Water Cost Differences Due to Regional and Seasonal Differentiation in Taiwan

ABSTRACT

Water is a fundamental resource on the Earth. It is needed for household consumption, agriculture, and industry. The water demand continues to increase with the growth of the population.Waterquantity and quality are necessary required forlivelihood, agriculture, and industry need, while the water right is obviously controlledfor water resources transfer.In this study, we apply statistical regression, present value conversion theory, and risk analysis concerned the characteristics of seasons and regions to research the relevant cost issues.With its irreversibility, the unit cost for each function combining the risks on both regions and seasons will be much more obviously important for sustainability. In this study, the analysis of the cost of rawwater and its cost differences in different locations and seasons are also discussed and the rationality of tap water fees is also elucidated, by comparing with Taiwan Water Company's Profit and Loss Summary of Water Supply Unit Sales from 2016 to 2020, we found water prices in Taiwan are too cheap, causing the Taiwan Provincial Water Company to lose money every year when selling water. The cost analysis of agricultural water and the accompanying transferring compensation fee for industrial use are also deeply analyzed.The analysis results for the whole Taiwanfound that water cost in southern Taiwan is very high, and the regional and seasonal differences are the largest. In addition, the risk of water shortage is very high in southern Taiwan, too, and it is the most noteworthy area in terms of water sustainability.

Keywords:*Raw WaterCost；Livelihood need WaterCost;Tap WaterCost; Agriculture Water Cost; IndustryWaterCost;*

INTRODUCTION

The 21st century is a century of fighting for water shortage. Without appropriate water resources management policies, crop production and wildlife survival will be affected. When the use of regional water resources exceeds the replenishment, the regional water resources will be irreversibly depleted.Water resources are an indispensable element for human survival. As humans survive on the earth, due to the rapid increase in population and the improvement in quality of life, the stable demand for water resources and high-standard water quality requirements are constantly changing in agriculture, industry and people's livelihood. Therefore, the structure of water resources demand and the impact of corresponding wastewater discharge onenvironmental pollution will be issues we must face.As far as natural and human life-support systems are concerned, it is an urgent topic to integrate the water (Book, 2013) and land resources in the upstream and downstream basins with surface water(H. Koch, *et al* 2013) and groundwater (M. P. Mendes, *et al*, 2012)in the regional and seasonal differences not only quantity or quality but also the costs, especially for Taiwan.

In Taiwan (Fig. 1), 75% of water resources are allocated in summer and autumn. Calculated based on the annual rainfall of 2,500mm, the total area of Taiwan is 36,000km^2, and the total water volume is approximately9.04×$10^{11}m^3$. However, based on the narrowwatershed with the steep slope is and the unstable geology, the flow channel is short and steep, and the mud content in the water is high, which greatly reduces the amountof available water. Water quality treatment is also a major problem. In addition, the water volume in the dry and wet seasons is greatly different, which is different from recent times, especially after the climate change and the greenhouse effect over the past two decades have made water resources more uncertain. The above factors have virtually increased the costs of development, transportation, treating and distribution of water resources.

Water pricing mechanism has the following problems: (1) Waterresources pricing is low and rigid, making it impossible to achieve water resource allocation setting efficiency (2) Adopting a unified water price violates the principle offairness in setting reasonable water prices and (3) The current water price does not reflect the environmental cost of water resources and violates the principle of environmental efficiency. Therefore, (1) reform the water price adjustment system and establish a water price evaluation committee; (2) cancel the unified water price and formulate a suitable water price mechanism according to different water standards; (3) set the basic domestic water consumption of the people and design an appropriate mechanism to maintain it in the water price system The basic needs of national livelihood, and (4) raising the current water price to reflect the cost of water resources will be the key points that need to be paid attention to in setting flexible (temporal and spatial difference) water prices. (H. M. Ravnborg and K. M. Jensen, 2012; J. Halbe, C. Pahl-Wostl, J. Sendzimir and J. Adamowski, 2013; and Que Yawen, 2021).

Therefore, how to analyze the cost of each unit of water resources more accurately has become a serious issue. In addition, soothing and mediating the siltation of the reservoir to extend the service life of the reservoir, improving water quality and increasing storage capacity, promoting and rewarding the effective recycling and reuse of water resources, promoting and rewarding water-saving equipment, collecting rainwater to replace the use of domestic water and setting the seasonal safe water output of each river basin are all problems that need to be actively faced and solved, because these will be a means to reduce the risk of water shortage. Of course, these will also be closely related to the analysis of water resources costs.

METHODOLOGY

The distribution of water resources is inherently uneven and risky in time and space, so it is even more difficult to grasp the stability of water supply distribution in different regions and seasons.A reasonable water pricing mechanism should be able to consider the principles of

Fig. 1 Taiwan administrative map(Ministry of Interior, Taiwan)

allocation efficiency, equity, financial needs, public health, and environmental efficiency. As for the intermittent allocation of water resources under drought conditions, public interests should be taken into consideration. On the premise of preserving water for the ecological environment, appropriate regulations should be constructed based on the user payment mechanism to reflect the scarcity and shortage of water resources(Snellen,W.B. and Schrevel, A. 2004).“It is also necessary to consider the losses to third parties such as the environment and the public. In terms of water price setting policies, finance (to achieve full cost recovery), society (to ensure that everyone has access to water) and environment (to motivate users to save scarce resources) are the three most important principles to set water price(World Bank, 1999 and Meran, G., et, al. 2021).The sustainability, affordability and fairness of water supply should be taken into consideration when setting water prices. In particularly, seasonal water prices and progressive water prices should be adopted to achieve the goals of environmental protection and social equity(IWA, UNEP. 2002 and Ezenwaji, et, al. 2015).The costs are, in a nutshell, just the so-called "internal costs" (Young, R.A. 1986. Rhodes, G.F. et. al, 1988. and Que Yawen 2007). When aquatic production along rivers and coasts is reduced and related ecological harm is caused, the compensation and rehabilitation costs required are often very large. Furthermore, when the supply or distribution of water resources is insufficient for use, wells are often dug to collect water, causing land subsidence. This not only affects people's livelihood, but also increases the cost of flood control and environmental protection investment. These will have long-term impacts, and this "external cost" (Rosegrant, M.W. et. al, 1994. Chakravorty U.E. Hochman, and D. Zilberman, 1995. and Rhodes, G.F., Jr and Sampath, R.K.1988)and will be a huge cost burden. There are two significant analyses and results of regional differences and seasonal differences on water costs or fees for raw water, agricultural water, domestic water, industrial water, and transferring compensation fee from agriculture to industry.

Full-cost pricing based on the use of water resources, supplemented by targeted subsidies, is a suitable way to set water prices.Efficient water pricing should internalize all water costs, including environmental and resource costs.Overall, water resource management and water price setting should meet the needs of sustainable development of the environment, society, and economy. The cost of supplying water resources, including operating costs, capital costs, opportunity cost, economic externality, environmental externality, and the sum of these costs is the total cost. From the supply side analysis, if the water price can meet all costs, the sustainability of water resources can be achieved, so its sustainable value in use (Rajesh, *et. al*,2016)

In research related to water resources demand and water price, if the transaction price is available, the transaction price data will be collected directly (Roozbahani, R. *et. al,* 2015. and Zhuang, W.2016). According to the news, the regression method is used to estimate the demand function or inverse demand function, which is a more accurate demand forecasting method. The better you understand the market transaction situation, the more detailed market information you can provide, and you can further use the estimated inverse demand curve to analyze the competition pattern of the monopoly or oligopoly market (Howitt, R. E. *et. al,* 1994).The study of water resource demand price elasticity is important information for the design of water pricingmechanisms (Rosegrant, M.W. *et. al,* 1994). In addition to calculating domestic water demand and analyzing the bargaining power of domestic water users and water supply units, the bargaining powerand negotiation power of domestic water users depend on the characteristics of their demand functions. If we further use the regression method to estimate the water demand function based on the daily, monthly and quarterly data of transaction water price and water volume, we can calculate the daily, monthly and quarterly demand flexibility of water resources.Water should be priced according to its economic value; but for natural resources, price signals that reflect scarcity and are successfully used to guide private sector investment and resource allocation are often absent or distorted, making public sector decisions related to natural resources complication. In addition to the financial benefits of being put into the derivative market of industrial production, water resources have functions and benefits in environmental, economic, and social aspects, such as personal survival, public health, ecological maintenance, environmental beauty, etc., all of which have non-market value. Only by comprehensively considering market and non-market values can water resources be allocated fairly and efficiently. The property characteristics of water resources often limit the function of the market. Therefore, the application of economic evaluation procedures preface, such as the non-market financial benefit assessment method understands the value assessment of water resources faced by demand, it can complement environmental and other humanistic and social factors and play an important role in pricing in water resources-related public policies. What is particularly important is that if there are accurate weather and rainfall forecasts, or water resource demand functions for various industries, it will help the allocation of water resources become more efficient. This can be a reference for Taiwan's drought and water shortage deployment.

For the analyses on the Water Cost Differences Due to Regional and Seasonal Differentiation in Taiwan, simple methodologies, statistical regression, present value conversion theory, and risk analysis concerned the characteristics of seasons and regions are utilized to obtain the key results with the explanations respectively as following section.

RESULTS

3.1 The Regional Differences (Fig. 2) on Surface Water

3.1.1 Surfacewater Cost

3.1.1.1 Agricultural Water Demand with its Cost not Including the Raw Water Cost

There are 17 irrigation associations in Taiwan (Luo, 2018). The research results are listed as in Table 1(Luo, 2018). In which data of the quantities of water consumption, rice production, pumping electricity fee and staff costs are supplied by government while else fee is collected from the real field data and analyzed based on the agricultural and economic methods.

3.1.1.2 The Regression of Raw Water Cost and Tap Water Fee

Because of the steep terrain, the riverbed in Taiwan is greatly reduced. In the case of rain, the flash floods are soaring and flooding, and the drought is bottoming out. The lack of water is the only way to build a reservoir dam to achieve effective river management. Water, increase the use of water such as irrigation, power generation, industrial and public water supply, and combine flood control and disaster relief, increase agricultural production, and develop tourism.

Taiwan reservoir management related units include the Water Resources Department of the Ministry of Economic Affairs (North, Central and Southern Water Resources Bureau). Total water discharge from reservoirs includes consumable and non-consumptive water. Consumable water consumption includes irrigation, productive and industrial water. In the early years of Taiwan, there were reservoirs (Luo, 2018). For analyzing the raw water cost (C), the effective volume (X) and the year innation of construction (T) of each reservoir will be the key factors. The regressingformula could be the form as following, and it is necessary to define the coefficients with the real data with statistics:

lnC_0=a+blnX+cln(T-1911)...(1)

Referencing Fig. 4 and Table 2 (Luo, 2018), the coefficients of a, b, and c are:

a= -15.0211, b=0.8415, and c=4.00297, with R^2= 0.8114

Here C_0: the annual reservoir cost in million NT; X: the annual operation water volume of reservoir; T: the established year of reservoir.

