Water for Quality Life and Sustainable Development in Taiwan

Principles for the Sustainable Development of Water Resources in Taiwan

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1.INTRODUCTION

At this, the beginning of the 21st century, as Taiwan's economy and democracy thrive, her population is unaware that their island is facing a crisis of safe water. Without innovative solutions, this problem will be difficult to overcome and the government will be unable to fulfill its responsibility to provide sufficient water. In the end, this will sabotage Taiwan's goals for socioeconomic development.

Over the past fifty years, water authorities have helped prepare the way for Taiwan's economic miracle. During each stage of economic development, Taiwan's hydraulic engineers have been able to ensure abundant water for both agricultural and industrial use (Figure 1), while working to upgrade the industry and related operations to provide water for quality life and sustainable development.

	Agricultural water (1945-1960)	Industrail water (1961-1981)	Domestical water (1982-1989)	Sustainable water (1990 -)
Economic Development	Food Security	Economic Growing	Life Quality Improvement	Sustainable Environment and Economic Development
Water Resources **Development**	**Agricultural Development**	**Multi-service Water Reservoirs**	**Public Water Supply**	Water Development and Environment Conservation

Figure 1 Water resource development and economic development in Taiwan

A number of key challenges, however, have arisen over the years, including water shortages since 2002, disputes over water resource development and conservation during the past decade, long-term negligence of water supply management, and inadequate government investment. Because of limitations in overall water resources, the exhaustion of suitable dam sites, new water resource administration and engineering technology being developed and applied too slowly, lack of water is not a thing of the future, it is a current reality. Furthermore, development of the island's water resources and the goal of attaining sustainability appear to be at a standstill.

The purpose of this study is to analyze core principles in the development of Taiwan's water resources and challenges encountered therein over the last fifty years, so as to ensure that the people of Taiwan can continue to enjoy plentiful water. Furthermore, this paper proposes principles for planning, constructing, and managing water resource development to develop sustainable water resources for Taiwan.

2. AN OVERVIEW OF TAIWAN'S WATER SITUATION

2.1 Limited Water Resources

Taiwan's average annual precipitation is approximately 2500mm[1] and total rainfall about 90 billion m^3. Due to the island's high population density, annual water allocation per person is only one-eighth the world average (Figure 2)[2]. Average annual runoff is 64.3 billion m^3. Dry season (November to April) runoff by region is around 9.8 billion m^3 or 63% of annual runoff in the north and 15.2 billion m^3 or 91% of annual runoff in the south, putting substantial pressure on the storage and allocation of water resources (Figure 3).

