Governmental and Non-governmental Reactions and Efforts to 2002 Taiwan Drought

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ABSTRACT

From January to June in 2002, the rainfall of the dry season (Nov to Apr of next the next year) in North Taiwan was lower, and all the monthly rainfalls from Jan to April were lower than that of previous years. Especially the rainfalls in Feb and Apr were just 15%~40% of the average of previous years, which is extremely lower, and resulted in that the river flow deceases abnormally; during the Mei-Yu season in April and May was no effective rainfalls to supply rivers and reservoirs, which caused that the Shihmen Reservoir, the main reservoir in North Taiwan, had the lowest water storage in its history. The water storage was getting worse and worse, and having serious impact on the use for each target, so the public water use and industrial water use had to be limited, and the agricultural cultivation had to be stopped to reduce the daily water supply of the Shihmen Reservoir, and wait for the rich rains.

March 1, 2002, the Ministry Of Economic Affairs (MOEA), the water authority in Taiwan, had formed an drought emergency group to cope with the drought; On May 1, the drought was getting worse, and the drought status was critical, so the Executive Yuan determined to form the "Central Drought Disaster Emergency Response Center" to give uniform orders to related departments in executing each emergency measures for the drought. The "Central Drought Disaster Emergency Response Center", under the principle of assuring the minimum impact on domestic water use and industrial water use, strictly conducted each drought emergency project, such as the irrigation suspension and land fallow, daily water control for the Shihmen Reservoir, water support from other areas, pressure reduction of tap water, water suspension and water supply rotation, well digging, and performed cloud seeding plan on the ground and in the air.

The critical drought in North Taiwan went on till July 2. Due to the intermediate Typhoon (RAMMASUN) brought rich rainwater to the watersheds of Feitsui Reservoir and Shihmen Reservoir, and thus caused the water level on the reservoirs rose rapidly and exceeded the drought warning line, so the drought was relieved.

To sum up all efforts by each department of Taiwan government for the six-month drought, only the "Enterovirus" event occurs, which was caused by unclean drinking water due to the tap water rotation by district. Fortunately, it was handled quite well by the health authorities, and effectively controlled in short time; social and economic activities did not

be seriously affected by water reduction, and on the contrary that caught the public attentions to saving water due to lack of water. Weather in people's lives or industries, the effect of conserving water during this period is beyond our expectation, which shows that non-governmental circles are willing to meet the governmental measures regarding conserving water and have common views living in this hard time.

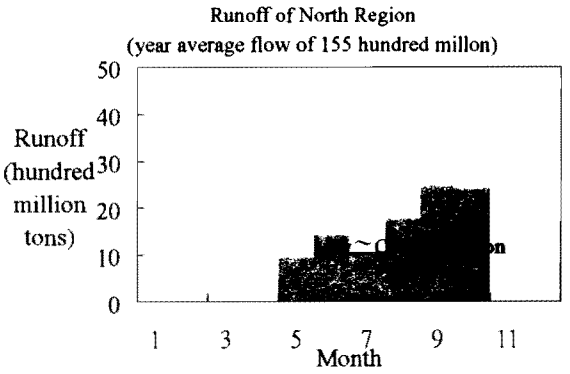
1. DISCUSSION ON CAUSES OF THE 2002 TAIWAN DROUGHT

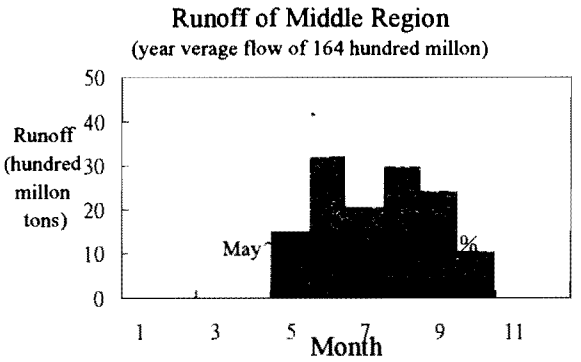
1.1 Taiwan Drought Periods Outlined

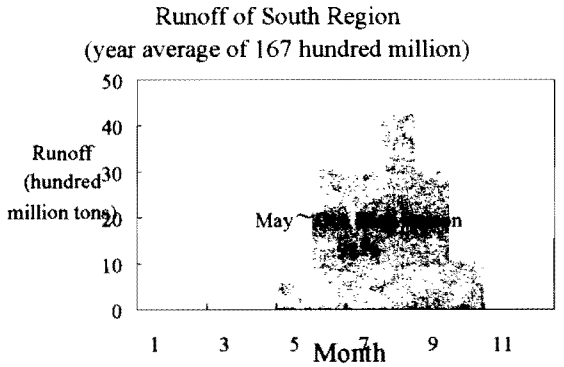
Taiwan is in the subtropical weather. The year average rainfall is 2,515mm, and is 2.6 times the average rainfall of the world, but the share per person per year is just a sixth of the average of the world; in the mean time, due to the influence of the various season periods and natural rivers dominated by steep slopes and surged flows, the runoff varies so much, and thus the river flow varies in dry season and flood season. In recent years, the demand of water sources grows, but finding new water sources is getting harder and harder because of the nature conditions. Once the long-term rainfall is lower, the river dries up, and thus the supply and the demand are no longer in balance, resulted in drought event, causing inconvenience for people, agricultures, commences, industries, etc.

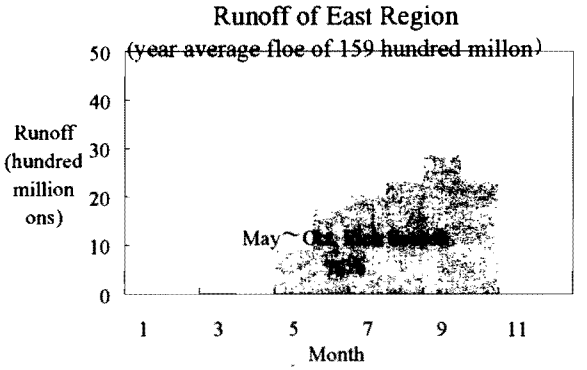
In Taiwan, 78% of the rainfall is concentrated on the Mei-Yu season and typhoon season from May to Oct. Based on the Taiwan rainfall distribution and the demand of flood control, the period from May to Oct is defined as the rich rain season, and the period from Nov to next-year April is defined as the dry season. Our year average runoff reaches 64,500 million tons, and the flows between the two seasons differ so much. The area closer to South Taiwan has more difference of rainfall between the dry season and the rich rain season. The flow ratio of dry and rich seasons in North region is 6:4; in Middle region is 8:2; in South region is 10:1; in East region is 8:2; the average period between dry season and rich rain season in North region is 9 years; the average period between dry season and rich rain season in Middle region is 10 years; the average period between dry season and rich rain season in South region is 11 years; the average period between dry season and rich rain season in East region is 9 years; all that shows that the probability of drought in Taiwan is very high (Fig 1).

