Proceedings
of the 3rd International Yellow River Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance

Volume Ⅱ

Yellow River Conservancy Press

The 3rd International Yellow River Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance

Organizer

Yellow River Conservancy Commission (YRCC), Ministry of Water Resources, P. R. China

Co – Organizer

Dongying Municipal Government of Shandong Province, P. R. China
Shengli Petroleum Administrative Bureau, P. R. China
Yellow River Shandong Bureau, YRCC

Sponsors

EU – China River Basin Management Program
Ministry of Environment, Spain
WWF (World Wide Fund for Nature)
Department for International Development (DFID)
World Bank (WB)
Asian Development Bank (ADB)
Global Water Partnership (GWP)
Challenge Program on Water and Food (CPWF)
International Network of Basin Organizations (INBO)
World Conservation Union (IUCN)
Asia Scientific Regional Office of Global Water System Program (GWSP)
National Natural Science Foundation of China (NSFC)
Tsinghua University (TU)
Center for Water Resources Research, Chinese Academy of Sciences (CAS)
China Institute of Water Resources and Hydropower Research (IWHR)
Nanjing Hydraulic Research Institute (NHRI)
Yellow River Water & Hydropower Development Corporation (YRWHDC)
International Economic Technical Cooperation and Exchange Centre, MWR (IETCEC, MWR)

Advisory Committee

Honorary Chairmen

Qian Zhengying, Former Vice Chairwoman of Consultant Committee of People's Republic of China; Academician of Chinese Academy of Engineering
Yang Zhenhuai, Former Minister of Ministry of Water Resources of China; President

of Chinese Society of Water and Soil Conservation; Honorary Chairman of GWP China
Wang Shucheng, Former Minister of Ministry of Water Resources of China

Chairmen

Hu Siyi, Vice Minister of Ministry of Water Resources, China
Jia Wanzhi, Vice Governor of Shandong Province, China

Vice Chairmen

Zhu Erming, Former Chief Engineer of Ministry of Water Resources of China
Gao Anze, President of Chinese Hydraulic Engineering Society (CHES)
Xu Qianqing, Academician of Chinese Academy of Engineering
Dong Zheren, Chairman of GWP China
Huang Ziqiang, Vice Chairman of Technical Committee of Yellow River Conservancy Commission (YRCC), MWR, China; Chairman of GWP China (Yellow River)
Zhang Jianhua, Mayor of Dongying Municipal Government of Shandong Province, China
Serge Abou, Ambassador of the Delegation of EC to China
Loïc Fauchon, President of World Water Council, France
Dermot O'Gorman, WWF China Representative
Paul Ching – Wu Chu, President of the Hong Kong University of Science and Technology

Members

Cao Zelin, Director General of Academy of Chinese Economics Limited, China
Christopher George, Executive Director of International Association of Hydraulic Engineering and Research, Spain
Dai Dingzhong, Professor of Chinese Hydraulic Engineering Society (CHES)
Des Walling, Professor of Department of Geography, School of Geography, Archaeology and Earth Resources, UK
Don Blackmore, Academician of Australian Academy of Science; Former Chief Executive of Murray – Darling Basin Commission (MDBC), Australia
Feng Guobin, Director of Henan Hydropower Engineering Society, professor, China
Gaetan Paternostre, General Manager of National Company of Rhone River, France
Gong Shiyang, Former Commissioner and Professor of Yellow River Conservancy Commission, MWR, China
Jacky COTTET, President of Rhône River Agency, France; President of the European International Network for Basin Organizations (Euro – INBO)
Khalid Mohtadullah, Senior Advisor of Global Water Partnership (GWP), Pakistan
Kuang Shangfu, Director General of Institute of Water Resources and Hydropower Research (IWHR), China
Liu Weimin, Director General of Qinhai Provincial Water Resources Bureau
Liu Zhiguang, Deputy Director General of Department of International Cooperation, Science and Technology, MWR, China
Pan Junfeng, Director General of Shanxi Provincial Water Resources Bureau
Pierre ROUSSEL, Head of the French General Inspection for Environment; Presidency

of the French "Scientific and Technical Association of Environmental Engineering"
Shao Xinmin, Deputy Counsel of Henan Provincial Water Resources Bureau
Tan Cewu, Director General of Shaanxi Provincial Water Resources Bureau
Wu Yiqun, Deputy Director General of Shandong Provincial Water Resources Bureau
Xu Wenhai, Director General of Gansu Provincial Water Resources Bureau
Wu Hongxiang, Director General of Ninxia Autonomous Regional Water Resources Bureau
Yves Caristan, Executive President of French Geological Survey Bureau (BRGM)
Zhang Jianyun, Director General of Nanjing Hydraulic Research Institute, China

Organizing Committee

Honorary Chairman

Chen Lei, Minister of Ministry of Water Resources, China

Chairman

Li Guoying, Commissioner of Yellow River Conservancy Commission, MWR, China

Vice Chairmen

Gao Bo, Director General of Department of International Cooperation, Science and Technology, MWR, China
Wang Wenke, Director General of Bureau of Comprehensive Development, MWR, China
Xu Cheng, Vice Commissioner of Yellow River Conservancy Commission, MWR, China
Yin Baohe, Director General of Xiaolangdi Multi – purpose Project Administrative Bureau, MWR, China
Yuan Chongren, Director General of Yellow River Shandong Bureau, YRCC
Gao Hongbo, Deputy Director of the Administration Office, Shandong Provincial People's Government, China
Lv Xueping, Deputy Mayor of Dongying Municipal Government of Shandong Province, China
Li Zhongshu, Deputy Director General of Shengli Petroleum Administrative Bureau, China
Emillio Gabbrielli, Executive Secretary of GWP Secretariat, Sweden
Andras Szollosi – Nagy, Deputy Assistant Director General of UNESCO
Kunhamboo Kannan, Director of Agriculture, Environment & Natural Resources Division, East and Central Asia Department, ADB

Members

An Xindai, Director General of Department of Water Resources Management and Regulation, YRCC
A. W. A. Oosterbaan, Senior Expert of International Affairs of Directorate of Sciences and Technology, Ministry of Transport, Public Works and Water Management, the Netherlands

Bjorn Guterstam, Network Officer of GWP Secretariat, Sweden
Bryan Lohmar, Economist of Economic Research Service, USDA
Chen Yiyong, Deputy Director General of Xiaolangdi Multi – purpose Project Administrative Bureau
Chen Yinlu, Deputy Secretary General of Dongying Municipal Government of Shandong Province, China
Du Zhenkun, Coordinator of GWP China
Guo Guoshun, Chairman of Labor Union and Director General of Administration Office, YRCC
G. H (Gordon) Huang, Professor of Canada Regina University, Canada
Hou Quanliang, Deputy Director General of Administration Office, YRCC
Huub Lavooij, First Secretary of the Royal Netherlands Embassy in Beijing
Jia Jinsheng, Deputy Director of Institute of Water Resources and Hydropower Research, China
Jonathan Woolley, Coordinator of Challenge Program on Water and Food (CPWF), Sri Lanka
Joop L. G. de Schutter, Dean of Department of Water Engineering, UNESCO – IHE, the Netherlands
Li Guifen, Professor of China Institute of Water Resources and Hydropower Research (IWHR), Council Member of IAHR
Li Jingzong, Director General of Office of Chief Engineer, YRCC
Li Xinmin, Director General of Department of Personnel, Labour and Education, YRCC
Li Ming, Professor of National Natural Science Foundation of China
Liu Shuanming, Director General of Department of Construction and Management, YRCC
Liu Xiaoyan, Deputy Chief Engineer, YRCC
Luo Xiangxin, Director General of Press & Publication Center, YRCC
Ma Chaode, Freshwater Programme Officer, WWF China
Paul van Hofwegen, Senior Expert on Water Management of World Water Council, France
Paul van Meel, TAT TL EU – China RBMP
Stephen Beare, Research Director of Australian Bureau of Agriculture and Resource Economics, Australia
Tan Guangming, Dean and Professor of College of Water Resources and Hydropower, Wuhan University, China
Wang Changci, Deputy Director General of Yellow River Shandong Bureau, YRCC
Wang Guangqian, Professor of Tsinghua University, China
Wang Jianzhong, Director General of Department of Water Policy, YRCC
Wang Xijun, Director General of Department of Water and Soil Conservation, YRCC
Wang Xuelu, Y. R. Wanjiazhai Water Multi – Purpose Dam Project Co., Ltd
Wouter T. Lincklaen Arriens, Lead Water Resources Specialist of Asian Development Bank (ADB)
Wu Baosheng, Professor of Tsinghua University, China
Xia Minghai, Director General of Department of Financial Affairs, YRCC

Xu Zongxue, Leading Professor and Deputy Dean, College of Water Sciences, Beijing Normal University, China
Yan Tongsheng, Deputy Division Chief of Shengli Petroleum Administrative Bureau
Yao Zijing, Director General of Office of Administration, YRCC
Yu Xingjun, Director General of International Economic Technical Cooperation and Exchange Centre, MWR, China
Zhang Hongshan, Deputy Chief Engineer of Shengli Petroleum Administrative Bureau
Zhang Jinliang, Director General of Office of Flood Control, YRCC
Zhang Junfeng, Director General of Department of Plan and Programming, YRCC
Zhang Yongqian, Professor of Academy of Chinese Economics Limited, China

Secretary General

Shang Hongqi, Director General of Department of International Cooperation Science and Technology, YRCC

Technical Committee

Chairman

Xue Songgui, Chief Engineer of YRCC

Members

Anders Berntell, Executive Director of Stockholm International Water Institute (SIWI), Secretary General of Stockholm World Water Week, Sweden
Bart Schultz, Senior advisor of Civil Engineering Division, Directorate General for Public Works and Water Management, Utrecht, Professor of UNESCO – IHE, the Netherlands
Bas Pedroli, Professor of Alterra Wageningen University, the Netherlands
Chen Jiyu, Academician of Chinese Academy of Sciences (CAS), Professor of Institute of Estuary and Seacoast Research, East China Normal University
Chen Xiaoguo, Chairman of Technical Committee, YRCC, MWR
Chen Zhikai, Academician of Chinese Academy of Engineering, Professor of China Institute of Water Resources and Hydropower Research (IWHR)
Cheng Chaojun, Deputy Chief Editor of Academy of Chinese Economics Limited, China
Cheng Xiaotao, Professor of China Institute of Water Resources and Hydropower Research (IWHR), China
Chih Ted Yang, Professor of Bureau of Reclamation, USA
Chin – Lien Yen, Professor of Taiwan University, Taipei, China
David Molden, Theme Leader of IWMI, Sri Lanka
Ding Dewen, Academician of Chinese Academy of Sciences (CAS), the First Institute of Oceanography, State Oceanic Administration, China
Dou Xiping, Chief Engineer of Nanjing Hydraulic Research Institute, China
Eelco van Beek, Professor of WL | Delft Hydraulics, the Netherlands
Gao Jun, Academician of Chinese Academy of Sciences (CAS)
Hongyuan Lee, Professor of Taiwan University, Taipei, China

Hu Angang, Senior Advisor of State Council, Professor of Tsinghua University, China
Hu Chunhong, Deputy Director of Institute of Water Resources and Hydropower Research, China
Hu Dunxin, Academician of Chinese Academy of Sciences (CAS), Professor of Institute of Marine Research, Chinese Academy of Sciences (CAS)
Huib J. de Vriend, President of WL | Delft Hydraulics, the Netherlands
Jean – Francois Donzier, Permanent Technical Secretary of International Network of Basin Organizations (INBO), General Manager of the International Office for Water
Ji Changming, Director of Graduate – student Institute of North China Electric Power University
Ji Chunlou, Deputy Director General of Chongqing Municipal Water Resources Bureau
Jinn – Chuang Yang, Professor of Chiao Tung University, Taipei, China
Joseph H. W. Lee, Professor of Hong Kong University
Kuniyoshi Takeuchi, Professor of Yamanashi University, Japan; Director of International Center for Water Hazard and Risk Management (ICHARM) under the Auspices of UNESCO
Laszlo Iritz, Vice President of COWI, Denmark
Lee Yee Cheong, Academician Dato' Ir, President Elect WFEO, Malaysia
Lei Tingwu, Professor of Northwest China Institute of Soil and Water Conservation Research, CAS
Li Jiayang, Vice Director & Academician of Chinese Academy of Sciences (CAS)
Li Lifeng, Director of Freshwater Programme Officer, WWF China
Li Wanhong, Professor of National Natural Science Foundation of Chinese
Li Wenxue, President of Yellow River Engineering Consulting Co., Ltd
Li Zhuofen, Vice President of the University of Hong Kong, Academician of Chinese Academy of Engineering, Academician of Canada Academy of Engineering, Director of Hong Kong Academy of Engineering and Science
Lin Binwen, Professor of Yellow River Conservancy Commission
Liu Bin, Deputy Director General of Gansu Provincial Water Resources Bureau
Liu Changming, Academician of Chinese Academy of Sciences (CAS), Professor of Beijing Normal University, China
Lu Yongjun, Deputy Director of River and Harbor Department, Nanjing Hydraulic Research Institute, China
Lu Youmei, Academician of Chinese Academy of Engineering (CAE)
Ma Jiming, Professor of Tsinghua University, China
Mao Zhi, Academician of Chinese Academy of Engineering (CAE), Wuhan University, China
Mohamed Nor bin Mohamed Desa, Director of Malaysia UNESCO Regional Humid Tropic Hydrology Center (HTC), Malaysia
Ni Jinren, Professor of Peking University, China
Peng Jing, Professor of Institute of Water Resources and Hydropower Research, China
Peter A. Michel, Head of Water Protection and Fisheries Division, Switzerland
Peter Rogers, Member of Technical Advisory Committee of GWP, Professor of Harvard University, USA
Ren Liliang, Dean of Water Resources and Hydropower Engineering College, Hohai

University
Richard Hardiman, Project Officer, Delegation of EC to China
Shi Changxing, Professor of Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Stefan Agne, First Secretary, Delegation of EC to China
Sun Honglie, Academician of Chinese Academy of Sciences (CAS)
Sun Ping'an, Chief Engineer of Shaanxi Provincial Water Resources Bureau
Tian Zhen, Director General of Inner Mongolia Water Resources and Hydropower Engineering Reconnaissance and Design Institute
Volkhard Wetzel, Director of Federal Institute of Hydrology (BFG), Germany
Wang Bingchen, Senior Advisor of State Council, Professor of Tsinghua University, China
Wang Hao, Academician of Chinese Academy of Engineering, Director of Water Resources Research Department of IWHR, Secretary General of GWP China
Wang Jiayao, Academician of Chinese Academy of Engineering, Professor of Science and Information Engineering University, China
Wang Jiyang, Academician of Chinese Academy of Sciences (CAS)
Wang Xianzhang, Chief Engineer of Henan Provincial Water Resources Bureau
Wang Yadong, Chief Engineer of Inner Mongolia Water Resources and Hydropower Engineering Reconnaissance and Design Institute
Wang Zhaoyin, Professor of Tsinghua University, China
William Bouffard, Head of the Coordination and Quality Unit for the Rhône River Basin Agency, France
Wu Bingfang, Professor of Institute of Remote Sensing Applications, Chinese Academy of Sciences
Xia Jun, Professor of Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences; Vice Chairman of IAHS and IWRA
Xue Saiguang, Chief Engineer of Ningxia Autonomous Regional Water Resources Bureau
Y. Cheng, Chairman of Sinotech Foundation for Research & Development of Engineering Sciences & Technologies, Taipei, China
Yan Dakao, Director General and Professor of North China University of Water Conservancy and Electric Power, China
Yang Guowei, Vice Chairman of the China Technical Advisory Committee (TAC), GWP – China
Zeng Guangming, Director of College of Environmental Science & Engineering, Hunan University, China
Zhang Baishan, Deputy Director General of Yellow River Shandong Bureau, YRCC
Zhang Hongwu, Professor of Tsinghua University, China; Deputy Chief Engineer of YRCC
Zhang Qiangyan, Chief Engineer of Sichuan Provincial Water Resources Bureau
Zhang Ren, Professor of Tsinghua University, China
Zhang Renduo, Professor of Ohio University, USA
Zhou Jianjun, Professor of Tsinghua University, China
Zhu Qingping, General Manager of China Water International Engineering Consulting Co. Ltd., MWR, China

Welcome

I, On behalf of the Organizing Committee of the 3rd International Yellow River Forum (IYRF) on Sustainable Water Resources Management and Delta Ecosystem Maintenance and the conference host, Yellow River Conservancy Commission (YRCC), warmly welcome you all over the world to Dongying to attend the 3rd IYRF.

Yellow River Conservancy Commission hosted the 1st and 2nd IYRF successfully in Zhengzhou in October of 2003 and October of 2005, respectively. The central theme of the 1st IYRF is "River Basin Management" and the 2nd IYRF is "Keeping Healthy Life of the River", which got high response and big support from water field around the world. We still remember, on the plenary and technical sessions of the past two forums, delegates carried on wide exchanges and discussions, which showed their latest research achievements sufficiently and analyzed the experiences of river harnessing and river basin management from different aspects. We collected all the valuable viewpoints and advanced experiences presented on the forum into proceedings, which promote the river basin management to keep healthy life of the river and scientific research etc. actively.

The central theme of the 3rd IYRF is sustainable water resources management and delta ecosystem maintenance. It is developed into eight sub – themes: (1) sustainable water resources management and basin ecosystem construction; (2) delta ecosystem protection and maintenance; (3) delta ecosystem and delta development modes; (4) strategies and practices on keeping healthy life of rivers; (5) river engineering and river ecology; (6) regional water resources allocation and interbasin water transfer; (7) water right, water market and water – saving society; and (8) high – tech application in modern basin management and its development trend. The Conference also arranges 18 special sessions jointly hosted by YRCC and the international well – known organizations as follows: Sino – Hispanic Water Forum; Sino – Dutch the 8th Joint Steering Committee; EU – China River Basin Management Programme; WWF – Integrated River Basin Management Forum; GWP High – level Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance; Sino – Norwegian Seminar on Sustainable Water Management; DFID – Special Session on Water and Soil Conservation; Yellow River Basin CPWF Workshop; EURO – INBO Special Session; Sino – Italian Cooperation Project on Environmental Protection; GWSP Session: Global Climate Change and

Water Resources Risk management of the Yellow River Basin; Sino – Dutch Project: Environmental Flow and Environment Protection for River Delta & Sino – Dutch Environmental Flow Training; Sino – Dutch Cooperation Project on "Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin"; Special Session of International Centre of Excellence in Water Resources Management (ICE WARM) Maximising the Benefits of Professional Development Activities; Post – evaluation Session on UNESCO – IHE – YRCC Professionals Training Program; Water Resources Allocation in China; Water Engineering Construction and Management in River Basins; and Management and Safety for Water Supply.

At present, about 800 experts and scholars from 64 countries and regions have registered for participating in the Forum and submitted more than 500 papers. After examined by the Scientific Committee, more than 400 papers are collected into the proceedings of the 3rd IYRF. Compared with the past two forums, the content of the 3rd forum is more abundant and the form of sessions is more multiform. The Conference will omni – directionally show the achievements on water conservancy of China and the Yellow River basin management, deeply discuss the focus and crux of river basin management, and hope to develop a mechanism for international cooperation and exchange more widely.

I am sure that with the effort of the Advisory Committee, the Organizing Committee, the Scientific Committee and all of the representatives will benefit from the conference in the professional field, and have a good time in Dongying. I believe that your experiences exchanged and your good suggestions for sustainable water resources management and delta ecosystem maintenance in the conference will influence the management of Yellow River and other river basins in the world actively in future.

Finally, I hope the 3rd IYRF be successful; hope the conference make a strong impression to every participant; and hope every participant be in good health and have a pleasant stay in Dongying.

Li Guoying
Chairman of the Organizing Committee, IYRF
Commissioner of Yellow River Conservancy Commission, MWR, China
Dongying, China, October 2007

Foreword

The International Yellow River Forum (IYRF) is a great event in water field, also a good chance for scientists who are engaged in river basin management, hydraulic research and management to exchange and discuss the river basin management and the science of water.

The 3rd IYRF is held on October 16 ~ 19, 2007 in Dongying, China. The central theme focuses on: Sustainable Water Resources Management and Delta Ecosystem Maintenance. The central theme involves the following eight sub – themes:

A. Sustainable water resources management and basin ecosystem construction;

B. Delta ecosystem protection and maintenance;

C. Delta ecosystem and delta development modes;

D. Strategies and practices on keeping healthy life of rivers;

E. River engineering and river ecology;

F. Regional water resources allocation and interbasin water transfer;

G. Water right, water market and water – saving society;

H. High – tech application in modern basin management and its development trend.

Eighteen special sessions jointly hosted by YRCC and relevant governments and well – known international organizations are arranged on the 3rd IYRF as follows:

As. Sino – Hispanic Water Forum;

Bs. Sino – Dutch the 8th Joint Steering Committee;

Cs. EU – China River Basin Management Programme;

Ds. WWF – Integrated River Basin Management Forum;

Es. GWP High – level Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance;

Fs. Sino – Norwegian Seminar on Sustainable Water Management;

Gs. DFID – Special Session on Water and Soil Conservation;

Hs. Yellow River Basin CPWF Workshop;

Is. EURO – INBO Special Session;

Js. Sino – Italian Cooperation Project on Environmental Protection;

Ks. GWSP Session: Global Climate Change and Water Resources Risk Management of the Yellow River Basin;

Ls. Sino – Dutch Project: Environmental Flow and Environment Protection for

River Delta & Sino – Dutch Environmental Flow Training;

Ms. Sino – Dutch Cooperation Project on "Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin";

Ns. Special Session of International Centre of Excellence in Water Resources Management (ICE WaRM) Maximising the Benefits of Professional Development Activities;

Os. Post – evaluation Session on UNESCO – IHE – YRCC Professionals Training Program;

Ps. Water Resources Allocation in China;

Ar. Water Engineering Construction and Management in River Basins;

Br. Management and Safety for Water Supply.

The preparation work for the 3rd IYRF was started after the 2nd IYRF. Since the Bulletin one was released, more than 500 papers have been submitted by about 800 decision – makers, experts and scholars from 64 countries and regions. Through the examining of the Technical Committee, more than 400 papers are collected into proceedings, including 322 papers are put into the following six volumes:

Volume I: including 52 papers under the sub – theme A

Volume II: including 50 papers under the sub – theme B and C

Volume III: including 52 papers under the sub – theme D and E

Volume IV: including 64 papers under the sub – theme E

Volume V: including 60 papers under the sub – theme F and G

Volume VI: including 44 papers under the sub – theme H

After the forum, Volume VII and VIII will be published, including about 100 papers. Total more than 300 papers are selected to present in 77 technical sessions and 5 plenary sessions.

We appreciate the generous supports of the co – sponsors, especially Dongying Municipal Government of Shandong Province, Shengli Petroleum Administrative Bureau of China, EU – China River Basin Management Program, Yellow River Water & Hydropower Development Corporation (YRWHDC), Comprehensive Development Bureau of MWR, Yellow River Wanjiazhai Water Multipurpose Dam Project Co. Ltd, Ministry of Environment of Spain, WWF (World Wide Fund for Nature), UK Department for International Development (DFID), Global Water Partnership (GWP), World Bank (WB), Asian Development Bank (ADB), Challenge Program on Water and Food (CPWF), International Network of Basin Organizations (INBO), National Natural Science Foundation of China (NSFC), Tsinghua University (TU), China Institute of Water Resources and Hydropower Research (IWHR), Nanjing Hydraulic Research Institute (NHRI), International Economic

Technical Cooperation and Exchange Centre of MWR (IETCEC, MWR).

We also would like to thank the members of the Advisory Committee, the Organizing Committee and the Scientific Committee, and all the authors presented in the proceedings for their outstanding contributions.

We sincerely hope that the publication of the proceedings of the 3rd IYRF will give an active impulse to the sustainable water resources management and delta ecosystem maintenance.

Shang Hongqi
Secretary General of the Organizing Committee, IYRF
Dongying, China, October 2007

图书在版编目(CIP)数据

第三届黄河国际论坛论文集 = Proceedings of the 3rd International Yellow River Forum/尚宏琦,骆向新主编. —郑州:黄河水利出版社,2007.10
ISBN 978-7-80734-296-0

Ⅰ.第… Ⅱ.①尚…②骆… Ⅲ.黄河-河道整治-国际学术会议-文集-英文 Ⅳ.TV882.1-53

中国版本图书馆 CIP 数据核字(2007)第 150063 号

出 版 社:黄河水利出版社
地址:河南省郑州市金水路 11 号　　邮政编码:450003
发行单位:黄河水利出版社
发行部电话:0371-66026940　　传真:0371-66022620
E-mail:hhslcbs@126.com
承印单位:河南省瑞光印务股份有限公司
开本:787 mm×1 092 mm　1/16
印张:151.50
印数:1—1 000
版次:2007 年 10 月第 1 版　　印次:2007 年 10 月第 1 次印刷

书号:ISBN 978-7-80734-296-0/TV·525　定价(全六册):1 200.00 元(US $ 160.00)

Contents

Delta Ecosystem Protection and Maintenance

Delta Ecosystem and Delta Development Modes

Study on Environmental Flows and its Evaluation Based on Eco – hydrology in Yellow River Delta Wetlands Sino – dutch Study Program YRD – EFS

Lian Yu[1], ***Wang Xingong***[1], ***Liu Gaohuan***[2], ***Huang Chong***[2], ***Wang Ruiling***[1], ***Zhang Shaofeng***[1], ***Liu Yueliang***[3], ***Bas PEDROLI***[4] and ***Michiel van Eupen***[4]

1. Yellow River Basin Water Resources Protection Bureau, Zhengzhou, 450004, China
2. Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, 100101, China
3. Yellow River Delta Nation Nature Reserve
4. Alterra Wageningen UR, The Netherlands

Abstract: Based on the principles of protecting integrity and stability of ecosystem, and aimed at promoting maintaining good situation of delta ecosystem, as well as improving the capacity and capability of the ecosystem and protecting biodiversity, this paper identified 23,600 ha wetlands as restoration scale which urgently needed to be supplied with freshwater in the Yellow River Delta. Whereas, this study adopted the principle and methodology of landscape ecology, with the supporting of RS and GIS and wetlands plant physiology, ecology and hydrology, made a study on Coupling mechanism between water and ecological process therefore, established the Environment flow calculation and evaluation model which is based on eco – hydrology field of the Yellow River Delta; Furthermore, this study apply pre – scheme methodology and planning evaluation concept of landscape ecology decision & evaluation support system to forecast and evaluate ecological effects on the wetlands with different wetlands water discharge scenarios, which focused on the relationship study between suitable habitat conditions for indicator species such as Red – crowned crane, Oriental stork, Sauder's gull and changing of ecological pattern after water supplement. In general, after fully took water resources, water allocation engineering measures and integrated requirement of wetlands ecosystem protection into account, this study proposed recommendation of supplying the Yellow River Delta wetlands with 0.35 billion m^3/a freshwater abstracted from the Yellow River to restore and protect the Yellow River Delta wetlands ecosystem.

Key words: eco – hydrology, Yellow River Delta, wetland, environmental flows

1 Background

1.1 The wetlands of YRD facing seriously unbalance problems

The Yellow River is the most important factors that maintain succession and develop of Yellow River Delta (YRD) ecosystem. Under the conjunct affection of unique Yellow River water and sediment and weak tidal of BOhai sea, Yellow River Delta forms the most complete and extensive young wetland ecological system in China, with abundant nature resources and a unique ecological status, whose unique original wetland is not only the suitable habitat of many rare and endangered birds but also is the important basement of study on the estuary in the wetland ecosystem's formation, evolution and development. The Yellow River Delta National Nature Reserve, as Chinese sole delta wetland natural reserve, has been included in the world and Chinese biodiversity conservation and wetlands protection list, and plays an important role in world biodiversity protection and strategic resources relating to the national and regional ecological safety in the process of the sustainable development.

However, there occurs river dried, freshwater wetlands shrank, vegetation degradation, species diversity decreased due to the water and sediment resources flowing into estuary decreasing, river channeling as a result of dykes construction, agricultural development and urbanization since 1990s, which threatened system stability and sustainability of economic and society of YRD. So it is one of the key problems to maintain Yellow River healthy life and requirements of society, economy and environment harmonious development in Yellow River delta that studying environmental flows, further optimizing water resources allocation of Yellow River, and realizing good development of YRD system.

1.2 Sino – dutch scientists studying ecological issues together

There are many methods to calculate environmental flows, and hydrological and ecophysiological methods are used frequently in the past, However, there are little studies in water – ecological process coupling effect mechanism, landscape ecology research, the definition of scientific ecology objectives and ecological valuation of water resources, and that eco – hydrology process studies in integrating surface water, ground water, soil water and physiological environmental flows of plant and ecosystem development, and rare species habitat protection are less. So it made the research outcomes can't meet the requirements of ecosystem protection and ecological allocation of water resources. In addition, the definition of environmental flows, is not only a technical question, but need consider the demands of society, economy and ecosystem synthetically. So YRCC invited research and nature protection institution of Netherlands and China to study YRD ecological issues and its environmental flows in 2003, and in Oct, 2005, the agreement signed by Chinese and Dutch governments, which decided studying the Yellow River estuary ecological environmental flows which providing technical supports for rational allocation of limited Yellow River water resources and for the management of Delta wetlands ecosystem.

2 General situation of research area

2.1 The Yellow River Delta

The Yellow River Delta extensively refers to the sector region that formed by entrance siltation extending, wavering, redirection, and deposit many years, belongs to accumulation influx with weak land formation and intensive tide, located between Laizhou Gulf and Bohai Bay in north Shandong province of China, with longitude 118°10′ to 119°15′ E, latitude 37°15′ to 38°10′ N. For convenient research, it divide into Neoteric Delta and Modern Delta according to times and specific geographic status. Neoteric Delta refers to the region of branch range trench with 135°angle which top to Ninghai, north from Taoer influx, south to sector region, more than 6,010 km^2 coverage and 350 km coast line while Modern Delta to the region that Kenliyuwa as peak, north starts from Tiaohe river, south to Songchunrong trench with 2,400 km^2 coverage.

2.2 The Yellow River Delta national nature reserve

To protect Yellow River wetlands of birds' habitat, China government set up Yellow River Delta Nation Nature Reserve (YRDNNR) in 1992. YRDNNR locates in both sides new silt region of the Yellow River entrance, and it is a wetland protected area mainly protecting the Yellow River new wetland ecosystem and endangered rare birds. The total area is 15.3×10^4 ha, of which core area is 5.8×10^4 ha, buffer area is 1.3×10^4 ha, and experimental area is 8.2×10^4 ha. Nature reserve can be divided into 2 parts, the north part lies in the region of Diaokou river, which is an old route of Yellow River before 1976, while the south part lies in the region of present route of Yellow River. The location of YRDNNR sees Fig. 1.

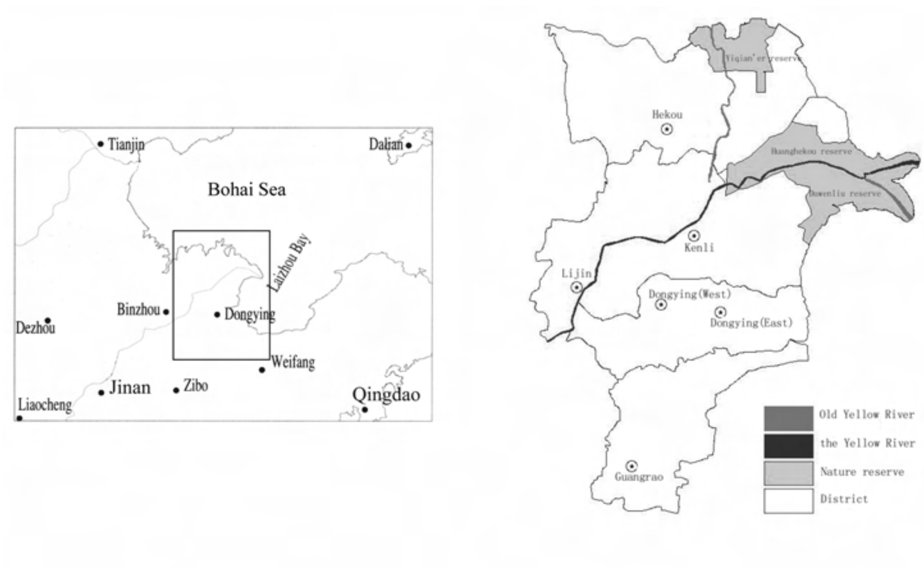


Fig. 1 Location of the Yellow River Delta

2.3 Vegetation and creature of research area

There are 42 family of spermatophytes, 393 species, and nation grade Ⅱ protection plant – wild Soya distribute broadly in nature reserve. The vegetations are mostly defoliate broad – leaf forest, defoliate bush, meadow, swamp vegetation, hydrophilic vegetation and man – made planting vegetation, and so on. Among of which, natural vegetation accounts for 91.9%, and it is the biggest beach natural vegetation area in China.

There are 1,543 kinds of wild creature, among of which aquatic ocean creature 418 species, national protection 6 species; freshwater fish 108 species, national protection 3 species; birds 283 species, nation protection grade Ⅰ 9 species, that is Red – crowned crane, White crane, Big bustard, Oriental stork, Black stork, golden eagle, Hooded crane, Sauder's gull, Ern, China goosander, nation grade Ⅱ protection 41 species, and such as Grey crane, Big swan, mandarin duck, etc..

3 Study route and methodology

3.1 Ecological survey

Detailed survey to altitude foliages and their succession role and terricolous creature, freshwater creature and creature lived in tidelands were carried through, and physiological observation and evaportranspiration test were made to reed, tamarisk and seablite, etc., and remote sense survey and evaportranspiration study were made to main vegetations, and these outcomes above were the foundation and boundary conditions of ecological model.

3.2 Study route

Based on the research of ecology and hydrology, the development status of the delta natural freshwater wetlands ecosystem and composition of the community were mastered, the dominant and indicative species were identified, those rules of environmental flows were studied using RS, GIS and ecological observed information, by data collecting and field work. And based on ecological succession role, land use actuality of Yellow River delta, and environmental flows of vegetation and habitat, from the viewpoint that guarantee service function exerting and maintain ecosystem stability of the delta, the scientific water discharge scale and water discharge depth of wetlands for surface water and ground water were defined. Then, set water discharge scenarios by considering ecology, hydrology, water resources, soil, plant physiology and experts experiences, and set up the hydraulic model of the ecological water discharge, groundwater model, Yellow River delta landscape ecology decision and evaluation support system, simulate response between the change of wetland eco - hydrology and wetlands vegetation successions, evaluate the changes of Landscape habitat suitability in different scenarios. Lastly, discuss and confirm water amount and process of maintaining the estuary wetland development and ecosystem stability considering the feasibility, society and ecological valuation, and put forward the feasible countermeasures. The study route is showed in Fig. 2.

3.3 Methodology

From the viewpoint of landscape ecology, traditional species - centered conservation is partial and unpractical and its results are unilateral because it ignores biodiversity patterns, processes and their interactions at multi - scales. Many researchers recent argued that! diversity of landscape and ecosystem should be considered in species conservation (Guan, 2003). For degraded ecosystem, measurements should be taken to rehabilitate the landscape structure and function (Mary, 2000; Charles, 2006). Domestic researchers have made some progress in theories of wetland protection and restoration (Cui, 1999), but few studies based on landscape ecology approaches have been reported except for Xiao's (2001) research on the Liaohe Delta. As one of main measures to restore the damaged wetlands, ecological water supplement should be considered synthetically from structure and integrity of ecosystem. However, the structures of wetlands were decomposed into each part in most present environmental flows research of wetlands and focused on some aspects and ignored wetlands ecosystem organic integrity and its function especially. The relationship and otherness between ecological process and ecosystem determined that the process of environmental flows will be distortion if we only study it based on traditional ecological model or hydrological model, and the results can't satisfy the demands of scientific allocation of water resources.

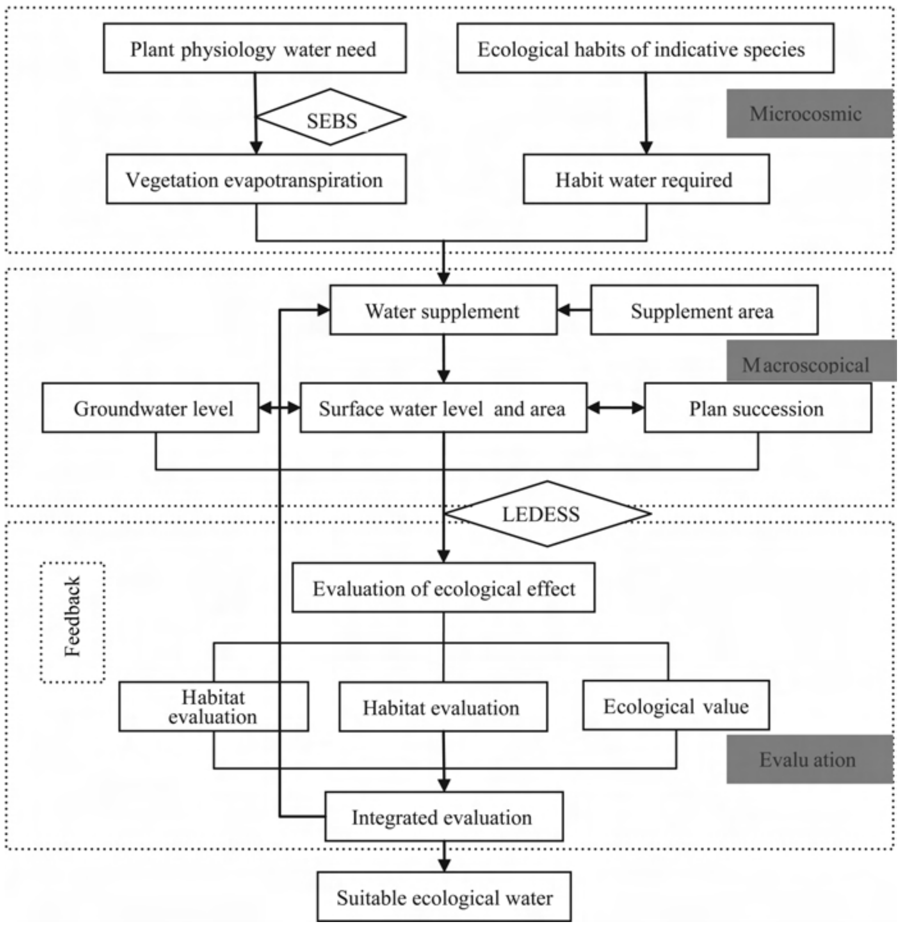


Fig. 2 The general research route of environmental flows etuary wetlands

Nevertheless, the simulation techniques of water circulation and ecological process are mature, so it is important that coupling these two kinds of models and establishing integrative and mechanism firm ecological and hydrological simulation system at present (Yang Denghua, 2007). This study established a system of wetlands environmental flows calculation and integrated evaluation that coupling with ecological and hydrological models based on the studies wetlands plants physiology and landscape ecology. And the results were calculated through "simulation – evaluation – modulation – simulation" circularly by assuming discharge scenarios. In the end, the best result will be chosen according to maximum benefit principles.

4 Scenarios Study for freshwater discharging

4.1 Reasonable wetlands scale to be restored

In recent decades, the quantity of water coming from the Yellow River is greatly decreased caused the probability of floodplain enormously decreased. Meanwhile, the high manpower of river channel in downstream of the Yellow River obstructs the natural connection between wetlands and river. Except for a small quantity of wetlands in the river channel, the benign growth of wetlands ecosystem will be hard to maintain unless most of the Yellow River Delta wetlands are compensated with water artificially. However, nowadays, water consumption of the basin increases rapidly. The contradiction between water resources supply and demand is increasingly acute, and there are more and more humankind disturbance in YRD, so it is unpractical to completely recover the delta wetlands into the past state, especially in the estuarine delta area which has greater economic development value. Therefore, to reasonably determine scale and mode of the protection for wetlands after guaranteeing its functions restored, and calculating the environmental flows of wetlands in competing water – consumed situations, high efficiently use the finite water resources of the Yellow River, and achieve win – win for regional ecology – protection and economic development become very crucial and necessary.

The definition of reasonable ecological objective is a key problem in today's competitive water – consumed condition, and it is a difficulty in studying of environmental flows at present. And the reasonable protective objective should think over not only maintaining the favorable service function of ecosystem, but restriction of key factor like water, people's value tropism, and possibilities of implement, etc. for YRD, This study considered that it should be defined from 3 aspects: the first are requirements of maintaining estuary ecosystem healthy, the second are demands of society or human beings; the third are actualities and possibilities of the Yellow River water resources. Synthetically considering the actualities of ecosystem units restoration and regional economy development and engineering pattern of Yellow River, and through ecological surveying and analyzing, and comparing different scenarios, the scale of fresh water wetlands in 1992, was taken as restoration objective (the freshwater wetlands' area is about 33,000 ha), when the national natural reserve were established, the Yellow River Delta wetlands were in a relative better state, the ecosystem of which was healthy and balanced.

4.2 Water discharge scope

Following factors are considered to determine the scope of ecological water discharge:

(1) Significance of wetlands protection. The 3 regions, Diaokou River, Yellow River estuary and Dawenliu together formed integrated wetlands ecosystem of nature reserve. According to the research of Zhao Maoyan, new Estuary of the Yellow River, old Estuary and Dawenliu regions are most important to snipes protection, which meet the criterions of international important wetlands. The wetland of old route – Diaokou River is an important wintering habitat of Swan, and is an essential ecological unit for the ecological integrality of nature reserve, whose abundant biodiversity and various ecological landscapes where salty and fresh water converging are playing important roles on maintaining ecological function of nature reserve and integrity of ecosystem. Recent years, the erosion speed of Diaokou River region descended slowly, and gradually came to balance, which reduced from 5 ~ 6 km^2/a in 1976 when the Yellow River changed its course to 1 ~ 2 km^2/a now.

(2) Important ecological protection region. In the nature reserve, there are many special protected communities existing in certain regions, which represent special succession stages of nature reserve, and have characteristics such as representativeness of ecology and landscape, community particularity and value particularity etc. and are the most valuable and representative regions of nature reserve. Hence, they should be protected specially. These regions are important

birds distributed region in Dawenliu, important nature mudflat and snipes habitat in Dawenliu, important seablite community ecological region near the artificial river mouth, important ecological region of Yellow River Estuary neonatal wetlands, and Yiqianr mudflat and birds important distributed region, etc.

(3) Land use actuality. The wetlands need to be discharged with freshwater are all chosen within the nature reserve. But now there are a lot of farmlands and roads and oil wells in it. So the restoration wetlands are mainly defined as the degraded saline land where the barriers are less. Fig. 3 is the Vegetation map of nature reserve based on spot 5 image of the Yellow River Delta in Sept. 2005.

(4) Probability and difficulty level of water discharge from the YR. At present, most wetlands in YRD can't be discharged water naturally from YR for the construction of controlling dikes along riverway, and only small area within the controlling dikes of present flowing route, whose area is about 12 km^2, can be flooded in wet season, . and the other wetlands of present flowing route region, which includes Yellow River Estuary and Dawenliu, is relatively easy to be discharged water from Yellow River after building discharge culvert and dam. However, it is difficult that discharging water to the wetlands of Diaokou river region for the restriction of the Yellow River flowing route and water transporting conditions.

Considering vegetation types and patterns and above factors, combining ecological protection plan, we determine the wetlands area that need ecological water discharging as degenerate reed wetland and part of shore tidal flat within natural reserve, the total area of which is 236 km^2 (Fig. 4). And the evaluation range of wetland habitat suitability is the whole nature reserve of the Yellow River Delta.

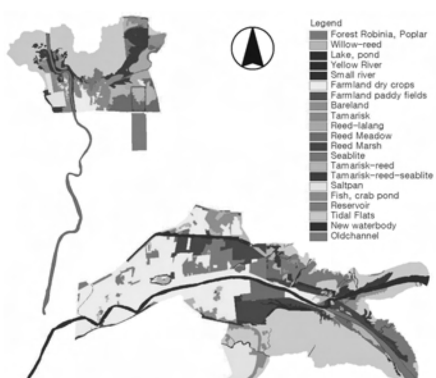


Fig. 3 The vegetation map of YRDNRR

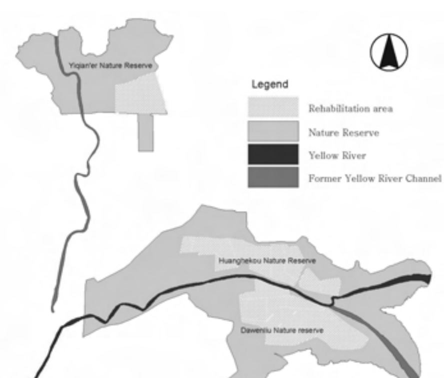


Fig. 4 Extent of the demonstration area

4.3 Discharge water scenarios

The primary ecological function of the Yellow River Delta wetlands is to protect habitats of endangered rare birds. Therefore, restoration water compensation of wetlands mainly consider representative vegetation and water demands of habitat or breeding of birds. In light of seasonal features of estuarine wetlands ecosystem, the estuarine wetlands environmental flows were divided into three periods such as April to June, July to October, November to March. Water demand ranges for different period as Table 1 shows. Take 2005 as actuality year. Then, three representative scenarios were brought forward. Planned objective of each scenario as Table 2 lists.

Table 1 The needed water depth for wetlands restoration

Period	Average water depth	Scope of water depth	Reasons
Apr. – Jun.	30 cm	10 ~ 50 cm	Reed germinating and birds inhibiting
Jul. – Oct.	50 cm	20 ~ 80 cm	reed growing and birds inhabiting
Nov. – Mar.	20 cm	10 ~ 20 cm	Birds inhibiting

Table 2 The planning objectives of different scenarios

Characteristics	Restoration area	Scenario A	Scenario B	Scenario C
Reed area	9,600 ha		23,600 ha	
Discharge period	6 ~ 7 month		3 ~ 10 month	
Water depth	50 cm	Minimum water depth	Middle water depth	Maximum water depth

5 Evaluation of ecological effect

5.1 Changing of ecotopes

Fig. 5(a), (b), (c) shows the simulated ecotopes of YRD natural reserve after 5 years for scenario A, B, C, respectively. Fig. 6 presents the comparison of simulated landscape units composition and their areas for each scenario.

According to Fig. 5 and Fig. 6, all scenarios can increase reed area notably through replenishing the wetlands with fresh water. Although the area of reed meadow keeps changed a little, the reed marsh area increase from current 5,600 ha to15,800 ha, 16,400 ha and 17,700 ha in scenario A, B and C respectively. From Fig. 5, we can see the landscape pattern changed a lot. After 5 years, former reed meadow wetlands evolved into reed marshes which are extensively distributed in the demonstration area. At the edge of reed marsh was small area of reed meadow and tamarisk. The replenishment fresh water is also beneficial to seablite development on the tidal flat because seablite prefers a fixed environment of freshwater and salty water. From Fig. 6, we can see the area of seablite tidal flat increases from 4,500 ha to 7,000 ha. So bare tidal flat decrease will do little damage to seabirds like saunder's gulls since the increased seablite tidal flat provides better habitat for their breeding, foraging and resting. In 3 different scenarios, the area of tamarisk increased a little but pond area increased notably, especially in scenario C, from 500 ha to 3,100 ha. As for YRD, large area ponds formed by scenario B and C have important ecological values in sustaining wetland water balance. Besides, ponds are optimal habitats for most swimming fowl like Red Crown Crane, Oriental Stork and swans. Of course, it is not the more water quantities we discharged, the better outcomes we can get for reed wetlands restoration. Keeping the restoration extent unchanged, the more the fresh water supply, the larger the wetland surface water depth. When water depth exceeds a certain number, the growth of reed will be prohibited. Then larger fresh water supply will only increase the area of pond, and reed marsh will correspondingly decrease.

From scenario A to B, when $0.71 \times 10^8\ m^3/a$ water were increased, pond area increased 1,700 ha, however, from scenario B to C when $0.68 \times 10^8\ m^3/a$ water were increased , pond area increased only 500 ha, but for reed wetlands, three scenarios have the almost same effect on reed wetlands restoration. Considering the change of habitat of rare birds, scenario B or C is superior to scenario A, and considering the shortage of Yellow River water resources, it seems scenario B might be a better choice than scenario C.

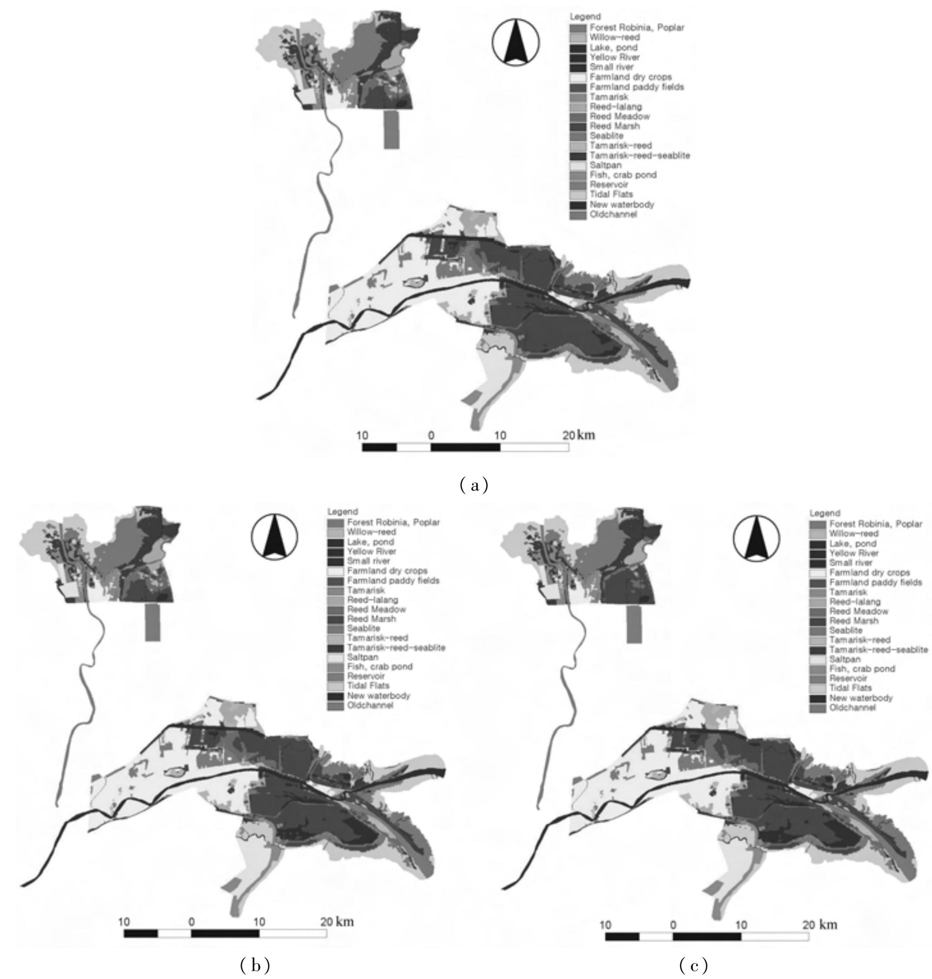


Fig. 5 Simulated ecotopes after 5 years according to three water discharge scenarios

5.2 Changing of habitat

Due to lack of data, it is hard to study all the habitats changes of species or groups in researching area under many circumstances. Many researchers appraise the influence to species habitat resulted from environment change through selecting indicator species. This study selects Oriental Stork, Red Crown Crane, Sauder's gull as water bird habitat indicator species of the Yellow River Delta wetlands. On one hand, these species are very sensitive to the habitats change and vegetation succession of wetland, etc. On the other hand, they represent the typical habitant type of the Yellow River Delta. Oriental Storks represent fresh water marsh bird's ecologic groups

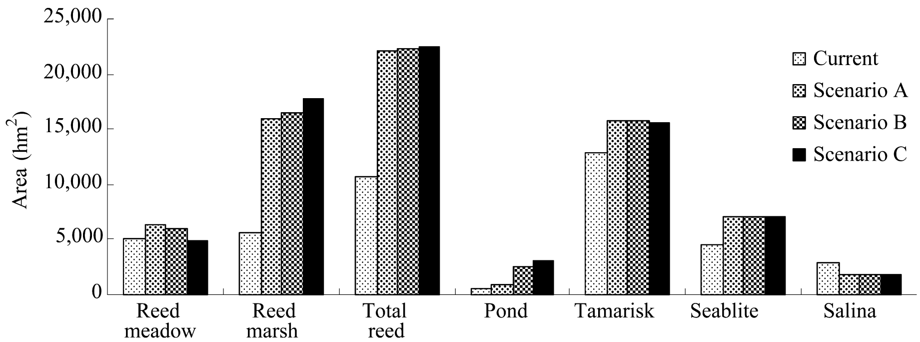


Fig. 6　Comparison of three scenarios for YRD wetland restoration

which take bulrush marsh as primary breeding and inhabit environment. Red Crown Crane represent fresh water marsh birds ecologic groups which takes reed marsh only as wintering habitat. While the Sauder's gull represent tidal flat birds ecologic groups which take winged seablite as typical living environment.

Each scenario will lead change of natural ecological unit and earth surface covering in the area, and will change influence of habitat broken factor. Thus result in the change of species habitat suitability and habitat quality, and finally influence ecology carrying capacity of species. In light of suitable site condition and natural succession rule of wetland vegetation, set up vegetation succession knowledge table under different water – salt condition and transfer it into knowledge matrix of LEDESS model, forecast different water compensation condition in the model to produce natural ecological unit and earth surface covering type. Make a stat. on diversified kind of vegetation area under different scenarios condition, and based on the demands of indicator species on habitat areas, there could get habitat suitability change of indicator species and carrying capacities of nature reserve under different scenario conditions, see Table 3 and Fig. 7.

The results of table 3 display that, for the existing circumstance habitat, the suitable type of Oriental Stork is mainly growth well reed swap in nature reserve with area of 13,100ha, which is 15% of the total habitat area, and the amount is about 90 in breeding season. The suitable type of Sauder's gull is the coastal plain of winged seablite tidal flat and river mouth inter – junction while suitable habitat area is about 41,000 ha, which is 48% of the total habitat area and the amount is 500 – 700 breeding double. The suitable habitat area of Red Crown Crane is 233,00 ha, which occupy 27% of the total while the wintering amount is about 60. All of which show that the Yellow River Delta has the condition and potentiality to be the breeding and wintering place and habitat of Oriental Stork, Red Crown Crane and Sauder's gull, especially to Sauder's gull, as one of 3 biggest breeding areas in the world, YRD has very big potentiality for the inhabiting and breeding of Sauder's gull. But the current situation is not ideal. So when we are implementing wetlands restoration, we should focus on the protection of biodiversity and restoration of habitat.

Table 3 Comparison of suitable habitat area and its carrying capacities in three scenarios for YRD wetlands restoration

Scenarios	Red crown crane		Oriental stork		Sauder's gull	
	Suitable habitat area (ha)	Amount (individual)	Suitable habitat area (ha)	Amount (individual)	Suitable habitat area (ha)	Amount (double)
Current	23,300	60	13,100	90	41,000	500 ~ 700
Scenario A	53,800	167	22,000	142	40,200	518
Scenario B	54,400	184	22,200	149	42,500	559
Scenario C	55,200	186	22,800	152	42,400	560

The results of Table 3 and Fig. 7 display that, under different water compensation plans the suitable habitat area of Oriental Stork and Red Crown Crane increased notably. The suitable habitat area of Red Crown Crane increased by 1.31, 1.33 and 1.37 times than the current situation while the amount reach to 167, 184 and 186 from 60 separately for scenario A, scenario B and scenario C. And Oriental Stork increased 0.68, 0.69, and 0.74 times than the current situation and the amount reach to 142, 149 and 152 in breeding season separately. These show that, the degenerative reed wetlands and alkali lands become the habitat type suitable for the Oriental Stork and Red Crown Crane living after ecological restoration. Especially the high quality reed marsh in the restoration zone turned into the ideal habitat for Oriental Stork living. For Sauder's gull, suitable habitat area increased slowly. It is shown that, the renewing of reed wetlands brings favorable effect to habitat for Sauder's gull. But redundant water compensation is not good to the improvement of habitat area quality for Sauder's gull because redundant water destroy the tidal flat habitat of brackish water inter – junction for Sauder's gull.

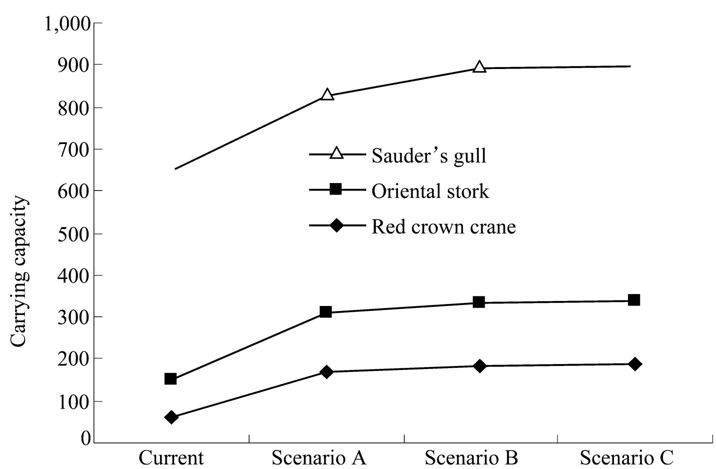


Fig. 7 Comparison of carrying capacity of indicator species in different scenarios

The change curves of carrying capacity in Fig. 7 show the amount of indicator species increased greatly compare to current situation. But along with the increasing of water, the amount of species increased slowly. For example, the amount of Red Crown Crane increased notably from current situation to scenario A and to scenario B, but from scenario B to C, the amount only increased a little. It showed the amount of Red Crown Crane not increased notably along with the increasing of water quantities, especially to Sauder's gull, which need alternate environment with freshwater and salt water and redundant fresh water or sea water are not favor for its inhibiting and breeding. When we restore the damaged estuary ecosystem, we should consider the characteristics of each protection species and their requirements, and harmonize the relationship of protection and rehabilitation between salt wetlands and freshwater wetlands. Based on the analysis above, from viewpoint of landscape ecology, we can say scenario A and B are superior to scenario C for gaining the maximum ecological effects.

5.3 Defining of environmental flows

Based on the principle of water balance and the environmental flows of wetlands in different phases (Table 1), and collect and use the relative data such as 30a series temperature, rainfall, and evaporation, and evaporation of remote sense, the discharge water quantities of different scenarios can be calculated, see Table 4. The results show the scope of complement water quantities is $2.78 \times 10^8 \sim 4.17 \times 10^8$ m^3/a. And based on the former analysis of the changing of habitat area and carrying capacities in different scenarios, we can get the following results. The scope of ecological environmental flows is $2.8 \times 10^8 \sim 4.2 \times 10^8$ m^3/a and the suitable water requirement is 3.49×10^8 m^3/a. In the allocation practice of water resources in Yellow River Delta, the water quantities discharged can be altered on annual climate conditions of YRD, 4.2×10^8 m^3/a water quantities is needed in dry year, 3.49×10^8 m^3/a is needed in normal year, and in wet year, 2.8×10^8 m^3/a water is enough. Suitable environmental flows is the water quantities which can make the habitat qualities of nature reserve to relatively ideal situation in normal year and the higher ecological effects can be achieved. Then the nature reserve ecosystem is stable, healthy and sustainable.

Table 4 The discharge water quantities of different scenarios Unit: 10^8 m^3

Scenarios	Water quantities for the south nature reserve	Water quantities for the north nature reserve	Total
A	2.35	0.43	2.78
B	2.95	0.54	3.49
C	3.52	0.65	4.17

6 Results

In terms of ecological s calculation, there are still some problems such as unclear coupling mechanism of moisture and ecosystem and unclear ecological effects of water supplements which can cause fuzzy calculation problems at present. In order to avoid these problems, this study developed ecological hydraulic and groundwater coupling models and LEDESS model as well as landscape ecology decision - making support system which based on ecology, hydrology, hydraulics, water resources, soil science, plant physiology, birds ecology and many experts' experiences. Therefore, combining these models, this study put forward an integrated eco – hydrology simulation system for the research of ecological water requirements of the Yellow River Delta. Under the support of this integrated system, through changing tendency and current situation analysis of vegetation types and lands utilization of YRD, moreover, considering other relevant factors such as the real water resources condition of the Yellow River, the scientific protection scales of estuary wetlands are defined and its environmental flows are calculated and validated in the support of this system and GIS techniques. The results are as follows: The area which need to be recharged ecologically would be about 23,600 ha, which is near to the area of freshwater wetlands in 1990s when the Yellow River Delta Nature Reserve (YRDNNR) was established initially, and the scope of ecological environmental flows will be $2.8 \times 10^8 \sim 4.2 \times 10^8$ m^3/a, and the suitable environmental flows will be 3.49×10^8 m^3/a in normal year. Here the areas of reed wetlands will reach to 22,000 ha from 10,000 ha, and seablite mudflats will reach to 7,000 ha from 4,500 ha and as wintering, inhabiting and breeding areas for many rare birds, its habitat quality and carrying capacities will increase notably. So the ecosystem of integrities and stabilities of nature reserve will be enhanced, and it is beneficial to maintain good ecosystems and sustainable development of whole YRD.

This study also shows that landscape ecology approaches are good ways to solve complex problems in ecosystem management. When use this methodology to deal with wetlands ecology rehabilitation issues, two aspects should be taken into account. Firstly, you can set up restoration targets based on historical and realistic landscape, which can provide spatial basis for the choice of restoration area; Secondly, you can use landscape pre – scheme methodology to simulate different landscape pattern which are supported by different restoration measurement scenarios and then to make integrated evaluate on ecology effects after restoration. Wetlands scenarios studying not only offers different ways and directions for the Yellow River Delta wetlands ecological protection, the defining of suitable water quantities for wetlands and its ecological effect valuation also offer effective technical support for scientifically and rationally allocating the finite Yellow River water resources in present situation that water resources supply and demand contradiction of the Yellow River basin is more and more acuity.

References

Charles Simenstad, Denise Reed, Mark Ford. When is restoration not? Incorporating landscape – scale processes to restore self – sustaining ecosystems in coastal wetland restoration. Ecological Engineering, 2006 (26): 27 – 39.

Mary E. Kentula. Perspectives on setting success criteria for wetland restoration. Ecological Engineering, 2000 (15) : 199 – 209.

Wu J G. Landscape Ecology—pattern、scale and grade. Beijing: Higher Education Press, 2000.

Zhao Y M, Song C S. Scientific Survey of Yellow River Delta Nature Reserve. Beijing: China Forest Press, 1995.

Guan Wenbin, etc. A vital method for constructing regional ecological security pattern: landscape ecological restoration and rehabilitation. ACTA ECOLOGICA SINICA, 2003, (1): 64 – 73.

Cui Baoshan, Liu Xingtu. Review of wetland restoration studies. ADVANCE IN EARTH SC IENCES, 1999, 14(4): 358 – 364.

Yan D H, Wang H, Wang F, etc. Frame of research work on ecological water demand and key topics. Shuili xue bao, 2007, 38(3): 267 – 273.

Zhao Y M, Lu J Z, Zhu Sh Y, etc. Study on shore birds of the Yellow River delta. ActaZoologicaSinica,2001, 47(special)157 – 161.

Xiao D N, Hu Y M, Li X Z, et al. Landscape Ecology Studies on the Deltaic Wetlands around Bohai Sea. Beijing Science Press,2001.

Li Xiaowen, Xiao Duning, Hu Yuanman. The landscape planning scenarios designing and the measures identification in the Liaohe River Delta wetland. ACTA ECOLOGICA SINICA, 2001,21 (3): 353 – 364.

Li X W, Xiao D N, Hu Y M. The effects of different land – use scenarios on habitat suitability of indicator species in the Liaohe River Delta wetlands. Acta Ecologica Sinica, 2001, 21(4): 550 – 560.

Discussion on Optimal deployment of water resources and adaptive management models in the Yellow River Delta

Li Fulin, ***Fan Mingyuan***, ***Bu Qingwei*** and ***Chen Fanglin***

Water Conservancy Research Institute of Shandong Province, Key Laboratory of Water Resources and Environment of Shandong Province, Jinan, 250013, China

Abstract: The downstream discharge of the Yellow River is not only the key water resources supplied for the development of Dongying City, but also important for maintenance the ecology availability of the river delta and estuary. Water diversion from the Yellow River is restricted by making policy for integration of water management in the whole catchments. For example, it is not allowed to divert water while the discharge is smaller than 50 m^3/s in Lijin Hydrological Station, the last one in the downstream of Yellow River. If it is considered to meet the water demands of wetland and sediment transportation, more than 5 billion m^3 and 15 billion m^3 of discharge should be maintained per year in Lijin Station.

Due to the restriction and water shortage in Dongying City, Strategy of optimal deployment of water resources should be firstly made to achieve the different demands of water uses in Dongying City. But it is not enough with the rapid economical development. New conception should be conduced for water resources management in the Yellow River Delta.

Adaptive management is a systematic and effective approach for improving water resources management though the steps of modeling, monitoring, decision making and assessment in the Yellow River delta. Different plans or scenarios should also be made by learning from the outcomes of operational programs in the future.

Key words: optimal deployment of water resources, adaptive management, Yellow River Delta

Yellow River Delta is a pie slice comprising Ninghai at vertex, Tuhairiver in the east and branch range Goukou in the south, total area is 5,450 km^2. The rapid development of economy and reduce of outer water resources, there is a conflict of water shortage and eco – environment depravation. So, it is necessary to apply multi – water source and multi – destination optimal deployment of water resources and adaptive management.

DongYing City is selected as a typical area, and its water resources supply and demand status, models of optimal deployment and adaptive management mode were discussed.

1 Water resource supply and demand equilibrium analysis and optimal deployment model

1.1 Water resource supply and demand equilibrium

1.1.1 Water resources and water supplies

(1) Local water resources. Local water resources include surface water and groundwater in Dongying City. The estimation of the annual average surface water resources is about 427×10^6 m^3, and the groundwater resources with its TDS less than 2.0 g/L is about 255×10^6 m^3. Taking out the repetitive computation of iteration, the total amount of the annual average water resources in Dongying city is about 616×10^6 m^3.

Water supplies under 50%, 75%, 95% guarantee Rate in DongYing City is 39.98×10^6 m^3, 30.31×10^6 m^3, 15.25×10^6 m^3 respectively. Groundwater exploitation is 95×10^6 m^3/a.

(2) Foreign water from Yellow river. Yellow river is the major water resources with the annual

average discharge of 31,700 × 10^6 m^3 from 1951 to 2005 in Lijin hydrologic station. (see table 1)

Table 1 The measured discharge of different years of Lijin hydrological Station

Time interval	1950 ($10^6 m^3$)	1960 ($10^6 m^3$)	1970 ($10^6 m^3$)	1980 ($10^6 m^3$)	1990 ($10^6 m^3$)	2000 ~ 2005 age ($10^6 m^3$)	Long – time average annual value ($10^6 m^3$)
Average	47,690	50,120	31,130	28,600	14,220	12,250	31,700
6 ~ 9 month	30,410	28,810	18,740	18,980	8,200	5,710	19,180

There are 658 plain reservoirs and seventeen water conservancy diverting water from Yellow River with capacity of 514 m^3/s. The total water storage capacity is 831 × 10^6 m^3. Under all kinds of conditions, Water supply at the guarantee frequency of 50%, 75%, 95% is 9,190 × 10^6 m^3, 4,789 × 10^6 m^3, 1,449 × 10^6 m^3 respectively While, the water supply allowed to be diverted from Yellow river for Dongying City is 780 × 10^6 m^3, including the water use index for Shengli Oil Field.

(3) Other foreign water resources. Other foreign water resources include Xiaoqing River, Zhimai River, Zihe River and so on. Water supplies under different guarantee frequency is listed in Table 2. We can see that the available water supplies from these foreign rivers is 107 × 10^6 m^3, 80.31 × 10^6 m^3 and 40.86 × 10^6 m^3 at the different guarantee frequency of 50%, 75%, 95%.

Table 2 Water availabilities of other foreign rivers

Foreign water resources	Average annual discharge ($10^6 m^3$)	The available water supplies at different guarantee frequency ($10^6 m^3$)		
		50%	75%	95%
Xiaoqing River	582	71.39	53.54	27.24
Zhimai River	286	35.69	26.77	13.62
Zhi River	104	—	—	—
total	972	107.08	80.31	40.86

Note: Due to the pollution of the upper stream of Zhi River and, no available supplied since 1980.

(4) Reclaimed water. At present, the collection capacity sewage is about 190 × $10^3 m^3$/d in Dongying City. A sewage treatment plant run in 2003. The Reclaimed Water of 35 × 10^3 m^3/d from sewage treatment plant can be used for irrigation and industry.

1.1.2 Water requirement for Economy and society

Economy and society water requirement include Domestic water demand, production water demand and ecological water demand. Therefore, only city ecological and environmental water demands are considered as ecological water demand.

Under 50%, 75% (95%) guarantee rate, water demand separately is 972 × 10^6 m^3, 1,109 × 10^6 m^3. (see Table 3)

1.1.3 Results

Water supply under the guarantee frequency of 50% is enough for the demands, while water shortage rate is 10.1% and 15.0% under the guarantee frequency of 75% and 95%. The important approach for solving this problem is water resource optimal deployment. (Table 4)

Table 3 Water demands for economy and society

Items of water demands	Domestic water		Industrial water					Ecology
	Citizen	Farmer	Agriculture (different pledge rate)			Industry	Architecture and tertiary industry	Ecological environment of city
			50%	75%	95%			
Water demand ($10^6 m^3/a$)	36.27	20.69	734.16	870.94	870.94	133.60	33.96	13.22

Table 4 Water supply and demand balance in Dongying City

Items	Guarantee frequency		
	50%	75%	95%
Water supply ($10^6 m^3$)	1,034	997	943
Water demand ($10^6 m^3$)	972	1,109	1,109
Water shortage (surplus) ($10^6 m^3$)	62	-112	-166
Water shortage rate (%)	—	10.1	15.0

1.2 Optimal deployment model for water resources

The key problem of optimal deployment is how to allocate efficiently the limited water resources to different users by using the hydro-engineering measures and other non-engineering approach.

Water resources system should be generalized firstly before building the optimal deployment models.

The gross of different water resources for a period of time in a natural area is:

$$\vec{W}_T^* = (W_{T1}^*, W_{T2}^*, \cdots, W_{Tn}^*)$$

In which, W_{Ti}^* ($i = 1, 2, \cdots, n$) is the amount of water resources, T is time, $i = 1, 2, \cdots, n$ is Items of water resources. α_T represents the exploitation degree of water resources in T time and it can be shown in $\vec{\alpha}_T = (\alpha_{T1}, \alpha_{T2}, \cdots, \alpha_{Tn})$ of which $0 \leqslant \alpha_T^* \leqslant 1$.

So the available water in T time is:

$$\vec{W}_\alpha = \vec{W}_T^* \cdot \vec{\alpha}_T = (W_{T1}^* \cdot \alpha_{T1}, W_{T2}^* \cdot \alpha_{T2}, \cdots, W_{Tn}^* \cdot \alpha_{Tn}) = (W_{\alpha 1}, W_{\alpha 2}, \cdots, W_{\alpha n})$$

Suppose there are m objects relating to the water supply in T time, matrix $WU_{n\times m}$ denotes sustaining ability of the unit of water resources relative to the water consumers, that is

$$WU_{n\times m} = \begin{bmatrix} Wu_{11} & Wu_{12} & \cdots & Wu_{1m} \\ Wu_{21} & Wu_{22} & \cdots & Wu_{2m} \\ \vdots & \vdots & & \vdots \\ Wu_{n1} & Wu_{n2} & \cdots & Wu_{nm} \end{bmatrix}$$

In the equation, $WU_{n\times m}$ is the efficacy matrix of water resources in T time: Wu_{ij} ($i = 1, 2, \cdots, n; j = 1, 2, \cdots, m$) is the efficacy coefficient, which denotes sustaining ability of the unit of water restores of the item i distribute water consumers of item j.

In fact, human activity and society economic activity follow the definite frame and proportion. Water resources also are distributed to each water consumer according to definite proportion. Then the coefficient matrix of water distribution is:

$$B_{n\times m}=\begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1m} \\ B_{21} & B_{22} & \cdots & B_{2m} \\ \vdots & \vdots & & \vdots \\ B_{n1} & B_{n2} & \cdots & B_{nm} \end{bmatrix}$$

$B_{n\times m}$ is the coefficient matrix of water distribution, B_{ij} ($i = 1,2,\cdots,n; j = 1,2,\cdots,m$) is coefficient of water distribution, denotes the scale which the item i of water resources distribution type j of water consumers, $0 \leqslant B_{ij} \leqslant 1$, and that $\sum_{j=1}^{m} B_{ij} = 1$.

Under certain level of society development, people have many types of water demands, which could be denoted by vector:

$$\vec{R} = (r_1, r_2, \cdots, r_n)$$

In the equation, $r_j (j = 1,2,\cdots,m)$ is the demand of part j, $\vec{R}$ is the vector of water demand. Suppose $\vec{r}_j$ denotes the unit of water demands of part j, so water consumption which satisfy all kinds of human demands can be expressed as:

$$\vec{R} = (\vec{r}_1, \vec{r}_2, \cdots, \vec{r}_n)$$

Then, the aim function of the model of the optimal deployment of water resources can be expressed as:

$$WRAB = \max\left\{\min\left[\sum_{i=1}^{n} (W_{ai} \cdot Bi_j) \cdot W_{u_{ij}}/r_j, j = 1,2,\cdots,m\right]\right\}$$

In the equation: min is the least value of the aspects for demands.

Limitative conditions of the aim function are:

$$\sum_{j=1}^{m} B_{ij} = 1 \quad \forall i$$

$$B_{ij} \geqslant 0 \quad \forall i, j$$

The model can quantify the least water consumption for the supreme water demands. The first objective achieve ecological environment protection by reducing water consumption and the second acquire the supreme benefits of economy by utilizing the water resources efficiently.

Compared to traditional management of water resources, the optimal deployment of water resources achieves water quantity balance of the higher level, that is: achieve the lest water consumption under same economic benefits and the most economic benefits under same water supply. But for the Yellow River Delta, regional optimal deployment of water resources can't solve the problem of ecological environment, and more influence factors should be considered.

2 Analysis of ecological water demand meeting in the Yellow River estuary

2.1 Estimation of ecological water demands of the Yellow River estuary

Without question, it is important to protect estuary environment by applying water resource optimal deployment. To achieve this goal, we must calculate different level water demands according to different functions.

(1) ecological basic flow (level I). Estuary ecological basic flow is the most fundamental water demand to maintain estuary eco - environment. According to 50 m^3/s flux (least), total water demand is $1,580 \times 10^6$ m^3/a.

(2) wetland ecological water demand (level II). Considering fish breed, vegetation evaporation, soil water demand and habitat water demand , some experts indicate that estuary minimum ecological water demand is $4,095 \times 10^6$ m^3/a.

(3) sediment flushing water demand (level III). Some experts found that water demand for carrying sand to avoid sedimentation was $15,000 \times 10^6 \sim 17,000 \times 10^6$ m^3/a through Qingshuigou waterway.

(4) estuary landscape flux (level IV). According to 1980's actual runoff, it is estimated that

$20,000 \times 10^6$ m^3/a water is needed to protect Yellow river estuary landscape.

2.2 Water demand meeting

To analyze water resource meeting degree, we selected two periods of time: before and after Xiaolangdi water conservancy operation. Because there are only six – year data, minimum low – water discharge (2002) was selected. (see Table 5 and Table 6)

Table 5 Analysis of ecological water demands in the estuary of Yellow River

Items	Before building of Xiaolangdi Reservoir (1951 ~ 1998)				After building of Xiaolangdi Reservoir (1999 ~ 2005)	
	50%	75%	95%	Average	2002 year	Average
Inflow discharge ($10^6 m^3$)	29,800	19,400	10,610	34,650	4,190	11,480
Ⅰ water demands of Ecological basal flux ($10^6 m^3$)	1,580	1,580	1,580	1,580	1,580	1,580
Ⅱ water demands of wetland ($10^6 m^3$)	4,095	4,095	4,095	4,095	4,095	4,095
Ⅲ water demands of sediments ($10^6 m^3$)	17,000	17,000	17,000	17,000	17,000	17,000
Ⅳ water demands of landscape discharge ($10^6 m^3$)	20,000	20,000	20,000	20,000	20,000	20,000
Demand – meeting degree	Ⅳ	Ⅱ ~ Ⅲ	Ⅱ ~ Ⅲ	Ⅳ	Ⅰ ~ Ⅱ	Ⅱ ~ Ⅲ

Table 6 Statistics of the water demand – meeting for the Yellow River estuary (Lijin hydrological Station)

Periods \ Levels	Ⅰ (number of years)	Ⅱ (number of years)	Ⅲ (number of years)	Ⅳ (number of years)
1951 ~ 1998	1	8	3	36
1999 ~ 2005	—	4	2	1
Total	1	12	5	37

It can be found that estuary of Yellow River water demand can not be met during all the time. Meeting status level is reducing because of Xiaolangdi water conservancy construction. If adverting water from Yellow River mainstream can not been controlled, eco – environment will gradually deterioration.

Because of so many uncertainties in Yellow River eco – environment, we must selecting some different management mode, then adaptive management is necessary.

3 Adaptive management mode

3.1 Conception

Adaptive management is a systematic approach for improving resource management by learning from management outcome. The focus is on action and learning , not in preparing to learn.

Why we carry out adaptive management? First, knowledge we get about natural resources is uncertain, environmental conditions are changing at any moment; second, we may make mistakes during projects' design, implement, monitoring and prospective management goals can not been achieved. So we must learn by doing.

Adaptive management includes assess problem, design, implement, monitor, evaluation; adjust and so on, and these procedures form an operating circle. (shown in Fig. 1)

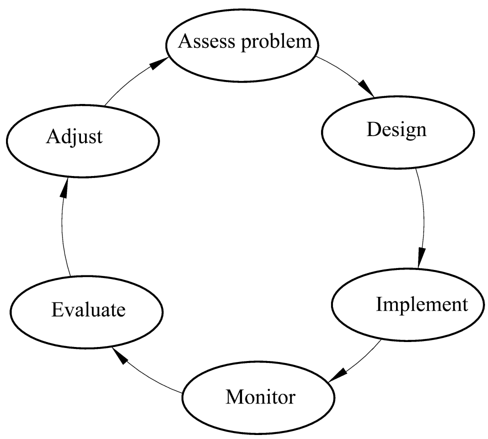


Fig. 1 process of adaptive management

Implementation of adaptive management consists of two stages: establishment stage and feedback stage. Every stage includes many operation steps. (see in Fig. 2)

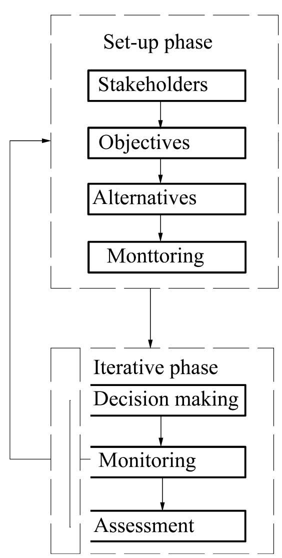


Fig. 2 Two – phase learning in adaptive management

3.2 Water resource adaptive management mode for Yellow River Delta

Adaptive management is good management, but that not all good management is adaptive management. At present, adaptive is used in river ecological restoration, and more and more in different scales watershed water resource management recently. For Yellow River Delta, runoff is badly influenced by precipitation and water conservancy, and there are many uncertainties. During water resource exploitation, there are many stakeholders including resident, industry, agriculture, oil field and so on. Water and sand harness are typical difficulties for Yellow River. Many scholars and experts bring forward different projects from different point of views, some of them are successful, and some others are unsuccessful. With the development of information and automation, water resource adaptive management is more important.

Based on practice experience and international research production, water resource adaptive management mode is initially formed. (see in Fig. 3)

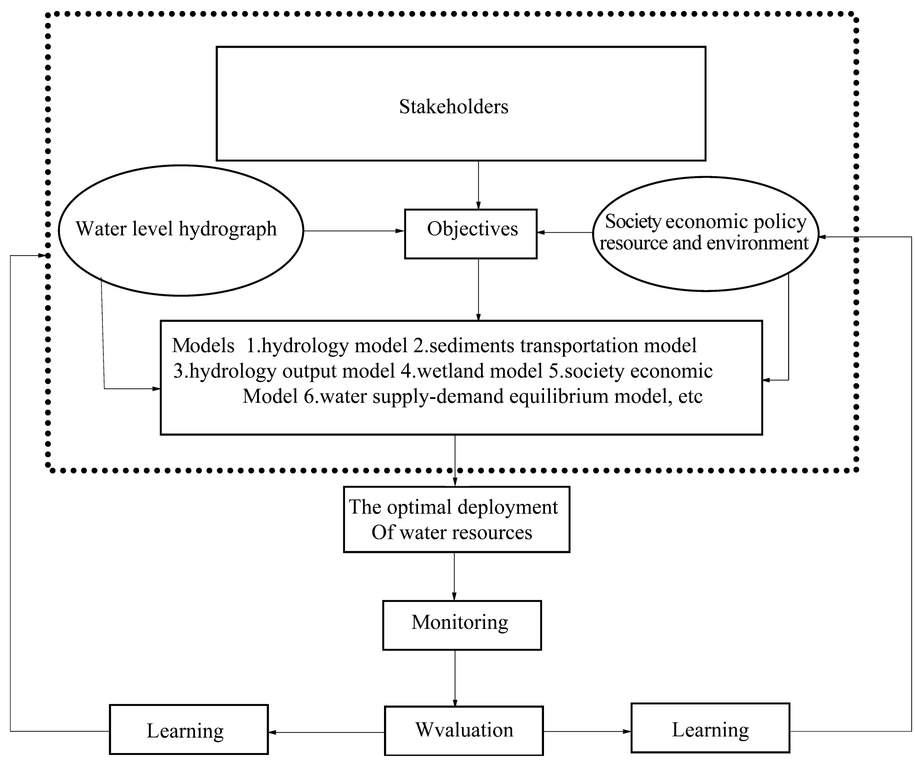


Fig. 3 The mode of adaptive management in the Yellow River Delta

4 Conclusions and suggestions

4.1 Conclusions

(1) Yellow river is the major water resource of Yellow River Delta and Dongying City, and is the most important water supply source. It can not only supply domestic and industry, maintain estuary water and sediments balance, but also insure ecological water demand. There is serious conflict between water supplies and demands.

(2) Under guarantee rate 50% of 2005, water supply and demand is balanceable in Dongying

City, but under other guarantee rate, water shortage appears. Some engineering projects and non – engineering approaches should be taken to achieve water resource optimal deployment.

(3) Adaptive management mode is provided to solve the problem of water supply and demand in Yellow River Delta.

4.2 Suggestions

(1) Make the best of Yellow river adverting, water conveyance and sluice establishment, advance utilization rate

(2) Enlarge reclaimed water using scale, preferentially consider use reclaimed water as industry cooling water and city landscape water.

(3) Implement river restoration project, improve water quality, insure foreign water mainly used for irrigation , river landscape and ecological demands.

(4) Activelydiscuss and practice adaptive management of Yellow river Delta water resource from regional and watershed sectors.

References

Li Fulin, Chen Fanglin, 2003. Shoreline changes of the Yellow River Delta and its sub – delta evolution trend, 1st International Yellow River Forum on River Basin Management, The Yellow River Conservancy Publishing House, (3):354 – 362.

Li Fulin, Pang Jiazhen, Jiang Mingxing. 2001. Conditions of flow and sediment discharge, and the macro – evolution property of the delta in Qingshuigou course of the Huanghe River, Actaoceano Logica Sinica, 23(1): 52 – 59.

Li Fulin, Pang Jiazhen, Jiang Mingxing. 2000. The shoreline change and its environmental effects of the Yellow River Delta, Marine Geology & Quaternary Geology, 20(4):17 – 21.

Li Fulin, Jiang Mingxing. 1999. Ditch the Yellow River water flow path River Delta area growth forecast, Transaction of Oceanology and Limnology, (3):16 – 22.

Hu Chunhong, Chen Xujian. 2006. Optimal deployment theory and mathematical model of water and sediment resources in basin and their applications in the lower Yellow River, Journal of Hydraulic Engineering, 37(12):1460 – 1469.

Shi Wei, Wang Guangqian. 2002. Estimation of Ecological Water Requirement for the Lower Yellow River, Acta Geographica Sinica, 57(5): 595 – 602.

Cui Baoshan , Li Yinghua , Yang Zhifeng. 2005. Management – oriented ecological water requirement for wetlands in the Yellow River Delta, Actaecologica Sinica, 25(7):1788 – 1795.

Dong Zheren. 2007. Ecological hydraulic Exploration. Beijing: China Water Conservancy and Hydropower Press.

The Current Situation and Requirements of the Legislation on the Ecosystem Protection in the Yellow River Delta

Sun Tinggang, ***Xu Jianzhong*** and ***Yang Shengquan***

Yellow River Shandong Bureau, Jinan, 250011, China

Abstract: Based on the objective requirements of the ecological system protection of the Yellow River Delta, this article made comments on the current situation of the legislation in related fields, and pointed out seven aspects of problems and shortcomings, including: ①the significant restrictions in industrial laws and regulations; ②incomplete law system in cooperation management; ③the law and regulation construction is in the state of uneven; ④part of the regulations are not in harmony with the special eco – environment; ⑤the phenomena of managing from many sides and self – governing are very common; ⑥the application of legislation in some fields encounters constrains; ⑦the un – perfective coordination mechanism in law enforcement. And the article listed out the legislation requirements and strategic proposals in the fields of legislative targets, principles, plans and managements and law executing coordination.

Key words: Yellow River Delta, ecological system, benign maintaining, legislation

1 The legislation requirements of the ecological system protection in Yellow River Delta

The protection of the ecological system in the Yellow River Delta involves the cooperation in many levels, many fields and many agencies, and the stakeholders concerned are very complicated. To realize the benign maintaining of the ecosystem not only requires good management among every agencies concerned by law, what is more, the particularity and practical demand for the eco – environmental maintenance of the Yellow River Delta shall be followed to establish a systematic and dialectical concept, and the management according to the law as well as the corresponding corporation in the related fields must be promoted. Up till now, much work in the legislation construction in related fields has been done and many achievements have been gained, but there are still some limitations and shortcomings in the overall harmonic development of the law system, influencing and restricting the legislation process of the eco – system protection in the Yellow River Delta.

(1) In order to overcome the limitation of industry management, protecting and improving the bio – environment, maintaining the bio – system in sound circulation and enhancing sustainable development of economy and society of the Yellow River Delta should be regarded as the common legislation targets in legislation system.

(2) In order to integrate and cooperate with every field in harnessing, management, exploitation and protection, four basic legislation principles must be insisted on, the first is to insist on overall enhancements and highlight the emphasis, enhancing equilibrium development in related law constructions and application fields; the second is to insist on the principle of integrated monitoring and sharing out the work and cooperating with one another, enhancing the harmony between the related fields and doing better for eco – system protection; the third is to insist on the principles of the overall plan and taking all factors into consideration for enhancing the harmonious development of eco – system protection and socio – economic development; the fourth is to be fully aware of the effect of harnessing the Yellow River delta on the protection of the eco – system, to insist on the principle that exploitation should obey harnessing and the harnessing should serve exploitation, enhancing the harnessing of the Yellow River delta and construction in every field to be carried on orderly.

(3) In order to meet the demands of macro – scope regulations, the legislation system in plan and management should be further perfected. The emphases shall be laid on: the first is to establish

and carry out the legislation rules for the integrated plan; the second is to define the relationship between related fields according to the effect on the protection of the eco – system in the Yellow River delta; the third is to adjust the laws and regulations in related fields to ensure the plan include the requirements of every field.

(4) In order to eliminate the management contradictions, the cooperation and connection with other fields should be enhanced, especially the overlapped matters shall be identified according to their importance, and a new legal system of coordinative management shall be sought after and established.

2 The current legislation situation in the ecological system protection of the Yellow River Delta

2.1 The current situation of the regulation construction

After many years of legislation practices, a series of laws and regulations about the treatment and development of the Yellow River estuary, distribution and utilization of the water resources, natural reserves management and protection, and seashore utilization and management, all of which closely relates to the ecosystem protection of the delta, have been published from the self management and protection requirements aspects, providing the foundation for law formation in each field. Besides, in the recent legislation construction (Table 1), the cooperation between the different requirements in related fields has been improved. For example, the Yellow River Water Regulation Rules specifies reasonable arrangement of water for the use of agriculture, industry, ecological environment, preventing zero flow into the sea as the basic requirements of the water regulations. And a series of effective laws and regulations have been set up.

Teble 1 The current situations of the laws and regulations in the protection of the ecological system in the Yellow River Delta

Related fields	The general situation of the current legislations
The harnessing and exploitation of the Yellow River Delta and the utility of the Yellow River water resources	The Water Law of the PRC, the Flood Prevention Law of the PRC, the Pollution Prevention Law of the PRC, the Water and Land Conservation Law of the PRC, the Water Regulation Rules of the Yellow River, Water Taking Permission and Water Resources, the River Channel Management Rules of the PRC, the Flood Prevention Regulations of the PRC, the Yellow River Channel Management Rules in ShanDong Province, the Yellow River Flood Prevention Rules in ShanDong Province, the Yellow River Delta Management Method, the Yellow River Project Management Method
Management and protection in the natural protection zone	The Environment Protection Law of the PRC, the Wild Animal Protection Law of the PRC, the Natural Protection Rules in the PRC, the Wild Plant Protection Rules of the PRC, the Forest and Wild Animal Type in the Natural Protection Zone Management Method (permitted by the national congress, and published by the forest department), the Forest and Wild Animal Type in the Natural Protection Zone Management Method in ShanDong Province, the State Level Yellow River Delta Natural Protection Management Temporary Law, etc.
The use and management of the ocean area	The Using Method of the Ocean area of the PRC, the Ocean Environment Protection of the PRC, the Management Law of the Pollution Posed by the Ocean Bank Protection Projects on the Environment of the PRC, the Environmental Protection Law of the Ocean Oil Dredging of PRC, the Management Rules of Using the Ocean Area in Shandong Province, the Temporary Method of the Ocean Area use Application and Improvement, etc.

2.2 The current situation of laws and regulations application

From the overall point of view, the fields mentioned above all put the application of laws and regulations in the highlight place, and established the executing mechanism in each field, and highly effective legislative monitoring system of clearly defined right and responsibility, standard behaviors and forceful supervision, providing strong guarantee for the harnessing of the Yellow River Delta, water resources, the natural zone protection and the management of the ocean area utility.

3 Existing problems

But, according to the overall requirements of the Yellow River Delta ecological system protection, there still exist some problems that shall not be ignored in the law and regulation construction.

(1) The feature of the sector legislation is quite prominent. The concert of the current regulations on the corporation between fields is not enough, showing obvious industrious management limitations. Take the related regulations of the natural protection zone as example, in order to do better managements in natural environment and the natural resources protection, the legal system of different management zone is established, including core zone, buffer zone, testing zone(see the map below). And a series of exclusive management requirements has been set up, such as the prohibiting of production activities and interfacing form human in the peace period from November 1 st of the first year to April 30 th of the next year. These requirements are necessary in the aspect of sector management, but restricted the harnessing and protection of the Yellow River Delta. The same thing happened in the related regulations of ocean area use management.

(2) The definition of the relationship between the responsibility and right is not in a scientific way, the legislation system in the corporation management is not complete, but with a stress in the sector management, and is not fit for the Yellow River Delta eco – system protection objective requirements. From the overall view, the harnessing of the delta area and water resources management are the most basic conditions of the existence and development of the eco – system in the delta area. But in the construction of the regulations in related fields, there exist phenomena of neglecting the requirements of the Yellow River Delta, causing the unclear definition in the relationship between responsibility and right and crossing and overlapping problems.

(3) The Relatively lag in part legislation construction causes uneven state of the law application in related field. From the total point of view, in the fields of the Yellow River water allocation and use, delta natural protection zone management, there are effective and feasible legislative regulations. But there is still relative lag in the Yellow River delta legislation construction. The embodies are in the following: first, there lacks detailed and practical management regulations; second, although the laws like the Yellow River Channel Management Rules, the Yellow River Delta Management Method have been formulated, compared with the laws in other fields, the effectiveness is weaker, the restriction force is not strong, and is hard to meet the demands of management requirements.

(4) There exists an unharmonious phenomenon in the rules of some related fields with the unique bio – environment of the Yellow River Delta. This presents as the following: first, the rules in the definition of distinguished line are taking the average big tide and high tide as the border that is in contradiction with the natural law of the siltation and extension of the estuary into the sea. Second, the exclusive management rules for the natural reserves entirely neglect the real fact that the Yellow River delta is totally within the ocean and river management scope, and is contradiction with the river channel rules.

(5) Management by many departments and self – governing is commonly witnessed. Because of the crossing and overlapping of the law application, the management of many elements and complicated management relationship have formed. Take the river channel that entering the ocean as example, the delta natural protection area is completely under the river channel management scope,

so there is crossing area of ocean and river management. Besides, the laws and regulations in national land resources, forest industry, environmental protection, grazing, and urban construction are also within the field of river channel management scope. So, many management entities have appeared. In every field, the laws and regulations are implemented and there is no inter – corporation and communication between them.

(6) There are constrains in the applications of laws and regulations in some fields which is unfit for the protection of the eco – system in the Yellow River Delta. Take the spare river channel of the Yellow River into the sea and the sediment receiving area in the shallow sea as the example, when the management of crossing and overlapping occurred, the laws and regulations could be executed with no efficiency due to the lower enforcement. This phenomenon does not match with the fundamental position of the Yellow River estuary harnessing in the protection of the eco – system of the Yellow River Delta.

(7) The conflict coordination mechanism in law enforcement is not complete. The contradictions arisen from in the protection of the eco – system of the Yellow River Delta has the features of cross fields and sectors, causing the increase of difficulties in cooperation. In recent years, some practice and researches have been actively carried out around the law executing cooperation. Take the border dividing of the Yellow River and the sea as example, the Shandong Ocean Area Use and Management Rule and the Yellow River Estuary Management Method specify that the boundary shall be designated by both the Yellow River Affair Bureau and the Ocean Management Department after the approval of the provincial government. Because of the incomplete cooperation mechanism, the contradictions in laws executing is not easy to be resolved immediately.

4 Suggestions

(1) Because the exploitation of the Yellow River Delta is very important to the protection of its delta eco – system, and many departments involved with different requirements, the cooperation of relationship of benefits is very complicated, legislation process shall be accelerated. And more effective laws and regulations based on the existing laws, such as the Yellow River Delta Management Method should be studied. The relationships between fields in the Yellow River harnessing should be adjusted and regulated, ensuring the sound development of the Yellow River harnessing.

(2) The special study on the Yellow River sediment receiving area management plan should be enhanced. The definition of the connecting area between the river and the sea should be decided according to the Shandong Ocean Area Use and Management Rule and the Yellow River Estuary Management Method.

(3) Because of the complication of the protection of the Yellow River delta eco – system, the integrated plan management of laws and regulations should be carried out urgently. As is strongly suggested that the Yellow River integrated harnessing plan should be quickly worked out and implemented, providing basic regulations to the delta development, harmonious economic and social development of the region, as well as the bio – environmental construction.

(4) The laws and regulations evaluation mechanism should be perfected and carried out, and the degree of current laws and regulations executing in related fields should be enlarged, enhancing connection with the laws and regulations in related eco – system protection in the Yellow River delta.

References

Gao Jixi, Li Zhenhai. The problems and suggestions on the Yellow River delta eco – system protection // The Yellow River Delta Problems and Harnessing Strategies Seminar [M]. Zhengzhou: Yellow River Conservancy Press, 2003.

Shuo Lishen. The problems in the harnessing of the Yellow River delta // The Yellow River Delta Problems and Harnessing Strategies Seminar [M]. Zhengzhou: Yellow River Conservancy

Press, 2003.

Xu Xuegong. The Yellow River delta bio – environment change and eco – construction // The Yellow River Delta Problems and Harnessing Strategies Seminar [M]. Zhengzhou: Yellow River Conservancy Press, 2003.

The Water Conservancy Studying Board of China. The Research Meeting on the Yellow River, The Suggestions on Enhancing the Yellow River Delta Research and Harnessing // The Yellow River Delta Problems and Harnessing Strategies Seminar[M]. Zhengzhou: Yellow River Conservancy Press, 2003.

The Yellow River research meeting. The general situation of the Yellow River delta harnessing and exploitations // The Yellow River Delta Problems and Harnessing Strategies Seminar [M]. Zhengzhou: Yellow River Conservancy Press, 2003.

Discussion and Research Orientation on the Serving Function of Yellow River Estuary Ecosystem *

Wang Kairong[1], *Jiang Naiqian*[1], *Dong Nianhu*[1,2] and *Wang Jinzhou*[3]

1. Yellow River Institute of Hydraulic Research, Zhengzhou, 450003, China
2. Yellow River Estuary Research Institute, Dongying, 257091, China
3. Information Center of Yellow River Conservancy Commission, Zhengzhou, 450003, China

Abstract: This paper briefly introduces the basic concept of ecosystem service and function division, and generally discusses the serving function of Yellow River estuary ecosystem from various aspects such as land accretion, substance production, water dispatching and supply, biodiversity, environment cleanup and so forth. In paper, the authors not only analyzes the current serving function of Yellow River estuary ecosystem and problems existed but also discusses the orientation of the research on serving function of Yellow River estuary ecosystem.

Key words: ecosystem, serving function, research orientation, the Yellow River estuary

1 Introduction

So – called ecosystem services are human living environmental condition and effect created and sustained by ecosystem and eco – process. It not only provides the food, medicine and other industrial and agricultural production raw materials for human beings but also sustains the life support system in which human beings exist and develop. Holdren and Ehrlich firstly put forward the ecosystem serving function concept in the paper 'Population and Global Environment' published in 1974. However, the concept was wide recognized and paid attention in 1990s with the paper 'World Ecosystem Services and Value of Natural Capital' published in Nature by Costanza and the book 'Natural Services: Human Society's Dependence on the Natural Ecosystem' as a marker. Based on the research achievement of Costanza, Chen Zhongxin and Zhang Xinshi abstracted the serving function of various ecosystems in China.

Costanza divided the global ecosystem serving function into 17 categories including gas regulation, disturbance regulation, moisture adjustment, moisture supply, erosion control, sediment holding, soil formation, nutrition circulation, exhausting gas disposal, pollination, animal control and protection, food production, raw material, genetic resources, leisure and culture, etc. These functions have become the basic ecosystem serving evaluation standard and reference by people. The paper analyzes and discuses the main ecosystem serving function and the improvement solution in future according to the actual situation of Yellow River estuary.

2 The main serving function of Yellow River estuary ecosystem

2.1 Land accretion

To the high sediment load estuary, the estuarial coastline had the stretch tendency toward outside sea due to the large amount of deposited sediment which loaded by river flow. According to the statistic, since 1855, the new land accretion area in the Yellow River Delta had reached 2,500 km^2 with 1 510 km^2 in the period from1855 to 1954, 548.3 km^2 from 1954 to 1976, 441.7 km^2 from 1976 to 2001. In the nearly half century, the average land accretion area was above 20 km^2 in each year and provided the broad national economy development space in the region of the Yellow

* The Project Sponsored By The NSFC (No. 50339050).

River Delta. However, with the dynamic evolution of mudflat wetland, the water environmental condition and the distribution of creatures in such area would be changed and finally this area would lose the characteristic of wetland and become the land. We should pay particular attention to this phenomenon.

2.2 Substance production

Estuary is a kind of ecosystem with high productive forces and so is the Yellow River estuary. Estuary aquatic production is the main protein sources for human beings. The abundant organic fragments in estuary always form the regular scale fishing ground. Dongying city is located at the estuary of the Yellow River with coastline 350 km, shallow area in which the bathymetric line is below 10 m is 4,800 km^2, the mudflat wetland area which is suitable to aquaculture is 120 thousands hm^2. The underwater world of Bohai Bay and Laizhou Bay for their particular geological conditions is the natural fish kingdom as well as the rare and excellent inshore fishing ground with plentiful fish, prawn and shell resources. They are crowned "the home of hundreds fishes" and "the home of oriental prawn" because of 517 species of sea creatures and more than 190 species of tidal zone creatures in there. There are dozens of economical fish species such as barracuda, weever, yellow – fin tuna, whitebait, needlefish and Nibea Albiflora etc. The most special one is the estuarine tapertail lanchovy which have formed two inshore fishing grounds in Bohai Bay and Laizhou Bay. According to the statistic in 2001, the annual amount of aquatic production in Dongying city was 290.9 thousand tons with 70.4 thousand tons freshwater aquatic production and 220.5 thousand tons seawater aquatic production which included 119.6 thousand tons of marine fishing and 100.9 thousand tons of aquaculture.

Besides food, estuary also supplies the plentiful raw material for human beings. There are 765 thousand hm^2 grassland, 10.5 thousand hm^2 willow forest and 121.5 thousand hm^2 Chinese tamarisk shrub forest in the region of Yellow River delta wetland protection zone. There are various salt – tolerance plants such as the salty alkali loose, the Chinese tamarisk, the Salicornia, the Spartina anglica etc. these plants all have the salt – tolerance characteristic and the exploiting value which can be used as the female parent for the breed improvement and the salt – tolerance plants breeding.

2.3 Water regulation and supply

The surface evaporation of estuary and the transpiration of plant can let a large amount of water into atmosphere and further affect the regional temperature and rainfall. Storing up water by estuary wetland can not only store flood but also recharge groundwater effectively. In July 2002, in the period of the first water and sediment regulation experiment in the Yellow River, the water discharge above 2,000 m^3/s in Lijin lasted 9.9 days and the maximum water discharge was 2,220 m^3/s. The large water discharge of flood peak entered the estuary area, made it possible that natural reservation and wetland could recharge fresh water by overbanking. It relieved the shrink extent and the alkali – saline aggravation of the Yellow River estuary wetland, diluted the water pollution in the estuary area, dramatically increased the unit organic substance quantity and category carried by runoff. These effects not only met the basic requirement for ecosystem environmental quality increasing for the region of Yellow River estuary but also provided the good habitats for birds.

In the region of Yellow River estuary, the overland water resources and groundwater resources are very limited. The flow of the Yellow River is the only available fresh water resources in Dongying city currently. In the period from 1990 to 1997, the annual average water supply in the region of Yellow River estuary was 1.509 billion m^3 which included 1.42 billion m^3 Yellow River flow. As we can see, the Yellow River flow occupied the crucial position for the social and economic development in the Yellow River delta especially in Dongying city.

2.4 Biodiversity

Biodiversity is the foundation of estuary ecosystem substance production as well as the important genic library related to the regional development in future. Estuary ecosystem has the clear edge effect characteristic and plentiful biological species. The diverse and complex environment in estuary provides the suitable habitats for various species. Related science investigation confirmed: There are 1,921 wild animals and plant species which include 641 aquatic animal species and 269 bird species in the national estuary natural reserve. Wild bird species consist of 17 orders, 47 families and 132 genus in total. There are 7 bird species in the first protection level and 33 bird species in the secondary protection level in 'The List of Wild Animals under National Protection'. 43.8% of bird species are waterfowl which number is 116 and belongs to 7 orders, 17 families and 51 genus. The hydrobios in the Reserve is also abundant and includes approximate 757 species according to the investigation.

2.5 Environment cleanup

The estuary environment cleanup function mostly includes two parts, the one is physical clean up and the other is biological cleanup. The physical cleanup means flow dilution, particles adsorption and sedimentation etc. Yellow Rive estuary is the kind of estuary with the high intensity suspended sediment – load flow. Along to the change of environmental factors such as water dynamical condition and salinity, a large mount of particles will settle down in the estuary area and the contaminant such as nitrogen, phosphorus, organic matter and heavy metals which were adopted by river will be removed from water. The reference (Che Yue, He Qing, 2001) points out: the activated part of heavy metal elements in estuary mostly is adsorbed in the surface of particulate suspended sediment during the process of solid – liquid balance. In the mixture area between salt water and fresh water, environmental condition changed and suspended sediment partly concentrated and dissolved and partly suspended again by the impact of tide wave, which caused heavy metal pollution by the combination with particles. In the conjunction of sea and river, tidewater strongly affected the intensity of metal in particles and the chemical component changed which showed the interaction of land and sea suspended sediment. Because of the large buffer capacity, the river with high sediment had more cleanup capability toward dissolved metals than the one with low sediment.

Biological cleanup in estuary is coupling with ecosystem. The high productivity of estuary can assimilate lots of nutritious salt in flow and absorb contaminant such as heavy metal and non – degradable organic matter. For example, the reed, which has the strong absorbable capability in nutritious salt and contaminant, is treated as the seed for wastewater treatment in a lot of ecosystem project and has the good effect in the area of deeply wastewater treatment.

3 The current situation and problems of the Yellow River estuary ecosystem serving function

Due to the particular geographical position, facilitated transportation and ample biological resources, estuary region is always the living site for human beings. However, it is inevitable that people's activities certainly will affect or disturb the structure and function of estuary ecosystem when people enjoy the serving function of them. The human interferences of estuary ecosystem mainly come from region and basin two field. The human interferences in region field are shipping development, fishing, tidal flat reclamation, coastline utilization and seeding, etc. On the contrast, the pollutant discharge and the construction of large water project are the main human interferences in basin field.

Since 1980s, there have been a remarkable change of water and sediment condition in Yellow River estuary due to the influence from climate change and human activities in the Yellow River basin. The average runoff and sediment load in Lijin station in 1990s was only 36.7% and 40.9 % of perennial one. With the decline of incoming runoff and sediment, the continuous increasing of water demands in the basin, the estuary was occasionally dried up. The drying – up days in 1995 was up to 122 and 226 in 1997 which was the worst year. The flood discharge days above 3,000 m^3/s slumped, there was 46 days in 1950s and 1960s and no more than 2 days in 1990s.

Combining with the change of water and sediment condition, a lot of new problems of the serving function of estuary ecosystem occurred.

From the angle of land accretion, since 1990s, there has been the sharp decline tendency of sediment load entered in to estuary in each year. In the period from1996 to 2004, the accumulated sediment load no more than 2 billion tons which was only 17% of perennial average ones in the past. The severe shortage of sediment load restrained the land accretion in delta. Using the RS technology showed the land changes in Yellow River estuary: From 1988 to 1996, the land area decreased 10.76 km^2 and the annual average was 1.3 km^2. From 1996 to 2000, the land area decreased 100.02 km^2 and the annual average was 25 km^2.

The change from incoming runoff and sediment concentration also changed the salinity and food fertility of estuary sea area which threat the offshore sea species and biodiversity and caused the dramatically drop of biological resources quantity. For example, Laizhou Bay is the main spawn site, habitat as well as the multiple and traditional fishing farm in Huanghai Sea and Bohai Sea. The statistic which based on the catch by dragnet from different time and season showed: the quantity, advantage and diversity of fish species in Laizhou Bay were changed notably. The average unit catch in 1959, 1982, 1992 to 1993 and 1998 were 258, 117, 77.5 and 8.5 kg/h respectively. It is clear that the fish resources are in the continuous recessive tendency.

In Yellow River delta, more than 70% of sediment size is silt level. The large soil porosity and small soil water content which are favorable for evaporation. Along with the sharp drop of runoff entered sea, water and sediment supply amount was significantly reduced and the wetland had the gradual trend of desertification. With the operation of Xiaolangdi Reservoir, the take – off of the south – to – north water diversion project and the large – scale implementation of water and soil conservation project in the Loess Plateau which will make a big effect to water and sediment allocation in the Yellow River and change the water and sediment condition accordingly, which certainly will bring important influence on estuary ecosystem.

4 The research orientation of the Yellow River estuary ecosystem serving function

4.1 The evolution law of estuary ecosystem

In the time sequence, the research orientation is the evolution process of estuary ecosystem. We use the key process in the evolution process of estuary ecosystem as the clue, study the evolution process of estuary ecosystem under the impact of nature and human activities in recent 50 years, and reveal the evolution law of estuary ecosystem.

In the space structure, the research orientation is ecosystem structure, function and process. We use the change process of water and sediment as cardinal line, probe the structure, function and eco – process of estuary ecosystem and the coupling principle among different ecosystems from region, sightseeing and system three dimensions, and deeply study the space distribution law of estuary ecosystem.

4.2 The drive of estuary ecosystem evolution

4.2.1 The impact of incoming water and sediment on estuary ecosystem

To analyze the relation of wetland and water and sediment resources in the Yellow River and study the impact of diverse incoming water and sediment on estuary wetland; to analyze the relation of coastal ecosystem biocoenotic change and water and sediment resources in the Yellow River and emphasize the impact of estuary salinity change on coastal sea creatures and incoming water and sediment of the Yellow Rive to migrating fish in estuary.

4.2.2 The impact of the change of Yellow River's flowing route entering the sea and river channel silt – up and stretch on estuary ecosystem

Due to the change of Yellow River's flowing route entering the sea, river channel silt – up and stretch, the lowland between various river channels formed the estuary wetland. Near the current Qingshuigou route and Diaohekou route opening which dried up for several years, the ecosystem was shifting from development to deterioration. To study the impact of the change of Yellow River's flowing route entering the sea and river channel silt – up and stretch on estuary wetland.

4.2.3 The impact of the human interferences on estuary ecosystem

In order to improve the channel situation of river tail, lighten the sand bar harm in river estuary, postpone the stretch of river channel, increase the sediment load entered the sea, relieve the pressure of flood control and ice flood control, the rive channel regulation measures such as cutting branch and reinforcing main stream, clearing sediments by means of converting flow, clearing sedimentation, utilizing tide, protecting flood plain and steadying main channel, building embankment was taken and the influence to wetland and coastal ecosystem in estuary was obviousl. Besides, with the economy development in Yellow River delta, the large – scale exploitation of oil field and agriculture, urban construction which will bring a certain influence on natural and artificial wetland.

4.2.4 The impact of natural factor on estuary ecosystem

In Yellow River delta, because of the geography location and climate environment, the ground level is low and easy to be attacked by Yellow River flood, tide, storm tide, waterlogging, drought etc. It is worth studying the impact of these invasions on estuary ecosystem. Besides, the elevation of sea level would flood a lot of coastal wetland and cause more storm tide and flood disaster which would generate the impact to wetland ecosystem.

4.2.5 The impact of water quality change on estuary ecosystem

Because of the development of economy, the water pollution in estuary aggravated which would make great influence to ecosystem. Therefore, it is necessary that studying the response of estuary ecosystem to the change of water quality.

4.3 The sustainable serving function of estuary ecosystem and regulation technology

First of all, to build the integrated quality evaluation system of estuary ecosystem, study the evaluation index, measures and threshold of estuary ecosystem safety and form the safety pre – warning system for estuary ecosystem. Secondly, based on the research of evolution law of estuary ecosystem, fully considered the impact to estuary ecosystem such as the change of water and sediment, river channel silt – up and stretch, human interferences and natural factors, through the filter of main control and sensitive factors for the change of estuary ecosystem, to construct the future environment evolution tendency model in three different period. Last but not the least, based on the above research, to build the decision – making support system for the serving function of estuary ecosystem and based on the relation of water and sediment resources, river channel silt – up and stretch, human interferences and natural factors to estuary ecosystem, to bring forward the optimizing and management system for the serving function of estuary ecosystem.

5 Conclusions

Estuary ecosystem is the one of the most important part of the Yellow River ecosystem. Therefore, its health is considered as the important marker for keeping the healthy life of the Yellow River. The sustainable delta ecosystem maintenance is also the one of the nine training ways for keeping the healthy life of the Yellow River. Yellow River estuary is the silt – up plain by Yellow River sediment as well as the international wetland, water area and coastal ecosystem protection area which listed in the 'China Biological Diversity Protection Action Plan'. Estuary is the ecosystem with important resources potential and environmental effects, except supporting the food, materials and water for human beings, also having the important effect in different areas such as ecological balance maintenance, biological diversity and rare endangered species maintenance, water conservation, flood control and drought relief, pollutant degradation and tourism resources support etc. The Yellow River estuary is located in the cross of river ecosystem and sea ecosystem, so it is liable to be affected by the oscillating of river tail and the change of water and sediment condition. Furthermore, the effects are always potential, lag and irreversible which should be draw more attention for us.

References

Lu Jianjian. Estuary Ecology. Ocean Press, 2003, Beijing.

Che Yue, He Qing. Distribution Features of Heavy Metal Elements in Suspension Load at Estuary. Northwest Water Power, 2001,1(4).

Ma Jianwei. Monitoring of Yellow River Estuary Land Change Using Remote Sensing Technology, Yellow River Conservancy Press, 2002, Zhengzhou.

Deng Jingyao. Study on Fishery Biodiversity and Its Conservation in Laizhou Bay and Yellow River Estuary. Zoological Research, 2000(1).

Problems and Protection Measures of the Yellow River Delta Ecology

Cheng Yiji*, *He Min* and *Xing Hua

Yellow River Estuary Research Institute, YRCC, Dongying, 257091

Abstract: The Yellow River Delta presents uncertainty, vulnerability and obvious wetland ecological features, and the species in intertidal zone and near coastal wetlands are numerous. Soil salinization, decrease of the Yellow River water and deterioration of wetland environment are outstanding problems of the Yellow River delta ecology. Some measures can be carried out to protect the ecology, such as establishing monitoring and evaluation system of the Yellow River Delta environment, enhancing an integrated regulation of the Yellow River water resources and ensuring environmental flows in the Yellow River estuary, restoring wetlands, expanding the Yellow River Delta National Nature Reserve, developing ecological economy, etc.

Key words: Yellow River Delta, ecology, problems, protection

1 Ecological characteristics of the Yellow River Delta

Located between Bohai Bay and Laizhou Bay, in the range of 118°10′ ~ 119° 15′ of east longitude and 37° 15′ ~ 38°10′ of north latitude, the Yellow River Delta is a continental weak tidal strong accumulation estuary, and was formed by ceaseless variance of the river course after diversions to Daqing River in Tongwaxiang in 1855. Generally it refers to a 6,000 km^2 fan – shaped area with the culmination of Ninghai, the Taoer estuary in the north, and Zhimaigou estuary in the south. In order to protect industrial and agricultural production in the estuary areas, in the past 50 years the culmination was moved downward to Yuwa, swing scope was narrowed to about 2,400 km^2 of the fan – shaped area from the north Chezigou, to the south Songchunronggou. Its special formation process and geographical location determines the ecological characteristics as the following.

1.1 Instability of the delta

As the Yellow River brought large sediment to the estuary every year, the estuary changed frequently in the state of natural estuarine sedimentation, extending, swinging and diversion. Since 1855 when the Yellow River was diverted into the sea through Daqing River in Tongwaxiang, its river course changed more than 50 times in the neoteric Delta, of which, the diversion near the axis point occurred 9 times, including 6 diversions with the vertex of Ninghai from 1889 to 1953; and 3 diversions after 1953 with vertices of Yuwa. Current water course was formed on May 20, 1976 after artificial interception in Luojiawuzi, running for 31 years, its estuary kept silting, extending and swinging. Before the flood season of 1996, in order to fully utilize the sand for land reclamation and to realize land exploitation of offshore oil, the "diversion in Qing 8" was implemented, river course below Xihekou was shortened to 16 km. Since 1997, especially, since the Xiaolangdi Reservoir was used to store water and sand, the sand entering the estuary has significantly decreased, river sedimentation and extension rate has slowed down. Influenced by the estuary course changes, the delta coastline kept changing. The delta coastline near the estuary extended to the deep – sea, while the coastline far away from the estuary was eroded, effected by ocean waves and tide. It is evident that the Yellow River delta coastal ecological environment is very unstable.

1.2 Vulnerability of ecological environment

The Yellow River Delta is in the intersection between land and sea where diverse ecosystems alternate, with land and meadow vegetation formation in shorter time, and higher salinity level of soil, leading to the vulnerability of the Yellow River Delta ecological environment generally.

1.3 Various species in wetlands intertidal and near coast

The Yellow River Delta verges the Bohai Sea. its coastline is 693 km long, beach is wide, and this delta is a good breeding grounds for seashell. There are nearly 40 species of seashells and 265 the largest species of birds in the wetland ecosystems near the Yellow River mouth, of which 152 species are stated in "Agreement of Sino – Japanese Protection of Migratory Birds and Their Habitats", with high biological value. As for the plant composition, the plant species fitting the ocean climate, damp soil and the coastal saline soil dominate. From the beach to the backland, with the decrease of salinity, vegetation distribution is gradually evolved from salt vegetation, marsh vegetation to meadow, sand vegetation, temperate deciduous broad – leaved woodland, shrub and cultivated vegetation.

1.4 Obvious wetland ecosystem characteristics

Affected by the Yellow River and other rivers, the Yellow River Delta presents obvious wetland ecosystem characteristics. Meadow is distributed in about 186,000 hm^2 and is composed of perennial halophytes which can fit salt, bear salt and resist salt. Swamps and water area is large, the waters area in Dongying city is about 240,000 hm^2 (including the beach), accounting for 30.4% of the city's land area.

2 Ecological problems of the Yellow River Delta

The main problems of the Yellow River Delta are soil salinization, water decreasing and wetlands environmental deterioration.

2.1 Soil salinity is high

The Yellow River Delta is new land repelling the sea, covered by 2 types of soil, i. e. wet soil and saline soil. From inland to coastal sea, soil changes gradually from the tidal to the saline. Most of the reserved land resources have high soil salinity, topography is low, groundwater is shallow, evaporation precipitation ratio is 3.5∶1, and threat from secondary salinization od soil is great. Groundwater level is high and infiltrated by the Bohai Sea water, so arbor trees with flourishing roots extending deeply into the ground can't be planted in most area of the delta. Under these land and plant conditions, the environment of the delta becomes quite vulnerable and is difficult to be restored and bear pollutions.

2.2 Yellow River water volume kept decreasing

With the increase of industrial and agricultural water consumption and continuous implementation of soil and water conservation measures in the Yellow River basin, water and sediment entering the estuary changed significantly. According to the practical statistical data from July 1950 to Dec. 2000, the water and sediment eigenvalue at Lijin hydrological station is shown in Table 1.

Table 1 Water and sediment eigenvalue at Lijin station

Year	Water volume (billion m^3)			Sediment amount (billion t)			Sediment Concentration (kg/m^3)		
	July – October	December – June	July – June	July – October	December – June	July – June	July – October	December – June	July – June
1950 ~ 1959	298.7	165.0	463.7	11.45	1.70	13.15	38.3	10.3	28.4
1960 ~ 1969	291.5	221.5	512.9	8.68	2.32	11.00	29.8	10.5	21.4
1970 ~ 1979	187.3	117.0	304.4	7.57	1.31	8.88	40.4	11.2	29.2
1980 ~ 1989	189.7	101.0	290.7	5.77	0.69	6.46	30.4	6.8	22.2
1990 ~ 2000	79.6	43.2	122.8	3.07	0.40	3.47	38.5	9.3	28.3
Average	206.8	127.8	334.7	7.23	1.27	8.49	34.9	9.9	25.4

The analysis of the table indicated that the distribution of water and sediment in a year and between the years was obviously uneven, in recent years water and sediment amount decreased noticeably. at Lijin station in 1990s, the average annual water volume was 12.28 billion m^3, only 26.5% of that in the 1950s, water volume in flood season was only 26.6% of that in the 1950s; the years when water volume was less than 5 billion m^3 were 1997 and 2000. 1997 was the driest year, when the water volume was only 1.91 billion m^3. Like the changes of water, sediment amount also decreased obviously. According to the statistical data of Lijin station in 1990s, the average annual sediment amount was 347 million t, only 26.4% of that in 1950s, sediment amount in flood season was only 26.8% of that in 1950s. As the sediment and water decreased synchronously, sediment concentration had no significant change in the trend. As the water consumption in the upper and middle reaches of the Yellow River increased, since 1970s, the inflow of the Yellow River has been decreasing gradually, and interception began to appear. During 28 years from1972 to 1999, interception at Lijin station occurred in 22 years, totally 86 times in 1091 days. Since 2000, due to the effective regulation of Yellow River Xiaolangdi Reservoir and reinforcement of the Yellow River water resources regulation and management, the interception of the Yellow River water has been restrained, but the Yellow River water volume still remained little.

2.3 Environment of wetlands deteriorated

2.3.1 Wetlands area decreases

During the 1950s and 1960s, due to abundance of water and sediment, estuary was aggraded and extended rapidly, about 25 km^2 of land was created annually. Since 1990s, the Yellow River water and sediment has decreased sharply, drying – up became a major characteristic of the Yellow River. The incoming sediment can only maintain the dynamic balance of the estuary, the coast far away from the estuary retreated very seriously. For example, in May 1996, a divagation project was built in Qing 8 section in the Yellow River mouth, after which the previous river channel lost sediment supplies, and the coastline evolved quickly under the oceanic dynamics. According to observation and calculation, the 2 m isobath retreated 432 m annually averagely, 10m isobath was at a balanceable state. For another example, after the Yellow River course was diverted from Diaokouhe to Qingshuigou, without runoff and sediment, the coastline evolved from advance into rapid retreat. From 1976 to 2000, 15 km wide coastline retreated 7.67 km averagely, and retreating area amounted to 115.1 km^2; 2 m isobath retreated 5.37 ~ 7.89 km, and seabed eroded 4.22 ~ 6.67 m; 5 m isobath retreated 3.12 ~ 5.96 km, seabed eroded 3.0 ~ 7.53 m; 10 m isobath retreated 0.82 ~ 4.3 km, seabed eroded 0.75 ~ 5.9 m. Delta wetland area will decrease continuously.

2.3.2 Environmental pollution is severe

The Yellow River delta wetland is polluted mainly by oil, fertilizer, pesticide, and living garbage. Due to the serious overlapping between some oil resources zone of the Shengli Oil Field and the Yellow River Delta Natural Reserve, the oil exploiting will destroy the natural ecology of the land. And the large area of the reserve is polluted by fertilizers and pesticide used in the farmlands in the reserve. In recent years, some pollutant transferred by the Yellow River and other rivers and living garbage influenced the wetland widely, which directly influenced the quality of the whole wetland ecosystem.

2.3.3 Biological resources decreases

There are many reasons for the decrease of the biology resources. Firstly, in recent years, due to the obvious decrease of the Yellow River runoff and construction of the training dikes, the natural overflow and deposition during normal flood were affected and blocked, then the exchange between the inland and sea was cut off, the inland food resources for the biologic species living in the shallow sea wetlands were lost, terrestrial wetlands shrank, therefore the species decreased. Secondly, the environmental pollution made reproduction ability of the species drop down, even made them die. Thirdly, the ravening exploitation from human being also made the species decreased.

3 Ecological protection measures of the Yellow River Delta

3.1 Establishing monitoring and evaluation systems of ecological environment in Yellow River Delta

At present, the monitoring on the Yellow River Delta environment is very imperfect and unsystematic, so it is suggested that the natural reserve, the Yellow River and ocean authorities jointly establish an organization for environmental monitoring and evaluation. Then, based on the spot ecological observation data, applying 3S and other advanced technology, ecological research and evaluation methods, we should conduct investigations on environmental status and natural resources protection and bio – diversity in the Yellow River Delta region, and analyze the existent main problems. We should analyze the environmental evolution process and rules, establish the model on the connection between the estuary water and major environmental factors to predict the environmental evolution in the future and supply the primary data for the ecological protection in the Yellow River Delta region.

3.2 Enhancinguniform regulation of Yellow River water resources, ensuring environmental flows in Yellow River estuary

Since 2000, due to the effective regulation of the Yellow River Xiaolangdi Reservoir and reinforcement of the Yellow River water resources uniform regulation and management, the Yellow River has never been intercepted. In the future the principles of basic volume for maintaining the healthy life of the Yellow River should be set up and environmental water use should be taken as the priority. The basic flow for maintaining the healthy life of the Yellow River still needs to be researched and demonstrated, but it must satisfy at least three requirements: to realize the scouring and deposition balance of the main channel by artificial harmonious water and sediment relations, to satisfy the water quality of the river, and to satisfy fresh water supply for the reproduction and metabolism of the main species in the estuary area. The present standard for no zero – flow at Lijin hydrologic station is no less than 50 m^3/s, which is only a symbol. Hence, the estuary environmental flows need to be confirmed by research and be ensured through uniform water regulation, and it can be entirely guaranteed by "South – to – North Water Transfer Project" in long – term.

3.3 Wetlands restoration

Since 1999, YRCC carried out uniform regulation of the Yellow River water resources, the Yellow River has never been intercepted for seven years. The Nature Reserve Administration Bureau carried out wetland restoration projects. Through the construction of tide barriers, cofferdams, septi – dikes and water diversion sluice, and the wetlands environment was improved, and the wetlands ecosystem was restored to some extent. Currently in the nature reserve, wild plants increased to 393 species, birds increased to 283 species. In the future this kind of projects should be implemented further, a series of measures should be taken to restore the wetlands and to improve the soil.

3.4 Reinforcing the management of the Yellow River Delta National Nature Reserve

The Yellow River Delta National Nature Reserve, established in 1992, plays an important role in protecting the nascent wetlands system, the rare, endangered birds, animals and plants. In the core area of the nature reserve, all exploitation is forbidden, such as seafood fishing and tourism, to reduce the ecological damage to the environment. In the pilot area, with the prerequisite of no damage to the environment, appropriate exploitation is permitted, but the wetlands where the oil resources exploitation has been completed should be gradually restored. In the future, with the sedimentation, extension and swing of the Yellow River estuary, the newly silted wetlands should be brought into the nature reserve and managed.

3.5 Developing ecological economy

The Yellow River Delta has unique and special topography, but the environment is fragile and vulnerable to be polluted. Therefore, the development of ecological economy is the only way. "Crop – economic – feed" triple cultivation mode should be positively developed, and ecological economic mode "fishery below crop" should be carried out. Afforestation projects should be promoted, especially the three shelter – forest systems in plain, inshore and around the city. The rich grassland resources in the Yellow River Delta should be utilized, professional breeding farms and families should be developed. Focusing on building "Maritime Dongying" strategy, aquaculture of special marine treasures, excellent freshwater fish and shallow sea shellfish should be developed preferentially.

In the process of industry development, the bearing capacity of the environment at the delta should be fully considered, the traditional mode of "treatment after pollution" should be avoided. Developing green industries and sustainable development is the inevitable choice of the Yellow River Delta. Institutional innovation, technological innovation and open to the outside world should be strengthened; the development of alternatives to oil industry, renewable energy industry should be accelerated; the new export – oriented modern industrial system with the core of green industry should be developed quickly; strict environmental standards of industrial projects should be required; and the negative impact of the development on the environment of the Yellow River Delta region should be minimized.

Management of the Yellow River Delta

—A Landscape – Ecological Challenge in a Dynamic Wetland

Liu Gaohuan[1], ***Bas Pedroli***[2], ***Michiel van Eupen***[2], ***Bianca Nijhof***[2], and ***Wang Xingong***[3]

1. Prof. Liu Gaohuan, State Key Lab. of Resources and Environmental Information Systems, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, 11 A Datun Road, Anwai, Chaoyang District, Beijing, 100101, China
2. Alterra Wageningen UR, The Netherlands
3. Yellow River Basin Water Resources Protection Bureau, Zhengzhou, 450003, China

Abstract: Yellow River Delta is one of the most important wetlands of china, but it is suffering the serious impact of the oilfield development, population increase, and land use change, etc. A comprehensive assessment on its sustainable development is made and main impacts that the Yellow River Delta faced are analyzed in this paper. Based on this, the recommendations for the further research and management are formulated, aiming to the balanced water allocation for sustainable development and nature protection.

Key words: freshwater wetland, integrated assessment, management

1 Prefaces

The Delta of the Yellow River forms a unique dynamic wetland of international importance for several species of Cranes, and for many migratory bird species along the East – Asian Flyway between Siberia and Australia. It currently suffers from water deficiency and conflicting land uses. How can landscape ecology help in developing sound solutions in this land accretion area extending from a millennia – old cultural landscape?

The delta of the Yellow River is a highly dynamic environment that is currently in a critical stage because of a sharp decrease in freshwater discharge over the past decade. Since the 1990s annual water flow has decreased more than 40% compared to the average of the 1950s and 1960s. This has led to prolonged periods of no flow conditions of 120 days per year and more in 1990s (Liu Gaohuan & Drost, 1997). The consequences are a reduced sediment inflow leading to loss of land, increased salinity intrusion and a reduction of nutrients into the sea. These factors have impact on the existing natural resources and ecological values of the delta. For instance, important bird protection areas are threatened as wetlands reduce in size. Also estuarine and marine primary production and fish yields have been dramatically declining over the years.

Observed river flow reductions in the Yellow River that is naturally a relatively low flow river, different from e. g. the Yangtse are largely due to increased water demands upstream, the construction of large dams and reservoirs in the river and its tributaries as well as water diversion works. Within the delta itself also large interventions and developments have taken place that affect the natural processes and resources, e. g. oil and gas exploitation, rapid urbanisation and agricultural modernisation. Hence there is a complex interaction and development going on between the natural delta dynamics and human interferences at various temporal and spatial scales. It is therefore not easy to assign clear cause – effect relationships between the observed rapid changes in the physical – ecological domain and the human interventions.

The water demand for sustainable environmental functioning of the Yellow River Delta is a complex issue, because of the highly regulated discharge of the Yellow River, the hardly known "natural state" of the wetlands, the complex developments in land use and stream regulation, and the dynamic processes in the land-sea interface. Setting targets for nature management is an interactive procedure (Pedroli et al., 2002), where minimum requirements could take a crucial function (Geilen et al., 2004). For this purpose an integrated assessment should provide a sound basis. A balanced water allocation for sustainable development and nature protection is a real landscape – ecological challenge, where stakeholder involvement to define realistic scenarios is a novel feature to the local community. This paper gives a first analysis and recommendations for its management.

2 The Yellow River and its delta

2.1 Yellow River Basin

The Yellow River (Huan He) is the second largest river in China after the Yangtse, and is considered the cradle of Chinese civilisation. From its sources in the Tibetan highlands at 4,500 m altitude it runs over a length of 5,500 km to the Bohai Sea (Fig. 1). The drainage area is 795,000 km^2. The population in the basin is about 150 million, which is roughly 10% of the total population of China. With an average annual precipitation of about 450 mm, far exceeded by evapotranspiration, the climate is predominantly semi – arid. The discharge of the Yellow River is relatively low. The average discharge at the delta is 1,330 m^3/s with a maximum at flood peak of 10,400 m^3/s, which is less than the Rhine (average discharge at mouth about 2,000 m^3/s). A more conspicuous difference with the Rhine is that drought situations with zero flow in the delta have occurred regularly in the 1990 s.

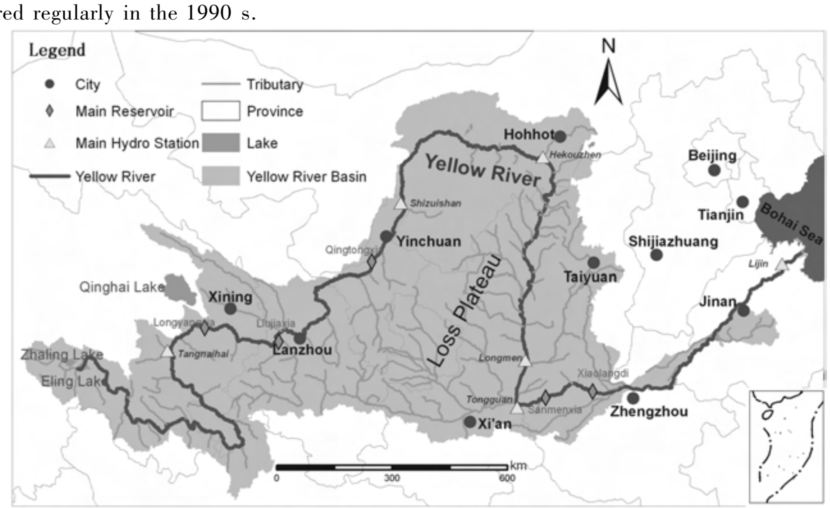


Fig. 1 The Yellow River Basin

The upper reach of the Yellow River (from its source to Hekouzhen, 3,500 km) drains 50% of the basin, and provides more than half of the basin runoff. It runs northward into the north Chinese desert plain.

The middle reach (from Hekouzhen to the Xiaolangdi dam, 1,200 km) covers 46% of the basin, and provides about 43% of the basin runoff. On its southward course, the river cuts through the Loess Plateau, the world's most erodible land surface. Massive amounts of loess soil enters the river, providing 90% of the river's total sediment load (Kemink et al., 2003; Winterterp et al., 2003). To this loess sediment the river owes its name.

The lower reach (800 km) has been regulated with levees for thousands of years, resulting in the so – called 'suspended' river, with a river bed sometimes as high as 10 m above the surrounding former floodplain. This stretch mainly serves as a discharge channel, disconnected from the drainage system around. The delta is a highly dynamic accretion area along the lowermost 100 km of the river (Fig. 2). The tail channel of the Yellow River had changed its course over 50 times from 1855 to 1976, resulting in the creation and accretion of the Yellow River delta. During this period, the coast line expanded into the sea by more than 50 km, forming 1,890 km^2 of new land in total, averaging 15 km^2 each year. The northern branch of the Yellow River (see Fig. 2) was abandoned by the river in 1976.

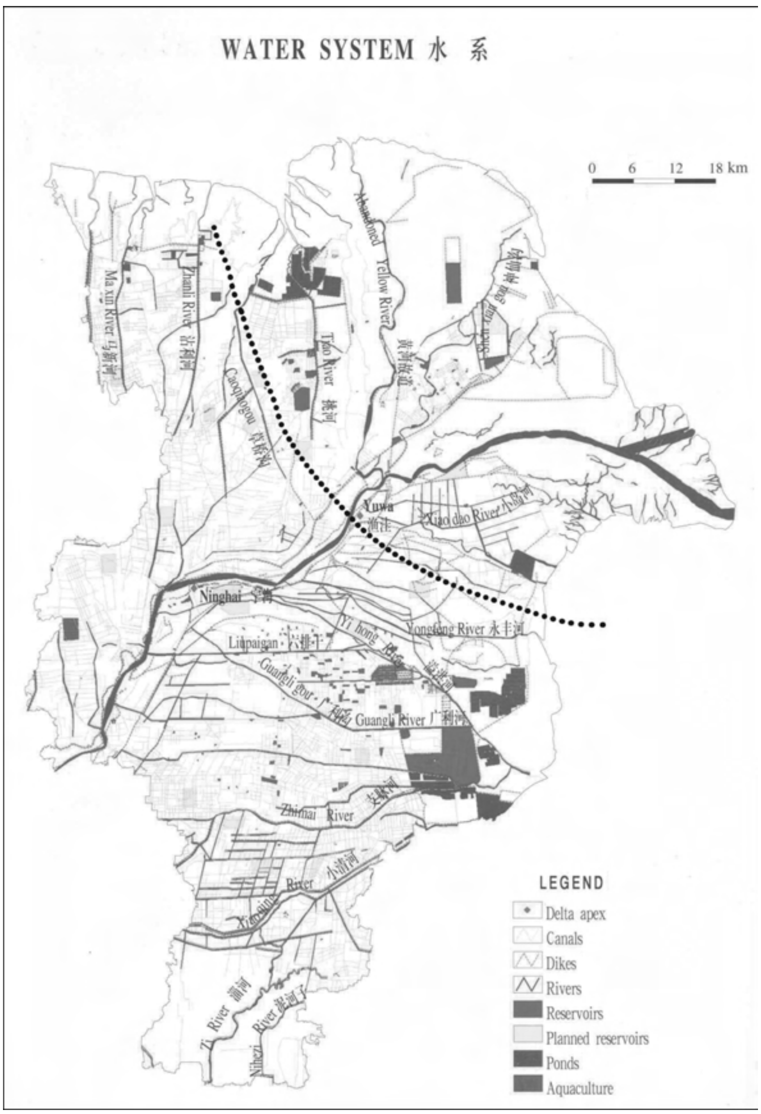


Fig. 2 Map of the water system of the Yellow River Delta

2.2 Yellow River Delta

The delta of the Yellow River is located between Bo Sea Bay and Laizhou Bay in the Shandong province. It is a strongly aggrading delta with weak tidal influence. The Yellow River Delta forms the most complete and extensive young wetland ecological system in China, with abundant nature resources and a unique ecological status.