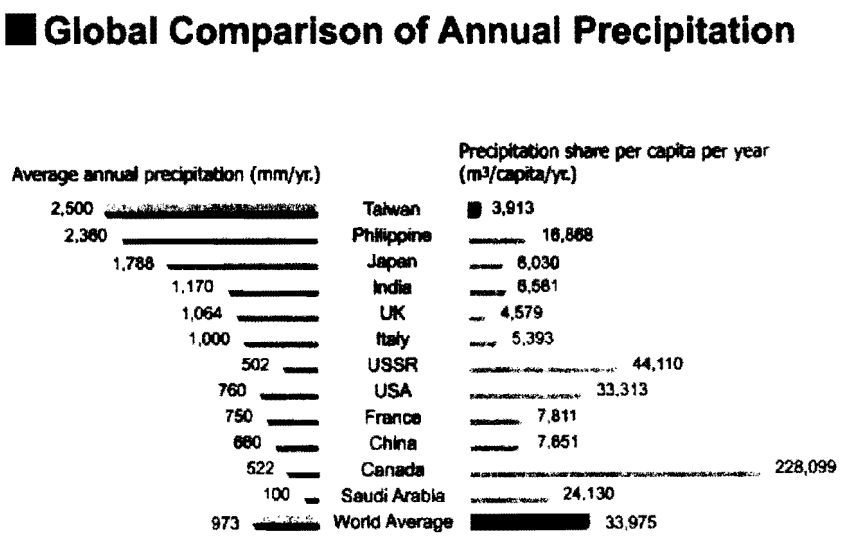

Figure 2 Global Comparison of Annual Precipitation

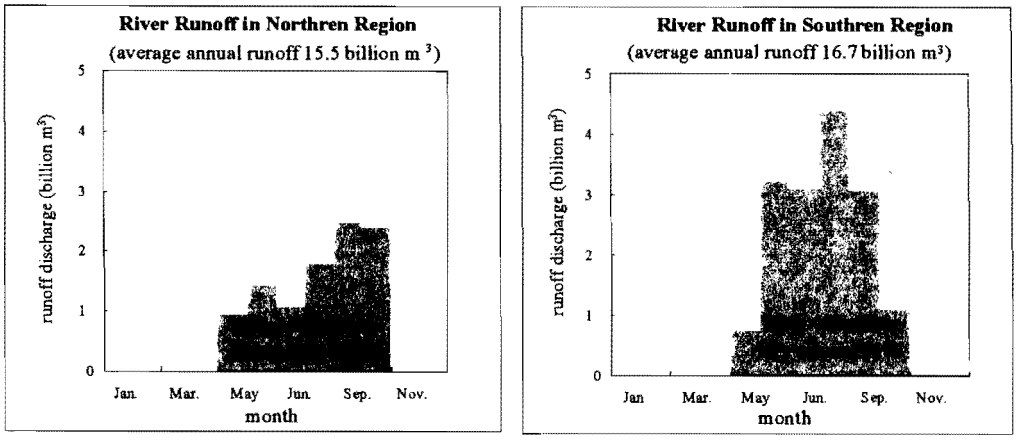

Figure 3 Regional River Runoff Distribution in Taiwan

Comparison of River Slops

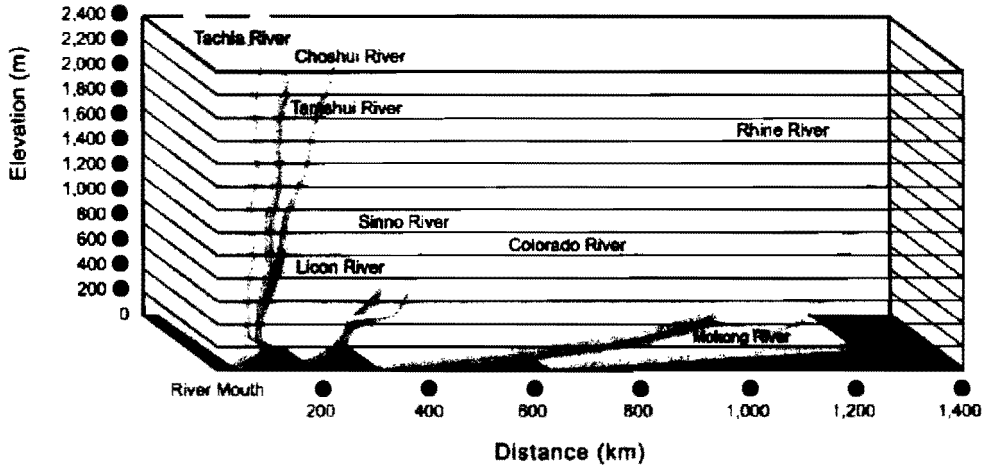

Figure 4 Comparison of river slops

Only 37% of the island's land area is below 100 meters in elevation and most of that is highly developed.[3] Taiwan's rivers are steep (the slope of upstream catchments exceed 1/100 and that of lower streams is 1/200~1/500) (Figure 4)[2]. contributing to reservoir and pollution challenges. Accessible water resources, estimated at 40.25 billion m^3, come from runoff catchments at elevations above 100 meters.

2.2 Heavy Water Demand

The 2003 United Nations World Water Development Report[4] indicates that in high-income countries, industry accounts for 59%, the public for 11%, and agriculture for 30%, of total water consumption. By contrast, industry accounts for 10%, public use for 8%, and agriculture for 82%, of total water use in low-income countries (Figure 5). In Taiwan between 1952 and 2001, agricultural consumption dropped from 98% to 71%, industrial consumption increased from 1% to 9%, and public water use soared from 1% to 20%. It appears that reductions in agricultural consumption were transferred to public consumption more than to industrial consumption. As a matter of fact, industries in Taiwan would like to take water from public water system, because of its lower water price. This caused high public water supply percentage, and hindering economic development.

Furthermore, average annual water consumption exceeded 18 billion m^3 (Figure 6), accounting for 45% of the above-mentioned accessible water resources. Plans to use 20 billion m^3 to meet demands to improve river ecologies and water quality are expected to bring water use to

