Water resources Operation System in China

Xiaohui Lei

2018.6.27

China Water Resources & Hydropower Research

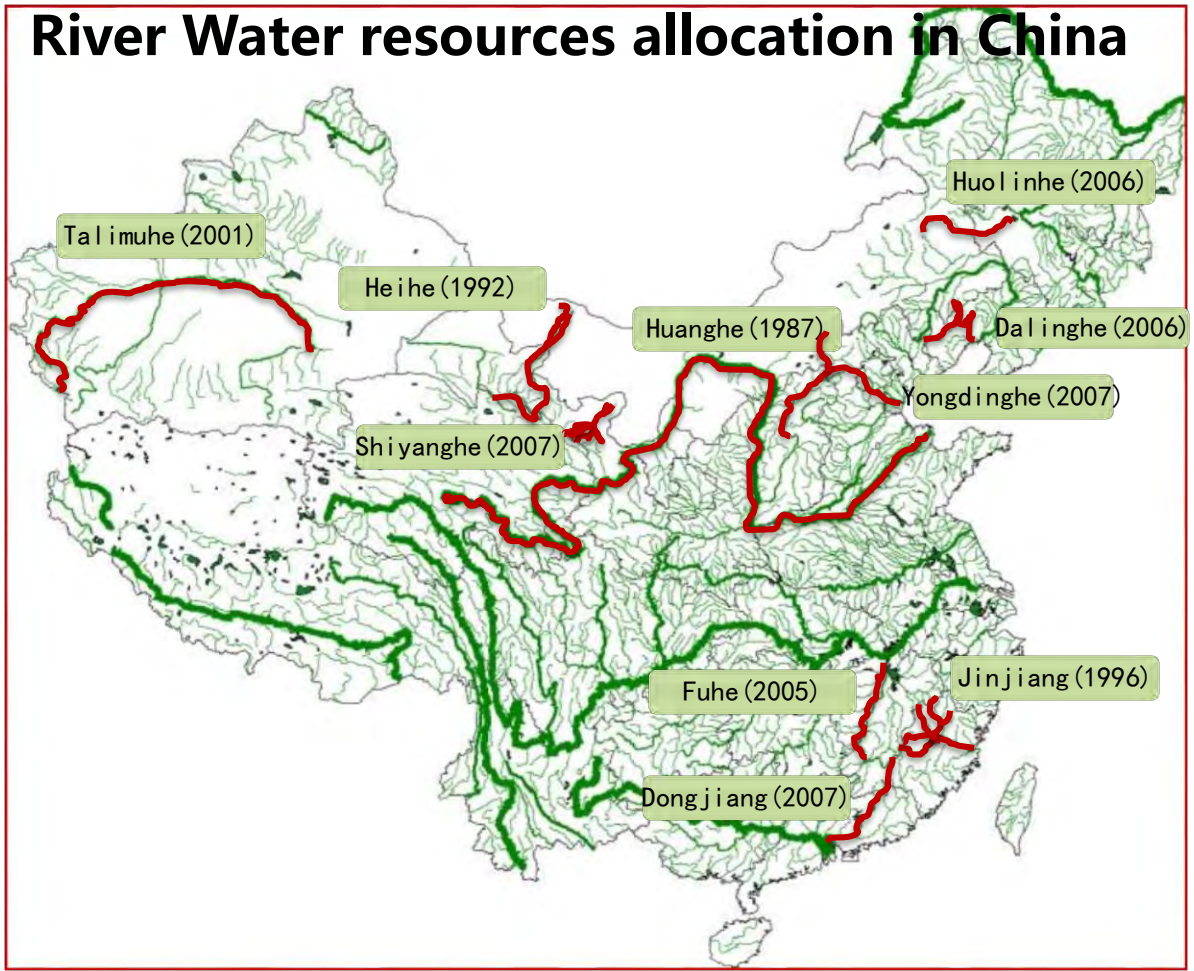
State key laboratory of Simulation & Regulation of Water Cycle in River Basin

CONTENT

CONTENT

1. Background

In the field of water resources research and practice, the allocation and operation management of river water resources has always been the hot topic.



- The trans-provincial water resources allocation of th e Yellow River formulated in 1987 is the most repres entative practice.
- By now, water resources allocation over 40 rivers have been achieved at national, watershed or provincial level.

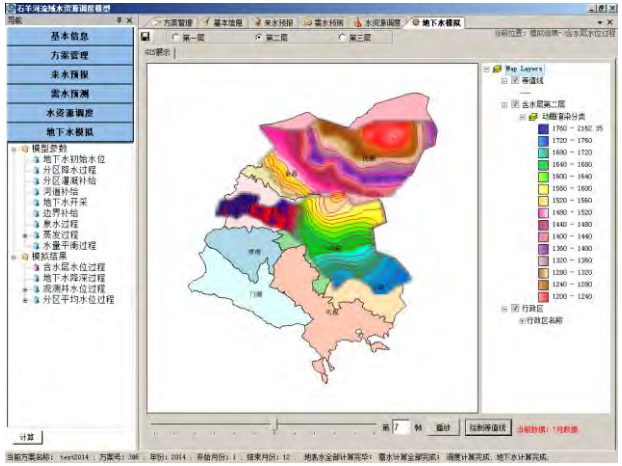
1. Background

City of Beijing

Various systems have been designed for specific Water resources operation applications with many drawbacks including **difficulty to develop**, **poor universality**.

Weihe

Shiyanghe



1. Background

National Water resources Monitoring Capacity construction project NWMC

NWMC (2012-2018, total investment of 4 billion CNY)

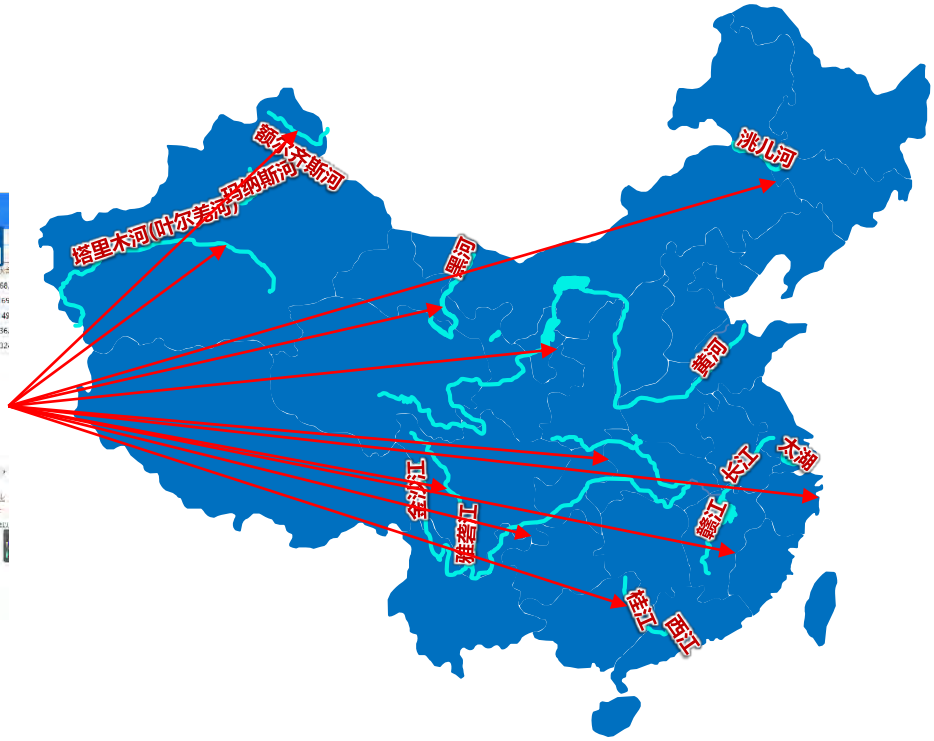
http://szyjk.mwr.gov.cn/

Water resources operation application system is the core software.

1. Background

Development Platform of Water resources Operation Software

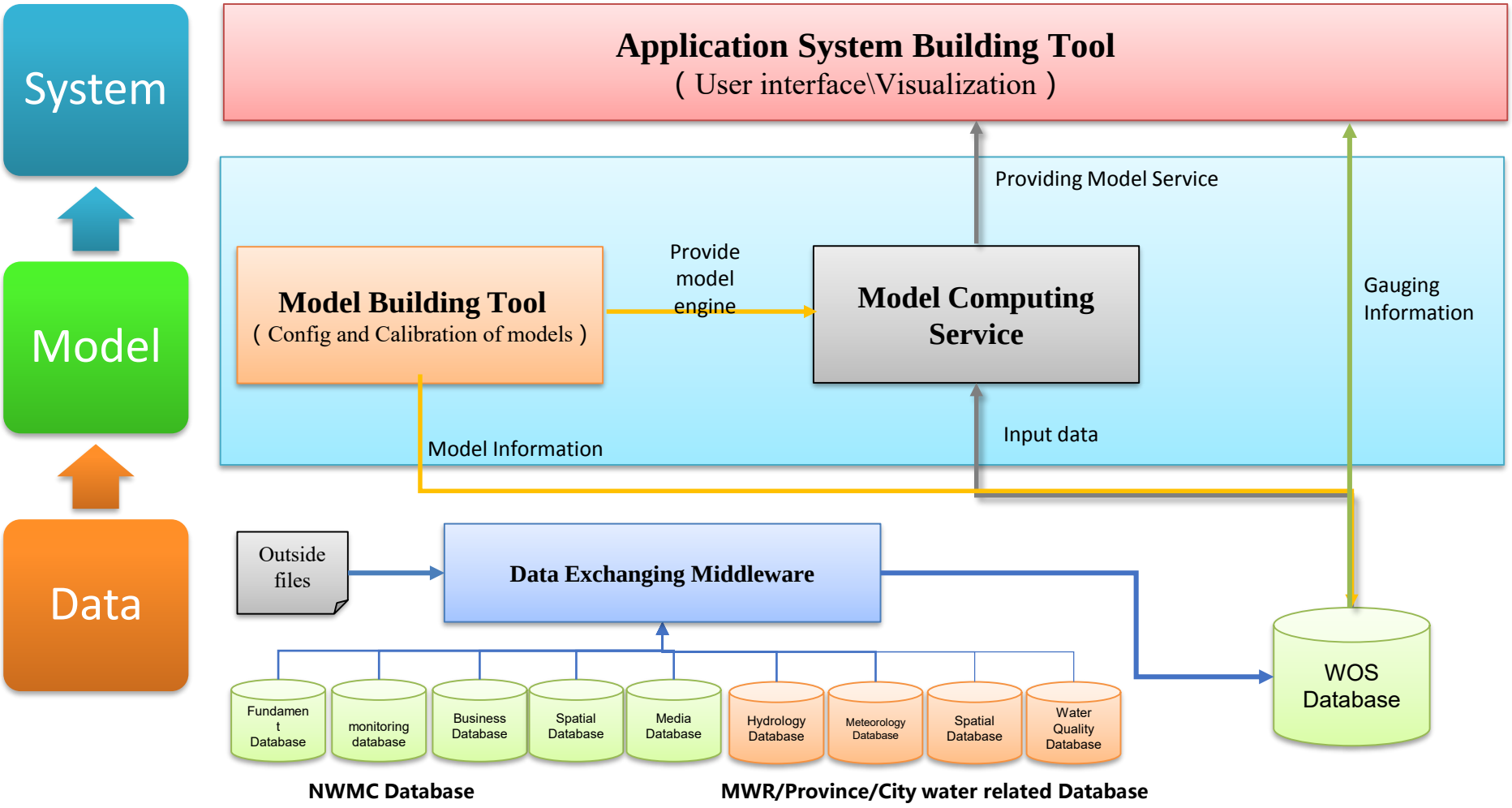
As the organizer of NWMC, We begin to develop a software that can generate a specific water resources operation software (WOS), we call it **Development Platform of Water resources Operation Software** (DPWOS).



1. Background

Development Platform of Water resources Operation Software

Structure of Development Platform



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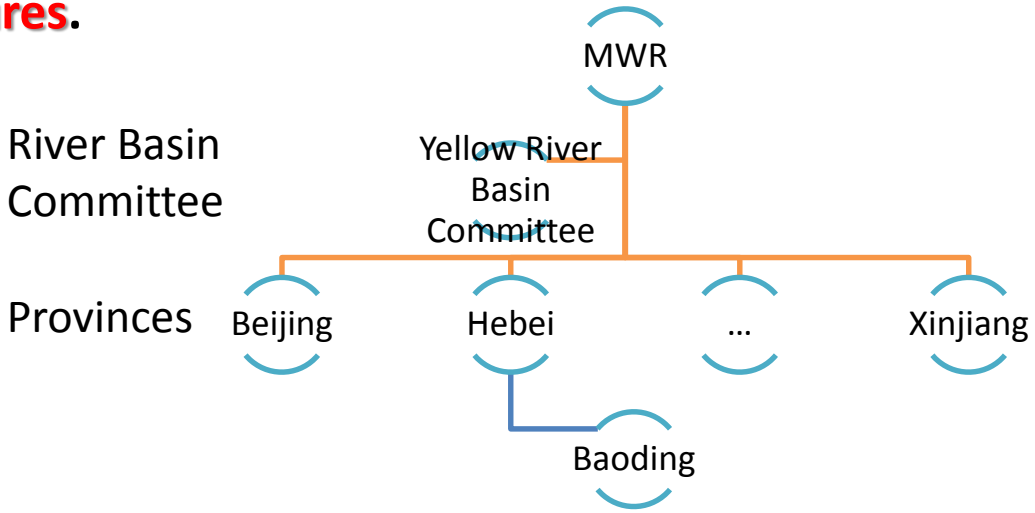
2.1 National Water Resources Monitoring Capacity

1. Water Resources Operation Database

Hydrological, water use and water quality monitoring capacity are greatly improved up to today, however water related data are distributed in different departments with different structures.

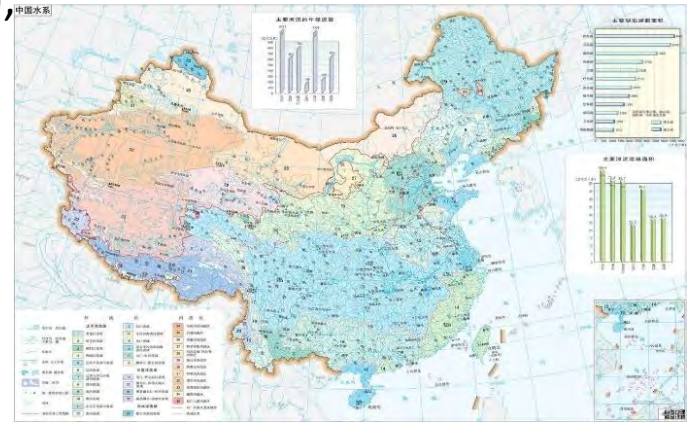


1. Hydrological Monitoring

- 54, 476 rainfall stations
- 7, 113 hydrometric stations
- 13, 579 water level stations

2. Water Use Monitoring

- Water use quantity monitored >= 50% (from 33%), 3, 119 billion m^3, 20, 248 water users.
- Non-agricultural water = 72%, 1, 532 billion m^3.
- Agricultural water=40%, 1, 487 billion m^3.



3. Water quality Monitoring

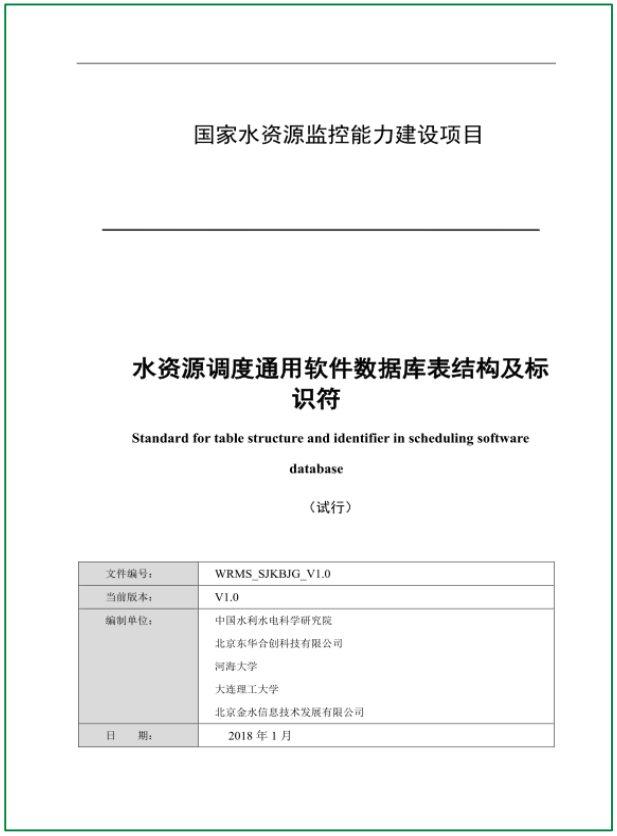
- 16, 123 Surface water stations
- 17, 836 groundwater stations.

2.2 Database Standardization

1. Water Resources Operation Database

Firstly, a database standard was established, about 6 categories, 118 database tables were designed for water resources operation system.

