Decision Support System of Regional Water Resources

Changjun Zhu
College of Urban Construction, Hebei University of Engineering, Handan, 056038, China
Email: christorf@126.com

Zhenchun Hao
State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University, Nanjing 210098, China

Abstract—It is very important to dispose the water resources rationally. Rational disposition of water resources is the nucleus of sustainable water resources utilization, and is the important way to solve the district water resource shortage and raises utilization efficiency of water resource. A decision-making variable model is established by groundwater, surface water and precipitation. Water resources managing decision support system in handan is developed on the language of visual basic, with the usage of database-access and the map-object GIS groups. And the system has the functions including managing function of data and files and editing function of images. During the model built, idea of decision-making variable deduction is adopted to transform three kinds of water to get the results of sustainable utilization of water resources. Finally Visual software is programmed Using GIS and VB language, and the rational blue print of water resources in this region can be decided applying optimized model. The system plays an important role in the water resources management.

Index Terms—decision-making variable deduction; water resources; decision support system; handan

I. INTRODUCTION

Water resource is one of the basic substances for human survival and development which is an indispensable natural. Since the latter half of 20th century, along with social development and economic growth and rising living standards, it is obvious for contradictions between water supply and water demand, and it is even more acute to earn water between industrial and agricultural. However, water shortage, pollution and rampant flooding is restraining global economic and social development, but also is one of the constraints faced in the process of building a moderately prosperous society. Throughout human history of development and utilization of water resources can be found that socio-economic development of water demand is far less than the amount of available water resources in the primitive stage of water resources, because of low levels of social productive forces, sparsely populated. Water seems "misdischarge". In the traditional stages of development and utilization of water resources, human take large-scale construction of water conservancy prohcrct as the main measures to meet the needs of socio-economic development on water resources. Along with the water shortage, floods, water pollution and other issues, inconsistent relationships among the water resources and social, economy and environment have become increasingly prominent. Traditional way of development and utilization of water resources has faced a great challenge to force the sustainable use resources development of ideological transformation. The water problem in Handan city is very pendent. There are also three major water problems. The first is the contradiction between water supply and demand, the second is the flood disaster and the third is water quality pollution, namely the so-called water sparsity, water flowage and water pollution. There is close relationship the realization of water resources’ sustainable utilization and the natural, social and economic factors in this region it’s bound to carry out the specific region [5]. The region is a complicated system with regional disparity and hierarchy. To the complicated system, a lot of research is to be done. In this paper, according to the sustainable development strategy, based on the systematic engineering theory and water resources systematic analysis, we studied this decision system. It will supply scientific basis to the reasonable utilization of the regional water resources in agriculture and water resources protection.

II. STUDY AREA

The annual rainfall in handan is 558.8mm, among them, it is 587.6mm in Fuyang land area, and 578.7mm in Zhanghe Mountain, 530.1mm in West Fuyang, 554.7mm in Weihe plain. Precipitation in eigenvalue statistics and different assurance can be seen in table 1.
where groundwater is abundant while rainfall and surface water is lack. Available water resources in handan area include Zhang river, Weihe river, fuyang river, etc. No major regulating reservoirs in this region, uneven distribution of precipitation, the river are not only transited for land surface water, along reservoirs in this region, uneven distribution of precipitation, the river are not only transited for land surface water. Therefore, calculation of water resources is a large and complex optimization model. The more difficult question is how to coordinate the relationships among precipitation-surface water-groundwater water to achieve scientific and reasonable utilization. In this paper, hierarchical analysis and decision variable subtraction are introduced to solve the water resources.

Decision variable subtraction method is that the meteoric of precipitation or surface water supplies should be subtracted from the decision variable of groundwater exploitation, then to optimize the decision variables.

Decision variable subtraction can be expressed as followings

\[
Q_g = \begin{cases} 
\leq Q_d, & \Delta Q_d = Q_d - Q_r > 0 \\
0, & \Delta Q_d = Q_d - Q_r \leq 0 
\end{cases} 
\]

(2)

Where rainfall is abundant and the surface water and groundwater are lack.

\[
Q_g = \begin{cases} 
\leq \Delta Q_d, & \Delta Q_d = Q_d - Q_r > 0 \\
0, & \Delta Q_d = Q_d - Q_r \leq 0 
\end{cases} 
\]

(3)

Where surface water is abundant while rainfall and groundwater is lack

\[Q_g = Q_d\]

where groundwater is abundant while rainfall and surface water is lack.

