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Watershed protection and landscape enhancement by utilization of river water

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Abstract: A scheme for watershed protection and landscape enhancement (WPLE) by utilization of river water was proposed to renovate water resources and protect ecological environment in Qiongshan City, Hainan Province, China. Utilization of river water may diminish the drought and flood risks. The scheme is beneficial to solve the problems of water resources shortage, groundwater declines and saltwater intrusion in the watershed. The object of the WPLE scheme is to achieve a sustainable integrated development of environment, ecology, economy and society. A kind of physically beautiful and functionally vivid landscape may exert its synthetical function on the diversity of landscape and the enjoyment of inhabitants. Feasibility of the scheme will be demonstrated by more experiments and tests, as well as observations in a long term.

Keywords: watershed; landscape; water resources; eco-environment

Introduction

A common phenomenon for water resources in the world is that water is plentiful during certain seasons, and drought conditions occur in other seasons. Similarly, water demand is also cyclical, with the highest demand often occurring when the least amount of water is available. Utilities therefore face a constant challenge of how to store water during times of plenty so that adequate resources are available when needed.

Storing water involves both watershed protection and water conservation (Lyle, 1994). Natural watershed is responsible for providing water to the environment. Sustainable management of the watershed can enhance the natural habitat, conserve water, and provide long-term water storage and flood protection. Water conservation could do with improvements of agricultural, industrial and municipal water consumptions, as well as with treatment and utilization of lower-quality waters.

Aquifer storage and recovery (ASR) is a form of conjunctive use where excess water is stored underground in a suitable aquifer and recovered later as needed (Dillon, 1998). ASR can provide an effective tool for sustainable development and management of available water resources within a watershed to balance the needs of competing water demands (Dodds, 2000). Drivers for ASR are also expanding beyond seasonal storage to include acting as a salinity barrier, aquifer replenishment, and for water quality improvement (Dabbagh, 2001). ASR operation has been developing in Australia, the United States, Israel, Netherlands, England, South Africa and other countries today (Eastwood, 2001).

In this paper, we present a scheme of watershed protection and landscape enhancement (WPLE) by utilization of river water in Qiongshan City, China, in which the basic principle of ASR is adopted and further extended to eco-environment protection, particularly to watershed protection and landscape enhancement.

1 WPLE scheme

1.1 Background

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Qiongshan lies on the Binhai Plain in the north of Hainan Province, close to the capital city of Haikou (Fig.1). Qiongshan has an area of 2068 km^2 and a population of 800000. It has a tropical monsoon climate with an annual average temperature of 23.8℃. Annual rainfall and evaporation average 1300 and 1900 millimeters, respectively. The rainy season starts in early May and ends in late October. Nandu River flows through the part of Qiongshan before emptying into the sea. Its length is about 311 km, with 69 km in Qiongshan, and average width is 800 m. The whole drainage area of Nandu River is 71.76 km^2, and annual average water discharge reaches 6.92 km^3. Near 60%—70% flow of the river happens during May to Oct. The radiant intensity, average temperature, average rainfall and relative humidity of air in Qiongshan in 2001 are shown in Fig.2. The bedrock of Qiongshan has formed over a long geological period, with a dense network of tidal canals. Typical acid red soils with thickness of 1 – 1.5 m have been developed under the sub-tropical and tropical climate(Zhu, 1999). The thickness of unconfined aquifer is 31 m, below which seven confined aquifers are situated. Total groundwater runoff reaches 10000 m^3/d.

Fig.1 Locations of the wisdom valley and Qiongshan City

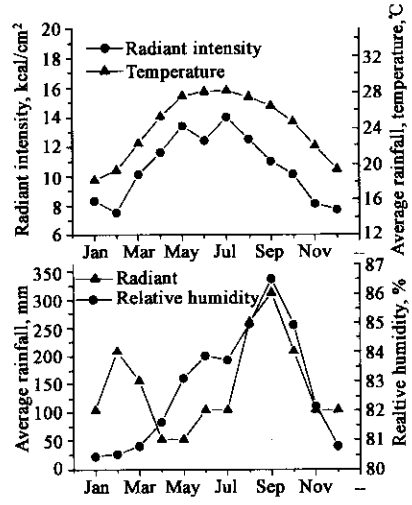

Fig.2 Radiant intensity, average temperature, average rainfall and relative humidity in Qiongshan in 2001