The area of the Yellow River Delta is about 750,000 hm^2. It is an internationally important wintering, stop – over and breeding site for migratory birds of the inland of Northeast Asia and around the Pacific Ocean (Barter, 2002). There are 272 species of Chinese red – list birds, such as Crested ibis, Hooded crane, Golden vulture. 65 percent of the bird species observed is protected by international agreements. Pioneer wetlands and habitats of rare birds in the Yellow River delta have an important status in the biological diversity conservation in China and the world. Therefore, the Chinese government defined a national wetland nature protection area in the Yellow River delta in 1992, which is also listed in the Chinese National Biological Diversity Protection Plan.

Although the delta is a relatively young land, land use is rapidly following because of the large land pressure in Eastern China. On October 1, 1983, a new petroleum industry city Dongying was officially established, endowed with the jurisdiction of the whole Yellow River Delta. At present Dongying has a population of over 500,000. As the second largest oil field of China, Shengli Petroleum Administration Bureau, established 1964, has many production units and facilities distributed in and around the nature reserve. From this point of view it has a close relationship with wetland management. In recent years, decreased sediment loads to the delta, canalisation of the river course to the delta and influences of urbanisation and pollution caused by oil fields, have led to a trend of rapid decrease of terrestrial wetlands in the Yellow River Delta.

2.3 Yellow River Delta National Nature Reserve

The Yellow River Delta Nature Reserve covers 153,000 hm^2. The aim of the Reserve is to protect newly – formed coastal wetland ecosystems and rare, endangered bird species. In two parts (see Fig. 3) it comprises 79,200 hm^2 of core area (dark green), 10,600 hm^2 of buffer zone (blue green) and 63,200 hm^2 of experimental zone (light green). The core area should be strictly protected, only open for scientific observation and research. The experimental zone can be used for scientific experiments, environmental education and tourism. There are still many human activities in the buffer zone due to historic reasons. Up to now, 515 oil wells are operated within the nature reserve, among which 94 in the core area, 35 in the buffer zone and 396 in the experimental zone, with an oil output of around 1.5 million tons, accounting for 4.5% of the total Shengli Oil Field production (Chen et al., 2005).

The Nature Reserve is near to a large number of local villages. Due to the remote location and saline – alkaline soil, the local people surrounding the reserve live in difficult circumstances. Thus, illegal reclamation, grazing and hunting activities frequently take place. In recent years with increased economic development and livelihood improvemeot, the market demand for seafood has increased and more and more people go to the reserve to catch fish, shrimps, crabs and molluscs – all of which exert high pressure on the reserve management. With the increasing prices of marine products, the local people have set up several markets for the purchasing and wholesale of aquatic products in different scales. According to a rough estimation, more than 8,000 persons go to the 131 km shoreline of the reserve to catch molluscs with an annual production of over 10,000 tons, and the marine products of the reserve constitute over 20% of the whole Dongying market (Chen et al., 2005). These activities are very important for local livelihood improvement yet have also caused ecological and administrative problems.

The most important characteristic of the area from the point of view of nature values is its unique ecosystem. The newly – formed wetland is the only area with such an initial ecological status in China. Among the breeding birds of the reserve, the Black – billed Gull Larus saundersi (approx 100 pairs) is an international red – list species. Many other rare and endangered species occur such as Red – crowned crane (Grus japonensis), of which about 800 arrive in the reserve each year and 200 of them winter here. The reserve is the northernmost winter staging area for this species. White Stork (Ciconia ciconia boyciana) take the reserve as a stop over station in its southward migrating in October and northward migrating in March. 700 ~ 800 of Great bustard (Otis tarda dybowskii) and 2,000 of Whooper swan (Cygnus Cygnus) are wintering here from November to April. Also 6,000 of Common crane (Grus grus) winter here from October to April.

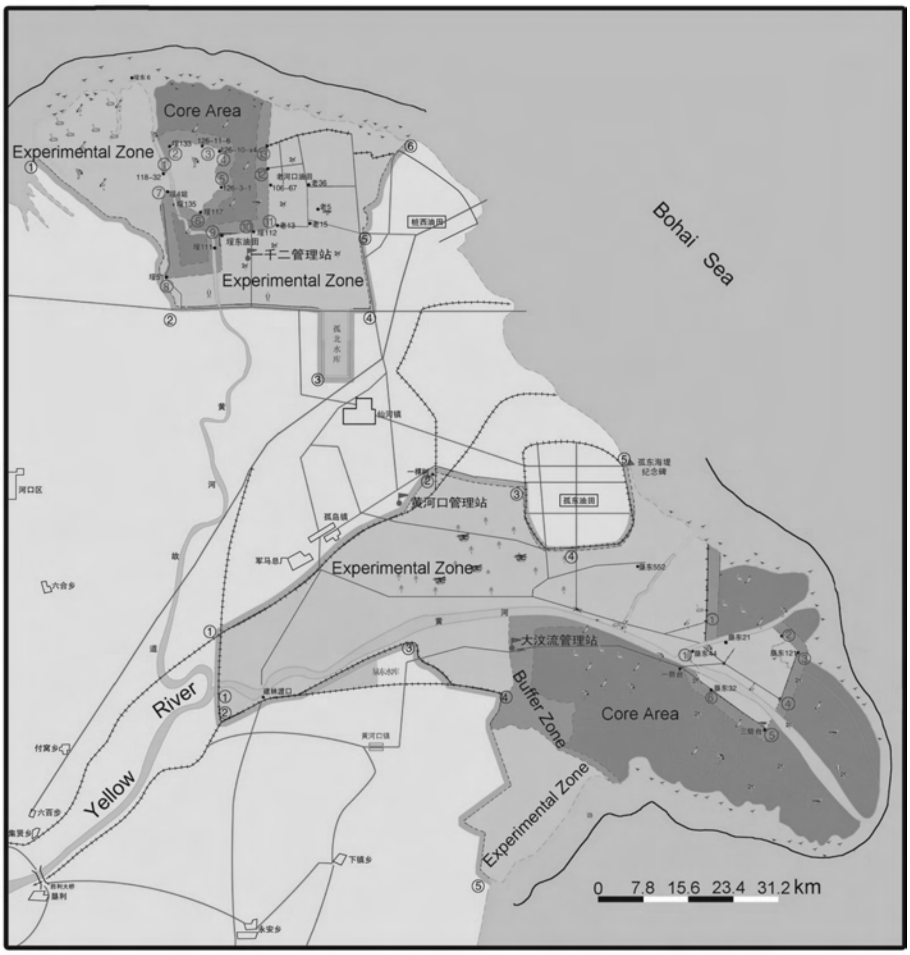


Fig. 3 The Yellow River Delta Nature Reserve

Wild Soy Bean (Glycine soja) is abundant in the reserve, which is a Chinese red – list plant species.

Because of coastal erosion, the northern part of the reserve has decreased with 50 percent in area in the recent 20 years. This may be considered a natural process: as soon as the river course has chosen a different outlet in the delta, no sediment is carried to such area any more. However, the result is harmful for the connectivity and integrity of the wetland ecosystems and the habitats that are used by rare bird species, if no other, new areas are developing elsewhere.

3 Integrated assessment

An integrated assessment of the resources of the Yellow River Delta is needed to safeguard sustainable development. However, the question is justified what is sustainable in this dynamic environment highly depending on river management in a densely populated agricultural landscape upstream.

3.1 Major weak points in the sustainable development of the area

(1) The pressure of food and energy demand by the increasing population resulted in large scale land resources exploitation in the past and present. Strong cooperation of local communities and support of authorities would be needed to safeguard the nature reserve from disturbing effects. Awareness of the ecological and landscape conditions of the reserve and adjacent regions have to be further improved with the authorities and local communities to gradually understand the value of the reserve.

(2) The fresh water deficiency poses serious problems both to land use and to sustainable development of the wetland area. Also the decrease in sediment transported by the Yellow River to the delta is a major problem, causing coastal erosion to be progressive.

(3) Last but not least the oil industry represents a major pressure on the area. Being the major economic motor of the region, it is also the main source of pollution in this area. It accounts for 40% of the total waste gas, 40% of the total waste water and 43.9% of the total industrial solid waste of Dongying Administrative unit.

3.2 Opportunities for strengthening ecological functions

As the government authority charged with wetland conservation and management, Shandong Yellow River Delta National Nature Reserve Administration Bureau has provided much support for the local community involvement in wetland management. The Bureau often holds joint meetings with local stakeholders to reach consensus on wetland management issues and achieve understanding and assistance from local people.

3.3 Developments threatening the international value of the area

A big threat of pollution and disturbance for the reserve from oil exploitation still exists. Practical cooperation is urgently needed now. The reserve can not achieve its protection objective until oil exploitation can safeguard the conditions to protect the reserve.

In addition, pollutants affect the ecosystem throughout the food chain. With the rapid development of the local economy, pollution will inevitably be a main threat to this coastal ecosystem.

4 Potentials for sustainable development of the Yellow River Delta

From the integrated assessment we deduce three key conditions to safeguard crucial ecological functions of the area, and also three key developments that may threaten its sustainable development.

4.1 Three key conditions for ecological functioning of the Yellow River Delta

For a complete wetland ecosystem in the Yellow River Delta at least three conditions should be fulfilled:

(1) For the natural succession of the delta ecosystems, sufficient fresh water and sediment from the Yellow River should be allowed to reach the delta at appropriate times of the year. Since the Xiaolangdi dam 800 km upstream was put into operation, there exists the possibility to generate ecological flows in the Yellow River.

(2) Due to the young age of terrestrial ecosystems typical for this unique delta, a complete gradient of habitat types ranging from mudflat to willow forest should always be present in the area, where the various succession stages of habitats form a pattern suitable for the target species. Such a dynamic system with shifting patterns of habitats can have an overall high performance (Van Looy et al., 2006).

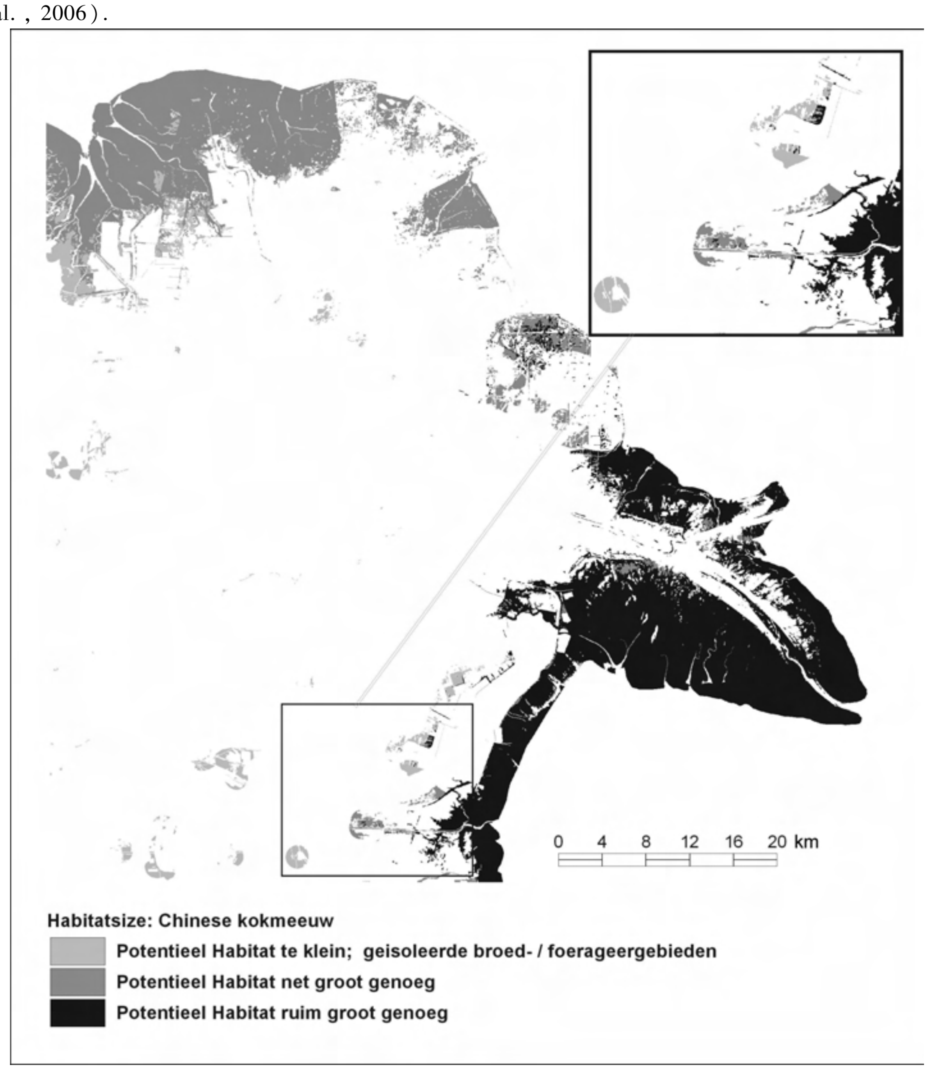


Fig. 4 Habitat suitability of the Yellow River Delta for the Sounder's Gull (Larus Saundersii). The Yellow River flows from west to east, with the mouth in the southeast. Zoomed in is on a southern partial area

(3) The environmental conditions should be conform minimum standards of water and soil quality.

4.2 Three key pressures to sustainable development of the Yellow River Delta

There are substantial threats to the functioning of a delta wetland ecosystem.

(1) The main pressure is the industrial development of the area, currently dominated by oil industry. Not only the environmental conditions are at stake here, but also the configuration and connectivity of the habitats are influenced by the infrastructural requirements of the industrial development.

(2) Second pressure is the development of land use needed to accommodate increasing population numbers.

(3) A third pressure is global change. Although the effects of climate change are not yet clear, they may be large both in terms of available fresh water from the Yellow River, and in terms of sea level change and storm surge incidence. Also predictability of the amounts of water and sediment may decrease. See Fig. 5.

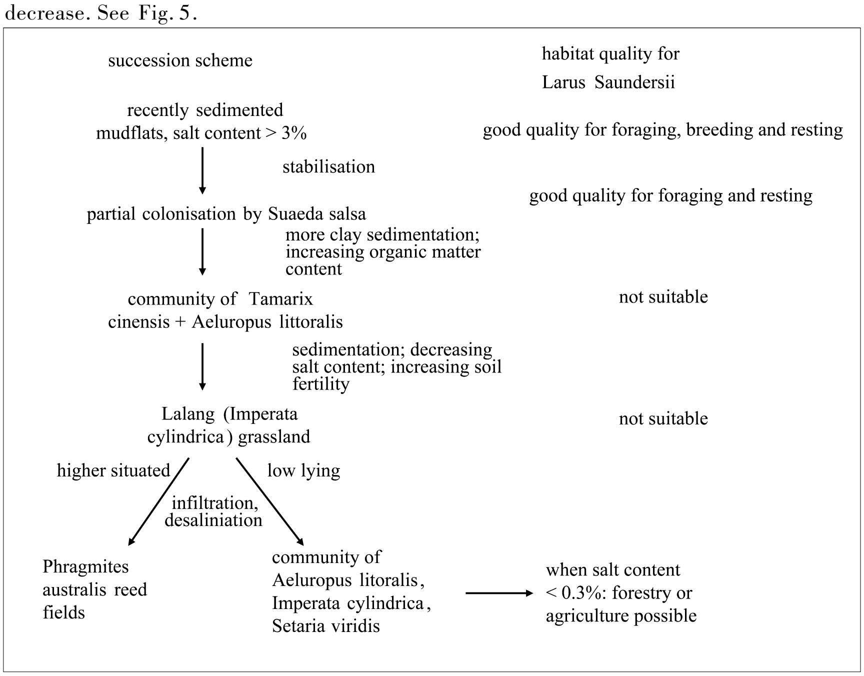


Fig. 5 Vegetation succession scheme voor de mudflats in the Delta of the Yellow River, indicating the habitat quality for the Suander's Gull (*Larus saundersii*)

4.3 Recommendations for management and further research

4.3.1 Research needed to fulfil the three key conditions

To answer the three conditions for sustainable ecosystem development, we formulate the following recommendations.

(1) A sound definition of the required quantity and timing of fresh water supply from the Yellow River is prerequisite for ecosystem functioning. For this, various strategies can account for the amount of surface area to be supplied with fresh water, which can be translated in numbers of breeding pairs or foraging individuals of the target species identified (Fig. 3). This was subject of a

recent study by the Yellow River Conservancy Commission, together with the Nature Reserve Administration, the Chinese Academy of Sciences, Alterra Wageningen UR and Delft Hydraulics.

(2) The optimal habitat configuration, which may be shifting in time but constant in surface area, should be defined using the habitat requirements of the target species identified. This is a major task of the Nature Reserve Administration, using in – depth knowledge available locally and with Wetlands International (Chen et al., 2005).

(3) Since the environmental conditions do not yet seem to be critical in most of the area – which is one of the assets of the Yellow River Delta this point is worthwhile to be strongly monitored. Here not only the area of the Reserve itself should be taken into account but the whole delta, since the target species tend to move around the whole delta.

4.3.2 Policy development required to manage the three threatening pressures

(1) Industrial development should keep pace with environmental management. This is a key challenge for the Oil industry themselves and the regional and national authorities, especially in this time of extremely high energy demand in the Chinese economy.

(2) Since the population should be able to develop a standard of living, the delta area should allow for land use to be developed. In principal this would not be a problem if the accretion of the delta would continue as natural. In that case aquacultural or agricultural land use would form a reclamation phase, following the last natural succession phase, as it has been the case for centuries and centuries along the mouth of the Yellow River. However, this not being the case when insufficient water and sediment are supplied by the Yellow River, strong regulation measures should be developed. For this, public awareness raising is urgently needed, so that the regulations could be defined in a participative process by the local communities themselves, for instance adopting wise use principles of the RAMSAR Convention.

(3) The effects of global change are less conspicuous, but it is strongly recommended to develop scenarios for changing river discharge patterns and for changing storm surges regime in the Bohai sea.

5 Conclusions

The Yellow River delta is underdeveloped in comparison with other big river deltas in China. How to promote social and economic development of the delta area in a sustainable way is now a big issue for the authorities and the community. Now China has to pay for its high economic development in last decade. The central government, Shandong provincial government and local authorities all are willing to take the Yellow River delta as an example of regional sustainable development. The Yellow River Delta Nature Reserve is the most important exponent of this development not only in the protection of newly – formed wetland ecosystems and rare and endangered bird species, but also in keeping a sound balance between the environment and economic development.

References

Barter M. Shorebirds of the Yellow Sea. Importance, Threats and Conservation Status. Wetlands International Global Series 9, International Wader Studies 12. Wetlands International, ISBN 90 5882 009 2. Chen Kelin, Yuan Jun & Yan Chenggao. Shandong Yellow River Delta National Nature Reserve. http://www.ramsar.org/cop7/cop7181cs05.doc.2005.

Geilen N., H. Jochems, L. Krebs, et al. Integration of ecological aspects in flood protection strategies: defining an ecological minimum[J]. River Research & Applications 2004, 20, 3: 269 – 283.

Guan Yuanxiu Liu Gaohuan. Remote sensing detection of dynamic variation of saline land in the Yellow River Delta[J]. Remote Sensing for Land and Resources, 2003,56(2): 19 – 22.

Kemink E., Z.B. Wang, H.J. de Vriend, et al. Modeling of flood defense measures in the Lower

Yellow River using SOBEK, International 1st Yellow River Forum on River Basin Management, Yellow River Conservancy Publishing House, Zhengzhou, China, 21 – 24 October, ISBN 7 – 80621 – 676 – 6, 2003, Vol. II: 212 – 223.

Liu Gaohuan. Integrated management of the Yellow River Delta Nature Reserve. Manuscript Chinese Academy of Sciences. 2006.

Liu Gaohuan, H. J. Drost (Eds). Atlas of the Yellow River Delta. Publishing House of Surveying and Mapping. Beijing. 1996. p80.

Pan Zhiqiang, Liu Gaohuan, Zhou Chenghu[J]. Temporal and spatial analysis of water demand of crop in the Yellow River Delta based on remote sensing. Advances in Water Science, 2005, 16(1): 62 – 68.

Pedroli, B., G. De Blust, K. Van Looy, S. Van Rooij. Setting targets in strategies for river restoration[J]. Landscape Ecology, 2002, 17(Suppl. 1): 5 – 18.

Van Looy, K., O. Honnay, B. Pedroli, S. Muller. Order and disorder in the river continuum. Continuity and connectivity contribution to biodiversity in floodplain meadows[J]. Journal of Biogeography, 2006, 33: 1615 – 1627.

Winterwerp, J. C., H. J. de Vriend, Z. B. Wang. Fluid – sediment interactions in silt – laden flow, 1st International Yellow River Forum on River Basin Management, Yellow River Conservancy Publishing House, Zhengzhou, China, 21 – 24 October 2003, ISBN 7 – 80621 – 676 – 6, 2003, II: 351 – 362.

Ye Qinghua, Liu Gaohuan, Tian Guoliang. Geospatial – temporal analysis of land – use changes in the Yellow River Delta during the last 40 years[J]. Science in China Series D, 2004, 47(11): 1008 – 1024.

Ye Qinghua, Tian Guoliang, Liu Gaohuan. Landcover succession of newly – formed wetland in the Yellow River Delta. Geographical Research, 2004, 23(2): 255 – 264.

Habitat Diversity Maintenance of Estuarine Wetland

Shang-Shu Shih[1], ***Yu-Min Hsu***[2], ***Gwo-Wen Hwang***[2] and ***Pin-Han Kuo***[1]

1. Taiwan International Institute for Water Education (TIIWE), Chian
2. Department of Civil Engineering, Taiwan University, Chian

Abstract: The historical aerial photos were used to analyze and predicted the temporal and spatial variations of the vegetation changes in Tanshui River mangrove wetland in Taiwan. The results show that habitat diversity decrease due to the mangrove (Kandelia Obovata Sheue, Liu & Young) spread. The related laws and Mai Po wetland experience were examined as well to maintain the diverse habitat. Moreover, a partial – deforest experiment in southern Shir – Tzi island is underway to study the role of mangroves in estuarine environments.

Key words: mangrove wetland, vegetation change, partial – deforest experiment

1 Introduction

This study focuses on three mangrove (Kandelia Obovata Sheue, Liu & Young) wetlands variations in Taiwan. These three estuarine wetlands located in Tanshui River and named Wa – Tzi – Wei, Chu – Wei and Guandu Nature Reserves form downstream to upstream. The schematic map shows below (see Fig. 1).

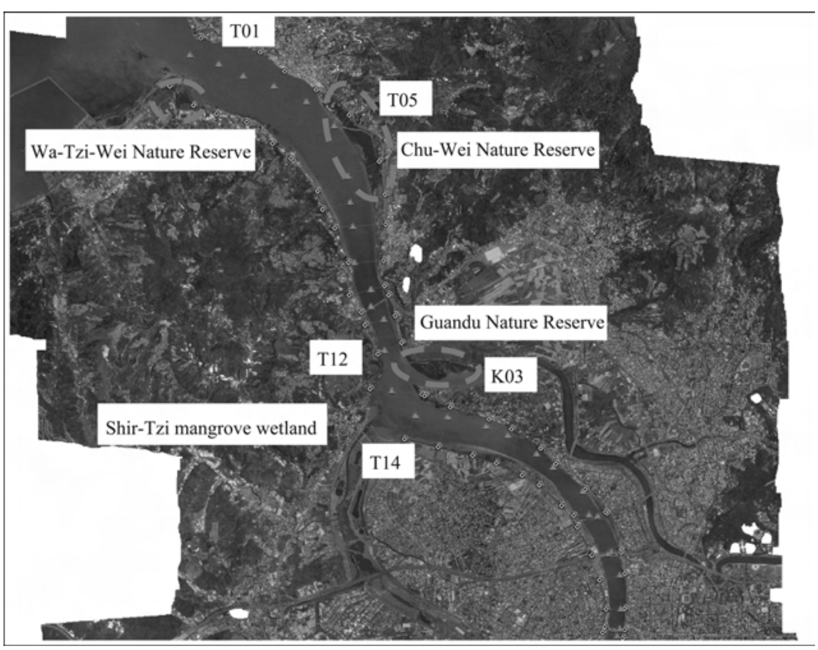


Fig. 1 The location map of three Nature Reserve Shir – Tzi mangrove wetland of Tanshui River

Mangroves are one of the most dominant vascular plants in estuarine environments due to their tolerance of high salinity and inundation and tall canopies over other plants. Besides aerial photographs classification to investigate the habitat variation, this study also examines the related regulation to manage mangrove coverage ratio. Moreover, Mai Po wetland experiences in Hong Kong are used to support the habitat diversity strategy.

2 Aerial photographs analysis

Literatures (Shih, 2005; Chang, 2000) are integrated with GIS technique in this study to classify the mangrove coverage area. ERDAS Imagine was applied to calculate the vegetation coverage area of three mangrove wetland, in which have been declared as Nature Reserves in 1986.

2.1 Guandu Nature Reserve

Fig. 2 and Fig. 3 presents the temporal variations of coverage area and coverage ratio, respectively, in Guandu Nature Reserve.

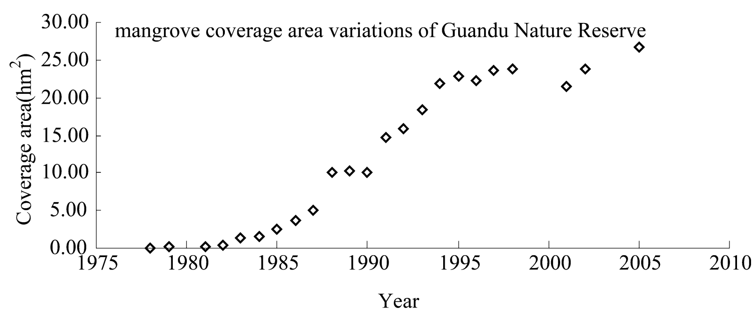


Fig. 2 Temporal variations of mangrove coverage area of Guandu Nature Reserve

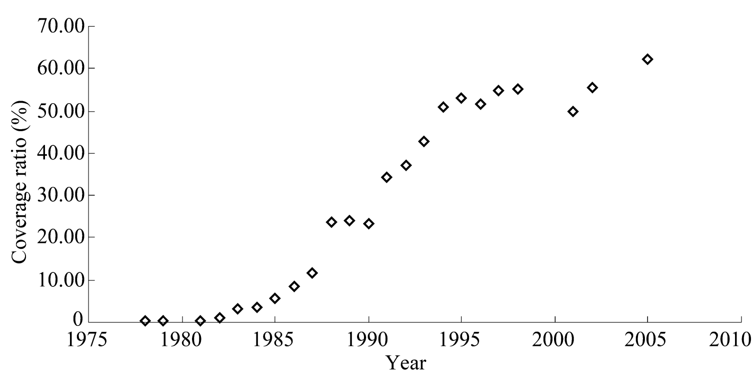


Fig. 3 Temporal variations of mangrove coverage ratio of Guandu Nature Reserve

From the data collected and calculated, both change of mangrove coverage area and ratio are positive, except the time period of 1989 ~ 1990、1995 ~ 1996 and 1998 ~ 2001. The maximum coverage ratio is about 62%. It's therefore concluded that the speed of mangrove spread would be calm while the coverage ratio is greater than 50%. Table 1 shows the increasing rate of mangrove coverage ration of different time period.

Table 1 Different time period for mangrove coverage increase of Guandu Nature Reserve

Time period	Coverage area variation per year (hm^2/a)	Increasing rate per year(%)
1978 ~ 1982	0.10	118.75
1982 ~ 1989	1.64	304.97
1989 ~ 1995	2.10	20.41
1995 ~ 1998	0.30	1.33
1998 ~ 2001	−0.79	−3.34
2001 ~ 2005	1.33	6.22
Average	1.21	24.20

* Where the coverage area variation per year = (coverage area of forward year minus backward year) / (total amount years of the time period) ; Increasing rate = (coverage area variation per year)/(coverage area of forward year).

From the results of Table 1, the mangrove coverage area is increasing from 1978 to 1998. The maximum increasing rate emerges among 1982 ~ 1989 and reaches approximately 305%. The dredge of Tanshui River, in which are also appeared during 1982 ~ 1989, seems has no significant influence decreasing the mangrove spread. Due to blight (Anoplophora chinensis (Forster)) (Shau et al. , 2000) , the increasing rate became moderate during 1998 ~ 2001.

2.2 Chu – Wei Nature Reserve

The temporal variations of mangrove coverage situations of Chu – Wei Nature Reserve are shown in Fig. 4 and Fig. 5, respectively.

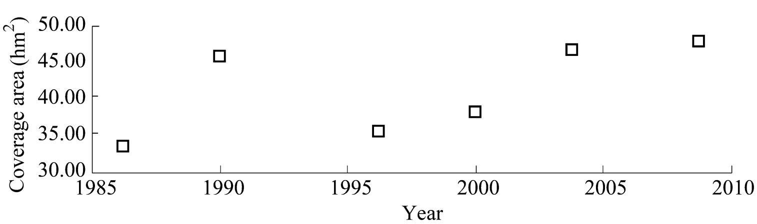


Fig. 4 Temporal variations of mangrove coverage area of Chu – Wei Nature Reserve

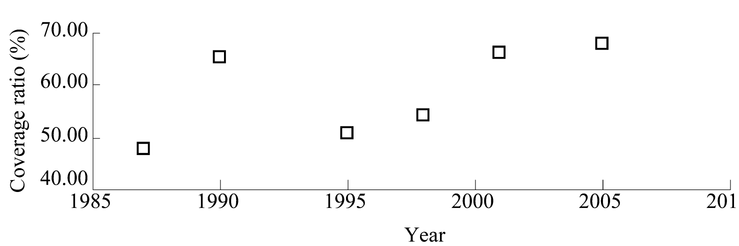


Fig. 5 Temporal variations of mangrove coverage ratio of Chu – Wei Nature Reserve

The maximum and minimum coverage ratios are about 68% and 48% , which occur in 2005 and 1987, respectively. In addition, the maximum decrease of coverage area figures from 1990 ~

1995. It's concluded that the shadow effect can suppress the mangrove spread and growth in this area and leads the maximum coverage ratio to 45% ~70%.

The increasing rate of mangrove coverage ratios of different periods are calculated in Table 2.

Table 2 Different time period for mangrove coverage increase of Chu – Wei Nature Reserve

Time period	Coverage area variation per year(hm^2/a)	Increasing rate per year(%)
1987 ~ 1990	4.11	12.23
1990 ~ 1995	–2.06	–4.48
1995 ~ 1998	0.86	2.42
1998 ~ 2001	2.81	7.36
2001 ~ 2005	0.32	0.68
Average	0.80	1.66

* Where the coverage area variation per year = (coverage area of forward year minus backward year) / (total amount years of the time period); Increasing rate = (coverage area variation per year)/(coverage area of forward year).

The negative increasing rate occurs during 1990 and 1995 which means a negative growth period of mangrove. The maximum and minimum increasing rate of mangrove coverage ratio emerges in 1997 ~ 1990 and 2001 ~ 2005, respectively.

2.3 Wa – Tzi – Wei Nature Reserve

Fig. 6 and Fig. 7 represent the mangrove coverage situations of Wa – Tzi – Wei Nature Reserve.

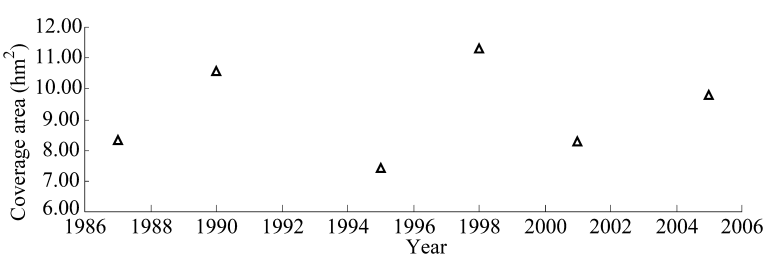


Fig. 6 Temporal variations of mangrove coverage area of Chu – Wei Nature Reserve

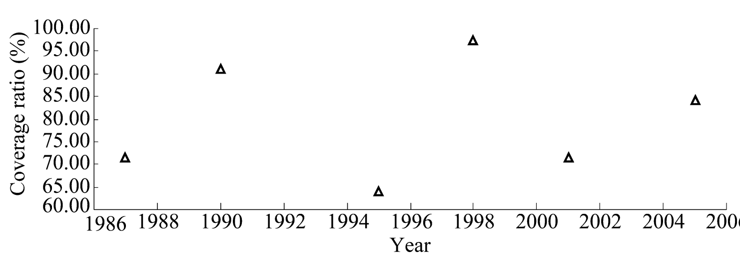


Fig. 7 Temporal variations of mangrove coverage ratio of Chu – Wei Nature Reserve

From above investigations, the mangrove coverage situations are alternative with increase and decrease of mangrove spread and growth. In other words, the mangrove coverage ratio increases during 1987 ~ 1990, 1995 ~ 1998, 2001 ~ 2005, but decreases during 1990 ~ 1995, 1998 ~ 2001. This interesting alternative phenomenon need further study to recognize the reasons behind.

The increasing rate of mangrove coverage ratio is calculated in Table 3.

Table 3 Different time period for mangrove coverage increase of Wa – Tzi – Wei Nature Reserve

Time period	Coverage area variation per year(hm^2/a)	Increasing rate per year(%)
1987 ~ 1990	0.75	9.03
1990 ~ 1995	– 0.63	– 5.95
1995 ~ 1998	1.29	17.43
1998 ~ 2001	– 1.00	– 8.84
2001 ~ 2005	0.37	4.44
Average	0.08	0.98

* Where the coverage area variation per year = (coverage area of forward year minus backward year) / (total amount years of the time period); Increasing rate = (coverage area variation per year)/(coverage area of forward year).

The maximum increasing and decreasing rate of this area occurs during 1995 ~ 1998 and 1998 ~ 2001, respectively. The tendencies of increasing characteristics in this region are totally different from Guandu and Chu – Wei Nature Reserve. The opinion of this research considers the much more serious estuarine circumstance than other two Nature Reserves, e. g. longer inundated time, higher salinity, and more violent tidal current and so on.

3 The related regulations and Mai Po experience

From field data surveyed and literature review(Lee et al., 2002; Shih, 2005), the mangrove coverage density of Guandu, Chu – Wei and Wa – Tzi – Wei Nature Reserve are approximately 3.65, 1. 35 and 3. 18 plants per meter square. Additionally, the "Regulations for artificial vegetation density in river" of Taiwan recommends the mangrove vegetation density as Table 4 indicates.

Table 4 The present vegetation density and recommended density of "Regulations for artificial vegetation density in river" of Taiwan

Site name	Present vegetation density (plant/m^2)	Recommended vegetation density (plant/hm^2)
Guandu	3.65	2
Chu – Wei	1.35	0
Wa – Tzi – We	3.18	0

The present density is far from the criterion of the regulation's suggestion. It seems that this regulation in not appropriate for stipulating the mangrove coverage density and maintain the diverse habitat.

Mai Po experience of Hong Kong therefore put to use in this research to establish the habitat diversity maintenance strategy of estuarine mangrove wetland. Management plan for the Mai Po marshes wildlife education centre and Nature Reserve 2006 ~ 2010 (WWF, 2006) states that The 2006 ~ 2010 Mai Po Management Plan is the third 5 – year Plan that has been drafted for the Reserve and was done based on the recommendations of the management plan for the larger Mai Po Inner Deep Bay Ramsar Site, advice from many experts, and the experience that WWF has gained since 1984 when they first became involved in the site's management. The inter – tidal mangroves on the estuary side of the gei wai are effectively undisturbed by people apart from dredging of the channels. However, the landward mangroves are being "invaded" by climbers, principally Derris trifoliata, which will cover and kill the mangroves if left unchecked. It is likely that this spread of D. trifoliata in recent years, is related to the silting up of the mangrove floor and eutrophication of Deep Bay (WWF, 2006). The mangrove coverage density is about 0.73 plant/m^2 of Non – gei wai area in Mai Po.

4 Mangrove deforest experiment

From related regulations assessment and Mai Po experience, we select 0.73 plant/m^2 as the preliminary maintenance objective of Tanshui River estuarine mangrove wetland. Meanwhile, a deforest experiment is established in Shir – Tzi island (also a mangrove wetland) to evaluate the recovery characteristics of mangrove, macroinvertebrate biomass investigation, water birds usage appearance in different habitat type, to study the role of mangroves in estuarine environments.

5 Conclusions

This study aims at the habitat diversity maintenance in estuarine wetland. Three Nature Reserve and Shir – Tzi mangrove wetland were investigated the present vegetation density and ideal density due to diverse habitat objective. From historical aerial photographs evaluations, the mangrove spread and growth are obviously and then reduce the habitat diversity of Tanshui River estuarine wetland. The related regulations in Taiwan and Mai Po experience of Hong Kong were also examined to obtain the desirable mangrove coverage density. The validation of this mangrove density maintenance and the role of mangrove in estuarine environment is under way study in Shir – Tzi mangrove wetland.

References

Chang C. J., 2000, Using SPOT satellite data to investigate the mangrove coverage area change, Master thesis of department of institute of fisheries science, Taiwan University.

Lee C. T., Y. B. Chen, W. L. Chiu, T. T. Lin, C. W. Chen and Y. J. Wang, 2002, The vegetation coverage variations of Guandu Nature Reserve during 1986 ~ 1998, Taiwan Journal of Forest Science 17(1): 41 – 50.

Shau G. J., W. L. Chang, W. L. Chiu, H. L. Hsieh, W. L. Wu, M. S. Chien, K. L. Ma, H. R. Liu, H. Y. Wu, P. F. Li and S. C. Lin, 2000, The environment investigation and research of Guandu Nature Park(II), Taipei Government Report.

Shih, 2005, Ecohydraulics model development and quantification of intertidal wetland, PhD thesis of department of civil engineering, Taiwan University.

WWF, 2006, Management plan for the Mai Po marshes wildlife education center and nature reserve 2006 – 2010.

Eco – based Water Quality Investigations of Jian – Chi – Chei Confluence in Tanshui River

Shang-Shu Shih[1], ***Tong-Jer Hu***[2], ***Pin-Han Kuo***[1] and ***Jin-Hao Yang***[3]

1. Taiwan International Institute for Water Education (TIIWE), China
2. Department of Civil Engineering, Lan – Yang Institute of Technology, China
3. Department of Civil Engineering, Taiwan University, China

Abstract: The eco – based water quality investigation consists of biotic organisms, e. g. fish, aquatic insect, algae, and the abiotic water quality, e. g., DO, BOD, S. S., electronic conductivity and so on. The eco – based water quality investigation results were examined the current ecological state of Jian – Chi – Chei confluence with modified ISC model. The results show that the scores of hydrology and streamside plant are relatively low which indicate the negative impact on longitudinal continuity because of reservoirs and dams along the river and only very few plants or grassland in the streamside. Among the five sub – indices, water quality reveals the highest score. Tidal effects, which influence the conductivity, may be the reason of this contradictive result. Since the DO and BOD factors, which may be more important, are not considered, the current ISC may not be able to represent the water quality properly.

Key words: eco-based water quality investigation, modified ISC model

1 Introduction

Keywords: eco – based water quality investigation, modified ISC modelRestoration is a complex endeavor that begins by recognizing natural or human – induced disturbances that are damaging the structure and functions of the ecosystem or preventing its recovery to a sustainable condition. River restoration requires an understanding of the structure and functions of stream corridor ecosystems and the physical, chemical, and biological processes that shape them (Stream Corridor Restoration, USDA, 2001). For stream restoration, the Committee on Restoration of Aquatic Ecosystems (National Science Council, 1992) suggested that decreasing the stresses of stream and river can directly improve stream ecological environment and achieve the objective of stream rehabilitation.

This study tries to address a whole new idea of environment condition base on eco – based investigation and analysis. Biotic and abiotic indicator of Jian – Chi – Chei confluence are investigated and put into a modified ISC model (Hu et al., 2007). The analyzing outcomes could provide further study and related government administrations for making decision in the future. The location map of the study area is presented in Fig. 1.

2 Literature review for water quality variation

Jian – Chi – Chei confluence located in the convergence of Ta – Han Creek and Hsin – Dien Creek, and whether named as Tanshui River from this place. As the data collected through the website of Environmental Protection Agency in Taiwan and the research of Shih et al. (2006), the most polluted river section of Tanshui River System appears in Jian – Chi – Chei confluence. Please refer to Fig. 2 to see the pollutant condition of Tanshui River System.

The sediment and pollution deposited in this region is a long term problem which may result from the lower ability of pollutants transport due to the wider channel with lower velocity. Meanwhile, large amount pollutants from industrial park or general family influx into Ta – Han Creek and makes this creek been polluted river. In opposition to this bad water quality condition, Jian – Chi – Chei has large amount delta formation due to natural sediment deposition. The tidal creek within the delta island can supply migrant birds' usage for resting and hunting. Therefore, this study attempts to figure out the integrity between ecological habitat condition and abiotic water quality. Three eco – based water quality indices were selected to present biota condition or river, i. e. IBI, FBI, and GI. Fish are good indicators of long – term effects and broad habitat conditions because they are relatively long – lived and mobile (Karr et al., 1986). Fish assemblage structure is reflective of integrated environmental health. Karr's IBI was used to assess the fish community assemblage (Karr, 1981, 1991; Karr et al., 1986). See Table 1.

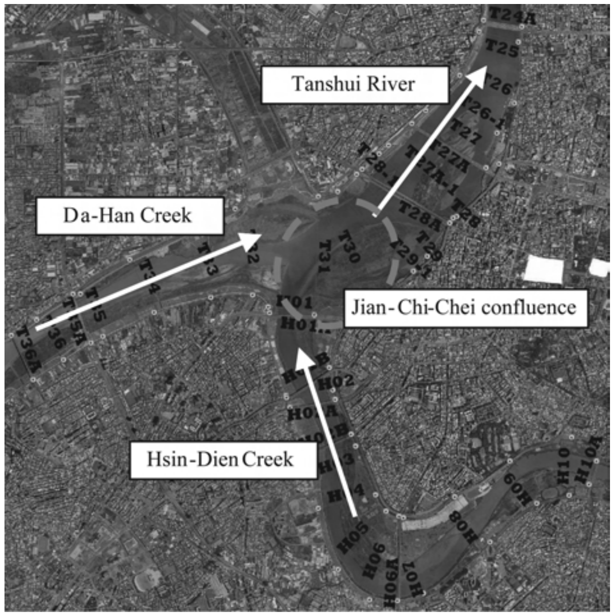


Fig. 1 The location map of Jian – Chi – Chei confluence in Tanshui River

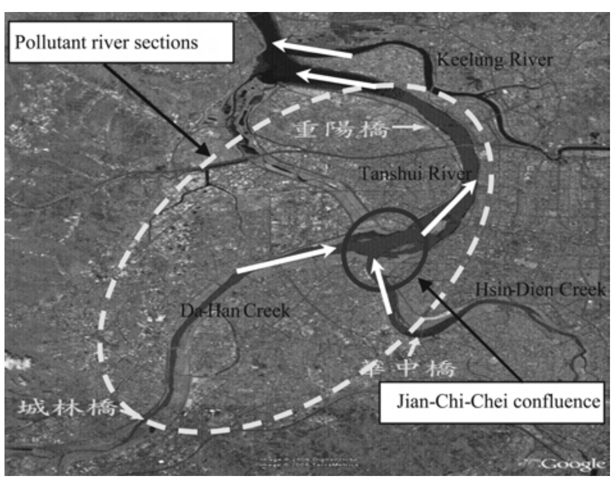


Fig. 2 The schematic map for the pollutant river sections of Tanshui River System

The FBI (Hilsenhoff, 1988) aquatic insects Hilsenhoff index (Family – level Biotic Index) is evaluated by the Benthic macroinvertebrates samplings. Benthic macro – invertebrate integrate the effects of middle – term environmental variations. See Table 2.

Table 1 Metrics used to assess biological integrity of fish communities based on Index of Biotic Integrity (IBI) (Hu et al., 2007; Karr, 1981, 1991; Karr et al., 1986)

Metrics	Scoring criteria		
	5	3	1
Species richness and composition			
1. Total number of fish species	310	4 ~ 9	0 ~ 3
2. Number of darter species	33	1 ~ 2	0
3. Number of sunfish species	32	1	0
4. Number of sucker species	32	1	0
5. Number of intolerant species	33	1 ~ 2	0
Trophic composition			
6. Percent of individuals as omnivores	< 60	60 ~ 80	> 80
7. Percent of individuals as insectivorous	> 45	20 ~ 45	< 20
Fish abundance and condition			
8. Number of individuals in sample	3,101	51 ~ 100	0 ~ 50
9. Number of hybrids or exotics species	0	1	32

Table 2 Family – level Biotic Index (FBI) values and levels (Hu et al., 2007)

Level	Values	Grade
Excellent	0 ~ 3.75	A
Very good	3.76 ~ 4.25	B
Good	4.26 ~ 5.00	C
Fair	5.01 ~ 5.75	D
Fairly poor	5.76 ~ 6.50	E
Poor	6.51 ~ 7.25	F
Very poor	7.26 ~ 10.00	G

Aquatic algae generally have rapid reproduction rates and very short life cycles, making them valuableindicators of short – term impacts. Genus Index (Wu, 1999; Wu and Kow, 2002), the ratio of abundance of Achnanthes, Cocconeis, and Cymbella to that of Cyclotella, Melosira, and Nitzschia, was thus used to analyze (Hu et al., 2007). The use of GI has the advantage that only identification to generic level is required, while the majority of conventional indices require identification to species. The relationship between the score and level is shown in Table 3.

Table 3 Generic Index (GI) scores and levels (Hu et al., 2007)

GI	Score range	Grade
Mildly polluted	> 30	A
Slightly polluted	30 > GI > 11	B
Gently polluted	11 > GI > 1.5	C
Moderately polluted	1.5 > GI > 0.3	D
Severely polluted	GI < 0.3	E

3 Eco – based filed survey and modified ISC model

3.1 Field survey

Field survey has been done at eight sites along Tanshui River. In this research, four among a total of eight (Fig. 2) are selected to represent the evaluation results. At each study site, field sampling procedures included an integrated assessment, which focused on the evaluation of physicochemical water quality, habitat parameters, and analysis of fish, benthic macroinvertebrates, and algae assemblages. Water samples were analyzed for turbidity, dissolved oxygen, pH, total phosphorus, and conductivity. Physical characterization included documentation of general land use, qualitative description of stream condition, summary of the riparian vegetation features, and measurements of instream parameters that included width, depth, flow, and substrate. Fishes were collected by electro fisher (8 A/12 V) (Hu et al., 2007). The collections were limited 100 m at one side per sampling site. Collected fish were held in aerated buckets for identification, enumeration, and fish length measurements. Species that could not be identified in the field were preserved with 10% formalin and stored until laboratory identifications could be made.

Remaining fish were returned to the stream after all collections were completed. Benthic macroinvertebrate assemblages were sampled initiated at the downstream boundary of each site and proceeded upstream utilizing Suber net sampler within the 100 m reaches by collecting three jabs. Samples were preserved in 10% formalin for identification. Each organism was identified to family level. Algae were collected from cobbles or boulders randomly sorted from each site. A tooth brush was used to remove diatom films from an area of ca. 100 cm^2 on cobbles or boulders. After dissolving and filtering, specimens are preserved in a 3% ~ 5% formalin solution for subsequent laboratory identification. The integration of structural and functional characteristics of community assemblages allowed for the evaluation of instream responses to stressors and impairments as detected by species diversity metrics. Assessment of fish, benthic macroinvertebrates, and algae communities provided insight into the relative condition of the receiving stream (Hu et al., 2007).

3.2 ISC model

ISC was developed in 1995 and then applied in Australia and other regions (Ladson et al., 1999) as an integrated measure of the state of a stream. The ISC is based on an assessment of five components of streams. Each of these components (a sub – index) is given a score based on the assessment of a number of indicators. ISC has been applied in Da – Kuo stream in Taiwan to check the effect of engineering. However, the necessity of modifying the ISC for reasonable use in Taiwan was proposed (Chou and Huang, 2003). The modification and development included reviewing previous assessment methods, and consulting with experts with knowledge of hydrology, geomorphology, aquatic ecology, riparian vegetation and function, water quality, and river management policy and practice. Results from the trials were discussed with Water Resources Agency (WRA) to make it more reliable.

Seventeen indicators in the modified – ISC were used to quantify aspects of stream condition. Related indicators made up each sub – index, i. e. hydrology, physical form, streamside zone, water quality, and aquatic life (Hu et al., 2007). The indicators determined the actual measurements that are required and these measurements are the basis of the indicator ratings. Considering the minimum amount of flow discharge to maintain the aquatic life is an important issue especially in a place with highly variable rainfall conditions as in Taiwan (Wang et al., 2000; Chou and Huang, 2003). Therefore, the indicator of baseflow requirement is added in the hydrology sub – index to rate this aspect. Because of the degree of diversity in a river and flexibility of most aquatic organisms, there is probably no such sharp cut – off or single minimum flow. The "baseflow requirement" indicator used in the ISC is a way to examine if the concept of minimum flow is taken into account when operating the artificial structures, which usually just consider the human needs.

In the evaluation of aquatic life, the biotic components with different life spans which respond differently to certain stressors were used as the input to understand the ecosystem. Based on the field survey and the calculation above, IBI, FBI, and GI obtained were used as the input to the aquatic life sub – index. The overall ISC score is the sum of sub – index scores and is between 0 and 50, the higher scores indicating better condition. Fig. 3 summarizes the basis for each of these sub – indices and the chosen indicators. ISC scores and its corresponding grade are shown in Table 4.

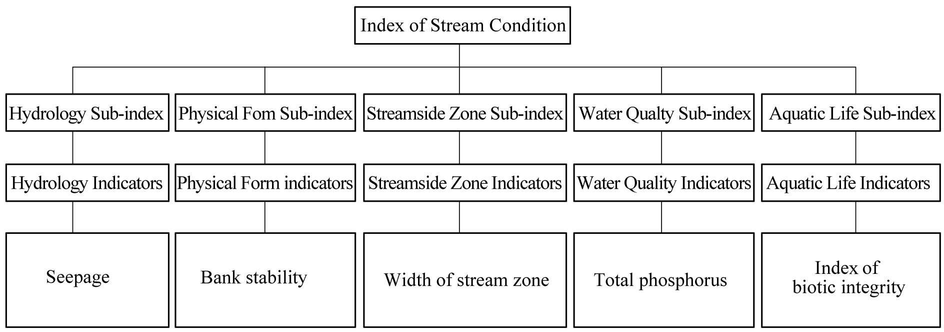


Fig. 3 Modified indicators under five sub – indices (i. e. hydrology, physical form, streamside zone, water quality, and aquatic life) used to assess the integrated measure of environmental condition based on the Index of Stream Condition (ISC). The maximum of each sub – index is 10. (Hu et al., 2007)

Table 4 Measurements and evaluation of the Index of Stream Condition (ISC) (Hu et al., 2007)

ISC scores	Evaluation	
45 ~ 50	Excellent	A
35 ~ 44	Good	B
25 ~ 34	Marginal	C
15 ~ 24	Poor	D
< 14	Very poor	E

(1) HY sub – index (Hydrology). The hydrology sub – index HY = SEEPAGE + DAM + BASEFLOW. Considering relatively natural riverbed, the score of "SEEPAGE" was assigned as 2; more than 6 dams built in Hsin – Dien Creek and Da – Han Creek, and no fish ladders constructed, the score of "DAM" was assigned as 0; there are two reservoirs existed in watershed of Tanshui River System more than 20 years, and not enough ecological baseflow influx into river, the score of "BASEFLOW" was assigned as 0. Therefore, HY sub – index in this research was calculated as 2.

(2) PF sub – index (Physical Form). The physical form sub – index $PF = \frac{10}{16}\left[\frac{1}{N_f}\sum_{f=1}^{X_f}(BANKS_f) + BEDS + IPHAB + AB_f\right]$. From field data surveyed, the PF sub – index in this research was calculated as 5 points.

(3) SZ sub – index (Streamside Zone). The streamside zone sub – index SZ = WIDTH + CONTINUITY + CEV. From the aerial photos investigated, along Jian – Chi – Chei confluence, only few riparian vegetations existed, therefore resulting in the score of "WIDTH" as 0; the score of "CONTINUITY" was also assigned as 0; from vegetation coverage investigation, the invasive alien plants consists more than 40%, the score of "CEV" was assigned as 0 consequently.

(4) WQ sub – index (Water Quality). As the data collected through the website of Environmental Protection Agency in Taiwan and the research of Shih et al. (2006), the average value of WQ sub – index is equal 5.8.

(5) AL sub – index (Aquatic Life). Hu et al. (2007) recommended the aquatic life sub – index AL = 1/3(IBI + FBI + GI). From eco – based investigations and evaluations, the scores or IBI, FBI and GI were 16, 8 and 0.06, respectively. Hence, the value of AL sub – index is equal to 3.9.

Integrating above 5 sub – indices, the value of ISC can be calculated as 18, and illustrated in Fig. 4. Since the ISC value is greater than 14 and less than 25, the present aquatic environment is under the grade of "POOR".

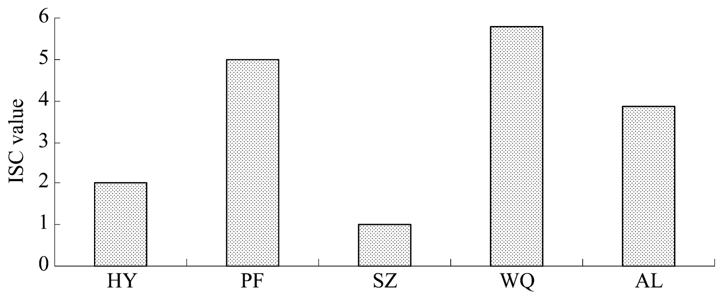


Fig. 4 The scores of each sub – index of ISC

4 Conclusions

Human impacts on the biological integrity of water resources are complex and cumulative (Karr, 1981). Karr (1981) states that human actions jeopardize the biological integrity of water resources by altering one or more of five principal factors—physical habitat, seasonal flow of water, the food base of the system, interactions within the stream biota, and chemical quality of the water. These factors which can be addressed in environmental management require a measurement of ecosystem health. Biological assessment addresses ecosystem health and cumulative impacts by concentrating on population and community level. U. S. EPA advises incorporating more than one assemblage into bio – criteria programs whenever practical. The results show that the scores of hydrology and streamside plant are relatively low which indicate the negative impact on longitudinal continuity because of reservoirs and dams along the river and only very few plants or grassland in the streamside. Among the five sub – indices, water quality reveals the highest score. Tidal effects, which influence the conductivity, may be the reason of this contradictive result. Since the DO and BOD factors, which may be more important, are not considered, the current ISC may not be able to represent the water quality properly. Meanwhile, in accordance with the pollutant river alike this paper, we recommend that IBI can represent or replace the aquatic life sub – index (AL).

References

Chou, C. M., Huang, S. M., 2003, The evaluation process of ecological engineering method by Index of Stream Condition. J. Chin. Soil Water Conserv. 34 (1): 25 – 39.

Hilsenhoff, W. L., 1988, Rapid field assessment of organic pollution with a Family – level Biotic Index. J. N. Am. Benthol. Soc. 7:65 – 68.

Hu, T. J., H. W. Wang and H. Y. Lee, 2007, Assessment of environmental conditions of Nan – Shih stream in Taiwan, Ecological Indicators 7 (2):430 – 441.

Karr, J. R., 1981, Assessment of biotic integrity using fish communities. Fisheries 6:21 – 26.

Karr, J. R., Fausch, K. D., Angermeier, P. L., Yant, P. R., Schlosser, I. J., 1986, Assessing biological integrity in running water: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5:1 – 28.

Karr, J. R., 1991, Biological integrity: a long – neglected aspect of water resource management. Ecol. Appl. 1 (1): 66 – 84.

Ladson, A. R., White, L. J., Doolan, J. A., Finlayson, B. L., Hart, B. T., Lake, P. S., Tilleard, J. W., 1999, Development and testing of an Index of Stream Condition for waterway management in Australia. Fresh Water Biol. 41 (2):453 – 468.

National Science Council, 1992, Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. National Academy Press, Washington, DC, pp. 8 – 15.

Shih, S. S., C. P. Chen, T. J. Hu, M. F. Ya, H. W. Wang, G. W. Huang and J. H. Yang, 2006, Evaluating Habitat Quality and Flood Impact of Jian – Chi – Chei Confluence in Tanshui River System, Taiwan International Institute for Water Education (TIIWE).

USDA, 2001, Stream Corridor Restoration: Principles, Processes, and Practices. The Federal Interagency Stream Restoration Working Group (FISRWG).

Wang, C. M., Lin, W. Y., Ko, S. Y., Chuang, C. K., Tu, Y. Y., Tsai, H. H., 2000, Phase study of ecology and fish cinservation around Li – Chi Stream of Cho – Shui River System. Monthly J. Taipower's Eng. 91 – 111.

Wu, J. T., 1999, A Generic Index of diatom assemblages as bioindicator of pollution in the Keelung river of Taiwan. Hydrobiologia 397: 79 – 87.

Wu, J. T., Kow, L. T., 2002, Applicability of a Generic Index for diatom assemblages to monitor pollution in the tropical river Tsanwun, Taiwan. J. Appl. Phycol. 14:63 – 69.

Delta Formation to Flood – Risk Raising Evaluation in Tanshui River

Shang-Shu Shih[1] **,*Gwo-Wen Hwang***[2] and ***Jin-Hao Yang***[2]

1. Taiwan International Institute for Water Education (TIIWE), China
2. Department of Civil Engineering, Taiwan University, China

Abstract: The purpose of this study was to evaluate the flood prevention, in – stream sediment deposition in the area of Jian – Chi – Chei confluence in Tanshui River. By using quasi two – dimensional model – NETSTARS, the safety consideration and sediment transport behavior has been investigated. The results reveal that there is no risk of flood protection. The flood water level only decreases 9 cm if the amount of in – stream sediment deposition causing to delta formation has been removed. From the historical aerial photo classification, sediment deposition in this area is a long term problem which may result from the lower ability of sediment transport due to the wider channel with lower velocity.

Key words: numerical simulation, sediment deposition, delta formation

1 Introduction

The main purpose of this study is to calculate whether flood risk raise due to delta formation of Jian – Chi – Chei confluence in Tanshui River. While delta formation in confluences might increase the flood risk, the delta island can provide water birds' habitat for resting and feeding. Therefore, if there's no flood risk resulting delta formation, the delta island is suggested to be reserved. Both of the aerial photographs classification and numerical model simulation are integrated. Quasi – two – dimensional model, NETSTARS, was used to investigate the flood risk and sediment transport characteristics. The location map of the study area is presented in Fig. 1.

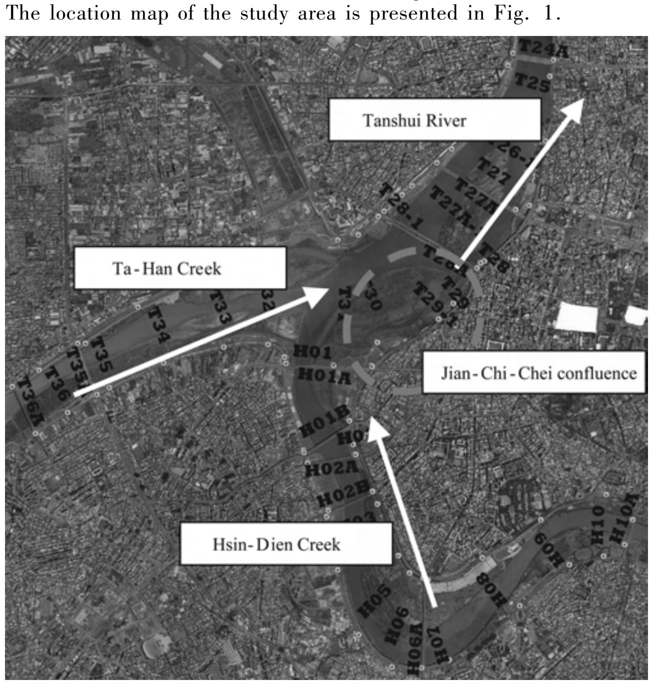


Fig. 1 The location map of Jian – Chi – Chei confluence in Tanshui River

2 Analysis of aerial photograph

Fig. 2 ~ Fig. 6 indicate the historical Jian – Chi – Chei confluence, which has been orthorectificated, of 2005, 2003, 2002, 1997 and 1992's aerial photographs, respectively.

Fig. 2 The aerial photo of Jian – Chi – Chei confluence in 2005

Fig. 3 The aerial photo of Jian – Chi – Chei confluence in 2003

Fig. 4 The aerial photo of Jian – Chi – Chei confluence in 2002

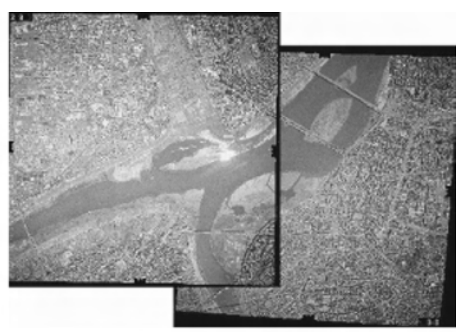


Fig. 5 The aerial photo of Jian – Chi – Chei confluence in 1997

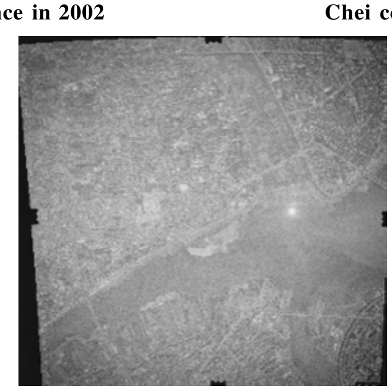


Fig. 6 The aerial photo of Jian – Chi – Chei confluence in 1992

The confluence delta formation was distributed into five pieces of delta islands. The schematic map of serial numbers of these five delta islands are shown in Fig. 7.

Fig. 7 The serial number of each delta island of Jian – Chi – Chei confluence in Tanshui River

Table 1 shows the area of each piece of delta island in different specific time. Besides, Fig. 8 represents the temporal variations of total amount of area of five pieces of delta islands.

Table 1 The area of each piece of delta island in different specific time

Delta island	Area(m^2)				
	1992	1997	2002	2004	2005
No. 1	*	53,831	36,565	58,412	21,812
No. 2	*	198,677	174,044	228,213	165,279
No. 3	*	842,524	200,498	1,123,902	342,281
No. 4	539,218		443,112	437,449	
No. 5	*	138,019	89,527	278,465	119,678
Summary	539,218	1,233,053	943,748	1,688,993	1,086,500
* Note	High tide	Low tide	High tide	Low tide	High tide

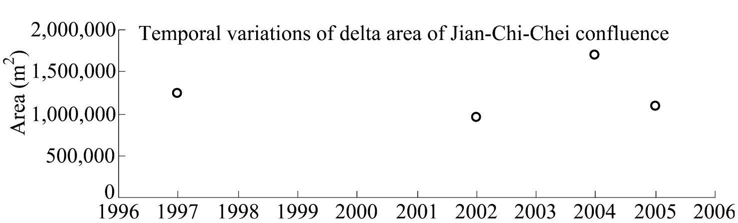


Fig. 8 Temporal variation of total amount of delta islands' area of Jian – Chi – Chei confluence

The maximum area appears in 2004, while the minimum area emerges in 2002. The typhoon Aere also occurs in 2004 summer and brings terrible damage to Taiwan, in which large amount sediment deposited in Jian – Chi – Chei confluence as well. That's why 2004's delta island area is largest. Besides, No. 1, 2, 3 and 5's delta island are not available in year 1992' s aerial photos cause of high tide level submerge most of delta island.

Although different water level of each specific time, the delta island area are not different significantly. Moreover, the delta island of Jian – Chi – Chei confluence could be investigated in year 1947's aerial photo, which was shown in Fig. 9 (Shih, et al., 2006). We therefore concluded that the confluence delta island has existed more than sixty years. The sediment deposition in this region is a long term problem which may result from the lower ability of sediment transport due to the wider channel with lower velocity.

Fig. 9 Year 1947's aerial photograph of Jian – Chi – Chei confluence (Shih et al., 2006)

3 Numerical model simulations

3.1 Introduction to numerical models

The hydraulic routing portion of this model is similar to NETSTARS (Lee et al., 1996), a model which is able to simulate the scour and deposition behavior of a channel network. The NETSTARS model is an uncoupled sediment routing model. It consists of two major parts, namely hydraulic routing and sediment routing. Suspended load and bed load are treated separately in sediment routing. A computation procedure is designed so that the split operation method can be utilized in a channel network. A brief description of the model is provided as follows; please refer to Lee et al. (1996) for detailed information.

Governing Equations: The Saint Venant equations are used in the unsteady flow computation. These include a continuity equation and a one – dimensional momentum equation:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \tag{1}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\alpha \frac{Q^2}{A}\right) + gA\frac{\partial y}{\partial x} + gAS_f - V_l q = 0 \qquad (2)$$

where: A is channel cross – sectional area; Q is flow discharge; t is time; x is coordinate in the flow direction; q is lateral inflow/outflow discharge per unit length; α is momentum correction coefficient; g is gravitational acceleration; y is water surface elevation; $S_f = Q|Q|/K^2$ is friction slope; $K = \frac{1}{n}AR^{2/3}$ is channel conveyance; n is roughness coefficient of Manning's formula and R is hydraulic radius; V_l is velocity component in the longitudinal direction of the lateral inflow/outflow. Equations and are transformed into difference equations using a Preissmann four points finite difference scheme.

3.2 Results and discussion

Six cases were designated for considering with and without dredge of each delta island that are described in Table 2.

Table 2 Six dredge cases description of Jian – Chi – Chei confluence

Case symbol	Dredge description	Related cross section	Dredge amount (m^3)
Case0	No dredge; present condition	*	0
Case1	Dredge no. 1 delta island	T26 – 1、T27、T27A	3,416,585
Case2	Dredge no. 2 delta island	T +27A – 1、T28、T28 – 1、T28A	3,718,431
Case3	Dredge no. 3 and 4 delta islands	T29、T29 – 1、T30、T31	5,110,795
Case4	Dredge no. 5 delta island	T32、T33	1,718,405
Case5	Dredge all the delta islands; ultra condition	T26 – 1 – T33	13,964,216

Under the steady – state hydraulic simulation case, the upstream and downstream boundary conditions, including 200 years return period floods discharge and the river mouth water surface elevation, were cited from the investigations conducted by the Water Resources Agency, Taiwan (1996). Meanwhile, the upstream and downstream boundary conditions of sediment transport simulations are provided in Fig. 10, Fig. 11 and Fig. 12, respectively. (Lee and Shih, 2004)

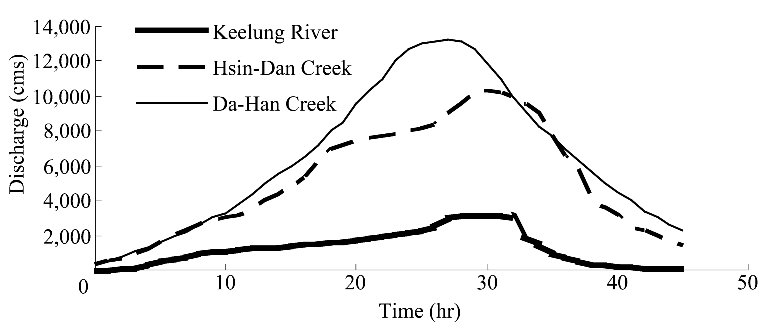


Fig. 10 The 200 – year flood hydrograph of Tanshui River System. (Lee and Shih, 2004)

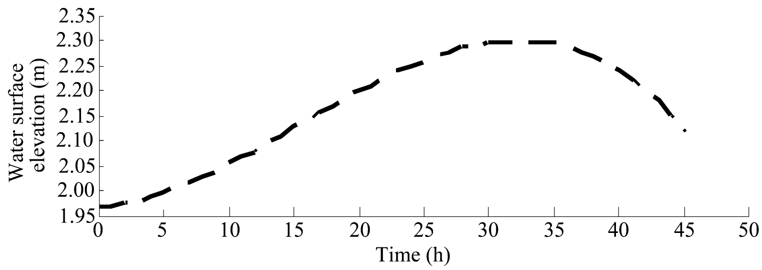


Fig. 11 Temporal variations of the water surface elevations at the river mouth during a 200 years flood event. (Lee and Shih, 2004)

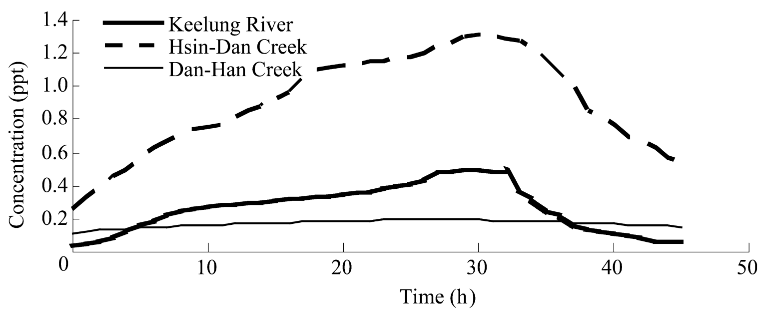


Fig. 12 The upstream sediment supplies of the Tanhsui River System, which includes. Keelung River, Hsin – Dan Creek and Dan – Han Creek, respectively

Hydraulic simulation: The hydraulic simulation results are presented in Table 3.

Table 3 The 200 years return period flood simulation results of Tanshui River

Crossection number	Water sufale elevation (m)					
	case0	case1	case2	case3	case4	case5
T026 – 1	7.16	7.16	7.16	7.16	7.16	7.16
T027	7.20	7.20	7.20	7.20	7.20	7.20
T27A	7.25	7.23	7.25	7.25	7.25	7.23
T27A – 1	7.31	7.27	7.29	7.31	7.31	7.26
T028	7.34	7.30	7.32	7.34	7.34	7.28
T028 – 1	7.35	7.31	7.32	7.35	7.35	7.28
T28A	7.37	7.33	7.33	7.37	7.37	7.29
T029	7.39	7.35	7.35	7.40	7.39	7.32
T029 – 1	7.43	7.39	7.39	7.43	7.43	7.35
T030	7.50	7.46	7.46	7.49	7.50	7.42
T031	7.54	7.51	7.50	7.53	7.54	7.45
T032	7.54	7.50	7.50	7.53	7.54	7.45
T033	7.70	7.67	7.66	7.69	7.70	7.62

The water surface elevation of present condition (case0), which is about 7.5 m, is much smaller than the dyke elevation along the river, which is approximately 10 m. It's therefore concluded that there's no risk with present circumstance. In addition, compared with present condition, the maximum reduction of water surface elevation of ultra condition (case5) is only 9 cm. In other words, the dredges of delta islands are not appropriate due to flood risk considerations. On the contrary, reduction of island elevation and dredge of tidal creek are recommended to supply better habitat for water birds usage.

Sediment transport simulation: Fig. 13 and Fig. 14 provide the results of sediment transport simulation, which represent Yang's formula (Yang, 1984) for total load routing and Mayer – Peter and Muller's formula (MPM) (Mayer et al., 1948) for bed load routing.

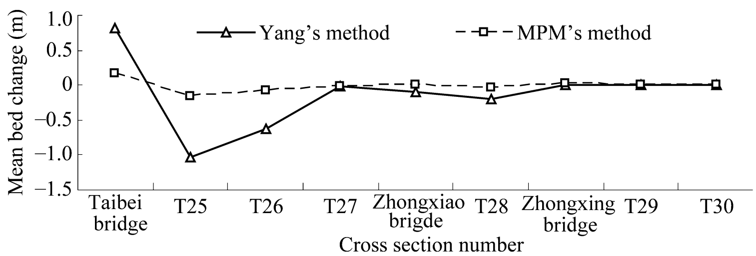


Fig. 13 Mean bed changes after 200 year return period flood hydrograph

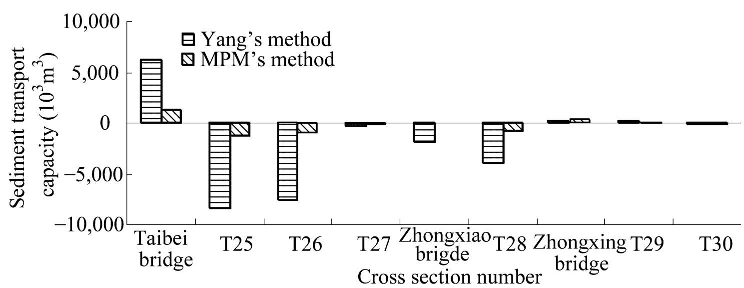


Fig. 14 Sediment transport capacity variations after 200 year return period flood hydrograph

The results reveal that bed change of Yang's method is more significant than MPM's method. Due to this region belong to river downstream, the concentration of suspended load is relatively high during flooding period. In this region, the bed load routing outcomes, i.e. MPM formula, is more reasonable than the total load routing outcomes, i.e. Yang's formula. In another words, both bed change and sediment transport capacity variation results point out that the Tanshui River is under stable slope of riverbed.

4 Conclusions

This study tries to evaluate the flood risk casing from delta formation. The simulation results indicate that there's no risk to the present flood protecting ability. Even remove (dredge) all the delta islands, the water surface elevation only reduce 9 cm, a very tiny benefit of flood demand. From the aerial photos collected and analyzed, we also find out that the delta formation of Jian – Chi – Chei confluence is a long term problem. More important thing is that ecological habitat construction. Reduction of island elevation and dredge of tidal creek are recommended to provide better habitat for water birds usage for resting and feeding.

References

Lee, H. Y. and S. S. Shih, 2004, Impacts of vegetation changes on the hydraulic and sediment transport characteristics in Guandu mangrove wetland, Ecological Engineering, 23(2):85 –

94.
Lee, H. Y. , W. S. Yu and S. J. Wang, 1996, Hydraulic, water quality and sediment transport characteristics of estuarine river (I), Hydrotec Research Institute of Taiwan University.
Lee, S. Y. , 1998, Investigations of tidal characteristics and simulation of an estuarine channel network, PhD thesis of Department of Civil Engineering, Taiwan University.
Meyer – Peter, E. and R. Muller, 1948, Formulas for Bedload Transport, IAHR, 2nd Meeting, Stockholm.
Shih, S. S. , C. P. Chen, T. J. Hu, M. F. Ya, H. W. Wang, G. W. Hwang and J. H. Yang, 2006, Evaluating Habitat Quality and Flood Impact of Jian – Chi – Chei Confluence in Tanshui River System, Taiwan International Institute for Water Education (TIIWE).
Water Resources Agency, 1996, Construction of Tanshui River model and assessment of Taipei flood protection ability project.
Yang, C. T. , 1984, Unit Stream Power Equation For Gravel, Journal of the Hydraulics Engineering, ASCE, 110(12):1679 – 1704.

Wise Use of Freshwater for Wetland Restoration in the Yellow River Delta Nature Reserve

Shan Kai and ***Lu Juanzhang***

Yellow River Delta Nature Conservancy, Dongying, 257091, Shandong, China

Abstract: The Yellow River Delta nature reserve is a kind of new – born wetland ecosystem nature reserve, featured by youth, frangibility and instability. With the influence from nature factor and human activities, some wetland area is degraded. Based on the analysis of new – born wetland ecosystem and ecosystem succession trend, the reasons of degradation are given and the importance of freshwater from the Yellow River is explained. To restore the degraded wetland, wise use of freshwater is the vital method. The article takes wetland restoration as example to show how to wisely use freshwater, introduce the objective, theory, means and project design for wetland restoration.

Key words: Yellow River Delta, wetland degraded, succession, freshwater, wetland restoration

The Yellow River Delta nature reserve (as YRDNR) is located in the mouth of the Yellow River to the BohaiHai sea, Dongying City, Shandong Province, with the geographical position from 118°33′ ~ 119°20′E to 37°35′ ~ 38°12′N. The total area is 153, 000 hm^2. Current Yellow River mouth is included in the YRDNR. Due to deposition of large quality of sand and mud carried by Yellow River, new – born wetland is formed year by year which makes YRDNR one of the most rapid land expanding reserves in the world[1]. The YRDNR is mainly involved in the conservation of new – born wetland ecosystem and rare and imminent – dangered waterfowl.

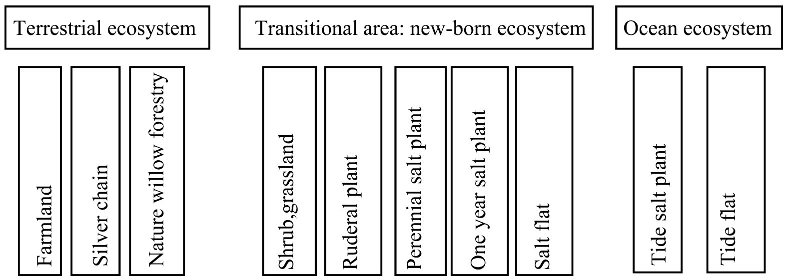
1 Ecology character

1.1 Ecology background

The Yellow River enters into Bohai Sea in the YRDNR, Where the deposition of large quantity of sand and mud in the estuary forms extensive wetland. As a new – born wetland ecosystem, YRDNR has three features. Firstly, wetland ecosystem is very young. Due to the young age of terrestrial land, various plant resources are still in the initial stage of succession and development. Secondly, the ecosystem is very frangible. As a transitional area from terrestrial ecosystem to ocean ecosystem, river and sea directly affect its stability, the zero flow of the Yellow River, storm tide, sea level rise, drought and human activities are the threatening factors which could make YRDNR in frangible state. Thirdly, the ecosystem keeps unstable. The new – born wetland is in its immature state as the formation, development and ecosystem succession are easily affected by human disturbance and eco – environment change.

1.2 Ecosystem succession

As a transitional area from terrestrial ecosystem to ocean ecosystem, YRDNR has both terrene and ocean features. According to plant characters and landscape, YRDNR can be divided into three sub – ecosystems, and by the sequence of formation of land, the succession of the three sub – ecosystems is described (see Fig. 1).



Tig. 1 Habitat types in YRDNR by the sequence of succession

2 Importance of freshwater

The main driving factors which cause ecosystem succession in YRDNR are depth of groundwater, mineralization and salt – alkali of land. All factors which make them change will finally change succession trend directly or indirectly. Ground land is the basis of wetland development, and the unstable ground land will make ecosystem succession and development changeable. The proportion between freshwater and salty water decides the ground land salt contain and condition, and affects the plant growth and landscape structure. In recent years, YRDNR habitats' type changed greatly which was mainly caused by freshwater supplied from the Yellow River. Freshwater is the key eco – factor for new – born wetland ecosystem. The process of its impact can be described (see Fig. 2).

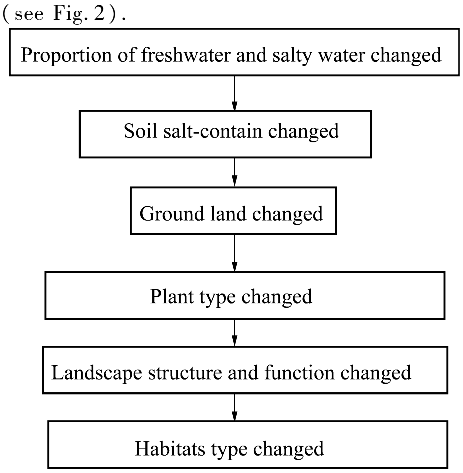


Fig. 2 Habitats' type changed process in YRDNR

Every factor which can change ground land will finally affect the wetland structure and its function, resulting in habitats type changed. Among all these factors, the proportion of freshwater and salty water is the most direct and vital factor. By the change of soil salt – contain, its influence becomes liable. The soil salt – contain changed procession is given (see Fig. 3).

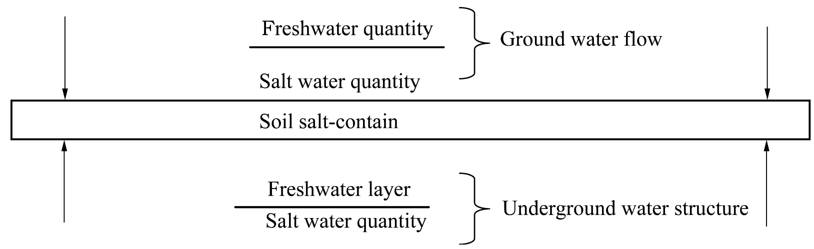


Fig. 3 Soil salt – contain changed procession

From 1976 to 1992, the new land formed by the Yellow River reached to 550 km^2 in total, 32.4 km^2 for each year, extending towards sea by 2 km yearly. The new – born wetland was formed by deposition of large quantity of sand and mud and the shoreline erosion. The formation and development of new – born wetland ecosystem went with the soil salt – contain decreasing. Proportion of freshwater and salty water will make soil salt – contain change and finally lead to a series of wetland ecosystem change. Salt water is supplied by sea, freshwater mainly by the Yellow River. How long the Yellow River flow – broken lasted, how many quantity of freshwater and sediment carried by the Yellow River will directly affect the stability and development trend of new – born wetland. So, the wise use of limited freshwater is a vital factor in YRDNR conservation.

3 Wise use of freshwater—wetland restoration

3.1 Reasons for wetland degradation

Wetland restoration is for wetland degraded. Among three sub – ecosystems in YRDNR (see Fig. 4). Terrestrial ecosystem has been formed for a long time and kept mature and stable. Ocean ecosystem lies in the estuary and near shoreline, tide regularly covers the mud flat and the habitat keeps stable. In estuary, with the sediment deposition, new land formed or erosion affected by flow of the Yellow River. As a transitional area from terrestrial ecosystem to ocean ecosystem, new – born wetland eco – system has both terrene and ocean features and easily affected by sea and the Yellow River. The area is immature and vulnerable, featured with youth, frangibility and instability.

Wetland degraded area lies in the new – born wetland on the south bank of Yellow River. The degraded reasons have mainly two: firstly, the area lack of freshwater supply. In 1996, the Yellow River changed its course and entered into sea northward. Without freshwater and tide cover forward, proportion of freshwater and salty water changed and soil slat – contain rose. Secondly, human disturbance, especially road built, broke off the exchange between fresh water and slat water. All these lead to the succession of community toward Salt flat or One – year salt plant. With GPS tracks to make map with GoogleEarth soft can show the landscape as below:

3.2 Restoration objective

The reason of wetland degraded is different and the objective for restoration is different. Restoration in YRDNR is based on the analysis of ecosystem succession and the reason for wetland degradation. These activities include storing enough freshwater from the Yellow River to establish a good ecosystem environment, using self – adjusted and self – restored eco – mechanism to make sure succession of community toward bio – diversity.

In order to reach these objectives, such measurement must be taken:

(1) Keep ground land stable.

(2) Change the proportion of freshwater and salty water and Input freshwater from the Yellow River.

Fig. 4 Landscape in degraded area

(3) Restore plant and increase the output of community biomass.
(4) Supply better eco – environment for succession.
(5) Restore healthy wetland landscape.
(6) Supply better eco – environment for bio – diversity.

3.3 Restoration theory and method

Restoration is an arduous task. In order to resume or rebuilt the degraded wetland, former eco – condition such as environment, biology, ecosystem function and development phase must be known. The degraded area in YRDNR took place in transitional area and the new – born ecosystem (see Fig. 1). The main reason of degradation is lacking of freshwater, high salinity in water and soil.

Based on the analysis of degradation, freshwater is the key factor for restoration. How to wise use freshwater to give the degradation area more freshwater and to construct a new eco – environment for wetland ecosystem development are prime question which should be taken into consideration. For these objectives, some activities must be taken:

(1) Restore ground freshwater and keep ground freshwater flow.
(2) Supply underground freshwater and raise underground freshwater layer.
(3) Lessen salinity in water and soil and establish a better eco – environment for wetland succession.

3.4 Restoration design

Totally restore the degraded wetland to its original status is difficult or impossible, and that is unnecessary. Before restoration, the objective of restoration must be taken into specific consideration for design. The YRDNR is mainly involved in the conservation of new – born wetland ecosystem and rare and imminent – dangered waterfowl. So the restoration design must meet two demands. Firstly, restore original wetland ecosystem and create suitable habitat for waterfowl. Secondly, effectively protect waterfowl and increase species and amount.

Supply enough freshwater is vital to restore original wetland ecosystem. Freshwater is mainly supplied from the Yellow River, but after 1972, especially in 1990s, the flow – broken happened more continually and lasted longer. To keep these limited freshwater, some project measure, such as build dam, must be taken to hold freshwater. After 2002, water and sediment adjustment experimentation began in the Yellow River, during this period, lots of freshwater were irrigated into restoration zone. In 2002, restoration zone covering 26.5 km^2 had been built out, and in 2006, another restoration zone covering 36.2 km^2 built out also (see Fig. 5).

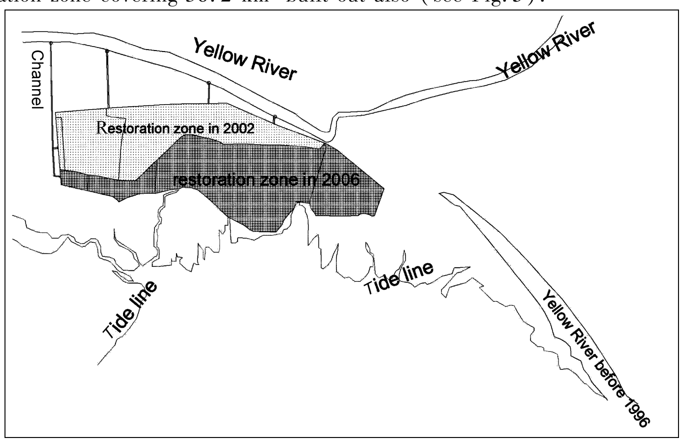


Fig. 5 Restoration zone in YRDNR

In restoration zone, the quantity of freshwater, depth and covering time will decide the salinity content in soil and change the ecological succession trend. Before restoration, ecological succession is towards Salt flat and one – year salt plant habitats as degrading process. After restoration, ecological succession is towards perennial salt plant habitats type as restoring process. The restoration result shows an extensive reed marsh landscape. The ecological succession trend comparison is given (see Fig. 6).

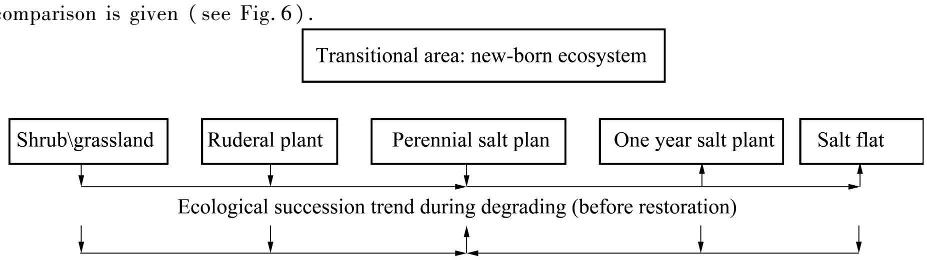


Fig. 6 Ecological succession trend comparison before and after restoration

During restoring, salinity decreasing is going with the long – time freshwater covered. In such eco – environment, reed which has wide adaptive ability for long – time freshwater covered and different salinity contain in soil will survive and reed marsh will become the dominant habitat. Single habitat type is not an idea habitat for birds' diversity, so habitat' structure must be adjusted to make man – made multi microhabitat. According to intermediate disturbance hypothesis and edge effect of ecotone theory, man – made multi microhabitat was designed.

(1) Use elevation difference to make different depth water zone. With GPS tracks and mapsource soft to analyze, the elevation in restoration area is different (see Fig. 7). When irrigating freshwater from the Yellow River, the depth of water is effectively controlled to form different depth water covered zone or land.

(2) Man – made edge effect of ecotone. Dam, channel, pond or pile – up land make up of edge effect of different plant community, which produce multi microhabitat.

(3) Keep landscape integrity and avoid fragmentation. Landscape heterogeneity change and fragmentation will abase the usage by waterfowl. In restoration design, except necessary dam or channel, other disintegrate will be avoided to keep integral landscape.

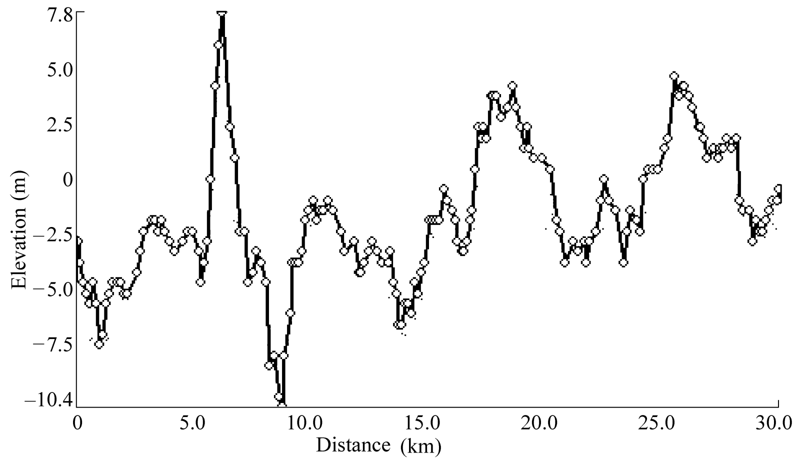


Fig. 7 Elevation in restoration area

3.5 Effect evaluation—take Red – crowned Crane as an indicator

To get ecological value is the main object for wetland restoration in YRDNR. Ecological value enhanced can be shown by wetland health and waterfowl protection effect. Red – crowned Crane is very sensitive to wetland change and can indicate the health of wetland, so it is a good indicator for wetland change. Red – crowned Cranes amount were got from continuous yearly survey. From 1998 to 2006, the amount of Red – crowned Cranes shows an increasing curve (see Fig. 8, data from Shan Kai). Compared with the amount from 1998 to 2001 and 2001 to 2006, there is a sharp rise curve. All those show the ecological value has been raised and protection effect is obvious by Red – crowned Crane as an indicator.

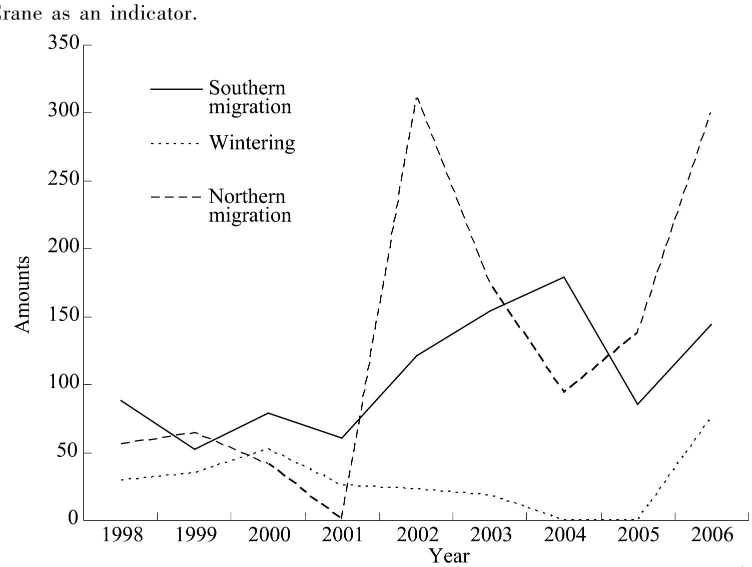


Fig. 8 Red – crowned Cranes amount change curve from 1998 to 2006

4 Discussions

Successful restoration is based on the scientific analysis of degrading reason, the knowledge of original ecological condition and the prediction of ecosystem succession. The reasons of wetland degraded are different, the measure taken to restore or reconstruct should be different. Lack of freshwater is the key factor leading to the degradation in YRDNR, so the vital and prime step is to irrigate freshwater to the restoration zone and store them.

Wetland restoration is not only an engineering design, but also an ecological design. The restoration design should be guided under ecological theory. In order to get wetland ecological value, some ecological ideas should be carried out during engineering process, such as restoration succession prediction, effect of edge and intermediate disturbance hypothesis.

The purpose of restoration should be taken into consideration before activities. Wetland is a synthetic system of social, ecological and economic value. To get what value should be decided at the beginning of restoration.

Finally, restoration should be feasible and the result should be predictable. Restoration is an arduous works and the works should be suitable for its eco – environment. During restoring, ecological factors are changed and original ecology balance will be broken. In the new – built ecological condition, the succession trend should be predictable based on the knowledge of ecological analysis.

References

Zhao Yanmao, Song Chaoshu, et al. Scientific survey of the Yellow River Delta nature reserve. Beijing: forestry publishing house, 1995.

Chen Weifeng, Zhou Weishi, Shi Yanxi. Crisis and protection of wetlands in the Yellow River Delta. Journal of Agro – Environment Service. 2003, 22(4):499 – 502.

Mu Congru, Yang Linsheng, Wang Jinghua, et al. Wetland ecosystem formation and its protection in the Yellow River Delta. Chinese journal of applied ecology, 2000,11(1):123 – 126.

Liu Gaohuan, H. J. Drost (eds). Atlas of the Yellow River delta. Beijing: the publishing house of surveying and mapping,1996.

Xi Jinbiao, Song Yumin, Xing Shangjun, et al. The characteristics and succession law of ecosystem in the Yellow River Delta area. Journal of northeast forestry university, 2002, 30(6): 111 – 114.

Zhang Jiaen, Xu Qi. Basic question discussion in restoration ecology. Chinese journal of applied ecology, 1999,10(1):109 – 113.

Cao Wenhong. The study on Yellow River Delta succession and its feedback. Journal of Sediment Reasearch, 1997(4):1 – 6.

Cui Baoshan, LiuXingtu. Review of wetland restoration studies. Earth science development study, 1999(14):358 – 364.

Zhao Kefu, Feng Litian, Zhang Shengqiang, Song Jie. The salinity – adaptation physiology in different ecotypes of Phragmites communis in the Yellow River Delta. Acta ecologica sinica, 2000(5):795 – 799.

Liu Yuhong, Yang Qing, et al. Research progress on impacts of wetland landscape changes on waterfowls habitats. Wetland science, 2003 (1):116 – 121.

Luo Xinzheng, Zhu Tan, Sun Guangyou. Wetland restoration and reconstruction in Da'an Paleochannel of Songmen Plain. Acta ecologica sinica,2003(23),244 – 250.

Luo Xinzheng, Zhu Tan, Sun Guangyou. Wetland restoration and reconstruction in Da'an Paleochannel of Songmen Plain. Acta ecologica sinica,2003(23): 244 – 250.

Chen Changdu(ed). Sustainable development and ecology. Beijing: Science Press, 1993.

Landscape Ecology Approaches to Wetland Restoration Decision Support: A Case study of the Yellow River Delta

Huang Chong[1], ***Liu Gaohuan***[1], ***Wang Xingong***[2], ***Lian Yu***[2], ***Michiel van Eupen***[3] and ***Wang Ruiling***[2]

1. Institute of Geographic Sciences and Natural Resources Research, CAS
2. The Yellow River Basin Water Resources Protection Bureau
3. Alterra, Green World Research, Wageningen, Netherland

Abstract: Landscape ecology has obtained much more emphasis in the field of conservation and restoration ecology since 1980's. Landscape ecology approaches to wetland restoration decision support are presented in this paper. The study shows that such approaches can contribute to setting up restoration targets on the one hand and to finding possible paths to realize them on the other. When the approaches are applied to the Yellow River Delta, three water discharge scenarios for wetland restoration are designed and evaluated, which provide powerful decision support for the Yellow River Delta wetland conservation and restoration.

Key words: landscape ecology, the Yellow River Delta, wetland, restoration, decision support

1 Introduction

The Yellow River is well known not only for its history and large drainage area, but also for its high sand content, limited water resources, and frequent floods and avulsions. Since the River changed its course from Jiangsu to Shandong Province in 1855, large amount of sediment has been transported to and deposited in the estuary. With speedy sediment accretion on the riverbed and fast extension of the river mouth, the Yellow River terminal reach frequently changed its course. Ten times avulsions since 1855 made terminal reaches twice sweep across the whole estuary delta, and formed large areas of fresh water wetlands.

In recent years, a sharp decrease of water quantity and frequent discontinuous flow happened in the Lower Yellow River caused by rapid increase of water consumption in the basin area. This leads to deficiency of suitable water needed by the ecological system of the estuarine delta. As a result, fresh water wetlands in the delta are diminishing and facing the danger of disappearance. Therefore, basic guarantee of water supply to the Yellow River estuary and ecological water demand for wetland restoration has become a key issue in maintaining the ecosystem of the Yellow River Delta. To counteract the drying up of the Lower Yellow River and the associated ecological damage, Yellow River Conservancy Commission has implemented a regulated discharge regime of the river since 1999, in order to recover the river stretches downstream of Lijin. This has relieved the danger of drying up and the water deficiency in the estuarine delta to a certain extent. However, there is still a long way to go to the optimal allocation of water resources required by ecological system of the delta.

The Yellow River Delta Environmental Flow Study (YRD – EFS) is an international co – joint programme supported by the Ministry of Water Resources (MoWR) of the P. R. of China (PRC) and the Ministry of Transport, Public Works and Water Management (PTW) of the Netherlands. Its objective is to develop an integrated and ecologically sound regional plan for environmental water demand that can meet requirements of both the YRD wetland ecological protection and the Yellow River Basin water resources planning. As part of the programme, the Yellow River Delta wetland restoration plans are studied. In this paper, landscape ecology approaches to wetland restoration decision support are presented. Three water discharge scenarios are analyzed and evaluated, which provides powerful decision support for the Yellow River Delta Environmental Flow Study.

2 The study area

The Yellow River Delta (YRD) is located in the northern part of Shandong province of China, lying in the south beach of Bohai Bay and the west coast of Laizhou Bay (Fig. 1). The region lies between eastern longitude from 118°33′to 119°20′, and northern latitude from 37°35′ to 38°12′. It belongs to the warm temperate area with semi – humid continental monsoon climate. And with 11.7 ~ 12.6 ℃ of annual average temperature, 550 ~ 600 mm of annual average precipitation (70% of which amasses in summer), 750 ~ 2,400 mm/a of evaporation.

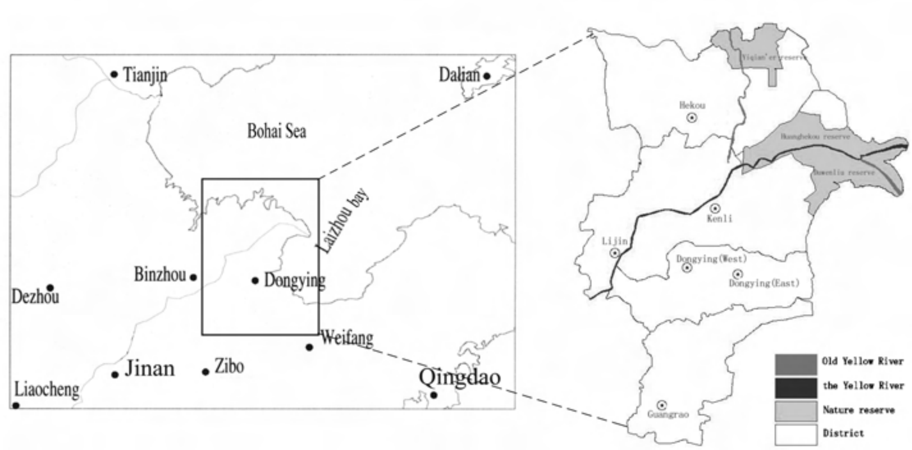


Fig. 1 Location of the Yellow River Delta

The Yellow River is the most important factor in controlling and sustaining ecosystem of the estuary area. In history terminal reaches of the Yellow River have undergone ten times avulsions and formed abundant wetlands on the delta. In order to protect the broadest and youngest wetland ecosystem in warm – temperate zone of China, the Central government approved of setting up the Yellow River Delta National Nature Reserve (YRDNNR) in 1992, which includes north Yiqian'er Reserve and east Huanghekou and Dawenliu Reserves (Fig. 1). The YRDNNR is a type of reserve to protect the natural wetland system of the Yellow River Estuary and the rare and endangered wildlife inhabiting in it. As an important site for breeding, wintering and roosting to the migratory birds migrating along the western Pacific coastline, the YRDNNR is designated in the Ramsar List of Wetlands of International Importance.

3 Methods

Landscape ecology is a cross discipline formed and advanced in recent years. It is to study the landscape unit composition, configuration and their interactions with ecological processes (Wu, 2000). As a tool for solving complex problems in ecosystem management, landscape ecology has obtained much more emphasis in the field of conservation and restoration ecology since 1980's (Harms, 1993; Apeldoo, 1998; Laura, 2001; Xiao, 2003). From the viewpoint of landscape ecology, traditional species – centered conservation is partial and unpractical because it ignores biodiversity patterns, processes and their interactions at multi – scales. Many researchers recent argued that diversity of landscape and ecosystem should be considered in species conservation (Guan, 2003). For degraded ecosystem, measurements should be taken to rehabilitate the landscape structure and function (Mary, 2000; Charles, 2006). Domestic researchers have made some progress in theories of wetland protection and restoration (Cui, 1999), but few studies based on landscape ecology approaches have been reported except Xiao's (2001) research on the Liaohe Delta.

In this paper, the framework of wetland restoration decision support based on landscape ecology approaches has three components (Fig. 2).

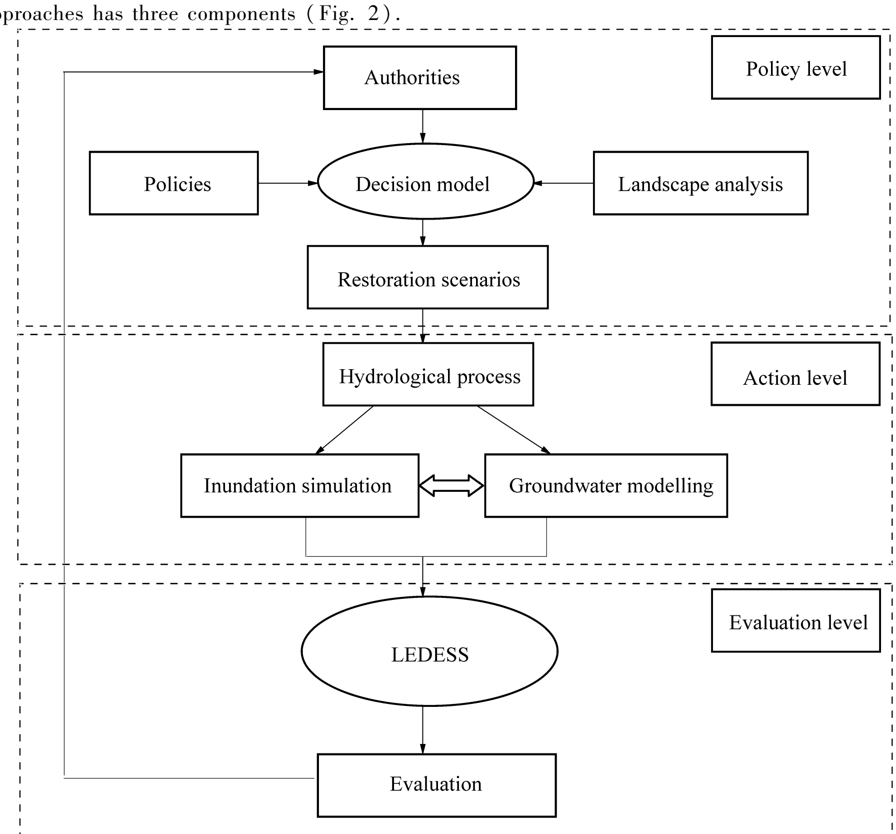


Fig. 2 An integrated framework for landscape ecology based wetland restoration

3.1 Policy level

Landscape level decision - making is a process that involves multiple objectives, large data sets, and many unknowns and uncertainties. As a kind of tool for decision making, scenario study can help authorities involved in ecological restoration by identifying decision variables, developing problem solving heuristics, and evaluating the consequences of alternative policy actions. At policy level, wetland current situation and future development trend are first analyzed. Taking state or local laws or regulations into account, wetland restoration targets are determined and different scenarios are designed, which will be implemented and valued in the next two components.

3.2 Action level

Water is the lifeline of wetland. Hydrological condition is very important for wetland formation, development and function sustaining. In flooding season, wetland surface water seeps into groundwater and transports salt to discharge area. In dry season, groundwater also supplies to surface soil and vegetation, to keep the ecosystem relative stable. At action level, flood inundation process, groundwater depth variation and their dynamic linkage are simulated as a whole. The modeling results will be used as input parameters for landscape development simulation and habitat evaluation in the third component.

3.3 Evaluation level

Ecological evaluation at landscape scale has more practical sense because it fully considers the effect of human beings activities such as land use, hydraulic engineering, wetland mitigation etc. In this study, LEDESS (Landscape Ecology Decision Evaluation Support System) was used as a tool for modeling and evaluating the landscape ecological effect of different scenarios. LEDESS is an example of a GIS based expert system developed by Alterra Green World Research. It is a computer model used to assess and evaluate the effects of land use changes on nature. LEDESS evaluates scenarios to see if they are possible from an ecological viewpoint and determines their consequences for nature and/or their economic effects. This way, choices can be made on what kind of nature type is desired and the suitability of the location as well as the economic profitability (Li, 2001; M. van Eupen, 2002). At evaluation level, data from the first and second component were input into LEDESS to simulate landscape ecological effects of different scenarios. Then evaluation results were returned to the policy level for decision - making.

4 Case study

Since the 1990s, water discharge to the Lower Yellow River decreased over 40 percent relative to average of the 1950s and 1960s. Actual water discharge at the Lijin section from 1999 to 2000 is only 23 percent of the average of past 30 years. Decrease of water quantity and increase of water utilization have caused severe drying up of the lower Yellow River and its estuarine delta. From 1995 to 1998, the river was dry during over 120 days every year, up to as much as 226 days at Lijin in 1997. This directly resulted in wetlands shrinkage and degradation. As important habitats for many rare and endangered birds, large area of reed marsh and seablite tidal flats rapidly disappeared.

In this study, a certain amount of Yellow River water was supposed to induct to the degraded wetland. By changing the wetland hydrological conditions, vegetation structure and habitat quality should be greatly improved. One target of the project is to restore the landscape structure and function of YRDNNR to that of 1992 when the Reserve set up. In general, it is difficult to decide what kind of habitat structure is most optimal. As for the YRDNRR, reed marsh plays a most important role in wetland ecosystem and provides good habitat for many rare and endangered birds. So the specific aim of this project is to restore reed mash to more than 20,000 hm^2 of 1992, and other important habitat types, at the same time, should not decrease too much. Fig. 3 shows the present vegetation map of YRDNRR which was interpreted from SPOT5 image of September, 2005. Based on the vegetation map and restoration targets, the demonstration area for wetland restoration was delineated in Fig. 4.

Due to severe water shortage in the Yellow River Basin, water demand for wetland restoration can not be unlimitedly satisfied. Under the guide of Yellow River Basin water resources planning this project designed three water discharge scenarios for wetland restoration: scenario A—2.78×10^8 m^3/a, scenario B—3.49×10^8 m^3/a and scenario C—4.17×10^8 m^3/a, respectively. Each scenario will result in different surface water and groundwater dynamics. In this study, surface water inundation processes were simulated using SOBEK hydraulic software, while the groundwater dynamics were modeled by MODFLOW software. Then the simulation results, combined with other data such as vegetation map, soil type map and soil salt content map, etc., were input to LEDESS, where an expert system of vegetation succession was built up to simulate the landscape development under different scenarios. Fig. 5(a), (b), (c) shows the simulated ecotopes of YRDNNR after 5 years according to scenario A, B, C, respectively. Fig. 6 presents the comparison of simulated landscape units composition and their areas for each scenario.

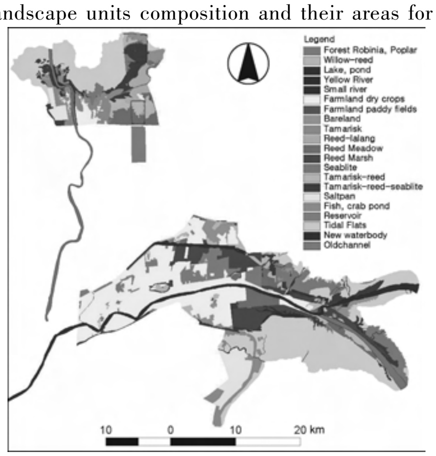


Fig. 3 The vegetation map of YRDNRR

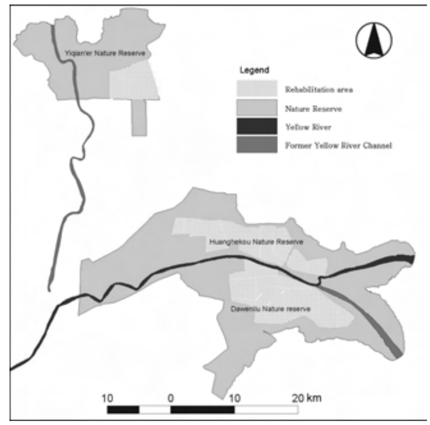
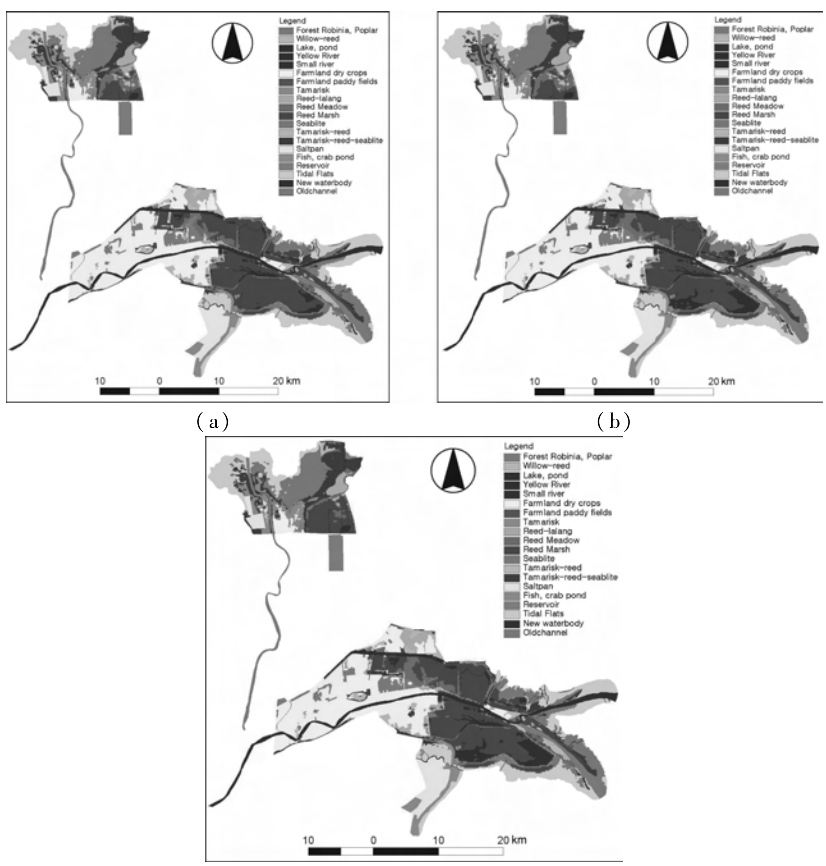


Fig. 4 Extent of the demonstration area



(a) (b) (c)

Fig. 5 Simulated ecotopes after 5 years according to three water discharge scenarios

According to Fig. 5 and Fig. 6, all scenarios can notably increase reed area through replenishment fresh water to the wetland. Although the area of reed meadow keeps unchanged, reed marsh area increases from current 6,600 hm^2 to 19,000 hm^2. From Fig. 5 we can see the landscape pattern changed a lot. Former reed meadow wetland evolved to reed marshes after 5 years, which are extensively distributed in the demonstration area. At the edge of reed marsh was small area of reed meadow and tamarisk. The replenishment fresh water is also beneficial to seablite development on the tidal flat because seablite prefers a fixed environment of freshwater and salty water. From Fig. 6 we can see the area of seablite tidal flat increases from 4,700 hm^2 to 10,500 hm^2, so bare tidal flat decrease will do little damage to seabirds like saunder's gulls since the increased seablite tidal flat provides better habitat for their breeding, foraging and resting.

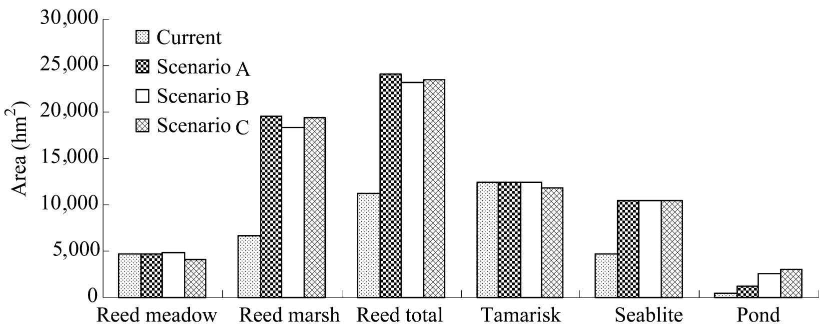


Fig. 6 Comparison of three scenarios for YRDNNR wetland restoration

Regarding YRDNNR as a whole, there's only a little bit difference among all scenarios in wetland vegetation restoration. When considering the north part and east part respectively, some obvious difference can be seen. In Yiqian'er reserve, almost all reed marsh have degraded to other land cover types because of no fresh water supply to the wetland since 1976 when the Yellow River terminal reach shifted to Qingshuigou. From Fig. 7 we can see that reed marsh was restored to about 1,500 hm^2, and reed meadow decreased by about 400 hm^2 for scenario A and B. For scenario C, reed marsh increased by 3,000 hm^2 and reed meadow decreased by 900 hm^2. So, for reed marsh restoration, scenario C is better than scenario A and B.

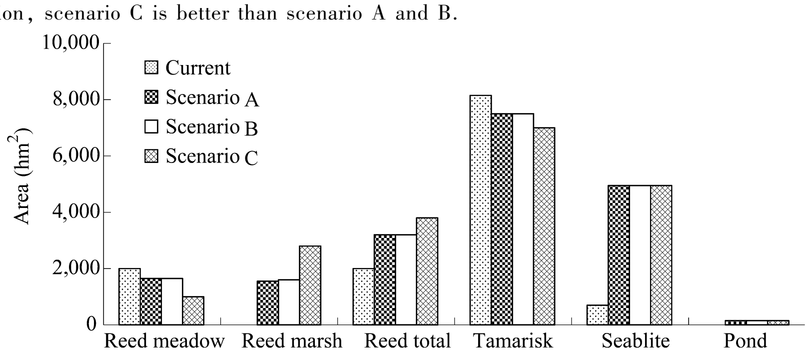


Fig. 7 Comparison of three scenarios for north Yiqian'er wetland restoration

In Huanghekou and Dawenliu reserves, three scenarios have the same effect on reed meadow restoration (Fig. 8). But with water discharge increase, reed marsh area restored by scenario A, B, C shows a trend of decrease, which is 18,000 hm^2, 16,800 hm^2, 16,500 hm^2, respectively. At the same time, the pond area has increased by 1,000 hm^2, 2,400 hm^2, 2,900 hm^2. That is to say, the largest water discharge didn't result in largest area of reed marsh. Keeping the restoration extent unchanged, the more the fresh water supply, the larger the wetland surface water depth. When water depth exceeds a certain number, the growth of reed will be prohibited. Then larger fresh water supply will only increase the area of pond, and reed marsh will correspondingly decrease.

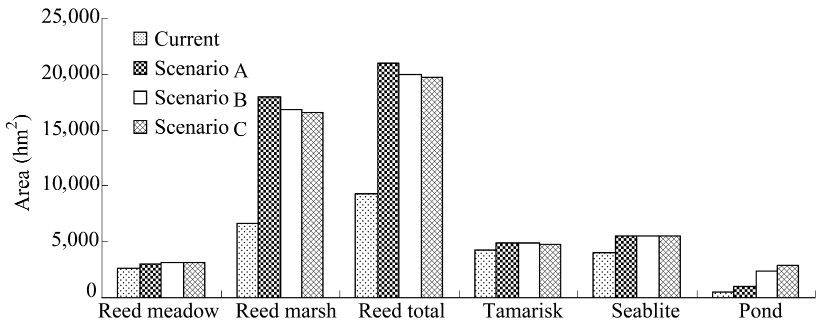


Fig. 8 Comparison of three scenarios for east esturary of Yellow River and Dawenliu wetland restoration

However, from the viewpoint of landscape ecology, the newly – formed pond is also a kind of beneficial habitat types. As for YRDNNR, large area ponds formed by scenario B and C have important ecological values in sustaining wetland water balance. Besides, ponds are optimal habitats for most swimming fowl like swan. So, for Huanghekou and Dawenliu reserves, scenario B or C is superior to scenario A. Considering the shortage of Yellow River water resources, it seems scenario B might be a better choice than scenario C in drought year.

5 Discussions and conclusions

In this paper, landscape ecology approaches to wetland restoration decision support were discussed. Three scenarios of water discharge were studied for the Yellow River Delta wetland restoration. Research shows that all scenarios can obviously increase the area of reed wetlands, which were used by many rare and endangered birds like red crowned crane as important habitats. Besides, flooding the bare tidal flat has greatly improved the seablite area. By comparison, scenario C is better than scenario A and B for reed wetland restoration in Yiqian ' er reserve. For Huanghekou and Dawenliu reserves, scenario B and C can result in higher landscape diversity, so the ecological value of scenario B or C is bigger than that of scenario A.

This study shows that landscape ecology approaches are good ways for solving complex problems in ecosystem management. When used in wetland restoration decision support, the approaches can help to set up restoration targets on one hand and to find the possible paths to realize them on the other hand. But some questions must be noted. First, it is difficult to get deterministic answers when landscape ecology approaches are used in decision making at landscape scale because Landscape level decision – making involves many uncertain factors. The approaches stress on exploring the possibilities of landscape development in the future, and they are not suitable for precise prediction. In addition, landscape evaluation model used in the research is a kind of expert system. Expert knowledge base determines the accuracy of evaluation results and the rightness of decision making. Developing science – based landscape evaluation model is a crucial step for the future research.

References

Apeldoo rn R C, Jan P Knaapen, Peter Schippers, et al. Applying ecological knowledge in landscape planning: a simulation model as a tool to evaluate scenarios for the badger in the Netherlands. Landscape and Urban Planning, 1998(41):57 – 69.

Charles Simenstad, Denise Reed, Mark Ford. When is restoration not? Incorporating landscape – scale processes to restore self – sustaining ecosystems in coastal wetland restoration. Ecological Engineering, 2006 (26): 27 – 39.

Harms W B, Knaapen J P, Rademakers J G M. Landscape planning for nature restoration; comparing regional scenarios. In: Vos, C & P. Opdam. Landscape ecology and management of a landscape under stress. IALE – studies 1. Chapman & Hall, London, 1993.

Laura R. Musacchio, Robert N. Coulson. Landscape ecological planning process for wetland, waterfowl, and farmland conservation. Landscape and Planning, 2001(56):125 – 147.

M. van Eupen, et. al. Landscape Ecological Decision & Evaluation Support System (LEDESS) Users Guide. Alterra – Report 447, Alterra, Green World Research, Wageningen, 2002.

Mary E. Kentula. Perspectives on setting success criteria for wetland restoration. Ecological Engineering, 2000 (15) : 199 – 209.

Cui Baoshan, Liu Xingtu. Review of wetland restoration studies. ADVANCE IN EARTH SC IENCES, 1999, 14(4): 358 – 364.

Guan Wenbin, etc. A vital method for constructing regional ecological security pattern: landscape ecological restoration and rehabilitation. ACTA ECOLOGICA SINICA, 2003(1): 64 – 73.

Li Xiaowen, Xiao Duning, Hu Yuanman. The landscape planning scenarios designing and the measures identification in the Liaohe River Delta wetland. ACTA ECOLOGICA SINICA, 200121 (3): 353 – 364.

Wu Jianguo. Landscape ecology: pattern, process, scale and hierarchy. Beijing: Higher education Press, 2000.

Xiao Duning, Hu Yuanman, Li Xiuzhen. Landscape ecology study on the wetlands along Bohai bay. Beijing: Science Press, 2001.

Xiao Duning, etc. Progress in landscape ecology research in arid area of China. Urumchi: Xinjiang people Press, 2003.

Analyse on the Change of the Yellow River Delta Wetlands

Shi Hongling, ***Wang Yangui*** and ***Liu Cheng***

International Research and Training Center on Erosion and Sedimentation,
P. O. Box 366, Beijing, 100044, China

Abstract: The Yellow River delta possesses of the fastest natural forming wetlands, and it is attractive in the world by its unique superiorities, especially by wetland eco – environment system. Based on the summarization of the wetland types, wetland distribution, wetland area changing and wetland ecological influence of the Yellow River delta, the crisis of wetlands are illustrated clearly, which include neo – tectonic motion and sea – level rising, water resources and sediment resources decreasing, natural disasters occurrence, human activities influence, etc. Finally, some rational strategies for wetland reserves are put forward.

Key words: wetland, the Yellow River Delta, crisis of wetlands, wetland reserves

1 Introduction

Wetlands are unique ecosystems, interacted with the terrestrial and aquatic environment. Wetlands play important roles in flood control, runoff adjustment, climate improvement, pollutants assimilation, environment beautification and ecology balance. Wetlands are regarded as the "kidney of our global", "cradle of our life", "sources of civilization" and "genic database of species". Therefore, wetlands, taking a same place with forests and seas, are one of the three basic ecosystems in the World Nature Reservation.

The Yellow River Delta with richness of potential resources is in blooming development. This area is attractive in the world by its unique superiorities, such as abundant fresh water from Yellow River, endlessly increased lands and wetlands, plenty petroleum as the second oil field in China, moderate climate favorable for crops, wide shallow sea and shoals affluent in halobios and salt, rich biodiversity, and natural scenery, etc. The Yellow River Delta possesses the youngest, widest, best saving and largest wetlands of China. Reserve of wetlands function is closely linked with these resources exploitation.

2 Wetland basic status in the Yellow River Delta

2.1 Wetland types

The wetland types and areas were studied by many researchers at different conceptions in different years. In general speaking, the Yellow River delta wetlands can be classified by 3 methods.

Firstly, depending on inundation degree, the wetlands in Yellow River Delta can be classified into epilittoral wetland, eulittoral wetland and sublittoral wetland. In the Yellow River Delta, wetland occupies an area of 4,500 km^2, of which 2,000 km^2 are epilittoral wetland, 1,000 km^2 eulittoral wetland and 1,500 km^2 sublittoral wetland (UNDP report, 1997). The characteristics of these types are as follows:

(1) Epilittoral wetland: the zone with ground elevation 3 ~ 5 m, groundwater table 1 to – 5 m, and degree of mineralization about 1 g/L. The ground slope in the zone is between 1/8,000 and 1/10,000, with year – round or seasonal ponds and water detention of 0.2 ~ 1 m depth. The water supply is mainly from the precipitation and rivers. Vegetation is dominated by waterlogged and salty – alkali soil plants.

(2) Eulittoral wetland: the zone with ground elevation 0 ~ 3 m, groundwater table – 1 m to

0 m. The width of the zone can be as much as 10 km. The area is periodically inundated by sea water. Soil in the zone is seriously salinized and only salty – alkali soil plants can grow in the zone.

(3) Sublittoral wetland: the marine zone with bed elevation 0 m to −6 m. Variation of tidal stage and complicated topography accommodate many species of fish, shrimp, shell fish and algae.

Secondly, according to the duration of water covered, wetlands can be classified into perennial watering, seasonal watering and eulittoral wetlands, as shown in Table 1.

Table 1 The wetland types and areas in the Yellow River Delta (Liu, 2000)

First level	Second level	Third level	Area (km^2)
Nature wetlands	Perennial inundated wetlands	Rivers	100.33
		Estuary lakes	49.07
		Intertidal water area	84.25
	Seasonal saturated wetlands	Uptidal high – saline area	228.93
		Reed marshes	243.82
		Other marshes	176.02
		Swamps	77.34
		Freshwater marshes	153.28
		Bogs	161.11
	Intertidal wetlands	Intertidal shoal	1,019.14
Constructed wetlands	Perennial inundated wetlands	Ditches	267.9
		Reserviors	144.1
		Pools	188.46
		Shrimp or crab pools	212.28
		Brine pan	191.03
	Seasonal saturated wetlands	Paddy fields	37.21

Note: Exclude sublittoral wetlands.

Thirdly, according to the location and conformation features, wetlands can be classified into coastal wetlands, estuary wetlands, rivers, marshes, bogs and swamps, etc. (as the natural wetlands), and reservoirs and paddy fields (as the constructed wetlands), as hown in Table 2.

From Table 1 and Table 2, the main wetland types in the Yellow River delta are natural wetlands such as the coastal wetlands, rivers and marshes.

2.2 Wetland distribution

In the littoral area in the east and north of the Yellow River Delta, especially between the XiaodaoRiver mouth in south and the Majia River mouth in north, there are large area continuity wetlands, in the forms of coastal shoal wetlands, the present and past channels of the Yellow River estuary wetlands, and riparian wetlands. While in the inland area in the middle and west area of the Yellow River Delta, owing to far away from the sea, high topography and human exploitation, etc. besides a few channels and depressions, there are scattered and separated constructed wetlands, such as reservoirs, pools and paddy fields, etc. (Xing, 2005). As shown in Fig. 1 and Table 3.

Table 2 Wetland types and areas in the Yellow River Delta (Cui, 2001; Zhao, 1997)

Types		Sub – types	Area(km^2)	% to total area
Natural wetlands	Coastal wetlands	Undertidal wetlands	1,500.00	24
		Intertidal littoral shore	1,220.61	19.6
		Uptidal high – saline area	294.20	4.7
	Estuary wetlands	Intertidal estuary wetlands	147.05	2.4
		Undertidal estuary wetlands		
	Rivers	Watercourses	233.92	3.7
		Ancient rivers and eatuary lakes	332.78	5.4
	Fresh – water marshes	Reeds and typhas marshes	236.00	3.8
	Bogs	Reeds bogs	382.47	6.2
		Quitch bogs	146.74	2.3
	Swamps	Chinese tamarisk wetlands	81.26	1.3
		Willow wetlands	6.75	0.1
Constructed wetlands	Reserviors and hydro – projects	Reserviors	164.26	2.6
		Pools	63.82	1.1
	Paddy fields	Channels	787.01	12.6
		Stability paddy fields	97.00	1.6
		Unstability paddy fields	20.00	0.3
	Brine pan		169.36	2.7
	Shrimp pool		353.28	5.6

I. Natural wetland
I_1. Sublittoral wetland
I_2. Intertidal wetland
II. River mouth wetland
III. River wetland
IV. Marshland
V. Wet meadow
VI. Constructed wetland
VII. Farmland

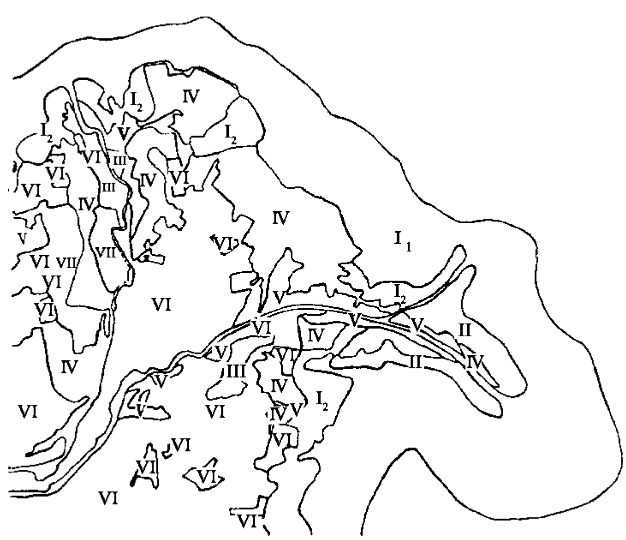


Fig. 1 Distribution of wetland in Yellow River Delta (Mu, 2000)
(coastal line based on the navigation chart in 1996)

Table 3 Wetlands area statistic in 7 districts of the Yellow River Delta (Cui, 2001) Unit: km^2

County	Inundated	Ditches	Reed marshes	Brine pan	Shrimp pool	Shoal
Wuli	47.8	123.44		129.48	84	209.27
Zhanhua	112.28	132.73	1.42	8.95	88.5	100.34
Hekou	73.54	100.15	116.3	472.8	430.49	
Lijin	33.46	71.58	17.77			129.74
Kenli	73.6	142.01	79.12		52.84	326.58
Dongying	106.88	156.5	18.96	8.33	55.29	110.55
Guangrao	14.46	60.6	2.94	22.6		21.78
Total	462.02	787.01	236	163.36	353.28	1,328.75

It is clear that the wetlands distribute densely in coastal areas, like the Hekou and Kenli districts, and more sparse with distance longer from sea, like Lijin and Guangrao districts.

2.3 Wetland area changes

As shown in Table 4, since 1980's, the total areas of wetlands and coastal shoal in the Yellow River delta have been still in increase, while the areas of reed marshes decreased in some degrees. The areas of constructed wetlands, reservoirs and pools also have been in a stable increase, while the paddy field changed from increase to decrease. Human activities, the Yellow River drying – up, and water resources shortage are the reasons for the area of wetlands alternation.

Tab 4 Changes in wetland areas of Yellow River Delta in different years (Chen, 2003) Unit: km^2

Types years	Paddy field	Reed marshes	Shoal	Brine pan	Reservoirs	Pools	Total
1981	4,763.6	69,223.9	80,000.4	335.2	1,954.1	3,000	159,277.2
1990	25,409	32,721	86,068	2,627.5	12,831.6	14,410	174,067.1
1998	19,103	24,382	101,914	3,721	14,410	18,846	182,376.0

2.4 The Effect of wetland on biodiversity of the Yellow River Delta

Depending on the integrated investigation of biodiversity in the YRD in 1996 ~ 1998, the biodiversity of YRD was classified into 4 groups. First one is halobios, the 116 phytoplanktons, 79 zooplanktons, 222 benthic faunas, 192 intertidal animals and 112 fishes have been appraised. Second one is fresh – water fauna and flora, the 291 limnoplankton, 144 zooplanktons, 69 fresh – water benthic faunas fresh – water fishes have been appraised. Third one is advanced plant, the 4 muskegs, 17 ferns, 18 gymnbsperm and 569 angiosperm have been appraised. Fourth one is terrestrial inhabited animal, 922 hexapods, 6 amphibians, 12 reptiles, 284 birds and 23 beasts have been appraised (Jia, 2002).

In the Yellow River Delta, the biodiversity of the shallow sea, littoral wetlands is various, so does the inland wetlands, such as the plants, insects, fishes, amphibians and birds. The reserve provides the birds with exceptional habitat for breeding, migrating, and wintering, making the reserve become an important "transfer station" in the inland of northeast Asia and around western Pacific ocean for bird migration. The nature preserve of the YRD is located at the new continent – building belt near the both sides of the Yellow River mouth, with the total area of 153,000 ha. It is one of the thirteen priority preserved wetlands zone appraised by the United Nations Environment

Programme [UNEP], it also was approved as the State Nature Preserve by the State Council of China in 1997 for protecting the wetland ecosystem of newly – formed land, rare and imminent – endangered birds. There are 393 vegetable planting and 1,542 wildlife inhabiting in the China newest, widest and youngest wetland ecosystem zone.

3 Crisis of wetlands in the Yellow River Delta

The wetlands in the Yellow River Delta are formed and developed by the co – action of neo – tectonic movement, sediment siltation, local precipitation, runoff and tidal currents. In recent years, although with more hydro – projects built, more constructed wetlands are appearing, some natural wetlands degraded or even disappeared by human activities, such as urban sprawl, landfill, diking, dredging, pollution, flood control, residential development, etc.

3.1 The neo – tectonic motion and sea – level rising

The Bohai Bay is dominated by long – term settlement in neo – tectonic motion; the average depth of the bay is 18 m. At Bohai seashore, most of areas covered by silt settling from the Yellow River are in an altitude lower than 3 ~ 5 m (UNDP report, 1997). Relative rising of sea level will inundate the coastal wetlands directly, then contribute to more storm surges and floods, and hence deteriorate the coastal wetlands eco – environment.

The coast of the Yellow River Delta belongs to silty sand, mostly composing with silty soil, and it is very instable in depression structure and physiognomy dynamics. Whether the coast aggradated or eroded, it fully depends on the incoming sediment load of the river. Once the volume of incoming sediment is insufficient, the wetlands in silt coast are easy to be eroded. Calculating the amounts and areas of eroded coast by satellite photography, it illustrated that besides the Yellow River mouth area, which was continually in aggradation, the other coast shores were eroded in past 20 years. Especially, the estuary of Diaokouhe River, the Yellow River old channel, and at the north edge of the delta, were eroded fastest and located in the focus of the tidal erosion. The farther from the estuary of Diaokouhe River, the less the erosion occurs. In the past, owing to lots of incoming sediment from the Yellow River, the total alluviation area is larger than the erosion area; while with the less incoming sediment of the Yellow River, extremely drying – up, in addition to the rising sea level, the coast would be eroded quickly, even the net erosion would take place.

3.2 Water resources

The local YRD yields little water resources. The direct surface runoff by precipitation is 0.448,5 billion m^3; as for underground water, except brine, salt water or brackish water which are more than 90% of the total, the underground water useful for agriculture or domestic consumption is only 58.472 million m^3, mainly distributing in the south of the Xiaoqing River. Fortunately, the Yellow River flows through the Delta in the length of 188km, and supplies lot of foreign water. According to the field data, the annual water volume at Lijing gauging station was 31.3 billion m^3 in the years of 1952 ~ 2005. While due to the effects of precipitation decreasing in water original area and water diversion increasing along the River, the incoming water of Delta was in a reduced trend after 1970. The annual runoff at Lijing station was 31.1 billion m^3, 28.6 billion m^3, 14.1 billion m^3 and 12.3 billion m^3 in the 1970's, 1980's, 1990's and post – 2000, respectively. Although water from the Yellow River is abundant in an annual average, it has the serous problem of seasonal shortage.

Less of the Yellow River incoming runoff will decrease the replenishment of fresh water for wetlands, and bring a lot of ecological problems. Such as soil salinization, phytocommunity inverse to salt – proof, vegetation cover decreased and original eco – system degradation, etc. owing to the balance of fresh and salinity destroyed. Moreover, less fresh water will reduce the wetlands clarification capacity, aggravate water pollution, and enlarge red tide probability. At present, the area of saline – alkaline soil accounts for 3/4 of the whole YRD area. Among that, high and moderate grades of saline – alkaline soil are nearly 440,000 hm^2, accounting for 56.2% of the total (Mao, 2003).