Standard for table structure and identifier in operation software database



国家水资源监控能力建设项目

水资源调度通用软件数据库表结构及标识符

Standard for table structure and identifier in scheduling software database

（试行）

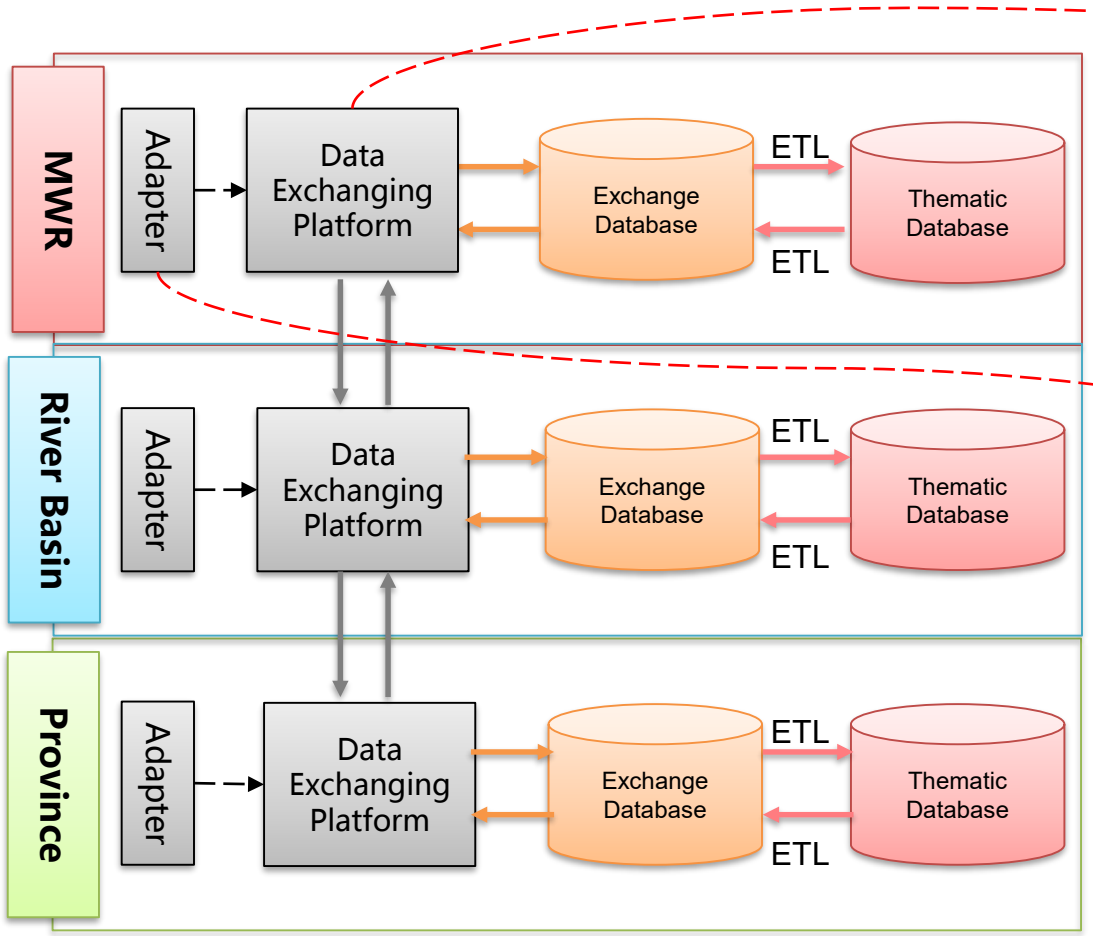
文件编号：	WRMS_SJKBJG_V1.0
当前版本：	V1.0
编制单位：	中国水利水电科学研究院 北京东华合创科技有限公司 河海大学 大连理工大学 北京金水信息技术发展有限公司
日　　期：	2018 年 1 月

Table Type	Count
Observed data	8
Entity data	20
Model data	11
Operation Business data	41
Model Cloud Service data	14
Platform System data	24

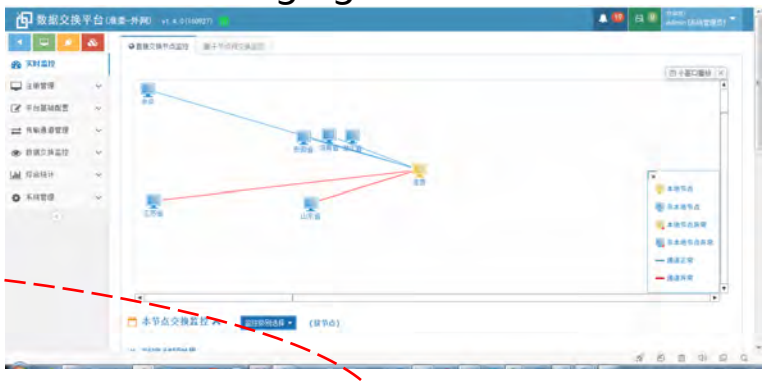
2.2 Database Standardization

2. Three-level Data Exchanging Middleware

A three-level data exchange system is developed for national-basin-provincial water resources management, which improves data consistency between different levels and departments.



Data Exchanging Platform Software



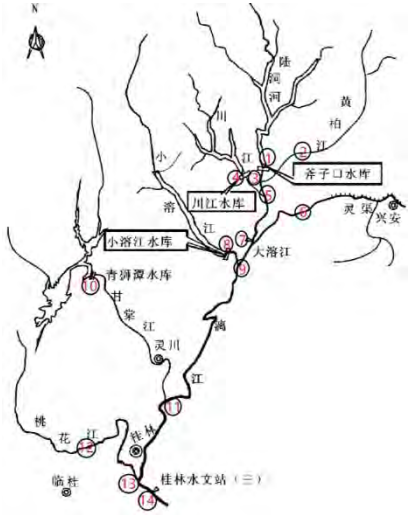
Data Exchanging Adapter Software

CONTENT

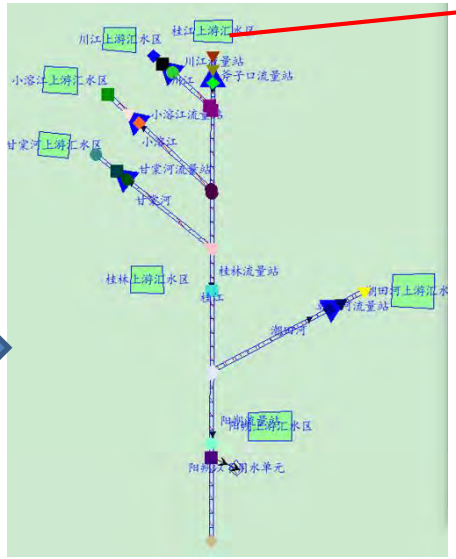
3.1 Challenging

Idea

Real Network



Generalized Network



Catchment Entity

Customized Model

Standard Model

parameter

Xinanjiang model

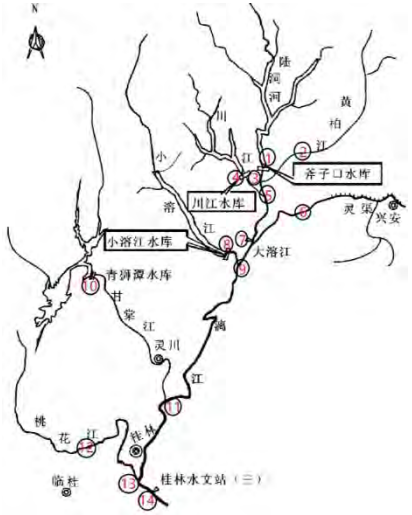
Our idea is develop a tool, with which you can draw **the generalized water resources network** which contains different water entities, including the catchment, river, intake, projects and soon on.

Such as the upstream catchment of Lijiang, you can build **a customized model** based on **a standard Xinanjiang model** by configuring the all related parameters.

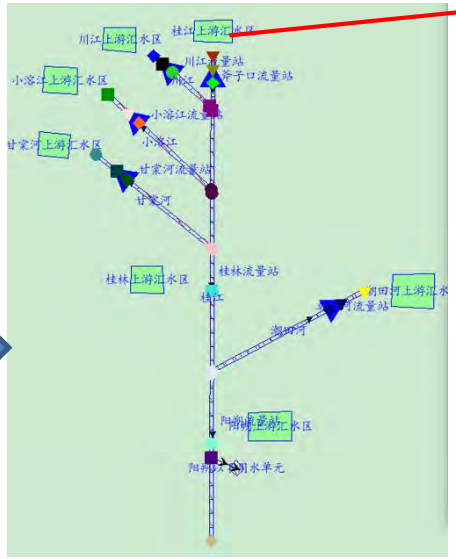
3.1 Challenging

Idea

Real Network



Generalized Network



Catchment Entity

Customized Model

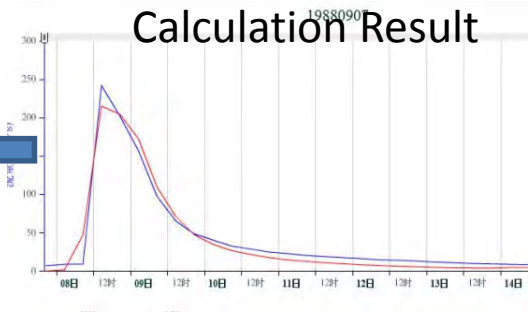
Standard Model

parameter

Xinanjiang model

Observed data

Calculation Result



User Interface

And you can get the **forecasting runoff** by inputting observed rainfall. Finally the manager or end user can get the **visualized result** with table, chart and soon on.

3.1 Challenging

Facing Problems

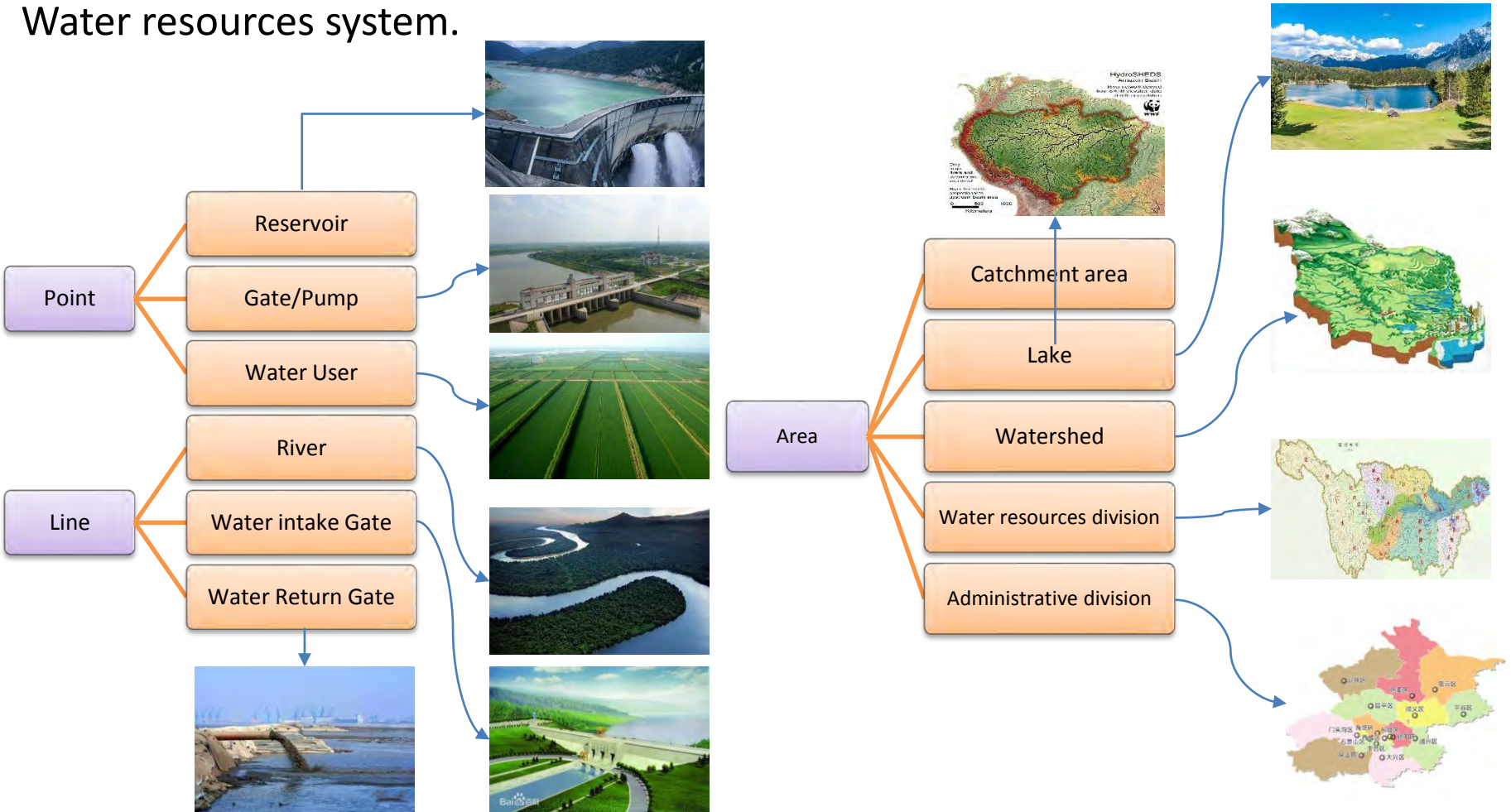
In model integration process, we are facing several challenges:

- Lack of water entity classification and management standard
- Lack of model Input/output interfaces standard
- Lack of convenient model building tool
- How to support different model encapsulation methods, e.g. exe/dll/jar
- How to support a large number of concurrent requests

3.2 Model Standardization

1. Water Entity

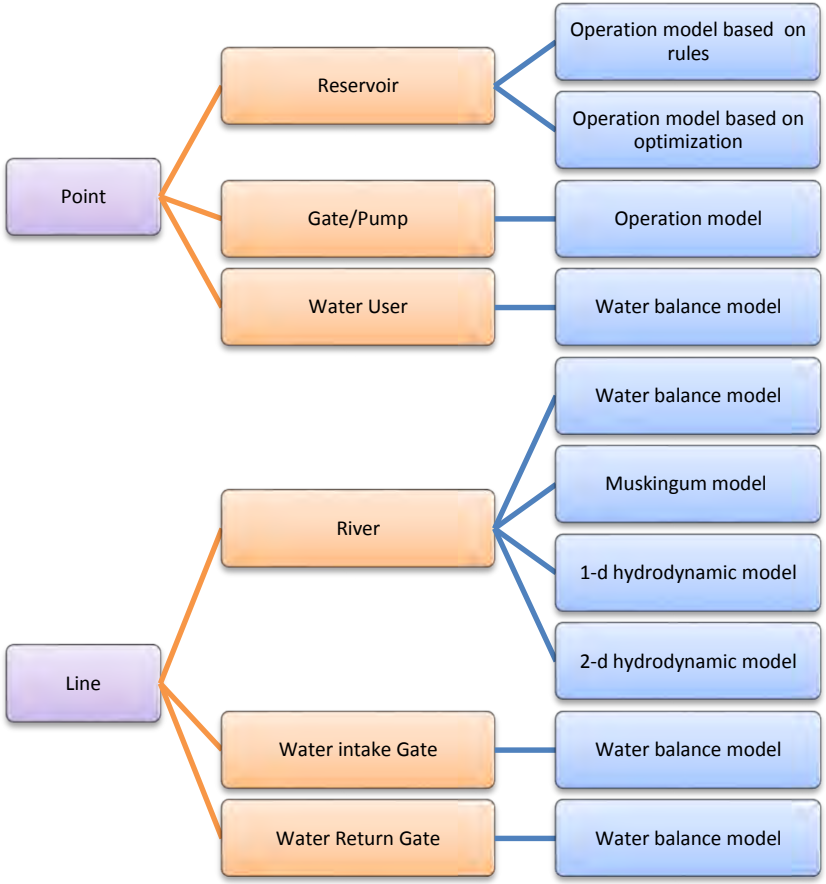
As you can see, there are many entities in a water resources system. And In our platform, we defined **3 categories** (point, line and area) and **13 types of water entity** such as reservoir, pump, river and etc. to classify the various entities within a Water resources system.

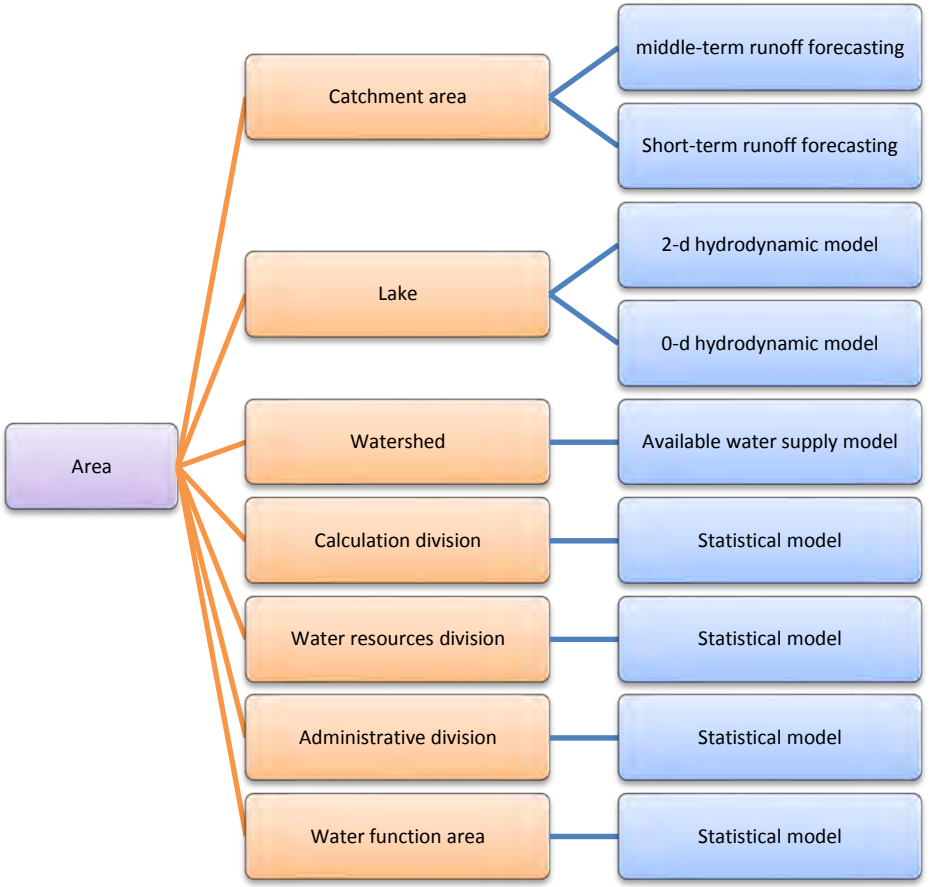


3.2 Model Standardization

2. Standard Models

Furthermore, there are **19 default standard models** in our software correspond to different types of entity, and it is assured that each type of entity has one default model at least.