Figure1 Taiwan Drought Periods Outlined









1.2 Rainfall Analysis of North Taiwan During Drought

From Jan to June in 2002, the North Taiwan (Taoyuan, Panhsin of Taipei) was in lack of water. The main cause was that the rainfall was lower during dry season, and the rainfalls from Jan to April were lower than that of previous years. Especially the rainfalls of Feb and April reached just 40%~15% of the average of previous years, which shows that the rainfall is extremely lower than that of previous years, and causing the observed flows of the Shihmen Reservoir decease abnormally, and resulted in that the hydrological surpass probability exceeds 90%. All that belongs the flow rate of drought. In addition, during the Mei-Yu season of April and May was no effective rain to supply rivers and reservoirs in time, and near the end of Feb the water storage of the Shihmen Reservoir was down to lower than the critical bond; meanwhile, comparing to the historical surpass probabilities, the probability is from 80% of Jan worse to 99% of April.

Comparing the rainfalls from Nov 2001 to April 2002 and previous rainfalls shows (Table 1) the average rainfalls of each month are lower than previous rainfalls. Especially on April, the accumulated rainfall on the reservoir watershed is just 17mm, which is the second low rainfall since the commencement of its operation, and is 11.3% of the previous average value of 151mm; the accumulated rainfall of 243mm is the lowest rainfall since the commencement of operation in 1964, which is merely 36% of the previous average rainfall of 680mm. Due to the abnormal dry weather, the reservoir faced the biggest drought since the commencement of its operation. The water levels from the middle of May to near the end of June all broke the historical records.

Table 1 Rainfalls of Shihmen Reservoir Watershed

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
1964	218.50	74.30	43.50	7.90	118.30	284.80	136.20	314.70	58.20	184.20	25.40	30.10	1496.10
1965	89.30	41.70	79.20	126.60	214.10	350.70	262.30	352.60	117.10	54.00	93.60	60.30	1841.50
1966	24.60	88.10	164.20	102.70	176.70	612.80	102.40	179.10	697.10	31.80	30.40	50.10	2260.00
1967	82.90	131.40	58.40	76.50	329.90	208.80	149.10	249.50	129.80	300.90	274.20	83.70	2075.10
1968	25.70	350.30	191.20	67.40	230.60	382.50	461.90	194.70	422.20	92.50	24.50	25.00	2468.50
1969	79.10	98.60	185.10	41.80	91.80	340.40	362.40	241.30	992.30	491.10	48.90	18.50	2991.30
1970	170.90	42.20	242.60	48.90	176.50	307.80	94.60	299.50	682.00	191.20	39.10	113.10	2408.40
1971	117.60	93.80	63.70	70.20	214.50	240.80	208.40	55.20	1187.70	123.60	65.10	92.20	2532.80
1972	152.80	111.50	39.50	101.10	242.30	267.60	570.50	904.60	46.70	25.20	123.90	127.10	2712.80
1973	124.20	62.80	55.80	239.60	127.20	219.40	138.00	228.50	171.10	316.30	96.50	35.10	1814.50
1974	37.70	119.50	103.00	268.00	324.90	580.30	187.40	129.40	261.00	522.00	76.40	106.10	2715.70
1975	104.50	77.90	227.40	110.40	337.00	440.20	213.00	546.20	371.70	239.70	54.60	147.60	2870.20
1976	68.80	60.70	83.30	79.90	275.40	160.10	173.40	554.10	209.80	57.70	40.70	20.60	1784.50
1977	139.60	71.20	41.20	33.20	247.10	385.80	491.60	331.10	393.00	59.20	75.80	98.30	2367.10
1978	133.80	87.20	389.90	156.90	318.20	181.20	59.60	219.60	348.70	287.00	53.40	137.70	2373.20
1979	58.10	63.80	174.40	132.50	286.00	385.20	112.00	939.00	157.70	248.80	131.90	28.90	2718.30
1980	126.00	179.50	84.70	221.90	176.80	173.60	102.80	315.30	284.50	107.90	126.40	32.80	1932.20
1981	16.50	131.40	191.20	84.40	389.90	689.20	538.20	141.60	353.40	98.30	134.20	84.80	2853.10
1982	37.60	129.50	142.90	123.90	131.70	255.90	576.40	386.80	140.20	21.00	87.30	70.00	2103.20
1983	142.00	540.00	596.50	98.80	269.90	190.70	112.80	134.20	265.70	83.10	26.60	39.80	2500.10
1984	34.70	55.50	148.10	278.10	335.60	540.10	100.80	919.70	187.30	120.80	69.10	22.40	2812.20
1985	65.70	541.40	106.60	206.70	119.60	239.80	236.70	701.90	380.70	238.10	81.90	182.70	3101.80
1986	30.00	174.50	363.90	63.90	419.60	434.40	172.30	583.50	459.70	43.60	148.40	45.10	2938.90
1987	42.20	74.00	257.70	100.50	241.70	203.00	537.70	148.50	473.30	394.60	57.40	47.10	2577.70
1988	86.80	61.10	180.70	254.20	174.70	147.60	83.00	230.60	379.90	286.60	62.90	32.60	1980.70
1989	57.30	19.20	99.90	236.00	369.20	141.40	362.40	226.10	787.40	66.70	60.40	98.70	2524.70
1990	152.20	116.80	108.70	527.80	84.80	437.40	99.00	1130.50	499.70	62.10	67.20	14.30	3300.50
1991	96.00	83.10	74.30	93.40	134.20	458.80	172.20	312.80	496.40	147.30	74.20	76.20	2218.90
1992	62.10	352.10	201.90	249.90	271.90	134.50	129.70	725.30	546.20	45.90	35.60	66.60	2821.70
1993	99.00	27.10	199.20	241.70	182.70	256.10	216.40	94.80	82.80	54.30	58.70	21.40	1534.20
1994	78.10	242.70	96.80	68.50	221.10	210.00	304.50	936.80	208.30	560.60	3.30	51.60	2982.30
1995	68.20	183.00	152.10	129.80	241.90	196.10	344.80	185.10	105.70	50.80	27.30	26.60	1711.40
1996	13.30	99.40	79.20	263.40	266.10	150.20	806.70	282.00	385.80	106.30	76.50	21.00	2549.90
1997	58.20	186.60	161.60	85.00	176.10	624.70	283.20	843.40	181.00	38.10	23.00	49.30	2710.20
1998	168.80	447.90	211.10	151.00	350.80	248.40	79.10	242.40	351.20	925.00	47.90	119.10	3342.70
1999	86.10	11.50	121.40	70.30	264.90	405.60	177.70	399.20	148.40	111.80	30.70	112.70	1940.30
2000	51.70	318.60	98.30	301.50	108.70	388.20	221.90	738.80	178.20	243.60	246.80	126.80	3023.10
2001	178.80	15.80	136.10	247.80	217.20	192.00	316.00	139.50	1536.00	182.10	28.70	38.30	3228.30
2002	59.80	46.10	51.55	17.10	109.85	157.40							441.80
Average	88.93	146.47	156.72	151.63	233.15	317.53	255.19	409.42	386.26	189.84	74.44	67.22	2476.79
Maximum	218.50	541.40	596.50	527.80	419.60	689.20	806.70	1130.50	1536.00	925.00	274.20	182.70	3342.70
Minimum	13.30	11.50	39.50	7.90	84.80	134.50	59.60	55.20	46.70	21.00	3.30	14.30	441.80

Note : 1.The historic records average is the average of 1964~2001.