3.3 Sediment resources

The Yellow River is well – known for its high sediment load. While with the decreasing of incoming water form the Yellow River, the incoming sediment are decreased sharply. According to Lijin gauging station in the years of 1952 ~ 2005, the incoming sediment load of the YRD was 0.778 billion t annually. Correspondingly, the incoming sediment of Delta was in a reduced trend after 1970. The annual sediment load at Lijing station was 0.109 billion t, 0.9 billion t, 0.64 billion t and 0.39 billion t in the 1970's, 1980's, 1990's and post – 2000, respectively. Among the sediment load transported by the Yellow River, nearly 20% of the incoming sediment load deposited in the river channel and the Delta, 50% in the estuary, and the rest 30% carried by tidal waves to the sea area deeper than 15 m.

The costal area of YRD is in alternations of extending by siltation of river sediment and retrograding by erosion of tidal current. Based on long time aggradation of the Yellow River sediment, the YRD land is extending to the sea year by year. The continent – building area was 2,500 km^2 after years of 1855, equivalent to an annual increasing rate of 22.5 km^2. In the different periods of years 1855 ~ 1954, 1954 ~ 1976, 1976 ~ 1992 and post – 1992, the annual increasing rate of continent – building area are 23.6 km^2, 24.9 km^2, 14.7 km^2 and 8.6 km^2 (Hu, 2005). With the less incoming runoff and sediment load, some coast has been retrograded, which cuts down the area of new wetland directly.

3.4 Natural disasters

The natural disasters effecting on the YRD wetlands mainly are storm surges and floods. Either in Bohai Bay or in Laizhou Bay, the surge phenomenon would occur when strong northeast wind is blowing in spring and typhoon in summer. Unfortunately, if a surge meets with a high tide accidentally in the Yellow River estuary, the storm surge of 2 ~ 3 m high brings disasters to the delta. According to local records (UNDP report, 1997) there occurred 96 storm surges of 2 ~ 3 m high in the Laizhou Bay from BC 48 to AD 1949, and 21 of them were specially great. Storm surges with wave height larger than 3 m may cause serious disasters due to the low and flat delta landform. Tidal surges hazard the wetlands biology, directly damage the vegetation, and consequently threaten the animals and birds inhabitant environment.

Floods are the most serious disasters in YRD. In history recorded, the biggest flood disaster occurred in 1846 with peak discharge of 36,000 m^3/s at Sanmenxia station and a runoff of 12 billion m^3 in 12 days. The second largest flood occurred in 1933 with a peak discharge 22,000 m^3/s. Owing to the capacity of the Yellow River channel downstream of Aishan is limited, it could not afford the flood discharge larger than 10,000 m^3/s, serious disaster and great loss were brought by large floods. According to local historical records, the dikes of the Yellow River in the delta area were broken at more than 70 places in 23 years within the period of 1883 ~ 1938, among them 50 dike breaks were caused by overtopping and 22 were caused by bank scouring. The flood not only made the wetlands suffering lots of economic damages, but also made the animals have to be immigrated. The depression would not be resumed in a long time after floods.

3.5 Human activities

Firstly, the agricultural development surely in some degrees destroyed the wetlands ecosystem, and decreased the biodiversity of wetlands, such as wetlands reclamation, irrational structure of crops, creating field by filling shoals, abused arrest and hunting of wildlife, excessive pasturage, etc. Secondly, as petroleum is concerned, in pursuit of high – yield and exploitation easy, the oil field was transferring to coastal wetlands with the new land formed by warping in recent years. Oil field construction not only occupied lots of wetlands, but also destroyed the potential ecosystem of stored wetlands for the rare birds. Thirdly, with the agriculture and oil field exploitation, the infrastructure of traffic and road are in fast development, which inevitably crash the unitary of wetlands ecosystem, and make wetlands gridding. Lastly, with the economic blooming of YRD, the wetlands were badly polluted by the petroleum leakiness, industrial waste (including sewage, exhaust gas and scrap), and agricultural non – point source discharge and consumer waste, among that the petroleum pollution is always the most serious one. More attention should be paid to the water quality of YRD, due to the increasing effluent of industrial and domestic sewage, water quality has and is being constantly deteriorated. For example, the integrated index of pollution in the Xiaoqing River and Guangli River was inferior to national grade V(Chen, 2003).

4 Wetlands conservation in the Yellow River Delta

Depending on the above – mentioned the crisis of the wetlands suffered, conservation measures should be emphasized on the following aspects.

4.1 Rationally utilizing the water and sediment resources of the Yellow River

The Yellow River water is of dominance for forming and keeping YRD original wetland ecosystem, and of main water resources. The incoming water and sediment of Yellow River inevitably makes wetland of YRD degradation. According to expert estimate, it would develop 10 ~ 20 km^2/a new wetland, when 0.5 ~ 0.6 billion t/a sediment from the Yellow River put into the area out the coast of 5 km with average – 3 m of sea level (Hu, 2005). Rational and scientific allocation of water resource along the Yellow River is very important to shorten or prevent the Yellow River from drying – up. Firstly, by legislation, the reservation measures of water source region should be strengthened; the schemes of water allocation and diversion in each district of the Yellow River basin should be scientifically planned. Secondly, the water – saving society should be gradually constructed and implemented both in ordinary life of citizens and agriculture irrigation, especially abolishment of the surface flooding irrigation. Thirdly, the structure of property should be modified. Such as some planned constructive items with large water consumption should be prudently considered, avoiding the conflict of the industry and agriculture with the wetlands. These actions would guarantee the sufficient water amount for sound sustainable development of wetlands.

Sediment as resources mainly uses to continent – building. It is assessed that the sediment deposited and build new land in the YRD at a rate of 23 km^2/a. Besides, it is an economic way to take advantage of sedimentation to fill offshore oil field and change the offshore operation to land extraction.

4.2 Efficiently controlling natural disasters

The frequent avulsions resulted from abundant sediment load of the Yellow River make the fluvial processes of the river tail channel so complicatedly, as well as the wetlands consequently. Stabilizing the tail channel of the Yellow River in a limited regime as long as possible is the essential strategy. The Qingshuigou River is the recent outlet of the Yellow River, and it has in operation for nearly 30 years in generally stable. For the flooding and tidal surge control of the YRD, the dikes and dams are the efficient tools. In the past few years, the increasing fresh wetlands extended 30 km to ocean by training dikes (Ding, 2001). In addition with new pools and swamps constructed by water diversion for warping near the levees back, the artificial wetlands increase rapidly. Regulated construction of wetlands can rationally mediate the distribution of inhabitant in the Delta and accordingly beneficial to local economic and eco – environmental development, and it also has been recognized as a feature of the Yellow River Delta wetlands evolution.

4.3 Harmonizing the wetlands exploitation and conservation; reduce the influence of human activities

The wetlands exploitation should be consistent with wetlands sustainable development. Wetlands allocation adjusting, wetlands function alternation and wetlands reproduction planning should be guaranteed in time to maintain or enhance the total amount or summarized area of wetlands. It is proved by long time practice that Nature Reserve is one of the best measures to protect the wetlands. Along with the industry and agriculture exploitation in the delta, the construction of Nature Reserve should be added in amount and enlarged in area. As the main invasion factor to the wetlands, oil field construction should be reduced to the lowest, and the annually occupied area should not larger than the wetlands accrual, especially if the oil extraction occurred in Nature Reserve, it would be forbad.

References

Chen Weifeng, Zhou Weizhi, Shi Yanyu. Crisis of wetlands in the Yellow River Delta and Its Protection [J]. Journal of Agro – Environment Science, 2003,22(4): 499 – 502.

Cui Baoshan, Liu Xingtu. Ecological Character Changes and Sustainability Management of Wetlands in the Yellow River[J]. Scientia Geographica Sinica,2001,21(3).

Ding Dong, Li Rihui. Wetland Research and Protection in the Yellow River Mouth [J]. Coast and Estuary Engineering,2001,20(3).

Hu Chunhong, etc. The complicated response of water course to the aberrance of runoff and sediment load in the Yellow River [C]. Beijing:Science Press,2005:271 – 276.

Jia Wenze, Tian Jiayi, Pan Huaijian. Study on the Biodiversity Protection and Its Sustainable Use in the Yellow River Delta[J]. Research of Environmental Sciences,2002,15(4):35 – 39.

Liu Zhenqian, Liu Xianguo, Liu Hongyu. Comparative study on wetlands in the Yellow River and Liaohe River Deltas [J]. Resources Science,2000,22(3).

Mao Hanying, Zhao Qianjun, Gao Qun. Consider the modes of resources exploitation under the limit of eco – environment sustainable development in the Yellow River Delta [J]. Journal of Nature Resources,2003,18(4).

Mu Congru, Hu Yuanman, Lin Hengzhang, Yang Linsheng, Wang Jinghua. Chinese Journal of Applied Ecology[J] 2000,11(1):123 – 126.

UNDP, Support for Sustainable Development of the Yellow River Delta General Report [C], Dongying, Shandong, China,1997.

Xing Shangjun, Zhang Jianfeng, Song Yumin, Xi Jinbiao, Wang Hailun, Cheng Tiquan, Wang Jian. Functions and Rehabilitation of Wetlands Ecology in the Yellow River Delta [J]. Shandong Forestry Science and Technology,2005,157(2).

Zhao Yanmao, Song Caoshu. The science review of Natural reserves in the Yellow River Delta[C]. Beijing: China Forest Press,1997.

Characteristics of the Spatial and Temporal Distribution for NDVI and Albedo in the Yellow River Delta Region *

Li Fapeng[1], ***Xu Zongxue***[1] and ***Li Jingyu***[2,3]

1. Key Laboratory for Water and Sediment Sciences, Ministry of Education, College of Water Sciences, Beijing Normal University, Beijing, 100875, China
2. Key Laboratory of Land Use, Ministry of Land and Resources, Beijing, 100035, China
3. Office of Chief Engineer, China Institute of Land Surveying and Planning, Beijing, 100035, China

Abstract: Ground surface parameters are most important parameters for numerical climate models and surface energy balance equations, and are the basis of surface mass conservation, energy balance study. Many scientists pay great attention to the methods of deriving these parameters from remote sensing data. On the basis of comparisons among precisions of the surface parameters from remote sensing data, the Validated MODIS NDVI and albedo L3 products are adopted in this study. The spatial and temporal characteristics of NDVI and albedo are investigated in the Yellow River Delta. This study will provide basis for understanding the flux of mass and energy, and further provide basis for maintaining the health of Yellow River Delta region, and the Yellow River basin.

Key words: NDVI, surface albedo, Yellow River Delta

The physical characters of underlying surface have some differences in spatio – temporal distribution, which affect the distribution of surface energy, momentum and mass greatly. Parameters describing surface characteristics include vegetation index, broad band albedo, surface temperature, and so on. They all have significant meanings in numerical climatic models and surface energy balance equations. Therefore, estimating these parameters accurately has an important realistic significance.

The vegetation indexes, especially the Normalized Difference Vegetation Index (NDVI), represent the quantity and vitality of vegetation, and reflect the density of vegetation cover, soil moisture and so on. Presently, the NDVI product from NOAA/AVHRR is widely used. Recently, MODIS has improved AVHRR NDVI. The NDVI from MODIS are estimated by using the first channel red band (0.620 ~ 0.670 μm) and the second channel near infrared band (0.841 ~ 0.876 μm), whose resolutions are both 250 m. MODIS is more sensitive to sparse vegetation area by avoiding the hydrosphere absorption zone of near – infrared band as a result of relatively narrow spectrum of the first and second band.

Surface albedo is the ratio of the amount of electromagnetic radiation reflected by a body to the amount incipient upon it, which can be affected by some factors such as physical conditions of underlying surface, spectral distribution of incidence radiation, solar zenith angle and solar spectrum, and also it has spatio – temporal variation, thus it has been paid great attention by scientists who are utilizing remote sensing data to estimate regional albedo. Wang et al. (2004) used MODIS MOD43B1 product, surface Bidirectional Reflectance Distribution Function (BRDF) parameter, to estimate sunny day albedo in China, and he used field data at Gaize station in Tibetan Plateau to validate the retrieved albedo from remote sensing data. The results indicated that satellite could well monitor albedo variation with time; MODIS albedo well matched with field observation, and the average deviation error was 0.049. Validation experiments in the Qinghai – Tibetan Plateau by Wang et al. (2004) and by Jin et al. (2003) in the USA both showed that the precision of

* Supported by the "Jingshi Scholar" Leading Professor Program, Beijing Normal University.

retrieved albedo from 1km resolution MODIS data varied between ±0.02.

In this study, the spatial and temporal characteristics of NDVI and albedo in the Yellow River Delta are investigated by analyzing the products of the NDVI and albedo from MODIS data, and the applicability of MODIS data for the study area is detected. Meanwhile, the surface characteristics of the study area are investigated primarily to understand the flux of mass and energy in the Yellow River Delta.

1 Study area description

The Yellow River Delta is located between the mouth of Bohai Sea Bay and Laizhou Bay, which covers the area from E118°07′ to E119°10′ in longitude and from N37°20′ to N38°10′ in latitude. It is one of the three largest Estuary deltas in China and is composed of the ancient, neoteric and modern deltas (Xu, 1990). The study area lies in the middle latitude zone. The climate is impacted by the Eurasia and the Pacific, thus forms warm – temperate semi – humid continental monsoon climate with clear seasons and overlapping rain and heat. The difference between temperatures in four seasons is obvious, and the annual average air temperature ranges between 11.7℃ and 12.6℃ in the study area. The annual average precipitation ranges from 530 mm to 630 mm. About 70% of the precipitation occurs in the summer. The Yellow River Delta, with plentiful natural resources, is the vital base to produce oil and marketable grain in China.

Considering the conditions of collected data, the integrity of administrative region and the convenience of investigation, the Dongying City, i. e. the area from E117°31′ to E119°18′ in longitude and from N36°55′ to N38°16′ in latitude, is selected. The location of the study area is shown in Fig. 1. The land use type in the Yellow River Delta includes farmland, woodland, grassland, wetland, water body, urban and built – up land and barren land, in which the area of farmland, woodland, grassland and wetland account for 80% of the total area.

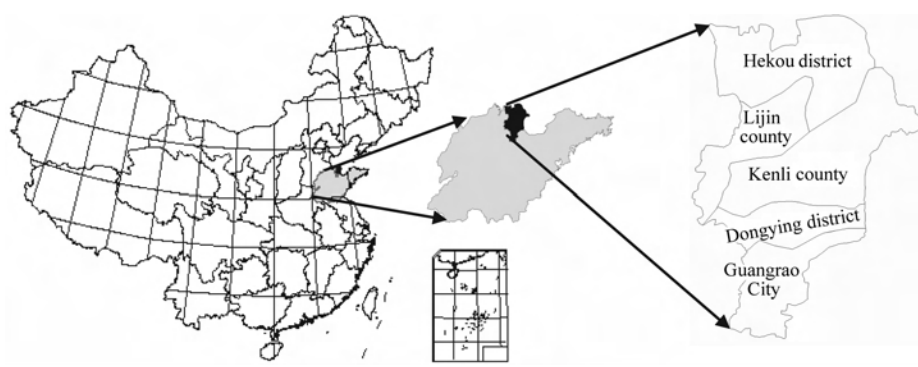


Fig. 1 Location of the Yellow River Delta

Wheat, cotton, corn, soybean and paddy are major crops in the study area. The cropping system involves "winter wheat – corn" with two harvests in one year, and "winter wheat – soybean – spring corn (broomcorn, coarse cereals)" with three harvests in two years. Additionally, the system of "wheat – paddy" with one harvest in one year exists in the study area. The planting calendar of crops in the Yellow River Delta is shown in Fig. 2.

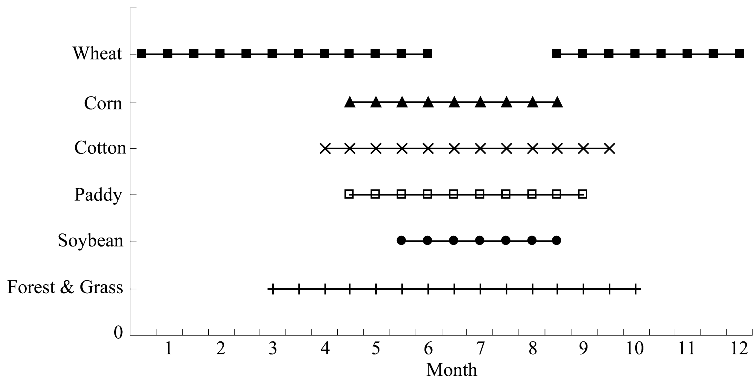


Fig. 2 Planting calendar of crops in the Yellow River Delta

2 Data and methodology description

Eliminating the atmospheric effect is necessary when obtaining the surface reflectivity from the remote sensing data. MODIS has made atmospheric correction to the satellite image for the first time (Vermote, 2002). The albedo of many sensors such as ASTER, AVHRR, ETM +, TM, GOES, MODIS, MISR, POLDER and VEGETATION were retrieved by Liang (2000; 2002), those results were compared with the observation data. The result showed that the standard error of the albedo retrieved from most sensors is about 0.2, which is satisfied with the precision of the surface parameters retrieval. In addition, MODIS has relatively more bands in reflection wave, therefore, the precision is comparatively higher during the course of transforming the albedo from the narrow band to the broad band. On the basis of research results obtained by Liang, the albedo of MODIS should be transformed from the narrow band to the broad band in this study, and the formula is as following:

$$\alpha = 0.160\alpha_1 + 0.291\alpha_2 + 0.243\alpha_3 + 0.116\alpha_4 + 0.112\alpha_5 + 0.081\alpha_7 - 0.001,5 \quad (1)$$

in which α_1, α_2, α_3, α_4, α_5 and α_7 are narrow band albedo from the channel 1, 2, 3, 4, 5, 6, 7 of MODIS, respectively.

The *NDVI* can reflect actual conditions of the vegetation index by eliminating effect of the cloud and many other factors to a certain extent. The *NDVI* is defined as follows:

$$NDVI = \frac{X_{nir} - X_{red}}{X_{nir} + X_{red}} \quad (2)$$

in which X_{nir} and X_{red} are spectrum reflectivity of the near infrared band and the red band, respectively.

In order to investigate the temporal and spatial characteristics of both NDVI and albedo in the study area, MODIS products with 1 km resolution in 2001 are selected in this study, including 16 – day global 1 km MODIS NDVI L3 products (MOD13A2) and 16 – day global 1 km MODIS surface albedo L3 products (MOD13A2). The edition of the data is 4.0. These data, recommended by MODIS science team, had been validated and the precision is accetable. But the data in June is not considered because of its incompleteness. On the basis of some statistical data of the topographic feature, as well as vegetation and soil in this study area, the MODIS data is processed preliminary by correcting, calibrating, interpolating and synthesizing in this paper.

3 Characteristics of NDVI

The spatio – temporal distribution of NDVI in 2001 are shown in Fig. 3. The values of NDVI range from 0. 00 to 1. 00 in the study area, there are some differences in monthly distribution.

Most of vegetation withers in January. The NDVI values range from 0. 00 to 0. 48 with the average of 0. 08, and the value in the most part of the study area is about 0. 02. It reflected the sparse vegetation cover and bare land cover in winter (see Fig. 2). The regions with higher values are mostly located in western edge and in southern part, Guangrao district, where winter wheat is planted. Furthermore, the value of NDVI in the Yellow River Delta Natural Protection Area is relatively higher in winter, which shows that the vegetation cover was better there.

With the growth of crops and other vegetation, the variation of NDVI during the period from February to May justly reflect the growth of vegetation cover. In February, the average value is 0. 65. With the growth of vegetation, the value grows to about 0. 70 in March and April, and it reaches 0. 77 in May. The spatial distribution of NDVI shows that the variation of vegetation is well reflected in southern part, because winter wheat are planted widely there, and then in western and middle northern part. These variations show great influences made by human activities in the study area.

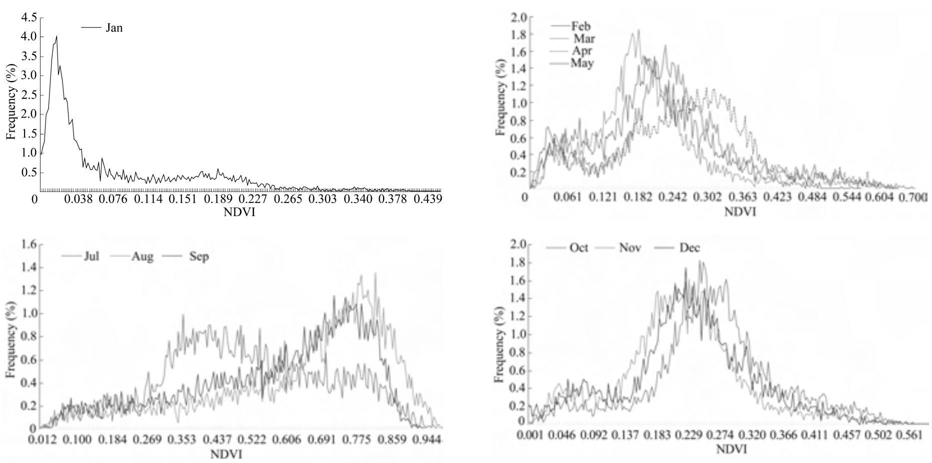


Fig. 3 Temporal variation of monthly NDVI in the Yellow River Delta

During July, August and September, NDVI has similar distribution. In July, the value of NDVI ranges from 0. 01 to 0. 91 and the average value is 0. 31. The NDVI value in most part of the study area range from 0. 25 to 0. 78, which accounts for 85% of the total area. The wide distribution range in July reflects the winter wheat has been harvested and other corps planted are in different growth periods. The value of NDVI in southwest part is higher, and the value in southern Grangrao decreases compared with that in May, which is approved that the impact of wheat harvest exists. The value of NDVI reached maximum in August, ranging from 0. 01 to 0. 99 with the average of 0. 65. Most of the values are about 0. 80 which shows higher vegetation cover in August when it is a preferable season for the growth of plants. Spatially, the study area, except the northern and eastern part where it is bare nearby the Sea, has a better vegetation cover in August. The value in September, ranged from 0. 01 to 0. 97, is lower compared with that in August. However the vegetation cover is still good and the value decreased in northern part. The result shows that the crops (such as soybean and corn) harvest have impact on the value of NDVI in September (Fig. 2.).

The distribution of NDVI in October, November and December are very similar. The values decrease obviously compared with that in July, August and September. The value of NDVI in October ranges from 0. 01 to 0. 88 with the average value of 0. 38. The value in most part of the study area range from 0. 25 to 0. 78, where it accounts for 82. 1% of the total area. Spatially, the value of NDVI in October is lower than that in September. But the value of NDVI in the Yellow River Delta Natural Protection Area changes unobviously, which exhibits a good vegetation cover there. The value of NDVI in other parts decreases due to crop harvesting. The value of NDVI in November ranges from 0.01 to 0.85 with the average value of 0.30. The values in most part of the study area range from 0.17 to 0.45, where it accounts for 78.87% of the total area. The value of NDVI in December ranges from 0.00 to 0.65 with the average value of 0.23. The values in most part of the study area range from 0.04 to 0.40, where it accounts for 92.63% of the total area. These values continue decreasing especially in the Yellow River Delta Natural Protection Area and the coastland, where vegetation withered seriously. The values in other parts are lower compared with that in other months. The vegetation cover is better in both southern and northern parts of the Natural Protection Area. In southern part, agriculture developed well and winter wheat is planted at most part of this area, as a result the value of NDVI is higher. Likewise, vegetation grows well in northern part, reflected by the higher NDVI value in remote sensing image.

Generally speaking, there are many saltmarshes in the coastal zone of the northern and eastern area influenced by the ocean. The main vegetation includes sparse vegetations such as Chinese tamarisk and covers worse in the year. Guangrao district is far away from the coast, influenced weakly by the flood disaster in the Yellow River. Therefore there is a relatively longer history of agriculture development, and there is relatively more intensified humanity reclamation as well. These results are validated in variation of NDVI value. By analyzing the seasonal change of NDVI, it also can be found that the vegetation cover in the Yellow River Delta Natural Protection Area is relatively better.

4 Characteristics of surface albedo

According to the transfer Eq. (1) calibrated by Liang et al. (2002), MODIS narrow band albedo is transferred to surface albedo. Fig. 4 shows the frequency distribution of monthly surface albedo. At the same time. Temporal and spatial variation of the surface albedo in the study area is discussed in detail.

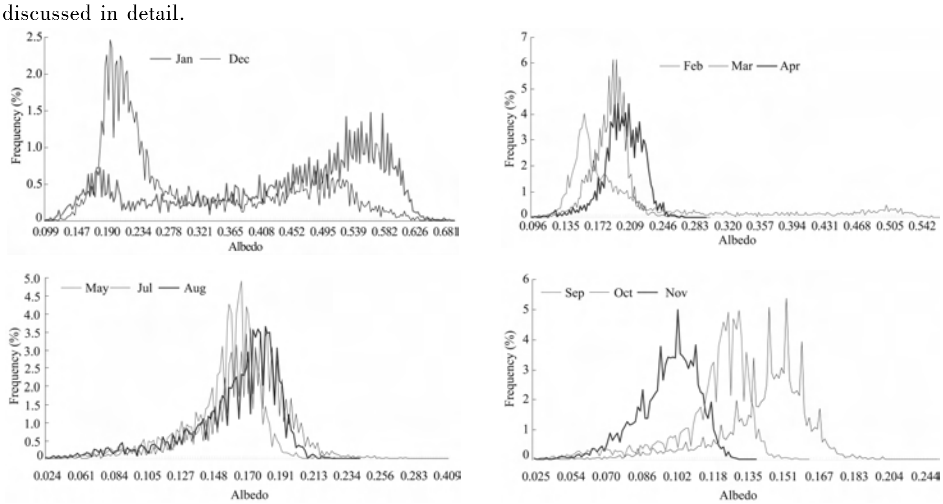


Fig. 4 Temporal variation of monthly albedo in the Yellow River Delta

The distribution range is broad for the surface albedo in December and January (0.02 ~ 0.70 and 0.09 ~ 0.72, respectively), in which the distribution frequency of 0.15 ~ 0.60 is higher than others. The albedo values in two months show double peaks distribution, in which the peak values are 0.16 and 0.48 in December, and 0.18 and 0.56 in January. Double peaks are relative to the bare land with withered vegetation and snow in winter, which is also validated in spatial distribution of the surface albedo in January. The peak values in two months are different, in which the albedo of December in most areas is about 0.16 showing the characteristics of broad distribution for the bare land. Moreover, the albedo in January is about 0.56 showing that snow and ice in the study area is mainly occurred in January. In the spatial distribution, the albedo in December is higher in the bare land of the central area, and lower in the coastal area due to the impact of the ocean. The vegetation cover is high in winter wheat district, Guangrao district, thus the albedo is low there. The albedo in both coastal area and water body is low in January, which shows the warm effect of the ocean to the alongshore lands. In addition, the albedo in other areas is highly affected by ice and snow.

There is a decreasing tendency for the albedo in February, March, and April compared with that in December and January, which shows the impact of vegetation growth on the albedo. The variation of albedo in three months show some interesting facts that the distribution ranges tend to be consistent with obvious changes of each peak value. The peak value of albedo is about 0.16 in February, 0.17 in March, and 0.19 in April, which shows slow growth of vegetation and small variation of surface soil water in three months. For the spatial distribution, the albedo in Guangrao district is higher than that in other dry bare area in February, reflecting the water conservation function of the vegetation which resulted from ice and snow in surface soil. In March and April, the albedo has a more obvious increasing tendency than that in February, especially in central area alongside with the Yellow River, which reflects the characteristics of small quantity of water and frequent drought in this season. Moreover, it shows some decreasing tendency for the albedo in southern part of Guangrao district, reflecting the actual plant growth.

The albedo values in May, July, and August show an obvious decreasing tendency compared with that in February, March and April, indicating that it is a very important period for the growth of vegetation in those three months. The variation of albedo in May, July, and August show some similar characteristics that the distribution ranges are narrow (0.04 ~ 0.49, 0.02 ~ 0.41, and 0.02 ~ 0.47, respectively), the distributions have single peak with similar peak values (0.19, 0.18 and 0.18, respectively). For the albedo values in July and August, there is a greater decreasing tendency indicating flourisher growth of the vegetation. It is very similar for the spatial distributions in those three months. High albedo occurs in the area alongside with the Yellow River and the depleted watercourse with better irrigation conditions, and also in Guangrao district. However, the albedo values are smaller in the coast bottomland area and the urban district because of high soil moisture, although the land cover is low.

The albedo variation in September, October and November indicate a trend of decreasing firstly and then increasing, with the average value of 0.15, 0.14 and 0.15, respectively. The results exhibit vegetation growth and the surface soil water variation. September is the harvest time, during which the land cover is very complex, so the albedo distribution range is also very broad. At the same time, the albedo in the area alongside with the Yellow River and its depleted watercourse is very high due to the impact of much rainfall. However, the harvesting time is finished in October with climax growth period of the grass, so the albedo distribution ranges become narrow with small peak values. Most of the albedo in October is lower than that in September. In November, only winter wheat is left in land (see Fig. 2), so the albedo exhibits increasing tendency, especially in the western dry part of the study area.

Generally speaking, the seasonal variation of albedo is more complex than that of NDVI, which reflects the complexity of impact factors. The albedo is very low for the whole year in the bottomland with large alkalescence in the northern and eastern coasts, especially in the tideland where it is much affected by the sea water. The variation of albedo has obvious seasonal characteristics than that of NDVI, which reflects that the albedo values are mainly affected by the land cover in the study area.

5 Conclusions

On the basis of precision comparisons among surface parameters from different sources of remote sensing data, the validated MODIS NDVI and albedo L3 products are adopted in this study. Some interesting conclusions can be obtained by analyzing the spatial and temporal characteristics of NDVI and albedo in the Yellow River Delta. It can be summarized as:

(1) The MODIS NDVI and albedo L3 products has a comparative precision, which can reflect some regulations for the change of vegetation cover and surface albedo in the Yellow River Delta. The change of land use type and regulation of the vegetation growth can be understood by analyzing the spatial and temporal characteristics of both NDVI and albedo.

(2) The spatio – temporal distribution of NDVI shows that there is an obvious seasonal change of vegetation cover in the Yellow River Delta, corresponding to crop cultivation activities. The monthly variation of NDVI is affected significantly by human activities, especially the agriculture cultivation in the study area.

(3) The temporal and spatial distributions of albedo show that there is an obvious seasonal variation for the albedo in the Yellow River Delta, and it is more complex than that of NDVI. It is indicated that the impact factors for the albedo are very complex, which is dependent on not only the surface physical characteristics, but also the mode of incidence solar radiation, solar zenith angle, solar spectrum, etc.

References

Jin, Y., C. B. Schaaf, F. Gao etal. Consistency of MODIS surface bi – directional reflectance distribution function and albedo retrievals: 1. Algorithm performance, Journal of Geophysics Research, 2003, 108(D5), 4158, doi: 10.1029/2002JD002803.

Liang S, Shuey C J, Russ A L, et al. Narrowband to broadband conversions of land surface albedo II Validation, Remote Sensing of Environment, 84(2002): 25 – 41.

Shunlin Liang, Narrowband to broadband conversions of land surface albedo I Algorithms, Remote Sensing of Environment, 76(2000): 213 – 238.

Vermote, E. F., N. Z. El Saleous, and C. O. Justice. Atmospheric correction of MODIS data in the visible to middle infrared: firstresults, Remote Sensing of Environment, 2002, 83, 97 – 111.

Wang Kaicun, Liu Jiaomiao, Zhou Xiuji et al. Validation of the MODIS global land surface albedo product using ground measurements in a semi – desert region on the Tibetan Plateau, Journal of Geophysics Research, 2004, 109, D05107, doi:10.1029/2003JD004229.

Xu Dianyuan. Study of Remote Sensing in the Yellow River Mouth [M]. Beijing: China Meteorological Press, 1990.

Fundamental Way to Improve Ecological Environment in the Yellow River Delta

Li Zegang [1], ***Yang Ming*** [1], ***Wang Xuejun*** [2] and ***He Ruiyong*** [1]

1. Yellow River Institute of Hydraulic Research, Zhengzhou, 450003, China
2. Zhengzhou Water Resources Bureau, Zhengzhou, 450006, China

Abstract: The Yellow River delta has a weak ecological environment basically for the reason of frequent changes of the flow path in history. In recent years, the ecological environment in the delta area has not improved still with barren lands and sparse vegetation. This paper discusses the limitations of the traditional countermeasures on flow path diversion, and provides the relatively fixed flow path in the delta area and the specific management measures, the water and sediment control works are the key to improve the ecological environment of the Yellow River delta. The author advised to build the water and sediment control works in the flow path at Xihekou (axial flow path diversion points) covering the area of 4,500 km^2 in the Yellow River delta, including fabric dam and flood diversion sluice with 3,000 m^3/s discharge.

Key words: ecological environment, the Yellow River delta, fixed flow path

1 Introduction

The wetland ecology in the Yellow River delta is the youngest wetland ecosystem which formed by the Yellow River to carry large amounts of sediment deposition. It took place frequent river diversions in history, so the ecological environment was unstable and weak, although the delta area has great economic development for oil exploitation, but remains barren land and sparse vegetation. YRCC has carried out the water and sediment regulation since 2002, there was about 20 million m^3 of Yellow River water irrigated wetlands and the wetland ecosystem in the Yellow River estuary has improved in some degree, however, because of the ever – changing currents, the sustainable development of the ecological environment seriously restricted in the Yellow River delta. Nowadays, there was an urgent requirement to fully understand the fundamental reworking of the Yellow River estuary in the direction of governance, sustainable economic development and ecological environment. On the basis of harmonious development between mankind activities and the Yellow River estuary, the control measures identified.

2 Artificial diversions and its limitations

As well we know, river diversions is a kind of damage for the original river course, the scattered flow also damages people's living environment, such being the case, why we proceed artificial diversion of river course? For the plain river with organic growth, water flows always carrying sediment from the beginning to fill up low – lying land or lake and sea and thus to form alluvial floodplain as well as an alluvial river formed. In the stable phase of a river, the complex alluvial process is still continuing especially during great flood process, generally, the river bed with mean sediment content of over 0.6 kg/m^3 will be deposited and heightened continuously, the deposition by over – banking flood formed river channel tableland and result in weak river channel stability and easily river burst and changes of river course. River diversions keep the Yellow River delta, but not beneficial for economic development in this area. Local river diversions by artificial flow diverting can produce temporary head – cutting and alleviate floods near the estuary of the Yellow River, however, the artificial arrangements seriously disrupted economic development in the delta area, basically restricted delta's sustainable economic development and improvement of the ecological environment as well.

3 Necessity of the flow path stability

To fix the flow path of river is a symbol of cultural development, stability of the river course is the natural requirement in the river development. Dating back in history, all the alluvial rivers in the world take on scatter condition during the initial stage flowing into open ground out of the river valleys and even entering into the river reach of delta area.

The stable river channel with normal flow is the best river channel which is the basis for effective governance. Generally each flow path during the river development can be divided into three developing stages, initial stage with scattered river channel, middle phase with single and stable river channel, late phase with scattered river channel once again, among which the middle phase has best river pattern and longest river trip. View from the angle of human society progress, the initial and late stage of river development with scattered river channel cannot provide living environment for people to farm and conduct other producing activities, while during middle phase with stable river channel, small river width, perfect river cross – section and long stable time which is suitable for middle and normal floods routing and providing suitable living environment for people. Therefore, people keep up indomitably with river management especially for normal river channel to prevent scattered flow path and try any possibilities to guarantee stable river channel, as a result many effective measures has been adopted to dredge river channel, construct embankments and other means to limit floods.

Modern economic development in the Yellow River delta needs the stable flow path of the river, the continuous change of river course becomes bad influencing factor for the economic production, only keeping stable flow path to keep best investment environment. Although with more and more sediment flowing into the sea and frequent changes of natural flow path at the estuary of the Yellow River, social development and scientific advancement provides great capabilities to control sediment deposition and stabilize flow path, finally to create long – term security environment for sustainable economic development in the Yellow River delta.

(1) Initial economic development in the Yellow River delta

During modern times, it has been promoted on economic development in the Yellow River delta, one of important indicators is oil extraction and large – scale development in this area, Shengli Oilfield found 69 oilfields in the delta area during the period from 1961 to 2001, the estuary of the Yellow River becomes main oil – producing area and China's second largest oilfield with current crude oil production capacity of 26.5 million tons per year.

(2) The flood control system built up in the Yellow River delta

During flood season in 1967, there occurred great flood with abnormal high water level that flooding the oil fields in the estuary area, which caused huge economic losses. Since then the government attached importance on production safety and continued to strengthen the embankments in the Yellow River estuary. After river diversion routing through Qingshuigou in 1976, south and north embankments and river control works have been reinforced and relaxed the flood situation. It has completed water management plan for stability of Qingshuigou flow path in 1989 and approved by the State Planning Commission in 1992, the first phase of project has been finished in 1999, the south and north embankment reinforced and extended to Qing – 7 cross – section which meets flood control standard at 10,000 m^3/s, meanwhile the river control works have been conducted at Qing – 4 cross – section.

(3) Well – done of seawall construction

Yellow River delta is a kind of muddy seashore with very serious erosion under ocean dynamic force in the reach of seashore without river flow, meanwhile the Yellow River estuary is the area with frequent storm tide which has large submerging range up to 20 ~ 30 km, each occurrence of storm tide always caused huge economic losses, therefore to protect seashores and reinforce seawalls is more and more on the current scheme for estuary management.

(4) Regional water shortage

Dongying city is facing the serious problem of water shortage, with annual mean total water of

0.532 billion m^3 and 296.5 m^3 per capita which occupied 10.98% of that in the whole China, as well as the weak surface water quality, there were 10 rivers polluted seriously with composite index above 10, the groundwater is classified at Xiaoqinghe river as salt water zone with high mineralization more than 2 g/L. The water resources from the Yellow River has good water quality, but with sharply decrease of water resources from the Yellow River into the sea during recent years, YRCC has conducted planned water allocation and allocated total water of 7 billion m^3 diverted from the Yellow River to Shandong province every year, and then Shandong province reallocate total water of 0.78 billion m^3 to Dongying city, including oilfields. Treated 1999 as standard year, according to the status quo of water use by social units and departments, when classifying with agriculture, industry, residents, rivers and lakes and ecological environment in city, and taking guaranteed admission $P = 50\%$, 75%, 90%, water demand should be 1.175 billion m^3, 1.333 billion m^3 and 1.5 billion m^3, respectively.

(5) Serious shrinking of the river estuary

The water and sediment from the Yellow River into the sea has keeping with lower degree since 1986, correspondingly the river channel has keeping deposition and shrinking state, the area of cross – sections was 2,000 ~ 2,500 m^2 and Bank – full discharge up to 5,000 m^3/s in 1984, while that decreased to 1,200 m^2 and 2,000 m^3/s in 1995, thus with large transverse gradient and causing tensional flood control situation.

4 Treatments of flow path stability

The key technology to long – term stability of flow path in the estuary is to build water and sediment control works to create fundamental conditions for water and sediment planned regulation and water resources multi – purpose utilization. Water and sediment control works in the Yellow River estuary are suitable to setup near the Xihekou flow path covering 4,500 km^2 of alkaline lands and coastline around the whole delta. The key water – control project consists of fabric dam and flood diversion sluice with 3,000 m^3/s. At present, Qingshuigou flow path possessed great capability to defense great floods using Diaokou old river – course as flood diversion channel. The basic operational mode is to choose Qingshuigou flow path and then flow into Laizhou Bay when the floods occurred with discharge more than 3,000 m^3/s, and if that less than 3,000 m^3/s choosing Diaokou river to discharge floods into the Bohai Bay.

The management objectives of water and sediment control works is, ① to realize scouring and silting dynamic balance of estuary seashore in the Qingshuigou flow path, ② to increase flood routing capacity of Qingshuigou flow path, ③ to realize water resources comprehensive utilization, improvement of alkaline lands and erosion seashores and protection of wetlands. As a result, to get rid of the feedback from estuary deposition and create a secure environment, also provide lower boundary controlling conditions for "no riverbed elevation," finally to realize win – win formula with sustainable economic development of the delta area and safety of the lower Yellow River.

Acknowledgements

This paper is supported by the National Foundation of Natural Science Commission of China and Yellow River Research Foundation (No. 50439020), and also supported by the "11th five – year plan" National Technology Support Program (No. 2006BAB06B02).

References

Qin Chongren, He Jiangcheng. Acta Oceanologica Sinica, Vol16, No.3, pp403 – 407, 1997.

Li Z. G. Basic Hydrologic Features Near the Yellow River Estuary Area [J]. Journal of Oceanography of Huanghai & Bohai Seas, 2000, 18(3):20 – 28.

Yang Ming. Study of One – line Model for Shorelines Change in Yellow River Estuary, Vo. 141, NO. 1 P. 12 – 16, [J]. Journal of China Harbor Construction.

Huang Haijun. Conception Model of Land Ocean Interaction in the Coast Zone of the Yellow River

Delta, NO. 5, 2004, [J] Advances in Earth Science.

Du Guoyun. Research of LOICZ and the Buffer Area in the Eastern Coast of Laizhou Bay, NO. 5, 2006, [J] Geographical Research.

Smakhtin, V. U.. Low Flow Hydrology: A Review, Journal of Hydrology, 2001, 240:147 – 186.

Arthington, A. H., King, J. M., O'Keefee, J. H., et al., Development of an Holistic Approach for Assessing Environmental Flow Requirements of Riverine Ecosystem, in Proceedings of an International Seminar and Workshop on Water Allocation for the Environment (eds. Pigram, J. J., Hooper, B. P.), The Centre for Water Policy Research, University of New England, Armidale, Australia, 1991, 69 – 76.

Practice on Water Environment and Eco – system Management of Foreign River Deltas

Tong Guoqing[1], ***Zhang Huaxing***[2], ***Sun Lijuan***[1] and ***Li Hongwei***[1]

1. Yellow River Shandong Bureau, YRCC
2. Department of International Cooperation, Science and Technology, YRCC

Abstract: This article first summarizes the profile of the foreign river delta harnessing; focusing on water environment and eco – system degradation, by some good examples in river estuaries harnessing, such as Australia, the Netherlands, the USA. Human activity is a main cause resulted in unbalance of the bio – systems of many estuaries in the world. Based on the above analysis, the article draws the conclusions how to maintain the river estuary health in our country.
Key words: delta, delta harnessing, eco – system, practice

1 Introduction of river deltas in foreign countries

Hurricane Katrina, which ravaged New Orleans and displaced more than half a million people, underlined just how dangerous living in a flood – prone delta can be. For some researchers this came as no surprise. By 2050, they believe that millions more living in low – lying river deltas will be equally vulnerable to rising sea levels, sinking land and storms.

Jason Ericson at the Department of land conservation and recreation of Virginia, and his colleagues identified five other deltas subsiding, if not more devastating, disasters: the Bengal delta in Bangladesh, the Yangtze delta in China, the Mekong delta in Vietnam, the Nile delta in Egypt and the Godavari delta in India. At a delta, the shoreline is a balance between sea level and sedimentation, says Daniel Stanley, an expert on the marine geology of deltas at the Smithsonian Institution in Washington DC. Any reduction in the amount of sediment reaching the deltas can alter this balance, causing deltas to subside.

While deltas are naturally vulnerable because they form in low – lying coastal regions, human activity leads to the additional risk. "The subsidence issue is related to population," says Robert Nicholls of the Tyndall Centere at the University of Southarmpton, UK. "It matters because the people are there, but they also contribute to their own risk," he says.

Most deltas are subsiding because dams and water use in the upstream prevent sediment from reaching the deltas. To make matters worse, people are also pumping out fresh water and petroleum from beneath the deltas, causing the sediment starved land to settle further.

Ericson and his colleagues found that 40 of the major deltas they studied were at risk: 68 percent of them were sinking because they were being starved of sediment, 20 percent were subsiding mainly because of the pumping out fresh water and oil, and in 12 percent of the deltas, rising sea level was the biggest problem.

Five of the six deltas most threatened by a rising waterline were also at risk from storms, the only exception being the Nile delta. Storm surges can overwhelm an already low – lying region.

The deltas in greatest danger lie in the arc from china to India, where populations are growing rapidly, and powerful typhoons and tropical cyclones are common. Geologically active mountains and heavy rains make south – east Asia the source of half the world's sediment supply, so large deltas are commonplace in the region, says Janok Bhatttacharya at the University of Texas.

2 Eco – system and water environment of foreign deltas

2.1 Deterioration of the water environment

Many estuaries in the world are facing environment deterioration. There are many reasons for the environmental quality decreasing in the estuaries, but the two important factors are population increasing and human activitiy.

In the USA, over 50 percent of population settles in the cities in the estuary areas. And the population here increases much faster than that in in – land. Population increasing and urbanization caused the death of some coastal habitats. In America, over 75 percent of export product and 80 to 90 percent of fishery product is from the coastal cities. Due to over fishing, deterioration of eco – system or pollution and change of marine water quality, the productivity decreased.

The break changes in bio – structures and species in the estuary areas have aroused more attention in the world. The level of biodiversity in the deltas reflects the extension in damage to the eco – system. In the USA, about 35% of the river deltas are shrinking and 10% are under damage. The eco – systems are threatened by point pollution and non – point pollution. And the floods from cities, farms, urban and forests contain many contaminants and also affect on water environment in the estuaries.

The increase of the population, on one hand, has destroyed the eco – system in the deltas; on the other hand, it caused hazard to the water environment due to the human activity. In addition the damaged environment has also brought crisis to human existence. In the delta areas where the population is high and the commercial is advanced, especially in the place where the storms are frequent, like the islands, the people's lives and fortune are lying under unsafety, as well as under threat.

2.2 Habitat degradation in the estuary delta

In order to maintain the health in the delta areas, the biodiversity, and the healthy environment of the delta area must be maintained. But due to over fishing, habitat deterioration, especially the vanish of the wetlands, the fishing industry in the USA is influenced greatly. The fish species are decreasing. And the biodiversity is under threat.

2.3 Sea water pollution

In order to maintain the healthy seashore, we have to get enough good water quality to ensure that the sea animal can reproduce safely. We have to guarantee the food is not polluted, and to enhance the economic capacity.

Pure sea water is the basic necessity to maintain a healthy sea environment. For example, to swim in polluted water or sea area is harmful to people's health.

To ensure the sea water is not polluted, we need to know the factors that influence the eco – system in the delta area. Because of the complicated factors that influence the sea water, it is necessary to study, survey and evaluate in a local scale.

3 Harnessing experiences for river delta in foreign countries

3.1 Australia

Australian governments pay much more attention to natural resources protection. They set up $1.25 billion fund for natural heritage protection, mainly used in land, vegetation, river and biodiversity protection. In order to protect river mouth, some laws, like the river delta protection plan are promulgated. A lot of lands in Australia had been developed as planting lands in the past. This caused vegetation deteriorated, underground water level dropped, and large scale water polluted. The eco – system was under threat. The governments used $700 million to save vegetation, forest and agriculture.

The river delta protection regulation is mainly focused on the pollution harnessing in the river mouth areas. It has been successfully used in many states, and is conformed with the environmental protection standard of the world. There are three stages in implementing this plan.

Firstly, the plan must be conformed with the national demands for river delta harnessing. And it should be provided with other projects to related departments, including the discussing by governments, communities, and environmental organizations. In the process of establishing the plan, some procedures, such as preparation, analysis of carrying out the plan, and decision making systems, must be initiated.

Secondly, the approval of the investments for the projects must be in position. At the same time, searching for relative measures which could improue water quality and maintain it in a long time must be carried out.

Finally, the plan must be renewed every 7 years.

Up till now, the improving water quality act has been accepted by the Australian governments. The plan is based on the water allocations of improving state water quality and environmental flow.

The plan has been carried out by Australian governments and related to state government, especially in some delta areas where the problems are serious. The plan has set standards for river basin management, integrated environmental flow and water quality. Once the plan is proved to be effective, the Australian governments will execute it through related laws. For example, in order to ensure the water quality in the Great Relf, Queenslands has the responsibility to control the pollution.

The Australian governments have invested a series related projects to harness the river deltas. For example, the Peel – Harvey Project which mainly includes water quality improvement sub – project, water sensitive urban design and water quality monitoring project.

3.2 The Netherlands (releasing the irrigated lands to the ocean)

The Netherlands schemed to return some irrigated lands near the ocean to the ocean. The natural agricultural policies made by the Dutch agriculture department are used to restore the natural landscapes in 30 years. Among the policies, the "eco – system corridor scheme" is to recovery the wetlands with the ocean as a chain, and to establish a 250 km bio – system zone from the south to the north which is based on wetlands as the center.

3.3 Management of the Danube River in Europe

The total length of the Danube river is 2,857 km with the area of 817,000 km^2. It flows across 17 countries in the Europe. The delta area of this river is the second biggest wetland in Europe. Now there are 13 countries which signed the wetland agreement. They are also the river protecting members. In order to protect the wetlands along the river effectively, five special groups are set up, they are accident emergence groups, reducing and draining group, draining control group, river basin management group and biological experts group.

3.4 Pollution control to protect the delta in Peru

There are around 2 million m^3 of waste water from industry and community. Such amount of water flows directly into the ocean without treatment. The suburb of Lima is the biggest area where waste water discharge. The pollution has damaged the seashore greatly. Two waste water treating plants have been built to treat the polluted water.

3.5 The USA

As mentioned above, many deltas in the USA were severely damaged, the reason covers two aspects, one is from human activity, and another is from natural disasters. For example, water drainage, making channels in the rivers, sand silting and depositing, dike and dam construction, agriculture farming, jetty building, construction implementation, foreign seeds introducing, tree cutting, mining development, grazing, earth surface sinking, sea level rising, drought and hurricanes etc.

Now, the federal government has passed laws (such as cleaning water law), economic enhancement and control measures, and wetland cooperation projects and wild animal's protection zone has been set up to protect the wetland in the estuary areas, such as the Hawaii reef protection area. Because of pollution, over fishing, over draining of oil, and climate change, the reef and marine animals in the world are facing danger; about one fourth of the total reef areas have been damaged. The USA has decided to build an area of 339,000 km^2 reef reserve to protect turtle, bird, sea dog and cetacean.

4 Conclusions

From the examples of foreign river delta harnessing, the following practices can be learned:

4.1 Much more attentions to eco – system protection in the delta areas in foreign countries

River deltas lie in the connection area of the river and the sea. Generally speaking, there are large areas of wetland, easily affected by the mutual function of the sea and the river. Together with other factors, such as human activity and hurricanes, the eco – system balance can be easily broken. With the decreasing in wetlands area and increasing in pollution, the biological environments are facing threat. Meanwhile, it brings quick disappearance of the biodiversity and the loss of the river delta functions. Consequently, the influence led to the loss of natural resources, deterioration of the environment, and even the economic development and human living conditions. The successful river delta harnessing experience pays more attention to eco – system healthy keeping. For example, the USA set up the Hawaii natural reserve, and the Netherlands build the eco – system zone based on the wetlands.

4.2 River delta harnessing is based on laws and regime

Today, the river mouth harnessing is based on laws and reasonable mechanisms such as in the Australia. But, nowadays, there is no this kind of special law in our country. So the most important thing is to make a sustainable development plan and river delta exploitation policies and related laws. Actively carry out the work about river delta eco – system protection legislation and build up the river delta protecting and reasonably exploitation orders step by step. The final target is to realize reasonable legal system, standardization, and reasonable regime to protect the river delta.

4.3 Establishing water pollution prevention and protection system.

From the examples of river delta harnessing in foreign countries, the common character can be drown as the concern on water pollution prevention and protection. Because the river mouth lies in the lower reach of the river, the pollutants from upper and middle reach concentrates in the lower reach. The slight pollution in the upper or middle can lead to serious pollution in the river delta. So the pollution control project in the river mouth is a system work connecting with the whole river and across border.

Enhance the pollution control and protection, at the same time, pay attention to water resources regulation, the adjustment of water use structure, wide spread the current water saving technologies, improving the water use efficiency. Protect the wetland in the estuaries. Forbid over development and the activity that will damage the wetlands. In some areas, the farmlands should be returned to forests, lakes, pastures and wetlands.

4.4 Widely using river delta harnessing models

Like the Australia, many countries are using the river delta decision making system to harness river mouth, making full use of the high technologic devices, such as the computer, to build digital models of the river deltas, to simulate the mutual actives of the river and the sea, evolution of the groundwater, monitoring of the pollution, and the eco – system protection. Some models and soft – wares, like the MIKSHE, can be introduced, but the best way is to develop the models of the river delta based on our country river characteristic, since the rivers in our country is different from that in other countries. For example, the Yellow River is famous for its much sediment, frequently changing. There is no model can be used currently. So we should develop the software to meet the requirement of the Yellow River based on foreign relevant model.

The Primary Research on the Ecological Water requirements of the Yellow River Estuary

Wang Xingong, ***Lian Yu***, ***Huang Jinhui***, ***Wang Ruiling***, ***Ge Lei*** and ***Lou Guangyan***

Yellow River Basin Water Resources Protection Bureau, Zhengzhou, Hennan, 450004

Abstract: The ecological water demand of the Yellow River estuary is dynamic and will change with the changing of protected target and its scale and the request of people. Based on the analysis of form and characteristics of ecological water demand, and according to the main ecological units of the Yellow River estuary and their function requirements, the ecological water demands in current protection levels are calculated with ecological methods, and are allocated in different time of a year. The results show the minimum and suitable ecological water demand of the Yellow River estuary is 4.703 billion m^3 and 6.816 billion m^3 respectively. For keep the biodiversity of estuary wetland and guarantee its eco – hydrological function, the minimum ecological flow: 75 m^3/s and 415 m^3/s should be fulfilled from November to March and from April to June separately, and the average minimum ecological flow in non – flood period is 200 m^3/s.
Key words: the Yellow River estuary, ecological water demand, wetland

Estuary ecosystem lies in the joint of river ecosystem and marine ecosystem, and it has unique environmental characteristics and important ecological service function because of being influenced by the interaction between land and sea, and this influence makes it to be a relatively fragile ecosystem at the same time. In recent years, because the water and sand resources from the Yellow River to estuary decreased, river way channelization, agriculture developing, and urbanization, the estuary ecosystem deteriorated seriously and the Yellow River's health was threatened, and the sustainable development of economy and society in YRD was affected. In 2003, YRCC put forward to the new idea of "maintain the Yellow River healthy life", it was clear defined that "meet the requirements of runoff process shaping to maintenance the Yellow River delta ecosystem healthy" in basin and region management and give priority to ensuring the "basic water requirements of river's life" in the Yellow River water resources management, so as to protect the integrity and stability of river ecosystems and to promote a good circulation of Yellow River delta ecosystems. To provide technical support for the optimal allocation of the Yellow River water resources and scientific basis for environment protection of estuary, we must make sure how much water should be supplied for the Yellow River estuary ecosystem for the Yellow River basin is seriously short of water resources, however, there is not answer to this question till now. Based on the analysis of form and characteristics of ecological water demand, and according to the main ecological units of yellow river estuary and their function requirements, the ecological water demands of current protection level are calculated with ecological and hydrological methods in this paper, and expect the results could offer technical supports to dispatch optimally water resources of the Yellow River and scientific basis for estuary environment protection.

1 Introduction of research area

The Yellow River delta is a sector area at the estuaries of the Yellow River, formed by silting, extending, swinging and deposition of the Yellow River, and it is an intensity deposit estuary with small tides. it lies between Laizhou Gulf and Bohai Gulf in the northern of China Shandong Province, ranging from 118°10′ E to 119°15′ E and from 37°15′ N to 38°10′N, and usually was compartmentalized to the neoteric Delta and the modern Delta by ages and geographical characteristics . The neoteric Delta is a sector area from Tao'er estuary to Zhimaigou estuary, Ninghai being its vertex. , and its area is more than 6,000 km^2. The modern Delta is from Tiao River to Songchunrong ditch, Yuwa being its vertex, and its area is more than 2,400 km^2. There are abundant animal, plant and wetland resources in the Yellow River delta, and the Yellow River delta national nature reserve lies new alluvial areas of both sides of the Yellow River estuary whose functions is to protect the new wetland ecosystems and rare and valuable birds, its total area is about 153,000 hm^2. The estuary wetlands play an important role on maintaining estuary bio – diversity and acting as rare birds' habitats.

2 Calculation principle and methods

2.1 Conception and composing of estuary ecological water demands

Ecological water demands are water quantities to keep the balance and normally development of ecosystem, and guarantee its basic functions to exert normally. Because there are different ecosystem types, ecological water demands include river ecological water demands, lake ecological water demands, wetland ecological water demands, droughty region ecological water demands and so on. Estuary ecosystem is an open and huge system, which needs well communication with other and superior systems, and at the same time, its open characteristics also requires that estuary system can achieve the matter and energy exchanging with land ecosystems and marine ecosystems. So there is a distinct difference between estuary ecological water demands and other ecological water demands. Suntao thought that target of estuary ecological water demands is to confirm the water quantities of maintaining estuary ecosystem healthy, which should include three types: the consumed water quantities by water circle, the consumed water quantities by bio – circle and the water quantities required by estuary creatures inhabiting. Liu jingling put forward to the conception of the estuary ecosystem basic flow which means the minimum flow to sea keeping or restoring estuary ecological functions and includes the least discharges required for evaporation and leakage, for hydrophytes, for bed – inhabit animal, for runoff or tideway, for restoring habitat, for preventing seawater intrusion, for tourism and entertainment etc. Thus the composing of ecological water demands is complex due to the complexity of structure and function of estuary ecosystem, and estuary ecological water demands should be the synthetically water quantities for all eco – unit ecological water demands instead of one of them. It should be studied aiming at different estuary ecosystem situations and protection functions and avoid overlaps when calculation.

According to the characteristics, functions of the Yellow River estuary ecosystem and objects of ecological water demands, it suggests that the Yellow River estuary ecological water demands should meet these requirements as follows: the first is for keeping certain scale wetlands to guarantee stability of ecosystem, the second is for aquatic animals breeding and maintaining bio – diversity in estuary area, the third is for the least discharge of river (basic flow), the fourth is for sediment transport and preventing coast erosion. Considering the complexity of water demand for preventing coast erosion which come down to water and sand resources of Yellow River, and the flow route in delta etc. , and overlap with water demands for sediment flushing, we only calculated the first three parts and don't consider the fourth in this paper.

2.2 Characteristics of estuary ecological water demands

2.2.1 Threshold value

For any ecosystem, ecological water demands is altering from minimum value to maximum value, and the lower limit is minimum water demands, and the upper limit is maximum water demands. The matter balance of ecosystem will be broken and some basic functions will be evidently weakened and the healthy of ecosystem would be harmed and become deteriorating in case exceeding the threshold values. There are different ecological water demands to different ecosystems and their different function requirements. The main aims of estuary ecological water demands are that confirming the best water demands characteristics of healthy estuary ecosystem, mastering the rules of ecological water demands of estuary ecosystem, and defining the scope of threshold value of ecological water demands so as to meet the estuary water demand of various ecological functions perfectly. Therefore, estuary wetland water demands were compartmentalized with maximum, minimum and suitable water demands based on the main eco – units of the Yellow River estuary in our studies.

2.2.2 Paying equal attention to water quantity and water quality

Estuary ecological water demands firstly should meet the water quantity requirements of different protection object, and at the same time it should meet the limits or requests of water quality for estuary aquatic and their habitats to pollution, sediment and nourishment.

2.2.3 Spatial – temporal diversities of estuary ecological water demands

The changing of seasonal climate, rainfall, evaporation and distribution of species population in estuary caused the ecological water demands change with time, and the variation of ecological water demands should accord with the natural allocation of runoff in estuary under the dynamic balance of the estuary ecosystem. At the same time, the requests to water quantity and quality and temporal variation of different estuary ecosystems or eco – units are different due to the differences of topography, physiognomy and the scale of estuary, i. e. the ecological water demands have the characteristics of spatial variation.

2.3 Calculation methods

2.3.1 The ecological water demands of estuary wetlands

(1) The protected scales of wetlands. The water quantity needed is different for different protected scales and different qualities. To make the limited water resources to be utilized efficiently and reach win – win results of ecological protection and economy development, we must ascertain how big wetland should be protected in different level years. With the support of remote sensing and GIS, the relationship between wetland area changes and water resources of the Yellow River from 1984 to 2004 was analyzed, and combining with the status quo of wetland protection, the perfect scale of wetland restoration was defined, and its area should be no less than the area of 1980's. In recent period, the freshwater wetlands, its area is 787 km^2 and is very close to the Yellow River should be restored firstly.

(2) Calculation methods. There are many methods to calculate wetland ecological water demand. These methods can be divided to 2 types: one is ecology method based on the composing of wetland eco – system, the other is hydrology method based on the whole wetland eco – system. The first is suitable to calculating the water requirements of meadow wetlands, and the latter is suitable to calculating the lake wetlands. Based on the wetland characteristics that it is disperse and there are many types in the Yellow River delta, we consider the ecological method is more suitable to calculating the water requirements, and in the calculating process, the ecological integrity and the ecological function will be considered, the advantages of the hydrology method will be adopted.

The estuary wetlands water requirements include vegetation evaportranpiration, soil water requirements, habitat water requirements and replenishment to groundwater. Among of these, vegetation evaportranpiration and habitat water requirements are the main parts. Vegetation evaportranpiration are the sums of vegetation transpiration and land and water bodies' evaporation, and it is consumed water of wetlands. Soil water requirements are the water needed to maintain the basic characteristics of wetlands. Habitat water requirements are the basic water needed by fish and birds inhabit and breed. The calculation method of different parts of wetlands requirements seen Table 1, and the parameters of vegetation and habitat water requirements seen (Table. 2 ~ Table. 3.)

Table 1 Calculation formulas of wetlands water requirements

Type of water requirements	Calculation formulas	Illumination
Vegetation evaportranpiration	$dW_p/dt = A(t)ET_m(t)$	dW_p: vegetation water requirements; $A(t)$: vegetationarea; ET_m: evaportranpiration
Soil water requirements	$Q_t = \alpha\gamma H_t A_t$	Q_t: Soil water requirements α: percentage of saturation hold water; H_t: soil thickness; A_t: soil area
Habitat water requirements	$W_q = A_t B_t H_t$	W_q: habitat water requirements; A_t: wetland area; B_t: percentage of water body; H_t: water depth
Replenishment to groundwater	$W_b = KIAt$	W_b: water replenishment to groundwater; K: filter coefficient; I: hydrolic grade; A: section area

Table 2 Calculation parameters of vegetation water requirements

Wetland types	Area(10^4 km^2)	Annual evaportranpiration (mm)	Annual rainfall(mm)
Reed wetland	276	1,200 ~ 1,900	550
Shrub etc.	511	1,000 ~ 1,800	550

Table 3 Calculation of habitat water requirements

Indicator species	Habitat	Water depth (m)	Water percentage (%)	Water requirements($10^8 m^3$)		
				Minimum	Suitable	Maximum
Red crown crane	Reed marsh	0.5 ~ 2.0	30 ~ 90	1.26	5.12	7.08

2.3.2 Water demands of offshore aquatic organisms in the estuary

(1) Water requirements of fish migrating. The main fish are saury, whitebait and eel etc. there are some saury spawn field below Sanmenxia of Yellow River in the anaphase of 1980s, and eel and saury can be captured. Yellow River Saury are important migrated economic fish in the Yellow River estuary, and they migrate from Bo sea to Dongping lake every year. There are little study about the relationship between fish survival and inhabiting and hydrological factors. In this study, Yellow River Saury is chosen as the indicator species and we consider if the water can satisfy them, and other creature can be satisfied too.

In R2CROSS method, the biologist abroad gave the average flow which can be meet the demand of fish spawn based on the protection of shallow beach, which is 0.3 m/s, but it is aimed to the inhabiting requirement of cold fish, and the domestic recent studies indicate that the suitable flow is 1 ~ 1.5 m/s. The water requirements of estuary aquatic organisms were calculated based on this result, and Liji section was chosen as the calculation hydrological section, and the relative water body in river are guaranteed. The result is 2.64 ~ 6.53 billion m^3, the same to say, the water requirements of estuary aquatic organisms are 2.64 ~ 6.53 billion m^3 (from April to June).

(2) Ecological water requirements of estuary and offshore area.

There are about 80 kinds of fishes at the Yellow River estuary offshore. Estuary is the mutual area of river and sea where river flow and tide affected each other. As the water flow into the sea from the river, the salinity of the the water increases from zero to the ordinary value of the sea, and the biotic communities are in the transition situations from terrestrial freshwater ecosystems to marine ecosystems. Salinity is one of the most sensitive factors to estuary environment, and it has a profound affection on the survival and distributing of creatures in the estuary. It is essential demand for habitat in the estuary to remain appropriate salinity. The lower salinity areas in estuary are the nursery sites of baby fish and invertebrates, and also are the important spawning field of migrating fish. The environment of inhabiting and spawning will be damaged if salinity becomes higher. Therefore the ecological water demands for offshore aquatic organisms in the estuary can be thought the water quantities from upstream to maintain the appropriate salinity of the estuary in a general way. The period from April to June is the peak season for fish and shrimp to spawn, and the suitable salinity of the sea is 23% ~27‰, the salinity within this range is important for fish and shrimp to spawn, and at the same time, the salinity of the Yellow River estuary and offshore area is about 30‰. According to relevant data, in this stage when the flow into the sea are 300 ~ 500 m^3/s, the salinity of tidal reach in the river is about 25‰ at high tide , and the relevant salinity at the offshore out of the river mouthes is about 30‰; at low tide the tongue of fresh water juts out the river mouth, the tidal reach of the river full of fresh water and the salinity is almost zero, and the relevant salinity is about 25‰ ~27‰ at the offshore out of the river mouth. Based on the analyses upwards, we can get the results when relevant the flow into the sea is 23.6 ~39.3 hundred million m^3, the salinity is appropriate for fish and shrimp to spawn and hatch.

The water quantities flowing to sea is a difficult question. It connected with fish migrating and offshore aquatic organisms' subsistence and fishery breeding, and it come down to many departments, such as sea, aquatic production and water conservancy etc. Based on the results above, we get the water requirements of offshore aquatic organisms in the estuary are 3 ~6 billion m^3, and it can be meet the demands of offshore aquatic organisms, and at the same time, satisfy the demand of fish in the estuary.

2.3.3 The basic flow in river course and the water required for sediment flushing

The basic flow of river course means the stable part in the discharge course line, and it is the perennial discharge in the river course, which is completely supplied by groundwater. Because the downstream of the Yellow River is suspended river, the basic flow of river course in estuary area is different from other rivers, and the basic flow here is the minimum river flow in order to maintain the water flow continuity and to meet the requirements of river landscape. The water required for sediment flushing means the flow that should be retained in the river in order to maintain dynamic balance of scouring and eroding. Basic flow adopts the former study results that the basic flow of river course is 50 m^3/s from November to March, and the water required for sediment flushing adopt Cui Subin and Song Shixia's results in "Study of Yellow River water environment protection down the Sanmenxia reach", and the basic flow of river course from April to Jane and July to October were covered by the minimum quantity that entered the sea and the water required for sediment flushing separately.

3 Result analyzing

The different type's ecological water demands were calculated in different methods separately. Considering the temporal characteristics of ecological water demand, the estuary ecological water demand season were divided three phases, i. e. April to June, July to October ,and November to March. Among of them, July to October phase is the flood season, and other phases are non – flood season. The calculation results and seasonal allocation see Table 3.

From Table 4 we come to conclusion as follows: not include water for flushing sediments, the minimum, suitable water demands of the Yellow River estuary are 4.703 billion m^3, 6.816 billion m^3 respectively and convert the minimum water quantity to flow, we can know the minimum flow requirement of different period through Lijin hydrographic section are 75 m^3/s, 415 m^3/s in November to March, April to June, separately. Including water for sediment flushing, the ecological water quantities are 19.7 ~24.7 billion m^3.

In the course of water quantity dispatching of Yellow River's water resources, YRCC looked upon 50 m^3/s of Lijin hydrographic section as a symbol that represents the Yellow River is not discontinuous and managed the water quantity dispatching in downstream of the Yellow River according to it. But the water quantity didn't include the water required by wetlands. As the habitats of many water birds living through the winter and multiplication, the minimum ecological water should be guaranteed to maintain wetland biodiversity and ecological function. By this token, the discontinuous state that the flows are 50 m^3/s is only a physical state, not in ecological state. If we want to guarantee the ecological discontinuous state of the Yellow River, the ecological water demands for all key ecological units or ecosystems must be taken into account synthetically, and the minimum ecological water demands should no less than 75 m^3/s in Lijin hydrographic section in current protection levels.

Table 4 The different grade ecological water demands of Yellow River estuary

Unit: 10^8 m^3

Period	Water quantity characteristics	Basic flow	Wetland ecological water demands	Water demands of offshore aquatic organisms	Water required for sediment flushing	Total ecological water demands	
						Not including water for sediment	Including water for sediment
Non − flood season (Nov. − Mar.)	Minimum water demands	6.52	3.15			9.67	9.67
	Suitable water demands	6.52	6.49			13.01	13.01
	Maximum water demands	6.52	9.23			15.75	15.75
Non − flood season (Apr. − Jun.)	Minimum water demands		2.63	30		32.63	32.63
	Suitable water demands		5.41	40		45.41	45.41
	Maximum water demands		7.69	60		67.69	67.69
Flood season (Jul. − Oct.)	Minimum water demands		4.73		150	4.73	154.73
	Suitable water demands		9.74		150	9.74	159.74
	Maximum water demands		13.85		>150	13.85	>163.85
Whole year	Minimum water demands	6.52	10.51	30	150	47.03	197.03
	Suitable water demands	6.52	21.64	40	150	68.16	218.16
	Maximum water demands	6.52	30.77	60	>150	>97.29	>247.29

4 Discussions

The ecological water demand of the Yellow River estuary is dynamic and will change with the changing of ecosystem protected targets and its scale and the request of people, and on the other hand, the water body area of wetland fluctuate between years is a normal nature situation, so the water demand of estuary is not a fixed value, and the calculation results proved it. In this paper, the ecological water requirements are feed back to Lijin section, and get the minimum, suitable flow of Lijin section. The result can give technical support to water quantity dispatching uniformly, water resource assignment of the Yellow River. In actual water quantity dispatching, many aspects such as the water quantities flowing to estuary from upstream of the Yellow River, the operation mode of Xiaolangdi reservoir etc. should be considered, and adjust the flow at Lijin section in non – flood season.

Because less of studies about relationship between water quantities and fish inhabiting, and water requirements flowing into sea in esturay is complicated, problem referring to multi – department and multi – discipline, so we only calculated the basic water requirements for estuary fish migrating and offshore creatures spawning and hatching, and how much water quantities required flowing to sea need us to do deeply studies in the future. At the same time, because there are few productions on estuary functions and values and their water demands mechanisms and rules, many problems, such as how to define the suitable protection scale of wetlands, the water demands characteristics of key species, the habitat suitability changes because of different ecological water allocations and so on, will be further studied in the future too.

References

Sun Tao, Yang Zhifeng, Liu Jingling. Study on the Ecological Water Demands for Typical Estuaries in Haihe River Basin. Acta ecologica sinica, 2004,24(12):2707 – 2715.

Liu Jingling, Yang Zhifeng, Xiao Fang, et al. Conformity Calculation Models on River Ecological Basic Flows[J]. Acta Scientiae Circumstantiae, 2005,25(4):436 – 441.

Guo Yuedong, He Yan, et al. Research on Eco – environment Water Demand of Zhalong National Natural Wetland[J]. Journal of Soil and Water Conservation, 2004,18(6):163 – 174.

Yang Zhingfeng, Cui Baoshan, Liu Jingling, et al. The Theory, Method and Practice of Ecological Water Demands[M]. Beijing, The Science Publishing Company, 2004.

Cui Shubin, Song Shixia. Study on Aquatic Environmental Protection below Sanmenxia of the Yellow River[R]. Water Resources Protection Bureau of the Yellow River Basin, 2002.

Changes of Robinia Pseudoacacia Planted Forest in the Yiqianer Nature Reserve Following the Super Storm Surge of Sept. 1992

Liu Qingsheng[1], ***Liu Gaohuan***[1] and ***Yao Ling***[2]

1. Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, P. R. 100101, China;
2. College of Resources and Environmental Science, Wuhan University, Wuhan, Hubei, P. R. 430072, China

Abstract: Based on the multi – temporal Landsat TM/ETM + data acquired from 1992 to 2001, integrated with a history of robinia pseudoacacia planted forest in the Yiqianer nature reserve of Yellow River Delta, robinia pseudoacacia planted forest changes following the super storm surge of Sept. 1992 and Aug. 1997 are analyzed. As a whole, the total area of robinia pseudoacacia planted forest continually decreased after the super storm surge of Sept. 1992 in the Yiqianer nature reserve. Before the super storm surge of Sept. 1992, the total area of robinia pseudoacacia planted forest was about 307.44 hm^2, but the total area decreased to about 176.85 hm^2 in Oct. 1993 and 110.34 hm^2 in Oct. 1995 after the super storm surge of Sept. 1992. Although the total area came back to about 138.69 hm^2 in Sept. 1996, the super storm surge of Aug. 1997 destroyed the robinia pseudoacacia planted forests again, and its total area sharply decreased to 41.31 hm^2 in Oct. 1997 and 34.02 hm^2 in May 1998 and 38.70 hm^2 in June 1999 and 29.70 hm^2 in May 2000. Thus it can be seen that defending the robinia pseudoacacia planted forest against super storm surge is very important for forest ecosystem health.
Key words: robinia pseudoacacia planted forest, yiqianer nature reserve, super storm surge, dynamic change

1 Introduction

The Yellow River Delta nature reserve consists of two separate parts: the floodplains and abandoned river mouth in the North (Yiqianer nature reserve) and the floodplains and the active river mouth in the East (Dawenliu nature reserve) (Liu, G. H., et al., 1997). The Yiqianer nature reserve (basically composed of the Yiqianer forestry centre) became the national nature reserve in Oct. 1992, and subsequently the Yiqianer forestry centre was accepted as the ecological and commonweal forestry centre by the people's government of Shandong province in 1999. In the Yiqianer nature reserve, the north coast line gradually erodes because the supply of sediments and fresh water have ceased since 1976.

Robinia pseudoacacia is a medium – sized deciduous tree, and easily transplanted and rapidly grown, and likes sun and tolerates a range of soil types and drought and salt and heat and pollution, and fixes nitrogen, and often used for the soil and water conservation, and becomes very trendy and popular planted tree in the whole China. In the Yellow River Delta, artificial robinia pseudoacacia forests are the principal forest land, and widely planted since the middle of 1970s, and main afforestation distributes in the floodplains and abandoned river mouth in the north (Yiqianer forestry centre and areas around DiaoKou River channel and ShenXianGou channel) and the floodplains in the east (Gudao forestry centre). Its area reached 12, 000 hm^2 in 1999, which is the biggest artificial robinia pseudoacacia forest in the eastern plain of China (Wang, S. M., 2002). But the dieback or dead of robinia pseudoacacia were noted at some areas of Yellow River Delta in the 1990s, which may be caused by intrinsic vegetation processes, land – use and/or other human – induced changes (e. g., pollution stress, oil exploitation, forest fire, deforestation), and natural disasters (e. g., insect infestation, storm surge). In the Yiqianer nature reserve, super storm surge is the uppermost natural disaster to robinia pseudoacacia planted forests.

The storm surge in the Yellow River Delta mainly results from strong north – east wind, which induces the collision between surge tide of the Bohai Bay and the high tide of Laizhou Bay. As a result of the flat topography at the mouth area, the 3 m higher storm surge can intrude upward into inland ten kilometers (Liu, G. H., et al., 1997). From 1960 to 1999, the 3 m higher storm surge had happened five times (1964, 1969, 1980, 1992 and 1997) (Compilation committee of History of Water Resources of Dongying city, 2003). According to history of Yiqianer forestry centre, the super storm surge of Sept. 1, 1992 destroyed about 533.3 hm^2 forest lands and the direct economic loss reached to about 1 million yuan RMB, and the super storm surge of Aug. 20, 1997 destroyed 866.7 hm^2 forest lands. In additional to the direct damage to robinia pseudoacacia planted forests, because the super storm surge flooded most areas of Yiqianer forestry centre and induced soil salinization, and therefore influenced robinia pseudoacacia growth during the subsequent period of time. The purpose goal of this study was to discover such effects through analyzing robinia pseudoacacia planted forest changes in the Yiqianer nature reserve following the super storm surge of Sept. 1992 and Aug. 1997, based on the multi – temporal Landsat TM/ETM + data acquired from 1992 to 2001.

2 Methods

2.1 Data collection

On the basis of phonological calendar of artificial Robinia pseudoacacia (Chen, K. J., 1998) in the local region and Landsat TM/ETM + imagery data quality and the time for super storm surge happened, nine different dates (Aug. 24, 1992, Oct. 30, 1993, Oct. 4, 1995, Sept. 20, 1996, Oct. 9, 1997, May 5, 1998, June 25, 1999, May 2, 2000 and Aug. 9, 2001) were selected.

2.2 Image preprocessing

Firstly, June 25, 1999 image was geometrically registered to a base map with a Transverse Mercator projection, Longitude of central meridian – 117°, Scale factor at central meridian – 1.0, Spheroid name – Krasovsky, False easting – 500,000 m. Then, June 25, 1999 image was used as the base image for geo – registered of the other eight images. The overall accuracy of the registration was less than 0.5 Pixel. In order to reduce overall workload, subsetted all of images via border of Yiqianer nature reserve.

2.3 Robinia pseudoacacia planted forests extracting from images

Because robinia pseudoacacia planted forests were only small parts of Yiqianer nature reserve (Fig. 1 (a)), image stretch and visual interpretation was used to extract robinia pseudoacacia planted forests from multi – temporal Landsat TM/ETM + images. In order to improve the precision and accuracy of image interpretation, firstly, Gaussian stretch (applying Gaussian stretch the whole image using statistics from the appointed window (the region surrounding by a black square) data) was used to contrast robinia pseudoacacia planted forests with surrounding surface features. Then, performed a high pass convolution on the stretched image, as a result, enhanced the edges of surface features in favor of visual interpretation (Fig. 1(b)).

The visual interpretation results from nine different images were listed in Table 1 and Fig. 2 and Fig. 3. As a whole, the total area of robinia pseudoacacia planted forest continually decreased after the super storm surge of Sept. 1992 in the Yiqianer nature reserve. Before the super storm surge of Sept. 1992, the total area of robinia pseudoacacia planted forest was about 307.44 hm^2, but the total area decreased to about 176.85 hm^2 in Oct. 1993 and 110.34 hm^2 in Oct. 1995 after the super storm surge of Sept. 1992. Although the total area came back to about 138.69 hm^2 in Sept. 1996, the super storm surge of Aug. 1997 destroyed the robinia pseudoacacia planted forests again, and its total area sharply decreased to 41.31 hm^2 in Oct. 1997 and 34.02 hm^2 in May 1998 and

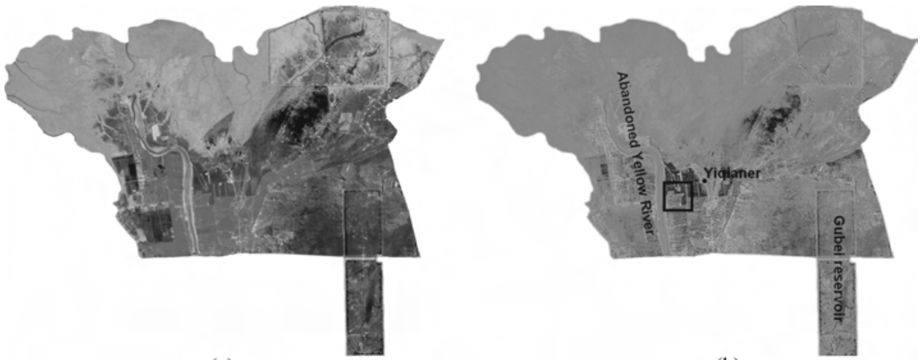


Fig. 1 Original and enhancement RGB432 images of Aug. 24, 1992

38.70 hm^2 in June 1999 and 29.70 hm^2 in May 2000. Because the robinia pseudoacacia planted forest health was bad and new plan for forest restoration was implemented in 2001, the rudimental robinia pseudoacacia planted forest was deforested.

Table 1 The area of robinia pseudoacacia planted forests from 1992 to 2001

Dates	8/24/1992	10/30/1993	10/4/1995	9/20/1996	10/9/1997	5/5/1998	6/25/1999	5/2/2000	8/9/2001
Area (hm^2)	307.44	176.85	110.34	138.69	41.31	34.02	38.70	29.70	0
Annual area change (hm^2)	0	-130.59	-66.51	+28.35	-97.38	-7.29	+4.68	-9.00	-29.70

3 Conclusions and Discussions

The direct damage to robinia pseudoacacia planted forests from the super storm surge is enormous, and the total area sharply decreased at the year following the super storm surge, as shown in Table 1 and Fig. 2 (Oct. 30, 1993 and Oct. 9, 1997). Robinia pseudoacacia grown in a seaward direction firstly began to die, and only robinia pseudoacacia distributed in upland still lived until 2001, as shown in Fig. 3. Because the super storm surge flooded most areas of Yiqianer forestry centre and induced soil salinization, and therefore influenced robinia pseudoacacia forest growth during the subsequent period of time, and the total area kept on decreasing. But robinia pseudoacacia can spread into surrouding landscapes and grow quickly and have self - improvement capability, the decrement of area became slow (Oct. 4, 1995 and May 5, 1998). The total area began to come back (restoration area was about 28.35 hm^2 in Sept. 1996) the four years after the super storm surge of Sept. 1992 and (restoration area was about 4.68 hm^2 in June 25, 1999) the two years after the super storm surge of Aug. 1997. The reasons why the time of day for beginning to restore after the super storm surge of Aug. 1997 was earlier than that of the super storm surge of Sept. 1992 maybe resulted from emban kment and sluice and saline - alkali discharge in 1998. Thus it can be seen that defending the robinia pseudoacacia planted forest against super storm surge is very important for forest ecosystem health. It was exciting that new plan for forest restoration and protection in Yiqianer nature reserve was begun to implement in 2001. The present study suggests that multi - temporal Landsat TM/ETM + data is explicit enough to be of operational use in monitoring robinia pseudoacacia planted forest changes following the super storm surge prior to a more detailed assessment.

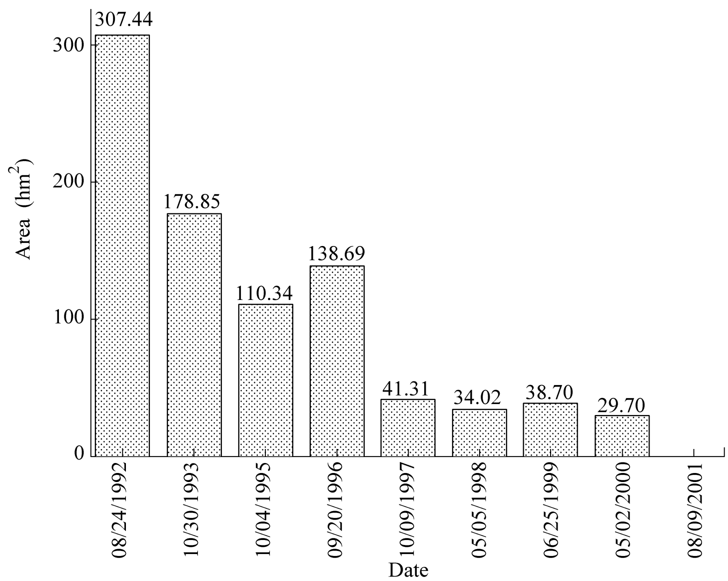


Fig. 2　The area of robinia pseudoacacia planted forest changes from 1992 to 2001

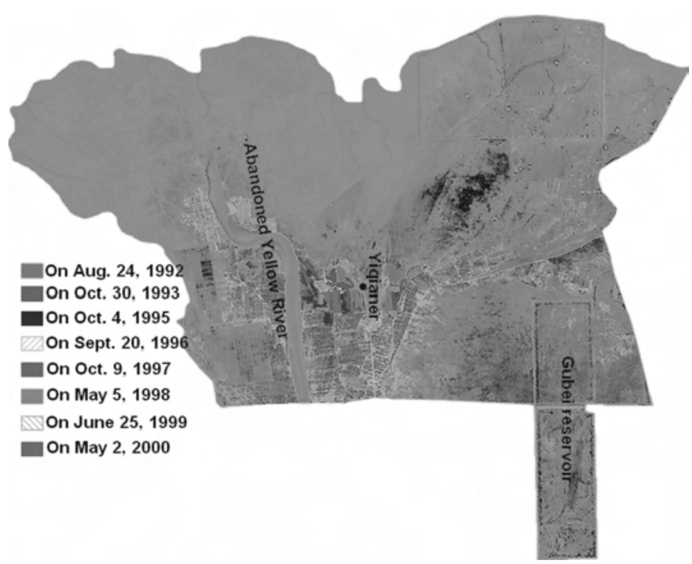


Fig. 3　Robinia pseudoacacia planted forest changes from 1992 to 2000

References

Compilation committee of History of Water Resources of Dongying city, 2003, History of Water Resources of Dongying city[M]. Red Flag Publishing House, Beijing, pp 67 – 89, 110 – 118.

Chen, K. J., 1998, Phenological phase observation of landscape trees in Dongying city[J].

Journal of Shandong Forestry Science and Technology, S1, 12 – 14.
Liu, G. H. and H. J. Drost, 1997, Atlas of the Yellow River Delta[M]. The publishing House of Surveying and Mapping, Beijing, pp 40, 53.
Wang, S. M., 2002, Quicken steps in greening in the Yellow River Delta[J]. Land Greening, 3, 18.

The Key Environmental Facors of Vegetation Degraded in the Yellow River Delta

Zhao Xinsheng*, *Cui Baoshan*, *Yang Zhifeng* and *He Qiang

State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China

Abstract: Using abundance matrix method of 18 plant species in 41samples in bulrush wetland of Yellow River Delta for TWINSPAN(Two – way Indicators Species Analysis). We combine the Yellow River Delta ecological effect, use the result of third compartmentalizeion and divide the communities in Yellow River Delta into 7 styles. Through analyzing the correlations between the different environmental factor, show that the soil salt is mainly made up by Na^+, Cl^-, K^+ and Mg^{2+}. From the result of CCA (Canonical Correspondence Analysis) analysis shows the degradation of Yellow River Delta has two orientations: ① Because of lacking fresh water, xerophytes are abundant, which usually could resist against drought, but could not resist salt. ② Caused by sea – erosion, the plants usually halophyte types, growing in inundation high salt or drought high salt environment. These different condition influence the vegetation distribution, then lead to the degradation of wetland communities. From this paper we can conclude that the key factors causing communities degradation are lack of fresh water and sea – erosion, it also shows that the ecology of wetland needs control the inflow of seawater and bring in fresh water.

Key words: TWINSPAN, CCA, degraded, environmental gradient, the Yellow River Delta, wetland

Until recently, about 50% primal wetland has disappeared. Because the weak protect, many wetland died away or degraded, caused many ecological environment problem, such as flooding, the decrease of biodiversity, pollution, eutrophication and so on, the sustainable development of wetland has been menace. Almost all the wetland has been disturbed by human, only stop disturbance cannot protect wetland, further more we cannot absolutely avoid disturbance, so using reasonable policy and technology to resume, rebuild and manage wetland, accelerate its structure and faction development are necessary to protect wetland. For natural wetland, the reason of its degradation is hard to decide, from macroscopical aspect, it also influenced by macroclimate, which hard to settle in short time, hence the discussion of environmental factors of wetland communities is significant.

One of recent research is focused on vegetation classification and compositor, which can reflect the relationship between plants and environment objectively(Zhang. F,Zhang J T 2000,Zhang X P, Wang M B. She B,2006). Since 1980s, TWINSPAN is the most common method in classifying vegetation, CCA is the latest method in this field (Zhang J T,2004). However, now these methods usually used in mountain, forest, grassland and sand, few of people use it into the study of wetland vegetation and the relationship of wetland vegetation and environment. In this paper, we first use TWINSPAN analysis method to classify the communities types of Yellow River Delta vegetation, then by CCA method analyze the main influent factors for vegetation distribution, confirm its environmental gradient. It provide a scientific data for Yellow River Delta reed wetland protection and resumption, ecological construction, decide the ecological water demand and so on.

Foundation item: the Major State Basic Research Development Program of China (973) (No. 2006CB403303), project supported by National Natural Science Foundation of China (40571149).

1 Study area and methods

1.1 Study area

The study area, Yellow River Delta Natural Reserve, situated at the entrance of the Yellow River to the Bohai Sea, within the range of 37°35′N ~ 38°12′N and 118°33′E119°20′E, mainly created to protect the new wetland ecosystem and rare and endangered waterfowls, is characterized with a temperate, continental monsoon climate, distinct seasons, and contemporary rain and heat (see Fig. 1). The annual average air temperature is 12.1 ℃, with 196 frostless days, and annual average rainfall and evaporation are 551.6 mm and 1,962 mm separately. Total area reaches 153,000 ha.

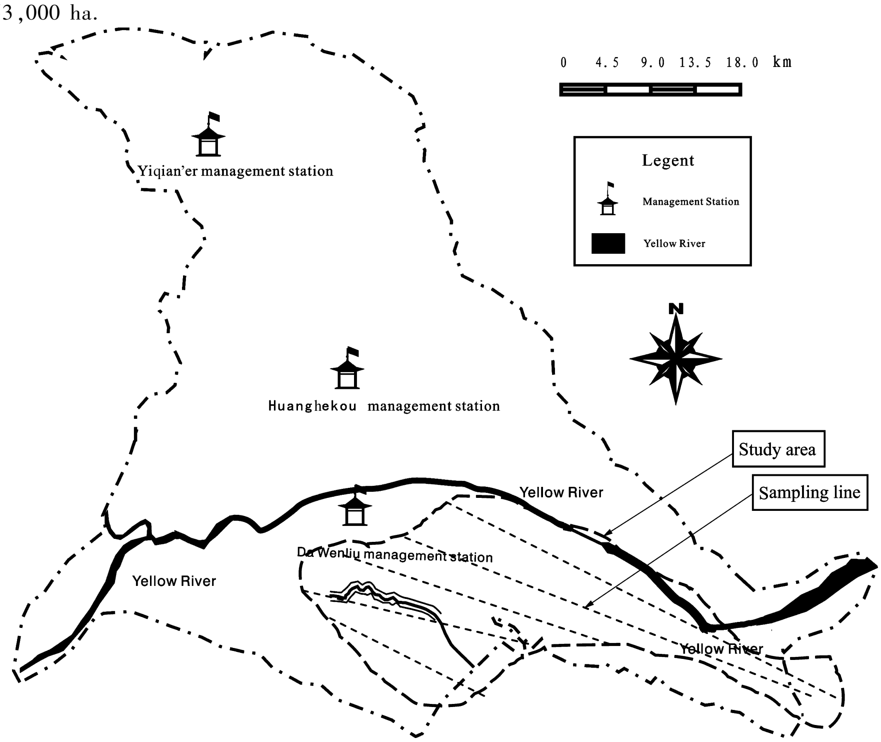


Fig. 1 The study area and the sampling line

In the reserve, secular water covered wetland (river, lake, estuary, pond, reservoir, aqueduct, saline, shrimp or crab pond and shoal) takes 63.06% of the total area; seasonal water covered wetland (tideland, reed swamp, other swamps, sparse wetland, shrub wetland, meadow and paddy land) takes 36.94% of the total area.

Compare to other estuaries, Yellow River Delta wetland is newly formed and has fragile ecosystem. Although with lower resistance capacity to environmental disturbance and easy to loss balance, it is an important transferring station for birds' migration.

Yellow River Delta is silted by soil lost from Loess Plateau. In 1855 ~ 1985, 19.982,1 ~ 26.642,8 km^2 land was formed per year in average. Since 1985, the land forming speed has slowed down because less and less water and sand was carried by Yellow River. The main soil types in Yellow River Delta are tidal soil and saline soil, soil salt content ranges from 0.6% to 3.0%, and NaCl. is the main component. Reed community grows in 0.5% ~ 1.5% salt content soil or 0.3% ~

0.4% salt content swamp or freshwater marsh in non – saline area. Freshwater resources and soil salt content are the main factors influence vegetation distribution in Yellow River Delta.

1.2 Study methods and data collection

1.2.1 Sampling strategy

Field investigation was carried on Yellow River Delta of Shandong Province(N37°45′37.9″, E119°03′28.9″) in 8 ~ 9, 2006. The area of sampling quads is 5 m × 5 m(for monitoring the region growing Tamarix chinensis and open area). They located randomly, and from it we take 5 investigation sampling which is 50 cm × 50 cm.

1.2.2 Data collection and measurement

Sampling quads were investigated and monitored the indexes of individual amount and structure of each species, abundance, etc. In the same time, we collected 0 ~ 20 cm surface soil samples 5 shares randomly and mixed equally for analyzing, as measure the indexes of the soil.

We use staff guage method(Using the soil surface as benchmark, higher then it is water deep, lower then it is water burial depth. In this paper, they all called "Water Depth". When it is a plus value, it shows the water surface is above soil surface, or others, it shows the water surface below soil surface). Though chemical analysis of extract liquid from soil, which the ratio of water to soil was 5∶1, we measured soil salt content, pH, Na^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}. The pH was measured by portable pH meter; soil salt content was measured salty of extract liquid from soil(ppr) by portable salt measure instrument, then switch it to soil salt content; Na^{+}, Ca^{2+}, Mg^{2+} was measured by ion chromatography; while Cl^{-} was measured by silver nitrate titration method. TC, TN was measured by element analyzer. TP was measured by ion chromatography after boiling and decompounding in the HF – $HClO_4$. The available K was measured by ion chromatography after extract by NH_4OAc. The soil content of organic was measured by potassium dichromate. We can consult the reference for the detail of this method.

1.3 Statistical analyses

We use MOPED for TWINSPAN analysis, TWINSPAN communities classified image was carried by Microsoft Excel v2003 and R language. We use ade4 and vegan of R language for CCA, and SYSTAT v12 for the correlation of environmental factors.

2 Results and discussion

2.1 The amount of each species in degraded area of Yellow River Delta

We use abundance matrix method of 18 plant species in 41 samples in bulrush wetland of Yellow River Delta for TWINSPAN(Two – way Indicators Species Analysis), and combine the Yellow River Delta ecological effect, use the result of third compartmentalize, divide the communities in Yellow River Delta into 7 styles, then named by the dominant species of each level and the compartmentalize of TWINSPAN, see Fig. 2 and Fig. 3.

(1) Community Ⅰ – Tamarix chinensis Lour – Suaeda heteroptera community: Typical as chionese tamarisk shrubbery community, it locates at the place that hasn't been restorted in the Yellow River Delta wetland.

(2) Community Ⅱ – Tamarix chinensis community: This community locates where restored area march with un – restored area.

(3) Community Ⅲ – Phragmites communis(L.) – Trin – Suaeda heteroptera community: This community distribute at highland of sandy soil with low salinity.

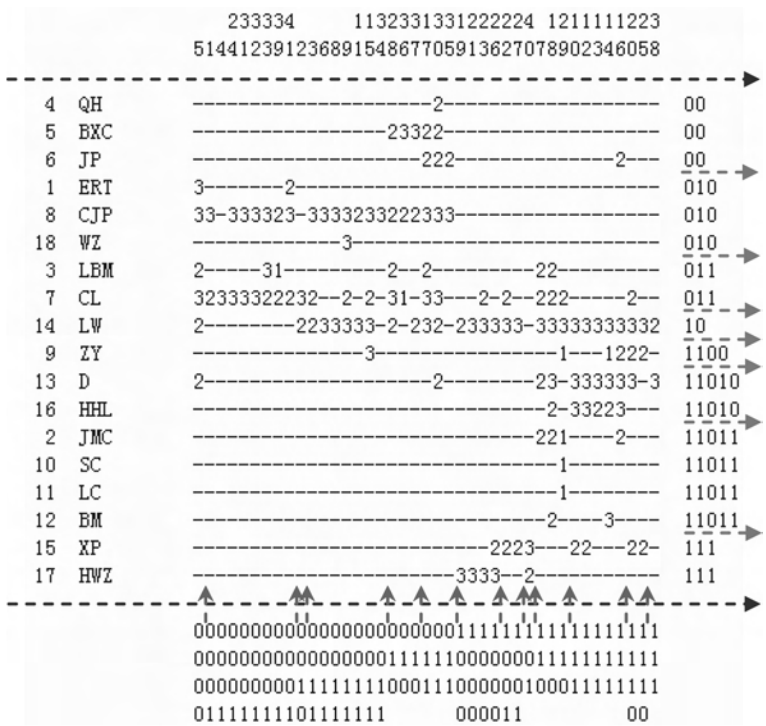


Fig. 2 TWINSPAN plot

Note: LW – (Phragmites communis (L.) Trin); XP – (Lepiironia rticulate (Retz) Domin); HWZ – (Myriophyllum spicatum); D – (Miscanthus sacchari florus); FZM – (Calamagrostis pseudophragmites (Hall. f.) Koel.); ERT – (Cynanchum. sibiricum Willd); JMC – (Sonchus brachyotus); ZY – (Aster tataricus); SCM – (Cyperus glomeratus L.); LBM – (Apocyman venetum); YD – (Glycine sojasieb); CMX – (Melilotus suaveolens Ledeb); CL – (Tamarix chinensis Lour); CJP – (Suaeda heteroptera); BXC – (Limoninum bicolor Bunge); JP – (Suaeda glauca Bunge); QH – (Herba Artemisiae Annuae); HHL—(Salix matsudana Koidz)

(4) Community Ⅳ: Phragmites communis (L.) – Trin – Lepiironia – rticulate (Retz) Domin – Myriophyllum spicatum community – As the end community of the hygrophilous vegetation, it locates at the place with long – term or temporary water.

(5) Community Ⅴ: Phragmites communis (L.) – Tamarix chinensis – Suaeda heteroptera – Limoninum bicolor Bunge community – This community locates at the place that was eroded by seawater with little fresh water and high soil salinity.

(6) Community Ⅵ: Imoninum bicolor – Suaeda heteroptera – Tamarix chinensis Bunge community – This community typically distributes in the degraded wetland with high soil salinity.

(7) Community Ⅶ: Phragmites communis (L.) – Miscanthus sacchari florus – Salix matsudana Koidz community – This community basically locates along the south bank of the Yellow River.

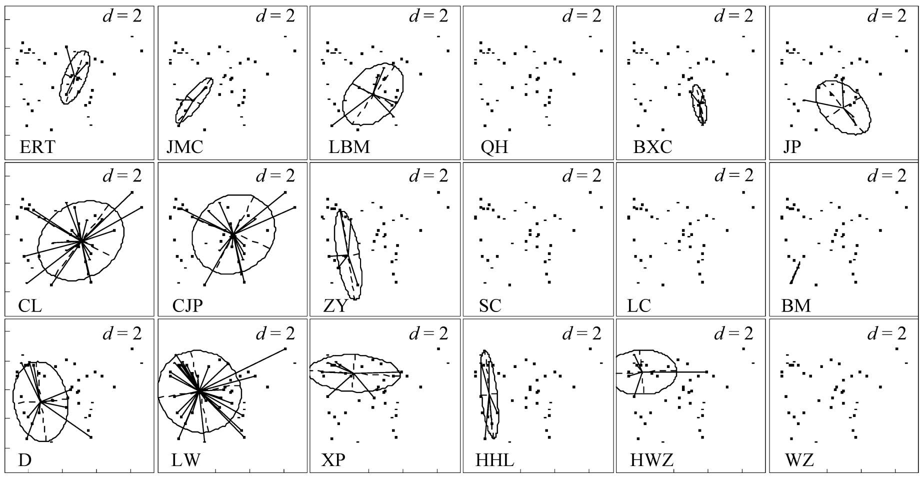


Fig. 3 The vegetation plot

2.2 The correlation analysis of environmental factors

The correlation analysis of environmental factors was listed in Table 1. Results showed that, moisture of soil (MS) had very significantly positive correlation with water depth (WD), and significant correlation with pH. The correlations between water depth (WD) and every other environmental factors were of weak significance, but most correlation coefficients were negative, mainly owing to the fact that water depth played a certain role in decreasing the content of environmental factors, especially salinity. pH had very significantly negative correlation with the content of Ca^{2+}, meaning that high content of Ca^{2+} could lower pH, which was in contradiction with the traditional opinion that the higher content of Ca^{2+}, the higher pH would be. Disturbance of other environmental factors might lead to the contradiction, but no scientific basis is reliable enough to explain it. Salinity of soil (SS) had very significantly positive correlations with the content of Na^{+}, Cl^{-}, and significant correlations with the content of K^{+}, Mg^{2+}, which showed that SS of the Yellow River Delta most contained Na^{+}, Cl^{-}, K^{+} and Mg^{2+} were less in it, further more, how to control Na^{+} and Cl^{-} is one of the critical techniques in water replenishing and salt leaching work of wetlands. Total carbon (TC) had very significant correlations with K^{+} and soil organic matter (SOM), and was correlated with Ca^{2+}. K^{+} had very significant correlations with Na^{+} and SOM, and was correlated with Cl^{-} significantly. Na^{+} very significantly correlated with Mg^{2+} and Cl^{-}. Mg^{2+} had very significant correlations with Ca^{2+}, Cl^{-}. Ca^{2+} was significantly correlated with Cl^{-}.

2.3 The key environmental facors of vegetation degraded in the Yellow River Delta

An abundance matrix formed by vegetations of 41 sample plots and an environmental factor matrix formed by WD, SS, SOM, pH, Na^{+}, Cl^{-}, K^{+}, Mg^{2+}, Ca^{2+}, TC, TN and TP were used to process CCA analysis, results were listed in Table 2, Table 3 and Fig. 3, Fig. 4.

CCA ordination graphs can perfectly reveal the correlation between plant species distribution and environmental gradient, environmental gradient is denoted by a line with an arrow, the length of the line shows how significant the correlation between plant species distribution and environmental gradient, the quadrant which an arrow lies in shows the positive or negative correlation between this environmental factor and ordination axes, the angle between an arrow – line and ordination axes shows how significant the correlation between this environmental factor and ordination axes. A vertica l line between a certain plant and an environmental – factor – line is drawn to analyze

Table 1 The relatvity of environmental factors

	MS	WD	pH	SS	TP	TN	TC	K⁺	Na⁺	Mg²⁺	Ca²⁺	Cl⁻	SOM
MS	1.000,0												
WD	0.722,1 ***	1.000,0											
pH	0.431,9 *	0.099,9	1.000,0										
SS	0.000,8	-0.060,0	-0.085,0	1.000,0									
TP	0.089,2	-0.047,0	0.081,6	-0.074,0	1.000,0								
TN	0.146,5	0.308,4	-0.002,0	-0.175,0	0.005,7	1.000,0							
TC	0.297,6	0.281,5	0.202,6	0.233,0	-0.017,0	0.057,9	1.000,0						
K⁺	0.275,1	0.284,4	0.219,2	0.485,4 **	0.026,0	0.125,9	0.695,2	***	1.000,0				
Na⁺	-0.011,0	-0.192,0	0.263,0	0.805,3 ***	0.033,7	-0.140,0	0.235,4	0.542,3 ***	1.000,0				
Mg²⁺	-0.184,0	-0.473,0	-0.216,0	0.561,8 **	-0.055,0	-0.237,0	-0.193,0	0.017,6	0.596,2 ***	1.000,0			
Ca²⁺	-0.333,0	-0.299,0	-0.637,0 ***	0.340,4	-0.071,0	-0.087,0	-0.417,0 *	-0.387,0	0.099,5	0.654,4 ***	1.000,0		
Cl⁻	-0.055,0	-0.224,0	0.033,1	0.871,7 ***	0.234,1	-0.152,0	0.169,7	0.401,8 *	0.869,7 ***	0.668,1 ***	0.357,8 *	1.000,0	
SOM	0.210,6	0.149,7	0.196,1	0.279,0	0.234,6	0.213,7	0.806,3 ***	0.591,7 ***	0.325,3	-0.059,0	-0.264,0	0.348,5 *	1.000,0

*** p < 0.001; ** p < 0.01; * p < 0.05。 t = 5.254,8, p = 5.588e-06; MS × pH: t = 2.468,6, p = 0.0180,5; MS × SS: t = -0.308,4, p = 0.759,4; MS × TP: t = 0.510,5, p = 0.612,6; MS × TN: t = 0.560,2, p = 0.578,5; MS × TC: t = 1.636,6, p = 0.109,8; MS × K: t = 1.616,3, p = 0.114,1; MS × Na: t = -0.626,4, p = 0.534,7; MS × Mg: t = -1.067,7, p = 0.292,2; MS × Ca: t = -1.897,3, p = 0.0652,1; MS × Cl: t = -0.678, p = 0.501,8; MS × SOM: t = 0.5687, p = 0.572,8; WD × pH: t = 0.015,4, p = 0.987,8; WD × SS: t = -0.405,1, p = 0.687,6; WD × TP: t = -0.366,1, p = 0.716,3; WD × TN: t = 1.779,4, p = 0.082,97; WD × TC: t = 1.673,9, p = 0.102,2; WD × K: t = 1.443,7, p = 0.156,8; WD × Na: t = -1.500,4, p = 0.141,6; WD × Mg: t = -3.970,4, p = 0.000,299,2; WD × Ca: t = -1.645,1, p = 0.108,0; WD × Cl: t = -1.583, p = 0.121,5; WD × SOM: t = 0.505,8, p = 0.615,9; pH × SS: t = -0.461,4, p = 0.647,1; pH × TP: t = 0.370,8, p = 0.712,8; pH × TN: t = -0.405,1, p = 0.687,6; pH × TC: t = 0.890,7, p = 0.378,5; pH × K: t = 1.076,2, p = 0.288,5; pH × Na: t = 1.751,3, p = 0.087,75; pH × Mg: t = -0.771,5, p = 0.445,1; pH × Ca: t = -4.526,8, p = 5.502e-05; pH × Cl: t = 0.373, p = 0.711,2; pH × SOM: t = 0.782,8, p = 0.438,5; SS × TP: t = -0.531,9, p = 0.597,8; SS × TN: t = -0.598, p = 0.553,3; SS × TC: t = 1.528,4, p = 0.134,5; SS × K: t = 3.302,3, p = 0.002,059; SS × Na: t = 7.923,3, p = 1.198e-09; SS × Mg: t = 3.326,8, p = 0.001,923; SS × Ca: t = 1.909,9, p = 0.063,52; SS × Cl: t = 9.863,1, p = 3.776e-12; SS × SOM: t = 1.77, p = 0.084,54; TP × TN: t = 0.033,1, p = 0.973,8; TP × TC: t = -0.147,1, p = 0.883,8; TP × K: t = 0.038,9, p = 0.969,2; TP × Na: t = 0.075,5, p = 0.940,2; TP × Mg: t = -0.388, p = 0.700,1; TP × Ca: t = -0.335,4, p = 0.739,1; TP × Cl: t = 1.574,8, p = 0.123,4; TP × SOM: t = 1.776,9, p = 0.083,4; TN × TC: t = 0.441,6, p = 0.661,2; TN × K: t = 0.660,3, p = 0.512,9; TN × Na: t = -0.480,3, p = 0.633,7; TN × Mg: t = -1.282,4, p = 0.207,3; TN × Ca: t = -0.271,6, p = 0.787,4; TN × Cl: t = -0.474,3, p = 0.638; TN × SOM: t = 1.434,4, p = 0.159,4; TC × K: t = 5.347,1, p = 4.168e-06; TC × Na: t = 1.305,8, p = 0.199,3; TC × Mg: t = -0.985,5, p = 0.330,5; TC × Ca: t = -2.616,6, p = 0.012,57; TC × Cl: t = 1.145,7, p = 0.258,9; TC × SOM: t = 7.633,6, p = 2.938e-09; K × Na: t = 3.931,5, p = 0.000,335,9; K × Mg: t = 0.598,8, p = 0.552,7; K × Ca: t = -2.352,6, p = 0.023,78; K × Cl: t = 2.545,6, p = 0.014,98; K × SOM: t = 3.624,1, p = 0.000,827; Na × Mg: t = 4.192,1, p = 0.000,153,5; Na × Ca: t = 0.417,4, p = 0.678,7; Na × Cl: t = 9.725,3, p = 5.598e-12; Na × SOM: t = 1.900,3, p = 0.064,81; Mg × Ca: t = 4.241,7, p = 0.000,1320; Mg × Cl: t = 4.794,2, p = 2.392e-05; Mg × SOM: t = -0.313,5, p = 0.755,6; Ca × Cl: t = 2.054,7, p = 0.046,65; Ca × SOM: t = -1.535,5, p = 0.132,7; Cl × SOM: t = 2.377,4, p = 0.022,43。

correlations between plant species and environmental factors, the nearer the intersection point of the vertical line and the environmental – factor – line away from the arrow, the more significant the positive correlation between this plant and this environmental factor, if the intersection point lies in the other end, this plant has a negative correlation with this environmental factor.

Table 2 The relativity of the vegetation species and environmental factors compositor axis

	SPEC AX1	SPEC AX2	ENVI AX1	ENVI AX2
SPEC AX1	1.000,0			
SPEC AX2	0.028,0	1.000,0		
ENVI AX1	0.926,3***	0.000,0	1.000,0	
ENVI AX2	0.000,0	0.826,2***	0.000,0	1.000,0

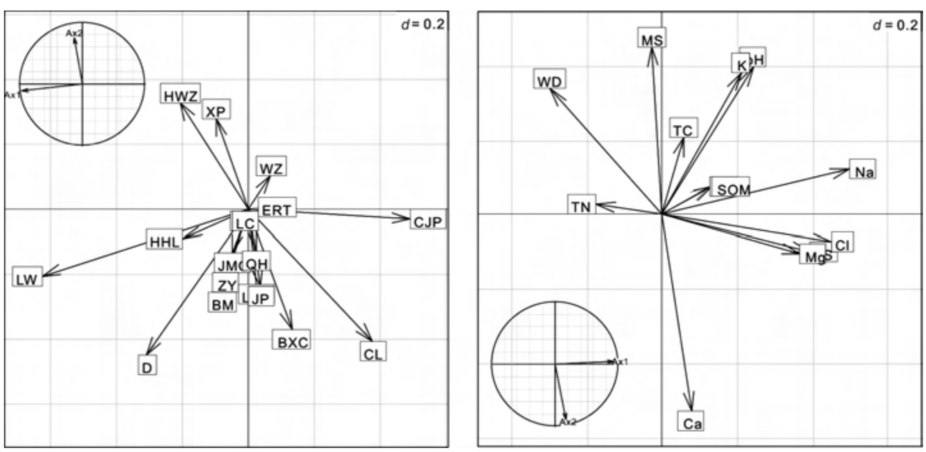


Fig. 4 CCA plot (Enviromental and vegetation)

CCA ordination graphs exhibit ordination axes of both plant species and environmental factors at the same time. Number 1 axe of plant species (SPEC AX1) had a very significant positive correlation with Number 1 axe of environmental factors (ENVI AX1), so is the correlation between SPEC AX2 and ENVI AX2 (correlation coefficients are 0.926,3 and 0.826,2) (Table 2). Table 2 showed that, WD had a significantly negative correlation with ENVI AX1 (correlation coefficient is 0.545,1). SS and Mg^{2+} both had significantly positive correlations with ENVI AX1 (correlation coefficients are 0.696,8 and 0.593,8). Na^+, Cl^- both had very significantly positive correlations with ENVI AX1 (correlation coefficients are 0.701,2 and 0.715,9). MS, WD, pH and TC all had significantly positive correlations with ENVI AX2 (correlation coefficients are 0.663,7, 0.572,8, 0.531,6 and 0.441,3). K^+ had a very significantly positive correlation with ENVI AX2 (correlation coefficient is 0.691,3). Na^+ had a significantly positive correlation with ENVI AX2 (correlation coefficient is 0.499,7). Ca^{2+} had a significantly negative correlation with ENVI AX2 (correlation coefficient is –0.467,2). No other significant correlations existed. SS, Na^+ and Cl^- had very significantly positive correlations with SPEC AX1 (correlation coefficients are 0.645,5、0.649,5 and 0.663,2). Mg^{2+} had a significantly positive correlation with SPEC AX1 (correlation coefficient is 0.550,1). MS and K^+ had significantly positive correlations with SPEC AX2 (correlation coefficients are 0.548,3 and 0.571,1). WD, pH and Na^+ had significantly positive correlations with SPEC AX2 (correlation coefficients are 0.473,3、0.439,2 and 0.412,8). Other environmental factors had no correlations with either SPEC AX1 or SPEC AX2.

Table 3 The relative coefficients of the environmental factors with the vegetation types and the compositor axis of the environmental

	SPEC AX1	SPEC AX2	ENVI AX1	ENVI AX2
MS	-0.155,6	0.548,3**	-0.168,0	0.663,7**
WD	-0.504,9	0.473,3*	-0.545,1**	0.572,8**
pH	0.163,5	0.439,2*	0.176,5	0.531,6**
SS	0.645,5***	0.199,6	0.696,8**	0.241,5
TP	0.203,9	0.072,1	0.220,2	0.087,2
TN	-0.343,4	0.030,4	-0.370,7	0.036,8
TC	0.030,7	0.364,6	0.033,2	0.441,3**
K^+	0.188,5	0.571,1**	0.203,5	0.691,3***
Na^+	0.649,5***	0.412,8*	0.701,2***	0.499,7*
Mg^{2+}	0.550,1**	0.010,3	0.593,8**	0.012,5
Ca^{2+}	0.250,8	-0.386,0	0.270,7	-0.467,2*
Cl^-	0.663,2***	0.221,3	0.715,9***	0.267,9
SOM	0.198,0	0.271,9	0.213,8	0.329,2

In the CCA ordination graphs of community samples, each plant species can be made into amplitude quantity graphs of monodominant community, which is helpful for us to find out factors that led to vegetation degradation in the Yellow River Delta, and to determine 7 plant community types in combination with the classification results of TWINSPAN. Specific details can be seen in former investigating results.

The CCA ordination graphs indicated that vegetation degradation in the Yellow River Delta happened in two directions: one is that, xeromorphic vegetation grew massively resulting from the lack of fresh water, which happened mainly in drought areas with low salinity and drought areas with high salinity. The other is that, the distributing areas of saline vegetation extended. It was the environment of water - flooded interaction that had resulted in the diversity of vegetation distribution in the Yellow River Delta, which further led to the problem of vegetation degradation.

Analyzed by CCA, we can see that the first ordination axe actually reflects the gradient change of the water depth and the soil salinity in the Yellow River Delta; while the second axe mainly reflects the gradient change of Ca^{2+} and pH. In conclusion, the main environment gradients in the Yellow River Delta are water depth and the salinity of the soil significantly related with the CCA axe 1. Along the axe 1, the water depth gradually rises while the salinity of the soil regularly decreases. Correspondingly, the halophytes represented by Tamarix chinensis Lour, Limoninum bicolor Bunge, Suaeda glauca Bunge, Suaeda heteroptera, gradually evolve into the light hydrophytes dominated by Phragmites communis, Myriophyllum spicatum, Typha angustifolla. The Fig. 5 shows that the degeneration of the wetland vegetations in Yellow River Delta mainly contributes to the comparative decrease of the freshwater resource caused by the high salinity of the soil when the seawater invades in; and we can also finds that the salinity, Na^+ and Cl^- have the greatest influences on the degeneration.

3 Conclusions

(1) Based on TWINSPAN, the reed wetland vegetation in the Yellow River Delta can be classified into 7 types: Tamarix - Suaeda heteroptera community, Tamarix community, Reed - Suaeda heteroptera community, Reed - Typha angustifolia - Myriophyllum spicatum community, Reed - Tamarix - Suaeda heteroptera - Limoniun community, Limoniun - Suaeda heteroptera -

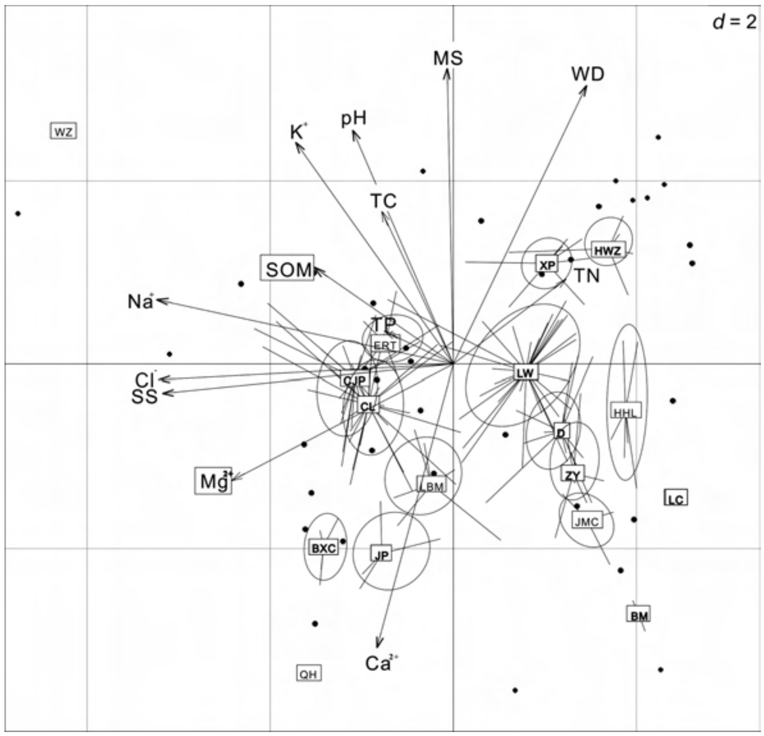


Fig. 5 The CCA ordination of sampling sites

Tamarix community, Miscanthus sacchariflorus – Reed – Willow community.

(2) Through CCA ordination, we found it was the high content of SS、Na^+ and Cl^- in the soil, that is lack of fresh water and seawater intrusion, that had led to vegetation degradation in the Yellow River Delta.

Acknowledgments

The authors wish to thank the Major State Basic Research Development Program of China (973) (No. 2006CB403303) and National Natural Science Foundation of China (No. 50239020). Thanks for Juanzhang Lv (the director of Yellow River Delta Management Bureau), Yueliang Liu (the General Engineer of Dawenliu Management station), Feng Lu (the assistant director of Dawenliu Management station) and Lidong Wang (missionary) for their help in data and literature information collecting and job going.

References

Zhang F, Zhang J T. Research progress of numerical classification and ordination of vegetation in China[J]. Journal of Shanxi University (Nat. sci. Ed.),2000, 23(3):278 – 282.

Zhang X P, Wang M B, She B, et al. Numerical Classification and ordination of forest communities in Pangquangou National Nature Reserve[J]. Acta Ecologica Sinica, 2006, 26(3): 755 – 761.

Zhang J T. Quantitative Ecology[M]. Beijing, China: Science Press, 2004.

Guo S L, Chen J H, Wang F, et al. CCA on the Relationship between the Main Tree Species with Their Environment in Jinhua Mountain, Zhejiang Province[J]. Journal of East China Normal University (Natural Science, 2002, 3: 98 – 103.

Zhao Q Fen, Chen G S. The Relationship between species siversity and altitudinal gradient for evergreen broad – leaved forests for Simian Mountain, Chongqing[J]. Journal of Sichuan Normal University(Natural Sc ience), 2004, 27(4):405 – 409.

Wang L, Zhang J T, Ou Y H. Ecological Relationship in Lishan Mountain Meadow[J]. Journal of Mountain Science, 2004, 22(6): 669 – 674.

Zhu Y, Qiu Y, Fu B J, et al. Numerical analysis on ecological gradient of plant communities in Donggou catchment, Hebei Province[J]. China. Chinese Journal of Applied Ecology, 2004, 15(5): 799 – 802.

Yang X H, Zhang K B, Hou R P, et al. Vegetation variations under different exclusion measures and their correlation to soil factors[J]. *Acta Ecologica Sinica*, 2005, 25(12): 3212 – 3219.

Liu K, Wang X K, Yang F, Guo R, et al. Piuns sylvestris community on Honghuaerji sandy land and its relationship with environmental factors[J]. Chinese Journal of Ecology, 2005, 24(8): 858 – 862.

Shu Y, Hu M Y, Guo D F, et al. The change of the habitat suitable for the Red – crowned Crane in Yellow River Delta[J]. Chinese Journal of Zoology, 2004, 39(3): 33 – 41.

Bao S D. Soil and Agricultural Chemistry Analysis[M]. Beijing: China Agriculture Press, 2000.

Water Quality Changes of Flatland Reservoirs in Yellow River Delta and Water Quality Restoration Techniques

Li Laijun[1], ***Xu Yonglin***[1] and ***Zhang Renjie***[2]

1. Water Supply Co. of Shengli Petroleum Administration Bureau, Dongying, 257097, China
2. Institute of Colloid Interface Chemistry, Shandong University, Jinan, 250100, China

Abstract: Recent year statistical analyses of the water quality detection data reveal the fact that the causes of the changes of water quality in the reservoirs drawing water from the Yellow River mainly include the characteristics of headwater system, the retention time of hydraulic power, the volume of replacement water and the water quality of the Yellow River. This paper explored the water quality restoration techniques of the above - mentioned reservoirs according to the water source conditions and the changes of water quality, the results of which indicate that some indexes such as algae, permanganate and dissolved oxygen tell obvious seasonal variations, and there exists a certain linear relationship among the azote, phosphor and algae content.
Key words: reservoir, the Yellow River, water quality, restoration

1 Introduction

Shengli Oilfield is located in the delta plain of the Yellow River. Because of the seawater encroachment, the superficial underground water tastes bitter and salty, so, the inflow from the Yellow River becomes the only source of water in the delta area. Influenced by the water quality, diversion conditions and drying up of the Yellow River, Shengli Oilfield had to construct 11 large and medium - sized reservoirs and 110 small reservoirs, with the total storage capacity of 450 million m^3 to draw water from the Yellow River from 1970 to 1999. Subject to the influences of the characteristics of headwater system, the retention time of hydraulic power and the volume of replacement water, the water quality of these reservoirs are worse than that of the Yellow River Therefore, according to the water quality testing results in recent years, the authors have analyzed the water quality of the Yellow River and these flatland reservoirs, and found out the regularities of water quality changes so as to explore the restoration techniques.

2 General situation of water sources

2.1 Process of drawing water from the Yellow River

The water of the Yellow River is pumped (or flows by gravity) to the water source areas by diversion dyke. When settled, the water will be impounded into the reservoirs.

2.2 Conditions of the reservoirs

Five most representative reservoirs with the biggest supply capacities are chosen for analysis (see Table 1). Xin'an Reservoir was put into use in June, 1980. After many years' operation, the silting problem has become very serious. Its actual capacity has reduced from 20 million m^3 to 14 million m^3. Minfeng Reservoir consists of six small reservoirs, which were built one after another from 1968 to 1982. It is able to hold 5.43 million m^3 of water. But as it has no desilting pools, turbid water flows directly into the reservoir. As a result, silting is also very serious. Lijin Reservoir was put into operation in November, 1991, the impounding depth of which is 3.5 m and the designed capacity is 20 million m^3. Having no desilting pools, it is silted with 1.2 million m^3 of sediment. Chunhua Reservoir and Gengjing Reservoir have desilting pools. Water from the Yellow River can be settled before it flows into the reservoir. Among these five reservoirs, Chunhua Reservoir, with the shortest operation time and the deepest impounding depth, belongs to the medium – sized overground lake – type flatland reservoir with "high dam and deep water".

Table 1 Basic conditions of Shengli Oilfield reservoirs

Sequence	reservoirs	Construction time	Designed capacity (million m^3)	Surface area (m^2)	Average depth (m)	Reservoir type
1	Minfeng	1968 ~ 1982	5.43	2.86	3.5	Overground lake type
2	Xin'an	1979 ~ 1980	20	6.41	4	Half – underground belt type
3	Lijin	1988 ~ 1991	20	6.1	3.5	Overground lake type
4	Gengjing	1989 ~ 1991	20	3.36	5.67	Overground lake type
5	Chunhua	1998 ~ 2000	33.41	3.62	8.3	Overground lake type

3 Contrast between Yellow River water quality and reservoir water quality (see Table 2)

3.1 The present situation of the Yellow River water quality

The water pollution of the Yellow River Valley has been getting more and more serious in the last ten years as a result of the rapid social and economic development, the heavier sewage discharge from both sides of the Yellow River, as well as the decreasing of the natural water. *The Yellow River Water Resource Bulletin of* 2003 *and* 2004 showed that the quality of water flowing into the sea only reaches Grade Ⅳ. And the major indexes exceeding national standard generally include ammonia nitrogen, chemical oxygen demand, and hypermanganate, etc.

Table 2 Average statistic about main indices in Yellow River water and reservoir water from August, 2003 to August 2006

Inspection item	Units	National standards	Chun hua	Geng jing	Min feng	Lijin	Xin'an	Yellow River water
pH	—	6 ~ 9	8.36	8.40	8.32	8.43	8.40	8.16
Dissolved Oxygen (DO)	mg/L	≥5	9.77	9.82	9.04	8.98	8.73	8.47
Potassium permanganate index	mg/L	≤6	3.27	3.58	4.11	4.40	5.57	3.84
Chemical Oxygen demand	mg/L	≤20	8.64	9.58	13.43	14.93	17.83	14.1

Table 2

Inspection item	Units	National standards	Chun hua	Geng jing	Min feng	Lijin	Xin' an	Yellow River water
Five - day BOD	mg/L	≤4	1.43	1.56	2.11	2.25	2.28	—
Ammonia nitrogen	mg/L	≤1.0	0.135	0.222	0.308	0.292	0.255	0.756
Nitrate	mg/L	≤10	1.95	2.26	2.53	0.921	1.043	3.5
Total nitrogen	mg/L	≤1.0	2.43	2.84	3.17	1.52	1.90	4.58
Total phosphorus	mg/L	≤0.05	0.016	0.024	0.038	0.035	0.036	0.054
Copper	mg/L	≤1.0	0.007	0.008	0.007	0.007	0.007	0.013
Zinc	mg/L	≤1.0	0.012	0.010	0.012	0.010	0.011	0.020
Hexavalent chrome	mg/L	≤0.05	0.010	0.015	0.020	0.018	0.017	0.051
Sulphate	mg/L	≤250	146	134	129	145	140	135
Chloride	mg/L	≤250	158	110	106	125	241	94
Fluoride(F)	mg/L	≤1.0	0.70	0.70	0.694	0.726	0.791	0.625
Iron	mg/L	≤0.3	0.037	0.109	0.15	0.132	0.093	0.56
Algae	ten thousand/L	—	611	946	2,744	1,412	4,092	—

According to the statistics results of 17 tests from August, 2003 to August, 2006 and *The Environmental Surface Water Quality Standard Grade* Ⅲ, the amount of total nitrogen, hypermanganate index, chemical oxygen demand, ammonia nitrogen, hexavalent chrome and iron content in the Yellow River water all go beyond the national standards. The content of common chemical targets such as iron, zinc and copper, chrome and other toxicological targets in the Yellow River water vary quite differently in different drawing periods. The differences among them are above 15 times.

Table 3 Statistics about the exceeding subjects of Yellow River water quality from August, 2003 to August 2006

Inspection item	Units	National standards	Average value	Maximum value	Minimum value	Exceeding frequency(%)
Permanganate index	mg/L	≤6	3.84	6.36	1.76	11.8
Chemical oxygen demand	mg/L	≤20	14.1	35.2	8.3	5.9
Ammonia nitrogen	mg/L	≤1.0	0.756	2.39	0.13	23.5
Total nitrogen	mg/L	≤1.0	4.58	7.41	2.23	100
Hexavalent chrome	mg/L	≤0.05	0.051	0.091	0.011	35.3
Iron	mg/L	≤0.3	0.56	3.19	0.16	47.1

3.2 The present condition of reservoir water quality

According to "The Environmental Surface Water Quality Standard Grade Ⅲ" (GB 5749—2002), (national standard of total phosphorus 0.05 mg/L), and the contrast of the qualities of the Yellow River and reservoir water (see Table 2), we can see that TN, and TP of the five reservoirs all exceed the national standards. Except Chunhua and Gengjing reservoir, the COD_{Mn}, COD_{Cr} of the other three reservoirs, the BOD_5 of Minfeng Reservoir, the pH and BOD_5 of Lijin Reservoir and the pH and Chloride of Xin'an Reservoir all go beyond the national standards.

3.3 Contrast between Yellow River water quality and reservoir water quality

The Yellow River water quality changes a lot after a long storage in the reservoirs. We can see from Table 2 that the pH value, Chloride and Fluoride content in reservoir water are all higher than those in the water newly drawn from the Yellow River. The hypermanganate indexes in Minfeng, Lijin and Xin'an reservoirs are higher than that in the Yellow River water while the hypermanganate indexes in Chunhua and Gengjing reservoir are lower. The content of Chemical Oxygen Demand (COD) in Chunhua, Gengjing and Lijin reservoirs are lower than those in the Yellow River water. The amount of total nitrogen, ammonia, nitrate nitrogen, total phosphorus and metallic ion such as copper (Cu), zinc (Zn), iron, chromium, etc, in all these five reservoirs are lower than those of the Yellow River water.

4 The analysis of causes and the regularity of water quality changes

There are mainly 5 characteristics of Shengli Oilfield water source system: ① Reservoir storage capacity is huge but the water storage depth is low; ② Raw water stays too long in the reservoirs; ③ The loss of water is huge because of evaporation and leakage; ④ The turnover volume in the reservoirs decreases year after year due to the rising water price, the enhancing water-saving consciousness and the influence of sewage recharge; ⑤ There are desilting pools in most reservoirs of Shengli Oilfield. Because of the great amount of silt and sand in the Yellow River water with bigger specific surface area which adsorb many things, some materials especially the metallic ion content in the Yellow River water are adsorbed and deposit down to the bottom of desilting pools. So the reservoir water quality is quite different from the quality of the water drawn from the Yellow River.

4.1 Algae

The pollution of algae is comparatively a serious water quality problem in the reservoirs of Shengli Oil Field, among which Xin'an Reservoir and Lijin Reservoir deserve greater concern. According to the survey of algae pollution of all the reservoirs storing the Yellow River water in Shandong Province in 2004, the quantity of biological algae content in Xin'an Reservoir ranks the first. On the one hand, most reservoirs were built long time ago, the volume of these reservoirs is large, the depth of water is shallow, and the retention time of hydraulic power is long. All the above factors provide the conditions of eutrophication of water objectively; On the other hand, the water drawn from the Yellow River is of poor quality. Its high content of nitrogen, phosphorus speeds up the propagation of all kinds of algae. Fig. 1 shows that the algae are smaller in quantity from January to May, which mainly consists of diatom, euglena, and blue algae. In June and July, the quantity of algae increases to some extent. From August to October, the suitable water temperature and plenty of sunshine lead to the explosive growth of algae. In 2004 and 2005, the quantity of algae in Minfeng Reservoir and Xin'an Reservoir is over 100 million pieces / liter respectively, and blue algae is much more than the other kinds (as in Xin'an Reservoir, see Fig. 2). From November, the quantity of algae is obviously reducing.

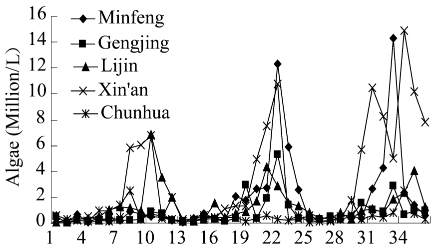


Fig. 1 Monthly graph of total amount of algae, from Jan., 2003 to Dec., 2005

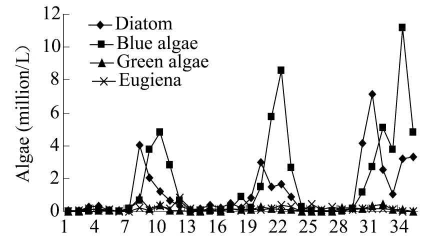


Fig. 2 Monthly graph of main algae in Xin' an Reservoir from Jan., 2003 to Dec., 2005

A great deal of dead algae deposited in the water of the reservoirs. From July to October, because of the rise of water temperature, dissolved oxygen (DO) decreases, the organism of dead algae becomes anaerobic and ferments. Nitrogen, phosphorus, etc, are released out and become pollution sources for the second time which boost the propagation of algae. In Fig. 1 we can see that, the amount of algae increases year after year, the pollution of algae in the reservoirs tends to be more and more serious.

4.2 Nitrogen and phosphorus

Nitrogen's cycle in reservoir water has four effects: ① Ammonification; ② Nitrification; ③ Denitrification; ④ Assimilation. Phosphorus mainly has three kinds of changes: absorbing sediment, releasing sediment or being absorbed by aquatic plant.

Figs. 3 and Figs. 4 show that: nitrogen in reservoir water is in constant conversion and circulation along with external environment and condition changes. The total nitrogen variation tendency is basically identical with that of nitrate nitrogen. The proportion of nitrate nitrogen in total nitrogen is relatively high; there is certain connection between the content of algae and them. From January to June, the water temperature is relatively low. There is relatively less content of algae, the content of DO is high, nitrification is strong, and the content of nitrate nitrogen is relatively high. From August to October, the algae grow rapidly. On the one hand, phytoplankton absorbs nitrate nitrogen strongly; on the other hand, because the water temperature is high, the content of DO is low, denitrification is strong, and the content of nitrate nitrogen is relatively low. Ammonia nitrogen's variation tendency (see Fig. 5) is not so obvious as that of nitrate nitrogen. This is probably because the water temperature is high between August and October, the content of DO is low at the bottom of water substance, and ammonification is strong.

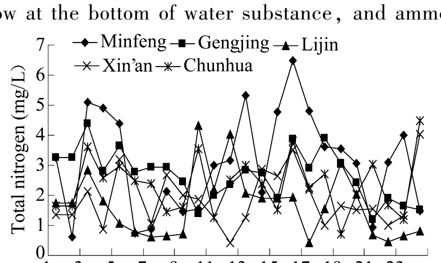


Fig. 3 Monthly graph of total amount of nitrogen from Jan., 2004 to Dec., 2005

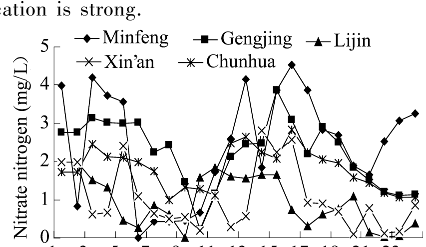


Fig. 4 Monthly graph of nitrate nitrogen from Jan., 2004 to Dec., 2005

The variation tendency of total phosphorus (see Fig. 6) is not so obvious as that of nitrogen in the water substance of the reservoirs. This is because, on the one hand, the vigorous metabolism of algae can absorb a large amount of nitrogen while there is less absorption of the phosphorus; on the other hand, such factors as temperature, pH value, dynamic condition of water and bioturbation function, etc., may cause phosphorus in the sediment to spread in water substance, thus having certain influence on nutritional status of water substance.