In order to promote sustainable development of Qiongshan City, officials from the local government together with researchers from Research Center for Eco-Environmental Sciences (RCEES) of the Chinese Academy of Sciences initiated a campaign of ecological city development. A new city area called the Wisdom Valley has thus being constructed by the government. The valley is located 5 km away from Meilan International Airport and a sea bridge connects the valley to Haikou City. The central task of the valley development is to encourage a kind of economically productive and ecologically efficient industries, a kind of systematically responsible and socially harmonious culture, and a kind of physically beautiful and functionally vivid landscape.

However, the valley is experiencing rapid population growth and water demand expanse. Lying on a water supply system, surface water is taken and carried by long distance conduit to the waterworks in Qiongshan City(Li, 2000). Yet finite water resources are even now the restrict factor against the valley's development. Water use has exceeded groundwater recharge. On average only about 7 percent of the mean

annual precipitation infiltrates deep enough to recharge the groundwater. Annual groundwater storage quantity is approximately 1.566 billion m^3 in Qiongshan City, in which only 449 million m^3 could be exploited. It is near 6 m of water table decline in Qiongshan over past 10 years due to overexploitation (Fig. 3). Overconsumption of groundwater resources in the area may also result in saltwater intrusion and may cause a drop in surface water level. On the other hand, during the flooding season, most of the water produced from rainstorm cannot be utilized due to its swift transport into the sea. Simultaneously, rainstorms produce a plenty of damaged water.

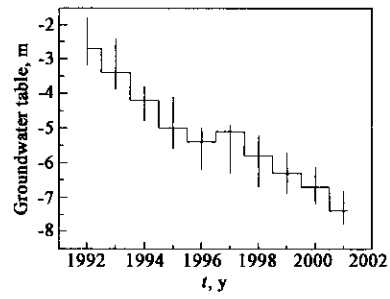

Fig.3 Groundwater table declines over past 10 years in Qiongshan

It is a contradiction of groundwater declines and flooding risks. Hainan Island is isolated from the mainland, thus its water resources are not related to any other water systems in China. Local rainfall is the only original resource for survival of livings and development of society and economy (Gu, 1995; Ma, 2001). Most water problems in Qiongshan may arise from four aspects: seasonal water shortage, sectional water shortage, hydraulic scarcity and low-efficient water use.

1.2 WPLE scheme

A common way to store water in China is to build dams and the accompanying reservoirs that flood large areas. Qiongshan's flat topography, however, leads to relatively shallow holding ponds that lose a lot of water by evaporation. In view of the high evaporation rates it can be cost effective to store water underground rather than on the ground. By capturing surplus water and artificially recharging it, the groundwater resources would receive additional replenishment thus boosting the amount of water available for later abstraction(Pavelic, 2000). Within the ecological city development plan, researchers in RCEES proposed a water plan for replenishing water resources, improving ecological environment and further ensuring sustainable development in the valley as well as in Qiongshan. The key point of the scheme is to store and utilize the Nandu River's water in the valley.

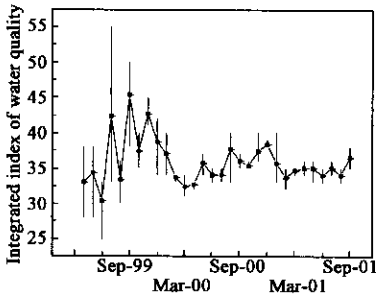

Fig.4 Integrated index of Nandu River's water quality (observation in Longtang Dam Monitoring Station)

The Nandu River has been practiced as water resources of Qiongshan City and Haikou City at its upper reaches over decade years. Water qualities at the upriver appropriately satisfy the Standards of River Water Resources(SRWR) in China while those at the lower reaches may not. The upriver water, however, only fits the second standard of SRWR based on a long-term observation in Longtang Dam Monitoring Station (Fig. 4). The upriver water qualities in 2001 tend to be more stable than those in 1999. Meanwhile, a consumption risk is still presented since the integrated index of water quality is around 35. Once the integrated index is over 50, it will be not suitable to be used as a source. Therefore, surface water storage may encounter the problems of both reserves shortage and water quality deterioration.