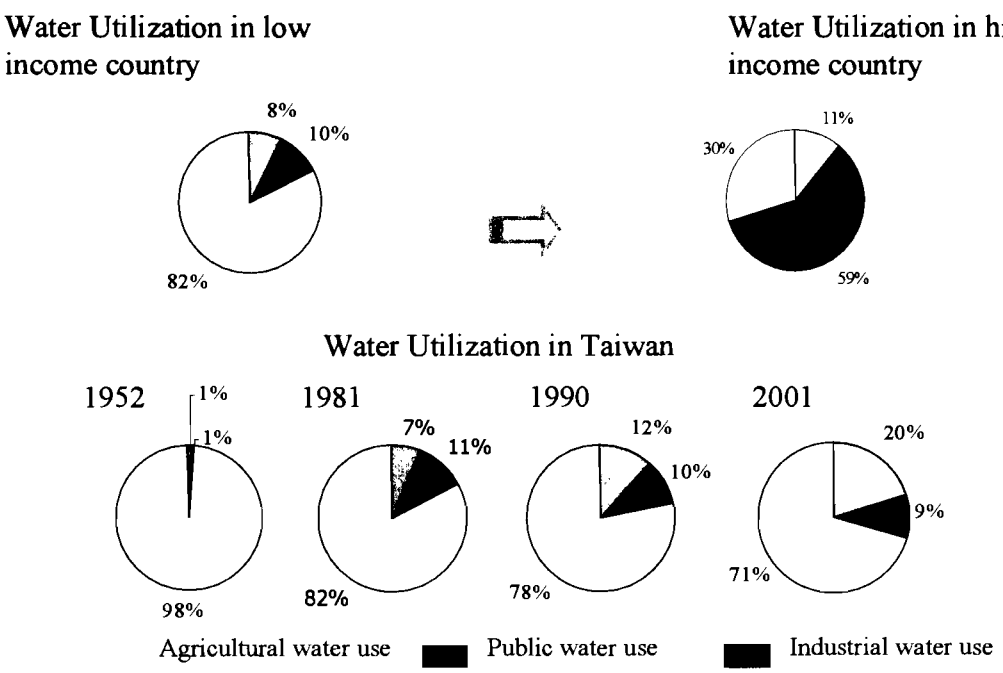

Figure 5 Percentages of multipurpose water consumption

the upper limits of accessible water supply (Figure 7).

■ Water Resource Utilization (Average values: 1990 ~ 2000)