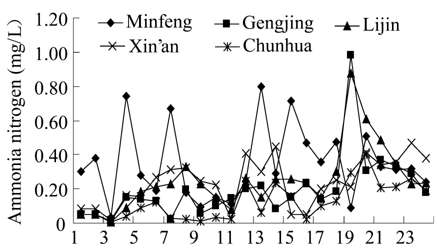


Fig. 5 Fig. 5 Monthly graph of ammonia nitrogen, from Jan., 2004 to Dec., 2005

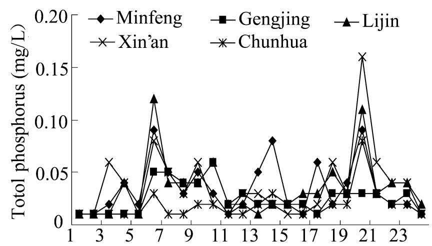


Fig. 6 Monthly graph of total amount of phosphorus, from Jan., 2004 to Dec., 2005

4.3 Heavy Metal

Heavy metal ions such as copper, zinc, iron and chromium are lower in the reservoir water body than those of the Yellow River water, which indicate that some heavy metal ions are deposited with the silt. From July through October, the annual content of heavy metal ions is slightly higher than the other months in the reservoir water body (see Fig. 7). Generally, because the water temperature from July to October is relatively higher, and the solubility rises with the temperature, some metal ions are released from the sediment again. Because metal ion constantly accumulates in sediment, the trend of the reservoir metal ion rises in the water body year after year.

4.4 Organic pollutant

Permanganate index, chemical oxygen demand, and 5 – day BOD are important indexes of the water pollution degree and are often regarded as the index to weigh the content of organic matter in the water. The bigger the value is, the more serious the organic pollution is.

According to statistics, the permanganate indexes, and chemical oxygen demand of Chunhua, Gengjing reservoirs are lower than those of the water drawn from the Yellow River, and the 5 – day BOD is also relatively lower. This is because, on one hand, the desilting pool is built in Gengjing and Chunhua reservoirs, some organic matter sink with the silt in the desilting pool; On the other hand, the completed time of the two reservoirs is short, the storage is large in depth, the ecosystem is comparatively complete, and the self – purification ability of water body is strong. From the statistic data (see Fig. 8) of January, 2003 through December, 2005, there is a downward trend year after year in the permanganate indexes of Chunhua, and Gengjing reservoirs, but the downward trend ceases up gradually.

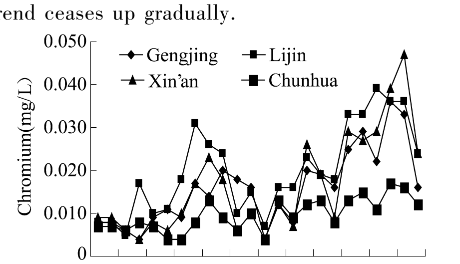


Fig. 7 Monthly graph of hexavalent chrome from Jan., 2004 to Dec., 2005

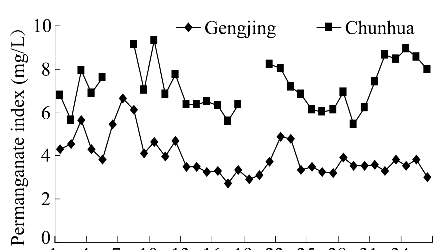


Fig. 8 Monthly graph of permanganate index from Jan., 2003 to Dec, 2005

The permanganate indexes, chemical oxygen demand, and 5 - day BOD of Lijin, Minfeng, and Xin'an reservoirs are relatively higher. This is because on one hand, there are no desilting pools built in the three reservoirs, the sediment deposit seriously and contain the comparatively abundant nutriment; On the other hand, the three reservoirs has been long in use, the storage is shallow in depth, the alga content is high, the ecosystem is not complete enough, and the self - purification ability of water body is relatively weak.

The main pollutant permanganate index in the reservoir water body (see Fig. 9), the chemical oxygen demand, the 5 - day BOD, the total number of bacteria, and the large intestine fungus group (see Fig. 10), etc. have obvious seasonal changes. Because the water temperature is high in summer, the microbial activity is strengthened, and the bacterium is easy to breed. Therefore the total number of the alga increases. In turn, the permanganate index, the chemical oxygen demand, and the 5 - day BOD increase in water at this moment. Finally the dissolved oxygen density reduces (see Fig. 11) in water and water quality becomes worse.

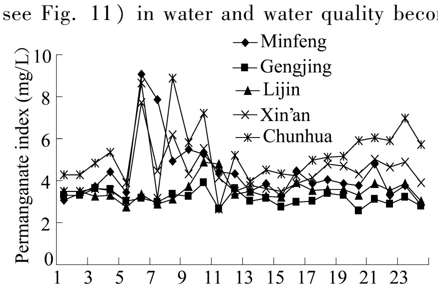


Fig. 9 Monthly graph of permanganate index from Jan., 2004 to Dec., 2005

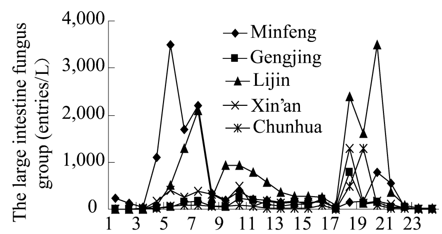


Fig. 10 Monthly graph of feces coliform bacteria groups from Jan., 2004 to Dec., 2005

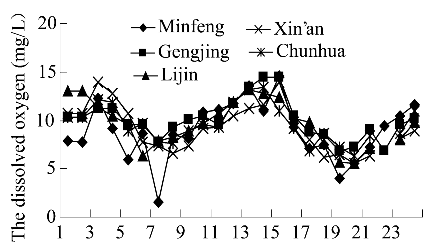


Fig. 11 Monthly Graph of Dissolved Oxygen from Jan., 2004 to Dec., 2005

4.5 Chloride

The Yellow River Delta is a saline and alkaline place. The surrounding and bottom soil of the reservoirs are the salt soil whose salt content is generally in 0.6 ~ 3.0, with NaCl as the main ingredient. The salt soil is a source of high content of chlorine ion; on the other hand, the reservoirs are very big in capacity, very small in depth, but cover a large area. In addition, another reason to cause high chloride and total solid content of solubility is the evaporation - concentration function. For instance, Xin'an reservoir owns a half underground strip structure. Its unique geological characteristics and the construction pattern of the reservoir cause the salt content of the water of the reservoir higher than other reservoirs. The two above - mentioned aspects have made the water fluoride of the reservoirs higher than the water drawn from the Yellow River.

4.6 pH

Since reservoir water is a kind of natural buffer solution, its pH rangeability is narrower than other indexes. Generally, the rangeability of water pH concerns not only the activities of aquatic beings and water temperature, but also the variation of the DP of CO_2 in the air and the decomposition of organic scrap in substrate substances. Compared with the pH in the Yellow River water, all the reservoirs have a higher pH value. And there is a certain linear relationship between the latter and the total quantity of algae, because much CO_2 has beenconsumed by fast reproduction and growth of algae which breaks the carbonate balance and finally causes a drop in water acidity.

Therefore, the retention of the Yellow River water has made the changes of some indexes of the water body become regular under the influence of the retention time, the turnaround speed, the characteristics of the headwater system, the environment and many other factors. For example, the changes of algae, permanganate index, chemical oxygen demand (COD), the 5 – day biological oxygen demand (BOD), dissolved oxygen (DO), nitrate nitrogen, and the total number of bacteria and caliform bacteria reveal obvious seasonal features. Moreover, the differences in the quantity, frequency and quality of the water diverted from the Yellow River lead to distinctions among the regular changes of some indexes in different reservoirs.

5 Water quality restoration techniques

There are 3 main factors influencing the water quality in the reservoirs: the quality of water drawn from the Yellow River, the characteristics of headwater system and the turnaround speed of the water stored in the reservoirs.

To improve the reservoir water quality we should adopt comprehensive measures. First of all, we should choose the right time to draw water from the Yellow River, especially when both the volume and quality of the water are favorable; secondly, open canals should be used to divert the Yellow River water to the reservoirs. The environmental protection around reservoirs and along canals should be enhanced to prevent pollutants from being discharged into the water. Meanwhile, a well – prepared crisis response against potential pollution incidents should also be made; fourthly, appropriate use of the reservoirs should be made to reasonably adjust water – supply volumes and accelerate the turnaround speed in the reservoirs; finally, it is also necessary for us to understand the causality between the regular changes of water source and pollution so that ecological restorations of water quality might be readily made.

(1) The elimination of waterweeds: Eutrophication substances should be removed from the water to prevent anaerobic fermentation of the dead aquatic plants at the bottom of reservoirs so that second – time pollution can be avoided.

(2) A serious problem concerning reservoir water quality is the algae pollution. Nitrogen and phosphorus are essential nutritious materials for plant growth. The best way to deal with these two elements should be ecological plant implementation and restoration. Artificial wetland biological &. chemical treatment system should be established in desilting pools (or near the entrance of diversion reservoirs without desilting pools). A large number of aquatic plants such as the reed and the stem of cattail suiting local conditions should be planted so that natural geographical and artificial wetland techniques might be made use of to treat the water entering the reservoirs by consuming the entrophication substance in the water and reducing the incoming pollutants. Meanwhile, these aquatic plants are also effective to absorb heavy metal ions.

(3) Raising such fish as grass carp, silver carp and bighead, etc. scientifically in the reservoir is a suitable way to solve the phytoplankton problem, especially the algae pollution. As the reservoirs of the oilfield were built a long time ago, the nutriment substance has accumulated abundantly, and as a result the planktonic organism grows rapidly. If the planktonic cannot be well utilized, their natural death will form a vicious circle, and then cause eutrophication and the second – time water pollution. According to the principle of ecological balance, it is reasonable to raise fish feeding on different planktonic organism in the reservoir to renovate the ecology system. At last the eutrophication substance is converted into aquatic product. It is a two – side benefit for this measure: on one hand, it can purify the reservoirs; on the other hand, it can harvest aquatic product. In recent years, by raising filtering fish such as silver carp, bighead, etc. in the

reservoirs, we have done some beneficial experiments in renovating the ecology system of the reservoir, and achieved some obvious results.

(4) Lijin, Xin'an, Minfeng reservoirs were built a long time ago and had no desilting facilities. As a result the reservoirs were deposited seriously and its self – purification capacity of water is weak. A large amount of silting sand has become a potential threat to the running of the reservoirs. The main method to eliminate this potential threat is to clear the sand and silt. By doing this, it can not only increase the impoundment of the reservoirs, but also completely remove the pollutants in the sediment such as nutriment substance, heavy metal from the water, so that the risk of second time pollution is reduced.

6 Conclusions

(1) A contrast study of the quality of the water drawn from the Yellow River and those stored in the flatland reservoirs on the Yellow River Delta reveals the fact that the change of the reservoir water quality of is caused by the characteristics of headwater system, the retention time of hydraulic power, the volume of the replacement water of the reservoirs and the quality of the Yellow River water.

(2) Influenced by such factors as the retention time, turnaround speed, the characteristics of headwater system, the alga in the reservoir water, the permanganate index, the chemical oxygen demanding (COD), the 5 – day BOD, dissolving oxygen, nitrate nitrogen, the total number of bacteria, and the coliform bacteria groups, etc. have obvious seasonal changes.

(3) The water quality of the reservoirs is greatly influenced by the retention time of hydraulic power and the storage depth. Because the retention time of hydraulic power in Minfeng reservoir is short, and its evaporation, concentration and substrate sludge release is weak; all its indexes are comparatively close to those of the Yellow River water quality. The mean scale of nitrogen phosphorus is (83:1), which is close to that of the Yellow River water quality (85:1). Chunhua reservoir is great in depth, and its self – purification capacity is strong. Therefore the permanganate indexes, the ammonia nitrogen and alga are low.

(4) It is necessary to take comprehensive measures to improve the water quality of the reservoirs. A protection system of source water area should be set up to protect the water resources according to the regularities of water quality changes. Engineering measures should also be taken to supply water so that the turnaround speed of water can be accelerated, the storage capacity can be increased, the water environmental capacity can be enlarged, and the self – purification ability of water body can be improved. By harvesting waterweeds, breeding fish such as grass carp, silver carp, etc. and planting aquatic plant such as the reed, the stem of cattail, etc. in scientific ways, natural geographical and artificial wetland techniques can be combined and utilized to restore the water quality of the flatland reservoirs in the Yellow River Delta, so that the water quality in these reservoirs can reach the requirements of The Environmental Surface Water Quality Standard (Grade Ⅲ GB 5749—2002).

References

Jia Ruibao, Zhou Shandong. Study in Algae Pollution Control of the Urban Water Supply, Shandong University Press, 65.

Qiao Guangjian. Analysis of Water Quality Space – time Changes in Zhu Zhuang Reservoir, hydroscience and engineering: Jan, 2003.

Zhao Kefu. Research on Adaptability of Different Ecotypic Reed to Salinity in Yellow River Delta, Ecology Journal: May, 2000.

Lei Yanzhi. Freshwater Aquiculture Water Chemistry, Guangxi Science and Technology Press: 1992, 42 ~ 76.

Dynamic Analysis of the Vegetation Pattern of the Yellow River Delta National Nature Reserve Based on Remote Sensing

Song Chuangye[1,2] and ***Liu Gaohuan***[1]

1. Institute of Geographic Science and Nature Resource Research, Chinese Academy of Sciences, Beijing, 100101, China
2. Graduated School of Chinese Academy of Sciences, Beijing, 100039, China

Abstract: Regional vegetation pattern dynamics has bigchange dueto the climate change and even global change. In this study, the Yellow River Delta was selected as the study area. By using 1986, 1993, 1996, 1999 and 2005 remote sensing data as basic information resource and with the support of GIS, a wetland vegetation spatial information dataset is built up. Through selecting the indices such as class percent of landscape (PL), number of patch (NP), largest patch index (LPI), mean patch size (MPS) and area weighted mean shape index (AWMSI) etc., the dynamic change of wetland vegetation pattern is analyzed. The result shows that the change of wetland vegetation pattern is significant from 1986 to 2005, and the wetland vegetation pattern tends to be fragmental. The decrease of vegetation areas may well be explained by the fact that the nature environment evolution (River channel migration and climate change) and the increase of the population in the Yellow River Delta.

Key words: Yellow River delta, vegetation pattern, remote sensing imagery, GIS analysis

1 Introduction

Vegetation is a useful descriptor of biotic communities as it is immobile, represents a major part of earth's terrestrial biomass (thus providing a useful index of productivity), and integrates abiotic site conditions (e. g. temperature, moisture, solar insolation, soil development, nutrient cycles). Therefore, vegetation pattern dynamics have great impact on ecosystem and climate. Moreover on the one hand, regional vegetation undergo a variety of changes in response to climate change and the activities of the human being.

Vegetation pattern dynamics investigation based on field measurements (Cannel and Jackson, 1985; Eriksson et al., 1994.) have inherent restrictions. In the first place, field plots subject to analysis represent only a discrete sample in a continuous spatial dimension. When information of non – sampled areas is required, extrapolation becomes necessary. In second place, gathering information from large areas may take long periods of time, which means that vegetation may change significantly before the inventory has been completed.

Remote sensing has been proposed as a possible solution to such restrictions. Many applied studies are already found in literature about the field. Remote sensing has the potential to identify a number of these changes including changes in above ground production, structure and cover, phenological growth characteristics, measurements of biomass (Ardo, 1992; Ander – son et al., 1993.) forest productivity (Ahern et al., 1991), tree cover (Dymond et al., 1992; Duncan et al., 1993; Zhuang et al., 1993) or leaf area index (Nemani et al., 1993) and ecotones/boundaries. Using remote sensing to detect changes in vegetation pattern and function may require monitoring at contrasting spatial and temporal scales. As with many other remote sensing applications, different remote sensing spatial, temporal, radiometric and spectral resolutions need to be considered to study signals of change in vegetation. Furthermore, investigators may need to integrate information from a variety of platforms, and utilize both digital and analog imagery.

Satellite data with high spatial and temporal resolution have been shown to be particularly valuable for tracking changes in vegetation at regional, continental and global scales. Useful sources of satellite data for vegetation studies are images from Landsat (MSS and TM), SPOT, RadarSat, NOAA, IRS, and many light – weighted satellite systems. Although its spatial resolution is not as fine as that of SPOT HRV data, Landsat data are the sole multi – spectral digital data with synoptic coverage extending back to 1972. In addition, these data are inexpensive and can be managed computationally even by a personal compute. Therefore, Landsat data have unique value and thus are extensively used for a variety of tasks, notably in natural resource surveys and environmental monitoring.

The Yellow River Delta is located in the northern part of Shandong Province, China, it is one of the most active regions of land – ocean interaction among the large river deltas in the world. The newly created wetland of the Yellow River Delta is a typical ecosystem of littoral wetland in estuary, in which there are rich wetland vegetation and hydrobios. It is an important transfer station, wintering habitat and breeding farm for birds in northeast Asian inland and the Pacific area. The newly created wetland of the Yellow River Delta has three obvious characteristics (Shangdong Vegetation, 2000): ① it is one of the most rapidly growing wetland ecosystem in estuary in the world; ② vegetation in the newly created wetland is in the initial stage of coming into existence and development; and ③ with land extending into Bohai Sea and vegetation developing toward seashore, there exists frequent succession among various vegetation communities. Because of these characteristics, the newly created wetland is very fragile. However, a considerable amount of oil and gas fields have been found in the Yellow River Delta. In the meanwhile, since 1984 population in the Yellow River Delta has been increasing at an annual growth rate of 10.5%. Unreasonable exploitation and use of natural resources have exerted serious pressures on the newly created wetland.

The yellow river delta has aroused the interest of many researchers in different fields (e.g., Pang and Si, 1979, 2000; Wright et al., 1988; Blodget et al., 1991; Frihy and Komar, 1993; Huang et al. 1994, 2002; Ji et al., 1994; Xue, 1993, 1994; Sun and Yang, 1995; Li et al., 1998a,b, 2000a,b; White and Asmar, 1999; Dias et al., 2000; Liu et al., 2001, 2002; Xu, 2002; Yu, 2002; Chang et al., 2004). The repetitive acquisition and synoptic capabilities of remote sensing systems can be exploited to provide timely broader scale spatial data for geographical information systems (GIS) (White and Asmar, 1999). Satellite images are especially valuable for study and frequent updating of maps in areas that are poorly accessible or contain rapidly changing landforms (Blodget et al., 1991).

The vegetation pattern of the delta is very simple and it was easily affected by the human and the nature environment evolution. Previous studies on the vegetation dynamics of the Yellow River Delta mainly depend on field job and not taking into account the pattern across the entire delta, hitherto few systematic study on the changing of vegetation pattern dynamics over the entire delta.

This study presents an application of Landsat imagery and GIS techniques to the study of vegetation pattern dynamics of the Yellow River Delta. An integrated analytical method combining image data analysis from 1986 to 2005 and GIS was used to quantify vegetation pattern trends in the Yellow River Delta. A geographically and temporally detailed assessment of vegetation pattern dynamics during the period of 1986 to 2005 was made. The factors or processes contributing to the observed spatio – temporal trends were further analyzed.

2 Study area and methods

2.1 Study area

The Yellow River Delta is located in the northern part of Shandong Province, China. It lies on the south side of the Bohai Sea, extending from 118°07′E to 119°18′E, and from 36°55′N to 38°12′N, with an area of 6,010 km^2.

The Yellow River Delta is one of the most active regions of land – ocean interaction among the large river deltas in the world. Large amounts of sand are carried by the Yellow River and deposited at the river mouth to form new land. Within the delta, the underground water table is high and the water is saline. The entire area is covered mainly by wet and saline soil, with meadow, especially halophytic meadow, being the typical natural vegetation.

The region is characterized with a temperate, semi – humid continental monsoon climate. The annual mean temperature ranges from 11. 5 to 12. 48 ℃, with the highest monthly temperature of 26. 6 8 ℃ in July and the lowest of 4. 18℃ in January. The annual rainfall is 590. 9 mm and evaporation of over 1,500 mm. The monthly maximum rainfall is 227 mm in July and the minimum is 1. 7 mm in January (Zang, 1996).

In this research, the area of the Yellow River Delta National Nature Reserve was selected as the study site. It is the newly created wetland of the Yellow River Delta and it is a typical ecosystem of littoral wetland in estuary, in which there are rich wetland vegetation and hydrobios.

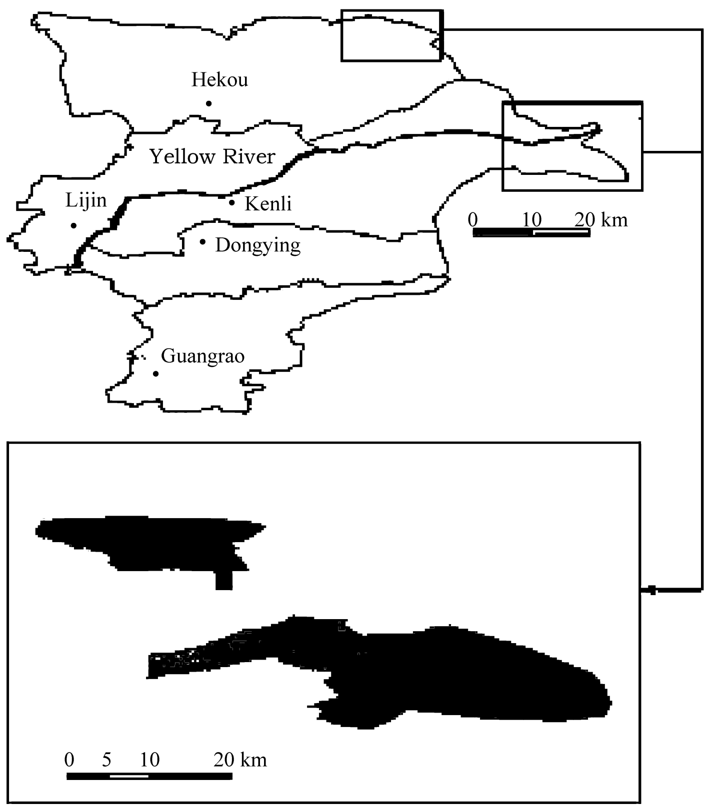


Fig. 1 The location of the study area

2. 2 Data sources

In this study, we used information from multi temporal remote sensing data of Landsat TM 1986, 1993, 1996, 1999 and 2005, totaling five scenes. Three visible bands (TM1, TM2 and TM3), the near – in – frared band (TM4) and the two middle – infrared bands (TM5 and TM7) of the Thematic Mapper sensor (TM) of Landsat satellites. The TM sensor has a spatial resolution of 30 m, given by its pixel width.

Field plots of the study were located in vegetation areas randomly. Field job was carried out in the growth season of 2000 ~ 2006 respectively. The placement of plots in the field was carefully done by means of georeferenced 1 : 5,000 Topographic maps. Plots had a foursquare shape, the radius of arbor plot, shrub plot and herbage plot are 20 m, 10 m and 1 m respectively. Plot values of vegetation canopy cover, stand stem height were selected.

2.3 Remote sensing data processing

Landsat Thematic Mapper (TM) images were used to study the dynamics of vegetation pattern of the Yellow River Delta since 1986. Satellite images were geometrically and radiometrically corrected. For geometric correction we used 1 : 25,000 scale topographical maps using first - order nearest neighbor rules. A total of 25 ground points were used to register the TM image subset with the rectification error of less than 1 pixel. Performing radiometric correction required information concerning the slope and aspect of field plots. These data were obtained from a 5 m resolution Digital Elevation model (DEM). The applied radiometric correction model (Pons and Sole′ - Sugranes, 1994) took into account both atmospheric effects and illumination effects due to the relief. Thus, the variance of vegetation radiometric responses coming from different light intensities (due to different slopes and aspects) was minimized. Finally, values of pixels of corrected images were given in reflectance (Mather, 1987).

Generally, the data in 1986, 1993, 1996, 1999 and 2005 are from integration of Landsat TM images of the newly created wetland of Yellow River Delta in the four seasons of the year. The synthetic images are first made to templates by unsupervised classification. Then, the training samples selected in the newly created wetland are added to the templates. The templates are evaluated and edited until recognition of the templates is satisfied. Finally, the image is zoned and classified by means of maximum likelihood classification. In other words, the unsupervised classification and the supervised classification are jointly used in order to improve precision of the classification.

The different growing seasons of various plants in the newly created wetland lead to seasonal change of land cover. Different plants growing in a single land unit lead to mixed pixels. Therefore, spectral characteristics of every land unit are quite different and all landscape types are not so easy to be identified only by means of spectral characteristics. However, artificial cultivation traces are very easy to be discriminated and farmland division is distinct. Farmland is first divided by visual interpretation and agricultural land - use types are interpreted according to the spectral characteristics, the way that a crop is growing, and the growing season. The farmland feature is extracted and made to mask. The farmland feature is then taken out from the image from the period when major natural vegetation is growing well. Combining with investigation on the spot, major quadrate selection and template edition, images from various periods are classified by ISODATA cluster analysis.

The accuracy of the images was assessed using ground data points not used in the classification process and other points of known conditions, such as vegetation areas visually surveyed, stand map identified in the image. We used equal control point methods in Erdas Imagine 8.6 program with at least 30 points for each class. The accuracy assessment of image is checked for each image separately and accepted if the accuracy is higher than 85%. After accuracy assessment, all images were clumped, eliminated 3 pixel × 1 pixel and vectorized in Erdas Imagine 8.6 programme. These coverages were preprocessed to eliminate areas less than 0.27 ha (corresponding to 3 pixel × 1 pixel) for faster analysis of spatial pattern.

2.4 temporal and spatial analysis of vegetation types

The spatial pattern of vegetation is important as it has important implications to the design and management of vegetation (Baskent et al., 2000). The spatial dynamics of the vegetation pattern refers to the temporal change in the size, number, shape, adjacency and the proximity of patches in a landscape. We used limited number of metrics or measurements as proxy to quantify and spatially analyze the change in spatial structure as demonstrated by Baskent and Jordan (1995a, b) and

McGarigal and Marks (1995).

Specifically, we used Fragstats™ (McGarigal and Marks, 1995) to quantify vegetation pattern of the Yellow River Delta for each vegetation class. FragstatsTM calculates a number of spatial metrics for each patch, for each cover class as well as for the entire vegetation. We analyzed selected metrics for the vegetation class for the vegetation in1986, 1993, 1996, 1999 and 2005. The metrics are: class percent of landscape (PL), number of patch (NP), largest patch index (LPI), mean patch size (MPS) and area weighted mean shape index (AWMSI).

Besides analyzing the changes in the amount of vegetation area and spatial pattern, the temporal transitions among the cover types are also documented and evaluated to see the inter temporal dynamics among various parameters indicative of the vegetation pattern. Annual deforestation rates were calculated using the compound – interest – rate formula due to its explicit biological meaning (Puyravaud, 2003). This is,

$$P = \frac{100}{t_2 - t_1} \ln \frac{A_2}{A_1}$$

where, P is percentage of vegetation loss per year, A_1 and A_2 are the amount of vegetation cover at time t_1 and t_2, respectively.

3 Results

3.1 Results of the remote sensing images classification

According to the classification of Shandong Flora and the Scientific Survey of the Yellow River Delta National Nature Reserve, in this study, the vegetation of the Yellow River Delta National Nature Reserve was classified into seven groups: Ass. Robiniapserd oacacia, Ass. Tamarix chinensis, Ass. Phragmites australis, Ass. Suaeda heteroptera, Waterbody, Farmland and Bare land (Figs. 2 ~ Fig. 6).

Ass. Robiniapserd oacacia is mainly the result of manual afforestation, it is mostly distributed on the northern bank of the yellow river and the east region of the old yellow river course. Ass. Tamarix chinensis is the natural shrubbery on the seashore. The distributed area is very large. Companions in Ass. Tamarix chinensis are Suaeda heteroptera, Apocynum venetum, Chenopodium album, Artemisia capillaries and so on. Ass. Phragmites australis is widely scattered in the Yellow River Delta National Nature Reserve, the area is the biggest. Ass. Suaeda heteroptera occours on the foreshore that have high groundwater and alkalinity.

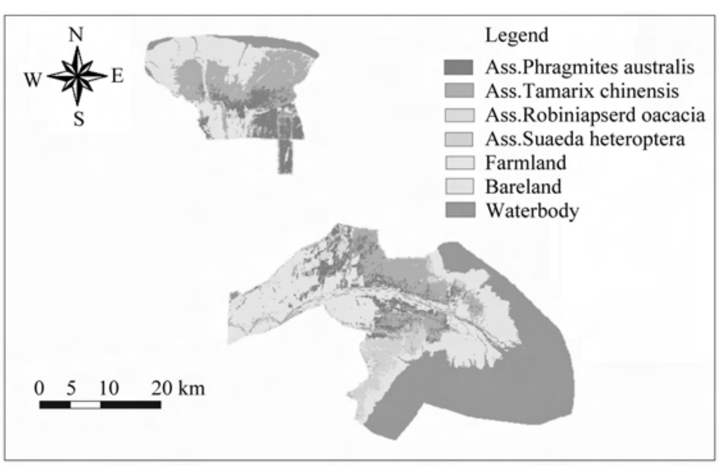


Fig. 2 Classification of Landsat Thematic Mapper (TM) image in 1986

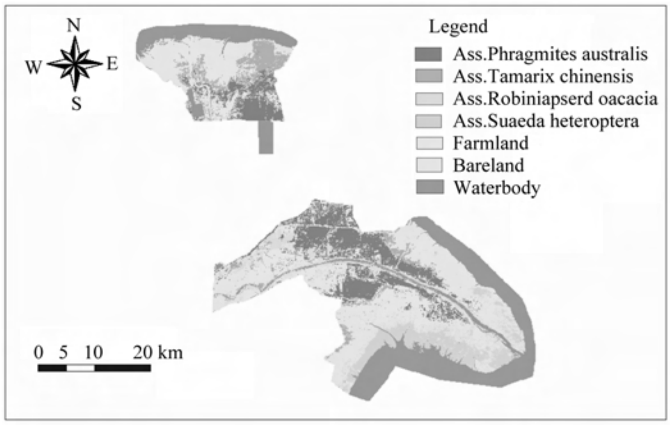


Fig. 3 Classification of Landsat Thematic Mapper (TM) image in 1993

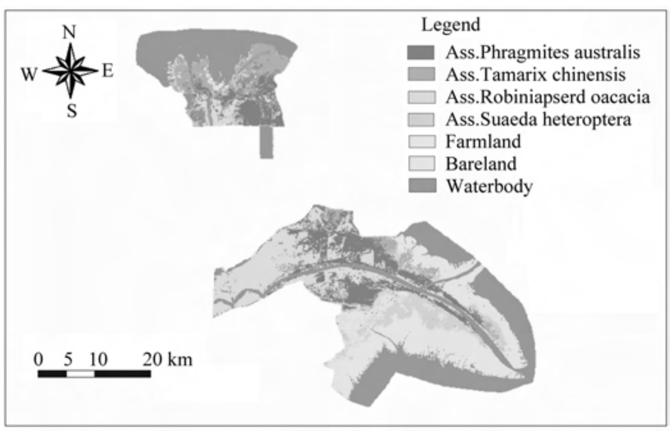


Fig. 4 Classification of Landsat Thematic Mapper (TM) image in 1996

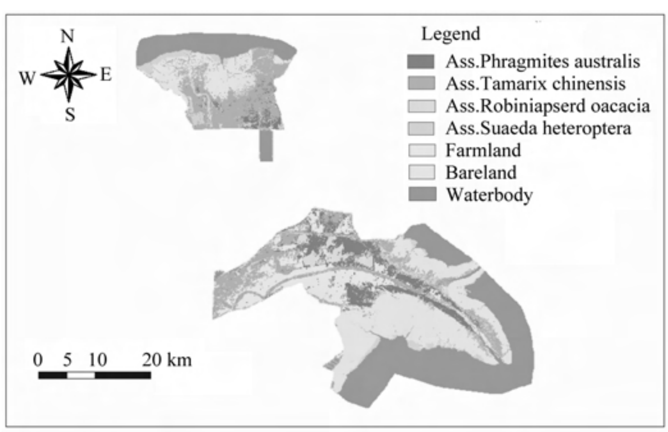


Fig. 5 Classification of Landsat Thematic Mapper (TM) image in 1999

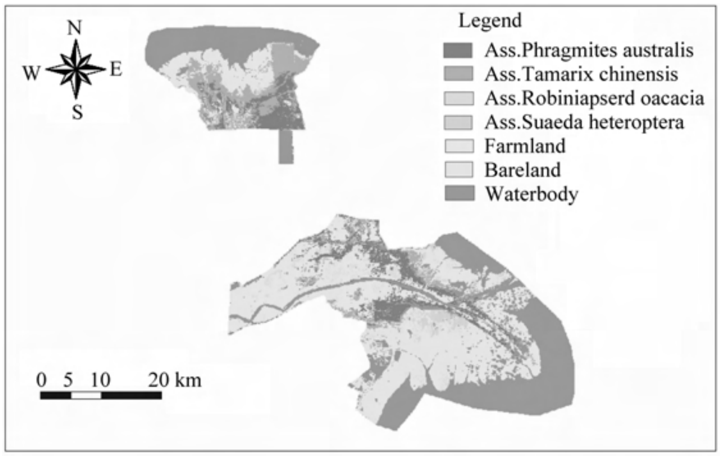


Fig. 6 Classification of Landsat Thematic Mapper (TM) imagen in 2005

3.2 Temporal and spatial change in vegetation pattern

Vegetation changes between 1986 and 2005 were mapped using classified Landsat images. Vegetation Cover type maps of 1986 and 2005 from the Landsat images between 1986 and 2005 were quantified with Fragstats 3.3. According to the analysis by Fragstats 3.3 of the classified Landsat images between 1986 and 2005 years, there was a net decline of 14,851.31 ha in vegetation as oppose to a net increase of 14,822.38 ha in non vegetation areas, this translates to an average 0.54% annual rate of vegetation decrease. The vegetation percentage of the whole Yellow River Delta vegetation dropped from 33.35% to 23.27%.

The spatial analysis of the vegetation pattern indicated that the total number of patches increased from 4,103 to 8,078 between 1986 and 2005 years as all patch types were taken into account. Almost fragmentation increased 5 times as mean patch size (MPS) decreased from 112 hm^2 to 21 hm^2.

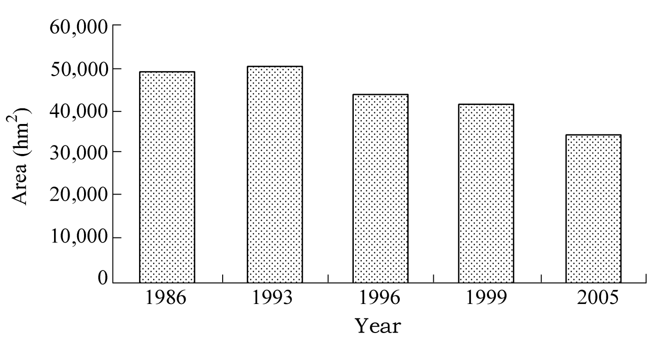


Fig. 7 Change of vegetation area from 1986 to 2005

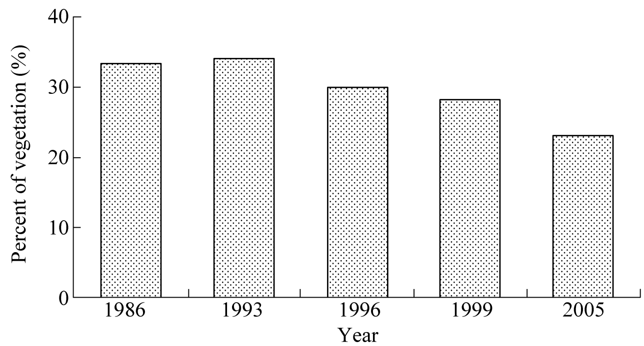


Fig. 8 Change of vegetation percent from 1986 to 2005

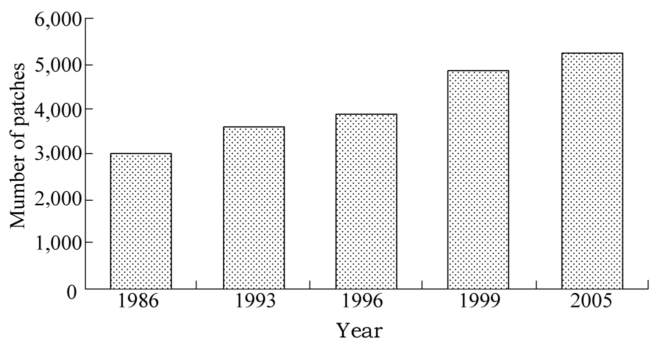


Fig. 9 Change of number of patches from 1986 to 2005

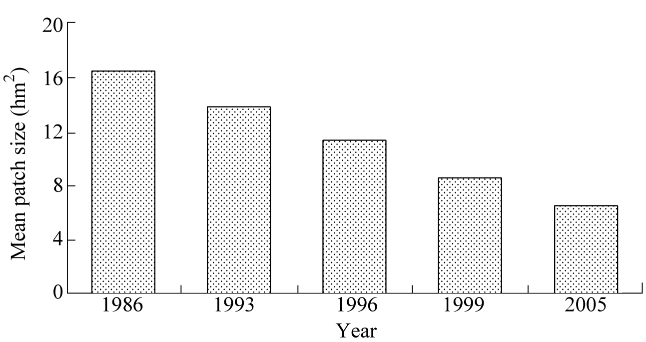


Fig. 10 Change of mean patch size from 1986 to 2005

3.3 Temporal and spatial change of the single plant community

The area of Ass. Tamarix chinensis decreased 13, 460. 14 ha, Ass. Phragmites australis decreased 421.8 ha, Ass. Suaeda heteroptera decreased 1,267.2 ha, however, Ass. Robiniapserd oacacia increased 497.9 ha. As an overall change, there was a net decrease of 10.08% in total vegetation areas (Table 1).

The Number of patches of Ass. Robiniapserd oacacia increased from 326 to 965 between 1986 and 2005, MPS changed significantly from 7.6 ha to 2.9 ha, Large patch index decreased from 0.5

to 0.18, Area – weighed mean shape index decreased from 286.3 to 54.3. The Number of patches of Ass. Tamarix chinensis increased from 1,417 to 1,539 between 1986 and 2005, MPS decreased from 19.3 ha to 9.01 ha, Large patch index decreased from 7.7 to 4.4, Area – weighed mean shape index decreased from 7,515.2 to 3,243.4. The Number of patches of Ass. Phragmites australis increased from 1,073 to 1,277 between 1986 and 2005, MPS decreased from 12.7 ha to 10.3 ha, Large patch index decreased from 2.3 to 1.7, Area – weighed mean shape index decreased from 1,306.2 to 1,162. The Number of patches of Ass. Suaeda heteroptera increased from 158 to 1471 between 1986 and 2005, MPS decreased from 35.6 ha to 2.9 ha, Large patch index decreased from 1.8 to 0.7, Area – weighed mean shape index decreased from 1,685 to 3.5. All these changes clearly indicate that the vegetation has been gradually fragmented and thus subjected to susceptibility of the area to further abrupt changes in the future.

From the tables we can also see that, except Ass. Tamarix chinensis, the area of those vegetation types in 1993 is larger than other four years. The number of patches, mean patch size, percent of vegetation, large patch index and area – weighed mean shape index all show the same trend.

Table 1 Change of ass. robiniapserd oacacia in the Yellow River delta from (1986 to 2005 vegetation cover map of Landsat)

Year	Class area (ha)	Number of patches	Mean patch size (ha)	Percent of vegetation	Large patch index	Area – weighed mean shape index
1986	2,477.43	326	7.59	1.68	0.52	286.31
1993	5,620.41	687	8.18	3.82	0.69	368.11
1996	2,413.53	118	20.45	1.64	0.27	227.42
1999	3,112.92	226	13.77	2.12	1.21	110.88
2005	2,775.31	965	2.88	1.89	0.18	54.3

Table 2 Change of ass. tamarix chinensis in the Yellow River delta from (1986 to 2005 vegetation cover map of Landsat)

Year	Class area (ha)	Number of patches	Mean patch size (ha)	Percent of vegetation	Large patch index	Area – weighed mean shape index
1986	27,325.08	1,417	19.28	18.58	7.72	7,515.03
1993	9,680.67	1,420	6.81	6.58	2.16	1,152.83
1996	11,117.79	1,417	7.85	7.56	2.17	1,162.13
1999	26,465.76	1,692	15.64	17.99	7.63	6,733.58
2005	13,864.94	1,539	9.01	9.43	4.39	3,243.4

Table 3 Change of ass. phragmites australis in the Yellow River delta from (1986 to 2005 vegetation cover map of Landsat)

Year	Class area (ha)	Number of patches	Mean patch size (ha)	Percent of vegetation	Large patch index	Area – weighed mean shape index
1986	13,623.93	1,073	12.7	9.26	2.32	1,306.18
1993	21,337.65	919	23.22	14.51	4.26	3,179.04
1996	19,463.58	1,159	16.79	13.23	4.29	3,468.03
1999	11,794.41	1,078	10.94	8.02	1.26	906.31
2005	13,202.01	1,277	10.34	8.98	1.72	1,162

Table 4 Change of ass. suaeda heteroptera in the Yellow River delta from (1986 ~ 2005 vegetation cover map of Landsat)

Year	Class area (ha)	Number of patches	Mean patch size (ha)	Percent of vegetation	Large patch index	Area – weighed mean shape index
1986	5,629.32	158	35.63	3.83	1.82	1,685.22
1993	13,568.94	586	23.15	9.23	6.46	6,718.59
1996	10,921.86	1,193	9.16	7.43	3.51	2,607.09
1999	10,199.43	1,854	5.5	6.93	0.77	242.12
2005	4,362.19	1,471	2.97	2.97	0.69	3.5

4 Discussions

The dynamics of vegetation pattern have been identified by repeated snapshot of satellite images coupled with GIS analyses from 1986, 1993, 1996, 1999 to 2005. The quantitative evidences of vegetation pattern dynamics presented here showed that vegetation decrease trend in regional level since 1993. The wetland vegetation pattern tends to be fragmental and the decrease of vegetation areas (except Ass. Tamarix chinensis) may well be explained by the fact that the nature environment evolution and the increase of the population in the Yellow River Delta.

Decreasing precipitation and increasing use of water resources were the main reasons that caused the decrease in runoff entering the river delta. The climate in the upper - middle Yellow River basin became gradually more arid in the last two decades causing decreasing precipitation (Xu, 2002). Agricultural irrigation and development of industry in the middle - lower Yellow River basin has exhausted large quantities of water especially since the 1970s. These natural and human factors have led to decreased water discharge even led to break – off water discharge occur in the lower Yellow River channel. Break – off water discharge in the lower Yellow River channel was first recorded in 1961, it occurred about 20 days in certain years of 1970s and 1980s. The days of break – off water discharge markedly increased in the 1990s and reached 220 days in 1997 (Wang and Zhang, 1998). The decline in the discharge and the lack of sediment supply from upstream due to river management has caused the decrease of vegetation area.

The decrease in runoff entering the river delta is also caused Yellow River channel migration. The Yellow River Channel migration was slower during the period of 1976 ~ 1987 (Yang, 1999). While the proportion of water discharge to sediment load underwent a favourable adjustment, the river channel changed from disorderly braiding to organized braiding, and from generally straight to slightly meandering straight (Yang, 1996). This change in channel pattern should favor a more stable fluvial environment. After 1987, the proportion of water discharge to sediment load in the lower reach of the Yellow River became less favourable, probably due to the fact that, according to hydrologic measurements (Ye, 1998), this reach was experiencing more flow interruptions. As a result, the longitudinal profile of the channel became more gentle (Yang, 1995), the capacity of the river to transport water and sediment diminished, and the channel became highly silted. This caused the channel to become less stable after 1987. Despite the Chinese governmental efforts to prolong the running time of the current river course (Yang, 1996), the channel showed an increasing rate of lateral migration during the period of 1987 ~ 1994. As the migration of the Yellow River channel, the water and sediment transported to the Yellow River Delta dropped, therefore the area of wetland vegetation decreased.

The driving forces of the vegetation patch change are also related to the rapid population growth, especially non peasant population growth in Yellow River Delta. In 1984, total population of Yellow River Delta is 1.427,5 million and the ratio of non – peasant population to total population is 14.76%, of which the annual growth rate is 4.12% on the average from 1978 to 1984. In 1991, the total population is 1.5852 million and the ratio of non – peasant population is 23.06%, of which the annual growth rate is 10.5% on average from 1984 to 1991. In 1996, the total population reaches to 1.657,7 million and the ratio of non – peasant population is 39.83%, of which the annual growth rate of non – peasant population is 16.12% from 1991 to 1996 on the average. The total staffs and workers of Shenli oil fields accounted for 72.7% of non – peasant population in Yellow River Delta. Development of Shenli oil fields has greatly promoted economic growth and disturbed vegetation of the newly created wetland. After development of Shenli oil field about 30 years, oil and gas wells have been scattered all over like stars in Yellow River Delta. Economically, the Yellow River Delta is not only an important base of petroleum production but also a significant food production base. "Development and conservation in the Yellow River Delta" has been listed as one of the priority projects in China's Agenda 21 (China Government, 1994). Due to its unique environmental condition and development potential, the Yellow River Delta has received great attention both at home and abroad.

The differences in temporal changes of vegetation areas may issue from the data quality as it would be affected by the data gathering methods. As Wrbka et al. (2004) and Peterseil et al. (2004) noted that the coarse spatial resolution of Landsat TM5 images of 30 m × 30 m may cause problems when depicting fine – grained vegetation landscapes. We realize that it could be insignificant to select smaller spatial reference units than 600 m × 600 m size because of relative monotonous vegetation cover in the Yellow River Delta while it is a difficulty to derive accurately vegetation values for bigger than 600 m × 600 m size of cells in this region due to higher difference of vegetation types in a small area. Despite these problems, satellite images are one major data source for vegetation dynamics on a regional scale. The encountered constraints can be considered as a more technical problem. Methodological enhancement is needed to solve the shortcomings of data. With comprehensive application of high – resolution remote sensing data in the future, it is impossible for assessment of environmental indicators. Besides the use of high – resolution satellite images, a large number of sample plots for the field survey may help to solve this problem (Peterseil et al., 2004).

From the above results and analysis, the decrease of the water transported to the Yellow River Delta is the one of the main reasons leading to the decreases of the vegetation. But, compared with other plant communities, Ass. Tamarix chinensis show a contrary trend. This may be explained by its special environment requirement. Based on the field work and soil environmental factors and groundwater analysis, we could see that the groundwater level where Ass. Tamarix chinensis distribute is lower than other plant communities, therefore, with the decrease in runoff entering the river delta, the groundwater level decreased and the area fit for Ass. Tamarix chinensis increased, so the area of Ass. Tamarix chinensis increased.

5 Conclusions

The study has revealed a spatial pattern of vegetation, as well as a temporal trend of vegetation pattern during the period of 1986 ~ 2005, followed by an increasing magnitude of change in the active Yellow River Delta. These changes can be largely related to modifications in the proportion of water discharge and sediment load caused by the complicated interaction between humans and the environment throughout the Yellow River drainage basin and in particular on the deltaic lowland.

Knowledge of vegetation pattern dynamics over deltaic lowlands is fundamental to the understanding of regional land use and land cover dynamics and this, in turn, is critical to subsequent management of the nature ecosystems. Satellite remote sensing allows a retrospective, synoptic viewing of large regions and so provides the potential for a geographically and temporally detailed assessment of changes in vegetation pattern.

This study demonstrates the usefulness of satellite remote sensing, digital image processing, and GIS techniques for the analysis of the spatio – temporal dynamics of vegetation pattern in the active Yellow River Delta. The availability of time – sequential Landsat images obtained by the world's best – established remote sensing satellite series has made it feasible to extract detailed information on vegetation pattern over extensive areas of deltaic lowlands. The operational use of such data for vegetation pattern surveys is really promising. Despite the recent development in image processing and information extraction technologies, skills – based image interpretation is still the premier approach for mapping vegetation pattern. The automatic approach of vegetation pattern mapping has been limited by the variations of environmental conditions. However, appropriate use of digital image processing techniques can ensure a significant improvement in image georeferencing and in information extraction. The use of geographic information system (GIS) technology has proven quite efficient for organizing geo – spatial databases and for facilitating vegetation pattern mapping and measurement, so that the spatiotemporal dynamics of vegetation pattern can be assessed systematically.

References

Ardo, J., 1992. Volume quantification of coniferous forest compartments using spectral radiance recorded by Landsat Thematic Mapper[J]. Int. J. Remote Sensing 13, 1779 – 1786.

Anderson, G. L., Hanson, J. D., Haas, R. H., 1993. Evaluating Landsat Thematic Mapper derived vegetation indices for estimating above – ground biomass on semiarid rangelands[J]. Remote Sens. Environ. 45, 165 – 175.

Ahern, F. J., Erdle, T., Maclean, D. A., Kneppek, I. D., 1991. Aquantitative relationship between forest growth rates and Thematic Mapper reflectance measurements [J]. Int. J. Remote Sensing 12, 387 – 400.

Blodget, H. W., Taylor, P. T., Roark, J. H., 1991. Shoreline changes along the Rosetta – Nile Promontory monitoring with satellite observations[J]. Mar. Geol. 99, 67 – 77.

Baskent, E. Z., Jordan, G. A., Nurullah, A. M. M., 2000. Designing forest landscape (ecosystems) management[J]. Forest. Chronicle 76 (5), 739 – 742.

Baskent, E. Z., Jordan, J. A., 1995a. Characterizing spatial structure of forest landscapes: a hierarchical approach[J]. Can. J. Forest Res. 25 (11), 1830 – 1849.

Baskent, E. Z., Jordan, J. A., 1995b. Designing forest management to control spatial structure of landscapes[J]. Landscape Urban Plan. 34, 55 – 74.

Cannel, M. G. R., Jackson, J. E., 1985. Attributes of trees as crop plants [J]. Natural Environment Research Council, Great Britain, 592 pp.

Chang, J., Liu, G. H., Liu, Q. S., 2004. Analysis on spatio – temporal feature of coastline change in the Yellow River Estuary and its relation with runoff and sand – transportation[J]. Geogr. Res. 23(3),339 – 346.

Dias, J. M. A., Boski, T., Rodrigues, A., Magalhaes, F., 2000. Coastline evolution in Portugal since the Last Glacial Maximum until present—a synthesis[J]. Mar. Geol. 170, 177 – 186.

Dymond, J. R., Stephens, P. R., Newsome, P. F., Wilde, R. H., 1992. NPercentage vegetation cover of a degrading rangeland from SPOT[J]. Int. J. Remote Sensing 13, 1999 – 2007.

Duncan, J., Stow, D., Fanklin, J., Hope, J., 1993. Assessing the relationship between spectral vegetation indices and shrub cover in the Jornada Basin, New Mexico[J]. Int. J. Remote Sensing 14, 3395 – 3416.

Eriksson, L., Lacaze, J. F., Noack, D., Pardos, J. A., Seoane, I., 1994. Forestry, Wood and Wood – based Products, Pulp and Paper[J]. European Commission. EUR15922EN, 315 pp.

Frihy, O. E., Komar, P. D., 1993. Long – term shoreline changes and the concentration of heavy minerals in beach sands of the Nile Delta[J]. Egypt. Mar. Geol. 115, 253 – 261.

Huang, H. J., Wang, Z. Y., Zhang, R. S., 2002. The error analysis of the methods of monitoring the beach changes using digital photogrammetry[J]. satellite images and GIS. Mar. Sci. 26 (3), 8 – 10.

Ji, Z. W., Hu, C. H., Zeng, Q. H., 1994. Analysis of recent evolution of the Yellow River Estuary by Landsat images[J]. J. Sediment. Res. 3, 12 – 22.

Liu, S. G., Li, C. X., Ding, J., Li, X. N., 2001. The rough balance of progradation and erosion of the Yellow River Delta and its geological meaning[J]. Mar. Geol. Quat. Geol. 21 (4), 13 – 17.

Liu, Y., Li, G. X., Deng, S. G., Zhao, D. B., Wen, G. Y., 2002. Evolution of erosion and accumulation in the abandoned subaqueous delta lobe of the Yellow River[J]. Mar. Geol. Quat. Geol. 22 (3), 27 – 34.

Li, G. X., Wei, H. L., Yue, S. H., Cheng, Y. J., Han, Y. S., 1998b. Sedimentation in the Yellow River Delta: Part II. Suspended sediment dispersal and deposition on the subaqueous delta[J]. Mar. Geol. 149,113 – 131.

Li, F. L., Pang, J. Z., Jiang, M. X., 2000a. Shoreline changes of the Yellow River Delta and its environmental geology effect[J]. Mar. Geol. Quat. Geol. 20 (4), 17 – 21.

Li, G. X., Zhuang, K. L.,Wei, H. L., 2000b. Sedimentation in the Yellow River Delta: Part III. Seabed erosion and diapirism in the abandoned subaqueous delta lobe[J]. Mar. Geol. 168, 129 – 144.

Li, G. X., Wei, H. L., Han, Y. S., Cheng, Y. J., 1998a. Sedimentation in the Yellow River Delta: Part I. Flow and suspended sediment structure in the upper distributary and the estuary [J]. Mar. Geol. 149,93 – 111.

Mather, P. M., 1987. Computer Processing of Remotely – Sensed images[J]. Wiley, England, 351 pp.

McGarigal, K., Marks, B. J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. U. S. forest Service General Technical Report PNW 351. Science 260, 1905 – 1910.

Nemani, R., Pierce, L., Running, S., 1993. Forest ecosystem processes at the watershed scale: Sensitivity to remotely – sensed Leaf Area Index estimates[J]. Int. J. Remote Sensing. 14, 2519 – 2534.

Puyravaud, J. P., 2003. Standardizing the calculation of the annual rate of deforestation[J]. For. Ecol. Manage. 177, 593 – 596.

Peterseil, J., Wrbka, T., Plutzar, C., Sch mitzberger, I., Kiss, A., Szerencsits, E., Reiter, K., Schneider, W., Suppan, F., Beissmann, H., 2004. Evaluating the ecological sustainability of Austrian agricultural landscapes—the SINUS approach[J]. Land Use Policy 21, 307 – 320.

Pons, X., Sole′ – Sugran ~ es, L., 1994. A simple radiometric correction model to improve automatic mapping of vegetation from multispectral satellite data[J]. Remote Sens. Environ. 48, 191 – 204.

Pang, J. Z., Si, S. H., 1979. Evolution of the Yellow River mouth: I. Historical shifts[J]. Oceanol. Limnol. Sin. 10 (2), 136 – 141.

Pang, J. Z., Jiang, M. X., Li, F. L., 2000. Changes and development trend of runoff, sediment discharge and coastline of the Yellow River Estuary[J]. Trans. Oceanol. Limnol. 4, 3 – 6.

Sun, X. G., Yang, Z. S., 1995. Prediction of modern Huanghe River Delta area increment by using the sediment discharge[J]. Oceannol. Limnol. Sin. 26 (1), 76 – 82.

Wrbka, T., Erb, K. H., Schulz, N. B., Peterseil, J., Hahn, C., Haberl, H., 2004. Linking pattern and process in cultural landscapes. An empirical study based on spatially explicit indicators[J]. Land Use Policy 21, 289 – 306.

White, K., Asmar, H. M., 1999. Monitoring changing position of coastlines using Thematic Mapper imagery, an example from the Nile Delta[J]. Geomorphology 29, 93 – 105.

Wright, L. D., Wiseman, W. J., Bornhold, B. D., Prior, D. B., Suhayda, J. N., Keller, G. H., Yang, Z. S., Fan, Y. B., 1988. Marine dispersal and deposition of Yellow River silts by gravity – driven underflows[J]. Nature 332, 629 – 632.

Xue, C. T., 1993. Historical changes in the Yellow River Delta[J]. China. Mar. Geol. 113, 321 – 329.

Xue, C. T., 1994. Division and recognition of modern Yellow River Delta lobes[J]. Geogr. Res. 13 (2), 59 – 66.

Xu, J. X., 2002. A study of thresholds of runoff and sediment for the land accretion of the Yellow River Delta[J]. Geogr. Res. 21 (2), 163 – 170.

Yu, L. S., 2002. The Huanghe (Yellow) River: a review of its development, characteristics, and future management issues[J]. Cont. Shelf Res. 22, 389 – 403.

Yang, X., 1995. Monitoring Morphodynamic Aspects of the Present Huanghe River Delta, China. An Approach to the Integration of Satellite Remote Sensing and Geoinformatic Systems (GIS). Unpublished Master's thesis, International Institute for Aerospace Survey and Earth Sciences, The Netherlands.

Yang, X., 1996. Satellite monitoring of dynamic environmental change of the active Yellow River Delta, China. International Archives for Photogrammetry and Remote Sensing XX – VII: 801 – 806.

Yang, X., M.C. _I. Damen & R.A. van Zuidam, 1999. Use of Thematic Mapper imagery with a geographic information system for geomorphologic mapping in a large deltaic lowland environment[J]. International Journal of Remote Sensing, 20(4): 659 – 681.

Ye, Q., 1998. Flow interruptions and their environmental impact on the Yellow River Delta. Acta Geographia Sinica 53(5), internet.

Zang, Q.Y., 1996. Nearshore Sediment Along the Yellow River Delta[M]. Ocean Press, Beijing, pp. 11 – 51.

Zhuang, H.C., Shapiro, M., Bagley, C.F., 1993. Relaxation vegetation index in non – linear modelling of ground plant cover by satellite remote – sensing data[J]. Int. J. Remote Sensing 14, 3447 – 3470.

Study about the Conditions of Ensuring Yellow River Delta Water Resources

Zhang Jianjun, ***Huang Jinhui*** and ***Yan Li***

Yellow River Water Resources Protection Institute, Zhengzhou, 450004, China

Abstract: About 90% water resources demanded by the Yellow River delta comes from the Yellow River. Defended by the embankments along the river, no sewage can flow into it from discharge outlets and tributaries, as a result, the water quality of the Yellow River delta is mainly decided by both the quality and quantity of the water released from the Xiaolangdi Reservoir and the sewage discharged in the lower reaches. Taking the water quality of Lijin section as a typical one for the Yellow River delta, 6 cross sections in the reach from Xiaolangdi to Lijin were selected for water quality evaluation, its change analysis and demonstration of water quality guaranteed condition of Lijin section. This research has revealed that assurance rate of water quality of Lijin section was 80% when the discharge of the Xiaolangdi is upto or over 230 m^3/s. If the quality of water discharged from the Xiaolangdi did not go beyond Class Ⅳ, the assurance rate of water quality of Lijin section was above 80%, the assurance rate of water quality of Lijin was 87% when the discharge of Lijin Section came to 88 m^3/s and above.

Key words: Yellow River, delta, Xiaolangdi, Lijin, water quality, water quantity

The water quantity of runoff and groundwater in the Yellow River delta is very limited and there is about 90% water resources depends on the Yellow River. The water quality and water quantity of the Yellow River have a direct effect on the industrial and agricultural production, as well as the local national economy development. Therefore, it's very important to definitude the condition ensuring water resources of mainstream in the Yellow River delta and realize the water quality objective to the continuous development of economy and society in the Yellow River delta area.

1 Introduction study river Section

According to the water function zoning of the Yellow River, the water quality objective of mainstream reaches in the Yellow River delta including the reserved zone of estuary and some reaches located in the development and utilization zones of Shandong province is standard Ⅲ. Because of the restriction of the embankments, no sewage can flow into the Yellow River from the discharge outlets and tributaries in the delta, and the water quality of the Yellow River in the delta is mainly decided by the water quantity and quality discharged from the Xiaolangdi reservoir upstream and the sewage amount discharged in the lower reaches. As a result, the study scope covers the range from Xiaolangdi cross section to the mouth of the Yellow River.

The reach below the Xiaolangdi refers to that from the dam of Xiaolangdi to the mouth of the sea, extending 895.7 km, featuring of typical wandering river, for its course sways frequently. Besides, it has a high silt content which deposited heavily on the river and more dangerous sections with it. The reach from Xiaolangdi to Huayuankou is the transition reach from mountainous area to plain, and it closes up near Taohuayu of the Yellow River valley where the lower riverbed has been raised, higher than the floor of levee about 3 ~ 5 m and the suspending river is formed.

Some main tributaries converge in this reach, such as Yiluohe, Qinhe, Sishuihe, Manghe, Natural Wenyanqu and Jindihe rivers. Amongs these rivers the Yiluohe and Qinhe have been polluted seriously and the quantity of pollution transportation is higher than the others which affect the water environment of the local area seriously.

2 Determination of study method

Lijin cross section is the last monitoring section before the Yellow River water emptying into the Bohai Sea, below which there aren't any sewage outlets in the lower Yellow River. Therefore, the water quality of Lijin cross section deems to be the water quality of the Yellow River delta. In order to find the conditions that can reach standard Ⅲ ensuring the water quality objective of water function zoning of the Yellow River mainstream in the delta, we must have a clear known about the responding relation of water quality and water quantity between Lijin cross section and the outflow of Xiaolangdi.

Making use of the water quality monitoring information of November 2002 to October 2005 of six routine cross sections including Xiaolangdi, Huayuankou, Gaocun, Aishan, Luokou and Lijin, we chose nine parameters as assessment factors, including PH, DO, permanganate index, COD_{Cr}, BOD_5, Ammonia Nitrogen, Volatilization hydroxybenzene, fluoride and oil etc. Furthermore, the evaluation was carried out respectively by every month, flood season, non – flood reason and all the year.

Based on the water quality evaluation, we made use of the statistics principle to demonstrate the water quality of Lijin cross section and had a minute investigation about the affect of the water quantity and outflow of Xiaolangdi to the water quality of Lijin cross section, and proceeded to put forward some specific requirements to ensure the water quality objective of Lijin cross section.

3 Water quality evaluation of study river section

3.1 Water quality evaluation results

An evaluation to 6 cross sections from Xiaolangdi to Lijin in the main Yellow River was carried out, see Table 1.

Table 1 Water quality evaluation results in study river section atpresent

Monitoring section	Period	Water quality category	Main factors exceeded Standard
Xiaolangdi	Flood season	Ⅲ	
	Low – water season	Ⅳ	COD, Ammonia nitrogen
	Average annual	Ⅳ	COD
Huayuankou	Flood season	Ⅳ	COD
	Low – water season	Ⅳ	COD, Ammonia nitrogen
	Average annual	Ⅳ	COD, Ammonia nitrogen
Gaocun	Flood season	Ⅲ	
	Low – water season	Ⅳ	COD, Ammonia nitrogen
	Average annual	Ⅳ	COD
Aishan	Flood season	Ⅲ	
	Low – water season	Ⅳ	COD, Ammonia nitrogen
	Average annual	Ⅲ	
Luokou	Flood season	Ⅱ	
	Low – water season	Ⅳ	COD, Ammonia nitrogen
	Average annual	Ⅲ	
Lijin	Flood season	Ⅲ	
	Low – water season	Ⅳ	COD, Ammonia nitrogen
	Average annual	Ⅲ	

Note: During water and sediment regulation, the high content sediment has bigger influence to water quality monitoring, so evaluation picked and got rid of the corresponding months during water and sediment regulation, 3 months in total, the same as below.

Water quality evaluation results show that the water quality in the study reach is relatively better during flood season, for water quality of all other cross sections, except for Huayuankou, satisfy Class Ⅲ standard, while it is worse during non – flood season, for only Class IV standard can be met, and water quality at Lijin can't satisfy the function target. For average annual condition, the water quality at Xiaolangdi, Huayuankou and Gaocun reach Class Ⅳ, and that of the sections below Gaocun measure Class Ⅲ.

3.2 Water quality change along the river

COD and ammonia nitrogen are the main pollution factors of the study reach, therefore, we respectively plotted their concentration change along the river during flood season, non – flood season and average annual concentration in order to reflect water quality variety condition along the study reach, see Fig. 1 and Fig. 2.

From Fig. 1, we can see that COD concentration is lower at Xiaolangdi, it reaches its highest while going to Huayuankou cross section, this is because the afflux of seriously polluted water from sewage outlets and tributaries (such as Yiluo River, Qin River, Xinmang River, etc.), making COD concentration go up suddenly. COD concentration descends gradually below Huayuankou section and becomes steady when it is going to Gaocun section and then keeps constant in the lower reaches, this is because the river lower Huayuankou is "suspended river" and no sewage entered, it is a self – purification reach. COD concentration differs obviously in different water period, water quality of each cross section is worse than Class Ⅲ standard in low – water season.

From Fig. 2, we can see that ammonia nitrogen concentration basically shows a descending trend along the study reach, it is little higher in Huayuankou than other sections. Average annual concentration in flood season can satisfy Class Ⅲ standard, while that in low – water season is worse, no concentration at Gaocun and upper sections can satisfy Class Ⅲ standard.

As a whole, in different periods, the worst water quality appears at Huayuankou cross section, below which, pollutants concentration gradually reduces, and the water quality at Lijin can satisfy Class Ⅲ standard under current pollutants exhausting condition.

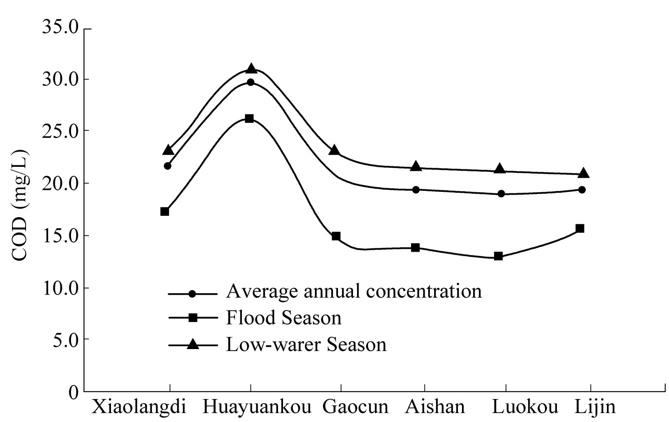


Fig. 1 Variety of COD concentration in different period along study river section

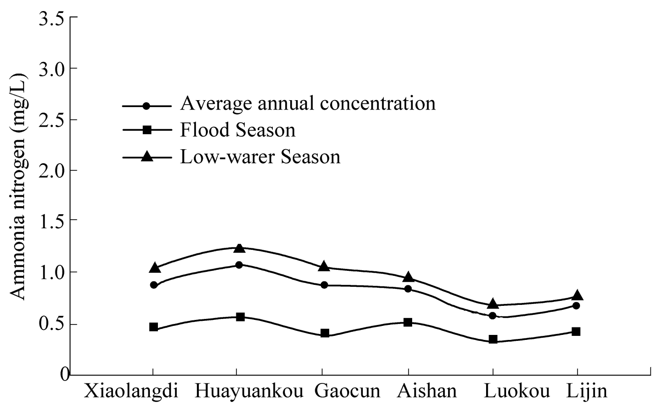


Fig. 2 Variety of Ammoria Nitrogen concentration in different periods along study river section

4 The conditions evaluation of the water quality guarantee at Lijin section

4.1 The correlation relationship between water quantity released by Xiaolangdi Reservoir and water quality at Lijin

4.1.1 Study thoughts

Monitored data of many years manifest that quality and quantity of water released from the Xiaolangdi Reservoir closely correlates with the water quality at Lijin, therefore, under such condition, we can take the Xiaolangdi section as water quality predominant section of the lower reaches.

The discharge of the Xiaolangdi Reservoir can be used to make comparative analysis with the observed data of water quality at Lijin in the corresponding time period. If the corresponding water quality of Q_{end} satisfies Class Ⅲ standard, then water quality of the main Yellow River in the delta can be ensured to meet the standard as shown in Fig. 3.

4.1.2 Analytical methods

The lowest critical flow discharge from the Xiaolangdi Reservoir Q_{end} can be calculated through the following steps:

Here, we introduce a concept – water quality assurance rate, namely, ordering the 33 months flow samples used in water quality evaluation from the biggest down to the smallest, and correspondingly ordering monitoring value of water quality index and flow of each month according as daily flow sample sequence.

In correspondingly water quality – quantity samples, if the water quality of all samples whose discharge is bigger than Q_1 reaches the standard, the corresponding water quality assurance rate will be 100%.

If only one water quality sample of the discharge bigger than Q_2 can't reach the standard, the corresponding water quantity assurance rate will be $(n_2 - 1)/n_2 \times 100\%$, n_2 is the sample sum that quantity is bigger than Q_2.

If there are two water quality samples whose discharge is bigger than Q_3 can't reach the standard, correspondingly water quantity assurance rate is $(n_3 - 2)/n_3 \times 100\%$, n_3 is the sample sum that quantity is bigger than Q_3.

……

If there are m water quality samples whose discharge is bigger than Q_n can't reach the standard, correspondingly water quantity assurance rate is $(n-m)/n\times 100\%$, n is the sample sum that quantity is bigger than Q_n.

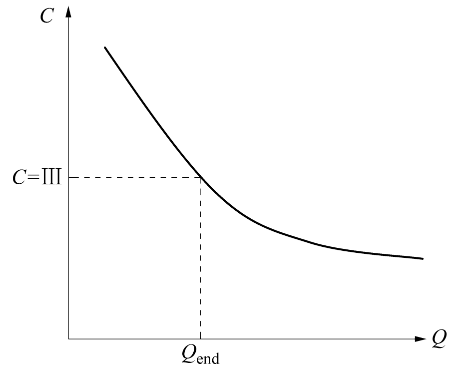


Fig. 3　Study Sketch map of water quality guarantee conditions analysis

4.1.3　Study results

As a whole, the water quantity correlationship between the Xiaolangdi Reservoir and Lijin is fairly good, as shown in Fig. 4. When the water released from the Xiaolangdi Reservoir is lower than 230 m^3/s, the corresponding water quality would be bad and the rate of water quality to the standard is lower. Under current pollutants exhausted condition, the water quality guaranteed rate at Lijin is 76% at Lijin, when $Q_{end}\geqslant 230$ m^3/s, the corresponding water quality guaranteed rate is 82%, but when water quantity from the Xiaolangdi Reservoir is lower than 230 m^3/s, the water quality guaranteed rate is only 55% at Lijin. Therefore, it is believed that, in order to insure water quality at Lijin, the water discharge at the Xiaolangdi section shouldn't be lower than 230 m^3/s.

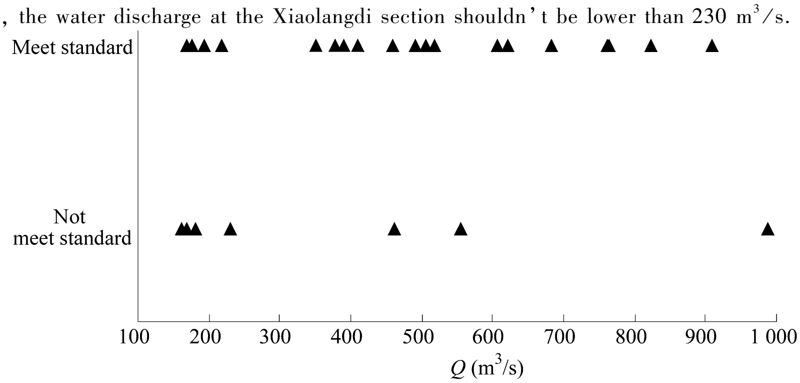


Fig. 4　Conditions of water quality meet standard at Lijin and corresponding discharge from xiao langdi Reservoir quantity Xiaolangdi Reservoir release

4.2　Response relationship between water quantity and water quality at Lijin section

And for the same reason, we can know the condition of water quality reaching standard at Lijin and its corresponding water quantity, as shown in Fig. 5. Under current pollutants exhausted condition, when water quantity at Lijin is lower than 68 m^3/s, the water quality guaranteed rate is only 44%, when water quantity at Lijin $\geqslant 230$ m^3/s, the corresponding water quality guaranteed rate is 87%. Therefore, it deems that, in order to insure water quality at Lijin, the water quantity at Lijin must higher than 90 m^3/s.

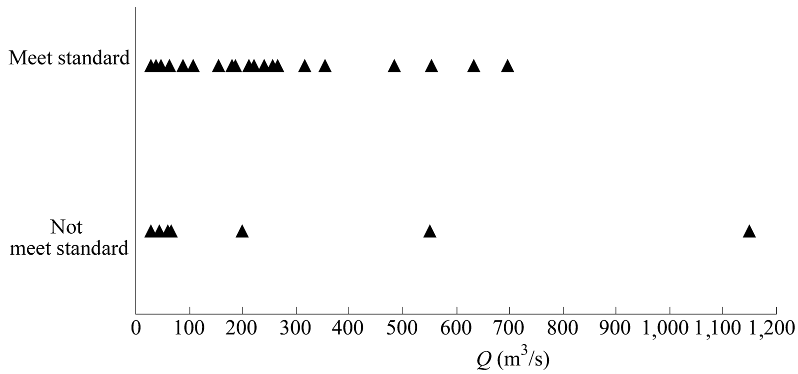


Fig. 5 Condition of water quality reached standard at Lijin and corresponding discharge

4.3 Relationship between Water quality of Xiaolangdi and water quality at Lijin section

Under current pollutants exhausted condition, the quality of water released from the Xiaolangdi Reservoir is worse than Class Ⅴ, the water quality guaranteed rate to be at Class Ⅲ at Lijin is only 29%, while water quality of the Xiaolangdi Reservoir is better than Class Ⅳ, the water quality reached Class Ⅲ standard at Lijin is 83%, as Fig. 6 showed.

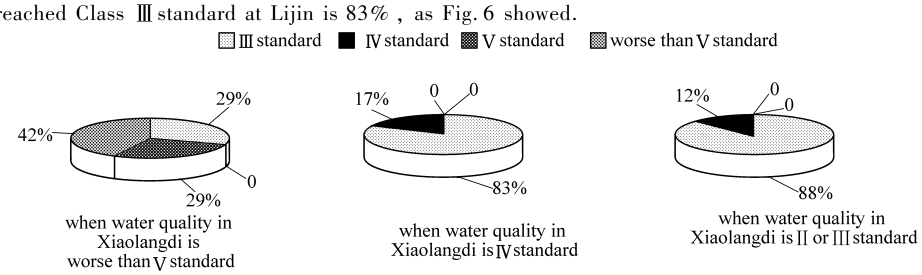


Fig. 6 Condition of water quality meet standard at Lijin and corresponding water quality of Xiaolangdi Reservoir

5 Contrast with the research results

In environmental and ecological water demand study, they give recommendatory water quantity at the Xiaolangdi and other 5 important sections below, considered need of near sea fishes, wetlands at delta and water ecology and water environment, as listed in Table 2. The minimum ecological and environmental flow at the Xiaolangdi and Lijin from their study are very close with our results.

Table 2 Environmental and ecological water demand below Xiaolangdi

Num.	Section	Recommendatory flow(m^3/s)	The minimum flow(m^3/s)
1	Xiaolangdi	450	260
2	Huayuankou	480	300
3	Gaocun	370	140
4	Luokou	300	100
5	Lijin	300	100

6 Conclusions

In summary, this research indicated that the water quantity of Xiaolangdi's outflow should not be lower than 230 m^3/s and the water quality should not be lower than Class Ⅳ, and furthermore, the discharge flowing into the sea from Lijin section should not be less than 90 m^3/s for satisfying the requirement of mainstream water quality of Class Ⅲ in the Yellow River delta.

Moreover, because there are large quantities of sewage flowing into the Yellow River from the reach upstream of the Xiaolangdi Reservoir and the reach from Xiaolangdi to Huayuankou, the possibility for the Yellow River delta to meet with sudden accidents of pollution still exists. As a result, the works of water resources protection for the reach upstream of the Yellow River Estuary should be strengthened and the pollutants discharged into this reaches should be controlled in the river capacity.

Reference

Hao Fuqin, Huang Jinhui, Li Qun. The Study of Eco – environmental Water Demand of Main Stream of Yellow River: Yellow River Conservancy Press, 2005. 169.

Habitat Suitability Analysis of Red – crowned Crane in Yellow River Delta Nature Reserve

Cao Mingchang[1,2] and ***Liu Gaohuan***[1]

1. Institute of Geographic Sciences and Nature Resources Research, Chinese Academy of Sciences
2. Graduate School of Chinese Academy of Science Beijing, 100101, China

Abstract: Considering the human activities' disturbances and selecting a series of landscape pattern indices, the habitat suitability of red – crowned crane in the Yellow River Delta Nature Reserve was analyzed from 1993 to 2005 based on its habitat map. The results show that human activities' disturbances, especially the construction of roads, became more serious than before in 12 years; the habitat suitability of 1999, with more habitat loss and fragmentation, is inferior to 1993 and 2005; 2005 is superior to 1993 without disturbances, whereas with disturbances. The two main factors resulted in habitat loss and fragmentations of red – crowned crane are fresh water sources and human activities disturbances.

Key words: red – crowned crane, YRDNR, habitat suitability, fragmentation

1 Introduction

Habitat is living site that is vital for wildlife's growth, breeding spread or migration[1]. Recently, due to the intensive human activities, global and region ecological environment encountered enormous changes that resulted in habitat loss and fragmentation, made the species endangered and threatened, and more seriously, leaded to global biodiversity loss. Red – crowned crane (Grus japonensis), which is one of the rare, threatened species in the world, only occurs in open wetland and is classified as vulnerable by IUCN. Much research involved its habitat selection, behavior of breeding, wintering and territory occupancy has been conducted for conserving its habitat. Due to its sensitivity for human activities, red – crowned crane only inhabits in wetland short of human disturbances which will influence on its growth and breeding by changing wetland environment significantly.

The Yellow River Delta Nature Reserve (YRDNR), which is plenty of wetland and marsh resources, is an important site for many waterfowls (includes red – crowned crane) inhabiting and breeding. However, since it was built up in 1992, wetland and habitat of red – crowned crane here have been undergone huge changes due to nature and human disturbances that lead to wetland deterioration and habitat loss and fragmentation of many waterfowls, especially of red – crowned crane. Therefore, based on the landscape ecology theory, in this paper the habitat suitability and fragmentation of red – crowned crane in YRDNR was analyzed by using geographical information system and remote sensing technique. Moreover, the main factors drive the changes of its habitat were discussed too.

2 Study site

YRDNR, which is located in the Yellow River Delta at Dongying city, was built up in 1992. It is a national nature reserve for conserving the new wetland ecosystem and threatened and vulnerable waterfowls inhabit here. It consists of two parts: the current and old (1976 before) courses of the Yellow River, which contain three management stations: the Yellow River Estuary, DaWenLiu and YiQianEr. According the statistics data in 1997, the area of YRDNR is 15.3 hm^2; and current and old course is 115,462 hm^2 and 37,538 hm^2 respectively. Abundant tidal flats and marshes rich in wetland vegetation and water organisms here provide waterfowls with the most suitable habitat environment. YRDNR is one site of the East Asia birds' migration network, a membership of East Asia – Australia wading birds network, and also a biosphere reserve of China MAB. However the second largest oil field of China, Shengli oil field, which threats to the habitat of waterfowls, is built up here too.

Red – crowned crane, with the amount 200 living through the winter and 800 of migration, is one of the most largest waterfowl populations inhabits in YRDNR; the main periods of its wintering in YRDNR are from the last – ten days of October to the first – ten days of December in Autumn, and from the first – ten days of February to the fist – ten days of March in Spring. Therefore, YRDNR is one of the important areas of migration and wintering for red – crowned crane.

3 Material and methods

3.1 The date source and processing

The data used in the study were TM data of 1993, 1999 and 2005, respectively. We performed the geometric rectification to the images by using ground control points (GCP) identified and selected from a topographic map at a scale of 1:50,000. we applied unsupervised classification and generated clusters using ISODATA clustering analysis. Field data were used to identify training classes and to label and merge clusters for identification. Singatures of identified clusters were subsequently used in a maximum likelihood classification to generate a land cover map, which consisted of lots of land cover types: forest, Chinese tamarisk shrub, reed meadow, reed marsh, seablite tidal flat, Chinese tamarisk – seablite tidal flat, bare tidal flat, salt pan, fishpond, deep water area, farmland, residential area and roads.

3.2 Habitat suitability of red – crowned crane

Red – crowned crane is a species of wetland, and accustomed to the habitat of marsh, tidal flat with no or little disturbances. Therefore, according to the its habitat requires, and considering the condition of land cover in YRDNR, we classified its habitat as three type: suitable, moderately suitable and unsuitable. Suitable contained reed marsh, Chinese tamarisk – seablite tide flat and seablite tide flat. Moderately suitable contained reed meadow bare tide flat, salt pan, fishponds, and unsuitable contained the remaining land cover types. According to this classification, a potential habitat suitability map of red – crowned crane was produced (Fig. 1). On the other hand, some study show red – crowned crane is apart from roads with the nearest distance 200 m, from oil well with 300 m because of its sensitivity to human disturbances. Base on this concept, we applied four types of human activities' disturbances, which is main road, rural road, residential area and agriculture activities respectively, to its habitat. We build 300 m buffer zone for main road and residential area, while 200 m for rural road and agriculture activities (farmland). a actual habitat suitability map can be generated by excluding buffer zones of the disturbances (Fig. 2).

3.3 Analysis methods

Based on the habitat suitability map of red – crowned crane, Fragstats 3.0 software was used to calculate the appropriate landscape indices that can reflect the habitat suitability and degree of fragmentation. In this paper, seven indices were selected as follows: total area (TA), which indicates change of habitat area; numbers of patch (NP), patch density (PD) and mean patch area (AREA_MN), which show the degree of habitat fragmentation; mean fractal dimension index (FRAC_MN) and perimeter – area fractal dimension (PAFRAC), which reveal the shape characteristic of habitat patches; mean Euclidean nearest neighbor distance (ENN_MN), which reflects the degree of isolation between habitat patches.

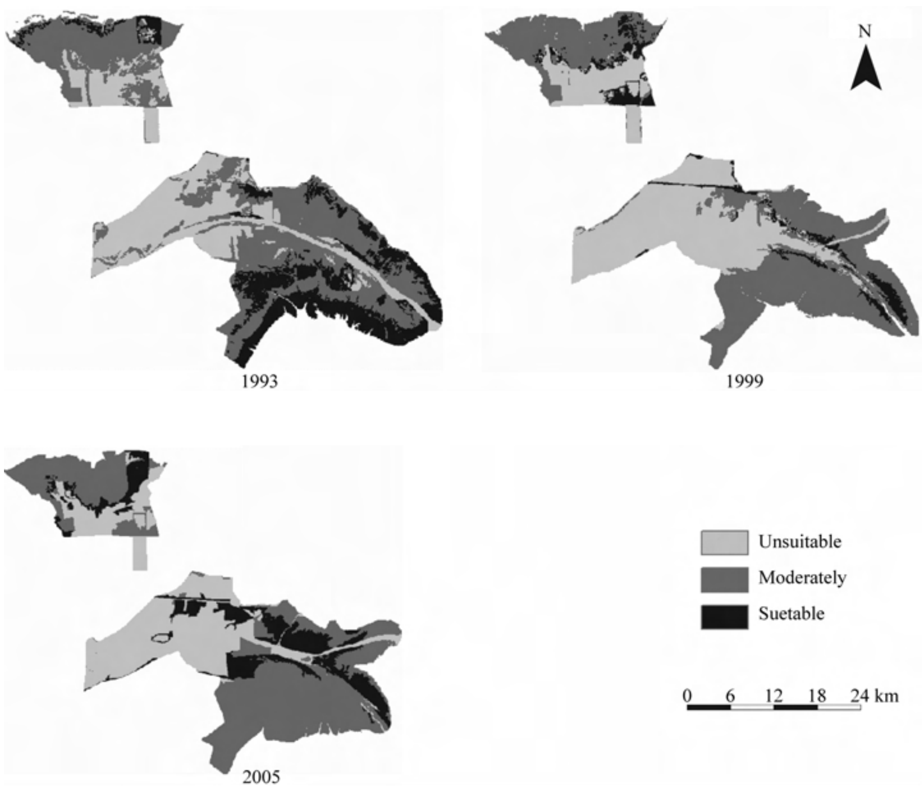


Fig. 1 The habitat suitability of red – crowned crane without disturbances in three periods

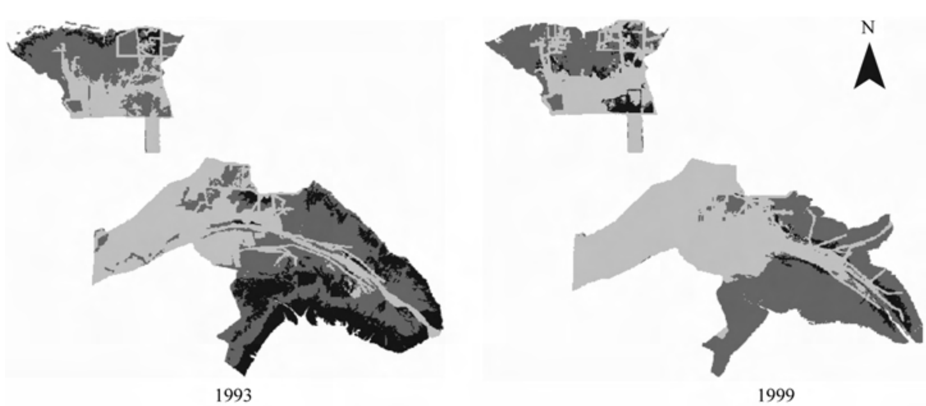


Fig. 2 The habitat suitability of red – crowned crane with disturbances in three periods

4 Results and discussions

4.1 Suitable and moderately suitable habitat area of red – crowned crane

The habitat area of red – crowned crane in YRDNR was calculated without human activities' disturbances and with disturbances in 1993, 1999 and 2005 respectively (Table 1, Table 2, Table 3). Table 1 revealed that the area of suitable habitat was decreasing from 1993 to 1999, and then increasing from 1999 to 2005 without disturbances. The area of suitable habitat in 1993 was 22,661.2 hm^2, decreased to 7,317.5 hm^2 in 1999, and then increased to 18,796.9 hm^2 in 2005. Moderately suitable habitat showed the similar trend that its area in 1999 was 5,823.2 hm^2 and 3,396.9 hm^2 less than 1993 and 2005 respectively, although its area changed insignificantly. As a result, unsuitalbe habitat in 1999, which occupied 43.6% of its total area, was the largest among three periods.

Table 2 showed that the decreased area of suitable habitat in 1993 was 1,097.1 hm^2, while 2, 881.9 hm^2 in 1999 and increased to 7,089.3 hm^2 in 2005 finally due to human activities' disturbances, of which the road disturbances was the largest, while the residential area had little influence on suitable habitat because of its sparse distribution in YRDNR. Moderately suitable reflected the same trend of suitable habitat as showed in Table 3, but its decreased area which was 8,076.2 hm^2, 8,512.4 hm^2 and 7,522.7 hm^2 respectively, was almost similar.

Table 1 The Total area of habitat suitability of red – crowned crane

	Total area		Suitable		Moderately suitable		Unsuitable	
	hm^2	%	hm^2	%	hm^2	%	hm^2	%
1993	116,700.7	100	22,661.2	19.4	57,152.5	49.0	36,887.0	31.6
1999	103,833.1	100	7,317.5	7.0	51,329.3	49.4	45,186.3	43.6
2005	112,509.3	100	18,796.9	16.7	54,726.2	48.6	38,986.2	34.7

Table 2 The total suitable area of red – crowned crane excluding disturbances

	Exclude road			Exclude agriculture activities			Exclude residential area			Sum	
	Suitable area hm^2	Decreased area hm^2	Decrease rate %	Suitable area hm^2	Decreased area hm^2	Decrease rate %	Suitable area hm^2	Decreased area hm^2	Decrease rate %	Decreased area hm^2	Decrease rate %
1993	21,616.3	1,044.9	4.6	21,614.3	2	0.01	21,564.1	50.2	0.2	1,097.1	4.81
1999	4,567.5	2,750	37.6	4,445.7	121.8	1.7	4,435.6	10.1	0.14	2,881.9	39.44
2005	12,149.3	6,647.6	35.4	11,743.2	406.1	2.2	11,707.6	35.6	0.18	7,089.3	37.78

Table 3 The total moderately suitable area of red – crowned crane excluding disturbances

	Exclude road			Exclude agriculture activities			Exclude residential area			Sum	
	Moderately suitable hm^2	Decreased area hm^2	Decrease rate %	Moderately suitable hm^2	Decreased area hm^2	Decrease rate %	Moderately suitable hm^2	Decreased area hm^2	Decrease rate %	Decreased area hm^2	Decrease rate %
1993	50,866.4	6,286.1	11	49,120.6	1,745.8	34,9076.3	44.3	0.07	8,076.2	14.07	
1999	43,264.3	8,065	15.7	42,853.3	411	0.8	42,816.9	36.4	0.07	8,512.4	16.57
2005	47,398.8	7,327.4	13.4	47,245.9	152.9	0.28	47,203.5	42.4	0.08	7,522.7	13.76

4.2 Habitat fragmentation of red – crowned crane

Table 4 and Fig. 3 showed the trend that NP, PD and ENN_MN of suitable habitat were decreasing from 1993 to 1999, while increasing from 1999 to 2005, whereas AREA_MN whether ever the disturbances existed or not. Therefore, it indicated that the fragmentation and isolation of suitable habitat was increasing significantly during 1993 to1999, while decreasing from 1999 to 2005. At the same time, they also show disturbances enhanced the fragmentation of suitable habitat, especially in 2005, for example, its NP increased from 38 to 132, PD increased from 0.009,1 to 0.031, and AREA_MN decreased from 494.65 hm^2 to 88.69 hm^2 smartly. In addition, FRAC_MN and PAFRAC showed that the shape of suitable habitat became more simple and regular. Shape with disturbances was more complex than without disturbances, especially in 2005 too.

Table 4 The landscape indices of habitat suitability of red – crowned crane

	Habitat types	Year	NP	AREA – MN	PD	FRAC_MN	PAFRAC	ENN_MN
		1993	80	283.27	0.018,3	1.132,6	1.546,3	247.69
Before disturbances	Suitable	1999	128	57.17	0.031,3	1.112,1	1.563,3	282.03
		2005	38	494.65	0.009,1	1.104,3	1.272,4	231.84
	Moderately suitable	1993	141	405.34	0.032,2	1.120,5	1.434,4	157.90
		1999	83	618.43	0.020,3	1.119,2	1.376,4	303.94
		2005	98	558.43	0.023,6	1.079,6	1.221,8	226.90
After disturbances	Suitable	1993	101	213.51	0.021,3	1.112	1.393,9	249.08
		1999	166	26.72	0.040,5	1.088,7	1.351,4	275.97
		2005	132	88.69	0.031	1.075,4	1.196,9	254.92
	Moderately suitable	1993	241	203.64	0.050,8	1.094,5	1.296,2	186.58
		1999	209	204.87	0.051	1.075,1	1.255	265.50
		2005	105	449.56	0.024,7	1.070,1	1.163,5	238.20

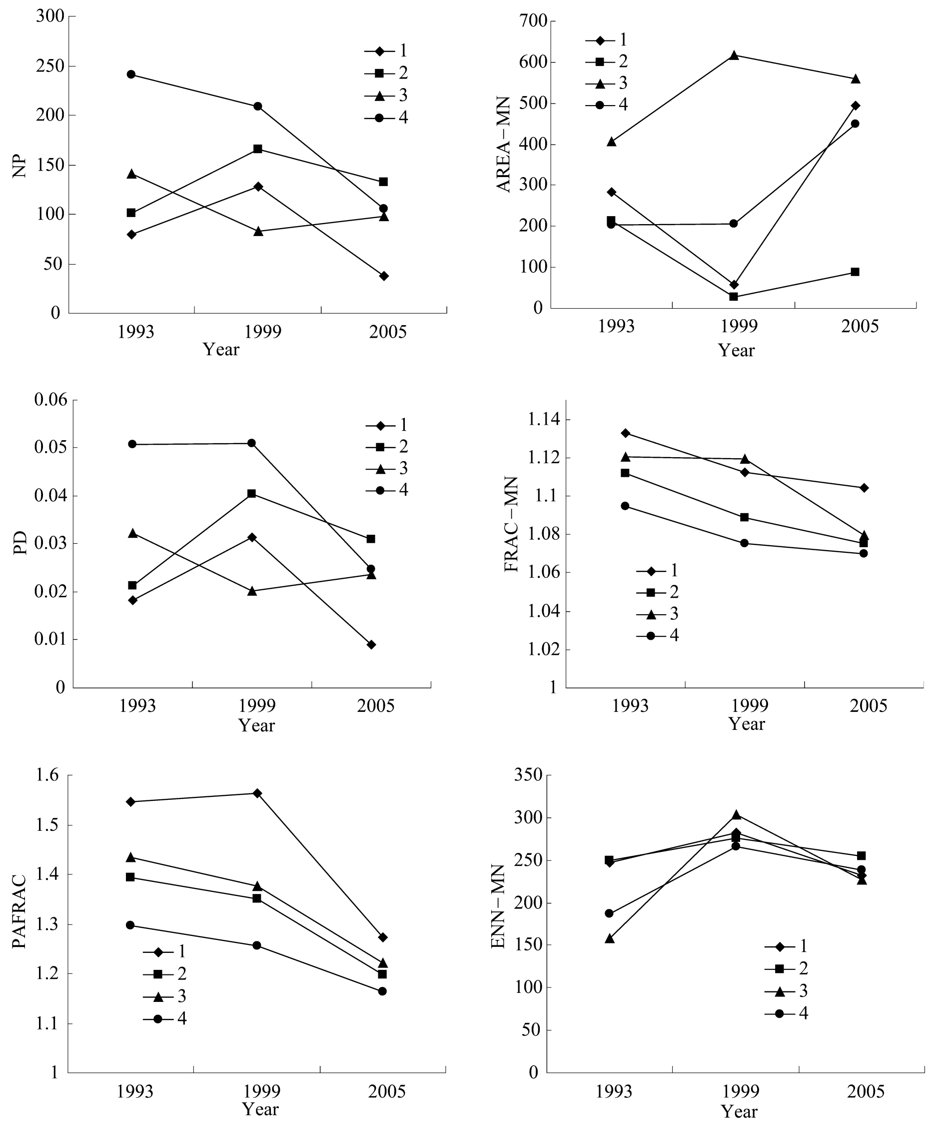


Fig. 3 The different landscape indices of habitat suitability of red – crowned crane

1. suitable habitat without disturbances; 2. suitable habitat with disturbances;
3. moderately suitable habitat without disturbances; 4. moderately suitable habitat with disturbances

Moderately suitable habitat with disturbances showed different trends from 1993 to 2005 compared to without disturbances. The best moderately suitable habitat was in 1999 without disturbances, while in 2005 with disturbances. In addition, FRAC_MN and PAFRAC showed that the shape of suitable habitat became simpler and more regular. This is similar to suitable habitat.

Overall, habitat suitability of red – crowned crane in 1999, with more habitat loss and fragmentation, is inferior to 1993 and 2005 no matter what disturbances existed. 2005 is superior to 1993 without disturbances, whereas with disturbances. It reveals that disturbances, which leaded to habitat suitability decreased rapidly, increased considerablely from 1993 to 2005.

4.3 Discussions

There are two main factors resulted in habitat loss and fragmentation of red – crowned crane: physical and human activities factor. Fresh water sources, which are determined mainly by the Yellow River runoff, are the main physical factor. Noticeablely, zero flow of the Yellow River occurred frequently since 1972, especially in 1990s, the frequency of zero flow increased significantly, and the continuous period enlarged smartly in the Yellow River (Table 5). Consequently, wetland ecosystem and habitat of red – crowned crane in YRDNR changed significantly. Table 5 showed that zero flow of the Yellow River was increasing since 1991, especially from 1995 to 1998, the continuous periods were over 100 days, and the longest period, which occurred at Lijin hydrological station in 1997, was 227 days. As a result, the habitat area of red – crowned crane was decreasing and became more fragmentized because of zero flow in the Yellow River from 1993 to 1999. The habitat suitability of red – crowned crane did not achieve to the level of 1993 again although the wetland restoration project was performed since 2002.

Another factor is human activities that consisted of oil exploitation and farmland reclamation. Because of oil exploitation of Shengli oil field, many establishments including roads, oil wells, and industry buildings were built up in YRDNR. There increased 268 km roads and 236 oil wells in YRDNR since 1993, at the same time, area of farmland increased from 15,363 hm^2 to 56,419 hm^2 due to farmland reclamation. As a result, human activities made the habitat fragmentation of red – crowned crane inherently caused by zero flow of the Yellow River deteriorated more considerablely.

In conclusion, the changes of fresh water sources were the intrinsic driver to lead to the habitat changes of red – crowned crane, and its habitat area, fragmentation, and suitability were determined by whether the fresh water sources are enough or not. In addition, the intensity of human activities improved or deteriorated this trend extrinsically.

Table 5 The period of zero flow in the Yellow River at Lijin hydrological station in 1990s

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Days of zero flow	16	82	61	75	122	132	226	142	42

References

Yan Z C, Cheng Y L. Habitat selection in animals[J]. Chinese Journal of Ecology, 1998, 17: 43 – 49.

Burkey T V. Extinction rates in archipelagoes: implications for population in fragmented habitats. Conservation Biology, 1995, 9: 527 – 541.

Wilcove D S, Dubow J , Philips A, et al. Quantifying threats to imperiled species in the Unite States. BioScience, 1998, 48: 607 – 615.

Laurance W F, Lovejoy T E, Vasconcelos H L, et al. Ecosystem decay of Amazonian forest fragments: a 22 year investigation. Conservation Biology, 2002, 16: 605 – 618.

WCMC. IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland. 1994.

SSCPIUCN. IUCN Red List of Categories. IUCN, Gland, Switzerland. 1994.

Collar N J, Crosby M J, Stattersfield A J. Birds to Watch 2: The World List of Threatened Birds. Cambridge, UK: Birdlife International (Birdlife Conservation Series No. 4), 1994, 74.

Li F, Yang H J, Zhang H H. The nest – site selection by red – crowned crane in the zalong wetland[J]. Journal of Northeast Forestry University, 1999, 27:57 – 60.

Ma Z J, Liu X P. Habitat change and suitability of red – crowned crane in Yancheng biosphere nature reserve[J]. Man and Biosphere, 1998, 5:5 – 8.

Li W J, Ma Z J, Wang Z J. The study of distribution of red – crowned crane's winter habitat in

Yancheng nature reserve[J]. Man and biosphere, 1997, 4:3 – 7.
Wan D M, Gao W, Wang Q Y et al. Effects of habitat fragmentation on nesting site selection of red – crowned crane[J]. Chinese journal of applied ecology 2002, 13:581 – 584.
Liu Z S, Wu J P, Li X M et al. Behavior of red – crowned crane during breeding season in zhalong nature reserve[J]. Journal of Northeast Forestry University, 2001, 29:92 – 95.
Zhang P Y, Li G Z. Study of red – crowned crane about its winter quarters and measures of protecting[J]. Journal or Biology, 2001, 2:9 – 10.
Li W J, Wang Z J. A winter habitat model for red – crowned crane[J]. Chinese Journal of Applied Ecology, 2000, 11:839 – 842.
Liu B. Winter numbers distribution of red – crowned crane on seaboard of yangcheng of Jiusu Province[J]. Acta Ecologica Sinica, 1990, 10:284 – 285.
Li F M, Li P. A comparative study on territories of white – naped crane and red – crowned crane[J]. Acta Zoologica Sinica, 1998, 44:109 – 111.
Zhao Y M. Scientific survey of The Yellow River Delta Nature Reserve[M]. Beijing: China Forestry Press, 1995, 115 – 117.
Li W J, Ma Z J, Wang Z J et al. A study on influential aspects relevant with habitat in natural reserve[J]. Acta Ecologica Sinica, 1999, 19:427 – 430.
Li X M. The present status and conservation of red – crowned crane in Halahai wetland, Heilongjiang, China[J]. Chinese Journal of Zoology, 2002, 37:64 – 66.
Wu J P, Liu Z S, Li X M et al. Breeding Behavior of red – crowned crane in zalong reserve, china [J]. Chinese Journal of Zoology 2002, 37:42 – 46.
Xiao D N, Hu Y M, LI X Z et al. landscape ecology research at wetland surrounding Bohai sea delta[M]. Beijing: Science Press, 2001, 106 – 07.
Yang L K. Effect of agricultural eco – environment from huanghe River cessation in huanghe River delta area and its countermeasure[J]. China environment management, 2005,3:27 – 30.

Protecting the Wetland of the Yellow River Delta and Prompting Sustainable Development of Water Resources

Liu Yanjing[1], ***Yang Lixia***[1] and ***Zong Jipeng***[2]

1. The Yellow River Estuary Bureau, Dongying, 257091, China
2. Kenli Bureau of the Yellow River, Dongying, 257500, China

Abstract: The Yellow River delta has rich wetland resources. Protecting and developing wetland is important to keep ecological environment security and to maintain water resource sustainable development. This article summarizes the Yellow River delta wetland, from regulating flood, reducing the flood peak, supplying groundwater – bearing stratum, improving water quality, preventing salt water invasion, and so on. This article also elaborates the wetland function, and analyzes the wetland current existence question, and proposes the countermeasures of how to protect and manage wetlands.
Key words: Yellow River delta, wetlands, protection, water resources, sustainable development

The wetland, the unique ecosystem, which is affected by land and waters each other, has reputation of "kidney of the Earth" and "cradle of the life". The wetland, the forest and the sea are three kinds of big ecosystem in the world. The wetland, which has the basic characteristic of seasonal or perennial ponding, the growth or perches the happy wet flora and fauna, and so on, has the richest biodiversity ecology landscape of the nature and one of the most important survival environment of human. The wetland not only provide many kinds of resources for humanity's production and the life, but also has the function to control flood, adjust runoff, improve environment, control pollution, protect species gene multiplicity, beautify the environment, maintain region ecological equilibrium, and so on . The Yellow River delta is situated at the shore of Bohai Sea, where Yellow River enter the sea. It is the massive silts which Yellow River carries sediment and deposit. The Yellow River delta is the biggest delta in our country, and is also the broadest, the most complete, the youngest wetland in the temperate zone of our country.

1 Survey of Yellow River delta wetland

The Yellow River delta is located in Dongying City, which governs Dongying, Hekou, Guangrao, Lijin and Kenli. It belongs to the North Temperate Zone half moist continental climate, in which four seasons is distinct, temperature is moderate, illumination is sufficient, annual mean rainfall is 533 mm and average temperature is 12.2 ℃. Because Yellow River carries silt, the area of the Yellow River delta increases by 2,000 ~ 3,000 ha, every year. There are 5 kinds of wetland, which are Shrubbery and thin forest wetland, the meadow wetland, the bog wetland, the rivers wetland and the Binhai wetland.

The natural protection area of Yellow River delta is established in October 1992 and it is state – level and authorized by State Department. The state – level nature protection area bureau of Yellow River delta was established . Since the area has constructed, the nature protection area has effectively fulfilled the responsibility of protection management, the scientific research monitoring, propaganda and education, saving species in danger of being die out, forest management, and so on. It has played the vital role in protecting rare birds which are dying out and newborn wetland ecosystem. Successively it is authorized to join "the protectorate network of Chinese and the biosphere", the wetland international Asian and Pacific organization "East Asian – Australasian Shorebirds Site Network", "the Northeast Asia crane class site network", and is listed by the country as one of 16 international significant sites in the filed of wetland and waters system. It is the

the national level demonstration nature site confirmed by National Forestry Bureau. The total area of nature protection area of Yellow River delta is 153, 000 ha (2. 295 million Chinese acres), thereinto, the core area is 58,000 ha (870,000 Chinese acres), the buffer is 13,000 ha (195,000 Chinese acres), experimental plot 82,000 ha (1.23 million Chinese acres). There are 1,543 kind of wild animal in the area. Thereinto, there are 283 kind of Aves, including 33 kinds of resident birds, 63 kinds of summer resident birds, 31 kinds of winter – resident birds, 156 kinds of transitory birds. The main protection objects are rare, precious and being die out Aves, such as, red – crowned crane, the white crane, the hoary – headed crane, Eastern white stork, the black mouth gull, and so on. "China and Japan Agreement on protecting Migratory bird and its inhabiting Environment" lists 227 kinds of birds, there are 155 kinds of birds in the Yellow River delta nature reserve, which accounts for 68. 3%. "China and Australasia Agreement on protecting Migratory bird and its inhabiting Environment" lists 81 kinds of birds, there are 53 kinds of birds in the Yellow River delta nature reserve, which accounts for 65. 4%. There are 393 kinds of seed plant in the nature reserve, among them, 116 kinds of wild seed plant. The representative xylophyte are locust tree, dryland willow and Chinese tamarisk. Herbaceous vegetation are Reed, jianpeng, and so on.

The Yellow River delta wetland ecosystem is the only one in the 3 big river deltas of our country, Yangtze River, Pearl River and Yellow River, which has important ecology protection value. Besides the river source area wetland, it is the wetland which has the biggest protection value. In the balance and evolution of the Yellow River delta ecosystem, the fresh water wetland is the interactive cushion area of land, freshwater waters and the sea ecology unit, is the essential ecology factor to maintain the estuary system balance and the biodiversity protection, and also is the core region and key protection object of estuary ecology protection. The fresh water wetland has ecology values and functions which are extremely important and cannot be substituted to maintain the estuary area health, to provide the birds the habitat to move, to reproduce and to perches, to maintain delta ecology growth balance, and so on.

2 Wetlands protection and water resources sustainable development

2.1 Concept of wetland

At present, the definition of wetland can be divided into two big kinds in the world. One is given by governor, the most authoritative of which is the definition in "Convention on Wetlands". Wetlands include marshes, peat lands, wet meadows, lakes, rivers, floodplains, river deltas, tide flats, reservoirs, ponds, rice paddies as well as marine areas with water depths under 6 m. The definition has produced the wetland boundary obviously, which has binding force in legal and is easy to operate the wetland management. The definition has the vital significance to the wetland management. The other kind of definition is given by the scientist from the scientific research, which thought the wetland is a kind of special transition ecosystem different from the water body and the land. It is the expansion overlapping spatial region in which aquicolous and terraneous ecosystem mutually extend. There is a kind of equilibrium system in Wetlands composed by the specific biota and its existence environment. In this system, the producer is the plant growing in Wetlands, moors and shallow water, the consumer is the animal growing in Wetlands, moors and shallow water, and the disintegrator is the specific microorganism group in the system. The soil in the wetland has obvious gleying. The wetland has close relation with the neighboring systems, exchanging matter and energy with them.

2.2 Important foundation of water resources sustainable development

The wetland is very important for the water resources sustainable development. As well as wetlands system itself constitutes independent ecosystem, it is a part of its drainage area system. The question of ecology wetland facing is also the question of drainage area existed. Protecting the

Yellow River delta wetland is equal to protecting the Yellow River delta region environment, then it will promote the Yellow River estuary water resources longtime and healthy development.

2.2.1 Purifying water resources

For multimillion years, the wetland is always a processing factory which purifies the surface water body, and this kind of function is called as the water self – purification. The Yellow River delta wetland is helpful to slow down the speed of water flow. The agriculture and human reject, and the industrial bringing by the runoff integrate with the deposit and subside. The nourishing substance is absorbed by the wetland plant, and stores up after chemistry and biology process. Dissolved oxygen decrease and water quality drops are avoided, because excessive nutrition can cause lake water eutrophication. The virulent can be adsorbed in small deposit surface or in the clay molecular chain, which is also helpful to pollutant storage and transformation and enables the water purify. Some wetland plants can effectively absorb the pollutant. Many plants in the wetland can concentrate the heavy metal in the organization, and the density higher than the water body above 100,000 times, such as emerging plant, floating plant and submergent plant. The hyacinth, cattail and bulrush have been successfully used to process the sewage.

2.2.2 Supplement ground water and becoming the water source of aquifer

A lot of water that we usually use is extracted from the aquifer. And the wetlands are the supplement of the aquifer. When water flows from wetland to underground water storage system, water storage layer is supplemented and becomes a part of the shallow layer groundwater system. The shallow layer groundwater system can supply water for the periphery area, maintain water level or finally flows in the in – depth groundwater system and becomes the long – term water source. If the wetlands are destroyed or disappear, the underground water will decrease.

2.2.3 Runoff regulating and flood detension

The wetlands can control the flood and adjust the discharge effectively. In the weather of much rain and in the season when river swells, the wetland stores excessive moisture content just likes "the sponge". The flood stored up in the wetland soil or preserved in lake bog in the form of surface water, river flood flux is reduced. Part of floods can be discharged in the short period from the wetland, and in the mobile process, by evaporating and infiltrating become underground water to remove. The disaster of the flood and drought could be avoided through the adjustment of the wetland. The wetland vegetation can slow down the flood speed, thus reduces flood peak water level.

2.2.4 Preventing salt water invasion

The Yellow River delta hypsography is quite low, the lower level basis of which is penetrable. The Yellow River delta wetland is located on the deeper salty water level. The weakness or disappearance of wetland fresh water aquifer, which can cause the in – depth salty water to move to the earth's surface, affects ecologic community and local resident's water supplement and urges the soil salinity. At the same time, fresh water right amount outflow on the wetland surface may limit the sea water to drain back. The rivers channel and the coast vegetation also prevent the tide from flowing into the river.

3 Existing problems

3.1 Pollution pricking up harm wetland ecosystem seriously

Pollution is one of the most serious threats which the wetland faces. The discharge of massive industrial waste and sanitary sewage not only cause the wetland water quality worsen, but also do serious harm to the wetland biodiversity. In recent years, the inshore water body also is polluted seriously and in the mass tends to worsen. Because of water pollution and excessively fishing, the offshore biology resources reduced and the offshore sea water bred pollution tend to be serious. Among them, the inorganic nitrogen and the inorganic phosphorus nutrition salt pollute most seriously, the area which exceed the stipulated standards is broad. In partial sea area, oil pollution is also serious, which not only destroyed the seashore landscape, but also directly created the biodiversity to lose.

3.2 Wetlands management and coordination mechanism is not perfect

The wetland protection management, the development and utilization involve broad aspect and many department, yet not forms the good coordinated mechanism. Different area, different department, has different benefit, because in wetland protection, utilization and management aspects have different goal. They do things on their own way and the contradiction was prominent, which has affected the wetland scientific management.

3.3 Lacks of scientific estimation on wetlands environmental effect and uniform indicator system

Since long ago, the Chinese wetland research, monitoring, protection and utilization lack uniform estimating indicator on wetlands, which adopts different observation and research technique. therefore, it is difficult to analysis data material by the numbers; The former appraisal on wetland function and benefit is mostly qualitative description, and lack system and quantitative research. The research on wetland ecology, economic and social effect value evaluation is quite are few, and cannot satisfy the request of government department and the social public roundly, systemicly, scientificly and exactly eveluate the wetland effect. This has affected enormously to the wetland protection and rational utilization.

3.4 Basic research is weak and the technical level is backward

At present, the basic research on wetland protection is extremely weak, specially in the field of structure, function, value of wetland lacking systemic and thorough research, which has restricted the wetland protection and management. The personnel engaged in the wetland research are very few, and the talented person seriously lack. Simultaneously the technical method on wetland protection and management is quite backward. Modern management technology and method are short.

3.5 Unreasonable utilization of water resources enables the wetland environment water shorting

Before water and sediment adjustment of Yellow River, the water volume is extremely withered. In 1997, Lijin hydrologic Station cutting off flow amount to 226 day, accounted for 62% of the whole year total number of days, which has seriously affected the downriver industry and agriculture production and the lives of the people. It also influenced the water source replenishment of Yellow River delta wetland. In the use of water resource, our country agriculture water account for 70% of the water volume, but the water utilization ratio is actually low, only 20% ~40%, and is lower than the developed country which utilization ratio is 70% ~ 80%; In addition, the traditional irrigation way often causes the soil salinization. Our country process water approximately account for 20% of total water consumption. In the industrial production, unit output value water consumption of China's industrial enterprise is 5 ~ 10 times of developed Country's. The industry circulation water rate is very low, and the fresh water resources waste is serious; At the same time, some middle and small scale enterprise directly disperse sewage into the river and lake, which both reduced the water utilization ratio, and polluted the wetland.

4 Countermeasure of wetlands protection and management

The Yellow River delta wetland protection essence is the foundation of Yellow River delta environment protection. The comprehensive investigation and research to the wetland, gaining wetland present and dynamic data and carrying on comprehensive and the effective protection to the wetland will promote the water resources sustainable development.

4.1 Strengthen propaganda and education and enhance the public wetland protection consciousness

The wetland protection and rational utilization of wetland resources lie on the understanding of public and managers to wetland importance. By propaganda and education, enhancing the understanding of public to wetland function, strengthening public's consciousness on wetland protection and the resources hardship and strengthening the sense of public participation can effectively protect and manage wetland. Establishing wetland park and adopting measure of wetland protection and ecology repair, excavating and showing wetland cultural and aesthetic value to the public and simultaneously displaying the wetland ecology nature service function, are the organic synthesis of wetland protection and rational utilization and one of ways to maintain and expand wetland protection area.

4.2 Formulate sustainable development wetland exploitation and use policy

The exploitation and using of wetland must maintain the integrality of wetland environment. The exploitation intensity should not surpass the speed of environment to renew and restore, protecting environment without net loss. When processing contradiction on wetland protection and using, wetland adjustment strategy can be used, namely total quantity balance, dynamic management, ecology restoration and function compensation. In line with the realistic scientific spirit, the wetland exploitation and using must be legal, reasonable, harmonious and continual.

4.3 Making wetlands laws and regulations, increasing the force to execute the law

Formulates the related special laws and regulations on wetland protection and reasonable development and the consummate necessary laws and regulations; increase the force on executing the law, the law enforcement department must take the illegal destruction wetland resources as an important task to carry on and live up to strict law enforcement and bringing violators to justice.

4.4 Implementing wetlands protection and restoration

In recent years, the Yellow River delta nature protection areas implement wetland restoration and depositing freshwater project, which enormously improved the Yellow River delta environment. The Yellow River delta 100,000 Chinese acres wetlands restoring project constructed 14.2 km tide control embankments, 6,000 m cofferdam, 4,450 m center separated dam, and constructed a brake with 2 gates. The project improved ecology and vegetation environment of the wetland.

4.5 guaranteeing water demand of ecosystem

Since water and sediment adjustment of Yellow River, approximately 20 million m^3 yellow river water fills the Yellow River delta wetland. Massive fresh water pouring into the wetland causes the Yellow River delta wetland ecology having a new look. The delta protection area presents a landscape full of vital force. In 2007, water and sediment adjustment of Yellow River period, with the aid of the Yellow River high water level, the nature protection area introduces more than 10 million m^3 yellow river water and store up water in 150,000 Chinese acre wetlands. Massive freshwater pouring into the wetland, the wetland reduction and salt alkaloid degree intensifying are effectively alleviated and soil quality and the wetland water body condition are improved.

References

Kong Fande. Ecology protection. Beijing: Environmental science publishing house of China. 2005. "National Wetland Protection Project Plan" (2004 – 2030). 2004.

Yang Yongxing. main characteristic of international wetland scientific research, Progress and Forecast, The geography science progress, 2002, Vol. 21, No. 2.

Hao Fuqin, Gao Chuande, Hunan Jinhui, Zhang Jianjun, Wang Xinggong. Brief analysis of Yellow River downriver course wetland. People's Yellow River, 2005, Vol. 27, No. 4.

Chang Xiaohui, Zhang Yuanfeng, Zhang Jianzhong. Yellow River wetland protection goal and its measure. Rivers ecology repair technology seminar collection. Beijing: Chinese water conservation water and electricity publishing house, in 2005.

Discussion on Water Resources Utilization and Ecological Protection in the Yellow River Delta

Lu Linhua, ***Liu Ling*** and ***Zhang Qiyun***

Kenli Yellow River Bureau

Abstract: The flood disasters, the supply and demand contradiction of water resource, the conservation of water and soil and the worsening ecology and so on are three major problems which the Yellow River faces for a long time, also are three big water problems which China faces in the new century, and the situation of water use is extremely stern. We have carried out large - scale exploitation on Huanghe River water resource using and we have already established more perfect supporting water conservancy system. The water diversion ability has reached 514 m^3/s. We have established 17 places irrigating area among more than ten thousand acreages, and designed 21.75 ha of irrigated area. Besides, it has seen the building of 658 reservoirs to hold 8.31 million m^3 of water. The problems that exist today are as follows. Water resource imbalance between supply and demand is gradually outstanding. The phenomenon of water resource waste is very serious. The cutoff or small rate of flow runs causes the depravation of ecological condition. Facing the serious circumstances, we think that we ought to take the following measures. Using unified management to harmonize the balance of water usage in every area. Use all kinds of measures to reduce the waste of resources. Insist on rational exploitation to protect ecological balance. This article from the present situation of water resources in the Yellow River delta, the existential question carrying on the discussion, proposed several measures of how to realize the protection of the Yellow River water resources and the ecology.

Key words: the Yellow River, water resources, utilization, ecology protection

1 Present ecological situation of the Yellow River delta

The Yellow River delta refers to the scope of Dongying City, the overall environment quality condition is good, which has certain ability to keep the environment tidy by itself, but the condition of the area is imbalanced. The monitor result indicated that, in the ambient air of the Dongying City, the year and daily average value of sulfur dioxide, the nitrogen dioxide respectively is 0.029 and 0.022 mg/m^3, which achieved the second level standard of the country ambient air quality, the year average value of the suspending particle is 0.218 mg/m^3, which slightly surpasses the national two levels of standard; The water quality of the Yellow River runoff and each large and middle scale reservoirs are better, which achieved Class Three of water quality standard of the national ground water, the content of the rivers water body pollutant achieved Class Five of water quality standard. The total area of the Yellow River delta is 805,000 ha, the average per person is 0.47 ha, at present there still had 350,000 ha wild alkali area waiting for developing, about 600 ha large expanse land waiting for developing amounting to 260,000 ha. According to the sustainable appraisal of land reserve resources, suitable agriculture land 86,500 ha, suitable for forestry and herd 131,300 ha, suitable aquatic product, salt industry 132,200 ha. Moreover in the water abundant year the Yellow River fills in the sea to produce land by 2,000 ha speed, the big piece of wet land maintains the primary ecology condition. It includes the rich mineral resource, and the forecast resource of petroleum measured about 7.5 billion tons, 80% centralize in Dongying City and its shallow sea area; The Binhai shallow area bittern reserves amounts to 7.4 billion m^3, the underground salty and mineral bed area 600 km^2, having the resource condition of producing 6 million tons crude salt yearly. The coastline is 350 km long, the shallow seas and tide lands area is 120,000 ha, separately occupying Shandong Province 1/10 and 2/3, minus 15 m isobaths epicontinental sea area is 4,800 km^2. The biological resources are rich, in the nature protection area altogether has 1,917 kinds of each living thing, in which 50 kinds of the wild animals and plants are the national key protection, and 47 kinds are in "Imminent danger Wild animals and plants International trade Joint pledge". The nature protection area altogether has each kind of plant 393 kinds. The vegetation area is 65,319 ha; the cover of vegetation area is 53.7%, composing the natural vegetation primarily, the area amounts to 50,915 ha, occupying the vegetation area 77.9%. The artificial vegetation in nature protection area mainly is the locust tree forest which artificially builds, the area is 5,603 ha, which becomes a piece with the artificial builds locust tree forest in the peripheral locality of nature protection area, the area amounts to 11,300 ha, but also has the natural reedy lake 33,000 ha. In the protectorate the animal may divide into the land vivid ecology group and the marine animal ecology group, altogether records wild animal 1,524 kinds. Marine animal ecology group, as a result of the inflow area of the Yellow River, the fresh water pours into, bringing massive nutrients, causing the natural condition in this area is superior, the software, the crust ocean resources are rich, becoming the important fish spawning ground and the feeding ground. The large area of epicontinental sea, shallow seas and the bog, the rich wetland vegetation and the aquatic biological resources provide finely perched the environment for the birds multiplication, the person to survive the winter, and becomes important stop over station linking the interior of Northeast Asia and the Pacific Ocean birds moved, survived the winter, the inhabit and the reproduction place.

The Yellow River delta area has the rich oil resource, the dense population, the developed economy. The development and use of the Yellow River delta has the vital significance in our country national economy. The Yellow River delta silts up the expansion closely due to the inflowing water and sand to the Yellow River, as well as the change of the road entering the ocean current. The Yellow River Lijin station 1990 ~ 1998 annually sand load is 414 million tons, is the least time in the near 50 years least. Especially since the 90's intermediate stages the blocked flow causes the development of Yellow River reduce greatly, even appearing the minus growth. According to the Yellow River hydro – conservancy committee Shandong waterway and water conservancy administration bureau material, from September 1992 to October 1996 the average value of silt is 13 km^2, from June 1996 to October 1996 the silt entered 21.89 km^2; From October, 1996 to October 1997 the silt entered only -10.44 km^2; From October, 1997 to October 1998 the silt entered 10.89 square kilometers.

2 The present situation of the Yellow River water resources use

The Yellow River delta is one of the emphasized areas lacking water in our country, the yearly average precipitation is 560 mm, in the summer or fall crops needing warmth and water 7 ~ 9 months, the precipitation account to 60% of the whole year. Multi – annual average water resources total quantity 17.306 billion m^3, surface water 448 million m^3, ground water 0.58 million m^3; Xiaoqing River, branch vein river 860 million m^3; The Yellow River nearly 10 years (1989 ~ 1998) the average water volume 15.94 billion m^3, which is the Yellow River delta main guest water resources, in the economy, the development of society has played the important strategic role. According to the material demonstrated that, 1950 ~ 2005 the Yellow River enters the Yellow River delta section yearly average diameter current capacity is 31.9 billion m^3 (Lijin Station). Yearly average water volume at Lijin Station in 1950s is 48 billion m^3, it reduced to 27.7 billion m^3 in 1980s, the yearly water volume in the 90's Lijin Station was only 14.2 billion m^3, less than the annual means about 45%. Because the serious flow carrying capacity, which caused the Yellow River downriver frequently to block the flow, in 1997 the broke current flow carying capacity was most serious, Lijin Station blocked the flow 226 days, also blocked the flow on the section of river to delay until nearby the Henan Kaifeng. From Yellow River water diverting aspect, since 1970s, large scale development and exploitation of the Yellow River water resources has been carried on along the Yellow River area, to 2002, the necessary water conservation system to divert, to fill, to draiage the water has been completely set up, and investment utilization directs yellow culvert and sluice altogether 16(not including necessary floodgate) , pumping station 22, directing the ability of the Yellow River water to achieve 514 m^3/s, having constructed Chinese 10,000 acre area above the Yellow River irrigated area 17, the design irrigated area 217, 500 ha, the whole city have constructed 658 plain reservoirs, The design reservoir capcity is 831 million m^3. In recent years, and the water volume of the Yellow River increased year by year, the irrigated area of the delta directing the yellow unceasingly to expand, comparing to the limited coming the Yellow River water, the supply and demand contradiction is incisive day by day, Since 1999, the synthesis dispatching system of the Yellow River water resources had prevented the Yellow River to block the flow, and alleviated the scarce water resources in the down stream area of the Yellow River,and improved the ecological environment in the Yellow River delta area,and has made the tremendous contribution for the national economy development.

3 Main problems of water resources and ecology protection

(1) Supply and demand contradiction of water resources is prominent day by day.

Along with society's development and the unceasing expansion scope of water supply, the water supply duty which the Yellow River undertook has already surpassed its bearing capacity, the supply and demand contradiction of the Yellow River water resources was incisive day by day. According to the material demonstrated that, the Yellow River yearly flowing volume is 58 billion m^3,which deducts maintaining water demand of the Yellow River ecological environment 20 billion m^3, and the evaporating leakage loss quantity 1 billion m^3 in the down river course, the surplus supply of the water volume is 37 billion m^3, in addition the ground water may mine quantity 11 billion m^3, then adjusts the water situation in the not crossing basin the total quantity of the possible supply of water resources in the Yellow River is 48 billion m^3. But according to prediction by experts, after adopting a series of saved water measures, the total water demand will achieve 52 billion m^3 in 2010 in the water district and outside of the basin, and go far beyond the Yellow River's water furnishing ability, the water resources was in short along with the yearly reduction of the coming water to the Yellow River, the supply and demand contradictory was prominent day by day. When Xiaolangdi completed it will alleviate blocking flow problem in the dry season due to the strengthening the reasonable regulations in our country, for the guarantee of the supply of fresh water for industry and agriculture production, we should consider to gather the uses of the water in the Yellow River flood season.

(2) Waste phenomenon of water resources waste is serious.

Because the partial irrigation areas ditch is aging, project necessary facility is worse, management is extensive, phenomenon of the submerging irritation is serious, the factors of the irrigation water utilization only is about 0.4, comparing with 0.7 ~ 0.8 in the advanced countries, the waste is extremely serious.

(3) The low flow of river courses or the small current capacity movement causes the delta ecological condition worsening.

(4) The inland rivers silt up seriously, creating draining water to be impeded, land salinity.

4 Countmeasures

4.1 Set up the authority of the Yellow River department, unify the dispatch, and coordinate the balance of water use in various regions

Under the scarce present situation of the Yellow River water resources, we must unify the dispatch on the main current and the important branch large – scale backbone hydraulic engineering, grasp the dynamic information of the entire river water resources, under the macroscopic instruction of the long – term demanding plan in the Yellow River water and the possible provision plan of Yellow River, according to the different needing management and the request able different level and the different aspect of water used plan in water use, practice the plan water used system comprehensively, coordinate the balance of water use in various area. Statistics indicated, the Yellow River in 1997 blocked the flow 226 days, in 1998 blocked the flow 142 days. In 1999 the Yellow River water only is 85% of the multi – annual, because the Yellow River department had taken the entire basin regulation measures, it blocked the flow only 8 days, the water situation is close in 1995 it reduced 105 days. Since 2000, the Yellow River has not blocked the flow. The fact proved that obeys the unification dispatch of the Yellow River business agency, the unification management, the unified plan, which is a effective way to alleviate the tense water resources of the Yellow River. According to the successful experience of the dispatch water volume in recent several years, still the following measures must be taken:

4.1.1 Strengthen the water volume dispatch work fatherly

We should carry out the total quantity diversion in the dispatch process strictly, the process diversion, change as necessary diversion according to the demanding change with the climatic factor, the track dispatch according to plans with the actual used water situation . Under the premise of water demand in the Yellow River ecology, to reduce the unnecessary waste in the Yellow River water resources as far as possible.

4.1.2 Regulate the strictness of water volume dispatches, increase the dispatch precision

At present the existing question is the water using unit transfer the risk of the declaration plan of water use which they should undertake themselves to the diversion department body . The water use unit has not passed through the strict investigation proof, reported to a higher authority the water use plan to be strongly at will, report the plan whether directs or not, to increase "the safety coefficient" so – called, causing the water volume dispatcher's basis largely distort, sometimes creating the waste of water resources .

4.1.3 Reduce or stop the administrative intervention

We must change the phenomenon that the present local administration leadership to add many administrative intervention on water resources diversion . Good policy if cannot obtain the implementation which does not have any significance. We must alleviate the tense aspect of the Yellow River downriver water use from the policy laws and regulations, and must carry out the instructions of the Yellow River water resources diversion in every sense of the term, and can not perform the administrative intervention policy normal implementation.

4.1.4 Establish responsibility investigates the system of water volume dispatch

The science dispatch, the fine dispatches are the necessary need for the scientific and sustainable usage of the Yellow River water resource. Regarding this, the water used control section not took it seriously. We should strengthen the propaganda dynamics, strengthen the communication, make the system, to those households who make declaration of water used planed and actual water used demand large difference and create the waste of water resources; we must investigate its responsibility.

4.2 Take each kind of measure to reduce the waste of water resources

Take the measure to reduce the waste of water resources, not only to impel the healthy fast development of current social economy and palsy an important role in the protection of the ecological environment, but also is a strategic action. I believed that, we should obtain it from following several aspects.

4.2.1 Reduce the waste of water resources, as soon as depending on the legislation, second depending on the law enforcement, third depending on the common law

Grasp to complete the necessary laws and regulations construction of "Water Law", speed up the consummation of water legal system. Increase the law enforcement dynamics fatherly, Investigate the illegal water matter case legally, strengthen the preventing and controlling work of pollution of water resources, mediate the water dispute matter promptly, to achieve that there is the law to depend on, the strictness to enforce the law, the investigate to illegal matters, and maintain the good order of water matter .

4.2.2 Adjust sailors reasonable

The Yellow River sailor is excessively low; people do not pay attention to saving the water, so that it has created the large waste of the water resources. In the total water volume of the Yellow River, the agricultural water use accounts for 78% , but the up – middle segment accounts for 61% in the total quantity of the agricultural water use, there exists the serious waste phenomenon in this 61% water volume. For instance, the Ningxia irrigation area has planting crops 450,000 ha, pilots 7.5 billion m^3; The He Tao area in Inner Mongolia has planting crops 600,000 ha, pilots 5 billion m^3. If according to the level of pilots in Inner Mongolia to compute, Ningxia may save water 3.75 billion m^3 every year, which is 50% of water volume in the Shandong multi – annual means directs. The National People's Congress Link Capital Entrusts Director Qu Geping talked about the crux which in the government of the Yellow River and frankly pointed out that, (Because sailor is excessively low, the greatly fills and platoon in up _ middle segment area, development of agriculture) the overdevelopment, the gain did not equal the loss;(For reduction of farmer's bear) the waste created by not raising the sailor is penny – wise and pound foolish. These two speeches should bring us enough attention and the pondering.

4.2.3 Take the essentially project measures

The project of water distribution channel guards against infiltrating the lining work of irrigation area played a vital role in saving the use of water. As the Kenli located in the Yellow River delta, within the boundaries there are the Shengli irrigation area, the Luzhuang irrigation area, Xishuanghe irrigation area, Shibahu irrigation areas, Wuqi irrigation areas and so on 5 big irrigation areas, at present, the main channels adopted the irrigation area which the lining work guarded against infiltrating are: the Shengli irrigation area, the lining work length main channel 34.43 km, the branch 8 km; Xishuanghe irrigation area total 26 km main channels in complete lining works. According to two irrigation area's statistics, its saving water rate achieved about 20% , the benefit is remarkable. At present the measure and implementation space for the project saving water is very big, including the main channel of three big irrigation areas which are not been transformed and the field Maoqu in the irrigation area which had been transformed and so on.

4.2.4 Encourage the common people to irrigate by the saving methods of Xiaobailong

The Xiaobailong irrigation not only is a beneficial supplement of the entire irrigation system, moreover is a important measure for saving water. It has strong mobility, few spend, and the zero abandoned water, obvious effect for saving water. The rate of the common people who use the Xiaobailong irrigation, achieves 20% ~ 36% in the entire irrigation scope on with the technical person in villages and towns water conservation station and farmers, this kind of measure. We knew from the conversisure not only saved the massive farmland and the investment, moreover saves the water about 40% ~50% .

4.2.5 Takes the essential non – project measures

First, strengthen the management of the water use. Strengthen the management water use is to implement the strict plan of water use, use water in fixed quantity. All levels of governments must regulate the measure to reward the households who save the water, to punish who waste water. Second, implement strictly the measurement of pilots and levies fee of the water and so on. At present, for the so – called farmer benefit the local authority, administratively intervening water resource management department, pilots the measurement department, which is a very big barrier to the objective measurement, and created obstacles in levies fee of the water, and encouraged the households to waste water resources strongly, this phenomenon had to improve. Third, the scientific administration. The local authority in order to seize the proper time of spring irrigation, violated the populace wish instructionally to pilot, which hag created the massive waste of water resource, so we needed the scientific view of development as the instruction, administrated scientifically, to achieve not only seizing the best piloted opportunity, but also making good use of the piloted water with the active attend of people.

4.2.6 Persist the equal attention between developing the source and reducing expenses

In striving for the water use target as far as possible, the same time to safeguard the river mouth area and agriculture production, domestic water, we also must pay attention to the scientific dispatch, mixes of the water used target. We must profit the experience from the Inner Mongolia, Ningxia transforms and experiment site of water right, to perform the study as soon as possible, from its long term and the strategic altitude to regulate the policy, to encourage the new water used households to investment the transformation project of saving water, obtains saves the water, so that can achieve the using right of saving part of water resoursediversion resources.

4.3 Persist reasonable developments, protect the ecological environment

Process the relation between resources development and the ecology protection correctly, persist development with the protection, protection with the development. The development of economy must follow the natural law, in the unification between near future and caring on the development of resources operation must have fully to consider the bearing capacity of ecological environment, we shouldn't allow long term, and pay attention to partial and overall situation. We should take the sacrifice of ecological environment, and exchange the partial economic interest at present. While increasing the constructive dynamics of ecological environment, we must persist protection first, the prevention primarily, the preventing and controlling union, to reverse the passive aspects of the traditional environmental protection by the one hand constructing the other hand destroying. We must make all levels of various departments realize the significance of protecting the environment, the harm of worsening the environment, the difficulty of reversing the worsening environment. Thus obey the instruction on the pilots of the Yellow River water resource consciously, to make sure the Li Jin station of the Yellow River does not block the flow.

4.4 Full understanding of the harmless of inland rivers silt up to the environmental protection

The inland river silts up, draining water blocks the channel, the pondering water cannot promptly been discharged from fields, at that time, which was the cause to the under – production of farmland, in the long – term run, it further intensified the salivation advancement of farmland, so the harmless to ecology are not allow to neglect . Therefore, the agriculture department not only from the harvest angle of protection agriculture, moreover from the angle of ecology protection, to take the inland river clear silt seriously, to give blood an unimpeded excretion channel. In the process of construction, we should consider the factors of draining water and preventing the sea water fill back, causing the advantageous aspect maximum, the disadvantageous aspect minor.

Effects of Different Wetlands Restoration Scenarios on Habitat Suitability of Indicator Species in Yellow River Delta

Wang Xingong[1], ***Song Shixia***[1], ***Wang Ruiling***[1], ***Han Yanli***[1],
Zhu Shuyu[2] and ***Michiel van Eupen***[3]

1. Yellow River Basin Water Resources Protection Bureau, Zhengzhou, China
2. Yellow River Delta National Nature Reserve Administration Bureau, Dongying, China
3. ALTERRA Green World Research, Netherlands

Abstract: Based on remote sensing and GIS technique, combined with the field survey, took advantage of scenarios study approach and deeision – making system of landscape ecology, aimed at issues that water shortage in the Yellow River Delta (YRD) wetlands caused deterioration of eco – environment, then formulated three restoration scenarios to wetland water demand. These scenarios are respectively current situation in 2005, restoring southern nature reserve (scenarios A), and restoring south – north nature reserve (scenarios B). Different water supply schemes are set up under each scenario. The evaluation on each scenario to suitability of indicator species shows that current wetlands of the YRD is poor for the habitat of rare bird; Scenario A2 takes reed marsh as main breeding habitat where is most suitable for Oriental Stork (*Ciconia boyciana*) with increased area of 8,307 hm^2, but no big change in suitable habitat coverage for Sauder's gull (*Larus saundersi*). Scenario B2, habitat coverage is most suitable for Oriental White Stork with increase of 12,035 hm^2 in area, and 298 hm^2 for Sauder's gull habitat coverage. This shows that two typical habitats, i. e. reed marsh and Seablite tidal flat, will improve mostly via restoration. Comparing different scenario, scenario B is best one in ecological effect.
Key words: Yellow River Delta, indicator species, habitat

As the core of ecological protection, bio – diversity is not only species diversity, gene diversity or ecosystem diversity, not yet simple summation of them, but also complex system concept with grade, space – time scale, and pattern characteristics. Biological diversity crisis and human changing landscape with unprecedented speed happened at the same time on the earth. From landscape ecology, traditional protection method that focused on natural species (species model of nature reserve) lacks of considering biological diversity pattern on sizes, process and relation among them. It is unilateral and infeasible obviously. Species protection should take the ecological system where they existed, landscape diversity and integrity into account (landscape model of nature reserve). Hence, biodiversity protection gradually transforms from single species conservation to landscape protection and landscape becomes optimum space – time size of biodiversity protection and management.