2. The average rainfall of 2001 is the third high of previous records 2001 (the highest is 1998, the second is 1990).

3. Rainfall on Sep 2001 is the highest in Sep records.

4. 2001 single month rainfall lower than the average is Feb, Mar, May, Jun, Aug, Oct, Nov and Dec.

5. The value of 2002 is the average of 10 stations.

1.3 Water Supply Status of North Taiwan

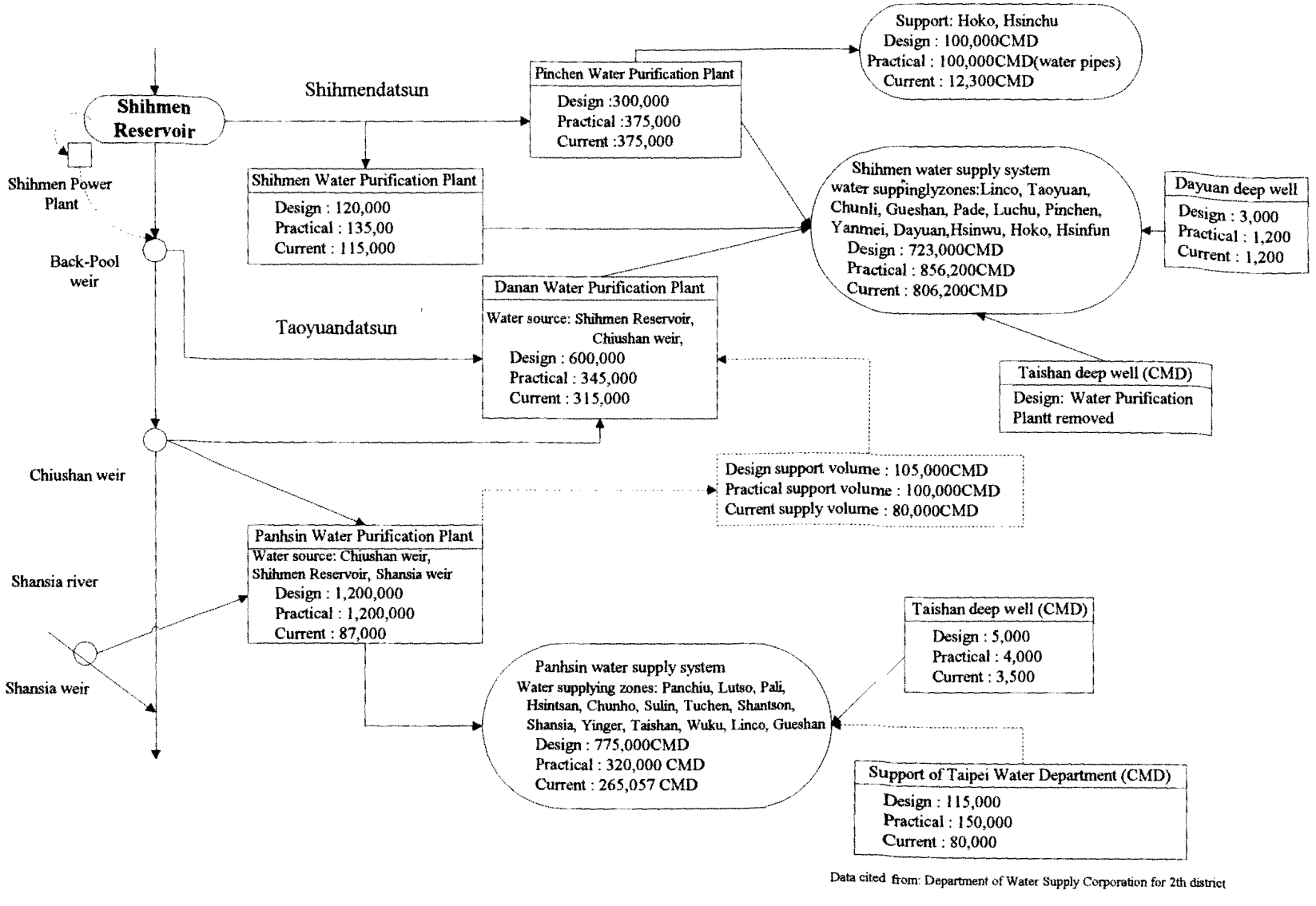
The watershed of the Shihmen Reservoir ranges 764 km^2, and the effective water storage is 2,357,500 million tons, which is a multi-purpose reservoir with advantages of irrigation, power generating, water supply, flood control and sightseeing. Water supplied areas are Taoyuan and Taipei regions (Panchiao, Hsinchuang, Yinker, Sulin), where the population, industries and agricultures are highly concentrated, so the demand of water is more. The daily average water for agriculture use is 1,800 thousand tons; the water for domestic use and industry use is 1,500 thousand tons (the distribution of public water supply is shown in Fig 2); the total is 3,300 thousand tons. With the rapid growth of industries in these regions in recent years, the year average water consumption supplying each target reaches 900 million tons, which means the reservoir shall be 4 times full each year so as to satisfy the demand of water use. Therefore, the spring rains, Mei-Yu season, typhoon rains, etc in a year are all playing an important role. Once the rainfall is lower, the water supply may be insufficient, and the drought occurs. In particular, in the early spring of each year, when the first-term transplanting rice seedlings by the Taoyuan and Shihmen Irrigation Associations needs water most, the drought may occur due to the lack of water storage of reservoir.

It depends on a comprehensive evaluation of the position of the reservoir water level of last year, the historical reservoir inflow data, the long-term weather forecast provided by meteorological agency and the year water-use project for each target to determine if the Shihmen Reservoir is able to supply sufficient water. After Nov 2001, the watershed of Shihmen Reservoir is still lack of rainfall, and the meteorological agency reported that the rainfall would be lower during Jan to March in 2002. Therefore, from Jan 2002, strengthen agricultural irrigation control, enhance the efficiency of water use; on Feb due to lack of spring rains in Hsin-Chu region, the flow of Taochen Creek deceases. Local farmers blocked the Taochen Creek water for the demand of the first-term spring cultivation, which made the water taken from the Taochen Creek by Water supply Corporation of the down stream decease from 200 thousand tons a day to 30 thousand tons a day, and also made the water storage of Paushan the First Reservoir and Yunghoshan Reservoir just can supply 30 days water for Hsin-Chu region. Therefore, the water supply corporation decided to cut 7% of the water supply of the Hsin-Chu Science-Based Industrial Park(HSIP), which caused panic of the Hi-Tech industries in the park, and public opinions arose, and thus the crisis occurs. As the HSIP crisis comes up, Water Resource Agency immediately formed the drought emergency group to deal with the crisis, deciding that the Shihmen Reservoir supported 35 thousand tons water to Hsin-Chu region (up to 80 thousand tons), declaring a farmland fallow of 15,000 ha in the Hsin-Chu Taochen Creek irrigation zone, using the

agriculture water of Taochen Creek to supply the HSIP and Hsin-Chu domestic water use. From then on, the water storage of the Paoshan the First Reservoir rose, and the water crisis of Hsin-Chu region and HSIP calmed down.(Fig.3)

