Chapter 5

The Planning, Management and Decision Support Systems of Kunming's Urban Drainage System

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5.1 Overview

5.1.1 Chinese Policy Background

To enhance the effectiveness of prevention and control of water pollution, a series of management requirements and technical targets are proposed in national and industry related policy documents. For example, the action plan for water pollution prevention and control demands for the rapid transformation from the existing combined drainage system to separated sewage system. If it is difficult to transform a given system of combined drainage, the measures such as intercepting the run-off, regulating and storing, and controlling should be taken into consideration. It is necessary for each city and region to determine the transformation mode of drainage system according to the demand of local water management.

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MHURC (2015)¹ [1] requests that the drainage water quality of lakes must not be lower than the surface water standard class IV. Except for the period of rainfall, the combined sewer should not directly discharge into the water body. The Technical guide lines for urban wastewater drainage requests that in areas where drainage pipes are laid below the groundwater level, the inlet water's chemical oxygen demand (COD_{Cr}) concentration of municipal wastewater treatment plants (WWTP) cannot be lower than 260 mg/L in dry days, or increase by 20% per year on the basis of the existing water quality concentration. The '13th five-year plan' for the construction of urban wastewater treatment and recycling facilities issued by the national development and reform commission and the ministry of housing and urban-rural development, demands to speed up the resolution of the uneven layout of wastewater treatment facilities and the implementation of stricter discharge standards in areas with serious water pollution.

The local government responded positively to the above policies. The implementation plan of the three-year critical action for the protection and governance of Dianchi lake (2018–2020) demanded that in 2018, Dianchi Caohai's water quality should reach class IV (compare Table 5.1). Dianchi's water quality throughout the year reached classes V, but was better in the dry season with class IV. In 2020 Dianchi Caohai and Waihai water quality should achieve class IV. In addition, the Chief River Commander's Order signed and issued by Kunming municipal party committee secretary in March 2018, demands to

- complete the construction of diversion and retention facilities for the channel and tributaries
- prevent the overflow when the initial rainfall of the channel and tributaries is 7–10 mm/d
- effectively reduce the pollution load of the water from the combined sewer flowing into lakes and rivers.

Furthermore, in order to effectively control the eutrophication of Dianchi water body, authorities ask to strengthen the control of discharge of major water contaminants and the so-called recycling of wastewater from the urban WWTP or re-use of urban wastewater. Therefore, Kunming compiled the main water contaminants discharge limit values for urban WWTP in Kunming (trial). The discharge limits of major water contaminants under normal operation mode of urban WWTP in Kunming administrative region and the limits of discharge of major water contaminants under rainy season operation mode of overflow sewage in rainy season were stipulated and stricter discharge standards were implemented to further reduce pollution in Yunnan.

¹ City office letter [2004] no. 153 issued by the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD).

Table 5.1 Discharge limit of major water contaminants in Kunming urban WWTP (trial)

Contaminants	Grade A	Grade B	Grade C	Grade D	Grade E
BOD5	4	6	10	10	30
COD	20	30	40	50	70
NH4-N	1.0 (1.5)	1.5 (3)	3 (5)	5 (8)	15 (20)
TN	5 (8)	10 (15)	15	15	30
TP	0.05	0.3	0.4	0.5	2

Values in brackets are valid from December 1 (inclusive) to March 1 (exclusive).

5.1.2 Current Status and Problem Analysis

Since the 11th five-year plan, a large number of water environment treatment projects have been built in the Dianchi basin, especially in the main urban area of Kunming. The administration of the main urban area of Kunming has built 15 WWTP (two are still under construction, compare Fig. 5.1). The total service area of the main urban sewage system is 518.8 km². The wastewater treatment capacity reaches nearly 2 million cubic meters per day, and the effluent quality is better than grade A. 19 storm water overflow tanks have been built (two of which are still under construction). In addition, 5,722 km of municipal network for drainage and 96 km of a circular sewerage system for collecting sewage around the lake have been built. Together, these components are forming an integral urban drainage system (compare Table 5.2).

On the one hand, the construction and operation of these projects have improved the collection and treatment of the domestic sewage in the dry season, and effectively reduced the overflow frequency of combined sewers in the rainy season. It helped reducing the pollution load, protecting the river channel and ensuring the safety of water quality which flow into the Dianchi lake. The Evaluation on the implementation of the 12th five-year plan for Dianchi lake governance compiled by the Chinese academy of engineering affirmed the achievements of Dianchi lake governance in recent years. The water quality in Dianchi has been stabilized and continuously improved. The pollution load from point sources has been significantly reduced.

On the other hand, because a transformation from combined to a separated sewer system is a difficult and complex task, the urban combined sewer system will still exist for several years. The relationship between runoff and performance of the drainage system has become increasingly complex. It is difficult to control the terminal drainage facilities that serve for both: the drainage of pollution in the dry season and the flood discharge in the rainy season (compare Fig. 5.2). This complex situation causes overflow discharges with negative effects for the receiving water bodies. Not only that, but also the treatment load between different WWTP is extremely unbalanced. There is yet a lack of data for the upstream pump stations of the receiving WWTP. The setting and timing of the stored capacity and discharged capacity of controlled retention facility lacks a sound data basis, and it is not effective

Fig. 5.1 WWTP within separate drainage areas in Kunming

Table 5.2 Overview of WWTP in Kunming city centre

Drainage Systems of...	Waste Water Treatment Plant	Catchment Area (m ²)	Planned Population (10 ⁴)	Planned Population Density (10 ⁴ per sq km)	Mean Inflow (10 ⁴ m ³)	Average Daily Capacity (10 ⁴ m ³)	Maximum Capacity in in Wet Yeather Condition (10 ⁴ m ³)
Western Catchment Area	WWTP No. 3	27,68	45,95	1,66	14,6	23,42	26,12
	WWTP No. 9	25,72	39,87	1,55	12,7	6,47	7,95
	WWTP No. 13 (Under construction)	20,06	21,32	1,06	6,8	N/A	N/A
Northern Catchment Area	WWTP No. 4	12,93	27,54	2,12	8,7	4,66	4,91
	WWTP No. 5	33,14	67,55	2,04	21,5	23,56	25,09
	WWTP No. 14	23,31	22	0,94	7	N/A	N/A
Southern Catchment Area	WWTP No. 1	17,95	36,95	2,06	11,7	13,85	15,67
	WWTP No. 2	24,21	54,03	2,23	17,2	11,73	12,47
	WWTP No. 7 & 8	37,11	36,74	0,99	11,7	32,61	36,39
	WWTP No. 10	20,32	46,7	2,3	14,8	9,55	10,58
South-Eastern Catchment Area	WWTP No. 6	39,1	63,32	1,62	20,1	14,1	17,6
	WWTP No. 11 (Under testing)	26,31	21,77	0,83	6,9	1,74	2,88
	WWTP No. 12	47,15	26,4	0,56	8,4	No data	No data
	Nijaiyang WWTP	66,13	39,02	0,59	12,4	No data	No data
	Luolonghe WWTP	97,68	60,56	0,62	19,2	6,18	7,21
Total (or average)		518,8	609,63	1.18 (average)	193,7		

to deliver all the treated sewage to the plant. In addition, the operational performance of completed governance projects is lacking of data, too, and the project operation is mainly focused on node optimization. With the increasing requirements for water quality protection of Dianchi, the consciousness for a dedicated water environment management system is also increasing. Therefore, new governance problems have posed new questions:

- How to reduce emissions by managing and controlling the system by using synergies of existing facilities?
- How to make decide on a scientific basis, whether to build new facilities or restore existing facilities

Fig. 5.2 Drainage systems facilities and examples for severe overflows

- How to improve the management of engineering measures and non-engineering measures in the governance of Dianchi.

