# SUSTAINABLE WATER MANAGEMENT AND RIVER DEVELOPMENT

## VOLUME I

Editors: Lin Luo
Shaw Lei Yu

PROCEEDINGS OF THE 5TH INTERNATIONAL CONFERENCE ON URBAN WATERSHED MANAGEMENT & MOUNTAIN RIVER PROTECTION AND DEVELOPMENT

APRIL 3-5. 2007
CHENGDU, CHINA

SICHUAN UNIVERSITY PRESS

# 可持续水管理与河流开发 上卷

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第5届城市流域管理与山区河流开发保护国际会议论文集

中国 成都 2007年4月3-5日

四川大学出版社

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责任编辑:毕　潜
责任校对:陈　寒
封面设计:罗　光
责任印制:杨丽贤

图书在版编目(CIP)数据

可持续水管理与河流开发=Sustainable Water Management and River Development:英文/罗麟,余啸雷主编. —成都:四川大学出版社,2007.4
ISBN 978-7-5614-3655-4

Ⅰ.可… Ⅱ.①罗…②余… Ⅲ.河流-水资源管理-研究-英文 Ⅳ.TV213.4

中国版本图书馆CIP数据核字(2007)第036889号

书名　SUSTAINABLE WATER MANAGEMENT AND RIVER DEVELOPMENT (volume Ⅰ & Ⅱ)

作　　者　罗　麟　Shaw Lei Yu
出　　版　四川大学出版社
地　　址　成都市一环路南一段24号(610065)
发　　行　四川大学出版社
书　　号　ISBN 978-7-5614-3655-4/TV·8
印　　刷　郫县犀浦印刷厂
成品尺寸　210 mm×285 mm
印　　张　46.75
字　　数　1350千字
版　　次　2007年4月第1版
印　　次　2007年4月第1次印刷
定　　价　160.00元

◆读者邮购本书,请与本社发行科联系。电话:85408408/85401670/85408023　邮政编码:610065
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◆网址:www.scupress.com.cn

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# STUDY ON THEORY METHODOLOGY OF WATER RESOURCES ASSESSMENT BASED ON THE DUALISTIC HYDROLOGICAL CYCLE MODEL

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**ABSTRACT**

The methodologies of water resources assessment at home and abroad have being developed with the development of society and economy. At Present, the traditional methodologies of water resources assessment are facing serious challenge in describing some exterior disturbances, such as stronger human activities, changing climate, etc., and meeting the requirement of water resources planning at various level. Therefore, a dynamic hierarchical assessment methodology of water resources is put forward in this paper. That is, based on regional precipitation is considered as the whole flux of water resources, the resources structure of precipitation is analyzed systematically including general water resources, special water resources, water resources with runoff form and available water resources according to the three principles of water resources assessment with effectiveness, controllability and recoverability. Compared to the traditional methodology of water resources assessment, the mode, extension and depth of water resources assessment in the dynamic hierarchical assessment methodology are further spread. In the quantities way, the dualistic water resources assessment model, coupling distributed hydrological model with physical mechanism and Lumped water resources allocation model, is employed. In additional, dynamic hierarchical assessment of water resources may realize by the dualistic model with changing underlying conditions and water use conditions.

**KEYWORDS**

human activities, water resources, assessment methodology, dualistic hydrological cycle, distributed hydrological model