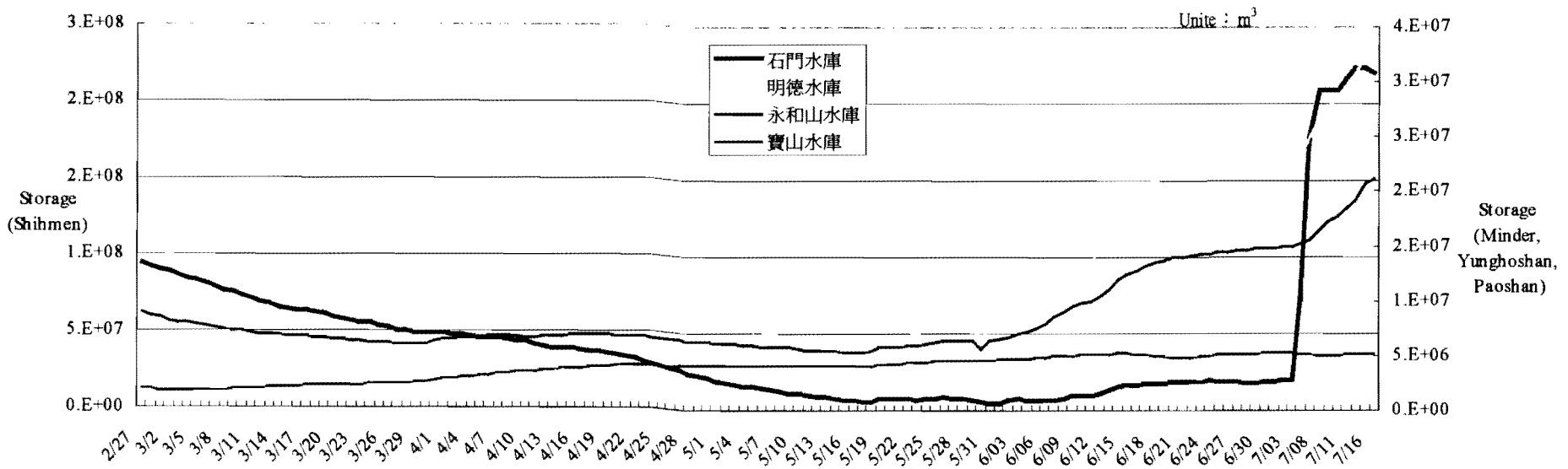
Though the HSIP crisis calmed down, the rainfall on Shihmen Reservoir is just remaining 46.1mm, which has 100mm different from the average of previous years. Taoyuan and Panhsin regions are having the water shortage ratio of more than 20%. Such status of shortage water is getting worse and worse; meanwhile, the water storage of main reservoir in Taiwan is lowering down due to the insufficient rainfalls, so each region in Taiwan is in critical status. The ministry of economic affair had formed a drought emergency group on March 1 for the increasing drought. That group is taking charge of the distribution of entire Taiwan water resources and water use; on May 1, Taiwan is still in drought condition, especially in the water supplied regions of Shihmen Reservoir is most. Therefore, Executive Yuan designates MOEA, under the "Disaster Prevention and Rescue Law", to form the "Central Drought Disaster Emergency Response Center" as to give uniform orders to each related department and agency and execute each drought resisting plan.

Figure2 The distribution of public water supply in Shihmen Reservoir



Data cited from: Department of Water Supply Corporation for 2th district

Fig3 Hydrographs in Jan ～ July in 2002



2. DROUGHT GRADES AND RESPONSIBLE ORGANIZATIONS OF TAIWAN

Taiwan is more likely to suffer natural disasters. To enhance the function of emergency rescue and ensure people's lives, bodies, properties and land safety, the government promulgates the "Disaster Prevention and Rescue Law". Drought is one of statutory major disasters, and MOEA is based on the law to set up the "Drought Disaster Prevention and Rescue Project" as the basis of executing emergency plans by each local government. All related departments and agencies should conduct the disaster prevention practices in peace time, warning before disaster, disaster emergency plans, and establish recovery and improving measures in order to deal with the demand of drought disaster prevention and rescue plans. The key points are as following:

1. Definitely mark off the responsibilities of MOEA and each related department and agency regarding drought disaster prevention and rescue.
2. Conduct the drought disaster prevention and rescue and preparation.
3. Establish the drought warning mechanism, emergency promulgation system and communication network among other agencies.
4. Form the emergency groups of each agency regarding drought disaster prevention.
5. Set up the standard operation procedures of drought disaster prevention and rescue.
6. Conduct the recovery affairs after drought.

The mechanism regarding drought disaster is as follows:

2.1 Drought Warning

The Water Resources Agency will hold the trend of drought and make warning; establish the coordination mechanism regarding drought warning and water resources supply and demand; collect the information regarding drought to evaluate and distribute the water resources and prepare response measures and promulgation. During the warning time of drought, each Water Resources Bureau (North, Middle, South) of Water Resources Agency will conduct reviews for the yearly project in use of water resources and conduct water supply evaluations, and pre-formulate the water distribution project based on previous records. If the evaluated results show that the water is not enough 3 months later, the irrigation water shall be the objective to be moved, and Water Resources Agency is taking charge of it. By doing so, we can enhance our water control ability, local water distribution and emergency projects so as to postpone droughts or execute the drought resisting projects through the drought warning while in drought.