5.1.3 Methods

In conclusion, the requirements for water environmental management of the “National Policy” are significantly increased. Therefore, the determination and the pressure to carry out Dianchi lake management are gradually increased. In the face of the problems of the Kunming drainage system and related treatment projects, effective storm water management measures are as follows:

- Supporting the objective of water quality improvement, the authorities carry out precision pollution control within the Dianchi basin
- Promoting the objective of capacity improvement, the authorities will use engineering governance decision-making;
- Stimulating the objective of effectiveness improvement, the authorities will implement a united regulating system.

The “source - network - station - plant - river - lake” integrated linkage management mechanism and technical system will be established for the total system performance maximization. It aims to combine, the overall planning of the rainfall collection, treatment and reuse facilities. This integrated approach should strengthen the interaction between the effectiveness of facility system and the quality of water environment. The integration will hugely impact on planning and design, operation management, optimization control and decision-making of Kunming urban

drainage system. Finally, let the project decision and system operation of Dianchi lake management become scientific and intelligent.

5.2 Managerial Decision Support System of Urban Drainage System

In order to scientifically and systematically govern Dianchi, data fusion management is required. It is necessary to rely on information means to assist the planning of Dianchi lake governance project, the scientific management of drainage facilities and the efficient operation. By establishing a comprehensive database with a standardized format, complete content and the latest updates, the data management and monitoring of massive drainage facilities can be realized. It serves to fully understand and get a clear picture of the current situation of drainage facilities. The management is aiming at establishing a systematic simulation decision-making tools and multi-level effectiveness evaluation index system. It should be combined with the monitoring data and multiple scenario simulation analysis and comparison. This system provides support for the decision-making and evaluation of Dianchi lake treatment project and the regulating control of drainage facilities. It not only enhances the capacity of decision support for major projects, but also optimize operational efficiency and effectiveness of existing facilities.

5.2.1 Data System

Data is the basis of decision-making. The goal is to realize the standardization and unification of a large amount of planning data, structural data and engineering operations and scheduling management data (compare Fig. 5.3). There is a need for data on drainage catchment areas, drainage systems, combined overflow basins, WWTP and other parts of the drainage system. Authorities will rely on a unified data centre to carry out data management. The unified data centre should make it connectable, shareable, and serviceable for decision-making. It should support data update and improvement and long-term accumulation in the process of construction and renovation of drainage facilities. Finally, it may provide long-term support for the evaluation of the application data, optimizing the design scheme of drainage facilities planning and regulating operation of engineering.

Firstly, the data standards need to be unified, and the data structure of the GIS data related to drainage of Dianchi lake needs to be harmonised and agreed respectively. Secondly, a unified management platform of database for drainage facilities should be developed based on data standards. Based on GIS technology, the platform realizes the display, query and edit of Kunming drainage facilities data, and maintains the complex network topological relationship of facilities dynamically. It can be

Fig. 5.3 The iterative update mechanism for the basic data of Kunming drainage facilities

used for facility connectivity and upstream and downstream analysis. Furthermore, it can be used as the supervision software for drainage GIS data rapid analysis and measuring projects. The uniqueness and effectiveness of the database are guaranteed by using unified data management software. Finally, a unified data management method should be formulated to clarify the feedback update mechanism and continuous update mechanism for the data, as to improve the refresh rate of data. Through appropriate data confidentiality mechanisms, the data security can be guaranteed and the abuse of urban infrastructure data can be prevented.

Through the construction of the unified data system, the drainage data standards, software tools and management mechanism of Dianchi basin are standardized. The existing resources can be fully shared to improve the investment efficiency of data system construction and the constant and frequent use of data.

The collection and transmission system should be constructed for all kinds of Dianchi lake operation data like:

- water quality and quantity data for key drains,
- water quality and quantity data of input and output water in storage pool
- key operation parameters, water quality and quantity data of Niulan River,
- the water quality and quantity data of tail water,
- the water flow and quality of the western traffic tunnel,
- water quality data of the main canal which intercepts sludge around the lake, etc.

By the means of data standardization in the projects, the effective accumulation and quick access of project-related data can be realized to ensure the long-term operation of the data centre.

5.2.2 *On-line Monitoring System*

According to the project decision-making requirements of monitoring data of local drainage system in Kunming, the advanced “Internet of things” technology is adopted. It will help to carry out the whole monitoring process of discharge sources, branch manholes and main manholes, pumping stations, storage facilities and WWTP of Kunming drainage system. Furthermore, meteorological observation data, river and lake water quality monitoring data and river hydrological monitoring data are processed and added to the system. The responsible institutions for the data are Kunming meteorological bureau, environmental protection bureau and hydrological and water resources bureau. The Dianchi lake treatment information collection system will be established with reasonable layout, clear level, complete functions, soft and hard integration and long-term effectiveness. Finally, the integrative comprehensive perception of “source-network-station-WWTP-river-lake” should be realized.

Based on the current evaluation, the online monitoring and early warning system for urban drainage network was established and operated in a long-term. It follows and holistic approach for the monitoring of the drainage network. It ensures continuous, accurate and updated monitoring data and helps to provide a reliable decision-basis for drainage engineering. Ensuring long-term stability, a standardised supervision mechanism is established. It can monitor the operation status and calculate risks for drainage facilities dynamically, quickly track and warn the drainage system management department. By collecting the long-term drainage operation data, it can be used to identify necessary maintenance and helps to derive operation rules for drainage facilities. It assesses and diagnoses the current operation status of drainage facilities, supports the decision of major projects, and assesses the implementation effects of sponge city, black smelly water, drains and other related projects quantitatively.

During the construction process of the online monitoring system, the following monitoring requirements are mainly considered:

- (1) Collection and accumulation of long-term monitoring data of the status-quo drainage system. Relevant facilities should continuously be monitored and tracked to accumulate data, so as to form localized technical criteria and provide experience and guidance for similar urban drainage pipe network construction and transformation. It cannot only improve the scientific and effective management level of the pipe network, but also improve the operation efficiency of the drainage system. It also supports the modification of the parameters and verification of the calibration of the mathematical model. And it also provides the basis for real-time warning forecasting and dynamic assessment.
- (2) Programming the scale of reconstruction design scheme and determining the reference basis of the planning and reconstruction design scheme. Based on accurate data and the mathematical model it provides the reference for the objective design and determination of pump station, sewage plant and other

- facilities, and objective evaluate the advantages and disadvantages of existing drainage system. According to the existing problems, propose the improvement for the planning scheme, and conduct scientific and systematic optimization.
- (3) With the continuous improvement of drainage pipe network construction, advanced monitoring and modelling is used to support the scientific decision-making and performance evaluation of facilities in accordance with relevant technical criteria and under the guidance of scientific concepts.

5.2.3 Model Simulation System

In order to comprehensively and objectively evaluate the operation effect of Dianchi treatment facilities, it is necessary to construct a comprehensive simulation system which integrates the source-network-station-WWTP-river-lake system, to realize the simulation analysis and evaluation of the system.