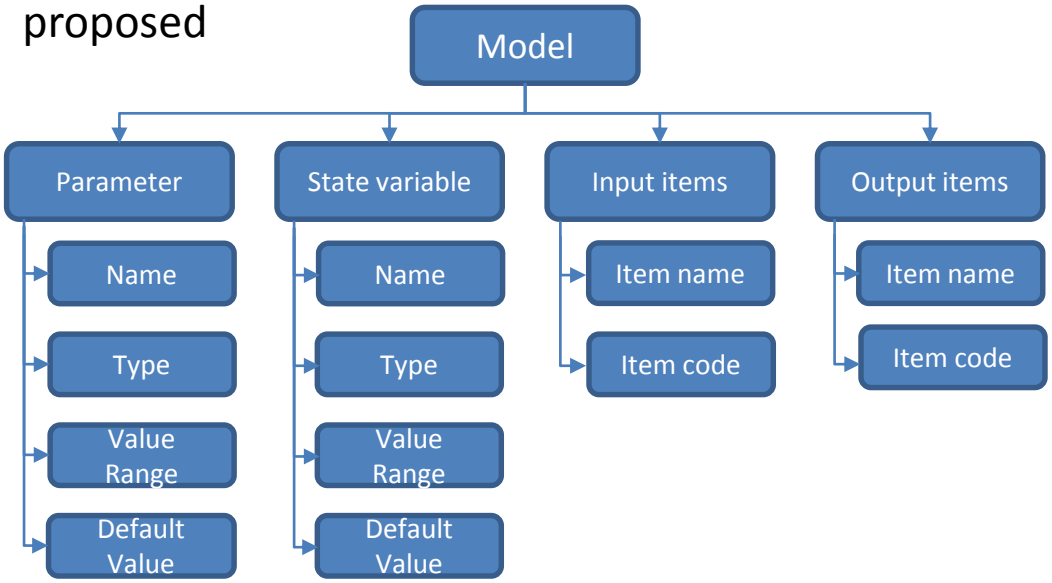




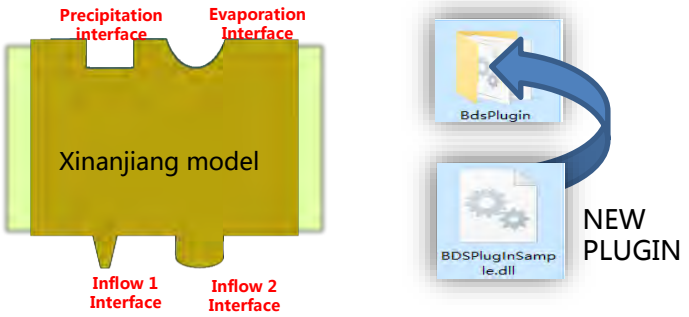
3.2 Model Standardization

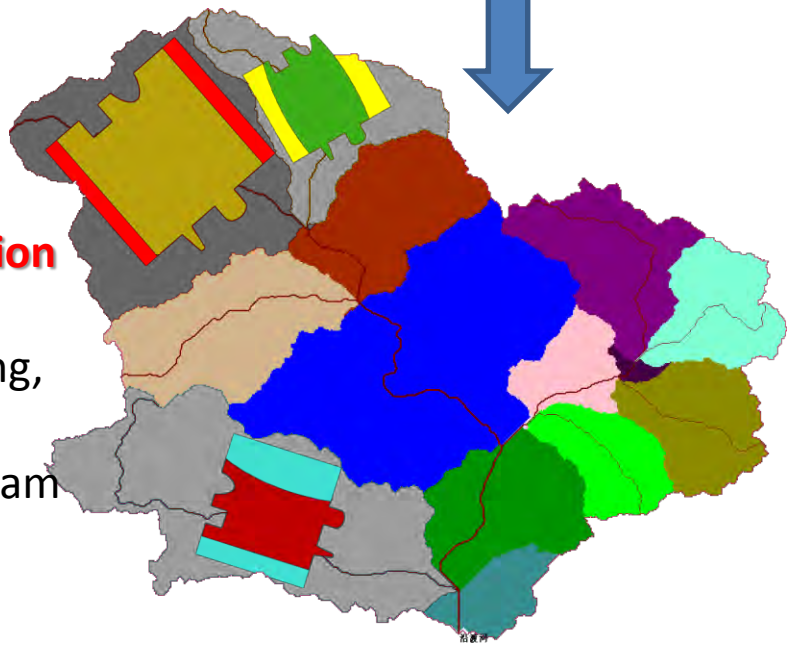
2. Standard Models

Standard interfaces of various models (Simulation, Forecasting and Operation) are proposed



Open system, plug-in expansion





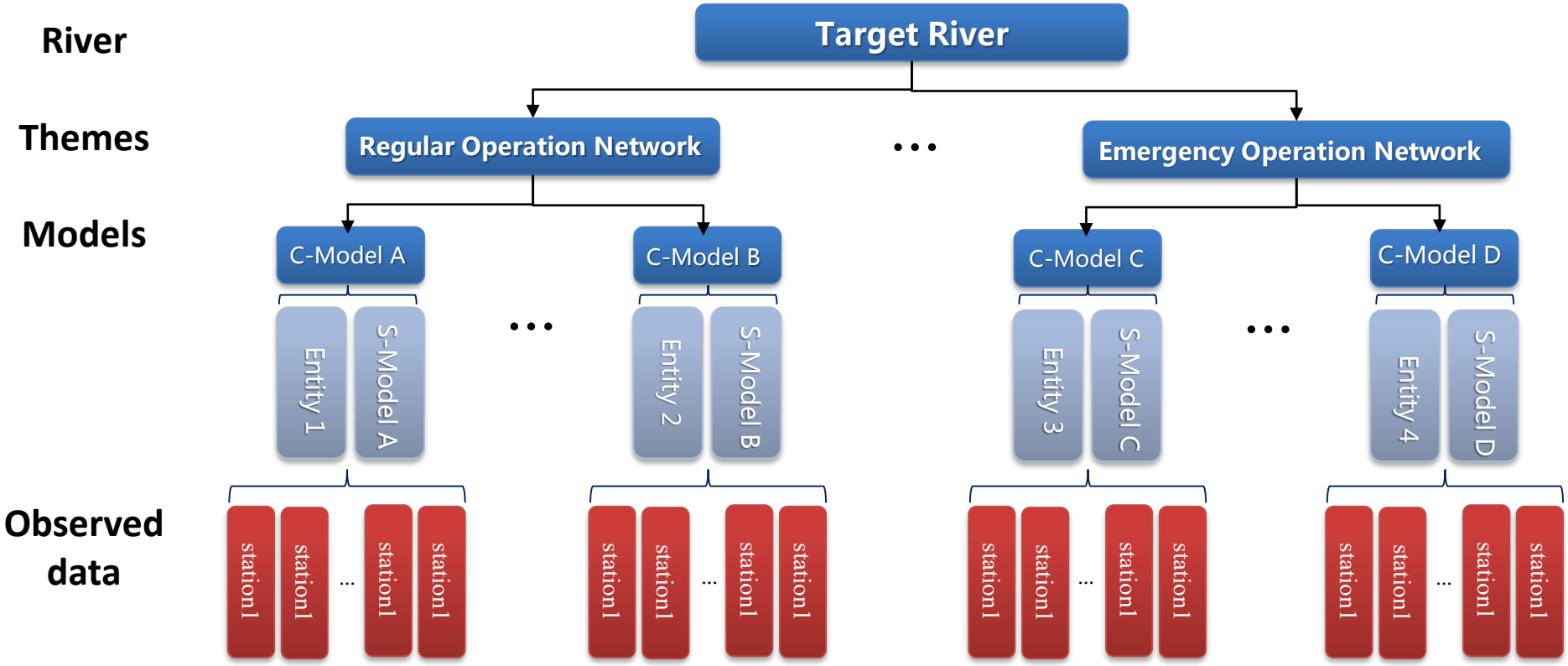
For example, by defining **standard hydrological simulation input/output interfaces**, the software can support different kind of hydrological models including xinanjiang, TOP model and shanbei model and so on, so we can connect different hydrological model in different upstream or downstream sub-catchment and **make our model library extensible**.

3.2 Model Standardization

3. Model Coupling

Generally different networks could be drawn for different water resources operation themes, such as **regular operation** or **emergency operation**.

For example, short-term forecasting model for emergency operation, and middle or long term forecasting model for regular operation.



3.2 Model Standardization

3. Model Coupling

Real Network

Take Lijiang river as example, which is composed of upstream river basin, reservoirs and river reaches, and we can set **different model compositions** for regular and emergency operation respectively.

Water Resources Network & Model Configuration

- Emergency Operation Themes
- Regular Operation Themes
  - Theme1
  - Theme2
  - Theme3
  - Theme4

River Basin Entity → Reservoir Entity → River Reach Entity

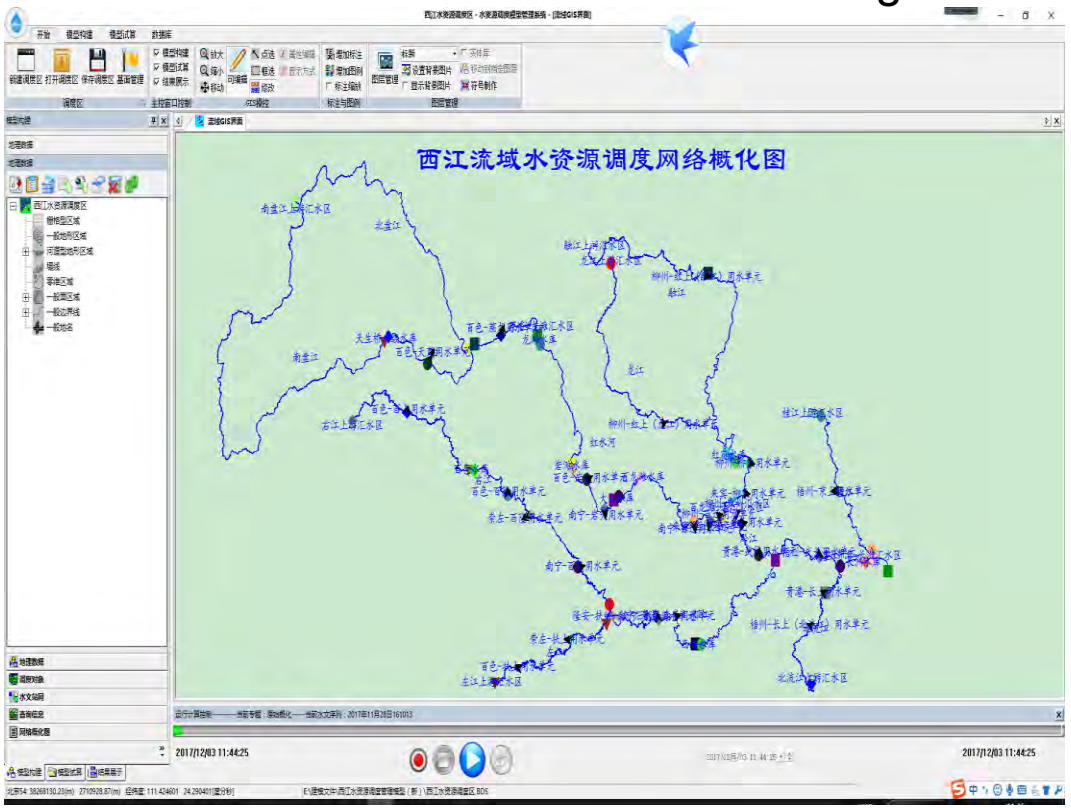
Theme1	Theme2	Theme3	Theme4
Xinanjiang Model	BP Model	AR Model	ELMAN Model
Operation Model with Plans	Operation Model with Rules	Optimal Operation Model	Optimal Operation Model
1-d hydrodynamic model	Muskingum model	Water balance model	Water balance model

3.3 Model Building Tool

Functions

- **Visual Modeling Toolbox** for all kinds of water entities
- **Topology Construction Toolbox** for related water entities
- **Parameter and model configuration** for each water entity
- **Parameter Calibration**

Software screenshots of Model Building Tool



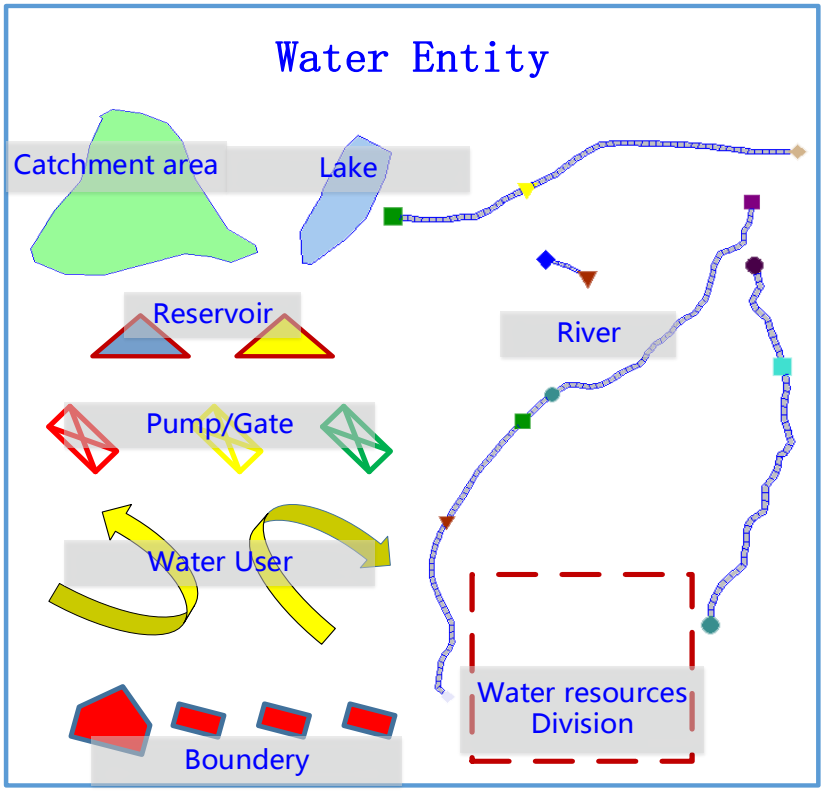
Usually, a fully functional water resources operation system needs a lot of models, therefore, we developed **model building tools**, with which the user can set all kinds of water entities, draw water resources network.

3.3 Model Building Tool

Functions

- **Visual Modeling Toolbox** for all kinds of water entities
- **Topology Construction Toolbox** for related water entities
- **Parameter and model configuration** for each water entity
- **Parameter Calibration**

Visual Modeling Toolbox covers all kinds of water entities.



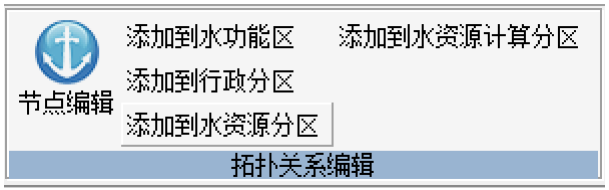
3.3 Model Building Tool

Functions

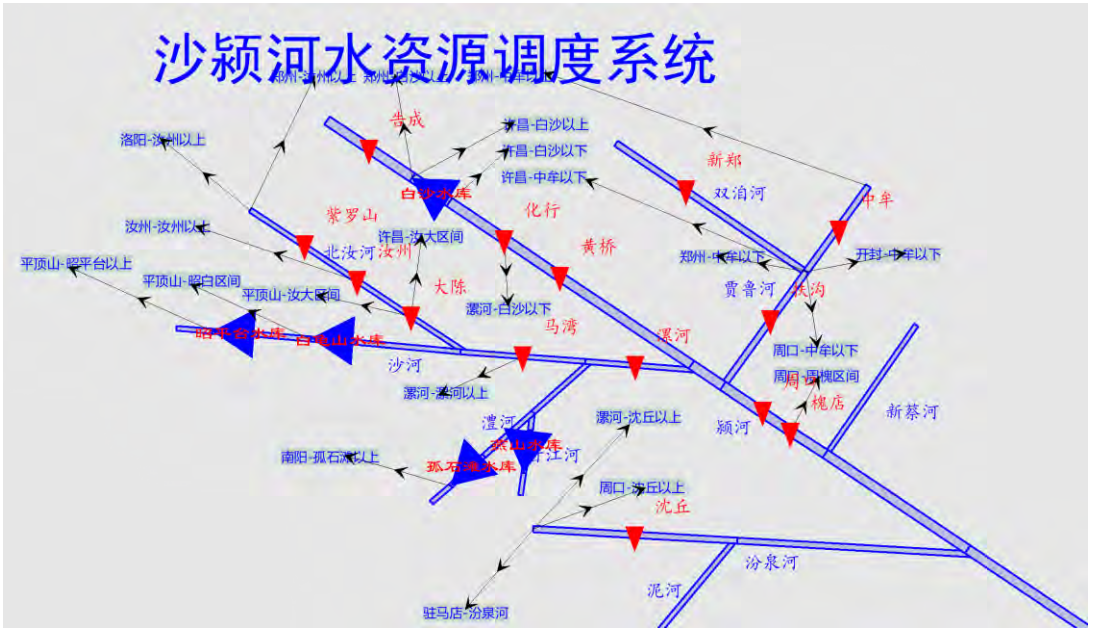
- **Visual Modeling Toolbox** for all kinds of water entities
- **Topology Construction Toolbox** for related water entities
- **Parameter and model configuration** for each water entity
- **Parameter Calibration**

The water resources network can be drawn through **Topology Construction Toolbox**.