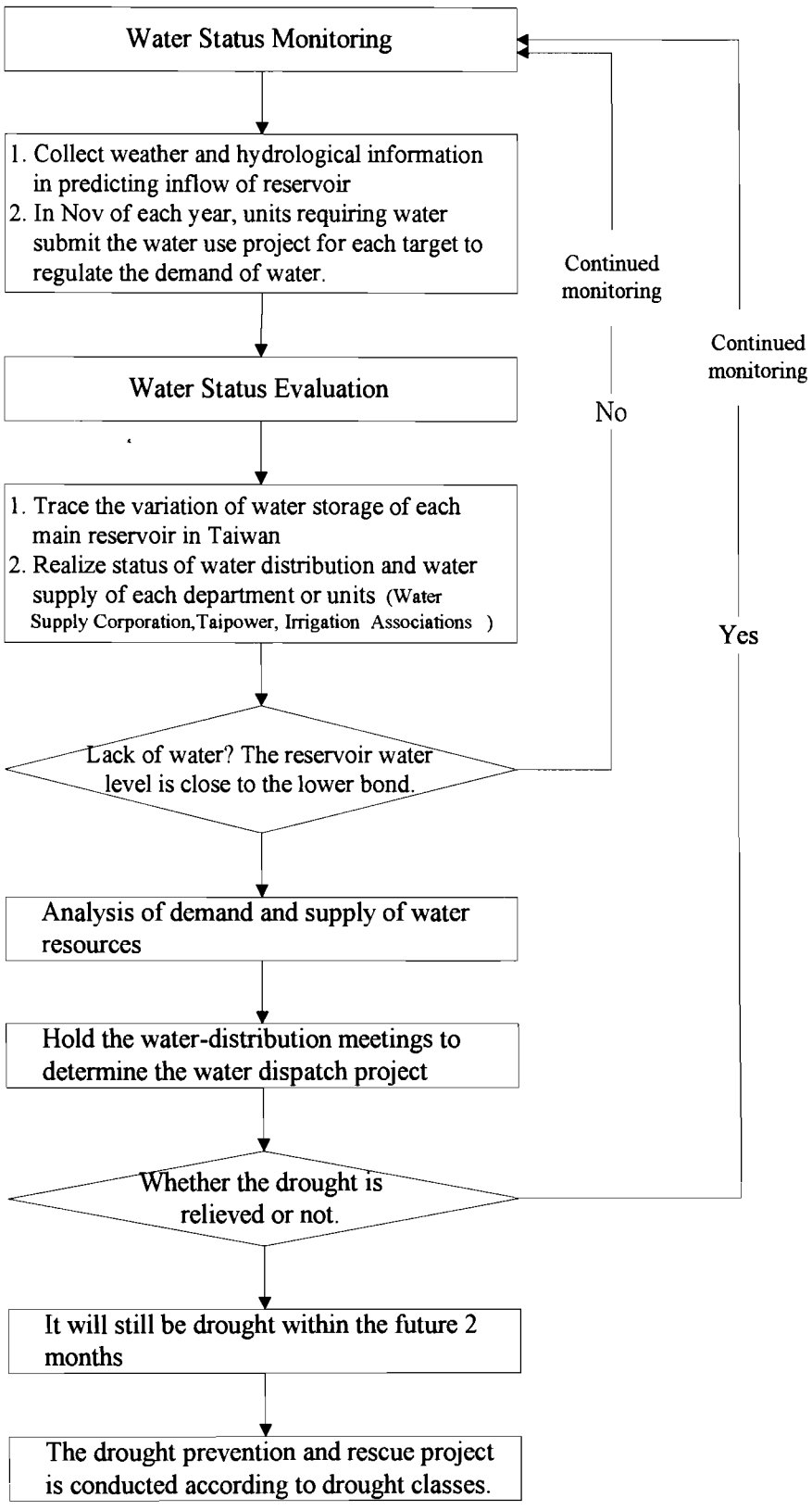
The drought warning procedures include the water condition monitoring and evaluation, which collect hydrological data and use hydrological models to evaluate the

current water condition. In other words, it is based on historical data, the flow in rich rain season, expected rainfalls and reservoir inflows to estimate the water storage in a certain time and the variation of the applicable water. The time period to predict the inflow is 3 months in principle in evaluating the water level changes in reservoir for future 3 months. If the evaluated water level may be lower than the level to supply water, then perform the water supply and demand modeling and submit the water resources supply and demand project.

Through the drought warning process, the water source of reservoir may not be able to supply the water required in the project or need helps from other areas, then perform the water supply and demand modeling, simulate different water supplying programs, long water supplying days (reducing water supply rate) or test the ability to supply water.

The drought warning flow chart is shown in Fig 4.

Figure 4 Flow Chart of Drought Warning



2.2 Emergency reaction during drought

Through the drought warning process and emergency reactions during drought, we can strive for reaction time and prolong the time to be drought, but such delayed time did not meet the Mei-Yu season or typhoon season, and the water status belongs to drought status, so MOEA and related agencies form the drought emergency groups to deal with this severe drought to perform each emergency measures.

1. Drought Disaster Classes

Taiwan drought disasters are divided into Class 1, Class 2 and Class 3 based on the public water supply and agricultural water supply status (Table 2):

Table 2 Classes for Drought Disaster

System	Level	Status description
Public Water Supply	1st	Water shortage rate above 30%
	2nd	Water shortage rate between 20% and 30%
	3rd	Water shortage rate between 10% and 20%
Agricultural Water Supply	1st	Water shortage rate above 50%
	2nd	Water shortage rate between 40% and 50%
	3rd	Water shortage rate between 30% and 40%

Note:1. Daily water shortage for public use(%)= (1－actual water supply／water demand) x100

2. 10 days water shortage rate for agricultural use (%) = (1－available water supply／water demand) x100

2. Drought Disaster Emergency Group Systems

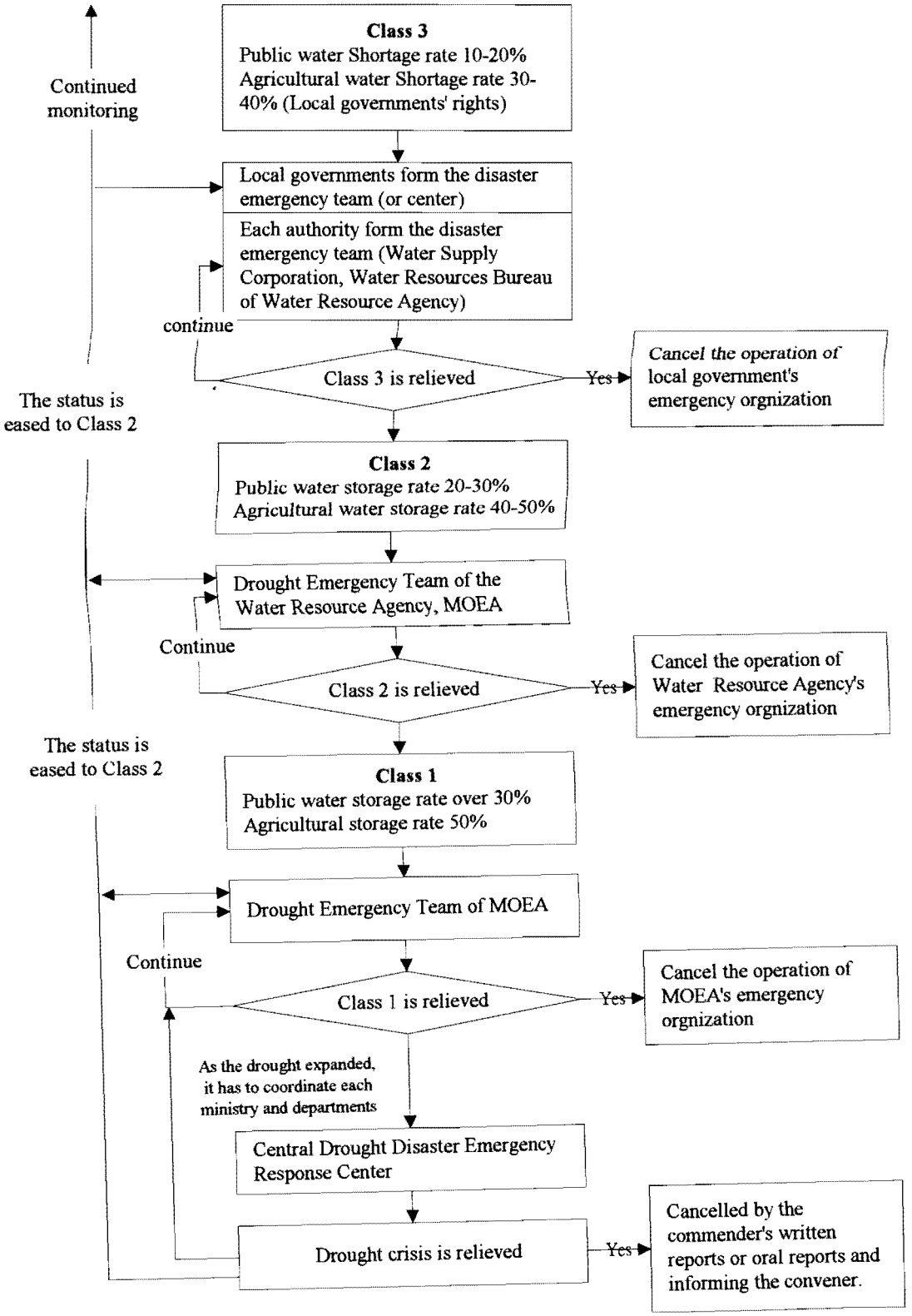
While in drought, the water authorities and related agencies in Taiwan shall be based on the class to form different emergency reaction group. The drought disaster emergency reaction standard procedures are shown in Fig 5.