# HYDROLOGY FOR SOCIETY IN THE 21ST CENTURY

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# INTEGRATED MANAGEMENT OF THE THREE GORGES HYDRO-COMPLEX

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**ABSTRACT**

The Three Gorges Project has an installed capacity of 22500 MW and generates nearly 100 million MW • h of electricity annually. The enormous amount of clean, renewable energy supplied by the Project has been playing an increasingly important role in China's economic development. The Three Gorges Reservoir is a multipurpose reservoir, serving the primary function of flood control and the secondary functions of power generation and navigation regulation. In addition, environmental and ecological regulation is becoming increasingly important as well. This paper presents the achievements that have been made in research on the integrated high-efficiency utilization of hydropower at the Three Gorges Reservoir, including the handling of the relationship between flood control, power generation, navigation and silting, the construction of the management and regulation system for the Three Gorges Hydro-Complex, the operating status and achievements of meteorological and hydrographic forecasts, accomplishments in flood control, power generation and navigation regulation, and the research and practical experience of silting in the Three Gorges Reservoir. It is also worth noting that the Three Gorges Reservoir has also obtained considerable achievements in the research of protecting the ecology of the drainage area through the power plant's operation and regulation, such as the study on improving the spawning of the top four domestic fishes downstream with artificial flood peaks. Statistics on its actual regulation and operation from 2003 to 2006 suggest that the Three Gorges Hydro-Complex has delivered remarkable benefits in flood control, power generation, navigation and various other aspects.

**KEYWORDS**

Three Gorges Hydro-Complex, Regulation Management, Flood Control, Power Generation, Navigation, Ecological Regulation

The Three Gorges Project (TGP) on the Yangtze River in China is currently the world's largest hydro-complex project. Following its completion, the project will control a drainage area of one million km$^2$ and have a flood-control storage capacity of 22.1 billion m$^3$, which will tremendously improve the ability to control flooding on the lower reaches of the river. The Three Gorges Reservoir, which extends 600 km, will fundamentally improve navigation on the upper reaches of the Yangtze River. The Three Gorges Hydropower Plant has a total installed capacity of 22500 MW and generates 1000 million MW • h of power per annum. This is the equivalent of

saving of 50 million tons of raw coal annually and a reduction of 100 million tons of carbon dioxide emissions.

The Three Gorges Project has enormous integrated benefits in flood control, power generation and navigation, playing a vital role in China's socio-economic development. On the other hand, the enormity of the benefits of the Three Gorges Project has presented the project's regulation management with unprecedented challenges. —how can a balance be struck among the various interests in flood control, power generation and navigation and how can efficient and effective regulation management be performed in order to maximize integrated benefits; moreover, the increasingly important issue of coordination and harmony with the environment and ecosystems has presented managers with difficult tasks.

## 1 MANAGEMENT SYSTEM

Integrated management of water resources is the prevailing trend in drainage area management. The prominent role and special status of the Three Gorges Project dictate that its management system must be based on an integrated management model.

First of all, the integrated management model means that the Three Gorges Project must perform multipurpose management with respect to flood control, power generation and navigation. Therefore, the government organized related departments in the drawing up of *the Specifications for the Cascade Regulation of the Three Gorges-Gezhouba Hydro-Complex* (hereinafter referred to as "*the Regulation Specifications*"; different regulation specifications are formulated for different periods, such as the cofferdam power generation period, the initial operation period, and the normal operation period); these specifications were then promulgated as laws and regulations for enforcement. They intend to balance the various interests and maximize integrated benefits from the perspective of multipurpose management. They are the current legal documents for the Three Gorges Project, and all regulation management measures must conform to them.

Additionally, the Gezhouba Hydro-Complex, which is a cascade complex about 38 kilometers downstream from the Three Gorges Dam, is an integral part of the Three Gorges Project. The Three Gorges and Gezhouba Cascade Hydro-Complex and its reservoirs must be placed under unified regulation.

The legal entity of the Three Gorges Project is the China Three Gorges Project Corporation, which is responsible for managing the construction and operation of the cascade complex on behalf of the State and performs unified regulation within the scope of duties defined in the "Regulation Specifications." The State Flood Control and Drought Relief Headquarters takes over the regulation and management of the Three Gorges-Gezhouba Cascade Hydro-Complex when the discharge exceeds a certain level during the wet season.

