 29.4 x 10^9 m^3, they provide 2.51 GW of electrical power, and water to irrigate 33,000 km^2. The combined capacity of the hydroelectric power stations installed at six of the mainstream reservoirs is 2.4 GW and the seven reservoirs have added some 6700 km^2 of irrigated land.(13) As was envisaged in the 'Technical and Economic Report' of 1954, electricity production is concentrated in the gorges of the upper reaches. An eighth reservoir is at present under construction on the mainstream at Longyangxia, furthest upstream of all projects so far. All eight will now be considered in detail.

The Longyang Gorge (Figure 5-3) is situated in Gonghe County, Qinghai, above the town of Guide. It is at 2500 m above sea level, some 40 km long, over 150 m deep, only 30 m wide, and has an average discharge of 640 m^3 s^{-1}. The proposed concrete dam will be 172 m high and will create a reservoir of 24.7 x 10^9 m^3 capacity, necessitating the evacuation of 26,000 人. Its installed generating capacity will be 1.5 GW and the annual energy output will be 6.0 TW h.(14)

Work began in 1977 with the construction of a diversion tunnel 661 m in length and with a maximum discharge of 3100 m^3 s^{-1}. The tunnel was completed in November 1979, and a 54 m high cofferdam capable of retaining 1.1 x 10^9 m^3 of water was reported to be in place in 1981. The project is planned for completion by 1985.

The Liujiaxia hydroelectric power station is situated some 100 km above Lanzhou, Capital of Gansu, in a deep and narrow gorge, just 1.5 km downstream of the confluence with the R. Tao. (Figure 2-1). The reservoir had an original capacity of 5.72 x 10^9 m^3 and its duties include flood control, irrigation and ice-jam control in the upper reaches, although it is primarily intended for electrical generation and, with an installed generating capacity of 1.225 GW, it is China's largest completed hydro-power station. It has a complicated layout in which part of the power station and some of the water and silt discharging sluices are built into the cliff of the right bank, and the 147 m high dam is extended beyond the gorge proper, such that the flood spillways are 700 m long and pass behind

龙 羊 峡

FIGURE 5-3 THE LONGYANG GORGE

Source: RHWCC, Eds., 1979, p. 39.

the highest point of the cliff. (Figure 5-4). Work began in 1964, the dam was completed in 1968 and the last generator set began operation in 1974.(15)

Although only 2.9% of the effective capacity of 4.15×10^9 m^3 had been lost in ten years' operation, sediment, nevertheless, is a problem, mainly because of the relative position of the silty R. Tao. Whilst in wet years, when the water level is high, sediment entering the reservoir from the river Tao forms a density current and is discharged quite easily, in dry years no such density current may form and sediment from the upper R. Tao is deposited in front of the dam. Between 1974 and 1976, when water was plentiful, only 0.57×10^6 t yr^{-1} of silt passed through the turbines. Then in 1977 and 1978 when the water level was low, the level in front of the dam rose 5.5 m and in 1978 about 10×10^6 t passed through the turbines, causing serious erosion.(16)

The dam of the Yangguoxia reservoir is only some 30 km downstream of Liujiaxia. Its original capacity was $220 \times 10^6 m^3$ and its purpose is for run of the river electricity generation. Work on the 57 m high dam began in 1958 and the first generator set went into operation in 1962, making it the first hydropower station to produce electricity from the R. Huang. The installed capacity is 352 MW. There is no specific facility for sediment discharge, and, in the period prior to the completion of the Liujiaxia reservoir, some serious sedimentation problems were encountered.(17)

The dam comprises two distinct parts. On the left-hand side is the power station and on the right, separated by a low wall, is a spillway section. Under favourable flow conditions, since the discharge capacity of the spillways is considerably higher than that of the turbines, the main flow should pass through the spillways and both the silt concentration and the total sediment discharge there should be higher than in the water passing through the turbines. (Figure 5-5). However, since the coarse silts and grassy debris could not pass over the spillway weir when the flow was relatively small, they tended to be carried towards the turbine intakes. In

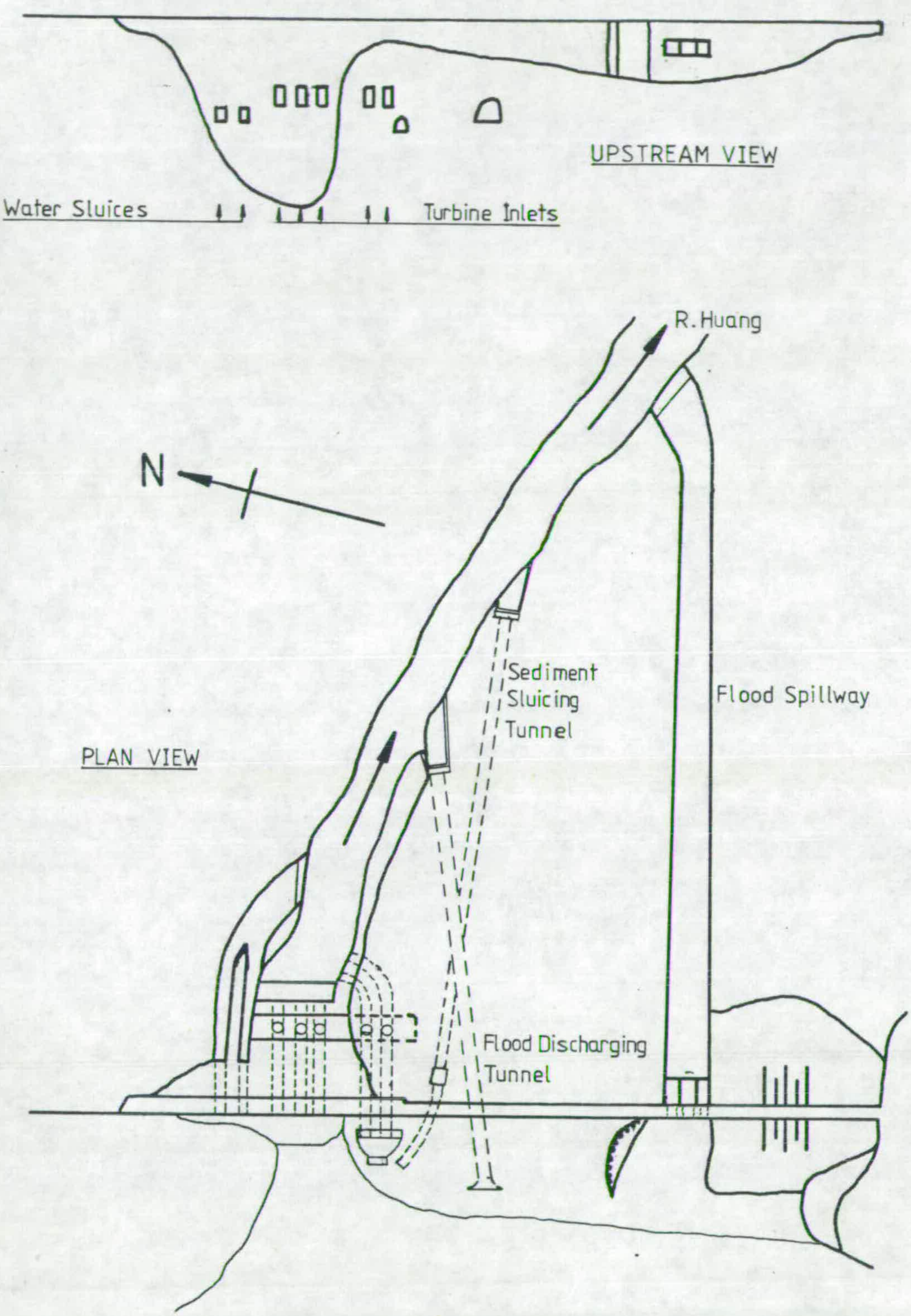
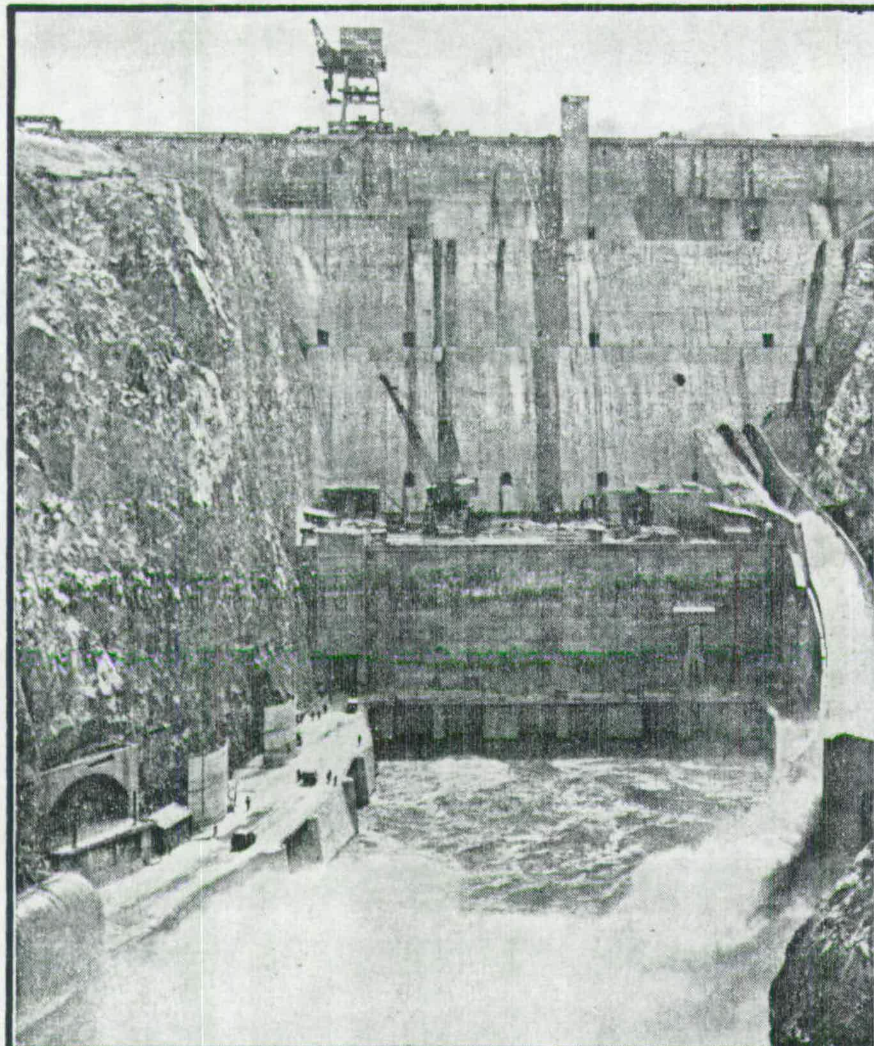


FIGURE 5-4 (a) GENERAL LAYOUT OF THE LIUJIAXIA DAM (Not to scale)

Source: SRIHEWL, et al., Eds., 1979, p. 318.



Above: Flood Discharging Tunnel Outlet,
Sediment Sluicing Tunnel Outlet,
Flood Spillway.

Left: Main Dam, Water Sluices, Turbine Outlets.

FIGURE 5-4 (b)DOWNSTREAM VIEWS OF THE LIUJIAXIA DAM SOURCE: HUANG Wei, 1978, pp, 88 to 89.

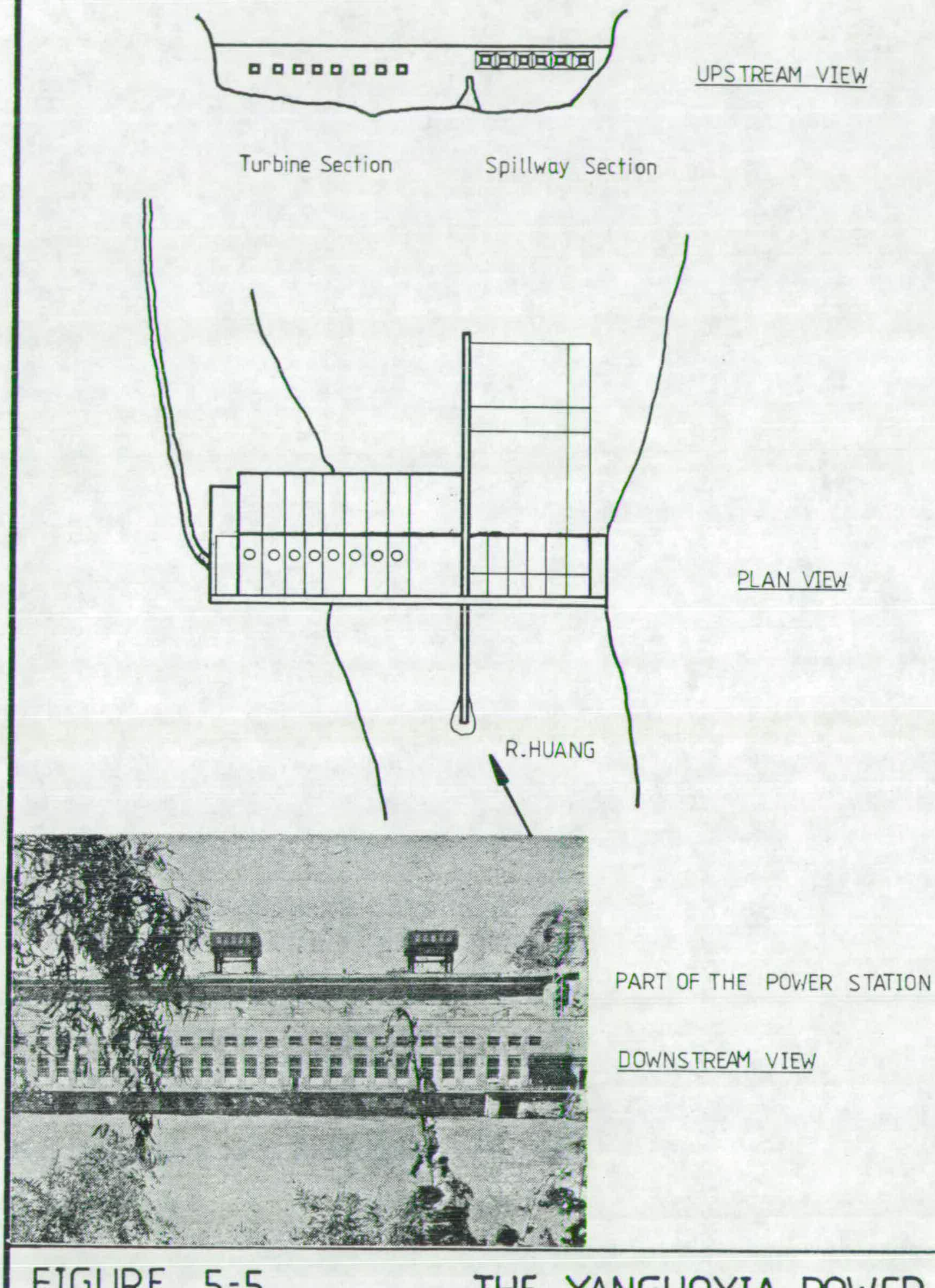


FIGURE 5-5 THE YANGUOXIA POWER STATION (Not to scale)

Sources: SRIHEWL, et al., Eds., 1979, p. 316. PU Naida, SU Fengyu, ZHANG Ruitong, 1980, p. 739. RHWCC, Eds., 1979, p. 46.

1964, the trash racks collapsed after becoming blocked in this way, and in the first ten years of their operation the turbines had to undergo extensive repairs on five occasions, of which some 80 % of the work was to deal with turbine blade erosion. The cost of the trash rack collapse has been estimated at ¥ 30 x 10^6 (£ 8.6 x 10^6). Meanwhile by October 1968, some 167 x 10^6 m^3 of sediment had settled in the reservoir, filling 76 % of its retention capacity.

Since the completion of the Liujiaxia reservoir these problems have been alleviated somewhat as the flow is now controlled by the upper dam. The amount and concentration of sediment entering the lower reservoir, however, depends upon density current discharge of the R. Tao silt load. Over the past ten years, some 7 x 10^6 m^3 of reservoir capacity has been regained and the remaining 50 x 10^6 m^3 or so can be maintained, although there is slight annual variation.(18)

The Bapanxia reservoir, just 17 km downstream of the Yanguoxia reservoir is another run of the river hydropower station, and clearly also comes under the influence of the two above. Its dam is only 43 m high and its reservoir capacity is 49 x 10^6 m^3. It has a low-head and an elaborate system of weirs to cope with the river's silt load. Construction began in 1969, electricity production began in 1975, and the final generator was installed in 1979. The installed capacity is 180 MW. (Figure 5-6).(19)

Like the Yanguoxia dam, the Bapanxia power station is separated from its accompanying sluices by a low wall. In this case the power station is on the right-hand side of the river, and the longitudinal part of the coffer dam has been converted to form a wall some 8 m higher than the turbine intakes. In this way the lower water layers, whose silt concentration is higher, are kept from the turbines and are led to the sluices. Thus, only the clearer, upper, layers may proceed towards the turbines. Within the area so formed, 90 m upstream of the dam, a transverse barrier, also built on to the coffer dam remains, forms a pond for silts which get over the outer walls. These measures are supplemented by silt discharging channels below the turbine intakes which lead away any silt carried beyond

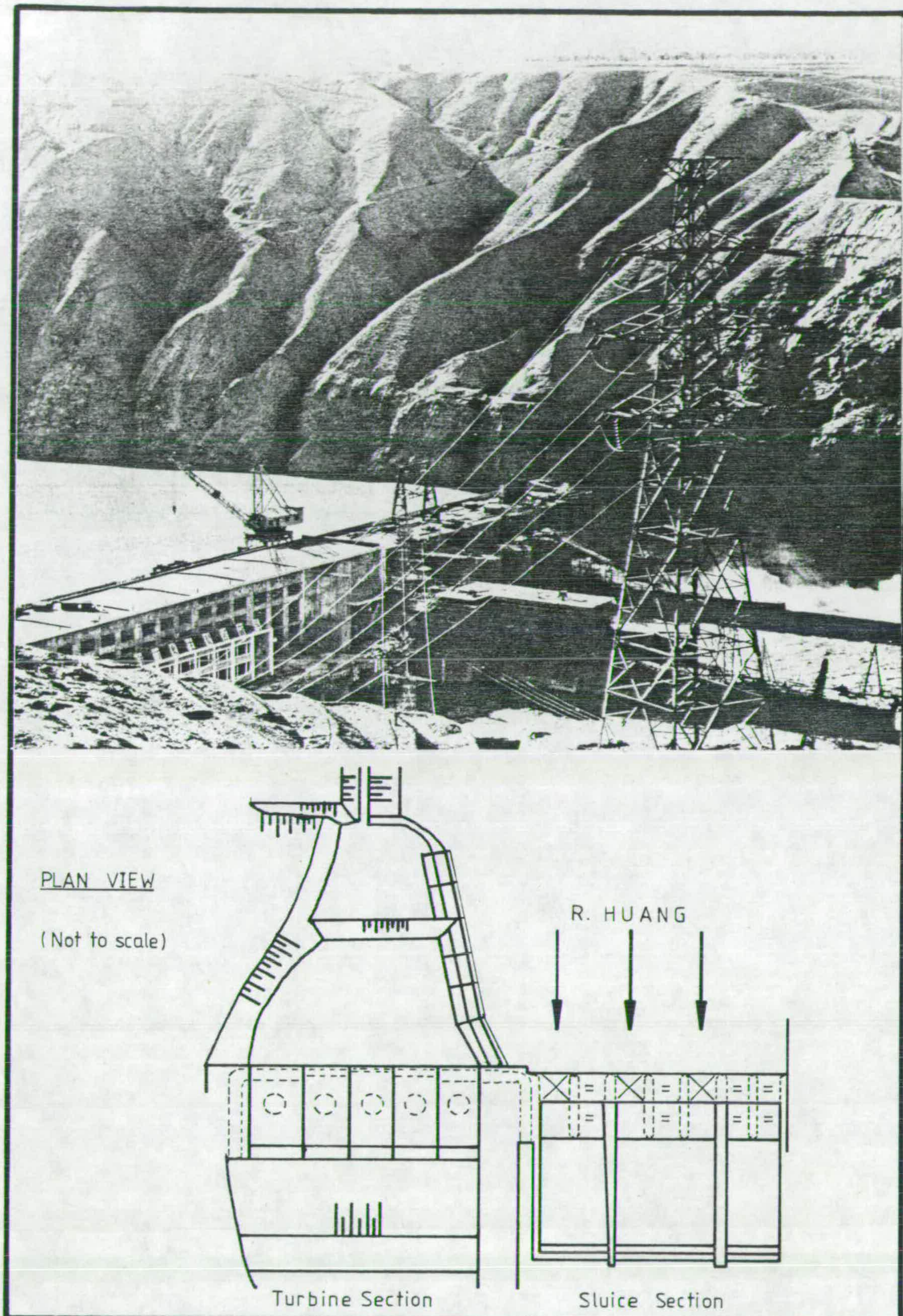


FIGURE 5-6 THE BAPANXIA POWER STATION

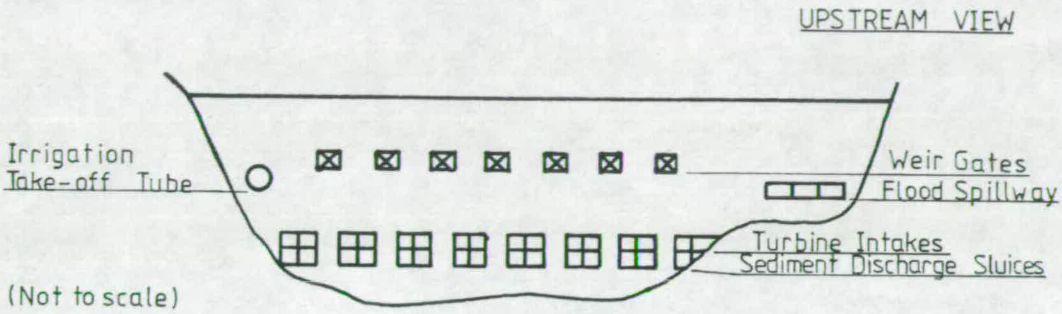
Source: SRIHEWL, et al., Eds., 1979, p. 322.

the pond and keep a clear space just in front of them, even when the turbines are not in use.[20]

Some 40 km upstream (South) of Yinchuan, Capital of Ningxia, the Qingtongxia reservoir performs multipurpose functions with emphasis on irrigation of the two halves of the Ningxia Plain. The dam in the Qingtong Gorge is 42.7 m high and the water collected in its reservoir of capacity 620 x 10^6 m^3 can be drawn for irrigation of 39,000 ha of the upstream Ningwei Plain, as well as providing 272 MW of electrical power. After passing through the turbines, some of the water is led to irrigate about 151,000 ha downstream, on the Yinwu Plain. Work began on 26 August 1958 and was completed in 1967. It is claimed that since the completion of the Liujiaxia reservoir upstream to guarantee the water supply, 70 GW h more electricity can be generated in Winter at Qingtongxia. The quantity of sediment passing through the turbines is reduced by the provision of sluices, with the same dimensions as the turbine intakes, some 6.15 m lower. (Figure 5-7). Measurements have shown that the sediment concentrations and absolute quantities in these sluices are between 7 and 8 times those passing through the turbines.[21]

The diversion weir, for the Hetao irrigation project, forms what is otherwise known as the Sanshenggong reservoir, which has a capacity of 80 x 10^6 m^3. It is not equiped with a power station. This barrage, was begun in the late fifties and completed in 1961 (Figure 5-8), is 2 km long and has 18 electrically controlled sluice gates capable of diverting over 500 m^3 s^{-1} of R. Huang water, for the irrigation of 387,000 ha.[22]

The middle reaches of the R. Huang mainstream contain only two reservoirs, situated at Tianqiao and Sanmenxia. The function of the Tianqiao reservoir is to provide a head for run of the river power generation. Construction was begun in April 1970, the first power was generated in February 1977, and the fourth set was installed in July 1978. However, owing to incompleted chemical grouting, the maximum water level by 1979 was still being held 2 m below the designed normal maximum level. The dam is 47 m high, the reservoir



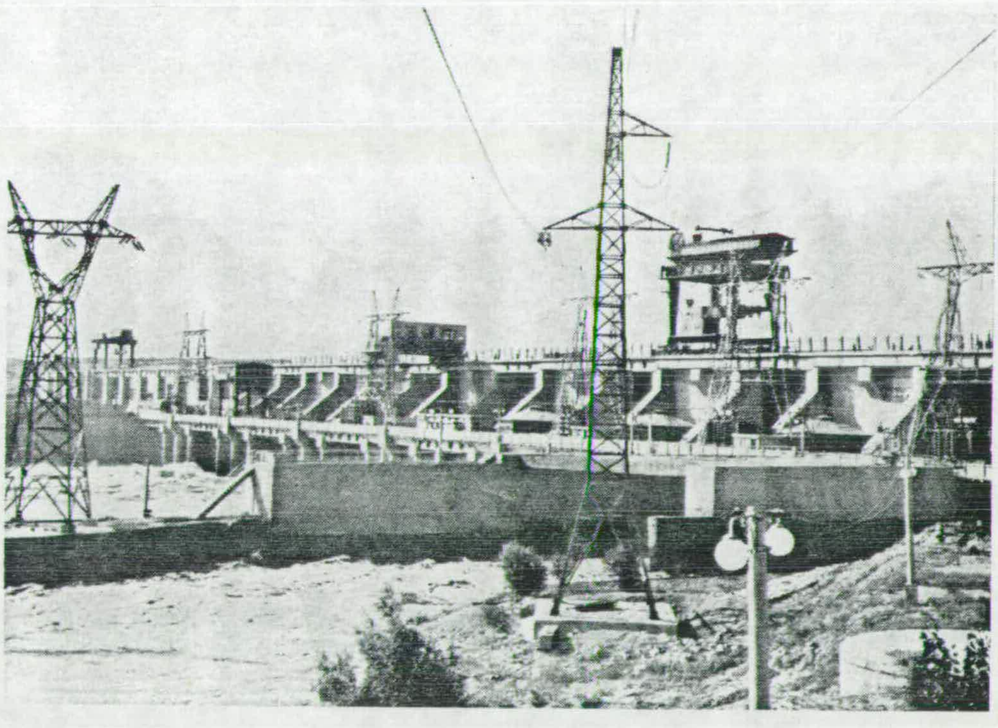


FIGURE 5-7 THE QINGTONGXIA MULTIPLE PURPOSE PROJECT

Sources: SRIHEWL, et al., 1979, p. 317. HUANG Wei, 1978, pp. 88 to 89.

