Support for the Sustainable Development of the Yellow River Delta

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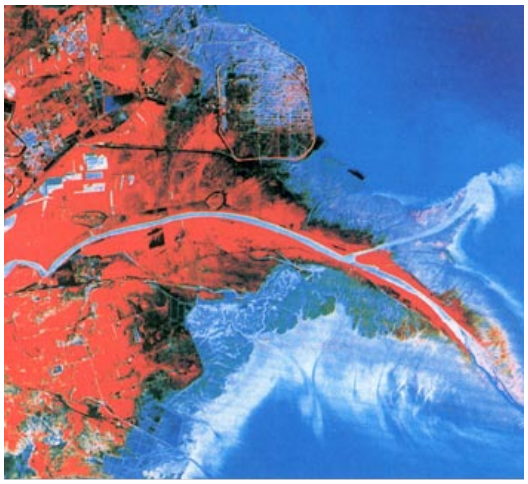
Contents

Summary

The environment in the Yellow River Delta (YRD) is under stress. A Sino-Dutch project contributed to the sustainable, long-term development of the Yellow River Delta. One of the challenges is to analyse how to best use the limited fresh water resources in a sustainable way. The Sustainable Development YRD project made use of valuable integrated framework with analytical tools in which future developments and strategies can be analysed in a systematic way.
Such an approach provides a strong incentive to start communication and mutual understanding between the different responsible authorities and stakeholders.
Various follow-up projects were proposed upon the finalisation of the YRD project and some of them were executed.
The results of these international cooperative activities confirmed that an integrated water management policy is the key element in the future development of the Yellow River Delta.

Yellow River Delta: a fast rate of development 1997 - 2010



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1. Introduction

A Sino-Dutch deltaic project focusing on the sustainable development of the Yellow River Delta (YRD, China) was undertaken between 1995 – 1997. The study area in the YRD encompasses almost 7900 km^2. The principle goal of this project was to contribute to the sustainable, long-term development of the Yellow River Delta through providing an integrated planning framework including environmental and technological planning tools. The project was co-sponsored and undertaken by the following organisations:

- Chinese authorities (China International Centre for Economic and Technical Exchange, YRD Conservancy and Development Research Centre and with experts for the State Planning Commission, China Institute for Water Resources, Institute of Geography of the Chinese Academy of Science and Beijing University);
- The CZM-Centre /Rijkswaterstaat/Netherlands /Ministry of Transport, Public Works and Water Management and the Netherlands Economic Institute/Ecorys;
- United Nations Development Programme under project CPR/91/144 (L. de Vrees & Wang Huijong – eds., 1997).

Three main objectives were defined by the project partners and contributed to:

- Stabilisation of the Yellow River channel in the Yellow River Delta (YRD) and control of sedimentation;
- Enhancement of the capacities for comprehensive and technical analysis, research and planning of local organisations;
- Production of inputs to an overall comprehensive plan for the sustainable development of the YRD including industrial and land use planning.

The results of this Sustainable Development YRD project aimed to provide the Chinese national and local policy and decision makers with an improved overview of the status, and the consequence of future strategies regarding the natural and socio-economic developments of the YRD. After completion of this Sustainable Development YRD project, several follow-up projects were carried out between 1998 and 2007, such as the Yellow River Delta Environmental Flow project. The project makes use of a valuable integrated and analytical approach. This systematic approach provides a number of proven tools to manage a complex deltaic/coastal area in an integrated way, now and in the future. These concepts on integrated management and sustainable development have been used in the follow-up projects in the YRD and along other parts of the Chinese coast (see CCC II-2-3 and II-2-4).

2. Some major aspects of the Yellow River Delta at the end of the 20th Century

The Yellow River Delta (YRD) contains rich and vast land resources. An example of the vast land availability: the averaged land occupancy per capita (0.48 hectare/ capita) is 5 times higher than the average in the Yangtze delta. There are also rich aquatic resources including abundant salt-water habitats. Major petroleum and natural gas reserves are the most important economic resources. They are located around Dongying and north of the river mouth. The oil installations are located on special, grid subdivided and embanked areas (visible on Integrated Development map - Figure 1), which are protected against flooding from the sea and the river. The fresh water resources mainly come from the Yellow River. Although overall on average fresh water is abundant, there are increasingly serious problems during dry seasons. In part, this is caused by increased extraction of water upstream.
Infrastructure in Dongying municipality, a city of almost 2 million inhabitants is well developed. Roads, highway, ports, railway, airport, power plant and distribution lines are all in place. The Shengli Petroleum Administrative Bureau has a dominant role in the socio-economic prosperity of this part of the YRD and has a big influence on the future development of this area.