## 2 MULTIPURPOSE MANAGEMENT

The solution principles of the multipurpose issue can be classified into three types by judging whether the objective utility function V exists in the decision analysis process and whether it can be expressed in an explicit formula. The three types are: (1) the objective utility function V exists and can be expressed in a mathematical formula; in this case, advanced estimates

preferred by the decision maker can be used to obtain a solution; (2) there exists a steady utility function V, but there is no attempt to give an explicit expression to it and only the general form of the function is hypothesized; in this case, the decision maker's preferences are becoming increasingly clear by interaction in the solving process; and (3) there exists no steady utility function, whether explicit or implicit; in this case, posterior estimates preferred by the decision maker can be used to obtain a solution.

The regulation management of the Three Gorges Project represents a typical issue of multipurpose decision-making. The enormous benefits of the Three Gorges Project include economic benefits, social benefits, and ecological benefits. In the objective function, benefits from power generations are easy to quantify, whereas it's hard to estimate the benefits in flood control, navigation and ecological environment. As such, it's not feasible at this time to build an explicit utility function for the Three Gorges Project, whereas it's feasible to follow the idea that "the decision maker's preferences are becoming increasingly clear by interaction in the solving process" as described in the second solution principle in the preceding paragraph. The following is an illustration of this point:

As the primary purpose of the Three Gorges Project is to control flooding, benefits in flood control, which top the list of the benefits that are hard to quantify, must materialize first. The materialization of benefits in flood control is assured with the flood-control regulation scheme provided in the "Regulation Specifications". The scheme has been built on the basis of the calculations and comparisons of multiple schemes and selected according to the decision-maker's preferences; it includes the head and discharge threshold values in all stages. While assuring that flood control requirements are met, benefits from power generation and benefits in navigation are optimized, and the solution to the benefits from power generation can be obtained with a joint optimized regulation model. In the meantime, navigation regulation is performed according to the requirements of navigational authorities to ensure that the water level, discharge and the magnitude of change of the water level on the related sections of the river are within the limits of the threshold values. When power generation and navigation clash with each other, they may interact according to the decision-maker's preferences in order to come up with a final scheme for resolving the clash. The "Regulation Specifications" contains a detailed description of the above contents. As the reservoir environmental and ecological benefits are taking an increasingly important position in the decision-maker's preferences, the "Regulation Specifications" also set forth requirements with respect to the reservoir environment, silt and the ecological regulation of the reservoir area. It should be noted that the above multipurpose decision-making process is based on the precondition that the safety of the hydro-complex is assured.

## 3 RESEARCH AND PRACTICE

The Three Gorges Project impounds water in phases. On June 1, 2003, the Three Gorges Reservoir lowered gates to impound water for the first time, kicking off operations in the cofferdam power generation period, in which the water level of the reservoir was maintained at 135~139m. In June 2006, the upstream Phase 3 cofferdam was blown up and the dam assumed the full role of blocking water. In October of the same year, impounded water reached a level of 156m and the hydro-complex entered into its initial operation period. It's projected that the

reservoir will begin normal operations in 2008, with a normal pool level (NPL) of 175 m and a flood control level (FCL) of 145 m.

The operation management of the Three Gorges Hydro-Complex has been going on for nearly four years, and the project's benefits in flood control, power generation and navigation have gradually come into play; benefits in various aspects are becoming increasingly apparent after the NPL reached the 156 m level. Over the past four years, the integrated regulation management system of the Three Gorges-Gezhouba Cascade Hydro-Complex has largely taken shape. Figure 1 shows the various data and related business processes in regulation management.