The YRD wetlands is a wintering, stop – over and breeding site for migratory birds of the inland of Northeast Asia and around the West Pacific Ocean, which plays a vital role in biodiversity protection, regional climate regulation and flood detention with its original wetland ecological system. However, in recent decades, due to the sharp reduction of the Yellow River water resources and human activities, ecological problems such as the wetlands degenerating, landscape structure changing greatly have severely destroyed bird habitat environment, restricted the ecological function of wetlands, and threatened the ecosystem sustainable development in the YRD. Based on the practice and planning of wetlands ecological restoration of local nature reserve, this paper draws up different scenarios for the YRD wetlands restoration according to the established landscape ecological decision and evaluation support system (LEDESS model) for the YRD wetlands, selects Oriental White Stork, Sauder's gull as the indicator species to quantitatively evaluate the ecological effects produced by different restoration scenarios, and offers scientific basis for this regional wetlands and biological diversity protection in view of landscape ecology.

1 Research area

The YRD generally refers to the sector region that formed by sediments, the advance of river mouth and the wandering of river tail. The Yellow River mouth belongs to the continental facies alluvial estuary with weak tide, located between Laizhou Gulf and Bohai Bay in the north of Shandong Province in China, its east longitude is from 118°10′ to 119°15′, north latitude is from 37°15′ to 38°10′. Generally speaking it is divided into the neoteric YRD and the modern YRD according to geographic age. The neoteric YRD starts at the point of Ninghai, covering the sector region with 135° angle from north Taoer creek mouth to south Zhimaigou creek mouth, more than 6,000 km^2 and 350 km coast. The modern YRD starts Yuwa as a peak in Kenli, stretching from north Tiaohe creek to south Songchunrong creek with 2,400 km^2 in area.

The national nature reserve of the YRD wetlands is located in both sides of the Yellow River estuany, which protected objects are mainly the new wetlands ecosystem and endangered birds. The total area is 153×10^4 hm^2, of which core area is 5.8×10^4 hm^2, buffer area is 1.3×10^4 hm^2, and experimental area is 8.2×10^4 hm^2. There are three monitoring stations in the nature reserve, the Yellow River mouth station, Yiqianer station, and Dawenliu station. The area that Yiqianer station administers is the bottomland formed before the Yellow River mouth diversion in 1976; while the Yellow River mouth and Dawenliu management station's region is the present Yellow River estuary after 1976.

2 Scenarios of Wetlands Restoration in YRD

2.1 Planning and evaluating function of LEDESS Model

As a typical spatial explicit model based on the grid geographic information system, LEDESS model can systematically utilize relevant spatial information and ecological knowledge to undertake the spatial simulation and quantitative analysis on the ecological result that scenarios might lead, and express the results in a spatial explicit way to make the policy makers visualize the ecological results led by every possible land use and management methods on habitat to make decision more scientifically. Besides, LEDESS model is also a professional model based on expert's knowledge database, which integrates the habitat process and the professional knowledge of the landscape management and is a rather efficient method to solve complicated problems on regional resources and landscape ecological management.

The establishment of LEDESS model based on the following theoretical premise: the vegetation dynamic is a process depending on the ecotope, regional landscape planning objective and management measures, while the suitability of animal habitat depends on the structure of vegetation. The model includes three modules: ① site succession module; ② vegetation succession module; and ③ habitat suitability module. Relationships among the three modules are shown in Fig. 1.

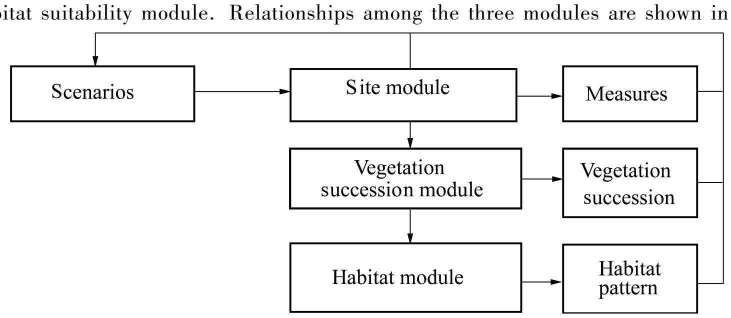


Fig. 1 Construction of LEDESS

Site succession module, through compare the site inorganic conditions to verify the consistency of ecological demands and ecological feasibility between landscape planning objective and realization means and the module output is the revised site condition map through certain measures; based on the site conditions, management modes and input of knowledge database system in its module, vegetation succession module to simulate vegetation succession, and module output is expected combined vegetation after a certain time; modules of habitat analysis is used to simulate the habitat suitability of indicator species according to the structure of vegetation and site conditions, and the output results include the habitat suitability grade of habitat patch specially for different species and ecological carrying capability of each habitat patch.

In light of decision and evaluation thought of landscape ecology making – decision system (LEDESS model), this paper sets different water quantity allocation scenarios for the YRD wetlands restoration, adopt experts knowledge database and comprehensive evaluation method, forecast vegetation succession rule and ecotope change after wetlands water supply, in accordance with relation that indicator species habitat suitability to different ecotope, judge the change of indicator species suitability to habitat after scenarios implementation and show in spatial explicit form, so as to determine the suitable scheme and management measures of the YRD wetlands restoration. Basic space data of research area originate from remote sensing image in 2001, vegetation type from SPOT image in 2005, and checked landscape type combined with field investigation in 2005.

2.2 Design of scenarios

2.2.1 Main factors

Scenarios making mainly focus on improving the YRD nature reserve ecological value to define development selection and each scenario contains a series combination of measurements. Among the key factors affected the YRD wetlands ecological value, one side is the Yellow River water resources, the other is human's disturbance, e.g. road construction, oil field exploitation, etc, and it is also the key reason to cause habitat fragmentation and quality lowering. Adoptable measurements are ① water supply, including location of fresh water intakes, water quality, and conveyance, etc; ② Reduction of disturbance in the wetlands restoration area; ③ Land use alternatives for the experimental zone. There are many measurements combination in theory. In order to ensure reasonable strategy making and reduce unnecessary analysis, this study will take wetland ecology water supply as main measurements, and reducing disturbance, vegetation restoration and land use mode adjustment as subsidiary measurements.

2.2.2 Scenarios analysis

(1) Range of water supply. In recent decades of years, the water quantity coming from the Yellow River is greatly decreased to lead the probability of floodplain enormously cutting down, at the same time, the channelization in the lower of the Yellow River stops the natural connection between wetlands and river, except for a small quantity of wetlands in the river way, the benign growth of wetlands ecosystem will be hard to maintain unless most of the YRD wetlands are supplied with water artificially. However, nowadays, water consumption of the basin increases rapidly, the conflict between water supply and demand is increasingly remarkable, so it is unpractical to completely recover the YRD wetlands into the past state, especially in the estuarine area which has greater economic development value. Therefore, to reasonably determine scale and mode of the protection for wetlands, high efficiently use the finite water resources of the Yellow River, and achieve double win for regional ecology – protection and economic development become very crucial and necessary.

When the national natural reserve were established in 1992, the YRD wetlands were in a relative better state, the ecosystem of which was healthy and balanced, therefore, during recovering the YRD wetlands, through research, determine to take scale of fresh water wetlands in 1992 as restoration reference. Considering the actuality of the Yellow River water resources and the continually increasing of new wetlands in the south, determine the wetlands ecological water supply area as degenerate reed wetlands and part of tideland in the natural reserve researched in this time, the total area of which is 236 km^2 (Fig. 2), the evaluation range of wetlands habitat suitability is the modern YRD which takes Yuwa as peak.

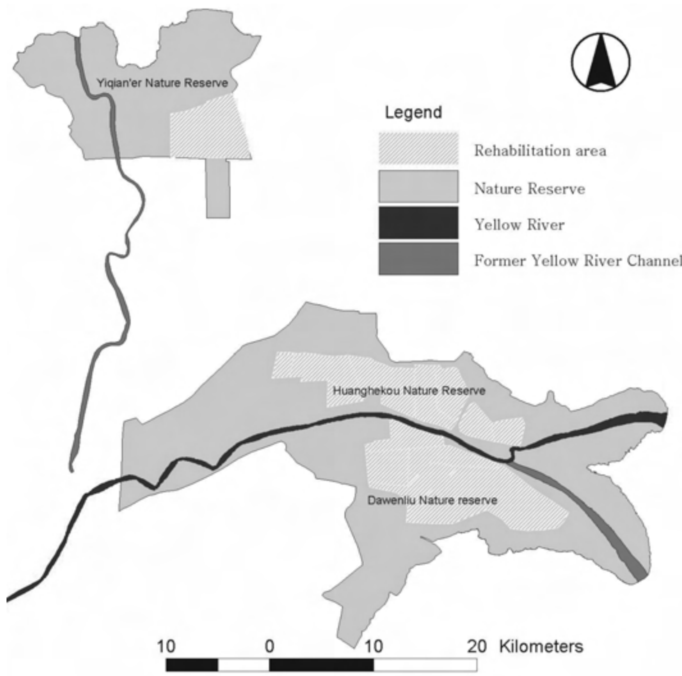


Fig. 2 Water supply restoration area of the YRD wetlands

(2) Requirement of water supply and Scenarios. The primary ecological function of the YRD wetlands is to protect habitats of endangered birds, therefore, wetlands restoration mainly concentrates on representative vegetation and water demand of inhabit or breeding of birds, in light of seasonal feature of estuarine wetlands ecosystem, the ecological water demand of estuarine wetlands is divided into three periods: April to June, July to October, and November to next March. Table 1 shows water demand range in different period. Take the year 2005 as actuality year, and bring forward three scenarios, each planning objective of scenarios is shown in Table 2.

Table 1 Water requirement range of restoration wetlands

Period	Average water requirement depth	Water requirement scope	Causes
Apr. – Jun.	30 cm	10 ~ 50 cm	Reed breed and growth
Jul. – Oct.	50 cm	20 ~ 80 cm	Reed growth and bird inhabit
Nov. – next Mar.	20	10 ~ 20	Bird inhabit

Table 2 Planning objectives and measures of each scenarios

Characteristics	Actuality	Scenario A (restoration southern nature reserve)			Scenario B (restoration south – north nature reserve)		
		A1	A2	A3	B1	B2	B3
Area of reed wetlands	9,600 hm^2	19,900 hm^2			23,600 hm^2		
Extracting water time	June ~ July	March ~ October			March ~ October		
Scheme	50 cm	Minimum water depth	Middle water depth	Maximum water depth	Minimum water depth	Middle water depth	Maximum water depth
Necessary infrastructure	Pump, channel, weir	Pump, channel, weir			Pump, channel, weir		
Measures to reduce disturbance	No	Close road and waste oilfield of restoration area			Close road and waste oilfield of restoration area		

3 Assessment of scenarios

3.1 Choice of indicator species

Due to shortage of researching data, it is difficult to study all the habitats change of species or groups in researching area under many circumstances. Many researchers evaluate the influence to species habitat resulted from environment change through selecting indicator species. The selection of indicator species should base on the following principle: ①Represent habitat requirement of a certain group; ②Compared to other species in the same group, it is sensitive to environment change with poor viability of species group. Under many conditions, indicator species are also the protective endangered species. This study selects Oriental Stork and Sauder's gull as indicator species of wading bird habitat of the YRD wetlands. On the one hand, these species are very sensitive to the habitats change and vegetation succession of wetlands, etc. On the other hand, they represent the typical habitant type of the YRD, Oriental Storks represent fresh water marsh birds ecologic groups which takes bulrush marsh as primary breeding and inhabit environment, while the Sauder's gull represent tidal flat birds ecologic groups which take winged seablite as typical habitat.

Oriental Storks, the first – class national protection birds, as large wading birds with features of geniality and alertness, are only contributed in Asia, mainly feeding on fish, batrachians, lizard and insect. The breeding environment of Oriental Stork is more typical, usually in the marsh area with sparse trees, most of all groups need widen and devious water area marsh environment. In 2003, Oriental Storks started to be birds breeding in the Yellow Rover Delta, which is benefited from prophase wetlands restoration project construction of natural reserve. Now in breeding season there are about 60 Oriental Storks.

Sauder's gull are rare endangered rare birds, total of that all over the world is about 8,000, suitable habitant is winged sea – blite tidal flat, according to the investigation in 1998, the amount of Sauder's gull propagating in the YRD area is about 1,200 ~ 1,500. It has been investigated that sequent several years the amount of Sauder's gull propagating in this area is basically stable.

3.2 Evaluation on habitat suitability

Different combinative type, matching methods of ecotope and earth surface covering decide habitat type of indicator species and suitability grade of habitat, according to investigation in the field and relevant literature, can determine the relation between different ecotope, earth surface covering and habitat suitability (see Table 3).

Table 3 Habitat quality grade compartmentalization of indicator species

Habitat grade	Valuation	Oriental Stork	Sauder's gull
The most suitable habitat	100	Core breeding place, foraging place: Bulrush marsh with perennial seeper	The primary core breeding: Winged seablite tidal flat
The secondary suitable habitat	50	General foraging place and migrating, resting: Bulrush meadow, Chinese tamarisk – bulrush community	The important foraging place and resting: Barren tidal flat on the supra – tidal zone, Chinese tamarisk – winged seablite community
The fringe habitat	10	Foraging place and migrating resting place during migrating season between times: Seablite	Foraging place and migrating resting place during migrating season between times: Chinese tamarisk – bulrush community, bulrush marsh
Unsuitable habitat	0	Fierce disturbance or habitat type of Individual never appearing: Chinese tamarisk, purple osier, paddy field, brine pan and winged seablite, etc.	Fierce disturbance or habitat type of individual never appearing: Chinese tamarisk, purple osier, cogon, farmland, etc.

Each scenario will lead change of ecotope and coverage types in the area, and will change influence of habitat broken factor, thus result in the change of species habitat suitability and habitat quality, and finally influence ecology carrying capacity of species. According to suitable site condition and natural succession rule of wetlands vegetation, set up vegetation succession knowledge table under different water – salt condition and transfer it into knowledge matrix of LEDESS model, forecast different water supply condition in the model to produce ecotope and coverage type. Making a static on diversified kind of vegetation area under different scenarios condition, determine carving up grade standard according to the habitat suitability in the Table 3, the habitat suitability change of indicator species under different scenarios condition is given in Table 4 and Table 5, the most suitable marsh area under different scenarios is shown as in Fig. 3.

Current situation: It can be seen from Table 4 and Table 5, for the existing circumstance habitat, the suitable type of Oriental Stork mainly is growth well reed swap in protected area with area of 29,274 hm^2, which is 22.6% of the total habitat area; the relatively suitable habitat area is 38,492 hm^2, which accounts to 29.7% of the total area. The suitable type of Sauder's gull is the coastal plain of winged seablite tidal flat and river mouth inter – junction, suitable habitat area is about 8,869 hm^2, which is 9% of the total habitat area; the relatively suitable habitat area is 55,689 hm^2, which occupy 56.5% of the total. All above show that the YRD has the condition and potentiality to be the breeding place and habitat of Oriental Stork and Sauder's gull.

Table 4 Comparison on habitat suitability area with different grade in each scenarios for Oriental Stork

Item	Most suitable habitat		Less suitable habitat		Margin habitat		Unsuitable habitat	
	Area (hm^2)	Percentage (%)	Area (hm^2)	Percentage (%)	Area (hm^2)	Percentage (%)	Area (hm^2)	Percentage (%)
Current	29,274	22.6	38,492	29.7	23,530	18.3	33,459	26.0
Scenario A1	32,238	25.0	37,225	28.9	25,797	20.0	18,598	14.4
Scenario A2	37,581	29.2	40,248	31.3	32,291	25.1	21,102	16.4
Scenario A3	38,212	29.7	39,406	30.6	29,998	23.3	21,050	16.4
Scenario B1	33,268	25.8	40,382	31.4	29,379	22.8	25,689	20.0
Scenario B2	41,309	32.1	37,365	29.0	29,963	23.3	20,081	15.6
Scenario B3	34,226	26.6	41,423	32.2	31,444	24.4	21,625	16.8

Scenarios A (restoration on south protected area): As can be seen from Table 4, 5 and Fig. 3, when restoring the south protected area under different water supply schemes the suitable habitat area of Oriental Stork increased accordingly; scenarios A2 increased by 8,307 hm^2, which accounts for 29.2% of the total habitat area; scenarios A3 increased by 8,938 hm^2, which accounts for 29.7% of the total habitat area; secondary suitable habitat area also increased in different extent; while unsuitable habitat area reduced to a considerable degree, these shown that: the degenerative reed wetland and alkali land become the habitat type suitable for the Oriental Stork living after ecology recovering, especially the high quality reed marsh in the restoration zone turned into the ideal habitat for Oriental Stork living. For Sauder's gull, A1, A2 suitable habitat area increased accordingly, A3 reduced a few. Through comparing scenarios A1, A2, and A3, it is shown that, the restoration of reed wetlands brings favorable effect to habitat for Sauder's gull; but residual water is not good to the improvement of habitat area quality for Sauder's gull, the reason is redundant water destroy the tidal flat habitat of brackish water inter – junction for Sauder's gull.

Table 5 Comparison on habitat suitability area with different grade in each scenario for Sauder's gull

Item	Most suitable habitat		Less suitable habitat		Margin habitat		Unsuitable habitat	
	Area (hm^2)	Percentage (%)	Area (hm^2)	Percentage (%)	Area (hm^2)	Percentage (%)	Area (hm^2)	Percentage (%)
Current	8,869	9.0	55,689	56.5	21,586	21.9	12,452	12.6
Scenario A1	10,069	11.7	43,136	50.0	23,682	27.4	9,452	10.9
Scenario A2	9,805	13.3	33,228	45.2	21,604	29.4	8,855	12.0
Scenario A3	7,975	10.9	35,419	48.2	17,434	23.7	12,664	17.2
Scenario B1	11,863	15.3	34,695	44.7	18,682	24.0	12,452	16.0
Scenario B2	9,167	11.8	38,427	49.5	19,223	24.7	10,875	14.0
Scenario B3	6,175	7.9	26,409	34.0	23,434	30.2	21,674	27.9

Scenarios B (restoration on north and south protected area): The Tables 4, 5 and Fig. 3 show that, when ecological water of north and south natural reserve under different water supply plans, the suitable habitat area of Oriental Stork increased accordingly, among of which B2 increased by

12,035 hm^2, which accounts for 32.1% of the total habitat area, it is increased by nearly 10%; the suitable habitat area of B1 and B3 increased in different extent. All of these shown that newly procreant highly quality reed wetlands of rehabilitation wetlands has replaced degenerative reed wetlands, saline land, and it became the suitable habitat of Oriental Stork. For Sauder's gull, under different water supply plan, the suitable habitat area of B1 increased by 2,994 hm^2, B2 increased by 298 hm^2, but B3 reduced 2,694 hm^2. All of these show that suitable ecological restoration brings relatively favorable effect to the most suitable habitat for Sauder's gull gull; but abundant water to wetlands may change the former tidal flat habitat type of Sauder's gull, and the favorable area may reduce.

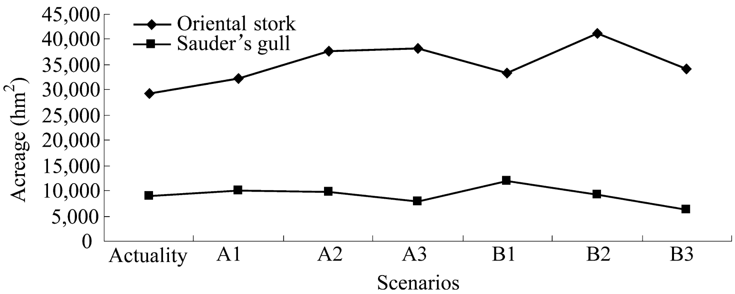


Fig. 3 Comparison of the most suitable habitats area of oriental stork and sauder's gull in each scenarios

3.3 Summary of Scenarios

Comparison of the most suitable habitat area for Oriental Stork and Sauder's gull in each scenario is shown in Fig. 3. From this figure we can see that, under the circumstance of without adopting any measures, the quality of the YRD wetlands is worst as the habitat place for rare bird breeding. Under the circumstance of making ecological water supply to the south of the nature reserve (scenarios A), the habitat quality of delta increased greatly, for the Oriental Stork who taking reed marsh as the main breeding and habitat places, the suitable habitat increased, unsuitable habitat reduced greatly, and the most suitable habitat of Sauder's gull increased also, but it is small. Under the circumstance of making ecological water supply to the north and south of the natural reserve (scenarios B), the increase of suitable habitat area for Oriental Stork is rather large, the existing situation of habitat quality for Sauder's gull upgrade accordingly, but abundant water compensation may reduce the suitable habitat area; for different water compensation plans, the increase of two indicator species suitable habitat area scenarios in A2 and B2 is most obviously; in scenarios B2, the most suitable habitat area of Oriental Stork and Sauder's gull increased greatly, which means that making ecological water supply to the wetlands will bring rather better ecological effect to the reed marsh and winged seablite tidal flat in the YRD, and it is useful to the protection of wetlands diversity. All in all, scenarios B2 is the most ideal ecological restoration scenarios.

4 Discussions

The study quantitatively evaluates habitat quality of the two indicator species (Oriental Stork and Sauder's gull) under the circumstance of different wetlands restoration scenarios via landscape ecological decision support (LEDESS model). The results show that the existing habitat quality of the YRD is worse as migration place, wintering place, and breeding for rare birds, because the no much water flowed into river mouth of the Yellow River in recent years, additionally river way canalization, the habitat crushed and degenerative caused by human's exploring activities. The habitat quality improves obviously after restoring wetlands through manually transferring water from the Yellow River. There are two parts (south and north) of the YRD national nature reserve, as an integration to maintain ecological integrity; meanwhile make the ecological water supply (scenarios B) and get the most ideal ecological effect. The habitat quality of the two indicators birds population representing different habitat improve much more. Under the circumstance of only making ecological water compensation on South (scenarios A), the habitat quality of birds population improve much more, but the suitable habitat of Sauder's gull in north nature reserve will disappear gradually. Comparing different water supply scenarios the abundant water supply or insufficiency water supply is adverse to the biological diversity protection of wetlands; suitable water supply is good to maintain ecosystem health and richen biodiversity of different type habitats.

There are a lot of factors affecting the habitat quality of the YRD. Except the water – sand resources of the Yellow River, human activities of oilfield development and construction leading to the habitat crushing is the important factor of causing the habitat quality descending, but the Yellow River Delta as China's important energy (Shengli oilfield) and agricultural development base holds an important strategy status, so this scenarios of studying wetlands restored only set in some scope of natural reserve, restoring measures are mainly limited ecological water supply. The consideration of the habitat quality effect caused by oilfield development and road construction can not be addressed in this study. It is obviously that if adopting feasible measures to reduce habitat crushing, the habitat quality of the YRD will further improve. Wetlands restoration scenarios not only offer different approaches for the YRD wetlands ecological protection, but also offer effective technical support for scientifically and rationally making use of the finite Yellow River water resources at present, because the supply and demand conflict of the Yellow River water resource is more and more outstanding.

References

Wu Jianguo. Landscape Ecology —pattern、scale and grade[M]. Beijing: Higher education Press, 2000.

Xiao Duning, Hu Yuanman, Li Xiuzhen, et al. Landscape Ecology Studies on the Deltaic Wetlands around Bohai Sea[M]. Beijing: Science Press, 2001.

Zhao Yanmao, Song Chaoshu. Scientific Survey of Yellow River Delta Nature Reserve[M]. Beijing: China Forest Press, 1995.

Li Xiaowen, Xiao Duning, Hu Yuanman. The effects of different land – use scenarios on habitat suitability of indicator species in the Liaohe River Delta wetlands[J]. Acta Ecologica Sinica, 2001, 21(4): 550 – 560.

Features of Wetland Changes in the Yellow River's Modern Delta During the Past 20 Years

Jiang Zhen[1], ***Liu Zhigang***[2] and ***Tian Kai***[3]

1. Department of Personnel, Labor and Education, YRCC; Zhengzhou, 450003, China
2. Department of Soil and Water Conservation, YRCC; Zhengzhou, 450003, China
3. Department of International Cooperation and S&T Management, YRCC; Zhengzhou, 450003, China

Abstract: Wetland, as likened to a kidney of the earth, exerts irreplaceable and enormous ecological functions. However, in the late 20th century, wetland had shrunk and degraded sharply. Therefore, in order to obtain the maintenance of the healthy wetland ecosystem, the research on the evolution of wetland has been one of those imminent and momentous issues of wetland science. In this paper, on the basis of the autumn data of remote sensing in 1986, 1996 and 2004, the spatial and temporal changes of wetland landscape are investigated in the Yellow River's Modern Delta during the past 20 years, using the approach of landscape graph spectrum.

Key words: wetland landscape, change, graph spectrum, the Yellow River's Modern Delta

1 Introduction

Wetland is a unique ecosystem with the richest biodiversity and the topmost ecological function in nature. Wetland, as likened to a kidney of the earth, also exerts irreplaceable and enormous ecological functions on retaining water resources and reserving gene storeroom etc. However, in the late 20th century, wetland had shrunk and degraded sharply. On this condition, in order to obtain the maintenance of the healthy wetland ecosystem, the research on the evolution of wetland has been one of those imminent and momentous issues of wetland science, using landscape ecological techniques (Yu, 2001; Yang, 2002; Lee et al., 2005; Huang et al., 2006).

The unique wetland ecosystem in the Yellow River's Modern Delta (YRMD) is formed by filling – up and frequent fluctuation of tail channel of the Yellow River. The total area of wetland in the YRMD is about 1,570 km^2. Most of the wetland is natural, as lots of seasonal rivers branches off in rivers' mouths to the sea (Zhang, 1997). Due to abundant new – born wetland and rare birds, this wetland has become not only one of the international important wetlands, but also the crucial symbol to maintain healthy river. However, in the last 20 years, this wetland ecosystem has suffered tremendous degradation, such as ongoing process of vegetation degradation, biodiversity threatened, imbalance between water and salt, and the lack of knowledge about the wetland etc. (Ding et al., 2006; Xu, 2006). Therefore, as it is so imminent to maintain the wetland ecosystem healthy nowadays, the research on the evolution of wetlands in the YRMD should be carried out as soon as possible.

In this paper, on the basis of these three sets of autumnal data of remote sensing in 1986, 1996 and 2004, it aims to investigate the spatial and temporal changes of wetland landscape in the YRMD during the past 20 years, using the approach of landscape graph spectrum and the technique of RS and GIS.

2 Classification and distribution of wetland landscape

With vast space and various types, the wetlands in YRMD are the patches and corridors of natural or artificial heterogeneity for the landscape of estuarine delta. Wetlands can be identified into three classes according to the wetland classification of Ramsar, the Outline of Investigation on the Wetlands in China❶ and the actual circumstances in the wetlands of YRMD (Bai et al., 2000). The classification, the average area and the distribution of wetland in the study area could also be obtained, using the primary interpretation of remote sensing images of the wetlands in 1986, 1996 and 2004 (Table 1).

Table 1 Classification, average area and distribution of wetland landscape in YRMD
(Bai et al., 2000; Zhao et al., 1995)

Classification 1st	2nd	3rd	Average area (km^2)	Percentage in total area (%)	Distribution
Natural wetland	Coastal wetland (CW)	Sub-littoral zone	168.95	11.04	Permanent shallow water region in coast with the depth of no more than 6 meters
		Intertidal zone	179.32	12.05	Tideland between high tide line and low tide line along the sea
		Upper tidal zone	97.31	6.10	The zone of average high tide line between spring tide and neap tide, supplied with the sea water
		subtotal	445.58	29.19	
	Riverine wetland (RW)	Water-course	37.18	2.38	Within watercourses of rivers, e.g. the Yellow River
		Floodplain	240.41	15.22	a seasonal water region stagnated by fresh water and located on both sides of current watercourse of the Yellow River
		Previous water-course (including lakes etc.)	30.71	1.99	The precious watercourse of the Yellow River, yoke lake and estuarine lakes etc., supplied with freshwater
		Subtotal	308.30	19.58	
	Swampy wetland (SW)	Herbage	—	—	Riverside and bottomland in estuary, reservoir and lake
		Shrub	61.84	3.92	Zone in intertidal zone, upper tidal zone and inland saline lagoon
		Scattered trees	78.59	5.11	The western of the north side of the Yellow River, and the east side of the previous watercourse of the Yellow River
		Subtotal	140.43	9.03	
	Meadow wetland (MW)	Reed*	242.13	15.26	Floodplain of rivers, coastal estuary and tide flat zone
		Subtotal	242.13	15.26	
	Other wetland (OW)	Saline lagoon	266.61	16.16	Zone interspersed among the whole delta, with no impacts of human activity
		Subtotal	266.61	16.16	

❶ The outline of investigation on the wetlands in China is written by both Chinese Ministry of Forest and Chinese Academy of Science in 1995. It is compatible to the wetland classification of Ramsar except for some part modification in combination with actual Chinese circumstances, including 5 types.

Contiuned to Table 1

Classification 1st	2nd	3rd	Average area (km^2)	Percentage in total area (%)	Distribution
Artificial wetland	Artificial wetland (AW)	Reservoir (including ponds etc.)	23.93	1.47	Low - lying area in the upper and middle reaches of the part of rivers in YRMD
		Paddy field	48.64	3.10	Cultivated land supplied with water resources and irrigation facilities
		Salt field	100.87	6.22	Area along the sea or near the estuary
		Subtotal	173.44	10.78	
Total			1,576.49	100.00	

Note: As an important wetland landscape in YRMD, and with the ecological significance, reed of swamp is combined with that of meadow so as to analyze easily in this paper.

As shown in the table above, with the average total area of 1,576 km^2 at three moments, the wetlands in YRMD mainly aggregate along the coast with vast space, while comparatively scatter with the area gradually reducing from the sea to the inland. And the classifications of wetland landscape (or patches) are distributed as follows: For the 1st or 2nd classification, the descending proportions of average area are coastal wetland (29.2%), riverine wetland (19.6%), saline wetland (16.2%), meadow wetland (15.3%), artificial wetland (10.8%), and swampy wetland (9.0%). For the 3rd classification, the larger average areas with more than 10% of total area are saline (266.61 km^2), reed (242.13 km^2), floodplain (240.41 km^2), inter tidal zone (179.32 km^2), and sub - littoral zone (168.95 km^2) in turn.

3 Approach of graph spectrum

As a method to express and investigate the information in a higher level, graph spectrum can concisely summarize and profoundly reflect the change rule of the landscape object in the space - time scale using multiform figures. Therefore, graph spectrum of wetland landscape is a new effective approach which well combines the figure thinking with the information thinking (Ye, 2003).

3.1 Data processing

In this paper, three sets of autumnal data, including two sets of LandsatTM432 data in 1986 and 1996 and one set of CBERS - 1 Landsat CCD data in 2004, are all collected from Institute of Geography and Resources in the Chinese Science Academy (Table 2).

Table 2 Image data of remote sensing (Ye, 2003)

Image type	Date
LandsatTM	1986 - 10 - 05
Seven wave bands with the resolving power of 30 m	1996 - 09 - 20
CBERS - 1 Landsat CCD	
Seven pieces of wave bands with the resolving power of 30 m one piece of panchromatic wave band with the resolving power of 15 m	2004 - 10 - 03

Depending on ARC/INFO, firstly images of remote sensing in the wetland of YRMD at three periods are classified. Then, all the vector data of three images are edited, tested and revised.

Finally, the images of the study area at three moments are processed or revised with the boundary standardization and unification.

Before analysis of graph spectrum, all data of images at three moments are to be transformed into grid formats, to be sampled again with a grid cell of 30 m × 30 m, and to be unified with same spatial resolving power.

3.2 Approach of graph spectrum of landscape information

Usually, the cell of graph spectrum of landscape information is made of both spatial and temporal cell, which is featured with comparative homogeneity. And this cell is the basic compound of space and time to build mathematical simulation model, and to reflect the history, the reality and the future of landscape. As a divided record of the most homogeneous process and space, the minimum cells of graph spectrum of landscape information extremely guarantee the spatial homogeneity, the simplicity and impartibility of events. Moreover, these cells are able to describe both spatial difference and temporal change, using a state variable of P (P_1, P_2, P_3, P_4,..., P_n). This state variable is an integrated method and an arithmetic foundation to investigate spatial pattern and geographic process of landscape, using graph spectrum of geographic information (Fig. 1) (Ye, 2003).

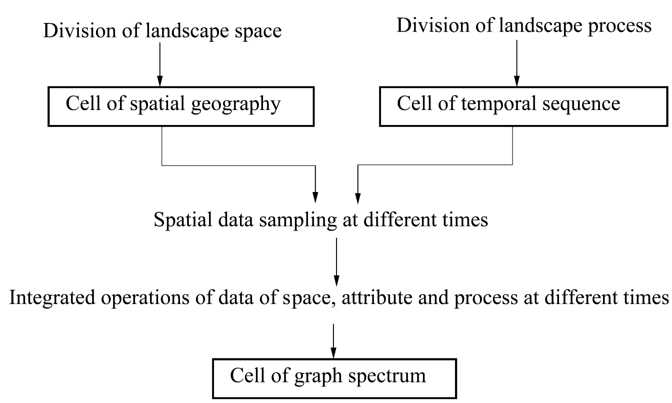


Fig. 1 The integrated process of cells of graph spectrum (Ye, 2003)

3.2.1 Determination of basic temporal cell

Because the different time of sampling corresponds to the different status variable of P, the research of given landscape process usually depends on the temporal interval of samplings. Generally speaking, the temporal scale is the minimum temporal cell of the landscape process, when the entire or partial temporal sequence (landscape process) of a certain event or its attribute is divided into the undividable minimum sub – process, or when the variable status of an event or its attribute becomes the most homogeneity (Lu et al., 1998). Therefore, the determination of temporal scale of sampling, namely cell of temporal sequence, is based on this minimum temporal cell. Here, according to the research objectives, the selection of optimal space – time scale is the prerequisites to ensure the success of compound investigation of pattern and process.

The evolution of landscape process would be well reflected by the choice of cells in different temporal sequences (usually carried out when landscape process is unacquainted) (Ye, 2001). The way to divide the cells in temporal sequence is based on the different development periods of the landscape process, or on the experiments, tests and adjustments of temporal scales one by one. Consequently, due to the limited availability of wetland data in YRMD, two cells of temporal sequence (1986 ~ 1996 and 1996 ~ 2004), are selected to investigate the evolution of wetland landscape according to the decreasing discharge at Lijin station since 1987, the unified water regulation in 1999 and the regulation of water and sediment in 2002.

3.2.2 Determination of basic spatial cell

At present, there're three approaches to determine the landscape cell, including filling - in map approach, overlapping map approach and regular gridding approach. The approach of regular gridding regards discrete regular grids with definite resolving power as basis cells. In fact, the gridding cell is the minimum spatial cell, which is perceptible and non - substantive under the condition of certain resolving power. However, this cell is able to determine the landscape cell with comparative homogeneity, and each cell represents a kind of landscape cell with comparative homogeneity. Obviously, it's more flexible and efficient to operate landscape cells of comparative homogeneity using such spatial cells. Although the precision is affected by the resolving power of grid, the approach of regular gridding is always adopted in the research of cell using GIS, because it can be well performed in the computer.

In this paper, the regular gridding approach is to be used to determine the basic spatial cell to investigate the evolution of wetland landscape in YRMD. That is to say, all the data will be transformed to the grid format, re - sampled with a grid cell of 30 m × 30 m, and then be unified with same resolving power.

3.2.3 Integrated data of the space, attribute and process

After temporal and spatial cells of the process or event in the landscape research determined, the temporal scale can be used as the interval of sampling. Then all the data and images at different times of sampling are dealt with the consolidated standardization and unification, when all kinds of advanced techniques are used and the field survey is combined with historical topographic maps. And next, all the attribute values are collected and developed into integrated data of the space, attribute and process of basic landscape cell during different periods of sampling using GIS. And then, all these integrated data during different periods are matched, harmonized or processed with algorithmic operations of maps in chronological order of sampling. Finally, the graph spectrum (the integrated data of the space, attribute and process) is obtained, in which the basic cell has the comparative homogeneity.

The formation of graph spectrums of wetland landscape in YRMD is to process relative data, using algorithmic operations of maps and the modules of Arc/info GRID. The temporal sequence is set as an axis, and the value of each cell is operated. The way of operation is that every two data in two neighboring times of sampling are combined into a compound data of the pattern and process with two or four digital codes. Then this compound forms graph spectrums of wetland landscape at relative temporal scale or interval of samplings (Ye, 2001). Here, as a record of its status during different sampling periods, the attribute value of every cell has two or four digital codes, and also is the integrated data of the space, attribute and process with the basis cell of graph spectrum.

3.2.4 Analysis of graph spectrum of landscape information

Firstly, the data needed is obtained using the arithmetic of spatial statistics. Next, the data is analyzed on the evolution of pattern and process, in order to grasp the intrinsic relationships of things in the dynamic changes of landscape process. Here, the main analysis is as follows.

Graph spectrum of different temporal cell. Every cell of graph spectrum records the beginning and ending status of its spatial/region cell in this temporal cell. And the cell type of graph spectrum is determined by the change of wetland classification of its spatial cell.

Landscape information listing of cell of graph spectrum. According to the ordering sizes of areas, variable classifications of wetland landscape are mainly listed using operations of graph spectrum.

Graphs of spatial statistical analysis. The features of graph spectrum of landscape information are analyzed in different spatial cells, and the correlations are investigated between landscape process and spatial pattern.

In which, the first one is the core of whole analysis of graph spectrum. In this way, with the help of graph spectrum in different periods, it is possible to basically understand the features of graph spectrum on the evolution of wetland in YRMD, as well as the features of variable processes on spatial pattern and landscape information. Furthermore, the research on spatial and temporal features of the pattern and process will be investigated.

4 Results of graph spectrum of wetland changes

In terms of data - processing in ARC/INFO and the integrated process of cell of graph spectrum, the results of graph spectrum of wetland changes in the YRMD during different temporal sequences are shown as follows.

4.1 During the first temporal sequence (1986 ~ 1996)

On the basis of the data of wetland landscape in 1986 and 1996, and after the integrated process of cell of graph spectrum, a map can be firstly gained to investigate the features of graph spectrum of wetland changes in YRMD during the first temporal sequence.

According to the operations of graph spectrum and the listing the cells of graph spectrum in the order of area size, the second result can be obtained to investigate the changes of main cells of graph spectrum during the period of 1986 ~ 1996 in the YRMD (Table 3).

Table 3 The sequence listing of main cells of graph spectrum of wetlands during the period of 1986 ~ 1996 *

Sequence number	Number of changing grids	Ratio of change (%)	Accumulative ratio (%)	Area (km^2)	Type of change
1	213,525	15.38	15.38	192.17	CW - OW
2	187,875	13.53	28.91	169.09	NW - CW
3	161,687	11.64	40.55	145.52	NW - OW
4	152,868	11.01	51.56	137.58	NW - MW
5	110,736	7.98	59.54	99.66	NW - AW
6	82,578	5.95	65.49	74.32	CW - NW
7	64,803	4.67	70.15	58.32	SW - NW
8	57,624	4.15	74.30	51.86	NW - RW
9	57,445	4.14	78.44	51.70	NW - SW
10	39,770	2.86	81.30	35.79	CW - MW
11	38,650	2.78	84.09	34.79	AW - NW
12	38,192	2.75	86.84	34.37	MW - CW
13	31,523	2.27	89.11	28.37	MW - RW
14	20 907	1.51	90.61	18.82	OW - CW
15	16,929	1.22	91.83	15.24	RW - MW
16	16,157	1.16	93.00	14.54	MW - OW

Note: NW represents the non - wetlands in this table. And it has the same meaning in all the following tables.

After the further investigation on the conversion information, the area matrix of transferring among wetland classifications during the period of 1986 ~ 1996 can be acquired (Table 4). In addition, the spatial location of any conversion can be searched using the spatial data.

Table 4 Area matrix of transferring on the changes of wetlands during the period of 1986 ~ 1996 Unit: km^2

	CW	RW	SW	MW	OW	AW	NW
CW	267.45	2.85	5.88	35.79	192.17	11.93	74.32
RW	1.37	230.57	0.13	15.24	0.45	0	4.89
SW	0	12.82	36.71	2.22	5.13	0.14	58.32
MW	34.37	28.37	9.66	92.26	14.54	1.22	5.31
OW	18.82	0.10	0.61	1.21	83.58	9.33	8.92
AW	0.37	0.25	0.21	2.44	0.06	27.74	34.79
NW	169.09	51.86	51.70	137.58	145.52	99.66	—

4.2 During the second temporal sequence (1996 ~ 2004)

Similarly, on the basis of the data of wetlands in the YRMD in 1996 and 2004, graph spectrum of wetland changes during the second temporal sequence is shown in one map.

The sequence listing of main cells of graph spectrum of wetlands during the second temporal sequence is shown in Table 5.

Table 5 The sequence listing of main cells of graph spectrum of wetlands during the period of 1996 ~ 2004

Sequence number	Number of changing grids	Ratio of change (%)	Accumulative ratio (%)	Area (km^2)	Type of change
1	210,223	19.08	19.08	189.20	OW – NW
2	138,415	12.56	31.65	124.57	CW – NW
3	128,768	11.69	43.34	115.89	CW – OW
4	70,566	6.41	49.74	63.51	MW – NW
5	68,836	6.25	55.99	61.95	NW – SW
6	68,555	6.22	62.22	61.70	NW – AW
7	65,757	5.97	68.18	59.18	OW – AW
8	60,301	5.47	73.66	54.27	OW – SW
9	47,025	4.27	77.93	42.32	NW – MW
10	41,805	3.79	81.72	37.62	CW – AW
11	28,625	2.60	84.32	25.76	NW – CW
12	23,421	2.13	86.45	21.08	MW – RW
13	23,229	2.11	88.56	20.91	OW – CW
14	17,240	1.56	90.12	15.52	AW – NW
15	14,209	1.29	91.41	12.79	SW – MW
16	11,650	1.06	92.47	10.49	RW – NW

The area matrix of transferring on the changes of wetlands during the second temporal sequence is shown in Table 6.

Table 6 Area matrix of transferring on the changes of wetlands during the period of 1996 ~ 2004 Unit: km^2

	CW	RW	SW	MW	OW	AW	NW
CW	202.69	3.65	0	7.03	115.89	37.62	124.57
RW	0.15	309.02	0.14	1.19	0.25	5.53	10.49
SW	0	1.42	81.78	12.79	0	0.02	8.90
MW	5.41	21.08	2.93	182.38	3.58	7.86	63.51
OW	20.91	3.60	54.27	6.34	107.96	59.18	189.20
AW	0.01	0.00	0.03	1.88	0.07	132.53	15.52
NW	25.76	6.65	61.95	42.32	8.05	61.70	—

4.3 During the whole period (1986 ~ 2004)

All kinds of wetland classifications have fluctuated or changed during the nearly 20 years. In order to understand the process of wetland changes during the whole period, it is necessary to investigate the status and its changes of every spatial cell of wetland at every sampling moment. Therefore, on the basis of the data of wetlands in the YRMD in 1986, 1996 and 2004, graph spectrum of wetland changes during the whole period of 1986 ~ 2004 is obtained in one map.

The area matrix of transferring among wetland classifications during the period of 1986 ~ 2004 is shown in Table 7. In addition, the spatial location of any conversion can be searched using the spatial data.

Table 7 Area matrix of transferring on the process of wetland changes during the period of 1986 ~ 2004 Unit: km^2

	CW	RW	SW	MW	OW	AW	NW
CW	138.87	6.08	10.00	29.87	94.70	103.31	207.55
RW	0.78	228.82	0.07	1.51	0	7.94	13.48
SW	0	16.06	43.02	0.25	0.88	7.40	47.74
MW	7.67	39.27	11.15	61.73	35.21	3.87	26.85
OW	6.67	0.87	43.89	0	50.50	13.65	6.99
AW	0	0.03	0.07	1.93	0	24.46	43.22
NW	100.94	54.31	92.89	158.64	54.50	143.81	—

5 Features of graph spectrum of wetland changes

The features of graph spectrum of wetland changes in the YRMD during different temporal sequences are shown as follows.

5.1 Graph spectrum of wetland changes during the first temporal sequence (1986 ~ 1996)

As shown in Table 3 and Table 4, the first largest change of wetland classification is the process from non – wetlands (NW) to wetland classifications during the period of 1986 ~ 1996. This change accounts for 52% in the total area of wetland changes, with the area of 655.41 km^2. In which, the new – born CW is quite larger with the area of 169.09 km^2 (14% in total area of wetland changes), the new – born OW (saline lagoon) is inferior with the area of 145.32 km^2 (12% in total area of wetland changes), and the new – born MW (reeds) has the area of 137.58 km^2 (11%

in total area of wetland changes).

Moreover, the secondary largest change is the process from CW to OW during the period of 1986 ~ 1996. This change occupies 15% in total area of wetland changes with the area of 192.17 km^2. And this kind of OW is mainly located between the previous watercourse and the current watercourse of the Yellow River in the YRMD.

Besides this, the tertiary largest change is the process from CW to NW during the period of 1986 ~ 1996. This change is about 6% in total area of wetland changes with the area of 74.32 km^2. And this kind of NW is mainly situated along the coastland near the mouth of previous watercourse of the Yellow River.

5.2 Graph spectrum of wetland changes during the second temporal sequence (1996 ~ 2004)

As shown in Table 5 and Table 6, the first largest change of wetland classification is the process from wetland classifications to non – wetlands (NW) during the period of 1996 ~ 2004. This change accounts for 42% in the total area of wetland changes, with the area of 412.18 km^2. In which, the non – wetland (NW) from OW (saline lagoon) is much larger with the area of 189.20 km^2 (19% in total area of wetland changes), and the non – wetland (NW) from CW is inferior with the area of 124.57 km^2 (13% in total area of wetland changes). These non – wetlands are mainly located between the previous watercourse and the current watercourse of the Yellow River, or along the coastland near the mouth of the previous watercourse and near the southern mouth of the current watercourse of the Yellow River.

Moreover, the secondary largest change is the process from NW and OW (saline lagoon) to AW during the period of 1996 ~ 2004. This change occupies 12% in total area of wetland changes with the area of 120.88 km^2. In which, AW from NW is much larger with the area of 61.70 km^2 (6% in total area of wetland changes), and AW from OW is inferior with the area of 59.18 km^2 (6% in total area of wetland changes) due to increasing salty fields. The kind of AW from NW is mainly located on the both sides of the previous watercourse and in the south of the current watercourse of the Yellow River.

Besides this, the tertiary largest change is the process from CW to OW (saline lagoon) during the period of 1996 ~ 2004. This change is about 12% in total area of wetland changes with the area of 115.89 km^2. And this kind of OW is mainly situated in the south of the southern mouth of the current watercourse and in the two sides of the mouth of the previous watercourse of the Yellow River.

5.3 Graph spectrum of wetland changes during the whole period (1986 ~ 2004)

As shown in Table 7, the first largest change of wetland classification is the process from non – wetlands (NW) to wetland classifications during the whole period of 1986 ~ 2004. This change accounts for 52% in the total area of wetland changes, with the area of 605.09 km^2. In which, new – born OW (saline lagoon) is quite larger with the area of 158.64 km^2 (11% in total area of wetland changes), new – born AW is inferior with the area of 143.81 km^2 (10% in total area of wetland changes), and new – born CW has the area of 100.94 km^2 (7% in total area of wetland changes). The new – born OW is distributed on the both sides of previous watercourse of the Yellow River, the new – born AW is in the inlands with middle or small reservoirs and salty fields, and the new – born CW is mainly on the both sides of the current watercourse of the Yellow River.

Moreover, the secondary largest change is the process from CW to other wetland classifications during the whole period of 1986 ~ 2004. This kind of change mainly includes the process from CW to non – wetlands (NW), AW and OW (saline lagoon). The NW from CW occupies 15% in total area of wetland changes with the area of 207.55 km^2, the AW from CW accounts for 7% in total area of wetland changes with the area of 103.31 km^2, and the OW is about 6.8% in total area of wetland changes with the area of 94.70 km^2. This change is mainly located along the coastland near the mouth of the previous watercourse of the Yellow River, or along the coastland between the previous watercourse and the current watercourse of the Yellow River, or along part of southern coastland below the current watercourse of the Yellow River.

Besides this, the landscape pattern of wetlands in the YRMD presents two series of transition in temporal and spatial scales during the whole period of 1986 ~ 2004. One is the transition of CW→ OW (saline lagoon)→SW or MW (reeds)→AW from the coastland to the inland, and the other is the transition of RW→ MW (reeds)→SW→AW from the riverbed to the outward. Except for those unchanged wetland, the majority of wetlands (66% in the study area) has fluctuated or changed intensely in the YRMD during the whole period. And CW and RW are the two wetland classifications with the larger unchanged areas.

5.4 Brief summary of changes of graph spectrum

According to all the features of graph spectrum of wetland changes or the changes of wetland structure, the brief summary is shown as follows during different temporal sequences.

- During the first temporal sequence (1986 ~ 1996)

❖ The non – wetland has dominantly changed into CW, OW and MW with the area of 655.41 km^2. The increasing wetlands are mainly located in the sand spit of the current watercourse of the Yellow River, on the both sides of previous watercourse of the Yellow River, or between the previous watercourse and current watercourse of the Yellow River.

❖ The CW has obviously changed into OW with the area of 192.17 km^2. The increasing OW is mainly located between the previous watercourse and current watercourse of the Yellow River. And the CW near the mouth of previous watercourse has been obviously eroded with the area of 74.32 km^2.

- During the second temporal sequence (1996 ~ 2004)

❖ The wetland classifications have dominantly changed into non – wetland (NW) with the area of 412.18km^2. The OW has decreased with 189.20 km^2 between the previous watercourse and current watercourse of the Yellow River. The CW has reduced by 189.20 km^2 near the mouth of previous watercourse and the southern mouth of current watercourse of the Yellow River.

❖ The NW and OW have obviously changed into middle or small sized AW with the area of 120.88 km^2. The increasing salty fields accounts for 90% of the increasing AW of middle size. The increasing AW from NW is mainly located on the both sides of previous watercourse and in the south of the current watercourse of the Yellow River. The increasing AW from OW is mainly situated between the previous watercourse and current watercourse of the Yellow River.

❖ The CW has obviously changed into OW with the area of 115.89 km^2, and is mainly located on the two sides of previous watercourse and in the south of the current watercourse of the Yellow River.

- During the whole period (1986 ~ 2004)

❖ Landscape pattern of wetlands in the YRMD presents two series of transition in the space – time scale during the whole period. One is the transition of CW to OW (saline lagoon) to SW or MW (reeds) to AW from the coastland to the inland, and the other is the transition of RW to MW (reeds) to SW to AW from the riverbed to the outward.

❖ Landscape pattern of wetlands is unstable in the YRMD. About 66% of the wetlands in the YRMD have changed intensely due to the fragile ecosystems.

❖ The 1st largest changes of wetland classifications are the process from non – wetland (NW) to OW, AW and CW, and the 2nd largest changes are the process from CW to NW, AW and OW. It is shown that OW (saline lagoon) and AW have increased rapidly, and that CW is the wetland classification with the largest transferring area.

❖ CW and RW are the two wetland classifications with the larger unchanged areas.

6 Conclusions

To summarize, some conclusions could be drawn as follows in terms of all the study above.

• The landscape pattern of wetlands presents two series of transition in the space – time scale in the YRMD. One is the evolution of coastal wetland to another natural wetland (saline lagoon) to swamp wetland (or meadow wetland) to artificial wetland from the coastland to the inlands, and the other is the evolution of riverine wetland to meadow wetland to swampy wetland to artificial wetland from the riverbed to the outward.

• Coastal wetland and riverine wetland are the two largest unchanged areas near the mouth of the previous watercourse and near the mouth or on the both sides of the current watercourse of the Yellow River. While, the wetlands changed intensely (66% of the study area) in the YRMD during the whole period of 1986 ~ 2004.

• Coastal wetland (which was changed to non – wetland, another natural wetland and artificial wetland) reduced dramatically by 1.3 times with the largest decreased area of 335.50 km^2. The decreased coastal wetland is mainly located in the northeast of the YRMD, near the mouth of the previous watercourse and in the south of the current watercourse of the Yellow River.

• Another natural wetland (which was non – wetland and coastal wetland) increased obviously by 1.9 times with the largest increased area of 113.24 km^2. The increased another natural wetland is mainly located in the northeast of the YRMD, on the both sides of the previous watercourse, and in the south of the current watercourse of the Yellow River.

• Artificial wetland (which was changed from another natural wetland, non – wetland and coastal wetland) increased by the rapidest rate of 3.6 times with the area of 238.54 km^2, and it is mainly located in the northeast of the YRMD, on the both sides of the previous watercourse, and in the south of the current watercourse of the Yellow River.

References

Bai, J. H., G. Y. Yu et al. (2000), The wetland resources and its strategies of sustainable utilization in the Yellow River's Delta, Bulletin of Soil and Water Conservation, 12(6), 6 – 9. (In Chinese).

Ding, D. F. ec al. (2006), The planning of integrated treatment in the Yellow River's Delta (draft), Technical Report, Yellow River Engineering Consulting Co., Ltd, YRCC, China. (In Chinese).

Huang, G. L., P. He and M. Hou (2006), The present research and its prospects of wetland in Chinese Estuary, Chinese Journal of Applied Ecology, 17(9), 1751 – 1756. (In Chinese).

Lee, G. Y. (2005), Maintaining the healthy life of the Yellow River, 374 – 420. Yellow River Conservancy Press, Zhengzhou, China.

Lu, X. J. et al. (1998), The analysis of perceived meanings in Geography, Geography Bulletin, 53 (2). (In Chinese).

Xu, L. J. (2006), The study on water requirements of wetlands in the Yellow River's Delta, Msc. thesis, The Chinese Science Academy, China. (In Chinese).

Yang, Y. X. (2002), The progress of international wetland science research and priority field and prospect of Chinese wetland science research, Advance in Earth Sciences, 17(4), 508 – 514. (In Chinese).

Ye, Q. H (2003), The research on the space – time features of graph spectrum of landscape information in the Yellow River's Delta, Post doctor's thesis, The Chinese Science Academy, China. (In Chinese).

Yu, G. Y. (2001), Views of some basic scientific problems of wetland research, Progress in Geography, 20(2), 177 – 183. (In Chinese).

Zhang Q. D. (1997), The resource and its sustainable development in Liaoning Province[M]. the Science Press, Beijing, China. (In Chinese).

Zhao Y. M., C. S. Song et al. (Eds.) (1995), Scientific Survey of the Yellow River Delta Nature Reserve, China Forestry Publishing House, Beijing, China. (In Chinese).

Outlook for Flood Risk Management Combining Coastal Erosion Protection in Mississippi River Delta *

Ma Guangzhou[1] ,***Huang Bo***[2] and ***Yang Juan***[3]

1. Yellow River Conservancy Press, Zhengzhou,450003,China
2. Shandong Yellow River Reconnaissance, Design and Research Institute, Jinan,250000,China
3. The Yellow River Engineering Consulting Company,Ltd. Zhengzhou 450003,China

Abstract: Delta areas are generally the younger region and more dynamic in nature than other regions. It confronts more flood risks due to climate change like sea level rising, unpredictable and more frequent extreme storm and increasing value of infrastructure and property along with economic development and population growth in recent years. More innovative approaches and alternatives to address flood problem based on regional development, water management, and environmental impact evaluation are required. Mississippi River Delta is threatened by floods from the river and storm surge caused by hurricane as well as tremendous coastal erosion. After hurricane Katrina in 2005, sustainable, long – term and comprehensive strategy and broader and more intensive partnership are required to strengthen the integrated management of flood control. Based on investigation of the situation in Mississippi River Delta and analysis of the problems, the paper puts forward the integrated measures towards flood risk management combining with coastal erosion protection, including "Multiple lines of defense" strategy, innovative flood protection structure, land use management and relocation of freshwater and sediment, and recommendations followed.

Key words: flood risk, coastal erosion, flood protection, wetland restoration, land use, Mississippi River Delta

1 Introduction

Coastal areas, which are generally densely populated and relatively developed as well in most countries, usually play an important role in industry, transportation and recreation etc. Two third of the important large cities in the world are concentrated in the coastal areas. In recent decades, as long as population growth, increases in standards of living, urbanization and industrialization in coastal areas, the value of infrastructure and property is increasing (Bart Schultz, 2006). On the other hand, climate change like globe warming, sea level rising, unpredictable and more frequent extreme storm, hurricanes and flood events, along with some negative human activities, makes coastal areas confront more flood risks.

The regional development of the coastal area based on the climate change, flood protection, land use, water management and environmental impact evaluation has become a global challenge. Many countries initiated new plans and measures on dealing with the problems between flood control and regional development in coastal area.

Two specific cases of the entire flood control programme in the Mississippi River Delta are the flood protection schemes of the urbanized area of New Orleans and the scheme to combat coastal erosion, which are concerned with potential development in social – economic and environment. The occurrence of hurricane Katrina in 2005 waked up the institutions in all levels and sectors within US and all over the world to reconsider and investigate the strategy on flood management and coastal erosion protection. Many plans and schemes are developed, as well as several international exchange programmes. The paper will investigate the situation in Mississippi River Delta, analyze

* Based on MSc thesis "Comparative Study of Flood Risk Management and Land Use in the Deltas of Rhine River, Yellow River and Mississippi River".

the problem, summarize some measures on flood control and restoration and provides some recommendations.

2 Mississippi River Delta

The Mississippi River drainage basin ("catchment") is the third largest in the world, exceeded in size only by the watersheds of the Amazon River and Congo River, about 4,760,000 km^2, and includes 41% of the contiguous United States (portions of 31 states) and parts of two Canadian provinces (Fig. 1).

The present – day Mississippi River Delta plain was formed 550 years ago through a natural process known as deltaic switching, which is the youngest region of its size in the nation. The major parts are located in southern Louisiana State, whose landscape comprises the alluvium, delta plain, passes, bays, bayous, lakes and natural levees. The majority of the area is lowland which is only several feet above sea level, even below sea level. Most of the population occupies narrow peninsula – like natural levees barely above the marshes and swamps. The mordern active delta is called "bird foot", extending further out into the Gulf of Mexico.

Fig. 1 Mississippi River Basin and Delta Area

The Mississippi River is the lifeblood of coastal Louisiana's industries, infrastructure, ecosystem, and culture. Navigation and big ports (19% of annual U. S. waterborne commerce and 20% of the U. S. import/export cargo traffic), oil and gas industry (one – third of the nation's oil and gas supply and 50% of the nation's refining capacity) (DNR, 2006), fishery (26% of the commercial fish by weight), recreation as well as wetland resources (25% of all U. S. wetlands) indicate the importance of Mississippi river delta, which greatly contributes to the Nation's economic development.

However, coastal Louisiana is one of the poorest areas in the United States. The Delta is characterized by a persistent poverty, sluggish economy, high unemployment rates, and problems arising from a legacy of racial segregation. Meanwhile, the Mississippi River Delta represents one of the most vulnerable regions of the Gulf Coast. The combined effects of engineered and altered landscapes, natural subsidence, and climate change had tremendous consequences for human well – being, natural resources, and biodiversity.

3 Flood risk

Flood risk in Mississippi River Delta derives from extreme flood from Mississippi River and storm surge caused by seastorm and hurricane.

The floods on the Mississippi River (the floods in 1849, 1850, 1882, 1912, 1913, 1927 and 1973) ever were serious threats in Delta area. However, the flood damage has been greatly decreased due to relatively perfect flood control project and more involvement of Federal government in building and management of flood control engineering works.

Comparatively, the storm surge caused by hurricane has become the top problem in flood management. Mississippi River Delta is highly susceptible to a direct hurricane impact according to the previous hurricane records. Averagely, every 16 years there was once hurricane attacking the area. At present, there are following limitations to deal with flood problem caused by hurricane:

(1) The limitation of forecasting the hurricane. Landfall position and strength change quickly in time, which are difficult to predict. Climate change increased the uncertainty of hurricane frequency and strength.

(2) The flood control of hurricane is considered as "local problem" for a long time. The hurricane protection works were not paid much attention by federal government and not managed and maintained perfectly by local.

(3) Coastal erosion especially wetland loss make the communities lost natural defense line and are vulnerable to storm surge.

From the topography view, Mississippi River delta is typical low – lying area, which is situated around sea level, even below sea level. Here take the city New Orleans as an example: 80% portion of the city of New Orleans lie below sea level, an average elevation of 1.8 m below sea level, a fact that has posed complex flood management problems since the city's founding in 1718. From the view of topography of the city, New Orleans lies in a bowl with the downtown area under about 3 m below mean sea level (Fig. 2). The storm surge created by hurricane can threaten the city from the sea and from the tidal Lake Pontchartrain to the north. During Mississippi floods the river itself threatens the city. The entire urbanized area is surrounded with levees, floodwalls and steel gates (to be closed above a critical level). Once the city is inundated, the water has to be pumped to drain from the lowlands. Long time immerging duration will make the infrastructures and property damaged more seriously. The flood water caused by hurricane Katrina cost 6 months to be pumped out completely.

Rapid land subsidence in recent years makes flood protection situation worse. The recent topographic survey to the elevation of the land surface in New Orleans indicates "Considering the rate of subsidence and sea level rise, the area of New Orleans and vicinity that are presently 1.5 m to 3 m below mean sea level will likely be 2.5 m to 4.0 m or more below mean sea level by 2100". The sinking land surface threatens New Orleans' infrastructure and handicaps the city's ability to survive the lake and gulf surges of powerful hurricane.

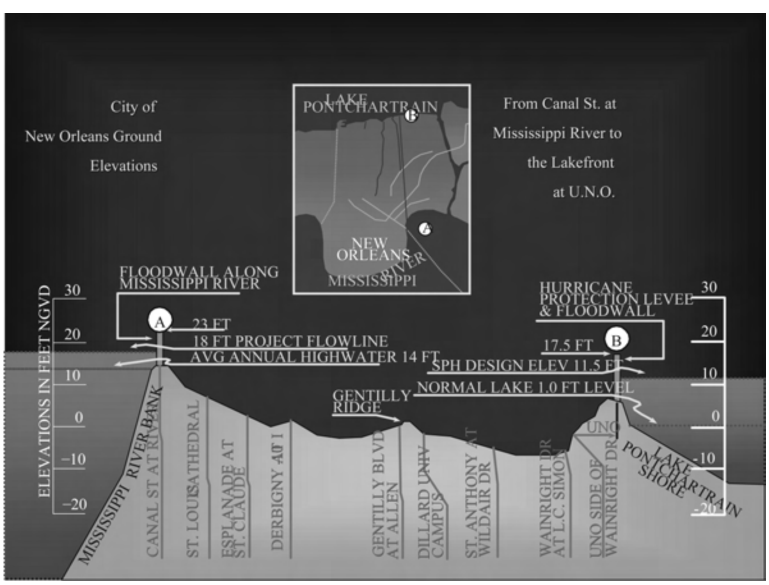


Fig. 2 Topography of New Orleans

4 Coastal erosion

During the 20th century, coastal Louisiana has lost over 4,800 km^2, an area more than 25 times larger than Washington, D. C. During the decade of 1990 to 2000, land loss approximately 66 km^2 per year—that is an entire football field every half hour, largely through conversion of vital coastal wetlands to open water (about 25% of wetlands lost in last 50 years). This loss accounted for an estimated 80% of the coastal wetland loss in the entire continental United States during 1990s. The Louisiana shoreline will advance inland as much as 52 km in some areas because of land loss.

Scientists estimate that if recent loss rates continue into the future, even taking into account current restoration efforts, then by 2050 coastal Louisiana is expected to lose more than 1,800 km^2 of coastal marshes, swamps, and islands. The loss could be greater, especially if worst – case scenario projections of sea – level rise are realized, but in some places there is nothing left to lose.

Many studies have been conducted to identify the major contributing factors and agreed that land loss and the degradation of the coastal ecosystem are the result of the cumulative effects of human and natural activities in the coastal area which severely impaired the deltaic processes and shifted the coastal area from a condition of net land building to one of net land loss.

(1) Decrease of freshwater and sediment delivered from Mississippi River. In the last century, the levees and associated navigational works of the Mississippi River prevent the overflow of fresh water and sediments into the adjacent marshes during spring floods. These structures extend to the river's mouth, where fresh water and heavy, delta – building sediments enter deep water on the edge of the Gulf of Mexico Continental Shelf. The wetlands do not receive the sediment and nutrients necessary to allow them to be sustainable.

(2) Relative sea level rise and land subsidence. As the sea level relative to the land surface is rising because the rates of coastal land subsidence are very high (3 ~ 9 mm/year), wetlands sink beneath the intertidal zone, and barrier island systems move shoreward and become thinner. Some barrier islands have submerged entirely in the last 50 years, and more are on the verge of total submergence.

(3) Saltwater intrusion from oil and gas exploration and navigation works construction. Development activities in coastal area have helped shrinking of coastal delta ecosystems. Canals built for oil and gas exploration, pipelines, well maintenance, and transportation have also contributed to wetland loss. Artificial canals and their associated spoil deposits are directly responsible for at least 10% to 30% of the loss.

Wetlands provide a natural buffer during storms by absorbing surging water. Wetlands are known to significantly reduce the storm surges associated with the more frequent tropical storms and smaller hurricanes. The diminishing buffer of coastal wetlands renders the city increasingly vulnerable to hurricane. Data gathered after Hurricane Andrew in 1993 allowed scientists to estimate that every 6 km to 7 km of wetlands reduce storm surge by an average of 0.3 m. In Louisiana's flat, low – lying coastal areas, these reductions in storm surge can mean the difference between an area that survives a storm and one that suffers significant damage.

5 The integrated measures towards flood control and wetland restoration

The flood damage caused by Hurricane Katrina has revealed that: ① flood risk closely connects with environment degradation; ② the efforts from single sector can not address flood problem and coastal erosion.

People started to reconsider hurricane protection plan combining with coastal restoration from sustainable, long – term and comprehensive vision. Excepting existing programmes like the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA); the Louisiana Coastal Area (LCA) Ecosystem Restoration Plan; the Coastal Impact Assistance Program (CIAP); hurricane protection proposals; and the US Army Corps of Engineers (USACE) Louisiana Coastal Protection and Restoration (LACPR) Study, some international exchanging projects are on-going, which are providing the experience and lessons about flood management in coastal areas between countries.

For flood management in Mississippi River Delta, broader and more intensive partnership are promoted and required, determining the success of any integrated management in the flood control related sector. It is obvious that no single sector can be expected to shoulder the management burden alone, and that far more integrative strategies need to be devised for each new project that is undertaken.

5.1 "Multiple lines of defense" strategy for hurricane protection

Barrier islands, healthy marshes, natural ridges adjacent to bayous, and cypress swamps provide a natural buffer during storms by slowing down and reducing incoming surges of water. This function, combined with man-made levees and other flood control measures, has allowed Louisiana's working coast to exist in a flood-prone area.

(1) The concept of natural lines of storm surge defense is based on the hydraulic principle that surge elevation is effectively reduced by the friction of flowing over a vegetated land mash.

(2) Historically an engineering "rule of thumb" has been used for estimating potential storm surge reduction in coastal Louisiana. The engineering "rule of thumb" for the effect of coastal wetlands in reducing storm surge elevation provides for an estimated 0.3 m of surge reduction for each 6 km of wetlands over which the surge must flow.

5.2 Innovative flood control structures

As hurricane protection options are considered for the coast, a balance must be struck between two urgent needs. On one hand, residents need storm protection. These communities could not exist without levees. In recognition of the need for structural protection, levees are recommended in high risk areas that must be protected if we are to avoid severe consequences for the state and nation.

On the other hand, there is legitimate concern that building levees across wetlands can stop the natural flow of water, creating impoundments that flood communities and lead to further land loss. Finding the right mix of options requires that innovative technologies to build modern flood control systems. It bears little similarity to the traditional earthen levee embankments that have historically dominated Louisiana's flood control plans. Levees must be built with innovative designs, since we now recognize the importance of tidal exchange and natural hydrology in sustaining wetland ecosystems. If a levee is deemed appropriate for an estuarine basin, we must do the following things:

(1) Use innovative levee designs and reduced levee footprints to minimize disruptions to the basin's tidal regime and hydrology.

(2) Keep the entire basin system functional and sustainable by using the levee in tandem with other measures, such as landward diversions and drainage structures. These areas must be managed to ensure that protection and restoration actions do not induce flooding in low-lying communities that are landward of levees. For example, once a levee is built, water flow through wetlands that are landward of the levees must be maintained, and even enhanced where necessary, to maintain natural cycles of water and sediment exchange. Levees built landward of wetlands are more resilient than stand alone structures because the adjacent marsh helps buffer storm surge and wave energy.

(3) Ensure that strict land use controls are enforced. Wet areas must stay wet, and community growth must be managed to minimize impacts on wetlands as well as risks to life and property.

5.3 Land use management for smart development and minimizing risk

Because flooding risk = likelihood of flooding × impact of flooding, Levees and restored wetlands cannot eliminate all flooding risks, whether from storm surges, rivers, or rainfall. Nor do levees protect against wind damage. For these reasons, storm related risks will remain facts of life in

Mississippi River delta, regardless of how many levees are built and wetlands are restored. In many areas, non – structural solutions will provide more protection more quickly than will massive building projects that take years to be constructed. Land use management is thus effective measure to reduce flood management during extreme events.

5.3.1 Land use planning and zoning

Wetland areas inside the hurricane protection system need to remain intact and undeveloped. Hurricane protection system can actually increase the assets at risk if it encourages development in wetlands or areas near the levee footprint. Such action would not only be risky from a safety and economic standpoint, but it would also degrade wetlands and eliminate interior flood storage capacity. Once a national and state commitment to build a levee is made, local governments must enforce appropriate land use planning and zoning regulations to ensure that the system, once built, contributes to the long – term sustainability of the region. Zoning actions by local governments, though not popular in Louisiana, are another means of protecting coastal wetlands. State legislation as well as departmental policies should provide incentives to local governing bodies to enact region – wide land use zoning, following the lead of some Louisiana communities which have already done so.

5.3.2 Relocation of the communities in low – lying areas

Not every south Louisiana community that wants levee protection from the largest of storms will get it. In some areas of the coast it would be difficult if not impossible to build and maintain these types of structural protection systems. In addition, there are simply not enough federal or state dollars available to make this solution feasible. As a result, communities where there is a dense concentration of assets at risk, such as New Orleans, Houma, Lafayette, and Lake Charles, will receive a greater level of structural protection than will other communities. The government should support and promote people to relocate from low – lying area and floodplain, which not only reduces the flood damage, but also keeps wetlands landward of hurricane protection systems to maintain these important natural buffer zones.

5.3.3 Address processes to acquire land rights for flood control works

Approximately 80% of coastal Louisiana is privately owned, and the rights of these landowners, including mineral rights, must be honored as components of the project planning which are constructed and operated. Multiple options must be available to reach fair and equitable solutions for building projects on private lands. The first course of action would be to acquire the necessary easements to construct the project. Another option would be to allow for separation of surface rights from mineral rights. The state could then purchase the surface rights to the land, while the original landowner would retain all subsurface (including mineral) rights.

In cases where such an agreement cannot be reached, expropriation is an option. Both DNR and DOTD have the capability to expropriate under Title 19 of the Revised Statues. Another choice for acquiring the necessary land rights to construct projects that are in the best interest of the public is an authority known as "quick take." When a negotiated settlement cannot be reached between the implementing agency and the landowner, "quick take" authority allows the agency to place the offered compensation in the court registry and file a lawsuit against the landowner.

5.3.4 Elevating and retrofitting structures

After hurricane Katrina, residents of south Louisiana must meet improved building standards, including raising their homes to avoid damage from storm surge. Hazard mitigation funds are available to citizens through their local parish Emergency Preparedness Offices. These funds can be used to elevate, retrofit, or buy – out homes that have suffered damage from flooding (see www.FEMA.gov). State – wide mandated freeboard standards (meaning standards that require homes to be built 0.3 ~ 0.6 m above FEMA base flood elevation) could be another tool that helps residents adapt to flood risks. Adoption of these kinds of measures would have the added benefit of lowering flood insurance premiums for homeowners (FEMA Louisiana Floodplain Management Desk Reference) as well as reducing storm damages.

5.3.5 Backfill and/or Plug Non – Essential Oil and Gas Canals

This measure will close non – essential oil and gas canals coast – wide to restore natural hydrology to wetland areas that have been adversely impacted by canal construction. Abandoned location canals, and other canals that can be eliminated without adversely impacting ongoing production operations, will be identified for restoration to mitigate the adverse effects of unchecked tidal exchanges. Restoration operations could include permanent plugs, spoil bank degradation and marsh creation by backfilling through dedicated dredging projects.

5.4 Relocation of freshwater and sediment for wetland restoration

This measure will identify and evaluate features that would greatly increase the deposition of Mississippi River sediment in shallow coastal areas and restore deltaic growth in the Mississippi River Delta Plain. Creating a sustainable deltaic system requires to reestablish the processes that originally created the landscape. Two types of projects, large diversions from the Mississippi River and alternative navigation channel alignments will be investigated. The large – scale river diversions could potentially maximize the river's sediment and freshwater resources available for ecosystem maintenance. Diversion sites, capacities, and outfall management measures would also be assessed to help optimize diversion plans while accommodating navigation needs.

5.4.1 Freshwater and sediment diversion

The most practical large – scale solution to coastal erosion and wetland loss is the diversion of Mississippi river waters into the wetlands through control structure or crevasses in the levee. The freshwater pushes back the encroaching saltwater wedge and coat the subsiding wetlands with new sediments. The impact areas of the first two major river diversions, Caernarvon and Davis Pond, have been operated. Others diversions, crevasses, and siphons are planned for the near future.

Where gated diversions are not practical, pipelines are used to siphon high river water over the levee to specific locations in the low – lying backswamp. Less costly to install but difficult to maintain suction, siphons are proposed to rebuild wetlands in eastern Orleans Parish, the only planned marsh creation that falls within New Orleans' limits. In all, as of August 2003, the Army Corps of Engineers, the state of Louisiana, and other federal agencies oversee 25 gated diversions, siphons, crevasses, and auxiliary projects in planning, construction, or operational phases throughout southeast Louisiana.

5.4.2 Beneficial Use of Dredged Materials

The beneficial use refer to the physical act of building wetlands with dredged material rather than the programmatic aspects which would result in project development and construction. It is a very promising option for restoring coastal wetlands and reducing land loss. The U. S. Army Corps of Engineers, New Orleans District (USACE – MVN) has the largest annual channel Operations and Maintenance (O&M) program and dredges an average of 60 million m^3 of material annually during maintenance dredging of navigation channels. Not all of this material is available for beneficial placement in the coastal ecosystem; however, there is the potential to use up to 25 million m^3 annually to enhance coastal wetlands through marsh creation, wetland nourishment, barrier island restoration, ridge restoration, and other techniques.

Additionally, Dedicated Dredging is a viable strategy across the coastal zone to build land where traditional marsh building processes do not occur or are infeasible. Its purpose is the utilization of dredged material to restore, create, or enhance coastal wetlands.

5.4.3 Availability of Mississippi River resources

The annual quantities of sediments available from the Mississippi River are significantly reduced (by 80%) from the quantities delivered by the river 50 to 60 years ago. Future rebounding in magnitude of annual supply of sediments is not a reasonable expectation. It is further noted that the majority of the sediment delivered is currently being carried out to the deep waters of the gulf and is unavailable for use. Plans to better utilize available Mississippi River resources should recognize:

(1) The maximum water available for simultaneous diversions is generally limited to 14,000 m^3/s in the winter, spring and early summer. Late summer and early fall will generally offer limited to no availability.

(2) The magnitude of water available for diversions along the river must consider that the total flow of the river at Head of Passes must be maintained at or above 7,000 m^3/s to control the salt – water wedge at Head – of – Passes.

(3) Multiple diversions from the river must be coordinated so that maximum benefit from the available sediment and fresh water is obtained.

(4) There should be much more diversion capacity built than can be diverted at any given time to allow pulsing and timing of the diversions for land building and habitat benefits.

(5) On average, there are about 72,000,000 m^3 of measured suspended sediments and an estimated 138,00,000 m^3 of unmeasured sediment load available for wetland restoration purposes. Suspended sediment can be captured and used by diversions. However, diversions must have deep intakes and be located in sediment rich areas of the river to divert the unmeasured bedload.

(6) The most effective way to utilize the bedload is by direct delivery/dredging or very large diversions near the mouth of the river.

6 Conclusions and recommendations

(1) Delta area is more dynamic in nature than other regions. River systems and landscapes in Mississippi river delta are significantly changed by human activities because of the needs of flood safety and economic development (navigation and gas and oil exploitation). These changes lead to the destruction of natural processing and deterioration of ecosystem; to certain extent, they do not reduce but increase flood risk in the coastal area.

(2) Along with the increase of the costs for construction and maintenance of flood control engineering works and uncertainty of structural measures due to climate change, non – structural measures (like flood preparedness, land use) play more and more important role, which could be achieved significant efficacy in damage reduction.

(3) We should recognize and respect the natural process of the evolution of river system and ecosystem in delta area, leave enough space for nature and environment in order to reach the long – term safety. During flood control planning, the careful consideration should be done to reduce or alleviate the adverse effect on ecological environment.

(4) The proper, wise and limited development strategy should be taken in vulnerable regions, which should adapt physical conditions and natural resources, in order to reduce flood damage and abuse of natural resources.

(5) Some measures should be taken to return natural processing and restore ecosystem in Mississippi River Delta. For example, freshwater and sediment diversion structures along the river have been built to prevent saltwater intrusion and restore wetlands.

(6) Flood control is essential part of integrated water management and more institutions are involved in different aspects. Technical solutions must be forwarded based on social policy papers in a phased realistic approach by consistent political help.

(7) Federal government should dominate the building and financing for great flood control projects, especially which can not be afforded by the local. So the Federal Government should be responsible for the building of integrated hurricane protection system in New Orleans in case that next disaster comes.

References

Gerry Galloway. USA: flood management - Mississippi River [J]. WMO/GWP Associated Programme on Flood Management. 2004.

DICK DE BRUIN. Similarities and differences in the historical development of flood management in the alluvial stretches of the lower Mississippi basin and the Rhine basin[J]. Irrigation and Drainage, 2006, 55(S1).

Richard Campanella. Geographies of New Orleans. Louisiana, 2006.

CPRA (Coastal Protection and Restoration Authority of Louisiana). Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast (Draft.)[EB/OL]. www.louisianacoastalplanning.org, 2007.

John M Barry. Rising Tide[J]. SIMON & SCHUSTER. New York, NY, 1997.

Ivor Van Heerden. The storm. VIKING, New York, 2006.

The Ecological Conservation of the Yellow River Delta Marsh

Sun Juan, ***Li Qiangkun***, ***Zhang Xia*** and ***Hu Yawei***

Yellow River Institute of Hydraulic Research, YRCC, Zhengzhou, 450003, China

Abstract: The Yellow River delta marsh is an important ecosystem in the Yellow River bayou, which has the functions as follows: keeping biologic diversity, storing floodwater and avoiding drought, adjusting climate and reducing pollution, defending natural calamities etc. The existence and change of the marsh have direct influence on the bayou eco – enliroinent. On the foundation of analysis of the actuality, the characteristics and change reasons of the delta marsh, discuss the particularity and indispensability of ecological conservation, confirm current protect measures and targets of the Yellow River delta marsh.

Key words: the Yellow River Delta, marsh, ecological conservation

The Yellow River delta is located in northeast of Shandong Province, which is the fan – shaped area formed by the Yellow River since 1855 when the Yellow River burst in Tongwaxiang and seized the Daqinghe River to enter the sea. The marsh of the Yellow River delta is the important area of keeping the ecological environment of the Yellow River delta, which has been placed in the key protective region of Chinese marsh ecosystem in "The action plan of Chinese protection of biological diversity". As the youngest marsh of the bayou marshes in our country, the Yellow River delta marsh has various cause – formation types, diversification of vegetation community and numerous kinds of animals and plants, which has been playing an important role in regulating the regional situation of water and heat, has an irreplaceable influence on the Yellow River delta, and is the important marsh ecosystem that needs to be protected in our country and even in the World. But the frailty of the ecosystem is obvious, and it is easy to change from the outside influence. With the large – scale development of the Yellow River delta, to strengthen the protection of the marsh ecosystem of the Yellow River delta is meaningful.

1 The present situation and characteristics of the Yellow River Delta marsh

Marsh is the intermediate region between the land and hydrophilous environment, is the unique ecosystem coming from the last interaction of land and water in the earth, is the richest biological diversity of ecosystem and one of the most important human survival environments in nature, which is called three big ecosystems of the earth together with forest and sea. The survival, multiply, development of mankind is closely linked with marsh. The marsh is not only offers a lot of resources for human production and life, but also has huge environmental function and benefit, has irreplaceable function in resisting flood and regulating runoff, saving flood and defending drought, controlling pollution, adjusting climate, controlling soil erosion, promoting to silt and making land, beautifying environment etc., which is praised as "the kidney of earth". Healthy marsh ecosystem is one of the most important components of ecological security system, and it is very important for realizing economic and social continuable development.

The Yellow River delta is in common boundary of the sea and land and the zone of salty water and fresh water, and belongs to half humid continental climate of the North temperate zone. Under the influence of the artificial disturbance as well as interaction of land and water, the Yellow River delta marsh has formed complex marsh types, which is the most wide and most concentrative Chinese warm humid marsh. The Yellow River delta is forming new bank land at a speed of 2,000 ~ 3,000 ha annually because of the carrying silt of the Yellow River. The present marsh total area of the Yellow River delta is 747,139. 4 ha, in which the marsh area of shallow water is the biggest taking 41.22% of the marsh gross area, beach marsh area ranks the second (including the sea marsh and river marsh) taking 24.64 % of the marsh gross area. The marsh of this region is divides into 9 kinds: ① shallow sea marsh; ② beach marsh; ③ river marsh; ④ lake and reservoir marsh; ⑤ pool marsh; ⑥ paddy field marsh; ⑦ canal marsh; ⑧ marsh and meadow marsh; ⑨ roadside marsh.

Because of the rich marsh types, the Yellow River delta has a more rich biological diversity. According to some investigation, the marsh of the Yellow River delta possesses 318 kinds or their mutations belonging to 185 genus below 64 family plant, 12 kinds of fern, 2 kinds of gymnosperm and 304 kinds of angiosperm. At the same time, there still exists plenty of 300 kinds of terraneous vertebrate approximately, 503 kinds of terraneous invertebrate, and 800 kinds of aquatic animals. Since the marsh of the Yellow River delta has the characteristic of vegetation and biological diversity, it has been placed in the key protective region of Chinese marsh ecosystem in "The action plan of Chinese protection of biological diversity". At the same time, the beach of shallow sea, marsh, land vegetation and the characteristics of ecological environment of the region of the Yellow River delta offer various perch environments for birds' multiplication and growth, migration and living through the winter, which is also the important migrant rest land, living through the winter land and breeding land migrating from the Pacific Ocean and Northeast inland Asian.

2 Reasons of ecological environment change of the delta marsh

The change of the marsh environment of the Yellow River delta has a considerable connection with the hydrological change of the entire valley of the Yellow River, at the same time the development of local land and minerals has also produced certain influence on the delta marsh environment, and the growth characteristics of delta marsh self is one of the factors arousing the marsh environment to change continuously.

2.1 The influence on the delta marsh from the Yellow River water

The Yellow River is the major fresh water supply source of the ecosystem of Yellow River bayou, and the Yellow River water resources have been playing an important ecological function in the marsh vegetation system of the bayou.

2.1.1 The decrease of the Yellow River water quantity causes the delta ecological environment to change

From 1970s to 1990s, because of the decreasing water quantity of upper reaches of the Yellow River, the Yellow River stopped flow frequently, directly caused the water resource scarcity of the bayou region of the Yellow River, and caused the ecological environment of bayou to worsen. In 28 years from 1972 to 1999, the lower reach of the Yellow River has stopped flow for 22 years. According to statistic of Lijin hydrological station, the water quantity from 1990 to 2000 is 12.58 billion m^3 in average possessing only 40% of the multi-average. The cut-off of the Yellow River for years has influenced the ecological environment of the delta greatly. The main influences are the 3 aspects as follows:

(1) Destroying the natural development process of the marsh ecosystem

The marsh of the Yellow River delta belongs to newborn land. It forms from constant route change, filling up and swing of the Yellow River. The ecosystem is very fragile, and its good development depends on the water and sand resource of the Yellow River mainly. The Yellow River water is the existent and evolutive foundation of the marsh ecosystem, so water shortage will obstruct marsh vegetation to grow seriously, and at the same time endanger the growth of various mollusks, planktons and fishes in the marsh, and influence the food source of rare birds. The cutoff of the Yellow River makes stoppage of the material and energy circulating of the marsh ecosystem, obstructs the natural succession of the marsh, and makes the marsh area decrease or disappear.

(2) The normal growth of the marsh vegetation and biology is influenced

The decrease of the Yellow River water will produce a greater influence on marsh, and vegetation community may present a contrary subrogation. With the decreasing and even cutoff of the Yellow River water, the marsh fresh water supply quantity will decrease, which may make marsh ecosystem evolve contrarily and the ecology worsen. The two banks of the Yellow River were the low salt and rich land, but since the Yellow River changed its course in 1976, the attack and erode from sea tide have been cutting a greater part of the original old bayou. Seawater flows backward along the old river course, so the soil of two banks returns salt, and the underground water salt quantity is increasing. The light salt – bear vegetation in original is replacing gradually by high salt – bear vegetation, even some nakedly. At the same time, the decrease of the Yellow River water has also produced certain influence on the fish of nearby bayou. According to original research, the fish quantity distribution in the bayou of Yellow River and its nearby sea area has a very close relation with the temperature and salinity of seawater. The temperature and salinity of seawater has a great relation with the supplementary fresh water resource of the Yellow River. The resource of fresh water can't get prompt supplement because of the cutoff of the Yellow River, which makes the survival environment of fishes deteriorate, and quantity is decreasing even some has died out.

(3) Serious coast erosion

The coast of the Yellow River delta is a sludge quality coast, and is formed by the mutual role by river and sea. It has a greater influence on the coast from the swing into ocean of the Yellow River of the road. Especially the delta forward position receives the influence of the silt of Yellow River entering sea and ocean power, rushing and filling change violently. The flow water area of the Yellow River, silt up and extend advance constantly along with the bayou. With the cutoff of the Yellow River, silt can't get prompt supplement, which makes the most of water fronts retreat, and silting speed also reduce considerably. Since 1980s, along with the aggravation of the constant cutoff of Yellow River, sharp decline of leak silt, the structural and function ecosystem of the original marsh of the Yellow River delta has not only been facing a new challenge and serious threat, but also a lot of area has been retreating from seawater intusion, and the tide marsh area has been decreasing.

In a word, because of the cutoff and silting reduction of the Yellow River, the developmental balance of delta has encountered damage: coast retreats more obviously, the steady growth of marsh gets influence, at the same time because of cutoff, fresh water to the sea is decreasing, so seawater invasion is aggravated, and soil salinization is aggravated, which produces negative effectiveness for the function and growth of delta marsh. Marsh is degenerate, which influences ecological diversity and the productivity of land and marine ecosystem, and the last result is the atrophy of marsh ecosystem. Since 1999, the united water regulation measure along the Yellow River has been taking, the phenomenon of cutoff of the lower reaches of the Yellow River is alleviated, but adequate water resource can not be offered still.

2.1.2 The pollution causes the Yellow River water quality to deteriorate and influences the delta ecosystem

Since 1980, the heavy pollution enterprises such as "little papermaking" and "little chemical engineering" in the Yellow River basin have developed very quickly. At the same time because of having no effective manage, pollution administration has not caught up with in time, so plenty of sewage waste water that were not handled and not reaching emission standard is drained into the Yellow River directly, which causes the gradual deterioration of water quality. The annual water resource bulletins of 2000 and 2001 announced that the reach of the Yellow River which can reach Ⅲ grade of water standard only takes 46.7% and 43.7% respectively. In some serious regions of water pollution, because the sewage discharge capacity of some city industries is so big that the water quality of some main draining river courses is lower than Ⅴ grade, even in some samples the poisonous material that would lead to cancer has been detected. Serious water pollution brings some great life influence. This serious pollution water flows downwards and pollutes the water quality and the soil of the Yellow River delta, influences the growth environmental condition of water and soil of marsh vegetation, and changes the growth balance of species.

2.2 The self – developmental characteristics of the marsh ecological environment

The reason of growth and decline of marsh includes these two aspects of natural and artificial factor. The Yellow River delta shows aspect mainly with the natural factor. Since the Yellow River carries about 10.5×10^8 t silt every year from the Loess Plateau and flows into the region of bayou, approximate 2/3 silts up on the delta and coast, 1/3 is transported to inner sea, the huge quantity silt causes the developing of the end of the Yellow River in a law of "silt up – extend – raise – swing – change the course", and the unceasing changes of the river courses has brought up the delta of fan type. From 1855 on, the end of the Yellow River has burst and changed the course more than 50 times. Under the runoff, silt of the Yellow River and ocean power mutual role, the end of bayou silt up constantly to extend, to swing, to change the route and to develop, new land area appears constantly. This kind of development characteristic of the Yellow River delta makes marsh ecosystem present some following characteristics: Original, naturalness, young, integrity and instability. The structure principle of delta marsh has decided that land ecosystem is from nothing to having, land resource increases constantly, landforms changes constantly, the old ecological balance near the bank sea area has being broken constantly. The ecosystem is often in changing, and structure is complex to show obvious changefulness and complexity. A lot of marsh landscape growth is in primary stage, structure and change shows obvious original state, landscape and ecosystem are younger in time and space, the succession of ecosystem starts from original succession, and succession process is obvious and complete. These factors make that the marsh of the Yellow River delta show obvious shortcomings of the ecosystem instability and the weak ecology support ability.

2.3 Artificial damages

In the process that the marsh of the Yellow River delta is in unceasing growth, is in relative development process, and its ecological environment is more fragile. The human actions such as constructing the levee of the Yellow River, cultivating wasteland, building cities, building expressway, constructing the sea levee and exploring petroleum are changing the tiny landforms form of this district fiercely and ecological environment. Though having adopted a lot of protective and control measures, but hypo – nakedly is still increasing, and pollution problem does not be solved still, broken phenomenon caused by mankind is still more serious. Developing as some oil field those that produce are born oil and dirty oil etc. may be transported through the runoff of the face of land to wetland. The very some agricultural development is the transformation use for wetland. The soil erosion that some agricultural development causes may make nearby wetland wither and even disappear. Some road construction may influence the moisture supply of wetland through the flow direction that influences the underground runoff and runoff of the face of land. Research proves that marsh though has exclude, reduces dirty ability, but this ability is limited. Regional resource development, oil field development especially has serious influences on the artificial ecosystem such as rice field, crab pool, pond and reservoir. According to some investigation, in the season of heavy rain, since product water is too much, the greasy dirt will be carried overflows nearby rice field, shrimp, crab pool a pond, reservoir and pollute plant and water body , after accumulating year by year, cause the pollution of water body and soil. The Yellow River delta land is rich and has a good value in use, however, because of the development for delta is eager for quick success and instant benefit with no programming, the delta landscape general layout of causing change, and influenced the marsh environment. Delta land saline phenomenon is so universal that the normal growth of the marsh vegetation of the Yellow River delta is influenced.

3 Marsh conservation measures

According to the marsh overall protection objective of our country, the marsh protection keys of the Yellow River delta is to offer enough water quantity and suitable water quality to protect the marsh scale or the area, take measures such as pollution control and land using way adjustment to maintain the basic function and the ecological property of marsh ecosystem, strengthen the protection and management of marsh and its biological diversity. At the same time, adopt ecological measures of artificial founding or resuming to create favourable conditions for marsh ecosystem health resumes.

3.1 Supply enough quantity fresh water resource

The Yellow River is the important factor to form and keep the marsh ecosystem of the Yellow River delta. In recent years, the Yellow River water quantity shows a decreasing tendency. With the constant cutoff of the Yellow River since 1972, the marsh of the Yellow River delta has gotten obvious influence. When the Yellow River water quantity is plentiful, the Yellow River carries plenty of silt to supplement the beach, delta and coast that have been instruded relatively, so the lower flat marsh gets the rich supply source of water that contains quality, and the biological survival environment produces virtuous circle. When the river runoff quantity is big, it may promote the water body environmental capacity and dilute pollution capacity to alleviate the river condition of water pollution. Satisfying the basic water requirement supply of the marsh ecological succession of bayou is the basic condition that realizes the ecological stability of bayou, therefore the water of the Yellow River has a very important influence for the marsh of the Yellow River delta, and the water quantity and quality change of the Yellow River will affect the water resource change in delta directly.

Strengthening the unified management of the Yellow River water and ensuring the Yellow River water have become the problem to guarantee the marsh of the Yellow River delta. Under the background of the Yellow River water resource with highly tense, the marsh protection of the Yellow River must be incorporated into the overall programming of the whole valley water resource management, the valley water resource management strategy of connection with marsh protection should be established, and ensure the ecological water requirement of marsh protection. Taking regional water resource carrying capacity and the capacity of water environment as foundation, through reinforcing the water resource allocation and management reasonably, carrying out the measure of control and the recovery of degraded marsh, according to the way of keeping ecological environment natural function of marsh, scientific, reasonable, continuous using delta marsh, making protection and using reasonably of the marsh to enter virtuous circle.

3.2 Resume vegetation structure to protect biological diversity

The major function of the Yellow River delta marsh is to purge water quality, degrade inland river contaminant, raise environmental quality, and store up flood detention etc. Existent environmental problems are disproportion spread, bad water supply, saline soil and exiguity vegetation and converse succession. Because the new immature soil hypo – saline is serious, the natural vegetation that forms under this kind of soil condition is meadow mainly, natural vegetation has grown in marsh and in saline soil mainly, including more than 10 kinds of communities. The characteristics are less stability community and monotonous kind composition. The vegetation composition belongs to herbaceous plant mainly. It is not firm for this marsh ecosystem, and its ecological function is fragile. Carrying out ecological restoration should ensure the supply of water source according to local conditions, protect original vegetation, and carry out breed with man – power, introduce into kinds and breed salt – endurable plants, increase vegetation kinds, and raise vegetation coverage. For cultivation in beach land caused the ecosystem converse succession in marsh, the damage for newborn marsh environment is apparent, should carry out ecological restoration in proper section and make ecosystem obey normal succession.

3.3 Strengthen to protect the fresh water marsh

Along with the decreasing of natural marsh area, the breakage of landscape patch, marsh area that can accept flood is also decreasing unceasingly, the adjusting flood ability is also decreasing constantly, so causes the change of marsh ecological function. Ecological environment is fragile, biological diversity is decreasing, so produces serious bad influence for this district ecological environment. In development and the balance of the ecosystem of the Yellow River delta, the fresh water marsh is the interactive glacis of the land region, fresh water region and ocean ecological unit of bayou, is the ecological crucial essential factor with the protection of biological diversity and keeping the system balance of bayou, is also the key regional and key protective object of the ecological protection of bayou. The fresh water marsh has a very important ecological value and function that cannot replace for keeping the region water and salt balance of bayou, offering birds migrate breed and perch existent condition, maintaining delta ecological growth balanced etc. Therefore strengthening the protection of the fresh water marsh is important. According to secondary planet photograph investigation information in the middle of 1980s, the fresh water marsh area of bayou was two millions hm^2 for a long period steadily, the aquicolous vegetation area of fresh water of marsh key area reached 1,600,000 hm^2, in which the marsh area directly relies on the runoff of the Yellow River is more than 20 thousands hm^2. After 1990s, the fresh water marsh accelerates to the salt marsh contrary of succession. To the beginning of 21 century, the fresh water marsh area had reduced by one million hm^2, the aquicolous vegetation area dropped to 480,000 hm^2, which has been threatening the stability of the bayou delta.

3.4 Strengthen macro – control, make a good protect programming and strengthen the development inspection and research of the marsh ecosystem

The marsh ecosystems of different genetic type, different succession state and different situation have different resources and environmental functions, need to strengthen macro – control, and make protection to plan. The resource and environmental function of marsh will be influenced probably apparently because the large – scale development campaign of the Yellow River delta marsh, so strengthen protection, program, construction of the development marsh, along with economic development, protect environmental function indeed and the resource of delta marsh ecosystem.

Marsh has an important role for river ecosystem, and one of the important tasks to maintain the healthy life of the Yellow River is to keep good development of river ecology. Reinforcing marsh inspection of the Yellow River will have an important significience of marsh protection the river and maintain the healthy life of the Yellow River. According to the ecological function, distribution and the type of the Yellow River delta marsh ecosystem, select the typical marsh ecosystem to carry out dynamic inspection, inspecting hydrology pattern, pollution situation and species situation and community trends fall etc., carry out dynamic analysis research , transfers monitor and study result to relevant department in time, adopt countermeasure and measure quickly to ensure the virtuous circle of the marsh ecosystem of the Yellow River delta.

4 Concluding remarks

Human society and marsh have formed a close connection in long – term interaction. The marsh has been also playing an important role in the development of regional economies. The change of marsh area, marsh water quality and the reduction of marsh biological diversity have already become the major process of marsh degeneration. To prevent the further deterioration in these processes, protect existing marsh and resume degraded marsh have become the most effective means to play benefits of ecological, social and economic marsh. Keeping the bayou delta ecological balance of the Yellow River has been becoming the important sign that maintains the healthy life of Yellow River.

References

The Total Report Compile Group of Chinese Protection Action Plan of Biological Diversity. The Chinese Protection of Biological Diversity of Action Plan[M]. Beijing: Chinese environmental scientific Publishing company, 1994.

Cai Xuejun, Zhang Xinhua, Xie Jing. The Ecological Environment Quality Present Situation and Protection Countermeasure of the Yellow River Delta Marsh[J]. Ocean Environmental Science, Vol. 25, No. 2, 2006(5).

Gao Jixi, Li Zhenghai. The Problem and Suggestion about the Ecological Protection in the Yellow River Delta[M]//The Problem of Yellow River Bayou and Control Countermeasure Seminar Expert Forum. Chinese Water Conservancy Academy, the Yellow River Seminar Edit. Zhengzhou: The Yellow River water conservancy publishing company, 2003.05.

Li Bing. Discussion about the Water Resource Ecological Problem of the Yellow River Bayou and its Administration[EB/OL]. http://www.paper.edu.cn

Han Yanzhu, Tian Lingyun, Xu Xuegong. A Preliminary Study on Wetland Ecosystem and its Protection of the Yellow River Delta[J]. Environmental Science and Technology. No. 2, 2000.

Delta Ecosystem and Delta Development Modes

Impact and Response of the Third Driving Force in the Estuary System: A Case Study of the Changjiang (Yangtze) Estuary

Chen Jiyu, ***Cheng Heqin*** and ***Dai Zhijun***

State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai, 200062, China

Abstract: Human activity impacts on the earth system in a scale from local, regional to global, which has been called as the third driving force of earth system. As an integrated complexity, the estuary system could be sensitive to both global changes and integrated natural and anthropogenic variations within the river watershed. More and more estuarine processes have been and will be controlled by the third driving force with an increasing intensity of resource exploitation and human – controlling in the estuary and watershed. Consequently, the healthy development of estuary system will be one of the most important theoretical and practical problems. As a case study of the Changjiang Estuary, the natural evolution with natural adjustment, developing human – control activities, reasonable or sustainable exploitation of natural resources and some suspensive problems are discussed, and some suggestions for harmonious consistency of nature with human being are supposed in the present paper.

Key words: Third driving force, earth system science, estuary system, impact and response

1 Introduction

Landform changes of the earth surface are usually known to be controlled by three parameters as the tectonic movement, exogenetic force and time. The tectonic movement is an endogenic force of the earth forming the basic pattern and modality of earth surface landform. Exogenetic force is an acting force from outer of the earth as fluvial flow, sand blown by wind, glacier and sea wave driven by solar energy. Here, time means an individual stage that each spatial modality pattern developed.

A new integrated scientific idea called as the earth system science (ESS) come into being to meet with a challenge for the global environment change of the earth in 1980s. The ESS highlights a monolithic system of the earth composed of atmosphere, lithosphere and biosphere. It pinpoints the global change of mutual interaction among physical, chemical and biological processes with an emphasis on the human – made global change, and finally reveals regular patters of the global change. Direct human activities have been characterized by hot spots for its increasing impacts in the global changes. And they affect on the earth system from local and regional to global to be the most severe impact. Therefore, the book entitled Earth System Science reported firstly the anthropogenic force driving the earth system change as the third driving force in a comparison with the solar and centrosphere (NASA report, 1988).

As a boundary between land and sea where exists the active interaction among the atmosphere, lithosphere and biosphere, the estuary acts as an integrated complexity embodied the global changes of the earth system. It is both the sink of riverine fluxes and the source of marine fluxes. The catchments' changes could be sensitive to be reflected in a pulse in the estuary system with natural evolution and increasing human activity. But the response to an integrated process of natural driving forces and anthropogenic force remain to be thoroughly studied in the estuary system, as a local or regional example of the earth system. Strength of the third driving force impact is not anymore comparably as that of the previously general anthropogenic impact. This comparison might be considered as to be similar to the handicraft industry instead of the large scale manufacture product after industrialization and the productivity change and science and technology improvement greatly change nature of anthropogenic impacts on the earth surface. It is no wonder that the strong human activity since the industrialization has been called as "Anthropocence" (Meybeck & Vorosmarty,

2005) and the profound anthropogenic impacts on the earth surface and outer space for recent 50 years have been highly concerned for their initiation of the global change. And the impacts of the third driving force will be thoroughly discussed as a case study in the Changjaing Estuary system.

2 Natural driving force patterns of the Changjiang Estuary system for the past centuries

As the first river in China and the third river in the world, the catchment area of Changjiang River is 1.8 million km^2 with a length of 6,300 km. The area of upstream to the Three Gauge Dam is 1 million km^2 with a length of 4,500 km. The length of middle reach between Yichang and Hukou is a little more 950 km, where was located large ancient lakes and is now located the middle reach basin as Dongting Lake and Poyang Lake. Datong, a hydragraphy station in the lower reach, Anhui Province is located at the tidal limit of tidal wave from the East China Sea to the Changjiang Estuary, and subsequently, which might imply sensitively intensity of tidal waves and interaction fluxes of water and sediment between the mainstream and distributaries. Mainstream of Changjiang River from Datong to Xuliujing is ca. 500 km long, whereas the mainstream from Hukou to Xuliujing is called as the lower reach of Changjiang River (Fig. 1).

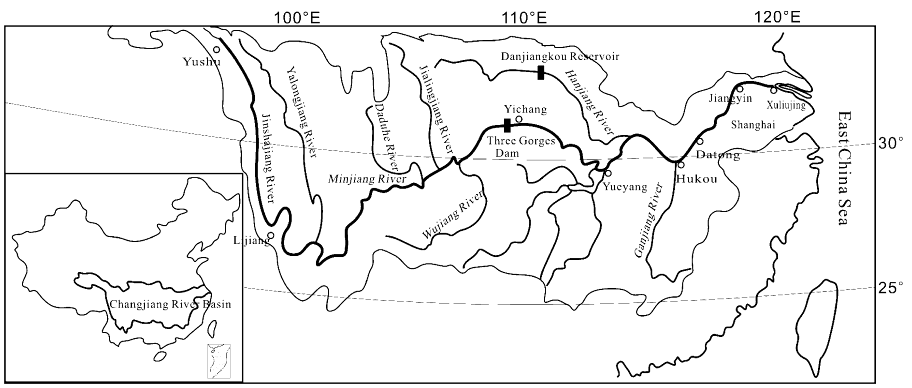


Fig. 1 Main channel and tributaries within the whole catchment of the Changjiang River

The Changjiang River sets up into the bifurcation at Xuliujing, and it is bifurcated into South and North Branch by Chongming Island, South and North Channel by Changxing – Hengsha Island and South and North Passage by the Jiuduansha Sand. So, the estuarine regime of three order bifurcations and four outlets into the East China Sea was formed. This branching river estuary downward from Xuliujing is called the Changjiang Estuary with a length of 140 km (Fig. 2).

The Changjiang Estuary has been composed of a huge funnel – shaped estuary filled in great quantity of sediments since the last deglaciation. The landscape of estuary naturally adjusts to the runoff and sediment discharge from the catchment. And hereinafter, the evolution of Changjiang Estuary generated mainly from natural parameters with a little human retreat or human passive resistance to the erosion by "muddy estrade", "tidal sidestep mound" and barriers or dikes to prevent the flood over the plain. Minor anthropogenic impacts on the estuarine processes were produced by the stake with block engineering to protect the erosion by river flow and tidal current. Natural evolution pattern of the Changjiang Estuary is the self – adjustment to the natural driving forces' change for more than six centuries.

Fig. 3 illustrates the river regime change of the Changjiang Estuary in 1330, when the main channel of Changjiang River located in the South Branch whose northern bank was individually limited by Jinghai (Nantong) and Haimen county. The upstream channel change led to the large erosion of the North Branch and most of land submerged under the water surface in the whole Haimen area, and seaward erosion to a boundary river southern to the Lusi during 14th century. The Haimen county government was transitorily moved to the Xingxiang town. It was very difficulty for

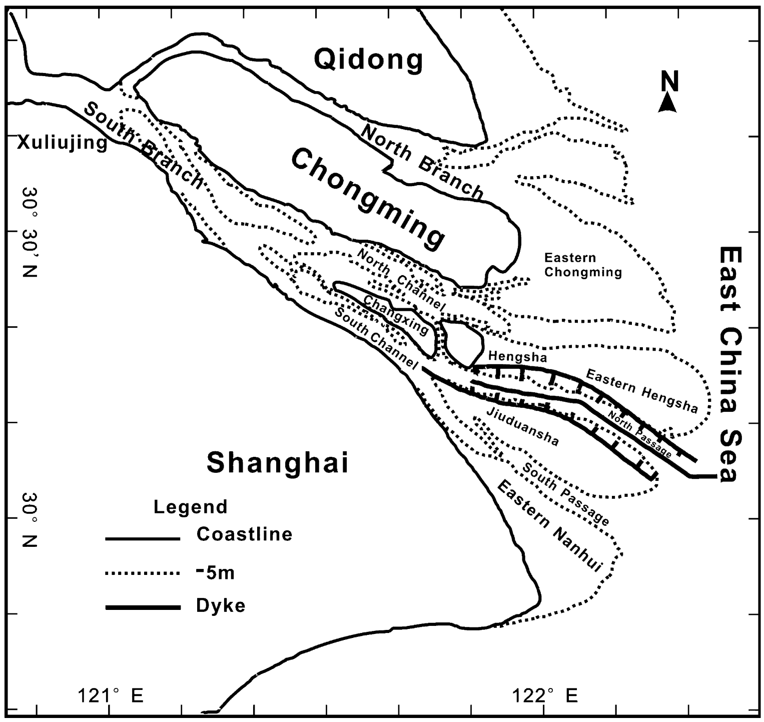


Fig. 2 Location of Changjiang estuary

the manpower at that time to control the tremendous natural evolution tendency as a great deal of erosion along the northern bank of the Changjiang Estuary.

Fig. 3 illustrates the river regime of the Changjiang Estuary in 1617 when the main channel was in the North Branch. The main channel of the estuary came back to the South Branch and deposition occurred in Haimen and Haimen District to be sited during 18th century. The northern Hugong dyke and old downtown were submerged into the water at Baoshan in Waigaoqiao area led by the great erosion along the South Branch to the Xuejingtang dyke, which was stabilized by the stake and stone on the bank.

Qidong became a land composed of sets of original mouth bars (Fig. 4) of the North Branch in 1905. And the North Channel was originally a secondary channel within the South Branch within which the contour -5 m did not run through before the middle of 19th century. It was becoming an estuarine branching channel as one of the second order bifurcation in the South Branch by the great floods in 1860 and 1870.

The North Passage was a flood – dominated channel during the middle of 20th century. And it was emerged by the great flood in 1949 and disastrous flood in 1954, and then has been becoming one of third order bifurcation in response to the South Passage in the Changjiang Estuary.

Those evolution processes above were belonging to the natural evolved patterns adjusting to water and sediment changes driven by natural forces. A natural driving force pattern had been supposed as deposition in the southern bank, combined estuarine bars, estuarine narrowing, channel deepening and the delta propagate in the Changjiang Estuary for two thousands of years (Chen Jiyu, 1995).

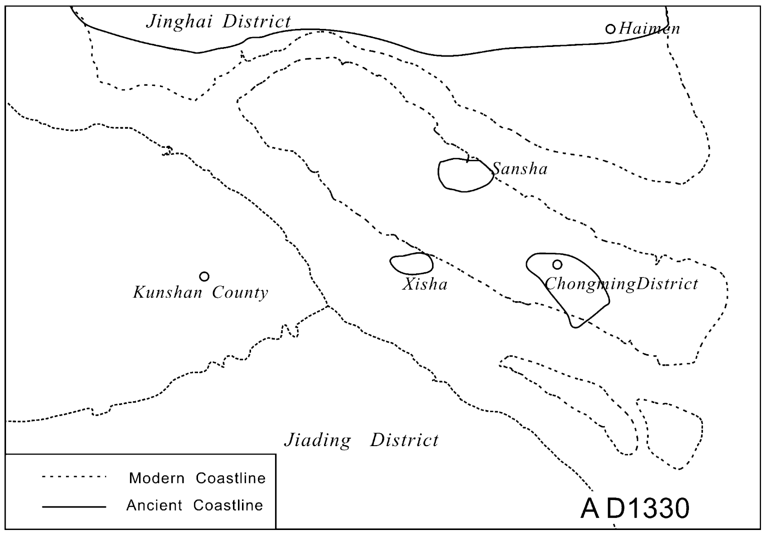


Fig. 3 Regime of the Changjiang estuary in AD 1330 (Zhou, 1999)

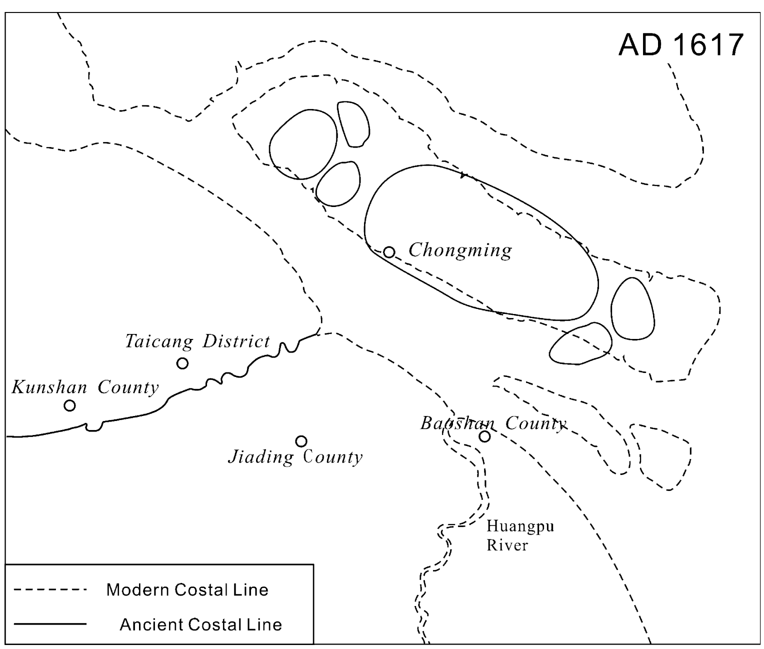


Fig. 4 Regime of the Changjiang Estuary in 1617 (Zhou, 1999)

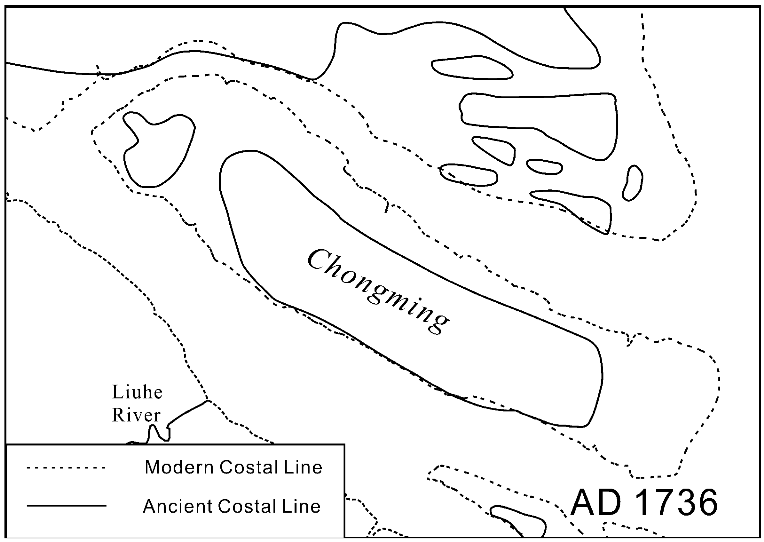


Fig. 5 Regime of the Changjiang estuary in the late Qing Dynasty (Zhou, 1999)

3 Intensity of the third driving force in the Changjiang Estuary system

3.1 Human control in estuarine channel regime

Embankment was constructed to protect the avalanche defense from the tide. And the great infrangible shore protection dykes were constructed to protect tidal flat and shore. Protection works were constructed in front of large scale levee in the Zhejiang province. Dams for the tidal flat protection were constructed in front of stake and stock engineering to constitute the Jiangnan dyke. This large scale of dykes could protect the shore erosion for the main source of endow with taxi and a land flowing with milk and honey, which cost huge sum of investment comparing to the period when the nature controlled the coastal levees. Whereas general coastal line, simple claybank could only protect the overflow of tidal flood. Therefore, the shore erosion rate could reach 100 ~ 200 m/d along the silty bank of Qiantangjiang River and some meters ~ tens of meters/day within the Changjiang Estuary. The northern bank of the Changjiang Estuary, Qidong and Haimen had a recession of 4 ~ 5 km during a half century when the North Branch channel changed from an ebb - dominated channel to a flood - dominated channel last century. The southern bank of Chongming Island, located in the river mouth as an estuarine bar, occurred landslip and the northern bank of Chongming Island deposited rapidly northward to 4 ~ 5 km for half a century. This kind of erosion and deposition of bank around the island induced the citizen in the island moved house two or three times in his life although there was dyke to protect the erosion and tidal overflow. From 1950s to 1990s, dyke construction and spur dyke building were reinforced and there were a number of 435 dykes including spur dyke and passing dyke in the Changjiang Estuary. In which, there were 220 dykes around the Chingming Island, 75 dykes around the Changxing Island and 39 dykes around the Hengsha Island. This shore protection engineering plays an important role in the stabilization of the river regime and sand bar. Consequently, how significant anthropogenic impacts on the river regime control engineering were, which could not be neglected and based on the facts that no change of basic estuarine pattern occurred after the great floods in 1998 and 1999.

3.2 Land resource exploitation of estuary system

Improvements of science and technology for recent 50 years have been made it possible to intensify the capabilities of human beings to acquire more natural resources. This has greatly affected or even indeed transformed the earth environment and/or earth system in a scale from the local or regional scale to the global. It has been becoming more and more notable for the third driving force to control the estuarine processes. And it has also increased great effectiveness of bottom stabilization for the erosion prevention to substitute the soft mattress for aggregate mattress composed of packs of reeds. Favorable technology progress has been made to substitute the filling sand within the geotextile for the scarcity of block stone to build the coastal protection dikes, which needed a majority of very expensive blocks with a long transportation. More solidity had been made for the levees and dikes to substitute the concrete lattice for slope protection using the large block stone. Large trapezoids were used to protect the basis of dykes with attenuation and to confirm the stream deflection and shore protection by infrangible spur dikes. Semi – cylinder trapezoids were used to construct the long training walls and hollow quadrels were used to consolidate the soft groundsill with high saturation in a requirement of engineering in the Changjiang Estuary.

Construction implements have been greatly improved as deep water assistant draining and large component lift on/lift off. These technological improvements with investigation of natural environment in detail and discipline knowledge and reasonable design and construction have made the obvious development of estuarine resource exploitation with the apparent shore protection to the invasion of strong storm and the erosion of shores as follows.

Land reclaimation of 1,007 km^2 is equal to ca. 1/6 of land area in Shanghai for recent 50 years because the Changjiang Estuary received a large quantity of sediments from the whole catchment greatly deposited on the tidal flat. Age and speed of coastline boost with the seaward deposition of tidal flat could be marked by courses of dykes and levees constructed for more than one thousand of years. A significant improvement of the land reclamation has been developed by the obvious impacts of the third driving force on the coastal zones for recent 50 years, especially for recent 30 years as follows:

(1) Deepened lower limit of the land reclamation from tidal flat. Before the 1980s the lower limit to reclaim was close to the mean high spring tidal level about 3.2 ~ 3.5 m (Wusong datum). Progress in the coastal engineering made it possible to substitute the soft mattress for aggregate mattress, and to substitute the concrete lattice for slope protection using the block stone after the 1980s. This advanced technology of coastal engineering has been applied to deepen the elevation of land reclamation to 0 m contour since the middle of 1990s, and even to − 2 m or − 3 ~ − 5 m locally to meet the land resource demands at the beginning of 21st century.

(2) Promoting sediment deposition engineering for the land reclamation. The land reclamation was speed up with an increasing intensity of the third driving force. For example, the land reclamation area were 133 ha for 5 years during 1979 and 1984 while the land reclamation reached 1,333 ha for 5 years during 2001 and 2005 on the eastern Nanhui tidal flat, which the land reclamation rate was speed up in ten times for the last two decades.

3.3 Estuarine channel regime regulation of the North Branch

3.3.1 Channel regulation of the North Branch

The North Branch changed from an ebb – dominated channel to a flood – dominated channel and then to form a tidal bore due to potentially affected by the large area of land reclamation under the combined natural and human effects during the last century. And then, a favorable type of channel has appeared with a significant change in river channel regime with tidal range and tidal prism decline due to the channel narrowing by the branching channel block for the land reclamation with 406 km^2.

3.3.2 Deep navigate channel regulation

The natural water depth is 5.5 ~ 6 m in the Changjiang Estuary, which shows a shallow nautical channel into the sea. In 1980s, the water depth with 8.0 m could be kept by dredging. But the dredging with earth volume 14 million m^3 could not meet the demands for the increasing container. During the end of 1990s, comprehensive control with dredging was applied to construct the double – dyke with a length of 100 km (the total length of both dyke) on the huge mouth bar of the Changjiang estuary. This new technics was systematically designed and constructed and then the first and second stage engineering of deep navigation channel with water depth of 12.5 m have been completed for 6 years during 1998 and 2003. The water depth of the deep channel has been increased from 7 m to 8.5 m and then to 10 m. It will be deepened to 12.5 m during the third stage engineering for the present time. Acquirement of the deep navigation channel sufficiently imply the significant impact of the third driving force supported by the new technology to achieve the water depth difficult to be acquired (Fan, 2004).

3.4 Freshwater resource exploitation

Great growth of population and urban area around the Changjiang Estuary, where located the largest city of China, Shanghai bring on the scarcity of water quality although it is a land flowing with milk and honey. Moreover, quality of supply water continuously has been going on deterioration in the Huangpu River, water resource of Shanghai. Freshwater was induced from Changjiang and reservoirs were constructed since 1980s. There are some present reservoirs as in the Table 1.

Table 1 Reservoir in the Changjiang Estuary

Reservoir	Capacity (million m^3)	Built year
Baogang	12	1985
Chenhang	8.3	1992
Shugou	0.6	1992

This kind of water supply is obviously not to meet the needs of city development and construction of the international mega – city, Shanghai.

4 The third driving force and salt water intrusion

4.1 Freshwater supply safety in the estuary

Freshwater resources in the estuary for the city will be inevitably controlled by the integrated impacts of mixed fresh and salt water. The interaction zone that the runoff flowed into the sea and the salt water intruded the river channel could form estuarine circulation. Impacted by the seasonal changes of runoff into the sea and the difference in strength of the tidal range variation, the salt water occur oscillation within the estuary. Therefore, the estuarine fresh water supply is affected by the salt water intrusion and then to induce the lack of freshwater acquirement intermittently. Lack of fresh water acquirement frequently occurs due to the salt water intrusion in spring tide during dry season from December to the next March each year. Distortion flow in each individual channel dominated by ebb or flood with a phase difference produced the transverse circulation between two bifurcated channels. For example, salt water intrusion with sediment from the North Branch dominated by flood tide into the South Branch dominated by ebb during the flood tide formed and then falls out into the sea along the South Branch during the ebb tide. This transverse salt water intrusion is the main source of salt water around the intake of Chenhang reservoir. So, a problem of freshwater supply safety exists for Shanghai, the largest city of China.

Demands for the fresh water supply have increased greatly with an increase of population in the developing city, especially since early 1990s, when the exploitation and opening of Puding, Shanghai started. A shortage of freshwater about 7 million tons per month will appear in response to the present water supply system for planning 20 million citizens of Shanghai. So, in 1990 The first author suggested that "Where we can find the clean water, here we get in the Changjiang Estuary", and then, the Changxing Island was considered to be a water resource for the construction of the Qingcaosha reservoir. This reservoir is now being implementing in 2007 after the in – situ measurements, investigations and researches of salt water and bathymetric contours in details, planning and designing for 10 years. One more reservoir proposal named Meimaosha Reservoir to be constructed for on the eastern Nanhui tidal flat to meet the needs of ecological water utilization, local water supply and the emergency water demands of extreme climate and outburst events was submitted also by the first author. This reservoir is being studied in the process of data collection and analysis. The area of these two reservoirs will be totally more than 100 km^2 and their total volume will 1 billion m^3. The freshwater supply will be provided sufficiently by the storage in the large reservoirs restored during flood prevented from dry and salt water.

Nevertheless, some suspicions exist for the present global climate change and the huge impacts of the third driving force in the drainage basin on land – sea interaction in an estuary where is sensitive to the impacts. This must restrict the mixture intensity of salt water and fresh water, and inevitably increase the complexity of the salt water intrusion and secure water supply. Some suspicions are as follows.

4.2 Frequency increase in the extreme climate occurrence by the global change

Flood with rainstorm has intensified and great drought can jeopardize profoundly in a scale of drainage basin. An extraordinary year of discharge occurred in 2006 as an extreme drought in the upper reach and an extremely lack of water quantity in the middle reach and salt water intrusion three months earlier than normal. Therefore, one suspicion was supposed about the water quantity in the different segment of the Changjiang River.

4.3 Unreasonable water allocation and storage in the upper segment

Water resource is to be monitored by a key project, Three Gorge Dam, within the drainage area of the upper segment as 1 million km^2 whereas the water discharge decay as the snow line is hoisting and the glacier is shrinking around the river source. This is the most important area to explore the water energy resource as a clear energy source. The total volume of 136 reservoirs built and building presently reach to 312 billion m^3. And even more, the step exploitation of water resource is being carried out along the Jinshajiang River and Daduhe River. Sets of reservoirs built will need large water storage to generate electricity. Disorder water storage and unreasonable water allocation of these reservoirs in a lack of seasonal precipitation will attenuate the normal function. This must inevitably produce the second suspicion about the intensity of salt water intrusion induced by the unreasonable discharge along the middle and lower segment out from the Three Gorge Dam.

4.4 Safety criteria of the discharge controlled at the Datong during dry season

Runoff decay from Yichang to Datong because it is diverged into the Dongting Lake and Poyang Lake and riverine wetlands during flood season, which is fluvial filtering of flood. An avoidance discharge for the secure freshwater supply in the Changjiang estuary was supposed to be 10,000 m^3/s controlled the South – to – North Water Transfer Project at the Datong Hydrographic Station during dry season. Its efficiency depends on the discharge of mainstream outlet from Three Gorge Dam and recharge from the distributaries of the middle segment. Assumed great drought in the upper segment and scarcity of recharge in the middle segment will be suspicious to be enough to reach the avoidance discharge controlled at the Datong. The avoidance discharge as 10,000 m^3/s as in fact is just applied for the demands of fluvial discharge while the range of salt water intrusion is dominated by the intensity of tide. For example, salt water intrusion occurred to have a negative influence in the freshwater acquirement for the Chenhang Reservoir in the estuary although the fluvial discharge reached 14,000 m^3/s on October 9, 2006 during spring tide in the fall at Datong. Therefore, the avoidance discharge at Datong should be fluctuated in a range varying with the tidal range in the estuary based on the basic fluvial discharge of 10,000 m^3/s controlled at Datong. The appropriate range of avoidance discharge or safety criteria change still remains to be studied.

4.5 Disorder freshwater acquirement in the lower segment

Greatly increasing quantities of freshwater have been provided to meet the demands of residential and industrial water uses for the developing cities, towns and villages belong to two provinces, Anhui and Jiangsu along the lower segment with a distance of 500 km from Datong to the estuary. More freshwater demands come from two catchments of Taihu Lake and Huaihe River. For example, the annual water yield is 17.7 billion m^3 within the Taihu Lake catchment while the water consumption reached 354 m^3/s in 2005. The shortage of water had been supplied by Water Diversion Project from the Changjiang River to Taihu Lake, which is equal to the water quantity of water to supply for the South – to – North Water Transfer Project. Another water diversion project is programming from Changjiang River to Huaihe River in Anhui Province and Jiangsu Province. Investigating data showed that the discharge of water diversion to large quantities of sluice is increasing annually and reached totally to 20,000 m^3/s in 2006. So, the supposed avoidance discharge of 10,000 m^3/s would not flow to Xuliujing due to an assumed great drought in the Jianghuai plain and the Taihu catchment and a disorder water acquirement along the banks of lower segment. Subsequently, it is almost impossible to transfer 15 billion m^3 water from Changjiang River to Huabei plain, Beijing and Tianjing area.

4.6 Sea level rise imposed land subsidence in the Changjiang delta

Coastland plain in the Changjiang delta, Taihu plain and Lixiahe lowland are all belong to the disk lowland. Larger sea level rise imposed land subsidence due to pumping of ground water and strata compression will intensify the intrusion of salt water and increase the frequency and strength of typhoon storm to significantly jeopardize the coastland under high tidal level, especially the delta plain with highly dense population and megacities. These must be suspicious.

To sum up, it is necessary to reinforce the impact research of natural disaster and it is more necessary to understand each individual inconsistency of water resource utilization with the third driving force, and then it is necessary to make an effective management within the whole catchment (Cai Qihua, 2006).

5 Conclusions

Since the industrial revolution in 18th century, the human activities have changed sharply estuaries in the western developed countries as the regulation of sea – entering channel in the estuary of Mississippi River and delta regulation project in Netherland. Changes induced by human activities within the watershed also have caused a river mouth shrinking and great delta change by Aswan Reservoir cross the Nile River. Most majorities of estuaries were nature in China and the Changjiang estuary was dominated by the natural parameters with minor anthropogenic impact before 1950s. Since 1950s sluice had been constructed for the separation of freshwater from salt water in many middle and small estuaries showing an increase in human control of estuarine processes. And since 1980s, increasing anthropogenic impacts have generated artificial estuaries as the present Qiantangjiang estuary from a natural estuary with a strong tidal bore. Consequently, since 1980s, benefit changes to the people in the Changjiang estuary and intensified control by human activities called the third driving force has caused a significant mouth shrinking as the water resource change, sediment decay, land exploitation restriction and great variation in the nutrient and pollutant into the sea, red tide and hypoxia, etc. The present paper can only discuss the water resource problem caused by the third driving force while its impacts in the estuarine landform, deposition and erosion of delta and offshore environment will be illuminated in the future.

References

Chen , J. Y. Natural adjustment and human control of the Yangtze River estuary [J]. Journal of East China Normal University, Monograph of the maximum zone and front in the Yangtze River Estuary (in Chinese), 1995. 1 – 14.

Cai Q. H. (eds). Healthy Changjiang: Protection and Development [M]. Changjiang Press, 2006.

Earth System Science Committee NASA Advisory Council. Earth System Science: A Closer View [J]. National Aeronautics and Space Administration, Washington, D. C., 1988.

Fan Q. J. The inovation of the Yangtze Estuary deepwater channel improvement project [J]. Engineering Science, 2004, 6(12): 13 – 26.

Meybeck M., C. Vorosmarty. External Geophysics, Climate and Environment: Fluvial filtering of land – to – ocean fluxes: from natural Holocene variations to Anthropocene [J]. C. R. Geoscience 337 (2005): 107 – 123.

Zhou Z. H.. Historical Atlas of Shangai [M]. Shanghai People's Press, 1999.

Reasonable Arranging of Spare Channel to lowering the Speed of the Estuary Extension

Hu Yisan

The Yellow River Conservancy Commission, Zhengzhou, 450003, China

Abstract: A great quantity of sediment, transported to the estuarial area of the Yellow River every year, has made the estuary in the evolution of sedimentation, extension, twisting and divagation for a long time. In the course of "small circle" and "big circle" evolution at the delta, sediment settled down, the delta level rose, the sand bar at the outfall successively extended to the sea, and the water level of the estuarial reach under the same discharge was raised, resulting in the sedimentation on the river reach above the estuary and continuous transferring to the upstream, which would affect the safety against flood. In case of the realignment of the estuarial channel, its length distinctly shortened to cause retrogressive scour and lowering of water level under the identical discharge, which is favorable for the safety of flood control. The estuarial and coastal areas are the major regions where the sediment running into the estuary is disposed. During the period from 1950 to 1985, only 33% sediment carried to the estuarial area was transferred to the sea and the remaining 67% was deposited on the delta and its upstream. In order to keep the long term stability of the Yellow River, it is essential to rationally arrange spare river channels, to make full use of vast area outside the delta, and to maintain the seashore line as long as possible for outer sedimentation so that the extension pace of the estuarial channel can be slowed down. At present, Diaokouhe, Maxinhe and Shibahu channels shall be regarded as the spares, in addition, the administrative scope shall be defined.

Key words: estuary, flow pass, delta evolution, spare channel, flood control, the Yellow River

1 Introduction of the Yellow River estuary

It has been over 150 years since the Yellow River breached in Tongwaxiang, Lankao, Henan Province in 1855. The Yellow River flows through the Delta and deposits for 120 years except the dyke breaching by explosive in Huayuankou in 1938.

The Yellow River delta lies between Bohai bay and Laizhou bay, which is like a fan. Its apex is Ninghai in Kenli county, from Tao'er river in the north to Zhimaigou in the south. The area of delta is about 6,000 km^2. The apex of the delta has moved to Yuwa since 1950' and the swinging area is from Chezigou in the north to Songchunronggou in the south with area of 2,400 km^2.

The Lijin hydrological station is responsible for measuring the runoff and sediment discharge of the Yellow River. It has been 80 years since the hydrological station was established in 1919. The runoff and discharge are in Table 1 according to the measured and computing data. The average runoff in Lijin station is 38.06 billion m^3 during 85 years from 1920 to 2004. Among these, the runoff in the flood season (July to October) is 23.85 billion m^3, accounting for 62.7% of the annual runoff. The annual sediment transport is about 0.964 billion tons. Among these, it is 0.823 billion tons in flood season, accounting for 85.4% of annual sediment transport. The annual sediment concentration is about 25.3 kg/m^3 and it is 34.5 kg/m^3 in the flood season. In the water and sediment distribution along time, the water and sediment are abundant in the early 50 years, and in the latter 35 years, these are becoming less. The annual average runoff in Lijin station is 49.04 billion m^3, and in the flood season it is 30.7 billion m^3, accounting for 62.6% of the annual runoff. The annual sediment transport is 1.238 billion tons, and in the flood season it is 1.052 billion tons, which accounts for 85% of the annual data. The annual average runoff is 22.37 billion m^3 from 1970 to 2004. Among these in the flood season, it is about 14.06 billion m^3, accounting for 62.9% of the annual runoff. The annual average sediment transport is 0.57 billion tons, and in the flood season it is about 0.495 billion tons, accounting for 86.8% of the annual data. Since the Xiaolangdi reservoir was put into operation in October 1999 and the water demand of the industry and agriculture increased in the upstream, the runoff decreased to 11.48 billion m^3 from 2000 to 2004 and the runoff in the flood season accounts for 51% of the whole year. The annual sediment transport decreased abruptly to 0.155 billion tons, only accounting for 16% of that – 0.964 billion tons in 1985.

2 Formation and development of the Yellow River delta

The Yellow River breached and seized Daqing River channel to enter the sea in Tongwaxiang in 1855. Because there were no dykes from Tongwaxiang to Zhangqiu, which was about 200 km, the water flew across a large area and most sediment deposited. A little sediment deposited from Xiaoshenmiao in Lijin to the sea.

Below Ninkai Kenli county, the groundwater is shallow and the land is salinizing. A few inhabitants lived there. After the Yellow River flows into estuarine area where the water goes into Bohai Sea along the lower land. Because the flow is dispersed, the water velocity is slow and the sediment is deposited. The river bed raised gradually. When the flood was coming, the river would change its channel and went into sea along other lower land. With time passing, the new delta of the Yellow River came into being gradually.

Because much sediment deposited in the estuary every year, the channel has been in the evolution of depositing – extending – swinging – changing. The channel changed naturally in the Yellow River delta before 1950 according to the runoff, sediment discharge, river regime and topography. The river selected its channel freely. Some people lived there after 1950. The channel in the estuary has influence on the flood control and ice – flood control before Ninghai. The Yellow River channel has been changed by man several times according to flood control, ice – flood control and channel evolution. The river channel changed nine times since 1855. The river channel changed in Hanjiayuan in April 1889. The channel changed in Lingzizhuang in June 1897 due to summer flood. The channel breached and changed in Yanwo in July 1904. The channel breached and changed in Balizhuang in July 1926. The channel breached artificially and changed in Jijiazhuang in September 1929. The channel changed in September 1934 because of the failure of plugging up the branches. There was one channel in the former channel changes, but this time, the river flows through Shenxiangou, Tianshuigou and Songchunronggou into the sea. The river breached artificially and flew into Huanghai sea and the river failed to the sea after Ninghai. After the dykes were closed in spring of 1947, the Yellow River resumed to its original channel and flew into the sea by Ninghai. The location where the Yellow River went to the sea was as same as that in 1938 (Table 2). The channel was cutoff in July 1953 and the river went to the sea from three – way into a single way – Shenxiangou. The channel was changed artificially through exploding and went to the sea through Diaokouhe in January 1964 due to the serious ice flood in winter of 1963. When the river was difficult to go to the sea, the channel was laid out and some river training works were built. The river changed its channel through cutoff and flew into sea through Qingshiugou channel until now.

After the channel changed, the river course shortened and the channel eroded in the downstream of channel – change – point. And the water level lowers with the same discharge. But in the downstream of the channel change point, the new channel was in the process of depositing – extending – swinging – changing. After the channel change point, there are three phases in the channel evolution: wandering – single – swinging. When the channel became single, the river regime was stable relatively. The water patterns are complex and the channel is not stable in the river mouth. With the sediment deposit, the water level increases. If the river meets floods, storm and blocked in the river mouth, the channel will swing and change. Point of branching out moves upwards until reaches the point of channel change. Then the channel will change. After the channel changes every time, the river course will show the following processes: the channel shortening—deposit extending—swinging and branching – channel shortening—deposit extending – channel change again. The water level in the estuary will be lowering—heightening—lowering—heightening—lowering. Such a circular evolution law is known as the "small cycle". The channel in the Yellow River delta has changed for about 50 times since 1855, among these it happened near the apex of the delta nine times. The shifting channel route obey the following rules: firstly go through the center of the delta, secondly the right, then the left, finally the center of the delta. So the laws of the entire cycle are called "big cycle". The routes are not repeated in the "big cycle". The evolution of the channel in the delta is in the following table.