Environment under stress
The environment in the Yellow River Delta is under stress and is being monitored by the government, especially in relation to:

- The level of industrial air pollutants, especially $SO_{2;}$
- The rivers flowing to the Yellow Sea, which were seriously polluted during the nineties of last century;
- Urban sewage water treatment. The level of microbial pollutants, which exceeded the national standards by a long way in the nineties, is now steadily improving.
- Ground water quality, which during the nineties was unsuitable for human use and irrigation (Yang Yuzhen et al., 2004).

The Chinese Government established two Nature Reserves. The one in the eastern part of the delta of 153.000 hectares, was created in 1992 (see Figure 5). It consists of both freshwater and saltwater wetlands. Those wetlands are visited each year by millions of migratory birds.

The area is however also renowned for a number of rare and endangered resident bird and plant species such as Saunder's Gull (*Larus saundersii*), Great Bustard (*Otis otis*) and Red-crowned Crane (*Grus japonensis).* Parts of the Nature Reserve area are under stress due to oil exploration and potential pollution from oil spills.

One of the challenges as a precondition for the sustainable development of the delta will be to analyse how best to use the limited supply of fresh water, and furthermore to understand the consequences of the limits to non-renewable energy resources.

Objectives and criteria for the sustainable development of Yellow River Delta

The project proposed four specific objectives for sustainable development:

1. Economic development: including increases in local income, to realise sustainable development through diversification of economic activity and optimising investment costs by economic cost-benefit analysis;
2. Environmental duality: this includes a guarantee of sufficient fresh water supply, maintaining a healthy environment for the local population, protecting the wetland nature reserve area and promoting development of environmentally sound industrial and agricultural activities;
3. Social development: including eradication of poverty, improvement of the education and health care system;
4. Safety: protection from dangerous flooding by rivers and the sea for the population and the infrastructure.

3. Results and products

3.1. Overview of products

The Sino-Dutch cooperation resulted in a number of different products. An integrated framework for analysis was provided, taking into account the various land and water-uses, natural processes as well as commonly defined strategies and scenarios. Alternative development scenarios were analysed and their consequences compared and assessed. Tools were developed for this purpose: such as the modelling of the river harnessing, the flooding module, the economic input & output tables, the description of the environmental situation and the Geographical Information System (GIS), all containing a wealth of information needed in order to make balanced choices for the future.

A comprehensive and multifunctional GIS Atlas was produced, which supported an integrated approach and provided a framework for analysis. By giving a spatial overview of the functional uses and natural processes in the Yellow River Delta, it demonstrated the potential interactions between them. Figure 1 gives an example of an Integrated Development map from the Atlas (Liu Gaohuan and Drost, 1997). Frequent monitoring and time series of airborne/satellite images inserted into the GIS facilitated temporal analysis of the highly dynamic Yellow River delta. The GIS tool also allowed a spatial, cartographic demonstration of the outputs of the analysis and consequences of the different strategies and scenarios.

Furthermore, capacity-building efforts were undertaken: several training workshops in China and dedicated training courses abroad were organised, covering the use of GIS and environmental and hydraulic monitoring. The scope and objectives of the project as well as strategies and scenarios were commonly identified during several workshops. During (inter)national conferences, the interim and final results were presented and discussed. All these project activities were organised with and for Chinese authorities and experts at the national, provincial and local level.

3.2. Sustainable economic and social development

In order to change the traditional approach of national planning and focus more on the local available assets, several tools were provided. These included Input-output analysis of different development strategies, a Social Accounting Matrix for determining the distribution of income and Scenario analysis of the influence of future growth rates.

Four different strategies were adopted:

1. Profit priority (enterprise becomes the major actor);
2. Target sector priority (Government targeting especially industrial policy);
3. Environmental priority (Government as major actor to correct the market failure in dealing with environment);
4. Social priority (Government plays a major role in achieving the social objective).

The project also introduced the notion of water pricing to the Water Authority of the province Shandong. Water pricing is a method for stimulating sustainable use of water for both industry and agriculture. Proposals were generated for optimising the use of water, popularisation of water saving techniques, utilising fully the water saving potential of the agricultural sector and using good quality water.