Where \(Q_s\), surface water flow; \(Q_g\) groundwater flow; \(Q_d\) water requirement.

Above equation is how to dispose the decision variable in any grid. Decision variable subtraction can be seen as one preprocess. The construction of the model can be expressed as followings

\[
\frac{\partial h}{\partial t} + \left( \frac{h}{k} \right) \nabla \left( \nabla \cdot h \right) + \left( \frac{h}{k} \right) \nabla \cdot (\nabla h) = W (x_1) \leq \xi (x_1) \leq 0 \]

(1)

Where \(h\) is water level, \(b\) is lower confining bed level; \(W\) is supply water in unit time and unit area; \(\mu\) is aquifer storage coefficient; \(q(x_1,y,t)\) is unit discharge; \(k\) is permeability coefficient; \(n\) is outside normal direction.

B. Establishment of sustainable quantitative model of water resource

Sustainable quantitative model of water resources is a large and complex optimization model. The more difficult question is how to coordinate the relationships among precipitation-surface water-groundwater water to achieve scientific and reasonable utilization. In this paper, hierarchical analysis and decision variable subtraction are introduced to solve the water resources.

Decision variable subtraction method is that the meteoric of precipitation or surface water supplies should be subtracted from the decision variable of groundwater exploitation, then to optimize the decision variables.

Decision variable subtraction can be expressed as followings

\[
Q_g = \begin{cases} 
\leq Q_d, & \Delta Q_d = Q_d - Q_r > 0 \\
0, & \Delta Q_d = Q_d - Q_r \leq 0 
\end{cases} 
\]

(2)

Where rainfall is abundant and the surface water and groundwater are lack.

\[
Q_g = \begin{cases} 
\leq \Delta Q_d, & \Delta Q_d = Q_d - Q_r > 0 \\
0, & \Delta Q_d = Q_d - Q_r \leq 0 
\end{cases} 
\]

(3)

Where surface water is abundant while rainfall and groundwater is lack

\[Q_g = Q_d\]

where groundwater is abundant while rainfall and surface water is lack.

Where \(Q_s\), surface water flow; \(Q_g\) groundwater flow; \(Q_d\) water requirement.

Above equation is how to dispose the decision variable in any grid. Decision variable subtraction can be seen as one preprocess. The construction of the model can be expressed as followings
C. Optimization model of water resources

Two-dimensional finite difference flow simulation model is adopted to integrate the model and simulation model, which can be seen as water balance constraints divided to the optimization model directly. The optimized model includes

1) Goal Function

   ① Economic goals

   The direct economic benefits brought by the development and utilization of water resources in the region are as the main economic goals. The economic goals can be expressed as followings

   \[ \max Z = \sum_{k=1}^{T} \sum_{l=1}^{I} \lambda_l f(H^k_l, C^k_s, Q^k_w, Q^r) \quad (4) \]

   Where \( k \) is phase loop variable; \( l \) is target loop variable; \( \lambda_l \) is target selection coefficient; \( f \) is composition relations of decision variables; \( H^k_l, C^k_s, Q^k_w, Q^r \) is water level, pollutants concentration; development and utilization of water and artificial water recharge decision variable set.

   ② Social goals

   In essence, the purpose of all economic activity is minimal consumption of resources for maximum national benefit. Water crisis enlightened us that the goal of government is to use renewable and limited water resources sustainable, and to create the greatest benefit for our country. Therefore, in theory, social economic can be measured using social welfare, Pareto standard can be used to determine the basic criteria of social welfare to improve. Because it is difficult to measure the social welfare and to express welfare function, in order to meet the operability requirements, the total water volume of the smallest are chosen to directly reflect the social objectives. Because the size of the regional water shortage and water scarcity directly impact the social development, reflecting increased water quality and quantity of services growth and increasing social needs of adaptation, which is directly related to the sustainable development of social security and social stability.