Topology construction toolbox



Water resources network of Shaying River



3.3 Model Building Tool

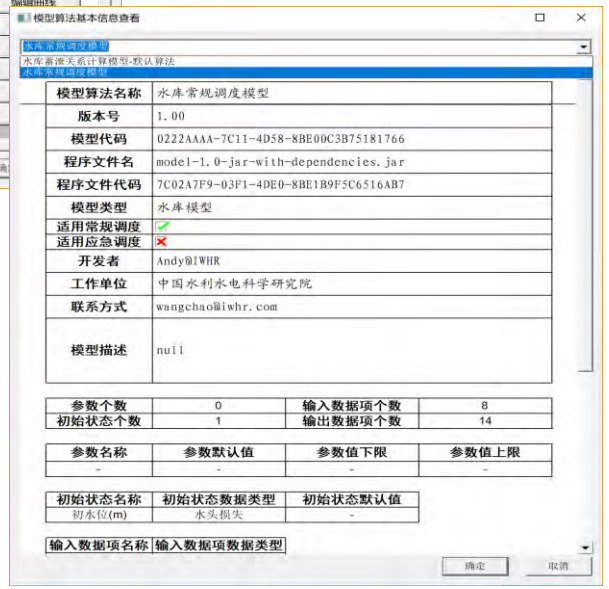
Functions

- **Visual Modeling Toolbox** for all kinds of water entities
- **Topology Construction Toolbox** for related water entities
- **Parameter and model configuration** for each water entity
- **Parameter Calibration**

Fundamental parameters configuration

- Configure entity parameters

- Configure model parameters



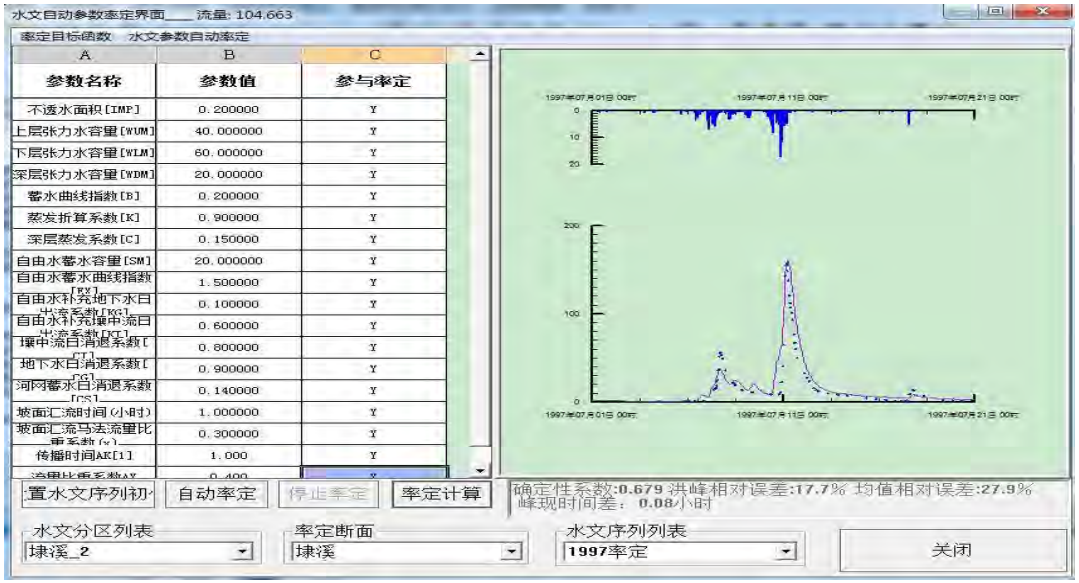
And you can configure the **parameters** and **model** for each entities

3.3 Model Building Tool

Functions

- **Visual Modeling Toolbox** for all kinds of water entities
- **Topology Construction Toolbox** for related water entities
- **Parameter and model configuration** for each water entity
- **Parameter Calibration**

→ Calibration of Model parameters

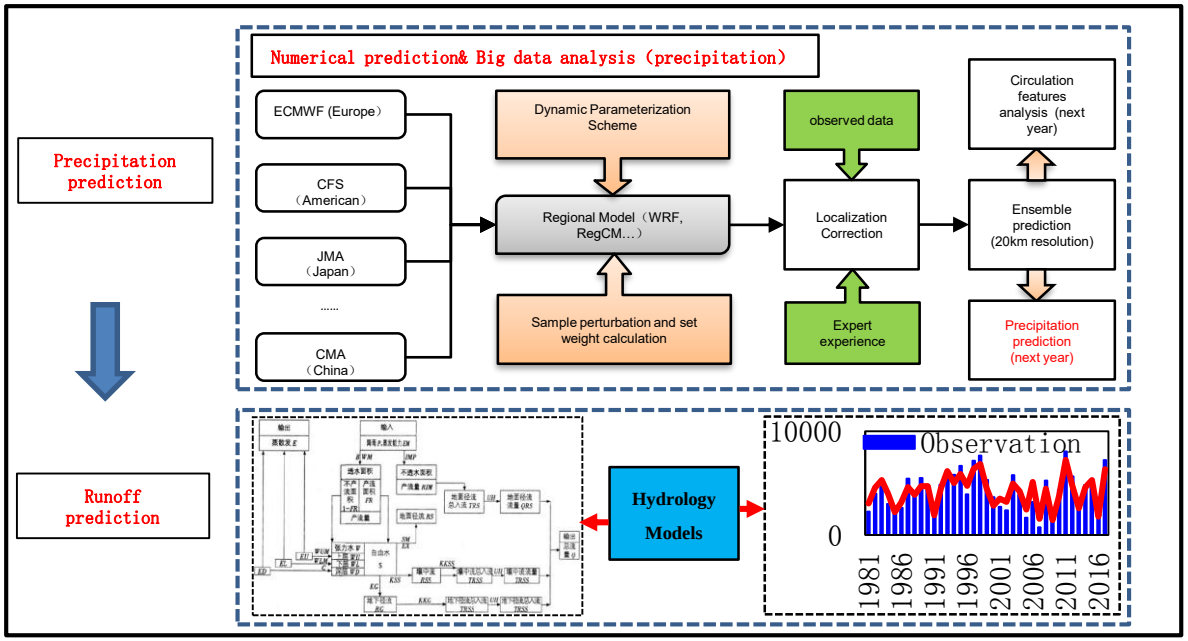


Finally the optimal parameters can be achieved by **Parameter Calibration** function.

3.4 Model Library

1. Medium-Long Term Hydrological Forecasting Model

Numerical methods



Time series

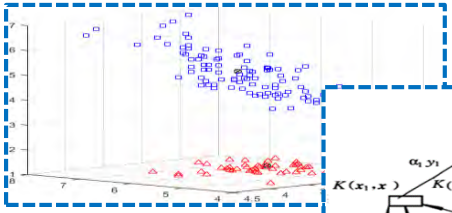
- Autoregressive model
- Markov transition model
- ……

$$z_{t,\tau} = \frac{x_{t\tau} - \mu_\tau}{\sigma_\tau} \quad \text{Standardized processing}$$

$$z_{t\tau} = \varphi_{1\tau} z_{\tau-1\tau} + \varphi_{2\tau} z_{\tau-2\tau} + \cdots + \varphi_{p\tau} z_{\tau-p\tau} + \varepsilon_{t\tau}$$

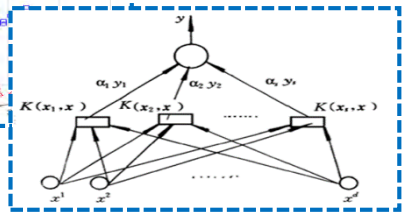
Clustering /Discrimination

- Stepwise clustering
- Distance discrimination
- ……



Modern statistical methods

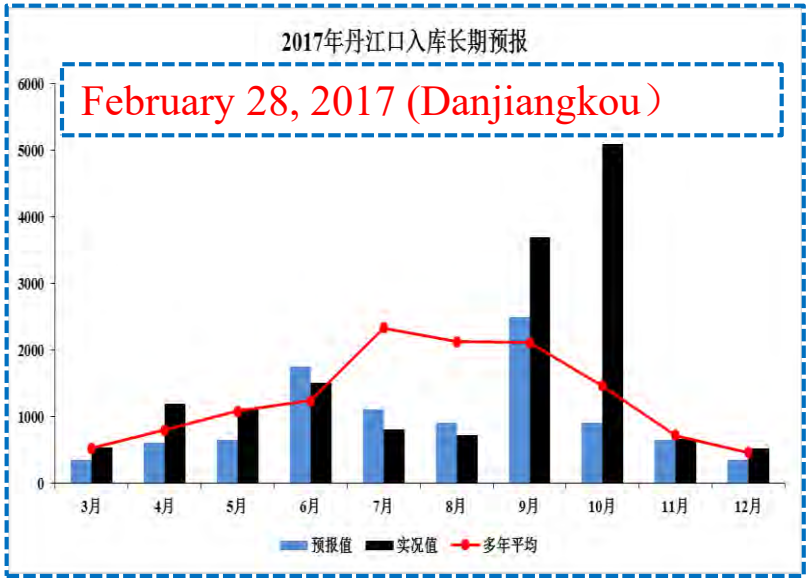
- Random forest model
- Support Vector Machine
- ……

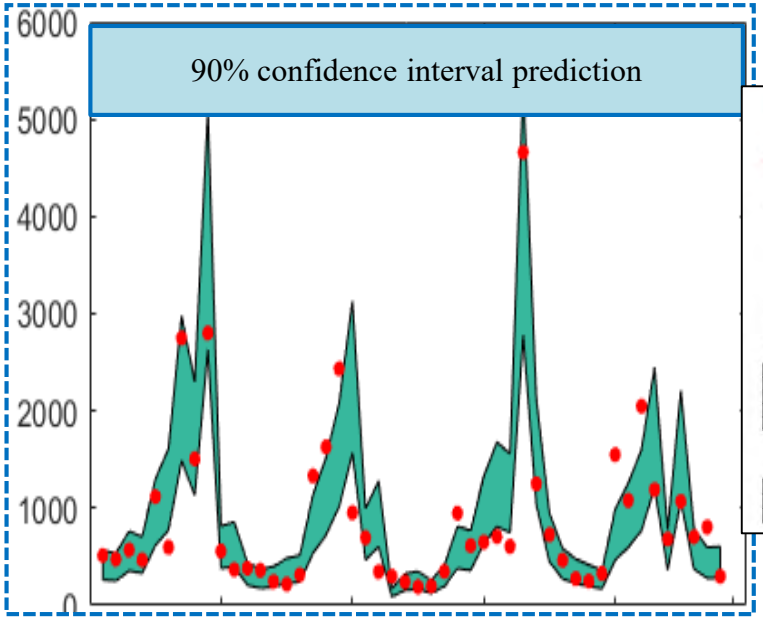


3.4 Model Library

1. Medium-Long Term Hydrological Forecasting Model

According to the above methods, a medium- long-term hydrological forecasting system platform was constructed. And the rainfall and runoff of Danjiangkou Reservoir in the next 3/6/12 months is predicted by using this system for each months.






丹江口水库降水径流预测

（第4期）

中国水利水电科学研究院　　2017年6月21日

一、降水预报

预计：未来3个月（2017年7月-9月），丹江口以上区域降水总量为303mm，较常年偏少3成左右。

表1 未来3个月降水量预报概况表（单位：mm）

时段	预报	多年平均	距平（%）
7月	108	170	-35
8月	82	146	-40
9月	112	113	0
合计	303	431	-30

二、入库径流预报

预计：未来3个月（2017年7月-9月），丹江口入库平均流量位于1417m³/s左右，较常年同期偏少约3成。

表2 未来3个月各月入库流量预报表（单位：m³/s）

时段	预报低值	预报高值	预报均值	多年平均	距平(%)
7月	1000	1600	1300	2332	-40
8月	700	1200	950	2427	-50
9月	1500	2500	2000	2110	0
平均	1067	1767	1417	2190	-30

三、5月份预报回顾

5月实际平均入库径流为1200m³/s，较常年同期偏多11%，回顾如下：

表3 5月份预报回顾评价表（单位：m³/s）

制作月份	预报值	绝对误差(m³/s)	距平误差(%)	定性评价
4月	1400	+200	+9%	正确
3月	1000	-200	-11%	正确

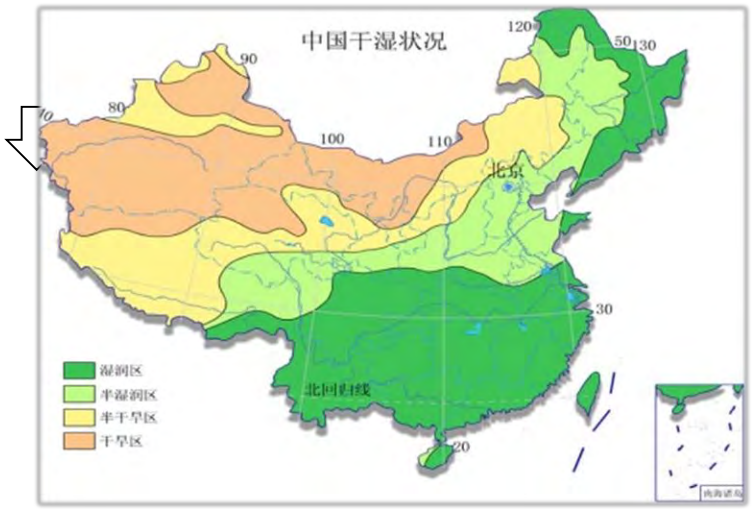
3.4 Model Library

2. Short-Term Hydrological Model

Considering differences in hydrological process in different regions, a multi-model database is established to realize the selection of multiple model methods. From river network in mountainous area to plains, all hydrological process can be simulated and analyzed.

Hydrological simulation

- Rainfall-runoff curve
- Unit hydrograph
- Linear reservoir method
- Muskingum routing
- Reservoir simulation
- Artificial neural network
- Xin'anjiang hydrological model
- Distributed hydrological model
- Dynamic model



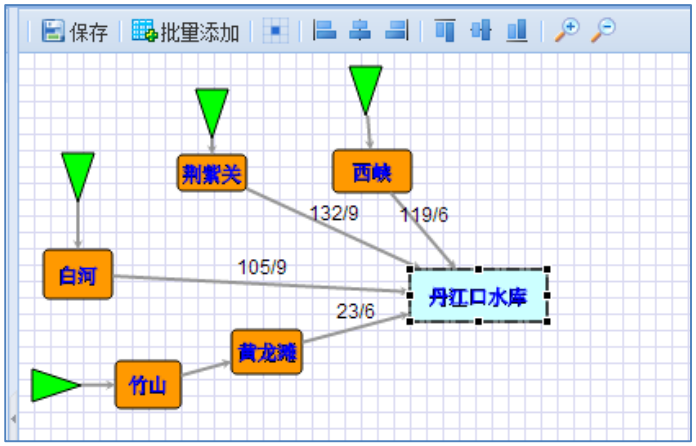
Model selection

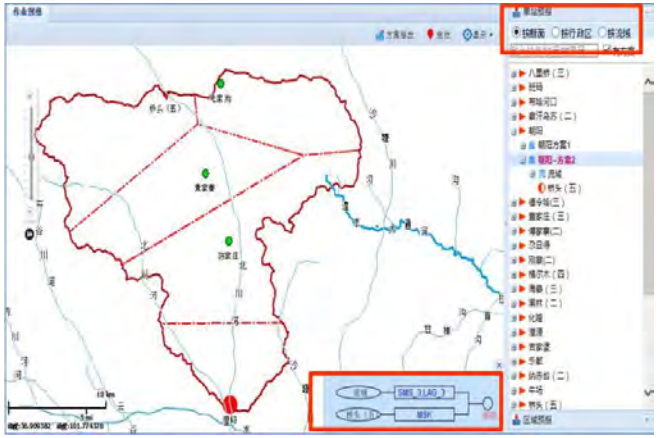
- Hydrological model
- Runoff yield + concentration
- Empirical method