Class 1: MOEA forms the "M.O.E.A drought disaster emergency group". If need other departments' help, form the "Central Drought Disaster Emergency Response Center".

Class 2: Water Resource Agency forms the "drought disaster emergency group of Water Resource Agency".

Class 3: the drought disaster emergency group formed by MOEA, reservoir management agencies, local government, Water Supply Corportation, industrial parks, science-based industrial parks, etc.

Figure5 Flow Chart for Drought Emergency Rescue



3. REACTIONS AND EFFORTS TO 2002 TAIWAN DROUGHT

3.1 Public water supply limitation measure

Since Mar 2002, Taiwan has no enough rainfall and keeps in dry condition, and thus the natural river flows decease, and the effective water storage of main reservoirs deceases also. Till the end of April, all the reservoirs reached the lower bond of water level. Therefore, from May 2, in 19 water supplying zones of Taiwan is three steps of public water supply limitation (Table 3). Each step is described as follows:

1. Step 1 water limitation (stop supply or reduce supply): while in drought, the water-shortage rate reaches 5%; stop the secondary water supply, such as fountain, street wash, drains, road surface, releasing fire hydrants and other water uses; reduce the water supply for users requiring large amount of water: the water user of more than 1,000 tons per month.

2. Step 2 water limitation (reducing the water pressure): with the continuing lack of water source, at the time other than peak time (PM 11:00~AM 5:00), reduce the water pressure in pipes to reduce tap water use.

3. Step 3 water limitation (rotation for water supply): the water source is no longer to provide normal water amount, separate the regions and rotate water supply with a schedule, or supplying water periodically.

Table 3 Water Supply Limitation Procedure

Region	area	Water supply status	Scheduled water-supply process
North Region	Keelung	Tenshue, Wunshan, Sichu use Step 3 water limitation	1. In Tenshue, Wunshan, Sichu, which are supported by Taipei Water Department, stop water 1 day in each 5 days from May 13. 2. Except Lunlinshan, White horse house and Chungyi street, all is water limitation on June 28. 3. From July 9, water limitation relieved
	Penhsin	Use Step 3 water limitation	1. In Lucho, which are supported by Taipei Water Department, stop water 1 day in each 5 days from May 13. 2. For other areas, stop water supply 1.5days in each 7 days (to meet week days), use Step 3 water limitation, started from May 13, relieved on July 5.
	Taiyuan	Use Step 3 water limitation	
	Hsinchu	Use Step 2 water limitation	1. Started from May 3；from Jun 14 relieve Step 1 water limitation；from July 5 relieve the water limitation
Middle Region	Chunan, Taofen	Use Step 2 water limitation	1. Started from May 3；from Jun 14 relieve Step 1 water limitation；from July 5 relieve the water limitation
	Miaoli	Use Step 2 water limitation	1. Started from May 3；from Jun 14 relieve Step 1 water limitation；from July 5 relieve the water limitation
	Taichung	Normal Status	1. From May 24, Step 1 water limitation relieved.
	Nantao	Normal Status	1. From May 24, Step 1 water limitation relieved.
	Changhua	Normal Status	1. From May 24, Step 1 water limitation relieved.
	Yunlin	Normal Status	1.From May 24, Step 1 water limitation relieved.
South Region	Chiayi	Use Step 2 water limitation	1. From Jun 6, Relieve Step 1 and 2 water limitation
	A-li-shan	Normal Status	1. From May 24 relieve Step 1 water limitation
	Tainan	Normal Status	1. From May 24 relieve Step 1 water limitation
	Kaohsiung	Normal Status	1. From May 24 relieve Step 1 water limitation
	Pintung	Normal Status	1. From May 24 relieve Step 1 water limitation
	Penhu	Use Step 2 water limitation	1. Started from Jun 20,; from July 5 relieve the water limitation
East Region	Yilan	Normal Status	1.From May 24 relieve Step 1 water limitation
	Hualien	Normal Status	1.From May 24 relieve Step 1 water limitation
	Taitung	Normal Status	1.From May 24 relieve Step 1 water limitation

3.2 The total daily water supply of Shihmen Reservoir shall not exceed 1340 thousand tons.

The Shihmen Reservoir provides 1,800 thousand tons a day to Taoyuan and Shihmen irrigation zones, and 1,500 thousand tons public water and industrial water to Taoyuan and Panhsin zones. Total is 3,300 thousand tons. On Feb, the water storage level of Shihmen Reservoir is very close to the critical lower bond, so according to the reservoir operation principles perform the water reduction for people, agricultures, and industries. Taoyuan and Panhsin are important cities for industries, and the water limitation will cause big impact to industries. After consideration, Water Resources Agency determined to terminate the first term crop cultivation of the Shihmen Irrigation Association to release impact of public water use and industrial water use, and the daily outflow is 1,800 thousand tons, and provide normal water supply to Hi-Tech industries using specific management; May 1, the drought disaster emergency center established, but the Shihmen Reservoir's effective water storage is lowering to the critical bond due to less rainfall in April, and according to the weather forecast the probability to rain is still low. To ease the lowering rate of water level, prolonging water supplying time to July, the Shihmen Reservoir conduct the volume control of water supply since May 3, where the daily water supply shall not exceed 1,340 thousand tons, and stop the Taoyuan irrigation water supply of 450 thousand tons and pond water instead, and expand the procedures of water limitation and water source distribution. About the time of executing each measure to the water level of reservoir is shown in Fig 6.

1.Taipei Water Department of Taipei city government provides water to Panhsin, Tenshue and Sichu regions to release the pressure of supplying water.

2.Combine the Shihmen Reservoir and the Chioshan Weir and Shansia River Weir.

3.Conduct the step 3 water limitation in water supplying zones of Shihmen Reservoir.

4.Conduct the tap-water network construction to dispatch water resources of Keelung Hsinshan Reservoir and Hsin-Chu Paoshan Reservoir in supplying Taoyuan and Taipei regions.

5.Boring emergency wells.