In Eq. (1) we can clearly see that the water resources have the time and space characteristics and it is limited. The later the building and the larger the scale, the higher the cost. Because water resources are becoming more and more precious, how to exert its benefits from all available water sources without causing environmental protection and social cost increase, and put forward the strategy to solve industrial water use, has become the bottleneck that must be broken under the premise of industrial development today (Water Resources Department of the Ministry of Economic Affairs, 2016-2019 with Table 2) Access to water is clearly a wider subject than availability and many other factors including cost, distance to water source, rights, authority and corruption can createwater poverty (the opposite of water security)at household

Fig. 2 Map of the four major regions in Taiwan(Ministry of Interior, Taiwan)

and community levels. The distribution of water infrastructure is inversely related to the global distribution of water insecurity risks. Many of the world's wealthiest nations also have the highest water security and investment in water storage has enabled growth where hydrological variability is high, although growth often requires ongoing non-infrastructural investment. Water can be obtained from the river directly with some taking-water constructions, digging wells for groundwater, constructing rainwater catchment for the collection systems, or desalination. Water-demand management is highly desirable and, in many cases, is a priority for water managers but, though its impact may be significant, its potential is still fairly limited over the medium-term(Water Resources Department of the Ministry of Economic Affairs, 2016-2019).**Transferring the annually mean cost of the reservoirs in Taiwan, 4.64 NT**

dollars in 1991 is the value. While the tap water cost C_1 also could be gained by:

$\ln C_1=1.727052+0.9090841\ln X$ …………………………………………………………..(2)

The definition of X is as the same as the above mentioned, and with R^2=0.926876

The mean tap water fee is 5.00 NT dollars in 1991, and the difference between 5.00 and 4.64 valued 0.36 is the management fee of Taiwan tap water company (Fig. 3).

Up to now, there are some brief and focused summary as follows:

(1) In Table 1, the mean costs of agriculture fee without raw water cost from theexpensive one to the cheap one is **the southern (green color, 0.278USD), thecentral (blue color, 0.216USD), the northern (red color, 0.209USD) and theeastern (purple color, 0.139USD)** in 1991.

In Eq. (1) and Table 2, reservoir volume and built year are two factors which influencing the annual cost while the built year has more obvious effect with coefficient c=4.00297 to the result than the one of reservoir volume of coefficient b=0.8415. This hints the time schedule is an important item to set the raw water cost.

(2) In Table 2, by converting present value, the raw water costs are **6.40 NTD (0.213 USD, green, south), 5.67 NTD (0.189 USD, blue, central), and 7.24 NTD(0.242USD, red, north) in 1991** with **mean 6.44NTD (0.215USD).**

(3) Combining the agriculture fee, we have **the southern (green color) 0.491USD, thecentral (blue color) 0.405USD, the northern (red color) 0.451USD and theeastern**(purple color) **0.381USDin 1991** in **mean0.432 USD (12.96NTD)** with1USD=30 NTD.

(4) From the view point of present-value, (the summed fee in 1991) × (compound interest rate of interest) with interesting rate, r1 =3%, and n=the calculationperiod=2020-1991=29, therefore, the raw water cost in 2020 will be:

the southern (green color) 0.502 USD, the central (blue color) 0.445 USD, (blue, central), and the northern (red color) 0.570 USD, and assumed thecost of the eastern will be the same as the northern one, with **mean0.507USD.**

Andthepayment from theagricultural water cost in 2020 will be:

the southern (green color) 1.157USD, the central (blue color) 0.954USD, thenorthern (red color) 1.063USD and the eastern (purple color) **0.898USDinmean1.018 USD** with 1USD=30 NTD.

In Eq. (2), tap water cost is very related the utilized water volume.

From the above analysis of the water prices of raw water and tap water, in addition to seeing that the size of the development scale and the development schedule will affectthe water prices, it also reflects that large-scale development is difficult in present times, and because of the recent rising in environmental awareness, it is even more difficult to promote water resources development plans(Ministry of Economic Affairs and Water Resources Department. 2016 and Water Resources Department of the Ministry of Economic Affairs, 2016-2019).

Based on the report of MOEAWRA1050299 (Ministry of Economic Affairs, 2016), it made the conclusions that “Water pricing strategies usually need to strike a balance between the financial feasibility of water utilities, social development goals, and economic efficiency. Therefore, they must be adjusted with changes in regulations, environment, and behavior, and general subsidies must be avoided as much as possible while taking care of Under the premise of protecting vulnerable families, a transparent pricing mechanism should be established. In addition to being conducive to supervision and control and increasing the costs required to protect water sources, it also considers future operational development and operational risk factors to meet the needs of water supply business operations. The direction of future water price adjustments will be towards "taking care of water for basic people's livelihood". Conducting discussionson" adjusting high water consumption rate brackets" and implementing the principles of "water equity and justice". For basic domestic water consumption, lower unit prices should be charged to ensure the necessary water for daily use are urgent. However, for users with large water consumption, the price difference should be increased based on progressive water consumption to reflect the cost of tap water and fairness and justice.

One of the biggest problems facing our country's current water resources management is the domestic "too low water price", which has resulted in the operating costs of water companies not being truthfully reflected in water prices(Ministry of Economic Affairs and Water Resources Department, 2016). This has gradually worsened the financial structure of our country's water supply corporations, resulting in the loss of related water-saving equipment and measures. (Such as repairing and updating leaking pipelines, etc.) Effective improvements have not yet been achieved. At the same time, low water prices will cause people to lack incentives tosave water, causing citizens and enterprises to lack the concept of saving water andfail to cherish water, thus leading to a waste of water resources. Therefore, setting "reasonable water prices" has become a part of the water resources strategy that cannot be ignored, in order to improve the deteriorating financial situation of domestic water
companies year by year and avoid the problem of water scarcity that our country will face in the future. Although my country's tap water price adjustment mechanism is regulated in the Tap Water Law, tap water prices have not been adjusted for a long time due to political factors. The water price of Taiwan Water Corporation has not been adjusted for 22 years. In 2015, as Taiwan suffered a severe drought that was rare in history, tap water prices have once again become the focus of attention. t can be seen from the 2016 water price calculation formula and the definition of detailed items thatthe cost reflected in the tap water price includes the water delivery stage from the raw water intake stage to the water delivery stage in front of the user's water meter. All tap water supply costs in the segment include raw water fees, purified water fees, watersupply fees, business expenses, management expenses, financial expenses and

Table 1 First Period Rice Harvest (March to June Total 122 days) with its corresponding fundamental cost analysis for each irrigation association■North■Center■South■East

Irrigation Association	Farming area(ha)	Water consumption (Tons)	Rice production (kgs)	Pumping electricity fee (USD/Ton)	Staff costs (USD/Ton)	Else fee (USD/Ton)	Total fee (USD/Ton)
Yilan	15,175	254,911,888	71,493,000	--	0.02	0.19	**0.221**
Pewichi	1,063	93,114,518	4,784,000	--	0.19	0.032	**0.084**
Taoyuan	22,645	2,089,897,863	107,807,000	--	0.017	0.026	**0.077**
Shihmen	10,516	731,551,594	41,097,000	--	0.018	0.025	**0.079**
Hsinchu	6,445	95,612,861	30,614,000	--	0.02	0.053	**0.281**
Miaoli	8,490	128,741,184	46,865,000	0.001	0.021	0.095	**0.340**
Taichung	29,249	5,398,536,269	150,632,000	--	0.017	0.020	**0.055**
Nantou	9,522	262,658,880	48,195,000	--	0.019	0.037	**0.177**
Changhua	37,308	414,189,274	211,677,000	--	0.022	0.063	**0.417**
Yunlin	25,108	179,253,389	135,585,000	0.005	0.036	0.153	**0.685**
Chianan	33,588	2,470,311,994	217,589,000	--	0.018	0.027	**0.103**
Kaoshiung	7,872	1,638,480,125	46,528,000	--	0.177	0.032	**0.068**
Pingtung	8,806	219,835,613	48,433,000	0.003	0.022	0.056	**0.255**
Taitung	4,716	264,831,999	22,165,000	--	0.019	0.037	**0.110**
Hualian	6,513	468,146,333	28,006,000	--	0.018	0.028	**0.085**
Chishing	860	58,891,882	4,386,000	--	0.021	0.182	**0.252**
Liukong	216	5,272,790	756,000	0.005	0.080	0.171	**0.349**

(1) Rice Unit Cost(80 年)：0.65 USD/kg

(2) Staff costs=(annual fee) $\times(\frac{122}{365})\div$ Water consumption

(3) Else fee={(Pipeline depreciation fee)+(Pipeline equipment maintenance fee)+(Irrigation fee)+(Service fee)+(Research fee)+(fee of management)+(Miscellaneous)} $\times(\frac{122}{365})\div$ Water consumption

(4) Total fee={(Rice production) $\times$ 0.65} $\div$ Water consumption +Pumping electricity fee+ Staff costs +Else fee.

* The mean agricultural water fundamental cost is 0.212USD/Ton with maximum value 0.685USD/Ton (Yunlin) and minimum value 0.055USD/Ton(Taichung), all the cost is without consideration of raw water cost, it means the civil engineering construction cost is not yet included.