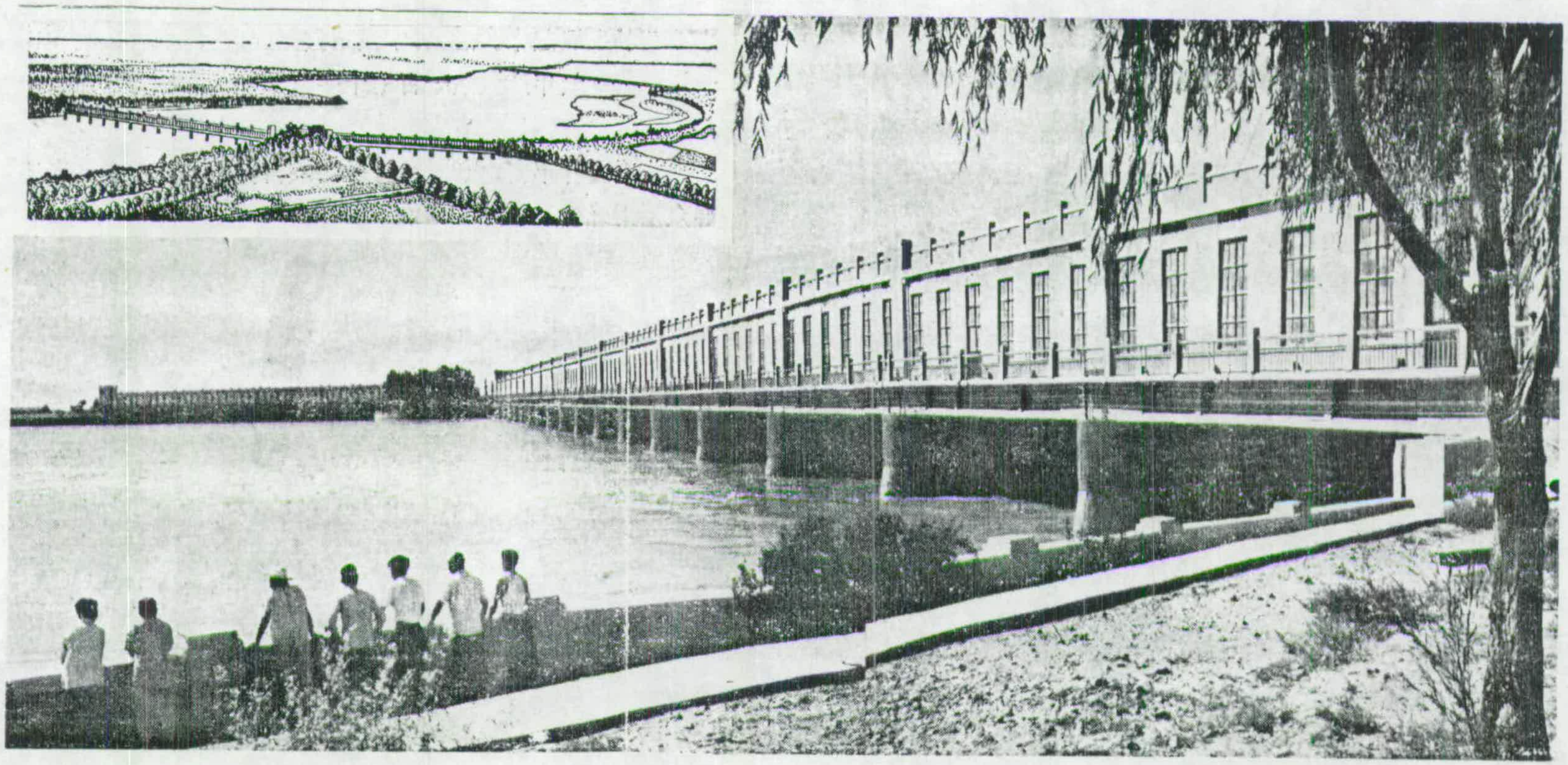


FIGURE 5-8 THE SANSHENGGONG DIVERSION HEAD-GATE

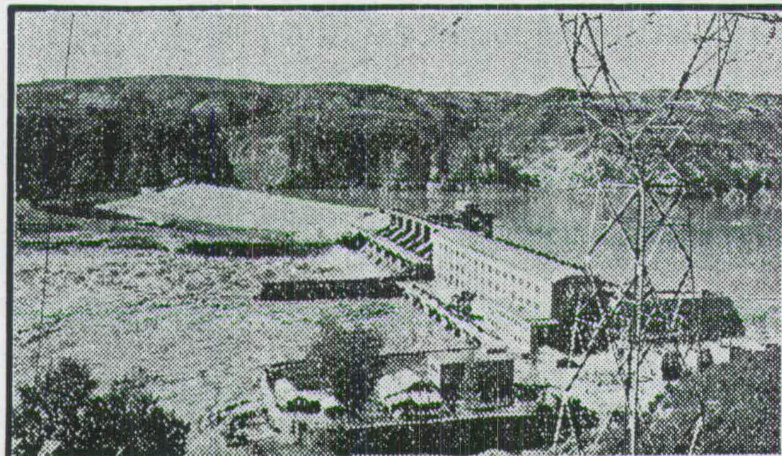
SOURCES: HUANG Wei, 1978, pp. 88 to 89.
RHWCC, Eds., 1979, p. 78.

retention capacity is 68 x 10^6 m^3 and the installed power generating capacity is 128 MW.

The dam of the Tianqiao reservoir is situated at a point some 10 km upstream of Baode, Shanxi, at the end of the 20 km Tianqiao Gorge, where the river contains, in midstream, the Shuizhai Islet. Just within the loess area, this project suffers extemely sharp flood peaks and a heavy silt load. The average runoff of 26.7 x 10^9 m^3 yr^{-1} gives an average discharge of 848 m^3 s^{-1}, but the largest recorded flood peak reached 10,700 m^3 s^{-1}. The silt discharge here is 351 x 10^6 t yr^{-1} with an average concentration of 13.1 kg m^{-3}. In the flood season silt can come at the rate of 100 x 10^6 t d^{-1} in concentrations up to 1.19 t m^{-3}. Furthermore, in Winter, ice flows of up to 292 m^3 s^{-1} may occur and, on average, some 100 x 10^6 m^3 yr^{-1} of ice must be dealt with. The dam design comprised, on the right-hand half of the river, from the islet to the bank, an earthen barrage, and on the left-hand side, a double layer sluice section for ice and water regulation, the power station with special sediment discharge channels below the intakes, and a set of three separate silt discharging sluices. (Figure 5-9).(23)

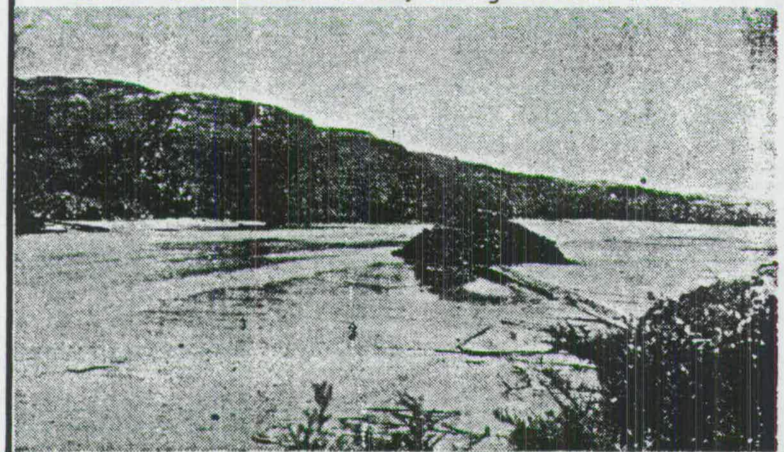
The function and design of the Sanmenxia reservoir has been described in some detail in Chapter 3 and, whilst it is clear that the problems of sediment control there are most acute, it may also be seen that consideration of such problems is an important factor in the design of any structure along the R. Huang; and the same may be said for the tributary reservoirs, whose losses have been described earlier (Chapter 1, Section 7, iii). Yet, reservoirs are not the only means by which the waters of the R. Huang and its tributaries are put to use, and it is useful, therefore, to take a more general look at the water resources of the basin and their use.(24)

The R. Huang basin lies in an arid and semi-arid region; together with the Huai and Hai river basins it accounts for a seventh of the national area, but only one twentieth of its total surface runoff. The R. Huang mainstream has a total fall of over 4300 m, which is estimated to be capable of generating some 20 GW of electricity, and of which some 10 % is being used; the water therein available for



Above: Downstream view

Below: Before construction, showing Shuizhai Islet



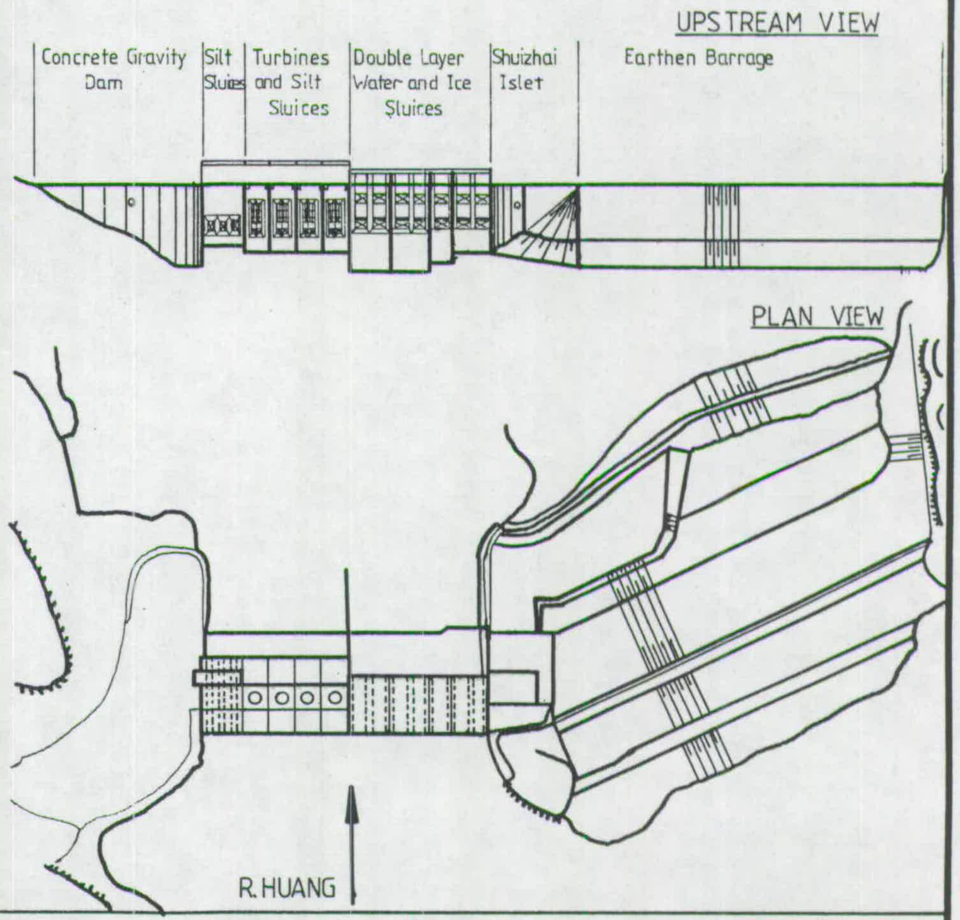


FIGURE 5-9 THE TIANQIAO POWER STATION

SOURCES: YE Nailiang, LONG Guorui, 1979.
GUANGMING RIBAO, 19 April 1979, p. 1.

agriculture amounts to 48 x 10^9 m^3 yr^{-1}, and if the silt is considered to be a useful resource, it is also an abundant one, 1.6 x 10^9 t yr^{-1}.

There has been a moderately rapid increase in the irrigated area of the R. Huang basin in recent years. In the 20 years from 1949 to 1969, for example, the world expansion of irrigated area was 150 %, the US and the USSR increased 70 %, Spain and Italy between 100 % and 200 %, and Romania over 600 %. In the R. Huang basin, over 30 years between 1949 and 1979, it has increased from 8000 km^2, none of which was along the lower reaches, to 33,000 km^2 (400 %). Furthermore, silty water is now drawn in the lower reaches through 72 take-off sluices, 55 syphon stations comprising 153 syphon tubes, and 240 suction boats, to irrigate 10,000 km^2, warp 1930 km^2, suppress alkalisation by the use of wet rice culture on 870 km^2 and consolidate the dykes at the rate of 50 x 10^6 m^3 yr^{-1}.(25)

Thus, in terms of the speed of development so far, this area could be thought to be doing quite well. Indeed, whereas the ratio of irrigated area to cultivated area worldwide is between 15 % and 20 %, in China it is about 30 %, and in the R. Huang basin it is between 25 % and 30 %. Yet the stringent local conditions bring problems which leave no room for complacency. The pressure of population for example may be illustrated by a comparison of the 0.09 ha 人$^{-1}$ of irrigated land in the US to the 0.05 ha 人$^{-1}$ in the R. Huang basin. Moreover, owing to the uneven distribution of rainfall and the generally arid nature of the area, these comparisons can only be regarded as qualitative; as in many places when there is no irrigation crops may not successfully be grown, whilst some places where there is irrigation may only be able to draw water once or twice a year. For these reasons alone, it is important that more of the 30 x 10^9 m^3 yr^{-1} of water that flows each year unused into the sea from the R. Huang, be used, or that the 20 x 10^9 m^3 yr^{-1} or so which is drawn for irrigation each year, be used more effectively.

The ratio of water drawn to water used, in irrigation schemes worldwide is 30 %. In the R. Huang basin above Huayuankou it is also 30 %. Even though this is not an unfavourable comparison, the wastage of water, and its attendant problems of alkalisation, are still seen as causes for some considerable concern. The practice of irrigation by swamping continues despite the fact that it can actually reduce yields as well as give rise to secondary alkalisation. If, for example, a certain irrigation district can increase its yields from 0.75 t ha^{-1} without irrigation, to 1.88 t ha^{-1} by using 1500 m^3 ha^{-1}, it does not follow that further increases in yield will accrue in direct proportion to further increases in water. A five-fold increase in water supply would typically bring about an increase to only 4.50 t ha^{-1}, not the expected 6.38 t ha^{-1}. Yet in the Hetao district of Inner Mongolia, dry crops generally are given 12,000 m^3 ha^{-1} and there have been instances there where it has reached 30,000 m^3 ha^{-1}.

The RHWCC gave the following data, in August 1980, on the use of R. Huang water in irrigation schemes along the lower reaches: Of the 90 irrigation districts, 12 are quite good, with proper auxiliaries such as drainage facilities, 64 are mediocre and 14 are a little lacking. On average between 9 x 10^9 m^3 yr^{-1} and 10 x 10^9 m^3 yr^{-1} of water and 200 x 10^6 t of silt are drawn each year. The total yield from an area of 16,000 km^2 has risen from 10 x 10^6 t in 1965 to 37 x 10^6 t at present, though owing to wastage and indefinite water supplies, only 10,700 km^2 can be regarded as being irrigated and only 4300 km^2 as being irrigated well. The rest is unstable but sometimes may receive irrigation. Sixteen irrigation districts have yields exceeding 3.75 t ha^{-1}, and only the People's Victory Canal district achieves over 7.5 t ha^{-1}. In the good districts water use is about 2300 m^3 ha^{-1} to 3000 m^3 ha^{-1} but in wasteful ones it can reach 12,000 m^3 ha^{-1}. The water requirement of wet rice paddy is variable, depending on the type, but it is much higher than for dry culture, and along the lower R. Huang, is about 22,500 m^3 ha^{-1}. Percolation losses account for half the water intake and the overall use ratio is about 30 %. Each year some 500,000 人 d must be used to remove silt from irrigation canals, where water cannot be used to flush it out because of poor drainage.(26)

In considering water use, it is important also to take into account water quality. Over 10,000 variously sized industrial sources of pollution have been identified which together contribute nearly 4×10^6 t of polluted water per day to the R. Huang. Of these, there are 176 major sources which together discharge nearly 2×10^6 t d^{-1}. From Table 5-1 it can be seen that 76.8 % of the pollution from these 176 major sources comes from a group of 100 in Gansu, Shanxi, Nei Menggu and He'nan, and it has been suggested that they should form the point of emphasis in future plans to reduce pollution. (27)

Table 5-2 shows the concentration of five pollutants in various sections of the river and, where applicable, the factor by which the highest level of each exceeds the criterion laid down by the State. One interesting fact to have emerged, though, concerns the arsenic content, where it has been found that the high levels occur mainly as compounds in the solid suspended load and follows closely the variations in the R. Huang's silt load. (Figure 5-10).(28) The arsenic content of water whose silt has been allowed to settle, nowhere exceeds the State's criterion. Whilst this is to be expected, since arsenic compounds are insoluble in water, it would seem advisable that some investigation be done into the rate of absorption of the various pollutants into the crops which benefit from warping or irrigation with turbid water.

The pollution problem, then, is very serious; but awareness of it is still quite new, monitoring is limited, and no concerted effort has yet been possible towards its resolution. Meanwhile, the rate of increase of pollution in recent years is quite alarming. Whereas in 1976, the average daily input of polluted water is given as having been 3×10^6 t, three years later in 1979 it was almost 4×10^6 t d^{-1}.

iv) Development of the Loess Plateau.

Chinese news reports over the last thirty years are littered with success stories concerning soil and water conservation, and yet

TABLE 5-1 SOURCES OF POLLUTION

	Qinghai	Gansu	Ningxia	Inner Mongolia	Shanxi	Shaanxi	He'nan	Shandong	Whole Basin
Polluted water ($t\ d^{-1} x\ 10^3$)	230	890	150	520	600	1013	321	232	3956
Proportion of total (%)	5·8	22·5	3·8	13·1	15·2	25·6	8·1	5·9	100
Number of major sources	18	24	18	12	41	29	23	11	176
Polluted water from major sources *	71	555	63	222	522	145	204	176	1958
Proportion of major source total(%)	3·6	28·4	3·2	11·3	26·7	7·4	10·4	9·0	100

Source: WANG Zhimin, 1980, page 63.
*units: $t\ d^{-1}$.
Note: The figures for Gansu and Shanxi are incomplete. They refer only to Lanzhou and Taiyuan, respectively. 'Polluted water' refers both to industrial pollutants and to household waste. The latter accounts for some 30% generally.

Source: LI Facheng, 1980, page 69.

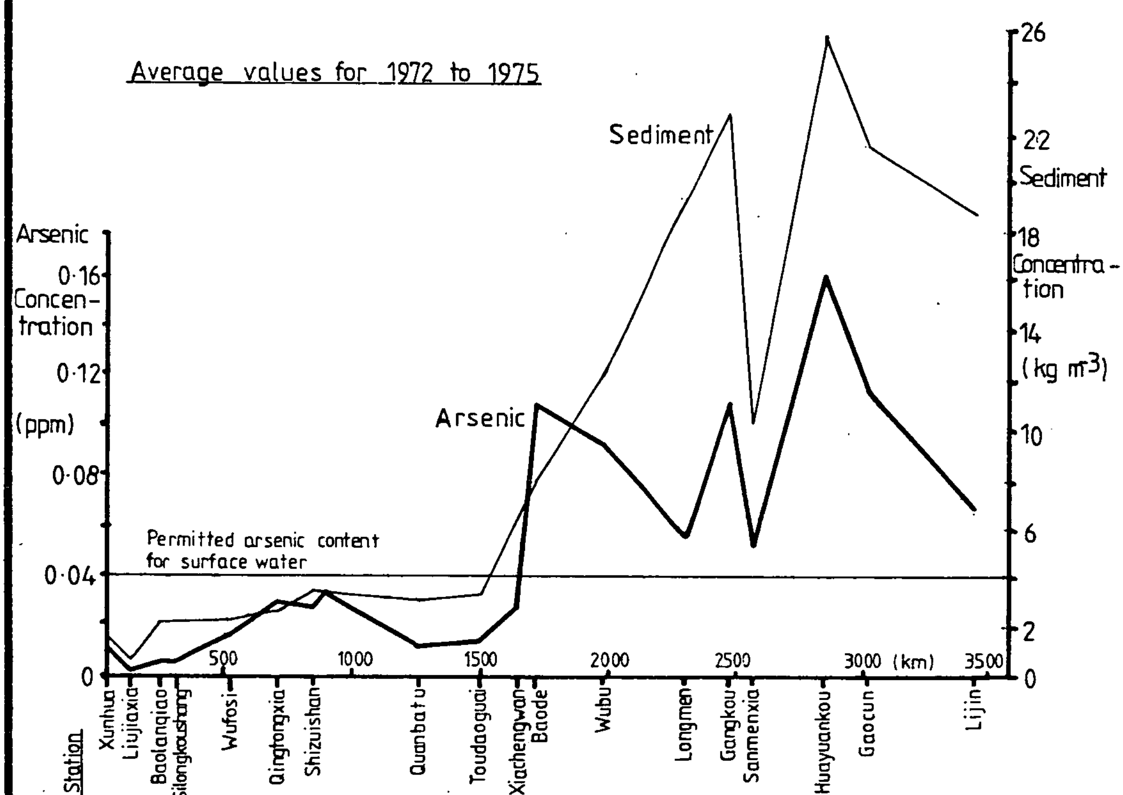


FIGURE 5-10 VARIATION OF SEDIMENT AND ARSENIC CONCENTRATIONS ALONG THE RIVER

TABLE 5-2 MAINSTREAM AND TRIBUTARY POLLUTION LEVELS

River	Station	PHENOL			CYANOGEN			ARSENIC			MERCURY			CHROMIUM		
		Average Content (mg l^{-1})	Maximum Content (mg l^{-1})	Max. as Multiple of State Safety Criterion	Average Content (mg l^{-1})	Maximum Content (mg l^{-1})	Max. as Multiple of State Safety Criterion	Average Content (mg l^{-1})	Maximum Content (mg l^{-1})	Max. as Multiple of State Safety Criterion	Average Content (mg l^{-1})	Maximum Content (mg l^{-1})	Max. as Multiple of State Safety Criterion	Average Content (mg l^{-1})	Maximum Content (mg l^{-1})	Max. as Multiple of State Safety Criterion
Huang	Xunhua	0·0017	0·005		0·0003	0·002		0·021	0·10	2·5	0·0003	0·0013	1·3	0	0	
Datong	Xiangtang	0·009	0·122	12·2	0·0012	0·004		0·009	0·05	1·3	0·0003	0·001	1·0	0·0001	0·002	
Huangshui	Minhe	0·005	0·014	1·4	0·003	0·012		0·015	0·09	2·3	0·0019	0·02	20·0	0·007	0·02	
Huang	Lanzhou	0·0065	0·016	1·6	0·0146	0·025		0·031	0·05	1·3	0·001	0·0045	4·5	0	0	
Huang	Anningdu	0·005	0·034	3·4	0·006	0·024		0·02	0·087	2·2	0·0004	0·0013	1·3	0·0001	0·002	
Huang	Qingtongxia	0·003	0·007		0·0005	0·002		0·011	0·04	1·0	0·012	0·043	43·0	0	0	
Huang	Shizuishan	0·0017	0·004		0·0006	0·002		0·013	0·02		0·0006	0·0011	1·1	0	0	
Huang	Dengkou	0·0503	0·145	14·5	0·0031	0·005		0·01	0·011		0·0024	0·004	4·0	0	0	
Huang	Wubu	0·002	0·013	1·3	0·0007	0·003		0·03	0·12	3·0	0·002	0·0069	6·9	0·0175	0·044	
Huang	Longmen	0·001	0·004		0·0006	0·007		0·056	0·217	5·4	0·0005	0·002	2·0	0	0	
Fen	Hejin	0·013	0·156	15·6	0·002	0·01		0·03	0·2	5·0	0·0003	0·0012	1·2	0·0007	0·014	
Wei	Huaxian	0·015	0·093	9·3	0·0002	0·005		0·117	0·733	18·2	0·0004	0·0023	2·3	0·003	0·02	
Huang	Sanmenxia	0·001	0·005		0·0003	0·007		0·069	0·567	14·2	0·0004	0·001	1·0	0·0002	0·005	
Yiluo	Shihuiwu	0·011	0·041	4·1	0·002	0·012		0·06	0·455	11·4	0·003	0·013	13·0	0·098	0·635	12·7
Qin	Wuzhi	0·002	0·008		0·002	0·008		0·057	0·259	6·5	0·0061	0·018	18·0	0·003	0·007	
Huang	Huayuankou	0·0057	0·034	3·4	0·0037	0·014		0·069	0·269	6·7	0·0048	0·025	25·0	0·0024	0·013	
Huang	Gaocun	0·0005	0·001		0·0008	0·002		0·207	0·899	22·5	0·0002	0·0007		0·008	0·022	
Huang	Aishan	0·001	0·002		0·0005	0·002		0·199	0·786	19·6	0·0004	0·0015	1·5	0·006	0·012	
Huang	Luokou	0·0006	0·002		0·0003	0·001		0·215	0·707	17·7	0·0004	0·0022	2·2	0·005	0·012	
Huang	Lijin	0·0006	0·001		0·0004	0·001		0·192	1·054	26·3	0·0003	0·002	2·0	0·005	0·011	