Figure6 Public Water Supply Distribution in Shihmen Reservior Supplied Zones

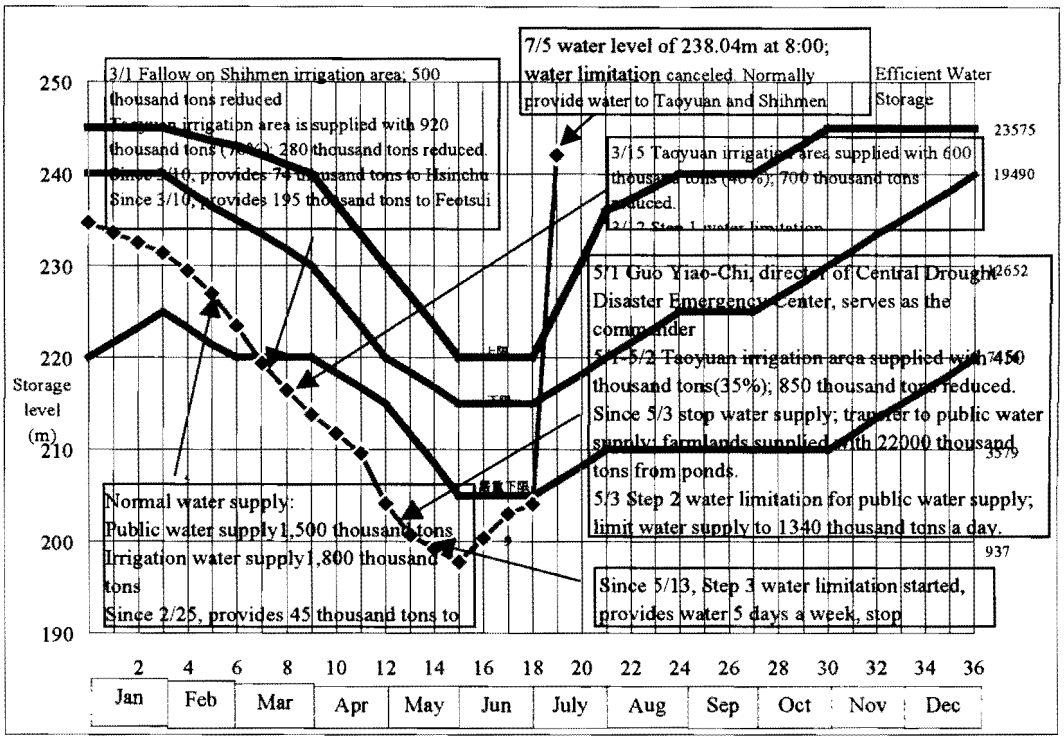
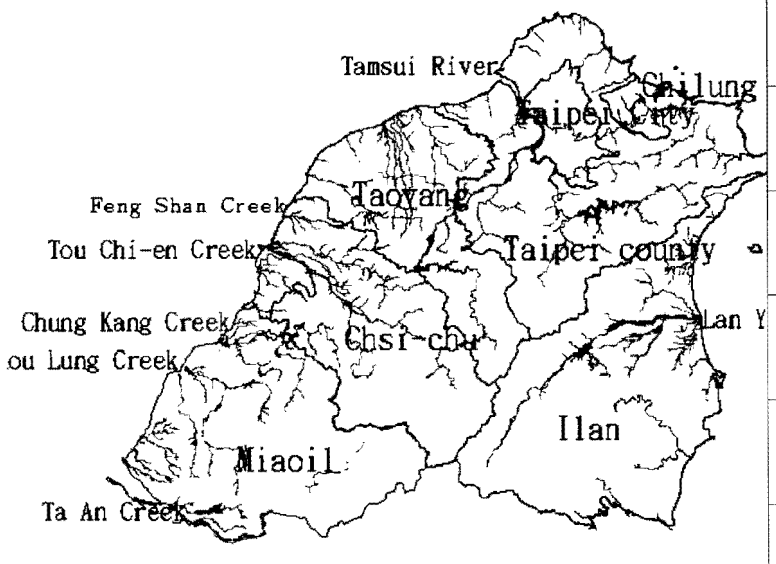


Figure7 Water Resources Map in Taiwan North Region



Hsin Shan Reservoir heightening construction	Hsinshan Creek, branch of Dawwulun Creek, upstream of Keelung River, Keelung city
Sizh Reservoir heightening construction	Nuannuan Creek, branch of Keelung River, Keelung city
Panhsin region water supply improvemewnt project	the connection of two water supply systems in Taipei
Lotung Weir	downstream of Lotung Creek, branch of Lanyuan creek, Ilan county.
Paoshan 2th Reservoir	upstream of Shihchin Creek, branch of Ermei Creek of Chungkan Creek, Paoshan village, Hsin-Chu county
Seawater desalination	along Hsinchu, Miaoli, etc.

3.3 Water conservation instructions and assistances for industrial users

1. Holding water conservation counseling and instruction lectures: Water Resource Agency is driving the water conservation project since 1996, and cooperated with the Industrial Technology Research Institute(ITRI) jointly form the "Water Conservation Corps" in helping Hsin-Chu Science-Based Industrial Park(HSIP) to conserve water and reuse water for industrial wastewater. There has been accumulated of many successful cases.

In this time, the user of more than 5,000 tons of water use in industrial zone of Taoyuan shall be the object to be instructed by the water conservation instruction and counseling group.

2. Helps to users requiring 24hr for special processing: the Industrial Development Bureau forms a special team in holding meetings regarding water limitation for industrial users, and colleting suggestion from them, and then with Water Supply Corporation jointly formulate a concrete water limitation project for industrial users to release drought impact; for special users having special processing needing 24hr to keep its function, prior to the step 3 water limitation, Industrial Development Bureau will inform each user to store water and adjust the processing, and meanwhile coordinated with water treatment plants around Water Supply Corporation in setting up the water supplying stations providing 24hr water service by adding tax to the original price, which will benefit users to hire big water trucks to take water.

3.4 Treatment for the "Enterovirus" event after water limitation

Since the step 3 water limitation begins, some of community users show the intestinal syndromes as the water limitation is over. Through health agency's investigation, the main cause is such water contaminated by wastewater, and the other cause is due to unclean tanks and underground pools having breaks. As the event occurs, the relevant units take the necessary measures immediately, so the "Enterovirus" event calms down in short time.

1. Health Department and Health Bureau: the health department immediately commences the epidemic situation promulgation system, and keep contact with each health unite. The epidemic investigation team went to epidemic zones helping local governments' investigation; local health bureaus set up medical stations to help people, and dispatch personnel to send bleaching water in disinfecting tanks and public health advertisements, etc.

2. Water Supply Corporation: provide special pleading lines to users. When the water is contaminated, immediately detect the leaks for pipes and repair them. If necessary, embed new sewers to connect the trunk sewers of tap water to the tanks in the

community, and set up water supplying stations providing clean tap water. After inspection and repair, inspect field water quality again at the same time; for user having contaminated tanks or water towers, help them clean pools or tanks and exclude contamination; as the water limitation is over, perform dewatering first, and exclude dirt in pipes, and then inform users to open the control valve, and then regain water service; inform users to close pumps and valves first in preventing contamination.