Researchers in RCEES drew an outline of transmitting river water to both surface channels and underground storage. The WPLE scheme consists of units, functions and objects (Fig.5). The basic units

are the river, the channels, the lakes and the unconfined aquifer. The Nandu River provides water source for the channels by which water is transported into the lakes as a temporary storage. The channels water may also partially serve as water sources for agricultural and industrial purposes. The lakes act as a central control for redistribution of the water to agricultural, industrial and commercial purposes in the valley. The stored water may be injected into the aquifer for long-term storage and recovery. It has not been considered to inject water into the confined aquifers due to safety consideration.

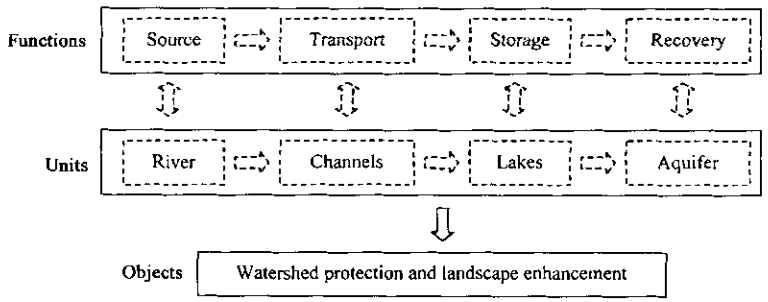

Fig.5 Scheme of WPLE by utilization of river water

Utilization of river water to WPLE presents an integral technology as well as a dynamic process. From the river to the aquifer, surface water translates into groundwater, which involves physical, chemical and biological purification processes. On the extended flow paths, it may be a natural process for the channels to transmit water to landscape and also to infiltrate water into the upper unsaturated aquifer. Both lakes and channels provide water for wetland, woodland and grassplot based on ecological conservation and development. Based on the units and their functions, objects of the scheme are to protect watershed, to enhance landscape, and then to improve ecological environment.

2 Discussions

2.1 Development of WPLE

In 2000, one channel was constructed to store and transmit water on its utility. A dam was built, separating the channel from the river. In the summer of 2001, surplus water in the river was transported into the channel. A single well was independently applied to cycle testing as well as to determine initial water chemistry and storage capabilities of the aquifer. Data, recorded electronically at the extensometer and the piezometers, are being collected periodically, entered into a database, and checked. Water tables are measured periodically in wells. Injection flow rates are monitored electronically. At present, it is difficult to analyze the irregular data and further determine the related parameters due to an unstable short-term operation on the single well. Work continues on the development and optimization of a two-dimensional groundwater model. An automatic control system for regulating the water transmission processes is being designed locally.

Furthermore, long term pumping records and extended monitoring activities are necessary in order to fully characterize aquifer systems in the area. Data collection on the number of permitted aquifer storage and recovery facilities is proposed. More geological data may be collected to further evaluate the possibility of the WPLE scheme. At present, a technical board, organized by RCEES and the local government, is examining the science of this process and determine what types of tests are needed and safe in the WPLE

project.

2.2 Watershed protection

Improvement of water use efficiency is an essential function of the WPLE system. First, the system is expected to meet consumptive demands and to reduce the pressure on natural groundwater resources. Annual water supply of Qiongshan was 2.3 billion m^3 in 2000, in which about 243 million m^3 was exploited from groundwater. It was estimated that annual water demand from groundwater in 2005 would reach 300 million m^3. The system has the potential to store up 15 to 30 million m^3 of water into the unconfined aquifer, which largely alleviate the pressure of groundwater supply and satisfy the demand of the valley.

Second, the system may also improve water quality besides enhancement of water supply capacity. The river water can be purified physically, chemically and biologically. Improvements of water quality initially take place by self-purifying mechanism going with the transmitting processes. Natural treatments primarily happen during surface water infiltrating into the soil.