   Assuming the regional water supply

   \[ x(t) = f(x_{in}(t), x_{pk}(t), x_{ek}(t)) \]

   Volume scarcity \( SO(x(t)) \) throughout the entire process of development and utilization of water resources, the social objectives can be expressed as

   \[ \min \{ TSO = \sum_{t=1}^{T} SO(x(t)) \} \quad (5) \]

   If domestic water consumption is \( D_{in}(t) \), water demand for production is \( D_{pk} \), ecological water requirement is \( D_{ek} \), then the \( SO(x,t) \) can be expressed as followings

   \[ SO(x(t)) = \sum_{k=1}^{K} (D_{in}(t) + D_{pk}(t) + D_{ek}(t)) \]

   \[ - \sum (x_{in}(t) + x_{pk}(t) + x_{ek}(t)) \quad (6) \]

2) Environment benefits goal

   To the water resources directly related to environment issues, the smallest amount of sewage can
be measured. In general, the emissions of major pollutants can be selected as expression.

If the regional water supply \( x(t) = f(x_R(t), x_{pk}(t), x_{ek}(t)) \) resulting the emission of major pollutants as \( BO(x(t)) \) in \( t \) period, then the environment benefits objectives can be expressed as followings in the whole process of water resources development.

\[
\min \{TBO = \sum_{t=t_0}^{t_n} BO(x(t)) \} \tag{7}
\]

Further, \( BO(x(t)) \) can be expressed as

\[
BO(x(t)) = \sum_{k=1}^{K} 0.01 \left[ d_{ik}(t) x_{ik}(t) + d_{pk}(t) x_{pk}(t) + d_{ek}(t) x_{ek}(t) \right]
\]

Where : \( d_{ik}, d_{pk}, d_{ek} \) respectively the content of main pollutants in sewage waste water in living, production, and ecological water in \( k \) region. Generally, BOD, COD, Tod can be as indicators of water quality.

\( h_{ik}, h_{pk}, h_{ek} \) is the emission factor of ecological water and sewage water.

2) Constraints

1) Conservation constraint

Conservation constraints are the simulation model of water resources system based on the mass conservation and energy conservation, as an aspect of constraints, its mathematical formulation is as follows

\[
[A] [H] + [B] [H] + g(Q_k^L, Q_k^K) = 0
\]

\[
[P] [C] + [R] [C] + f(Q_k^L, C_w) = 0
\]

Where \([A] [P] [B] [R]\) is coefficient matrix.

2) Water restriction

\[
\sum_{k \in \Delta} Q_k^L \geq D_k^L \quad D_k^L ---- water requirements in k stage.
\]

3) Water system constraints

\[
\sum_{w \in \pi} Q_w^K \geq W L_k^K \quad W L_k ---- sewage water capacity in k stage.
\]

4) H_i \geq H'_i \quad i \in \Delta, H'_i ---- controlled water level, \( \Delta \)---set of control point

\[
C_s^K \leq C_s' \quad w \in \pi, \quad C_s'^K ---- control values of regional concentration
\]

IV. WATER RESOURCES MANAGEMENT DECISION SYSTEM

1) In order to depict water resources information vividly, figure management system is developed by Visual Basic program, MapInfo and surfer software.

2) SURFER is coupled into VB program by OLE to make up underground water flow field model. Equivalent-value line can be drawn automatically by SURFER to depict the state of groundwater vividly.

3) The aim is to get the largest water resources quantity of the study area, and the decision-making variable is to artificially using water resources quantity. The state variable is ground water flow, the limiting set is water-quantity equilibrium equation. Prepare for flood, deduce draught-disaster protect water resources from pollution. Sustainable water resources model is made up.

4) The decision system is made up of prediction model and optimize model. It can be seen in Figure1.

The following two objectives of this system are establishment of spatial information database and attribute information database of water resources in handan to share information resources; coupling the numerical simulation and GIS to provide a scientific basis for water resources decision-making in handan. The main functions are as followings.