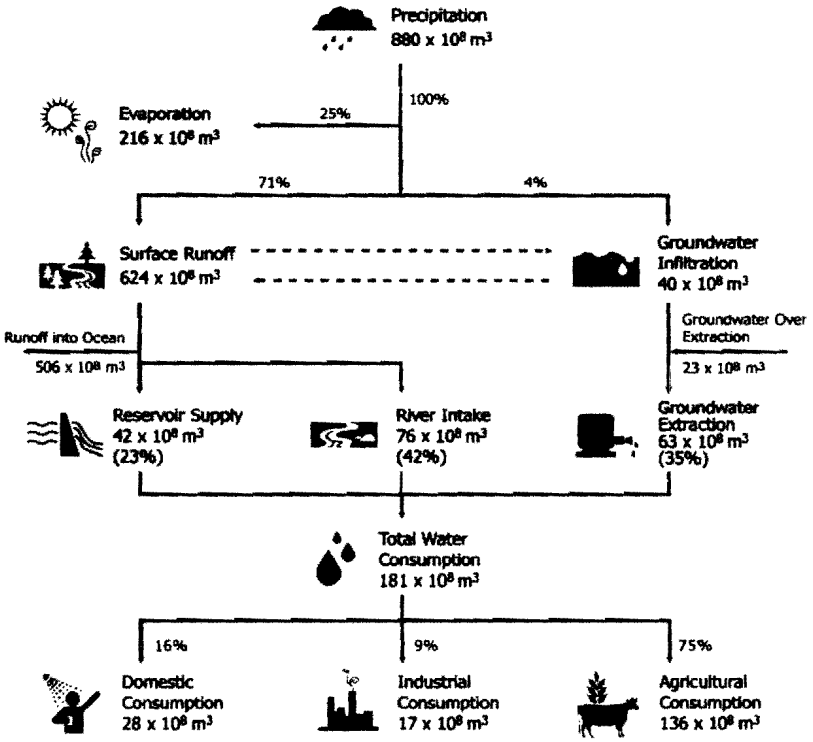

Figure 6 Water Resources Utilization in Taiwan

■ Estimation of water demand and utilization beyond the year of 2021

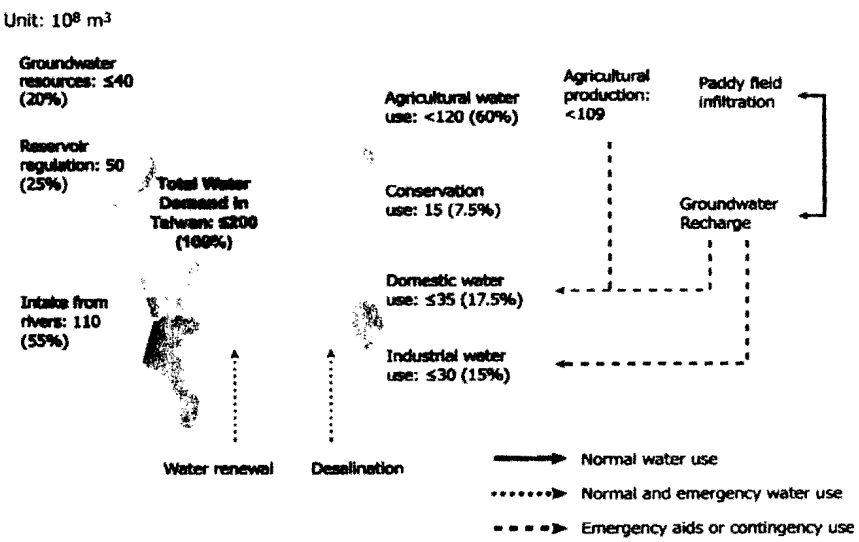

Figure 7 Future Plans for Total Water Use In Taiwan

2.3 Rapid Changes in Hydrological Conditions

Land over 1000 meters in elevation is generally classified as water quality and quantity reservation areas. However, hills and plateaus at 100~1000 meters above sea level, which account for 31% of these areas in Taiwan, have been seriously overdeveloped and the hydrological conditions of catchments have changed as a result. Recent years have witnessed similar annual runoff, but with dramatic increases in flood peak flows and in number of days with low river flow (Table 1). A great deal of uncertainty exists in regards to water resources, leading to fierce bidding for reservoir water for all types of consumption.

Weather changes have played a major role in the increase in annual monsoon (Northeast monsoon seasons) rainfall variations, decreased rainfall from typhoons, and resultant increases in the risk of water supply shortages (Table 1).

Table 1 Hydrologic Data for Ching-Mei River at the Po-Bridge Station

Year	Annual Runoff (cms-day)	Max. Peak Discharge (cms)	Number of Days with Discharge of Less Than 1 cms
1992	3277.05	208	21
1994	3198.70	705	2
1996	3558.84	894	15
1999	3345.29	362	0
2001	**3670.85**	**1500**	**52**

Sources: Hydrological Year Book of Taiwan, R.O.C.
(1992, 1994, 1996, 1999, 2001)

3. CRISIS AND CHALLENGE

3.1 Increasing the Upper Limit of Taiwan's Water Resources

Taiwan's hydrological cycle appears to have changed. Increased pavement in catchment areas has enabled rainfall and floods to make a beeline through floodways and rain drainage systems for the sea, thereby interrupting natural ponds as well as infiltration and percolation hydrological cycles, causing problems for water storage above ground and reduced river base flow. Following upper stream intake, most remaining runoff in waterways is discharged into lower streams or the sea and is regarded as wastewater after only being used once, resulting in a