Source: WANG Zhimin, 1980, pages 64 and 65.

there has been no noticeable reduction in the silt load of the R. Huang. Whilst this discrepancy may be accounted for in part by exaggerated reporting, there are also more legitimate reasons. For example, the effect of conservation in one region may be masked by deterioration in another region, as is explained here by Comrade Gao Bowen,

> "Some people say that soil and water conservation is ineffective, 'See, after thirty years there still has been no noticeable reduction in the R. Huang's silt'. The actual situation really isn't like that. Soil and water conservation has a history of thirty years, but for various reasons the work has been discontinuous and actual development has only had ten years; For a while in the past, since undue emphasis was placed on grain, quite a few districts destroyed forest and grassland and opened up wasteland, and there was serious opening of wasteland on steep slopes. Places which originally had no loss became serious loss areas, control and destruction went on side by side, and some destruction was greater than control; Add to that, that in carrying out basic road, railway, mining and water conservancy construction etc., attention was not paid to erosion control, so large amounts of silt were added to rivers. That is to say, it would not be equitable to blame soil and water conservation for those aspects."(29)

Other reasons, as explained in Chapter 3, would be the extreme variability of the R. Huang silt load, which would make even quite large changes difficult to discern in the short term, and the failure of the early methods, once they had been applied.

Statistics for the loess plateau in the period to the end of 1978 give,

> "Terraces, stripfields, damland and waterland, 38,000 km^2, afforestation and grass sown, 28,000 km^2, over 60,000 km^2 brought under control,"(30)

and to the end of 1980, from a different source,

> "People living along the upper and middle sections of the river have over the past three decades planted trees and grass to 35,300 km^2..... meanwhile people have built terraced, raised and irrigated fields totalling 31,800 km^2 ..... soil erosion has ..... been brought under control in areas totalling 75,000 km^2 ..... this helps prevent about 100×10^6 t of top soil from being washed away."(31)

These two are not entirely consistent, but the order of magnitude of the work so far is illustrated. The figure for the reduction of the silt load of the R. Huang contained therein is in good general agreement with that of 50×10^6 t yr^{-1} estimated by other sources to be held back in the precipitation dams of N. Shaanxi alone.[(32)] It should be pointed out that the above quotations refer to an area of some 430,000 km^2 of the middle and upper reaches, loosely termed the 'loess plateau' in many Chinese sources, not to the smaller area of 280,000 km^2 as described in Chapter 1, and that they do not take into account any land newly opened. In the very few outstanding places where comprehensive control has been carried out successfully, the so-called 'model districts', much better results have been achieved. This is taken to illustrate good future prospects. As an example, details pertaining to several small catchments are given in Table 5-3. Table 5-4 shows that larger catchments have also begun to obtain good results.

The problem, then, is no longer just a technical one, but also one of economics and politics: How to ensure that the correct measures can be adopted on a larger scale, and how to determine just what those measures should be. This was the subject of much debate in the late seventies, which is described in the next section. But it is necessary first to consider the other important aspect of this work, apart from reducing the sediment load of the R. Huang, which may be used as a criterion by which to judge its success or otherwise so far, namely, the living standards of the local people.

Here again it may be said that in most of the area little or no improvement has occurred; in some areas there has been moderate improvement but it is offset by retrogression in other areas. Only very few areas, where the work has been done especially well, have shown an outstanding improvement. Before attempting to assess the overall changes, it is of interest to take an example of each of the two extremes; first, of an area where incorrect policies have been reported to have caused some deterioration, and then of the well publicised 'model districts'.

Guyuan County is situated in the headwaters of the R. Qingshui in Southern Ningxia.[(33)] It has an overall sediment yield modulus of about 5000 t $km^{-2} yr^{-1}$ and 86.1 % of its area is considered to suffer soil and water loss. There are 4500 gullies and 20 % of the land is occupied by riverbeds. From the Civil War to 1977, the population

TABLE 5-3 EFFECTIVENESS OF COMPREHENSIVE CONTROL IN REDUCING SOIL AND WATER LOSSES IN SMALL CATCHMENTS

GULLY	LOCATION	Catchment Area (km²)	Degree of Control (%)	Annual Loss Modulus		Reduction	
				Runoff ($m^3 km^{-2} \times 10^3$)	Erosion ($t\ km^{-2} \times 10^3$)	Runoff (%)	Erosion (%)
Chacaizhu	Lishi, Shanxi	0·19	88	13·8	7·4	59·9	63·0
Wangjia	Lishi, Shanxi	9·1	57·5	28·5	15·9	43·5	57·6
Gaojia	Zhongyang, Shanxi	14·1	41·4	28·8	15·8	>95	>95
Nanqu	Hequ, Shanxi	26·9	69·2				63·0
Nanxiaohe	Qingyang, Gansu	36·3	58	15 to 20	4 to 6	55·6	97·2
Jiuyuan	Suide, Shaanxi	70·7	35·7	24·3	18·0	24·2	55·1
Lihong	Youyu, Shanxi	36·0	70		9·3	60	61·7

Source: GAO Bowen, 1980, page 12.

TABLE 5-4 EFFECTIVENESS OF SOIL AND WATER CONSERVATION IN REDUCING FLOODS AND SEDIMENT OF MEDIUM SIZED CATCHMENTS

RIVER(S)	Catchment Area (km²)	Degree of Control (%)	Reduction		Notes
			Floods (%	Sediment (%)	
R. Nanchuan, Shanxi	810	22·8	41·4	26·5	
11 R. Huang tributaries in Western Shanxi	58888	26·3	34·5	38·4	After 1970 compared to before 1969
Rivers Jing, Wei, and Beiluo, Shaanxi	110372			22·1	1970-78 compared to 1950-59
R. Wuding, Northern Shaanxi	30217			52·3	1970-78 compared to 1950-59

Source: GAO Bowen, 1980, page 13.

increased from about 193,000 人 to 473,000 人 , the tilled area increased by 820 km^2, and the total grain yield increased from 80,000 t to 90,000 t, but the forested area shrank between 1968 and 1978, by some 20 %, and 13 Communes lost all their pastureland. As a consequence, it is reported, the climate became more extreme, becoming more arid and more prone to violent storms. In the 16 years to 1965 only four storms affected more than 67 km^2 and the largest affected 140 km^2, but in the 13 years thereafter, nine such storms occurred and the largest affected an area of some 400 km^2. Since the Civil War, 227 km^2 has been lost by the extension of gullies and this continues at a rate of some 12 $km^2\ yr^{-1}$. 88 reservoirs built in the same period, in total have already lost 110 x $10^6\ m^3$ of their original 286 x $10^6\ m^3$ storage capacity. Meanwhile, this region, which was renowned in the late fifties for its abundance, has become a supplicant for State aid. The grain yield fell from 414 kg $人^{-1}$ in 1944 to 190 kg $人^{-1}$ in 1977. In 1956 over 4340 t of cooking oil and 23,000 pigs were sold to the State, but in 1976 the amounts sold had fallen to 425 t and 20,000 head respectively. Similarly, in 1977 only 890 cattle were sold, whereas in 1958 some 3000 had been sold. The total number of domestic animals in 1979 was only one fifth of the number in 1957. Between 1970 and 1979 total grain sales to the State amounted to 60,000 t, but purchases were 85,000 t, the average annual food provision is now only 100 kg $人^{-1}$ and the average annual income now is only ¥ 29 $人^{-1}$ (£ 8.3 $人^{-1}\ yr^{-1}$) whilst the collective received State aid of ¥ 13 x 10^6 between 1970 and 1976, and ran up a further debt of ¥ 26 x 10^6 with the People's Bank, making a total debt of ¥ 26 x 10^6, (£ 7.4 x 10^6) or ¥ 55 $人^{-1}$.

At the other extreme is Gaoxi Gully of Mizhi County, N. Shaanxi, a small tributary catchment to the R. Wuding, only 400 ha in area, with a population of 348人(in 1962), and which has received much attention in the press as a model district.(34) In the fifties there were 207 ha, (or about 0.74 ha $人^{-1}$) of tilled land distributed over the 40 hilltops and 21 gullies, but no forest or grassland. Yields were between 225 kg ha^{-1} and 375 kg ha^{-1}, and there was no money income. In 1958 the RHWCC launched a pilot project with terraces on the hills, some gully dams and some grassland for the rearing of horses. In 1961 (during the 'three hard years'), there was a lack of pasture, and nine head of cattle and 100 sheep were sold, which reduced the available manure. Despite this setback the tilled area had been reduced, by 1971, to 71.3 ha, 70 ha had been forested and 67 ha put to grass. In 1974 a high lift pump (120 m) was added which could stabilise agricultural production on the terraces, of which there are at present 43.3 ha and there are 112 productive gully dams. Although half the catchment has yet to be treated, the Brigade is already far more prosperous than in the fifties. The total grain yield for example has risen from a little over 48 t to 280 t despite a reduction in tilled area (including terraces) of over 50 %. Furthermore, the annual production of every labourer in husbandry is worth ¥ 1140 (£ 326) and of each one in forestry, ¥ 917 (£ 262). This arrangement, whereby agriculture, forestry and husbandry occupy equal areas has become known as '3-3 Control'.(35)

Similar results have been obtained in other model districts, as is shown in Table 5-5. It is necessary, however, to consider the extent to which they represent the development of the region and the overall balance between such advances, and the various retreats.

One fairly complete published summary of the current overall situation reads thus,

> "This region has 123 Counties in Shaanxi, Gansu, Ningxia, Nei Menggu and Shanxi, covers an area somewhere in excess of 200,000 km^2 and supports a population of 24 x 10^6 人. At present, agriculture is given precedence, but the unit production of cereals is only 1.25 t ha^{-1} and in quite a few places it is only 0.225 t ha^{-1}, 0.300 t ha^{-1} or 0.375 t ha^{-1}. Food provisions and levels of income for peasants are very low. According to statistics from 121 Counties, there are 45 (i.e. 37 %) where the average provision is less than 0.150 t $人^{-1}$; and 65 Counties (i.e. 57 %) where the income is less than ¥ 50 $人^{-1}yr^{-1}$". (£ 14.3 $人^{-1}$). (36)

Another writer, referring to the same 123 Counties and the same population of 24 x 10^6人, gives the area as "about 300,000 km^2, of which 66,000 km^2 are tilled".(37) The discrepancy is probably due to the fact that these articles are written in general terms, yet both approximate to the 280,000 km^2 area of severe erosion (k>5000 t km^{-2} yr^{-1}) described in Chapter 1, and may serve to indicate that, for the

TABLE 5-5 ECONOMIC DATA FOR VARIOUS MODEL SMALL CATCHMENTS

CATCHMENT OR BRIGADE	Catchment Area (km2)	Total Annual Income (¥ × 10^3)	Proportion Earned by Forestry, Husbandry, and Side-lines (%)	Gross Per Capita Income (¥)	Land Productivity (¥ km^2 x 10^3)	Grain Yield Per Capita (kg)	Year
Quyu Brigade, Hequ, Shanxi	12·6	820·0	55	279·8	64·7	546	1979
Nanqu Gully, Hequ, Shanxi	27·0	1560·0	58	195	58·0	416	1979
Wangjia Gully, Lishi, Shanxi	9·1	213·9		230	23·5		1978
Erlang Gully, Jingchuan, Gansu	34·2	1175·0		127	34·4		1979
Xiaogaoling, Huangyuan, Qinghai	13·2	599·5	41·7	352	45·4	629	1979
Guandaoliang, Lishi, Shanxi	0·28	24·3	67·6	478	86·2		1979
Gaoxi Gully, Mizhi, Shaanxi	4·0	130·0	84·4	295·4	32·5	534	1978
Xiaosi Gully, Yan'an, Shaanxi	1·8	37·0	50·0	264·2	20·0	650	1978

Source: GAO Bowen, 1980, page 14.

TABLE 5-6 TOTAL GRAIN YIELDS OF EIGHTEEN COUNTIES IN GANSU

Year	1953	1956	1960	1967	1973	1975
Yield (t x 10)	0·622	1·182	0·573	1·260	0·934	1·462

Source: GAO Bowen, 1980, page 2.

most part, life on the loess plateau is still very difficult.

Another aspect to be considered is the stability of production. In the model districts a good level of stability is a contributing factor to their prosperity but, as the total yields over 18 Counties in Gansu indicate, the loess plateau as a whole has yet to achieve such good results. (Table 5-6). The total possessions of each of 90 % of the families from one of these Counties (Huining County) is reported to have a value of less than ¥ 30 (£ 8.6).(38) The loess plateau remains one of the poorest regions of China.

More details are available for that part of Shaanxi which falls within the R. Huang basin, and these are presented in Table 5-7. The area involved is some 124,000 km^2, of which 101,400 km^2 (82 %) is considered to be an area of soil and water loss, and 30,813 km^2 (24.8 %) is cultivated. From the table it may be seen that there has been rapid progress in all the aspects of development shown. The areas given over to agriculture by the new methods, and to forestry and husbandry, have all increased markedly and, with improvements in water storage and in irrigation, there has been an approximate threefold increase in both per unit and total grain yields. Yet there are also some disturbing signs, for this threefold increase in grain yields has been accompanied by a doubling of the population and a near 14-fold increase in the number of pigs. (Some of the coarse grains or sweet potatoes grown as pig feed are usually included in the grain yield).(39) Thus on average the people's diet will now contain less lamb and more pork and the improvement in cereals will not have been spectacular. Whilst the dietary balance may have improved, it is unlikely that there has been a significant improvement in the per capita food consumption and, as mentioned above, it has not yet become stable. It is also apparant from the table that only about 5 % of the power used in pumped irrigation could come from hydroelectric power stations in the locality.

As has been shown above, the region is capable of supporting a far greater and more varied plant cover than at present, and that it is, thereby, able to become a markedly more prosperous region.

TABLE 5-7 SHAANXI PROVINCE RIVER HUANG CATCHMENT* SOIL AND WATER CONSERVATION DATA

		1949	1956	1965	1979
Area sown to grass	(km^2)		26	519	2407
Conservation forest	(km^2)		466	3117	9020
Area closed for natural forest recovery	(km^2)				1549
Total area of 'Basic Fields'	(km^2)		59	1050	6152
Level terraces	(km^2)		26	690	3424
Bench terraces	(km^2)		23	392	2183
Gully damland	(km^2)		10	67	419
Land formed by river straightening	(km^2)				126
Total water storage capacity	($m^3 \times 10^6$)		0·033	0·676	3824
Number of reservoirs					1497
Capacity of reservoirs	($m^3 \times 10^6$)				3621
Number of ponds					43500
Capacity of ponds	($m^3 \times 10^6$)				203
Number of hydropower stations			4	163	1325
Hydropower station total installed capacity	(MW)		0·412	9·358	84·832
Powered irrigation total installed capacity	(MW)				1842
Number of pumping stations					22000
Pumping station installed capacity	(MW)				718
Number of powered wells					147000
Powered well installed capacity	(MW)				1124

Continued

TABLE 5-7 Continued

	1949	1956	1965	1979
Effective irrigated area (km^2)	1367	3174	5570	11212
Number of silt precipitation dams	0			33244
Grain yield per unit area ($kg\ ha^{-1}$)	848		1643	2730
Total grain yield ($t \times 10^6$)	2·365		4·500	6·625
Population (人 $\times 10^6$)	9·301			20·358
Large domestic animals (头 $\times 10^6$)	1·227		1·690	1·723
Pigs (头 $\times 10^6$)	0·366		1·975	5·063
Sheep (只 $\times 10^6$)	3·662		3·662	5·711
Area under preliminary control (km^2)		1296	9258	23052
State investment in soil and water conservation in given year (¥ $\times 10^6$)		7·7	5·4	10·5
Silt lost to R. Huang (%)		100		74

Source: Shaanxi Province Bureau of Hydropower, personal notes taken during fieldtrip, July 1980.
*Area of Shaanxi within R. Huang catchment, 124,000 km^2; Area of severe soil and water losses within the catchment, 101,400 km^2; Area under cultivation (1979), 30,813 km^2.

Furthermore, a significant reduction in the silt load of the R. Huang would be expected to result from the more widespread introduction of the same conservation practices. Progress has been shown to be very rapid on a small scale, but there have been problems in co-ordination which have prevented similar success over larger areas.

2) The Debate and Future Prospects for Loess Plateau Development.

By the late seventies it was clear that new policies would be needed to promote the widespread successful development of the loess plateau; but there was some contention over what they should be. The debate was reported in the press and continued for well over a year before, at a special conference held in March and April 1980, a general consensus was obtained and a policy was decided. In this section some of the principal issues will be presented and the outcome described.

The debate opened with the publication, on 26 November 1978, in the Renmin Ribao, of two articles under the overall heading, 'On the Construction Policy Question of the N.W. Loess Plateau.'(40) The first article, by Comrades Tong Dalin and Bao Tong, called for a policy in which predominance would be given to both silviculture and animal husbandry, whilst the second article, by Comrade Shi Shan, favoured placing the emphasis on husbandry alone. The two articles used very similar arguments, and even quoted each other extensively, to support the idea that agriculture should give way, respectively, to forestry and husbandry, or forestry alone. Since these articles form the point of reference for the debate as a whole, it is worthwhile to describe their contents in some detail.

Comrades Tong Dalin and Bao Tong begin by giving examples, including that of Guyuan County (See above), of the decline of agricultural yield in some parts of the loess plateau and held that the reason for such decline is,

> " .. the flouting of natural laws by opening wasteland to tilling, ruining forests and grasslands, thus wrecking the plant cover and destroying ecological conditions."

The outcome of such activity has been, they claim, not only to reduce the area given over to forestry and husbandry, but also both to destroy the ecological basis for agriculture in the region, and to send silt to the lower R. Huang. Without the protection of forests and grasslands, the desert has encroached upon N. Shaanxi, the rainfall has declined, the weather has become uncertain and the frost-free period has become changeable. Furthermore, without the same protection, engineering measures cannot provide the kind of improvement of which they should be capable. They draw upon historical data to support their contention that restoring the vegetation cover would solve the problem of the R. Huang,

> "According to historical records, in the 2100 or so years from the Qin dynasty to just before liberation, the R. Huang broke the dykes along its lower reaches in a fairly large way, 973 times. Yet in the 580 years from Wang Mang to the Sui, it only did so twice. At that time, this region had very little cultivation, nomadic grazing was predominant and so the situation on the lower R. Huang was much better."

Reporting on a recent (unspecified) symposium, they assert that there was unanimity on the viewpoints that in the long run it is inappropriate for agriculture to predominate on the loess plateau, that animal husbandry, or forestry and animal husbandry should be given precedence, and that agriculture and the capital construction of fields can only be done well once forestry and husbandry are under way. Yet, they also report a divergence of views over the process by which such a withdrawal of tillage might be achieved.

On the one hand there was the opinion that the construction of 0.1 ha 人$^{-1}$ to 0.2 ha 人$^{-1}$ of 'basic fields' capable of stable yields of between 400 kg 人$^{-1}$ and 500 kg 人$^{-1}$, should be a precondition for replacing tillage with forestry and husbandry. On the other hand, the view of Comrades Tong and Bao was that the region should be divided into parts best suited for agriculture, forestry and husbandry respectively, and the appropriate measure for each locality should then be undertaken with vigour. In justification of their viewpoint, Comrades Tong and Bao write,

> "In the short term we might lose a few thousand million <u>jin</u> of grain (if we work well we might not lose any grain), but what we'll gain is a few thousand million <u>jin</u> of meat and other pastoral and silvicultural products ..... The basic cause of the failure of agriculture to get going in this region is none other than the destruction of the plant cover and the ecological environment, so if we were to wait until after grain is under way and only then get down to solving the problems of plant cover and the ecological environment, in practice it would be but procrastination." (41)

These two different viewpoints were to form the main point of contention in the ensuing debate.

Comrades Tong and Bao put forward four proposals:

i) The necessary investigations be expedited so that proper regional plans might quickly be drawn up, showing clearly the activities to which each area is best suited.

ii) In a few 'rather well understood' places (such as Mizhi County, Shaanxi) bases should be established for the study and development of comprehensive control involving agriculture, forestry and husbandry.

iii) In those areas where the suitability of forestry and husbandry has already been established, a policy of support and encouragement of the development of silvicultural or pastoral production should be carried out.

iv) Research into the modernisation of forestry and husbandry should strenuously be promoted and public debate encouraged.

The third proposal is the most controversial, since it amounts to a call for political and economic changes, including changes to agricultural taxation in the area,

> "Under the precondition that the rights to self rule of the production teams be respected, authorise them to replace tillage with forestry and husbandry. Simultaneously, establish various economic systems to serve forestry and husbandry; authorise the production teams to sell the products of forestry and husbandry to the State; guarantee that the level of the commune member's provision for those teams who fulfil their quota of silvicultural and pastoral products will not fall below the level of their grain-producing neighbours; commend those teams which over-fulfil their pastoral and silvicultural quotas in the same way that we do those who over-fulfil their agricultural quotas."

In his article, Comrade Shi Shan repeats the arguments for increasing the plant cover index, from the points of view of the local ecology and economy, and the control of the lower R. Huang. In this respect it is compatible with the application of the former article's suggestions for those areas better suited to animal husbandry. Yet for bringing about a general increase in plant cover, he mentions only husbandry. His reasons are that husbandry is stable and that grass is cheap and grows quickly. Moreover, he sees animal husbandry as the key to agriculture and silviculture,

> "Develop animal husbandry first and then develop cultivation and forestry .... fix the proper ratios between artificial fodder and pastures, forests and tilled land, to achieve an overall development of agriculture, silviculture and husbandry. Over twenty years' experience has proved that if you demand animal products you also get grain; but if you demand grain directly, then you lose both grain and meat."