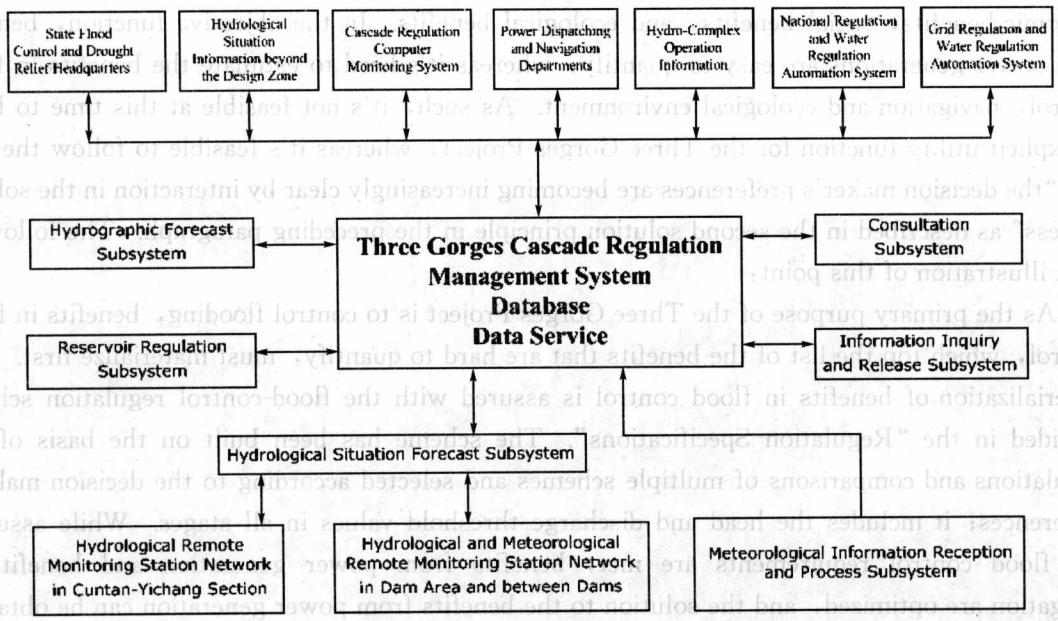


**Figure 1 Regulation Management Data and Business Flow Chart of Three Gorges-Gezhouba Cascade Hydro-Complex**

Figure 1 indicates that the meteorological and hydrographic information collection system is the foundation of the entire regulation management, while forecasts are the basis of regulation management decisions. Moreover, many departments are involved in regulation management, including the State Flood Control and Drought Relief Headquarters, the Yangtze River Flood Control Headquarters, transportation and navigation departments, the State Power Grid Company, etc.

The integrated regulation management of the Three Gorges Hydro-Complex involves a lot of work in various aspects. The following section is a description of the research achievements obtained from regulation management practice since the reservoir was put into operation.

### 3.1 Meteorological and Hydrological Forecasting

(Ⅰ) Meteorological Forecasts

At present, meteorological fore # asts take place as follows: at 9: 30 each morning, precipitation in the six sections in the upstream valley (see Table 1 & Figure 2) is forecasted and published; on Thursday and Sunday, precipitation in the upstream valley for the following week is forecasted; on the 10th day of each month, precipitation trends for the following month are forecasted; in March, precipitation trends in the wet season is forecasted. In the wet season or in other special circumstances, regulation departments will consult with meteorological and hydrographic departments through the consultation system.