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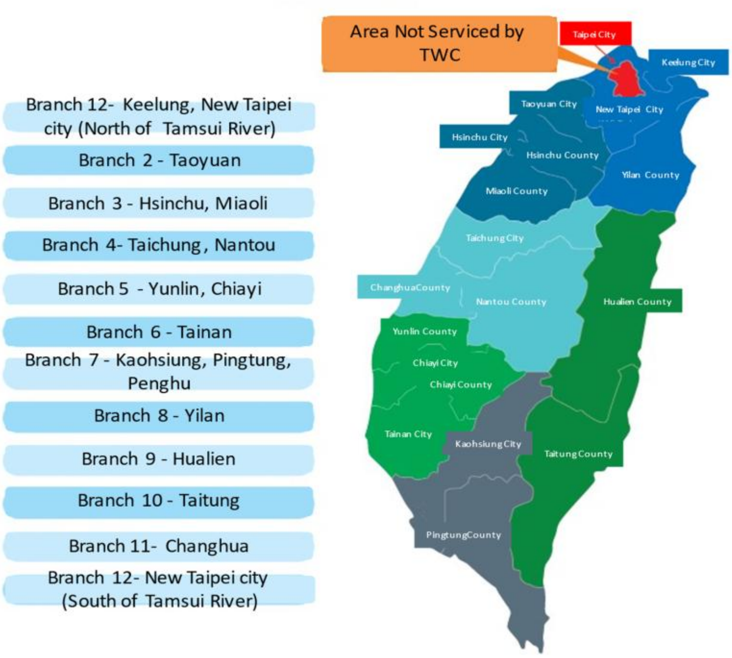

Branches of Taiwan Water Corporation

Fig. 3 Branches of Taiwan Water Corporation (Taiwan Water Corporation)

Table 2 Unit Primary Water Cost with Different Reservoirs or Weirs in Taiwan 1USD=30 NT $

North Center South ( ):the present price in 1991

Name of Reservoir (Weir)	Established Year	Total Cash (10 Thousand NT＄)		Annual Cash (10 Thousand NT＄) (2)=(1)×9.55%	Annual Water supply (3) (10 Thousand Tons)	Unit Primary Water Cost (2)/(3) (NT＄/Ton)
		Cash of Established year	(1)Cash flow of 1991			
Shimen	1964	318,300	1,099,408	104,933	68,100	1.54 (3.42)
Balhe	1965	22,852	82,791	7,906	2,745	**2.88(6.21)**
Mingdo	1970	21,735	71,727	6,850	3,329	**2.06 (3.83)**
Zengwen	1973	603,842	1,281,172	122,352	73,049	**1.67 (2.84)**

Xinshan	1979	24,690	30,221	2,886	542	5.32 (7.86)
Fengshan	1984	83,000	89,267	8,525	15,431	0.55 (0.68)
Yonghe	1984	126,000	135,513	12,941	6,826	1.90 (2.34)
Beoshan	1985	63,000	69,048	6,594	1,665	3.96 (4.73)
Ronilten	1987	156,000	166,717	15,921	4,278	3.72 (4.19)
Foicul	1987	1,145,464	1,145,464	109,391	20,800	5.26 (5.92)
Luyotan	1997	1,060,000	1,060,000	101,230	30,483	3.32 (2.79)
Nanhua	1993	995,700	995,700	95,089	29,200	3.26 (3.05)
Modan	1995	780,000	780,000	74,490	3,710	20.08 (17.83)
Chichi (Weir)	1999	3,265,000	3,265,000	311,808	47,400	6.58 (5.19)
Baoshnnil	1998	1,860,000	1,860,000	177,630	7,416	23.95 (19.47)
Menueng	2001	5,330,000	5,330,000	509,015	40,600	12.54 (9.33)
Penlin	2001	4,980,000	4,980,000	475,590	34,100	13.95 (10.38)
Geinmin	2001	3,050,000	3,050,000	291,275	24,000	12.14 (9.03)
Coast Res.	2001	4,500,000	4,500,000	429,750	30,000	14.32(10.66)
Da-ching (Weir)	2001	400,000	400,000	38,200	5,000	7.64 (5.68)
Kaoping Downstream(Weir)	1996	500,000	500,000	47,750	10,000	4.78 (3.56)

other operating expenses. In addition, the addition of reasonable profits from the operations of public institutions shows that the water price reflects not only all costs of water supply business operations, but also allows water companies to enjoy reasonable profits. When calculating the average water price, the cost is based on the final accounts of the last three years plus the costs required for operation and development, and finally adjusted for price changes. Before the water price formula was adopted, the Taipei City Government held a meeting of the Taipei City Government Tap Water Price Evaluation Committee (referred to as the Taipei City Water Price Evaluation Committee) in June 2015 to review the North Water Department's tap water price adjustment plan. From June to September, the Water Price Evaluation Committee held a total of 4 meetings to complete the review. Later, it was approved by the Taipei City Government and discussed by the Taipei City Council. After approval, the North Water Department established the project on March 1, 2016.Water prices will be raised daily. The adjusted average water price is 12.14 NTD per kilowatt hour is higher after compared with Taiwan Water Company's average of 10.96 NTD per kilowatt hour. The average water price in the before mentioned increase plan is calculated based on the new water price formula. Although the Ministry of Economic Affairs' "Water Price Calculation Formula and Detailed

Items" defines each cost in detail, the new water source protection costs and future operational development added to the original water fee are and disaster preparedness are not clearly explained, causing several problems in the calculation process of the average water price(Water Resources Department of the Ministry of Economic Affairs ,2016-2019).

According to the profit and loss profile of water supply units from 2016 to 2020 provided by Taiwan Water Corporation (details as Fig. 3 and Table 3, and Executive Yuan 2020), the average cost of water sales per unit in 2020 is expected to be approximately 11.45 NTD (the same for the following units), including sales cost of 9.70 NTD, operating costs Expenses of 1.46 NTD and non-operating expenses - financial costs of 0.29 NTD are the highest inthe past five years. Comparing the details of water sales costs in each year, in addition to direct sales costs such as raw water costs, water purification costs, and water supply costs increasing year by year, business and management When operating expenses do not show a downward trend, borrow money from external sources.

Due to the increase in service costs, etc., the cost of selling water per unit has increased year by year. Without significant changes in the selling price of tap water, the profit and loss of tap water sales has been 0.01 NTD and 0.22 NTD per unit from 2016 and 2017 years, and has been transferred since 2018. Loss, and the amount of loss is increasing year by year. In 2020, it is expected to lose 0.48 NTD per unit of water sales.

Table 3. Taiwan Water Company's Profit and Loss Summary of Water Supply Unit Sales from 2016 to 2020 unit: NTD/m^3

Items\Year	2016	2017	2018	2019	2020
Sale costs	9.29	9.18	9.60	9.55	9.70
Raw water cost	***2.24***	***2.29***	***2.33***	***2.34***	***2.34***
Water purification fee	1.97	1.90	1.98	2.01	2.00
Water supply charges	5.08	4.99	5.29	5.20	5.36
Operating costs	1.44	1.39	1.45	1.47	1.46
Business expenses	0.98	0.95	1.00	1.00	1.00
Management costs	0.44	0.42	0.42	0.45	0.44
Other operating expenses	0.02	0.02	0.03	0.02	0.03
Non-operating expenses - financial costs	0.22	0.20	0.21	0.28	0.29
the average cost of water sales per unit	10.95	10.77	11.26	11.30	11.45
Unit selling price	10.96	10.99	11.00	10.96	10.97
Unit profit and loss	0.01	0.22	-0.26	-0.34	-0.48

The annually mean cost of the reservoirs (called raw water) in Taiwan, 4.64 NT dollars in 1991 is the value. By comparing with the one in Table3, it is found that the cost of raw water is seriously underestimated. From the view point of present-value, the payment from the industrial unit is:

(the summed fee in 1991) × (compound interest rate of interest) with interesting rate, r1 =3%, and n=the calculation period=2020-1991=29, therefore, the compensation fee in 2020 is 10.93 NT dollars. The difference of the raw water cost in 2020 is 10.93-2.34=8.59 NT dollars. By proportional conversion, the sale costs is 9.70×(10.93/2.34)=45.31NTD (or 1.51USD), while 51.24NTD (or 1.71USD) for unit selling price.

(4) Due to (2) In Table 2, by converting present value, the raw water costs are 6.40 NTD (0.213USD, green, south), 5.67 NTD (0.189 USD, blue, central), and 7.24 NTD (0.242USD, red, north) in 1991 with mean 6.44NTD (0.215USD), and with (the summed fee in 1991) × (compound interest rate of interest) with interesting rate, r1 =3％, and n=the calculation period=2020-1991=29, **the unit sale cost will be: 62.52 NTD (2.08 USD, green, south), 55.39 NTD (1.846 USD, blue, central), and 70.70 NTD (2.357 USD, red, north) with mean 62.87NTD (2.096 USD), whilethe unit tap water fees are: 70.71 NTD (2.357 USD, green, south), 62.64 NTD (2.088 USD, blue, central), and79.96 NTD (2.665 USD, red, north) with mean 71.10NTD (2.370 USD).**

3.1.1.3 Industrial Water Cost

MOEAWRA (2016) reported that in the manufacturing sector, according to the industry association data, the main water markis the chemical materials manufacturing industry (water expenditures account for between 6.8% and 8.7%), followed by electronic components (water expenditures account for between 4.3% and 5.5%) and basic metal manufacturing (water expenditures account for 3.3% to 5.0%), computers and electronic products (water fee expenditures account for between 1.1% and 2.0%), plastic products (water fee expenditures account for between 0.9% and 2.2%), non-metallic mineral products (Water fee expenditures account for between 1.1% and 1.7%), petroleum and coal products (water fee expenditures account for between 1.2% and 1.8%), textile industry (Water fee expenditures account for between 0.9% and 1.4%). Since there are too many factors that affect the performance of the output value and added value of various industries, it can be found from the above-mentioned data observation that when simply using water consumption per unit output value or operating income to predict future changes in water consumption, special care should be taken in using the meaning of this indicator. In the same report, the results show that there are significant differences in the caliber categories used by different water consumption (p-value<0). Most small water users use caliber categories. 13mm, 20mm and 25mm water pipes (accounting for 99.4% in total), of which diameter 20mm accounts for 63.4%; large water users mostly use water pipes with diameters of 40mm, 50mm, 75mm and 100mm, accounting for about 83% in total. The chi-square fitness test for water use categories for large and small water users is shown. The results show that there are significant differences in the performance of different water consumption categories (p-value<0) for small water users. 93.8% of the distribution of water use categories is ordinary water use; the distribution of water use categories of large water users is based on ordinary water use.

Water, commercial water, industrial water and institutional water accounted for 88%, of which industrial water accounted for 45.3%. On the other hand, Taiwan Water Company users whose monthly water consumption is less than 1,000m^3. A K=4 cluster analysis was performed on the observed values of the degree to evaluate the grading of current water charges. The ANOVA analysis results are shown that there are significant differences in the monthly water consumption of each cluster (p-value<0), and the range distribution of each cluster shows that the division of monthly water consumption is not consistent with the division of water charges. Compiling the water consumption proportion of diameters, it is found that 60.7% of water consumption is concentrated in diameters of 20 (mm),25 (mm), 13 (mm), the following is the water consumption proportion of each caliber. After analyzing the proportion of water types in calibers, it was found that more than 92% of calibers 13, 20, and 25 are general water, followed by about 2% for active and reserve water, and industrial and commercial accounts for about 1%. Therefore, analysis shows that the diameter of water used for general domestic water falls approximately in the 13-25mm range. In order to clarify the water demand of the above-mentioned calibers and consider that water charges are affected by calibers and grade intervals, water grade intervals are used for distribution analysis below. This grade interval adopts water price charges of the current Taiwan Water and the planning in the report of the Water Conservancy Department of the Ministry of Economic Affairs (2015) Water consumption tax grading structure, as the classification of grading above 1,000 degrees (m^3/month).