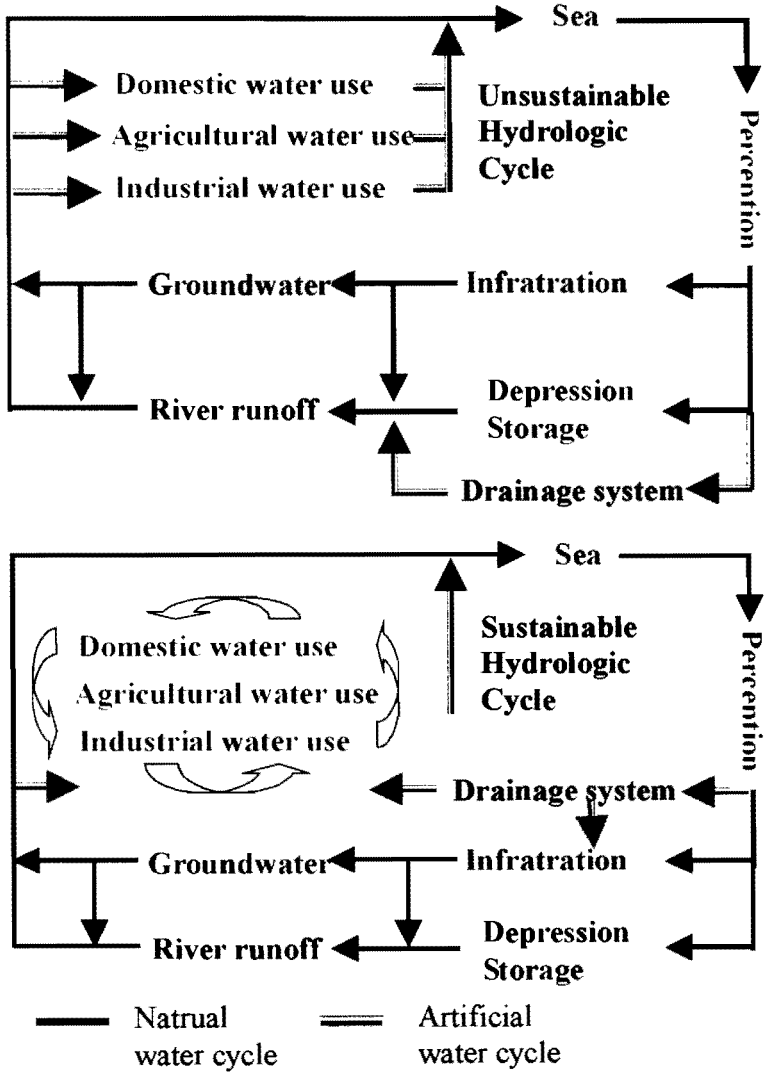

Figure 8 Unsustainable and Sustainable Hydrologic Cycles

high correlation between both water supply and demand as well as possible pollution at middle and lower stream (Figure 8). The past 19 years (1983 to 2002) saw sections of rivers free from pollution plunge from 74% to 62% and seriously polluted sections climb from 6% to 14% (Table 2). Today, as reductions in natural river runoff threaten biological systems, the key to increasing the upper limits of water supplies is to focus on restoring the natural hydrologic cycle by increasing water available at mid and lower stream and promoting efficient use of water resources.

Table 2 River Contamination in Taiwan

Unit: %*

Year	Degree of Contamination			
	None	Minor	Medium	Severe
1983	74.0%	3.6%	16.7%	5.7%
1986	73.6%	3.8%	12.3%	10.2%
1989	67.4%	7.0%	12.5%	13.1%
1992	59.1%	13.4%	16.2%	11.3%
1995	62.1%	12.6%	9.8%	15.5%
1998	64.3%	9.3%	15.1%	11.3%
2002	**62.4%**	**12.1%**	**11.5%**	**14.0%**

Note:(*) Percentage of contaminated rivers divided by total number of rivers (Source: Environmental Protection Administration)

3.2 Adjusting Competition on All Consumption Targets

Water rights disputes on multipurpose reservoirs, reparations to farmers for shifting agricultural consumption for other purposes, and the outcry for compensation to residents in protected area where water quality and quantity should be conserved, are all the result of intense competition for water resources. Present short-term allocation measures including government practices favoring compensation during the dry season fail to violate the principle of user pays. The idea that victims or restricted parties should be compensated has been distorted to become something more like "the squeaky wheel gets the oil." There is a definite and urgent need for an efficient year-round water resource administration system or organization.

3.3 Employ Crisis Management for Water Shortages

Construction of weirs for water intake, building dams to store water, and drilling wells to tap groundwater are needed to develop water resources in Taiwan. Irrigation associations, public water supply corporations, and individual water intake units contribute to building the water transport system. In recent years, development of new reservoirs in Taiwan has approached a standstill (Figure 9) as characterized by delays in the construction of the Mei-Lung Reservoir. Other factors leading to this standstill include lack of dam sites for new reservoirs, and damage to ecology by on-stream hydraulic structures. Furthermore, inadequate support between independent and parallel transportation systems has resulted in the inability of water resources to meet quality requirements and a stable supply of water to maintain economic activities. Further development of water resources, therefore, is the only way to deal with the growing risk of water shortages.