Table 2 The statistics of the channel shifting since 1855

Apex of the channel	Sequence	Duration	Location of channel change	Location of entering the sea	Reasons of channel change
	1	July 1855 ~ April 1889		Xiaoshenmiao	Breached in Tongwaxiang and went to the sea through the channel of Daqinghe in June 1855
	2	1889.4 ~ 1897.6	Hanjiayuan	Mansituo	Ice – flood ovetopping
	3	1897.6 ~ 1904.6	Lingzizhuang	Siwangkou	Overtopping in summer flood
	4	1904.7 ~ 1926.9	Yanwo Koujiazhuang	Shunjianggou Zhenzigou	Breached in summer flood
	5	1926.7 ~ 1929.9	Balizhuang	Diaokou	Breached in summer flood
Around Ning hai	6	1929.9 ~ 1934.9	Jijiazhuang	Nanwangsha	Breached through man – made
	7	1934.9 ~ Spring 1938	Yihaoba	Shenxiangou, Tianshuigou, Songchunronggou	Channel change due to failure of closing branches
		Spring 1947 ~ 1953.7	Yihaoba	Shenxiangou, Tianshuigou, Songchunronggou	
Around Yu wa	8	1953.7 ~ 1963.12	Xiaokouzi	Shenxiangou	Man – made cutoff, changing several branch into one channel
	9	1964.1 ~ 1976.5	Luojiawuzi	Diaokouhe	Breached artificially
	10	1976.5 to now	Sihekou	Qingshuigou	Channel change by man – made coutoff

During the evolution of the channel in "small cycle" and "big cycle" in the Yellow River delta, because of sedimentation and the increase of the delta elevation, the river mouth bars extended to the sea and the area of the delta was becoming bigger. The delta may erosion recede by wind and sea current where the river does not flow. The area of the Yellow River delta has increased by 2,500 km^2, and the yearly average increase 22.5 km^2 since 1855. Among these, the average area of land making was about 24 km^2 before 1976, while it was only 8.624 km^2 from 1992 to 2001.

Table 3 The extending and eating away of the Yellow River delta

Times	Area of extending (km^2)	Area of eating away (km^2)	Net area of extending (km^2)	Net area of extending yearly (km^2/a)
1855 ~ 1954	1,510		1,510	1,510/64 = 23.6
1954 ~ 1976	650.7	- 102.4	548.3	548.3/22 = 24.9
1976 ~ 1992	499.9	- 82.5 (north of Qingshuigou) - 37.9 (south of Qingshuigou)	64.4	364.4/16 = 22.8
1992 ~ 2001 (estimated)	81.7	- 4.4	77.3	77.3/9 = 8.6
1855 ~ 2001	2,742.3		2,500	2,500/111 = 22.5

3 Demand of flood control to lower the extension of the channel

With the river channel deposit and extension, the water level with the same discharge increases. The river channel slope is becoming mild with the riverbed increase. The capacity of the sediment transport becomes small and the sediment deposits. Therefore, the riverbed becomes higher. In this process, the change will cause the decrease of sediment transport capacity, the siltation of the river channel and impact on the security of the flood control. This kind of erosion will transfer upwards along the channel. The stable gradient of the estuary channel is about 0.000,8 ~ 0.001,1. When the channel extends 10 km, the datum of the erosion will increase 0.8 ~ 1 m. The shoreline in the river mouth extends more than 20 km in recent 50 years. This causes the water level increasing 2 m with the same discharge.

As mentioned hereinbefore, the channel of the estuary will change several times in the process of the deposit and extension, during which it will shorten and erode upwards. The erosion is limited because the shortened channel is short. When the channel changes, the shortened channel is long and the eroding channel upwards will long. The water level could lower with the same discharge in the erosion channel. These will benefit to the flood control.

So, in order to keep the safety of the lower river, especially the section below Luokou, necessary measures should be taken to slow the extension of channel in the estuary.

4 Arranging the spare channel reasonably

Before 1960', A few inhabitants lived and there were no industries in the estuary. In order to alleviate the pressure of flood prevention and ice - flood prevention in the upward channel, the channel can change in the appropriate locations. The man - made cutoff in Xiaokouzi in July 1953 and artificial breach in Luojiawuzi in 1964 were easily implemented. After the channel change, the pressure of the flood control and ice - flood control were alleviated. There were not big influence and losses in the estuary.

4.1 Yellow River Delta is the only route to the Yellow River

The inhabitants are increasing with the development of Shengli oil field after 1970. The oil can be extracted everywhere and the estuary area contributes to the state economic development enormously. How to appropriately arrange the river channel with the development of the oil industry has been becoming more important.

The Yellow River is the 'mother' river in China. There were five major channel changes in the history. The present channel is still the optimal one since the river channel change in Tongwaxiang in 1855 according to the evolution of the channel and the state economic development. The Yellow River must flow into the sea through the correct channel in order to guarantee the development of the agriculture and industries along the river. People's life and development of the local economy is inseparable from the Yellow River. So we must leave rooms to the Yellow River and the Yellow River delta is the only way for the Yellow River running.

4.2 Delta and its coastal region are the main area to control silts

The sediment that was carried into the estuary mostly deposits in the delta and coastal areas. Some of them are transported into the sea (not in the measured area). The distribution of sediment from 1950 to 1985 is in Table 4. The table shows that the sediment volume transported to the sea accounts for 33% of the total. The sediment that deposits near the delta accounts for 44%. The sediment volume transportation to the sea is related to current intension and sediment conditions. The sediment that deposited in the river channel accounts for 2%, and 8% of the total sediment transported to the sea. 90% of the total sediment deposited along the coastal area from 1986 to 1991 in Qingshuigou channel. That was 19% deposited in the channel, 61% deposited in the coastal area and 20% transported to the sea. The sediment transported to the sea is decreasing. That will accelerate the extension of the delta.

Table 4 Distribution of the sediment in the river mouth **Unit: 10^8 t**

Duration	1950 ~ 1960 (Shenxiangou)		1964.1 ~ 1976.5 (Diaokouhe)		1976.6 ~ 1985.9 (Qingshuigou)		Average	
Annual sediment in Lijin	13.2	Accounting for in Lijin (%)	10.8	Accounting for in Lijin (%)	8.61	Accounting for in Lijin (%)	10.5	Accounting for in Lijin (%)
River channel elevation	3.5	26.0	2.33	21.6	1.52	17.6	2.42	23
Sea area in delta	4.7	36.0	4.76	44.1	4.96	57.6	4.62	44
Transportation the sea	5.0	38.0	3.71	34.3	2.13	24.8	3.46	33

The channel extends and the coastal line moves ahead near the river mouth. When the river channel changes, the coast will eat away. Under the momentum of the sea water, the shoreline moves afterwards. The sediment eroded by the sea water and mostly deposit near the place where they eroded. The cross sections that are vertical to the shoreline are becoming mild according to the measured data. The phenomenon of the coast eaten away is that the sediment moves in a short distance, but can not increase the capacity of holding sediments, that is to say, it has a little influence on the lifetime of the channel.

4.3 Preparing several spare channels in delta

Among the nine times of the channel changes of the Yellow River, there were six times regarding Ninghai as the apex before 1950, ranging from Taoerhe to Zhimaigou. About 1,510 km^2 were produced from 1855 to 1954. About 23.6 km^2 were produced every year. The shoreline is 128 km long and the shoreline moves 11.8 km towards the sea. The shoreline moves 0.18 km towards the sea every year. The apex moved to Yuwa in the three times channel change after 1950, ranging from Xiaochezigou to Nandadi. The net produced area was 700 km^2 from 1954 to 1984 and 23.3

km^2 was produced every year. The shoreline was 80 km. The whole shoreline moved towards 8.75 km and average 0.29 km every year. The velocity of the shoreline moving ahead increased 60% in the condition of almost the same produced area. The faster the channel moves ahead, the faster the river mouth bar extends. We should try to make the shoreline moving towards the sea as long as possible in order to keep the Yellow River safe. We should lower the velocity that the shoreline moves towards the sea. That is to say, we lower the velocity of the channel extension in the estuary. Now the oil industries are developing quickly and the population is relatively density, some spare channels shall be prepared for future use. At present, Diaokouhe, Maxinghe and Shibahu channels are selected as spare channels.

4.4 Strengthening the management of the spare channels

The spare channels must be programmed for administration and their management shall be strengthened. The development of the industries and towns shall avoid the limitations of the spare channel management. Once the spare channels are used, the losses can be reduced. The facilities to be built within the management scope of the spare channels shall have no impacts on their use. The buildings set up in the spare channels shall be removed before they are put into use. The spare channels should keep their original conditions and not developed unauthorized. If the spare channels do need to be developed, the permission shall be obtained from the Yellow River Estuary Bureau.

Countermeasures for Yellow River Estuary Comprehensive Treatment

Li Wenxue, ***Ding Dafa***, ***An Cuihua*** and ***Yao Tongshan***

Yellow River Engineering Consulting Co. , Ltd. Zhengzhou, 450003, China

Abstract: Based on deeply analyses of the main existing problems of Yellow River estuary treatment, the requirements of Yellow River downstream flood control and sedimentation reduction and estuary area socio – economic development and eco – environment protection, this paper put forward the strategy for Yellow River estuary comprehensive treatment as well as the countermeasures for flow path into sea, flood control, storm tide control, water resources utilization and protection, eco – environment protection, management system and investment mechanism for the purpose of further coordination of the relationship among Yellow River estuary treatment, eco – environment protection, and socio – economic development in Yellow River delta area.
Key words: Yellow River estuary, delta, comprehensive treatment, countermeasures

1 Overview of Yellow River estuary delta

The modern Yellow River estuary delta generally refers to the sector area about 6,000km2 with Ninghai as its apex, which starts from Tuhai River estuary on the north and extends southwards to Zhimaigou river estuary. Less water with more sediment and relatively poor sea dynamic force in estuary creates a strong accretion estuary for Yellow River, resulting in continuous coastline extension to the sea. The measured statistics for 1950 ~ 1999 shows that about 73% of sediment into Yellow River downstream is transported to the delta area, and the annual mean sediment into the delta area is about 0. 87 billion tons. The special natural condition leads to broad wetland in Yellow River delta. Yellow River delta national nature reserve has a total area of 0. 153 million hm2, in which the core area of 0. 058 million hm2 and main functions is to protect new wetland ecosystem and rare and critically endangered birds , which is the important transfer station, the area of living through winter, inhabiting and breeding for bird migration from northeast inland of Asia and the west Pacific Ocean.

The Yellow River delta had less human activities in the history, but the migration for reclamation increased continually from 20th century. Since oil field was developed in 1961, especially after Dongying was established as a City in 1983, great socio – economic changes in Yellow River delta have been taken place. With land area of 7,923 km^2, population of 1. 946,2 million and GDP of 116. 6 billion Yuan, Dongying City now has become the important base for oil extracting and processing and the important economic zone of Shandong Province.

2 Main problems existing in Yellow River estuary treatment

In early period when Yellow River changed its course in 1855, the estuary was stable because large amount of sediment deposited in flooding plain upstream of Taochengfu and less sediment entered the estuary. After 1872, with the improvement gradual of downstream dike , the sediment into the estuary increased to lead to gradual estuary sedimentation, extension, and frequent swinging of the end of river channel. In a long period, estuary area on both banks downstream of Ninghai has dike of only 20 km, and the end of river channel is in a natural state of flux. Yellow River returned to the original course in 1947, from then to 1949, the left dikes in Yellow River estuary were constructed to Siduan and the right dikes were extended to Songjiajuan of Kenli County.

After 1949, with economic development in estuary area, the requirements for flood control was improved, arbitrary course changes was not permitted. Three artificial river course changes have been conducted as planned. After Yellow River have been changed to Qingshuigou flow path, Yellow River Conservancy Commission, Shengli Oil Field and Dongying local government have tried great efforts on treatment of Qingshuigou flow path. Since 1996, Nation has implemented Phase I Works of Yellow River flow path treatment into sea. The dike construction, river course treatment, Qing 8 bypass and some other construction works have upgraded the flood control capacity of river section in estuary, which stabilized the course upstream of Qing 7, reduced sedimentation of lower stream of Yellow River, and ensured the industrial and agricultural production and the safety of people's life and property.

Estuary treatment is an important component of Yellow River. The treatment in the 20 previous years has gained a lot of achievements, offering great promotion of socio – economic development in estuary area. Now the main problems existing in estuary treatment are as follows.

2.1 Unclear orientation and layout of Yellow River estuary treatment

Since 1990s, condition of flow and sediment entering the estuary has been changed greatly due to continuous low flow and less sediment, and as well as the increase of artificial interruption and change of water conservancy conditions, i. e. , operation of Xiaolangdi Reservoir, water and soil conservation , construction of key reservoirs on the stem and tributaries. The future flow and sediment condition will have great impact both on operation life of Qingshuigou flow path and on the arrangement of planned standby path. The general arrangement for Yellow Rive estuary flow path is the basic precondition for estuary treatment and development. At present, although Diaokouhe flow path has been ascertained as standby flow path, but macro consideration and arrangement in general flow path layout are absent, meanwhile, the concern, protection and management for standby Diaokouhe flow path from all aspects are not sufficient.

2.2 Imperfect flood control works which leading to low flood control capacity

Since 1990s, more serious sedimentation in main river channel and rise of relative erosion in estuary base level have resulted in decrease of bankfull discharge , rise of water level of equal flow, and decrease of flood discharg capacity. Bankfull discharge has decreased from 5,000m^3/s in 1980s to less than 3,000 m^3/s, and it was recoverd to some extent due to the water and sediment regulations of Yellow River after 2002. According to the design flood level, the dike of the left bank with the length of 26.8 km can not satisfy the requirements for height, covering 54% the left dike. The left dike whith full length can not satisfy the design requirement for width. The current height and cross – sections of river training works are not sufficient. The current river channel treatment works are not adequate, the individual works length is not enough to control river flow. Parts of dams buttresses are not high enough to control the flow tendency.

2.3 Imperfect system for storm tide control and low capacity against tide disaster

After many years' construction, the tide control works in Dongying City has got a certain capacity against storm tide, but the lack of general planning and the imperfect tide control system lead to integrated tide control capacity decrease. The notable tide control problems in north bank section of Yellow River in Dongying City are as follows: most of the storm tide control sections from Chaohe river to Tiaohe river have lost storm tide control capacity due to the discontinuity, capacity of Gudong and Zhuangxi storm tide control dikes close to the sea decreases because of coastal erosion and the impact from continuous sea – bottom scouring. In the dike section of Guanglihe ~ Zhimaigou which is about 5 km long, there is no storm tide control works.

2.4 Shortage of local water resources and serious pollution and waste of water resources

Dongying City is located in coastal area with poor local water resources, and the main water source for socio – economic development comes from Yellow River because Xiaoqing River and

Zhimaigou River which flowing through the district are polluted seriously and the available water is less. Water utilization efficiency at present is low due to the waste of water utilization, and it mainly present as less associated water – saving works in irrigation area, low reuse rate of industrial water, and large evaporation and leakage loss of plain reservoir. The local water quality deterioration accelerates the contradiction between water resources demand and supply. Meanwhile, serious over – extraction of groundwater in some areas leads to ground collapse, sea water rushing – in and some other eco – system problems.

2.5 Estuary eco – system damages in different degrees due to multiple factor

In the recent 20 years, with continuous industrial and agricultural development, Yellow River water and sediment entering the sea has reduced greatly, some problems appear in the estuary area, i. e., shrinkage of natural wetland, threat to biological diversity, salification of land, degeneration of natural pasture, etc. From 1993 to 2005, the natural wetland areas in Yellow River delta national nature reserve had reduced about 40%. The wild soybean in second protection class which grew in broad area now only appears in a few areas, and Yellow River Daoyu fish, China prawn and some other fishes have almost been extinct. The census in 1980 shows that the original wetland in Yellow River delta was 0.185 million hm^2, but sampling investigation at present shows that pasture in the first and second protection class which still have the original productivity before 20 years only takes 30% of the total area, and the theoretical stock – carrying capacity rate is 33% less than that in 1986.

2.6 Unsuitable current management system for Yellow River estuary treatment

At present, besides Yellow River Conservancy Commission in charge of Yellow River, the management system including local government, local government departments for land, sea and Yellow River delta national nature reserve, Shengli Oil Field Management Bureau, Jinan Military Region Production Base and some others have participated in management and development of Yellow River estuary. Yellow River Conservancy Commission is mainly in charge of estuary treatment project management. These management departments follow different management policy and legal rules in disorderly management status for different purposes, resulting in unfavorable management system, and non – harmonization for estuary treatment and development. The current management system can not satisfy the requirement for Yellow River estuary treatment progress, it has been a key limiting factor for estuary treatment.

3 Estuary treatment requirement of Yellow River treatment and development and regional development

3.1 Requirement of Yellow River downstream flood control and sedimentation reduction

From a long – term view, with water and soil conservation on Loess Plateau, sediment holding up by some reservoirs as well as downstream water and sediment diversion, the volume of sediment entering estuary area will decrease in a certain degree, but in the future a long period, Yellow River will still be a sediment – laden river, and the general tendency of estuary river course sedimentation and extension will not be changed. The annual mean water volume and sediment volume at Lijin Section from 2000 to 2020 are estimated as 20.54 billion m^3 and 0.385 billion tons respectively. The annual mean water volume and sediment volume at Lijin Secton from 2020 to 2080 are estimated as 18.114 billion m^3 and 0.579 billion tons respectively without considering the operation of Guxian Reservoir. The annual mean water volume and sediment volume at Lijin Secton from 2020 to 2080 are estimated as 18.099 billion tons m^3 and 0.528 billion tons respectively if Guxian Reservoir is put into operation in 2020. Large amount of sediment deposits in estuary area, leading to continuous increase of estuary delta area and river course extension, and this is unfavorable for downstream course scouring and flood control. According to the general requirements for Yellow River downstream flood control and sedimentation reduction, a larger sea area for sediment should be reserved at estuary to reduce estuary extension ratio and impact of retrogressive deposition as much as possible. Multiple measures should be adopted to reduce lower river course sedimentation and make the estuary river section sufficient discharg capacity.

3.2 Requirements of regional socio – economic development

Yellow River delta area is abundant in natural resources, including land, oil and gas, sea, etc. Located in around – Bohai – Sea economic circle and northeast economic zone, the delta is in the favorable geographic location, which has great development value and potential. It will be the important open economic area for energy, heavy chemical and agricultural development in 21 century. Yellow River estuary treatment has very significant impact on Dongying socio – economic development. Socio – economic development in estuary area requires a long – term stable flow path in Yellow River estuary. Controlling of flow path wandering range is advantageous for land resources development and infrastructure construction, which should reduce the impact on sea – farming development and port business as much as possible. Meanwhile, embankment project construction shall be strengthened to enhance the flood control capacity and to provide favorable condition for Yellow River water diversion.

With a large storage of oil and natural gas, Yellow River delta is the "Golden Triangle" of Shengli Oilfield. After 40 – year exploration, more than 30 oil fields and gas fields haven been found in the delta. The oilfield development requires Yellow River estuary treatment provide safety guarantee of flood control, and at the same time, flow path arrangement should combine with oil filed development, it shall favor the acceleration of filling sea for more land in the proposed areas (i. e. North bypass recently), shall favor turning oil extraction in the sea into oil extraction on land, shall favor removing the threat from coast erosion to storm tide control dike.

3.3 Requirement of eco – system environment protection

Yellow River delta wetland is a vulnerable eco – system itself who has poor water recharge condition. Most of the wetland is seasonal or short – period swamp except the tide – touched wetland and the river wetland with perennial flow and storage . The water and sediment resources of Yellow River is the decisive factor for wetland evolution, and Yellow River wetland is the core of Yellow River delta eco – system which plays a key role in maintaining benign Yellow River estuary eco – system. Estuary treatment must guarantee the water demand of estuary wetland to promote a sound circulation of estuary eco – system.

4 Countermeasures for Yellow River estuary comprehensive treatment

4.1 Treatment thought

Yellow River estuary comprehensive treatment shall base on scientific development to smooth the relationship among Yellow River estuary treatment, eco – system protection and socio – economic development in delta area in a correct way. Firstly, the treatment shall follow natural evolution regularity of Yellow River delta, exert fully resource superiority and promote sustainable regional socio – economic development with the precondition of guaranteeing the safety of lower reach flood control and the basis of maintaining a sound eco – system in Yellow River estuary. Secondly, the socio – economic development in estuary area shall obey the general layout for estuary treatment, take eco – system supporting capacity into consideration, and persist in the principle of harmonization between human and the nature. Thirdly, estuary treatment shall be in the mode of all – around strategic planning, integrated consideration, reasonable arrangement, and in – stages implementation for the purpose of maintaining the lasting peace and stability in Yellow River downstream and promoting the sustainable regional socio – economic development.

4.2 Main countermeasures

According to the general arrangement for Yellow River downstream flood control and sedimentation reduction and the requirement for estuary treatment from comprehensive estuary delta development, the strategy of Yellow River estuary comprehensive treatment is put forward as follows:

(1) In Yellow River estuary delta area, select Qingshuigou, Diaokouhe, Maxinhe, Shibahu and some other flow paths as the future flow path into sea for Yellow River. Qingshuigou flow path will be used form now, the standby Diaokouhe flow path will be preferred after Qingshuigou is used, and then other standby ones will be used.

(2) According to course – change controlling condition of 10,000 m^3/s at water level of 12 m (Dagu Elevation System) at Xihekou, stabilize the current Qingshuigou flow path of Yellow River relatively to realize 50 – year safety of the whole river flowing through construction and management of flood control projects.

(3) Establish delta tide control engineering system in Yellow River estuary to upgrade the capacity against storm tide disaster.

(4) Optimize water distribution for Yellow River eco – system, guarantee water volume for estuary eco – system, and restore wetland eco – system in Yellow River delta national nature reserve to realize a benign maintaining of estuary eco – system.

(5) Make reasonable water distribution for economic, people living and eco – system, and provide water resources guarantee for construction of efficient eco – system economy in Yellow River delta through comprehensive measures, i. e. , extension of warer source, saving, protection, and optimization, etc.

4.2.1 Arrangement of flow path into sea and flood control measures

According to course – change controlling condition of 10,000 m^3/s at water level of 12 m at Xihekou, the bypass change flowing sequence of the current Qingshuigou flow path is: current Qing 8 bypass → north bypass → original river course→ current Qing 8 bypass. Planned arrangement of towards – sea flow path shall be considered, and river regulation, dike consolidation by warping, dredging and some other comprehensive treatment measures shall be taken to keep the Qingshuigou flow path stable in the period of about 50 years. Diaokouhe flow path is protected as the main standby flow path.

The dike section which present height and strength can not satisfy the requirement for standard of planned level year shall be raised and consolidated. The works at vulnerable site shall be upgraded. Dike consolidation by warping shall be intergrated with dredging to avoid flushed breach and outburst induced by flood flowing along dike. For the river section above Qing 7, construction of river channel treatment works shall be strengthened to stabilize river flow and control river channel of middle flow for the purpose of smoothing the flow path of estuary section and upgrading the capability to discharge flood and sediment into the sea.

4.2.2 Storm tide control measures

Yellow River estuary storm tide control system consists of storm tide control works in the south and north side of Yellow River. In the south side of Yellow River, the bank section from Yellow River to Zhimaigou river, continuous storm tide control works consisting of tide control dike and gate shall be constructed. In the north side of Yellow River,. standby Diaokouhe flow path will be preserved in management range of Diaokouhe course (the bank section from Tiaohe river to Diaokouhe), and continuous storm tide control works consisting of storm tide control dike and gate shall be constructed in bank sections from Chaohe river to Tiaohe river and from Diaokouhe to Yellow River respectively. At present, the key point in storm tide control works construction is the bank section from Chaohe river to Tiaohe river in the north side of Yellow River.

4.2.3 Water resources utilization

According to the requirements for Dongying local socio – economic development and eco – system environment construction, the main measures for Dongying water resources development and utilization are as follows:

(1) Strengthen management of the water utilization from Yellow River, establish strict water price system, intensify upgrading of water saving in the existing irrigation area, adjust agricultural planting structure, optimize agricultural production mode, initiate efficient ecological agriculture to improve efficiency and benefit of agricultural water.

(2) Enhance industrial and domestic water saving. In implementation of thermal power plant and industry with high water consumption, air condensation, reuse of treated wastewater, and direct use of sea water shall be taken into consideration preferentially to solve the problems in water utilization for manufacturing base development in multiple approaches including broadening of warter sources and water saving.

(3) Raise the utilization rate of local runoff through measures for water resources protection and river gate project construction and with combination regulation of small reservoir.

(4) Use groundwater resources reasonably, and strictly restrict over – extraction of groundwater.

(5) The auxiliary works in Phase I Works in the East Line of South – to – North Water Diversion Project will be completed in 2010, the auxiliary works in Phase III Works in the East Line of South – to – North Water Diversion Project will be completed in 2030, and the efficient and full utilization of the water volume allocated from the East Line of South – to – North Water Diversion Project will resolve the problem of water shortage.

4.2.4 Environment protection

According to the requirements for maintaining a benign eco – system in Yellow River delta, eco – system water supply and distribution planning shall be constituted with river channel base flow, estuary wetland and estuary offing as the main supply objectives to provide important basis for Yellow River eco – system water dispatching. Based on the impact from ecologic evolution factor in the estuary and infrastructure construction, and with the combination of current situation of estuary eco – environment protection, the main work is to recover the degenerated wetland in Yellow River delta national nature reserve in Qingshuigou flow path in advance, recover the eco – system in estuary seashore wetland gradually, recover other degenerated wetland in Yellow River delta national nature reserve, river wetland, estuary seashore wetland, wetland in oil field and mine area, etc., and establish monitoring network for estuary eco – system and environment to realize dynamic monitoring for estuary and environment.

4.2.5 Establishments of management system and mechanism

In order to make an overall execution of all the tasks for the comprehensive treatment of Yellow River estuary area, the authoritative, efficient and harmonious management system for the comprehensive treatment shall be established, all kinds of management mechanisms shall be perfected, constitution of policy and legal rules shall be strengthened, duty and right shall be ascertained and relationship shall be harmonized further, and the key management position and function of Yellow River estuary management organization shall be enhanced. Firstly, raise the harmony of the combination of basin management and district management on the basis of ascertaining the event settlement right. Secondly, advance the democratic consultation mechanism, and establish joint conference system for comprehensive treatment of Yellow River estuary. Thirdly, based on the actual Yellow River situation, study and establish the multi – party investment mechanism for the comprehensive treatment of Yellow River estuary, including the investment from the country, local government and the benefited enterprises, etc., and constitute fund collection and utilization method. Fourthly, carry out Method for Yellow River Estuary Management in all around, deal with everything in strict accordance with the laws, bring the violator to justice, and confirm the authority of Method for Yellow River Estuary Management.

5 Conclusions

From the view of river treatment, the comprehensive treatment of Yellow River estuary area covers some pairs of problems, e. g. , downstream and estuary, river and sea, water and sand, flood control and water supply, engineering construction and environment protection, etc. From the view of regional economic development, the problems in the harmonious development of economy and society, resources development and utilization, and environment protection must be faced and solved, and all of these lead to the estuary treatment become a complex and perennial problem. The widely recognized concept of harmony between the human and the nature, the effective implementation of authoritative and scientific planning of estuary comprehensive treatment are the important preconditions and foundation to realize the sustainable development of Yellow River estuary area.

References

Chinese Hydraulic Engineering Society, Yellow River Research Society. Conference of the Yellow River Delta Problems and Countermeasures[M]. Zhengzhou: Yellow River Conservancy Press, 2003

Li Guoying. Keep the Healthy Life of Yellow River[M]. Zhengzhou: Yellow River Conservancy Press, 2005.

The Strategies of Land Development in the Yellow River Delta

Du Yuhai

Shandong Bureau, YRCC, Jinan, 250013, China

Abstract: The Yellow River delta is rich of land resources. But due to the influence of the factors of flow way into the sea, fresh water resources, ocean and land salinity, there are still 2.6 million mu lands undeveloped. The potential development is very huge. The land development strategies should be based on the combination of exploitation and protection in order to improve the salinity of the land, improve the land quality and develop the eco – economy.

Key words: the Yellow River delta, land development, eco – economy

1 Introduction

The current Yellow River delta was formed after the Tongwaxiang dike breach happened in 1855, and then the flood flew into the Daqing river. After many years' constant changes of the river channels, the river comes into being. It lies within eastern longitude from 118°10′ to 119°15′, northern latitude from 37°15′ to 38°10′, with an area of 6,000 km^2. In the area, 2,500 km^2 were created after 1855, and that is also the youngest land in China. Most of the area lies below the altitude 5.0 m (Huanghai sea level, hereinafter). The climate in this area belongs to warm, semi humid and semi drought continental monsoon style. The climate has the characteristic of sea monsoon, with four different seasons. And the average temperature is 12.5 ℃. The average annual rainfall of this region is 537 mm, among which 70% is concentrated in the period from June to September. The average annual water surface evaporation amount is 1,846 mm.

The land resource in the Yellow River delta is rich, the undeveloped land is about 170 thousand ha. At the same time, the land development in this region is constrained by many factors. So adopting what kind of development strategy is of vital importance.

2 The main constrained factors in land development

2.1 The Yellow River course into the sea

Because of the special characteristic of the Yellow River's much sand, the lower reach of the Yellow River has the evolution rules of silting, stretching, swinging, and changing courses. The bigger changes of the river course happened 10 times after 1855. So, in history, this area is under the threat of Yellow River floods frequently. The current Qingshuigou river course was formed in 1976, and the river flows 30 years so far along the course. Although the river course can last for some time, the river course change is inevitable. The regional development and the river course entering the sea formed the mutual constraints with each other.

On one hand, the urban development of the region requires the river course entering the sea not to change as freely as before. And we must consider the urban development construction situation. On the other hand, urban development construction must consider the Yellow River course entering the sea. At present, the Yellow River Delta Management Regulation has been issued, and the protection area of standby river course entering the sea has been clarified. Within this area, some human activities, including some development construction activities, will be constrained strictly.

2.2 Fresh water resources

Most of the rivers in the Yellow River delta are seasonal rivers. And the amount of the underground water can be used is very limited. The main type of the underground water is salted water or slight salted water with high mineralization. And most underground water can not be used as fresh water. So, 90% of water use in this region depends on the Yellow River. But due to the limitation of water resources of the Yellow River, the water allocated to the delta area each year is very limited. Especially in recent several years, the water amount from the Yellow River decreased dramatically. Generally, the water entering into the delta region is hard to meet the demands of the current ecology – system, industry, human life and agriculture. According to the prediction of the river flow of the Yellow River, the scarcity of fresh water resources in the delta region will last a long time. So, it is very difficult to realize the land development through using more water from the Yellow River.

2.3 Land salinity

The lands in the Yellow River delta are newly created lands. And the types of the soil are mainly tide soil and salt soil. Most of the lands are highly salted because of the low elevation of the land, the low underground water, and the shortage and uneven of the rainfall, and the large evaporation. Especially the lands formed after 1855, the salinity is more serious, and most of the lands undeveloped lie there. There are some plants that can endure salinity, mainly including some grass plant and shrub plant. But the growing is not good.

When drought season comes, large lands appear desolated, lacking virility. The salinity of the earth is the main reason why the eco – environment is so tender, and also is the main factor that constrains the land development.

2.4 Ocean

Because the Yellow River delta is sand coast, and the land elevation is low, it is under the threat of ocean floods, tsunami, sea level rising, and erosion of the seashore. There were four times storm tides that were as high as or above 3.5 m since 1949. Among which, the storm tide happened in April 5 th, 1964 inundated the land within the seashore about 22 ~ 27 km. The storm tide happened in Sep. 1st,1992 made the ocean flood inundated the area 10 ~ 20 km within the shore, and made 13 people die, 50 people surrounded by the flood, and destroyed many manufacture and living facilities, directly causing 500 million yuan lost. Additionally, although the area of the Yellow River delta appears an increasing trend, there are still some problems of erosion of the seashore. For example, in the Laodiaokou where the river enters the sea, the sea banks are always in the state of erosion after 1976, and in the most serious place, the eroded bank is more than 11 km.

3 The basic principles of the land development

3.1 In accordance with the Yellow River delta integrated harnessing plan

The silting, stretching, swinging, and course changing are the natural rules of the Yellow River delta itself. With the development of economy and society in the delta, the swinging and course changing freely can not be accepted. The Yellow River delta integrated harnessing plan provides the basic frame for the delta harnessing, the river course harnessing and other activities in the long run. And plan is a directive document for people to carry out human activities in this region. So, to develop lands in this region, we should abide by the Yellow River delta integrated harnessing plan. And we should do under the basic principles and guide lines of the plan. Especially, attentions should be paid to the Yellow River sand management and the river course changing in the delta.

3.2 Fitting for the fresh water resource carrying capacity

Because of the serious scarcity of the Yellow River water resources, it is hard to increase the water allocation in the delta area, as becoming the unchangeable trend. With the development of the society, there are some factors that require more water such as the population increasing, the improving of living standard of the people, the development of industry. The development of lands must be based on this reality. And the fresh water carrying capacity must be taken into account. Evaluations on water demands of new projects must be made. The scale of the projects that have no enough water source must be restricted. And the projects that have no way to resolve the water source problem must be prohibitted.

3.3 Paying attention to eco – environment construction

The amount and distribution of plant area, forest and rainfall is small and uneven. And the salinity is very serious. This leads to the vulnerability of the eco – environment. If there are some improper actions in land development, it is easy to make the environment further deteriorated. For example, the lost balance of the eco – system and the environment pollution. So, attentions must be paid to eco – environment construction. We must start from building sound environment, improving the capacity of the eco – environment to realize the good development of the eco – environment.

3.4 Combining the development and protection

The large area of the Yellow River delta, not only includes the current river course where the Yellow River enters into the sea and the place that is planned to be used as standby course, but also includes the national level natural protection zone that basically protects natural wet land system and birds. So the land development in this region must be combined with protection together. The land development that is outside the river course (including the standby course) and the natural protection zone has relatively few restriction factors, and can be considered in the first priority. The land development within the Yellow River flowing region must abide by the Yellow River Delta Management Regulation and some other rules. In the natural protection zone, protection should be placed in the first place, and any harm and destroy to the protection lands from any department or private should be prohibited.

3.5 Meeting demands of the entire economy and society development

When speaking of land development, people may first think about the food production, especially the current cultivated land resources gained more and more attentions from people. However, the development of the lands actually should take the resources, environment and the whole economy and society together into consideration. The saying that the development should be fitted for the whole economic and social development demands is just to make it coordinated with economy increasing and social environment protection, to meet the increasing material and mental demands of the people. It requires not only to produce the good social, economic and eco – environmental benifit, but also to improve the sustainable development and harmony between nature and human.

4 To develop eco – economy is the direction of land development in the delta

In broad sense, the eco – economy includes the eco – agriculture, eco – industry and eco – tour. The essence of the eco – economy refers the economy development based on the capacity of the eco – environment, ensuring the reproduction of economy at the same time ensuring the reproduction of the nature, and to realize the two wins of economy development and environmental protection, and to build up the integrated eco – system in which the economy, society and nature are in sound circulation. Considering the capacity of the Yellow River delta eco – environment and the capability of the nature reproduction, the land development in this region must enhance the eco – enconomy greatly.

4.1 Eco – agriculture

The eco – agriculture refers building up one or more high effective no waste systems that are mainly focused on one product, integrated development, changeable in many levels, and in good circulations, based on the fundamental equations of the energy changing and the co – living and co – supporting rules in the biologic system. Firstly, the planting structure should be decided and the primary production should be arranged. The primary product is the base of the eco – agriculture. It provides the most primary product of the whole system, and decides the development direction of the system. Considering the local climate, nature and water resource carrying capacity, the forest, fruit and grass land planting can be greatly developed, as water from natural rainfall can basically meet the demands of these crops. And these help to improve the local eco – environment. Properly arrange the food productions because they need relatively more water. Scientifically arrange economy crops to gain better economy effectiveness.

Secondly, according to the planting structure, reasonably arrange the raising product, making part of the primary product updated.

Thirdly, according to the situation of planting and feeding products, actively develop the byproduct manufactories, and at the same time pay attentions to the eco – system protection and water reuse. To enhance the primary reproduction together further promoting the value of the agriculture productions. Thus, the sound eco – agriculture based on forest, fruit and grass planting, together with feeding and reproducing can be built.

4.2 Eco – industry

Eco – industry is to simulate the eco – system functions, and to build up the industry eco – system chains of producer, consumer, and transfer. The target is to build low consumption, low or no waste and the harmony between industry development and eco – environment. The key of the eco – industry is the industry structures biologically behaved. The industry chains consist of resource producer as primary producer, manufacturer as consumer and reverser as transfer in the eco – chain.

The Yellow River delta is rich in resources. The potential development capacity is very huge. Currently, the industry products are mainly focused on resources manufactures, and the re – products still have a distance to meet the demands of eco – industry, and the recycling product is very weak. From now on, attentions should be paid to processing industry and recycling industry. The processing industry should be no pollution and no waste, changing the primary products in the goods that can meet the demands of people. The recycling products make the by – products become another resource and do no harm the environment, and changing them into new industry products.

4.3 Eco – tours

The eco – tour was first issued by a special counselor Ceballas – Lascurain from The World Conservation Union in 1983. At that time, he pointed out two main elements of eco – tour: one element is that the objective of the eco – tour is natural scenery, and the other is that the objects of the eco – tour can not be damaged. So, the eco – tour can not be equal to the traditional tour which require not damaging the eco – environment and traditional historical culture and is better for the long time sustainable use the tour resource.

The Yellow River delta has a very special characteristic. As a tour object, the natural scenery is very rich. If it is combined with eco – agriculture, eco – industry, the eco – tour resources can be improved further. People come here to have a tour, not only can they enjoy the natural scenery, but also can they increase their knowledge and get good education. Such can enhance the responsibility of loving the nature and protecting the nature.

Up till now, the tour industry in the Yellow River delta is in the state of starting, and there is much space to be developed. In the future, we should develop the tour industry strictly around the principle of taking the natural scenery as the tour object and the tour object can not be damaged. Do well in eco – environmental construction and the related infrastructure construction and the system building, attracting people to come here to have a visit. When people's mental needs are met, at the same time, the economy and society is developed. Also, attentions should be paid to protection, especially to protect the wet lands. When people are having a tour, they left only foot prints and take only photos. Such can make the tour resources a long time and sustainable use.

5 Salinity harnessing is the base of land development

To develop lands in the Yellow River delta, the salinity of lands is one of the most serious problems whether to developing eco – agriculture, eco – industry or to develop eco – tour or eco – environment construction. Because of the salinity of the lands, it is hard to ensure the primary production in the eco – agriculture and the eco – environment is very vulnerable. So if we want to get better effectives of economy, society and biology, the salinity of lands must be harnessed, and the land quality must also be improved, and this is the base of developing eco – economy.

The main reasons for salinity of the lands are listed as follows. The first is the high mineralization of the underground water due to the sand filling into the sea from the Yellow River. The second is the little and uneven distribution of the rainfall and big evaporation. The third is the low elevation of the ground and the high underground water table. As the first two reasons can not be changed by human, so, changing the elevation of the ground and underground water table are the best ways to change salinity of the lands, and also these two methods can be easily realized. If we control the underground water table at 3 m or deeper, we can control effectively the underground water evaporation and the rising of salted water to the ground, and reach the goals of changing the salinity of the lands and get the lands quality improved.

At present, parts of delta embankments have been strengthened by dredging and warping project. The soil of the top land in the dredging and warping zone is fitted for planting. So we can conclude there are following main measures to change the salinity of the lands. The first is to take the advantage of making full use of Yellow River sand resources and the large undeveloped land to improve the lands quality through self silt disposing or through machines; The second is through digging deeply and filling highly. The water body formed by digging deeply can maintain the characteristic of the wet lands; and the ground surface formed by filling highly can improve the situation of salinity and the land quality. Thus, the structure of earth lying in the up of the land and water lying in the lower layer of the land can be formed in most of the area. And the primary land development of planting in the up and breeding in the lower layer can be carried out. The interphase scenery of blue and green can be formed. This can make good foundation for realizing the comprehensive effectiveness of economy, social and eco – environment development.

Here, special attention should be paid to the point that the development of the delta should be carried out within scientific principles, avoiding short – eyes behaves. Up till now, the harnessment of the land salinity in the delta area has been done for many years, but there is still lack of over all plan that suits the development of eco – economy which should rouse the attention of people.

6 Conclusions

With the progress and development of the society and science, people have the ability to develop and protect the Yellow River delta area well. We believe that in the near future, the land salinity in most of this area can be harnessed and the capacity of the eco – environment can be greatly improved. The Yellow River delta will not be a place of desolation but a place full of vital force, and the long time harmony between the people and the nature can be realized.

Morphological Change of the Yellow River Estuary and its Training

Wang Wanzhan and ***Gao Hang***

Yellow River Institute of Hydraulic Research, Zhengzhou, 450003, China

Abstract: The paper presents the fundamental features of the morphological change of the Yellow River estuary due to the river inputs, tides, waves and other factors, and outlines the basic information of the estuarine training.
Key words: Yellow River Estuary, shore, tides, waves, channel avulsion, shift

1 Basic information of the Yellow River Estuary

The Lower Yellow River used to shift frequently on the Northern China Floodplain on the area north of the Huai River. It has alternately changed its course 9 times on the modern delta since 1855 when it switched its course northwards into Bohai Sea. It flowed as Shenxiangou River (S. R.) in 1953 ~ 1964, Diaokou River (D. R.) in 1964 ~ 1976 and Qingshuigou River (Q. R.) since 1976.

1.1 Regimes of flow and sediment coming to the estuary

Flow and sediment processes coming to the estuary, which is monitored at Lijin Hydrometrical Station about 100 km upstream of the river mouth, sees great variations in annual flow and sediment load, with long term averaged sediment concentration of 25 kg/m^3 (Table 1). Although much less annual sediment load coming to the estuary during Q. R. is universally taken as the key factor contributing to its longer running life of the estuarine course, it is not enough in describing why the D. R., which had received a middle – level sediment load and concentration, had surprisingly run for the shortest years (i. e., only 4 years) with a single channel of the three rivers.

Table 1 Average flow and sediment load

River course	Running life (a)	Water (billion m^3)	Sediment load (billion t)	Concentration (kg/m^3)
Shenxiangou (S. R.)	1953 ~ 1963	459	11.8	25.7
Diaokou River (D. R.)	1964 ~ 1976	433	11.0	25.4
Qingshuigou (Q. R.)	1976 ~ 1995	252	6.3	25.1
S. R. (single – channeled)	1953 ~ 1959	476	14.5	30.5
D. R. (single – channeled)	1968 ~ 1972	348	8.6	24.7
Q. R. (single – channeled)	1980 ~ 1995	245	5.8	23.7

1.2 Tidal conditions

There are two tidal amphidromic points with the constituent M2 within the Bohai Sea, one is close to the mouth of S. R. and the other close to the coastal city of Qinghuangdao. The tidal range varies, but around 1.0 m in the waters bordering the delta which contains diurnal, semi – diurnal tides and the tides between. Local tidal current is found the strongest, 1.84 m/s, measured at flow surface, near a protruding river mouth.

The local tidal current process lags about 3 hours, or 90 degrees in phase, behind the tidal level process with HHW corresponding to the stagnant tidal current. The estuarine channel has its lower reach, 15 ~ 30 km long, influenced by tides. The tidal current – influenced channel is found quite short, i. e. , only 2 ~ 3 km upstream of the river mouth during dry season and 0 km during the flood season.

1.3 Waves, water temperature and salinity

Water bordering the delta receives full directional spectrum of waves with the strong waves coming from NE, which has the significant wave heights bigger than 2.1 m, and maximum breaking depth of 4.6 m. The NE strong waves have been found playing significant role in changing the local morphology (Wang, Zhang 2007)。

Salinity wedge is found to intrude the estuarine channel only 2 km during flood seasons and about 10 km during dry seasons. Temperature in the sea changes with seasons. The water sees lower temperature near shore than offshore in the winter while it sees the reverse in the summer.

2 Morphological changes of the channel and the shore

2.1 Longshore sediment transport (LST)

Annual net LST load is estimated around 83,000 m^3, passing southeastwards a cross section normal to the middle eastern shore of the delta in 1985 (Wang, Zhang 2007), 91% of it contributed by the strong NE waves (Fig. 2). Similarly, the net LST is found 200,214 m^3, moving westwards on the northern shore. The LST movement is evidenced by the underwater moving spits on the northern shore.

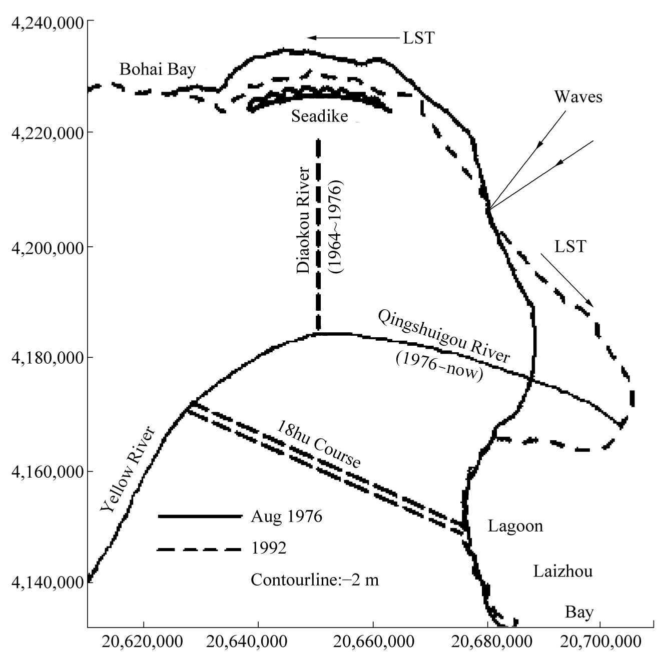


Fig. 2 LST and the Yellow River deltaic chore

2.2 Shore changes

In terms of ratio of the sediment load transported to the deep sea to the load at Lijin, S. R. sent most (38%) while Q. R. did the least (21%). Similarly, in terms of land made by per 0.1 billion t of sediment load, S. R. created the smallest (1.9 km^2/0.1 b. t) while Q. R. did the largest (3.5 km^2/0.1 b. t). Both indexes indicate a strong flow field in the water near the S. R and a weak one near Q. R..

The deltaic shore has extended seawards at a rate of 0.2 ~ 0.7 km/a since 1855, and could be made in a dynamic equilibrium state, as a whole, if the river empties 0.2 ~ 0.4 billion t of sediment into the sea.

The shoreline retreat near D. R. since the river was abandoned in 1976, is caused not only by the decrease in river sediment fed but also by the planting of a stretch of seadike near the Feiyantan oil field. With the seadike, the shore erosion has taken place not only at the dike toe but also downcoast, which is commonly seen along sandy shore with a stretch of seadike.

The eastern shoreline before 1996 turned clockwise so that it approached to be perpendicular to the NE approaching waves, decreasing LST rate gradient (Wang, Zhang 2007).

2.3 Morphological changes to the river course

A typical course of the Yellow River on the delta often evolves through three stages, i. e, with multiple branches in the first stage, with a single channel in the middle stage and channel avulsing in the last stage.

2.3.1 Channel length to the mouth

The estuarine channel extension rates of S. R., D. R. and Q. R. are found at 3.45 km/a in 1953 – 60, 2.68 km/a in 1964 ~ 1976, 2.0 km/a in 1976 ~ 1995, respectively. The Q. R. channel length has maintained relatively constant in the late years due to mild river sediment load.

2.3.2 Changes in channel morphologies

Despite the facts that the lower Yellow River bed and estuarine bottom have risen by a similar margin, about 2 ~ 3 m since 1949 (Fig. 3), and that the upper part of the estuarine channel is found easily eroded by high flow and deposited by low flow, which is similar to the Shandong part of the Lower Yellow River in this aspect, but the middle and lower estuarine parts are found liable to be deposited even under high flow, due to effect of tides, and further, the middle part has a continuously decreasing slope while the lower part keeps a steep slope. Consequently, the longitudinal profile of the estuary gradually evolves into one with a terrace shape. The process is similar to those within the sediment – laden reservoirs like the Xiaolangdi reservoir (Wang, Zhang 2006) (Fig. 4).

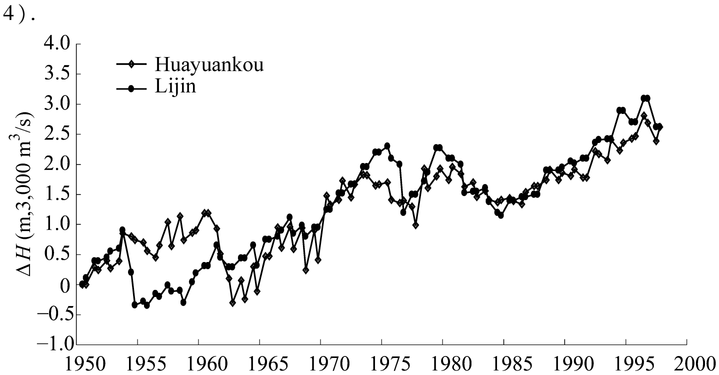


Fig. 3 Change in the Lower Yellow River Bed

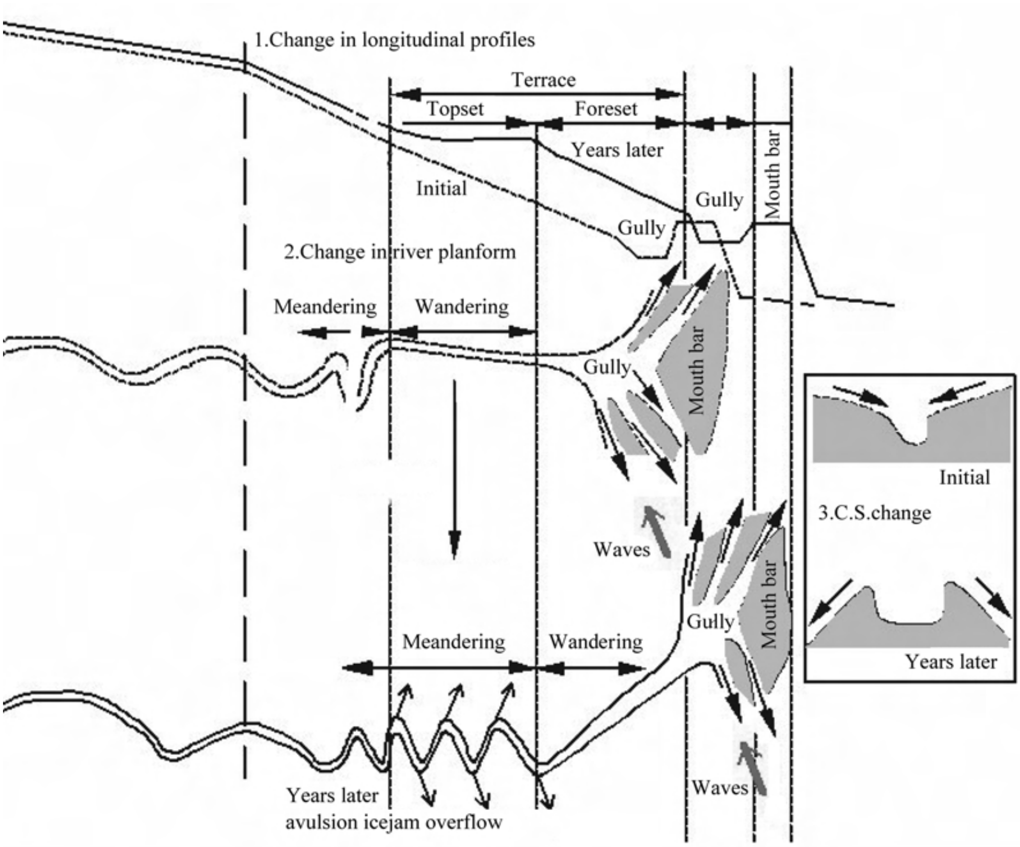


Fig. 4 Morphological change of the Yellow River estuary

With its slope decreasing, the middle part evolves from straight to meandering while the lower part remains straight and wandering. In the same period the lateral slopes of the local floodplains have been increasing. When the slope of the middle part decreases to a critical extent, the first channel avulsion will take place, always at the site where the middle and the lower parts meet. Then channel avulsion will move upstream until the delta apex. In addition, the mild – sloped part is liable to be overflowed and be ice jammed(Wang,zhang 2006) (Fig. 4).

2.3.3 Effect of the river mouth bar on sediment transport seawards

It is found that there always exists a transverse gully formed just landwards of the river mouth bar (Fig. 5). More importantly, somewhere within the gully there always is a maximum sediment transport seawards(Wang, Xia 2003) , which means the rive mouth bar has resistant action on sediment transport seawards as expected, but the action is limited just downstream of the maximum transport site. Again, it justifies that the deposition within the estuarine channel is not caused by the river mouth bar, but by tides as mentioned in section 2.3.2. Of course, the understanding doesn' t deny the necessity for further research on the effect of the attempt to remove the river mouth bar on its immediate upstream channel.

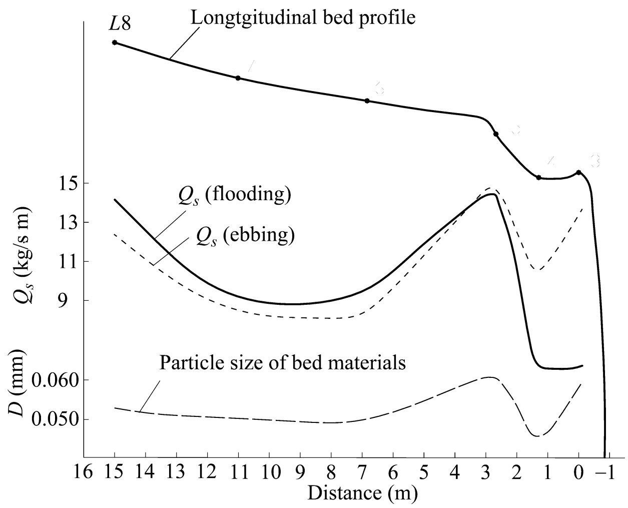


Fig. 5 Effect of the river bar on sediment transport

2.4 Morphological effect of estuarine extension on its upstream channel

So far, harmonious understandings have been achieved about the effect of the estuarine channel shortening on the morphology of its upstream channel. The channel shortening may lead to erosion to the upstream channel, depending on other factors, say, whether or not there are significant differences in channel bottom elevations between the new channel and the abandoned one.

In contrast, there are greatly differing ideas about the effect of the estuarine extension in terms of the length of the affected upstream channel, which can be categorized into three groups. One holds that the estuarine extension has caused the whole Yellow River bed (i. e., 900 km – long upstream channel) to rise by an identical margin (Wang 1982). The second group holds that the effect cover about 220 km upstream (Pang 2003). And the last holds that effect covers quite shorter, (i. e. 70 km, at most) upstream (Zeng et al. 1997).

The great differences are caused by the complexity of the morphological changes and unavailability of a numerical model of high precision for the Yellow River estuary system.

3 Training of the estuary

Training of the Yellow River estuary is subject to the local social, economic and technological developments. Until 1949 river dikes for the lower Yellow River had been gradually expanded downstream but not to the coastline in 1855. Namely, there was no training done to the estuary at that time.

In July 1953, a significant attempt in the training was done to the then three active courses by abandoning two of them and converging all the flow to the left one, i. e., Shenxiangou River (S. R.) in order to improve the flood delivery. Another training attempt was done on January 1, 1964 to alleviate ice jam – caused flooding by abandoning the S. R. and creating a new course, called Diaokouhe River (D. R.) since then. In 1975, the D. R. had to be abandoned due to the flow level has reached the design level, so another new course, called the Qingshuigou River (Q. R.) since then, has come into existence.

In summary, before the early 1960s, when oil had not been found on the Yellow River delta, the estuarine courses had run at large with less training efforts to them. Afterwards, the local increasing oil mining and the other industries led by the former have made more and more demands for the river training hoping for a flood – free environment.

3.1 In 1949 ~ 1976

In response to more and active economic activities on the delta, training efforts were made to the estuary. The river dikes were expanded to the estuarine channels, like the Deltaic Southern River Dike and the Backdrawn River Dike, Deltaic Eastern River Dike and Deltaic Northern River Dike, and approach channel to the Q. R. In addition, the South – expanded Dike Ring was completed south of the southern river dike around Lijin for the top first purpose of solving ice jam problems caused by the local narrow channel, and for flood control and diversion for land warping and irrigation. Besides, 18Hu diversion – for – land – warping works was completed in 1969. Water diversion gates were completed at Wangzhuang, Gongjia, etc. Irrigation – supporting works were made at Shengli, Xiaokaihe, etc. Water drainage channels were made along the Xisha River, the Maxinhe River and other small local rivers on the delta. A stretch of sea dikes were built along the northern deltaic coast against storm surges' attack.

3.2 In 1976 ~ now

3.2.1 In 1976 ~ 1993

In response to more rapid economic development on the delta, training activities were intensified to the Q. R. since 1976. The Deltaic Southern River Dikes were improved and a new stretch of backdrawn river dike was built starting from Aug. 1976. Dredging was done in the Lijin channel as a trial project in 1977, from which it was found that dredging was able to decrease the local channel slope, but cause deposition 300 m downstream unfortunately.

Another trial training campaign was done to the estuary in 1988 ~ 1993, which includes blocking the branches from the river, removing the flow barriers in the channel. Besides, dredging by towing rakes, by thruster stirring and by flow jetting were carried out in the lower Q. R. A 40 km stretch of low – crested mound was made. Flow guiding groins, 12 km long, were modified. Flow guiding works were made at the course change site (Xihekou) and downstream. The Deltaic Northern River Dike was expanded along the No. 6 Road to the Gudong Dike Ring. Diversions for land warping were done in the flood seasons. All the measures mentioned here and others not mentioned acted up together hoping for enforcing the Q. R. to flow into a single channel, improving the flood control situation.

3.2.2 Phase – one training works for the Yellow River estuarine course after 1993

A milestone was erected in the course of the Yellow River estuary training in the late 1980s and the early 1990s. Plan for the Yellow River Estuarine Course Training, which was completed by Yellow River Conservancy Commission (YRCC) in 1989 and approved in 1992, includes the following main points, among others, as follows (Fig. 6).

By following the principle that the training of any Yellow River course should be in harmony with the local economic development on the delta, the plan proposes to maintain the Q. R. running on a long term basis. The next course will be either of the abandoned D. R. or the abandoned Maxinhe River, both of which should be protected and reserved. It is estimated that the Q. R. can run another 30 ~ 50 years before it expires if the design flow level is controlled between 12 ~ 13 m for a flood of 10,000 m^3/s, on the following conditions:

(1) that the river course is used in the sequence from the channel in 1987 to Northern Fork 1, then to North Fork 2.

(2) that structural and non – structural measures are taken. The Deltaic Northern River Dike is expanded. The Southern Dike of the Gudong Dike Ring is expanded. The Deltaic Southern River Dike is heightened, made stronger and is extended. Seven flowing guiding works along the reach from Yihezhuang – Q7 are completed. Branches downstream of the Q7 blocked. Irregularly timed channel dredging is done. Supporting works are made for North Fork 1, and other measures (Fig. 6).

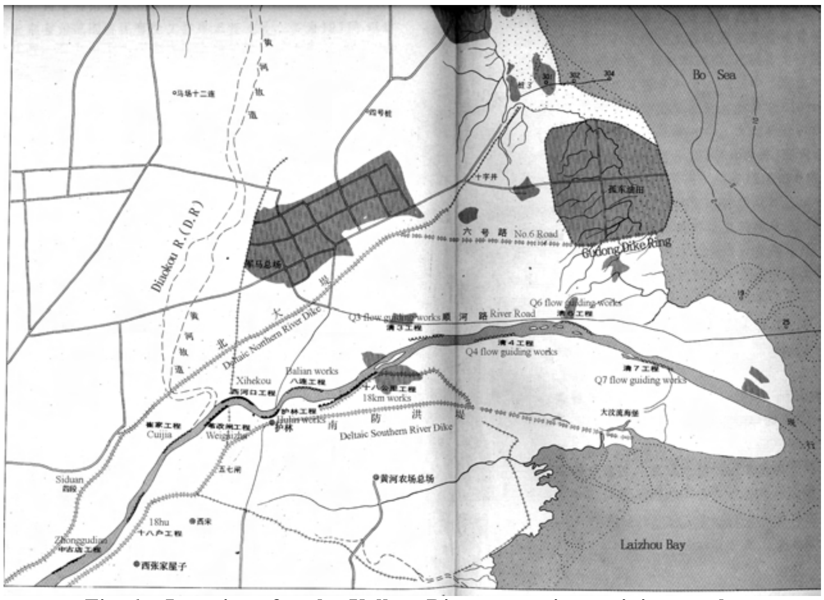


Fig. 6 Locations for the Yellow River estuarine training works

(3) In line with the plan, Proposal for Phase One Training Works for the Yellow River Estuarine Course, with a budge of 0.364 billion yuan in RMB, was made in 1993 and got approved in 1996. All the works listed in the proposal had been completed before they passed the official examination in June 2006. They provide a safe environment for the deltaic social and economic development.

3.2.3 Man – made estuarine channel shift at Q8

In order to mitigate flooding risks on the delta, extend the years of the Q. R. running and make new land for the oil mining, a proposal, which had been justified that it wouldn't interfere in the Plan made in 1989 as mentioned above, got approved to shift the lower Q. R. at Q 8 to the left. The man – made shifting, which made the length to the sea 16 km shorter, was found to make the upstream channel under erosion to some extent.

3.2.4 2000' Implementation Scheme for the Yellow River Estuary Training and Service Setup

In order to keep the training sustainable, the National Minister of Water Resources approved in 2001 the 2000' Implementation Scheme for the Yellow River Estuary Training and Service Setup, which includes the broadening of the Deltaic Northern River Dike and the construction of the river dike road, diversion for land warping at Lijin, construction of the river dike road at Lijin, construction of the extension to the Dongba flow guiding works, setup for a professional flood emergency team armed with mechanized facilities, construction of the river dike road at Kenli, and setup for a hydrometric station at T – crossing. Most of the items had been completed by Oct. 2005.

3.2.5 Channel dredging for river dike broadening

Channel dredging for the local river dike broadening was completed in 1997 ~ 1998, 2001 ~ 2002, and 2004 in the river reaches between Zhujiawuzi and the cross section Q3. There was 10.57 million m^3 of sediment was removed out of the dredged channel, which is 53.6 km and used to broaden the local river dikes of 24.8 km.

With data analysis and numerical modeling, it is found that the channel dredging from Nov. 1997 to May 2005, made deposition 4.42 ~ 5.28 million m^3 less in the channel from Lijin – Q6 than that without such dredging.

3.2.6 Non – structural measures

Non – structural measures have gradually come to the list of the training measures. One of the examples is given here, which shows the change in ice – caused flood fighting. In 1950s, measures for fighting the ice jams or ice – formed dams were often by exploding and breaking. Later on, it was found that the Southexpanded River Dike Ring works didn't achieve significant effect in ice fighting(Chen 1996). Since the late 1970s, the Sanmenxia Reservoir has come into use to prevent ice jamming or ice damming, consequently having much less occurrences of ice troubles since then.

An empirical ice model had been used for the Yellow River estuary before the operation of the Xiaolangdi Dam starting from 1999. Unfortunately, the applicability of the empirical model to the estuary has been disabled because the dam operating has changes the channel of the Lower Yellow River and the estuary significantly. Therefore, it is of importance to develop a morphodynamic and ice – dynamic coupled model

Another example in using non – structural measures in the whole river (including the estuary) training is by operating the Xianglangdi Dam to flush and deliver the sediment to the sea. It is found that the channel bottoms of both the lower Yellow River and the estuarine channel has been made about 1m lower, and narrower since the Aug. 1996 than before, due to the combined effect of the shortening of the estuarine length, the channel dredging, the dam operating including the regulating of flow and sediment processes.

The Yellow River Conservancy Commission has been completing physical and numerical models, including the physical and the numerical models for the Yellow River Estuary.

3.3.7 Problems in the 21 st – century integrated training of the Yellow River

YRCC, in the recent years, has been making a plan for integrated training of the Yellow River Estuary with flood control and ecological protection included.

The problems nowadays are, among others, flooding risks, unbalance between supply and demand for the Yellow River water and sediment, how to determine the ecological objectives to be protected and the measures for them, competing for the limited deltaic land areas one between next river course and the local social – economic developments.

4 Conclusions

In the past decades, masses of efforts have been directed to the monitoring and research on the Yellow River including the estuary, resulting in rich research results and knowledge of the fundamental facts and the laws governing changes of the estuary in terms of morphology and other aspects, which have provided firm technical support for the policy making in the training.

(1) The current Yellow River estuarine course has been made to run for 31 years, which is much longer than the average life span, i. e., about 10 years, of the late river courses on the delta.

(2) Influenced by the river flow, sediment, tides, waves and other factors, the Yellow River estuarine course, the current one and the previous ones, tends to morphologically evolves from deposition/extending seawards process to avulsing/shifting process. Further, the estuarine extension seawards is sure to make its upstream channel rise despite greatly differing understandings of the affected length.

(3) An integrated plan for the training of the estuary is a must to be under development. Harmony between the deltaic social/economic development plans and the Yellow River training plans should be essential and must be made, all subject to the nature of the dynamic river. Large enough room should be prepared for the river to go on the delta.

(4) It is necessary to have a sustainable monitoring and research on the Yellow River including the estuary.

References

Yellow River Reconnaissance, Planning, and Design Institute. Report for the Plan for Training of the Yellow River Estuary[R]. Aug. 1989.

Wang Wanzhan, Zhang Huaxing, Morphological Changes of the Yellow River Deltaic Shore[J]. Journal of Yellow River, No. 2, 2007.

Wang Wanzhan, Zhang Junhua. Study on the Morphological Changes of the Yellow River Estuarine Channel[J]. Journal of Scientific and Technical Developments in Water and Hydropower, No. 2, 2006.

Wang Wanzhan, Xia Xiujie, et al. Should the sand bars at the Yellow River mouth be removed? // Proceedings of 1st Yellow River Forum[M]. zhengzhou. Yellow River Press, 2003.

Wang Kaichen, Relations between the lower Yellow River and the estuary[J]. Journal of Sediment Research, 1982(2).

Pang Jiazhen. Morphological changes of the Yellow River estuary on its upstream channel // Proceedings of Conference on the Problems and Training of the Yellow River Estuary, edited by Chinese Hydraulic Association and Yellow River Study Association[M]. Zhengzhou: Yellow River Press, 2003.

Zeng Qinghua, Zhang Shiqi, et al, Morphological Changes of the Yellow River Estuaryandits Training[M]. Zhengzhou: Yellow River Press, 1997.

Report for current situation in training the Yellow River Estuary, Problems, Proposal[R]. Yellow River Estuary Bureau, Nov. 2006.

Chen Xiande. Yellow River Hydrology[M]. Zhengzhou: Yellow River Press, Oct. 1996.

The Study of Twin – jetties to Harness the Yellow River Estuary by Using the Sea Energy

Li Xining[1] , ***Yu Xiaolong***[2] and ***Zhang Sheng***[3]

1. Yellow River Shandong Bureau, Jinan 250013, China
2. Reconnaissance, Design and Research Institute, Jinan 250013, China
3. Shandong Longxinda Consultation and Supervision Limited Company, Jinan, 250013, China

Abstract: Construct twin jetties in the Yellow River estuary, transport the sediment to the deep area in the sea, which is of great sea energy, in order to decelerate the speed of the sand aggradation and steady the estuary watercourse to the sea. Study indicates that the twin jetties whose design breadth is 500 m should be arranged between the high water level and −10 m isobathic line. In the plan, the twin jetties, whose watercourse breadth is from quondam 1 ~ 2 km to current 0.5 km, looks like a trumpet. The construction of the twin jetties is: the geogrid section from quondam diversion dike to low tide line, the sand fill tube bag section from low tide line to −2 m isobathic line, the concrete hydrodynamic flashboard section from −2 m isobathic line to −10 m isobathic line.

Key words: estuary, harness, channel, sea energy, twin jetties

1 Instruction

Estuary, where kinetic condition and river channel process are complicated because of the dual functions of tides and rivers, is the area where the river flows into the ocean. Generalizing the internal and international experience of harnessing estuary, we can conclude that it's a valid approach that to combine river regulation and river dredging together to harness the estuary. For example, Mississippi was harnessed in the 1830's in order to clean out the entrance bar; at first, chain dredgers were used to dredge the sea – route, but watercourse was filled up as soon as the storm occurred. Subsequently the twin jetties was introduced, spur dikes were built inside of the diversion dike in order to restrict water current and accelerate the velocity of flow, which makes the needed water depth. The furcation of upriver left bank was regulated by spur dike cluster in the interest of increasing SW watercourse branch flux , which counteracted the restriction of harbor entrance; The waterway axes deflected 35° toward east in order to avert from the threat of the aggradation which was caused by seawater and freshwater mixing together in flood season. By taking the above – mentioned engineering measures, the water depth of the estuary entrance bar riverway was maintained. Rhine frith where Holland inflood the North Sea, at first was managed from the partial standpoint in very long period, and wasn't taken into account from the overall situation, therefore it doesn't attain the wanted effect, whereafter the river regulation programming was instituted and then put in practice, and the effect was prominent after semicentennial people's hard work. The new watercourse in Rotterdam was excavated in the 1860's, in the beginning navigation channel whose size is 50 m wide and 3 m deep was dredged up within the scope of 5 km waterways, which was expected to form the wanted size by scouring and also expected that sediment depositing in estuary was swept away by tide, but it didnt achieve the anticipant result. Since 1881, manual measures were afresh adopted, and then people began to build spur dikes and simultaneously to dredge up the watercourse and the shoal of estuary. By combining training works and river dredging together, the new watercourse was successfully constructed and was open to navigation favorably. In the late 1960's, the new harbor of Holland was enlarged especially by dint of dredging to maintain the biggish water depth besides constructing south & north dike and other projects. Seine, Delaware River, Saint Lawrence were mostly harnessed by means of combining river regulation and river dredging together. Yellow River estuary is where sea energy and river energy combine. Study suggests that Bohai Sea current (including tide current, gravity current, wind current, storm current, residual current, etc), wind field and Yellow River surface flow interact, and the interaction can produce great power that is able to transport sediment towards open ocean and the area that is away from estuary, further more this kind of power will increase with the sand spit's reach, the maximal sand – transporting function lies on the direction of the sand spit's reach. It is supposed that if some projects which can scour sand by flow contraction are built in both sides of the sand spit in addition to dredging, entrance bar can be swept away, sediment discharge will increase, the pace of aggradations will be minished, and then the purpose of prolonging the current life of the Yellow River waterway will be achieved. Making use of the twin jetties which makes the Yellow River water flow towards deep water area where there is great sea power can strengthen sea energy and river energy, enhance the transportability of sediments, decrease the amount of the sand aggradation, and can achieve the efficacy of sand scouring by flow contraction.

2 The intention of building twin jetties

When watercourse arrives at estuary, it loses engineering restriction, and the stream flows in river channel which is formed by the sediment depositing not long ago, the extension of aggradation is increasing, the watercourse gradient ratio disappears, the silt – carrying capacity of the watercourse itself declines greatly, which is the basic reason why the sandy estuary of Yellow River deposits and sways. The sediment that is transported from Yellow River drainage area to estuary district has three end – results: namely land、contiguity to the sea and open oceans. The sediment depositing on land aggrades the riverbed and drives up the surface of the delta; the sediment transported to open oceans, some of which diffuse distance even out of Bohai Sea, some of which settle in the area away from the estuary, which aggrades the seabed; The sediment depositing in contiguity to the sea sedimentate to be land, which causes the seacoast of the estuary extend. According to the statistic since 1855, the renascent land of the Yellow River delta has an area of 2,470 km^2, thereinto in the past actual 64 years through 1855 ~ 1953, the renascent land has an area of 1,450 km^2, 23 km^2/a; in the past years through 1953 ~ 1991, the renascent land has an area of 1,020 km^2, 26 km^2/a. Since QingShui channel which is the current access to the ocean was used, twenty percent of the sediment which should be transported to the ocean sedimentated on land, sixty percent sedimentated in contiguity to the sea, twenty percent sedimentated in open oceans.

The intention of the twin jetties construction is to make the Yellow River water flow into the ocean chronically and to steady the estuary and the river trend. Encircling the aim, the duty of the twin jetties construction is to lead the water current inflood into the ocean, to scour sand by flow contraction, to make the best of the river energy and the tide energy in order to enhance silt – carrying capacity, to transport sediment to the open oceans, to eliminate the aggradation brought by shore current, to decrease the amount of sediment aggradation, to keep the estuary unblocked. Considering orographic condition of the shallow sea、storm effect、construction and other factors, subsection schemes of the twin jetties should be planned, then each subsection scheme which is economical and technically feasible should be selected among those planned schemes.

3 The research of the arrangement of twin jetties

The twin jetties which are arranged from the high tide line should make full use of the sea energy. Considering that the stream surface of the debouchment and the sea level intersect at – 10 m isobath, meanwhile the toe of slope of the entrance bar is also at – 10 m isobath, namely the leading edge of sand spit is at – 10 m isobath, therefore the tail end of twin jetties is arranged at – 10 m isobath.

The design flow of twin jetties is 3,000 m^3/s, which keeps downstream flow not occurring on the flood plain under the control of the Xiaolangdi reservoir. The river's main channel around the area is about 500 ~ 600 m wide. Because the twin jetties which is a kind of overflow dike should scour sand by flow contraction, 500 m is elected as the direct distance between the twin jetties.

The orientation of the twin jetties should be consistent with the tide as much as possible. The direction of the strongest wind in estuary district is ENE which is the tide ' s direction, so the orientation of the twin jetties should be ENE. At present the orientation of watercourse to the ocean is ENE, thus the twin jetties is arranged along the orientation of the current river channel.

The design trait of the twin jetties is: the south part is long (till − 10 m isobath) , the north part is short (till − 5 m isobath) , and the south part is higher (the design elevation of the south side of twin jetties corresponds to the water level of 3,000 m^3/s) , the north part is lower (the design elevation of the north side of twin jetties corresponds to the water level of 2,000 m^3/s) . The north side length of twin jetties is shortened in half ,which makes for transporting the river sediment towards the north, further more, the sediment transported to the north can subside to defend the Guyongdong levee. Under the condition of the great northeaster in winter and the condition of both the higher south side of the twin jetties and the lower north side of the twin jetties, storm rapid flow can engender silt − carrying effect which can take away the river sediment and keep the harbor entrances flowing.

For the sake of construction convenience and integrity, the original diversion dike extends through to the diversion dike below the high tide line. The left bank extends 5 km from the transect Cha 3, the right bank extends 6km from transect Cha 2, as a whole the extension part appears a trumpet, which makes for storing up tidewater at the time of spring tide and sweeping away entrance bar at the time of ebb tide. In a sense, the twin jetties act as a reservoir storing up tidewater. In the mass, the twin jetties is divided into four parts: the extension section, the claybank section combining geogrid of 5km in length, the sand fill tube bag section of 2. 5 km in length, the hydrodynamic flashboard section of 2. 63 km in length. The left side of the twin jetties has a length of about 15. 13 km, the right side about 16. 13 km. To avoid being scoured, 2 km long slope protection of prefabricated concrete blocks or dry stone wall is used at the back − end of the extension section.

4 The structure design of the twin jetties

4.1 High tide line ~ low tide line

The extent between high tide line and low tide line is about 5 km, flood plain is flat, and it is convenient for traffic.

It is analysed and compared that both geogrid and plastic woven bag filled with soil are suitable to this section. Geogrid can combine the earth better and can be seasoned with groundwork distortion, furthermore geogrid can be operated conveniently. Compared with geogrid, operational procedure of plastic woven bag filled with soil is complex, therefore it is appropriate to choose the scheme of geogrid which is paved three layers whose spacing is 0. 5 m.

Compared with slope protection of dry stone wall at the aspect of building and economy, slope protection of prefabricated concrete blocks is adopted. To avoid mound ' s collapsing, huge stone blocks or wire box filled with stone blocks are used to be base frame, and a layer of filtration fabric is paved between soil and prefabricated concrete blocks. In this section, the design top width of twin jetties, whose design slope gradient is 1∶2. 5, is 5 m wide. It is evaluated to invest about 6. 73 million Chinese Yuan/ km.

4.2 Low tide line ~ − 2 m isobath

The extent between low tide line and − 2 m isobath is about 2. 5 km, which belongs to shoal areas. Compared with portable dam and riprap dam at the aspect of building and economy, sand fill tube bag which is of excellent adaptive capacity to distortion under water is economical and can be easily put in practice, at the same time, people nowadays possess of mature experience in sand fill tube bag by practice, so sand fill tube bag is recommended. In this section, twin jetties are constructed with sand fill tube bag whose diameter is 0.8 m. Sand fill tube bags, one end of which is pouring lip whose length is 1m and whose diameter is 0.2 m, the other end of which is spilling lip whose length is 1m and whose diameter is 0.2 m too, link together by cords. To meet the demand of suspension resistance, sand fill tube bags are filled with slurry whose concentration is within 1,100 ~ 1,300 kg/m^3.

Compared with slope protection of prefabricated concrete blocks, slope protection of earthwork module concrete is adopted because earthwork module concrete which is of excellent erosion resistance、flexibility and integrity can be operated under water. Furthermore, earthwork module concrete is of good mechanization of operation and of low upkeep costs. To avoid mound's collapsing, huge stone blocks or wire box filled with stone blocks are used to be base frame, and a layer of filtration fabric is paved between soil and prefabricated concrete blocks. In this section, the design top width of twin jetties, whose design slope gradient is 1:2.5, is 5 metres wide, and it is evaluated to invest about 14.54 million Yuan/ km.

4.3 −2 ~ −10 m isobath

The extent between −2 m isobath and −10 m isobath is about 2.63 km, and this section's water depth is between −2 ~ −10m, which makes it difficult to operate. Let's compare the floating caisson with the hydrodynamic flashboard.

Relative to other construct techniques, the floating caisson is of great bearing capacity, big rigidity, small excavation quantities, simple construction equipment, convenient operation, but before the floating caisson is put in water, people should do hydraulic pressure and watertightness experiment, none but the experimentation is successful, the floating caisson can be put in water, furthermore, it is inconvenient that the floating caisson is transported from product factory to building site. In estuary district, the hydrodynamic flashboard has been used widely in the field of retaining wall, baffle dike of critical levee section, therefore people have had considerable experience in design and execution, and have possessed some matching construction equipments by perennial great effort. The hydrodynamic flashboard is of low cost, few − maintenance, convenient operation, more prefabricated part, which can leave out a lot of construction work quantity of cofferdam, excavation and dam body. In conclusion, we apply the hydrodynamic flashboard to this section. Sheet pile wall is a kind of water − retaining or earth − retaining structure which is made up of sheet piles. Permanent sheet pile wall is usually used in the field of dock and harbor engineering and river engineering, such as wharf, dike, embankment. Sheet pile wall is especially favourable under water. In the light of under stress, sheet pile wall can be classified the cantilevered sheet pile wall and the anchored sheet pile wall, the cantilevered sheet pile wall mainly keep the stability by dint of the enough burial depth; while the anchored sheet pile wall keep the stability by dint of the underprop which is installed at the top of the sheet pile wall. Because this engineering section lies abyssal zone, moreover it is difficult to install underprop, then the cantilevered sheet pile wall is selected. The doublebank sheet pile wall applied to this section, which is 8 ~ 18 m high, is made up of two rows of singlerow sheet pile wall which is 0.3 m thick, and reinforced concrete apical plate connects the doublebank sheet pile wall whose thickness is 3.6 m. It is evaluated to invest about 78.46 million Yuan/ km.

5 Conclusions

Since the first waterway regulation projects and twin jetties projects have been sequentially put in practice in the late 1990's, the first aim that QingShui channel can steady itself current routeway for 30 years has been achieved, which solves the estuary district instability situation that is "the pressure of the water cause the Yellow River Levee to crack twice in three years, and there is a river diversion every ten years". Nowadays the Yellow River delta which was desolate, uninhabited and of major floods before has developed into a new economic growth zone in eastern China, and

Dongying, which is of economic prosperity and is in beautiful surroundings these days, has grown into a modern and popular coastal city where the local people are living and working in peace and contentment. It is supposed that QingShui channel can extend the time limit of itself current routeway for another 30 ~ 50 years if twin jetties projects contiguity to the sea, which makes full use of river energy and sea energy to transport sediment and to decelerate the speed of sand aggradation, is carried into execution unceasingly. By then, the Yellow River delta will show itself a new aspect of the long – term stability, prosperity and development, and sequentially the outstanding economic benefit, social benefit and ecological benefit will come into being.

Research on Yellow River Estuary Flow Course Schemes

An Cuihua*, *Ding Dafa*, *Tang Meiying* and *Chen Xiongbo

Yellow River Engineering Consulting Co. , Ltd. ,YRCC Zhengzhou, 450003,China

Abstract: Estuary features and evolution tendencies of the Yellow River (YR) are analyzed in this paper. Following the YR estuary evolution law and locol economic and social sustainable development, the feasible YR estuary flow course and schemes are put forward. Diversion control standards of YR flow courses, branch diversion schemes for flow course of Qingshui Gully and spare estuary flow course schemes are studied. Arrangement of the YR estuary flow courses are presented.

Key words: Yellow River estuary flow course, flow course scheme, flow course of Qingshui Gully, spare estuary flow course

The YR estuary belongs to the type of weak – tide continental facies; after large amounts of sediment are transported into the YR estuary region, most of them deposit along coast making land accretion to make the estuary deposit, extend, swing and divert its course with ceaseless circulation and evolution, except that the rest is transported into the deep ocean area directly or indirectly by tidal current or residual current, etc.. There are abundant resources, such as ground, oil, natural gas and brine, etc., unique environment in the YR estuary region. Under the precondition of ensuring flood prevention safety of Lower YR, the YR estuary flow sourse should be appropriately arranged on considering the sustainable development of economy and society, and the environmental protection of estuary region.

1 The evolution tendency of YR estuary

1.1 Runoff and sediment load variations in recent years

1.1.1 The decreasing of quantities of water and sediment is considerable, which has brought about continuous low water for years

Since 1970s, the incoming water and sediment of YR estuary has been gradually decreased, especially since 1980, the decreasing range has become more considerable. The annual average water and sediment quantities at Lijin hydrologic station for following periods are 46.36 billion m^3 (W) and 1.315 billion t (S) for 1950s, 51.29 billion m^3 (W) and 1.100 billion t (S) for 1960s, 30.42 billion m^3 (W) and 0.888 billion t (S) for 1970s, 29.07 billion m^3 (W) and 0.646 billion t (S) for 1980s, 13.15 billion m^3 (W) and 0.379 billion t (S) for 1990s, and 11.48 billion m^3 (W) and 0.155 billion t (S) for the period between July, 2000 and June, 2005, respectively. The incoming water quantity since 2000 can only occupy 24.8% of the 1950s', while the 1990s' incoming sediment quantity is 28.8% of the 1950s'; and due to the debris – retaining function of Xiaolangdi Reservoir, the five – year average sediment quantity can only occupy 11.7% of the 1950s' since the reservoir has been used.

1.1.2 Before the Xiaolangdi reservoir was put into service, sediment concentration changed a little, sediment discharge conditions were worse

The annual average sediment concentration at Lijin hydrologic station in following periods are 28.4 kg/m^3 for 1950s, 21.5 kg/m^3 for 1960s, 29.2 kg/m^3 for 1970s, 22.2 kg/m^3 for 1980s, and 28.9 kg/m^3 for 1990s, respectively. The sediment concentration of estuary region has been considerably decreased since the reservoir was put into service, the five – year average sediment concentration is 13.5 kg/m^3.

1.1.3 The occurrence probability of median flood decreases, while the peak discharge reduces

Since 1987, the probability of median flood appearing in the Middle and Lower YR has decreased. Number of days when discharge is over 4,000 m^3/s or between 2,000 to 4,000 m^3/s, before 1986, between 1987 and 1999, and since 2000 at Lijin hydrologic station are 17.7 days or 40 days, 0.9 day or 11.4 days, and 0 day or 13.6 days, respectively.

1.2 Variation tendency of sediment load

On considering that before putting the western route of South – to – North Water Diversion Project into service, the diversion scheme provides 37 billion m^3 as YR water supply and the water and soil conservation decreases YR sediment 0.5 billion t, the annual average quantities of water and sediment of 79 – year serial between July, 1919 and June, 1998 at four stations (Longmen Station, Huaxian Station, Hejin Station and Zhuangtou Station) are calculated as 29.89 billion m^3, among which the water volume during flood season is 14.95 billion m^3, occupying 50.0% of the annual, and 1.022 billion t, among which the sediment quantity during flood season is 0.917 billion m^3, occupying 89.7% of the annual, respectively. The representative serial length of water and sediment load is considered as 80 years. The series of 1978 ~ 1982 + 1987 ~ 1996 + 1971 ~ 1975, which is joined with the sediment load series applied in "Research on Xiaolangdi Reservoir Performance Modes" and "Flood Control Programming of YR Basin", etc., has been selected for the series of 2000 ~ 2020, and the annual average quantities of water and sediment in those four stations are 30.84 billion m^3 and 0.99 billion t, respectively. The 2020 ~ 2080 sediment load series adopts the 60 – year series of 1950 ~ 1998 + 1919 ~ 1931 consistent with the phase results of "YR Guxian Hydrocomplex Proposal", the annual average quantities of water and sediment in those four stations are 29.40 billion m^3 and 0.965 billion t, respectively.

The average quantities of water and sediment at Lijin station during 2000 ~ 2020 period are 20.54 billion m^3 and 0.385 billion t respectively, considering the scouring and silting adjustment of Longtong Reach, regulation and scouring and silting of Sanmenxia and Xiaolangdi reservoirs, as well as scouring and silting adjustment in Lower YR. Without considering putting Guxian reservior into service, the quantities of water and sediment at Lijin station during 2020 ~ 2080 period are respectively 18.114 billion m^3 and 0.579 billion t. If Guxian reservior is put into service in 2020, the annual average quantities of water and sediment at Lijin station during 2020 ~ 2080 period are respectively 18.099 billion m^3 and 0.528 billion t, sediment concentration is 29.1 kg/m^3.

1.3 Evolution tendency of YR estuary

Tidal current is the major and eternal among oceanic dynamics of YR estuary, and plays a crucial role on long – term sediment transportation. However, for certain special short terms, the function of waves is also indispensable. Oceanic sediment transportation is quite complex due to many influencing factors. Recent research results indicate that the relatively balanceable sediment quantity along YR estuary coastline is about 0.3 billion t, while incoming sediment quantity of YR estuary is about 0.6 billion t, so the YR estuary delta cannot reach homeostasis, the estuary deposition and extension is inevitable.

2 Estuary flow courses selection and utilization patterns

2.1 Estuary flow course selection

During a certain period in future, the estuary evolution will still follow the natural law of deposition, extension, swing and diversion, only the evolution rate will slow down to the history. Therefore, it's very necessary to leave the swing space to YR estuary and to leave several flow courses in delta region for utilizing sea areas available.

The sea area in YR delta can be divided into the east and the north. The sea area to the south Songchunrong Gully in the East can be utilized by Shibahu flow course; about 62 km long sea area from Wuhaozhuang (in the north) to Songchunrong Gully (in the south) belong to Qingshui Gully flow course, 100 km long north sea area from Tuhai estuary to north of Wuhaozhuang can be utilized by Diaokou River and Maxin River courses.

Flow courses of Qingshui Gully, Diaokou River, Maxin River and Shibahu (see in Fig. 1), have been selected as future YR estuary courses in the delta region, following the evolution law of deposition, extension, swing and diversion of YR estuary and comprehensively considering the historical status of YR flow courses, the characteristics of delta sea area, all previous flow course layout and the development of society and economy in estuary region. The issue of YR, especially YR estuary is complicated, with unceasing variations of the situation, Shenxian Gully may also be utilized as the YR flow course for the future.

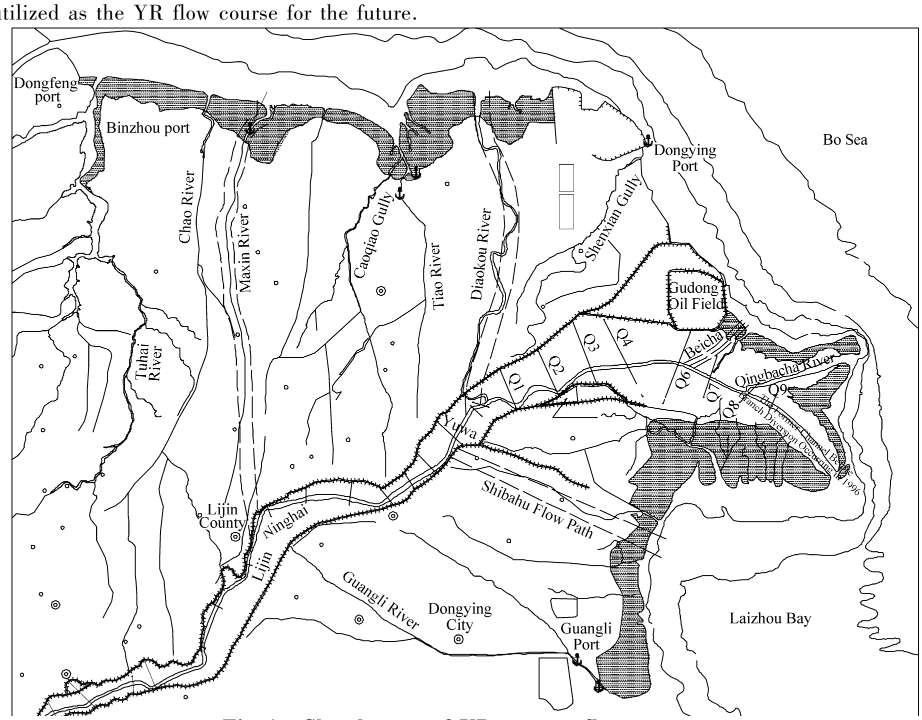


Fig. 1 Sketch map of YR estuary flow courses

2.2 Research on flow courses utilization patterns

According to present research and knowledge, flow course utilization patterns generally include three kinds, namely, to long – termly stabilize the flow course of Qingshui Gully, to arrange cyclic flow courses and to relatively stabilize the flow course of Qingshui Gully.

2.2.1 To long – termly stabilize the flow course of Qingshui Gully

The core of this pattern is "one principal with one secondary; stabilizing the river by two courses; high – level flood diversion, building training dikes into sea". Current flow course of Qingshui Gully being main channel, double training dikes are constructed in the estuary into 3 m deep sea water, flood capacity between dikes is 3, 000 m^3/s, the consequent bulkhead is constructed to make compound river beds in the middle of dikes. Flow course of Diaokou River acts as accessorial course, the flood diversion gate with 3,000 m^3/s capacity is constructed near Xihekou section. The dredging fleet is simultaneously founded to duly dredge the possible local depositions below Xihekou to maintain stable river bed between dikes. It is wished to stabilize the estuary flow course and to make all the YR incoming sediment carried into deep sea, to achieve long – term estuary stabilization, which is favorable to the development of economy and society in estuary region. Main problems are listed as the followings:

(1) It's hard to achieve the long – term stabilization of estuary. The Yellow River will still carry heavy sediment load during a quite long period from now on, whose average annual incoming sediment load at estuary is about 0.6 billion t. The oceanic transportation capacity isn't large enough to carry all sediment into deep sea, the deposition and extension of estuary is inevitable and the long – term stabilization of estuary cannot come true.

(2) The diversion gate constructed at Xihekou, decreases the flood discharge below Xihekou, facilitating to lower flood water level in the reach below Xihekou in short term. However, discharge in channels below the diffluent point will decrease, flow silt – carrying capacity will also decrease, deposition will increase or scouring will decrease, which will further feed back channels above the diffluent point, so constructing the gate is disadvantageous for flood prevention in lower reaches above Xihekou in long views.

(3) The engineering investment for estuary stabilization is too large, the investment just in Phase I (including double training dikes, diversion gate and Diaokou River) amounts to 3.5 billion yuan RMB except for the annual river dredging investment.

2.2.2 To arrange cyclic flow course

The most representative scheme is to arrange cyclic flow course between Qingshui Gully and Diaokou River. For this scheme, the river barrage is constructed near Xihekou, while the former Diaokou River channel is regulated, Qingshui Gully and Diaokou River act as flow course and flood diversion channel in turn, in order to achieve the long – term availability of current flow course and maintain the lasting peace and stability of YR estuary.

The advantages of this flow courses pattern are: it can fully utilize two sea areas of Bohai bay and Laizhou bay for sediment transportation, make two estuary sea areas receive supplies of freshwater and sediment continuously, restrain eroding and receding of the coastline, it is in favor of protecting the delta environment, especially the benign maintaining of the nature reserve of Diaokou River. But, this pattern still has following problems based on current researches. Firstly, constructing a river barrage near Xihekou, is equivalent to constructing a new erosion horizontal plane, whose influence on Lower YR Reach requires further study. Secondly, lots of details such as how to arrange alternation and alternation standards require further study. Thirdly, alternation of two flow courses will make the population, farmland oil well and other production or living facilities stay perennially in influence by flow course changes, which arises directly unfavorable influences on production and living of local area. Fourthly, those two rivers need to be constructed and managed simultaneously, engineering investment is enormous, management is complex and control is difficult.

Therefore, this pattern isn't appropriate at present.

2.2.3 Relatively stabilizing the Qingshui Gully course

The principle for this flow course pattern is to fully consider the sustainable development of local economy and society, based on well maintaining YR estuary ecology, under the precondition of ensuring the safety of flood prevention in Lower YR. In order to ensure the safety of flood prevention for Lower YR and minish the disadvantageous feedback on lower reaches by the estuary deposition and extension, the water level of 10,000 m^3/s discharge at Xihekou will be controlled no higher than 12 m. Necessary engineering measures will be adopted to exhaust the flow course potential and to relatively stabilize the flow course before diversion standard is met. At present, Qingshui Gully course should be fully utilized.

To some extent, this flow course pattern absorbs the advantages of alternation pattern and long – termly stabilizing pattern; firstly, the alternation pattern and this pattern both achieve purposes of flood prevention and deposition reduction through shortening river length. Simultaneously, the relatively stabilizing pattern further considers development requirements of local economic arrangement, and concerns the pattern of long – term stabilizing Qingshui Gully course.

In summary, the future flow course arrangement should adopt the relatively stabilizing pattern, in the near future, Qingshui Gully course should be utilized first.

3 Diversion control standards for estuary flow course

Under the precondition of ensuring the safety of flood prevention in Lower YR, based on well maintaining YR estuary ecology, the arrangement for YR estuary flow course needs fully consideration of the sustainable development of local economy and society. Diversion (Branch diversion) control standards of estuary flow course are results of comprehensive coordination after considering the interaction of above three factors. In "Programming Report on Estuary Flow Course of the Yellow River" ratified by the State Planning Commission in 1992, the diversion control standard is that the water level of 10,000 m^3/s discharge at Xihekou is no higher than 12 m based on the flood prevention capacity in estuary region. Further researches on control standards of diversion have been conducted based on current circumstance.

Based on requirements of flood prevention and deposition reduction of Lower YR, the channel length should be as short as possible, and the water level of diversion control should be as low as possible. While based on requirements of the social and economic development of estuary region, relatively stable YR estuary flow course is required, and water level of diversion control should be as high as possible. The flood control water level of dikes in YR estuary region is presently 17.63 m (Dagu Alti) at Lijin Station, and 12 m at Xihekou, by which Lower YR dikes have been arranged. If the diversion control standard of flow course is increased to that the water level of 10,000 m^3/s discharge at Xihekou is 13 m, in the final phase of flow course enormous feedback on Lower YR channel deposition would occur. Flood prevention level of estuary region need be increased, the dikes of estuary region need be heightened 1 m. Because potential of using Qingshui Gully course is still large, it's inadvisable to increase the diversion control level presently. Otherwise, it will result in frequent estuary channel diversions, increased diversion works investment, great influences on economic development of estuary region. Therefore, when the estuary dikes level have reached 12 m, the flood control water level of 10,000 m^3/s discharge at Xihekou, it's not necessary to lower the diversion control standard. Thus, the diversion control standard of 10,000 m^3/s discharge at Xihekou will maintain the water level not exceeding 12 m.

Due to the effect caused by human activities, such as the using of Xiaolangdi Reservoir, the possibility of 10,000 m^3/s floods at Xihekou decreases, corresponding water level of moderate flood as the diversion control standard need be carried out. Based on the relationship characteristics between water level and discharge at Xihekou section and actual section data, refering to the research results of annual flood regulation pre – schemes for Middle and Lower YR, when the water level of 10,000 m^3/s discharge at Xihekou reaches 12 m, water level of 5,000 m^3/s and 3,000 m^3/s discharge are reservedly calculated as 11 m and 10.3 m respectively. Namely, if the water level of 5,000 m^3/s discharge acts as the diversion control standard, the water level will not exceed 11m; and if the water level of 3,000 m^3/s discharge acts as the standard, the water level will not exceed 10.3 m.

4 Research on Qingshui Gully course scheme

Since Qingshui Gully course was put in use in 1976, its performance period has been divided into two phases, the former channel phase and Qing 8 branch phase. The former channel phase can be divided into the phases of channel forming and flood plain silting, headward scouring and the headward deposition. After the Qing 8 branch diversion in 1996, the phases of headward scouring in the same year, alternation between scouring and deposition, and deposition presented successively, the river length below Xihekou reached 57.6 km by Oct. 2003.

4.1 Branch schemes of the flow course

The sea area of Qingshui Gully course is about 62 km wide between Wuhaozhuang (in the north) and Songchunrong Gully (in the south). Three flow branches can be arranged, current Qing 8 branch, Beicha and former channel before branch diversion in 1996. Making near future river length of Qingshui Gully course as short as possible and the flow course relatively as stable as possible concerned, four combined schemes of Qingshui Gully branches are studied out for comparing: current Qing 8 branch (12 m) + Beicha (12 m) + former channel (12 m), Beicha (12 m) + current Qing 8 branch (12 m) + former channel (12 m), current Qing 8 branch (65 km) + Beicha (12 m) + former channel (12 m) + Qing 8 branch (12 m) and Beicha (65 km) + Qing 8 branch (65 km) + former channel (12 m) + Qing 8 branch (12 m).

4.2 Longevities of flow courses

Longevities of flow courses can be analyzed by two methods, sediment mathematic model calculation and sediment storage volume estimation, the former has been conducted by Yellow River Engineering Consulting Co., Ltd., YRCC (YREC) and Institute of Water and Hydroelectricity Research (IWHR). Their results are nearly the same, both are over 50 years. According to the sediment storage capacity of sea area, it's reserved estimated that the longevities with and without Guxian Reservoir are 61 years and 51 years respectively. Therefore, under conditions of such auxiliary engineering measures as dike and channel regulation, river dredging and flow course training, the Qingshui Gully (three branches) longevity for another 50 years or so is possible.

4.3 The comparison and selection of branch diversion schemes

4.3.1 Longevities of flow courses

Calculation results of YREC and IWHR both indicate that under the same conditions of incoming water and sediment, the longevities of combined flow courses are mainly influenced by sediment storage capacity of sea area. Therefore, the use order of branches for each scheme cannot influence much on total useful longevity of Qingshui Gully course.

4.3.2 Flood prevention and its feedback on lower reach

As for scheme 3 and scheme 4, river length reaches 80 km (below Xihekou) later, in near future river length is shorter, water level is lower, water level increases slowly, the probability of high water level and transverse and diagonal stream is small, the period when median flood contacts the dikes is shorter, and the threaten to the safety of estuary dikes is slighter. Comparing the quantitative flood prevention effects, the flood prevention loss of farmland and property in estuary foreland in four schemes don't differ too much, the loss in scheme 3 is smallest. It is thought that scheme 3 and scheme 4 are better than scheme 1 and scheme 2.

Because the water level in coming 20 or 40 years in scheme 3 and scheme 4 is lower, the feedback scope on lower reach of headward deposition is smaller than that in scheme 1 and scheme 2, so scheme 3 is the best.

4.3.3 Influence on oilfield development

Influences on oilfield infrastructures in those four schemes differ little. In scheme 2, scheme 4 and scheme 3, the course is diverted to Beicha immediately or early, a large area of foreland in Beicha sea area can be silted earlier, which can quicken oil prospecting and exploitation in this region, moreover, the safety factor of Gudong polder dike also increases with the silting and uplifting of the foreland.

4.3.4 Influence on local economy

The branch diversions in those four schemes only involve the region below Qing 6 section, where the nature reserve (area) was formed by the YR fresh water and sediment supply, except for some oil wells, no population, farmland and other local economy are involved. Therefore, the influence of four schemes on the region below Qing 6 section can be considered as the same, while the influence on the region above Qing 6 section mainly embodies the flood prevention.

The comprehensive comparison and selection indicate that each scheme has advantages and disadvantages. As a whole, scheme 3 is the best, so it is recommended as the scheme of Qingshui Gully course.

5 Research on spare estuary flow course schemes

Research on spare flow courses concerns schemes of Diaokou River, Maxin River and Shibahu courses.

5.1 Fundamental circs of flow courses

Former flow course of Diaokou River has been out of use for about 30 years, its present landform and physiognomy changed much compared with those in initial period of no using. Former dikes have become badly broken with no flood control capacity. In the flow course of Diaokou River, Shengli Oil Field has successively discovered ten oil fields and blocks, and constructed large numbers of oil and gas manufacturing facilities. Trunk roads such as Donggang Port first class accommodation highway have been built. Farms or forestry centers have been mainly distributed at the middle and upper part of river channel. Salt industry and breed aquatics are mainly distributed alongside Tiao River estuary. There are 6,751 people residing concentrated in the farms.

The flow course of Shibahu, is located between Yongfeng River, at Kenli county along south bank of YR, and Songchunrong Gully, flows eastward into Laizhou Bay, Bohai Sea, is the shortest course in current YR delta. If it's put in use, the north dike can be performed by YR south levee, a new dike needs to be constructed to the south of the course. There are trunk and branch canals of Shuanghe irrigation area in its passing areas. The average ground gradient is about 1/5,000. There are mainly 33 villages of Kenli County, 14.2 thousand population in the channel.

The channel width of current Maxin River is 14.5 ~ 17 m, gradient is 1/9,000 ~ 1/10,000, slope gradient is 1∶3. Maxin River course will be formed by widening current Maxin River, the length below diversion point is 62 km, and length below Lijin Station is 70 km. As the YR estuary flow course, new dikes of the river need to be constructed alongside. 75 natural villages of Lijin county, 25.9 thousand people, and 79.2 thousand mu farmland are influenced.

5.2 Sediment storage capacity in sea area and flow course longevity

Under conditions of current channel and sea area boundary, if the control standard is that the river length of Diaokou River course below Xihekou don't exceed 80 km, the sediment pile-up scope is within 25 km to the coastline, the deposition width is 50 km, the sediment storage capacity of Diaokou River sea area is calculated as about 14.5 billion m^3, if sea area uneven coefficient is 0.8, storage capacity is 11.6 billion m^3. If 70% of the incoming sediment deposits within the sediment pile-up scope, the unit weight of deposits is $r_s' = 1.1\ t/m^3$, and the long-term average annual incoming sediment quantity is 0.579 billion t, it's calculated that the longevity of Diaokou River course can be 31 years.

The sea area of Shibahu course is close to that of Qingshui Gully course, its south is restricted by Xiaoqing River, after completely using of Qingshui Gully course, the sediment pile-up width is small. If the control standard is not influencing the Xiaoqing River estuary, the estuary extension length is 30 km, deposition width is 20 km, the sediment storage volume is calculated as about 3.18 billion m^3. Weak tides in this sea area considered, 80% of the incoming sediment is estimated to be deposited in this area. If the annual average incoming sediment quantity is 0.579 billion t, it's calculated that the longevity of flow course of Shibahu can be about 6 years.

There are Dongfeng port and Binzhou port 24 km to the west of the Maxin River course, and state-class Huanghua big port about 40 km to the west. If the control standard is not influencing the using of Dongfeng port, Binzhou port, Huanghua port and Tuhai River estuary, the sediment pile – up scope is within 30 km to the coastline, the deposition width is 50 km, the sediment storage capacity is calculated as about 15.3 billion m^3, the longevity is 33 years. If the sediment pile – up scope is less than 128 km river length below Lijin station, this flow course can extend 58 km to the sea, the sediment storage capacity is calculated as about 39 billion m^3, and the longevity is 85 years.

Sediment pile – up width is 50 km as the sea area and the area within 30 km ranging from the coastline as the sediment pile – up scope it's calculated that the sediment storage volume is about 15.3 billion m^3, and the useful life for flow course is 33 years. If confirming the river length below Lijin Station not exceeding 128 km as the sediment pile – up scope, it's calculated that this flow course can extend towards ocean for 58 km, the sediment storage volume is about 39 billion m^3, and the useful life for flow course is 85 years.

5.3 Flow course engineering and investments

The diversion point of Diaokou River is at Cuijia controlling works, the main flow course engineerings include closure works, diversion works, entrance channel cutting, dikes and necessary river regulation works. The investment is 1.103 billion yuan RMB.

The diversion point of Shibahu course is located between the desilting gate of Shibahu and Ershiyihu, flow course landform is low, entrance channel needn't be cut. The main flow course engineerings include diversion and closure works, dikes and necessary river regulation works. The total investment is 1.402 billion yuan RMB.

The Maxin River course is diverted at Wangzhuang village, YR, flows northwards to the sea. The main diversion engineerings include entrance channel cutting, dikes, closure and diversion works, river regulation works and other relevant reconstructions. The total investment is 2.819 billion RMB.

5.4 Analysis of spare flow courses schemes

As for flow courses length, at the beginnign of diversion, Maxin River and Shibahu are 30 km shorter than Diaokou River, which can engender the larger headward scouring, benefit channel flood prevention of lower reach. As for the sea area conditions, the Shibahu course is the worst, whose using can bring disadvantageous influences on Xiaoqing River estuary and Guangli Dock, Maxin River and Diaokou River are better, but Maxin River is about 22 km away from the Dongfeng port, about 41 km away from Huanghua port, even nearer to the Tuhai River estuary, the using of Maxin River course will influence them. As for the longevities of flow courses, Shibahu course is the shortest, if the control standard is not influencing the normal using of Dongfeng port, Binzhou port, Huanghua port and Tuhai River estuary, the longevity of Maxin River and Diaokou River course is almost the same, otherwise, the former would be much longer. As for the influences on society and economy, because Maxin River is located at more developed section in estuary region, as much as 25.9 thousand people are involved, and also part oil field facilities are influence. While the Diaokou River course is the previous channel and has already been confirmed as the spare course, there are fewer constructions within the channel and the least population will be influenced. As for the total flow course engineerings investment, Maxin River is the largest, Shibahu Route and Diaokou River are the median and the smallest, respectively. After comprehensive comparison and selection, the Diaokou River course should be put in use first after exhausting Qingshui Gully.

6 Conclusions

(1) The YR estuary will still be a heavy sediment one during a quite long period, and the estuary evolution will still follow the natural law of deposition, extension, swing and diversion, only with a relatively smaller evolution velocity than history. Therefore, estuary swing space must be left while developing the YR delta.

(2) Following the natural evolution law of deposition, extension, swing and diversion of YR estuary, under the precondition of ensuring the safety of flood prevention in Lower YR, based on well maintaining YR estuary ecology, fully considering the sustainable development of local economy

and society, Qingshui Gully, Diaokou River, Maxin River and Shibahu courses are selected as future YR estuary flow courses in the delta area. In the near future Qingshui Gully course should first be put in use for about 50 years. Then Diaokou River course should be put in use before other spare courses.

(3) As for using the Qingshui Gully course, branch diversion should be arranged designedly. At present, Qing 8 branch should be kept in use until the river length below Xihekou reaches 65 km, then diverted to Beicha, which would be used until the water level of 10,000 m^3/s discharge at Xihekou reaches 12 m, then diverted to previous Qingshui Gully branch used until 1996, previous branch would be used until the water level of 10,000 m^3/s discharge at Xihekou reaches 12 m, then diverted to Qing 8 branch, Qing 8 branch would be used until the water level of 10,000 m^3/s discharge at Xihekou reaches 12 m, then diverted to the spare estuary flow course. The flow course will be comparatively stabilized in Qingshui Gully during about 50 years.

(4) It's necessary to reinforce the management of spare flow course of Diaokou River, and restrict the development and construction in the managing scope of spare flow course, in order to avoid larger economic loss while reusing the flow course.

References

Li – Guoying, Maintaining the Healthy Life of the Yellow River [M]. Zhengzhou: Yellow River Conservancy Press, 2005.

Chinese Hydraulic Academy. The Yellow River Research Society. The Yellow River Estuary Problems and Harnessing Measures Proseminar [C]. Zhengzhou: Yellow River Conservancy Press, 2003.

The Father's Retrospect and Expectation of Qingshui Channel of the Yellow River for 30 Anniversaries

Li Shiguo*, *Wang Junming*, *Guo Xunfeng* and *Zhang Shiming

Yellow River Estuary Management Bureau, Dongying, 257091, China

Abstract: Qingshui channel has gone for 30 years from May of 1976. It has changed the natural evolvement rule of chop and change every ten years of the Yellow River bayou, and made great contribution to the Economic and Social development of Yellow River delta and the exploiture of Sheng Li oil field. How Qingshui channel goes stability for 30 years is because of not only impersonal conditions but intervene of manpower. We analyse the main reason, summarize the fathered achivement, and conclude the main matter, then we bring forward the fathered thoughts and measures in the near future.
Key words: fathered project, the stream of rinsing channel, Yellow River bayou

1 The fathered retrospect of Qingshui channel' route

The Yellow River tenaculums a great deal of bedload to bayou, figure the basic attribute of filling up, extending and swinging changes route of bayou. The sector area about 6,000 km^2 from the peak of Kenli Ninghai, north from Tuhai bayou, south to branch Range canal bayou, The enter sea route of the Yellow River has 9 great fluxes from the Yellow River burst and change route to Bohai sea from Daqinghe in1855. Thereinto, the Yellow River has changed route for 6 times from the peak of Ninghai in 1889 to 1953, and 3 times from the peak of Yuwa in 1953 ~ 1976. On the whole, the Yellow River once changes it's route every 10 years. The Qingshui channel is active route to sea and is the 9th changing route. The frontal 6 times are natural swinging changing route and the latter 3 times is results of manpower intervene. Especially the Qingshui channel is the best fierce one, which is the designed changing route of worth name manpower management. This changing route provides gold experiences to control the route changing and continues to actualize scheming route changing. Multinomial project measures have been actualized after Yellow River went all right. These measures make great process for stabilizing the route during the 30 years.

1.1 The background of route changing and prophase preparation

The Qingshui channel route was determined by reconnaissance and study time after time in the evening of 1960 s. During the flood season in 1967, Diaokou river route extended 27 km, average ply of filling up was about 3.5 m, the tail reach gradient became slow, and the same flow water level increased. When there was flood peak of 10,400 m^3/s in Lijin hydro – station on October 16, the best high water level since there was hydro – records appeared in Luojiawuzi hydro – station, it was higher 0.76 m than 10,400 m^3/s in 1958 , which resulted in ceaseless precipices in dikes, projects and controls, submerged 1,330 thousands of bottomland, 12,500 people were hit, also heavily intimidated the exploitation of oil field. Then respect branches determined to alter the Qingshui channel route for the sake of improving disadvantage phase of the Yellow River bayou. In terms of reconnaissance circs and recent father ideas about Report of Yellow River Bayou as well as the project of changing route's accidence enlarge design of the Yellow River bayou, they finished digging of leading river, dyke of preventing flood, addition and extending of south dyke and creative dyke, and the addition and extending thereinafter four sects. The projects of south bank's addition of preventing flood, also leading river to expand silt in Shibahu starting working one after another, cut – off stream and stock are launching on. They also finished infrastructure of north levee (east levee to flood bank) according to the standard of 10.0 m (Dagu) water level of west bayou in

1974.

Water and electricity office had an informal discussion in Zhengzhou on December, 1975. When the water level of west bayou had neared to the route changing standard of 10 m, they determined to change the route of Qingshui channel before the flood season according to the task of preventing flood in 1976. For assuring the success of route changing, they also finished the tasks of repairing north bank, reinforcing south preventing flood bank, the exploring of west bayou and east bank's flood gate and affiliated projects in spring of 1976. Thus, it took a period of 9 years from the prophase preparation of the Yellow River changed route from Diaokou river to Qingshui channel, and changed to Qingshui channel route to sea in May of 1976.

1.2 The harnessing practice during the Yellow River going

The Qingshui channel was billabong between primary immortal channel's fork river old haunt and primary Sweet water's old haunt, it's hypsography was lower about 1.5 m to 4.0 m than both sides, and it's ground altitude was mostly lower than 3.0 m (Yellow Sea's altitude). The orifice of entering sea was in the hollowness between the prominency of two old haunts. They crevassed in west bayou of east bank and stop up old haunt, The Yellow River leads water overflow to sea by Qingshui channel. After the Yellow River went all right, according to circumstances and danger circs, also conceive to the exploring need of Shengli oil field, they constructed one after the other projects, such as the cancel of preventing flood dyke, the addition of north bank, Hulin control project, Weigai gate and west bayou control project, 30 km and 22 km danger projects and so on since 1997. The Gudong oil field was discovered in the beach that new filled up at north bank of Rinsing channel route. For the sake of accelerating the exploring of oil field, developed area was enclosed by preventing flood surround dyke which was built at the north river – beach in 1985. A 6th road was built to link north and Gudong surround dyke, and Binhai built coastwise sea wall and basically stop up the north beach of north river – channel.

The primary plan of Qingshui channel route was to go for 12 to 14 years, and had go for 12 years up to 1987. Riverway after West bayou extended 56 km, it extended sum to 29 km. Since the length of the river extended and fall get to slow, tail reach presented a state of broad, fleet and messy, and formed a complexion of apposed 6 forks entered to sea. And the block – sand grew so rapidly as to grievously block water and sand, resulting in approach – bale. For the sake of extending Qingshui channel route's going time, aim to the position of unceasing exasperate, according to the exploiture of oil field and the construct need of the Yellow River delta, the government of DongYing provided policies, and oil field contributed, respected the Yellow River segments provided techniques, combined to do an experiment for dredging up bayou at April 1988. Up to 1993, more than 80 branches were walled up, 4 river balks were dredged; made use of raking, shooting stream to plush sand and truster – stirring to drag silt out and home for more than 5,000 times; 10 km leading bank was new constructed, and 12 km was alter – repaired; West bayou and Balian control – leading projects were constructed; North bank prolong project that followed 6th road which was 14.4 km, the tip which linked to Gudong south surround – bank moved the swing – peak of bayou to Qing7; 18 flood and expand silt gobs were constructed, the experiments of expand silt in flood season were carried on; cut – bend and adopt – frank were put up in Qing 10 in 1993, and digged leading river for 2,000 m.

Along with the development of Economic and Social Affairs of theYellow River delta and the exploiture of oil field, it demands the relatively stability of the Yellow River route entering to sea, and shoots at to a longer time of the Qingshui channel's active route going on. Therefore, Shandong Yellow River affairs – office organized to accomplish "the technic – consultation Report about Prolong the Active Route of Yellow River Baoyou (the Qingshui channel route)", and on this base, the Yellow River – irrigation works Committee united Victory oil manage – office worked out "The Programming Reports of the Enter – sea Route of Yellow River" in 1989 and was authorized by Project Committee in 1992. Again, Shandong Yellow River affairs – office worked out "the First Period Suggestion Book about the Father of Yellow River's Enter – sea Route", which was authorized in 1996 with the total invest of 3. 64 hundreds million yuan. The main items were: the higher and reinforce projects of North bank prolong project that followed 6th road and North surrounding – bank of Gudong oil field and about pricipice – projects, the higher , reinforce and prolong projects of South flood – prevent bank, the repair projects of riverway below Qing7, the defend – fill up projects of North bank, the route – change, leading – river and dig projects of North – Folk 4 and so on. Thereinto, China oil – natural gas head office contributed 2. 10 hundreds million yuan, and answered for the construct and manage of control – leading projects below Cuijia in north bank; Irrigation – work office invested 1. 04 hundred million yuan, Shandong 0. 5 hundred million yuan, were charge of the construct and manage the projects of south – bank.

Up to May 1996, the route of Qingshui channel had gone all right for 20 years. During this period, water transfluxed Lijin station was 5,075 hundreds million m^3, sand was 134 hundreds million tons ,a great deal of bedload entered to bayou and made the route ceaselessly filled up and prolonged, the length of river pilled up and extended from 27 km of early days of riverway – changing to 65 km,the total prolonged length was 38km. The corresponded water level of flux about 10,000 m^3/s had be driven up from 10. 0 m at period of riverway – changing to11. 12 m. Additionally the continuous low water, the main slot of bayou reach occurred serious filling – up, and the ability of letting got weak. In order to reduce prevent – flood's stress and prolong the useful time of the Qingshui channel route, combined with the need of oil extraction of Victory oil field, under the premise without affecting the programming of Yellow River's enter – sea route, granted by the Yellow River irrigation – work committee, the project of man – made making branch was carried on at section about Qing 8 before flood season of 1996. The position of branch was chosen below 950 m of Qing 8, the aspect of enter – sea was east lightly partial north, then shaped an angle of 29°30′ with the riverway before making branch, and had a distance of 14 km with North Folks bayou; relative debase of the whole bayou reach riverbed adjusted from 0. 9‱ to 1. 2‱, the length of route shorten 16 km.

Came into 90 s of 20 century, owing to the extended little – flux water of bayou, the filled – up reach was main pilled in great slot, the water depth of flat beach diminished, the whole great slot present a posture of shrink. Therefore, some experts advanced to make use of digging and dredging up to boost the bayou's ability of transiting sand, and reduce the filling of bayou, dredge the feature of river; and use the digged sand to reinforce bank. For exploring the key techniques and means, from November of 1997 to December of 2004, 3 times projects of digging – river and boosting – bank were carried on in bayou reach, the above boundary was Jifeng precipice project and the nether boundary was Qing 3 section, the whole length referred was 53. 6 km. Thereinto, Jifeng precipice project to CS6 section was segment of digging – river, the river length referred was 33. 2km;CS6 to CS3 section was dredged – up between the first digging – river and the second one, the river length referred was 20. 1 km. The total sand digged during the 3 times projects was 10,570,000 m^3, the bank length of reinforced was 24. 8 km.

For assuring the continuity of bayou's father, in 2001, Irrigation – work office authorized to actualize "The Implement Scheme of Construction Items of Yellow River Bayou of 2000". The main projects was dike – road, expanding silt and boosting bank, river – repairing and observation – study of bayou, the construction of professional mobile emergency troop, the construction of special hydro – station at t – shaped crossing and so on.

1.3 Harnessing effect

1.3.1 Establishing flood-preventing projects system initially

During the going period of the Qingshui channel route, some projects measures were adopted such as the extending of bank about 80 km, and the ability of prevent flood improved to 10,000 m^3/s, 12 precipice and control – leading projects were new built, flood – preventing projects system were preparatory formed, so that insured the peace of bayou for 30 years, it provided security insure for the development of Economic and Social Affairs of Yellow River delta and the exploiture and construction of Victory oil field, and well economical and social benefit was realized.

1.3.2 The fixed going number of year of the Qingshui channel route

The Qingshui channel route was primary planned to go for 12 to 14 years, but in fact the time has reached 30 years. There are main two reasons: The first reason is that, during this period, water and sand is less, the speed of filling – up and extending is slower, and it's the dominant factor of long going of the route. The circumstances of water – sand and route – extending during the period that Yellow River's three routes were specialized in the following sheet (Table. 1). It's obvious that there are direct ratios between the average annual sand quantity and speed of flow route expansion, i. e. more sand quantity and more speed of extending. During the going period of Immortal channel and Diaokou river route, annual flux of Lijin station and sand – transit are equal, so that annual length of extending is the same level; During the period of going of the Qingshui channel route, annual flux of Lijin station and sand – transit are obviously less than the forth two rivers's, and it's annual filling up and length of extending are obviously shorter. Secondly, the construction of a great deal of fathering projects make an important role to the stability of route. Riverway controlling – system of flood is primary formed by the repair projects that new built, valid controlled length of riverway has improved, so that riverway boundary is reformed, swing evolvement is tied, keep the adverse phase that beach bank collapsed seriously within limits, potential is added to actual entering – sea route and prolonging the time of river's going. It's analysed that now when flux is 10,000 m^3/s in Western river – bayou, water level is 11.20 m, and lower 0.8 m than route – changed of 12 m, all of that say that there are great potential of the Rinsing channel route. The built of North bank prolong project that followed 6th road that is prolonged cut and stop up north folk river, stop the possibility of flood entering in sea along north of Gudong surround – bank; banks of both sides become flood barrier, and reduced occur ratio of swinging route – changing; The implement of projects that river – digging to bank – reinforce both reduce pilling – up of river bayou (it's less 5,000,000 m^3 than before river – digging), and reinforce bank of 24.8km; fathering – experimenting projects of gob validly cut and stop up the folk channel, make the river feature in arrange, and reduce the altitude of Lanmensha, also open the gob. In the mass, it play a important role to the stability going for 30 years of The Rinsing channel route.

Table 1 The sheet about water – sand and route – extending

route of entering – sea	time of river going	years of river going	annual flux (hundred million m^3)	annual sand (hundred million t)	length of extending (km)	ratio of extending (km/a)
Immortal Channel	1953.07 ~ 1964.01	10.5	459.12	11.85	21	2.00
Diaokou river	1964.01 ~ 1976.05	12.4	453.73	11.15	33	2.66
Rinsing channel	1976.05 ~ 1996.06	20	257.82	6.16	38	1.90
	1996.07 ~ 2005.06	9	103.39	2.03	10	1.10

2 The main problems

The fathering practice of bayou boosted the relative stability of Qingshui channel route and get nice social – economic effect. But, there are some issues that can not be ignored: the first is the trait that the Yellow River is full of bedload which can not be changed, still a great deal of sand is transited to bayou, the circs of entering – sea route extending, swing to change folk will occur, there is still threaten of flood. Secondly, the posture of part riverway is adverse, transverse fall is larger. The transverse altitude of beach side to bank of Qing 1 to Qing 7 reach is 1.2 m to 2.45 m, transverse fall gets to 4 ‱ ~ 10 ‱, if floodplain occur, even medium flood will result in the sharp change of river posture, and shape the passive phase of prevent flood of transverse river or flood along bank, even danger of burst will occur to dike. Thirdly, the standard of projects is low and hidden trouble is too much. Most bayou dikes are built in the former civil one, though were reinforced for several years, but the quality of dike base and body are poor; 26.8 km of dike left of bayou can't reach the designed normative height, all breadth is less 2 ~ 4 m than criterion, unsclerotized reach of top dike account for 93%. Height of precipice projects and section of base rock are lack, grade is steep, there is larger lack of backup rock. The length of precipice and control projects by river below Shibahu is only account for about one to fifth of all riverway length, Some single project length is shorter, the capability of control slide – force. Fourthly, financing channel is not expedite, the latter father projects of bayou can't be actualized prosperous; Observation and study can't be actualized well – off, and there are short of science and technology fruit to virtually direct fathering practice.

3 Fathering ideas and suggestions in the near future

According to the actual issues, fathering idea of the Rinsing channel route in the near future is: in term of ideas of "The Programming Reports of the Enter – sea Route of Yellow River" that was authorized by Project Committee in 1992 and item arranges, combine the position of the development of Economic of Yellow River delta and the exploiture layout of Victory oil field, reinforce fathering, perfect the system of flood – preventing projects more, and positively actualize river – digging, scientifically deal with and utilize sand of riverway, as long as possible to prolong the time of use.

3.1 Reinforce fathering and perfect system of projects

Nowadays, there are not only a great deal of population in bayou, but rising Dongying and the secondly largest product base of petrol – oil in our country, so that assuring flood – preventing is more important than any period in history. Thus, flood – preventing projects need to perfect as soon as possible, thereinto, dike projects must adapt to the flood – preventing standard of relative water level of 12 m and 10,000 m^3/s in West bayou; control – leading projects from Cuizhuang to Qing 7 riverway need to be more perfected to stable the main slot of this reach, and positively take actual measures to hold back and abase the adverse position of transverse fall of riverway; projects below Qing 7 section should take repairing measures according to the material circs of river's evolvement to appropriately control river slot, and keep the medium water entering sea.

3.2 Actualize river – digging projects to restrain the filling up and driving – up of riverbed

The observation and study about three river – digging projects taken in bayou indicated that, the rational digging in main slot of riverway can actually restrain filling – up and driving – up of river slot, especially digging and dredging up in bayoou reach. Thereby, tail reach below Lijin should be take general projects of digging and dredging – up. It is forecasted annual average filling – up sand is about 7 million tons thousands in the future 20 years in Lijin to Qing7. If keep the balanceable principle of filling up and digging in main slot, dig ceaselessly, then the driving up of riverload and filling up of upriver reach will be actually restrained. The digged sand can be used to reinforce banks of both sides to improve the intention of flood – preventing, also can be used to fill up dyke – channel river to reduce transverse fall of sections and perfect shape of section; the same way, the sand can improve saline of bayou, and add to useful land to create conditions for the vigorously development of high efficiency and environmental agriculture of bayou. Thus, not only the useful number of year of once changed river can be prolonged but the effect of folk changed can be added again, so that the aim of prolong the number of useful years of actual route will be realized.

3.3 Dredge up gob to reduce bayou's adverse reactive effects of bayou to up riverload

The ceaseless filling up is the main reason for the fall of lower reaches of Yellow River get slow and filling up trace to the source, and at the same time bring to adverse effect to flood and sand discharge of Yellow River. Sand digging and dredge up keep the bayou's expedite and actually reduced the relative corrasive base level, then erode traced to the source of longer time under definite conditions will occur. And unite the exploitation of oil field, discharge position of bedload is schemed to arranged, then the aim of sae – land exploitation and reduce the cost can reach. So that dredge up project of gob is suggested to actualize as soon as possible.

3.4 Card the system of fathering, solve the channel of financing

Nowadays, because of the different ideas for raising found of flood – preventing and fathering item of bayou, still the item can not realize. We suggest that according to actual law and statutes and the development and change, definite the main body of investing, card the financing channel, realize now latter fathering projects of bayou as soon as possible, further perfect system of flood – preventing and fathering.

3.5 Increase devotion of scientific study, perfect means of study, improve level of fathering

A very important issue that restrains development of observation and study of bayou is lack of intention channel of invest and scientific research fund. So that intend fund of research in bayou is suggested to built, adding the devotion of scientific research, improving research level and quality of results to adapt to the need of fathering practices of bayou. Nowadays, what is exacted to research is as follows: prolong the going number of year of the Rinsing channel route as soon as possible, reduce means of adverse feedback effects of bayou, environmental system of bayou is well kept, research of continuous utilize of water resources, and the important issues of the transmigrating utilize of the Rinsing channel and Diaokou river. At the same time, General Fathering Layout of Yellow River bayou is came on as soon as possible to definite the researching and fathering aspect, thereby providing thereunder for fathering of bayou.

References

Bayou Managing Office of Yellow River. Ideal of Yellow River[M]. Jinan: QiLu Press, 1995.

Jia Zhenyu, Li Shiguo and so on. The Paragraph's Choose of River – Digging and Dredging up Projects of Yellow River Bayou, Demos Yellow River, 2006(11).

You Baohong, Li Jingyi and so on. the Analyse of General Effects of River – Digging and Bank – Reinforcing Projects at Yellow River's Bayou[J]. Demos Yellow River, 2006(11).

Projects Investment System Study in the Estuary of the Yellow River

Li Shiguo[1], ***Li Jingyi***[1] and ***Zhang Sheng***[2]

1. Yellow River Estuary Management Bureau, Dongying, 257091, China
2. Longxinda Company, Jinan, 250011, China

Abstract: This paper analyzes the construction of management model and discusses the investment system in the present. The controlling the estuary of the Yellow River not only is crucial to the social and economic development of the Delta, but also has influences on the flood control and the river channel change. In order to layout and construct overall, the central government should pay for the investment of the construction projects.

Key words: river training projects, construction, investment system, estuary of the Yellow River

1 Introduction

The sediment in the river deposits and forms the modern Yellow River delta with area of 6,000 km^2 since the Yellow River changed its channel to Bohai Sea in 1855. The channel of the Yellow River in the delta obeys the rule of depositing – extending – swinging – changing circulating and expanding the delta. According to the historic records, the main channel changed 50 times among these, the main channel changed obviously ten times from 1855 to 1976 in the delta, which apex is NingHai, north to Tao' er River and south to ZhiMai River. The main channel changes was limited in the fixed area through man – made channel with development of the agriculture and industry. The apex of the delta moved to Yuwa cross section, north to Tiao River and north to SongChunRong River. The delta area is about 2,200 km^2.

The Yellow River flows through Lijin, Dongying, Hekou, Kenli and empties itself into Bohai Sea with 138 km long. The channel becomes wide gradually and it is difficult to control flood. The channel from Mawan to Wangzhuang is famous for its narrow. The narrowest part in Xiaoli is only 460 m wide. After Yuwan section, the channel is shallow and wide.

2 Evolution of the construction management system

At the beginning of the main channel of the Yellow River changed, there were a few inhabitants and the river changed its channel itself. The main channel should keep stable relatively with social and economic development, especially the development of the ShengLi oil field. The construction projects in the estuary experience different stages.

2.1 Dykes built mainly by the organization and the government assisted

The dykes were called folk weirs in Qing dynasty and called folk dykes since 1949. The apex of the delta was Ninghai before 1949 and it was Yuwa since 1949. The river channel changed frequently and the dykes built alang channel changed. So there are many old and new dykes, and this dykes waste others are popular.

The Yellow River flew into Daqing River and took it as its own channel since 1855. The common people built folk dykes automatically in 1867. When the Yellow River breached again in 1889, Zhangyao, the governor of Shangdong province, reported to the central government and built dykes along the channel. After that, the dykes were mainly built by the common people. The military of Kuomintang built the dykes from Jifeng to Minfeng in Kenli county in the right side with

15 km long, and in the left side from Qilonghe in Lijin county to Yong' an town in Kenli county with 40 km long. The principles of controlling the river at that time were to repair the dykes where had questions.

2.2 Times that government built dykes and controlled the floods

The dykes were built and repaired and took Yuwa as the apex since People ' s Republic of China was founded. The central government is in charge of rebuilding the dykes in the estuary and flood control since the Yellow River flows it original channel into the Bohai Sea. The folk weirs after Siduan in Lijin county became dykes except a part of folk dykes. The dyke in the left side were strengthened and widened in 1950 and the dykes in the right side were also built. The dykes in the estuary were built three times since 1952. The dykes in the estuary reached the standard that the design flood control discharge was 10,000 m^3/s. The central government paid for the construction and management.

2.3 The Shengli oil field investes mainly and the government implements

80% of the oil is produced in the estuarial area. The Yellow River breached at Xihekou Dongdadi dyke on May 20, 1976. And the dyke was repaired and the river flowed into the sea by Qingshuigou. The Gudong oil field was found in the north side of the QingShuiGou channel in 1984. In order to develop the Gudong oil field, Shengli oil field financed to build the dyke and circled the exploiting area in 1985. It built No. 6 road, which connected Beidadi dyke and Gudong Weidi dyke.

Qingshuigou channel has worked for 12 years since 1987. The channel after Lijin is 12 km longer than before. The main channel deposited seriously and the flood could not discharged easily, which inflenced the production of the oil field. According to the development of the oil field and the delta, appoved by YRCC, authority of Dongying supplied policy, Shengli oil field supplied founds, YRCC supplied technologies in order to extend the Qingshuigou channel. They began the experiments to control the estuary from April 1988 to 1993. Shengli oil field finaced to build the dykes after Yuwa and Siduan and the government took charge of the construction from 1985 to 1995.

2.4 Central government, local government and oil field invest and manage together

With the development of the Yellow River delta, the channel in the estuary needs to keep stable for a long time. According to the layout report of the Yellow River' s channel to the sea, Shangdong Yellow River Affair Bureau finished the suggestion report about the first time river training works. The state planning commission approved it and the total investment was 0.36 billion Yuan. Among the investment, Oil and Natural Gas Company will pay 0.21 billion Yuan, the water resource ministry will invest 0.21 billion Yuan and Shandong government will finance 50 million Yuan. The projects were finished in 2003 and the oil field financed to build the Qingba projects. The governor of the local government is responsible for flood control.

3 Investment system discuss

The estuary is an important part of the whole basin. It is the region that the river and the sea act each other. The estuarial questions in the world are caused by the oceanic factors. The natural disasters come from tide and storm. The questions in the estuary of the Yellow River are complicated because there are more sediment and less water. The flood control is also a main issue. The detailed problems are following: ① more and more sediment deposits in the estuary, which extends the channel of the estuary. These restrain the development of Shengli oil field. ② When the channel in the estuary extends a certain length, the riverbed will raise and the water level will increase at the same discharge. The evolution of the estuary not only influences the estuarial area, but also influences on the upstream channel. So it is necessary to layout overall.

Nowadays, the opinions are not the same about the project investment in the estuary. I believe: Shengli oil field works as a company according to the Company Law and the state regulations. It could not finance the Yellow River projects. Shengli oil field pays taxes to the government and the state should finance the infrastructure. In the other hand, Shengli oil field finances only to protect their oil facilities and can not think about the overall plan. The success examples in the controlling river estuary in the world prove: if we succeed to control the estuary of the river, all the problems will be resolved. The Yellow River management rules was approved and implemented on May 1 2005. The rules stipulate definitely that the project in the estuary should be layout by the country and implemented according to the construction procedure. So the central government should pay for the projects in the Yellow River estuary.

4 Conclusions

The construction management system has experienced many stages: the folk people built and managed, the central government built and managed, the central government, local government and oil field invested together. Now, no one finances it. The folk people and oil field finance it in order to protect themselves. The central government, local government and oil field invested and managed together to boost the harnessing of the estuary. The oil field cares about their oil facilities, the local government thinks about the social and economic development of the delta duo to different goals, both of them do not care whether the projects have impacts on the upstream. it is disadvantage to construct and manage the project overall in the estuary. So the central government should finance the projects.

Reference

The Yellow River Estuary Bureau. the Yellow River Record[M]. JiNan: QiLu Press, 1995.

Economic Benefits for the Freshwater Inflows in the Colorado River Delta

Enrique Sanjurjo Rivera

National Institute of Ecology, Mexico

Abstract: An evaluation of the economic benefits of maintaining in – stream flows in the Colorado River Delta, using the Contingent Valuation Method is presented. A total of 614 surveys to water users, fishermen and tourists in the region were applied. The estimated amount of the benefits of in – stream flows in the Colorado River delta is of 3.8 million U.S. dollars per year, although this is a conservative amount. Through a cost – benefit analysis, it was calculated that 2.28 dollars would be generated by each dollar invested in securing an in – stream flow in the Colorado River. This shows that if the benefits generated by in – stream flows were a private firm it would be a profitable investment to maintain water in the river and charge for this. Being these benefits a public good, it is the obligation of the government to create the conditions to guarantee that these benefits are provided. This specific report presents the research results of a complete team and is based in three previous papers that have not been presented all together yet.