Firstly, a dynamic model for pollution flux in the land and water areas of Dianchi Lake should be established. It simulates the main processes of rainfall, runoff, nonpoint source pollution-point source import - pollutant flux and transfer - surface emissions and the entrance of runoff and pollutant loads, into Dianchi through tributaries. Then the data of sewage and pollution load, treatment reduction and water inflow for each sub-basin were obtained.

Secondly, a 3D-model of water quality and algae for Dianchi needs to be established to simulate how pollutants are transported and transformed within the waterbody. It is designed to analyse the relation between amount of water in tributaries and the water quality of contaminated waterbody of the Dianchi. Combining a land-water management model, helps to better understand the contribution of the tributaries on the water quality of Lake Dianchi. The analysis of the major factors which are impacting the water quality and the duration of water not meeting the standard of the requirements, helps identifying the water reaches that would meet the requirements. It would also help to find as the impacted watercourses, estimating the control value of contaminants in each estuary and the targeted value to reduce to.

At the same time, it is necessary to model the drainage system. The operating rules of the drainage system on dry days and rainy days were simulated and analysed with the water quantity and water quality constraint conditions of the given drainage system. Make a systematic evaluation of the design of drainage pipe networks, retention facilities and WWTP, and analyse and study a variety of optimal operation scheduling strategies such as integrated design of multi-pump stations, trans-regional control, and the integrated design of pipe network and WWTP, retention facility and pump station, etc. The mathematical model is used to carry out annual simulation analysis and evaluation on the implementation effect of various optimized operation and design strategies and analyse the response relationship between drainage facilities and water environmental protection.

Finally, in order to maintain data quality and also keep up with the current data need, regular upgrade and maintenance are needed for the database and models based on land use change, management change, change of layout of the treatment plants and the change of rainfall, etc. so that decision making would become easier.

5.2.4 Performance Evaluation System

The evaluation objectives, decision-making objectives and specific evaluation indexes of the system are determined hierarchically (compare Table 5.3). It supports the scientific decision making of Dianchi management by evaluating the situation and management scenarios.

Models are used to simulate the ongoing operation of the drainage system and to draw the water balance relationship diagram of the study area. The operating condition of the drainage system in the area is analysed. Analysis parameters are in particular core indices such as the overflow frequency, the annual overflow rate of the retention basin/catchment area, the annual overflow frequency of the controlled overflow structure, the retention facility, which is coordinated with the annual wastewater treatment quantity and pollution load of the WWTP. The result is the annual evaluation report and conclusions for problem diagnosis. Existing problems in the current operation scheme are pointed out and the inconsistencies of the existing drainage facilities are clarified.

In the decision-making process of the Dianchi Basin, major projects affecting the drainage system should be based on the above-mentioned model. The decision support should address site selection and scale determination of the WWTP, the site selection and scale determination of the retention facility, the construction of major sewers, the reconstruction or new construction of large pumping stations, in particular, projects that have a large impact on the operation of upstream and downstream related drainage facilities, complicated and variable boundary conditions, and inter-connected relationship upstream of the facility. We need to collect necessary monitoring data, and determine and validate model parameters. The mathematical model is used to simulate and analyse the system response under various working conditions, multiple scenarios and multiple different planning schemes. It is used to quantitatively evaluate the impact of key points, and support the planning and control of related major projects. After the project is completed, the effect evaluation should be based on the measured data, and the model should be used to optimize and improve the operation and design strategy, improve the investment operation efficiency of major projects, and maximize the efficiency of project investment.

Table 5.3 Parameters of performance evaluation

Evaluation of ...	Objective of decision	Specific evaluation index (Gross/arid day/rainy day)
Receiving water	Evaluating the overall pollution control effect of the basin dynamically, to decide the focus of systematic pollution control projects and clarify the key pollution control catchment area.	Control the total pollution load before discharging into the river Target reduction of the regional pollution load Water quality achieved rate of key section
Service zone or Catchment area	Making decisions on the overall project scale and related control index of the area drainage collection and treatment system, in order to ensure that the river water quality does not degrade from upstream to downstream.	Regional pollution load Pollution load collected and treated by regional drainage system Pollution load reduction rate Total pollution load discharged by the regional drainage system Overflow pollution load of storm water overflow discharge Control rate of total annual runoff / Annual overflow frequency, and annual control rainfall in millimetres of overflow
Engineering facilities – drainage system	Making decisions on drainage system construction, reconstruction, maintenance, strategic dispatch or Unicom	Overloading rate of drainage system Collection rate of drainage system Achieved rate and increase rate of influent COD concentration of the drainage system.
Engineering facilities – retention facilities	Making decisions on retention facilities' scale, key parameters of running schedule	Annual reduced overflow frequency of retention facilities Annual wastewater treatment capacity and pollution load of WWTP matched by retention facilities
Engineering facilities - WWTP	Making decisions on WWTP scale, processing capacity and running model	Pollution load reduction of WWTP Total pollution load of tail water discharged by WWTP

5.3 Progress in Practical Application

5.3.1 *Data Construction and Application*

5.3.1.1 Data Standard Establishment

Digitization of the drainage system is a complicated and systematic project, characterised by a long construction period. The accurate and effective collection of drainage data is the key to the effectiveness of digitization of the drainage system. During the 12th Five-Year Plan period, Kunming City carried out the construction of drainage facilities such as retention facilities and pumping stations. Combined with the needs of engineering and operation management, several digitization projects of the drainage system projects have been launched. Due to lack of standard requirements for drainage facility data, standards of drainage monitoring equipment and monitoring strategies during the design and construction process, some drainage data cannot be collected accurately. This is leading to a lack of key data for drainage facility management. It can ultimately affect the effectiveness of drainage digitization projects. The technical level of drainage facility design and management is effectively improved based on the lesson learned from the digitization of existing drainage systems. Therefore, we need to establish relevant standards, standardize and guide the design and construction process of drainage facilities and reserve the integrated data interface for post-information system construction.

Based on the relevant digitization experience of the Kunming Dianchi Investment company, the Technical Standards for Data Management of Urban Drainage Facilities in Yunnan Province (DBJ53/T-93-2018) [2] were established. This realized the regional expansion of national standards and the establishment of a harmonised data format, complete content and dynamic update for an urban drainage facilities basic database. At the same time, the Technical Standard for Online Data Collection of Urban Drainage of Yunnan Province (DBJ53/T-94-2018) [3] was established. This set standards for online data collection and transmission of drainage facilities, harmonised the list of key information data and technical standards for drainage facilities data such as retention facilities, pumping stations and pipe networks. It also ensures the timeliness and authenticity of the dynamic data of drainage facilities. The preparation and implementation of the above data and collection standards ensure the uniformity of the GIS data and dynamic monitoring data of the drainage facilities at the source, and provides reference for the compilation of other relevant standards of the Dianchi governance information system.

The next steps will be based on the technical needs of digitization of Dianchi governance, combined with the promotion and development of related projects, summarizing and refining, compiling corresponding technical standards, standardizing technical work and related data, thus providing a complete standard system for digitization of Dianchi governance.

5.3.1.2 Data Platform Construction

The network topology structure follows the principle “one centre, two sub-stations, several field control points”. The investment company is the host for the data centre, and the drainage company and Dianchi water service were used as the extension sub-station to realize the on-demand calls to data resources and the application (compare Fig. 5.4). It is integrated with nearly 70 core hardware devices such as necessary servers, workstations, disk arrays, switches, and intrusion prevention devices, and deployed with more than 60 sets of core basic software such as database, ArcGIS, configuration software, PLC programming software, watershed drainage model software, network security management software, antivirus, network video software and so on. These field control points provide reliable guarantee for daily network operation and maintenance, data storage and backup, video online monitoring and information system operation and development, and provide basic guarantee for the stable operation of the company’s information systems.