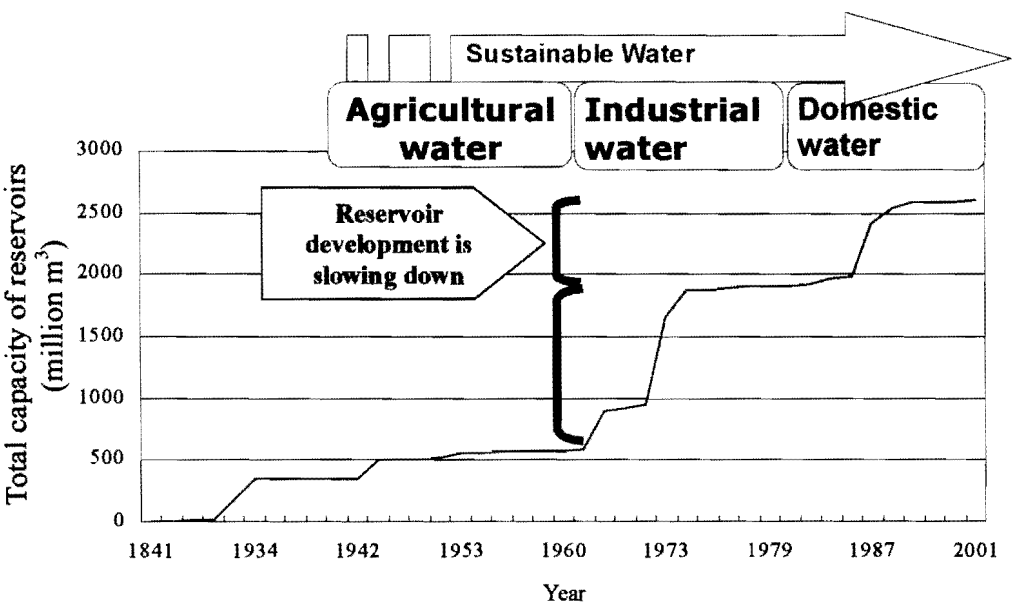

Figure 9 Reservoir Developments in Taiwan

4. THE PRINCIPLE OF SUSTAINABLE DEVELOPMENT FOR WATER RESOURCES

Sustainable development is an innovative idea stemming from the awareness of "limits to growth"[7] shaped during the first oil crisis. Brought to the fore by the UN Human Environment Conference in Stockholm, Sweden in 1972,[8] this concept focuses on curbing economic development and environmental conservation. It was stressed further in *Our Common Future*, proposed by the UN World Environment and Development Committee in 1987, and incorporated into Agenda 21 as an action plan in the UN Environment and Development Conference in Rio de Janeiro, Brazil in 1992.[9] With the signing of the Forest Pact (1992)[9], the Weather Change Outline

Pact (1994),[10] the Biological Diversity Pact (1993), and the Kyoto Protocol (1997),[11] it is increasingly becoming feasible implement sustainable development. The principles of Agenda 21 have become a guiding light for human activities.

4.1 Keys To Attaining of Sustainable Development

The 1972 UN Human Environment Conference Declaration Environmental set into motion the concept that protection of the environment is the responsibility of mankind. Furthermore, *Our Common Future*, a report proposed by the UN World Environment and Development Committee in 1987[12], further explains the importance of sustainable development in this way: sustainable development is needed "to meet the needs of this generation, while not disrupting the need of future generations for development."[13] The principles of sustainable development include generation equality, environmental burden sharing, equal concerns, beforehand prevention, social justice, enthusiastic participation, and cost internalization. The three points below are key to the realization of sustainable development for water resources expressed in the action plan released by the World Summit on Sustainable Development (WSSD).[14]

a. Increasing supply of safe water

b. Integrating water resource administration

c. Using rational water pricing and transfer mechanisms to curb competition for water

4.2 Principles for the Sustainable Development of Water Resources in Taiwan

Most theses[15, 16, 17, 18, 19] on the sustainable development of water resources in Taiwan are research statements. This paper proposes, however, steps to implement the principles as set forth by WSSD as listed below, so as to attain sustainable development of water resources in Taiwan and, thereby, alleviate the current crisis and challenges facing Taiwan.

a. Promote and encourage active water quality protection measures to increase accessible water supply
   - Measures—
     Implementing upper stream catchments and establishing ecological corridors for rivers
     Encouraging ecologically minded agriculture and industry in rural areas
     Increasing percentages of wastewater sewage system in urban areas
   - Indicator of success—increases in unpolluted river sections

b. Develop new water resources and expand available water resources
   - Measures—
     Promoting reuse of water and sewage recycling systems
     Establishing desalination plants and deep sea water utilization plants
   - Indicator of success—increases in the proportion of newly developed water resources in overall water consumption

c. Integrate water resource transport systems to satisfy demands for quality and quantity
   - Measures—
     Taking the role of regional water bank or water distribution companies or sectors, thereby creating multifunctional irrigation associations

Establishing high quality water supply system by setting up an independent, high-tech industry to transport and distribute drinkable tap water

- Indicator of success—increases in the ratio of water supplied by outside irrigation associations and water supply corporations

d. Set up a year-round water resource distribution mechanism to lower risk of water shortages

- Measures—

Promoting drought warning indicators and implementing a year-round water resource allocation system

Establishing a water price discount measures for residency suffering water cut due to water rationing policy

Establishing a drought fund to be added to water prices to compensate residents for having water cut as well as that for transferring water consumption to other sectors in drought seasons

- Indicator of success—a government budget to pay for shifting water consumption

e. Develop nature-friendly reservoir construction and management technology that keeps in mind both conservation and development

- Measures—

Establishing nature-friendly lake reservoirs

Developing sedimentation removal technologies for reservoirs

5. PLANNING, CONSTRUCTION, AND MANAGEMENT MODELS FOR THE SUSTAINABLE DEVELOPMENT OF WATER RESOURCES

A traditional planning model was designed to develop water resources to meet demand (Figure 10), a construction model designed to decrease construction cost, and a management model designed to maximize water yield. Even with occasional adjustments to the models (Figure 11)[20], the goal of sustainable development will still remain unattainable without innovations to bring significant breakthroughs. This paper proposes, therefore, the following principles for planning, construction, and management to help in attaining sustainable development for water resources (Figure 12, 13).