Comrade Shi makes some estimation of the income likely to accrue from changing to animal husbandry. He writes that each hectare may be sown with 7.5 kg of seed, costing about ¥ 15 (£ 4.3) and from the third year, 18.75 t ha^{-1} yr^{-1} of fresh grass or 7.5 t ha^{-1} yr^{-1} of dry grass will be gained. He claims that 15 sheep or between 600 and 750 rabbits may be fed on the 18.75 t of fresh grass.

He also calls for political and economic changes, but is careful to emphasise that his is a regional plan and must be adapted to each locality,

> "The State would demand only livestock produce and oils and gradual self-sufficiency in grain. Moreover, it would allow a period of adjustment (this applies to the region as a whole. With specific reference to individual Counties, Communes, Brigades or Production Teams, whether husbandry is given precedence and just how agriculture, forestry and husbandry are combined, definitely must be decided in accordance with local conditions)."

In the ensuing debate there emerged two important areas of discussion. The main one, as already mentioned, concerns the relative importance of agriculture, silviculture and husbandry to the region as a whole, with special emphasis on the role of grain production. The second one, the lesser question, is about how to handle the relationship between silviculture and husbandry. Whilst there is no call for a continuance of the extensive hilltop tillage which has proven so destructive in the recent past, a number of Comrades believe that agriculture should still form the basis of loess plateau development. As was mentioned by Comrades Tong and Bao in their article, this would be done, in the view of the protagonists of agriculture, by providing about 0.1 ha 人$^{-1}$ of 'basic fields' as a precondition to the withdrawal of tillage from the hilltops. These agricultural protagonists are obliged, therefore, to draw the distinction clearly. Here are two examples, "I consider that the problem arising in construction of the loess plateau is not that the policy of making grain the key link itself has problems but that this policy was unable properly to be grasped, so that wasteland was freely opened. It was not united with forestry and husbandry, and thus created serious soil and water losses."(42)

and,

"Agriculture on the loess plateau is not done ideally enough, not altogether because the production policy doesn't tally with the natural characteristics of the region, or violates natural laws, but because of adherance to old practices; advanced agricultural science has not really entered this region. For example, methods which reduce or avoid tillage have an outstanding significance to soil and water conservation, but it seems that nobody is advocating them. As long as we do well scientific tests, a definite degree of soil improvement and reduction in soil and water losses can be had."(43)

Most of the agricultural protagonists, however, see the construction of basic fields restricted to its role as a means to promote silviculture and husbandry in the kind of comprehensive control scheme used in 'model' districts, such as those of N. Shaanxi. Others see it as an end in itself which, in order to be successful, needs to be united with the other activities and, thereby, has their promotion as one of its beneficial side effects. However, the reasoning of both groups of agricultural protagonists stems from consideration of the food needs of the area and the poor communications which, in their view, make self sufficiency in grain imperative. One example of the extreme difficulty of the problem of guaranteeing food supplies is given by Comrade Li Erzhong in support of his view that agriculture is necessary for a transitional period,

"Some Comrades suggest that we concentrate our efforts on silvicultural and pastoral production and leave the food problem to be solved by the State. Couldn't construction then be done more quickly? This is impossible and in practice wouldn't work. In 1972, Yulin was troubled by drought and over two million people were short of grain. The whole country mobilised 1400 lorries to move grain and it took a whole year to move about 100×10^3 t. As a result, the price of the grain, plus the cost of transportation, came to about ¥ 2 kg^{-1}. Moreover, the amount of grain was still insufficient."(44)

To which it may be added that the normal price of grain in Xi'an is ¥ 0.3 kg^{-1}, and that transported to Yan'an, it costs ¥ 1.6 kg^{-1}. In Beijing it is about ¥ 0.3 kg^{-1}, depending on the quality.(45)

Whilst Comrade Li is criticising the more extreme antagonists of agriculture, its more extreme protagonists do not stop at self sufficiency in grain, but would press for the region to become a net exporter.

Those in favour of agriculture point to the suitability of loess soil, it having, for example, much calcium carbonate. They also claim that the climate is not generally unfavourable. Thus, high yields may be obtained as long as the work is well done, and this need not necessarily lead to greater soil and water loss. They take issue, particularly, with the protagonists of animal husbandry over the relative merits of crops and grass. Comrade Zhang Qinwen, for example, points out that engineering measures do conserve both water and soil, whilst overgrazing has been responsible for the destruction of many good pastures, bringing about serious soil and water losses to the detriment of soil fertility. He calls for the use of fallow rotations, an agricultural method, to restore these lands to their pastoral use.(46)

A more common point of contention, though, concerns Comrade Shi's estimates for the income likely to accrue from husbandry. Comrade Yang Wenzhi, for example, reports that at the experimental centre at Ansai, Shaanxi, only 7.5 羊 ha^{-1} may be grazed, and Comrades Cui Qiwu and Wen Dazhong point to a flaw in Comrade Shi's argument,

> "A comparison of grain and fresh grass yields produced under differing conditions has no significance whatsoever. Plots with grain yields of only 0.225 t ha^{-1} are of course barren plots with poor management. If no other measure is taken on this kind of land, then we're afraid there's no way that 18.75 t ha^{-1} of fresh grass can be obtained ... On the other hand, if we were to create conditions capable of producing 18.75 t ha^{-1} of fresh grass and then change to grain, its yield probably would not be only 0.225 t ha^{-1} to 0.30 t ha^{-1} ....."(47)

They continue by suggesting that the dry matter yields of grass and grain crops in areas where the work is done well, are about the same, but that grass has further to be converted to meat before it is of use to man, with associated losses in energy.

The latter point is not specifically answered by the other contributors to the debate. Neither is the objection, of Comrades

Cui and Wen, to the assertion, by Comrades Tong, Bao and Shi, that the absence of many recorded instances of serious flood on the lower R. Huang in the 580 year period, from Wang Mang to the beginning of the Sui, may be interpreted as the result of animal husbandry predominating on the loess plateau. On the contrary, they argue, that was the period following the large-scale efforts of Wang Jing and Wang Wu in controlling the lower R. Huang (Chapter 2) and, on the other hand, many records of the time were destroyed in war; whilst there exists other historical evidence to suggest that floods continued to occur not infrequently.

The case given for agriculture to be brought to predominance, may be summarised thus: The apparent failure to bring soil and water loss under control, to raise yields, and to put an end to the practice of shifting cultivation, has not been the result of over-emphasising grain production, but of not emphasising it in the right way. Provided that the work be properly done, then high and stable grain yields will result, and soil and water will be retained. Meanwhile, the necessary conditions will be provided for husbandry and forestry to develop gradually. The evidence put forward to suggest that emphasising agriculture, or failing to emphasise forestry and husbandry, cannot but cause a continuing deterioration along the lower R. Huang is fallacious. It is clear that only by giving emphasis to agriculture can the region feed itself. Should the other activities gain predominance they would fail to provide sufficient food for the local population, who would be obliged to continue the practice of shifting cultivation.

At the end of his article emphasising the role of agriculture in the transitional period, Comrade Liu Wanquan puts forward five proposals which, he writes, are supplementary to the four already put forward by Comrades Tong and Bao.[(48)] They are:

i) Extensive areas with a sparce population should emphasise husbandry or forestry and husbandry.

ii) The majority of areas should emphasise farmland capital construction and strive for one man one <u>mu</u> (0.067 ha) of 'basic fields'. When the food provision is thus guaranteed, tillage on the slopes should be replaced by husbandry and forestry.

iii) In building 'basic fields', work should start on the slopes, usually by terracing. The building of gully dams should proceed with great caution.

iv) The State should help by providing tractors and bulldozers.

v) The State should adopt new policies to encourage the construction of 'basic fields'. For example, on building one mu of level terraces, award some fertilizer; when grain yields then rise, do not raise the State purchasing quota.

Both the protagonists of agriculture, and those of some combination of husbandry and forestry, thus support the idea of comprehensive development, provided it be done well, in the areas where the necessary conditions obtain. Yet, as far as the techniques to be adopted in this respect are concerned, there is nothing new. As Comrade Yang Wenzhi remarks,

> "Concerning the question of regulation policy. Whether slopes should be regulated or gullies is an old question which received heated debate in the fifties. It seems it should be 'slopes and gullies together regulate' with emphasis on the slopes ..... Daquanshui of Yanggao County(Shanxi), back in the fifties summarised their experience by coining a doggerel:
> 'Water is a dragon, from its head start to restrain,
> If you only cure the bottom, all will be in vain.'
>
> Herein is wrapped a profound scientific principle. Some of us have forgotten this experience and as a result have suffered great loss."(49)

Thus, it may be deduced that the debate is not so much about what is most suited to the loess plateau, since all are acknowledged to be suitable at different places and under different circumstances, or about the general techniques to be used, but about the political and economic changes which should be made in order to stimulate various activities in different areas. This may explain why Comrades Tong and Bao appear happy to accept 'Comprehensive Development' in 'a few rather well understood places' while urging the establishment of new economic systems to serve forestry and husbandry; and, at the same time, Comrade Liu is happy to accept forestry and husbandry in 'extensive areas with a sparce population' while urging material incentives for the construction of 'basic fields'.

It has already been seen (Chapter 3) how the national policy, "Make grain the key link and ensure comprehensive development", did not lead to the widespread and varied development of the loess plateau which was intended. Several reasons were given for its failure, which principally amounted to an overemphasis having been placed upon grain production at the expense of the other activities. Comrades Tong, Bao and Shi are, now, concerned to see that in those areas where agriculture is least suited there are policies which allow for its substitution by the other activities. Meanwhile, the protagonists of agriculture are concerned that in areas where it is best suited, tillage should not suffer because of its mistaken application in other regions. They also wish to safeguard its proper use in the transitional period in circumstances such as obtain in the various 'model' small catchments of N. Shaanxi. Therefore, if the various arguments are viewed in terms of an attempt to redress the balance, by placing emphasis on previously neglected activities, whilst being careful not to allow a greater attack on agriculture than really is justified, then the apparent contradiction, between the protagonists of silviculture or husbandry and the protagonists of agriculture, disappears.

The unity of purpose behind the rhetoric may be illustrated by the frequent calls, amongst contributors representing all the various allegiances, for policies which allow the necessary degree of variety. Three examples are given below, beginning with one from the original article by Comrades Tong and Bao,

> "If you act according to objective laws you can't have any dangerous incident, and if you respect the right of the production team to self rule, you can't create great confusion."

Secondly, from Comrade Yu Zheng,

> "Is giving priority to forestry and husbandry in contradiction with making grain the key link? I think not. Giving priority to forestry and husbandry certainly is not to reject agriculture and certainly does not mean not sowing grain, but means using land rationally, having forestry where forestry is suited, husbandry where husbandry is suited and agriculture where agriculture is suited. If no grain were sown at all, but reliance were put on other provinces to provide it, then it would be inviting chaos and is not feasible."(50)

Thirdly, Comrade Song Chaoshu,

> "I am in accord with the construction policy for the N.W. loess plateau indicated by Comrade Tong Dalin, but when executing specific measures one must still consider their adaptation to local conditions and guard against cutting everything from the same template."(51)

It would be incorrect, however, to suggest that the unity was apparent at once to many contenders; it is rather the case that the points of agreement were initially treated as coincidental, and only later recognised as holding for, and allowing for, all aspects of control. The attitudes of some of the protagonists of forestry alone or husbandry alone may illustrate that what initially appears to be a rather one-sided emphasis on the benefits of the chosen measure, eventually gives way to the acceptance of wider and more general principles. Comrade Shi, for example, seems quite determined when he says,

> "Why should precedence not be given to silviculture? The reason is that the results of growing grass are seen more quickly, it can grow longer, faster, and be first to bring the economy alive and begin to make the people prosperous."

but he goes on to add the caveat,

> "Of course, this is not to reject that regions which can be afforested should be afforested at the same time, and also does not obstruct the process of other farmland capital construction works."(52)

Similarly, Comrade Liu Jiasheng writing in favour of silviculture begins in stern tone,

> "I personally consider that to adopt a policy giving precedence to husbandry would be inappropriate. I shall bring it up here for discussion with Comrade Shi Shan. Since a place such as this which has lost the basic conditions for developing agriculture suffers both drought and serious soil and water losses, it doesn't appear that you can grow grazing grass everywhere, and even if it can survive, the grass yield cannot be very great. More importantly, only by relying on the development of forestry can the natural conditions of the region basically be changed and soil and water losses completely controlled. According to scientific determination, only once the forest cover index of the region has reached about 50 %, can you talk of sowing grass and greatly developing husbandry."(53)

but in his next paragraph writes that, provided overgrazing be avoided,

> "In this region unite the development of forestry and agriculture, act according to local conditions and where appropriate sow fodder grass. It is possible to develop a

> few sheep and cattle with pen raising predominant. It is also completely what should be done."

It may be seen that most of the arguments for any particular measure hold in specific areas, but would fall down if any attempt were made to extend them to the whole of the loess plateau. Also, it may be seen that much of the original confusion arose because of the ambiguity of the term 'loess plateau' (Chapter 1). In the gullied plateau region to the South, for example, the plateau surface is flat and whilst attention must be paid to the prevention of gully formation and extension, the region as a whole is well suited to agriculture. Some people include in the term, this, and even the Guanzhong Plain and other parts further afield. In such a way, it would appear that the region as a whole is best suited to agriculture. Yet of the loess plateau proper, as described in Chapter 1, the gullied plateau region occupies only some 17 %, the rest largely comprising the gullied hillocks region; and, since the larger part is suited best to some combination of forestry and husbandry, albeit to be achieved to a greater or lesser degree by carefully uniting them with the construction of 'basic fields', it is arguable that the loess plateau as a whole is not suited to agriculture but to forestry and husbandry. This ambiguity was finally cleared up at a 'Scientific Research Work Symposium on Soil and Water Conservation, Agriculture, Silviculture, Animal Husbandry and the Comprehensive Development of the N.W. Loess Plateau' held at Xi'an in March 1979.

The participants were over 130 leading cadres, specialists, scientists and technologists from 80 or so units, from various educational institutions and from provincial governments. Although they confirmed a general policy of 'Comprehensive development of agriculture, silviculture and husbandry with overall regulation', they agreed that it should be carried out with various emphases, according to local conditions.(54) They also drew up four broad categories for regional planning,

> "Firstly, agricultural regions, including places South of Yan'an such as N. Wei, E. Gansu and Central Shanxi, which belong to the category semihumid, temperate and cold climate, with annual precipitation above 500 mm to 600 mm, where the average annual temperature is over 10° C, there is quite a lot of plateau surface, and quite large potential strength.

"This region should pay attention to the development of agriculture so as to achieve a surplus in grain, and some Counties should become base areas for grain, cotton and oil products. Field protection forest belts and slope-protection forests should vigorously be built and fodder grass should be sown for husbandry on appropriate parts of the plateau surface and some gentle hills.

"Secondly, forest and pasture areas, including the belt of gullied hillocks in S. Gansu, S. Ningxia, N.W. Shanxi and to the North of Yan'an. This comprises forest, grassland and the transitional land belt in between, has a semi-arid, dry and cold climate with 400 mm or 500 mm annual precipitation. Soil and water losses here are 100 % serious; the Eastern regions and the critical sand-blown places already suffer the threat of wind erosion; a large area has been opened to cultivation and the plant cover has suffered destruction; agriculture is influenced by topography and climate and yields are low and unstable. This region should emphasise afforestation, the sowing of grass, and the development of silviculture and husbandry. On stream berms and gentle slopes, where appropriate, basic fields should be built and we should struggle for self-sufficiency in grain under the conditions which obtain in normal years.

"Thirdly, pastoral regions, including several places in Central Gansu, S. Ningxia, N.W. Shanxi, N. Yulin and N. Nei Menggu. This is the grassbelt and belt of desert scrubland with a semi-arid cold climate and less than 400 mm of annual precipitation. The Winters are long and cold and Spring and Summer have much drought and wind. The soils are very sandy and both wind and water erosion are serious. The crop growing period is short and there are quite a number of conditions adverse to the development of agriculture. In this region stockbreeding should be developed, windbreak forests and grazing forests vigorously should be built and where appropriate agriculture should be developed to struggle for basic self-sufficiency in grain.

"Fourthly, silvicultural regions, including various counties in the Ziwu, Huanglong, Lao, Qiao, Liupan and Long mountains and part of the Lüliang mountain district. The terrain is quite high and the rainfall quite plentiful, with thin soil layers, mainly stony hills and a few remnants of secondary forest. These regions should, with emphasis on silviculture, protect existing forests, actively develop water retention forests and guarantee these regions' agricultural and pastoral development."

These regions are shown in Figure 5-11. It is interesting to note the extremely cautious tone of the above report, care having been taken to emphasise its general nature and, it seems, also to avoid too severe an iconoclastic approach towards the once incontrovertible self-sufficiency in grain.

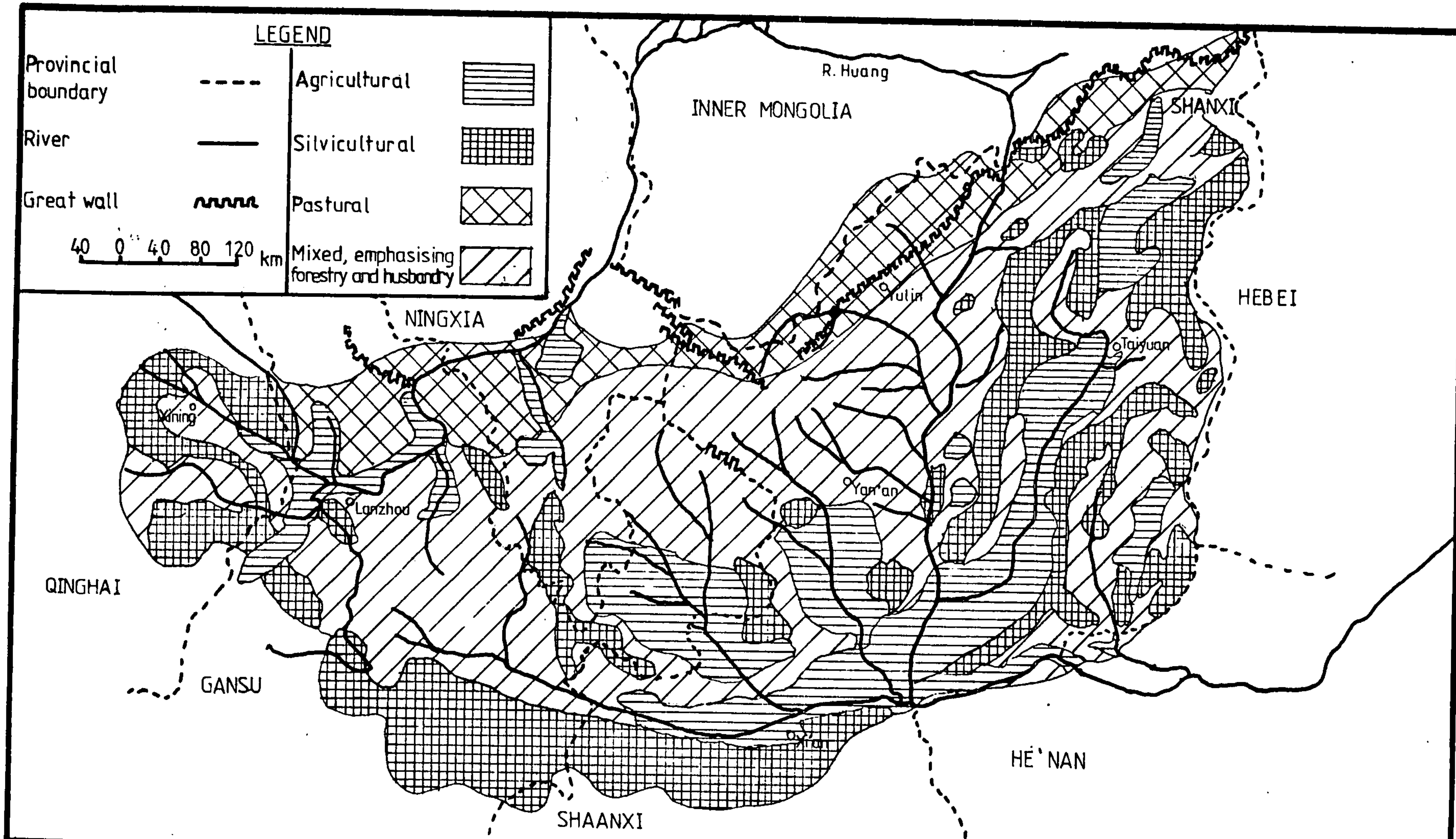


FIGURE 5-11 ECONOMIC REGIONS OF THE CENTRAL R. HUANG AREA SOURCE: Note 55

Yet although this decision greatly clarifies the debate, it does not resolve the main problems, which concern the political and economic changes required to bring about the necessarily flexible initiatives. Before going into detail of these, however, it is worthwhile to mention, briefly, the question of nomenclature. In view of the over-literal interpretation of such policies as 'Make Grain the Key Link' and 'In Agriculture Learn from Dazhai', and given the apparent Chinese propensity for giving whole sets of policies a single name, it might have been thought desirable to invent a new name for the policies to be adopted on the loess plateau, and the debate around them, even though they had not yet been fully determined. On the other hand, it would not appear wise to announce a policy which could easily be misinterpreted. In the event, no special name was announced but, instead, constant reference was made to the call of Comrade Deng Xiaoping that,

> "The loess plateau should be built into a pastoral and silvicultural base."(56)

In late March and early April 1980, in Xi'an, the same conclusion was reached by one 'Scientific Symposium on the Comprehensive Control of the Soil and Water Losses of the Loess Plateau'. It was, therefore, to be the outcome of the debate, which Comrades Tong, Bao and Shi had begun with their articles of 1978, that the area was to become a 'pastoral and silvicultural base'. During the course of the debate a number of calls had been made for political and economic changes and it is essential to consider the predominant issue and what changes to it were adopted.

The most common calls concerned compulsory sales of grain to the State, in effect a grain tax. Depending upon the locality in question, calls were made for such sales to be reduced, suspended, or replaced by sales of other produce. In areas where agriculture is well suited, the argument goes, the result of the State demanding too much grain has been to inhibit the integration of the other activities into the local economy. Thus, yields from the monoculture cropping practices so caused become unstable or fall. Not only then is there not enough to eat but, also, there is no other economic activity and the peasants' basic condition may not be changed. If the State purchasing burden were to be lightened, more land and effort could be devoted to the other activities. One example of such a demand is that made by Comrade Yang Wenzhi,

> "If the obligatory sale of grain to the State were reduced slightly, then in normal years there would be enough grain to eat. However, if as soon as harvests increase, State purchases also increase, and become too great, then there is not enough grain and this affects the masses' enthusiasm. This is a political problem."(57)

Indeed it is, for it would appear that much of the grain bought in this way must be sold back for food. This was to become an important factor. But, first, the calls for changes to the grain tax in areas where agriculture is not so well suited should also be considered.

The specific proposals of Comrades Tong, Bao and Shi have already been quoted. Their concern would seem to be twofold: to end compulsory grain sales in certain regions so as to reduce to a minimum the factors promoting agriculture where it is ecologically unsound; and to provide support and incentive to stimulate the development of pastoral and silvicultural activities.

The various calls for a temporary suspension of compulsory sales apply principally to the areas suited to 'Comprehensive Control', and is a sign of optimism that it was believed that within a few years the economy will have improved sufficiently for them to recommence. The arguments which apply to the other regions apply also here; namely, that such a move would free resources so that other economic activities may be pursued, and that, thereafter, if the tax could be paid in a variety of ways, the local economy would become better suited to the local ecology. Furthermore, as mentioned previously, owing to the instability of yields at present, much of the grain sold to the State, subsequently must be repurchased. Thus the demands for high compulsory grain sales turned out to be but accountancy. This was often used to support calls for compulsory grain sales to be abolished, either temporarily or permanently, so that in normal years self sufficiency may be achieved and, in abundant years, grain could be stored for use in years of crop failure. The State would intervene only in cases of severe hardship.