- The systems launched are:
- the development practice of the Kunming main city pipe network information system,
 - Kunming main city retention facility information system,
 - Kunming lake East coast information system,
 - the Western Catchment Operating System and
 - a series of application software.

Fig. 5.4 Network topology following the principle “one centre, two sub-stations, several field control points”

The systems are based on the above-mentioned basic software and hardware and network platform (see picture above), combined with the specific management needs of various periods and various engineering projects, through the customized development method. It provides a corresponding business subsystem for the asset management, monitoring and retention facility monitoring and management of the Kunming drainage network, and drainage system operating analysis.

Based on the experience, they developed information management function modules for some regions and some facilities. The modules provide a functional foundation and valuable experience for the next step of digitization.

However, in general, the existing related application software systems are not strong overall. The functions are strongly limited, the operation methods are not user friendly enough, some functions are isolated, the operation and maintenance are not in place and a complete set of Kunming drainage information application software systems have not yet been formed. In the next step, the development needs to be based on the overall requirements of drainage management, unified data standards and system architecture to plan the software application functions. It also integrates existing related modules, information and functions, providing an integrated visual management decision window of drainage planning management in Kunming.

5.3.1.3 Data Feedback and Application

With the rapid development of Kunming, the urban drainage facilities are constantly upgraded. Based on years of experience in drainage facility data management, Kunming Dianchi Investment has proposed a management mechanism for data feedback and update. The data feedback and update workflow include data collection and processing, on-site data monitoring, data management and storage, data applications and feedback as shown in Fig. 5.5.

Before the urban drainage facilities data is updated, new and reconstructed drainage blueprints within the data detection scope of this stage are collected, and the data problems reported by the data use unit are formed to a fault detection map. The effective development of the fault detection map clarifies the scope of data measurement and improves the working efficiency of the field measurement unit. At the same time, through the spatial superposition analysis with the existing drainage facility data, a repeated mapping of the drainage facility data is avoided. This could save money for data collection.

At present, most urban drainage facilities data detection does produce unclear relationship between mapping results and existing data topologies. In the management mechanism of data feedback and update the connection requirements of the data detection results are clarified. It provides evidence for establishing clear data on urban drainage facilities. The main connections are shown in Fig. 5.6.

In 2015, in the process of establishing the drainage system water model in the southern part of the main city, the data of the 101.2 km drainage pipes was manually supplemented (compare Fig. 5.7). This was done due to the incomplete data at

Fig. 5.5 Data feedback update workflow

the time, which caused the uncertainty of the simulation results and affected scientific decision making. However, through the implementation of the Kunming main city data measurement project (Phase I), the measurement group supplemented and improved the 174.4 km drainage pipe data, and the length of the pipeline coincident with the manually added pipeline was 84.26 km, and new drainage system data of 90.14 km was added. The data complements the integrity of the urban drainage

Fig. 5.6 Integration of drainage facilities in the data management system

facility database, provides the basic information for the model analysis of the drainage system, and improves the credibility of the model analysis results.

In the data feedback application process, the tracking and improving of the existing drainage system is supported as well. For example, after verifying the misaligned of the QIAN WEI West Road sewage on site (compare Fig. 5.8), combined with the hydraulic model analysis of the area and the actual flooded water situation, a comprehensive plan for the transformation of the displaced manholes and for the prevention of floods is proposed.

With the help of the model, the impact of the node is systematically evaluated. The operation of the pipeline after the transformation of the misaligned manhole is shown in Fig. 5.9.

After the implementation of the misaligned manhole reconstruction project, the pipeline operation status has improved significantly, and the pipeline overflow capability has been improved. The modified manhole can match the demand for the overflow capacity of the sewage pipeline in the development and construction of the Qianwei West Road area. This case of finding suspected data and making improvements is also an indication of the importance of data verification feedback. Through doubtful data, it can help managers to improve the problem of drainage network and improve the operational efficiency of the overall system.

Through the continuous data updates of several projects, a unified drainage facility data update software platform has been initially developed. It is based on unified data and a complete GIS database of the city's drainage facilities, and has more than 4,100 km of drainage facilities data.

At the same time, a dynamic data acquisition system is connected to relevant dynamic monitoring data of the facilities. It consists of objects such as main sewage plant, retention facility, pump station and pipe key nodes in the main city. At the same time, a dynamic update mechanism for data has been established. Through the method of annual measurement and verification, it is possible to continuously update and improve the basic data of drainage facilities such as drainage pipes,

Fig. 5.7 Overlay analysis of data updated by measure and by manual addition in the Southern Catchment

ditches, rivers, sluice gates, valves, discharge ports, drainage pump stations, WWTP, etc. It can continuously improve the integrity and quality of current drainage data.

Fig. 5.8 QIAN WEI West Road flooding situation

Fig. 5.9 Operation of misaligned manhole before and after project implementation

5.3.2 Online Monitoring Application

5.3.2.1 Monitoring Network Construction

The monitoring network design is based on the needs of related projects. It aims to determine reasonable monitoring points. The arrangement of monitoring points should be closely linked with the purpose of acquisition and application of monitoring data (compare Table 5.4). The purpose of monitoring should not only meet short-

Table 5.4 Monitoring stations in the Kunming drainage system

Project	Types	Quantity	Subtotal	Total
Monitoring of the circular sewer around the lake	Flowmeter	8	33	135
First stage of coordinated and efficient project	Flowmeter	25		
Northern catchment water level monitoring	Water level gauge	6	101	
Southern catchment water level monitoring	Water level gauge	6		
Western level water level monitoring	Water level gauge	19		
Drainage company drainage online water level monitoring	Water level gauge	70		
Panlong River main stream water quantity automatic monitoring station	Flow monitoring station	1	1	

term assessment and verification needs, but also focus on long-term data demand on planning and management of drainage system. Based on the fully understanding of the local drainage network, the river, land use type, urban water accumulation point, and the status quo of the project improvement project, the location of monitoring site is arranged (compare Fig. 5.10).

In the monitoring of the drainage network, not all monitoring points are installed permanently. Instead, we consider temporary measurements to reduce monitoring costs. There are three types of data monitoring services: single sampling, short-term temporary monitoring, and long-term temporary monitoring. It is necessary to combine on-site investigation and on-site inspection to optimize the selection of monitoring methods.

- (1) Conduct field investigations on suspected areas, configure portable liquid level flow meter to quickly monitor instantaneous flow rate, and select and test the sample with serious problem according to the size of the drainage and the pollution status.
- (2) Discharge orifices or manholes with larger instantaneous monitoring flow or larger suspected problems: Quickly install related online monitoring equipment for online monitoring of short-term dry season flow, and obtain continuous flow monitoring data for at least 7 days to ensure the validity of monitoring data and collect monitoring data online.
- (3) For areas with outstanding short-term temporary monitoring problems or areas suspected of mixed rain and sewage, install relevant online monitoring equipment for on-line monitoring of long-term temporary flow. The continuous flow monitoring data cover at least 6 typical field rainfall events, each monitoring point lasts for 2 to 3 months during the rainy season to ensure the validity of

Fig. 5.10 Monitoring facilities

monitoring data and collect monitoring data online. This allows for the selection of a reasonably applicable monitoring method based on the specific needs of the project.