According to this, it can be divided into 7 categories in total. The grade span description is as follows in Table 4:

Table 4 The definition of Level Degree: m^3/month

Level	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
degree	1-10	11-30	31-50	51-1000	1000-3000	3000-6000	＞6000

It was found that water consumption is concentrated in three levels: 11-30 degrees, 31-50 degrees, and above 6,000 degrees, accounting for about 81.09% of the total water consumption. Detailed analysis of water consumption categories of 11-30 degrees, 31-50 degrees, and above 6,000 degrees, it was found that about 92% of the 11-30 degrees and 31-50 degrees are ordinary water, with active and reserve water accounting for 2% and 1% respectively. In addition, among the water consumption above 6,000 degrees, industrial water accounts for about 84%, followed by military aircraft and agencies each accounting for about 4%, and commercial water accounting for 3%. Therefore, it can be found that the water consumption between 11 and 50 degrees is mostly for general domestic water consumption, and the demand for industrial water is slightly higher than the water consumption range above 6,000 degrees. From the analysis of industrial water characteristics, it can be seen the industries with the largest total water consumptioninclude the electronics industry, basic metals, chemical materials industry, papermaking, textile industry, food industry, etc.; most of the water consumption in various industries is contributed by high water consumption levels. Among the above-mentioned water-consuming industries, except for the electronic industry and basic metals, which mainly use tap water, other industries use water rights as their main source.

Since major industrial water users all use tap water as their main source of water, their water prices are calculated based on the cost of tap water of 11 NTD/m^3. While from the above analyzing result (4).

(5) **The industrial water cost could be treated as the unit selling prices, *without Includingindustrial sewage treatment fees whichare the external cost items, such Asenvironmental treatment costs*,**will be 62.52 NTD(2.08 USD, green, south), 55.39NTD (1.846 USD, blue, central), and 70.70 NTD(2.357 USD, red, north) with Mean62.87NTD (2.096 USD), while 70.71 NTD (2.357USD, green, south), 62.64 NTD(2.088 USD, blue, central), and 79.96 NTD (2.665 USD, red, north) with mean 71.10NTD (2.370 USD).

3.1.1.4 Transferring Compensation Fee from Agriculture to Industry

Putting forward the strategy to solve industrial water use, has become the bottleneck that must be broken under the premise of industrial development today. Access to water is clearly a wider subject than availability and many other factors including cost, distance to water source, rights, authorities and corruption can create water poverty (the opposite of water security) at household and community levels. The distribution of water infrastructure is inversely related to the global distribution of water insecurity risks. Many of the world's wealthiest nations also have the highest water security and investment in water storage has enabled growth where hydrological variability is high, although growth often requires ongoing non-infrastructural investment. A typology of temporary transfers typically occurring during a drought on how water is transferred in practice from agricultural to industrial uses is an urgent issue in Taiwan due to the higher uncertainties of water resources not only on regional differences but also on seasonal significant such as wet and dry seasons.If the source is large, the impact on irrigation users may diffuse and be unidentifiable. If the transfer is a large portion of the source (often the case during droughts), then temporary allocation directly impacts on a known group of farmers who may have to be compensated for their (temporary) loss. Once the emergency is over, allocations revert to the original pattern, always with the possibility that drought will return sometime in the future. Transfers can be distinguished according to the share of the source of origin that is diverted.On the consideration of transfer mechanisms utilized in their implementation, the first type of transfers occurs through the transfer of formal rights to the use of water. These aretypified by practices in developed countries. Negotiations can include financial compensations and/or efforts by the agricultural sectors to reduce its losses or its consumption.The charge of industrial water on compensation by transferring from agriculture, not including the water quality treatment, contains primary water cost (Luo, 2018) with the consideration of storage scales and the effects of constructed timing, the rental fee of transferring system, the fee of management, the labor cost, and the government fallow grant due to the farming fallowing. In Luo, 2021, The rental fee for transferring water (Agriculture Irrigation Association) could be calculated based on the formula from agriculture irrigation associations, which now belong to Agricultural Committee of the Executive Council, as following:

(Annual transferring water volume) ×(Discount rate)+Accumulate fee= The payments.

Here, for example, the annual transferring water volume is 30,000,000 Tons, and the discount rate, 0.55, with the accumulate fee 637, 550 NT dollars in 1991, there, the rental fee per cubic meter water will be 0.57 NT dollars. **The transferring management fee is 0.27 NT dollars. The lost for farming fallow (Department of Agriculture and Forestry, Taiwan Province) is given as 6.59 NT dollars.**

The net fee for transferring water from agriculture to industry is summed as:

4.64+0.57+0.27+6.59=12.07NTD (or 0.402USD with 1USD=30NTD)

with the operation fee: 0.57+0.27+6.59=7.43NTD (or **0.248 USD** with *1USD=30NTD*)

The total transferring fee can be calculated by 12.07÷(1-0.071)=13.00, here the value of 0.071 is the rate of water deployment by reservoir management bureau. The 13.0NTD/m^3 will be treated as the mean transferring fee in 1991, while the real transferring fee for different regions will be considered the agricultural water cost as:

The Southern: 〔**(0.491+0.248)** ÷(1-0.071)〕=**0.796USD;**

The Central: 〔**(0.405+0.248)** ÷(1-0.071)〕=**0.703USD;**

The Northern: 〔**(0.451+0.248)** ÷(1-0.071)〕=**0.752USD;**

The Eastern: 〔**(0.381+0.248)** ÷(1-0.071)〕=**0.677USD;**

The Mean: 〔**(0.432+0.248)** ÷(1-0.071)〕=**0.732USD;**with 1USD=30 NTD.

From the view point of present-value, the payment from the industrial unit is:

(6) The Industrial Water Cost in 2020:

(The summed fee in 1991) × (compound interest rate of interest) × (compound interest rate of exchange), with interesting rate, r1 =3 ％, and n=the calculation period=2020-1991=29, therefore, **the compensation fees in 2020 is 1.876USD, 1.657USD, 1.772USD, 1.595USD, and 1.724USD for the southern, the central, the northern, the eastern and the mean, respectively.**

3.1.2Groundwater Cost

Although Taiwan's average annual rainfall is as high as 90 billion tons (100 millioncubic meters), it may be affected by problems such as uneven spatial and temporal distribution of rainfall, limited capacity of water storage facilities, steep river slopes and rapid flows, as well as surface water sources that are polluted and affected by tides. The utilization of surface water sources is insufficient and it is necessary to rely on groundwater resources to supplement the water needs of various standards. Among them, the unbalanced development of land use and industry in some areas of the southwestern plains of China. In order to stabilize water use, ground subsidence has occurred due to excessive pumping of groundwater, resulting in land salinization and seawater intrusion into groundwater aquifers in coastal areas. In the future, global climate change will continue to affect the land use and industrial development., the greenhouse effect and the impact of high urbanization, we will face challenges such as increased surface runoff, reduced groundwater recharge, and rising sea levels. In order to ensure the sustainable use of water and land resources and the normal operation of important public constructions, groundwater environmental protection work must still be carried out in a reasonable manner. Utilize groundwater to effectively slow down ground subsidence. Through the continuous improvement of basic groundwater environment information and the research and development and integration of scientific research technologies, groundwater conservation and ground subsidence prevention and control strategies will be refined, and combined with the results of smart water management, we will use modern science and technology to build a dynamic groundwater management mechanism to assist groundwater control districts and counties. The municipal government has implemented water well and pumping management, and at the same time strengthened groundwater recharge and benefit assessment to slow down subsidence and prevent seawater intrusion.

Groundwater Conservation Management and Ground Subsidence Prevention and Control Phase 3 Plan (2021-2024)(Executive Yuan, 2020) with the main scope of work covers the entire Taiwan. The 9 major groundwater areas (see Fig. 4)are targeted at counties and cities where stratum subsidence has occurred or are likely to subside, especially the central Yunlin area where subsidence continues to subside, and are aimed at effectively slowing down stratum subsidence, improving rational use of groundwater, and preventing seawater intrusion. As the goals, they are listed as follows:

1. Effectively slow down formation subsidence.
   (1) The groundwater level has risen to more than 0.2 meters, and the significant subsidence area in Taiwan is less than 200 square kilometers.
   (2) Groundwater recharge volume is 10 million tons/year.
2. Improve the rational utilization of groundwater.
   (1) Inspect 800 factories in groundwater control zones to avoid illegal use of groundwater.
   (2) Complete the estimation of groundwater utilization, rational utilization, and recharge in two major groundwater areas, including the Zhuoshui River alluvialfan and the Pingtung Plain, so as to establish a groundwater supply and demand management mechanism.
3. Prevent seawater intrusion.
   (1) Complete the investigation of the high groundwater salinization or seawater intrusion areas in Jia-nan, Chang-yun, and formulate prevention and control strategies.

(2) The Chang-yun-jia area does not exceed Provincial Highway 17.

The performance indicators, measures and targets are:

1. By 2024, we should continue to maintain the normal functioning of the existing 832

groundwater level observation wells and the well network automatic transmission system, replace the old ones with new ones for 80 observation wells, and strengthen the construction of 40 new groundwater wells. The observation wells, handled 600