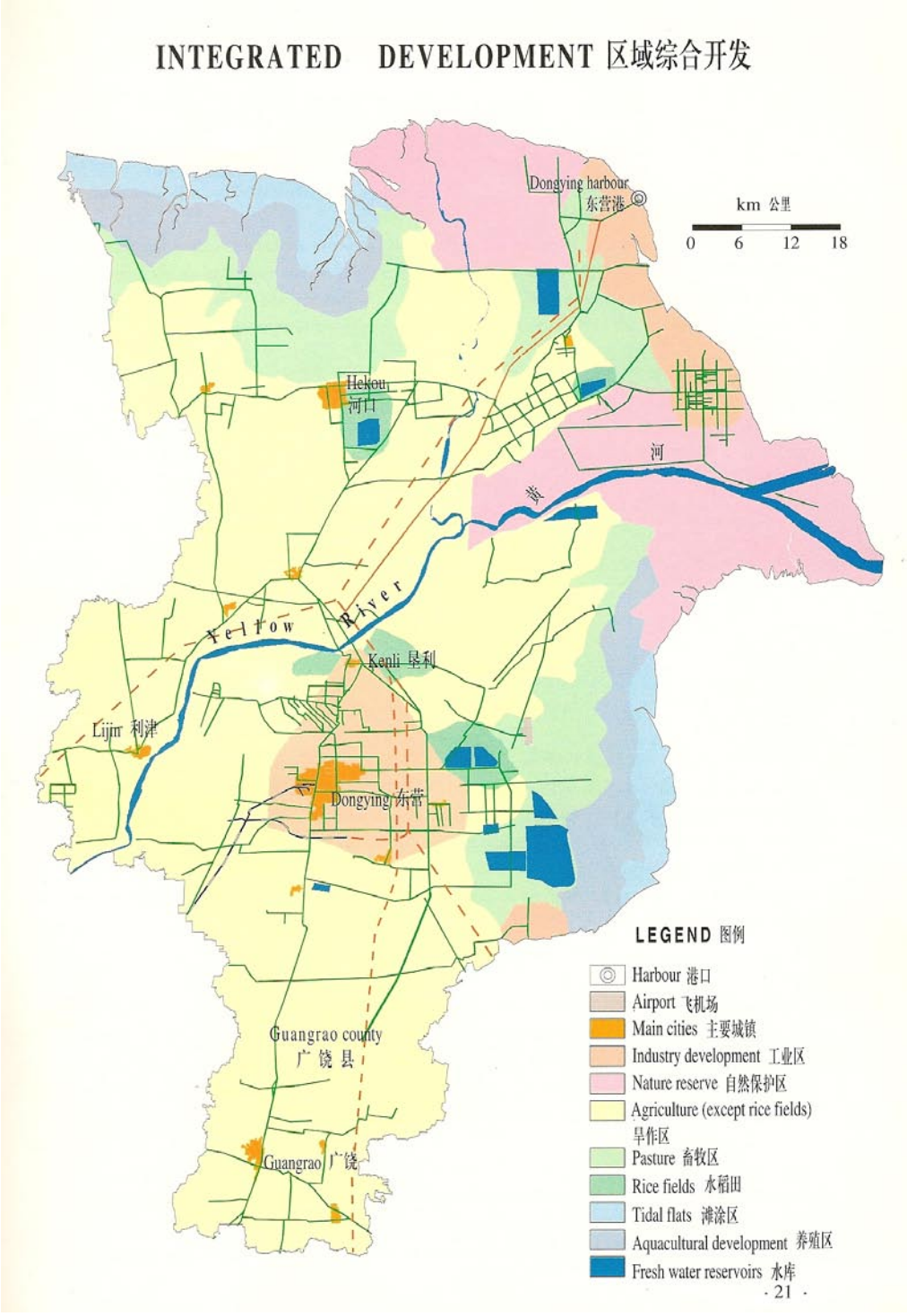


Figure1: ***Integrated development of the Yellow River Delta,*** *with cities, nature reserves and large oil industrial parks: one around Dongying and the Godong Oil Field 20 km south east of Dongying Harbour. (source: 'Atlas of the Yellow River Delta' - Liu Gaohuan and H.J. Drost, 1997)*

33 Safety: Channel of the Yellow River Delta and the coastline

River course

A precondition for the development of the delta is the stabilisation of the channels of the Yellow River to prevent breaching of dikes. The lower part of the river in the past changed its course frequently and unexpectedly (Figure 2). Investments and developments near the mouth of the Yellow River cannot be sustained without taking into consideration the dynamics of the river course and the nature reserve.

During the planning of measures to control the position of the river courses, several aspects need to be considered. In the short-term a fixed river course seems most beneficial for the local socio-economic development of the delta.

However, in the long-term, the river course management will influence the development of the whole delta. In fact, the whole delta is determined by the pattern of deposition of the sediment in the Yellow River. The shape of the present delta and its coastal contour is the result of the interplay between the changes of the river and the actions of the sea.