In view of the observations of some comrades, on the need for local self-sufficiency (the comment of Comrade Li Erzhong, for example, has already been quoted), one might wonder whether such a scheme could really provide sufficient food. According to Comrade Zhang Tianzeng, of the Chinese Academy of Sciences, although it is said that hilltops are needed for food production, in fact, whilst it is true that so many hilltops have been opened to cultivation, only about a third are used in practice. Comrade Li Kaiming, also of the Chinese Academy of Sciences, points out that through careful work yields may be raised by as much as 70 % in one year and may, on slopes, be within 0.375 t ha^{-1} (Chapter 3, Section 3, ii), that is, 25 %, of the yields normally obtained from terraces.(58)

A further perspective on the question of grain self-sufficiency is given by Comrade Yang Tingxiu, of the Research Commission on Agricultural Modernisation, by his remark, that in the said 123 Counties, in the agricultural year 1977 to 1978, there was an agricultural yield some 350×10^3 t surplus to the requirement of the agricultural population, and it is only when it is assumed that the same agricultural production should also provide for the other sectors of the community (towns), that it becomes a deficit of some 250×10^3 t.(59) To provide foodgrains as such is not so great a problem, then, but growing grain does not increase income and has not been stable. This is the reason why other economic activities such as the growing of fruit should be promoted.

According to Comrade Shi, a five year moratorium was subsequently granted on State grain purchases in some areas, although it is not clear to which ones this applies. Fourteen Counties have been declared 'Control Experiment Counties' and receive special temporary (unspecified) aid. Meanwhile aerial seed broadcasting is to be carried out in a big way for from 3 years to 5 years.(60) No report has been found in the press which gives confirmation or details for the region as a whole, but a Xinhua News Agency report appearing in the Remnin Ribao in June 1980, shows the beginnings of a move in the same direction, by the Shaanxi Provincial Party Committee,

> "Dealing with stockrearing, the Provincial Committee has decided to abolish all unreasonable restrictions .....

"collective cattle may be owned and reared publicly, or owned publicly and reared privately; investment support will be given to collectives, Commune members and individuals who experience difficulty in rearing large domestic animals, pigs and sheep; no restriction shall be placed upon the numbers of large domestic animals, pigs and sheep fed and reared by Commune members or individuals. For each large domestic animal raised by Commune members, where there are the conditions, 0.067 ha of land for the growing of fodder should be given, or the brigade should collectively do the planting and provide fodder grass to the Commune member.

"Dealing with accelerating afforestation ..... State owned forests which the State cannot manage in the short term, may be given to local Commune Brigades for afforestation. The woods so created will belong to whoever creates them; they may also be managed jointly by State and Collective, according to contract, the benefits being divided proportionally; scattered fragments of State owned forest or natural secondary forest which the State cannot manage may, under the precondition that ownership be not altered, be entrusted for nurture and management to Commune Brigades, the benefits being divided according to a signed contract ..... Barren mountains, land and deserts, belonging to collectives, may in part be distributed to Commune members for afforestation or sowing to grass, who plants it owns it, supported by issuing a Forest Rights Certificate.

"The development of forestry and husbandry both require resolution of the foodgrain problem ..... self-sufficiency in foodgrains may be carried out under present conditions, whilst constructing a pastoral and silvicultural base ..... whether they be collective or individual, field management or diversified enterprises, all require the establishment of a strict production task system with payments calculated according to output. With regard to those Brigades which are scattered, have low levels of management, where production has not got going over a long period, the Commune members' income is small and life is hard, a production task system comprising payment partly in kind may be carried out, based upon work groups; certain individual households may be permitted fixed output quotas. Commune Brigades with high proportions of forestry, husbandry and oils, may substitute these products for grain in their State purchasing quotas.

"Furthermore ..... agricultural sidelines processed by the County, may be given over to the Commune Brigades to do, or may be done jointly, dividing the benefits; the State will put aside some money as a floating fund to support Commune Brigade enterprises and diversified activities; all unreasonable prohibitions on household sidelines shall be lifted and support will be given with investment, seedlings and techniques. The Provincial Committee also decided to smash the demarkation of administrative districts. Within and outwith the Province several large towns will open distributive departments for the special produce of North Shaanxi."(61)

It is possible to conclude that in the important area of local economic policy, at least, the lessons of the past have been learnt and changes are under way to attempt to redress the balance and bring about a more varied economy. This should be more stable and eventually, it is hoped, will lead to a more prosperous region as well as to a reduction in the problems of the R. Huang. It should be remembered, though, that only one aspect of the new policies has been discussed here. Other aspects include the level and use of State aid, the relationship between technical experts and party officials, new legal restrictions, and the slow progress of the restoration of various technical organs. One example of the latter point has already been quoted (Chapter 3, Section 3,i) and, although it would appear from other sources that work has been particularly slow in establishing new administrative organs, the following quotation from Comrade Tong Dalin may serve to illustrate that the scientific contingent at least, is making a healthy comeback,

> "At present there are here, nine scientific research and teaching units, i.e.; the Northwest Agricultural Institute, the Northwest Silvicultural Institute, the Soil and Water Conservation Institute of the Academy of Sciences, and the Agricultural and Silvicultural Scientific Institute, Plant Institute, Water Conservancy Institute, Agricultural and Silvicultural College, Water Conservancy College and Wugong Agricultural Research Centre, under Shaanxi Province. Researchers and teachers number over 2000 人 and students, over 3000 人. What a valuable strength this is!"(62)

3) Prospects and Diverse Opinions on the Future of the Lower River Huang.

As was shown earlier (Section 1,ii, of this chapter), the ability to control R. Huang floods is at present limited and the condition of the lower reaches is continuing to deteriorate. The construction of a new tributary reservoir is already in progress to improve the situation and in addition, advanced plans have been drawn up as a basis for further development stages. There are several alternatives, however, from amongst which the final choice has yet to be made. In this section some of the alternative strategies are presented with tentative observations on how well each is being accepted.

i) The Northward Transfer of Southern Waters.

The general aridity of Northern China and the relative abundance of water, both South of the Changjiang, and flowing in it (its annual discharge is twenty times that of the R. Huang), formed, in the 1950s, the basis for the concept of Northward Transfer of Southern Waters. Recently, such transfer of water has been suggested as a method for resolving the sediment problem of the lower R. Huang.

According to Comrade Wang Huayun, research into various possible routes for such a transfer began shortly after the Civil War and, in 1958, formal 'scientific investigation and surveying work' began with the organisation of a team to prospect from the upper Changjiang to the R. Huang. Over fifteen different possibilities, some not restricted to the two rivers' upper reaches, were suggested, from which Comrade Wang chose four generally representative routes for further description in his article.(63) The following synopsis is illustrated by Figure 5-12.

In route No. 1, water would first be diverted, by means of a 250 m high dam from the R. Tongtian (middle part of the upper Changjiang above Yushu), in Qinghai, across the grasslands to Mt. Que'er, and thence through a 6.5 km tunnel to join the R. Yalong, a sub-tributary of the Changjiang. At Ganzi another dam would be used to divert the waters Northwards from the R. Yalong to join the R. Huang near the

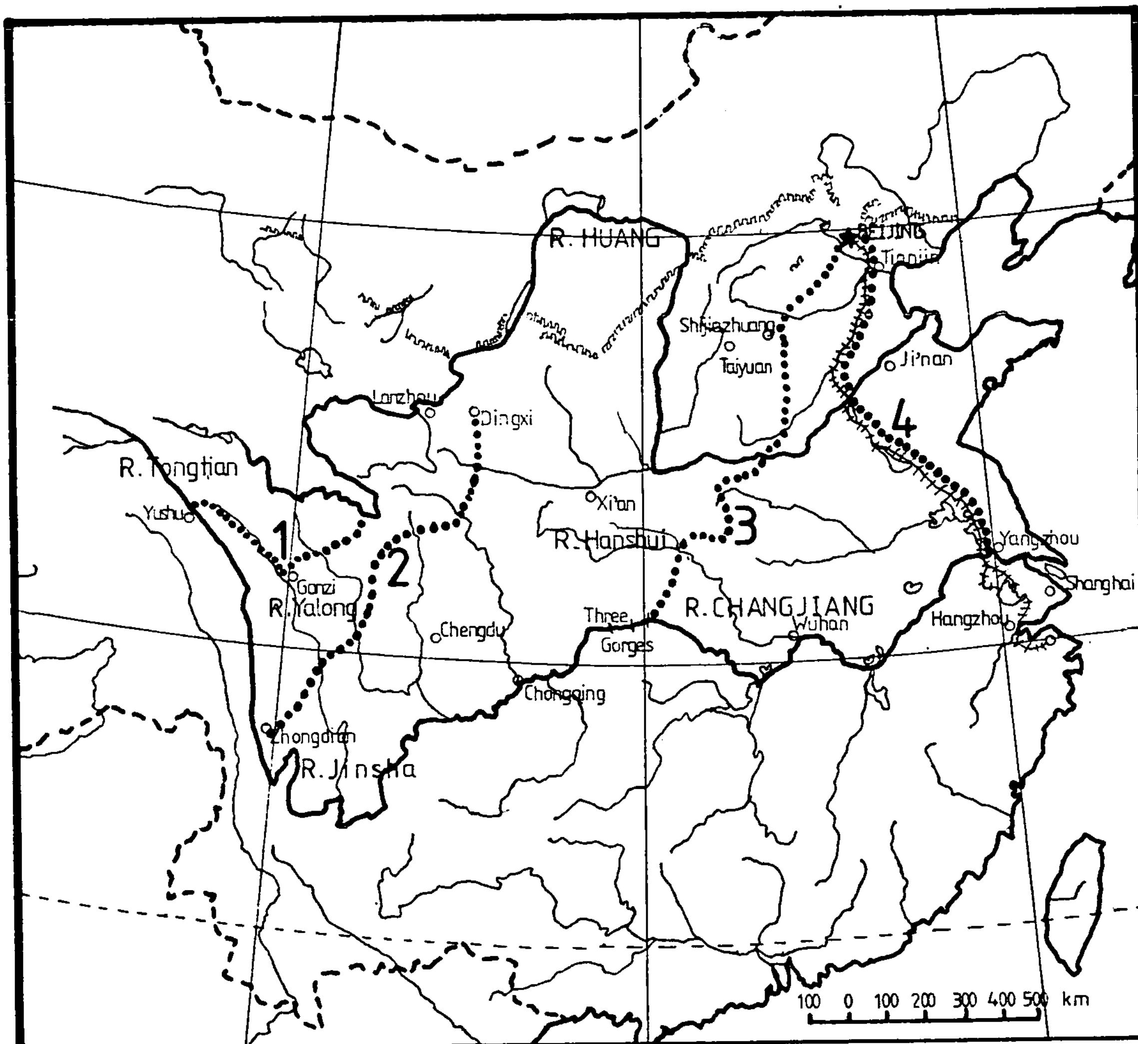


FIGURE 5-12 FOUR GENERAL ROUTES FOR THE NORTHWARD TRANSFER OF SOUTHERN WATERS, AS IDENTIFIED BEFORE 1960

Drawn according to the description in the text.

common meeting point of Qinghai, Sichuan and Gansu Provinces. Some 22.1×10^9 m^3 yr^{-1} of water would be diverted along this 1680 km route, of which 405 km comprises the R. Yalong, and 1283 km would be canals. Eight dams between 150 m and 250 m high, 20 tunnels totalling 51 km (longest single tunnel, 7 km), and 2.5×10^9 m^3 of earthworks would be required.

Route No. 2 is more ambitious and apparently more speculative, since several alternatives are given for the method by which water would be diverted at the Southern end, some involving unprecedentedly high dams made by using explosives to topple cliffs and block gorges. The more conventional alternative, though, would use a 150 m high dam to divert the R. Jinsha (lower part of the upper Changjiang) at Zhongdian County, just within Yunnan Province, and then would use 5 dams each between 150 m and 250 m high, 15 tunnels totalling 57 km, and several tens of milliards of cubic metres of earthworks to form a 6800 km route, crossing four large rivers and skirting the Sichuan basin, to Dingxi in Gansu Province.

Route No. 3 would divert water from the Changjiang at the Three Gorges reservoir and lead it 400 km to the Danjiangkou reservoir on the R. Hanshui. From there, it would be led for 500 km through the Fangcheng Pass to cross the R. Huang at Taohuayu, and then a further 700 km following the Guangzhou - Beijing railway line to the Capital. The middle section would require some 0.56×10^9 m^3 of earthworks, but no other estimate is given.

Route No. 4 would involve modification of the Grand Canal for the purpose of raising Changjiang waters, from Yangzhou, 60 m to 70 m and transferring them 650 km to join the R. Huang via Lake Dongping. Ten pumping stations were envisaged to supply some ten milliard cubic metres per year (about 320 m^3 s^{-1}). Under the planned Weishan project, the waters just below the lake, could be diverted into the Northern half of the Grand Canal where they would flow by gravity to Beijing.

Discussion of these grandiose schemes reached its climax towards the end of the Great Leap Forward, and provides another illuminating insight into the psychological climate of the time, during which, it will be remembered, the dam at Sanmenxia was nearing completion. Whilst planning was on a conceptual level only and it was acknowledged to be but a long term solution, such emphasis was placed on these schemes' merits as to cause one to wonder at their failure to have been implemented. The Northward transfer of Southern waters would be capable, it was claimed, of resolving the fundamental cause of China's agricultural and industrial problems, namely the uneven distribution of the country's water resources, and, thus, would be an unprecedented achievement of enormous value,

> "The Northward transfer of Southern waters is not only an effective measure to balance Northern and Southern waters, to guarantee stable bumper yields in the agriculture and husbandry of the North China Plain, the loess plateau, the deserts and the grasslands, and to guarantee water supplies to industry, mines, towns, navigation and for going green, but it is also a great and magnificent project for the transformation of nature and deserts to the service of Communist construction."(64)

However, a great deal of research work would still, under the best of conditions, have had to have been carried out before specific proposals could have been made, and it is not surprising that after the initial interest not much was heard on the subject for some twenty years. It is even less surprising in view of some of the changes which took place in that period. For example, the general discrediting of large scale projects by such failures as at Sanmenxia, the temporary ban on the use of R. Huang waters for irrigation of the North China Plain which followed serious alkalisation there, and the political turmoil which wreaked havoc for the decade thereafter, would all have worked against any rapid development of the schemes for interbasin transfer.

So after the first rush of interest it would seem that the plans were shelved, and this is confirmed by Greer, who reports statements made in 1974 by R. Huang officials, that no water was being transferred into the R. Huang basin and that no plan for such transfer was under consideration.(65)

Then, at the Fifth National People's Congress in February 1978, in his report on the work of the government, Chairman Hua Guofeng announced as one of the tasks to be completed before 1985,

> "Projects to divert water from the Changjiang to areas North of the R. Huang",(66)

and three of the four general routes later re-emerged for consideration, the exception being route No. 2, which received no further attention. First to be made public was the Eastern route (previously No. 4). A team of 100 cadres, engineers, and technicians under the State Planning Commission, the Ministry of Water Conservancy and Power, 4 Provinces and 1 Municipality, had made a survey from May until July 1978 and had declared the route 'Economical, rational and feasible'. Yet, following its announcement in August 1978, a number of dissentions and alternative proposals were raised, notably with the re-publication in February 1979, of the middle route (formerly route No. 3).(67)

Subsequently, from 29 March until 11 April, 1979, a forum, held in Tianjin to discuss the three routes, is reported to have agreed that whilst all three are in general practical, each plan needs some improvement. Furthermore, they considered the construction of the Western route (No. 1), to be beyond China's capability for the time being, though surveys should continue.(68)

Research work continued, and a further symposium and field study were held jointly by the United Nations University and the Institute of Geography of the Chinese Academy of Sciences in 1980. This concentrated upon the many environmental questions to have emerged. Papers from the symposium are expected to be published soon.(69) The three routes will now be discussed in their new forms.

From July to October 1978, the Northward Transfer of Southern Waters Prospecting Team under the RHWCC, partly in collaboration with the Jiangsu Provincial Institute of Geography, carried out surveys of a number of possible versions of the Western route. In their very brief synopsis, published in Renmin Huanghe magazine, they give examples of the possible routes from two tributaries of the R. Tongtian to various points on the R. Huang or its tributaries. (Figure 5-13).(70) Two of the eleven examples, S-Z and D-H, rely on gravity, whilst the others would require some form of pumping.

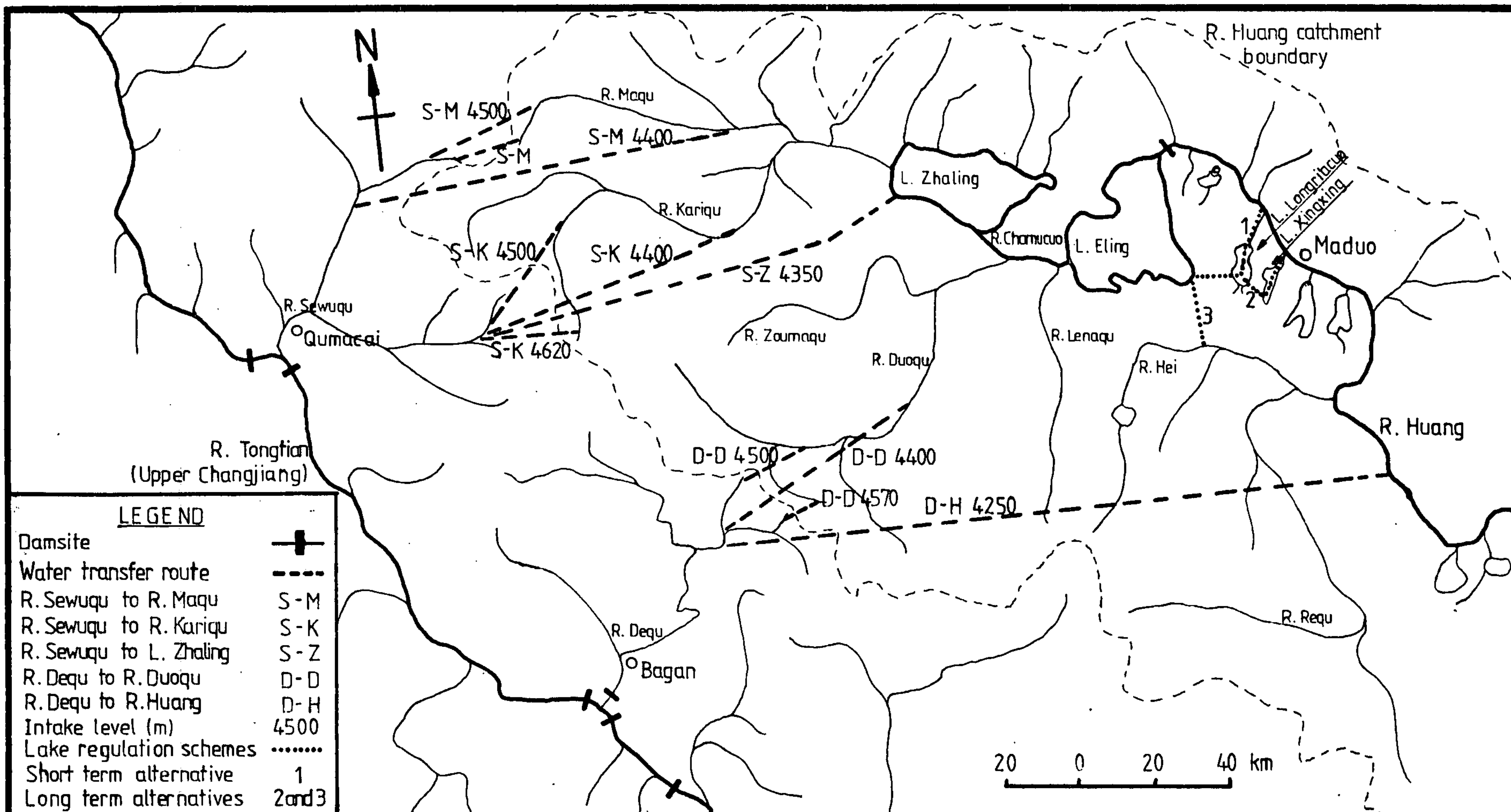


FIGURE 5-13 RECENT PROPOSALS FOR INTERBASIN TRANSFERS BY THE WESTERN ROUTE, AND TO EXPLOIT LAKES ZHALING AND ELING

SOURCES: Notes 71, 72.

Rough data for four of the routes are shown in Table 5-8, and illustrate the more moderate nature of these proposals. Between $7.85 \times 10^9\ m^3\ yr^{-1}$ and $10.35 \times 10^9\ m^3\ yr^{-1}$ of water may be transferred by these schemes, which would involve dams, between 155 m and 379 m high, across the R. Tongtian. None of the routes exceeds 200 km. The pumped schemes would raise water some 120 m to 380 m and consume between 3.5 TW h yr^{-1} and 14 TW h yr^{-1} of electrical power.

In a preceding article in the same issue of Renmin Huanghe, the Prospecting Team suggest modifying the existing outlet of the lower of the R. Huang's two largest freshwater lakes, Lake Zhaling and Lake Eling, or adding a new outlet, so as to augment their natural regulative capacities.(71) In dry years the two lakes' water level could be lowered by up to 8 m and 12 m, respectively, which would increase the water supply by $9.5 \times 10^9\ m^3$ (62 % of the stored volume), whilst reducing their area by 354.5 km^2 (31 %). In abundant years the water level could be raised by 9 m, which would increase the two lakes' capacity by $6 \times 10^9\ m^3$ whilst increasing their area by a total of 50 km^2. Since the annual runoff here is about $500 \times 10^6\ m^3$, the regulation afforded by these modifications would be significant and, moreover, the scale of the engineering works required, would be very modest; one scheme for example would need 33 km of canals, 1.6 km of tunnels and total earthworks of $7.65 \times 10^6\ m^3$. This is presented as a short-term plan.

In the long term this scheme would be combined with the foregoing water transfer scheme, whereby some $7.85 \times 10^9\ m^3\ yr^{-1}$ would enter the lakes from the R. Tongtian. There are two possible new outlets which allow for 140 MW to 150 MW of electrical generating capacity. (Figure 5-13). One route would require 28 km of canals, 1.6 km of tunnels and $15 \times 10^6\ m^3$ of earthworks to lead the water back to the R. Huang via two smaller lakes, whilst the other route would require 21 km of canals, 6 km of tunnels and $6 \times 10^6\ m^3$ of earthworks to lead the waters into a R. Huang tributary, the R. Hei.

Although these new route 1 type transfer schemes are still speculative, and should be regarded as long term possibilities, the modest scale of the lake modification scheme and its relatively large

TABLE 5-8 BASIC DATA FOR FOUR OF THE SUGGESTED TRANSFER SCHEMES

ROUTE (see figure 5-13)	S-M 4500	S-K 4500	D-D 4400	D-H 4250
Total length (km)	123·5	142·5	63·7	176·8
Tunnels (km)	49·9	55·9	23·5	175·0
Earth and stone to be removed ($m^3 \times 10^6$)	47·4	50·0	18·2	55·7
Concrete ($m^3 \times 10^6$)	4·7	5·4	2·6	16·4
Net water lift (m)	219·8	224·0	305·7	Gravity scheme
Annual energy consumption (kw hr x 10^6)	6410	6540	11270	

Source: RHWCC, Northward Transfer of Southern Waters prospecting group, Eds., 1979a, p. 51.

effect make it quite an attractive proposition. This would be even more so in view of the critical situation which developed at the construction site of the Longyangxia hydropower station in the Summer of 1981, when unexpectedly large flood peaks occurred and threatened the coffer dam (Section 4). In addition to the more moderate scale of these new proposals, it is interesting to note that one of the principal benefits is seen to be their ability to regulate the water for electricity generation in the upper R. Huang,

> "In comparison with some of the interbasin water regulation works in this country and abroad, the amount of work is not large. This scheme plays quite a sizeable role in resolving the water supply problem of the arid Northwestern region and in raising the guaranteed output of the R. Huang mainstream power stations. With regard to the scale of the project, building this type of works is also possible."(72)

However, no announcement has been made to confirm that any such scheme will go ahead in the near future.