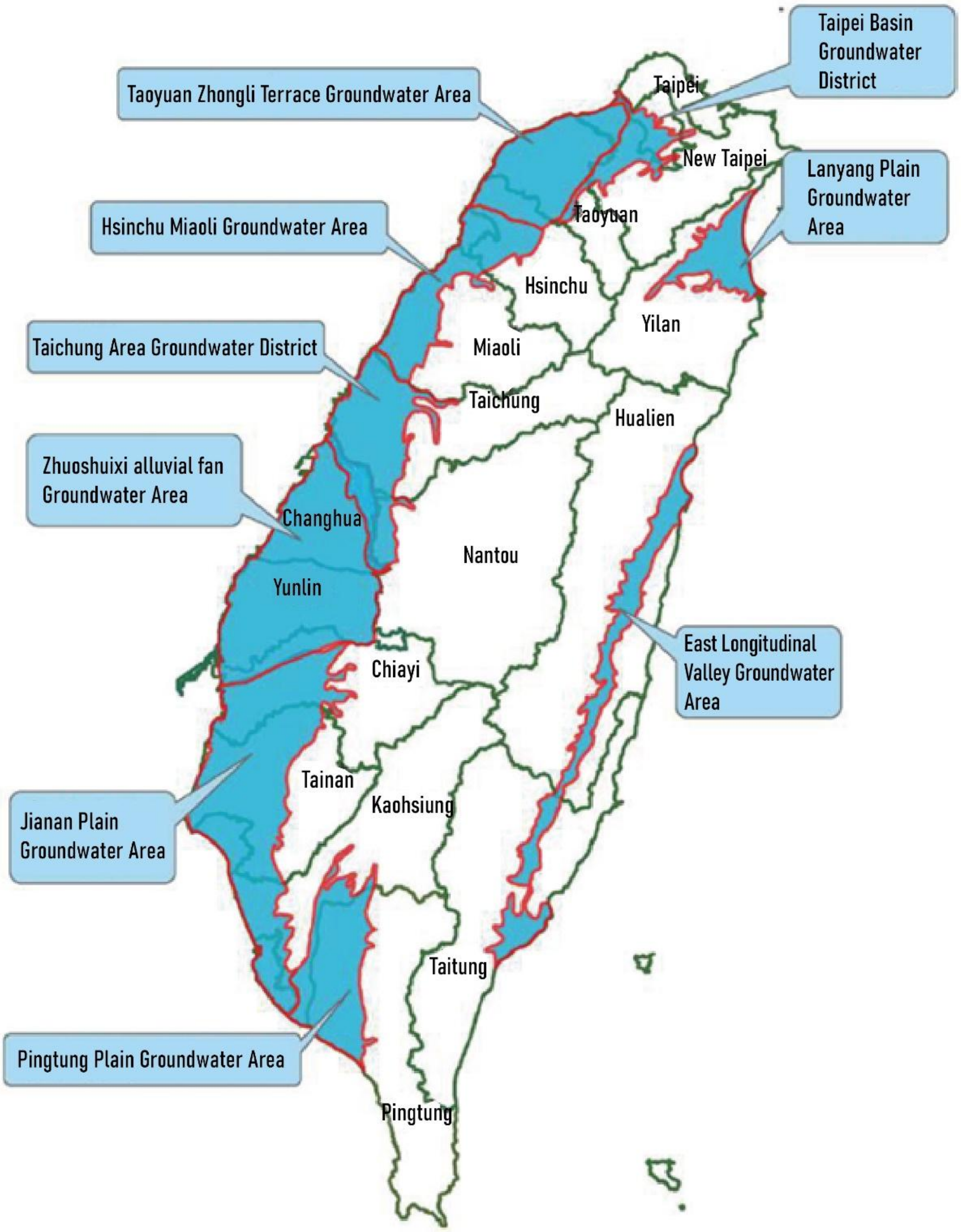

Fig. 4 Map of Taiwan's groundwater distribution areas(Ministry of Economic Affairs, Taiwan)

observation wells (including new and existing) well body photography and water quality testing, completed the Zhuoshui Creek alluvial fan and Pingtung Plain-regional management water level and operation indicators, and determined the completion of the groundwater area Hydrogeological parameters and potential water volume analysis models are used to estimate the reasonable utilization amount to promote smart management of groundwater utilization.

2. In addition to maintaining and integrating monitoring and analysis, the stratum subsidence monitoring network has 55 stratum subsidence layered monitoring wells, 30 GNSS fixed tracking stations and 7 stratum subsidence deep piles, and handles 9 area level detection and monitoring and analysis using radar interferometry technology. It also adds or updates 12 stratigraphic subsidence layered monitoring wells and 12 GNSS fixed tracking stations as necessary to conduct an integrated analysis of stratigraphic subsidence changes in each region year by year.
3. In addition to maintaining the existing target of about 130 million tons of groundwater recharge per year in the second phase (2015 to 2020 Year) of the plan, groundwater recharge has continued to recharge more than 10 million tons every year. By 2024, the cumulative recharge reached 40 million tons. In 2024, the central Yunlin indicator well water level rose by 0.2 meters, and the water level in indicator wells in other areas rose by more than 0.3 meters.
4. Unregistered wells were managed and illegal wells were disposed of, and 800 factories in the groundwater control area were inspected; and the groundwater water management early warning contingency plan for Huwei, Tuku,Yuanchang and Dapi of central Yunlinand large water users to mainly industrial emergency water pumping control mechanism and promote trial implementation depending on water conditions.
5. According to the year-by-year level inspection data of the subdivisions, the significant subsidence area in Taiwan in 2024 was less than 200 square kilometers, and the scope of seawater intrusion was controlled. Chang-yun-jia did not exceed Provincial Line 17.

The changes in significant subsidence area and annual maximum subsidence ratebetween 2001 and 2019 years are shown the maximum annual average subsidence rateand significant subsidence area changes in Changhua, Yunlin, Chiayi, and Pingtungareas from 2015 to 2019 years are detailed that formation subsidence in each region ismainly related to excessive groundwater extraction (Executive Yuan (2020). It is determined by the rainfall andgroundwater

level in Yunlin area.

The monitoring data of formation subsidence areshown that subsidence mainly occurs during the dry season, but is also affected by thehydrological rainfall of the year.

In the recent years (Executive Yuan, 2020),1) the stratigraphic subsidence in the Changhua coastal area hastended to ease. In the future, continuous monitoring will be the focus and efforts will be made to avoid causing subsidence again; (2) The Yunlin area is a key area for stratigraphic subsidence prevention and control at this stage. Stratum subsidence occurs in most plain areas of the county. The inland industry is mainly agriculture; the coastal area is aquaculture. Subsidence mainly occurs in the dry season, and the high-speed railway passes through the central part of the country. The subsidence area has always been the focus of public opinion and should be listed as a priority area for disposal. In addition to groundwater environment monitoring, the correlation between industrial water use characteristics and formation subsidence should be understood as a basis for strategies to reduce, rotate or stop groundwater pumping, and handle well management, groundwater recharge, rational use of groundwater, and water environment improvement; (3) The subsidence situation in Chiayi's coastal areas has been relatively stable in recent years, changing with the increase or decrease in industrial water demand and water supply. The reasons for occasional significant subsidence in some inland areas are the same as before. It is advisable to pay special attention to the changes in subsidence along the high-speed rail line and monitor them in the future. Industrial water demand, reducing groundwater pumping is the main focuses of prevention and control; (4) The significant subsidence area in Pingtung area in recent years has been limited to the vicinity of the outlet of Linbian Creek, and the industry is mainly aquaculture. The coastal Jiadong area has a long-term cumulative subsidence of more than 3.5 meters and is an important fishery aquaculture town. The focus of preventionand control is to ensure that the industry and For the balanced development of water and land resources, in terms of the business powers and responsibilities of the Ministry of Economic Affairs, the main focus of the work is to take into account the rationalutilization and conservation of groundwater, as well as the improvement of the drainage environment; (5) The scope of seawater intrusion in the Pingtung Plain is mainly distributed in coastal stratum subsidence areas, affecting the use of groundwater in inland areas. In addition to preventing stratum subsidence, coastal areas should also pay attention to the issue of seawater intrusion. In order to avoid affecting the sustainable utilization of water and land resources, this period's plan The plan should first investigate and assess the scope of seawater intrusion or salinization of groundwater aquifers in the southwestern coastal areas and formulate relevant prevention and control strategies, and then gradually control the scope of seawater intrusion or salinization through measures such as reducing groundwater pumping and recharge.

Some important topics are still needed to pay attention (Executive Yuan (2020),there are:

1. The underground hydrogeological conditions of the alluvial fan are complex, and there are many water pumping units. It is difficult to clearly clarify the mechanism of stratum subsidence

triggered by pumping behavior. Although the main compaction time and depth of the stratum can be inferred from the groundwater level and stratum subsidence monitoring data, it is still impossible to It has been scientifically verified by observation monitoring data that significant

subsidence during the dry season is affected by water regimes or industrial pumping. Moreover, under different hydrogeological and water conditions, the correlation between pumping behavior and groundwater levels and formation subsidence has yet to be clearly established. Therefore, existing observation and monitoring stations In addition to maintaining normal operation and providing long-term and complete monitoring data, the network must appropriately improve the accuracy and density of hydrogeological parameters,
construct a numerical model of specific groundwater environment, and combine advanced monitoring technology to improve monitoring and early warning effectiveness to grasp the real-time dynamics of the groundwater environment. Promote the rational use of groundwater
and continuously review prevention and control benefits and strategies.

2. The Zhuoshui River alluvial fan and the Pingtung Plain are important granaries. The utilization of groundwater has always been higher than that of other groundwater areas. The soft geology can easily cause stratum subsidence. Therefore, in areas with significant stratum subsidence, in addition to promoting the rational use of groundwater, we should also strengthen groundwater recharge to slow down subsidence. However, rainfall in the two regions is concentrated during the wet period, and the rainfalldistribution will be more extreme in the future due to global climate change. Moreover, the complex and fragmented geology of the two alluvial plains and high land use density are not conducive to the storage of excess rainfall after natural infiltration as asupplement. Water recharge source and large-scale, regular groundwater recharge. Therefore, in addition to supplementing hydrogeological survey data as necessary to evaluate feasible recharge methods in the area, it is also necessary to confirm the recharge benefits and evaluation methods to clarify the contribution of different recharge methods and mechanisms to groundwater conservation.
3. Water wells are facilities for drawing groundwater. We continue to conduct surveys of basic well registration information such as well locations, specifications, and pumping times. This is an important reference for understanding regional groundwater utilization needs and dispatching planning and management. Although there is legal basis for disposing of large numbers of unregistered water wells, However, due to concerns about people's livelihood and industrial development, it is difficult for county and municipal water conservancy units to effectively manage and control water wells. Factors such as the cooperation of well owners during the implementation process and the management intensity and manpower of county and municipal governments will all affect the groundwater utilization survey and Unregistered
water well management and disposal process. Although water well management has practical difficulties, it is still necessary to continue to assist county and municipal governments in the groundwater control zone to actively promote implementation,

strengthen the management of the well sinking industry, encourage the public to report new illegal well sinking, and investigate Taiwan Electric Power Company's reports of electricity theft and user unauthorized use. Electricity connection and other information, and check large water users, grasp water use information and confirm whether there is any illegal well pumping behavior in order to facilitate the implementation of groundwater pumping management.

4.Industrial transformation, water conservation (throttling), water resources development and dispatch (open source) and water well management measures complement each other to get twice the result with half the effort and improve the efficiency of stratum subsidence prevention and groundwater conservation. The Yun-zhang area uses Zhuoshui Creek as the main water supply source. There is a lack of surface water sources during the dry season, and there are limits to the stable supply of surface water resources. Since the Yun-zhang Plan and Action Plan was approved in August 2019, the Agricultural Statistics Annual Report of the Committee of Agriculture shows that the first-phase rice harvest area in Chang District increased from 55,408 hectares in 2011 to 58,830 hectares in 2017. The area did not decrease but increased.

When water demand cannot be reduced, the possibility of pumping groundwater increases. Monitoring results show that the main subsidence. This occurred during the dry period of Phase 1. How to reduce the demand for groundwater pumping during thedry period is the key to slowing down the subsidence of the strata in the area.The topic is also the main factor affecting the effectiveness of the prevention and control plan. Since the matter involves the business standards and powers and responsibilities of each agency, in addition to raising the level of coordination and supervision to facilitate discussion and consensus and promoting the best plan, it also requires continuous guidance and improvement of water wells. All owners must cooperate with their will and abide by the farming system or accept appropriate compensation to meet the policy needs of groundwater environmental protection and stratum subsidence prevention and control, reduce pumping, rotate pumping, or stop groundwater pumping during fallow periods.