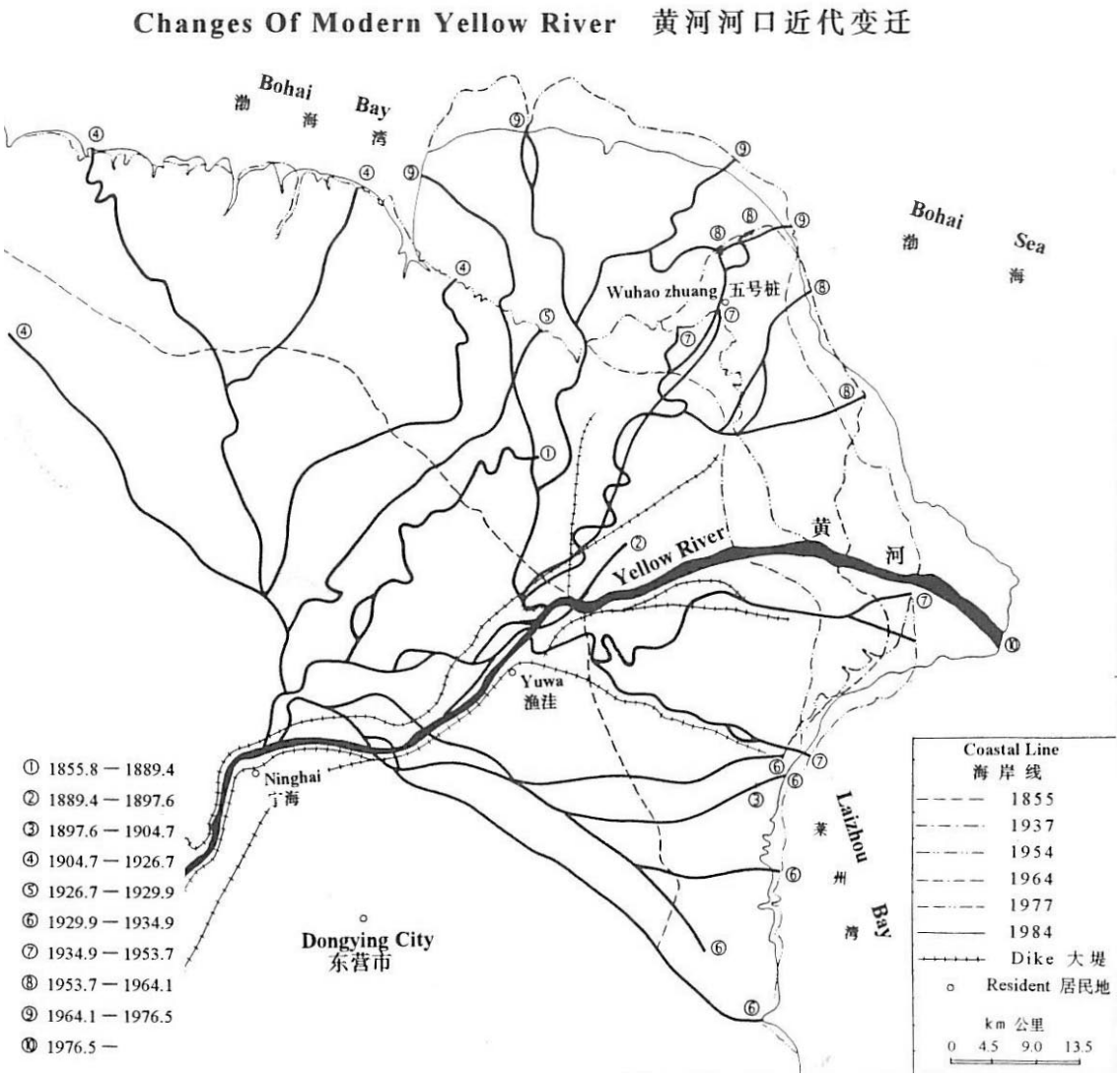


Figure 2: ***River course changes in the modern Yellow River Delta*** *(after Liu and Drost, 1997) showing:*

- *The last apex is located around Yuwa, and the previous apex was found more up-stream at Ninghai;*
- *The large dynamics of the delta shoreline encompassing several tens of kilometers of coastal accretion of the central deltaic part during the last century.*
- *The coastline of the central delta has been moving seawards by 30-40 km since 1855. With the bed slope of about 10^{-4} in the downstream part of the Lower Yellow River this means a vertical bed level increase along the whole river by about 3-4 m.*

This fast growing delta is a direct manifestation of the most heavily sediment loaded river of the world. Its dynamics strongly effects the socio-economic development of the delta.