3.4 Model Library

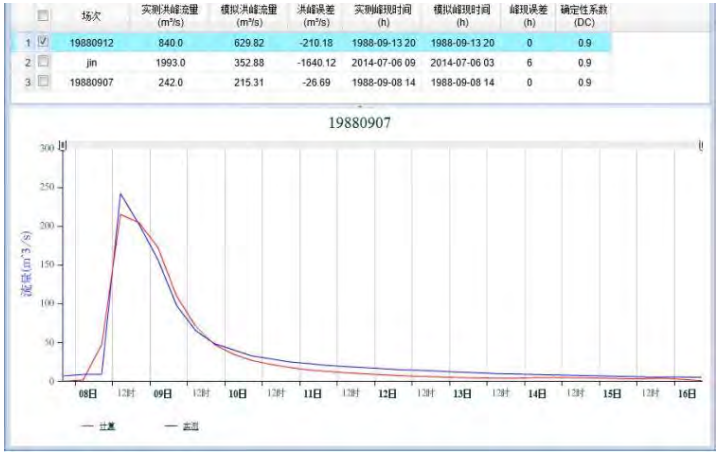
2. Short-Term Hydrological Model

Model Configuration





Model Result Analyzing

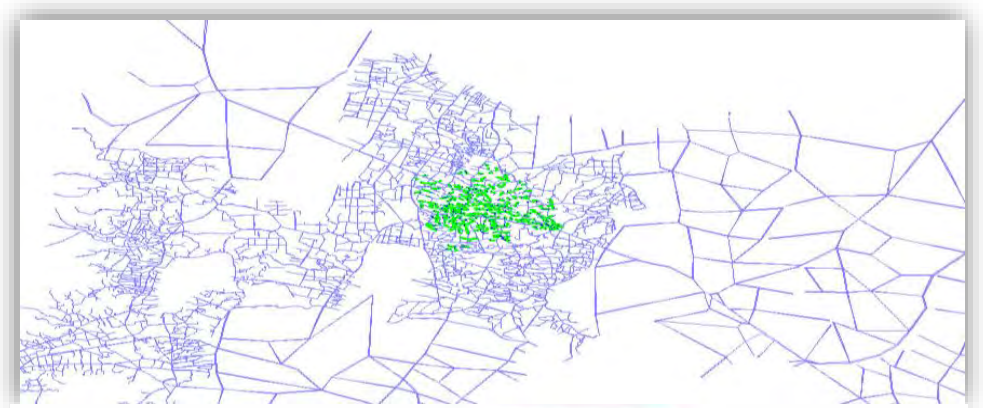


3.4 Model Library

3. Hydrodynamic Model

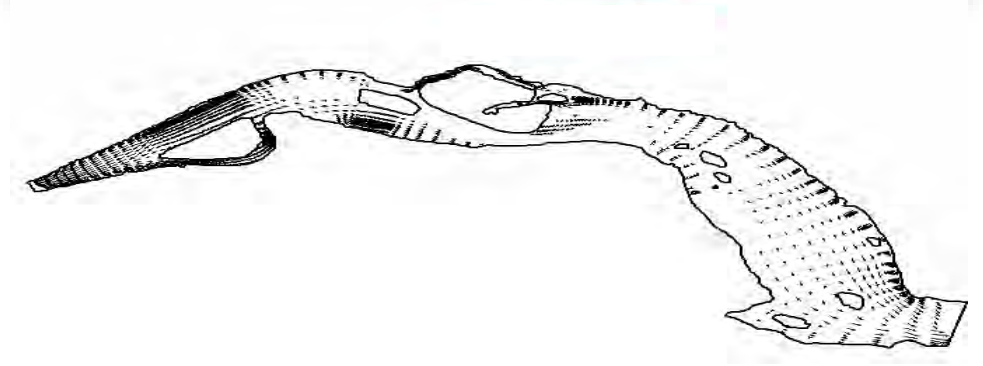
1d-HydroDynamic Model

three-stage optimization algorithm for river network based on segment-river-conjunction point mode



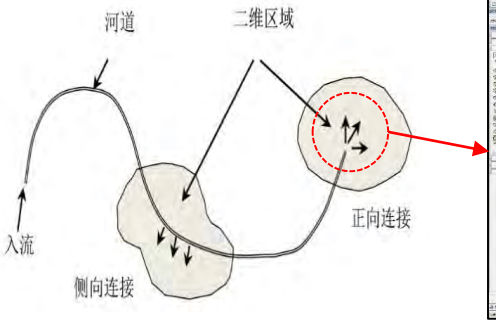
2d-HydroDynamic Model

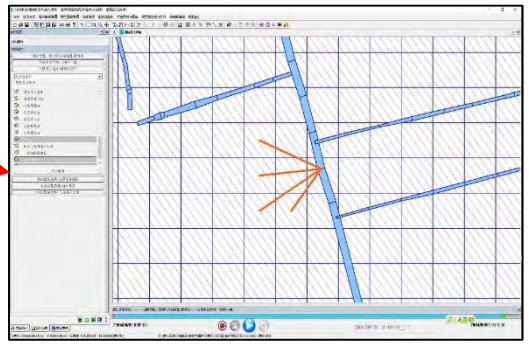
The two-dimensional riverway was disassembled into three types of computational units



1d and 2d coupled HydroDynamic Model

Two different coupling modes of forward connection and lateral connection.



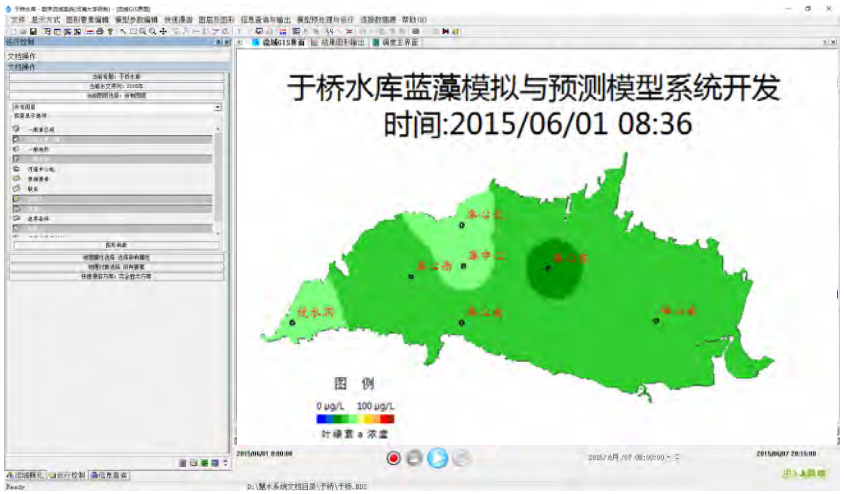


3.4 Model Library

4. Water quality Model

Hydrodynamic and water quality simulation for Taihu river network and Lake after the water diversion from Yangtze river to Taihu, including TN, TP, COD, BOD, DO etc.,

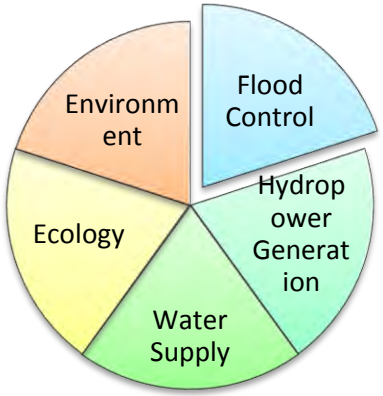
Hydrodynamic and water quality simulation
Algal growth and evolution of Yuqiao Reservoir



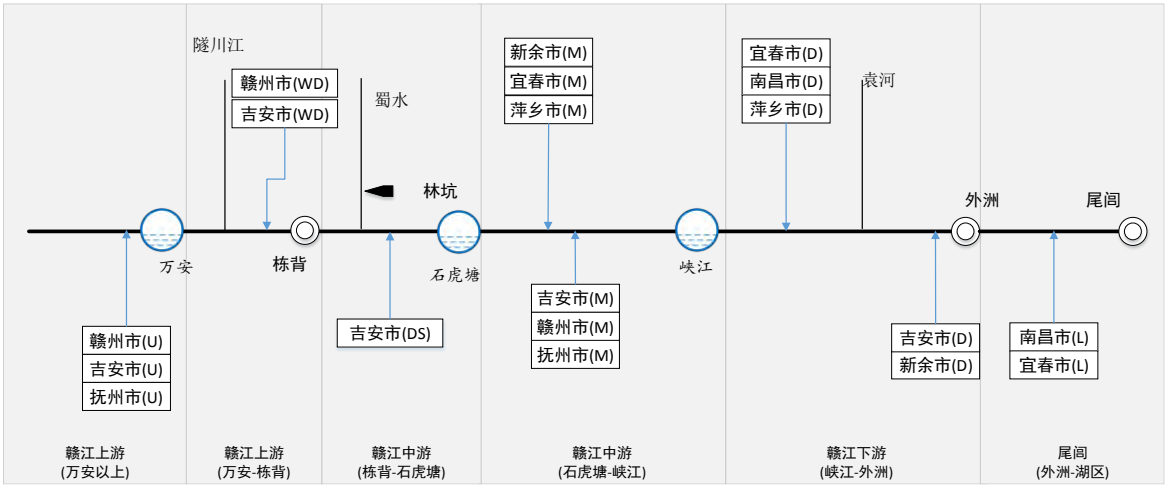
3.4 Model Library

5. Operation Model

Multiple Objectives

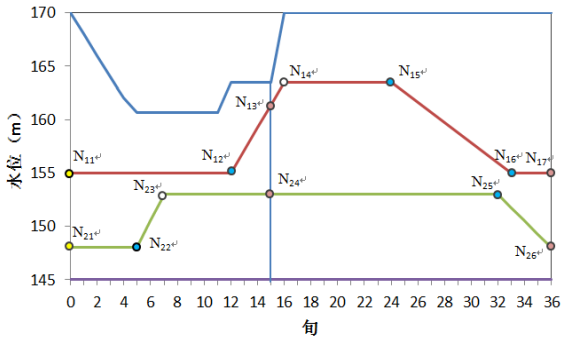


Middle/Long term Water Resources Network

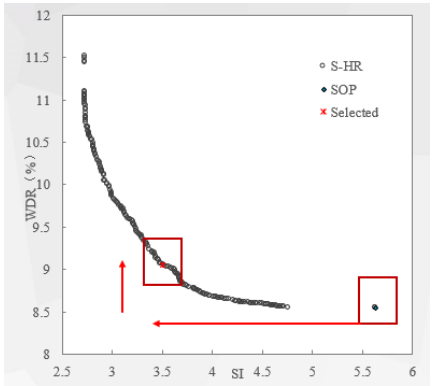


Water Project operation could be achieved based on rules or optimization.

Reservoir Operation Rules



Multiple Objectives Optimization



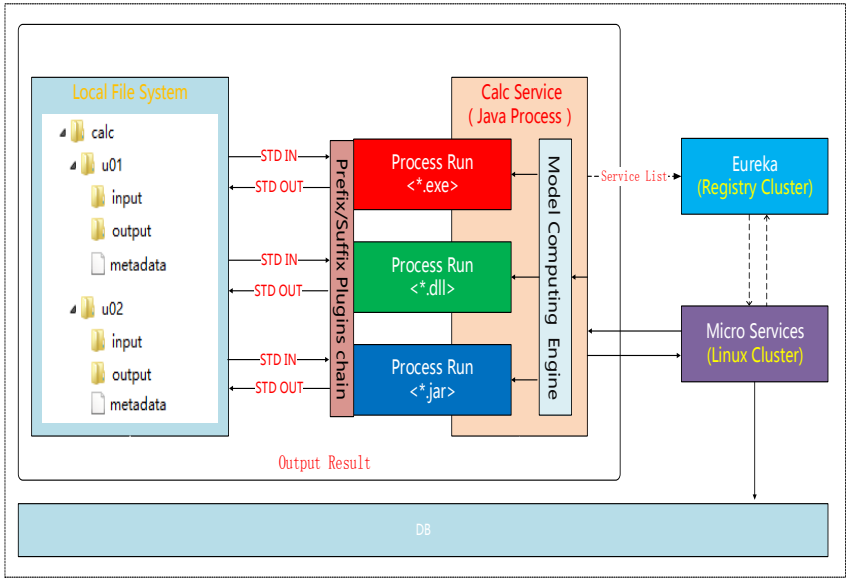
3.4 Model Library

Model computing engine for different model

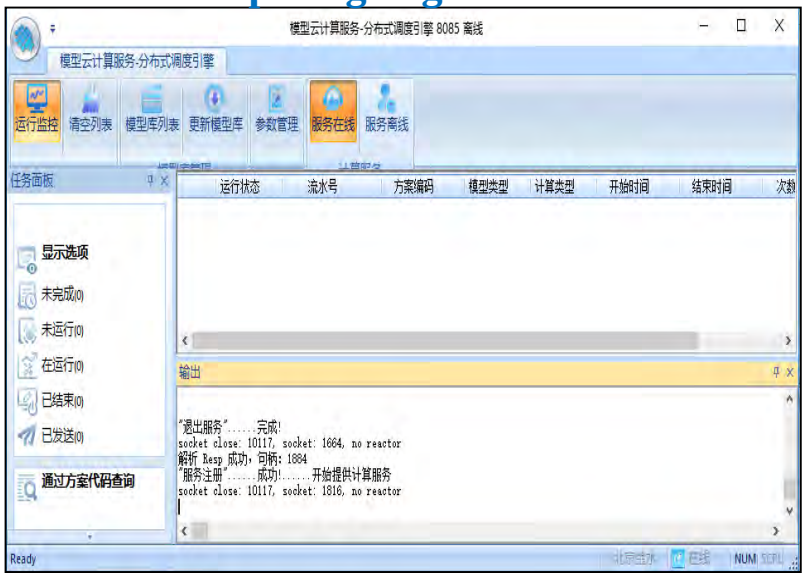
In view of the **existing professional models**, such as Jar, EXE and DLL, with files as interfaces, it is difficult to realize multi-user concurrency and difficult to monitor the running state of programs.

A model computing engine is developed, which can access different types of professional model computing files and **upgrade** model computing software to model computing Web services.

Model computing engine system architecture

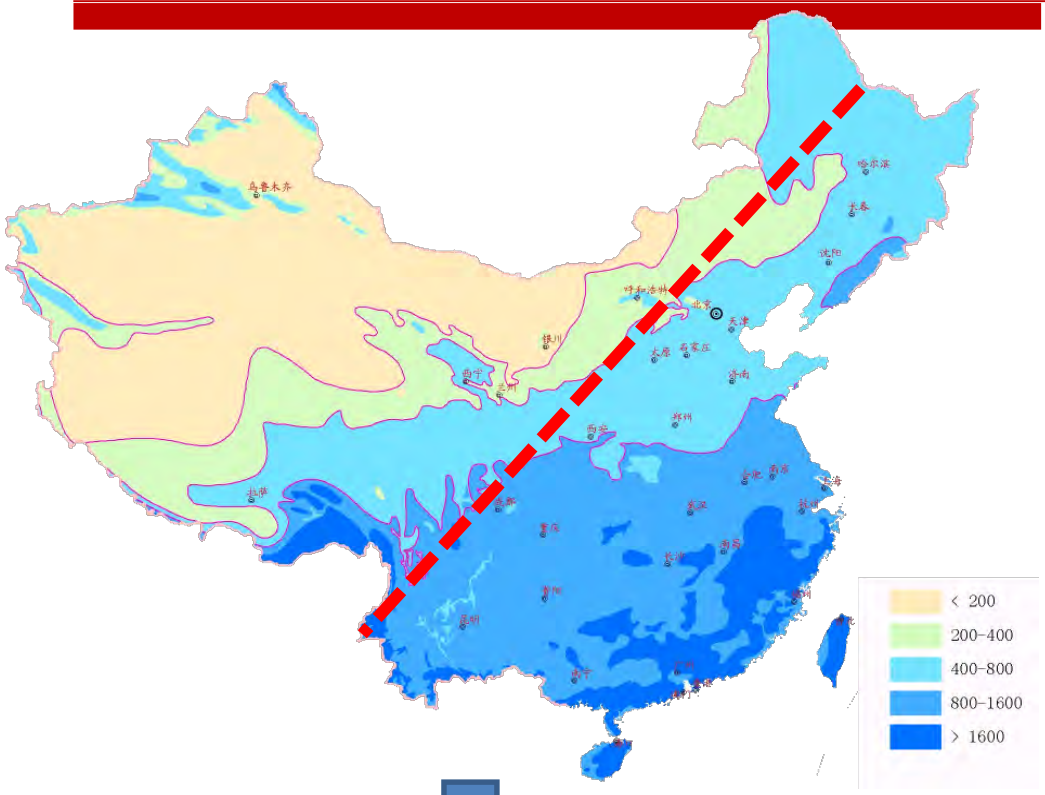


Model computing engine user interface



CONTENT

4.1Challenging



China has a vast territory, diverse climate and large differences in water use characteristics.