5. In order to protect the groundwater environment and prevent ground subsidence, in addition to prohibiting and restricting the use of groundwater, land use patterns with high freshwater consumption and industrial development should be avoided. If necessary, environmental restoration engineering measures such as comprehensive water control, industrial adjustment, and landform transformation should be combined. to achieve overall prevention and control results. In addition to continuing to promote water conservation in industry and people's livelihood, the Agricultural Committee must cooperate with continued industrial guidance work, such as promoting circulating aquaculture, water-saving irrigation, reducing farmland pumping, stopping pumping in rotation or fallow, and adjusting storage and replenishment, etc., in order to reduce the demand for fresh water supply; the Ministry of

Interior assists county and city governments in accordance with the Land Planning Act to review urban and non-urban land use management and utilization restrictions for implementation by land development planning authorities to avoid exacerbating ground subsidence due to over-pumping of groundwater. The above-mentioned ground subsidence prevention and control-related businesses require the cooperation of various ministries and county and municipal governments to promote implementation in order to improve the overall effectiveness.

6. The manpower and funds required for various groundwater conservation and ground subsidence prevention and control measures should still be widely listed, such as improved water well management, reduction of groundwater pumping, subsidies, compensation or incentive supporting measures for industries, and the implementation manpower of various agencies, etc. Can project funds be widely listed? The smooth acquisition of water sources and land for accelerating groundwater recharge willdirectly affect the overall effectiveness of the project.

In 2020, groundwater over-pumping reached 1.5 billion tons, which is equivalent to a loss of 11.8 billion yuan of water resources. The highest over-pumping rate was 630million tons in the Zhuoshui River alluvial fan, followed by 510 million tons in the Jia-nan Plain. Although there was rainfall replenishment, However, years of over-pumping and long-term use beyond the limit have also caused the crisis of ground subsidence.

Construction projects in Taichung City drain an average of more than 90 million tons of groundwater every year. The City Water Conservancy Bureau took the lead in the country in drafting the "Taichung City Groundwater Resources Maintenance Fee Collection Autonomy Ordinance" to encourage builders to replenish water by charging fees. If they replenish water, If the pumping capacity reaches one-third of the pumping capacity, maintenance fees will be waived.

Groundwater must be extracted when excavating basements for large-scale construction projects. In the past six years, Taichung City has pumped an average of 90,342,000 tons of water per year, and all this groundwater is discharged directly into drainage ditches.

Taichung City is the first local government in the country to charge groundwater resource maintenance fees, but it has been collected abroad for a long time. In order to use and manage water resources more efficiently and raise the funds needed for management, they have launched water resource management fees or water resources taxes.**Germany charges about NT$ 9 per cubic meter for groundwater extraction and NT$22per cubic meter in the Netherlandswith considering the factors such as land subsidence and sea level rise**(Executive Yuan, 2020).

The rainfall difference between Taiwan's wet season and dry season is huge, the water resources environment has changed significantly, the economy is booming, and the demand for water has grown significantly. Large-scale construction projects have pumped out groundwater to lower the water level to facilitate underground construction; coupled with the current groundwater There is no need to pay for pumping water like tap water. Industrial and commercial places use a large amount of water, which intensifies the consumption of groundwater. Based on the conservation of water resources and the effective management of groundwater resources, autonomous regulations are formulated. The persons obligated to pay water resources maintenance fees are building contractors and industrial and commercial business places such as factories, companies, hotels, B&Bs, tourist amusement parks, golf courses, etc. that have obtained groundwater water rights certificates.

Groundwater control areas charge 3NDT/ m^3 regardless of the amount of extraction; non-groundwater control areas charge no fee if the annual extraction volume is less than 100,000m^3 , and charge 1 NTD/ m^3between 100,000 and500,000m^3. From 10 to $10^6 m^3$, 1.5 NTD/m^3, and 2 NTD/m^3 for more than $10^6 m^3$. As long as the building contractor can propose **a recharge and water injection plan,** for example, recharging the pumped groundwater to the groundwaterlayer, discharging it into rivers or reusing it, **reaching one-third of the pumped amount, the payment can be exempted.** Maintenance fees collected will be used to promote groundwater resource conservation, sustainable development research, water conservancy-related facility maintenance, etc.

3.2 The Seasonal Differences of Water Costs

3.2.1The Seasonal Differences on Surface Water

Based on the stream discharge measured data of 19 main rivers from Hydrological Year Book of Taiwan R.O.C. within 1994 and 2014, the hydrological characteristic of flood season discharge ratio, discharge of flood season divided by the one of whole year, is calculated and showed as the followings (Luo, 2017, and Water Resources Department of the Ministry of Economic Affairs 2016-2019):

A. Whole Taiwan Island: Range from 0.548 to 0.891 with mean 0.742;

B. Northern part of Taiwan: Range from 0.489 to 0.837 with mean 0.650;

C. Central part of Taiwan: Range from 0.669 to 0.957 with mean 0.802;

D. Southern part of Taiwan: Range from 0.606 to 0.948 with mean 0.820;

E. Gao Ping Region: Range from 0.734 to 0.955 with mean 0.869;

F. Taitung Region: Range from 0.429 to 0.955 with mean 0.754;

G. Hualien Region: Range from 0.532 to 0.797 with mean 0.679;

H. Yilan Region: Range from 0.498 to 0.853 with mean 0.618;

By combining the results of Southern part of Taiwan and Gao-Ping Region, the mean is 0.845; and the mean with the combinations of Taitung Region, Hualien Region, and Yilan Region is 0.684. By comparing those hydrological characteristic of flood season discharge ratio with those of hydrological characteristic of flood season rainfall ratio in Figure 3 (Luo, 2017-1), we could find the results show a little bit difference except the ones of Eastern part of Taiwan.The larger the magnitude of the ratio for both of the rainfall and the discharge, the higher the water shortage risk is.

Taiwan is surrounded by the sea and has a warm and humid climate. The average annual rainfall in 2016 was 3278 mm. Compared with the average annual rainfall of 2497 mm in previous years (1949~2015), it was about 31% more. It is a wet year. Rainfall patterns are extremely unevenly distributed in time and space, with huge differences between wet and dry periods. In 2016, Taiwan's wet season rainfall accounted for 72.6%, and the average wet season rainfall over the years accounted for 77.7% of the annual rainfall. The difference between wet and dry periods in each region: in 2016 and previous years, the rainfall in the northern region accounted for 63.8% and 64.6% respectively, the central region accounted for 59.8% and 77.2% respectively, andthe southern region accounted for 82.0% and 89.0% respectively. The eastern region accounts for 79.7% and 77.7% respectively. It can be seen the gap between abundance and dryness in the southern region is more significant than the other regions.

The flow of rivers in Taiwan in 2016 was higher than the historical average, with a total runoff of approximately 88.055 billion cubic meters, which was approximately 36.38% higher than the historical (1949~2015) total runoff average of 64.567 billion cubic meters. In 2016, the runoff in the northern region was 19.493 billion cubic meters, accounting for 22.1%; the runoff in the central region was 17.938 billion cubic meters, accounting for 20.4%; the runoff in the southern region was 24.331 billion cubic meters, accounting for 27.6%; and the runoff in the eastern region was 24.331 billion cubic meters, accounting for 27.6%. 26.293 billion cubic meters, accounting for 29.9%.

The average annual rainfall in 2017 was 2,601 mm. Compared with the average annual rainfall of 2,509 mm in previous years (1949~2016), it was about 4% more. It is a normal year. Judging from the long-term records of annual rainfall from 1949 to 2017, we can see that high and low water years occur alternately. In the past, the cycle of high and low water years has been shortened from 19 years to 7 years recently, and the cycle of high and low water years has been greatly reduced. The gap in rainfall is getting wider and wider, with either too much water or too little water. The fluctuations in water regimes between good and dry years have intensified, which means that extreme events of drought and flood occur more frequently. Rainfall patterns are extremely unevenly distributed in time and space, with huge differences between wet and dry periods. In 2017, Taiwan's wet season rainfall accounted for 80.1% of the total, while the average wet season rainfall over the years accounted for 77.6% of the annual rainfall. The difference between wet and dry periods in each region: in 2017 and previous years, the northern region accounted for 63.4% and 64.6% of the rainfall during the wet season, the central region accounted for 83.1% and 76.9% respectively, and the southern region accounted for 91.3% and 88.9% respectively, the eastern region accounted for 83.1% and 77.7% respectively. It can be seen the gap between abundance and drought in the southern region is still the most significant one.In 2017, the flow of rivers in Taiwan was higher than the historical average, with a total runoff of approximately 73.14 billion cubic meters, which was approximately 12.7% higher than the historical (1949~2016) total runoff average of 64.888 billion cubic meters. In 2017 of Taiwan, the runoff in the northern region was 18.0 billion cubic meters, accounting for 24.6%; the runoff in the central region was 18.82billion cubic meters, accounting for 25.7%; the runoff in the southern region was 16.48 billion cubic meters, accounting for 22.6%; the runoff in the eastern region was 16.48 billion cubic meters, accounting for 22.6%; The flow volume was 19.84 billion cubic meters,accounting for 27.1%.

The average annual rainfall in 2018 was 2,423 millimeters, which is close to the average annual rainfall in statistical years (1949~2017) of 2,511 millimeters. Theaverage rainfall in 2018 is a normal year. And judging from the long-term records of annual rainfall over the years, it is a wet year and a wet year. occur alternately. Rainfall patterns throughout the year are also unevenly distributed in time and space, with huge differences between wet and dry periods. Over the past years, the rainfall in wet periods in Taiwan has accounted for 77.6% of the entire year, with the northern, central, and southern regions accounting for 64.6%, 77.0%, and 89.0% and 77.8%, respectively with the largest difference between abundance and drought in the southern region.

In 2018, Taiwan's rainfall during the wet season accounted for 78.3% of the whole year, with the northern, central, and southern regions accounting for 58.9%, 77.0%, 93.6%, and 76.8% respectively. It can be seen the difference in wet and dry periods in the southern region is more severe than in previous years.