Key words: colorado river delta, contingent valuation, in – stream flows, total economic value

1 Introduction

The reduction of river flows caused the ecological degradation of the Colorado River delta. However the delta is still one of the most important wetland ecosystems in North America and one of the strongest opportunities for U.S. – Mexico collaboration for the conservation of biodiversity along the border. Restoring its ecological integrity requires an annual maintenance in – stream flow and an over – bank flooding event every 4 years. Water requirements for the restoration are not always free – disposal, often someone will have to pay for having the required in – stream flow: NGOs, farmers, etcetera. Once these costs are taken into account, identifying the benefits and the benefit – cost ratio of the restoration project turns into a relevant issue.

Since 2004 the National Institute of Ecology has been working with local organizations in the Sonoran Desert to identify the economic benefits of allowing the water flow through the Colorado River. Some of the benefits that have been identified are: fisheries at the delta, dependent fisheries at the California Gulf, bird – watching, hunting, domestic recreation services, existence value for local people, recreational services for foreign visitors. For these values a set of contingent valuation surveys has been conducted: 6 questionnaires to more than 800 respondents.

2 Methodology

2.1 The contingent valuation question

In 1993, the National Oceanic and Atmospheric Administration (NOAA) published the Report of the NOAA panel on Contingent Valuation (Arrow et al, 1993). This report gave some guidelines for using contingent valuation for the estimation of passive use values. The Contingent Valuation (CV) method has been used also for recreational values (Mitchel and Carson 1989, Azqueta and Perez, 1996, among others). Some theoretic innovations on the statistical analyses of the answers and on the survey design have been developed for improving this method (Kriström 1990, Duffield and Patterson 1991). The main issues to consider when developing a CV survey are: elicitation format, payment vehicle, question format, interview format and complementary questions.

(1) Elicitation format. The willingness to pay format will be used instead of the compensation required (willingness to accept) because the former is more conservative.

(2) Payment vehicle. A common approach is to make a referendum in which respondents vote whether to tax themselves or not for a particular purpose. For this particular study, the payment vehicle depend in the type of benefit measured. For this case study, different benefits were estimated and different payment vehicles used. For the existence value for local people an extra price to eater tariffs was proposed; for recreational services an entrance fee; for hunting and bird – watching the price of the hole trip; for fisheries the gasoline price was used; and finally for the people that rent land for having a leisure house for weekend by the Hardy River, an increase on the leasing price was used.

(3) Question format. The question format may be open – ended, this scenario lacks realism since respondents are rarely asked to place a value to a particular good in their everyday lives (Schumann, 1996). Another alternative is to use a dichotomous choice: single or double bounded. In the double bounded dichotomous choice format the respondent will be asked for a lower or a higher price depending in her first response (Cameron, 1988, Hanemann, Loomis and Kannien 1991, among others) while in the single bounded format the respondent will face only one value (Bishop and Heberlein, 1979). Some aspects to be addressed carefully are the starting point bias (Whitehead, 1993), and the warm – glow phenomena (Diamond and Hausman, 1993). For all cases a single bounded approach was selected because it takes away some of the bias associated with follow – up questions about the WTP.

(4) Interview format. The most used formats for the interview are: face – to – face, mail and telephone (Mitchel and Carson, 1988). For this study for all cases a face – to – face format was chosen.

(5) Complementary questions. The contingent valuation survey must include some follow – up questions that help to interpret the responses. Among the items that will be helpful are: income, attitudes toward the environment and knowledge of the site. According to Mitchel and Carson (1988) a good survey will follow the next order: introductory questions, contingent valuation questions and finally the follow up questions.

2.2 Contingent valuation analysis

For analyzing the single bounded dichotomous question (Bishop *y* Heberlein, 1979, Hanemann, 1984, Cameron, 1988) a random utility model was chosen.

Let the utility of the person j (U_j) to be a function of her income (Y_j) and a vector of socioeconomic characteristics (Z_j), let U_{ij} to be the utility when she enjoys a public good and part of her income (t_j), and let U_{0j} to be the utility when she does not enjoy the public good but does not loose part of her income. The this individual will have an affirmative question for a dichotomous question if

$$U_1(Y_j - t_j,\ Z_j,\ \varepsilon_{1j}) > U_0(Y_j,\ Z_j,\ \varepsilon_{0j}) \tag{1}$$

where ε_{ij} is a random error term. Given that U_j has a deterministic and a random term, the U_j can be written as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{2}$$

where V_{ij} is the deterministic component and ε_{ij} eis the random one, thus:

$$P_r(SI_j) = P_r(V_1 + \varepsilon_{1j} > V_0 + \varepsilon_{0j}) \tag{3}$$

Let F_ε be the density function of the errors ej, defined as:

$$e_j = \varepsilon_j = \varepsilon_{1j} - \varepsilon_{0j} \tag{4}$$

then the density function may be expressed as:

$$P_r(SI_j) = F_\varepsilon(V_1 - V_0) \tag{5}$$

Following Haab *y* Mc Conell [2002] this expression could be written as:

$$P_r(SI_j) = 1 - F_\varepsilon[-V_1(y_j - t_j,\ Z_j) - V_0(Y_j, Z_j)] \tag{6}$$

When the deterministic part of the equation is a linear function of the income and other variables, then the conditional utility function could be written as:

$$(Y_j): V_{ij}(Y_i) = \alpha_i Z_j + \beta_i (Y_j) \quad (7)$$

In this case the probability of obtaining an affirmative response is

$$P_r(Yes_j) = P_r(V_1 + \varepsilon_{1j} > V_0 + \varepsilon_{0j}) \quad (8)$$

where

$$V_{1j} = \alpha_1 Z_j + \beta_1 Y_j y V_{0j} = \alpha_0 Z_j + \beta_0 Y \quad (9)$$

Assuming that $\beta_0 = \beta_1$, that $\varepsilon_j = \varepsilon_{1j} - \varepsilon_{0j}$ and that $\alpha = \alpha_1 - \alpha_0$. The lineal model could be expressed as:

$$P_r(SI_j) = P_r(\alpha Z_j - \beta t_j + \varepsilon_j) > 0 \quad (10)$$

For estimating a Probit model, it is assumed that the errors are independent, have a normal distribution with mean cero, thus $\varepsilon = \varepsilon_1 - \varepsilon_0$ will also have a normal distribution with mean zero and variance σ^2. Letting $\phi = \varepsilon / \sigma$, then $\phi(N(0,1)$ such that:

$$P_r(\varepsilon_j < \alpha Z_j - \beta t_j) = P_r(\phi < \alpha Z_j / \sigma - \beta / \sigma t_j) = \Phi(\frac{\alpha Z_j}{\sigma} - \frac{\beta}{\sigma} t_j) \quad (11)$$

Where $\Phi(\cdot)$ is a normal Cumulative Density Function (CDF). Eq. (11) aloud the estimation of: $\alpha / \sigma y \beta / \sigma$.

A shock price in which respondent j is indifferent between having or not the public good need to be found for estimating her willingness to pay, as shown in Eq. (12).

$$\alpha_1 Z_1 + \beta(y_j - \mathrm{WTP}_j) + \varepsilon_{j1} = \alpha_0 Z_j + \beta y_j + \varepsilon_{j0} \quad (12)$$

From Eq. (12) it is possible to estimate the WTP, as:

$$\mathrm{WTP}_j = \alpha Z_j / \beta + \varepsilon_j / \beta \quad (13)$$

thus the expected value of the WTP of the respondent j will be written as:

$$\mathrm{WTP}_j = \alpha Z_j / \beta \quad (14)$$

A central tendency measure that could give information to decision makers is the WTP expected value for the average respondent:

$$E_\varepsilon(DAP \mid \alpha, \beta, \bar{z}) = \left[\frac{\alpha / \sigma}{\beta / \sigma}\right] \bar{z} \quad (15)$$

The random utility model described in the last paragraphs was used for all those data bases in which it was possible to do this complete model. But in some case more simple estimations were done. For the case of the people that rent land for having a house for weekends by the Hardy River a Probit model was estimated. In this case an index (I_i) was defined as:

$$I_i = \alpha_i + \beta_i P \quad (16)$$

The probability of an affirmative answer was calculated by valuing the index I_i in a normal distribution.

Other cases with more simple estimations were: fisheries and bird – watching. For these cases the sample size was not big enough for an econometric analysis. Then the social benefit for having the public good at price zero was estimated as the discrete sum of the areas obtained as the number of affirmative responses times the proposed price. This simple exercise is discrete and non – parametric approach, which is in principle very similar to the more sophisticated exercises.

3 Results

Table 1 shows the estimated benefits for the in – stream flows in the Colorado River delta. A remarkable issue that can be observed in Table 1 is that the highest value is a non – use value (existence) that represents 76 percent of the total value estimated. Thus, the use values such as fisheries, hunting and recreation represent all together less than one fourth of the total.

Table 1　Estimated benefits of the in – stream water flows at the Colorado River Delta

User	Value type	Estimated figure million dollars	
		A year	Perpetuity
Households nearby[a]	Landscape and existence value	0.288	28.788
Visitors to Colorado River[b]	Recreational use	0.033	3.270
Weekend recreational Villages[c]	Recreational use	0.000	0.034
Visitors to Hardy River[c]	Recreational use	0.041	4.050
Fisheries[d]	Direct use in production	0.001	0.060
Bird – watchers[d]	Direct use in consumption	0.002	0.185
Donors[e]	Existence	0.018	1.750
Total		0.383	38.137

a. Estimations using a Random Utility Model (Sanjurjo, 2006).
b. Estimations using a Random Utility Model (Sanjurjo and Islas, 2007).
c. Estimations using the predicted survival function with a Probit model (Sanjurjo and Carrillo, 2006).
d. Estimations using a discrete sum of the affirmative responses, times the proposed price (Sanjurjo and Carrillo, 2006).
e. The figure of 1.75 year is a clear under – estimation, based on direct donations for ecosystem restoration. A fraction of the donations with components of research, management and education were not considered.

A project for letting 2 m^3 per second to flow into the river, and only once every four or five years to let 30 m^3 per second during no more than two months, has been proposed. With this project almost all benefits estimated in Table 1 could be obtained (all except for fisheries for which more flows will be needed). With only the 2 m^3 per second (without the flooding flows of every 4 to 5 years) most of the benefits will still (all except for an increase in birds for bird – watching and hunting). As a result of these, a total amount of 3.8 million dollars may be obtained bay only letting 2 m^3 per second to flow into the river in a permanent way.

The cost of doing that will be between 9 million to 12 million dollars at once and 0.5 million more every year. With these figures, Table 2 shows the cash flow of the project.

The Net Present Value of the mentioned project is 15.4 million dollars. The Internal Rate of Return is of 25 percent. The project will produce 2.28 dollars for each dollar invested. This means that if maintaining inflows were a private good it will be a great business to do that. But given the characteristics of a public good private markets will not provide it in an optimal way, and the state will need to provide the conditions for providing this water flows.

Table 2　Cash flow of the project for maintaining water flows at the river

Year	Benefits (B)	Costs (C)	B – C	PV (B – C)
0	0	120	– 120	– 120.0
1	13	5	8	7.0
2	25	5	20	16.8
3	38	5	33	24.8
Perpetuity	380	50	330	225.4
Sum				154.0

References

Arrow, K., R. Solow, P. R. Portney, et al. 1993. Report of the NOAA Panel on Contingent Valuation, National Oceanic and Atmospheric Administration (NOAA).

Bateman, I. J., R. T. Carson, B. Day, et al. 2002. Economic Valuation with Stated Preference Techniques: A Manual, Edward Elgar.

Bateman, I. J., I. H. Langford, S. F. Jones, et al. 2000. Bound and path effect in double and triple bounded dichotomous choice contingent valuation, Paper presented at the Tenth Annual Conference of the European Association of Environmental and Resource Economists (EARE), University of Crete.

Bishop R. C. y T. A. Heberlein. 1979. Measuring Values of Extra – market Goods: Are Indirect Measures Biased?, American Journal of Agricultural Economics, 61: 926 – 930.

Bradley, M. 1988. Realism and Adaptation in Designing Hypothetical Travel Choice Concepts. Journal of Transport Economics and Policy 22, 121 – 137.

Cameron, T. A. 1988. A New Paradigm for Valuing Non – market Goods using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression. Journal of Environmental Economics and Management, 15: 355 – 379.

Cameron, T. A. y M. D. James. 1987. Efficient Estimation Methods for Use with Closed – Ended Contingent Valuation Survey Data. Review of Economics and Statistics, 69: 269 – 276.

Carrillo – Guerrero, Y, 2005. Valor de los flujos de agua dulce en el Delta del Río Colorado: pesquerías, recreación y biodiversidad. Reporte preparado por Pronatura Noroeste para el Instituto Nacional de Ecología.

Diamond, P. and J. Hausman. 1993. On contingent valuation measurement of non – use value, en H. J. Hausman (ed), Contingent Valuation: A Critical Assessment, North – Holland.

Duffield, J., and D. Patterson. 1991. Inference and Optimal Design for a Welfare Measure in Dichotomous Choice Contingent Valuation. Land Economics 67 (2): 225 – 239.

Estrella, A. 1997. A New Measure of Fit for Equations with Dichotomous Dependent Variables, Federal Research Bank of New York, Research Paper No. 9716.

Freeman III, M. 2003. The Measurement of Environmental and Resource Values: Theory and Methods, Resources for the Future.

Glenn, E., C. Lee, R. Felger, and S. Zengel. 1996. Effects of Water Management on the Wetlands of the Colorado River Delta, Mexico. Conservation Biology 10:1175 – 1186.

Green, W. H., 1997. Econometric Analysis, Prentice – Hall.

Habb T. C. y K. E. Mc Conell. 2002. Valuing Environmental and Natural Resources: The Econometrics of Non – market Valuation, Edward Elgar Publishing.

Habb T. C. y K. E. Mc Conell. 1998. Referendum Models and Economic Values: Theoretical, Intuitive, and Practical Bounds on Willingness to Pay. Land Economics, 74: 216 – 229.

Hanemann, W. M. 1984. Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses. American Journal of Agricultural Economics, 66: 332 – 341.

Hanemann, W. M., J. Loomis and B. Kannien. 1991. Statistical Efficiency of Double Bounded Dichotomous Choice Contingent Valuation, American Journal of Agricultural Economics, 73: 1255 – 1263.

Johnson, F. R., K. E. Mathews, and M. F. Bingham. 2000. Evaluating Welfare – Theoretic Consistency in Multiple – Response, Stated – Preferences Surveys, TER Technical Working Paper No. T – 0003. Triangle Economic Research.

Krinsky, I. y A. Robb. 1986. On Approximating the Statistical Properties of Elasticities. The Review of Economics and Statistics, 86: 715 – 719.

Kriströ, B. 1990. A Non – Parametric Approach to the Estimation of Welfare Measures in Discrete Response Valuation Studies. Land Economics 66 (2): 135 – 139.

Long, J. S. 1997. Regression Models for Categorical and Limited Dependent Variables. Thousand Oaks.

Maddala, G. S. 1983. Limited – dependent and Qualitative Variables in Econometrics. Cambridge University Press.

Mitchell, R. C., and R. T. Carson. 1989. Using Survey to Value Public Goods: The Contingent Valuation Method, Resources for the Future.

Ready, R. y D. Ho. 1995. Statistical Approaches to the Fat Tail Problem for Dichotomous Choice Contingent Valuation, Resource and Energy Economics, 71: 491 – 499.

Sanjurjo E. e I. Islas. 2007. Valoración Económica de la Actividad Recreativa en el Río Colorado. Artículo aceptado para la revista: Región y Sociedad No. 39. El Colegio de Sonora, México.

Sanjurjo, E y Y. Carrillo. 2006. Beneficios Económicos de los Flujos de Agua en el Delta del Río Colorado: Consideraciones y Recomendaciones Iniciales. En Gaceta Ecológica No. 80. Instituto Nacional de Ecología. México. pp. 51 – 62.

Sanjurjo, E. 2006. Aplicación de la Metodología de Valoración Contingente para Determinar el Valor que Asignan los Habitantes de San Luís Río Colorado a la Existencia de Flujos de Agua en la Zona del Delta del Río Colorado. 20 pp. PEA – DT – 2006 – 001., Instituto Nacional de Ecología, México.

Schumann, H.. 1996. The sensitivity of CV outcomes to CV survey methods, in D. J. Bjorntad y J. R. Khan (eds), The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs, Cheltenham, Edward Elgar.

Valdés – Casillas, C., E. P. Glenn, O. Hinojosa – Huerta, et al. 1998. Wetland management and restoration in the Colorado River delta: the first steps. CECARENA – ITESM Campus Guaymas, Sonora.

Land Use Control in a Delta

W. J. M. Snijders

Road and Hydraulic Engineering Institute, Ministry of Transport, Public Works and Water Management. P. O. Box 5044 2600 GA Delft, The Netherlands

Abstract: From a delta rivers pour their water and silt into a sea or lake. Deltas, more so than other areas, are still in the process of formation and thus are relatively dynamic in nature. Generally a delta consists of rather a flat stretch of land, much of which is flood prone.

The danger of flooding used to be a natural hazard but that is not longer the case. Since man occupies the lands in the delta he manages and manipulates the water levels of the farmlands and built – up areas. At the same time the discharge, the amount of silt and the quality of the water in the river are influenced by man upstream to a certain degree. And in the coastal zone erosion and sedimentation are in a sort of equilibrium: erosion is intense during a storm surge, sedimentation occurs anywhere where currents slow down. This balance is disturbed when structures like harbours and sea defences fixate the coastline and put a limit on the system's resilience.

Thus nowadays people are more inclined to regard flooding as a man's collective failure: something that may happen but that is not allowed to happen. With flood risk management is understood that all fair, accountable measures are taken so that damages, casualties and human misery that may occur during flooding will be avoided.

In this contribution "land use control in deltas" is addressed in which flood risk management is a decisive issue. Five principles are discussed that play a key role, culminating in a conclusive note on physical planning.

Key words: land use, diversity of animals and plants, human activity, land use management, innovation and development, delta

1 Go along with natural processes

The knowledge about using the delta for man's sake starts with knowing how the dynamics of water and earth particles in and around the delta work. What is the river's discharge, its sand and silt content, its ice – load in winter, and the distribution of it all throughout the year? How, when and where erosion and sedimentation take place? What are patterns of coastal sea water and marine sediment movements and how can storm surges have an effect on the delta, either when it its shores are protected or not? This knowledge is vital if one has to deal with questions like how and where to project (new) developments or how to improve the protection of actual landforms.

If one takes into account what natural processes will bring about anyway, one is more able to be cost effective while erecting and maintaining flood defences.

2 Healthy delta waters

Regards healthy ecosystems two criteria are important: the quality of the environment – either in a chemical sense and regards the presence of a diverse population of plants and animals – and the extent and situation of the habitats that we allow nature to flourish in.

The water system should be safeguarded from chemical and organic pollutants, of which most of them arrive by means of the river. Many dissolved and suspended pollutants and organic pathogen particulates are a direct hazard for life forms that depend on the water system. Especially chemical pollutants often are persistent. Having been clung to silt – particulates and having been settled down in a sediment layer for years they may become a threat one day again once they will be taken up by plants and animals while feeding.

Some plants and animals are respected for their "wildlife" qualities. But the role of nature goes beyond that because biota carry life and are part of ecological cycles like the food chain and cycles of oxygen, carbon, etc. from which man is dependent for its very existence. In times of plenty one can spare many a specimen, but with the actual rate of development in the world however all life forms are gradually becoming more precious. Being replaceable or not, scarce, being an essential part of the food chain and contributing to bio – diversity are important criteria to come to judgements in these.

Deltas are especially important because fresh waters meet there the coastal, saline environment yielding to a high bio – productivity. Deltas are also junctions on migration – tracks for many birds and other species and they offer an unprecedented chance for robust and unique nature reserves to flourish.

3 Human activities in the delta

The human occupation of the landmass is accompanied by investments in land for agriculture, the extraction of resources like oil and minerals, premises for housing, industry and services, roads and other transportation networks, waterworks, defences against flooding, etc. Investments are protected against any loss and as a result leave the land spatially immobilized. This often contradicts with the dynamics of the rivers and coastlines.

Man also has immaterial, intangible interest in the land: apart from value for nature as discussed before, there are social and cultural values like the "spirit" in local communities, archaeological treasures and a richness that landscapes can offer the visitors.

Regards human activities in town and country planning we distinguish high dynamic and low dynamic functions. Areas with heavy investments are characterized as low dynamic. They are not easily to be converted, removed or replaced and there is an urgency to keep them from any flood risk: town centres, residential and industrial estates, roads, railways and (air) ports and robust nature areas which function in a way we value highly.

If one thinks about changing a land use one has to take into account that these processes are costly and time and energy consuming and that many interest will become involved.

4 Contingencies

Like in playing chess, in town and country planning one has to be aware of all possible scenario's that may occur and one has to find oneself to be prepared for all possible effective solutions that keeps one from misfortune or disaster.

An important scenario for climate change has to be considered that acknowledges sea level rise, different patterns of precipitation in the catchments area of the river and more intense storm surges at sea. But other, rather different scenarios may be useful to consider as well: one that deals with an increased risk on damages and casualties due to population growth, expected socio – economic expansion in the region, urbanization, an increase in commercial activities and one that forecasts changes in human behaviour patterns, e. g. how one deals with collectivism – individualism, changes in lifestyle, recreation, tourism, etc.

Regards solutions two contingencies can not be missed: redundancy and the chain of safety.

Critical systems can best be provided with a redundant back up. Like a big aeroplane is provided with more than one system for landing, for braking, etc. , our safety against flooding could best be serviced with more than one system to prevent flooding.

In case of an extreme river discharge some excess water may be temporarily stored in a detention area or flood mitigation reservoir, or may be channelled off through a spillway to overflow an area or a bypass towards other regions or more downstream. Also the discharge capacity may be enhanced by an enlargement of the floodplain area or by dredging practices.

The main coastal hazard takes place when simultaneously a strong wave – impact and a high storm surge level can be experienced on the shore. Areas that are protected by a single line of defence can alternatively be protected by a breakwater that reduces extreme waves significantly and a separate defence that withholds the water mass at about storm surge level.

Prevention of flooding by means of flood defences is one way of dealing with flood risks in the so called chain of safety. Other measures one may take are a policy in spatial planning not to allow investments being made in more or less flood prone areas, operating an emergency planning which includes a flood warning system and evacuation plans, preparing for an adequate insurance system, a recovery of damages and the disruption of everyday life after a flood.

5 Innovation

All that has to be done to safeguard areas from flooding can be helped by applying innovative techniques, proposing new legislation, institutional improvements, and by optimising cross – partner cooperation.

By means of technology one can think of improving the system of flood protection itself by rearranging the water system – e. g. by installing a storm surge barrier – or by enhancing the strength of the levee or flood walls e. g. by allowing overtopping while keeping the defence itself breach – free.

Pitfalls in legislation and institutional functioning can be overcome by improved rules and legislation and rearranging parts of institutional responsibilities.

A third improvement can be sought in improving the way different partners cooperate. Partners involved in an endeavour often have common interests and opposing interests at the very same time. In process management public and private stakeholders and interest groups are brought together in terms of ambitions and resources, in supplying creativity and knowledge and thus to contribute efficiently to the decision making process.

6 Management of space

There are many interests that want to make use of the delta. At any time there are settled interests, initiatives for development and proposals to rearrange an area.

A delta is a dynamic area and two factors are decisive regards a proposed land use: the competition among stakeholders about rights to use land and flood risk management.

If the participants can be positive to a situation the situation is right.

Participants involved in decision making are the authorities, stakeholders, interest groups and local residents. Procedures help them to streamline the process that starts with agenda – setting, and proceeds with designs, implementation, use, maintenance and compliance. A proper division of rights, costs and risks among stakeholders will be the base for any agreement that has to be made (Fig. 1).

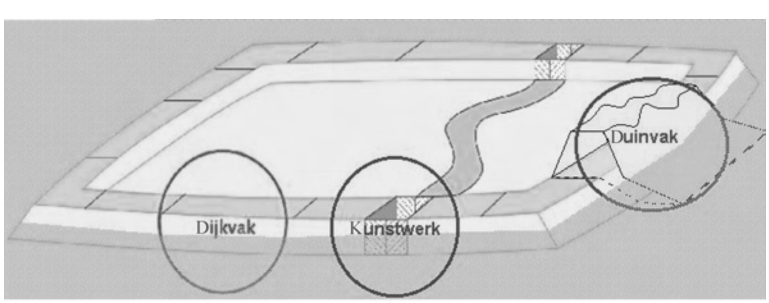


Fig. 1

Flood hazards can be minimized by flood defences that will be operational around flood proof, well protected areas. Based on the present population and the invested interests one will select an appreciated protection levels for the area concerned, e. g. one with a return period for flooding of 1,000 years. The proper system of flood defences will have an asset management based on cost effectiveness. The life cycle costs of the investments made in flood defences will have to be minimized regards their lengths and prices per km.

Coast Reshaping Process at the Modern Yellow River Deltas

Chen Xiaoying, ***Chen Shenliang*** and ***Li Xiangyang***

State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai, 200062, China

Abstract: Due to the limited sediment supply from the Yellow River and its frequent shifts, the Yellow River subaerial delta is mainly subject to reshaping processes in the form of erosive and accretive patterns. Based on coastal landforms, sediments and hydrologic data, Principal Component Analysis and dynamical geomorphology method have been applied to analyze mechanism for the coastal profiles evolution of the Yellow River delta. The results show that the coast of the Yellow River delta is divided into three geomorphic zones: the area near abandoned delta, estuarine area, and Laizhou Gulf. For nearshore zone of the abandoned delta, waves stirring up sediment and tidal current transporting sediment play a great role in coastal erosion. The intensity of erosion resistance of bottom sediment affects directly the erosion speed changes. The depths of the erosion – accretion balance zone on coastal profiles are controlled by ocean dynamics, especially by tidal currents velocity. For the area near current estuary, the coasts have been deposited rapidly. The distance it moved forward to sea is dominated by the relative intensity of fluvial and marine processes. For the area near Laizhou Bay, the coasts keep stable. On account of the influence of tidal current field, most of the sediment supply of the Yellow River can't reach the area.

Key words: the Yellow River Delta, Principal Component Analysis, accretion and erosion, temporal and spatial evolution

1 Introduction

Deltas are geomorphologic features resulting from interacting river and marine dynamics (Ren, 1994). The former essentially supply sediment to the coastal system whereas the latter basically stir up and transport the sediment moulding the riverine deposits (Jiménez, Sánchez – Arcilla et al., 1997; Sánchez – Arcilla et al., 1998). When the sediment supply from river is larger than the sediment removal capacity by coastal dynamics, the delta is continuously prograding. In contrast, when the river supplies are small compared to the marine transport capacity, the coast is subjected to erosion processes.

The modern Yellow River Delta, situated between Bohai Gulf and Laizhou Gulf, has developed since 1855. The subaerial delta occupies around 5,000 km^2 area and 350 km – long coastline. It has formed from Ninghai, extending westward to the Taoerhe River estuary, southward to the Xiaoqinghe River estuary, and eastward to take on a great fan shape (Fig. 1). The Yellow River was originally well known as it's the highest sediment load. (Milliman and Meade, 1983; Qian and Wang, 1980). The delta area was increasing at the rate of 23.6 km^2/y from 1855 to 1954. (Li, 2000; Hu and Cao, 2003) and coastline had been prograded at the rate of 160 m/yr during the period from 1855 to 1996. However, the sediment discharge of the Yellow River has been a drastic decrease in recently years. Accordingly, the delta has been prograded slowly. For example, the velocity of forming land for the Yellow River Delta is 14.7 km^2/y from 1976 ~ 1992, but it had fallen to 8.6 km^2/y after 1992. It is worse that there exists erosion along the estuarine coasts in recent years.

The frequent course shifts is another character of the Yellow River. There have been 3 times large – scale river course shifts taking place naturally or artificially since 1953 (Fig. 1), i. e. the terminal channel flowing to sea was Shenxiangou course in 1953, then it was shifted to Diaokou course from 1964 to 1976, and then shifted artificially to Qing Shuigou in 1976, and finally shifted artificially again to Qing 8 which is at the north bank of the 8th section of the Qingshuigou course.

In the past, numerous studies have focused on the deltaic sedimentation, riverbed aggradation and stability of terminal course on the Yellow River Delta (Xue, 1993; Yu,2002;Li and Zhuang et al. ,2000). Due to the migration of river course and a drastic decrease of sediment load since 1976, the hydrodynamic condition has been changed greatly, accordingly, the coastal geomorphology has been reshaped and a new coastal dynamic system was built. Base on the latest measured data, the aim of this paper is to illuminate the late reshaping processes of the Yellow River Delta under the control of hydrodynamic factors respond to river course changes and the decrease of the sediment supply. It might form a basis, from which planners can develop sound proposals for the sustainable development of the coastal zones and its resources.

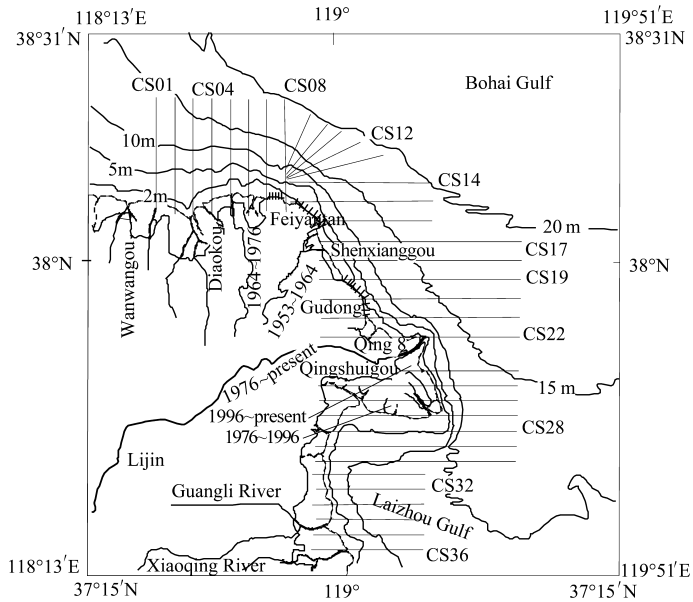


Fig. 1 Location map of the modern Yellow River and its historical migration since 1953

2 Data and methods

2.1 Data sources

Since 1971, Thirty – six shore – normal bathymetric survey transects (1 ~ 18) were repeatedly surveyed at the nearshore zones around the Yellow River Delta between September and October each year (Fig. 1). Each of them, representing the various sub – environments, extends from a point known depth near shore to the deeper sea. In addition, the bottom sediment samples which cover nearshore zones were collected from CS5 to CS10 respectively in 2000 and 2004. Monthly sediment and water discharge were calculated from daily measurements from 1950 to 2005 at the Lijin Hydrological Station which is about 100 km upstream from the river mouth, and can estimate accurately water and sediment of the Yellow River. The velocity and direction of wind were from the Gudong Station, and tidal currents data was measured in Feiyantan in April 2004 which is in the north of the Yellow River Delta.

2.2 Methods

Coastal profiles are combine – effective results among waves, tidal currents, winds and coastal topography. So spatial and temporal changing processes of coastal profile can reflect main evolution of the coastal system responds to various hydrologic conditions. Principle Component Analysis is the one of the effective methods (Xiang and Li et al., 2003; Dai and Chen et al., 2002). In this paper, every beach profile is divided into some 1m – high units from shore to deeper sea. Every unit volume is calculated, and then a volume matrix of different units on every profile is built. With Principal Component Analysis, the volume matrix can be decomposed orthogonal matrix of time and space. Then the principal components with biggest contribution rate can be found, which can reflect basically time – spatial characters of coastal profile.

3 Hydrological conditions

3.1 A drastic decrease of water and sediment discharge

According to the data of the Lijin Hydrological Station from 1976 to 2005, the water and sediment discharge of the Yellow River have been an obvious decrease tendency (Fig. 2). This trend can be approximated a line regression:

$$SD = -0.277,7Y + 9.233,3 \ (r = 0.71,\ n = 30,\ \alpha = 0.001)$$

$$WD = -9.267,3Y + 351.23 \ (r = 0.66,\ n = 30,\ \alpha = 0.001)$$

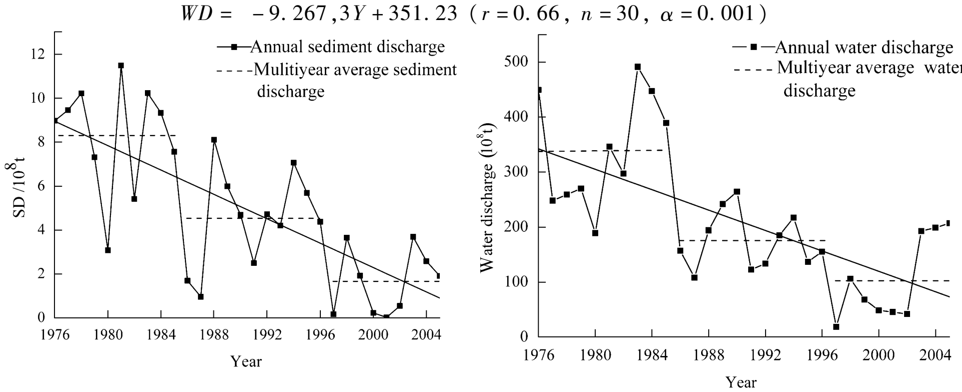


Fig. 2 Annual *SD* and *WD* changes in (A) SD, (B) *WD* at the Lijin Hydrological Station from 1976 to 2005

where, *SD* is sediment discharge(10^8 t), *WD* is water discharge(10^8 m^3) and *Y* is calendar year from 1976 to 2005. Their changes can be roughly divided into three stages, i. e. high water and sediment discharge phase (1976 ~ 1985), medium water and sediment discharge phase (1986 ~ 1996), and low water and sediment discharge phase. The Yellow River had a mean water discharge of 334.51×10^8 m^3/y and a sediment load 8.32×10^8 t/y during the period from 1976 to 1985, however, they had reduced quickly to 103×10^8 m^3/y and1.63×10^8 t/y, respectively, from 1997 to 2005.

3.2 Wind and waves

According to measured velocity and directions of wind at Gudong Station during the period of January to December in 2005, the most frequent wind is from SW with a frequency of 33.64%, and the second is from NE and SE with frequency of 25.68% and 22.03%, respectively. But the strongest wind is from NE at the average rate of 6.82 m/s and maximum velocity of 20.9 m/s.

The waves are closely consistent with wind direction and velocity from sea because the Yellow River is located in semi – closed Bohai Gulf. As shown in Fig. 3(b), waves prevailing direction is from NE with a frequency of 10.3% and the maximum height of 5.2 m. Wave from SE is also often observed with a second frequency of 8%. There are quite different frequencies for various height grades of waves, e. g. waves with height < 0.5 m have the highest frequency of 51.1%, waves with wave height 0.5 ~ 1.5 m have the frequency of 36.3%, waves with wave height 1.5 ~ 3 m have the frequency of 11.8%, and waves with wave height 3.0 ~ 5.0 m have the lowest frequency of 0.5% (Zang, et al., 1996).

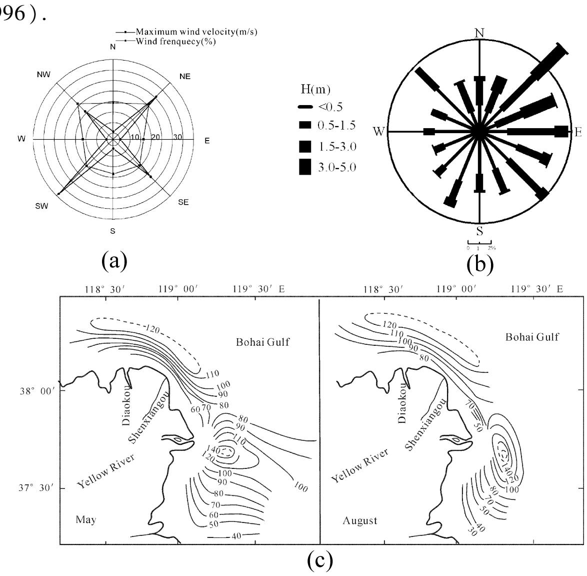


Fig. 3 Change of wind rose and wave rose and tidal current velocity recorded nearshore of the Yellow River delta
(a) Annual change of wide velocity and direction; (b) Annual change of wave; (c) Tidal current velocity nearshore of the Yellow River delta

3.3 Tidal currents

The Yellow River delta is located near amphidromic point of M_2 tidal component. Including amphidromic point, tides of the limited areas around it belong to regular diurnal tide, and then show a transition to semi – diurnal tide towards south and west. In response to the complex tides, there exist two high current velocity zones which are located near Shenxiangou estuary and Qingshuigou estuary, respectively (Fig. 3 (c)). The former doesn't change with season generally and the center velocity of 1.20 m/s because of approaching the amphidromic point of M_2 tidal component. The latter has been formed resulting from the spit rapidly stretching into sea after the Yellow River terminal channel was migrated to Qingshuigou course (Chen and Chen et al., 2006; Pang and Jiang, 2003; Chen and Chen, 2005), so the high velocity area changes with season. In spring, the area is limited with a maximum current velocity of 1.40 m/s; but in summer, water and sediment discharge are abundant, the high velocity area becomes widely and the maximum current velocity gets to 1.80 m/s.

4 Morphodynamic classification and time – spatial features of various area

4.1 Morphodynamic classification

The erosion and accretion by 5 m isobath and 10 m isobath are compared which represent shallow area and deep area of coastal profile along the Yellow River Delta, respectively (Fig. 4 and Table 1). It indicates that their recession rates have been decreased, particularly, have been retreated during the recent years. According to statistics in Table 1, let *R* be zero, then *SD* is 2.65×10^8 t/y for 5 m isobath and 2.31×10^8 t/y for 10 m isobath, approximately 2.48×10^8 t/y on average. This value is closely to the results by Liu (Liu and Li et al., 2001) which could be treated as a critical rate of river sediment supply to recession. The river sediment load has decreased below this critical rate since 1997 (Fig. 2), except for 1998 and 2003, when the progradation of 5 m and 10 m isobaths may have been replaced by a recession.

Based on recession and progradation of 5 m and 10 m isobaths, the coastal region of the Yellow River Delta is classified into three distinct geomorphic zones, i. e. the abandoned estuary area (AEA) which covers the profiles fromCS01 to CS18; current estuary area (CEA) which covers profiles fromCS19 to CS28; and Laizhou Gulf area (LGA) which covers profiles from CS29 to CS36. The AEA have been retreated entirely except for the area near Wanwangou estuary which had been abandoned a long time. The CEA has been progradated since 1976 in the rough. However, it can be subdivided into three units: Gudong area (CS19 – CS21), Qing 8 estuary area (CS21 – CS24) and the old Qingshuigou estuary area (CS25 – CS28). Since the sea wall was built along Gudong area in 1985, the sea bed near the root of sea wall has been suffered from serious erosion, and the coastal profile of deeper sea is prograding seawards at a low speed. Qing 8 estuary area has been in a state of rapid progradation since 1976. The old Qingshuigou estuary area has switched from obvious progradation to drastic recession since it was abandoned in 1976. For LGA, the coastal profile is basically stable near shore.

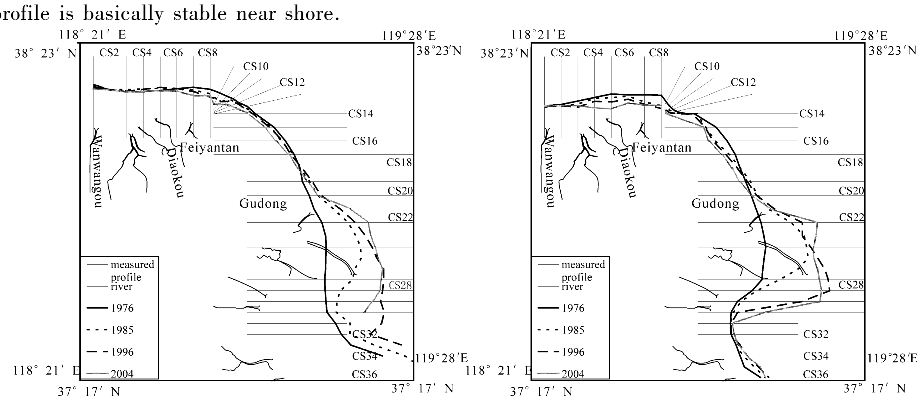


Fig. 4 Long – term shifts of 5 and 10 misobaths in the subaqueous Yellow River Delta (A) The shifts of 5 m isobaths; (B) the shifts of 10 m isobaths

Table 1 Relation of progradation rate R to riverine sediment SD, taking 5 and 10 m isobaths as examples

Item	5 m isobath			10 m isobath		
	1976 ~ 1985	1986 ~ 1996	1997 ~ 2004	1976 ~ 1985	1986 ~ 1996	1997 ~ 2004
Time interval (years)	9	11	8	9	11	8
Progradation (m)	1,409.70	1,558.31	−826.43	2,443.24	2,888.10	−1,016.76
Progradation rate R (m/y)	156.63	141.67	−103.30	271.47	262.55	−127.10
River sediment load S (10t/y)	8.24	4.55	1.60	8.24	4.55	1.60
Relation between progradation rate R and riverine sediment load S	$R = 167.11\text{Ln}(S) - 162.95$; $R = 0.95$; $n = 3$			$R = 257.76\text{Ln}(S) - 215.96$; $R = 0.94$; $n = 3$		

4.2 Principal component analysis for the typical profiles of AEA

After volume matrix of different units on every profile is decomposed into orthogonal matrix of time and space, the cumulate contribution rates are listed on Table 2. It indicates that the cumulate contribution rates of the first and the second eigenfunction is higher than 85% roughly in AEA and LBA, so they can be used to explain the principal processes of coastal profile evolution in these two areas. The first eigenfunction reflect the general changing tendency and the second eigenfunction can explain the concrete patterns of profile evolution. For CEA, the cumulate contribution rates of the first eigenfunction is much larger than 85%, except for Profile CS19, thus the first eigenfunction can be reflected the evolution of CEA. Additionally, based on the analysis above, the coast near Wanwangou estuary is basically stable, so it is emphasized to analyze the area which is located to area of Wanwangou estuary.

Table 2 Contribution rates of eigenfunction for typical profiles along coasts of the Yellow River Delta

Profiles / Contribute rates(%)	AEA					CEA			LGA	
	CS04	CS06	CS08	CS09	CS14	CS19	CS22	CS24	CS28	CS32	CS36
The first eigenfunction	68.67	72.35	80.62	79.53	71.50	60.79	96.47	96.53	88.58	73.71	57.33
The second eigenfunction	20.22	20.19	17.48	17.42	19.04	34.12	2.71	2.97	7.61	24.78	24.47
Cumulate contribution rate (%)	88.89	92.54	98.10	96.95	90.54	94.91	99.18	99.50	96.19	97.49	81.80

4.2.1 Time eigenfunction characters of coastal profiles in AEA

From curves of the first eigenfunction for each profile (Fig. 5), it shows that the function value apparently increases from 1971 and gets to a peak in 1974. However, there is a drastic decrease from 1975 to 1980, and then the curves become gentle from 1981 to 1998, and finally it is decreased slowly again from 1999 to 2004. Like curves of the first eigenfunction, the curves of the second eigenfunction take on a similar changing tendency. In response to the curves changes, the evolution processes of AEA can be divided into four stages: the rapid accretion stage (1971 ~ 1974), the rapid erosion stage (1975 ~ 1980), accretion – erosion adjustment stage (1981 ~ 1998), slow erosion stage (1999 ~ 2004).

4.2.2 Spatial eigenfunction characters of coastal profiles in AEA

The curves of the first spatial eigenfunction represent the average degree of accretion – erosion of coastal profile. As shown in Fig. 5(b), all curves of the first spatial eigenfunction has the same change tendency, moreover, there exists a noticeable peak zone which stands for the area with drastic change of accretion – erosion. It can be drawn out that the profile evolution of AEA is dominant by a regular discipline. The profile topography has been changed greatly from 2 m to 12 m depth and then been changed gently at the slope from 14 m to 15 m depth.

The second spatial eigenfunction embodies the evolution patterns of coastal profile. Seen from the curves of the second spatial eigenfunction, there is a node with the value of zero on each profile where accretion and erosion get to be in a state of dynamic balance. The negative value represents erosion and the positive value represents accretion. So it can be stated that there exists erosion – accretion balance zone (EABZ) on every profile of AEA. The area which is shallower than EABZ is suffered from erosion and the area which is deeper than EABZ is prograding seawards slowly. In addition, seen from the curves, the depth of EABZ is different for the various profile of AEA. The depth of EABZ of the coastal profile is the largest, located in northeast part of the Yellow River Delta. And then it decreases gradually southwards and westwards, respectively (Table 3).

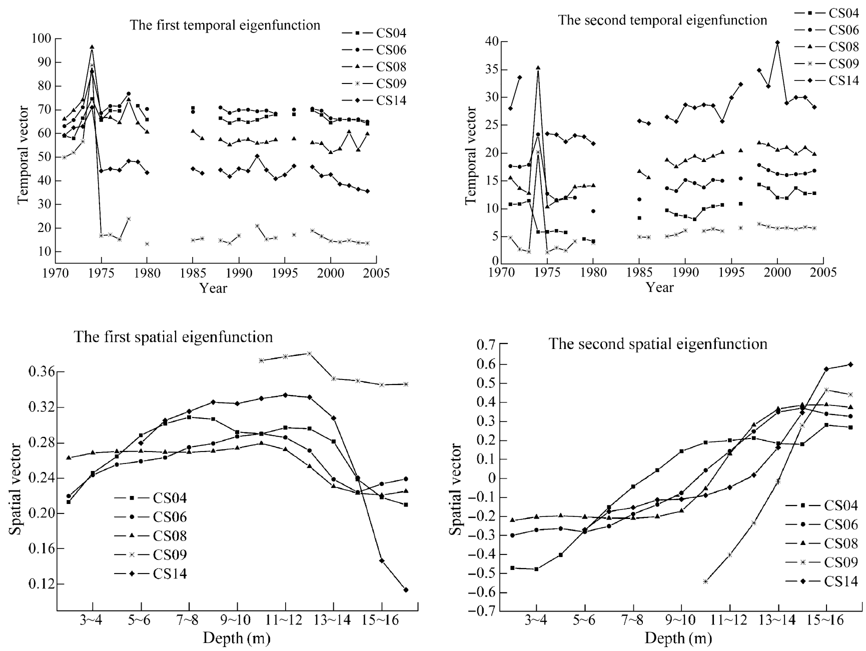


Fig. 5 (a) The temporal eigenfunction of AEA, (b) The spatial eigenfunction of AEA

Table 3 The average depth of the erosion – accretion balance zone (EABA) along coasts of the Yellow Rier Delta

Profile	CS04	CS05	CS06	CS07	CS08	CS09	CS10	CS14	CS16	CS27
The depth of EABZ (m)	8.5	9.0	10.3	12.0	12.6	13.9	14.5	13.2	12.0	13.5

4.2.3 Temporal and spatial evolution mechanism analysis

Based on the measured data, we take Profile CS07 for an example to explain the evolution of the AEA (Fig. 6). The course of Yellow River flowing into sea is at Diaokou estuary before 1976, when AEA was dominant by the fluvial processes. So a rapid progradation happened in AEA. However, since the river course was shifted to Qingshuigou estuary in 1976, the AEA was abandoned completely and had no fluvial sediment supply. In fact, the sediment supply was decreased remarkably in 1975. Consequently, the area was dominant by marine processes resulting in entire erosion of the coastal profile from 1975 to 1980. However, the retreat rate had been decreased and an EABZ appeared on every profile from 1981 to 1998. By comparison of the depth of EABZ, the shallower area was eroded and the deeper area was prograded seawards. With the combined effect of waves and tidal current, loose density sediment was stirred and washed out firstly, close – grain sediment left, which resulted in the stronger erosion resistance of the bottom sediment and retreat rates decreasing gradually. Accordingly, the depth of EABZ became shallower and shallower and finally disappeared, i. e. the depth of EABZ on Profile CS07 had been decreased from 12.4 m to 9.7 m or so, and had been disappeared after 1999 when the whole profile was eroded at the same speed in the rough.

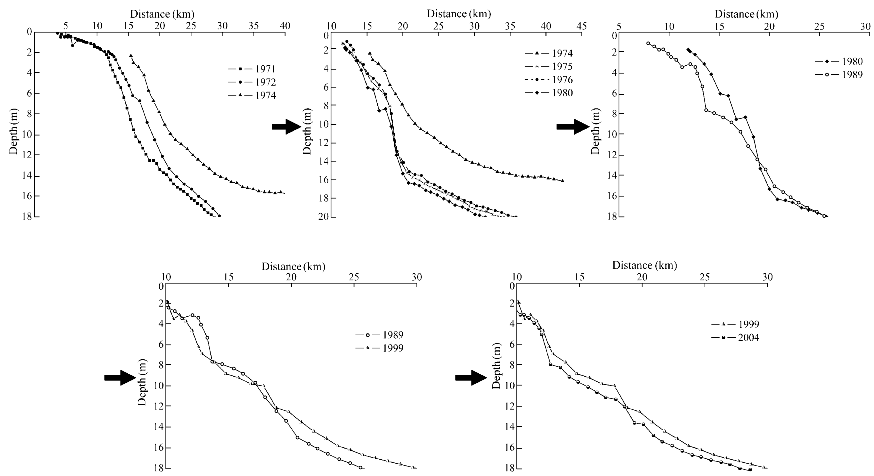


Fig. 6 The evolution processes of measured profile near the abandoned estuary area (using Profile CS07 as an example)

4.2.4 The reshaping processes by the marine dynamics

Since the Diaokou estuary course was abandoned since 1976, the fluvial sediment supply ceased, and coastal topography readjustment caused the shoreline to retreat. The marine processes have been preponderant in the AEA, especially for the combined effect of waves and tidal currents.

(1) Waves reactions of AEA. Wave stirs up sediment mainly by means of wave breaking and wave disturbing. The coast of AEA has a trend of E – W, which intersected the directions of strong waves and frequent waves (Fig. 3(b)). So wave reactions play a great role in the evolution. According to Code of Hydrology for Sea Harbours, if profile gradient $i \leqslant 2‰$, the maximum value is 0.60 which is the ratio of breaking wave height to the water depth where waves begin to break. Coincidentally, the profile gradient is from1‰ to 2‰, thus, based on the data of Fig. 3B, the wave breaking depths for various grades of waves are calculated listed on Table 4. In addition, the frequencies of waves breaking and waves disturbing are calculated on frequencies of various grades waves (Table 4). As for waves disturbing depths, they can be considered as critical depths which can be worked out according to Sato Formula (Li and Zhu, 1997) as follows:

$$H_0/L_0 = 2.4(D_{50}/L_0)^{1/3} H_0/Hsh(2\pi h/L)$$

where: H_0 and L_0 represent wave height (m) and wave length (m) in deep sea, respectively; D_{50} is grain size of bottom sediment (m), h is wave disturbance depth (m), H and L represent wave height (m) and wave length (m) at the depth of h, respectively.

It can be seen from Table 4 that the frequencies of wave breaking and wave disturbing was decreased with water depths increased, and the influenced area from wave disturbing was more wide compared to wave breaking. The frequency of wave breaking got to 98.2% at the water area shallower than 5m, which coincided with the coarser range of bottom sediment on the profile in AEA (Fig. 7). The bottom sediment was coarser with high percent of sand at the shallower water area than −5 ~ −6 m. In contrast, the bottom sediment was finer with low percent of sand and high percent silt and clay at the deeper water area than −5 ~ −6 m, moreover, the percent of them was relatively stable not changing noticeably with water depth changes. It indicates that wave breaking had influenced greatly on the bottom sediment of the profile in AEA. On the other hand, the frequency of wave disturbing was decreased to 0.5% outer the water area of 13m depth. Wave disturbing mainly took place in the water area deeper than 13m, which consistent with the area of rapid erosion roughly. So wave disturbing was another important reason of coastal erosion in AEA.

Table 4 Wave breaking depth, disturbing depth and their corresponding frequency

Wave grade (m)	$0 \leqslant H < 0.5$	$0.5 \leqslant H < 1.5$	$1.5 \leqslant H < 3.0$	$3.0 \leqslant H < 5.0$
Breaking depth (m)	0 ~ 0.84	0.84 ~ 2.5	2.5 ~ 5.01	5.01 ~ 8.35
Breaking frequency (%)	51.1	35.3	11.8	0.5
Disturbance depth (m)	0 ~ 1.56	1.56 ~ 6.59	6.59 ~ 13.10	13.10 ~ 15.30
Disturbance frequency (%)	98.7	47.6	12.3	0.5

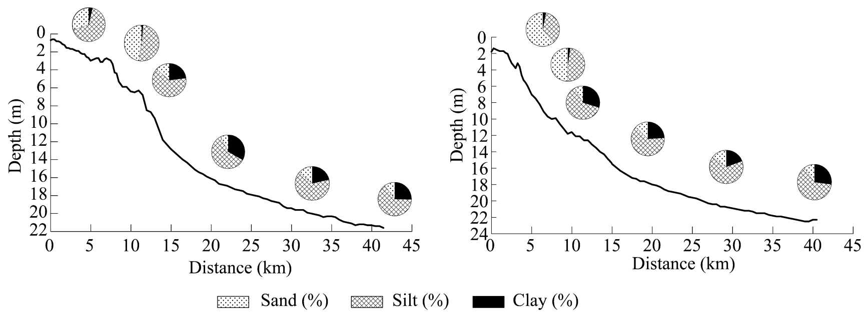


Fig. 7 The grain composition changes with deeper water at underwater slope in AEA

(2) Tidal current reactions of AEA. According to the data of tidal current and bottom sediment in AEA, the threshold velocity of motionless sediment is calculated (Fig. 8). It shows that the tidal current velocity was basically smaller than the threshold velocity of the sediment, accordingly, the tidal current couldn't stir up the sediment and only transport the sediment stirred up by waves. Seen from Fig. 8, the tidal current velocity was below than 20 cm/s at the area shallower 5 ~ 6 m in nearshore zone, undoubtedly, where tidal current had little effect on the bottom sediment of profile and waves predominated. But tidal current prevailed with a maximum velocity of 68 cm/s and increased with deeper water depth at the outer of the area which was deeper than 6 m depth. Grain sediment was stirred up by wave breaking and wave disturbing in nearshore zone, and then was transported seawards by strong currents. With much higher tidal current velocity, more sediment had been transported seawards, and the erosion area of coastal profile become larger. The important consequence is that the position of EABZ on the profile will be much deeper. It can be found from Fig. 3(c) and Table 3 that the depth of EABZ on the different eroded profile has related closely to the velocity of tidal current. The closer it is to amphidromic point of M_2 tidal component, the deeper is the position of EABZ in the east of Profile CS4. It reaches to a maximal value of 14.5 m near amphidromic point of M_2 tidal component, and then becomes shallower southwards away from the amphidromic point of M_2 tidal component. However, its depth increases obviously near Qingshuigou estuary (CS27).

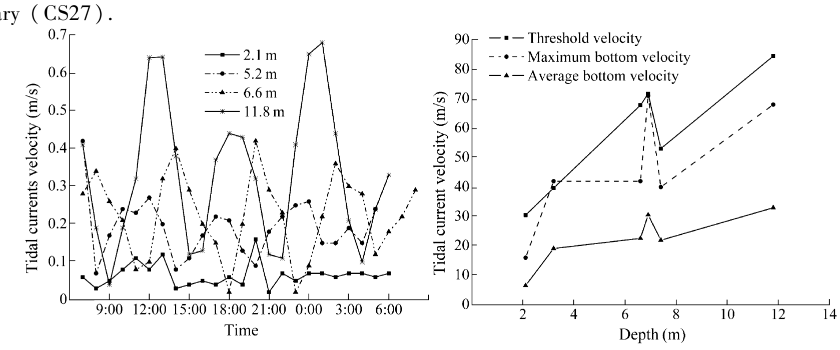


Fig. 8 Current velocity variations in the offshore of AEA

4.3 Principal component analysis for the typical profiles of CEA

4.3.1 Analysis of temporal evolution

The first spatial eigenfunction curves (Fig. 9(a)) shows that each profile curve ascends sharply from 1976 to 1985, and then goes stable from 1986 to 1996, and ascends again from 1997 to 2004. It means that profile evolution consisted of three stages: rapid progradaion phase (1976 ~ 1985), stable phase (1986 ~ 1996) and slow accretion phase (1997 ~ 2004).

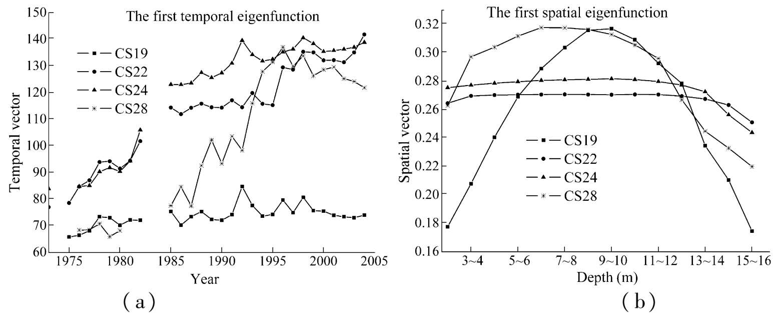


Fig. 9 (a) The temporal eigenfunction of CEA, (b) The spatial eigenfunction of CEA

Since the Yellow River course was migrated artificially to Qingshuigou estuary in 1976, in the initial stage river bed was widened continuously resulting in decrease of the flowing velocity and the capacity of carrying sediment falling, which leaded to a rapidly sediment accretion. Besides, tides blocking and flocculation of fine – grained sediments, which was resulted from confluence of salt and fresh water, accelerated the accretion near river mouth. Therefore, sediment accretion prevailed over the marine dynamics reaction, and the profile had been prograded seawards entirely at a high speed. However, when river channel became stable flowing to sea, its capacity of carrying sediment gets strong, couple with estuarine spit protruded seawards where the energy was easy to focused, tidal current velocity in front of river mouth became stronger and more sediment was transported to outer sea. Because sediment supply from the Yellow River had been decreased, marine dynamics eroded reaction is more and more obviously relatively. Except that the profile near river mouth had accretion, the others didn't prograded any more, and had been adjusted during the period from 1986 to 1996. The river course was shifted artificially to Qing8 estuary in 1996. Although river sediment load was less, due to a shallower water area at the Qing8 estuary, the sediment easily deposited, undoubtedly, the slope near Qing8 (CS22) was prograded seawards. At the same time, the sediment supply of the old Qingshuigou estuary ceased, the morphdynamic readjustment caused the shoreline to retreat rapidly after 1996.

4.3.2 The feature analysis of spatial evolution in CEA

In general, seen from the curves of the first spatial eigenfunction (Fig. 9), the profiles of CEA are prograded seawards. There is a wide peak zone at the water depth of about 2 ~ 14 m, where accretion is stronger, except for Profile CS19 of Gudong area. However, the function value decreases sharply when water depth is 14 ~ 15 m, where erosion and accretion obviously decrease.

The diffusion of suspended sediment from the Yellow River rests with tidal currents field (Zang, et al., 1996). The great deal of sediment flowing to sea carried by the Yellow River was obstructed by developed river mouth bar firstly and much coarser sediment deposited. So the sedimentary environment of fine sand and slity fine sand had formed in front of river mouth (Pang and Jiang, 2003). There was a high tidal current zone where velocity reached 140 cm/s (Fig. 3(c)) in the water area of 10 ~ 15 m depth which lied in front of estuarine spit. When the Yellow River flowed into sea blocked by the strong tidal current, the fluvial velocity would be decreased rapidly. It's self – evident that a weak tidal current zone formed between estuary and the high tidal current zone. Consequently, most of fine sediment deposited in this area (2 ~ 14 m), and the rest is transported towards north and south of estuary by reciprocating current. This is why the area, which is deeper than 14 m in CEA, is deposited weakly.

For Gudong area where sea walls were built in 1985 (Fig. 1), Profile CS19 is taken from as an example to analyze. Due to the decrease of sediment discharge of the Yellow River, the profile had been prograded so slowly. What's more, with the continuous decrease of sediment discharge, Gudong area hadn't been supplied by the river sediment, and marine dynamics played more and more important role in evolution of Gudong area, e. g. after the waves struck the sea wall strongly the reflection waves formed, which caused the bottom sediment disturbed heavily and stirred up (Chen and Chen et al., 2005). Therefore, the sea area in front of sea wall was suffered from serious erosion, especially after 1998.

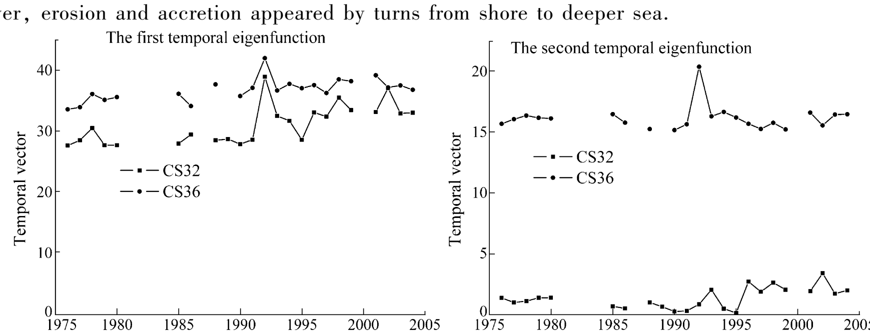
The old Qingshuigou estuary, as an abandoned estuary since 1996, has been dominated by marine dynamics. Under the combined effect of waves and tidal currents, the protruding estuarine spit was suffered from quite serious erosion and retreat. The thickness and range of deposition were reduced rapidly; however, there is a slow deposition in the area of 5 ~ 12 m because of tidal current transporting sediment stirred up seawards.

4.4 Principal component analysis for the typical profiles of LGA

From the time eigenfunction curve (Fig. 10(a)), it can be seen that the coast profiles of LGA basically kept stable except for the obvious accretion in 1992.

From spatial eigenfunction curve (Fig. 10(b)), it can be found that the whole coast of LGA shows stability. The first eigenfunction curves basically have no obvious peak and have a lowest value in the water area of from 3.5 m to 4.5 m, which shows erosion – accretion of the coast profile in LGA were not obvious and more lightly in the shallower water area. On the other hand, the second eigenfunction further reflects the concrete form of profile evolution. Erosion played a main role in the shallow area, while slight accretion was dominant in the deep area in the north of LGA, e. g. Profile CS32. Erosion and accretion are alternant from shore to deep sea in the south of LGA, e. g. Profile CS36.

Tidal current transporting sediment had an important effect on the erosion – accretion in LGA. The eroded sediment coming from the old Qingshuigou estuary was transported seawards by the tidal current. When flood tides took place in Laizhou Gulf, flood current flowed towards to west and then turned to north clockwise in south coast of Laizhou Gulf. Then it would be met with the flood current flowing towards south – west in the south of estuary, which induce the drastic decrease of tidal current velocity and some fine sediment to deposit in the south of estuary. When ebb tides took place in Laizhou Gulf, all tidal currents flowed towards northeast (Hu and Ji et al., 1996), the majority of sediment would be transported towards northeast and not deposited in Laizhou Gulf. So Laizhou Gulf was only a channel for sediment transporting outwards and the coast basically remained stable. Fine sediment from the Yellow River was transported towards south and deposited in the area located to north of Guanglihe River roughly, where all the profiles showed slow deposition except slight erosion in the range depth of 4.5 ~ 5.5 m. For the coast profiles located to south of Guanglihe River, erosion and accretion appeared by turns from shore to deeper sea.



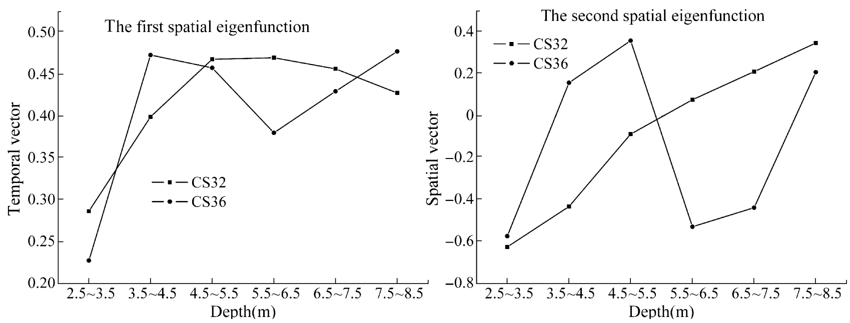


Fig. 10 (a) The temporal eigenfunction of LGA, (b) The spatial eigenfunction of LGA

5 Conclusions

Principal component analysis is an effective way to be applied to analyze spatial – temporal evolution of coastal profiles. The coast of the Yellow River can be divided into three areas: the abandoned estuary area (AEA), current estuary area(CEA) and Laizhou Gulf area(LGA).

(1) For AEA, the coast of Wanwangou estuary, abandoned for a long time, was relative stable because the geomorphology had been readjusted automatically resisting strong erosion. But the sea area of the Diaokouhe estuary and Shenxiangou estuary, abandoned for a short time, showed continuous erosion since 1976. The erosion processes of coasts can be divided into four stages: rapid accretion stage (1971 ~ 1975), rapid erosion stage (1976 ~ 1980), accretion – erosion adjustment stage (1981 ~ 1998), slow erosion stage (1999 ~ 2004). During the accretion – erosion adjustment stage, there was an erosion – accretion balance zone (EABZ) on every profile, whose depth mostly depended on the tidal current velocity. The higher tidal current velocity was, the shallower the depth of EABZ.

(2) The coastal profiles near the Qingshuigou estuary performed continuous progradation. The evolution process was concluded as three stages: rapid progradaion phase (1976 ~ 1985), stable phase (1986 ~ 1996) and slow accretion phase (1997 ~ 2004). All the profiles have been prograded seawards generally. The distance they moved forward to sea was dominated by the comparison between the sedimentation and the erosion by marine dynamics. The coast showed rapid progradation when fluvial sediment load is so large that sediment deposition is superior to the marine ability of removal sediment, whereas the coast was prograded slightly, even retreated, in the contrary case.

(3) The coast of Laizhou Gulf remained stable, and no obvious erosion – accretion occurred as time went. Because of the influence of the tidal current field, a small part of suspended sediment from the Yellow River is transported to Laizhou Gulf. Erosion and accretion perform alternately in the shallow area from shore to sea, simultaneously, the slow deposition prevailed in deep water area.

References

Cheng G D. 1987. Evolution and Framework of the modern Huanghe River Delta[J]. Marine Geology & Quaternary Geology, 1 – 18.

Chen X Y. , Chen S L et al. 2005. Coastal erosion mechanism along Gudong and Xintan coasts of the Yellow River delta. Coastal Engineering, 24(4): 1 – 10.

Chen X Y,. ,Chen S L. , Yu H J, et al. 2005. Coastal profile types and evolution of the Yellow River delta. Advances in Marine Science, 23(4) : 438 – 445.

Chen X Y. , Chen S L. , Liu Y S. 2006. Sediment differentiation along nearshore zone of the Yellow River Delta. Acta Sedimentologica Sinica,24(5): 714 – 721.

Chinese Editorial Group of Coastal Zone Hydrology. 1995. Coastal Zone Hydrology of China. Beijing: Ocean Press, 178 – 181.

Dai Z J., Chen Z S., Ou S Y. 2002. Characteristics of daily variation processes over a month for beach profiles between headlands in Shanwei, eastern Guangdong. Journal of tropical oceanography. 21(1): 27 – 32.

Hu C L., Ji Z W., Wang T. 1996. Characteristics of ocean dynamics and sediment diffusion in the Yellow River estuary. Journal of Sediment Research, (4): 1 – 10.

Jiménez, J A., Súnchez – Arcilla A., et al. 1997. Processes reshaping the Ebro delta. Marine Geology, 144: 59 – 79.

Li G X., Zhuang K L., et al. 2000. Sedimentation in the Yellow River delta, Part Ⅲ: Seabed erosion and diapirism in the abandoned subaquous delta lobe. Marine Geology 168: 129 – 144.

Li Zegang. 2000. Basic Features of hydrologic elements in the sea area near the Yellow River estuary. Journal of Oceanography of Huanghai & Bohai Seas, 18(3): 20 – 28.

Li P., Zhu DK. 1997. The role of Wave Action on the Formation of the Yellow River Delta. Marine Geology & Quaternary Geology, 17(2): 39 – 46.

Liu S G., Li C X et al. 2001. The rough balance of Progradation and Erosion of the Yellow River Delta and its Geological Meaning. Marine Geology & Quaternary Geology, 21(4): 13 – 17.

Milliman, J D., &meade, R H. 1983. World – wide delivery of river sediment to the oceans. Journal of Geology 91(1), 1 – 21.

Pang Jiazhen, Jiang Mingxing. 2003. On the evolution of the Yellow estuary (Ⅰ) – Ⅰ. Hydrographic characteristics. Transactions of Oceanology and Limnlogy, (3): 1 – 13.

Qian Ning, Wang Keqin, Yan Linde et al. 1980. The source of coarse sediment in the Yellow River and its effect on the siltation of the lower Yellow River. Corpus of the first international symposium on river sedimentation. Beijing: Guanghua Press, 53 – 62.

Ren M E. 1994. Three Deltas in China. High Education Press, Beijing. Súnchez – Arcilla, A., Jiménez, J A., & Valdemoro, H I. 1998. The Erbo Delta: morphodynamics and vulnerability. Jouranl of Coastal Research14(3): 754 – 772.

Xiang W H., Li J F et al. 2003. The Characteristics of Topography Change on Nanhui Nan Shoal, Shanghai. Journal of East China University(Natural Science), (3): 49 – 55.

Xue C. 1993. Historical changes in the Yellow River delta, China. Marine Geology, 113: 321 – 329.

Yu L S. 2002. The Huanghe (Yellow) River: a review of its development, characteristics, and future management issues. Continental Shelf Research, 22: 389 – 403.

Zang Q Y et al. 1996. Nearshore Sediment along the Yellow River Delta[M]. Ocean Press, Beijing.

Study on Ground Water Level & Water Balance Influence under Different Water Compensation Schemes of the Yellow River Delta

Lou Guangyan[1] ,***Fan Xiaomei***[2] ,***Zhang Shaofeng***[1] ,***Ge Lei***[1] and ***Li Rui***[1]

1. Yellow River Basin Water Resources Protection Bureau, Zhen zhou 450004, China
2. Institute of Geographical Sciences and Natural Resources Research, CAS, Beijing 100101, China

Abstract: According to the study on factors of weather, hydrology, and geology of the Yellow River Delta, screen and identify three factors of river feeding, precipitation supplement and evaporation capacity which impact much on the Yellow River Delta ground water level, and establish reliable groundwater model in virtue of software Visual Modflow. Through simulating the status (selecting 2004), further define the influence degree of the river feeding, precipitation supplement, and evaporation capacity on ground water from the aspect of water balance. Seen from analysis on water balance in 2004, groundwater cannot maintain balance and supplement capacity cannot meet the evapotranspiration demand of vegetation, therefore it is necessary to adopt man – made water compensation to improve the water balance of this region. According to wetland composition while building the nature reserve of the Yellow River Delta wetland and its present actual situation, define the water compensation area and preliminarily select water compensation scheme, which are 278 million m^3, 349 million m^3, 396 million m^3 respectively (proposed) and study the influence of different water compensation schemes on ground water level and water balance. Study and analysis shows that there still exist deficiencies in the present water compensation scheme. Deeper study on water compensation schemes is needed to improve ground water situation.

Key words: groundwater, modflow, water compensation, water balance

1 Introduction

The Yellow River Delta locates between Laizhou Bay in north Shandong province of China and Bohai Bay, general referring to sector region formed by siltation, extension, sway, course diversion and sediment of Yellow River in sea entrance over many years, belonging to accumulation estuary with relative weak land and intensive tide, its east longitude is from 118°10′ to 119°15′, north latitude is from 37°15′ to 38°10′, which is the largest delta in China. Administrative region is divided into two districts——Dongying and Hekou, three counties —— Guangrao, Lijin, and Kenli. Location is shown in Fig. 1.

The general terrain of the Yellow River Delta is flat, high in the west and south, and low in the east and north. The highest elevation of southwest is 28 m, the lowest elevation of northeast less than one meter with natural slope 1/8,000 ~ 1/12,000, while the highest elevation of west is 11 m, the lowest elevation of east 1 m with natural slope 1/7,000 and the beach is 3 ~ 5 memers higher than the ground. Except the area to the south of Xiaoqing River as alluvial plain, the rest of Dongying city is the typical delta landform deposited by Yellow River. Due to Yellow River frequent redirection and bursting in the history, complex micro physiognomy are formed as hillock, slope and billabong arranged alternatively, figure intervening in long direction, wave rolling in traversing. Main types of landform are slow hillock, flood plain, inclined flat, flat billabong and foreshore.

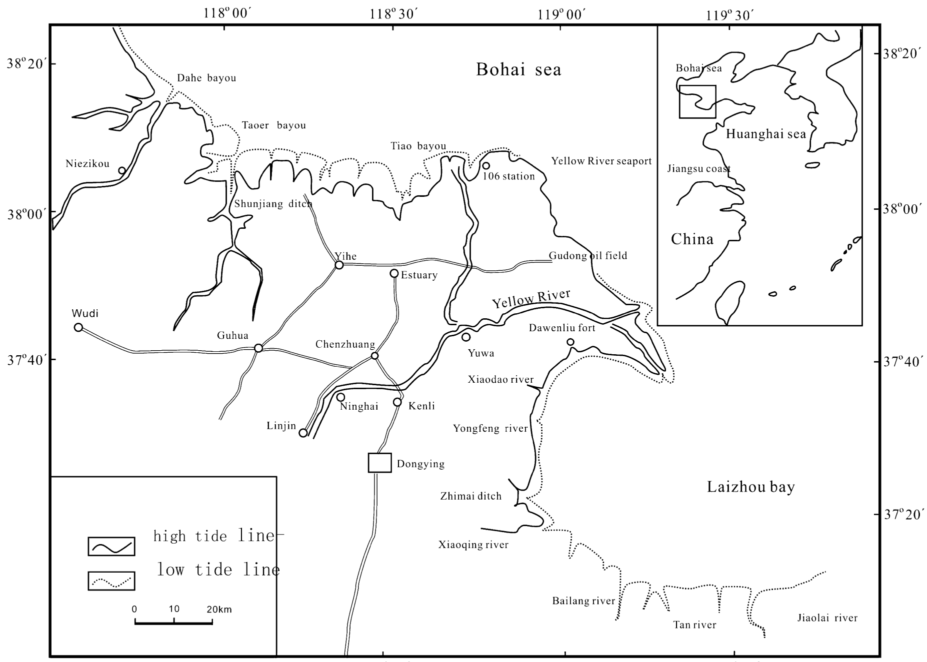


Fig. 1 Geodrawingic location of The Yellow River Delta

The Yellow River Delta belongs to warm temperate zone semi – wetness, semi – dryness, and territoriality monsoon climate with annual rainfall 537 ~ 630 mm. Annual rainfall changes greatly, and rainfall season distributes uneven, mainly in June to September, up 74% of annual rainfall. Daily evapotranspiration capacity fundamentally changes from zero to 11 mm, and evapotranspiration varies in different months, of which, every year from March to October the evapotranspiration capacity is relative low, monthly evapotranspiration capacity between 8 ~ 50 mm and smaller regional change, high from April to October and monthly evapotranspiration capacity between 50 ~ 120 mm.

Water resources of Yellow River Mouth Delta are mainly surface water runoff and farthing groundwater resources. From analysis on relation between rainfall and runoff, average runoff capacity over many years is 4.47×10^8 m^3 [1], of which only 1.35×10^8 m^3 freshwater of south of Xiaoqing river can be used for irrigation and drinking. Due to severe land salinity, quality of running off water deterioration, no development value in other areas, Yellow River water at present is the important freshwater resources of mouth delta, up more than 90% of industry production and people's life of Dongying city.

2 Variation of groundwater level and identification of influential factors

2.1 Variation of groundwater level

Groundwater in the Yellow River Delta Region is generally shallow buried, about 0 ~ 5 m. The distribution rules of buried depth of groundwater are deeper buried along the Yellow River course groundwater and shallow buried areas groundwater adjacent to the sea and below the billabong of the river.

According to the water level variation of observation well in Yuwa in a year, we drew the dynamic variation curve of ground water level in Yuwa observation well as in the following Fig. 2.

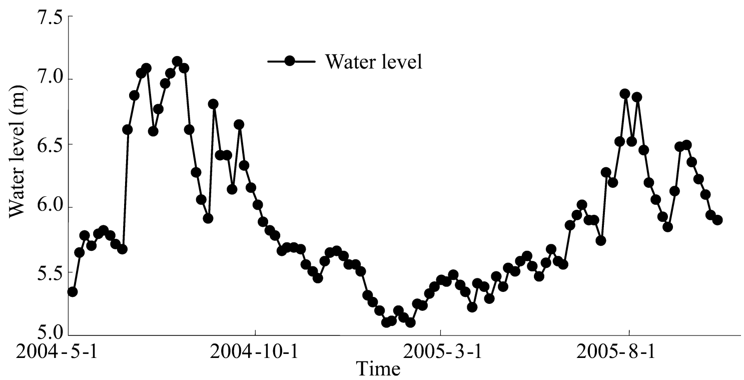


Fig. 2 The dynamic variation curve of ground water level in Yuwa observation well

Seen from the dynamic variation curve of groundwater level in the observation well in Fig. 2, peak value and alley value come once in a year, while valley value in the March or April in Spring, peak value in the June, July, August in summer. The variation trend of the groundwater level of the whole year is first slowly decreasing, then rapidly increasing, then gradually decreasing and finally going stable.

2.2 Identification of influential factors

According to the investigation on the Yellow River delta, there are several modes of water compensation of ground water in the Yellow River Delta such as inwelling, river feeding, precipitation, irrigation regression recharge, etc.. River feeding and precipitation are the main modes and there are different discharge methods in the Yellow River Delta such as ground water discharging into the ocean, evapotranspiration, discharging into river way or ditch, or artificial draw – out and so on of which evapotranspiration is the main method of discharge. Through the variation curve of precipitation, river level & evaporation amount and the groundwater level variation of Yuwa observation well in following Fig. 2, the impacts of the three factors on the ground water level will be analyzed.

2.2.1 Variation of precipitation of the Yellow River Delta

The variation of yearly precipitation in the Yellow River Delta is very large. In the empirical precipitation information from 1966 to 2001, the precipitation reaches the maximum 968.1 mm in 1990, 1.8 times of the average value; and the minimum 327.0 mm in 2000, only 60.8% of the average value.

Fig. 3 is drawn by the monthly average information statistic from 1996 ~ 2001 of Dongying city.

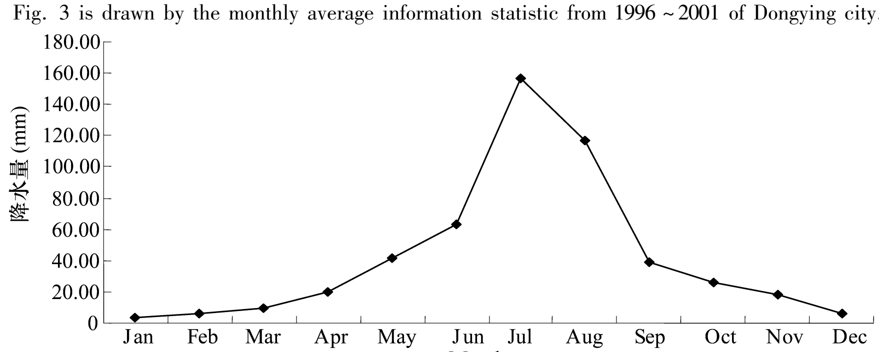


Fig. 3 Variation of Precipitation of the Yellow River Delta

Seen from the dynamic variation of precipitation in the Yellow River Delta in Fig. 3, precipitation in January is lower, then increasing gradually. The precipitation is mainly in June – August, reaches the maximum value in July, and then decreases sharply. Precipitation in the Yellow River Delta has distinct seasonality. The groundwater level variation of observed well in Yuwa also has distinct seasonality. Both of two peak values come at the same time, which indicates the groundwater level is greatly influenced by precipitation.

2.2.2 Variation of water level of the Lijin section

According to the observed water level of Lijin section from 2004 to 2005, the following dynamic variation curve of water level is drawn and shown in Fig. 4.

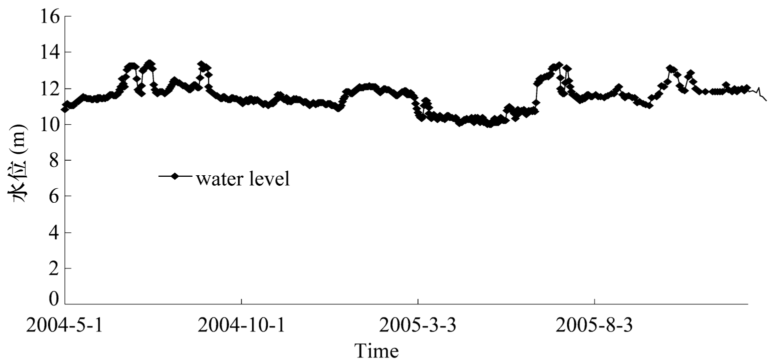


Fig. 4 Variation of water level of the Lijin Section

Seen from the water level dynamic variation of Lijin section from 2004 to 2005, generally, the water lever is lowest in March and April in spring, gradually rises again in June – September, highest in July for the flood season and decreases in October – December. The peak and alley value of groundwater level in observation well of Yuwa and the peak and alley value appear at the same time. There is better relativity between the aviation of groundwater level in Lijin and Yuwa, which indicates that the groundwater level is greatly influenced by the water level of river.

2.2.3 Evapotranspiration variation

Dongying City weather station was selected to stand for meteorological conditions of the Yellow River Delta, according to statistical data of evaporation capacity of Dongying City in 2004, following variation curve of evaporation capacity is plotted, shown in Fig. 5.

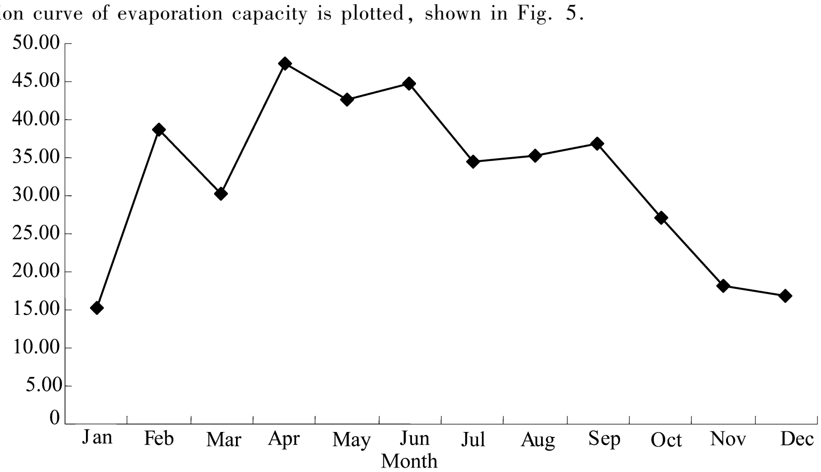


Fig. 5 Evapotranspiration variation of the Yellow River delta

From variation of evaporation capacity of the Yellow River Delta in Fig. 5, from April to September, evaporation capacity is relatively high, among 40 ~ 45 mm/day. Evaporation capacity in February is close to 40 mm/day too. After October, evaporation capacity descended gradually, lowest in December and January, which is about 15 mm/day.

Evaporation capacity affects ground water level greatly. Especially from April to September, evaporation capacity was relatively high. In Fig. 2, variation of ground water level of Yuwa observation well shows that ground water level appeared valley value in April, of which factor of evaporation capacity can not be overlooked.

Integrative Fig. 2 variation of ground water level of Yuwa observation well, Fig. 3 variation in precipitation of the Yellow River delta, Fig. 4 Lijin dynamic variation of fracture plane water level and Fig. 5 evapotranspiration variation of the Yellow River Delta showed that variation of ground water level is affected by these three factors together. Wholly, in non – flood – season, ground water level is affected by river provision greatly. From June to August, ground water level is affected by precipitation provision much, and evapo – transpiration affects water level much, especially from April to September with relatively high evaporation capacity.

In conclusion, ground water level of the Yellow River Delta is finely correlated with river provision, precipitation provision and evapotranspiration, which are important factors affecting the ground water level variation.

3 Groundwater numerical model of the Yellow River delta

3.1 Numerical simulation of current situation of the Yellow River delta

3.1.1 Building model

Occurrence of ground water of the Yellow River Delta is generally shallow, approximately 0 ~ 5 m. In accordance with existing hydrological geology conditions, refer to geologic examination result in the Yellow River Delta made by the geology team (Dezhou) of the second hydrological geology engineering of Geology and Mineral Resources Bureau of Shandong Province. We can generalize models as anisotropic, anisotropy phreatic aquifer, use finite difference method to build phreatic water unsteady flow kinematic model and divide research unit into 200 line × 200 column rectangular element.

Dividing zones of conductivity and storage specific yield are shown in Table 1.

Table 1 Dividing zones of conductivity and storage

zones	type	Permeability coefficient (m/d)	storage
1	sand layer contained fresh water	4	0.2
2	mucilaginous layer contained fresh water	0.5	0.1
3	Sand and mucilaginous layer contained fresh water	1.2	0.15
4	sand layer contained bittern water	1	0.2
5	mucilaginous layer contained bittern water	0.001	0.1
6	sand layer contained salt water	2	0.15
7	mucilaginous layer contained salt water	0.002	0.2
8	Sand and mucilaginous layer contained salt water salt water	0.2	0.1
9	others	0.05	0.7

In 2004, Geographical Science and Resource Research Institute of Chinese Academy of Sciences laid 18 water level observation well of ground water to observe water level for a long time. Diameter of observation well is 50 mm, depth of 5 ~ 6 m, and bottom is screen pipe. Observation well has two functions. First is to simulate layout of ground water level, and the result can be used in model as initial level data; second is to revise and calibrate parameter. Directive contrast of ground water observed value and calculated value in position of observation well could be seen more directly if model can reflect variation of ground water level. Details are seen in Fig. 6.

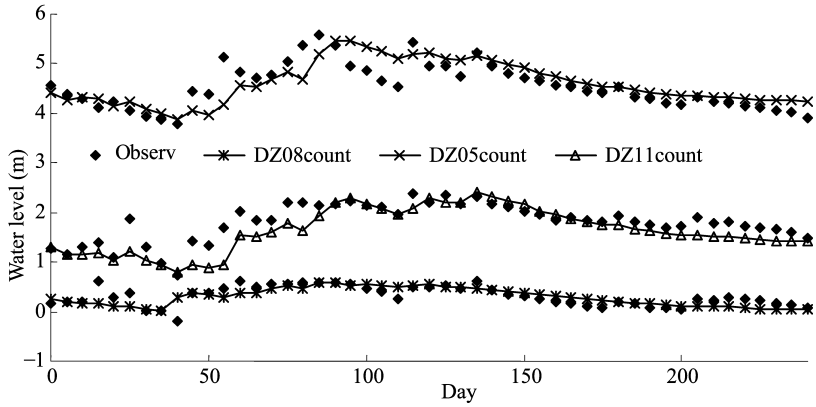


Fig. 6 The fitting hydrograph of ground water level

Fig. 6 is the fitting hydrograph of ground water level and actually measured observation well water level evaluated by model. Known from this figure, model can reflect the trend of variation of ground water level and can be used to simulate and predict variation situation of water level in future.

3.1.2 Analysis on regional water balance

Study water balance of the Yellow River delta, and then further analyze the influence degree of precipitation, river and evaporation capacity on ground water level, which could provide technical support and scientific basis for constituting the strategy of improving the ground water situation in the Yellow River delta.

The specific situations of water balance of the Yellow River Delta are shown in Table 2.

Table 2 Water balance of the Yellow River Delta

		May	June	July	August	Sep	Oct	Nov	Dec
IN	Total	7,940.51	18,574.30	20,369.25	10,751.16	6,390.80	580.15	1,062.89	745.95
	Rain	5,148.83	15,477.90	18,687.37	9,414.48	5,903.93	336.77	722.41	587.79
		64.84%	83.33%	91.74%	87.57%	92.38%	58.05%	67.97%	78.80%
	River	2,262.39	2,964.23	1,640.12	1,278.93	357.05	9.68	137.43	6.02
		28.49%	15.96%	8.05%	11.90%	5.59%	1.67%	12.93%	0.81%
	Sea	529.29	132.17	41.76	57.75	129.82	233.70	203.05	152.14
		6.67%	0.71%	0.21%	0.54%	2.03%	40.28%	19.10%	20.40%
OUT	Total	13,310.33	10,026.40	10,062.68	10,205.86	9,697.96	6,758.19	4,088.73	2,723.88
	Evapotranspiration	12,132.16	9,553.43	9,741.64	10,073.53	9,631.04	6,749.58	4,087.49	2,720.52
		91.15%	95.28%	96.81%	98.70%	99.31%	99.87%	99.97%	99.88%
	Sea	1,178.17	472.97	321.04	132.33	66.92	8.61	1.24	3.36
		8.85%	4.72%	3.19%	1.30%	0.69%	0.13%	0.03%	0.12%
	Balance	−4 418.38	9,025.81	10,665.01	725.71	−3,461.84	−6,250.30	−3,129.35	−2,088.22

As shown in the input item of Table 2, generally speaking, rainfall supplement takes a large proportion in the input item, taking up over 65% basically. Especially from June to September, rainfall supplement absolutely takes a leading status. It can be seen that infiltration capacity of rainwater changes with season change obviously and from June to September is the primary water compensation time; after September, rainfall supplement decreases obviously and river supplement also takes up a certain proportion in the input item. As shown in simulation from May to December, river supplement takes a bigger proportion in May, June, August, November and a quite small proportion in October and December. This indicates that the distribution of river supplement is not even; and seawater compensation takes up a certain proportion from October to November, which explains that salinity of ground water increases to some extent.

It can be seen from output item in Table 2 that quantity of ground water which evaporation and vegetation transpiration consumes takes absolute advantage in the total drainage quantity, all of which is over 90%, smaller quantity entering the sea.

Seen from the balance items in Table 2, the balance item is positive from June to August and input item is larger than output item, which indicates that rainfall compensation and river feeding in this period can meet the demand of vegetation transpiration. However, out of this period, balance item is negative and input item is smaller than output item, which indicates that rainfall compensation and river feeding in this period cannot meet the demand of vegetation transpiration. Generally, ground water is in unbalance state. In order to improve unbalance state of ground water and meet the demand of vegetation evapotranspiration, some measures should be taken. Precipitation is relevant to climate, which is almost impossible to be changed, and the range of lateral seepage supplement of river is very limited. Therefore, we could not rely on precipitation and lateral seepage supplement of Yellow River to improve the unbalance state of ground water, so manual intervention should be adopted to implement the artificial water compensation in the Yellow River Delta.

3.2 Forecasting simulation of the Yellow River delta

3.2.1 Water compensation zone in fresh water wetland of the Yellow River delta

Yellow River, as the most primary fresh water resource of the Yellow River Delta, has very valuable and rare resource, therefore, selection of ecological water compensation zone and quantity of water compensation are worthy of deeply studying and discussing.

The selection and confirmation of ecological water compensation area of this research primarily is based on construction area of the Yellow River Delta nature reserves built in 1993 and is determined by comprehensive investigation combined multiple ways such as wetland research, expert consultation and so on.

Shown in Fig. 7.

The area enclosed by blue lines in the Fig. 7 is where should be adopted artificial water compensation. In light of DEM and different geographical locations, water compensation zone is divided into six budget zones. Zone 1 is northern nature reserve, with water compensation area of 3,671 hm^2 and initial proposed water compensation of 49,076,131 m^3; Water compensation area of southern nature reserve includes five budget zones such as zone 2, zone 3, zone 4, zone 5 and zone 6 with an area of 22,401 hm^2 and initial proposed water compensation are respectively 81,561,829 m^3, 36,255,644 m^3, 16,216,112 m^3, 35,921,428 m^3, and 96,654,978 m^3. At present, select three different water compensation schemes of respectively 278 million m^3, 349 million m^3 and 396 million m^3 and analyze to compare the influence of different water compensation plan on both the flow field of ground water level and the balance of water quantity in water compensation area to provide references for making further strategies on water quantity balance of ground water.

Area of Budget zone and proposed water compensation amount of each zone is shown in Table 3 in detail.

Fig. 7 Water compensation zone in fresh water wetland of the Yellow River delta

Table 3 Area of budget zone and proposed water compensation amount of each zone

	zone 1	zone 2	zone 3	zone 4	zone 5	zone 6	Total
Area(hm^2)	3,671	5,101.3	2,712.3	1,213.2	2,686.8	7,229.6	22,614.2
Compensation (m^3)	43,250,987.8	71,880,761.8	31,952,241.6	14,291,323	31,657,697	85,182,414	278,215,425
Compensation (m^3)	54,263,987.8	90,183,761.8	40,088,241.6	17,930,323	39,718,697	1.07E +08	349,057,425
Compensation (m^3)	61,605,987.8	102,385,762	45,512,241.6	20,356,323	45,092,697	1.21E +08	396,285,425

3.2.2 Analysis on flow field of ground water level

Analyze and study the change of ground water level in different water compensation schemes of 0.278 million m^3, 340 million m^3 and 396 million m^3 and the influence of the water compensation on the ground water level. The changes are shown in Fig. 8, 9, 10 and 11.

Analysis on spatial distribution of ground water: Seeing from the ground water isopleths corresponding to different water compensation capacity as shown in Fig. 8, 9, 10 and 11, the flow field of ground water takes on the trends in general as follows: equipotent surface distributes in circle along Bohai Sea. The flowing direction of the ground water is in accordance with the elevation change direction of the land surface. As the existing Yellow River watercourse and Yellow River old watercourse being the watershed, it drains into the sea in three main flowing directions, which are north, northeast and southeast. Near to the current Yellow River, the ground water level is high, isopleths density is intensive, and the supplement function of the river is intense. The influence of the river lateral seepage supplement is within the scope of 2.5 km along the river. In old Yellow River course, with deeply buried of the ground water and small evaporation from the phreatic water, the ground water level is slightly higher than the surroundings, therefore it forms ground water mound that take old water course being as ridge. Flat ground water level lowers along the descending direction of the land surface altitude, and hydraulic gradient borders upon the change scope of land surface altitude isopleths. In contiguity to the sea area, the isopleths of ground water changes smoothly with small water power slope, where the ground water drains to the sea with slow flowing. To analyze the Fig. 8, 9, 10 and 11, in general there is little change in the distributing trends of the ground water flow field, and the flow direction of the ground water keeps accordance with the change direction of the landscape altitude. However, as for partial zone, there are changes of ground water level, especially in the area of water compensation. Ground water level of water compensation zone in Fig. 9, 10 and 11 is obviously higher than that in Fig. 8 that has no water compensation. Under the situation of adopting different water compensation schemes of 278 million m^3, 349 million m^3 and 396 million m^3, the ground water level of the supplementing zone is slightly different, but the change is relatively tiny. In general, the ground water level is a little higher under the situation of supplementing water 349 million m^3. In sum, the influence of water compensation towards the ground water is rather complicated and needs further research.

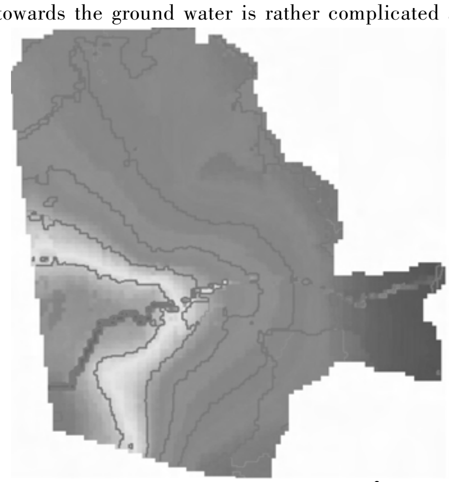


Fig. 8 The contour of 0 million m^3

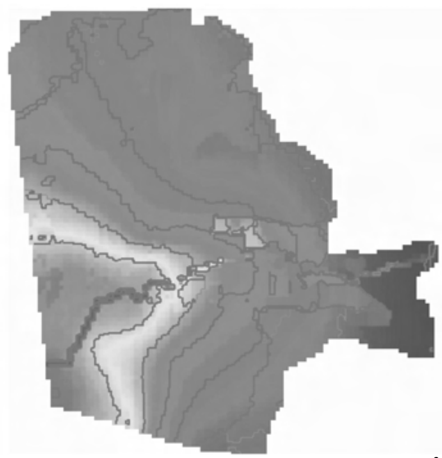


Fig. 9 The contour of 278 million m^3

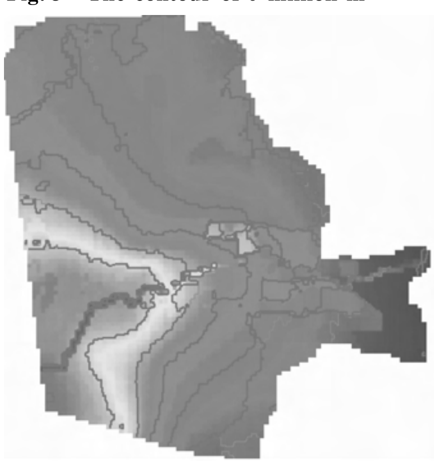


Fig. 10 The contour of 349 million m^3

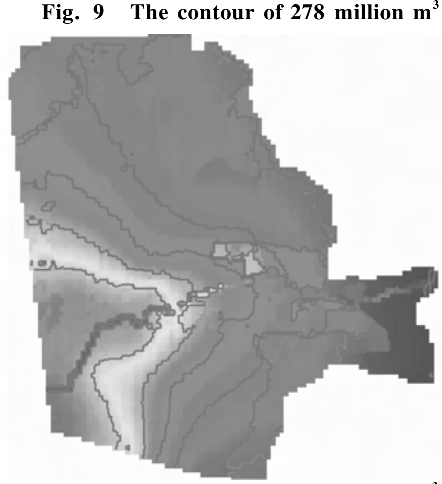


Fig. 11 The contour of 396 million m^3

3.2.3 Analysis on water balance

Having researched the water balance and analyzed the water compensation, whether the input item is larger than output one in this zone, namely whether the supplement capacity can meet the demand of the vegetation transpiration and phreatic evaporation, it has important significance to the management and improvement of the ground water.

The water balance situation in each budget zone under different water compensation schemes are shown in the variation curve of water balance of budget zone in Fig. 12.

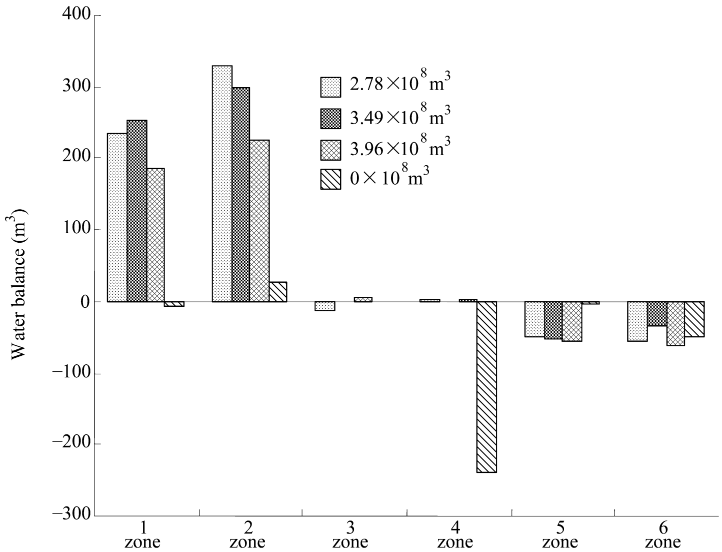


Fig. 12 The water balance situation in each budget zone

As is shown in Fig. 12 of water balance change in budget zones, under the situation of zero water compensation, other zones are all negative except zone 2, which indicates that the input item is smaller than output item and the water compensation capacity can not meet the demand of vegetation transpiration and phreatic evaporation. This situation is most obvious in zone 4. Under the condition of 278 million m^3 the balance item is positive in zone 1, zone 2 and zone 4 which indicates that the input item is larger than output item and the water compensation capacity can meet the demand of vegetation transpiration and phreatic evaporation. Oppositely, the balance item is negative in zone 3, zone 5 and zone 6 which indicates that the input item is smaller than output item and the water compensation capacity can not meet the demand of vegetation transpiration and phreatic evaporation. Under the condition of 349 million m^3, the balance item is positive in zone 1, zone 2 and zone 3 which indicates that the input item is larger than output item and the water compensation capacity can meet the demand of vegetation transpiration and phreatic evaporation. Oppositely, the balance item is negative in zone 4, zone 5 and zone 6 which indicates that the input item is smaller than output item and the water compensation capacity cannot meet the demand of vegetation transpiration and phreatic evaporation; Under the condition of 396 million m^3, the balance item is positive in zone 1, zone 2, zone 3 and zone 4, which indicates that the input item is larger than output item and the water compensation capacity, can meet the demand of vegetation transpiration and phreatic evaporation. Oppositely, he balance item is negative in zone 5 and zone 6 which indicates that the input item is smaller than output item and the water compensation capacity cannot meet the demand of vegetation transpiration and phreatic evaporation. Comparing with the water compensation schemes of 278 million m^3, 349 million m^3 and 396 million m^3, water compensation schemes of 396 million m^3 is relatively superior, but this water compensation scheme can't meet the vegetation transpiration and phreatic evaporation demands of the supplement capacity of ground water in the budget zones. Therefore, further adjustment and research on water compensation schemes are needed to improve the situation of ground water.

4 Conclusions

(1) According to the study on factors of weather, hydrology, and geology of the Yellow River Delta, screen and identify the three factors of river feeding, precipitation supplement and evaporation capacity that impact much on the Yellow River Delta ground water level.

(2) Taking the modern the Yellow River Delta as the research area, establishing reliable groundwater model in virtue of software Visual Modflow and simulating the present situation (selecting 2004), the influence degree of the river feeding, precipitation supplement, evaporation capacity on ground water can be further ascertained from the aspect of water balance. Seen from analysis on water balance in 2004, groundwater cannot maintain balance and supplement capacity cannot meet the evapotranspiration demand of vegetation, therefore it is necessary to adopt artificial water compensation to improve the water balance of this region.

(3) According to wetland composition while building the nature reserve of the Yellow River Delta wetland and its present actual situation, ascertain the water compensation area and preliminarily select water compensation scheme (proposed) and study the influence of different water compensation schemes on the flow field of ground water level and water balance. Under this proposed water compensation scheme, the flow field of ground water level on the whole remains that equipotential surface of the flow field is located in a circle along Bohai Sea, the variation trend of ground water flow is the same as the surface elevation variation trend, but ground water level changes in some parts. Comparing with the water compensation schemes of 278 million m^3, 349 million m^3 and 396 million m^3, water compensation scheme of 396 million m^3 is relatively superior, but this water compensation scheme cannot meet the vegetation transpiration and phreatic evaporation demands of the supplement capacity of ground water in the budget zones. Therefore, further adjustment and research on water compensation schemes are needed to improve the situation of groundwater.

References

Water Resources Bureau of Dongying City. the "Eleventh Five – Year Plan" of Water Conservancy Development and Reform in Dongying City, 2005.

Liu Rui, Chen Ying etc. Analysis and Suggestion on Water Environmental Quality of Dongying City, Shandong Water Conservancy, 2005(1),28 – 29.

Frans Klijn, 1999, Eco – hydrology: groundwater flow an site factors in plant ecology [J]. Hydrogeology Journal, 1999(7):65 – 77.

O. Batelaan. Regional groundwater discharge: phreatophyte mapping, groundwater modeling and impact analysis of land – use change. Journal of Hydrology, 2003, 275:86 – 108.

The Editor Committee of Dongying City Water Conservancy Annals. Dongying Water Conservancy Annals[M]. Beijing: Hongqi Press, 2003.

Zhao Yanmao, Song Chaoshu. Scientific Study Collective of Nature Reserve in the Yellow River Delta [M]. China Forestry Publishing House, 1995.

Zhao Yingshi, Principles and Methods on Application and Analysis of Remote Sensing [M]. Science Press, June, 2003.

Liu Gaohuan, H. J. Drost. Sustainable Development Collective Drawings of the Yellow River Delta [M]. Beijing: Surveying and Mapping Press, 1996.

Guo Huirong etc. Calculation on Transformation Quantity between Yellow River Water and Ground Water of Upper Stream of Sanmenxia Reservoir Region [J]. People's Yellow River, 2006, 28 (7).

The Harnessing History and Countermeasures Research of the Yellow River Estuary Channel

Tang Meiying, ***Ding Dafa***, ***He Yuchuan*** and ***Wang Hongsheng***

Reconnaissance, Planning and Design Company, Ltd., YRCC, Zhengzhou, 450003, China

Abstract: The harnessing of Yellow River estuary is a very important part of the Yellow River harnessing, which is related to the flood control safety of the downstream of the Yellow River and the economic and social development and the benign maintaining of Yellow River delta ecology. This article has analyzed the Yellow River delta evolution since 1855 and the variation situation of flow course for different periods, while concludes the main harnessing process and harnessing measures of Yellow River estuary. Viewing from requirements of keeping the healthy life of the Yellow River and ensuring the sustainable development of estuary region, it presents such countermeasures as to further enhance the engineering flood control construction, to stabilize the flow course of Qingshui Gully, to schedule the spare flow course, to well deal with the relationship between Yellow River estuary harnessing and the economic and social development and benign ecological maintaining, and to establish a perfect scientific management system.

Key words: Yellow River estuary, harnessing countermeasure, estuary flow course

1 The Yellow River estuary harnessing and development

The Yellow River delta is located between Bohai Bay and Laizhou Bay, belonging to land – phase weak – tide intense accumulation estuary, and has been developed and formed after the continuous variance of flow courses after diverting to Daqing River following the Tongwaxiang breach in 1855. The estuary delta generally means that its peak is Ninghai, and its north Boundary is the Tao'er River estuary, while its south one is Zhimai Gully, forming the sector district with a current area of over 6,000 km^2 or so. In order to protect the industrial and agricultural production of the estuary region, the diversion peak of estuary reach has been moved downwards around Yuwa, and the swinging diversion scope has also been narrowed to a sector district with area of over 2,400 km^2, north from Chezi Gully, while south to Songchunrong Gully, during recent 50 years.

Due to large quantities of sediments annually transporting towards the estuary of the Yellow River carried by the Yellow River, it makes the estuary stay in the long – term cyclic evolution of natural deposition, extension, swinging and diversion. Since 1855, there have been nine great diversions of the flow course of Yellow River estuary (the first flow course is Daqing River following the Tongwaxiang breach in 1855), there are six diversions during the period from 1889 to 1953, whose peak is around Ninghai, while there were three diversions after 1953, whose peak is around Yuwa. The Yellow River delta evolution generally experienced three phases, namely, the initial one, which means the period after diverting to Bohai Sea from 1855 to 1889, the median one, which means the natural variance duration of estuary channel basically lasting from 1889 to 1949, and the terminal one, which means the man – made schemed diversion since 1949.

The Yellow River lower channel is famous for heavy deposition, easy breach and frequent diversion all over the world. It considers the lower immense plain district of Huai River and Hai River as the flood – plain of Yellow River flows, and the Yellow River estuary changes with the diversion of Yellow River lower channel, while its flows sometimes pour into Huanghai Sea, and sometimes pour into Bohai Sea.

The Ancient River Harnessing Period. The Capital of North – Song Dynasty was Kaifeng, and then, the main Yellow River flow course was the North one flowing into Bohai sea. The North – Song Dynasty paid enormous attentions to control the Yellow River in order to prevent its capital from flood disasters and to guard against external aggression of Liao Country and Jin Country newly developed in the North, and to stabilize the society while to develop the economy. There had been great progresses in such aspects as building and constructing techniques of dike or fascine, river harnessing measures as cut – off and dredging, etc. , as well as developing channel transportation, irrigating farmlands and silting, etc. And therein, Mr. Ou Yangxiu first related the estuary deposition and its influences in his memorial to the throne. Mr. Suzhe concluded causes for Yellow River hardly forming itself as the river pattern of making river branches at central bar and for the Yellow River estuary hardly possible to form the reticular shape under deposition status in his memorial to the throne.

Ming Dynasty and Qing Dynasty selected Beijing as capital with a quite long dominance period, both considered the channel transportation maintenance as their state plan. Those two dynasties proposed that the river harnessing would not only simply avoid its disasters but also try to exert its benefits for supporting the channel transportation, and also paid great attentions to the estuary harnessing. The exact and detailed research and analysis on characteristics, evolution rules and harnessing measures of the Yellow River and estuary have been presented within such books of those two dynasties written by river – harnessing officials as Mr. Pan – Jixun's "General view of river deference", Mr. Wangong's "River harnessing", Mr. Jinfu's "River harnessing strategy", and Chenhuang's "Depiction of river deferemce", etc. , and the "Canton annal" or "County annal" of districts alongside the Yellow River, as well as various historical materials recording and narrating great events of river defense. Contents for analysis and research not only limit to the Yellow River lower channel, but also relate to the fundamental rule of estuary natural evolution, the bed formation evolution of estuary reach, and various harnessing measure of the estuary.

The neoteric river harnessing period. During the end of Qing Dynasty and the beginning of the Republic of China, the society stayed in turbulence, and warlords were in – fighting, while the Japanese army invaded China, resulting in no time to harness the Yellow River. There were hardly any researches on the Yellow River estuary. Only Mr. Li Yizhi, Mr. Zhang Hanying, Mr. An – Lisen (of Norway nationality), and the Second Investigation Commission of Japan East Asian Research Institution, etc. , related the estuary situation and relevant estuary harnessing issues, but without any conditions to fulfill.

The modern river harnessing period. During 1950s, the research data of Yellow River estuary are mainly the historic investigation of estuary channel and survey report, and is complemented by the estuary situation introduction. During 1960s, it begun to systematically summarize the fundamental situation and basic rule of Yellow River estuary, and firstly present the concept of "small cycle" of channel swinging of Yellow River estuary, while then, such harnessing and programming tasks as the flood and ice flood prevention, schemed diversion and water engineering, etc. , have also been centralized to fulfill. During 1970s, there have been greater breakthroughs and evolutions of scientific research on estuary, mainly representing as following:

(1) It primarily summarized the general evolution rule of river pattern of "small cycle" as the "random – pluming – straightness – bending – branching – larger branching – random – by diversion", and made discussions on branching and swinging conditions and judging index.

(2) It definitely distinguish swinging from diversion, and presented the classifying problem of swinging, simultaneously analyzed the diversion effect.

(3) It presented that viewing from the long – period macroscopic indirect influence, the relative uprising of estuary extension is the dominant factor to induce lower channels continuously deposited after analyzing the relationship between the estuary extension and lower level rising as well as the contrast of backwater deposition forms.

(4) It discussed estuary harnessing issues through such forms as summarizing the dredging history and developing the flume dredging experiment, etc. .

As to the harnessing measures of Yellow River estuary, it has been mainly carried through with requirements of the estuary delta reclamation, population increase, as well as the industrial and agricultural development.

Since 1855, as the Yellow River channel diverting into Daqing River then flowing into Bohai

Sea sea, the estuary region has always been untraversed during a quite long period. In 1882 (the eighth year of the dominance of Guangxu of Qing Dynasty), reclaiming residents began to appear, and until 1910 (the second year of the dominance of Xuantong Qing Dynasty), the population of reclaiming residents gradually increased, and a large area of badlands was reclaimed, which was the cause for the name of Kenli county. During that period, as large quantities of sediments had been deposited within the flooding district above Taochengpu, the sediment pouring into the estuary was less, and the estuary was comparatively stable. After 1872 (the eleventh year of the dominance of Tongzhi of Qing Dynasty), as the lower emban kment gradually matured, the sediment transported to the estuary increased, and the problem of estuary deposition and extension had gradually been unveiled, while the swinging and variance of estuary channel had gradually become frequent. In order to protect the farmland of reclaiming residents, about 20 km folk banks had been built between fields along the river within the estuary region below Ninghai area, which were all constructed and defended by the local people, while the estuary channel had still been in the natural variance situation. Before or after 1947 when the Yellow River returned to its former channel, the Bohai Sea Liberated Area re – blocked the estuary reach for four phases, and until 1949, the left dike had been constructed to Siduan, while the right one had been construced to 7.5 km east to Songjiajuan, Kenli county.

After the foundation of the People's Republic of China, the Yellow River delta development has received great attentions from the Party and the chinese Government, and there have been three times migrations from southwest Shandong and neighboring counties to reclaim the badland, while such villages as Youlin, Xinlin, Jianlin, Yilin, etc. continuously appeared nearby Kenli county Boundary, and larger scales of farm, forestry center and army horse ranch were established in succession. The oil exploitation started in 1961, and then, the oil encounter was organized, and Shengli Oilfield was constructed. The appearance of large – scale farm and pasture as well as the oil exploitation, especially since the foundation of Dongying City in 1983, the economic and social situation of the Yellow River delta has been changed so much that this delta has become the important oil exploitation and processing base in China at present.

Along with the development of estuary region, the random diversion of sink channel was no longer allowed for the increase of the urgent flood control requirement. In order to protect the industrial and agricultural production of estuary region and decreasing the flood control burden of Yellow River Lower Reach, three man – made diversions were implemented respectively in 1953, 1964 and 1976, and the Qing 8 man – made branch diversion was implemented in 1996, while Phase I projects of estuary harnessing projects officially ratified by the State Planning Commission was also implemented.

2 Research on estuary harnessing countermeasures

2.1 To further strengthen the flood prevention engineering construction and to comparatively stabilize the flow course of Qingshui Gully

To comparatively stabilize the estuary flow course is the requirement for the sustainable development of economy and society of estuary region. Under the precondition of no influence on the safety of Lower Yellow River flood control, it's possible to achieve the relative stability of current flow course of Yellow River estuary during a quite long period through correct manual intervention within the reasonable scope.

According to the 12 m level of 10,000 m^3/s discharge at Xihekou as the diversion control condition, the flow course performing sequence is thought to be Qing 8 branch—Beicha—formal channel through the same design water sediment series as "Xiaolangdi reservoir performance mode research" and utilizing the mathematic model of two – dimensional sediment water dynamics for simulation forecast. And the calculation results indicate that it can keep the flow course of Qingshui Gully stable during 50 years or rather longer on condition of designedly arranging the estuary flow course and taking such comprehensive measures as channel harnessing, stabilizing dikes by silting the backs, and river dredging, etc..

The main short – term (before 2010) constructional measures includes heightening and reinforcing the dikes whose height and intensity cannot satisfy the flood prevention standard at present, reinforcing dikes by river dredging and back silting, the reinforcement of river regulation works of the reach above T – shape road, etc.. The long – term (2010 ~ 2020) measures include the reinforcement of river regulation works such as river control and dangerous engineering, and the diversion engineering planning, etc., and simultaneously managing and protecting the flow course of Diaokou River as a spare flow course.

2.2 Planning the spare flow courses

Current research results indicate that the Yellow River will still be a heavy – sediment – laden river with a certain quantity of ocean sand, estuary deposition and extension will be ineluctable. Therefore, a long – period stabilization of current flow course is also limited, and there also exists the probability of forcing the estuary to divert as sudden large floods occur during the using of flow course. So, on long – term thinking, diversion spaces for estuary flow course must be left, namely, the spare estuarty flow course, in order to ensure the flood protection safety of downstream of the Lower Yellow River.

The spare ocean flow courses include Diaokou River and of Maxin River course to the south of Qingshui Gully. Thereinto, Diaokou River course is the former flow course, which is the previous course (1964 ~ 1976) and still remains the previous form at present, if diverting to this flow course, the interfere to the exploitation of oil field and delta is less, and the ocean dynamical condition at estuary is quite beneficial, but it closes to Qingshui Gully course, whether the estuary sediment deposition can influence the Dongying Seaport still need to be studied. Maxin River course is near Wangzhuang, Lijin, and flows to the ocean northwards. Short cutting the narrow reach near Wangzhuang will benefit the ice flood control, and it's quite far away from the Qingshui Gully course, which is beneficial to postpone the coastline extension, but there are number of residents within the flow course, whose resettlement is difficult, the investment for constructing a new river is also quite large, and the defending task for initial period of flow course is rather troubled.

By analysis of current situation, the Diaokou River course can be actualized much easier than Maxin River course, therefore, it's idea to select Diaokou River course as the spare one.

2.3 To well deal with the relationship between the Yellow River estuary harnessing, society, economy and environment

The estuary harnessing must give attentions to the layout of local economic development, while the economic layout must obey the estuary harnessing in general, both need to accord with the environmental construction. Therefor, it is suggested to orient social and economic development target of estuary region as water – saving eco – economic region based on the construction of petrochemical processing, high efficient agriculture (herd, fishery) of and the nature reserve, featured by urbanization and cyclic economy.

There are plentiful oil, natural gas and brine resources in the estuary region, condition for developing the petrochemical processing is richly endowed by nature; and as the natural reserve cored by the estuary wetland is one of the features of this region, the basis is favorable, it is suggested to further consolidate this advantage, maintain the ecosystem, and develop the eco – tourism; the land resource in estuary region is plentiful, so it is suggested to develop high efficient eco – agriculturest such as quick growing economic forest, intercrop Chinese dates (forest) and grains; and due to the scarce fresh water resources, it is suggested to restrict the high water consuming industry, improve the recycling rate of water, control irrigation water quantity and construct a water – saving eco – economic region.

2.4 To make harmony of the management and investment systrm of the Yellow River estuary

The estuary harnessing involves not only the current channel, but also the spare flow course, coastline, uniform collocation of water resources, entironmental protection and relevant constructions etc. in the delta, is related to several units and departments, only the Yellow River estuary managed uniformly can the harnessing be carried through orderly.

Chronically, each the Yellow River estuary (below Siduan or Ershiyihu) project is together managed by the Yellow River departments, Shengli Oil Management Bureau, and Dongying city, the engineering investment is also raised by those three parties. All the departments claimed their management power and then managed in their own way, constructed unorderly projects, which have produced many disadvantageous influences on flood control and comprehensive management and development of estuary.

In order to ensure the flood control safety of estuary enrironment, necessary flow course and silt storage scope of estuary, to create a good for social and economic development of estuary region, and to actualize harmony between human and nature, it is suggested to bring the estuary harnessing into the national capital construction system, the nation invest and manage the harnessing uniformly, and according to the priciple of "the uniform management, graded responsibility", corresponding management regulation be constituted and published as soon as possible, the responsibility and power of relevant departments in the estuary harnessing be definituded, which can make the process of estuary harnessing healthy and orderly.

2.5 To reinforce the estuary observation and scientific research

Full, accurate and rich observation data is important basis for developing the scientific research of the Yellow River estuary region and constituting the harnessing plans. At present, the scientific research of the Yellow River estuary lags, goes against the estuary harnessing process. It is suggested to increase the investment, establish the estuary scientific research fund; reinforce the prototype observation of the estuary evolution, hydrology, silt and oceanic dynamic factors; especially build the estuary model experiment base as soon as possible, which can provide the scientific references for analyzing, studying, cognizing and further mastering the internal natural rules of estuary evolutions. Due to the complexity of the Yellow River estuary issues, it is suggested to further multi – discipline and multi – department cooperation, especially conduct the scientific research in virtue of the mathematic model, physical model and other modern scientific and technologic means, which can provide the decision – making support for constituting the scientific and reasonable harnessing plan of estuary region; and continue conduct the estuary dredging experiments, which can provide technological support to the Yellow River estuary harnessingand delta development and protection.

2.6 Other harnessing measures

Other measures and approaches of estuary harnessing are mainly listed as following: ① to restrict the estuary flow direction by diversion works; ② to dredge the estuary; ③ to actualize sediment transport by oceanic dynamics; ④ to construct high – level flood diversion works at Xihekou; ⑤ to harness the sand bar; ⑥ to scour the silt by diverting seawater, and so on.

Some of above harnessing measures have been quite mature, and functioned importantly during the estuary harnessing practice, such as river regulation, heightening and reinforcing dikes, and so on; some of them are reasonable, have been planned to implement or partially implemented, such as building the estuary physical model experiment base, planning the spare flow course construction, and so on; some of them are still in the pilot phase, such as dredging the sand bar, etc.; some of them are disputable and still need demonstration, such as skillfully utilizing the oceanic dynamics, consolidating the estuary, high – level flood diversion at Xihekou, and diverting seawater to scour the current estuary flow course, and so on. These measures greatly enrich the connotation of estuary harnessing measures and provide powerful technical support to prolong the life of Qingshui Gully course, to reserve the spare flow course, and to keep the healthy life of the Yellow River.

3 Conclusions

The Yellow River estuary harnessing is an important part for the flood control and silt reduction system of Lower the dounstream of the Yellow River, and one of the important measures to maintain the healthy life of the Yellow River. The Yellow River estuary management is related to such factors as Lower Yellow River flood control, social and economic development of delta and entironmental protection, etc.. Therefore, the Yellow River estuary harnessing should follow the natrual evolution rule of Yellow River delta, preconditioned on the flood control safety of Lower Yellow River, based on improving Yellow River delta entironment, completely exert the resource predominance of delta region and advance the sustainable development of local economy and society. The overall programming, overall plan, the reasonable arrangement strategies should be carried out to realize for the lasting peace of Lower Yellow River and sustainable development of local economy and society. Short – term harnessing measures should involve strengthening the construction of flood control project and non – constructional measures based on Qingshui Gully course, prolonging the life Qingshui Gully course, to guarantee flood control safety and necessary water resources for delta development and construction. Long – term harnessing measures should involve designedly arranging the spare etuary flow course and implementing timely artificial diversion.

References

Chinese Hydraulic Academy, The Yellow River Research Society. The Yellow River Estuary Problems and Harnessing Measures Proseminar[C]. Zhengzhou: Yellow River Conservancy Press, 2003.

The Feasibility Research Report on Yellow River Estuary Recent Flood Control Project Construction [R]. Zhengzhou: Reconnaissance, Planning, Design & Reaearch Institute. Yellow River Conservancy Commission, 2003.

The Yellow River Estuary Harnessing Programming Report[R]. Zhengzhou: Reconnaissance, Planning, Design&Reaearch Institute. Yellow River Conservancy Commission, 2000.

Using Sediment Discharge in the Yellow River to Accelerate the Oil Fields Development

Wang Junming*, *Li Shiguo*, *Xue Yonghua* and *Wang Yong

Dongying bureau of YRCC, 257091

Abstract: With the sharply reduction of the sediment discharge in the Yellow River, the coastline in the delta is chiefly retreated contrary to before, and the area is decreasing, which has disturbed the exploitation of the oil fields and the local economic sustainable development. For that, there are two advices: firstly, the Beichahe distributary should be provided as earlier as possible to protect the Gudong embankment by the sedimentation; secondly, the distributaries of Qingshuigou and the Diaokouhe should be used as the outlet by turn to maintain the dynamic Diaokouhe coastline changeless.

Key words: Yellow River, sediment, coast erosion, embankment protecting

The Yellow River carries a huge amount of sediment to the river – mouth area every year, but most of the sediment have been deposited in the river channel near the mouth or entrapped in the near shore. The heavy load of sedimentation in the lower river channel causes the riverbed to aggradation, the growth of the course and the base level upraising which can result in the rapid aggradation of the riverbed, and also this enlarged the potential flood risk on the floodplain.

Since 1949, the Yellow River has changed its course 3 times, Shenxiangou distributary, Diaokouhe distributary and Qingshuigou distributary, all of which resulted from artificial engineering in 1953, 1964 and 1976 respectively. Although deposition rates decreased in the early shifts, the rapid deposition and the stimulus to the riverbed aggradation came back quickly with the perpetual sediment discharge from the upper reaches.

The total discharge of the river water is $5,075 \times 10^8$ m^3, and that of sediment is 134×10^8 t, recorded at the Lijin Hydrological Station from the Qingshuigou distributary formed (1976) to May of 1996. With this plentiful sediment transported to the river mouth, the spit is slowly moving seawards, and the course increased 38 km from the initiatory 27 km to 65 km. The water level at a discharge of 3,000 m^3/s is higher than that of 10,400 m^3/s in 1958, while the water level of a 10,000 m^3/s discharge at Xihekouhen had risen from 10.0 m (Dagu, 1976) to 11.12 m. The course decreased 16 km after the artificial channel diversion project, which is virtual to mitigate the hazard risk, maintain Qinghuigou channel and pump oil for Shengli Oil Field, was actualized near the Qing – 8 section in May of 1996. Since the Qing – 8 distributary formed, the water level at the same discharge fell down, and there appeared the upward erosion. It is very important for us to actively use the sediment to assist the local development. From 1996 on, due to the sediment delivered into the sea has decreased sharply, the pattern of change along the delta coastline show different. Once deposition coexisted with erosion and deposition is primary, but after 1996 this reversed. The area of the delta began to reduce with the shoreline position retrograding, which result in losing land and affecting the sustainable regional development.

1 Changes of the water and sediment discharge

According to the statistic data, the Yellow river had a mean water discharge of 324.42×10^8 m^3 per year from 1950 to 2003 and 418.52×10^8 m^3 per year for 1950 ~ 1985. The water discharge has decreased significantly since 1986, as result of less rainfall for several years, vast water used in winter and springtime due to the development of agriculture and population. The mean water discharge for 1986 ~ 2003 is 136.22×10^8 m^3 per year, which is equivalent to 42.0% and 32.5% reduction compared with that for 1950 ~ 2003 and 1950 ~ 1985 respectively. Especially during these recent dry climate years and after the uniform management of the river water in 1999, the mean discharge for 1999 ~ 2003 is $78.92 \times 10^8\ m^3$ per year, which is equivalent to 24.33% of the mean discharge during a longer time. It is clear that the water discharge has decreased seriously since 1999.

From 1950 to 2003, a mean suspended sediment load transported into the estuary area is 8.14×10^8 t per year. After 1986, in the shorting of water and sediment load period, the mean sediment discharge is 3.41×10^8 t per year, which is equal to 41% of that for 1950 ~ 2003. However, after 1996, the mean sediment discharge is only 1.85×10^8 t per year as much as 23% of that for 1950 ~ 2003.

2 The influence of coastline erosion on oil extraction

As the sharp decline of the water and sediment delivered in the Yellow River, the erosion along the delta is becoming worse and worse. By observation, during the period of 1996 ~ 2004, the area of the delta reduced at a rate of 7.6 km^2 per year. Since the Diaokouhe distributary was abandoned in 1976, the nearby coastline has been still eroded, until 2000, the promontory of the Diaokouhe spit retrograded landwards 10.5km and the 0m isobath retrograded maximally landwards 11.9 km in the 20 years period. The outermost of the abandoned Qingshuigou spit retrograded landward about 3.1km from 1996 to 2004 due to lacking of sediment supply. Shoreline retreats give us a big burden for oil extraction, which will cost much more and be full of difficulty in oil extraction.

The beach outside of the sea embankment has been eroded and washed endlessly, for example the altitude of the beach outside the Gudong oil field lowered from 0.5 m of 1996 to −4.5 m of 2002 (Fig.1). Then a series of problem appeared: on the one hand, the height of the embankment is relatively increased leading the embankment to miss its steady standard, and enlarge the hazard risk in collapse; on the other hand, the drastic power of the wave caused by the outside beach subsidence and the deeper water. When the Gudong embankment was formed, the altitude of the beach was 0.55 m, and the elevation of the embankment top was designed to be 5.66 m by the standard, in actually 5.6 m. But now, the altitude of the outside beach is −4.5 m, and the elevation of the top should be no less than 9.26m, so at present, the height of the embankment can not achieve the request.

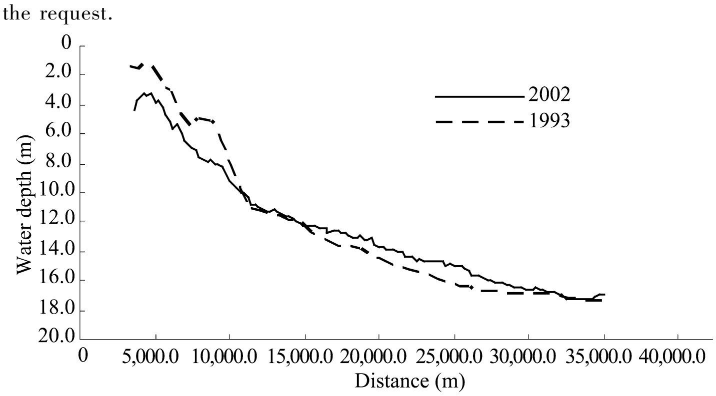


Fig.1 Comparison of the water depth of in the 4200000 section between 1993 and 2002

3 Using sediment discharge in the Yellow River to accelerate the oil fields development

3.1 Protect the Gudong embankment by the sedimentation in the Beicha River

The objective of the estuary management is not only for decreasing flood risk but also facilitating the sustained regional economic growth, for example, the Gudong oil field was built on the new land formed by sedimentation. By about 20 years time, this embankment has been constructed to a standard circular embankment, which can defend against the super tide that happened one time every 50 years statistically, to guarantee the exploiture and the production from the destruction of the usual tide. In June of 1986, in order to deliver sediments to the east of the Gudong oil field sea area and decrease the embankment destructed risk caused by tide, the Beichahe distributary was excavated by Binhai oil field in the left bank about 500 m below the Qing – 7 section. However, considering the shiftable course and the endangered embankment, the Beichahe was stifled in October of 1987. After more than ten years, land surface outside of the Gudong embankment has been eroded and washed seriously because of the sharply decline of the sediment load and the influence of wave, tide, storm surge and so on, and contemporarily, the sloping field of the dike lost steady and collapsed. We spend lots of money to mend them every year, but the danger is still enlarging.

Qing – 8 divulsion was planned to be the outlet for 4 ~ 5 years in order to silt up new field for oil pumping. 10 years elapsed, the reach from the Xihekou to the river mouth advanced from the 49 km to 59 km, but the target can not to be achieved due to the change of the water and sediment discharge. Since 2002, the Xiaolangdi reservoir has made 4 times experiment for adjusting the run off of water and the sediment load, whose aim is to change the sedimentation process in the lower riverbed. It is certain that deposition in the river mouth accelerate resulting from the sediment transported from upriver. By statistic, during 2000 ~ 2004, the sediment aggraded at the estuary is 4.579×10^8 m^3 (5.49×10^8 t), accounting for 93.5% of the 5.87×10^8 t contemporarily recorded at Lijin. The course advance at a rapid rate (about 1 km/a) though the sediment load is not huge. If this experiment can be done when the water is enough, the aggradations at the spit will accelerate certainly under this water and sediment condition. When the planned object is achieved, the Beichahe project should be actualized as early as possible to protect the Gudong embankment.

3.2 Use qingshuigou and diaokouhe by turns, balance the dynamic coastline along the Diaokou river estuary

Since the artificial Qingshuigou distributary was formed in 1976, coastline erosion has appeared in Diaokouhe estuary due to shortage of sediment supply. During 1976 ~ 1986, the Diaokouhe spit retrograded landwards about 6km, and the area decline about 100 km^2, while that for 1986 ~ 2000 is about 1km and 37 km^2 respectively. Before 1986 the rate of erosion was much quicker, and it was slower after 1986. The coastline retrograded during 1976 ~ 1980, 1980 ~ 1990 and 1990 ~ 1995 at a rate of 0.9 km per year, 0.24 km per year and 0.15 km per year respectively, and the average annual retrogradation rate is 0.43 km during the 19 years time. Until May of 2000, the 0 m isobath at the promontory of the Diaokouhe spit (Feiyantan oil field) retrograded 10.5 km in the 24 years time, while the nearby 15 km coastline averagely retrograded 7.67 km at a rate of 0.319 km per year, and the area decreased 115.1 km^2 at a rate of 4.8 km^2 per year, which would be much more if there is no Zhuangxi embankment. At present, the 0 m isobath has moved into the Feiyantan oil field, and a road from east to west has been flooded by the high water. In case of letting it have its swing, the oil fields of Feiyantan, the 106 Station and so on nearby the Diaokouhe estuary will became the maritime oil fields. For that, the Qingshuigou and the Diaokouhe distributary should be the outlet of the Yellow River alternately in the right time to maintain the shoreline around the Diaokouhe changeless.

3.3 Facilitate the oil extraction with the dredged sediment

The characteristic of a huge sediment discharge in the Yellow River can not be changed in a short time, and the sediment transported to the river mouth will cause the mouth advancing seawards and increase the length of course perpetually. So it is necessary to conduct the planned dredging in the river mouth area by the advanced technique and equipment in the world. At the same time, filling some estuary area with the sediment can facilitate the oil extraction, decline the cost and accelerate the economic development.

4 Conclusions

In the last decades, as a result of the decline of the sediment discharge, erosion plays an important role in coast changing around the Yellow River Delta, and the conduced problems are the soil erosion and the seawater intrusion with upstream movement, which have an important influence upon the oil industry, agriculture and the environment. The decreasing sediment is valuable and should be used best. It is significant to conduct the prepared diversion without increasing the flood risk, and we must use the limited sediment to balance the dynamic coastline for accelerating the local and oil industry development.

Research on the Feedback Influence of Estuary Evolution for Lower Reachs of the Yellow River *

Chen Xiongbo, ***An Cuihua***, ***Qian Yu*** and ***Peng Yu***

Yellow River Engineering Consulting Company, Ltd. Zhengzhou, Henan 450003, China

Abstract: This paper analyzes the macroscale, mediumscale and microscale feedback influence induced by the estuary evolution of the Yellow River (YR) on channels of the Lower Reachs, among which exists a dialectic and united relationship for illumination. The estuary length is a control factor to determine the feedback influence. In order to decrease the feedback influence induced by the estuary deposition and extension on lower channels, it should take comprehensive control measures within the YR Middle and Upper Reachs, Lower Reachs and Sink Reachs to keep the river length as short as possible.

Key words: the YR estuary, lower channel, feedback influence, river length

1 Current situation of research

For the feedback influence induced by the deposition and extension of YR estuary on lower channels, there are two major viewpoints at present: ①the incoming water and sediment condition is the main factor to determine the deposition of YR Lower Reach, and the river length and deposition volume influenced by estuary deposition and extension are limited, which can be intituled as "the Streamwise Deposition Theory"; ② the estuary extension is the direct cause for the deposition of Lower Reach, and the longitudinal profile regulation of lower channel is approximately the parallel rising, which belongs to the backward deposition from the macroscopical viewpoint, and can be intituled as "the Parallel Rising Theory".

The difference between those two viewpoints lies in that the former is to study the feedback influence induced by the estuary deposition and extension on lower reaches from a comparative short – period scale, while the latter is to analyze the scour and fill volume from the macroscopical and long – period point of view, and can be considered that the form regulation of bed longitudinal profile is the approximate parallel rising.

2 The macroscale and mediumscale feedback influence of estuary evolution on the Lower Reachs

2.1 The macroscale influence of estuary deposition and extension on the Lower Reachs

From the coastline transition of Bohai Bay, it's viewed that once the route where the Yellow River flows, its coastline continues to move outward, and along with the delta deposition upraising, if it still wants to maintain the channel drainage sanding slope, it requires to lift the channel level of the Upper Reach, which further produces the similar effect of datum level uplifting, while the feedback influence upwards transmits. It analyzes the relationship between the breaching and overflowing part and its occurring time of formerly performing channels of the Yellow River during Ming and Qing Dynasty, and between the lower channel breaching place and its occurring year before and after breaching of Tongwaxiang, both of which indicate the estuary extension influences

* State Science Support Program Thesis: Research on the Optimized Matching Model for Sediment Space of the Yellow River; Thesis Number: 2006BAB06B03.

the deposition course of lower channel through the backward deposition. Therefore, the macroscopical feedback influence of YR estuary evolution can spread to the whole lower channel.