The middle route, diverting water from the Danjiangkou reservoir on the R. Hanshui, re-emerged almost unchanged. Its great advantage was held to be that it would rely only upon gravity, which would save running costs. One advocate of this route, Comrade Xiao Bingjun, proposed short-term and long-term versions. In the short-term, the dam of the Danjiangkou reservoir would be raised by 13 m, to 175 m, to give a capacity of 34×10^9 m^3 under a normal high water level of 170 m. However, water would have to be stored which at present is used to generate power, and the output of the Danjiangkou hydropower station would be reduced by between 700 GW h yr^{-1} and 1.7 TW h yr^{-1}. Nevertheless, Comrade Xiao suggests that this can be supplemented from the Gezhouba project under construction in the Changjiang Gorges or by fossil fuel power stations. The water diverted from the Changjiang would amount to 30×10^9 m^3, some 17×10^9 m^3 of which would be distributed North of the R. Huang. Since the trunk canal would connect ultimately with the Bo Sea at Qinhuangdao (Hebei) and Tianjin, it would become both a major source of water and a principal drainage channel for the North China Plain.(73)

In the long term, water would be diverted from the Yangtse tributaries, the rivers Bailong and Jialing into the upper reaches of the R. Hanshui near Yangpingquan, S.W. Shaanxi. This would have the added advantage of providing extra potential for two existing hydropower stations on the R. Hanshui. Furthermore, water could eventually be diverted from the proposed Changjiang Gorges reservoir, and would flow to the Danjiangkou reservoir by gravity. One report even suggests that in the very long term, this canal might be extended Southwards to Guangzhou.(74)

The suggested use of the middle route, or part of it, has found favour with some of the champions of the Taohuayu project on the R. Huang (Section 3,iii). They see the use of that reservoir to facilitate the crossing of the R. Huang by the diverted R. Hanshui waters, as affording an opportunity to regulate the sediment concentration of the lower R. Huang and scour the bed. At the same time it would obviate R. Huang silt entering the canal (Section 3,iv).(75)

When interest in the schemes for water transfer had re-emerged in 1978 with the emphasis on the Eastern route, there were few changes of detail, but the most important two concerned the scale of the project and the method of crossing the R. Huang. Since the river had not become clear after the construction of the Sanmenxia reservoir, and the Weishan diversion weir had been bypassed, it was considered best for the water transfer canal to pass under the R. Huang's elevated bed in tunnels. The annual water volume to be transferred had risen to 30 x 10^9 m^3 and to raise this water 40 m to the level at which it would pass under the R. Huang, thirty pumping stations in fifteen stages would consume one gigawatt of electrical power. Under this scheme, 1120 km of the original canal would have to be dredged and widened, whilst 250 km would be newly excavated. The Northern half of the system, as before, would rely on gravity.(76)

The middle and Eastern routes were both proposed as ways to overcome a perceived water shortage on the North China Plain, particularly North of the R. Huang, and in the industrial cities to be found there. However, they met with environmental objections which applied, to different extents, to both. For example, although the Changjiang has abundant water supplies which are less extreme in their variation than those of the R. Huang, seasonal changes still occur and, in 1978, when the river was low, encroachment of sea water was so serious in the vicinity of Shanghai that for a period the drinking water was unpalatably salty. Fears were raised that to remove Changjiang waters, especially by the Eastern route, could cause Changjiang sediment to be deposited higher in the estuary, that the power generation potential of the Changjiang would be reduced, that schistosomiasis might spread Northwards, and that any South-North canal would block, or raise the level of, the already poor West-East drainage system of the North China Plain, bringing further alkalisation problems.(77)

Discussion at the various forums also centered around the joint questions of whether the apparant water shortage was real and could economically be resolved by interbasin transfers, and secondly, if so, which route should be chosen. The Eastern route involves large running costs, would not reduce sedimentation in the R. Huang and seems to create more severe environmental problems. In contrast, the middle route uses gravity as the motive force and may be used to scour the lower R. Huang. This route includes some, albeit meagre, consideration of drainage, but it would require engineering on a somewhat larger scale and is therefore of a longer term nature. The frequent shortage of ready water is not disputed, and emergency transfers have had to be made from the R. Huang, via the People's Victory Canal, the R. Wei (卫) and the Grand Canal, to the Tianjin area.(78) Yet there is a strong body of opinion that the way to resolve this problem is not to transfer water but to make better use of existing resources.

Professor Huang Wanli, of Qinghua University, for example, proposes a threefold solution to the shortages. One aspect of his plan is for the control and use of the lower R. Huang by distributing $20 \times 10^9\ m^3\ yr^{-1}$ of silt and water over the Northern part of the North China Plain. (Section 3,ii). The other two aspects are increased storage and use of present surface runoff, and the development of underground water resources, including their in situ storage.(79)

Professor Huang considers the main water sources which at present contribute to the runoff of the Northern part of the North China Plain, to be as follow: Precipitation over the R. Hai catchment, estimated at $68.7 \times 10^9\ m^3\ yr^{-1}$, of which only $6.8 \times 10^9\ m^3\ yr^{-1}$ becomes surface runoff; Runoff entering from outwith the catchment, of which some $15.8 \times 10^9\ m^3\ yr^{-1}$ enter from the Taihang mountains to the West, and $5.8 \times 10^9\ m^3\ yr^{-1}$ in smaller rivers such as the R. Luan.(80) Thus a total of some $28.4 \times 10^9\ m^3\ yr^{-1}$ is available as surface runoff. However, most of it occurs in July, August and September, whilst it is needed for agriculture principally in May and June. At present only $10.8 \times 10^9\ m^3\ yr^{-1}$ of this is stored for use at the end of the following Spring and Professor Huang proposes that it be increased to an average of $14 \times 10^9\ m^3\ yr^{-1}$, by providing more storage for both the runoff of normal years and the rarer, larger floods. It should be pointed out though, that in his two articles (in the Guangming Ribao and the Gongcheng Kancha magazine), he does not address the problem of reservoir sedimentation.

Of the above $68.7 \times 10^9\ m^3\ yr^{-1}$ precipitation in the R. Hai catchment, Professor Huang estimates $34.4 \times 10^9\ m^3\ yr^{-1}$ escapes as evaporation or transpiration, and some $27.5 \times 10^9\ m^3\ yr^{-1}$ seeps into the deeper layers and becomes underground flow. If the underground water is used extensively in May and June, it will be replenished in July, August and September, he argues, and if it were kept deeper than 4 m below the surface, it would no longer be lost through evapotranspiration. Furthermore, the underground remains of past riverbeds may be regarded as ready made reservoirs. At present some $10 \times 10^9\ m^3\ yr^{-1}$ of underground water is used, but by reducing evapotranspiration losses in such a way, Professor Huang estimates that a further $10 \times 10^9\ m^3\ yr^{-1}$ to $15 \times 10^9\ m^3\ yr^{-1}$ could be made available.

Together these two schemes would provide an extra $29 \times 10^9\ m^3\ yr^{-1}$, to which may be added $20 \times 10^9\ m^3\ yr^{-1}$ from his R. Huang scheme, and $20.8 \times 10^9\ m^3\ yr^{-1}$ aleady being used. Of the total $70 \times 10^9\ m^3\ yr^{-1}$, he argues that $50 \times 10^9\ m^3\ yr^{-1}$ is available in the short term and so the Northward transfer of Southern waters is unnecessary. As for lands South of the R. Huang, he suggests smaller scale irrigation schemes based on the R. Hanshui.

It would seem most likely then, that the whole question of the Northward transfer of Southern waters, whilst being the subject of much continuing research, will not be resolved for some time. However, although no such work is foreseen for the near future, it seems almost certain that this is not the end of the matter.

ii) Large-scale Dispersal of Silty Water.

In September 1979, Professor Huang Wanli published his own, controversial, "General Plan for the Control of the R. Huang", and the following is taken largely from his synopsis, which appeared in the February 1980, edition of Renmin Huanghe.(81) He begins by identifying five erroneous prejudices in the concepts of R. Huang control held commonly (including by himself) hitherto. They are, in a translation of his own words,

> "i) Making Soil and Water Conservation the basis of R. Huang Control.
> ii) Doing the utmost, as the principle of river control, to carry silt to the sea.
> iii) Considering that water and silt flows should be concentrated instead of dispersed.
> iv) Turning the elevated channel system into an engineering method for warping lowlands along the two banks.
> v) Failing to summarise clearly the points of error in the Sanmenxia dam plan, and therefore being unable to make a proper reconstruction."

The professor then points out that above Mengjin the river flows in a concave catchment some 700,000 km^2 in area, of which some 133,000 km^2 is cultivated, whereas the whole of the North China Plain, 250,000 km^2 in area, of which 167,000 km^2 is cultivated, is a large conical delta created by the past wanderings of the R. Huang. We should, he writes, respect this natural regime and, therefore, not block up silt, by such methods as precipitation dams, once it has entered the gullies. Soil and water conservation, likewise, should vigorously be undertaken only to develop the locality, as any benefit it may have towards the R. Huang is purely coincidental. This approach counters error No. 1, above. Meanwhile, to counter error No. 2, the dykes should not be used to flush all the silt to the sea. Instead, the entrances to all the original, interconnecting, low lying, river channels should, in a controlled way, be completely opened. The main channel and floodplain cross-sections should all be fixed so that as the water flows, it will scour the main channel and deposit upon the floodplains. This will then, also, counter errors No. 3 and No. 4, since it will not be scattered deposition by warping, but orderly, dispersed sediment transportation.

On the question of the proper use of the Sanmenxia reservoir, Professor Huang advocates full purgation of the 5.5×10^9 t of accumulated silt so as to provide sufficient capacity fully to regulate both water and silt in the lower R. Huang and, until this has been done, he would postpone the construction of the proposed Xiaolangdi reservoir downstream (Section 3,iii). In order so to do, he would make use of the 16 m drop downstream of the dam, by re-opening the bed of the old Ghosts' Gate, at a level of 260 m, and thereby flush out the deposits. At the same time, he claims, some one gigawatt of power could be generated as before, and water could still be stored without giving rise to retrogressive backwater deposition. During the Spring drought, large amounts of silty water would be released and would flow steadily through 20 or more distribution channels along the banks of the river for warping over 33,000 km^2 of low lying fields on the North China Plain. The R. Huang main channel would still be the principal flood discharge route, but it would become scoured successively deeper and thus effect its ultimate control.

In other words, only floods of sufficient size to scour the whole of the lower reach would be allowed to enter it. Smaller floods would be stored and released periodically into other channels, of the appropriate design to carry both water and silt long distances to where they may be used in orderly warping. These distribution channels themselves would not suffer deposition and, because of their proper design, would maintain deep main channels and high floodplains. In time, the flood carrying capacity of the lower R. Huang, through constant scouring of its main channel and deposition on its floodplains, would increase sufficiently to end permanently the threat of diluvium. In times of extraodinarily large floods, all the various distribution channels could be opened at once, for, as Professor Huang claims, when spread over the whole North China Plain, even a 1000 year flood would be only 0.024 m deep.

Much interest has been aroused by this scheme, but it would be fair to say that it has not gained general acceptance, as many doubts remain as to whether it could be made to work in practice. One point which immediately springs to mind, is the question of drainage. Since sufficient drainage could not be provided for earlier large-scale irrigation schemes, should not that question be addressed specifically by the author of this one? Also, one might expect considerable practical problems in matching the fluvial and alluvial conditions, required for the proper operation of the distribution canals without deposition, to those obtaining in the supply system, if the reservoir at Sanmenxia, for example, is to be kept clear. All this is not to say that such an idea indeed would not work but, in view of its large-scale and radical nature (although the investment would be quite low), it would seem that Professor Huang will need a lot more campaigning for his colleagues to be convinced in sufficient number to realise his scheme. This is how he puts his case,

> "How can it be said that the present type of general plan, to intercept upstream and discharge downstream, to regard water and silt as frightful beasts of prey, the R. Huang as an evil river and to raise the dykes every few years, makes rational use of water and silt resources? Could the two guarantees proposed by Premier Zhou while he lived - to guarantee the lower reaches and to guarantee Xi'an, be achieved? In the long run, could we, with complete confidence, control the R. Huang? Unless water and silt are distributed for irrigation and fertilisation along the two banks, how are we to answer the masses' censure, 'Only manage a line, don't care about the two large strips'?"(82)

iii) Intercept, Discharge and Deposit.

Inasmuch as all the other major proposals for control of the R. Huang are based upon the widely supported general plan known as 'Intercept, Discharge and Deposit', (拦、排、放), it may be considered to be the orthodox view. As is described below, however, there are different shades of opinion as to the point of emphasis, and the specific engineering structures to be built for its realisation. The example of the opinion of the Sediment Research Laboratory of the Hydraulic Engineering Department of Qinghua University is fairly typical, and has been published in full in a magazine enjoying international circulation. Here this, and others, are discussed together.(83)

The cornerstone of the orthodox views is that the long term solution to the R. Huang problem lies in soil and water conservation on the loess plateau. The points at variance concern what short and medium term measures should be applied in the meantime. The term 'intercept' has two meanings; one being in situ interception by soil and water conservation, and the other referring to storage reservoirs on the tributaries and downstream. It is claimed that the two proposed reservoirs described below, at Longmen and Xiaolangdi, respectively, could together trap some 20 x 10^9 t of silt and significantly reduce sedimentation in the lower R. Huang for 30 or 40 years. Four deliberate types of 'deposition' are identified; deposition by natural or artificial floodpeaks on the floodplains between Longmen and Tongguan, in Meng and Wen Counties between Mengjin and Taohuayu, and in the lower reaches; deposition to consolidate the dykes, possibly using sediment suction boats; deposition of low-lying land just outwith the dykes, using syphons, for example; and deposition some distance away in schemes to transport sediment in high concentrations for warping. Finally, there are two methods of 'discharge'; one by regulation of the river channel to increase its flood and sediment discharge capacities, and the other by using reservoirs to regulate both water and silt so as to reduce deposition and send as much of the silt as possible to the sea. None of these methods is exclusive of the others.

The analyses described in Chapter 1, Section 3, iii, have shown that the floods which give rise to serious deposition in the lower R. Huang are those which originate in the coarse sediment source area comprising some 110,000 km^2 of the loess plateau. Since, unlike in other semi-arid areas, virtually all the soil eroded from the slopes of smaller tributary catchments is transported out of the local watershed and into the mainstream, it would appear that any reduction in erosion would directly reduce the silt content of the R. Huang. However, in order to satisfy themselves that this would have a beneficial effect in the distant lower reaches, the Qinghua University Sediment Research Laboratory (QUSRL) went a stage further. They considered whether the reduction in oncoming water, commensurate with the reduction in oncoming silt load due to conservation work would seriously affect the silt carrying capacity of the lower reaches. They also considered whether any reduction in the oncoming silt load of the larger tributaries would be negated, there and in the mainstream, by clearer water leading to increased erosion of the riverbed.

Their findings are as follow: Most of the tributaries of the middle reaches contain silt concentrations over 100 kg m^{-3}, and those with over 400 kg m^{-3} are not uncommon. Upon joining the mainstream, these concentrations are greatly reduced by mixing with clearer water from the upper reaches, the average annual mainstream concentration, for example, being 37 kg m^{-3} at Longmen and 30 kg m^{-3} at Huayuankou. Since the tributary and mainstream concentrations are not of the same magnitude, a large reduction in both the water and silt of the tributaries would have a much greater relative effect on the silt content of the mainstream than on its water content. For example, if both the silt and water of the tributary rivers Huangpu, Kuye and Wuding were completely stopped, the average annual silt concentration at Longmen would fall by 27 % to 27 kg m^{-3}, which would clearly be beneficial in the lower R. Huang.

For an answer to the second point, the QUSRL turn to the example afforded when clear water was discharged continuously from Sanmenxia in the early sixties (Chapter 3, Section 6,vi). In that instance, after one year d_{50} at Huayuankou had increased by 30 % and the capacity to pick up bed silts had fallen by two-thirds. Once an armoured bed had, thereby, become established, the amount of sediment picked up therefrom remained low. From this example QUSRL draw the following conclusion,

> "This explains that after control of the coarse sediment source area has been achieved and fairly clear water is discharged, whilst at first the river channel may supplement the amount of sediment in the flow to a certain extent, after armouring and slope adjustments of the bed, the ability to pick up silt will quickly

fall to a relatively low level and the amount of supplementary silt from the bed will be greatly restricted."(84)

Whilst the principle of relying on soil and water conservation work, concentrated in the coarse sediment source area, for the long term solution to the R. Huang problem is, thereby, established, and has been generally accepted, it is conceded that it would be unwise to underestimate how much time such a process will require. Indeed, the RHWCC prefer to base their plans on the assumption that there will be no reduction in the sediment load of the lower reaches.(85) That is to say, that any reduction which might be expected cannot be measured on the same time-scale as normal planning for river control. Thus, the various propositions for shorter term solutions to the problem assume a semi-permanent nature.

From 18 to 29 October 1979, the Chinese Society of Hydraulic Engineering held, at Zhengzhou, a symposium on plans to control the lower R. Huang. Some 220 delegates attended, representing various units within the Ministry of Water Conservancy, the Chinese Academy of Sciences, and relevant universities and colleges. Wide ranging discussion was held on various proposals for the control of the river including a number which illustrate various points of emphasis within the orthodox view. In the following description of some of the engineering measures discussed at the symposium, it should be borne in mind that they are not necessarily mutually exclusive. First of all, opinions on improving the ability of the lower reaches to discharge flood peaks using exising facilities will be discussed.

Some comrades question the concept of guarding against the 'greatest possible flood', put at 46,000 $m^3 s^{-1}$ at Huayuankou.(86) They point out that the criterion on the Changjiang, and for the cities of Beijing and Tianjin is only a 100 year flood, whilst even the advanced nations could not afford much more, the Mississippi, for example, being protected to a criterion of once in somewhere between 100 years and 500 years.

Comrade Zhao Yean considered the present flood carrying capacity to be sufficient for all but the rarest of floods and, owing to the high silt content of flood peaks on the R. Huang, dams or flood retardation areas have only restricted roles, since once used, they become filled with sediment. Conversely, he argued,

> "Every extra 1000 $m^3 s^{-1}$ of flood carrying capacity is equivalent to the construction of a reservoir or flood retardation area with a capacity of one milliard cubic metres."(87)

Therefore, he advocated putting emphasis, with due regard to the special characteristics of deposition in the lower R. Huang, on consolidating the dykes so that all but the rarest floods (those which would overflow them rather than break through them) would be contained; on restricting such deposition as is unavoidable to the floodplains and to the broad upper part of the lower reaches; on increasing the ability to regulate the fluvial conditions of the lower river; and, unusually, on sending all water not used in Shandong in Winter (the period when the Shandong stretch of the lower reaches suffers deposition) either Northwards to irrigate the R. Hai basin, or Southwards to the R. Huai basin.

Amongst suggestions as to how to increase the flood carrying capacity of the lower reaches, a number deal with ways which involve deposition as well as discharge. The use of sediment suction boats and syphons for dyke consolidation, as already described, continues to have its advocates. But, it is also emphasised that at a cost of several tens of millions of Yuan each year, it cannot be regarded as a long term solution.(88) The QUSRL points out that, unlike in the middle reaches, there is no difference in the order of magnitude between the silt concentrations in the mainstream and that in the stream from which silt and water is being removed since in the lower reaches they are the same stream. Therefore, they argue, after deposition, the water should be returned to the river.(89) They consider two specific proposals, one on the floodplains and the other outwith the dykes, but they are on very different scales and are not directly comparable. Nevertheless, it may be said that schemes which use the floodplains have the advantage that, after settling the silt, the water returns to the river by gravity.

Some comrades called for a further round of reconstruction at Sanmenxia, both to provide a more lively response to changes in oncoming water and silt loads, and because the present discharge capacity is thought still to be too small.(90) They point out that, under the present operational regime, guaranteeing Spring irrigation downstream has meant that the bed level at Tongguan which had fallen 1.8 m in 1973, has since risen again by about 1 m. Furthermore, in the event of extraordinary floods occurring in successive years, as happened between 1841 and 1843, Xi'an could not be safeguarded and, after the flood peak would have passed, huge amounts of sediment would be worked by smaller flows into the lower reaches and cause serious deposition there. The least to be done, now, should be to reopen the four remaining bed sluices.

The QUSRL propose a set of general guidelines for the use of reservoirs on the middle and lower R. Huang.(91) In order to promote 'discharge', they draw on the fact that the sediment discharge in the lower R. Huang is proportional to the square of the water discharge, and propose the creation of artificial flood peaks to scour the whole lower reach. In order to promote 'deposition', they propose that, as long as the dykes are not endangered, reservoirs should not restrain waters from covering the river floodplains as such inundations, and their subsequent deposition on the floodplains, are beneficial to channel and floodplain morphology. As for 'interception' by reservoirs, they point out that deposition in the lower R. Huang is predominantly composed of coarse silts (>0.05 mm). Thus, to intercept fine silts in reservoirs would have a smaller effect on deposition downstream than would interception of coarse silts.

Some comrades consider that the R. Huang has already risen to the extent that demands a change in course and have put forward various opinions. These include, building a third dyke to one side of the existing system, thereby creating three dykes and two rivers, or building the third dyke and then allowing the river to abandon its old course. However, this type of proposal has met with considerable opposition, not only because it would inundate agricultural land such as that at present cultivated in the Beijin detention area alongside the Northern dyke, but also on the grounds that this proposal's protagonists were mistaken, and that the present course of the lower R. Huang can still be regarded as quite young.(92)

The main proposals for new reservoirs as part of the Intercept, Discharge and Deposit viewpoint will now be described. The three contenders would be situated, respectively, at Taohuayu, Xiaolangdi and Longmen (Figure 2-1), and would work alone or in conjunction with each other or the Sanmenxia reservoir according to various proposals.

When proposed as part of the 1955 Comprehensive Plan, the reservoir at Taohuayu was to have served the multiple purposes of reducing all floods to 6000 $m^3 s^{-1}$, generating 220 MW of electricity and, by removing any silt entering the waters below Sanmenxia, providing clear water for the Gangli or Huayuankou irrigation project and a clear crossing for the proposed Beijing to Guangzhou canal.(93) Under the present proposals its only purpose is to substitute for the Beijin retardation area, as a reserve measure against the largest of floods, which it would reduce to 22,000 $m^3 s^{-1}$, though investigation for its future integration with the Northward transfer of Southern waters middle route (Section 3,i) has also been proposed.(94)

Situated just above the crossing of the R. Huang by the Beijing to Guangzhou railway line, the right bank would comprise the low loess bluffs of Mangshan but for the left bank there would be just a large expanse of R. Huang floodplain and the dykes thereupon. The proposal is for a dam, 30 m high, across the mainstream, and a 59 km perimeter dyke to enclose a large area of the Northern floodplain, together to provide a storage capacity of some 6 x 10^9 m^3. A very large discharge capacity would ensure that even a flood peak of 20,000 $m^3 s^{-1}$ would raise the water level by only 0.1 m. Since it would be below the major tributaries, it could control 68.5 % of the drainage area between Sanmenxia and Huayuankou, and since it is so near to Huayuankou, its control would be very responsive, as it would not have to rely upon predictions to know the water level thereat. It is estimated that despite deposition when not in use, after 35 years 3.2×10^9 m^3 of capacity would remain. It would take 5 years to build, and cost some ¥ 750×10^6 (£ 214×10^6), which makes it the cheapest of the options under consideration, and the quickest to show results.(95) The area to be flooded is desolate and sparsely populated.

The disadvantages seen of this scheme, include the difficulty of maintaining the perimeter dyke, its effect on the R. Yiluo, whose water level in the lower reaches would be raised, the poor geological conditions (the site is on alluvial silt), and its failure to provide any benefit other than as a standby for the control of extraordinary floods.

The proposed reservoir at Xiaolangdi is conceptually more conventional, being of a gorge type, similar to the Balihutong reservoir proposed by Reybold, Growden and Savage (Chapter 2, Section 2), in the Civil War period. However, one of the proposals for a reservoir here would put it to use in a most unconventional way, to creat hyperconcentrated flows artificially. The two approaches will be considered separately.

The Xiaolangdi site is above the rivers Yi, Luo and Qin, and a reservoir there could control only 13.7 % of the drainage area between Sanmenxia and Huayuankou. Other measures would have to be found to protect the lower reaches from flood peaks up to 30,000 m^3 s^{-1}, which is the estimated maximum discharge at Huayuankou, taking into account use of the Xiaolangdi reservoir.(96) However, according to the advocates of this scheme, it would not be as grave a situation as it seems. They claim that since the total water volume of a twelve day extraordinary flood is 20×10^9 m^3 and the narrow Shandong reach can safely handle half this amount, only 10×10^9 m^3 remains to be overcome. The Sanmenxia reservoir may store 3×10^9 m^3, which is less than the total contribution from above Sanmenxia irrespective of the major source area and is, therefore, constant.(97) The Beijin and Dongping retardation areas together may take 4×10^9 m^3, and the task of the Xiaolangdi reservoir would be limited to the remaining 3×10^9 m^3. It should be recognised, though, that such an analysis is based on unstated assumptions about the shape of the flood peaks and if these were to include that the flow be steady, for example, they would be dubious. The use of the Beijin and Dongping retardation areas is also most undesirable, as mentioned previously (Section 1,ii).