At the mouth of the river, the delta grows into the sea and new land is created. At other locations where the sediment supply from the river is limited coastal erosion takes place due to tidal flow and wave action. The river always tends to find the shortest way to the sea. Regular, lateral movements of the river course form a fan-shaped (sub) delta, commencing at the apex (= head of the fan-shaped delta).
The management of the river course since 1976 is characterised by keeping the existing course of the channel at the same alignment for as long as possible. After extensive studies and modelling, three alternative schemes were analysed and compared. In the end, it was decided to form a Northern Branch with an most seaward apex in the Qingshuigou Channel, which was implemented in 1996. This scheme was also the most advantage for oil exploration because north of the river mouth, oil reserves are present near the shore and with such branch more easily accessed. Consequently, it is expected coastal erosion in the northern part of the delta, around the old river mouth (before 1976, indicated with nr 9 in Figure 2) will continue into the future.
It should also be realised that there is an interaction between the river course management and the development of the river basin upstream. For example, the construction of the large reservoirs upstream and the water diversions along the river have decreased the water and sediment input to the delta substantially in recent years (Wang et al, 2008 - see Figure 3 and CCC II-2-3). Therefore, the creation of new land at the river mouth after 1996 has not been as fast as was anticipated.

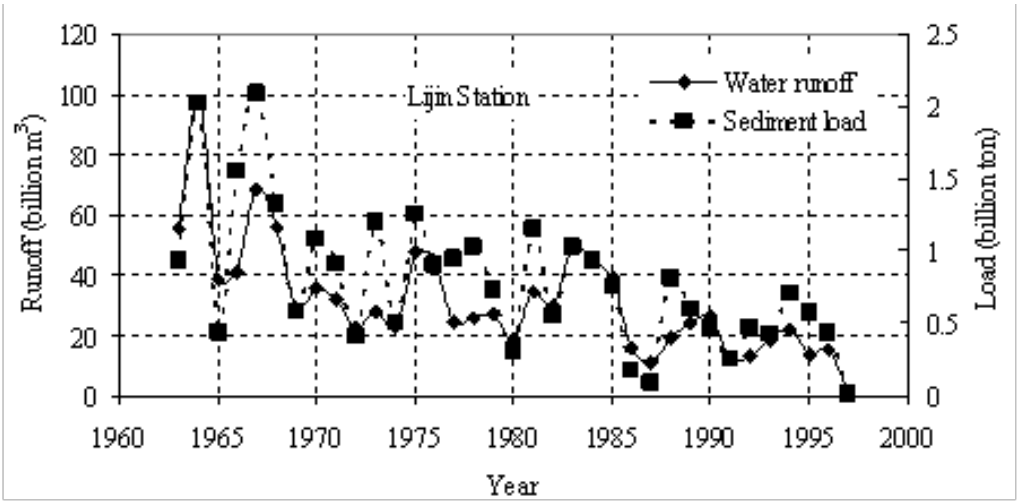


Figure 3: ***Variation of annual runoff and sediment load*** *in the period from 1960 to 1997 at Lijin Station, in the Yellow River Delta. (after Wang et al, 2008)*

Risk analysis and follow-up
Finally, risk analysis for flooding hazards was made. As a result, it was proposed to apply norms for flood prevention of once in 100 years event as the most appropriate frequency, taking into consideration the costs and benefits.
Various follow-up studies were proposed upon the finalisation of the YRD project, some are being executed such as a continuing study on the future of the present channel, the so-called Qingshuigou Channel of the Yellow River Estuary in relation to long term management (see e.g. Li et al, 2001).

3.4 Integrated water management in the Yellow River Delta

Fresh water is of key importance for many economic activities in the Yellow River Delta. It is used as drinking water, for growing crops, for industrial activities and for maintaining healthy ecosystems throughout the Delta. Of all the consumers, agricultural irrigation has the highest demand, which is not surprising because of the high evaporation rate during most of the year. This evaporation causes capillary rise of the saline groundwater into the top soil, which has to be flushed with fresh water. The sea also has a major influence on the surface and ground water and the soils of the Delta. The low topographical level of the delta, not more than a few meters above sea level, results in much of the ground water being in contact with the sea and has the same, or higher, salinity than the seawater. Currently around two thirds of the Delta has moderate to serious salinity problems.