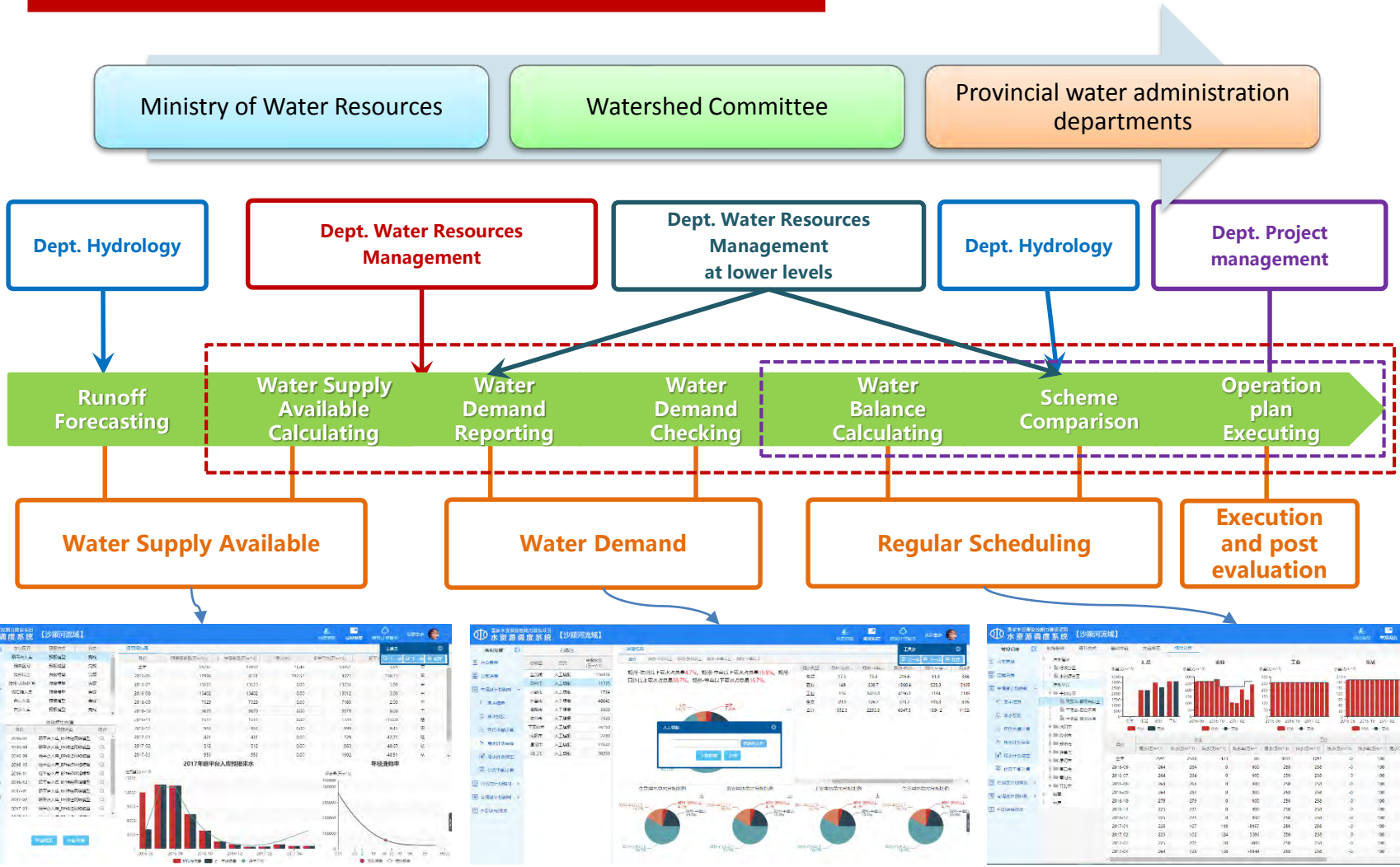
So, how to make the water resources operation system suit for different river?

How to make the system suit for different river?

1. **Business Standardization**
2. **Application System Building Tool**

4.2 Business Standardization

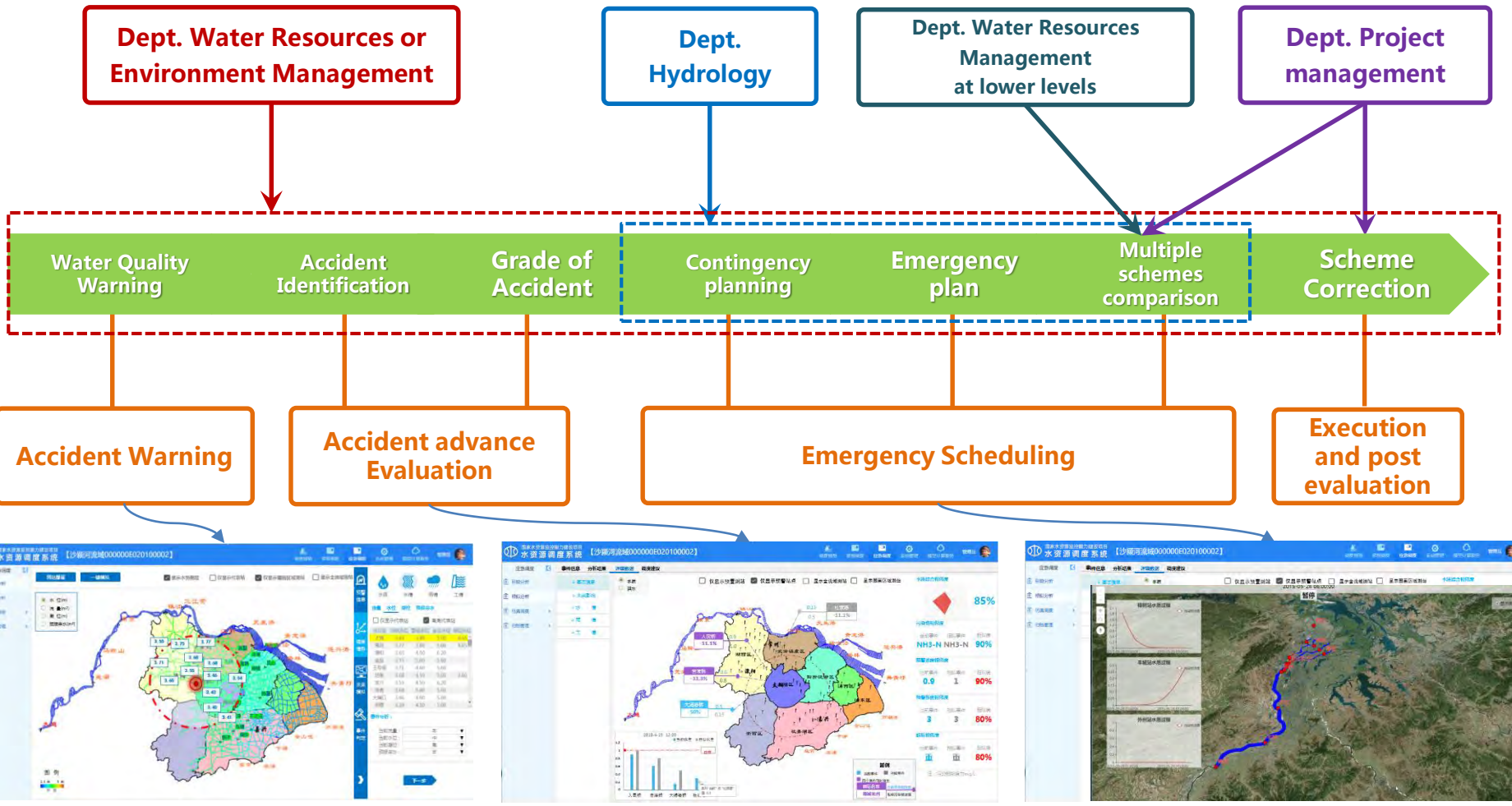
1. Regular Operation



The standard regular operation business includes water supply available calculation, water demand calculation or report, regular water resources scheduling and execution.

4.2 Business Standardization

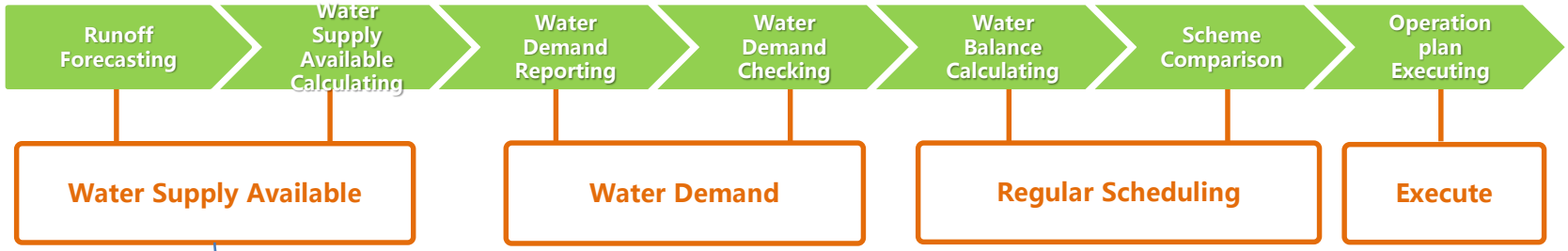
2. Emergency Operation

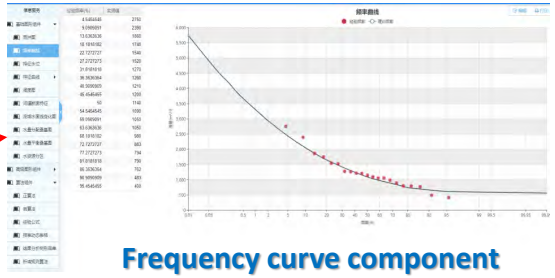


Emergency operation business includes accident warning, accident evaluation, emergency scheduling and execution.

4.2 Business Standardization

3. Web User Interface Components



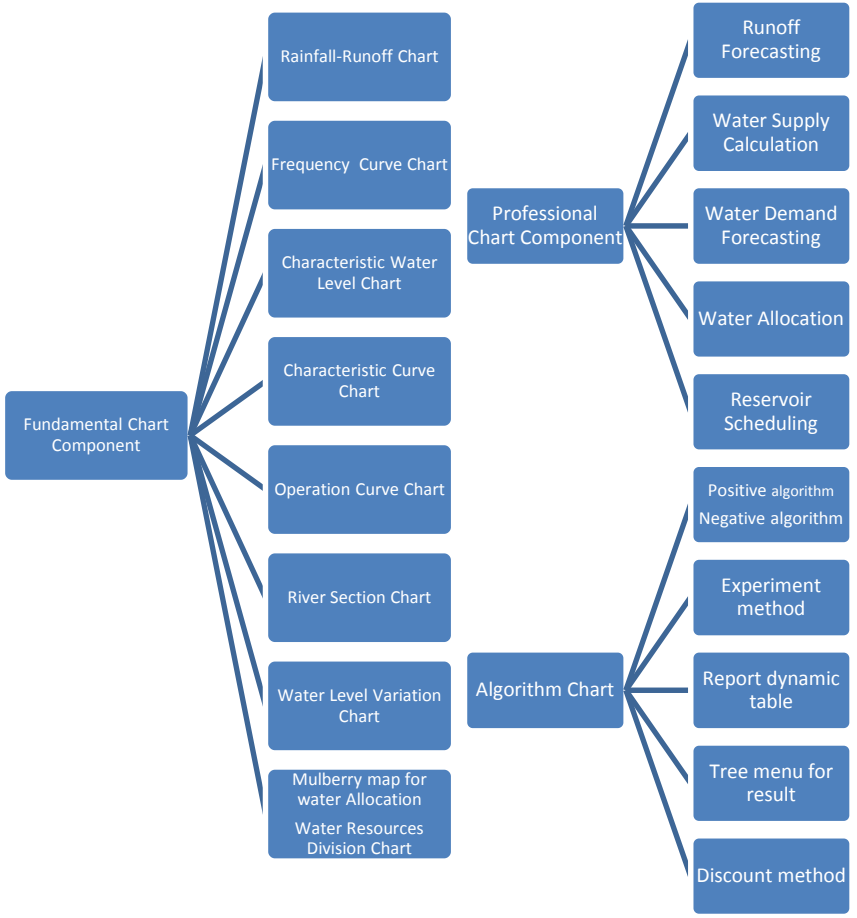


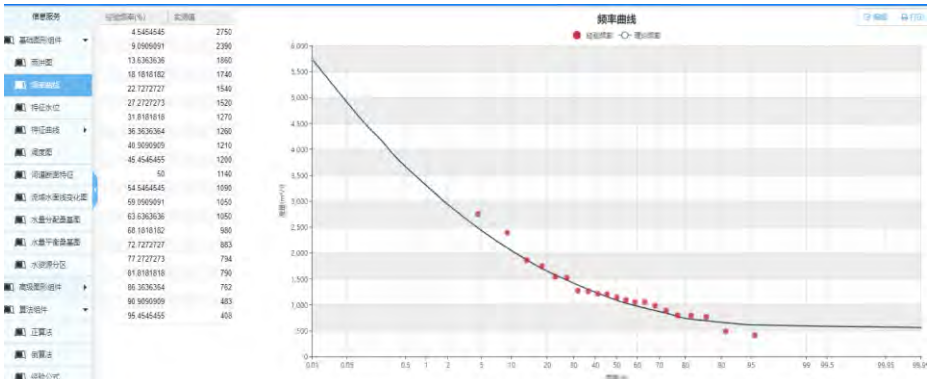
And as you can see, we develop **a standard web user interfaces** for each business steps. This is the user interface for water supply calculation. And which is composed of many standard user interface components, such component for frequency curves.

4.3 Application System Building Tool

3. Web User Interface Components

The web user interface components have **3 types** including **9 fundamental charts** components, **5 professional chart** components and **6 algorithm** components.





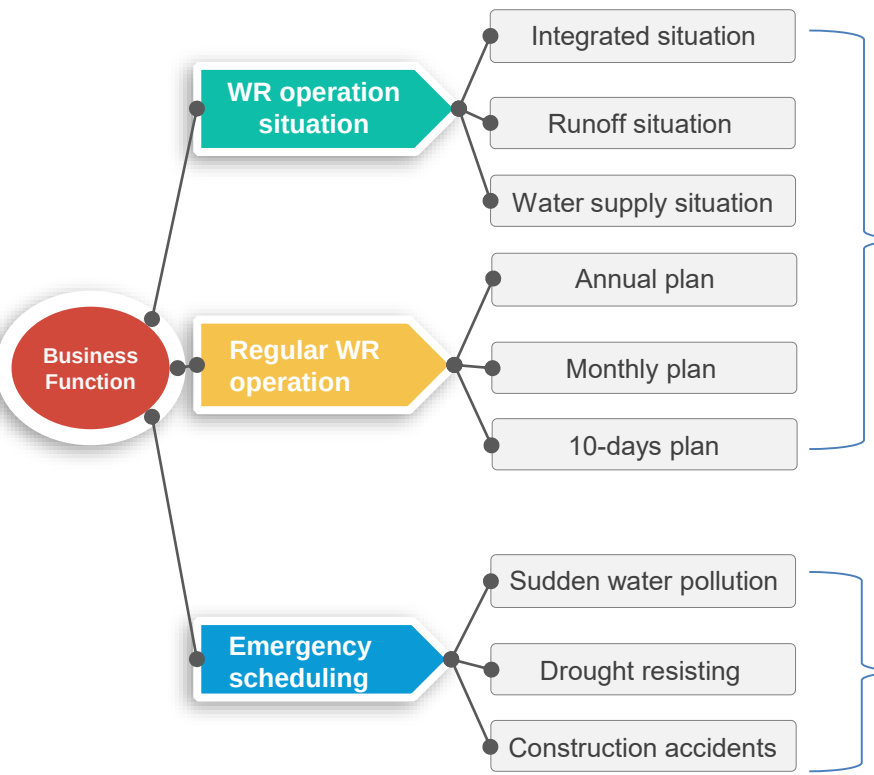
Fundamental Chart Component
—Frequency Curve Chart

Professional Chart Component
—Middle/long term forecasting

4.3 Application System Building Tool

3. Web User Interface Components

In addition, building tool also provides **a complete set of business application system templates** that support the regular and Emergent water resources operation for system customization and secondary development.