In the construction process of the monitoring system, it is necessary to pay more attention to the maintenance during the operation. This will ensure the quality of the data and ensure the successful operation of the equipment, thus providing effective and timely monitoring data for drainage management.

5.3.2.2 Water Quantity Analysis and Decision in the Northern Catchment

At present, the use of monitoring data for decision support in Kunming is mainly reflected in the long-term monitoring and quantitative evaluation of the drainage water system in the dry season and the rainy season. Based on a water balance analysis, the actual amount of water in the service area of the sewage treatment plant is analysed. This provides data support for the potential tapping and reconstruction of the district's sewage plant. In addition, based on the water quality balance analysis, the inflow and infiltration of the area, the pollution by storm water discharge, and the implementation of diversion and transformation, treatment and separation projects are studied.

A more representative implementation of monitoring-based decision support applications is the rapid monitoring and evaluation of dry season traffic in the Northern Catchment in 2017 (compare Fig. 5.11). The purpose of the project is to obtain the real-time monitoring data of the dry season sewage discharge in the Northern Catchment of the dry season. This is based on the one-month flow monitoring and water quality test in the dry season. A second purpose is to effectively analyse and evaluate the distribution of sewage flow in the dry days of the area, the amount of sewage in the service area of the WWTP and the pollution load. In

Fig. 5.11 Implementation of monitoring equipment

response to the problem of inflow and infiltration of external water, detailed flow monitoring and necessary water sampling and laboratory analysis are carried out to quantitatively determine the inflow and infiltration of external water, and identify the reason for the low influent concentration of the WWTP during the dry season. This provides monitoring data basis for the current situation analysis of drainage network, planning and scale analysis of WWTP, and provide scientific support for the improvement of the drainage network system and the water quantity regulation of the WWTP and scale assessment of the new WWTP.

In order to understand the amount of sewage in the catchment area of the fourth and fifth WWTP, 19 continuous monitoring points and 3 temporary monitoring points are set up in the upstream sewers and upstream of the fourth and fifth plants respectively. They represent the connection between the fourth and fifth WWTP and the sewers in the area with the Second Ring North Road as a boundary.

Based on the statistical analysis of the monitoring data the following key conclusions were drawn: (1) the total amount of pollution generated in the catchment area of the fourth and fifth WWTP are basically in equilibrium with the statistical processing volume. Under the premise that the WWTP starts the first-level intensive treatment, the fourth and fifth WWTPs can basically eliminate the amount of sewage produced by the Northern Catchment; (2) Based on the measured discharge and water quality data, it is estimated that the amount of external water in the fourth WWTP accounts for 64% of the total treated volume, reaching $83,000 \text{ m}^3$. The amount of external water in the fifth WWTP accounted for 77% of the treated volume, reaching $150,000 \text{ m}^3$. In the monitoring area, external water accounted for more than 70% of the total water. (3) The 14th WWTP has been analysed. The increasing population and thus, the significant increase in sewage, characterises the development of the northern catchment area. Therefore, the long-term planning dimension of the fourteenth WWTP is at about $200,000 \text{ m}^3$.

The core functionality of the monitoring and assessment project for the dry season in the Northern Catchment area is to provide strong data-based decisions support for the design and operation of the new fourteenth WWTP in the northern catchment area. Moreover, it has the character of a pilot project for the new WWTP in the southern and western catchment areas.

5.3.2.3 Equilibrium Analysis of Water Volume for the Eastern and Southern Catchment Areas

To support the water balance analysis in the eastern and southern catchment areas, it is necessary, to effectively collect data about the drainage system's status in the dry and rainy season. This consists of analysis of the distribution of sewage in dry and rainy days, the discharge of sewage generated by the districts, the impact of rainfall on the sewage system, and the dimensions of the sewage treatment plants in the area. The second and seventh WWTP are operating at their design maximum, even at dry weather days. The tenth WWTP has not reached the design maximum, but has problems with a low efficiency. By the implementation of the flow measurement

service, high-quality monitoring data can show the amount of sewage in dry and rainy days in the catchment area. It analyses operation risks or changes and accurately assesses the water distribution and water balance of the sewage system during the dry season. Thus, the flow measurement is set up in order to analyse and diagnose the inflow and infiltration of dry and rainy days in the drainage network.

According to the topological relationship of the four WWTPs and drainage facilities in the eastern and southern catchment areas of the main city, 25 discharge monitoring points were set up in the WWTPs incoming sewers.

The monitoring system consists of

- 10 monitoring points in the service area of the main city east area,
- 15 monitoring points are set up in the service area of the southern part of Kunming main city.
 - Among them, the first WWTP system sets 5 discharge monitoring points;
 - the seventh and eighth WWTP system sets 5 discharge monitoring points;
 - the second WWTP system sets 10 discharge monitoring points;
 - the tenth WWTP system sets 5 discharge monitoring points.
- At the same time, a rain gauge was distributed in the first WWTP, the second WWTP and the tenth WWTP.

Three rain gauges are used to obtain rainfall data to identify rainfall events, to analyse the water volume in the dry and rainy days, and to verify the drainage system model in dry days and rainy days. The specific location and distribution of monitoring points are as follows.

In order to effectively assess the current sewage collection capacity and load in the dry area of the study area, authorities quantitatively evaluate the water equilibrium relationship between the WWTP systems. The dry weather data analysis is based on the monitoring data obtained by the online discharge monitoring equipment (compare Fig. 5.12). A data set is effective only if it is not affected by the rainfall 48 h after the end of the rainfall, and dry weather not less than 7 consecutive days. Through the statistical analysis of the effective data of each monitoring station a number of main parameters are calculated. They cover the daily average flow rate, the maximum water level and the average flow rate are obtained, and the daily average flow rate, peak flow rate and maximum water level in dry weather. The following map of the dry water volume can be obtained based on the analysis of dry weather of the sewage entering the plant in the system in the study area. The equilibrium diagram illustrates the relationship between the water volume of the existing drainage system, and lays a foundation for the water supply in the next step of the joint operating work, and also characterizes the current imbalance of water volume in each area.

Fig. 5.12 Dry weather analysis of drainage system of WWTPs 1, 2, 7+8 and 10

5.3.3 Model Evaluation and Decision

5.3.3.1 Model Decision of the Storage Project in Western Catchment

With the rapid development of urbanization, the urban drainage system will become more and more complex and larger. The traditional design analysis method is not systematic, the theoretical calculation derivation is different from the actual management operation, and it cannot provide good technical support for the design and reconstruction of urban drainage facilities. Based on the drainage network hydraulic model technology, the evaluation and decision-making system was first applied in the feasibility study of the “Kunming main city western film retention facility project” (outside the second ring). The model was used to analyse the current operation of the area and comprehensively select various design schemes, and scientifically and rationally propose the design and transformation plan of the district.

The area of the main city west area is 66.9 km², of which the area of the diversion system is 33.79 km², and the area of the combined sewer system is 32.65 km², in total 22 combined sewer overflows.

The drainage system of the western catchment could be comprehensively and meticulously analysed by the development of the hydraulic model of the drainage network. The set up and implementation of the model is based on the following:

- basic data collection and analysis of the pipeline network,

- dynamic data monitoring,
- mapping of the foundation structure of the hydraulic model of the drainage network system,
- model parameter mechanism research,
- model checking and verification.