2.2 The media influence of estuary deposition and extension on the Lower Reachs

Since 1950s, when there has been existing the detailed field - measured material relating to the YR estuary district, and has experienced three small cycles as the Shenxian Gully period from 1953 to 1963, the Diaokou River period from 1964 to 1975, and the period of the former channel of Qingshui Gully from 1976 to 1996. As the lower channel has been greatly influenced by the operation of Sanmenxia Reservoir during the period of 1960 to 1964, the streamwise scouring occurred, while the branch river diversion simultaneously occurred at the estuary, it requires to consider the period from 1953 to 1975 as a cycle while analyzing the medium influence. It analyzes changes for water level and deposition volume of the lower channel during the period from the starting point to the end point for each small cycle, and researches the feedback influence of estuary evolution on lower reach, which can be intituled as the media influence of the estuary deposition and extension on the Lower Reach.

2.2.1 Water level changes

Fig. 1, as follows, shows the level process of past years before and after flood season, as the discharge is 3,000 m^3/s at each lower station during the period from 1954 to 1996.

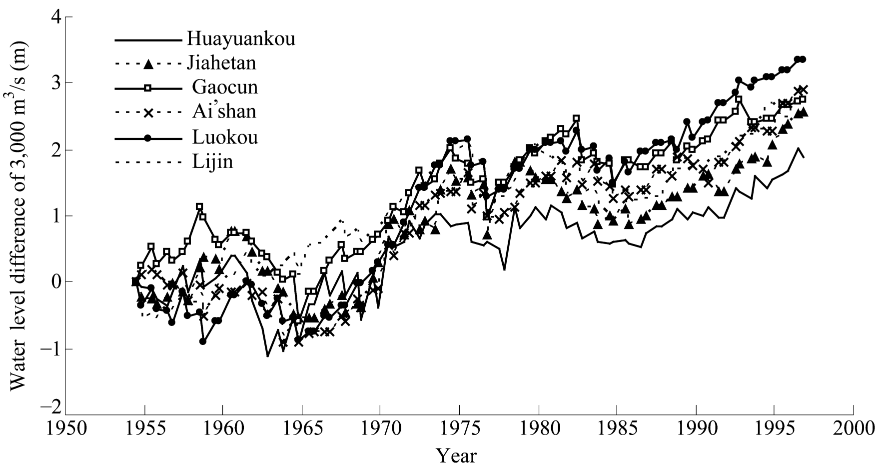


Fig. 1 The water level at 3,000 m^3/s discharge of YR Lower Reach from 1954 to 1996

On analyzing Fig. 1, all the water level at each station of two respective periods from 1954 to 1975 and from 1954 to 1996 represent that the level rising value for Luokou Station and Lijin Station are the largest, while that for Huayuankou Station is the smallest, and those for three stations of middle reach just belong to the medium state featured by larger Lower value while smaller Upper value, which is the longitudinal profile form typically influenced by the backward deposition. Within the period of once a small cycle completed by the flow path, the estuary extension can produce a far - reaching feedback influence on the Lower Reach, whose influencing scope can extend to Huayuankou.

2.2.2 Regulation of the lower channel scour and deposition volume

It requires to take a rather long period of several years to regulate the scour and silting of and longitudinal profile of YR lower channels, which have been induced by much larger changes or occurring successive movements of the channel boundary condition. Though, when the sediment discharge condition approaches the annual average situation, and during the time interval of stable estuary deposition upraising, the scour and silting regulation for the whole lower channel, encircling the comparative balance, is relatively much rapider, which further makes the scour and silting evolution of the whole lower channel fundamentally maintain the comparatively stable in – phase ascending and descending tendency during 1970s. And after 1980s, the following situation has taken place, for the water level of three stations as Huayuankou, Jiahetan and Lijin, the level rising, occurring at reaches of the upper and lower of the Lower Reach, is relatively lower, while those at the lower middle reach are relatively higher, but from the level variation process of YR lower reach, it's viewed that no following situations have taken place, yet, no reach slope above Gaocun Station has apparently become flat, while no reach slope below Luokou has apparently become steep. From the medium viewpoint, the estuary extension can produce a far – reaching influence on the lower channel deposition.

Based on the above – mentioned analysis, when the incoming water and sand condition and the estuary datum condition enormously changed, it will induce severe regulations on reaches of the upper and lower end of YR Lower Reach, which consequently represents the feature of reaches of the upper and lower end occurring with corresponding changes according to the respective dominant influence factor, and their non – synchronization; though finally, those two conditions will quite quickly tend to the comparatively stable balanced longitude profile, while evolve and develop in step with the estuary relative datum situation, and the scour and silting of the whole lower reach will achieve the general in – phase development encircling comparatively balanced longitude profile waves. On considering the annual average, the deposition volume and level upraising value of YR lower channels are all of lower larger as upper smaller, which indicates the lower deposition belongs to the backward deposition from the medium scale.

3 Analysis of the regulation on longitude profiles of the YR Lower Reach and estuary district

3.1 Regulation of longitude profiles of the YR Lower Reach and estuary district under different sediment – water conditions

The period from 1950 to 1960 was the plentiful and heavily silt – laden series, during which the occurrence time for major floods was excessive, and the overbank flood silted beaches while scoured channels, making great influences on the longitudinal and transverse distribution of the scour and silting volume. For longitudinal slopes of 1960 and 1950, except those of Gaocun ~ Sunkou Reach decreased, those of the rest lower reaches all increased. After the river length of estuary district became shorter, the slope became higher.

The sediment control period of Sanmenxia Reservoir was from Oct., 1960 to Oct., 1964., during which the lower channel occurred with scour and silting. There had been 2.31 billion t sediment scouring within the Lower Reach, while the intensive scouring had occurred within reaches above Sunkou. The streamwise scouring intensity gradually decreased. The longitudinal slope of channels above Sunkou in 1964 was nearly the same with that in 1960, and the slope of reaches from Sunkou to Lijin in 1964 all decreased, comparing with that in 1960, which has decreased 9.8% at most, while the longitudinal slope of reaches below Lijin increased, which was influenced by diversions.

During the period from Oct., 1964 to Oct., 1973, large quantities of sediments have been desilted by Sanmenxia Reservoir, resulting in heavy deposition. The deposition distribution of lower channels has changed, yet, the upper and lower reach enlarged, while the middle reach narrowed. As channels have been severely deposited, level of each station along the lower channel all markedly rose, and the annual average rising value of such stations within the Upper Reach as Tiexie and Peiyu, etc. was quite small, while that of the rest stations was all within 0.2 ~ 0.3 m. On comparing the longitudinal slope of each reach in 1973 with that in 1964, the rest reaches all hardly changed much, except that the Sunkou—Ai'shan Reach decreased 5.2%.

During the period from Oct. , 1973 to Oct. , 1980, the annual average deposition volume within the Lower Reachs was 0. 181 billion t, though, among which most sediments deposited on the flood – plain, and the level of reaches above Huayuankou annually lowered 0. 02 ~ 0. 05 m, while that of the Jiahetan—Zhangxiaotang Reach annually rose 0. 05 ~ 0. 10 m, and that of the reach from Daoxu to Lijin basically didn't rise, which was influenced by backward scouring induced by the estuary channel diverting to the flow path of Qingshui Gully. Comparing the longitudinal slope of each reach in 1976 and 1980 with that in 1973, the variations were small. The estuary, which diverted after flooding in 1980, had formed the straight single channel, while the slope of reaches below Lijin was still higher than that in 1973.

During the period from Oct. , 1980 to Oct. , 1985, the incoming water was rather plentiful, while the incoming sediment was quite less, and the median discharge experienced a long period, and 0. 485 billion t sediments in total had been scoured within the lower channel, and viewing from the longitudinal slope of each lower reach in 1985, which had been compared with that in 1976, that of the Huayuankou—Ai'shan Reach slightly decreased, while those of reaches below Ai'shan slightly increased, and for the main, there were no marked variations. Channels within the estuary district unbarred, and the flow level of Lijin—Xihekou Reach in 1985 lowered about 0. 7 m than that before diversion, which moderated the flood prevention burden of estuary district to some extent.

During the period from Oct. , 1985 to Oct. , 1996, there were low incoming water and sand, and the annual average deposition was 0. 247 billion t within the lower channel, which mainly concentrated within the upper reach, while the deposition volume of Tiexie—Jiahetan Reach occupied 50. 2% of the total one within the Lower Reach, and the deposition of reaches below Sunkou all concentrated within the main channel. The water level of reaches above Jiahetan annually increased 0. 10 ~ 0. 16 m, while that of the Jiahetan—Liujiayuan Reach annually increased 0. 12 ~ 0. 16 m, and the level rising value of the reach close to estuary was a bit higher, while those of reaches below Zhangxiaotang annually increased 0. 15 ~ 0. 17 m. In 1996, as the outlet regulation initial period, the longitudinal slope of reaches below Lijin increased, though lower than those of the initial period of preceding three diversions.

The period from Oct. , 1996 to Oct. , 2000 was the very low water and sediment quantity series, and there were 0. 186 billion t sediments in total deposited within the lower channel, most of which were in the main channel, while mainly centralized within the Jiahetan—Luokou Reach, indicating the deposition centroid downwards shifted, and the longitudinal slope of the Lower Reach increased. The estuary district was influenced by diversion, among which the Lijin—Xihekou Reach was mainly influenced by the streamwise scouring, while reaches below Xihekou were mainly influenced by backward scouring, and the longitudinal slope of estuary decreased.

The period from Oct. , 2000 to Oct. , 2004 was the very low water and sediment quantity series, but through the debris – retaining performance and sediment regulation of Xiaolangdi Reservoir, there had been 0. 82 billion t sediments scouring within the channel, whose scouring volume centralized within the main channel, and scouring parts were mainly within reaches above Gaocun, while the longitudinal slope of Lower Reach decreased. Expect for being influenced by fresh water scouring, the estuary district had been undertaken the second and third projects of river dredging and bank fixing, while the longitudinal slope continued to decrease.

On viewing from the regulation part of lower deposition volume of each time interval, it has been gradually downwards shifting year after year, which has a close relationship with the regulation of bed longitudinal slope. After Xiaolangdi Reservoir was operated, the most of scouring volume was within Henan Province, and the longitudinal slope of Lower Reach decreased.

3.2 Analysis on influence factors of the longitude profile of YR Lower Reachs and estuary district

3.2.1 Regulation features of the longitudinal profile of YR Lower Reachs

Fig. 2 shows the relationship between the average sediment concentration and the scour and silting volume of unit – cubic water of YR Lower Reachs. Viewing from the following Fig. 2. the critical sediment concentration is about 18 ~ 22 kg/m^3 while the scour volume equals to the silting volume.

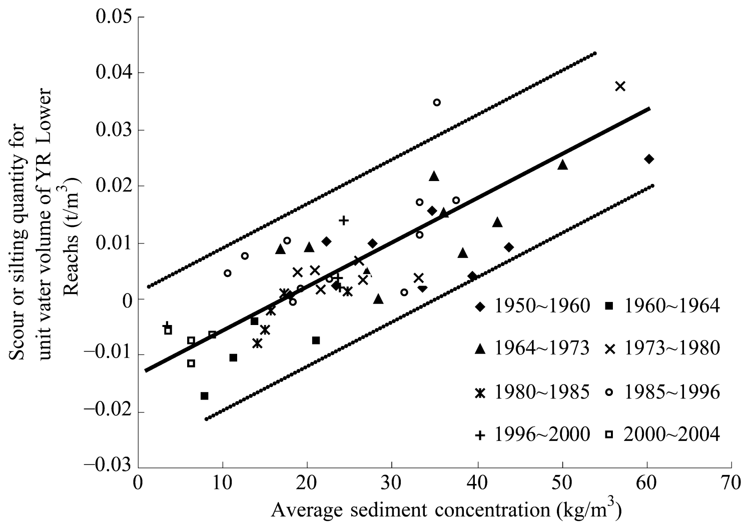


Fig. 2 The relationship between the annual average sediment concentration and scour and silting volume of unit – cubic water of YR Lower Reachs

3.2.2 The regulation mechanism of longitude profile of YR estuary district

During the initial phase of diversion, the channel length was shortened shortens, and the erosion datum level relatively became low which make the slope of reach nearby the estuary suddenly increase, the bed scour, and the bed surface lower, while the lowered bed again changes the erosion datum level of upper section of this channel, which also makes the channel repeat the scouring and lowering process of the former channel, and moves in such cycles, the estuary diversion influence continues to transfer towards the Upper Reach, along with the streamwise dissipation induced by the transforming – generated flow kinetic energy, this energy cannot but wearing away at a certain point within the channel, where the estuary evolution influence can be ignored.

During the late phase of stream diversion, the deposition of sink channel extends, the slope of reach nearby the estuary becomes lower, the flow sediment – carrying capacity and flow depth becomes small, the sediment – carrying capacity increases, and the reach slope develops towards the direction of aggrandizement, while the rising bed through deposition makes the erosion datum level of lower boundary of upper reach of abutting channel rise, and moves in such cycles, the deposition and extension influence continues to transfer towards the Upper Reach, the potential energy increment induced by the deposition and extension, finally become zero at a certain point, namely, the most far away position for developing the channel deposition and extension influence.

3.2.3 The relationship between the longitudinal slope and incoming water and sand, etc. of YR Lower Reachs and estuary district

Variations for longitudinal profile of the Huayuankou—Lijin Reach relate to conditions of incoming water and sediment, which can be expressed as following:

$$\ln J = 0.007\,2 \times \ln S - 0.006\,1 \times \ln Q + 0.417 \times \frac{L}{L_t} + 12.69 D_{50} - 0.942 \tag{1}$$

Within Eq. (1), J represents the slope, whose unit is 0/000; Q and S, respectively represents the average discharge and sediment concentration of intake station; L, represents the distance from the Reach to Tiexie; L_t, represents the calculated average space from Tiexie to the Estuary within the time internal; and D_{50}, represents the median grain diameter of bed sand, whose unit is mm. Fig. 3 shows the comparison between the calculation value in Eq. (1) and the field – measured value, which concludes that those for reaches above Lijin comparatively accord with each other.

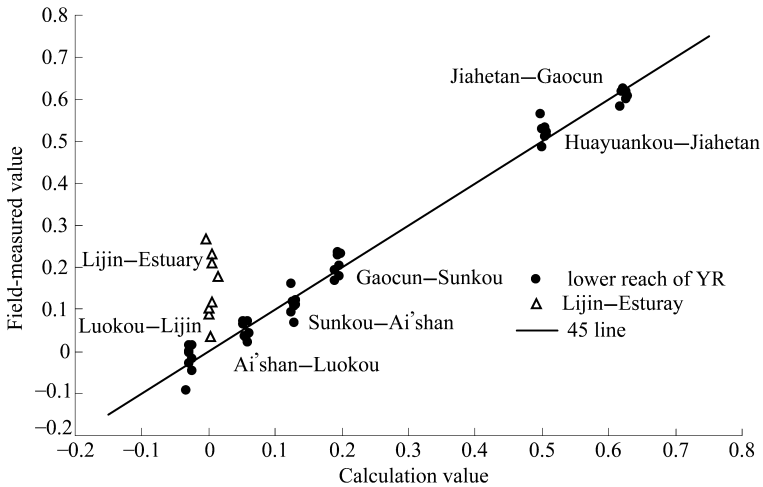


Fig. 3 Comparison between calculation value in Fq. (1) and field – measured value of each reach

It also can view from Fig. 3 that there is a rather bigger deviation between the calculation value in Fq. (1) and the field – measured value of each estuary reach below Lijin. Such a relational expression can be formulated as follows, through utilizing the field – measured data of Lijin—Sea Outfall Reach:

$$J_0 = 0.08 \times \ln S - 0.054 \times \ln Q - 0.315 \times \ln L_0 + 2.51 \quad (2)$$

within Eq. (2), J_0, represents the longitudinal slope of Lijin—Estuary Reach, whose unit is 0/000; Q and S, respectively represents the average discharge and the sediment concentration of Lijin Station, and L_0, represents the river length below Xihekou. The calculation value in Fq. (2) can quite well accord with the field – measured value.

Through analyzing variation features of the longitudinal profile of YR Lower Reach, it's known that, viewing from the microcosmic point, the incoming water and sediment quantity is the control factor to determine scour and silting characteristics of the Huayuankou—Lijin Reach, and the course for channel durative deposition is that its longitudinal slope can hardly reach the one required by balancing the sediment transportation. If the sediment concentration becomes higher, while the discharge becomes slower, the longitudinal slope will increase, which indicates that the deposition volume in upper stream is bigger than that in lower stream, showing itself as evident streamwise deposition form, which can make the flood prevention and deposition reduction of the Lower Reach disadvantageous.

4 The microscale feedback influence scope of estuary evolution on the Lower Reachs

4.1 Judgment on the influence scope of backward deposition and backward scouring

There are two kinds of feedback influences of estuary evolution on the lower channel, namely, the backward scouring and the backward deposition. The former develops from the lower to upper reaches, making the bed lowering extent lower bigger while upper smaller. Based on the level of

3,000 m^3/s discharge, it can find out the end – to – end section for joining the level lowering scope of lower bigger while upper smaller and that of upper bigger while lower smaller, namely, the upper bound of backward scouring. Similarly, it can confirm the upper bound of backward deposition.

4.2 The influence scope of backward scouring and backward deposition for each flow path

The upper bound of backward scouring or backward deposition during each time internal since 1953 is listed in Table 1.

Table 1 The influence scope of backward scouring or backward deposition

Flow path	Time internal	Backward scouring	Backward deposition	The Lijin Station S/Q	The diverted river length shortens (km)	The flow Path extends (km)	The influence scope	The distance apart from Yihaoba(km)
Shenxian Gully	1953.7 ~ 1955.7	√		0.018,5	11	4.5	Liujiayuan	156.6
	1961.7 ~ 1963.10		√	0.008,52		18.5	Daoxu	61.9
Diaokou River	1966.7 ~ 1969.7	√		0.016,4	22	20.3	Lijin	27.5
	1974.7 ~ 1975.10	√		0.021,2		24.1	Zhangxiaotang	72.9
The former channel of Qingshui Gully	1976.7 ~ 1979.7		√	0.030,7	37	18.7	Lijin—Yihaoba	0 ~ 28
	1979.7 ~ 1982.7	√		0.033,6		26.3	Mawan	41.5
	1982.7 ~ 1985.7	√		0.014,4		29.4	Liujiayuan	156.6
	1990.7 ~ 1993.7		√	0.052,7		35.0	Lijin	27.5
	1993.7 ~ 1995.10		√	0.050,8		38.9	Qinghezhen	99.1
Qing8chahe River	1996.7 ~ 1998.7	√		0.089,6	16	5.5	Mawan	41.5
	1998.7 ~ 2000.7		√	0.114		9	Lijin	27.5

4.3 The control factor for determining the influence scope of backward Scouring and backward deposition

Viewing from Table 1, it's known that the following factors are the ones determining the feedback influence scope of estuary evolution on lower channels: ① It is the incoming water and sand condition, which has considered the incoming sand coefficient of Lijin Station as its representative; ② It is the length of shortened river length as diversion, ΔL; and ③ It is the extension length of flow path, L_S, L_C, the space between the influence scope of backward scouring and Yihaoba, can be expressed as:

$$L_C = 1.00 \times 10^{-4} \times \left(\frac{S}{Q}\right)^{-1.75} \times (\Delta L)^{5.51} \times (L_S)^{-3.89} \tag{3}$$

L_Y, the space between the influence scope of backward deposition and Yihaoba, can be expressed as:

$$L_Y = 144.5 \times \left(\frac{S}{Q}\right)^{0.352} \times (\Delta L)^{-1.75} \times (L_S)^{1.78} \tag{4}$$

Fig. 4 shows the comparison between the calculation values of those two expressions and the field – measured values, and within each contrast, the two values are both close to each other. Viewing from those two expressions, if the incoming sediment – water coefficient of Lijin Station becomes smaller, the length of shortened river length as diversion will become longer, and the extension length of new river will become shorter, while the influence scope of backward scouring will extend; whereas, if the incoming sediment – water coefficient of Lijin Station becomes bigger, the length of shortened river length as diversion will become shorter, and the extension length of new route will become longer, while the influence scope of backward deposition will extend. The estuary length directly determines the length of shortened river length as diversion and the extension length of new route. Therefore, the estuary length is the control factor to determine the influence scope of microscale feedback.

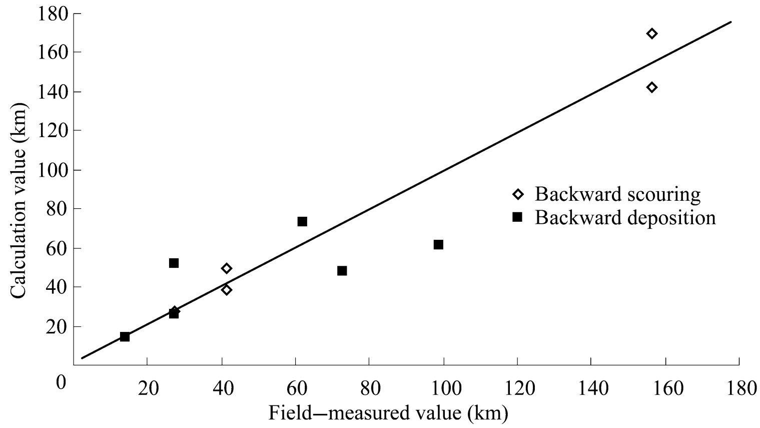


Fig. 4 The comparison between calculation value and field – measured value for the influence scope of backward scouring and backward deposition

5 Measures for mitigating the feedback influence of estuary evolution on the Lower Reachs

5.1 Summary for the feedback influence of estuary evolution on the Lower Reachs

Viewing from the macroscopical point, the feedback influence of YR estuary evolution on the Lower Reachs is the deposition and extension of estuary and the general outward movement of coastline, which produces a far – reaching influence on the lower channel, and makes the levee – breaching site continue to move upwards. Viewing from the medium point, it represents that, during the time internal from the initial point to the terminal point for one flow path, the influence of estuary datum level can spread to the alluvial reach of the whole Lower Reach, and the deposition within Lower Reaches belongs to the backward deposition. Viewing from the microcosmic point, the scour and silting process of lower channels is influenced by both the sediment – water condition and the estuary datum level, whose main mode is the streamwise one, while the secondary mode is the backward one. There exists a dialectical relationship between the feature of macroscopical, medium and microcosmic feedback influence of estuary evolution on the Lower Reach of antitheses and uniform. The channel length is the key factor to feedback influence. It ought to retain the river length as short as possible, in order to decrease the feedback influence of estuary deposition and extension on lower channels.

5.2 Measures to decrease the feedback influence of estuary evolution on the YR Lower Reachs

For retaining the river length as short as possible, it should undertake the comprehensive management on YR Upper and Lower Reaches and the estuary sink reach in aspects of incoming water and sediment, channel regulation, arranging flow path by plans, and increasing the ocean sediment – carrying capacity, etc.. ① It should take such measures for sediment reduction as the water and soil conservation construction, the construction and improvement of water – sediment regulation system, and the desilting project construction, etc. towards the YR Middle Upper Reach; ② It should take measures including the channel regulation and water diversion and diversion of sediment towards the Lower Reach; ③ The sink reach management includes measures of reasonably arranging flow path, river dredging, desilting by diverting high sediment – laden floods, and constructing double guide levees to strengthen the ocean sediment – carrying capacity etc. .

References

Qian Yiying, Ye Qingchao, Zeng Qinghua. Water and sediment variety and river bed changes of stem stream of the Yellow River[M]. Beijing: Press of the constructional materials of China, April of 1993.

Xie Jianheng. River channel changes and research of river regulation[M]. Wuhan: Press of Wuhan University, May of 2004.

Important Measures to harness the Yellow River Estuary

—The Idea of Conducting the Land Reclamation in the Yellow River Estuary

Jiang Shuguo[1], ***Liu Jinfu***[1] and ***Zhang Sheng***[2]

1. Jinan Yellow River Engineering Bureau, Jinan, 250000, China
2. Shangdong Longxinda Consultant and Supervision Limited Company, Jinan, 250032, China

Abstract: Recently, "blocking, arranging, adjusting, putting, digging" is the main way to govern the Yellow River silt. The area of the Yellow River estuary has the world's best young land. We use the water volume to maintain a healthy life of the Yellow River and plan to go on the land reclamation which will reduce the deep river estuary, extend the life of the river and transform the land. This is an important event that will benefit the contemporary era and future generations. So we should actively promote. This paper attempts to demonstrate the feasibility of soil and the alluvial effect of the river estuary through investigating the local environment.

Key words: water volume, sediment volume, alluvial silt volume, benefit, understanding

By the effect of Bohai and the Yellow River estuary area, the Yellow River estuary form many saline wetlands. Using the existing gate to transfer water, together with the transformation of the appropriate the original channel of some, of the saline wetlands (not affect the ecological environment as a precondition), warping improvements that enable improved land for the benefit of humanity, to reduce the volume of silting of the river mouth. It is helpful to improve the overall value of a healthy life of the Yellow River. According to the understanding of the situation, we propose a way to the implementation of this idea.

1 Road steady flow of the Yellow River Mouth existing necessity

The Yellow River Mouth locates in the north of ShanDong Province and the south of Bohai. As the Yellow River silted up, in the mouth, the surrounding land is intituled as a young Yellow River Delta. Yellow River Delta and the Beijing – Tianjin is the Shandong Peninsula linking the two zones in economically developed regions, is one of China's three major deltas. Yellow River Delta is vast, rich in oil, natural gas, brine and other resources, there are large areas of shallow sea waters shoals and grasslands. In particular, Shengli Oilfield has developed into China's second largest oilfield , yields about 30 million tons, according to oil field exploration, only underground water flow and access to the sea nearby oil reserves amounted to 37.06 million tons. According to the records, the Yellow River mouth near total area of 4,500 km^2 of wetlands, in which Wetland areas 1,500 km^2, 330 km^2 saline. Hekou new creation by both sides of the Yellow River is China's warm most integrated, the most extensive, the youngest wetland ecosystem. Yellow River Mouth flatness of the land is vast. Lower Yellow River is the "Golden Triangle", a great potential for exploitation. However, the development of the Yellow River and Yangtze River Delta, Pearl River Delta lags far behind compared to, the reasons are manifold. Yellow River Road, the current instability is one of the important reasons. The comprehensive development of the Yellow River Delta, especially oil exploitation and demand the Yellow River mouth must have long – term stability. Therefore, it is very necessary to accelerate the management of the river, it will not only affect the Yellow River Delta region now, but to the future, and long – term stability throughout the lower reaches of the Yellow River plays a crucial role. Various projects, such as the construction of diversion dike, water and sediment regulation, diversion warping. Life can play an extension of the existing road into the currents that flow path to achieve the goal of long – term stability. This article Warping proposed for the management of the estuary, to be explored.

2 Basic data

2.1 Basic ideas

The river is the world's most complex and the most difficult to control one of the estuary, the research and management of their practice extremely challenging. "silted up, extending toward diversion" is a certain river water and sediment conditions in the natural law, this is a basic understanding of the Yellow River management of the estuary. We believe that the project will take measures to cross the Yellow River diversion sluice saline wetland warping for the Yellow River, reduce access to the sea of mud that can extend the life of existing estuary flow path.

2.2 Statistics of the culvert sluice active

According to the survey of the situation on the spot, cross the river embankment, below Lijin (left) and Kenli (right), there are a total of seven culverts with 471 m^3/s of the total maximal design flow. Dongguan gate (left, Lijin), Stake Number: 309 + 350 embankment, design flow is 1.0 m^3/s. Wangzhuang gate (left), Stake Number: 328 + 368 embankment, design flow is 120 m^3/s. Shenxiangou gate (left), Stake Number: 18 + 112 north levee, design flow is 25 m^3/s. Xishuanghe gate (right, Kenli), Stake Number: 239 + 054 embankment, design flow is 100 m^3/s. Shibahu gate (right), Stake Number: 246 + 500 embankment, design flow is 200 m^3/s. Wuqi gate (right), South Stake Number: 3 + 000 south levee, design flow is 15 m^3/s. Kendong gate (right, Stake Number: 18 + 000 south levee, design flow is 10 m^3/s.

2.3 Statistics of the amounts of extraction water and sand into the sea in the recent river regulation

The first Regulation is from 9:00 am on July 4, 2002 to 9:00 a m on July 15. During the 11 days, 2.606 billion m^3 of the total volume of water is discharged, and in the lower watercourse the silt washed out is 36.2 million tons.

The second regulation began from 9:00 am on September 6, 2003, ended at 9:30 am on September 18, lasting 12.4 days. 2.719 billion m^3 of water and 120.7 million tons of sand entered into the sea with 45.6 million tons of river erosion downstream.

Regulation is the third time since June 19, 2004, at 8:00 a m on July 13 to end after 24 days discharged five days to remove the small flow actually lasted 19 days. Based on Lijin 4.539 billion m^3 of water flowed into the sea in conjunction with 68.59 million tons of sand, with 64.22 million tons of river erosion downstream.

According to the above three water and sediment regulation of statistics: the average annual amount of water and sand are 3.288 billion m^3 and 75.16 million tons into the sea respectively.

2.4 Statistics of average annual runoff and sediment yield during 1950 to 2005

In Lijin during 1950 to 1985, the average annual flow is 41.909,9 billion m^3 and the average annual sediment load is 1,049.5 million tons.

In Lijin during 1986 to 2005, the average annual flow is 13.185 billion m^3 with the average annual amount of 315 million tons of sediment.

3 Amount of sedimentation and estimation of investment

Yellow River Delta wetland is 4,500 km^2 (1,500 km^2 of wetland protection zone) and 330 km^2 saline. In the case without affecting the ecological environment, according to deposition 1,330 km^2, with an average height of 1.2 m silt, 2.394 billion tons of Yellow River silt are required. According to data after 1986, according to half of the amount of sediment diverted through the gates to cross Yellow River, it will be 15 years to complete the sedimentation. Land compensation by 300 yuan per mu annually and cost of a four – year development cycle, total compensation per cubic meter by 4.6 yuan, then 13.406 billion yuan have to be invested.

4 Implementation projects and benefits evaluation

Under China's current reality, it is proposed to adopt land development for Warping. By local government departments and the Yellow River Estuary Development Office component, under the Shandong provincial government and the Yellow River in Shandong Discuss dual management, classification and the establishment of warping Command, specifically responsible for attracting investment, planning, design, construction, management and command. An annual investment of 894 million yuan, then it could take 15 years to build 1,330 km^2 of land. Siltation takes a piece of a piece of development, one square kilometer development as a unit, each unit for one acceptance. Land development may be allowed for 30 years since the development of acceptance, after which the land will be returned to the local government of original owners. The land without original owner will transferred to Yellow River Estuary Development Office. If the annual income of 800 yuan per mu, or 500 yuan income, then it will take 13.4 years to recover investment, and the net income of 30 years will be 16.519 billion yuan (static value).

5 Benefit analysis

5.1 Extend the life of estuary flow path

From the Yellow River itself is concerned, if there is a reduction of 2.394 billion tons of silt deposit in the riverway and the mouth, then the deposition of the watercourse and the extension speed of river mouth could be delayed, thereby prolonging the life of the Yellow River Estuary flow path.

5.2 Reduce the siltation in the riverway

During 29 years from 1954 to 1982, the average extension of the coastline is 0.43 km. If 2.394 billion tons of silt deposits in the river mouth, according to projections from 1950 to 1986, Yellow River will extend 981 m. This could result in the gradient decrease in lower reach, which will lead to a certain degree siltation of downstream river.

5.3 Reconstruct the land in the estuary region

If some 2.394 billion tons of silt deposits on the part of wetlands and saline lands, 1,330 km^2 of land will be developed for use enormous social benefits. If the income of 500 yuan per mu, with an area of 1,330 km^2, according to terms of 15 years 15 billion yuan income will be attained. And the proceeds will be a long – term future.

5.4 Levy fee from tail water use

In order to take advantage of tail water we can layout unified flow path, and supply fresh water to agriculture, oil fields and masses. And charge in terms of national provision.

6 Siltation and reform measures

6.1 Unified planning

In the towns and districts within the scope of siltation, based on the unified understanding and the leadership, implement unified plans and handle the relations between upstream and downstream, water and drainage, and creation and production. In a scheduled primers, will take the silt, silt row after combining upstream and downstream first priority after a general principle. According to the existing channels of the need to raise a lot of the need to continue to extend the extension implemented in phases, prepared a step – by – step process.

6.2 Silt transformation methods

Silt build by a large area. As for waterlogged focus for the base, open ground and rare villages populated area the large area warping can be taken. For a siltation area of several million mu of land, it can be divided into a number of small pieces with a piece of 1,500 acres in general.

Silt build by a small patch. For closer villages along the channel sand base and the zones without concentration in sand saline and wetland areas, the approach may be taken to build a small patch of silt. Responses can be 150 mu of a piece divided.

6.3 Sediment sand combined with silt soil

Use the irrigation district as sediment drainage and use alkali depression and the wetlands on the way as sedimentation area, will – creation, reducing the silt in watercourse will kill two birds with one stone. However, this needs to achieve combination of sand and soil sedimentation. The sedimentation is planed to be above 1.2 m thick, so under normal circumstances sediment sand should dominate in the early stage. When reaching 0.9 m thick, the sedimentation of silt soil dominates, which can benefit for land development. According to the Yellow River water and sediment, the sand deposition should be carried out during June and September and in the times of water and sediment regulation. In the other time the silt soil should be performed. The sand amount in the diversion water by culvert during June and September may be up to 50 kg/m^3.

6.4 Supporting projects

According to the culvert flow in the head of the channel, supporting projects should be sound to ensure control extraction and evacuation water. Reclamation dam should achieve quality standards to ensure the safety of water storage. And drainage gutter should meet the requirements for draining alkali. Based on past experience, after silt land reform, we must continue drainage works to prevent back to base in order to develop and use them.

6.5 Technical measures

(1) Increase sediment diversion. To increase water sediment the measure of stirring sediment by machine can be used in the headworks river to increase concentration. The sediment transport

accepted by channels can be determined by experiment.

(2) Low diversion. Subsequent imports are advised to choose the low – lying areas. Not too much water into the hills than down. This uniform deposition has lesser impact on reclamation dam.

(3) High leaks. Discharging should select in the higher topography areas without more sediment being carried in the drainage or making the silt area deep gully.

(4) Multiple meatus. Due to different shapes, different level of the terrain, we should base on different conditions and adopt multi – mouth discharge with multi – mouth alternately. This can result in effective manner with silt homogenous. If inlet and discharge be fixed, some corners can not be silted well, and more grit could be deposited in the inlet, which is inconvenience for farming.

(5) Diversion. Small banks can be built in the area in terms of the topography, which may make flow oriented corners so convoluted flow, and reduce the velocity, lead to uniform deposition. On the sections of low – lying and fast flow, appropriate interception may prevent silt and sand from separating.

7 Basic understanding

7.1 Warping mature experience, tremendous social benefits

For warping in the lower reaches of the Yellow River, there is a mature experience. The implementation of warping and reconstruction land may play a marked role in reducing the silt in water curse of river mouth, which can result in tremendous overall social benefits.

7.2 The reduced sedimentation amount by feedback needs to be determined by experiment

Because the speed reduction of sedimentation may result in slowing down the extension of the mouth, the reduced sedimentation volume in the watercourse can be identified by model experiments.

7.3 The key point of keeping the healthy life of the Yellow River is Lower Lijin

Maintaining the healthy life of the Yellow River should also include the estuary harness and maintaining the water requirement for the healthy life of the Yellow River water, as well as the effective use of sediment in Lijin.

Research on Useful Life for Flow Path of Qingshui Gully at Yellow River Estuary *

Qian Yu, ***An Cuihua***, ***Wan Zhanwei*** and ***Li Qingguo***

Yellow River Engineering Consulting Co., Ltd., Zhengzhou, 450003

Abstract: This paper applies the sediment numerical model to forecast the useful life for flow path of Qingshui Gully. Calculation results are analyzed by combining those of the mathematic model applied by China Institute of Water Resources and Hydropower Research, and analyzed by applying the storage volume approximation method. We draw the conclusion that the flow path for Qingshui Gully of Yellow River Estuary can maintain its performance for about 50 years.
Key words: Yellow River (YR), flow path of Qingshui Gully, useful life for flow path, scheme

1 Introduction

Owing to large amounts of sand incoming and weak ocean dynamics of YR estuary, large quantities of sediments deposit around the outfall, forming the rapid deposition and extension for estuary. Companied with the deposition and extension at the end of sink channel, the channel erosion basis comparatively upraises, the reach gradient ratio drawing near the estuary becomes smaller, the flow debris – laden force diminishes, and the bed level rises, the channel depth thus becomes small, then this causes the debris – laden force to increase until adapting to the incoming water and sand, and there is no more any deposition in channel. During this process, the deposition – upraised bed makes the lower boundary erosion basis of abutting upper – section channels lift, and herein moves in cycles, the influence of backward deposition continues to transfer towards the Upper Reach. The lifting bed induced by backward deposition makes the homo – discharge flow level upraise without ceasing, which further aggravates the flood prevention pressure until another diversion appears.

There have been previously several researches on useful life of flow path for Qingshui Gully. From the research on "The Yellow River Flow Path Into Sea Programming Report", compiled by YREC (The Yellow River Engineering Consulting Company, Ltd.), it considers that the useful life of flow path for Qingshui Gully can last for 30 years or so when the level of 10,000 m^3/s discharge at Xihekou is 12 m, while from the research on "The Yellow River Estuary Flood Prevention Scheme Report", it considers that its useful life is about 65 years. In "Research on Prolonging the Useful Life of Flow Path for Qingshui Gully at Yellow River Estuary", written by Li – Diankui, etc., it considers that the current flow path of Qingshui Gully can still perform over 100 years under utilizing several comprehensive control engineering terms as oceanic dynamics, etc.. Recently, several terms of estuary area as sediment discharge one, channel boundary one, and sand – storage sea – area boundary one, etc., have been enormously changed, and correspondingly, the useful life of flow path for Qingshui Gully should also change a lot; therefore, it's quite necessary to make researches and discussions on the useful life of flow path for Qingshui Gully.

2 Flow Path Branch – diversion Schemes

The Branch diversion should be arranged in a planned way for employing the flow path of

* State Science Support Program Thesis: Research on the Optimized Matching Model for Sediment Space of the Yellow River; Thesis Number: 2006BAB06B03.

Qingshui Gully. The marine area of deposition for flow path of Qingshui Gully is about 62 km in width, including the area from Wuhaozhuang (in the North) to Songchunrong Gully (in the South). It studies out the local diversion for flow path of Qingshui Gully, which bases on the existing condition of flow path of Qingshui Gully, and simultaneously combines with marine area condition and possible flow path arrangements. The possible schemes are Qingbacha River, Beicha and the former channel before branch diversion occurring in 1996 (Fig. 1).

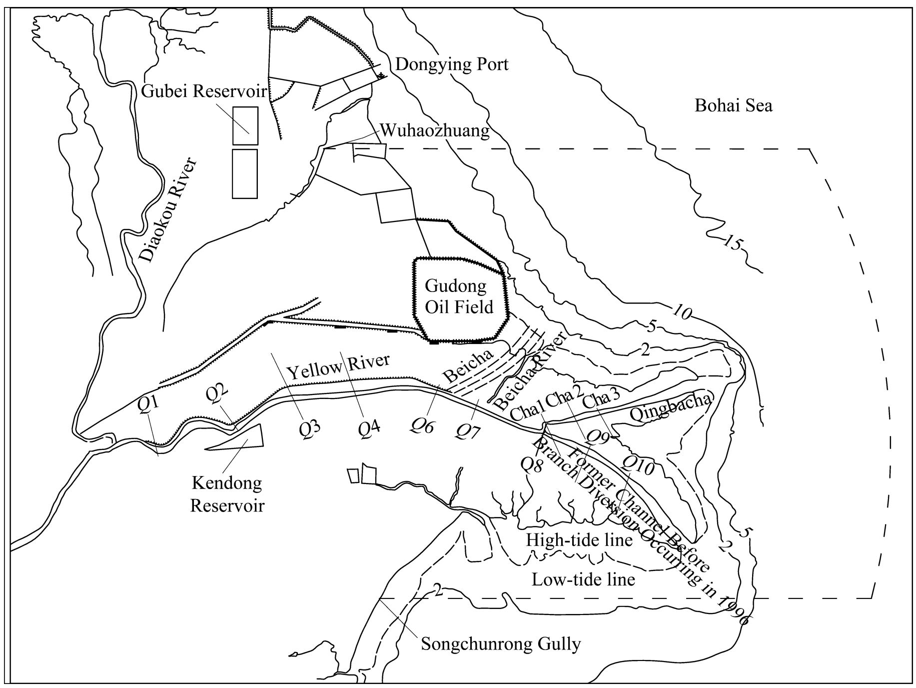


Fig. 1 The Sketch Map of Flow Path Schemes for Qingshui Gully of YR Estuary

Based on the flood control ability of estuary, it considers that the water level at Xihekou should not exceed 12 m while the discharge is 10,000 m^3/s, which means that, the diversion control condition for each river branch within this flow path can be fixed that water levels should reach or lower than 12 m while the discharge is 10,000 m^3/s at Xihekou, and the final diversion control condition is that the water level at Xihekou can reach 12 m at the 10,000 m^3/s discharge.

The establishment of diversion scheme considers the requirement of various aspects, such as the flood prevention and deposition reduction of YR lower channels, the development of local social economy, and the entironment protection, etc., and especially emphasizes on following two aspects, one is that the current flow path of Qingshui Gully should be as short as possible, whose purpose is to lower the flood level of YR lower channel as low as possible, and to make cyclic use of each channel river on confirming 65 km, the longest river length below Xihekou which once appeared at YR estuary, as the control condition of branch diversion during the process, and the other is to make the flow path comparatively stable as much as possible, which benefits the development of local society and economy together with the entironment protection, and to employ each river branch on confirming 12 m, the level of 10,000 m^3/s discharge at Xihekou , as the control condition of branch diversion. Hereby, four branch – diversion combination schemes of Qingshui Gully flow path are formulated on considering various kinds of possible situations.

(1) Current Qingbacha River (12 m) + Beicha (12 m) + Former Channel (12 m)

It keeps on employing Qingbacha River. While the water level at Xihekou reaches 12 m at the 10,000 m^3/s discharge, it will divert to Beicha, and then, it will divert to the former channel of Qingshui Gully flow path, which has been still in performance until 1996, while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and it will again divert to the spare ocean flow path while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance.

For this scheme, the time for branch diversion is the least, and its flow path is comparatively stable comparing with other schemes.

(2) Beicha (12 m) + Current Qingbacha River (12 m) + Former Channel (12 m)

Beicha has been presently employing as the ocean flow path, which had been diverted from Qingbacha River, and will divert to Qingbacha River while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and then, Qingbacha River will divert to the former channel of Qingshui Gully flow path, which has been still in performance until 1996, while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and the former channel will again divert to the spare ocean flow path while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance.

(3) Current Qingbacha River (65 km) + Beicha (12 m) + Former Channel (12 m) + Qingbacha River (12 m)

It keeps on employing Qingbacha River, which will divert to Beicha while the river length reaches 65 km below Xihekou during its performance, and then, it will divert to the former channel of Qingshui Gully flow path, which has been still in performance until 1996 while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and it will again divert to Qingbacha River while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and it will finally divert to the spare ocean flow path while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance.

For this scheme, the flow path length is rather short, while the time for branch diversion is comparatively much more.

(4) Beicha (65 km) + Qingbacha River (65 km) + Former Channel (12 m) + Beicha (12 m) + Qingbacha River (12 m)

It has presently employed Beicha as the ocean flow path, which had been diverted from Qingbacha River, and will divert to Qingbacha River while the river length reaches 65 km below Xihekou during its performance, and then, Qingbacha River will divert to the former channel while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and the former channel will again divert to Beicha while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and Beicha will once again divert to Qingbacha River while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance, and Qingbacha River will finally divert to the spare ocean flow path while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its performance.

For this scheme, the current flow path is the shortest, which can lower the flood level of YR lower channel, but the time for branch diversion is the most.

3 Sediment and Runoff Conditions

The representative serial length of sediment discharge is considered as 80 years. It considers 500 million t as the sand decreasing quantity by conducting the water and soil conservation and confirms 37 - billion m^3 as diversion volume within the diversion scheme under this sediment discharge condition. It has selected the series of 2000 ~ 2020 as the 20 - year series of 1978 ~ 1982 + 1987 ~ 1996 + 1971 ~ 1975 joining with the sediment discharge series applied within the project of Xiaolangdi Reservoir performance mode research and YR basin flood control programming, etc.. The 2020 ~ 2080 sediment discharge series adopts the 60 - year series of 1950

~1998 +1919 ~1931 consistent with phase results of YR Guxian Dam Project Proposal. The eigenvalue of sediment discharge quantity result for four stations at Longmen, Huaxian, Hejin and Zhuangtou as the representative series is in Table 1.

Table 1 Water and sediment discharges of four stations at Longmen, Huaxian, Hejin and Zhuangtou for each representative series

Representative series	water quantity (100 millions m^3)			Sediment quantity (100 millions t)		
	Flood season	Non-flood season	Whole year	Flood season	Non-flood season	Whole year
1950 ~ 1998 + 1919 ~ 1931	143.1	150.9	294.0	8.59	1.06	9.65
1978 ~ 1982 + 1987 ~ 1996 + 1971 ~ 1975	152.5	155.9	308.4	8.73	1.21	9.94
1919 ~ 1997	149.5	149.4	298.9	9.17	1.05	10.22

Based on the selected representative water and sediment discharge series, it puts forward the sediment discharge condition entering YR lower channels on considering the scouring and silting adjustment of Longtong Reach, and the adjusting calculation and sediment scouring calculation of Three Gorges and Xiaolangdi Reservoir under the above performance mode. Then, it puts forward the result of incoming sediment discharge condition at estuary district through calculating the mathematic model of lower channel. The sediment discharge series is confirmed under two circs, namely, with or without considering putting Guxian Reservoir into service in 2020. Please take references of Table 2 and Table 3.

Table 2 The water and sediment condition for entering lower channels without putting guxian reservoir into service

Station	Time Period	Water quantity (100 millions m^3)			Sediment quantity (100 millions t)			Sand concentration (kg/m^3)		
		Flood season	Non-flood season	Whole year	Flood season	Non-flood season	Whole year	Flood season	Non-flood season	Whole year
Xiao hei xiao	Former twenty years	151.19	176.72	327.91	4.00	0.01	4.02	26.5	0.1	12.2
	Latter sixty years	143.06	159.19	302.25	9.09	0.03	9.12	63.6	0.2	30.2
	Eighty Years	145.09	163.58	308.67	7.82	0.03	7.85	53.9	0.2	25.4
Ai' shan	Former twenty years	134.66	129.59	264.25	3.24	0.70	3.94	24.1	5.4	14.9
	Latter sixty years	126.39	109.94	236.33	5.73	0.76	6.49	45.4	6.9	27.5
	Eighty years	128.46	114.85	243.31	5.12	0.74	5.86	39.8	6.4	24.1
Lijin	Former twenty years	118.44	86.96	205.40	3.39	0.46	3.85	28.6	5.3	18.7
	Latter sixty years	110.78	70.36	181.14	5.36	0.43	5.79	48.4	6.2	32.0
	Eighty years	112.70	74.51	187.21	4.87	0.44	5.31	43.2	5.9	28.3

Table 3 The sediment discharge condition for entering lower channels while putting guxian reservoir into service

Station	Time Period	water quantity (100 millions m^3)			Sediment quantity (100 millions t)			Sand concentration (kg/m^3)		
		Flood season	Non – flood season	Whole year	Flood season	Non – flood season	Whole year	Flood season	Non – flood season	Whole year
Xiao hei xiao	Former twenty years	151.19	176.72	327.91	4.00	0.01	4.02	26.5	0.1	12.2
	Latter sixty years	143.94	158.12	302.06	7.18	0.06	7.24	49.9	0.3	24.0
	Eighty years	145.75	162.78	308.53	6.39	0.04	6.43	43.8	0.3	20.9
Ai' shan	Former twenty years	134.66	129.59	264.25	3.24	0.70	3.94	24.1	5.4	14.9
	Latter sixty years	126.95	109.25	236.20	5.10	0.66	5.76	40.2	6.1	24.4
	Eighty years	128.87	114.34	243.21	4.64	0.67	5.31	36.0	5.9	21.8
Lijin	Former twenty years	118.44	86.96	205.40	3.39	0.46	3.85	28.6	5.3	18.7
	Latter sixty years	110.94	70.05	180.99	4.89	0.39	5.28	44.1	5.5	29.1
	Eighty years	112.81	74.28	187.09	4.52	0.40	4.92	40.0	5.4	26.3

4 Useful life for flow path

4.1 Calculation results for sediment mathematic model

The forecast of useful life for flow path has been respectively carried out by Yellow River Engineering Consulting Company, Ltd (also called YREC for short) and China Institute of Water Resources and Hydropower Research (also called IWHR for short). YREC has adopted the quasi – two – dimensional sediment mathematic model of YR estuary for calculation, while IWHR has adopted the mathematic model of one – and – two – dimensional connection unit for calculation, and those two adopted mathematic models have both been verified by employing the actual measurement material. Model results are well consistent with the actual, so it can be employed to forecast the useful life for flow path.

The calculation has been carried out according to the above – mentioned sediment discharge series of putting or hardly putting Guxian Reservoir into service on confirming the actually measured landform in May, 2004 as the initial bed boundary condition, and on considering 20 km as the sea area sand storage width for each river branch. Calculation results are listed in Table 4, Table 5, Table 6 and Table 7.

(1) Current Qingbacha + Beicha + Former Channel (Also Called Scheme 1 for Short)

For the useful life for this flow path combination, YREC has respectively calculated it for 65 years or 60 years while considering or not considering putting Guxian Reservoir into service, with a five – year space between those two calculation results, and IWHR has respectively calculated it for 63 years or 53 years while considering or not considering putting Guxian Reservoir into service, with a ten – year space between those two calculation results. The useful life for this flow path combination can be extended due to the debris – retaining function exerting after putting Guxian Reservoir into service.

(2) Beicha + Current Qingbacha + Former Channel (Also Called Scheme 2 for Short)

For the useful life for this flow path combination, YREC has respectively calculated it for 66 years or 60 years while considering or not considering putting Guxian Reservoir into service, with a six – year space between those two calculation results, and IWHR has respectively calculated it for 64 years or 56 years while considering or not considering putting Guxian Reservoir into service, with a eight – year space between those two calculation results.

Table 4 Results of useful life for flow path, river length and water level at Xihekou ($Q = 10,000\ m^3/s$) of each scheme without putting guxian reservoir into service

Scheme	The flow path combination	The control condition	YREC Useful life for flow path: This Flow Path	YREC Useful life for flow path: Accumulated	YREC River length (km)	YREC Level (m)	IWHR Useful life for flow path: This Flow Path	IWHR Useful life for flow path: Accumulated	IWHR River length (km)	IWHR Level (m)
1	Qingbacha	12 m	32	32	81.44	12.00	32	32	75.86	12.00
	Beicha		16	48	80.13	12.00	13	45	70.05	12.00
	Formal Channel		12	60	79.51	12.02	8	53	77.12	12.00
2	Beicha	12 m	31	31	80.21	11.99	34	34	74.17	12.00
	Qingbacha		19	50	80.77	12.01	14	48	75.73	12.00
	Formal Channel		10	60	80.35	12.01	8	56	74.77	12.00
3	Qingbacha	65 km	18	18	65.12	11.23	22	22	65.43	11.41
	Beicha	12 m	19	37	80.49	12.00	15	37	73.58	12.00
	Formal Channel		10	47	80.10	12.01	7	44	77.93	12.00
	Qingbacha		18	65	80.77	11.99	16	60	76.25	12.00
4	Beicha	65 km	23	23	65.86	11.32	26	26	65.97	11.73
	Qingbacha		8	31	66.77	11.45	6	32	65.82	11.92
	Formal Channel	12 m	8	39	79.83	12.03	7	39	80.70	12.00
	Beicha		12	51	80.86	11.99	12	51	74.63	12.00
	Qingbacha		17	68	80.86	12.00	12	63	72.93	12.00

Table 5 Results of useful life for flow path, river length and water level at Xihekou ($Q = 10,000 m^3/s$) of each scheme while putting guxian reservoir into service

Scheme	The flow path combination	The control condition	YREC Useful life for flow path: This flow path	YREC Useful life for flow path: Accumulated	YREC River length (km)	YREC Level (m)	IWHR Useful life for flow path: This flow path	IWHR Useful life for flow path: Accumulated	IWHR River length (km)	IWHR Level (m)
1	Qingbacha	12 m	34	34	82.92	12.00	34	34	72.32	12.00
	Beicha		19	53	76.88	12.01	19	53	66.11	12.00
	Formal channel		12	65	82.26	11.99	10	63	77.58	12.00
2	Beicha	12 m	38	38	80.06	12.01	37	37	73.30	12.00
	Qingbacha		18	56	81.62	12.00	18	55	69.11	12.00
	Formal channel		10	66	79.54	12.00	9	64	77.69	12.00
3	Qingbacha	65 km	20	20	66.42	11.29	22	22	65.22	11.41
	Beicha	12 m	28	48	81.28	12.02	24	46	70.16	12.00
	Formal channel		12	60	79.87	11.99	13	59	78.45	12.00
	Qingbacha		13	73	83.76	12.00	9	68	69.92	12.00
4	Beicha	65 km	24	24	65.91	11.26	27	27	65.36	11.66
	Qingbacha		9	33	65.67	11.47	9	36	65.09	11.78
	Formal channel	12 m	11	44	80.60	12.00	10	46	74.50	12.00
	Beicha		17	61	83.03	12.00	17	63	76.24	12.00
	Qingbacha		18	79	82.67	12.01	14	77	72.85	12.00

Table 6 Useful life for each flow path while hardly – putting Guxian reservoir into service

Scheme	YREC Useful life for flow path (Y)				IWHR Useful life for flow path (Y)			
	Qingbacha	Beicha	Formal Channel	Σ	Qingbacha	Beicha	Formal Channel	Σ
1	32	16	12	60	32	13	8	53
2	19	31	10	60	14	34	8	56
3	36	19	10	65	38	15	7	60
4	25	35	8	68	18	38	7	63

Table 7 Useful life for each flow path on putting Guxian reservoir into service

Scheme	YREC Useful life for flow path (Y)				IWHR Useful life for flow path (Y)			
	Qingbacha	Beicha	Formal Channel	Σ	Qingbacha	Beicha	Formal channel	Σ
1	34	19	12	65	34	19	10	63
2	18	38	10	66	18	37	9	64
3	33	28	12	73	31	24	13	68
4	27	41	11	79	23	44	10	77

(3) Current Qingbacha + Beicha + Former Channel + Current Qingbacha (Also Called Scheme 3 for Short)

For the useful life for this flow path combination, YREC has respectively calculated it for 73 years or 65 years while considering or not considering the Guxian Reservoir performance, and IWHR has respectively calculated it for 68 years or 60 years while considering or not considering putting Guxian Reservoir into service, with a eight – year space between those two calculation results.

(4) Beicha + Current Qingbacha + Former Channel + Beicha + Current Qingbacha (Also Called Scheme 4 for Short)

For the useful life for this flow path combination, YREC has respectively calculated it for 79 years or 68 years while considering or not considering putting Guxian Reservoir into service, with a eleven – year space between those two calculation results, and IWHR has respectively calculated it for 77 years or 63 years while considering or not considering putting Guxian Reservoir into service, with a fourteen – year space between those two calculation results.

The results indicate that those two model results on useful life for different flow path combinations are all over 50 years. Among those four schemes, the useful life for flow path of Scheme 4 is the longest, while Scheme 1 and Scheme 2 are much shorter, and Scheme 3 is medium.

4.2 Sand storage volume approximation method

The main factor determining the useful life for flow path is the sand storage volume of sea area, while the sand storage volume of sea area is determined by the sand pile – up scope, the water depth, and the allowable prograding length of sea area.

Based on the topographic map of 1∶100,000 scale plotting surveyed by Shandong Hydrologic Water Resources Bureau of Yellow River Conservancy Commission during the period from July to October, 2000, the calculated sand storage capacity of sea area for three river branches of Qingshui Gully, totally 60 km as the width scope, is listed in Table 8 on considering 20 km as the deposition width for each river branch.

Table 8 Sea area sand storage capacity of qingshui gully flow path

Apart from Xihekou	River branch			
	Qingbacha	Beicha	Formal Channel	Totaling
65	18.45	68.42	5.93	92.80
70	33.70	86.14	17.72	137.56
75	49.00	103.77	30.94	183.71
80	64.58	121.51	43.98	230.07
85	80.16	139.64	57.02	276.82

Note: Apart from Xihekou refers to the extension coastline distance (km) ranging from Xihekou.

The terminal river length of Qingshui Gully flow path is about 80 km based on analysis, while the level at Xihekou is 12 m. On considering the scale of sediment transporting into deep sea is 20%, and the dry bulb density of sediment is 1.1 t/m^3, the sea area sand storage capacity of Qingshui Gully flow path ranging 80 km from Xihekou is 31.6 billion t. To conduct the flow path performance in term of the above – mentioned sequence of sediment discharge series, it's estimated that the useful life for flow path is about 51 years, while hardly considering putting Guxian Reservoir into service, and about 61 years, while considering putting Guxian Reservoir into service.

4.3 Comprehensive analysis

From the results calculated by several methods, there are no obvious differences for each method, the useful life for each flow path combination is all over 50 years, which can be considered as the reasonable calculation results. Results of useful life for flow path calculated by YREC and IWHR by employing the mathematic model, either for single river branch, or for flow path combination, their differences are less, all within 7 years. According to the sand storage capacity of sea area, while allowing some leeway, it's estimated that the useful life for flow path can still extend another 61 years on confirming the Guxian Reservoir performance as its condition, and it can still extend another 51 years on hardly confirming Guxian Reservoir performance as its condition, respectively.

The useful life for flow path is much longer for this programming, comparing with that of Qingshui Gully pre – estimated by employing the "Programming Report on Ocean Flow Path of the Yellow River", being accomplished in 1992, and with other flow paths in history, whose main reasons are as follows:

(1) There are few channel improvement projects within the sparsely peopled and desolated delta of YR estuary before founding the People's Republic of China, and the channel breach makes natural diversion of its flow path frequent occurring, which induces the useful life for each flow path less than 10 years. This kind of channel boundary condition no longer exists now.

(2) The useful life for flow paths of Shenxian Gully and Diaokou River after the foundation of PRC is, respectively, ten – year – and – five – month (from July, 1953 to Jan., 1964) and twelve – year – and – five – month (from Jan., 1964 to May, 1976), during which their flow paths have respectively extended 23 km and 33 km, while the corresponding level of 10,000 m^3/s discharge at Xihekou during the terminal flow path performance is about 10 m at Dagu, and their annual average sand quantities are respectively 1.202 billion t and 1.099 billion t, with the same total quantity of ocean sand as 13.2 billion t for each flow path during the period of flow path performance. Before entering the flood period in 2005, the performance period of Qingshui Gully flow path has passed 29 years, whose ocean sand quantity is about 14.6 billion t, and the average river length for three river branches at Xihekou is presently about 54 km on considering 12 m, the level of 10,000 m^3/s discharge at Xihekou, as the diversion control condition, while the river length below Xihekou can extend to 80 km, and the sea area of three river branches, totally 60 km wide (where is larger than that of Shenxian Gully or Diaokou River), can hold 23 billion m^3 sands,

about 25. 3 billion t sands. Sand quantities of the earlier 61 years on considering the Guxian Reservoir performance and the earlier 51 years on hardly putting Guxian Reservoir into service are, respectively, 31. 62 billion t and 31. 654 billion t; if 20% of each is deemed to be transported into deep sea, the sediment deposited in shoreward is 25. 3 billion t, showing that it's possible to achieve the flow path performance of Qingshui Gully over 50 years.

(3) For the average water and sand quantities for 50 years, which is forecasted to adopt by the useful life for flow path of "Programming Report on Ocean Flow Path of the Yellow River", which was accomplished in 1992, the former is 25. 66 billion t, and the latter is 0. 854 billion t, among which the average sediment quantities for the period from the first year to the tenth year, for the period from the eleventh year to the twentieth year, for the period from twenty – first year to the thirtieth year, and for the period from thirty – first year to the fortieth year, are 0. 967 billion t, 0. 981 billion t, 0. 574 billion t and 1. 056 billion t, respectively. In term of achieving the performance of flow path as current channel, Beicha 1 and Beicha 2 formulating in those days, the useful life for flow path calculated by IWHR is about 50 years, while that calculated by Shandong Yellow River Water Affair Bureau is 31 years, and that of Qingshui Gully adopted by the Report, allowing some leeway, is about 30 years. The ocean sediment quantity calculated by Shandong Yellow River Water Affair Bureau during the performance period of flow path is 26. 13 billion t, which for this programming, equals to the sediment quantity of earlier 51 years on considering the Guxian Reservoir performance, or that of the earlier 43 years on hardly considering the Guxian Reservoir performance. It also illuminates that the main cause for the useful life for flow path of this programming longer than that of the "Programming Report on Ocean Flow Path of the Yellow River", which was accomplished in 1992, appears that the sediment quantity adopted by the latter is quite large, while its results also allow much more leeway.

For reliability, achieving analysis from all aspects, the adopted useful life for flow path of Qingshui Gully (for three river branches) is about 50 years. It ought to illustrate that, only under the precondition of certain engineering projects, the flow path of Qingshui Gully can keep on its performance for another 50 years. Under the influence of natural evolution, it cannot eliminate the possibility of late – lying branch swinging, even of natural diversion, and as in history, many flow paths took place diversions before estuary channel evolves to the final stage. Before 1979, the swinging scope for channels of flow path of Qingshui Gully was large, while the beach face deposition was quite regular. Due to functions exerting by such projects as Hulin, and Shisigongli, etc., channels of the South Bank smoothly developed, though the flood period for north half part of its flow path was short, resulting in the low – lying topography of North Dike. After 1985, the main channel gradually appeared sedimentation, and due to the property of singleness and straightness for channels, the incoming water quantity for recent several years, although some flood – plains took place deposition, most of which belonged to the beach lip deposition, while less of which were beach face deposition areas, forming a quite great transverse slope. The transverse height difference of Section Qing 1 to Section Qing 7 from breach lip to bank base reaches 1. 2 ~ 2. 45 m, and their transverse slope reaches 4‰ ~ 10‰. Under such a condition, on encountering the situation of floodwater overflowing the flood plain, the river regime can suddenly change, and induce the right – angled stream in all probability, which will make the stream rush to dikes of both riversides with the risk of breaching. Therefore, In order to comparatively stabilize the flow path and have the actual flow path diverted to the spare ocean one while the level of 10,000 m^3/s discharge at Xihekou reaches 12 m, it requires to reinforce the construction of such flood prevention projects as dike and channel improvement, etc. for flow path of Qingshui Gully, and of some auxiliary engineering measures for managing the flow path, while to prevent the stream from appearing random and unnecessary branch swinging or diversion.

5 Conclusions

Under the precondition of certain engineering projects, and through certain planned artificial branch diversions, the flow path of Qingshui Gully can keep its performance for another 50 years or so. The major factor influencing the useful life for flow path of Qingshui Gully is the sand storage capacity of sea area. But we also draw the conclusion that the performance order of flow path for river branches can also influence the useful life of the whole flow path through the results of mathematic model, whose reason is that the level of 10,000 m^3/s at Xihekou has been considered as the control condition for branch diversion of flow path. When the water level at Xihekou reaches 12 m at 10,000 m^3/s discharge, the river length below Xihekou makes a difference, and then it results in the difference of sand storage volume of sea area for each scheme while further influences the useful life for flow path.

References

Xi Jiazhi, Lu Jianyi, etc.. "The Yellow River Flow Path Into Sea Programming Report" [R], Zhengzhou: The Yellow River Engineering Consulting Company, Ltd., 1989.

An Cuihua, etc.. "The Pre-feasibility Study Report on Occasion for the Yellow River Flow Path Into Sea Diverting to Beicha" [R]. Zhengzhou: The Yellow River Engineering Consulting Company, Ltd., 1996.

Li Jingzhong, etc.. "The Yellow River Estuary Flood Prevention Scheme Report" [R]. Zhengzhou: The Yellow River Engineering Consulting Company, Ltd., 2000.

Research on the River Branch Scheme of Qingshui Gully Flow Path of the Yellow River

Tang Meiying, ***Chen Xiongbo***, ***Cui Meng*** and ***Qian Yu***

The Yellow River Engineering Consulting Company, Ltd. Zhengzhou, 450003, China

Abstract: Since 1976, the flow path of Qingshui Gully at the estuary of the Yellow River (YR) has been performing for 30 years, while it has already diverted to Qingbacha River for 10 years. It considers that the useful life for flow path of Qingshui Gully will continue for another 50 – year, and suggests that the performing sequence for flow path of Qingshui Gully is as follows: Qingbacha River will divert to Beicha while flowing to the site, about 65 km below Xihekou, and Beicha will then divert to the former channel while the corresponding flow level of 10,000 m^3/s discharge at Xihekou reaches 12 m (Dagu Elevation, and the same as follows) during its flowing, and the former channel will again divert to Qingbacha River while the corresponding flow level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its flowing, and Qingbacha River will finally divert to the spare ocean flow path while the corresponding flow level of 10,000 m^3/s discharge at Xihekou reaches 12 m during its flowing, all through making researches on such aspects as the feedback influence induced by deposition within lower channels, performance cost, effects of flood control and influence on the coastal dike safety of Gudong Oil Field, etc..
Key words: the Yellow River estuary, flow path of Qingshui Gully, Qingbacha, Beicha, formal channel

1 Introduction

On May, 1976, the ocean YR estuary diverted to Qingshui Gully from Diaokou River, and the initial river length shortened 37 km after diversion. Before entering the flood period in 1996, the Qingba – branch – diversion has been actualized at the site, 950 m above the Qingba – section, and 65 km, as the former river length below Xihekou, has shortened to 49 km, whose shortened river length was 16 km, while at present Qingbacha River has still been the performing flow path. Since 1976, it has been performing for 30 years, and the river length below Xihekou has reached 60 km. It's necessary to carry through research on the river branch scheme of Qingshui Gully in order to employ the sand storage capacity of maritime space of Qingshui Gully as much as possible, and to prolong the useful life for flow path of Qingshui Gully as long as possible. There are three formulated local river branches of ocean flow path of Qingshui Gully, namely, the first is current Qingbacha River, the second is Beicha, and the final is the formal channel before diverting in 1996.

For the branch – diversion combination scheme, on mainly and simultaneously considering the flood prevention and sediment reduction of the YR Lower Reach as well as the development of local society and economy and the entironment protection requirement, it simulates two diversion conditions, namely, one is to confirm 65 km, the longest river length below Xihekou, which once appeared at YR estuary, as the control condition of branch diversion during its flowing (for short as the branch – diversion intermediate control condition, and the same as follows), and to make cyclic use of each river channel, while the other is to make the flow path relatively stable as much as possible, which benefits the development of local society and economy as well as the entironment protection, and to employ each river branch on confirming the level of 10,000m^3/s discharge at Xihekou reaching 12 m as the control condition of branch diversion (for short as the branch – diversion final control condition, and the same as follows). Hereby, it formulates four branch – diversion combination schemes of flow path for Qingshui Gully on considering various kinds of possible circs.

(1) Scheme 1: Current Qingbacha River (12 m) + Beicha (12 m) + Former Channel (12 m). Namely, It keeps on employing Qingbacha River, which will divert to Beicha while reaching the branch - diversion final control condition during its flowing, and then, it will divert to the former channel of flow path for Qingshui Gully, which has been still in performance until 1996, while reaching the branch - diversion final control condition during its flowing, and it will again divert to the spare ocean flow path while reaching the branch - diversion final control condition during its flowing.

(2) Scheme 2: Immediately Diverting to Beicha (12 m) + Current Qingbacha River (12 m) + Former Channel (12 m).

(3) Scheme 3: Current Qingbacha River (65 km) + Beicha (12 m) + Former Channel (12 m) + Qingbacha River (12 m).

(4) Scheme 4: Immediately Diverting to Beicha (65 km) + Qingbacha River (65 km) + Former Channel (12 m) + Qingbacha River(12 m).

2 Researches on Branch Diversion Schemes

2.1 The Useful Life for Flow Path

Under the same incoming water and sand condition, the useful life for flow path combinations is mainly influenced by sand storage capacity of sea area. Therefore, the successive sequence of employing the branch diversion of flow path for each scheme cannot influence much on the total useful life for flow path of Qingshui Gully. As to the useful life for the whole flow path of Qingshui Gully, it can be considered that there no differences exist among those schemes under the same incoming water and sand condition, and calculating from now on, their useful lives for flow path can all exceed 50 years.

2.2 Comparing the Feedback Influence on the Deposition of Lower Channels

2.2.1 The River Length Below Xihekou

The average river length below Xihekou of above - mentioned four schemes under the design sediment discharge condition has been listed in Fig. 1. Although there is only a little discrepancy among the terminal river length of each scheme, which is controlled by the 12 m - level at Xihekou, the late - lying river length of Scheme 1 is quite long. During recent 40 years, for years when the river length shorter than 65 km, Scheme 1 is 25 years, occupying 60% of the total performance year of flow path; that of Scheme 2 occupies 68% of the total performance year of flow path; that of Scheme 3 occupies 90%, and that of Scheme 4 occupies 78%. Therefore, viewing from the time for 80 km - long river length appearing, recent years when the river length shorter than 65 km and the average river length, Scheme 3 and Scheme 4 are the much more optimized ones.

2.2.2 Water Level at Xihekou

The late - lying mean level as 10,000 m^3/s discharge at Xihekou of above - mentioned four schemes under the design sediment discharge condition has been listed in Fig. 2. As to the time for the first 12 m - level appearing as 10,000 m^3/s discharge at Xihekou, it appears earliest in Scheme 1, and then appears in Scheme 2, while the level peak finally appears in Scheme 3, and its appearing time in Scheme 4 is 4 - year earlier than that in Scheme 3.

Viewing from the 2004 ~ 2040 period, for Scheme 3, it all long maintains a rather lower water level during the whole performing period, and its homo - discharge flow level hardly obviously heightens, and for Scheme 4, the average level is also quite low, while the highest average level appears in Scheme 1, and the secondly higher one appears in Scheme 2. The same conclusion is also expressed by the flow level calculation result of 10,000 m^3/s discharge at Lijin Section.

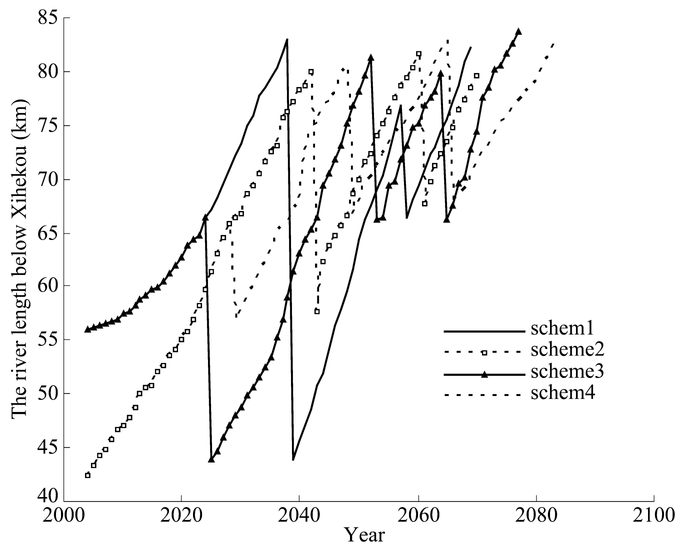


Fig. 1 The River Length Below Xihekou of Each Scheme

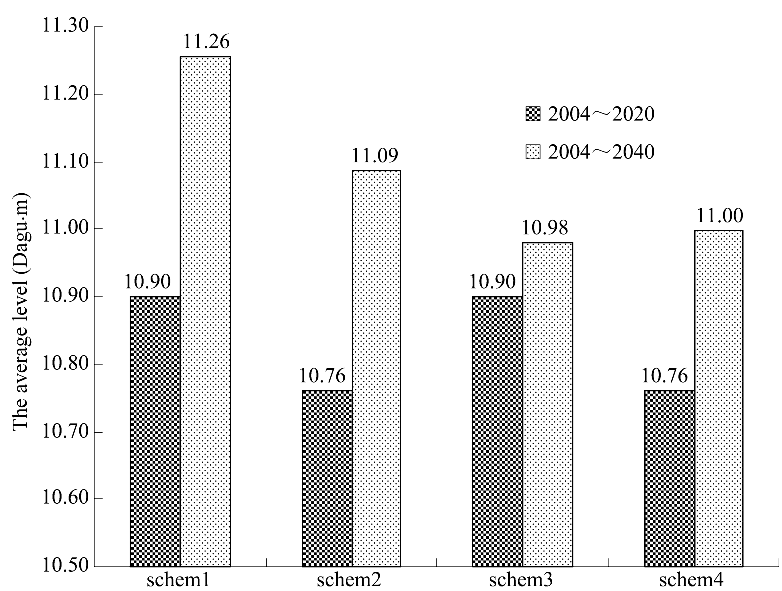


Fig. 2 The Comparison Chart of the Average Level as 1,000 m^3/s Discharge at Xihekou of Each Scheme

On considering the sharply heightening late – lying flow level and the rather higher flow level under the homo – discharge of estuary sink reach during a long period, it certainly will aggravate the flood and ice flood control burden within the estuary district. As to Scheme 3 and Scheme 4, it can maintain a comparatively lower level within the estuary district during a quite long period, and accordingly, for the flood and ice flood control, the task is quite less, and the pressure is quite small, while it can reduce the input intensity for flood control project. Therefore, as to the late – lying level – heightening difference, it's viewed that Scheme 3 and Scheme 4 are better than the other two. Especially for Scheme 3, its annual average water level is the lowest, its time for the first flow level peak appearing is the latest, and its comparatively upraising velocity is also the slowest.

2.2.3 The Lijin – Xihekou erosion and aggradation volume

The erosion and aggradation volume of above – mentioned four schemes for Lijin – Xihekou Reach has been listed in Fig. 3, and the accumulative erosion and aggradation volume of each scheme is almost the same, but during the earlier 40 years, those of Scheme 1 and Scheme 2 are rather more, while those of Scheme 3 and Scheme 4 are quite less.

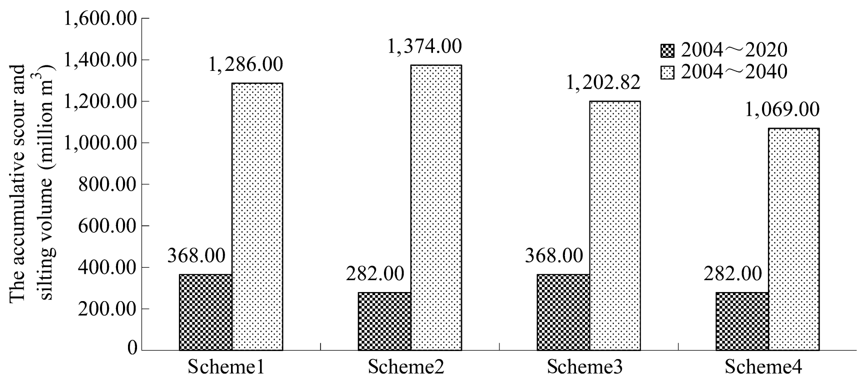


Fig. 3 The Comparison Chart of Scour and Silting Volume of Lijin – Xihekou Reach For Each Scheme

2.2.4 The Scope of Feedback Influence of Estuary Deposition and Extension on the Lower Reach

Based on the deposition characteristic, change of water level and reach scour and silting volume for each scheme, and influence scope of backward deposition for those above – mentioned four schemes, the calculation results indicate that there finally exists a little difference among the influence scope of backward deposition for each scheme, but for Scheme 3, its influence scope is quite narrow during recent 40 years.

2.2.5 The Difference of Safety Degree for Late – lying Flood Control of Estuary Reach

There has still existed a 54% deficiency in height of the fortifying levee at the YR estuary, and the left – bank levee width hasn't entirely reached the design standard at present. Under the condition of the fortifying levee construction not reaching the design standard, there also exist some differences among their flood control safety degrees due to the discrepancy of river length or water level of those four schemes. First, when the high level appears and the right – angled or oblique river occurs, for Scheme 1 and Scheme 2, as the late – lying channel length is long and the probability for high level appearing and right – angled or oblique river occurring is high, their threaten to dikes is much higher than that of Scheme 3 and Scheme 4. Second, for Scheme 1 and Scheme 2, the flooding probability of normal flood increases, and the period for flood flowing alongside dykes correspondingly prolongs, while the dyke safety degree correspondingly decreases, which indicate that, for Scheme 3 and Scheme 4, as the late – lying channel length is short, the flow level is low, and the plane reach discharge is high, while under the same late – lying sediment discharge condition, their threaten to dikes is comparatively lower, and the dyke safety degree is comparatively higher.

2.3 Comparing the Performance Cost of Flow path

It continues to employ the flow path of Qingshui Gully, while the State keeps on the flood control input both in late – lying and long – term. Under the precondition of eliminating the same input for those four schemes while not influencing the comparison conclusion of schemes, the calculation result indicates that under the condition of making the input of flood control project for those four schemes the same, the statistic – state input extent has the direct ratio relationship with the branch diversion time; as requiring several branch diversions for Scheme 4, its total investment is the most, while those for Scheme 3 and Scheme 2 are much less, and the static – state investment for Scheme 1 is the least. As the static – state investment cannot reflect value factors of time, it needs to employ the dynamic indexes for further comparison and selection during the scheme research. Due to the different arrangement for branch diversion of each scheme, among those four schemes, time for initialing the branch diversion input will be different from one another, while in addition, the implementation of branch diversion measures can greatly shorten the river length while lower the water level, making the time for initialing the flood control planning input of each scheme different, which will all reflect on the dynamic investment and annual performing cost of flow path. The calculation result has been listed in Table 1. Viewing from comparing the dynamic cost, Scheme 3 is the optimized one, while next are Scheme 1 and Scheme 4, and Scheme 2 is the worst.

Table 1 Comparing the Performance Cost of Flow Path of Each Scheme for River Branches of Flow Path of Qingshui Gully

Item	Scheme 1	Scheme 2	Scheme 3	Scheme 4
The Total Statistic – state Investment (Ten Thousand RMB)	20,078	21,727	22,013	26,507
The Total Dynamic Investment (Ten Thousand RMB)	11,329	14,754	8,899	11,901
The Annual Cost During Flow Path Performance (Ten Thousand RMB)	1,135	1,478	891	1,191
The Annual Cost During Flow Path Performance for Earlier 30 Years (Ten Thousand RMB)	368	485	286	381

2.4 Comparing the Flood Control Effect

Waterside flood control effects of those four schemes are the same, and during the construction of beach oil field, its flood control has been considered. Therefore, it only requires comparing the flood damage loss on beach farmland and property of those four schemes. Namely, which one induces the less flood damage loss, that's the one that can produce the higher flood control effect.

YR beach villages below No. 1 Dam Section mainly distribute within the left bank, involving nine villages such as Ai'lin, Xinxing, and Qianjinyi, etc., with a total population of 2,493 people (referring to the data of 2003), and a total farmland area of 261.2 thousand mu, among which there are 196.5 thousand mu at the left bank, while 64.7 thousand mu at the right bank.

It analyzes the flood control effect of each scheme by employing the frequency method, and their calculation results are listed in Table 2.

Table 2 The Comparison Table of Flood Damage Loss During Performance Period of Flow Path of Each Scheme for River Branches of Flow Path of Qingshui Gully

Item	Scheme 1	Scheme 2	Scheme 3	Scheme 4
The Annual Value of Flood Damage Loss on Property During Performance Period of Flow Path (Ten Thousand RMB)	38	34	34	33
The Annual Value of Flood Damage Loss on Farmland During Performance Period of Flow Path (Ten Thousand RMB)	1,621	1,641	1,618	1,647
The Annual Value Subtotal (Ten Thousand RMB)	1,658	1,675	1,652	1,681

Viewing from the above table, there exists a little difference among annual values of flood damage loss for flow way performance of each scheme, among which the above – mentioned annual value of Scheme 3 is the lowest.

2.5 The Difference of Late – lying Coastal Dike Security of Gudong Oil Field

The annual yield of crude oil exploited by Gudong Oil Field is 3 ~ 5 million t, bringing a vast economic benefit. The ground elevation of this oil field is mostly within 0 ~ 2 m, and around this oil field, it is protected by a 30 km – long embankment. The coastwise length of its east embankment is about 5 ~ 6 km long at present, and the surge can produce enormous threatens to the safety of this embankment section. On surge occurring, this embankment section has always been in danger, and Shengli Oil Filed annually puts about 60 million RMB to 100 million RMB as its maintaining expense on Gudong coastwise dike. After diverting to the flow path of Beicha, along with the deposition, extension and upraising of left – bank beach of the flow path of Beicha, it can gradually make the coastline apart from the embankment until to avoid the wave and surge from destroying it, which can thereby improve the embankment safety degree and make benefits of the production and construction of Gudong Oil Field. Viewing from this angle, it's better to utilizing Scheme 2, Scheme 3 and Scheme 4 of Beicha as earlier as possible, comparing with employing Scheme 1.

3 Conclusions

3.1 Flood Control and Its Feedback Influence on Lower Reach

During their performance periods of flow path for Scheme 3 and Scheme 4, the year when river length reaching 65 km (below Xihekou) appears rather late, late – lying flow level is quite low, level rising velocity is quite slow, probability of high water level and right – angled stream and oblique occurring is low, period for median flood flowing alongside the dike is rather limited, and degree to threaten the estuary dike safety is low. On comparing the quantitative flood prevention effect, for those four schemes, the flood prevention loss of plowland and property, etc., which comparatively occurs within the estuary district floodplain, is with less discrepancy, among which the loss of Scheme 3 is quite small. It can be considered that Scheme 3 and Scheme 4 are better than Scheme 1 and Scheme 2.

Due to the quite low flow level of late – lying 20 or 40 years of Scheme 3 and Scheme 4, whose late – lying scope of influence on backward deposition of Lower Reach is narrower than those of Scheme 1 and Scheme 2; though there exists a little difference among the final scope of influence on backward deposition for each scheme, and for late – lying scope of influence, that of Scheme 3 is quite narrow, which is even narrower than that of Scheme 4. Therefore, Scheme 3 is the optimized viewing from the angle of decreasing the feedback influence on lower deposition.

3.2 Influence on the Development of Oil Field

Influences of those four schemes on oil field infrastructures are with less discrepancy. For Scheme 2, Scheme 4 and Scheme 3, as their flow paths immediately divert to Beicha or divert to Beicha as soon as possible, and in this way, a large area of floodplain within Beicha sea area can be silted at the first opportunity, which can quicken the operation of oil prospecting and exploitation within this district, and moreover, the safety factor of Gudong east embankment also increases along with the uplifting of flood – plain deposition.

3.3 Influence on Local Economy

For those four schemes, their channel diversions only relate to the district below Qing – 6 section, where has become the nature reserve (area) formed by the YR fresh water and sediment supply, and been hardly relevant to population, plowland and other local economic patterns, except for founding some oil wells. Therefore, the influence of four schemes on the district below Qing – 6 section can be considered as the same, while the influence on the district above Qing – 6 section mainly embodies the flood prevention aspect.

The comprehensive research indicates that each scheme has its own advantages and disadvantages, and viewing from the overall, Scheme 3 shortens the channel ocean distance, and maintains a rather lower level under the homo – discharge of estuary reach, whose safety degree for flood control is quite high, while it can lower the flow level so as to make the ocean outfall favorable and decrease the flooding probability and reduce the potential threaten induced by natural breaching and overflowing as well as disadvantageous sediment discharge condition to the overall layout of flow path. For Scheme 3, it can maintain the quite low water level in short – term, whose feedback influence on the backward deposition induced by the Lower Reach is small, and from the quantitative angle, its late – lying engineering investment scale is quite small, and its input intensity of flood control is quite low, while its flood damage loss is also comparatively small, under the precondition of its quite high late – lying safety degree of flood control at the estuary district.

Furthermore, for its flow path diverting to Beicha as soon as possible, a large area of floodplain can be silted within Beicha sea area, which can quicken the operation of oil prospecting and exploitation of the district, and moreover, the safety factor of Gudong east embankment increases along with the uplifting of flood – plain deposition. All the above – mentioned can make benefits to the development and construction of the delta and Shengli Oil Field, as well as to improve the district economic development and the state economic construction, while cannot produce too many disadvantageous influences on the entironment inside the nature reserve. Therefore, it suggests considering Scheme 3 as the recommended one for the performance sequence of flow path of Qingshui Gully.

References

The Layout Report on Ocean Flow Path of the Yellow River[R]. Zhengzhou: Reconnaissance, Planning, Design&Reaearch Institute. Yellow River Conservancy Commission. Ministry of Water Resources, 1989.

The Layout Report on Occasion for Ocean Flow Path of the Yellow River Diverting to Beicha[R]. Zhengzhou: Reconnaissance, Planning, Design&Reaearch Institute. Yellow River Conservancy Commission. Ministry of Water Resources, 1997.

Discussion on the Measures of Stabilizing Estuary and Integrated Development of the Yellow River Delta

Xu Hongzeng, ***Liu Wenbin***, ***Li Jianlai***, ***Lu Shuhui***, and ***Chen Shengjian***

Research Institute of the Yellow River Estuary, Donyying, 257091

Abstract: Through the analysis of the coastal current in the Yellow River estuary maritime space, combined with utilizing oceanic dynamics for sediment transportation tostabilize river channel of estuary, and put forward the measures and suggestions to maintain the healthy life of the Yellow River, protect the estuarial and marine ecology, achieve holistic and harmonious development and the balance between the mankind and the nature in the Yellow River Delta area.

Key words: oceanic dynamics, sediment transport, course, ecology, environment

1 Introduction

Bohai Sea is an epicontinental sea with the trumpet – shaped figure approximately in the southwest, covering the total area of 77,000 km^2, the mean depth of 18 m. It is wide in south direction and narrow in north direction, NE – SW length is about 550km. Bohai Sea channel width is approximately 100 km. The Yellow River is the second longest river in China, and the longest river flowing into Bohai Sea. It is famous in the world for it's the amount of sediment and the frequent flood disaster. The annual average sediment concentratior reaches as high as 25.2 kg/m^3, which is the highest in all rivers of the world.

The oceanic dynamic of the Bohai Sea is huge to the transportation of the Yellow River sediment. The oceanic dynamic includes tidal flow, wind current, wave, rushing stream, and circulatory flow etc. Their effects are important to the transport of the Yellow River sediment. Tidal flow is the seawater's regular nonstop movement in the sea. Usually, the tidal flow amounts to 90% of the Bohai Sea ocean current. The oceanic dynamic in the Bohai Sea almost is the tidal flow. The tidal flow is the dominating and nonstop force to transport the sediment.

2 Situation of the Yellow River mouth and inshore area

In 1976, the Yellow River mouth changed to Qingshui channel from Tiaokou channel, which was located at Bohai Sea's north – west. Up to May 1996, the water discharge was 507.5 billion m^3, the sediment discharge was 13.4 billion tons in the paet 21 years. The great deal sediment went into the estuary to expand the delta. The mouth slit continuously stretches into the sea. The geomorphology changed greatly on the coast and the subaqueous delta. The bay of 100 km^2 in the mouth had disappeared, and became a 30 km long did mouth into the sea, a new delta had formed. The control and guide engineering not reach the intensity planned, and the little water discharge from the Yellow River, the ability of transporting flood was weak. As the demand of the oil extraction on the shallow sea, the distributary was changed at the Q8 profile in the July 1976. The direction of the new distributary was from 113° to 83°, and the angle with the former is 29°30′. The mouth of the new distributary had extended 8.5 km to the sea from 1976 to the end of 2004.

There are 4 strong tidal flow regions and 2 weak tidal regions in the Bohai Sea (Fig 1). The strongest region Locate at the north of the Laotieshan Channel. The largest velocity is over 6 sea miles per hour. The second region locate at the front of the last mouth, and the largest velocity is over 4 sea miles per hour. The third locate at the Dengzhou Channel, over 3.5 sea miles per hour. The fourth is near the amphidromic point of M2 tide and the north of the Bohai Bay, 2.5 sea miles per hour. There are two weak tidal flow region. One locate at the top of the Laizhou Bay, the other loeate at the southeast direction of the Qinhuangdao, and the second amphidromic point of M2 tidelie here. The largest velocity in the two regions is about 1 sea mile per hour. The sea force in the new mouth is weaker than that in the former mouth. The velocity is below 1 sea mile per hour.

The effect of the sediment transportation by the tidal flow is represented on the back and forth movement of tidal flow and the movemont of the strong tidal region. In the region of the former mouth, the duration of the flood and the ebb current are long, it is about 4 ~ 5 hours. The time is short and the velocity is small from the flood cument to the ebbcarrent and the tidal flow moves back and forth. In a tidal period, the speed of the flood and the ebb current can reach 2 sea miles per hour. The current moves back and forth in 20 km range.

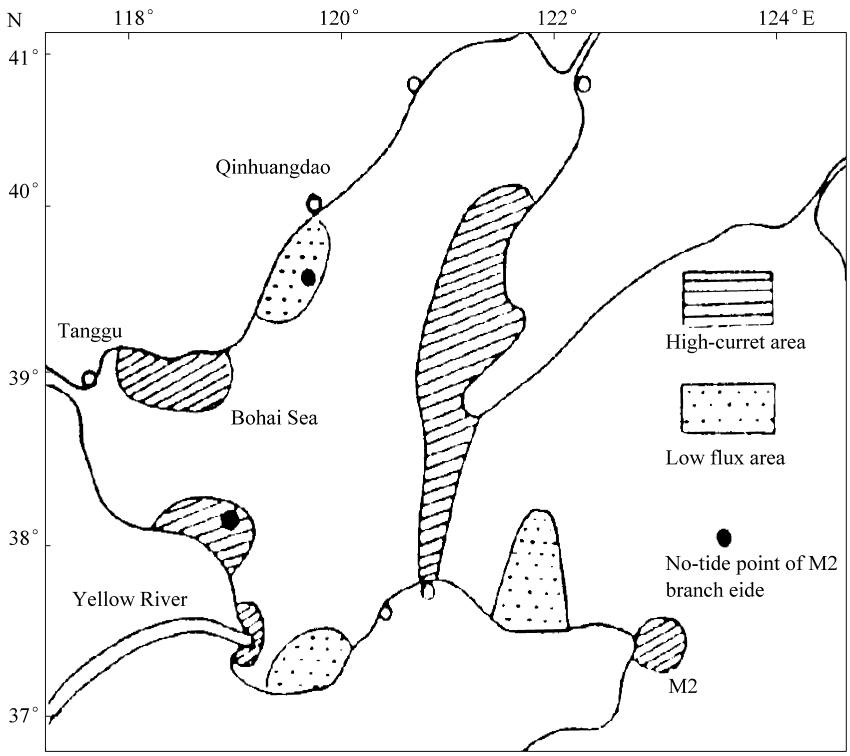


Fig. 1 Bohai Sea Tide Figure

There is a strong tidal flow region near the Yellow River mouth. The region is narrow, extend from NW to SE, the same with the depth isobath, divided by the isobath of 2.2 sea miles per hour. The center of the region is situated near the 10m isobath. The region has two high velocity centers: one is in the last mouth; the other is in the mouth of the Shenxiangou. The formation of the strong current region is related with the mouth bar and its extension to the sea. When the mouth extends to the sea, it can strengthen the tidal current. The strong current can transport more and bigger sediment to the both sides of the mouth. The current is the main oceanic force to obstruct the growth of the mouth and to extend the time of the usage of the Qingshuigou channel.

3 Deposition and erosion of delta coast

From 1970s, the sediment transporting into the sea decreases sharply. The most coasts are eroded except the protruding mouth spit extending to the sea. According to the analysis of the Landsat digital images, the Q8 distributary mouth extends 5 km from Sep 2000 to Sep 2004, the other regions are eroded back. The Shengli Oil Company has more than ten oil fields: the Gudong, the Wuhaozhuang, the Zhuanggu46, the Zhuang106, the Shallow Sea out the Sea wall, the Feiyan Beach, the Hero Beach, and the New Beach etc. Their coasts are eroded back. The hidden troubles usually happen. The sea walls are dangerous with "the deep water near the bank, the bases are weak", the Feiyan Beach oil field will become the oil field in the sea. With the coast erosion, the tidal channels beside the road become deeper in the oil field. Most roads are damaged by the tidal current. The workers security decreases, the investment to service the sea wall increases, the oil extraction cost grows from land extraction to sea extraction. The government and the Shengli Oil Company spend a lot of money on the sea dike construction to slow the coast erosion. Even worse is that the sediment into the sea decrease rapidly in recent years. This results in the deterioration of the ecology and environment. Annual 25 km^2 land deposited is disappeared. Compared with 1970s, the wetland shrinks a half, fish species decrease 40% and the birds decrease 30%.

4 Suggestions

(1) According to the tidal flow distribution near the Yellow River mouth, the strong tidal flow in the former mouth, the suggestion is that the channel should shift to the former mouth when the situation come up to the demand of the oil extraction from the sea to the land, or the sediment deposit too much in the new mouth. We have to use the successful experience on the Mississippi estuary harnessing. The control flow project must be build under the Q7 profile in order to restrict the flow to the strong flow region. The sediment will be transported by the strong tidal flow. The channel will last for long time.

(2) Started from 2002, the Yellow River carried out the regulation of water and sediment on the opportunity of regulation of water and sediment every year we Should hold and the flood season, carreis on the perturbation in the Yellow River estuary gate and the sandbar place, scour the discharge of silt using the dredge boat. Aas a resmlt the river mouth is unimpeded and the goal of stabilizing flow route will be achieved.

(3) Through the survey on the spot and theory calculation, the scientists find out the critical balance for the coastal deposition and the erosion is 0.3 billion tons sediments and 12 billion m^3 runoff peryear in the delat. In order to stop the coast and land erosion, improve the disadvantage of the oil extraction and the environment, we must do the research on the balance to the deposit and erosion, enhance regulation capacity for runoff in the Yellow River, and maintain the balance of the deposit and erosion.

(4) In order to maintain the Yellow River health, be harmonious with Nature, we must insist on the water regulation to ensure no drying-up in the lower Yellow River. The ecology in the Yellow River delta is improved distinctly, especially in the national nature reserve. The wetland is protected efficiently, and some new wetland is rehabilitated. And the delta become the important "transfer station" for the migrant in N – E Asia and round the west Pacific Ocean. Recently, some rare kinds of birds come here. There are 1,921 kinds wildlife in the nature reserve, more than 50 species are listed in the first and the second grade of national protection catalogue, like red – crowned Crane, Songjiang weever, wild soybean.

But the 50 m^3/s runoff at the Lijin hydrological station can not guarantee no drying-up in the lower Yellow River. Along the 100 km river bed below the Lijin station, there exits 13 big or medium scale culvert and pumping stations. In the peak period of water using, it is difficult for water flowing into the sea.

(5) The stability of the channel into the sea is the base for the management to the distributary and the development of the economy in the Delta. But the aim of the management is not only the stability. With the society development, there is a higher need to the management to the Yellow River Delta. In the precondition of the stability the channel to the sea, the Yellow River must suit to the development of the agriculture and the industry, the usage of the water resource, the circulation of the ecology in the national nature reserve in the Delta, maintaining the health of the Delta and the ecology of the Bohai Sea, which is the new situation. So, how to confirm the management scheme for

the channel in the new situation is the topic on integrated development of the economy, society and nature.

5 Conclusions

Bcause of many disasters of the Yellow River, the management of the Yellow River estuary is an important entorprise. That benefits the nation and the people. But high sediment concentrations in the Yellow River, its management in the estuary is much more complicated than that in other big rivers' estuaries in the world. Therefore, Strengthening the research and management of the Yellow River estuary, stabilizing the distributary into the sea, promoting overall economic development in the Delta, maintaining the healing life of the Yellow River and bringing benefit to human and nature, will be the common topic that the water conservancy field pay attention to.

References

Li Diankui, etc. Research on extending service of the Qingshuigou channel of the Yellow River estuary[M]. Zhengzhou: Yellow River Conservancy Press, 2002.

Cheng Yiji, etc. Analysis on coastal current near the new mouth of the Yellow River estuary[J]. Coastal Psojects, 2000,(4).

The Change Analyses of Seabed – clay Eroding – silting in the Yellow River Estuary after Flowing by Qingshuigou Course Since 1996

Yang Xiaoyang[1] , ***Guo Huimin***[1] , ***Huang Jianjie***[2] and ***He Min***[1]

1 Yellow River Estuary Research Institute, YRCC, Dongying, Shandong 257091
2 Investigation & Study Department of Dongying Municipal Government, Dongying, Shandong 257091

Abstract: It has been ten years since the Yellow River changed its riverway from Diaokou Course to Qingshuigou Course in 1996. At Q – 8 estuary, seabed landform has been remodeled largely as a result of seabed – sediment which come from the Yellow River depositing and fusing continuously. By dint of the analyses of the softwares (for example AutoCad, Surfer, etc.), the range of sediment depositing and the status of sediment eroding – depositing in different sections have been obtained.
Key words: seabed – sediment, section, surfer, eroding – depositing

1 Forward

The Yellow River Delta lies between the southern of Bohai Bay and the western of Laizhou Bay in 117°31′ ~ 119°18′E and 36°55′ ~ 38°16′N. It mostly locates the site of Dongying City and Binzhou City in Shandong Province. It is piled up neoteric delta and present – day delta composite. Neoteric delta shape its sector figure, its vertex is Ninghai, the west line is Taoer estuary and south line is branch estuary, since the Yellow River burst its banks from Tongwaxiang and flowed into Daqing River in 1855. Its land area is 6,000 km^2. The present delta shape its sector figure, its vertex is Yuwa, the west line is Tiaohe estuary and south line is Songchunrong estuary, since 1947 and now it continues. Its land area is about 2,400 km^2. The Yellow River is a high sediment concentration river, its clay content, average perennial from 1950 to 2004, 8×10^8 t. As a result, a mass of sediment lays deposit in the estuary. The sediment deposition leads the riverway of estuary extending, swing, and changing its riverway highly frequenly. Since flowing into Daqing River at 1855, it has been changed 10 times by human or naturally.

2 The water – sediment conditions after the Yellow River changed its riverway to Q – 8 Course in 1996

Since 1996, the water – sediment become imbalance. In 1996, the 96 – 8 floodwater result in the watery content is equal to average value. But since 1996, the water – sediment content reduced continually. At 1997, the water – sediment content was the lowest. At Lijin station, the river had dried for 226 days. At T – shaped station is 282 days. In non – flood season, the water amount was 2.5×10^8 m^3, the sediment content was 0.06×10^8 t at Lijin station. And at same station, the water amount was 16.3×10^8 m^3, the sediment content was 0.08×10^8 t in flood season. The data above is record – holder about the Yellow River. At 1999, the Yellow River Administer Committee practiced adjusting the water content in regional. The Yellow River has not dried for at Lijin station anymore, but the water – sediment content has been diminished. And annual water – sediment distributes asymmetrically. The sediment in river is assembled at 1 ~ 2 floods, from August to September in flood season.

Table 1 The water – sediment conditions in 1996 ~ 2004, Lijin station

period of time(Year)	runoff ($1\times10^{8}m^{3}$)	runoff/ average in several year s(%)	sediment load ($1\times10^{8}t$)	sediment load/ average in several year s(%)
1996	158.8	49.30	4.37	55.05
1997	18.8	5.84	0.14	1.76
1998	107.3	33.31	3.81	47.99
1999	66.0	20.49	1.89	23.81
2000	49.1	15.24	0.25	3.15
2001	46.3	14.37	0.20	2.52
2002	41.7	12.95	0.60	7.56
2003	191.3	59.39	3.81	47.99
2004	198.26	61.55	2.701	34.03
average	139.48	43.30	3.37	42.49

3 The new surface's change of seabed – sediment eroding – depositing after flowing from Qing – 8

3.1 Analysis measure

Collect undersea – depth data which measured since 1996(this year the Yellow River flowed into Qing – 8) , the data of 1996, 2002, 2003, 2004 were obtained. Because lacking of the data of 1996, the researching adopted undersea – depth data of 1993 as background data. Handling Excel, Surfer 8, etc calculator software, dealing with metrical data, to contrast and to analyze undersurface clay eroding – depositing status in the Yellow River Delta(annual topography of undersurface the Yellow River Delta in Fig. 2. Undersurface eroding – depositing status in Fig. 3).

To analyze eroding – depositing, making 2 years' grd data which had be transacted subtract each other, the eroding – silting state was acquired. We contrasted the data between 1993 ~ 1996, 1996 ~ 2002, 2002 ~ 2003, 2003 ~ 2004, and involved section CS14 ~ CS33. The result from detailed calculating is as follows:

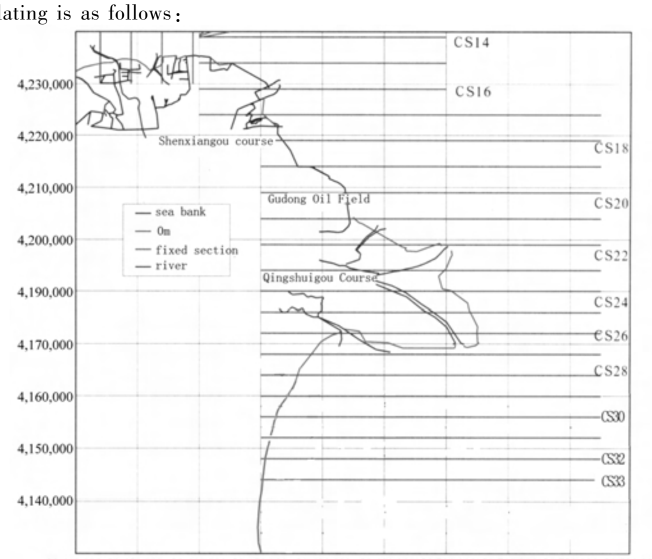
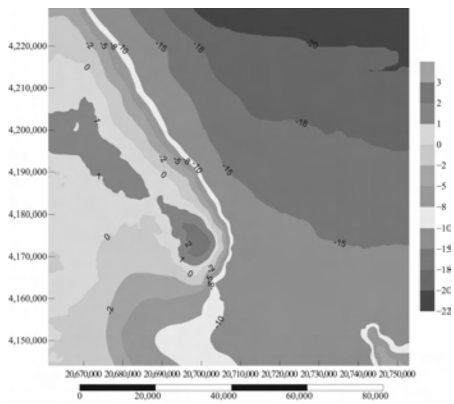
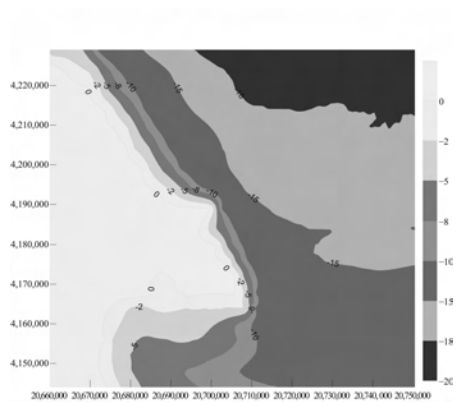


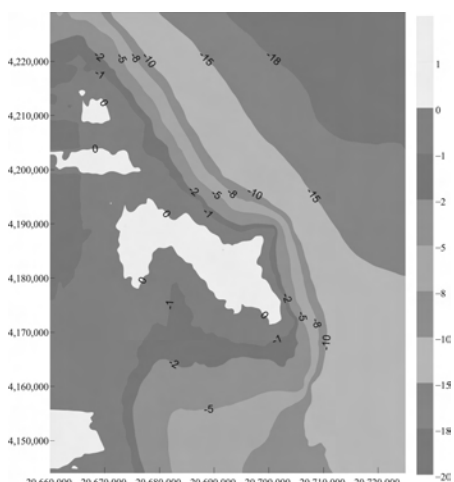
Fig. 1 Section location round Qingshuigou Course maritime space



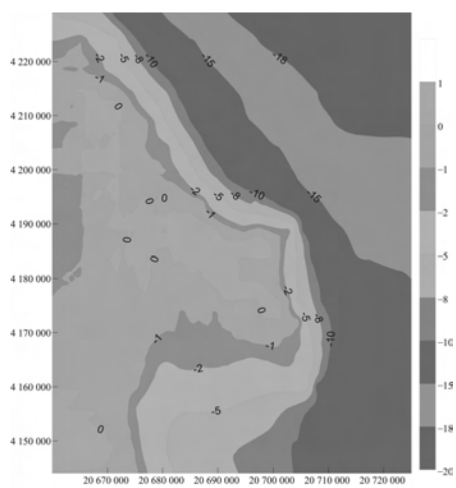
The undersurface topography in 1993



The undersurface topography in 1996

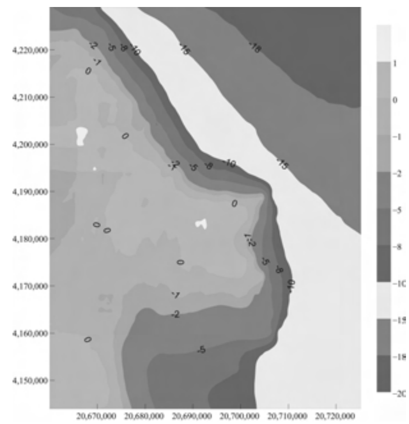


The undersurface topography in 2002



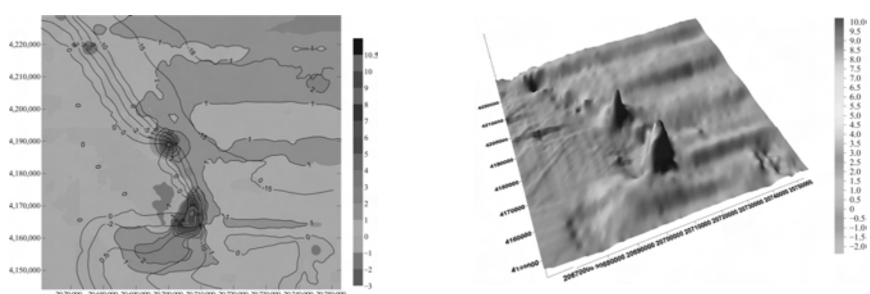
The undersurface topography in 2003

Fig. 2 The undersurface topography 1993 ~ 2004 (1993 , 1996 , 2002 , 2003 , 2004)

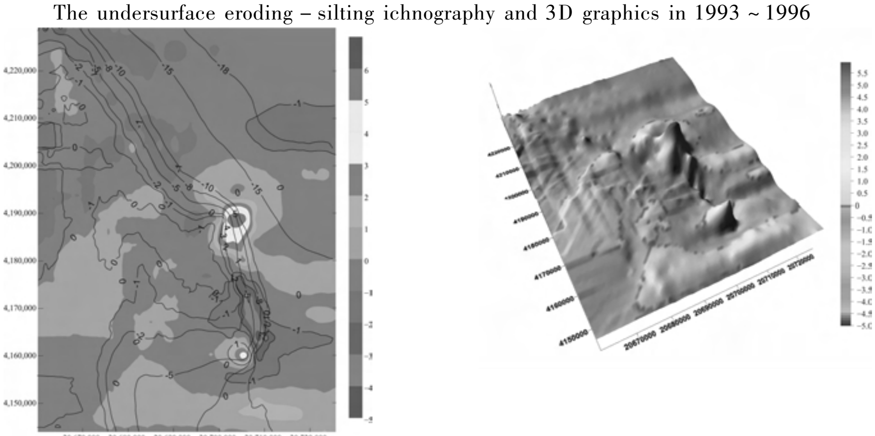


The undersurface topography in 2004

Continued to Fig. 2

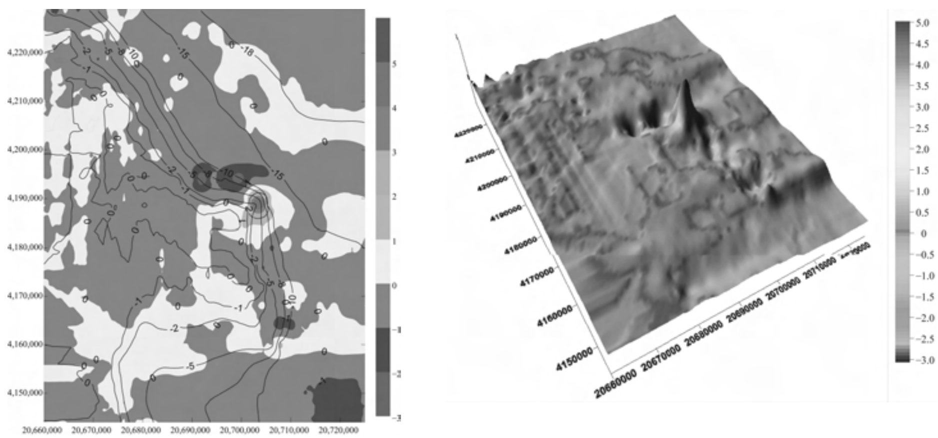


The undersurface eroding – silting ichnography and 3D graphics in 1993 ~ 1996

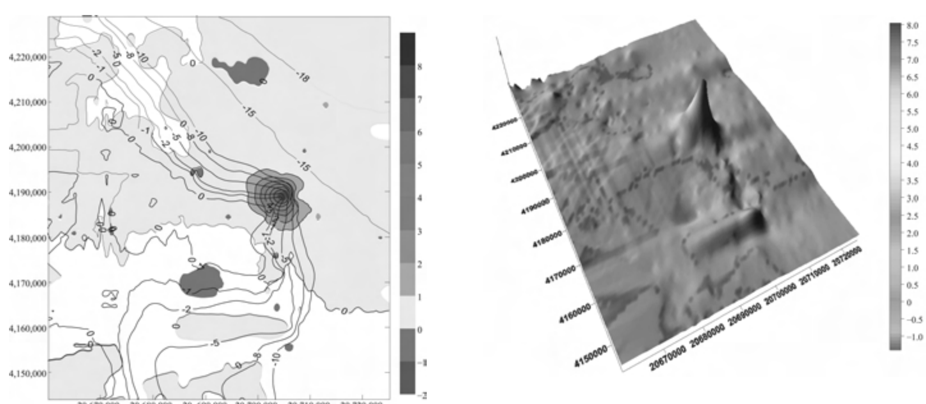


The undersurface eroding – silting ichnography and 3D graphics in 1996 ~ 2002

Fig. 3　The undersurface eroding – depositing ichnography and 3D graphics



The undersurface eroding – depositing ichnography and 3D graphics in 2002 ~ 2003



The undersurface eroding – depositing ichnography and 3D graphics in 2003 ~ 2004

Continued to Fig. 3

3.2 The undersurface delta character during different period in Qing – 8 Course

The new estuary began to extend into sea Since it changed its waterway to Q – 8 Course in 1996 (In Fig. 2) , at the same time, the old estuary began to be eroded because of the decrease supplying of clay. The contour – lines of the new estuary are specially denseness from 2 m to 10 m, but since 10 m, the contour – lines relatively exiguous, and extrusion is not evidence. It shows undersurface landform grade is precipitous where depth between 2 m to 10 m , and is grading where depth over 10 m.

3.3 Analyses the change of seabed – sediment eroding – depositing at undersurface delta in different years

Using the 5 years data(1993、1996、2002、2003、2004) , to calculate adjacent period seabed – clay eroding – silting, distributing status pictures were achieved, 1993 ~ 1996, 1996 ~ 2002, 2002 ~ 2003, 2003 ~ 2004. The results are listed in the Table. 2.

3.3.1 Analyses of seabed – sediment eroding – depositing at undersurface delta 1993 ~ 1996

Comparing with 1993, at new estuary clay silted. Silting capacity is 21.8×10^8 t, the average silting – thickness is 0.234 m, the max silting – thickness is 10.21 m, it appeared in the old estuary. At the both sides of the new estuary, clay eroded lightly. The eroding capacity is 4.42×10^8 t, the max eroding locates at CS16 section, the thickness is 2.38 m.

Table 2 The seabed – sediment eroding – depositing result at new estuary of Qingshuigou at undersurface delta in different years

period of time	1993 ~ 1996	1996 ~ 2002	2002 ~ 2003	2003 ~ 2004
silting capacity($\times10^8$t)	21.8	2.15	0.52	2.23
eroding capacity($\times10^8$t)	4.42	4.94	0.77	0.18
eroding – silting capacity($\times10^8$t)	17.38	–2.79	–0.25	2.05
eroding – silting thickness(m)	0.234	–0.395	–0.148	0.143
The max silting – thickness (m)	10.21	5.95	5.02	8.04
The max silting – thickness (m)	–2.38	–5.02	–3.07	–1.40

Note: The eroding—silting region is calculated when the eroding—silting thickness over 1 m.

3.3.2 Analyses of the change of seabed – sediment eroding – depositing at undersurface delta 1996 ~ 2002

Comparing with 1996, the total instance in the research sea area is eroding, the eroding – silting capacity is -2.79×10^8 t, silting capacity is 2.15×10^8 t, the max silting – thickness is 5.95 m, it appeared at the new estuary, And in the southern of the old estuary, the silting – thickness is over 3 m. The eroding capacity is 4.94×10^8 t, is larger than silting capacity. the max eroding – thickness is 5.02 m. at this period, the character of eroding – silting is all area took place eroding but at new estuary and the southward of the old estuary. The silting part which thickness over 2 m presents south – north ellipse.

3.3.3 Analyses of the change of seabed – sediment eroding – depositng at undersurface delta 2002 ~ 2003

Comparing with 2002, the research sea area is eroding, the eroding – silting capacity is -0.25×10^8 t, and the average eroding – thickness is – 0.148 m. and the silting capacity is 0.52×10^8 t the max silting – thickness is 5.02 m. The eroding capacity is 0.77×10^8 t, the max eroding – thickness is 3.07 m. the eroding – silting character is ,all area was in balance basically, but silting at the new estuary. It took place eroding seriously at the north of the new estuary, and it is the max eroding – thickness (– 3.07 m). The area of the eroding – thickness over – 1 m is 37.37 km^2, in the front of the new estuary, which take on south – north ellipse.

3.3.4 Analyses of seabed – sediment eroding – depositing at undersurface delta 2003 ~ 2004

Comparing with 2003, the total instance in the research sea area is silting, the silting capacity is 2.23×10^8 t, and the average thickness is 0.143 m, the max silting – thickness is 8.04 m. the eroding capacity is 0.18×10^8 t. the max eroding – thickness is 1.40 m. At this period, the character of eroding – silting is all area took place silting but at the northward of the new estuary and the southward of old estuary. And at the new estuary, it appeared silting seriously, the silting – thickness is over 8 m.

4 Conclusions

In conclusion, from the Yellow River flowed in Qing8 course from 1996 to 2004, in 8 years, the characters of eroding – depositing are:

The old estuary was eroded because of the reducing supply of sediment. After flowed Qing8 course, The new mouth depositing and extending, show itself with ellipse, which long axis is less than 15 km, and the short one less than 10 km. And it shows the sediment deposition one – off distributing character. In the new estuary depositing is severity, and in the old estuary eroding is severity. In the other area, the eroding – deposting thickness is less than 1 m.

References

Yellow River Estuary Administer Bureau. Yellow River in Dongying[M]. Jinan: Qilu Publishing Company, 1995.

Li Diankui, Yang Yuzhen, Cheng Yiji, etc. The research of extending Qingshuigou course period [M]. Yellow River Conservancy Press, 2002.

Cheng Yiji, Yang Xiaoyang. The observation and research of the shore – eroding in Yellow River Delta and Currently Estuary[R]. 2003.

Cheng Yiji, Yang Xiaoyang. The research of the contain – clay area in Yellow River Estuary, 2006.

Analysis of Deposition and Elongation of Estuary Channel Since Water and Sediment Regulation of Xiaolangdi Reservoir

You Baohong, ***Guo Huimin*** and ***Lu Shuhui***

Institute of Yellow River Estuary Research, Dongying 257091, China

Abstract: According to analysis of estuary deposition and erosion recently, the estuary channel has been eroded, water lever of the same discharge decreased since water and Sediment regulation. But the erosion of the channel below Qing 6 section is unobvious. There are also some problems, tor example, silt transport power is insufficient, erosion and elongation rate is too fast, river position changes greatly. So the authour put forward some recommendations such as enforcing river dredging, carrying out Sediment roiling together with water and sediment regulation, perfecting river training works as soon as possible etc..
Key words: water and sediment regulation, deposition and elongation, Yellow River estuary

Since 1986, because rainfall in Yellow Rive basin kept little, and water diversion in winter and spring increased obviously due to blooming of industry, agriculture and population, the water amount reaching the lower reach decreased greatly, zero – flow happened frequently, so the main channel shrank seriously, overland discharge decreased obviously, flood preventing capacity is too small. In 1999, YRCC carried out uniform water regulation, receiving capacity of the main channel increased obviously, social, economic and ecological benefit was obvious.

1 Water and silt conditions of the estuary since water and Sediment regulation

Statistically, since river channel was changed to Qingshuigou (1976 ~ 2005) average runoff of Lijin hydrological station is 20.759 billion m^3, sediment load is 494 million t, and sediment concentration is 23.78 kg/ m^3. In past 20 years (1986 ~ 2005) the average runoff of Lijin station is 14.219 billion m^3, sediment load is 325 million t, which is 31.5% and 34.2% less than the average of years respectively. Though average runoff and sediment load of the past 20 years in Lijin station decrease, the sediment coefficient changes greatly from the average of years (0.036,1 kg · s/m^6) to the average of 1986 ~ 2005 (0.050,7 kg · s/m^6), so the collocation of water and silt is worse. The number of days when average discharge is larger than 2,000 m^3/s decreases obviously from 29.2 d/a of years series to 14.7 d/a of 1986 ~ 2005 series. From 2002 to 2005, Xiaolangdi reservoir was carried out water and sediment regulation, average runoff of Lijin Station is 16.005 billion m^3, average sediment load is 218 million t, which are 22.9% and 55.9% less than that of years respectively. Average runoff is large than that of 1986 ~ 2005, but sediment decrease obviously, collocation of water and silt is better, and sediment decrease to 0.026,9 kg · s/m^6. Lasting time of medium discharge increase, the number of days when average discharge is larger than 2,000 m^3/s is 28.8 d, which is close to that of long series. The water and silt character of Lijin station since water and silt regulation is shown in Table 1.

Table 1 Water and silt character of Lijin station 2002 ~ 2006

year	runoff (10^8 m^3)	sediment load (10^8t)	average sediment concentration (kg/m^3)	Maximal discharge (m^3/s)	The number of days when the average discharge is larger than 2,000 m^3/s
2002	41.89	0.54	12.97	2,500	9
2003	192.72	3.70	19.19	2,740	52
2004	198.81	2.58	12.96	2,940	25
2005	206.76	1.94	9.24	3,090	29
The avorage	160.05	2.18	13.62	—	28.8

2 Analysis of estuary erosion, deposition and evolvement

2.1 River channel erosion and deposition

The erosion and deposition of the Yellow River estuary channels is affected by various factors, such as water and silt amount of the river basin, estuary evolvement, oceanic dynamics, human activities, and their interaction form erosion and deposition of streamwise or trace to source in estuary and river channels above it. Fig. 1 shows the erosion and deposition of Lijin to Qing 7 section since the utilization of Xiaolangdi reservoir. On October 1999, Xiaolangdi reservoir began storing water, the estuary channel kept eroded since 2000. Statistically, from 2000 to 2004, the river channel from Lijin to Qing 7 was eroded 44.37 million m^3, of which the main channel was eroded 37.88 million m^3, accounting for 85.3%. So main erosion happened in the main channel, which is advantageous for reducing water level of same discharge and increasing flow receiving capacity. Shown in the erosion and deposition of different reaches, river channel from Lijin to 7 section was eroded 27.22 million m^3, erosion intensity was 589 thousand m^3/km, and intensity of the reach near the estuary was larger than that of the reach far from the estuary, which presented the character of streamwise erosion. Shown in the erosion and deposition process of different reaches year by year, the estuary channel presents the character of erosion in flood season and deposition in non – flood season. Though the peak flood discharge in 2000 and 2001 flood season were not too large, only 950 m^3/s, the coming water were also clear, sediment concentration was only about 5 kg/m^3, and 3,496 thousand m^3 silt was dredged from Yihe to Zhujiawuzi in 2001 non – flood season. Since 2002, water and silt regulation has been continuously conducted, medium discharge lasted long, sediment concentration was low, water and silt condition was good, and so the river channel lower than Lijin was eroded continuously.

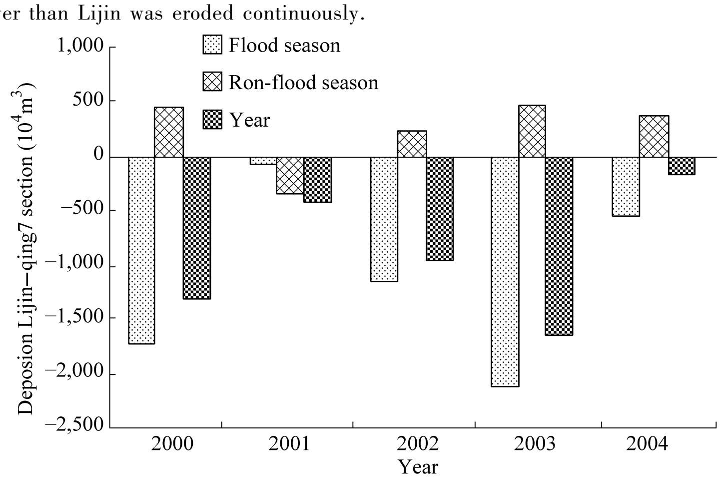


Fig. 1 Erosion and deposition of river channels from Lijin to Qing 7 section in 2000 ~ 2004

2.2 Section shape change

The shape of the Cross section is important index which reflects river channel stabilization and flood discharge ability. The river course erosion and sedimentation evolvement is reflected through the cross section shape adjustment. Fig. 2 and Fig. 3 show the actual section of Yuwa and Qing 6 since 2000, and the Table 2 shows the main channel shape change according to transect data.

Shown in the tables, in recent years main channels of these two cross sections are relative quite stable, and the lateral oscillation is not great. Yuwa cross section is located in the transition from flexible river course to estuary, Qing 6 cross section is located in the river mouth section, and two cross section shape changed inconsistently. After 1996 river course was changed to Qing 8, in 1997 ~ 1999 the water sand condition was extremely disadvantageous. In flood season the biggest peak discharge was 3,200 m^3/s, flood season mean discharge was only 408 m^3/s, in 1997 river dried up in Lijin for 226 d, in 1998 river dried up in Lijin for 142 d, in flood season and the non - flood season main river channels both have siltation. Before 2000 flood season, these two cross section main channel width was 497 ~ 594 m, the depth was 2.66 ~ 2.82 m, the weted area was 1,404 ~ 1,578 m^2, the width deep ratio ($\sqrt{B}/H$) was 7.9 ~ 9.2. After 2000, the estuary river channel kept eroded, main channel in Yuwa section was obviously broadened, depth change a little, and wetted area increase obviously. But main channel in Qing 6 section was narrowed, depth got shallow, and wetted area also decreased. Before 2005 flood season, the width of Yuwa main channel increase to 655 m, depth reduced to 2.76 m, wetted area increased to 1,807 m^2, width deep ratio ($\sqrt{B}/H$) was 9.3; width of Qing 6 reduced to 586 m, depth was reduced to 2.2 m, wetted area reduced to 1,297 m^2, width deep ratio ($\sqrt{B}/H$) was 11.0.

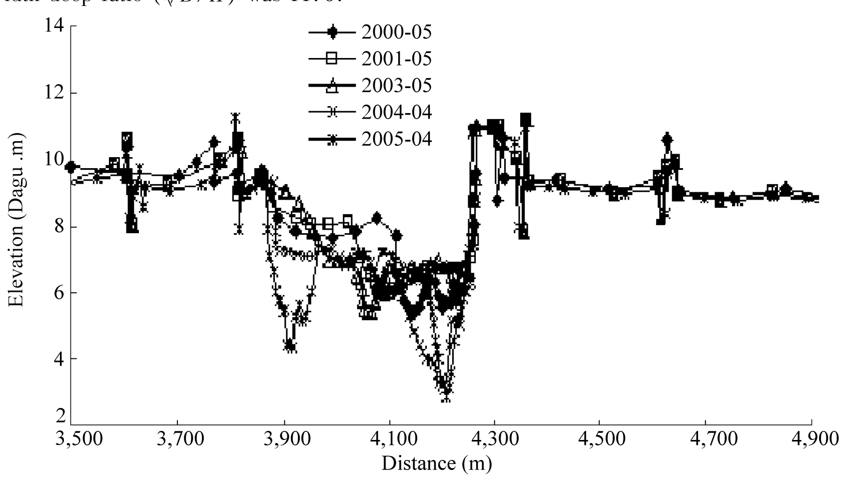


Fig. 2 Figure of actual ruwa section

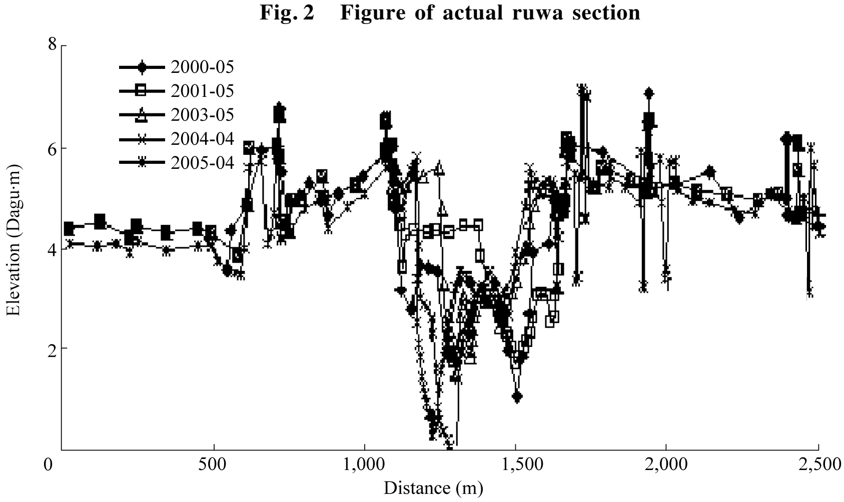


Fig. 3 Figure of actual Qing 6 section

Table 2 Shape changes of main river channels at Yuwa and Qing 6 section

Time	Yuwa			Qing6		
	B(m)	H(m)	$\sqrt{B}/H$	B(m)	H(m)	$\sqrt{B}/H$
2000 - 05	497	2.82	7.9	594	2.66	9.2
2001 - 05	660	2.47	10.4	601	2.43	10.1
2002 - 05	660	2.89	8.9	601	2.32	10.6
2003 - 05	660	2.51	10.2	601	2.06	11.9
2004 - 04	660	3.06	8.4	601	2.55	9.6
2005 - 04	655	2.76	9.3	586	2.20	11.0

2.3 Changes of water lever under the same discharge

The water level under Luokou decreased year by year since water and sediment regulation (Table 3). From 2002 to 2006 before flood season, the water level of stations decreased generally 0.6 ~ 0.96 m, and the range of water level fall decreased streamwise, which reflect the character of river channel streamwise erosion. The water level decrease of estuary channel is related to water and sediment regualtion and the erosion caused by changes of border conditions by dredging.

In 2005 May, the channel from Yihe to Zhujiawuzi was just dredged, and in flood season water and sediment regulation was conducted. The water level under Luokou station presents the trend of "dropping in two end, lifting in the middle", and the water level drop was related to dredging. In 2004 April, the 3rd dredging project was carried out from Jifeng to Yihe, in June the water and sediment regulation was conducted, until 2005, water level in Liujiayuan section station droped 0.5 m, water level in other station droped 0.25 ~ 0.45 m, waterl leverl drop of estuary was larger than upper reaches, which showed dredging function to reduce the water level under same discharge.

Table 3 Water level of stations below Luokou under the dischange of 3,000 m^3/s(m)

time	Luokou	Liujiayuan	Qinghezhen	Lijin	Yihao	Xihekou
2002 ~ 2003	-0.05	-0.04	-0.08	0.03	-0.02	-0.12
2003 ~ 2004	-0.23	0.08	-0.08	-0.20	-0.08	-0.16
2004 ~ 2005	-0.27	-0.50	-0.45	-0.25	-0.45	-0.32
2005 ~ 2006	-0.35	-0.40	-0.35	-0.30	-0.15	0
2002 ~ 2006	-0.9	-0.86	-0.96	-0.72	-0.7	-0.6

2.4 Changes of estuary deposition

By contrast and analysis of sea area topographty below water in 2000 June and 2004 July (shown in Fig. 4), the deposition of the sea area was happened mainly beside the estuary from 2000 to 2004, the mouth advanced 5 km to the sea, the water depth of the maximal deposition was lager than 10 m, erosion happened to the south of the estuary and the maximun was 2 m. In most areas erosion and deposition was balanced. Observation area was 626.6 km^2, of which deposited area was 471.5 km^2, accounting for 75.2%, and eroded area was 155.1 km^2, accounting for 24.8%, which was 1/3 of deposited area. Deposition amount from 2000 to 2004 was 506 million m^3, erosion amount was 48 million m^3, and net erosion amount was 457.9 million m^3, accounting for 93.5% of coming silt (587 million t). Most silt was deposited near the estuary. Statistically, from 2000 to 2004, annual sediment load of Lijin station was 20 ~ 258 million t. Though the annual sedimont load is not too much, the elogation rate was still large (the average is 1 km/a).

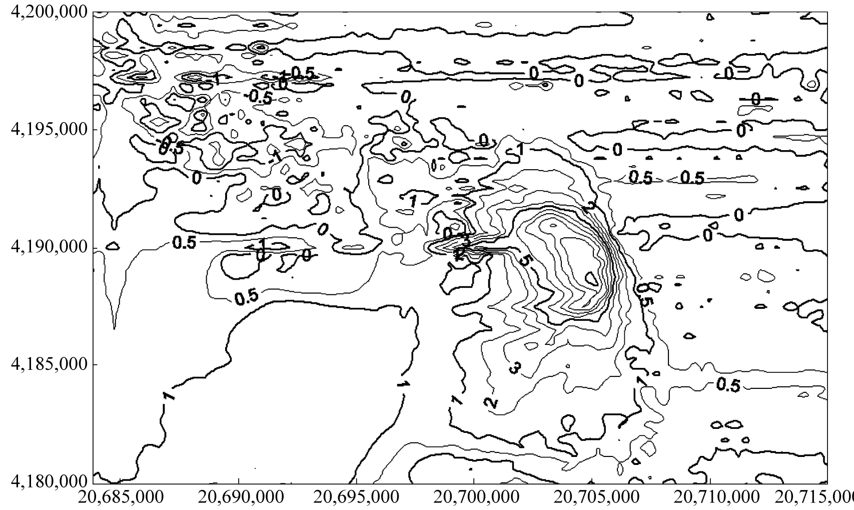


Fig. 4 Deposition and erosion ichnography of Yellow River mouth sea area in 2000 ~ 2004

3 Existing problems

3.1 Deposition decrease Yellow River estuary is unobvious

The riverbed in Yellow River estuary is related to water and silt condition of Lijin, the silt scourand deposition adjustment is influenced sensitively by channel deposition, elongation, and sand bar. Statistically, from 2002 May to 2005 April, channel from Lijin to Qing 6 was eroded 28,594 thousand m^3, but channel below Qing 6 was deposited 720 thousand. During the water and sediment regulation of 2004, river channels from Lijin to Qing 6 were eroded 7.03 million m^3, but decreased from Qing 6 to Cha 2 were deposited 3 million m^3. The eroded silt from upper reach by water and sediment regulation was piled in the estuary, made it deposite and elongate, chronically, streamwise deposition is inevitable to cause bad feedback to the whole lower reaches. According to the analysis of the channel section, wetted area of Qing 6 section was smaller than that before water and sediment regulation. The above showed that deposition decreased in estuary is less than that in upper reaches.

3.2 The capacity of sediment load is weak and the deposition elongation in the Yellow River estuary speeds up

Part of the silt entering the estuary is deposited in the delta area, the rest is deposited in the sea area and outside. Silt transported to land, littoral zone and sea respectively is: 26%、36% and 38% in Shenxiangou period (1950 ~ 1960); 13.2%、56% and 30.8% in Diaokouhe period, 1965.6 ~ 1976.5; 19.5%、59.9% and 20.7% in Qingshuigou period, 1976.5 ~ 2000.10, namely more than 20% silt was transported to the sea deeper than 12m. But in 2000 ~ 2004, silt transported to the sea, was less than 10% most silt of Lijin was deposited near the estuary, which accelerate elongation of estuary channel, made gradient smaller, chronically, will cause streamwise deposition.

3.3 River training works is unsound, and river shape changes greatly

The river training works Shibahu is onloy 1/5 long of the river channel. The controlling length is insufficient, and there is no training works in river channels below Qing 4, The flood lasts a long period during in water and sediment regulation, silt concentration is small, erosition power is strong, so river shape below Shibahu changed greatly, and even some beach strand collapsed seriously. Because 22# dam of Balian works hasn't been completed, flow delivering capacity is insufficient, made Hong nizui projects collapsed. When the flow got straight, flow move down, 2 km of bottomland below 21# damcollapsed, forming sharp curve, effluent derection leaning to upper part of Qing 3 works, made flow of Qing 3 up, so 600 m long beach strand above 1# dam collapsed, so the river channel of Dingzilu sway to the right, water pumping ship left the main flow, can not pump the water. Near Qing 8 "S" curve appeared, and the evolvement trend is disadvantageous.

4 Recommendations

4.1 Enforcing river dredging, and decreasing the impact from channel deposition in lower reaches

Continuous deposition and elongation are the main reason for gradient decreasing and streamwise deposition, and also disadvantageous to flood and silt discharging. Dredging can keep the estuary expedite and lower the erosion base level, make it eroded streamwise in long distance under certain water and silt conditions, which is a effective measure preventing riverbed from lifting. The deposition decreasing function of water and sediment regulation is limited, while water and sediment regulation continued, estuary dredging should be unremitted, especially the channel below Qing 7 section can be dredged to improve the border conditions, increase channel water and silt coad capacity, to reduce feedback by estuary deposition and elongation and ensure safety of agriculture and industry in estuary bottomland.

4.2 Carrying out silt roiling and dredging, together with water and sediment regulation,

The sand is very disadvantageous to flood and silt discharging. Especially in ice flood season, drift ice often block the estuary channel to freezing, causing ice water overflow, threatening the safety of estuary region. And the hunch of the sand bar partially lift the erosion base level, the blocked water automatically search short cut to the sea, facilitate course changing, afterwards new sand bar will be created near the new estuary, leading to less gradient, which bears a new larger course changing. So in order to keep the flood and silt discharging smoothly, and ensure flood control safety, increase capacity of sedimont discharging, sand bar should be roiled together with water and silt regulation to extend using period of current course.

4.3 Perfect river training works as soon as possible

Facing the river reaches where position change greatly, works control length is insufficient, river regulation should be enforced, node works shoule be perfected. Currently, Shibahu controlling works should be extended upwards, Balian, Qing 3 works should be perfected, river channel from Qing 6 to Qing 8 should be regulated to control transverse sway of the channel effectively, to stabilize the main channel.