Regular Operation

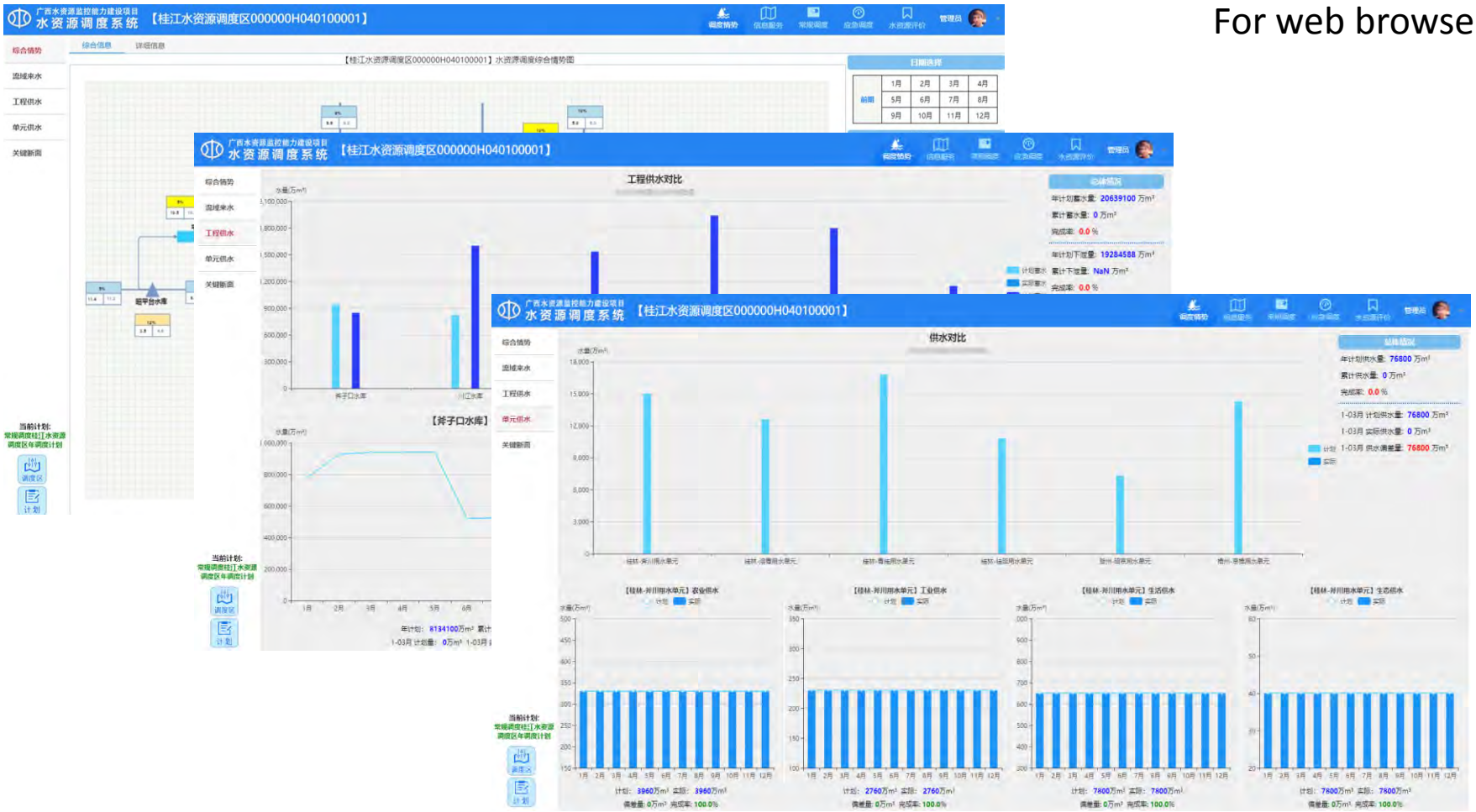
Emergent Operation

4.3 Application System Building Tool

3. Web User Interface Components

1) Operation situation and Trend

For web browser

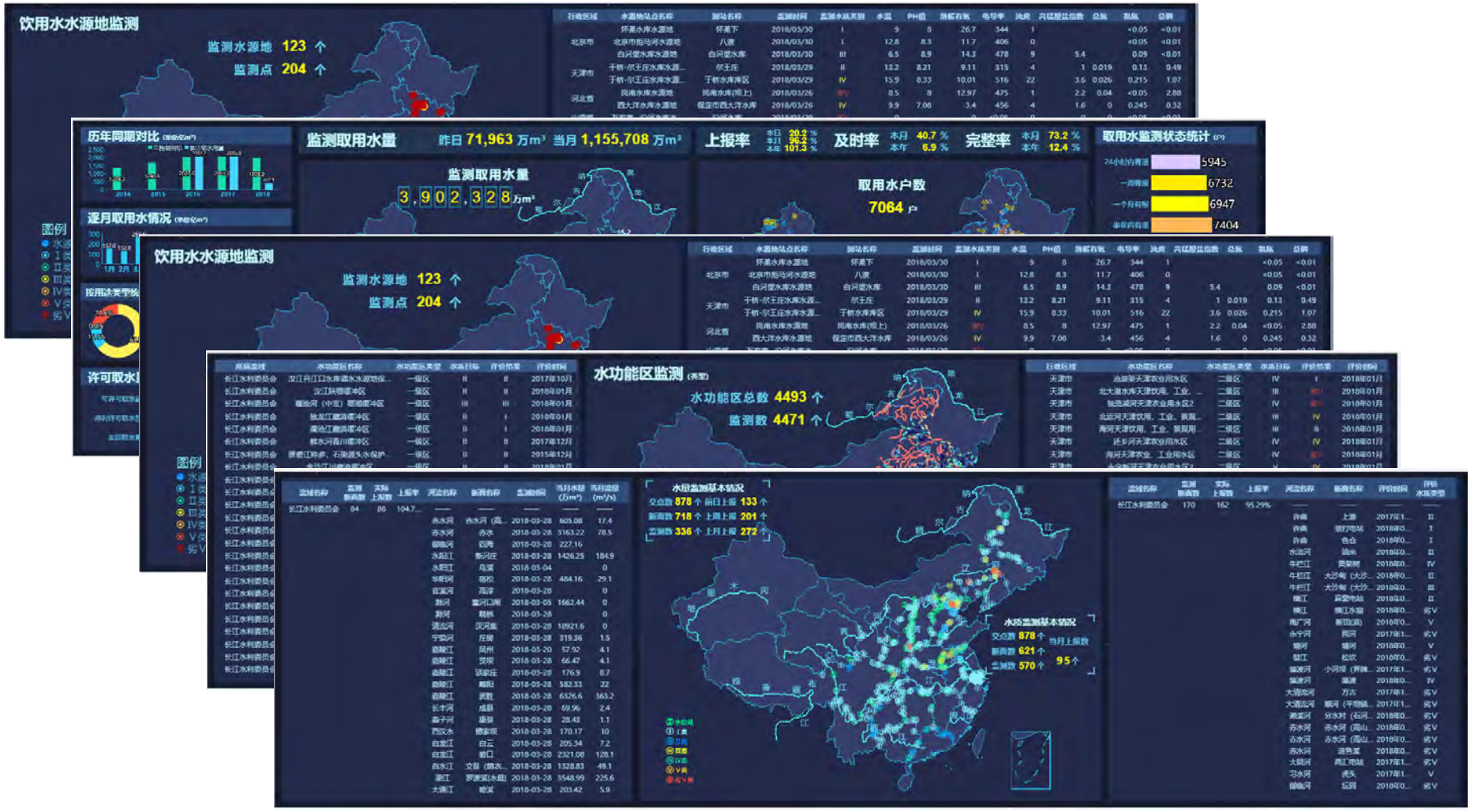


4.3 Application System Building Tool

3. Web User Interface Components

1) Operation situation and Trend

For Large screen



4.3 Application System Building Tool

3. Web User Interface Components

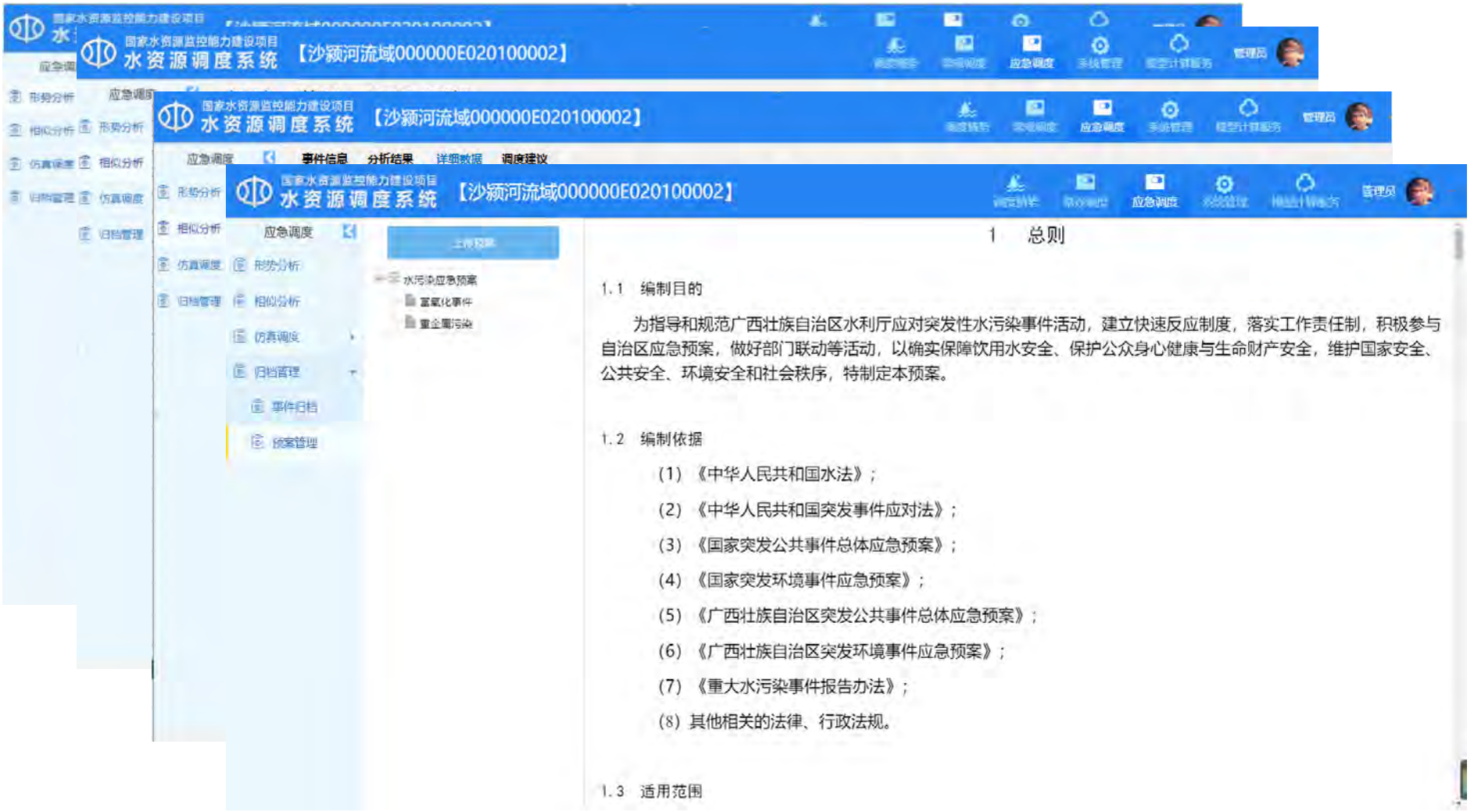
2) Regular Operation

月份	农业				工业				生活			
	需水(万m^3)	供水(万m^3)	缺水(万m^3)	缺水率(万m^	需水(万m^3)	供水(万m^3)	缺水(万m^3)	缺水率(万m^	需水(万m^3)	供水(万m^3)	缺水(万m^3)	
全年	2991	2568	423	86	3091	3091	-0	100	2318	2318	0	
2016-06	264	264	0	100	258	258	-0	100	193	193	0	
2016-07	264	264	0	100	258	258	-0	100	193	193	0	
2016-08	264	264	0	100	258	258	-0	100	193	193	0	
2016-09	264	264	0	100	258	258	-0	100	193	193	0	
2016-10	279	279	0	100	258	258	-0	100	193	193	0	
2016-11	225	225	0	100	258	258	-0	100	193	193	0	
2016-12	225	225	0	100	258	258	-0	100	193	193	0	
2017-01	225	107	118	-5157	258	258	-0	100	193	193	0	
2017-02	225	102	124	-5386	258	258	-0	100	193	193	0	
2017-03	225	205	20	-800	258	258	-0	100	193	193	0	
2017-04	264	126	138	-5144	258	258	-0	100	193	193	0	

4.3 Application System Building Tool

3. Web User Interface Components

3) Emergency Operation



CONTENT

5 Platform Application

Development Platform of Water resources Operation Software

Data

1. Database and Exchange:
Implementation of full data access

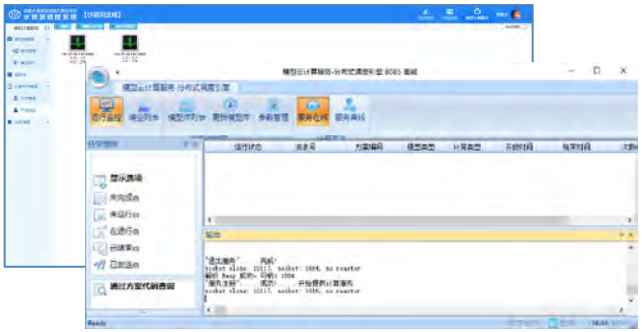
System

4. Application System Building Tool:
Implementation of fast system building

MODEL

2. Model Building Tool:
Implementation of fast model building

3. Model Computing Service Software:
Implementation of model computing cloud



5 Platform Application

The **V1.0 Version of the platform** has been distributed 7 basins and 32 provincial project offices for the customizations of them own river water resources operation software.

- 53 representative trans-provincial rivers
- 7 basins and 32 provincial offices


国家水资源监控能力建设项目办公室文件

水资源办〔2018〕1号

关于下发国家水资源监控能力建设项目（2016-2018年）三级通用等相关软件的通知

各流域机构、各省（自治区、直辖市）、新疆生产建设兵团水资源监控能力建设项目办公室：

按照《水利部关于印发<国家水资源监控能力建设项目实施方案（2016—2018年）的通知>》（水财务〔2016〕168号）工作部署，我办统一组织开发了《水资源业务管理通用软件（V3.0）》、《水资源调度通用软件（V1.0）》和《水资源集成支撑软件（V2.0）》，现下发给你们。具体事项通知如下：

一、下发软件内容

本次下发的三级通用等相关软件内容主要包括《水资源业务管理通用软件（V3.0）》、《水资源调度通用软件（V1.0）》和《水资源集成支撑软件（V2.0）》的软件安装包、数据库运行脚本、用户使用手册及"readme.txt"文档等。

Documents


水资源调度通用软件V1.0版本正式发布！

2018-01-24 IWHR水资源调度

水资源调度通用软件V1.0版本定制部署主要包括以下四个步骤：① 数据库定制；② 模型管理系统定制部署；③ 模型计算服务软件定制部署；④ 应用系统定制部署。各步骤定制部署视频链接附后。