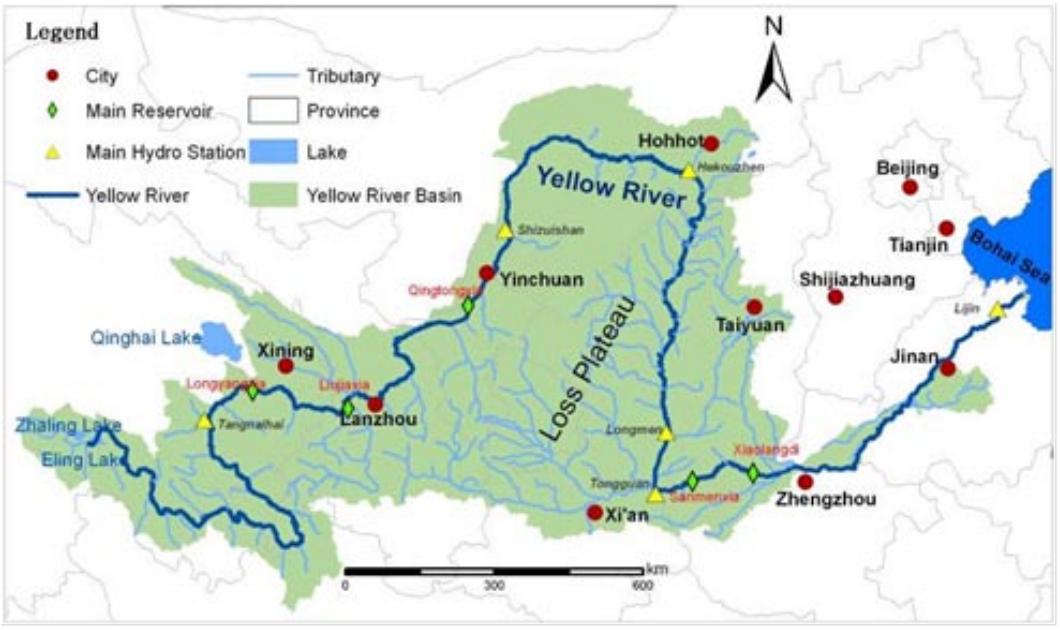


Figure 4: ***The Yellow River Basin****: the second largest river basin of China - 800,000 km2, accommodating 9% of the Chinese population and with the Three Gorges Dam near Lanzhou and the main Hydro Stations.(map: © Shannon, Creative Commons Attribution-Share Alike)*

Conflict between supply and demand

Because evaporation is much higher than the annual rainfall in the delta, the most important source of freshwater is the Yellow River. Unfortunately, the Yellow River basin (Figure 4) is very deficient in water resources. The conflict between supply and demand is prominent. Since 1992 the annual discharge of the lower Yellow River reached dangerously low levels, leading to frequent periods of zero discharges of more than 100 days per year. From 1995 to 1998, the river was dry during more than 120 days every year, up to as much as 226 days at the town of Lijin, in the delta (Figure 1), in 1997. This regular drying up of the lower Yellow River had a serious impact on the downstream socio-economic functions and caused considerable ecological damage in the delta. Therefore, the Yellow River Conservation Commission (the basin wide administrative agency) implemented a regulated discharge regime of the river from 1999, in order to restore the river downstream of Lijin (Liu Xiaoyan *et al.*, 2006). This alleviated to some extent the risk of drying up and water deficiency in the lower delta. However, there is still a long way to go to provide optimal allocation of water resources required by all economic sectors and the ecosystems of the delta (Liu Gaohuan & Drost, 1997; Liu Gaohuan, 2006).

Optimising freshwater use from the lower Yellow River requires a balance between the demands from the domestic and economic sectors and the nature reserve while leaving sufficient water discharge at the mouth of the river to minimise seawater intrusion. Because of the highly variable water demands and supplies over the months of the year, this requires sound water management from month to month or even day to day.

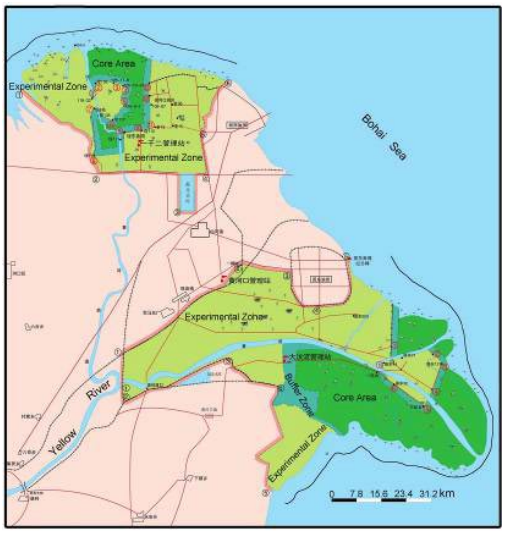
Involvement of stakeholders

The planned development of the Delta uses the opportunities that are offered by the natural conditions such as new land, mineral resources and water, while ensuring a favourable environment for man and nature. Because water remains a critical issue for many of the economic sectors, much attention is paid to water saving techniques and other innovations (such as desalination). Besides technical solutions, there is a continual need for close cooperation between the many stakeholders in the delta who are dependent on fresh water. Their water demands need to be quantified and allocated in time and space; for this the Yellow River Conservation Commission has the main responsibility. In order to fulfil this responsibility, knowledge and information has to be available both from the physical (supply) side as well as from the water demand side. In addition, in order to plan, forecasts and predictions need to be made with respect to both of these. Decisions on water allocation should be transparent, based on scientific evidence and commonly agreed assumptions. This requires the involvement of all relevant stakeholders who need to provide adequate information on their requirements.