After setting up an operational model, authorities were able to finally applying the hydraulic model to complete the current situation analysis, optimization scheduling and design check.

Firstly, through the establishment of the drainage system hydraulic model, it systematically points out the data problems such as dislocation, reverse slope, large pipe connection, no downstream connection, rain and sewage mixing, and sewage direct discharge into open channels. This improves the accuracy, timeliness and completeness of the drainage facilities database in Kunming. Secondly, the areas with the most serious overflow pollution in the system are determined. Thirdly, by the development of the model project, the resulting data transfer to and application of the project results in the operation management, optimization planning and design transformation of the drainage system in Kunming can be realized.

Based on the GIS data of the existing drainage pipe network of Kunming City, the project establishes a hydraulic model for the west part of the main city, combined with the measured water quantity and water quality data, simulates the hydraulic model of the current drainage system, and evaluates its drainage capacity and pollutant control effect. The feasibility and necessity analysis of storm water and sewage diversion and construction of combined retention facilities are carried out. The optimized engineering design is completed taking into consideration the analysis of environmental and economic benefits. The core requirement is that the total pollutant load discharged into the water body in the drainage area of the combined retention facility is not greater than the discharge from the new diversion or separated system.

The model is used to analyse the pollutant reduction efficiency of the retention facilities in different locations, different water discharge nodes, different design volumes, etc. The comprehensive design ratio is selected to achieve the optimal design of the project. The design scheme and the rainwater and sewage separation within the district are compared with each other to determine the economic and environmental benefits, and finally determine the project implementation plan (compare Fig. 5.13).

Based on the simulation and evaluation, it is proposed to set up three retention facilities of 24,000, 16,000 and 14,000 m³ respectively to solve the problem of combined sewer overflow pollution in the pumping station areas of Wangjiaqiao and Zhenghe road. In other combined sewer areas, due to the small overflow pollution or the constraints of land use, the new regulation and storage facilities are not economically advised. It is recommended to reduce this part of the combined sewer overflow pollution by optimizing the operation of the western catchment and implementing the urban village reconstruction.

Using the model for long-term simulation calculation, after the implementation of the Western Catchment retention facility project, the annual intercepted combined

Fig. 5.13 Retention facility engineering analysis

sewage volume is 1.129 million m³, and the total amount of overflow sewage in the combined area is reduced from 32.2% of the total annual runoff in the area to 17.9%. The total amount of combined overflow pollution is 199.6 t COD_{cr}/yr, and the engineering benefits are very obvious.

The model-based evaluation and decision-making technology has been applied in the feasibility study of the *Kunming main city south section retention facility project* (outside the second ring) and the *Dianchi basin precision pollution control decision-making project*. The former has carried out a powerful demonstration on the necessity of the construction of the storage facilities in the southern catchment. The latter carried out a simulation analysis of the water quality evolution of the Dianchi Lake, the total water pollution load of the Weishui River, and the total pollution load of the ditch. Based on the water quality response analysis, it guided the overall and orderly construction of the Dianchi Lake treatment project.

5.3.3.2 Accurate Pollution Control Decision in Panlongjiang Catchment

Based on the basic data of river basin key management projects, plots, drainage, and rivers, and monitoring data, the project will establish a land pollution load flux model in Panlongjiang catchment, a three-dimensional water quality-hydrodynamic model of Panlongjiang and a land-water response model of the Panlongjiang catchment (compare Fig. 5.14). These models identify the priority section of the Panlong River and the corresponding water quality contribution, propose effective engineering

Fig. 5.14 Project technology roadmap at the Panlong River

projects and key treatment areas for “precise pollution control”, develop water pollution control engineering assessment and accurate pollution control decision system in Panlongjiang catchment. It realizes the benefit evaluation of key management engineering systems after the implementation of the “13th Five-Year Plan”, and form a key management project library that needs to be added or upgraded in the “14th Five-Year Plan” Panlongjiang catchment to provide a basis for scientifically and effectively carrying out water pollution prevention and control in Dianchi Lake Basin.

Two WWTPs, seven water pumping stations, seven retention facilities, and a sewage system of about 689.59 km and a drainage channel length of about 142.93 km have been built in the study area (based on the latest exploration data of the year 2018 in the Panlongjiang catchment). The sewage system mainly includes three types: a separated system for wastewater and rainwater and a combined sewer system. The total wastewater sewage system is 333.97 km, the rainwater system is 350.06 km, and the combined sewage is 3.74 km long.

The technical set up generally follows the sequence of “river course – discharge - sub-zone - key project”. The analysis steps for the components are described as follows:

River course: Identify the section of water quality change, establish the response relationship between the discharge and the change of water quality along the river course, and determine the comprehensive index system and quantitative requirements for achieving the water quality goal of the area;

Discharge: Monitor the water flow and load of key discharges, and determine the important discharges affecting specific sections and their contribution rate based on the water quality response with the Panlong River;

Sub-area: Identify the sub-area area importing into the discharges, monitor and simulate the flow and load of the sub-area;

Key projects: Establish the evaluation index system for the project, focus on the impacts of the project on the water flow and load for the sub-area and the discharge, as well as its impacts on the water quality for specific sections of the Panlong River, and propose the quantitative index requirements for optimization or new construction.

For the model evaluation the evaluation indicators of drainage facilities were carefully analysed and calculated. Also, comprehensive assessment of the area and the convergence of water and land were conducted. The results systematically reflect the benefits of engineering governance (compare Fig. 5.15).

Based on the overall idea of precise pollution control and the support of models, it is possible to carry out simulation for comprehensive analysis and evaluation of various management scenarios. Scenarios are including

Fig. 5.15 Results of the comprehensive 2018 assessment

- the overflow analysis of main discharges under different rainfall conditions,
- the assessment of primary strengthened pollution reduction and the water quality improvement of the 5th WWTP,
- the water quality impact assessment of the Panlong River because of the discharge from the tail water of the 4th and 5th WWTP, and
- the water quality impact assessment of the Panlong River under the operation of the 14th WWTP and so on.

The scenario modelling can support the scientific decision-making process for relevant treatment plans. Take the water quality impact assessment of the Panlong River under the operation of the 14th WWTP as an example.

According to the project feasibility study design document of the 14th WWTP, the completion of the 14th WWTP may largely influence the wastewater treatment and the water quality in the Panlong River area. The implementation of the measures for the 14th WWTP is divided into 2 stages: near future and long-term. So here we show two important scenarios based on the relevant construction documents, namely:

(1) *The near future operation:*

On the basis of the current situation in 2017, the overloaded wastewater of the 5th WWTP will be transferred to the 14th WWTP. Under the recent conditions of 14th WWTP, its advanced treatment capacity is 100,000 m³ per day (The tail water does not enter the Panlong River), and its primary treatment capacity after reconstruction is 400,000 m³ per day, with water entering the Panlong River. The advanced treatment capacity of the 5th WWTP has dropped from 240,000 m³ per day to the design capacity as 185,000 m³ per day (the water does not enter Panlong River just like the current situation in 2017). The situation of the 4th WWTP and other drainage facilities remain unchanged.