3.5 Cloud seeding

In North Taiwan, early spring is in lack of rains. The Shihmen Reservoir's water level is lowering down, causing water supply crisis in Taipei and Taoyuan. To increase the rainfall probability in watershed of Shihmen Reservoir, the Water Resources Agency and the Taiwan air-force meteorology union and the meteorological bureau jointly form a cloud seeding team in executing ground and air cloud seeding missions. After the meteorological bureau provides applicable weather data, the Water Resource Agency will select an suitable location to set up manually-operated seeding generators in making the ground cloud seeding, and the air-force meteorology union perform the air cloud seeding in order to increase the rainfall in watershed and ease the drought crisis.

Ground cloud seeding are performed using silver iodide (cooling clouds). During Mar to Jun, 42 times ground cloud seeding (25 times at Shihmen Reservoir) completed; Taipei has 4 stations; Taoyuan, Hsin-Chu, Miaoli have 13 stations; Chiayi and Nantau has 5 stations; it takes 173 hours to release silver iodide (at Shihmen Reservoir 90 hours). The accumulated rainfall in a day is 179mm at Shihmen Reservoir, and the expanse used is 540 thousand NT (Table 4); in the sky of Shihmen Reservoir, 9 batches 18 sorties has been executed, and the expanse used is 3,600 thousand NT.

Taiwan never normally performs the ground cloud seeding researches at a fixed location. The related data is vacant; therefore, the results about this cloud seeding is hard to judge; besides, this cloud seeding is based on if the clouds passing by includes mist, and such weather is able to provide rainfall also. Therefore, it is very hard to judge if rain caused by nature or cloud seeding.

The probability of the occurrence of drought in North Taiwan increases for the dense industries and population growth. Since 2003, Water Resources Agency will combine meteorological, hydrological, ecological and other experts, at Shihmen Reservoir and Feitsui Reservoir, to perform long-term researches regarding normal cloud seeding as the basis of evaluating the effect of cloud seeding, and establish the estimation model for cloud seeding.

Table 4 2002 Cloud seeding on Shihmen Reservoir

Month	DAY	Water level (0:00)	TIME	PERIOD (hr)	Effective water storage (ton)	Inflow (ton)	Outflow (ton)	Rainfall (mm)
3	14	218.16	15:30~19:30	4.00	66,109,441	804,384	2,239,488	3.15
3	16	217.63	01:00~06:00	5.00	63,876,667	1,081,728	1,246,752	6.15
3	19	217.02	13:50~14:30	0.67	61,353,810	616,896	1,836,864	0.00
3	22	216.05	16:00~20:00	4.00	57,444,404	649,728	2,058,048	3.75
3	24	215.50	12:00~18:00	6.00	55,282,956	767,232	2,157,408	1.95
3	27	214.52	12:30~14:20	1.83	51,529,427	787,968	1,904,256	1.20
3	29	213.90	06:00~10:00 18:30~24:00	9.50	49,218,710	914,976	1,753,920	9.65
4	6	212.95	18:00~20:00	2.00	45,772,977	976,320	1,206,144	0.30
4	9	212.43	05:50~10:00	4.17	43,934,976	754,272	1,753,056	0.50
4	11	211.73	09:00~10:00	1.00	41,513,837	751,680	1,833,408	3.20
4	24	207.96	13:50~15:30	1.67	29,493,379	724,032	2,217,888	2.80
5	11	200.28	11:30~16:00	4.50	9,961,187	668,736	1,381,536	2.80
5	16	198.51	12:00~15:00	3.00	6,327,070	561,600	1,300,320	2.85
5	17	198.13	00:00~04:00	4.00	5,586,508	1,282,176	1,338,336	36.30
5	23	198.78	04:00~10:00	6.00	6,861,686	1,969,920	1,206,144	12.40
5	29	198.91	14:00~16:00	2.00	7,121,604	594,432	1,345,248	0.10
5	31	198.00	02:45~19:00	16.25	5,336,323	846,720	1,353,024	33.50
6	4	198.62	14:00~17:00	3.00	6,544,029	1,587,168	1,341,792	15.05
6	6	198.80	14:00~17:00	3.00	6,901,567	1,488,672	1,343,520	16.10
6	12	200.42	11:40~16:20 20:00~23:00	7.67	10,261,814	3,511,296	692,928	3.45
6	13	201.69	03:40~04:00	0.33	13,079,148	3,511,296	1,507,680	21.60
6	14	202.55	14:50~15:00	0.17	15,080,646	2,484,864	797,472	0.60
6	19	203.73	13:50~14:30	0.67	17,952,724	1,134,432	653,184	1.40
Accumulated rainfalls				90.42				178.80

3.6 Drought Resisting and Other related measures

1. Water limitation advertisements: establish a "drought resisting website" to promulgate information of water limitation to people through website.

2. Exclude mud and silt in reservoirs to enhance its capacity: during drought, perform dredging at Shihmen Reservoir and Feitsui Reservoir to increase their capacity.

3. Each agency or department shall perform water conservation: central agencies and local agencies and schools shall perform relevant water conservation measures.

4. Crack down the illegal pumping ground water: local governments arrest the illegal that pumps ground water illegally.

5. Health and disaster prevention: set up special water supplying stations and provide water car services to medical units to prevent the influence from water limitation; provide the water limitation regions the fire rescue water and locations to get water. If severe disaster occurs, cancel the water limitation.

6. Perform water quality monitoring in reservoirs and rivers: Environmental Protection Agency of the Executive Yuan performs periodical monitoring of water quality variation in reservoirs and rivers to ensure water quality.

7. Forest fire prevention: hot dry air lies in dry season. Mountains are easily causing fire. That shall be prevented with the forest authority and local fire protection units.

4. CONCLUSION

The 2002 North Taiwan drought crisis was eased through the application of the drought disaster prevention and rescue systems, and under the cooperation and coordination with each related agency and units.

After this drought, Water Resources Agency based on the North Taiwan water sources development project speed up the construction of the second Paoshan Reservoir in Hsin-Chu, which will be completed in 2004 in order to ensure the water use of Hsin-Chu and HSIP; also conduct the water supply improvement project for Panhsin, Taipei, and expand the Tsutien Water Treatment Plant, which will be complete on Dec 2003, and then it will increase 530 thousand tons water supply; perform the tap-water pipes connection work and change old pipes to enhance the tap- water management; besides, along the coast of Hsin-Chu, plan to build a seawater desalination plant with daily production of 70 thousand for industry use. The construction of seawater desalination plant will use BOT to entrust non-governmental circles, and Taiwan government will promise to purchase, which will catch non-governmental circles' interest to the construction and reduce the cost.

Except multi-development to water resources and water supplying facilities, Taiwan government will enhance the water resources management, and drive the rationalization of tap-water price and the price adjustment during drought, which provides reason to conserve water and stop wasting water; strive for collecting rainwater, industrial wastewater reuse and rain water/grey water supplying system in promoting water advantages; enhance land conservation and reservoir watershed conservation to maintain the function of reservoir; establish the drought warning and monitoring system to build the forecast model for the drought; establish regional water resources management system and enhance water resources management; besides, the current drought classes of Taiwan and the procedures and measures of water limitation will be adjusted and improved in the future.