a. Principles for planning

Multipurpose—developing water resources to meet demands, multiple use of water to reduce demand for raw water and satisfying essential ecology water demand

Nonlinear—increasing usable water reservoir facilities, defining water quality and quantity reservation areas, and including feedback mechanisms in planning procedures

b. Principles for construction—lower construction costs and less damage to nature are equally important

Rebuilding protected habitats for plants and animals, nature-friendly stream flows, and sediment transport should all be part of reservoir construction

c. Principles for management—integrate water resources to meet different demands in terms of quality and quantity

Establish water management system capable of independent water resources administration, an integrated transport and distribution system, and diversified water supply

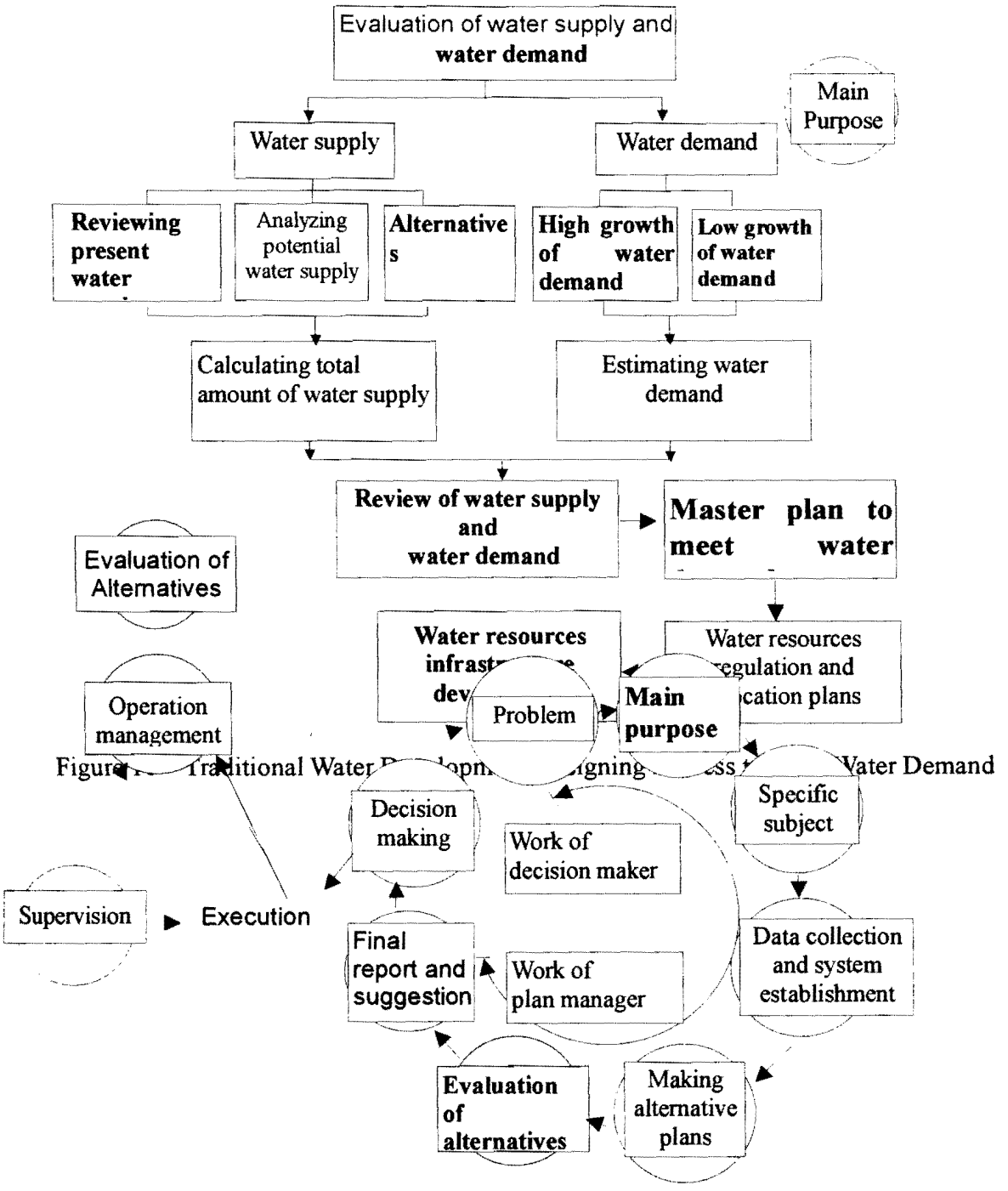