- (2) Based on the near future operation of the 14th WWTP, we improve the capacity of advanced treatment of the 14th WWTP from 100,000 to 200,000 m³ per day, and the tail water still does not enter the Panlong River. At the same time, closing the 4th WWTP and transferring its wastewater to the 5th WWTP for treatment. By setting the above conditions to the model and performing simulation evaluation, comprehensive evaluation and comparison of engineering benefits can be carried out, and the improvement effect on water quality can be objectively evaluated (compare Fig. 5.16).

5.3.4 System Joint Operation

With the improvement of drainage facilities in Kunming City, four relatively independent drainage areas have been delimited in the main city, including the drainage systems of the western, northern, southern and south-eastern area. During the 12th Five-Year Plan period, the systematic joint operation technologic research and engineering demonstration were first conducted in the drainage system of the western

Fig. 5.16 Evaluation of improvement effect on water quality

area, which focused on the improvement of water environment and water ecology of the old canal for grain transportation.

At the beginning of the project, there was only the 3rd WWTP, located in the lower reaches of the old canal and adjacent to Caohai. Four pumping stations, Tudui, Zhangfeng, Wulong River and Zhuangfang were set outside and could be directly connected to the fine grille gallery of the 3rd WWTP via a pressure pipe. With the development of the city, the 9th WWTP was built in the northwest area in 2014 in order to alleviate the load of the 3rd WWTP. Besides, some dividing weirs were set up on the three main trunk sewer that originally led to the 3rd WWTP, so that the wastewater in the northwest area was preferentially sent to the 9th WWTP, and the excess wastewater could be diverted to the 3rd WWTP. In the dry season, the wastewater in the area can be fully collected and treated. Due to the difficulty in implementing the transformation to separate system, the combined sewer system still exists. There are five main overflow structures for combined sewer system along the old canal. During the 12th Five-Year Plan period, in order to alleviate the problem of rainwater overflows over the dam in the rainy season, five rainwater retention facilities were installed at the end of the main sewer system, with a total retention capacity of about 56,000 m³. A complex drainage system was formed in the study area, called Plant-Station-Pool-Net. Flows in the service area of the 9th WWTP can be described clearly. There are two independent treatment processes in the service area of the 3rd WWTP as well as several pumping station and retention facilities. Thus, flows analysis in this catchment is more complex.

Firstly, based on the results of field survey and drainage model, 19 online liquid level monitoring devices were installed at the end overflow, diversion, confluence, low-lying and sensitive control points, and the data can be transmitted to the remote operating centre in real time via wireless. It is convenient to monitor the load in

real-time and control the drainage system in real time. This can provide support for the analysis and control for the plant-network joint operating model.

Secondly, through the transformation of a self-control system and the construction of a data acquisition system, the function of data acquisition and remote monitoring of the two WWTPs, five retention facilities and four pump stations in the West Zone was realized.

Thirdly, based on the analysis of the drainage GIS data and the historical data of the monitoring points, the basic framework of the drainage facilities operating control in the western area was built. The control strategy was determined through the analysis of operating parameters, the load of WWTP, the operation load of sewer system, and the overflow of the key outlets. Around the goal of optimized load distribution and discharge overflow control, we developed a three hierarchical control strategy and algorithm, consisting of:

- plant-plant load distribution control,
- plant-station flow balance control,
- station-pool-network coordinated control.

Among them, the plant-plant load distribution is controlled using the water level at the fixed weir. This control is aiming to solve the problem of balancing the load between the plant and plant. The plant-station flow balance control focuses on the priority of the peripheral pumping station along the WWTP (compare Fig. 5.17). The plant-pool-network coordinated control is based on the online water level of the

Fig. 5.17 Diagram of joint control of drainage system in the western area

pipe network and is calculating when the water enters the retention facility and when it is emptied.

After the basic preparatory work, the selection of the core operating strategy and the development of algorithms, the hardware integration was carried out in addition to the digitization of the drainage system. The construction management department had organized the basis for the system modelling. With the construction of the software platform, the comprehensive management and analysis of the drainage GIS data can be realized. The process elements of the drainage facilities in the western area can be fully monitored. They include pump stations, WWTP, retention facilities, sewage system monitoring points and so on. The operating instructions can be automatically generated and issued, and the historical operating records are logged and can be checked.

The pilot project started construction in May 2017 and was completed on August 1, 2017. After nearly one month of commissioning, it entered normal operation on September 1. A comparative analysis of the operational effects of dry seasons during the same period in 2017 and 2018 was carried out. In the case of similar rainfall, the total overflow of the main discharges in this area decreased from 640,000 tons to 350,000 tons, with the reduction rate reached 45.3%. During this same period, the treatment capacity of the 3rd WWTP and the 9th WWTP increased by 7.1% and 34.2% respectively. Due to the lack of complete rainy season operational data for the demonstration project, a statistical analysis for three months around August 1, 2017 of the operational effects was carried out. In the case of similar rainfall, the total overflow of the main discharges decreased from 5.98 to 5.65 million tons, with the reduction rate reached 5.5%. During this same period, the treatment capacity of the 3rd WWTP and the 9th WWTP increased by 19.3 and 22.9% respectively. In addition, the liquid level of the pipe network is significantly reduced compared to the previous period, effectively alleviating the overload condition of the pipe network (compare Tables 5.5 and 5.6).

Generally, the operation effects of the project can mainly be concluded from following aspects:

- effectively reducing the polluted overflow of the combined discharges into the river;
- improving the influent load of the WWTP and its operating efficiency;

Table 5.5 Comparison of effects before and after the implementation of the joint operating system in the dry season (January to April) of the years 2017 and 2018

Year	2017	2018
Precipitation	90,1	86,4
Overflow Discharge (10,000 tons)	64	35
Overflow reduction rate	45,3	
Treatment amount of the 3rd WWTP	2684	2875
Increase rate of treatment amount of 3rd WWTP	7,1	
Treatment amount of the 9th WWTP	628	843
Increase rate of treatment amount of 9th WWTP	34,2	

Table 5.6 Comparison of effects before and after the implementation of the joint operating system in the rainy season of 2017

Date	May to July	August to October
Rainfall	474,3	477,6
Overflow discharge (10,000 tons)	598	565
Overflow reduction rate		5,5
Treatment amount of the 3rd WWTP	1980	2362
Increase rate of treatment amount of 3rd WWTP		19,3
Treatment amount of the 9th WWTP	572	703
Increase rate of treatment amount of 9th WWTP		22,9

- reducing the overload rate of the drainage pipe network, and therefore improving the flood prevention and emergency response capability in the rainy season;
- sharing information and providing feed-forward support for process optimization of the water purification plant and emergency response in the rainy season, which helps to ensure stable operation of the WWTP.

The pilot research and engineering practice in the western area develops a multi-facility joint operating control algorithm and systematic integration scheme with distinguished characteristics of real-time, robustness and universality. It provides underlying technical support to the construction of integrated efficient system in other drainage areas in Kunming and even to the operating control to the water circulation system of the Dianchi Lake.

5.3.5 Summary of Application Benefits

The digitization of the management of the urban drainage system in Kunming, as described above, help to build an integrated management of plant-network-river-lake system. The application benefits are mainly the following:

- (1) Accurate and comprehensive reflection of the current status of Dianchi treatment facilities
This component can promote periodic and iteratively updated on-site data verification and supplementary surveying based on the existing drainage network data of Kunming City and the “Technical Specifications for Data Management of Urban Drainage Facilities in Yunnan Province”. It can also realize data standardization and consolidation, as well as carrying out topology inspection and correction, and finally building a GIS database of drainage facilities. The GIS basically reflects the status quo. It helps to operate an effective online monitoring network to accurately reflect the operation dynamics of drainage facilities, which can provide reliable information to management and decision-making process. In the application process, establishing a data sharing and supplementary update mechanism can further improve the data quality and use value.