The specific proposal is for a dam 151 m high forming a reservoir of capacity 12.65×10^9 m^3, of which some 8×10^9 m^3 would be used to collect silt so that the lower R. Huang would run clear for 10 years; and about 4×10^9 m^3 would be permanent flood regulation capacity. It would provide irrigation for 13,000 km^2 of land and produce between 1.5 GW and 1.8 GW of electrical power. There would be considerable technical problems in building the dam, since alluvial deposits at the site are over 70 m thick, of which the top 14 m to 20 m comprise fine silts, and the geological layers are uneven and faulted. This project would inundate 80 km^2 of cultivated land, necessitate the evacuation of 120,000 人 , and cost ¥ 1800×10^6 (£ 514×10^6). Owing to its larger capacity, the use of Xiaolangdi reservoir, instead of that at Sanmenxia, to store Winter waters, would obviate the contradiction between Winter flood control and Spring irrigation. Furthermore, unlike the Taohuayu reservoir, one at Xiaolangdi would provide a lively response to small, medium and large floods, as well as extraordinarily large ones.

The proposal by Comrade Fang Chongdai to use the Xiaolangdi reservoir to create high concentration flows will now be described.(98) To form hyperconcentrated flows which do not give rise to deposition, requires not only a high silt content, but also a sufficient proportion of very fine (<0.01 mm) particles. Comrade Fang proposes that two tubes each 7 m in diameter be installed to pass through the dam, with their outlets higher than their inlets, the latter being at 135 m, the bed level. This would create, he suggests, a concentrating funnel from which to draw highly concentrated waters. In order to provide a high proportion of fine silts, explosives may be used within the reservoir area. In such a way, he claims, silt may be transported over 1000 km without deposition. It may then be used without fear of alkalisation, owing to its relatively low water content. Furthermore, only clear water would be passed into the lower R. Huang, which would thereby become deeper and more stable.

Comrade Fang's is only one of several such propositions, and whilst it is very unlikely that this type of plan will be adopted in the near future, it is nevertheless considered to be a subject for serious research. One problem is to adapt experience gained in the irrigation canals of Shaanxi and indoor test facilities, to river channels.(99) Although hyperconcentrated flows have been used to transport sediment over long distances in the former situation, on the rare occassions that they have occurred in the lower R. Huang, they have subsequently dispersed, and resulted in deposition downstream.

The Longmen site has many points of similarity with Xiaolangdi site, but also significant differences. The reservoir, formed by a 206 m high dam, would have an initial capacity of 12.5 x 10^9 m^3 of which some 8 x 10^9 m^3 would be used to collect silt over a 10 year period, and about 4 x 10^9 m^3 would remain as permanent regulation capacity, very similar to the proposed Xiaolangdi reservoir.(100) Flood prevention by the Longmen reservoir also would have to depend upon improvements downstream, and provision could not be made here to deal with floods arising below Sanmenxia. Protagonists of this proposal, however, claim that the extra control, of 13.7 % of the area between Sanmenxia and Huayuankou, afforded by the Xiaolangdi reservoir, is not significant, and point out that the proposed reservoir would, owing to its position, selectively trap silts from the coarse silt source area. It would, therefore, have a relatively greater beneficial effect on the lower R. Huang than would a reservoir at Xiaolangdi which trapped silts from both fine and coarse source areas. The proposed Longmen reservoir would also provide the first effective control of the Tongguan confluence, to the benefit of protecting Xi'an and the Guanzhong Plain.

Although there is not much to choose between the two with regard to flood control, there are significant differences in their benefits and environmental impacts. The money cost of the Longmen reservoir, ¥ 2000 x 10^6 (£ 571 x 10^6), is very slightly higher, but only 18.7 km^2 of cultivated land would be lost and only 8000 人 would have to be evacuated. The total installed generating capacity is the same, 1.5 GW, but the total annual energy supply is greater (6.7 TW h yr^{-1} as opposed to 4.7 TW h yr^{-1}), as is the guaranteed output (520 MW as opposed to between 180 MW and 290 MW). Furthermore, it is claimed that some 600 MW used in pumped irrigation at present, would be saved. The area to be irrigated by the Longmen reservoir, some 10,700 km^2, comprises Southern parts of the loess plateau in Shaanxi and Shanxi where water shortage is very severe and where the thick and porous loess would not be as susceptible to alkalisation as is the North China Plain. Geological conditions at the Longmen site are good, the alluvial cover being only between 10 m and 17 m thick and there being no fault. The R. Huang and its tributaries here flow in deep gorges and no serious effect is to be expected from retrogressive backwater deposition.

The curious reader would perhaps welcome some speculative comment on which measures are most likely to be adopted, and such an attempt shall here be made. But, it is made difficult because the survey and preliminary design for the various proposals is not yet complete. This problem was well recognised at the 1979 meeting in Zhengzhou,

> "Survey and design work for the key projects should be grasped. At Xiaolangdi it is underway, but a schedule has yet to be arranged for that at Taohuayu and we propose that it be done soon .... so that a deep analysis and comparison may be made with regard to these two projects on the basis of equal amounts of work, and a policy quickly decided. The design force for Longmen is insufficient and needs to be strengthened .... The data provided at this symposium is uneven with regard to the three projects, and a number of comrades have complained ...... from now on, every scheme should be based on an equal footing." (101)

In his article, written on 27 January 1980, Wang Huayun discloses that to carry out design work for the Longmen and Xiaolangdi reservoirs, and some tributary reservoirs, has already been sanctioned, whilst he lists as a 'task for this year' the completion of a comparison between the Xiaolangdi and Taohuayu schemes. (102)

On the basis of the above descriptions only, it would seem that the cheapest, most effective measure for flood control, and the one with the least adverse environmental impact is that proposed for Taohuayu. Yet, just as with the Sanmenxia project before, the leadership is confronted by further demands which mean that any decision is, at least in part, political,

> "In 1978 when reporting the flood prevention symposium to the State Council, the two provinces, Shanxi and Shaanxi, requested the Longmen project, and He'nan and Shandong requested the Xiaolangdi project."(103)

Now, both these projects fail to provide a very convincing response to the flood control problem and both would require continued maintenance of the Beijin flood retardation area. Meanwhile, according to one estimate, the Beijin area would need an additional investment of ¥ 200 x 10^6 (£ 57 x 10^6) to give the required standard of protection, and, if even used once losses would amount to ¥ 570 x 10^6 (£ 163 x 10^6); which two items together exceed the investment for the construction of the Taohuayu project.(104)

Again based on the above, sparse, descriptions, it would seem that if one of the large projects is to proceed, then it should just be that at Longmen, as, whereas the costs are similar, the benefits of the Longmen project are considerably greater than those of the Xiaolangdi project and the adverse environmental effects are fewer. The political effects constitute another question, but one which shall not be addressed here.

The above is by no means all embracing, but it covers the major proposals. In view of its unchallenged popularity, and its relative simplicity, a further programme to reopen the remaining four bed sluices at Sanmenxia is to be expected. The project at Taohuayu, should it, after further research, turn out to be feasible, would also seem very desirable for R. Huang control, whilst for direct economic benefits it would best be combined with the Longmen project. For the actual outcome we are obliged to wait and see.

<u>Notes to Chapter Five</u>

1. Except where otherwise indicated this sub-section is from WANG Huayun, 1980.

2. ibid., pp. 2, 3.

3. WU Zhiyao, XI Jiazhi, 1979, p. 11.

4. WANG Guoan, 1979. QUSRL, personal communication, 1982.

5. WU Zhiyao, XI Jiazhi, 1979, p. 12.

6. QUSRL, 1981, p. 8.

7. WU Zhiyao, XI Jiazhi, 1979, p. 9.

8. RENMIN HUANGHE, Eds., 1979, pp. 56, 57. QUSRL, Personal communication, 1982.

9. WANG Huayun, 1980, p. 12.

10. ibid., p. 1.

11. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2. Overbank floods: floods which rise onto the flooplains. They do not necessarily attack the main dykes.

12. RENMIN HUANGHE, Eds., 1979, p. 58.

13. WANG Huayun, 1980, p. 2. WANG Huayun, 1979, p. 2.

14. BEIJING ZHOUBAO, 1979. RHWCC, Eds., 1979, p. 38. XINHUA, Xining, 25 November 1979. XINHUA, Beijing, 22 September 1979. RENMIN RIBAO, 22 September 1979. XINHUA, Beijing, 15 September 1981.

15. PU Naida, SU Fengyu, ZHANG Ruitong, 1980, pp. 737. QIAN Ning, DAI Dingzhong, 1980, p. 24. RHWCC, Eds., 1979, p. 43. SRIHEWL, et al., Eds., 1979, p. 318.

16. PU Naida, SU Fengyu, ZHANG Ruitong, 1980, pp. 739, 743.

17. RWHCC, Eds., 1979, pp. 47, 48.

18. SRIHEWL, et al., Eds., p. 316. QIAN Ning, DAI Dingzhong, 1980, p. 26. PU Naida, SU Fengyu, ZHANG Ruitong, 1980, pp. 744, 745.

19. RENMIN RIBAO, 22 September 1979.

20. SRIHEWL, et al., Eds., 1979, p. 320.

21. RHWCC, Eds., 1979, p. 63. XINHUA, Yinchuan, 27 August 1958. HUANG Wei, 1978, p. 87. SRIHEWL, et al., Eds., 1979, pp. 316, 362.

22. RHWCC, Eds., 1979, pp. 79, 80.

23. RHWCC, Eds., 1979, pp. 107 to 109. YE Nailiang, LONG Guorui, 1979, YE Nailiang XU Wenshan, 1981.

24. The data for the next four paragraphs, except where otherwise indicated, is taken from LIU Shanjian, 1979.

25. WANG Huayun, 1980, p. 3.

26. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2.

27. WANG Zhimin, 1980, p. 64.

28. LI Facheng, 1980.

29. GAO Bowen, 1980, p. 10.

30. WANG Huayun, 1980, p. 2.

31. XINHUA, Xi'an, 1 December 1981.

32. Fieldtrip notes, 18 July 1980, as for note 38 of Chapter 3.

33. This description is taken from TONG Dalin, et al., 1978. SHI Shan, WEI Mai, ZHONG Wennan, 1979. GU Jianpeng, YU Zhongcheng, 1980.

34. This description is taken from: TONG Dalin, et al., 1978. GUO Yandi, 1978. LIU Wanquan, 1979. Fieldtrip notes, 22 July 1980, Conversation with Comrade ZHAO Boyue, Shaanxi Hydropower Bureau. LIU Ye, 1962.

35. 3-3 Control refers to three equal areas, or three thirds, and is used to advocate a balanced approach among Agriculture, Silviculture, and Animal Husbandry.

36. TONG Dalin, BAO Tong, in TONG Dalin et al., 1978. SHI Shan, 1980, gives for comparison, in the Country as a whole, the proportion of the population whose income is less than ¥ 50 yr^{-1}, as 27.3 %.

37. SHI Shan, in TONG Dalin, et al., 1978.

38. GAO Bowen, 1980, p. 2.

39. 25 % of the yield of sweet potatoes, for example, in the figure for grain yield, according to DICKINSON H, School of Engineering, Edinburgh University.

40. TONG Dalin, et al., 1978.

41. One _jin_ is 0.5 kg.

42. SHAN Lun, in YU Zheng, et al., 1978.

43. LI Lianjie, reported in WANG Huandou, WANG Zhaolin, 1979.

44. LI Erzhong, 1979.

45. Fieldtrip notes, 22 July 1980, as for note 34.

46. ZHANG Qinwen, 1979.

47. YANG Wenzhi, in YU Zheng, et al., 1978. CUI Qiwu, WEN Dazhong, 1979.

48. LIU Wanquan, 1979.

49. YANG Wenzhi, in YU Zheng, et al., 1978.

50. YU Zheng, et al., 1978.

51. SONG Chaoshu, in MA Xingnian, et al., 1979.

52. SHI Shan, reported in WANG Huandou, WANG Zhaolin, 1979.

53. LIU Jiasheng, in MA Xingmian, et al., 1979.

54. WANG Huandou, WANG Zhaolin, 1979. This article is the XINHUA report of the symposium.

55. WIDMER Urs, 1981, p. 95.

56. ZHANG Xiuping, WANG Huandou, WANG Zhaolin, 1980. SHI Shan, 1980, begins his disscussion, for example, "Comrade Xiaoping has pointed out that the loess plateau should be built into an animal husbandry base and a silvicultural base, and that trees and grass should be sown by using aerial seed broadcasting. This strategic decision raises the construction of production on the loess plateau into a new stage".

57. YANG Wenzhi, in YU Zheng, et al., 1978.

58. Fieldtrip notes, 20 January 1981, as for note 55 of Chapter 3.

59. ibid.

60. ibid.

61. XINHUA, Xi'an, 24 June 1980.

62. TONG Dalin, 1980. See also, YANG Hanxi, in MA Xingmian, et al., 1979. It is hoped soon to publish English translations of some twenty of the newspaper articles which make up this debate.

63. WANG Huayun, 1959a.

64. HAO Burong, 1959, p. 147.

65. GREER Charles E, 1975, p. 100.

66. Foreign Languages Press, 1978, p. 45.

67. XINHUA, Tianjin, 23 April 1979. GAO Xia, 1978. XIAO Bingjun, 1979.

68. XINHUA, Tianjin, 21 April 1979.

69. NICKUM James E, Ed., 1981, p. 269.

70. RHWCC, Northward Transfer of Southern Waters Prospecting Group, Eds., 1979a.

71. RHWCC, Northward Transfer of Southern Waters Prospecting Group, Eds., 1979.

72. As for note 70, p. 51.

73. XIAO Bingjun, 1979.

74. XINHUA, Tianjin, 23 April 1979.

75. RENMIN HUANGHE, Eds., 1979, pp. 57, 62.

76. GAO Xia, 1978, XINHUA, Bejing, 25 August 1978.

77. XINHUA, Tianjin, 19 April 1979. CHEN Baolian, 1979.

78. ibid. XINHUA, Beijing, 25 October 1952. XINHUA, Tianjin, 24 May 1958. XINHUA, Beijing, 19 August 1981. LIU Zongyao, 1979.

79. HUANG Wanli, 1979. HUANG Wanli, 1980a. Fieldtrip notes, Lecture given by Professor Huang to Geography and Geology Departments of Acadamia Sinica, 24 March 1980.

80. In July 1982 full-scale construction began on a scheme to divert 1×10^9 m^3 yr^{-1} from the R. Luan to Tianjin along a 223 km route. It includes an 11 km tunnel with a discharge capacity of 60 m^3 s^{-1} through the Yan mountains, 100 bridges, the excavation of a channel 130 km in length, and the dredging of some existing rivers, (XINHUA).

81. HUANG Wanli, 1980, Fieldtrip notes, 24 March 1980, as for note 79.

82. HUANG Wanli, 1980, p. 55.

83. QUSRL, 1981. JIANG Huichou, 1980.

84. QUSRL, 1981, p. 4.

85. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2.

86. RENMIN HUANGHE, Eds., 1979, p. 59. DAI Dingzhong, 1980, p. 53.

87. ZHAO Yean, 1980, p. 54.

88. BAO Xicheng, 1980, RENMIN HUANGHE, Eds., 1979, p. 62.

89. QUSRL, 1981, p. 7.

90. RENMIN HUANGHE, Eds., 1979, p. 59.

91. QUSRL, 1981, p. 8.

92. RENMIN HUANGHE, Eds., 1979, pp. 61, 64, 79.

93. RHWCC, Eds., 1959, p. 238.

94. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2. 30 August 1980, as for note 45 of Chapter 3.

95. RENMIN HUANGHE, Eds., 1979, pp. 54, 56, 63.

96. Fieldtrip notes, 10 August 1980, as for note 37 of Chapter 2. WANG Huayun, 1980, p. 12. WU Zhiyao, XI Jiazhi, 1979, p. 13. RENMIN HUANGHE, Eds., 1979, pp. 54, 56, 58.

97. The total water volume of a twelve day extraordinary flood arising above Sanmenxia is given as 16 x 10^9 m^3 and of one arising below Sanmenxia, 8 x 10^9 m^3. (RENMIN HUANGHE, Eds., 1979, p. 56).

98. FANG Chongdai, 1980.

99. RENMIN HUANGHE, Eds., p. 65.

100. WANG Huayun, 1980, p. 12. RENMIN HUANGHE, Eds., 1979, p. 57.

101. RENMIN HUANGHE, Eds., 1979, pp. 55, 59.

102. WANG Huayun, 1980, pp. 12, 13.

103. ibid., p. 12.

104. RENMIN HUANGHE, Eds., 1979, p. 57.

Chapter Six

Summary, Conclusions and Prognosis

1) Summary.

Two parallel and interrelated themes have dominated this thesis, namely, the regulation of the lower R. Huang and the development of the loess plateau. They are linked most strongly by the extreme sediment load of the river, which is unrivalled in any other large river of the world, since over 90 % of the 1.6 x 10^9 t yr^{-1} of sediment in the lower reaches has its origin on the loess plateau. Deposition of this sediment has, since before historical times, raised the bed of the lower river until it exceeded the level of its surroundings and found a new course, forming, by repetition, the great North China Plain. Today this process continues but, although the bed has risen above the level of the surrounding plain, the river is prevented from changing course by over 1300 km of dykes. Protection of these dykes, and the continued need to raise them every decade or so, are major burdens to flood control. Meanwhile, the loss of this fertile topsoil is an important factor in the continuing poverty of the loess plateau region, where hundreds of years of erosion has so dissected the terrain as to make communications difficult and to destroy the delicate, former, ecological balance.

Silt is not the only factor linking the loess plateau and the R. Huang. Both are affected by the unequal distribution of rainfall over the loess plateau area. Since this is generally confined to heavy Summer storms of limited area and duration, most places on the loess plateau suffer a severe lack of water. During the storms, on the other hand, an excess of surface runoff gives rise to the severe erosion whose sediment yield so troubles the R. Huang. Furthermore, this type of rainfall distribution gives rise to sudden flood peaks, in the lower river, which are a threat to the dykes.

Yet, the relationship between the loess plateau and the R. Huang is not altogether direct, and is subject to certain limitations. Whereas it seems clear that a reduction in soil and water losses from the loess plateau will be of benefit to both areas of concern, it is not immediately apparent what benefit the loess plateau might gain from hydraulic peace along the lower R. Huang. The missing factor, the plant cover of the area will, if increased, improve local conditions, reduce the silt load of the river, and attenuate its flood peaks, but if the main concern is the R. Huang, then only some 110,000 km^2 of the loess plateau's 280,000 km^2 area need be treated. It can be seen therefore, that there is considerable room for political choice in what is essentially a question of the allocation of resources.

When the construction of reservoirs is considered, this becomes even more apparent. Reservoirs are one means by which the loess plateau may make use of the R. Huang, to facilitate irrigation and for the provision of electrical power. However, exploitation of the river in its middle reaches has only a limited benefit towards flood control in the lower reaches, as in the case, for example, of the proposed Longmen and Xiaolangdi reservoirs. Conversely, there was the case of the original Sanmenxia scheme, where upstream areas were to lose prime arable land for the sake of flood control and irrigation downstream.

The relationship between the development of the loess plateau and flood control along the lower R. Huang is very close and, of itself, warrants a comprehensive approach. The difficulty in deciding how best to allocate resources within the basin further adds to this need. Yet, it may be remembered that there is nothing new in this for, as this study has shown, such a point of view was already being expressed in general terms in the first half of the Twentieth Century. Also, the 1955 Multiple Purpose Plan which, it is claimed, still forms the basis of all work in the R. Huang basin, purports to take a whole-basin approach to the problems it addresses. It is, therefore, of some interest to consider what this study has revealed about the extent to which basin-wide planning has been implemented.

Since the organisational structure is centred upon the RHWCC and has a strongly comprehensive character, conflicts between the local authorities in different parts of the basin are considerably ameliorated. Yet, it is open to question whether the approach has been as fully integrated as might have been hoped at the time of the establishment of the RHWCC. The key role given to the Sanmenxia reservoir within the multipurpose plan, for example, seems to have been out of balance with a truly comprehensive view. This would not apply to its ostensible, and very long term, role as one of a series which formed the 'staircase' to control the whole river. Yet, in practice, where resources were limited, it was the one structure upon which the whole of the lower reaches was to have depended. It is true that other structures were to be built downstream, but the point is that these, together with the Sanmenxia reservoir, formed a comprehensive plan for the lower reaches, not for the whole basin. It may be argued that this is a consequence of its position within the basin, but that does not take into account the disproportionately large investment it required, which took away resources from work in other parts of the basin. Of course, the Sanmenxia reservoir, in its original form, was to rely upon soil and water conservation in the middle reaches. However, as this study has revealed, the failure of soil and water conservation work to make any significant reduction in the silt load of the lower R. Huang, was not an important factor in the decision to abandon the original design of the dam and to change the operational regime of the reservoir. Thus, the Sanmenxia reservoir represented a plan to control the lower R. Huang and develop its resources to the neglect of the need to develop the loess plateau or to exploit the river or its tributaries elsewhere. Surely, a comprehensive approach would have sought to control the river downstream as economically as possible, so that there would be more left to invest in the loess plateau region.

This does not apply only to money, but to the degree of emphasis placed on the various parts of the basin, in general. This study has shown, for example, that the technical means for comprehensive development of the gullied hillock region were known in the fifties. The same is true of the social and economic constraints of the problem. For example, it was known that in order to withdraw tillage from the hilltops, another reliable and local source of food must be found for the peasants. However, these matters did not enjoy sufficient attention in the implementation of the overall plan for the R. Huang basin, and all but a handful of individual places in the gullied hillock region of the loess plateau remain as barren and as poverty-stricken as before.

One of the points which this thesis has revealed is that, in the short term, regulation of the R. Huang did not proceed along a comprehensive, basin-wide path as was claimed, but put a disproportionate emphasis on the large-scale capital-intensive projects, of which the Sanmenxia reservoir is the most notorious example. The reasons for this imbalanced approach in the fifties, have been shown to have closely related to the ideological and psychological climate of the time. The experts and the RHWCC debated the various options, but the decisions were made by the politicians who brought upon themselves the unenviable task of choosing amongst sets of assumptions, many of which were unchecked. At that time, it appears that sight had been lost of questions of scale, including the time scale, since it was supposed that the problem of the lower R. Huang could not afford to await the results of further research. The choice between indiginous and imported technology, and the relative importance of experience gained at home or abroad, was influenced in a similar way. However, the failure of the Sanmenxia reservoir, in its original form, shows up this imbalance only inasmuch as these questions of the timescale and the effects of the ideological and psychological climate are concerned, since only these aspects are reasons for the adoption of an inappropriate design for the reservoir itself. The subsequent failure does not prove the point, which is nevertheless valid and important, that the scale of project at Sanmenxia was not commensurate with whole basin planning. What proves that point, is that, even if the Sanmenxia reservoir had functioned according to the original plans, including the improvement of so much land downstream, the provision of electrical power, navigation and, of course, flood prevention, it would still have provided only a local solution, whilst taking a disproportionate share of the available resources of all kinds, to the detriment of other needy areas within the basin.

In the late sixties and early seventies, there was a failure once again to implement a rational comprehensive plan but, as has been shown, the reasons were more strictly political. A mixture of political chaos and dogmatism led to the destruction of too much of the infrastructure for any such plan to have been followed, and to the adoption of all sorts of inappropriate policies, especially with regard to the development of the loess plateau.

Nevertheless, throughout the past thirty-odd years, significant advances have been made in response to specific problems. It has been suggested that some of these even owe a debt to the anarchy of the Cultural Revolution in that it allowed existing practices to be challenged. In other respects, it is apparent that the basin-wide organisation of the RHWCC, afforded the opportunity for experimentation and improvements in a well coordinated manner, and the rapid propagation of new ideas and techniques. What could be seen as failure of large scale projects, accompanied by success with small scale ones, is better understood in terms of the need for a whole-basin approach to the many problems of the R. Huang basin. For, those schemes which have failed, have been shown to be those which were out of line with the declared comprehensive approach, whereas the remarkable successes, which at first seem isolated, have in common that they are integrated into an appropriate place within the basin-wide overall plan. This is not to claim that any advance necessarily has application all over the basin, but that the research towards such advances has been facilitated by a basin-wide approach. At the same time, the proportion of total resources taken by these items, is in general agreement with their role within the basin scheme. It is not the small scale of the successful projects, as such, which is important, but the appropriateness of whatever scale is chosen, for its application. An example of this is the development of an understanding of how to deal with sediment problems in hydropower stations. The complicated design of the Tianqiao hydropower station owes much to the experience accumulated gradually throughout the basin, and it cannot be said that this project is on a particularly small scale.