Figure 11 Decision Making Strategies for Sustainable Water Development Planning

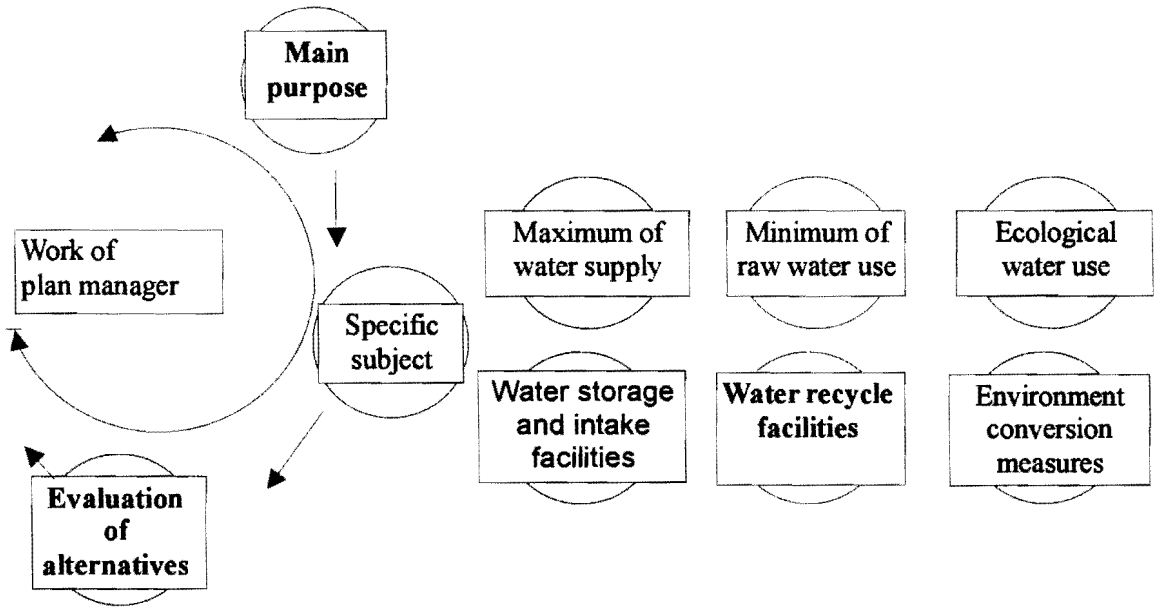

Figure 12 Sustainable Water Development Planning Model

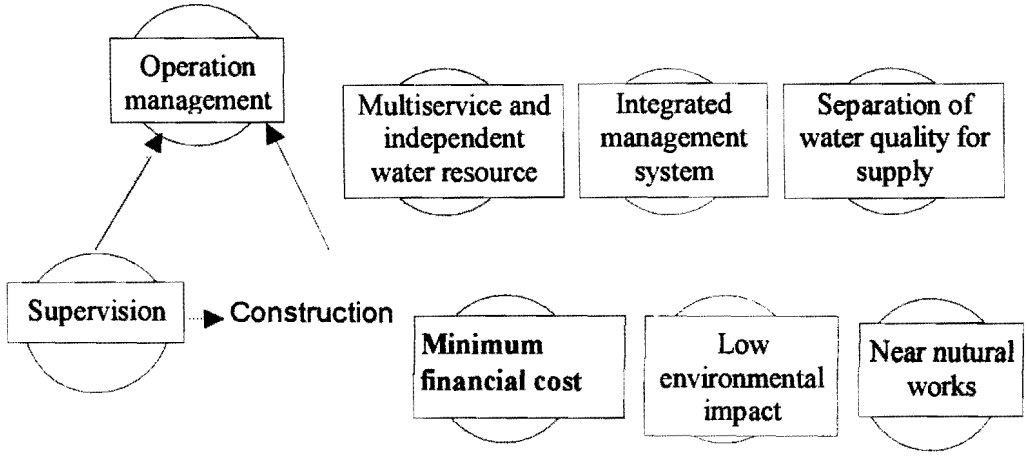

Figure 13 Water Resource Development and Management Model

6. CONCLUSION

Innovative solutions are the best way to tackle the challenges, both present and future, facing mankind. The problems related to essential water resources in Taiwan are no exception. This paper proposes operational principles as mapped out in a planning, construction and management model for the sustainable development of water resources. Changing the thinking prevalent in administrations and organizations dealing with water is a must if we are to achieve the ultimate goal of finding a balance between producing water resources of high quality and yield and environmental protection.

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