图 软件部署流程

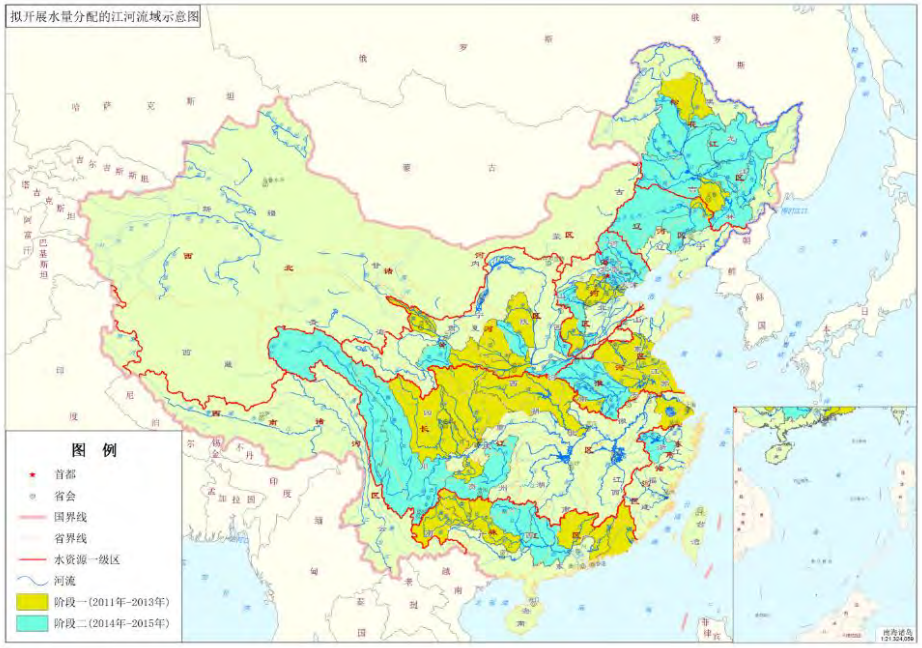
1. 水资源调度通用软件V1.0 数据库定制部署

https://v.qq.com/x/page/r0545wc5wrn.html

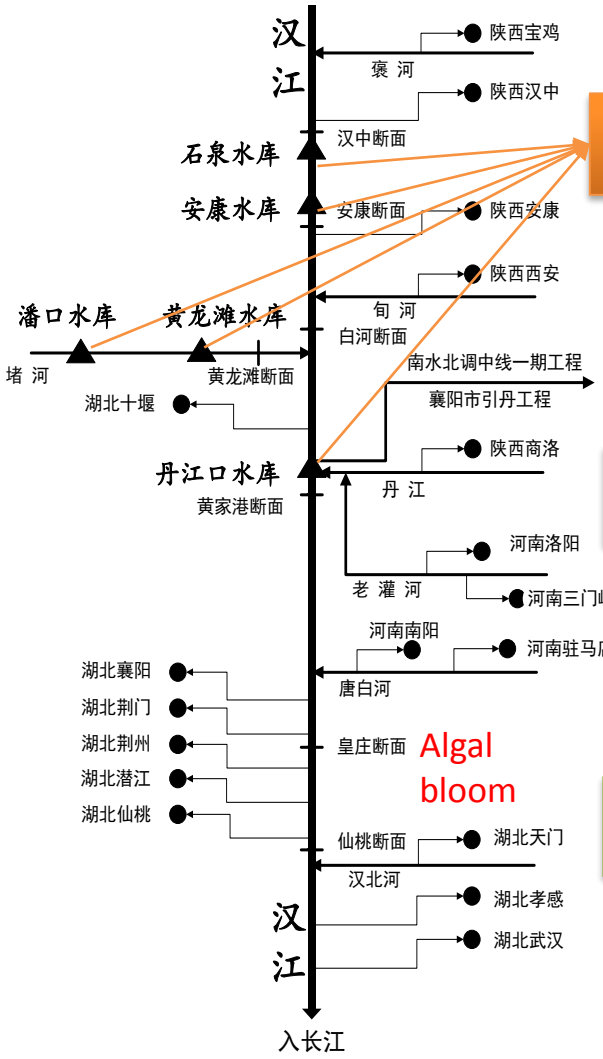
2. 水资源调度通用软件V1.0 模型管理系统定制部署

https://v.qq.com/x/page/n0546o7npq0.html

WeChat Subscription



5 Platform Application—Hanjiang River



Conceptual net diagram of water operation of Hanjiang River

Multipurpose reservoir

- Flood control
- Water supply
- Hydropower

Cross-basin water diversion

- Hanjiang- to-weihe
- South-to-north (middle line)
- Yangtze-to-han

Ecological problems

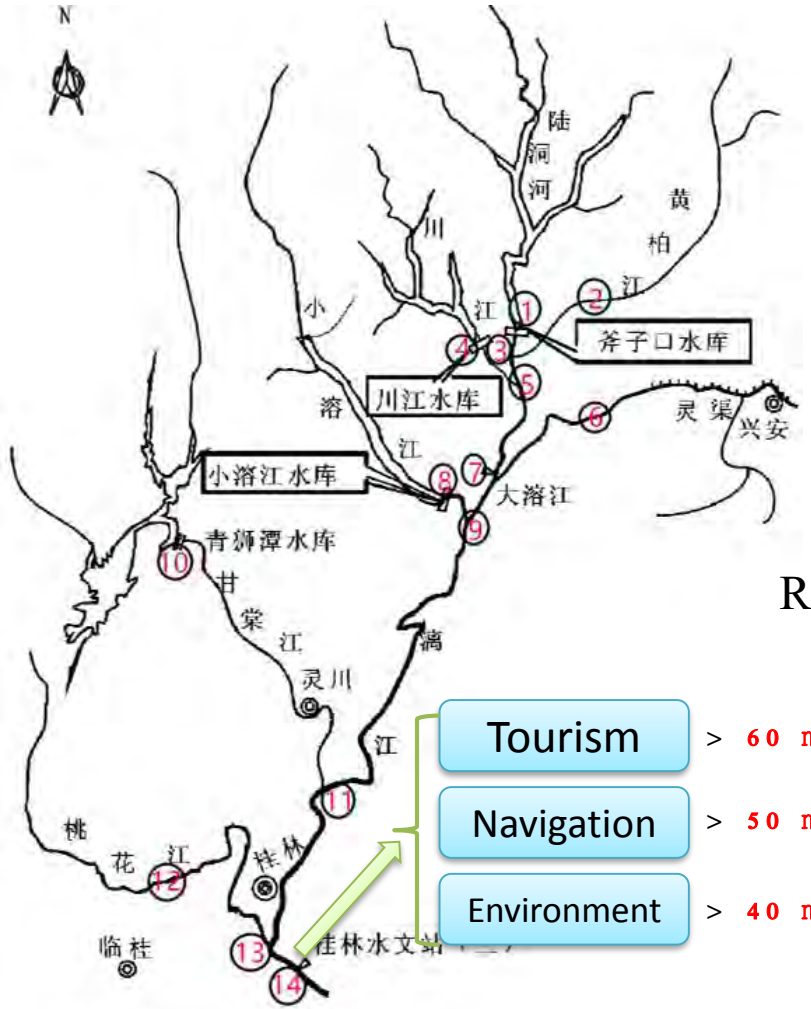
- Algal Blooms
- Fish reproduction

Water resources operations with multiple objectives including water supply, hydropower and ecological conservation

Long term runoff forecasting

Multi-objective scheduing Result

5 Platform Application—Lijiang River

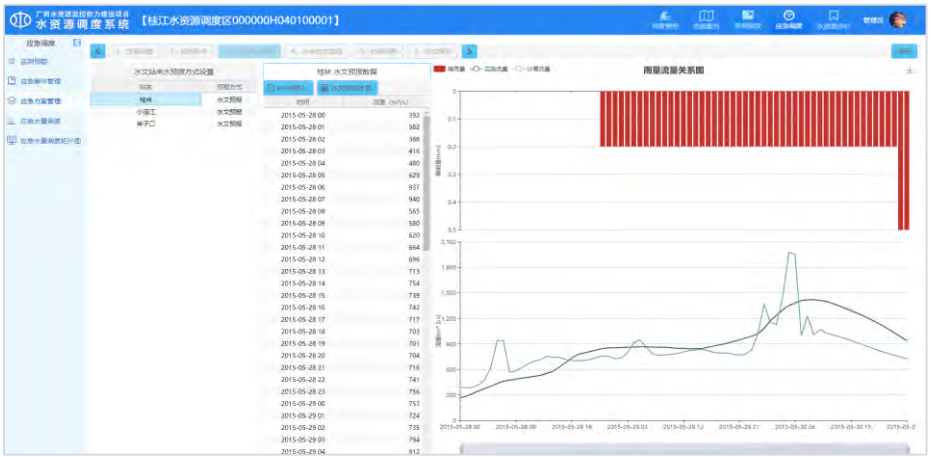


Tourism > 60 m^3/s

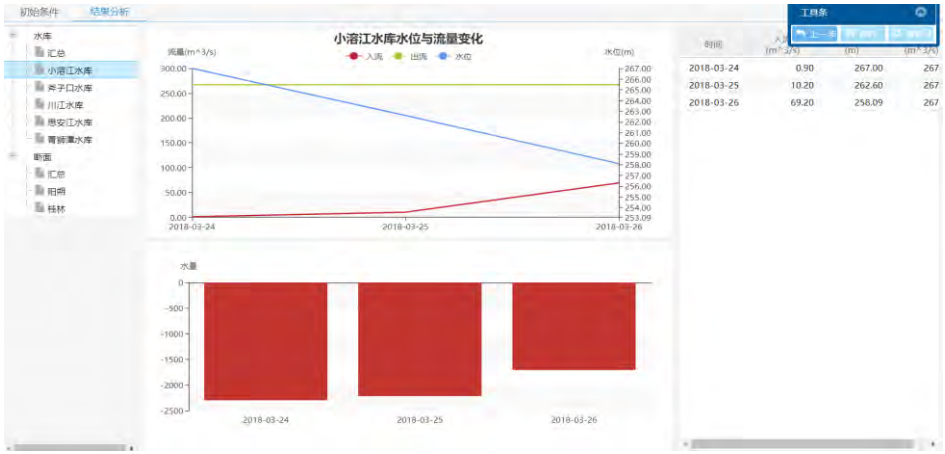
Navigation > 50 m^3/s

Environment > 40 m^3/s

Short term runoff forecasting



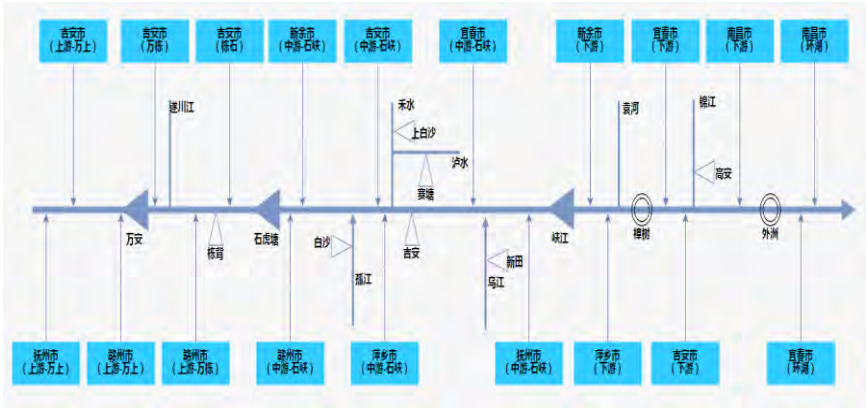
Reservoir operation for downstream flow requirement



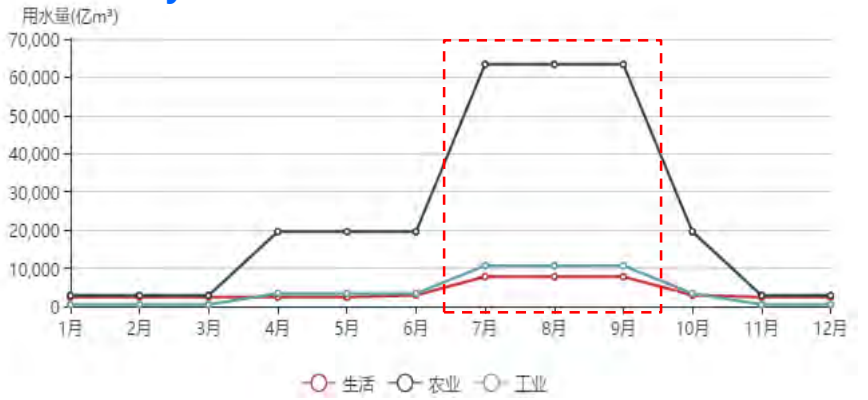
The scenery of Guilin is world-renowned.

5 Platform Application—Ganjiang

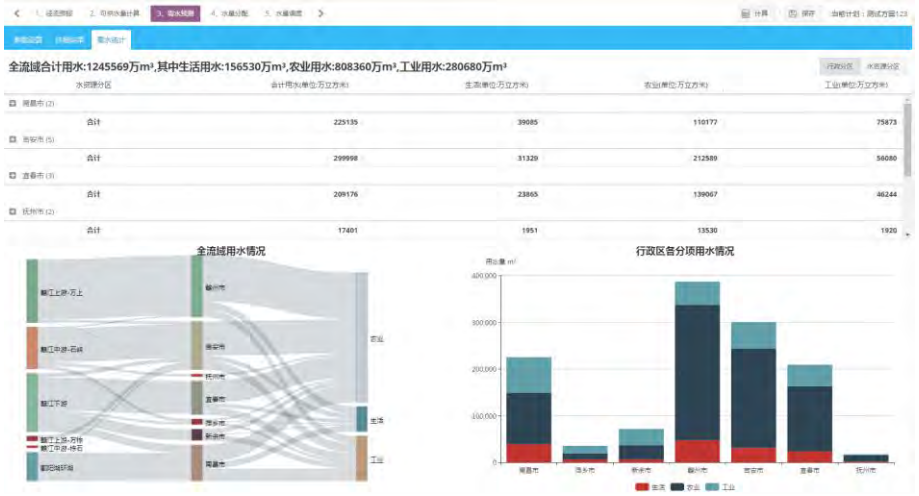
Water Resources Network



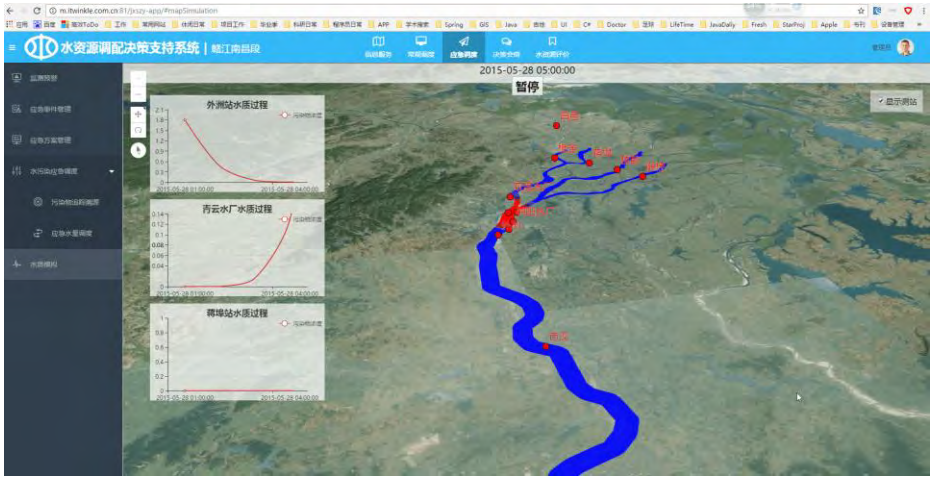
Yearly distribution of different Water uses



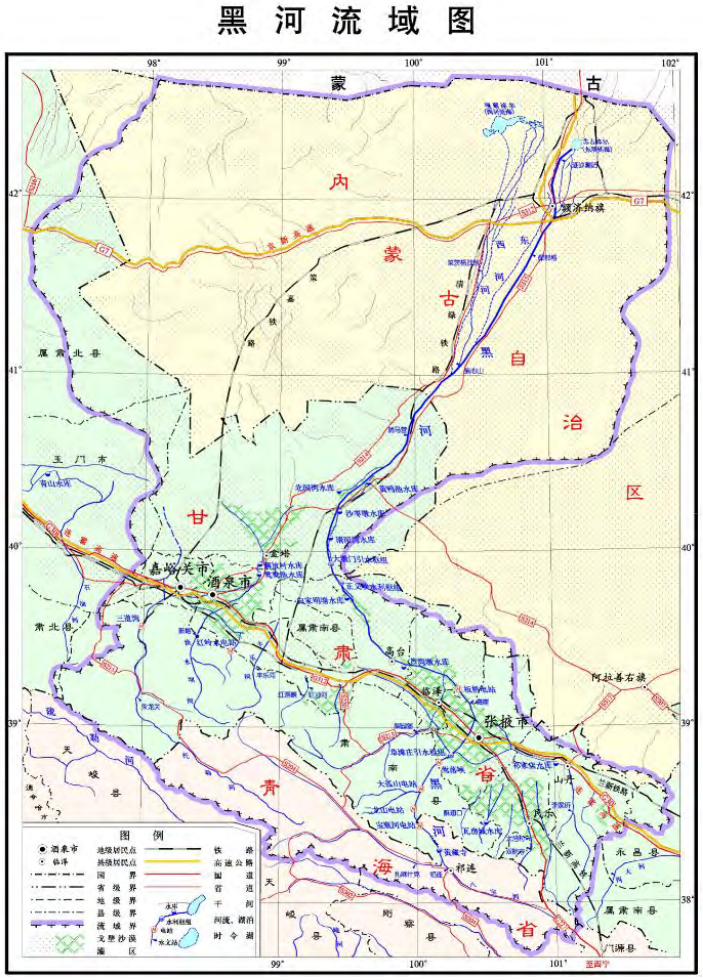
Regular operation for year plan



Emergency operation for accident pollution

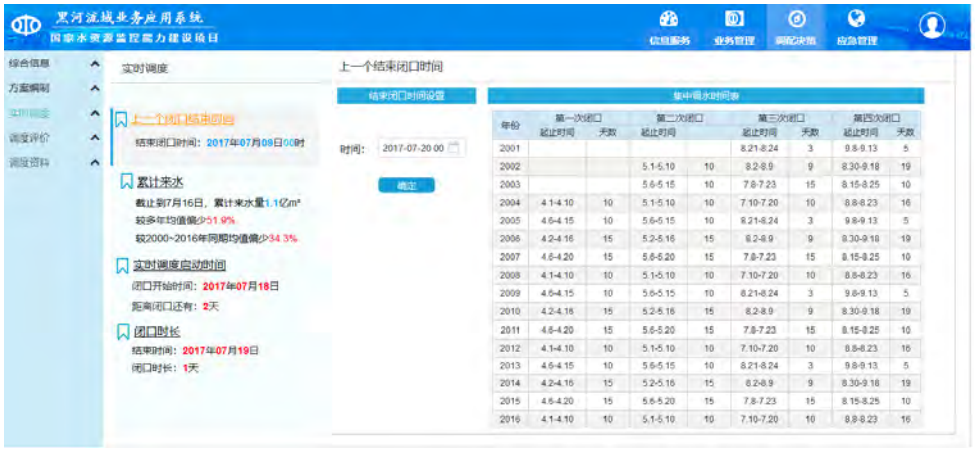


5 Platform Application—Heihe

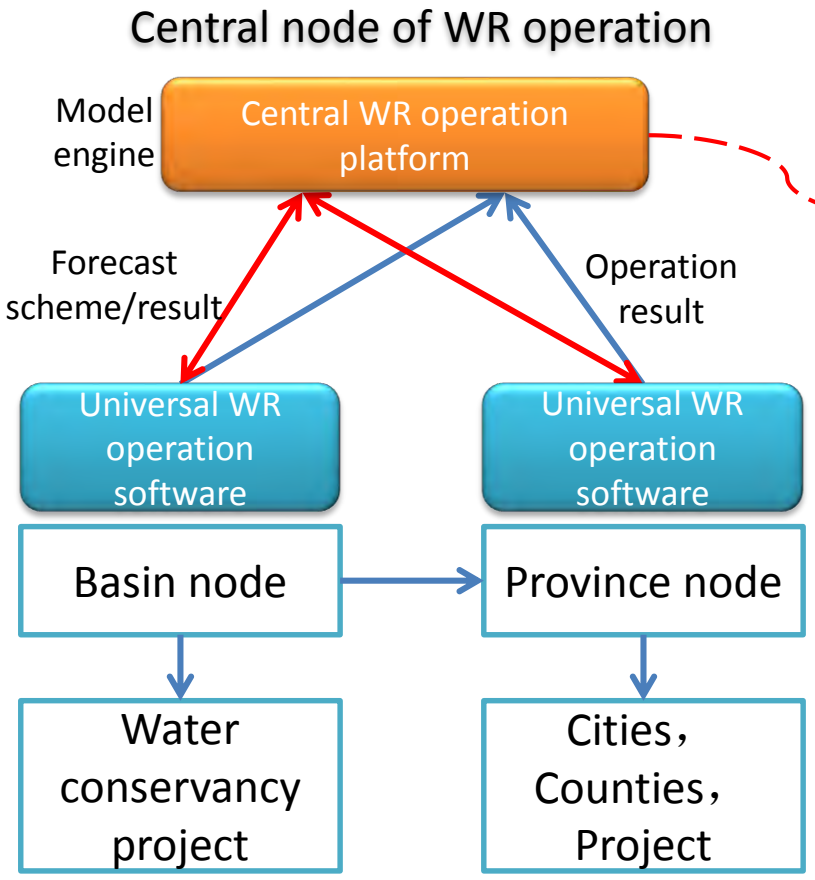


Water Resource Operation Situation and Trend

Realtime dispatching instrunction



5 Platform Application—MWR system



MWR node

This is the central node of the water resources operation in China. The system is deployed in **Ministry of Water Resources**. And all water resources operation related information of all trans-provincial rivers in china could be obtained through the system.


Thanks