In 2018, Taiwan's rainfall during the wet season accounted for 78.3% of the whole year, with the northern, central, and southern regions accounting for 58.9%, 77.0%, 93.6%, and 76.8% respectively. It can be seen the difference in wet and dry periods in the southern region is more severe than in previous years. The average total runoff over the years (1949~2017) was 65.006 billion cubic meters, while the total river runoff in Taiwan in 2018 was approximately 61.473 billion cubic meters, of which the northern region had a runoff of 11.701 billion cubic meters (the average over the years was 15.145 billion cubic meters meters), accounting for 19.0%; the runoff in the central region is 13.276 billion cubic meters (the average over the years is 15.368 billion cubic meters), accounting for 21.6%; the runoff in the southern region is 23.389 billion cubic meters (the average over the years is 17.522 billion cubic meters)), accounting for 38.0%; the runoff in the eastern region is 13.107 billion cubic meters (the average over the years is 16.971 billion cubic meters), accounting for 21.4%. Although the rainfall in 2018 was close to the historical average and was considered a normal year, the difference in water volume during the wet and dry periods in the southern region was even more severe. Rainfall during the wet period accounted for 93.6%. As a result, the southern region suffered from a severe drought during the dry period in the first half of the year and the river runoff was reduced. Affected the inflow of the reservoir, only 1.8% of the water storage capacity of the Zengwen Reservoir (in

Tainan)was left in June. The 0823 tropical depression flood event hit the south on August 23, but the Jia-nan Plain was soaked in water.

The average annual rainfall in 2019 was 2,450 millimeters. Compared with the average annual rainfall in previous years (1949-2018) of 2,508 millimeters, it is close to the average annual rainfall in previous years and is a normal year. Judging from the long-term records of annual rainfall over the years, wet and dry years occur alternately. Rainfall patterns throughout the year are unevenly distributed in time and space, with huge differences between wet and dry periods. Over the past years, Taiwan's wet season rainfall has accounted for 78% of the entire year, with the northern, central, and southern regions accounting for 65%, 77%, 89%, and 78% respectively, especially in wet periods. The southern region has the largest difference in abundance and dryness. In 2019, Taiwan's wet season rainfall accounted for 79% of the year, and the northern, central, and southern regions accounted for 67, 79, 90, and 75% respectively. It can be seen the difference in wet and dry periods in the southern region is more severe than in previous years.

From the above information it shows 1949 to 2018, the regional seasonal rainfall ratios in the wet and dry periods are as follows:

The abundance-to-dry ratio in the northern district is 6.5:3.5, that in the central district is 7.7:2.3, that in the southern district is 8.9:1.1, and that in the east district is 7.8:2.2.

However, by 2019, the ratio of good times to bad times is even more dangerous: theabundance-to-dry ratio in the northern district is 6.7:3.3, that in the central district is 7.9:2.1, that in the southern district is 9.0:1.0, and that in the east district is 7.5:2.5.

Therefore, it can be seen the difference in rainfall (which can be regarded as surface water flow) in each region is very different, especially in the southern region, followedby the central region.

Here, the average of abundance-to-dry ratio is set as 5:5 (50％: 50％), then the insufficient of water for each district will be 1.7 (17％), 2.9 (29％), 4.0 (40％), and 2.5(25％) respectively for the north, the center, the south, and the east. Therefore, the seasonal raw water cost will be the regional raw water cost multiplying the factor each 1.17, 1.29, 1.40, and 1.25 for the north, the center, the south, and the east separately. These situationscould be treated as the assumption the devices of water storage are well done. Now the problems we need to consider is the risk for each regional-seasonal situations for each district by applying:

Risk= 1- $(1-P)^N$……………………………………………..………………..(3)

with P= the probability for each district, and N=the observing or expecting period.

If N=5 years is given, and 17％, 29％, 40％, and 25％ respectively for the north, the center, the south, and the east is substituted into for each, we have the occurrence of the risk for each district will be: 60.61％, 81.96％, 92.22％, and 76.27％, separately for the north, the center, the south, and the east. And they show the quite high occurrence sensitively to seasonal influences.

3.2.2 The Seasonal Differences on Groundwater

In the absence of a clear definition of "safe groundwater yield", the groundwater management level is the result of statistical analysis using historical groundwater level data recorded by each observation well. It can be used as a reference value to judge whether the groundwater level status needs to be strengthened, meaning that when the water level in an observation well is lower than the management level, it means that the observation well and its adjacent groundwater levels are at a relatively low historical level. If it continues to be lower than this standard, management should be strengthened.

The groundwater management level is based on the frequency analysis of historical groundwater level data recorded by each observation well, and the water level exceedance probability values of 75, 25 and 10% respectively represent the safe water level, lower limit water level and severe lower limit water level, which can be used to determine whether the groundwater level status is Reference values that need to be strengthened.

Based on the content of the special issue on Taiwan's hydrological environment (from 2016 to 2019, Chinese version) published by the Water Resources Department of the Ministry of Economic Affairs (2016-2019),the following is excerpted:

Comparative results of groundwater level data between 2016 and 2015, Taiwan, show that in Taiwan, except for the Penghu groundwater district, most groundwater observation well water levels declined in 2016, while the water levels in the remaining nine groundwater districts mostly increased. Among them, the Taipei Basin and PinghuBasin Water levels in more than 90% of observation wells in the East Plains groundwater area have increased. The groundwater level in 2016 of Taiwan was then compared with the management water level. Among them, **more than 20% of theobservation well water levels in the Lan-yang Plain, Xin-miao area, Taichung area and Huadong Longitudinal Valley were lower than the management water level,** indicating that their groundwater levels were lower than the management level. The environmental condition is poor and management must be strengthened. Overall, the groundwater levels of 606 of Taiwan's 751 observation wells in 2016 were higher than those in 2015, accounting for about 81% of the total, and 629 werehigher than the management water level, accounting for about 84% of the total, **or means 16% of the total lower than the management water level.**

Comparison of groundwater level data between 2017 and 2016 shows that in Taiwan, except for the Lan-yang Plain and Taoyuan Zhongli Platform groundwater areas, most groundwater observation well water levels increased, while the remaining eight groundwater areas mostly declined, among which, nearly 96% of the observation well water levels in the East Longitudinal Valley groundwater area have dropped. The groundwater level in 2017 was then used to compare with the management water level. Among them, **more than 50% of the observation well water levels in groundwater areas such as Taichung area, Zhuoshuiriver alluvial fan, Huadong Longitudinal Valley and Penghu areawere lower**

than the management water level; showing that their groundwater levels were lower than the management water level. The environmental condition is poor and management must be strengthened. Overall, the groundwater levels of only 163 of the 794 observation wells in Taiwan in 2017 were **higher than the groundwater levels in 2016, accounting for about 22% of the total**, or said **78% of the total lower than the groundwater levels**. The main reason for this is that Taiwan had low rainfall at the beginning of the year and entered a drought. Therefore, continuous monitoring and strengthening of management are still required. According to the changes in groundwater levels in each month of 2018, **more than 20% of the observation well water levels are lower than the management water level** in most months, indicating that most groundwater environmental conditions in 2018 require continuous monitoring. Overall, the groundwater level status (elevation) of more than 450 of Taiwan's 830 observation wells in 2018 was s**lightly worse in December than in December of the previous year, accounting for about 54% of the total.** The reason for this is mainly due to the impact of the global downturn at the end of 2017. The rainfall in Taiwan is relatively low and it is related to drought. Therefore, continuous monitoring and strengthening of management are still required.

According to the long-term groundwater level record in the past 10 years from 2009 to2018, the groundwater areas where the water level of observation wells in groundwater areas mainly showed an upward trend include the Taipei Basin, Taoyuan Zhongli Platform, Lan-yang Plain and Penghu area; while the water levels in groundwater areaobservation wells mainly showed a downward trend. The groundwater area includes the Xin-miao area, Taichung area, Zhuoshui river alluvial fan, Jia-nan Plain, Pingtung Plain and Huadong Longitudinal Valley, etc. Representative observation wells from each groundwater zone were taken to illustrate the water level change trend in the past 10 years. If extreme climate events occur frequently in the future, the role of groundwater in water supply will become increasingly important. Therefore, continued conservation and management of groundwater will not only prevent the deterioration of the groundwater environment, but also contribute to water resource management and provide citizens with high-quality water environment and ensure the stable development of the country.

Comparison of groundwater level data between 2019 and 2018 shows that in 2019, most (at least 50%) of groundwater observations were observed in groundwater areas such as the TaoyuanZhongli Platform, Xin-miao area, Taichung area, Zhuoshuiriver alluvial fan, and Jia-nan Plain. The well water level is higher than that in 2017, and the water level changes mostly show an increase. Overall, 499 of the total 828 groundwater observation wells in Taiwan in 2018 were higher than the groundwater level in 2017, accounting for about 60% of the total **(40% lower).** In addition, compared with the management water levels of various observation wells, 426 were higher than the management water level, accounting for about 52% of the total**(48% lower).**

After sorting, it is found in our study that the maximum number of groundwater levels that need strict management is 78%. The seasonal groundwater cost should multiple **the safe factor 1.78.** The risks, in Eq. (3), with P= 78%, P= 54%,P= 48%, P= 40%, respectively, and N=5, are 99.95%, 97.94%, 96.20%, and 92.22%, and they show the extremely high risk on reoccurrence in the future. Groundwater is a kind of emergency water, also called life-saving water, proper utilization and management are important principles for groundwater management.

DISCUSSION

Low water price in Taiwan is no longer news. The average water price per unit is only 11 NTD. In other words, a 10NTD coin can buy about one ton (1,000 liters) of tap water, which is equivalent to more than 1,660 cans of bottled water. This kind of water price is the second lowest in the world, lower than South Korea's 18 NTD, and even only 1/3 of Japan's water price. Low water prices have caused per capita water consumption in Taiwan to rise year by year, which has also affected the operating performance of water companies. The water company stated that due to long-termcooperation with the government's low water price policy, the water price has not been adjusted for 27 years. The average water supply investment return rate in the past 10 years has been -0.32%, resulting in an annual loss of approximately 1.7 billion, whichin turn affects various policy investment plans. At the end of 2019, long-term borrowings reached 74.1 billion NTD(Ministry of Economic Affairs and Water Resources Department ,2016).

From the end of 2020 to the first half of 2021, Taiwan suffered the most severe drought in a century. The water storage rate of many reservoirs was only in single digits. Taichung, Miaoli and North Changhua areas implemented the "5 supply, 2 stop" zoning water supply measure for 61 days, setting a record The longest implementation time record in history. In response to the drought, the Water Resources Department promoted the construction of drought-resistant wells and pumped groundwater for emergency response. The Water Resources Department stated on the 11th that the previous heavy rains not only improved the water conditions in the reservoirs, but also the current groundwater levels have returned to normal.

The Water Resources Department pointed out that groundwater, surface water, and reservoir water are both important sources of water in Taiwan. In times of drought, groundwater is a more stable source of disaster relief water. In response to the severe drought, in order to stabilize people's water supply needs, drought relief wells and emergency well drilling were launched. During the drought relief process, the cumulative water pumping volume reached 63.4 million tons, giving full play to the function of groundwater as life-saving water.