A. Function of decision system

1) Map management

The features of this module are designed for water resource information management. Users can edit the map in this module. Users can directly control the display of layers, zoom in or out. Users can also increase the layers and add data types. The whole process is easy, fast and intuitive. And users can also control the displayer of various layers or not.

2) Automatic Mesh Function

According to the users’ request, the system can automatically divide the study area into different numbers of square grid and can be numbered and display. Fig.3 is the 110 grid by automatic mesh.
Figure 2. The plan of regional water resources management decision system.
3) Resources situation

The system can display the situation of groundwater (Fig.6), surface-water (Fig.5) and rainfall (Fig.4).

4) Simulation and rendering of groundwater contour

The function of this module is to simulate the changes of groundwater levels when the exploitation quantum changes. By simulation, users can intuitively understand the trend of water level. According to the changes of groundwater extraction, groundwater contour can be drawn for finding the contour changes. Fig.7 is the distribution of simulated groundwater level, and Fig.8 is the distribution of observed groundwater level. Fig.9 is the comparison of simulated level with observation level. By comparison, the results is reasonable.
B. Optimization of water resources

Water resources management decision system in Handan city is a computer system based on the development-making of groundwater resources, surface water and atmospheric water. The system breaks through the existing results that most were only based on the existing fixed data of the data base to decide. Based on the existing data and according to the decision-maker’s idea, choosing the project, exploitation time, site and quantity, using the groundwater numerical simulation prediction model and estimation decision module; respond the landing condition exploiting quantity condition and groundwater flow field condition when exploiting, and supply dynamic and convenient groundwater resources management decision. In the decision-making process, whether the regional groundwater numerical simulation prediction model is exact or not, it will directly influence the reliability of the decision results. So, building up the exact regional groundwater numerical simulation prediction model is the key to carry through the right regional groundwater resources management decision. In this paper, the sub area method is adopted to effectively solve the calculation problem of the great area groundwater resources using the computer. In the process of three kinds water translation first adopt idea of decision – making variable deduction to solve the three kinds water treatment method that puzzled people in the long time. Fig.10 is the optimization result. Seen from the fig.10 the system’s running results afford the water resources management decision project of Handan city: by means of optimization collocation, we can get that west mountainous area is basically atmosphere water, while east plain is basically groundwater and the area including the river is basically river. So according to the management system, we can get the best plan for the utilization of water resources.

V. CONCLUSION

According to the introduction of water resources decision support system's structural framing, the principle of design and the basic function, Some Characters are summarized as follows:

The system design has manifested face the question principle.

The system has certain applicable scope. It can carry on significant industrial policy for the related water resources development and appraisal of the environmental policy adjustment to provide decision-making and the early warning information.

The decision support system function is complete. Namely it has the functions of simulation, prediction, optimization, the analysis and management.

System's organizational structure is quite reasonable. The system is made up of model base, the database and the interactive contact surface. Data transfer completes through the database between the models. The man-machine interaction contact surface provides the information to the policy-maker by the electronic forms, the graph and the document, the policy-maker may carry on the transfer, the establishment and the revision by revising the parameters.
ACKNOWLEDGMENTS

This study was funded by the National Basic Research Program of China (2010CB951101), the National Natural Science Foundation of China (Grant No. 40830639, 50879016, 50979022 and 50679018) and the Special Fund of State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering (1069-50985512).

REFERENCES


Changjun Zhu received his B.S. in China University of Petroleum in 1999 and M.S. in the Chinese Academy of science, in 2002. Since then, he worked in Hebei University of Engineering and now he is the associate professor of Hebei University of Engineering from 2009. Now he has received Ph.D. in the College of Hydrology and Water Resources, Hohai University in Nanjing, China. His main research interests are in numerical environment modeling

Zhenchun Hao received his B.S. and M.S. in the College of Hydrology and Water Resources, Hohai University in Nanjing, China, in 1981 and 1984, respectively. He continued his education at the same university where he received a Ph.D. in hydrology in 1988. Now he is a professor of hydrology at the College of Hydrology and Water Resources, Hohai University in Nanjing, China. His research interests include large-scale hydrological modeling, watershed hydrological modeling and ecological hydrology.