Third, it is possible that both flood risk and drought risk may be relieved. During the flooding seasons, channels may scatter surplus water into the lakes and the aquifer so that water is redistributed on the ground and underground. Water produced from rainstorm could catch more dispersed and stationed space rather than the limited watercourse of the Nandu River. Consequently, the WPLE system washes away stormwater, preventing it from replenishing the valley. During drought seasons, on the other hand, the stored surface water may attend to the urgent consumption, and groundwater may be pumped and recovered for the same expenditure. The WPLE system, as an emergency storage, also prevents ground subsidence and saline intrusion.

Protecting the watershed is the highest priority in sustainable water management. Often referred to as landform engineering, its primary goal is to manipulate and enhance the natural flow of water to improve the site's ability to catch, hold, and absorb water. The valley's topography can be used to guide water through the constructed channels and lakes, which are effective methods of collecting water to storage areas as well as distributing the water back to the site. Moreover, the WPLE system could be viewed as a stormwater retention system that provides a more environmental and aesthetic alternative to conventional drainage system. Retention system stores runoff water to be released slowly and/or absorbed into the ground, and provides flood protection. In addition, groundwater sources are the cleanest and most energy-efficient source. The WPLE scheme can improve water use efficiency and provide sufficient groundwater for the valley.

2.3 Landscape enhancement

It is plainly evident from all the previous principles and guidelines that site design and landscaping are inherently linked with water. Sufficient water supply, therefore, has an enormous impression on landscape. The WPLE scheme involves both watershed protection and landscape enhancement. It is a main difference from ASR that the WPLE system emphasizes ecological improvements. The channels may be favorable to redistribution and reutility of water resources during the transmitting processes. Channels and lakes at first represent themselves as landscape appearances. They also enable moisture to not only spread into air, but also penetrate more widely into soil and further cultivate plants that enrich the landscape. Consequently, channels flow as well as lakes may be more truthfully fitting for municipal green scenes.

The WPLE system may improve the ecological environment of the valley. Since groundwater levels in

depleted aquifers are restored and groundwater discharge is maintained, adequate water could be allocated to protect water dependent ecologic systems. A kind of physically beautiful and functionally vivid landscape may exert its synthetical function on the diversity of landscape and the enjoyment of inhabitants. The key of the WPLE scheme is the ecological integration. It is aimed at improving its structural coupling, metabolism process and functional sustainability through cultivating an ecologically vivid landscape, totally functioning production and systematically responsible culture(Wang, 1999). It is also significant to protect biological diversity and further to provide for equity within and between generations.

2.4 Arguments of the WPLE scheme

Environmental impacts from water source developments may arise from the impact of the proposed development itself on the environment(Xiao, 2000). Though it has been planned to construct the WPLE system in the valley, opponents argue that many important questions remain unanswered in terms of the feasibility of the WPLE scheme. The counterviews involved with the fact that:

· Water in the channels and the lakes may be likely polluted by the developed industry and agriculture in the valley, which is seriously harmful to human health;

· Constructed channels may change the local land pattern, which may damage the inherent ecological system;

· Recovery mechanisms are not clear, thus it is not absolutely, physically available in the future. The stored water have migrated downgradient from potential users;

· Compatibility of the injected water with the aquifer water, recovery efficiency, and the effects of the recovered water on the environment are unknown;

· It is not clear, even cannot predicted, that the complicated interactions from the WPLE system might be surely beneficial to its development of the valley.

There are still many concerns related to the WPLE scheme. However, the scheme provides a chance of a backup water source for watershed protection and landscape enhancement. In order to extend the applications of the WPLE system, feasibility of the WPLE scheme will be demonstrated by more experiments and tests, as well as observations in the long run.

3 Conclusions

Utilization of river water to watershed protection and landscape enhancement may benefit to the development of Qiongshan City, which provides a sounds framework for future planning, investigations, and research and development of water sources to meet the valley's increasing demands. The provision of adequate water to protect ecological systems dependent on water resources will be a fundamental concern in the scheme. The system may not only alleviate the pressure of groundwater supply but handle with the problems of groundwater declines and saltwater intrusion in the watershed as well. Channels and lakes represent themselves as landscape appearances, perfectly fitting for municipal green scenes. A kind of physically beautiful and functionally vivid landscape may exert its synthetical functions on the diversity of landscape and the enjoyment of inhabitants.

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