Similarly, to call for a comprehensive approach for the whole basin is not meant to imply that every project should be of multiple purpose kind. One of the reasons for the adoption of an out of proportion scheme at Sanmenxia was that it was thought desirable to solve as many different problems as possible with one intervention. The present debate, about the next stage in the implementation of a general whole-basin plan, is also directed to this problem, since there is a considerable body of opinion advocating the Xiaolangdi reservoir simply because it may have multiple purpose uses. The question which should be addressed is, rather, which of the various alternatives serves the whole basin better? An expensive one with multiple uses at one place, or a cheaper one with limited uses, but integrated with other projects made possible elsewhere by the savings?

This thesis has been used to record details of an investigation into the implemenation of the basin-wide approach to the problems of the R. Huang and both advances and deviations have been identified. The various problems have been the topic of much debate in China and it is to be hoped that in the future more advances and fewer deviations will be made. Some problems, such as pollution, are only just beginning to be recognised, whilst others, such as the development of the loess plateau, are old problems, but ones whose solution needs to be developed over a long time. Inasmuch as all this varied work is proceeding under a body with basin-wide responsibility, the RHWCC, and the deviations of the recent past are now being corrected, it may be said that even if, in the short term, the implemenation of a basin-wide approach was only an illusion, in the long term it will probably be a reality.

This study has revealed, in particular, the wide range and extreme nature of the problems of the R. Huang. In the search for solutions to these problems, advances have been made as the result of positive experience, both theoretical and empirical, and as lessons learnt the hard way. Whilst it is one thing to gain knowledge, it is quite another to apply it. The foregoing Chapters have included mention of a number of contentious issues to which such an observation would be relevant. It may be useful, therefore, to draw a distinction between the advances made, by whatever process, and the extent to which the less tangible aspect, their application, has been grasped. In casting a critical eye over China, perhaps some application will also be found elsewhere in the world for what is seen, or seen to be absent.

The most readily assimilated knowledge to have emerged from work relating to the R. Huang over the last thirty years, would be direct technical advances such as those described in Chapter 4. Examples come as a result of observation, whence we now know that only a relatively small area of the loess plateau acts as the source of most of the coarse grains of R. Huang silt; as a result of laboratory experiments, whence new insights have been gained into the properties of hyperconcentrated flows; and as a result of a conscious trial and error process whereby new ways to use the silt of heavily laden streams have been found.

Knowledge of this type was also gained as a beneficial side effect of occurances which in other respects were none too welcome. For example, the Sanmenxia debacle promoted the study of the conditions necessary to flush out reservoir deposits and this led to the development of the techniques for operating reservoirs in such a way as to maintain a long term useful storage capacity. Meanwhile, the extent and effects of the armouring of the bed of the lower R. Huang under clear water conditions were also derived.

Such knowledge, which could be called factual knowledge, has also been gained in the political and economic spheres, though it may be somewhat less tangible. The example which springs to mind is the confirmation of the principle that on the loess plateau, the peasants' food provision must be guaranteed before they can withdraw tillage from hilltops. More narrowly economic rules, such as the economic value to be expected of various crops, or the suitability of any given region to agriculture, silviculture or husbandry, have also been established.

Such knowledge gained from work on the R. Huang is very extensive and is often referred to in Chinese literature. It surely must represent a significant contribution to Chinese science and technology and must justify the pride of those responsible. Its extent may be estimated from the examples in the foregoing Chapters or from other sources, but, in any case, is not in doubt.

Far less tangible is knowledge which may be called procedural knowledge, or how to avoid mistakes. And it is with some consideration of the extent to which this type of knowledge has been made available, and grasped, in the work on the R. Huang over the last thirty years, that this summary will be concluded. Inasmuch as the Sanmenxia reservoir has been discussed extensively, it will provide a good basis for a consideration of whether lessons which could have been learned have indeed been learned. Certainly, as the following quotation shows, there is considerable recognition that there are lessons which should be learned,

> " Within China's water conservancy construction, instances of inappropriate planning, violation of objective laws and the incurrance of nature's punishment, can't be reckoned to be few, and these lessons, learnt at an exhorbitant price, should be thoroughly assimilated."(1)

It is very difficult to comment upon the extent to which the Sanmenxia affair led to any change in Chinese attitudes towards foreign experience and expertise because, for political reasons, China until recently has had very limited involvement of that kind. Another study has shown that China, all along, was anxious to avoid any political obligation resulting from foreign technical aid.(2) So much was this so, indeed, that for nearly twenty years following the Sino-Soviet split, all foreign involvement in China was severely restricted.

Yet, it would be an exaggeration to claim that this political act was a result of the Sanmenxia affair. Although the usefulness of the

Soviet experts has been brought into question by Klochko, 1964, this study has made it clear (Chapter 3, Section 2, iv), that the Chinese were, in general, happy with the work of the Soviet experts and, furthermore, acknowledge responsibility for accepting an erroneous design for the Sanmenxia project. The severe isolation of China, therefore, was a political phenomenon of much wider dimensions than any one, albeit major, project currently benefitting from Soviet assistance.

The Sanmenxia affair is, nevertheless, very illustrative of the pitfalls associated with technology transfer. A number of Chinese comments were made to this effect in the fifties, as was reported in Chapter 3. It is to be expected that errors so expensively and extensively apparent would have increased the general awareness of the importance of finding solutions well suited to the locality in which they are to be applied and the importance, therefore, of local experience within these considerations.

Other aspects of the Sanmenxia experience may be considered quite readily and, as the examples of previous chapters show, there is a good general awareness of the possible problems of large engineering projects. Furthermore, there would appear to be a growing concern for the conservation of the plant cover in many different parts of China, to which the disastrous effects of the denudation of the loess plateau, both on the locality and along the faraway lower reaches of the R. Huang, are often referred as pertinent negative examples.

In the Summer of 1981 heavy rainfall, occurring over parts of Qinghai, Sichuan and Southern Shaanxi, gave rise to serious flooding in the basins of the rivers Huang, Jialing, Hanshui and Wei.(3) What is interesting about the flood peaks of those of the above which are Changjiang tributaries, is that they have been attributed to denudation of the hills in their upper reaches. This, in turn has been blamed on 'leftist thinking'.

The ways in which 'leftist thinking' are held to have manifested itself here, are just the same as those which this study has investigated with respect to the loess plateau. They are summarised in the China Daily as the two errors,

> "Concern for short-term interests only, at the expense of the future",

and,

> "the policy of 'taking grain as the key link in agriculture' — which entailed land on river banks and opening up wasteland indiscriminately to grow grain".(4)

It is reported that in the early fifties, 19 % of Sichuan was covered in forest, which subsequently fell to 9 %. It is also reported that damage has occurred to water conservancy projects with insufficient flood resistance, just as has been the case on the loess plateau. In the floods of 1981 for example, 14,000 weirs and dams were washed away in Sichuan.(5)

The increased awareness of ecological problems is to be welcomed as a step in the right direction. Nevertheless, it should be remembered that although the link between the denudation of the loess plateau and the problems of the lower R. Huang was well known, this awareness alone was insufficient to effect a change. In the report of the Sichuan floods, we find a similar example of the failure of the real lessons of the loess plateau to have been learned,

> "It is of particular concern that protection of forests and prohibition of tree felling is still not on the agenda. For instance, in 104 State-run tree farms, only 760,000 m^3 of wood should be felled yearly, but the State annual target is set as high as 2×10^6 m^3".(6)

On the other hand, ecological questions did play an important role in the discussions over the Northward Transfer of Southern Waters, as described earlier. In particular it is noticeable how lessons have been drawn from the attempts of the early sixties to irrigate large areas of the North China Plain with clear water from the Sanmenxia resevoir.(7) Whereas, in view of the extensive debates of the fifties and their failure to avert the adoption of the modified Soviet design for the Sanmenxia reservoir, one might regard with scepticism the statement,

> "The Chinese Society of Hydraulic Engineering, in accordance with the opinion of leading comrades of the Central Committee that in order to accept the past lessons of the Sanmenxia project and avoid possible harm, people with different points of view should be called together for a meeting and do an even better job of the Northward transfer of Southern waters, ... held a symposium,"(8)

Yet, it would appear that in this instance a very careful approach is indeed being made to the subject and it is unlikely that any plan of this kind will be undertaken in a rush.

Another example of caution is offered by the complaints about the lack of data, from some Comrades at the 1979 Symposium, on the control of the lower R. Huang, which may be taken as an indication that at least the scientific community will not again be satisfied to proceed with an engineering project based largely upon guesswork. Or so it would seem but, from the following quotation, it would appear that at least one other large project was recently begun before a proper understanding of the sedimentation problems of the locality had been gained,

> "Work on the first key installation to be built on the mainstream of the Changjiang - Gezhouba, was forced, also because of scientific problems, to a halt for two years whilst experiments were done and the design revised, causing a several fold increase in the investment. The warning of the front cart provides food for thought. If, in the project to be undertaken in the Three Gorges, the sedimentation problem is not resolved very early on, especially if appropriate soil and water conservation measures are not adopted in Sichuan ..... then there is bound to be the danger of falling again into the Sanmenxia rut".(9)

The same article also complained of a general lack of emphasis on the part of some officials towards the constraints imposed by sediment,

> "In 1978 when the water level was abnormally low in the Liujiaxia resevoir, the leaders still lop-sidedly emphasised electricity generation, which brought large amounts of silt into the ante-dam area. In just three months, May to July, deposits in front of the turbine intakes rose greatly and there was a sharp increase in the amount of sediment passing through them. In these three months the amount of sediment to pass through the turbines was equivalent to 2.6 times that of the previous

three and a half years, causing serious damage to those parts in contact with the water. Now no.4 machine is out of action awaiting large-scale repairs."

Those concerned with appropriate technology probably would welcome some comments on the scale of modern Chinese waterworks and whether any discernable change may be attributed to the experiences of the last thirty years in R. Huang control. As revealed, (Chapter 5, Section 3, iii), there still exist many pressures on the government to mount further large-scale projects for the provision of hydroelectricity and irrigation from the R. Huang, and it is interesting to note that even though the flood control problem could be solved readily and cheaply by the Taohuayu project, discussion of the other two, whose main advantages are not in flood control at all, but in the provision of other benefits, took place at meetings ostensibly to discuss flood control. This is precisely the type of confusion which was apparent at the meetings of the fifties where the Sanmenxia project was discussed. Furthermore, the reports of the 1979 Symposium do not address the question of what measures have to be taken on the North China Plain in order to make use of the proposed storage at Xiaolangdi. But, rather as in the fifties when the Sanmenxia reservoir was under discussion, it is assumed that one large project to provide electricity and irrigation is necessarily a good thing, even, in the case of the Xiaolangdi reservoir, where 80 km^2 of cultivated land would be lost and 120,000人 would have to be moved. It is assumed that electricity and water thus provided downstream could be put to use without serious problem.

The decision as to new engineering projects on the lower R. Huang has yet to be announced, and it may well be that these fears turn out to be unfounded, and a cautious approach, such as that found with regard to the Northward transfer of Southern waters, will prevail. The QUSRL are quite explicit in their warning,

> "There is still the need to construct some key projects, with a control function, on the mainstream of the R. Huang. The design and use of these projects cannot pay regard only to the requirement for irrigation and electricity, but at the same time must take into consideration the urgent necessity and the possibility for a reduction of deposition in the river channel",(10)

Yet, whether or not it will be heeded, we are obliged to wait and see. Meanwhile on the Changjiang, the first stage of the Three Gorges project, the Gezhou dam, is under construction. Insufficient information is at hand to speculate upon when the next stage will proceed, if at all, or on how large it would be, but there is potential there for a scheme several times larger than any on the R. Huang. It is to this proposed project which one should look in the future for clues as to whether the lessons of the R. Huang have indeed been learned.

For a more succinct admonition, the opinion which some comrades expressed at the 1979 Symposium will more than suffice, not only with regard to the R. Huang, but in water conservancy construction everywhere,

> "When constructing the Sanmenxia project in 1958, our knowledge of the R. Huang problem was insufficient, we made some mistakes and did some foolish things. So much so, that even today, 21 years on, we are still obliged to discuss these lessons; It is exactly 21 years to the turn of the Century, let us hope that when people then talk of today's affairs, it won't again be talk of lessons, but of experience". (11)

2) Conclusions.

In conclusion, the main weaknesses and strengths shown by the work of the Chinese in managing the problems of the R. Huang basin will be listed. Firstly, the weaknesses which have been found, include:

i) Trying to run before being able to walk.

A number of the other weaknesses listed below are related, to a greater or lesser extent, with this. Whilst it may be desirable to control the river, exploit its resources, and promote the development of the region and the country as rapidly as possible, the Chinese experience of the late fifties has provided a good example of more haste resulting in less speed.

ii) Predisposition towards foreign experience and expertise.

The Chinese experience includes a good example of a case where foreign experience and expertise proved to be disastrously inappropriate, despite being based upon a generally higher technological level. The choice of the foreign before the domestic, furthermore, shows that the value of the higher foreign technological level, as perceived by the Chinese in the late fifties, was allowed to mask the question of its appropriateness to domestic circumstances.

iii) Lack of coordination and communication.

An important factor, in the slow progress of much of the work, has been shown to be due to poor delegation of responsibility amongst the various bodies concerned. This lack of coordination has been enhanced by poor communications in general and even, at times, obsessive secrecy.

iv) Political interference.

As must be the case when allocating scarce resources over a large area and amongst divergent groups of interest, there is an important role for the exercise of political choice. Yet, the work in the R. Huang basin fell victim, from the late fifties to the early seventies, to various degrees of excessive emphasis being given to political ideals, at the expense of technical and other considerations. These political ideals themselves, were often arbitrary, being based upon dogma and, misunderstood or taken out of context, were applied blindly, with disastrous result. A number of the other weaknesses identified in this list are also related to this problem.

v) An imbalanced approach.

Despite being based upon a commendable policy of whole-basin development, there have been a number of departures from that policy, in its implementation. These have given rise to instances of imbalance sufficiently severe to hinder seriously the progress of the work.

On the other hand, the strengths which have been found, include:

i) Whole-basin organisation.

Even if not used as effectively as might have been hoped, the RHWCC's whole-basin scope of operations subsists, giving a comprehensive structure to the work.

ii) Thorough data collection.

A major contribution to the understanding of the problems involved has been made by the thorough, large-scale and systematic data collection activities and, albeit somewhat hindered by the weaknesses in coordination and communication (iii, above), the spread of the knowledge so gained amongst the various organisations concerned.

iii) Thorough discussion.

Even though subsequent decisions have been, at times, in error, there has been a useful airing of views at extensive symposia on most of the major issues within the basin. This continues to be the case.

iv) Political independence.

China has steadfastly avoided the common pitfall of allowing foreign aid to result in foreign domination. Furthermore, in later years there has been a strong trend towards self reliance and self help, which increases the degree of emphasis placed upon domestic experience and expertise.

v) Flexibility.

Not only has China shown a willingness to acknowledge and to learn from mistakes, but the experience thus absorbed has led to the disussion of less simplistic solutions than those tried previously.

Empirical advances, often based upon traditional methods, have been incorporated into the work, as have some of the experience and more modern techniques available from abroad. There has been a good general willingness to adapt broad principles to specific local needs. It should be pointed out furthermore, that in this way many of the shortcomings identified above have since been rectified.

3) Prognosis

The formal writing of any thesis is a lengthy process, and by the time it is ready for submission there is often new information to be considered. This is especially so when dealing with China, where rapid change is taking place as new policies are sought to promote recovery from the chaos of the past decade or so. Furthermore, some informal comment on the direction of these changes may be useful despite its necessarily speculative nature. Since completion of the main text the author has had the opportunity to return briefly to China, and this section is intended to introduce some supplementary comment, mainly based upon the discussions there.

The debate about what to construct as the next stage in the plan to control the lower R. Huang is still continuing, but it would appear that the trend is for the Xiaolangdi reservoir project to take precedence over the Longmen and Taohuayu projects. No further information is available with respect to the Longmen project, but it is said that one major reason for the apparent lack of interest is that its useful life, so far as its effect on the lower reaches is concerned, would only be about ten years. The Taohuayu project is still under consideration, but does not seem as popular as before. It is interesting to note, however, that the reasons given are severely practical, and do not make reference to its failure to provide multi-purpose uses.

Three Major problems have been identified with respect to the Taohuayu project. they are all related to the fact that apart from the cliffs along the right (Southern) bank, it would have to rely upon a long earthern dyke built onto the river floodplains. Firstly, under normal circumstances deposition would occur whenever any but the largest type of flood peak occured. The useful capacity would therefore diminish rapidly. Secondly, at present the land around the confluence of the rivers Qin and Huang is highly productive and wheat yields in Wen and Wushe Counties are of the order of 3 t ha^{-1} to 3.75 t ha^{-1}. This would presumably apply to the floodplains as well as the surrounding land. However, the floodplains here are between 6 m and 7 m above the level of the surrounding land, and it is thought that if water were to be stored in a reservoir built onto the floodplains, then seepage would cause alkalisation problems in the wheat fields outwith the dykes. Thirdly, whereas success has been had in using dykes to contain the transient Summer flood peaks of the lower R. Huang, it is feared that earthern dykes would prove impossible to maintain, if used in the proposed way, because they then would be permanently under water and prone to collapse through seepage. The Xiaolangdi reservoir is preferred because, although, 7×10^9 m^3 of capacity will be lost in the first ten to twelve years, thereafter a long term storage capacity of some 5×10^9 m^3 can be maintained. Moreover, by careful choice of reservoir operational regime, including the creation of downstream artificial flood peaks, selectively trapping silts, and using the clearer Autumn flood peaks to discharge silt deposited during the turbid early Summer flood peaks, it is estimated that the lower reaches would not suffer any serious aggradation for thirty years. It also has multipurpose uses.

It is reported that preliminary solutions have been found to the problems of earthquake resistance, construction of a 70 m deep anti-seepage wall, prevention of floods caused by landslides into the reservoir area, and choosing the correct material for the centre of the rock fill dam.(12) However, and despite the benefits mentioned above, the author is still not convinced that this is the best choice to meet the immediate needs for the control and exploitation of the river. The reasons are as outlined in Chapter 5, Section 3, iii: The Xiaolangdi reservoir would still rely upon the Beijin retardation area, but the cost of bringing it up to the required standard and of using it once, according to one estimate, could already exceed the cost of the Taohuayu project. Furthermore, it should be remembered that this would be in addition to the cost of the Xiaolangdi reservoir itself. Much is now being made of the technical problems associated with the Taohuayu project, but most of these problems would only arise if it were to be used to store water, whereas under the operational regime described in Chapter 5, in which it acts only as a standby, this clearly would not be the case in normal years. Meanwhile, the 151 m high rock fill dam proposed for Xiaolangdi, for example, would be much higher than any existing such dam in China, and, as the above list of problems already being tackled there indicates, this project is far from straightforward. Furthermore, it is said that the Xiaolangdi project would be complemented by large pumping stations in Shanxi and Shaanxi to help overcome the shortage of water on the loess plateau. Of course, the view of an outsider is based upon scanty information, and has to be speculative. Nevertheless, having taken a good look at some of the lessons of the Sanmenxia reservoir, one is bound to have reservations about another project apparently chosen for its multipurpose uses, but where much agricultural land is to be lost. In addition many people will have to be moved, the technical problems are many, the technological scale is, in one respect, larger than has hitherto been the case in China, and which in any case may not resolve the flood problem of the lower R. Huang as effectively as a less costly alternative.

In May this year (1982), the State Council established a coordinating group, for soil and water conservation, consisting of representatives from the State Planning Committee, the State Economic Committee, the Ministry of Water Resources (the new name for the Ministry of Water Conservancy and Electrical Power), the Ministry of Agriculture, Animal Husbandry and Pisciculture, and the Ministry of Silviculture. The head of the group is Comrade Qian Zhengying, concurrently head of the Ministry of Water Resources. In August, the fourth National Soil and Water Conservation Conference was held in Beijing, and it was decided, inter alia, to create eight points of emphasis in soil and water conservation. They are: the R. Wuding catchment; the R. Huangpu catchment; the R. Sanchuan catchment; all in the R. Huang basin; Dingxi County in Gansu; the R. Liu catchment in the R. Liao basin;

the upper reaches of the R. Yongding in the R. Hai basin; Xingguo County in Jiangxi; and the reservoir area of the Gezhouba project on the Changjiang.(13) That noticeable progress has already been made in the development of the loess plateau is witnessed by the remark, made to the author recently in China, to the effect that it is being said in Shaanxi that the peasants once again may now eat their fill.

It is very difficult to assess the extent to which the lessons of the past have been assimilated. As was mentioned in the Summary, the technical lessons appear to have been studied and grasped well, but for the organisational ones the situation is not so clear. Caution has been shown in dealing with the question of the Northward transfer of Southern waters, but doubt still remains over the choice of technological scale elsewhere. The enormous Gezhouba project on the Changjiang was cited in the Summary as an example of a large project being begun before all the relevant facts were known, and it would appear that the choice of the Xiaolangdi reservoir as the next stage on the R. Huang, may be yet another such case. It would seem that, although specific problems are tackled and resolved satisfactorily, there remains the need to pay more attention to the overall view. This may be particularly difficult in China, where specialisations tend to be narrow.

The educational system has been thoroughly restored in the past few years. Entrance to university is no longer dependent upon political or ideological purity, but is strictly according to examination results. Competition is fierce and the standards are high. The diligence of Chinese students is outstanding and if one were to accept the implied premise that study is all there is to university life, that of Western students would not bear comparison. However, this system seems conducive to the rigidly segmented style of work from which the above lack of overall view stems. Of course, academic exchange is not stifled. On the contrary, it is encouraged, but students tend to concentrate and become specialised in a narrow field and then, as would seem logical, to be assigned a post within their speciality. They do not have much to say, however, in the selection of their specific work post and, once accepted, it may not be changed freely. Thus, once a young person has begun his or her career, and to some extent even before, there will be little opportunity to gain a broad spectrum of practical experience.

The problem of making more people aware of the lessons of the past is, however, taken very seriously in high places and the importance of assimilating such experience into the normal school syllabus is also recognised. For example, at the Fourth National Soil and Water Conservation Conference, mentioned above, Vice Premier Wan Li, of the State Council, called for materials on the protection of resources and the environment to be included into middle and junior school textbooks.(14)

Another factor of importance in the past, was direct political interference in everyday academic affairs. Although steps have been taken to eliminate this problem, people still seem somewhat reluctant to depart from the norm and take on broader responsibilities. Decisions are often made only after consideration by large committees or large conferences. But why should many people necessarily produce more realistic results than few? This would be a difficult question to answer in China where the ideas of broad consultation and expertise lie uneasily together. If the answer is to be found in the establishment of a corps of experts, then they would have to have broad experience and be receptive to the new, often imprecise, ideas which arise in the interdiciplinary meetings. If committees or conferences were to remain paramount, the value of expertise might be lost, unless the experts amongst the members present, happen also to be persuasive orators. This appears to have been the case in the meetings of 1957, to discuss the design of the Sanmenxia reservoir, where the experts were overpowered by the intensity of feeling of others who, with the best of intentions, were trying to force the pace of China's development.

Despite past history and the particular difficulties in China, it should be pointed out that both professionalism and the wider acceptance of personal responsbility are on the increase. For the sake of the Chinese people, who have many development problems to overcome, it is to be hoped that this trend will continue, away from the conservatism of over reliance on narrow collectivism.

Notes to Chapter Six

1. CHEN Baolian, 1979.

2. MOSELY Paul, 1977.

3. XINHUA, Xi'an, 7 September 1981. XINHUA, Beijing, 10 September 1981. XINHUA, Beijing, 11 September 1981. XINHUA, Beijing, 12 September 1981. XINHUA, Beijing, 14 September 1981. XINHUA, Beijing, 15 September 1981.

4. CHINA DAILY, Eds., 1981.

5. ibid.

6. ibid.

7. XINHUA, Tianjin, 19 April 1979. CHEN Baolian, 1979.

8. XINHUA, Tianjin, 19 Zpril 1979.

9. DAI Dingzhong, WANG Guiyin, 1979. 'The warning of the front cart' is part of a Chinese proverb: The overturned cart ahead is a warning to the carts behind (前车之覆, 后车之鉴). It means that lessons should be drawn from others' mistakes. The 'Three Gorges' are the three gorges on the Changjiang.

10. QUSRL, 1981, p. 2.

11. RENMIN HUANGHE, Eds., 1979, p. 54.

12. RENMIN HUANGHE, 1981, No. 6, p. 80.

13. RENMIN RIBAO, 24 August 1982, p. 2.

14. ibid.

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