Box: **The Yellow River Delta Environmental Flow project**

The Yellow River Delta Environmental Flow project (Lian Yu et al., 2007) was designed to provide essential information and scientific knowledge with respect to the environmental water demands of the lower (new) delta and its nature reserves. It was carried out during 2005-2007 as a bilateral cooperation between Dutch and Chinese research organisations. The integrated approach included hydraulic modelling of the water flow and water depths in the delta (Zeng Bin Wang et al., 2007) combined with groundwater dynamics and evapo-transpiration (Figures 6 and 7), and subsequent modelling of the vegetation and habitats for specific red-list bird species, like Saunder's Gull (*Larus saundersii*), Great Bustard (*Otis otis*) and Red-crowned Crane (*Grus japonensis,*).

Examples were given for the habitat suitability of these species and the succession in their habitats. The analysis was based on an integrated assessment of various management strategies, defining the amount of water and the distribution of water flows over the year, as required for sustainable development of the internationally valuable wetland ecosystems in the Yellow River Delta.



The Nature Reserves in the delta are a real test case, not only with respect to protecting recently formed wetlands and rare and threatened bird species, but also in finding a balance between environmental values and economic development. The project showed that a landscape-ecological study with a proper representation of surface and groundwater dynamics enables the assessment of alternative water management strategies to safeguard essential nature values, without imposing unrealistic water requirements from the Yellow River.

Figure 5: ***The two Nature Reserves in the Yellow River Delta****, with Core areas in dark green and Experimental areas in light green and the embanked, gridded oil industrial park. (source: Yellow River Conservation Bureau)*

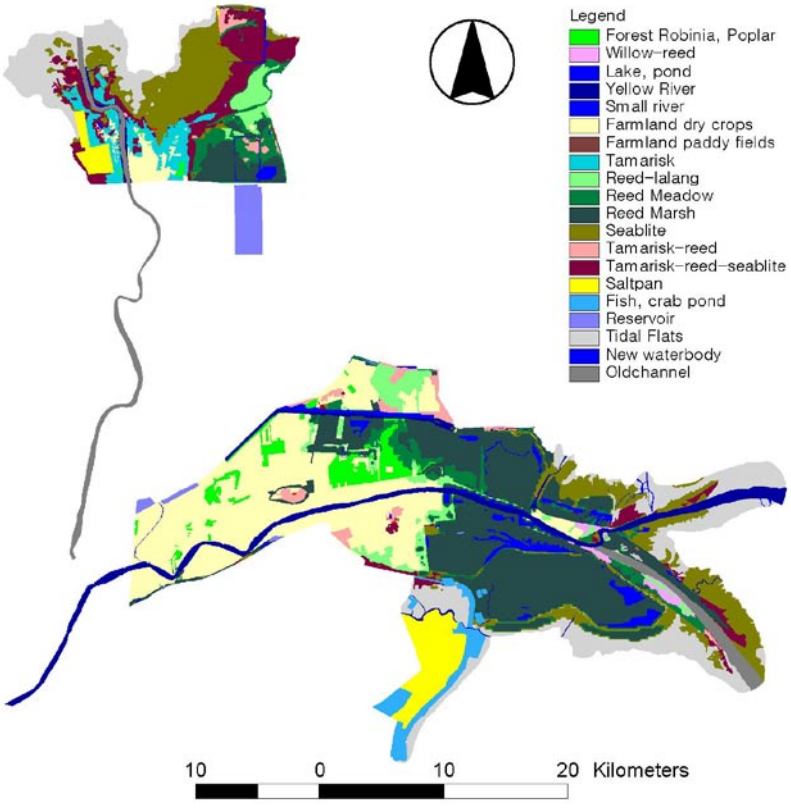


Figure 6: ***Simulated development of vegetation types after 5 years of improved freshwater supply*** *- output from LEDESS model, see Figure 7.*
(source: Lian Yu et al. 2007)