The Yun-zhang area has experienced over-pumping of groundwater for many years, making it the area with the most severe stratigraphic subsidence in Taiwan. The mitigation strategies that the Water Resources Department continues to promote include encouraging the use of surface water and building surface water sources such as Hushan Reservoir and artificial lakes to replace the use of groundwater. In recent years, the water resources department has also increased the amount of groundwater recharge through "river channel" projects. Unfortunately, the replenishment volume in recent years is far less than the over-pumping volume. The Water Resources Department stated that groundwater management on the "demand side" is more important. In the future, it does not rule out the deactivation of public wells and 260,000 private wells in Yun-zhang area. After being managed, the amount extracted should be able to be monitored in real time; for agricultural irrigation wells with the largest water consumption, the Agricultural and Food Administration will continue to provide guidance to farmers to switch to drought-resistant crops.

The Yun-zhang area shows that the area of subsidence accounts for 99% of Taiwan's total. The Water Resources Department's prevention and control strategy ismulti-pronged, starting from the supply and demand side. On the one hand, it increases the amount of surface water sources and groundwater recharge. On the other hand, it strengthens the reduction of groundwater pumping and improves water managementefficiency. In recent years, there has been progress in groundwater recharge in the Yun-zhang area. For example, this year's "river channel" project to increase the water coverage area by 106 hectares in the fan top area of the Zhuoshui River alluvial fan is estimated to increase the annual groundwater infiltration recharge in the Yun-zhang area. The injection volume reaches 30 million tons, which is equivalent to the water consumption of 2,000 hectares of first-phase rice cultivation. Despite this, according to statistics from the Water Resources Department, groundwater over-pumping in the Zhuoshuiriver alluvial fan area is still quite serious. In 2019, the over-pumping amount was nearly 630 million tons, far exceeding the amount that the above-mentioned man-made facilities can pump. In addition to increasing the "supply side" of groundwater recharge and surface water source options, it is more important to start from the "demand side" and properly manage groundwater consumption. Priority has been given to decommissioning public water wells in the Yun-Chang area, including wells of the Taiwan Water Company, the Farmland and Water Conservancy Department, the Taiwan Sugar Company, Chang-yun Elementary and Middle Schools and factories. As of the end of 2020, a total of 5,254 wells have been sealed and filled. In response to climate change, some Water wells were decommissioned and converted into drought relief reserves. By the end of 2020, there were 463 public water wells in use or with reduced pumping in the Yun-zhang area, with a total pumping volume of approximately 106.54 million tons. "It is of course possible that all of them will be decommissioned in the future." Groundwater accounts for about 33% of Taiwan's total water supply, which is much higher than the 25% of reservoirs. The Water Resources Department has activated a total of 352 "drought-resistant wells" this time. Although the extraction is for a short period of time, it will not cause negative environmental impacts. However, what is worrying is that the government still cannot grasp the actual amount of groundwater used in Taiwan, let alone measure it reasonably. extraction standard. With huge groundwater management problems, increasing water consumption year by year, and climate change factors, Taiwan, which has just taken a breather from the severe drought, has no money to spend.

Whether they are water wells built under the forward-looking plan or newly dug during the drought relief period, they must undergo rigorous geological analysis, water content assessment and water pumping tests to ensure that water pumping will not cause the formation to rapidly compact or sink, and that the amount of water pumped will be sufficient. The total volume limit must be controlled within the "safe groundwaterdischarge yields" to maintain a certain groundwater level.

In order to adapt to the public water supply system, most of the public drought-resistant wells opened this time are located near water pipelines and water purificationplants. Overall, the number is small and acceptable for short-term use. The current withdrawal volume should not cause long-term negative effects.

The so-called "safe groundwater yield" is a very vague concept. In the early days, aslong as pumping water would not cause significant "leakage", that is, a drop in the groundwater level, it was considered a safe water yield. However, no one knew how to set a reasonable water yield, clear specifications, there is no set of measurement standards for the range within which the leakage drop should be controlled, and therefore it is difficult to establish objective extraction volume limits. The government has long lacked overall groundwater consumption statistics. There is a considerable amount of uncertainty about the actual consumption in Taiwan, and it is unable to set a reasonable limit on the total consumption. In fact, not only Taiwan, but also the international community still lacks standards for measuring the reasonable amount of groundwater pumped (safe water output).

According to statistics from the Water Resources Department, groundwater accounts for about 33% of Taiwan's total water supply, which is much higher than the 25% of reservoirs. The management and maintenance costs of groundwater are different from those of reservoirs, but they are definitely not a minority. The government invests a lot of resources and funds every year in the conservation of water source recharge areas, "but there is no such direct connection with water users." In the future, the government will gradually build a smart management system for water wells. By installing smart water meters, the water pumping behavior of users can be recorded and reported back in real time to compare whether the amount of water rights applied for has been exceeded. The government will also use the "water level data" of nearby areas. Monitoring wells monitor groundwater levels and will notify users to reduce pumping when the water level is too low. Related control technologies can solve the problem, and key governments are willing to pay more management costs. Groundwater will become an increasingly important resource. The government must establish standards and upper limits for water rights issuance, grasp actual water consumption through smart water meters and other equipment, and set regional and overall total volume controls.

We have not included the treatment cost of industrial wastewater in the cost of industrial water, such as industrial wastewater charge unit price of 1.88USD/ m^3;COD, 2.41USD/kg; SS, 2.36USD/kg; pH, 3.33USD/$m^3$for Changbin Industrial Zone, while with the given concentration in mg/liter of each COD or SS, the cost in USD/ m^3 obtained, because we assume that the manufacturer will completely treat it before discharging it. This treatment cost should be handled solely by the manufacturer, but the risk must still be considered,because if discharge due to incomplete treatment will become an external cost. We can tentatively consider 20% of the manufacturer's expenditure on wastewater treatment as this cost. Of course, we can also estimate it higher. This end is adjusted for the degree of environmental impact. In addition, discharged waste water has a huge impact on aquatic products, especially pH value, nitrite and BOD. These can be regressed into relevantformulas as the basis for sensitive analysis of external loss costs, and further calculate each influencing factor.

$$Y=a_0+a_1X_1+a_2X_2+a_3X_3+a_4X_4+a_5X_5 \quad \text{...(4)}$$

$$(b_0)\quad (b_1)\quad (b_2)\quad (b_3)\quad (b_4)\quad (b_5)$$

Here, a_i the regressing constants, while b_i the sensitivity for each influence factor.Y, in output of the aquatic products: X_1, PH value; X_2, nitrous acid; X_3, Nitrate; X_4, Phosphate; and X_5, BOD or COD.The larger negative value b_i the influence factor, the greater the reduction in output of the aquatic products. An increase of one unit, such as 1 mg/liter, will result in a loss of aquatic products, which will be a convincing result.

The subsidence caused by over-pumping of groundwater will also form an external cost, because the government must invest in remediation and prevention work. Thiscost should be included in order to truly reflect the cost of pumping groundwater.

CONCLUSIONS

This is an urgent work to develop water resources development and utilization methods that take environmental sustainability into account with the best current technologies, formulate appropriate policies, legislations, systems and institutions to use economic tools, and provide sufficient information management to protect water resources as a public asset.The environment is the cornerstone of social and economic development. Environmental water rights should be clearly defined and regulated in order to regulate the retention of an appropriate proportion of environmental water and ensure that the distribution and utilization of water resources will not damage the environmental system and cause irreversible environmental harm. Only then can water resources be conserved and ensure sustainableutilization of water resources.Climate change is expected to have considerable impacts on water resources, which, in turn, can lead to social instability and conflict, often followed by displacement of people and changes in occupancy and migration patterns. The production losses due toclimate change may drastically increase the problem of poverty, food insecurity and malnutrition in several developing countries. We have the constructive conclusions that:

The Regional Difference of Water Costs on Surface Flow Water in 2020:

1. Raw Water Cost:

The southern (green color) 0.502 USD, the central (blue color) 0.445 USD, blue, central), and the northern (red color) 0.570 USD, and assumed thecost of theeastern will be the same as the northern one, with mean 0.507USDwith 1USD=30 NTD.

2. Agricultural Water Use(with Raw Water Cost):

The southern (green color) 1.157USD, the central (blue color) 0.954USD, thenorthern (red

color) 1.063USD and the eastern (purple color) 0.898USD in mean 1.018 USD with 1USD=30 NTD.

3. The Unit Tap Water Fee:

The southern (green color) 2.357 USD, the central (blue color) 2.088 USD, thenorthern (red color) 2.665 USD, with mean 2.370 USD.

4. The Industrial Water Cost:

The industrial water cost could be treated as the unit selling prices, withoutIncluding industrial sewage treatment fees which are the external cost items, suchas environmental treatment costs,

5. Transferring Compensation Fee from Agriculture to Industry:

1.876USD, 1.657USD, 1.772USD, 1.595USD, and 1.724USD for the southern, the central, the northern, the eastern and the mean, respectively.

The Regional Difference of Water Costs on Groundwater in 2020:

In Taiwan, without considering the external cost due to the influence on environment,the costs could be:

1. Groundwater control areas charge 3NDT/ m^3 regardless of the amount ofextraction;

2. Non-groundwater control areas charge no fee if the annual extraction volumeis less than 100,000m^3 , and charge 1 NTD/ m^3between 100,000 and500,000m^3. From 10 to 10^6m^3, 1.5 NTD/m^3, and 2 NTD/m^3 for more than 10^6m^3.

3. Considering the environmental impact factors of ground subsidence caused by groundwater extraction, the cost of groundwater should be compared with that in the NetherlandsNT$ 22 per cubic meterwith considering the factors such as land subsidence and sea level rise.

The Seasonal Difference of Water Costs on Surface Water in 2020:

The seasonal raw water cost will be the regional raw water cost multiplying thefactor each 1.17, 1.29, 1.40, and 1.25 for the north, the center, the south, and theeast separately.

The problems we need to consider is the risk for each Regional-Seasonal situations for each district with N=5 years is given, and 17%, 29%, 40%, and 25% respectively for the north, the center, the south, and the east issubstituted into for each, we have the occurrence of the risk for each district willbe: 60.61%, 81.96%, 92.22%, and 76.27%, separately for the north, the center,the south, and the east. And they show the quite high occurrence sensitively toseasonal influences.

The Seasonal Difference of Water Costs on Groundwater in 2020:

The seasonal groundwater cost should be the regional groundwater cost multiplethe safe factor 1.78.

ABBREVIATIONS AND SYMBOLS

a, b, and c: arbitrary coefficient on regression in Eq. (1)

a_i: the regressing constants, while

b_i: the sensitivity for each influence factor in Eq. (4)

C_0: the annual reservoir cost in million NTD

C1: tap water cost in NTD

N: the observing or expecting period

P: the probability for each district

T: the established year of reservoir.

X: the annual operation water volume of reservoir

X_1: PH value

X_2: nitrous acid

X_3: Nitrate

X_4: Phosphate

X_5: BOD or COD

Y: output of the aquatic products

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