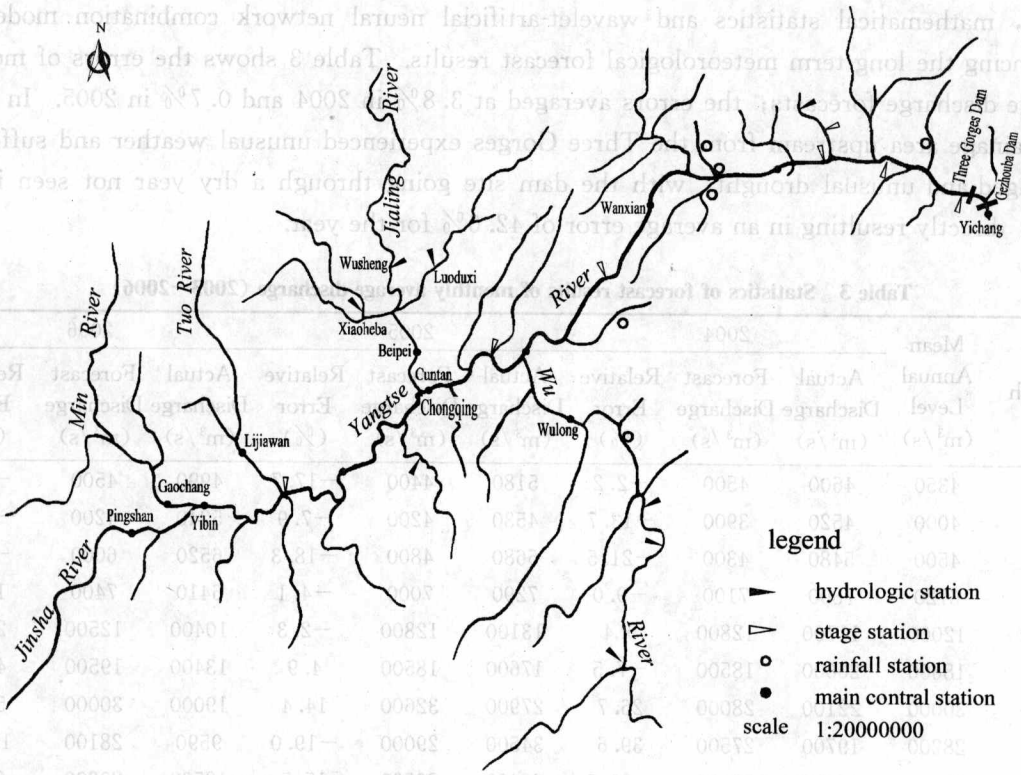


**Figure 2 Sketch map of TGP upstream watershed**

Table 1 shows the accuracy of short-term (24h and 48h) precipitation forecasting in 2004—2006; Table 2 shows the accuracy of 24-hour heavy precipitation forecasting in 2004—2006.

**Table 1 Statistics of accuracy of short-term precipitation forecasts in 2004—2006 (%)**

| | | Min Tuo River | Jialing River | Wu River | Yibin-Chongqing | Chongqin-Wanxian | Wanxian-Yichang | Overall |
|---|---|---|---|---|---|---|---|---|
| 24h | 2004 | 75 | 86 | 79 | 77 | 82 | 86 | 81 |
| | 2005 | 69 | 77 | 80 | 73 | 77 | 80 | 76 |
| | 2006 | 81 | 87 | 85 | 84 | 89 | 85 | 85 |
| 48h | 2004 | 69 | 69 | 67 | 67 | 71 | 72 | 69 |
| | 2005 | 75 | 76 | 78 | 72 | 75 | 78 | 76 |
| | 2006 | 81 | 85 | 80 | 78 | 87 | 81 | 82 |

**Table 2 Statistics of accuracy of 24-hour heavy precipitation forecasts in 2004—2006 (%)**

| | Mintuo River | Jialing River | Wu River | Yibin-Chongqing | Chongqin-Wanxian | Wanxian-Yibin | Overall |
|---|---|---|---|---|---|---|---|
| 2004 | 25 | 75 | 63 | 31 | 61 | 57 | 52 |
| 2005 | 50 | 65 | 50 | 38 | 52 | 54 | 52 |
| 2006 | 83 | 75 | 66 | 21 | 54 | 62 | 60 |

The tables show that in 2004, 24 h and 48 h precipitation forests in the upstream valley were 81% and 69% accurate respectively, and that the 24 h forecast of precipitation exceeding 20 mm was 52% accurate. These three indicators stood at 76%, 76% and 53%, respectively in 2005, and reached 85%, 82% and 60%, respectively, in 2006.

(Ⅱ) Hydrographic Forecasts

(1) Long-Term Hydrological Forecasting

Long-term hydrological conditions are forecasted using the dry season graded recession