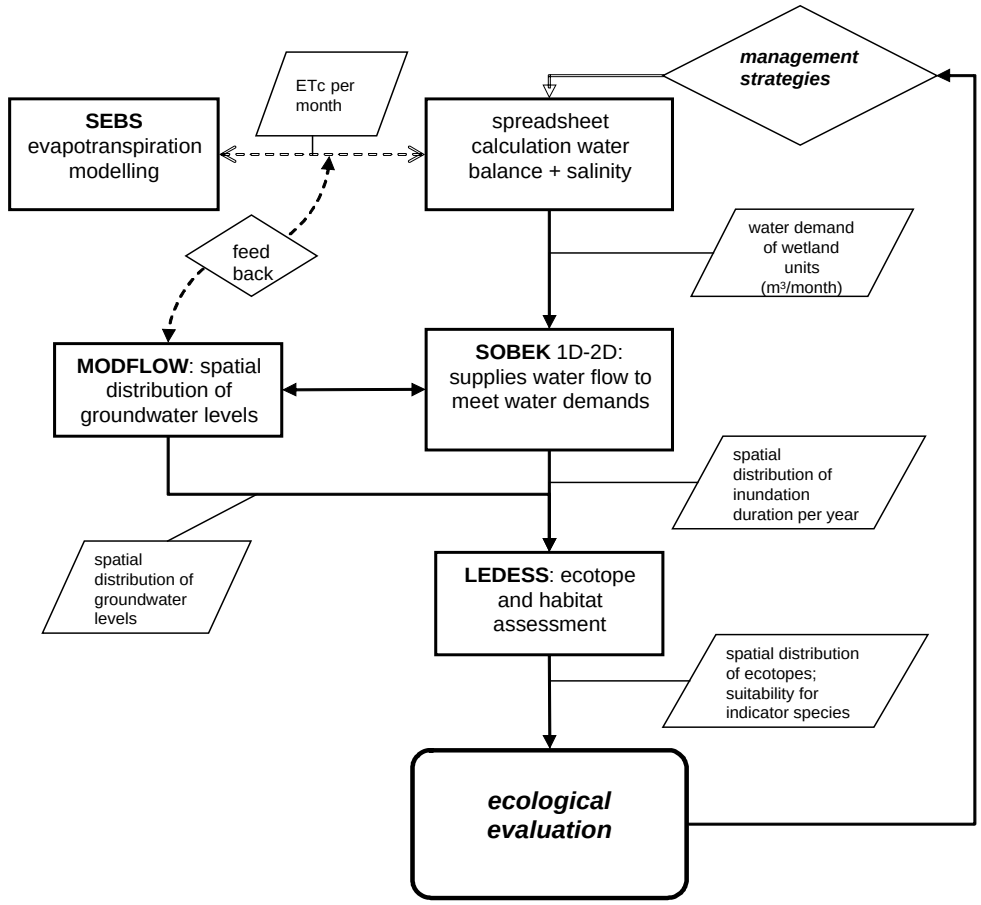


Figure 7: ***Computational framework for the assessment of ecological water requirement*** *the Yellow River Delta Environmental Flow project. (source: Lian Yu et al. 2007)*

4. Conclusions

Natural and socio-economic developments in a dynamic deltaic area are intertwined. This calls for an integrated approach whereby economic, environmental and social developments are balanced. The management of the river course in the delta should not only include short-term local considerations, but also geared to a long-term overall vision. This vision includes the development of the entire river basin and the whole delta including the coastal zone.

The challenges for the future are manifold. They contain ongoing high economic development in China and Shandong Province, the increasing demand for energy and fresh water, the challenge to comply with the latest environmental standards and the changing water and sediment flows of the Yellow River due to upstream developments. In addition the possible effects of climate change such as changes in rain-fall patterns, increasing relative sea level rise and associated salt intrusion and the expected change in flooding risk, both from river floods and from storm surges are important. These challenges require an integrated water management policy, which is the key element in the future development of the delta.

To combine spatial and temporal aspects in an integrated approach, greater insight into the complex processes associated with the development of the river and its delta including the marine and coastal processes are required. This calls for a series of programmes and research projects whereby systematically the sustainable development objectives of the delta are defined and realised. Such a comprehensive effort is a continuous process in which feedback loops, including evaluation of sustainable measures have an important place. Such an approach requires continuation and reinforcement of the recently begun cooperation between the many agencies and departments involved in the delta. It

will also require a robust system to monitor change, continuously upgrading the design framework for integrated analysis, which aims to provide information on the status, overview and consequences of policy options.
It is also clear that this approach provides a strong incentive for communication and mutual understanding between the different sectors and strong support for the sustainable development of the Yellow River Delta.

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