(2) Systematic diagnosis and evaluation of construction and renovation plan for Dianchi

Based on the mathematical model, this element can establish a specialized analysis and evaluation. It helps to carry out simulation and quantitative evaluation of the engineering schemes for Dianchi Lake governance. This system can systematically analyse and scientifically diagnose the effects of the facility construction including:

- analyse the problems and defects of the existing renovation plan, and diagnose the risk of relevant decisions;
- provide decision making support for planning and transformation project, large-scale project, operation scheduling, linkage control etc.

The assistant management staff can quantitatively evaluate the load and operating status of the water supply and drainage system with the joint application of online monitoring and model, and then evaluating the relevant planning and transformation plan, improving the application benefit.

(3) Improvement of the operating efficiency of large-scale projects and optimize investment

Based on the simulation optimization analysis method of complex system, a new planning and design evaluation and optimization process is established. The problem diagnosis, scheme formulation and engineering decision-making process of the drainage system are assisted by means of monitoring and modelling with the purpose of improving the water quality of Dianchi Lake and the overall operating efficiency of the drainage system. Meanwhile, it carries out the research on joint control. It also improves the reliability and effectiveness of the overall operation of the drainage system. The system helps with the overall optimization and synergy scheme by a multi-objective optimization method. It also fully mines the potential of existing drainage facilities, sewage systems and WWTP and their existing capacities to reduce unnecessary or inefficient construction investment.

(4) Improve the decision-making level of the planning and construction of pollution control projects in Dianchi Lake Basin

Whether it is possible to improve the planning and design decision-making level of major projects depends largely on whether the related status data of the drainage facilities are truly and completely grasped. The improvement also depends on whether the overall operational data are truly diagnosed and evaluated during the engineering planning and construction decision period. This program has designed a new and improved database, necessary hardware support, scientific decision-making mode, and visualized control system. It helps the decision-makers of the investment company to grasp the whole process information of the related project as detailed and comprehensive as possible. The process information is a solid foundation for big data analysis. Based on a large number of updated data and advanced model analysis methods, it is possible now to comprehensively evaluate the operating situation

of system, optimize relevant details, thereby improving the decision-making level of engineering planning and construction.

- (5) Build a long-term dynamic decision-making model combining technology and management

The complexity of the drainage system determine that the state of the drainage system is dynamic and stays to some extent uncertain. This program builds a long-term dynamic decision-making model. On the one hand, it helps to establish an iterative data update mechanism and an online monitoring and early warning system for drainage facilities to form a drainage monitoring network. It can truly assess the existing status of the drainage facility and operates the monitoring and early warning. On the other hand, it establishes a decision support model with joint application of multiple models. It quantitatively simulates and analyses the engineering planning scheme and gives decision-making suggestions. At the same time, it can use online monitoring, model simulation, multi-objective optimization, big data analysis and other means to forecast the status of drainage facilities in the future, comprehensively and systematically analyse the historic, current and future development of the Dianchi pollution control system to promote the scientific decision-making.

5.4 Conclusion and Prospects

Integrating the monitoring and model system to form an intelligent decision-making and control system that can quantitatively evaluate and support decision making, and to realize the unified integration of the whole process information of “source-network-station-WWTP-river-lake” system can effectively support the refined, scientific, systematic, intensive governance of Dianchi and serve the long-term water quality improvement. In the process of Dianchi Lake management, it is of great significance to employ advanced information technology and the core technology system including basic data, online monitoring, simulation, evaluation and decision-making and intelligent control, and build an integrated management and control mechanism of source-network-station-WWTP-river-lake system to effectively support engineering decision-making and operation control.

Especially with the further growth of urban areas of Kunming, the drainage system is becoming more and more complex and larger, which increases the pressure of planning and decision-making. The existing local problem analysis and diagnosis methods have been unable to meet the needs of optimization and improvement for complex drainage system. In order to increase effectiveness of the large number of existing drainage facilities and engineering projects it is necessary to implement new technology. They aim at a number of tasks such as

- objectively evaluate the operational efficiency of the existing systems,
- propose necessary new construction and reconstruction projects, and
- provide clear, comprehensive and practical instructions for the future drainage information construction in Kunming.

To do so, we comprehensively use advanced technologies such as GIS technology, network communication, industrial automatic control and drainage system simulation. These are the core components to build a comprehensive management and control platform capable of managing a large amount of spatial and attribute data of the drainage system in a long-term, effective and dynamic manner. On the basis of the implemented functions and acquired data of the new information system, we need to form a comprehensive database of drainage system in the downtown area. We also construct various business modules and professional analysis modules required by the digital management of the drainage system. With them, we step by step study and explore the intelligent control mode of the drainage network. Finally, we can achieve the construction goal of building the “source-network-station-WWTP-river-lake integrated management system”. This will help to comprehensively improve the diagnostic analysis level, planning decision-making level and performance evaluation ability of the drainage facilities in Kunming.

In the planning management and engineering decision-making process of the drainage system in Kunming, we should continuously explore the planning and control mode of “source-network-station-WWTP-river-lake” integration to realize the goal of overall decision diagnosis and optimization. We should promote continuous improvement of digitization to motivate the transformation of management and control and realize scientific decision-making and intelligent operation of drainage facilities. We do that by providing a unified decision-making analysis platform for Dianchi water environmental governance, realizing the whole process information management of “source-network-station-WWTP-river-lake” system. We should also provide reliable, unified and detailed data interface and systematic system for the call of relevant business systems, and finally promote the transformation and improvement of urban management mode.

In the iterative improvement process of the integrated management system, it is also necessary to actively draw on international advanced experience, especially the close cooperation between SINOWATER and FiW in Sino-German cooperation projects. We should further promote the development of the drainage system in the future in Kunming. Including but not limited to the following points:

- (1) The acquisition of data is the basis and core of all work, its collection and transmission need to be continuously implemented in the project construction. And it is necessary to ensure capital investment.
- (2) Applying models to guide designing process and performing systematic and scientific decision-making are essential means.
- (3) Continuously and steadily promote rain and sewage system separation, LID source reduction measures of rainwater runoff combined with the long-term urban expansion and transformation.
- (4) Improving the efficiency of the sewer system and reduce the difficulty of operation and maintenance. Separation of wastewater from rivers by setting up facilities within the open sewage channels
- (5) Sewage system inspection, infiltration protection, operation and maintenance of sewage systems are very important.

- (6) The implementation of new treating methods like soil/wetland treatment should be followed by the match of adjusted retention facilities and the scale of WWTP.
- (7) The initial rainwater interception and limit of the separated system should be sent to the WWTP.
- (8) One of the objectives of the next stage of the WTTP is the treatment of micro-pollutants.

Integrating the monitoring and model system to form an intelligent decision-making and control system that can quantitatively evaluate and support decision making, and to realize the unified integration of the whole process

To conclude, the establishment of a scientific and effective “source-network-station-WWTP-river-lake” integrated management system and its rational application to actual planning and decision-making is not a one-step process. It requires the long-term and unremitting efforts of decision makers, planning designers, professional technical teams and operating management staff to build an integrated drainage management system, which is scientific, practical and can meet the local technology needs.

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