REPORT ON THE FLOOD FORECASTING

& WARNING SYSTEMS

IN THE TAN-SHUI RIVER

March 1972

OVERSEAS TECHNICAL COOPERATION AGENCY

Tokyo, March 18th, 1972

Sir,

We have pleasure in submitting herewith the Report on the Investigation for the Establishment of the Flood Forecasting and Warning System in the Tan-shui River.

Our mission, consisting of four hydrologists and three tele-communication experts sent to Taipei for a month, has made a comprehensive study on the above subject.

The elaboration of the study and the preparation of the Report have been completed in Japan.

We sincerely hope that the Report would be helpful to the establishment of the flood forecasting and warning system in the Tan-shui River and that it would also serve as a witness of the everlasting friendship between the people of China and Japan.

In conclusion, we should like to take this opportunity to express our appreciation of the assistance we received from all with whom we came in contact through the course of investigation.

Yours very truly,

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To: The Director,
Taiwan Provincial
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CHAPTER I INTRODUCTION

1.1 Background of Survey

The Government of the Republic of China has long recognized the need of an improved flood forecasting and warning system in the Tan-shui river basin and incorporated its establishment plan in the flood control project recently mapped out for the river. *

Generally, flood forecasting work is broadly classified into two stages, i.e., the forecasting of rainfall which causes floods and the forecasting of discharge and water stage from the predicted or observed amount of rainfall.

In the case of the Tan-shui, the Taiwan Provincial Weather Bureau, which takes the leading part in the forecasting of rainfall, is carrying out the necessary research activity and construction of various facilities with the U.N. technical assistance. Two rader stations have already been built, one in Hua-lien and the other in Kao-shiung, and another is expected to be shortly constructed in the vicinity of Taipei.

For the forecasting of discharge and water stage, on the other hand, necessary studies are being conducted by the Taiwan Provincial Water Conservancy Bureau which has made useful proposals regarding the method to be employed in actual forecasting and warning services. ** With respect to the facilities for the forecasting and warning, it is planned that 10 rainfall telemeter stations, 7 water stage telemeter stations, 2 water stage informing offices, 2 relay stations and 2 central control offices will be constructed during the three to four year period subsequent to 1971. Construction of these facilities, which will augment the coverage and efficiency of the existing 9 rain gauge stations and 4 water stage stations, is expected to incur a total cost of US$1,075,000 including the cost of the aforementioned 1 rader station to be soon completed. *)

With the view to expediting the establishment of these facilities in the basin, the governments of the Republic of China and Japan reached a technical cooperation agreement under which Japan was to undertake, with due note taken of the resolution passed at the third session of the Typhoon Committee of ECAFE/WMO, **) a survey on the method of forecasting and on the installation of forecasting facilities by a team composed of a number of hydrologists and tele-communication experts.

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* General Planning Committee on Water Resources, Ministry of Economic Affairs: Report of the Study on the Flood Prevention Project in Taipei District, June 1970, p. 10.

** Hsing-ming Chang et al: Comprehensive Report on the Study of Flood Forecasting and Warning Method in the Tan-shui River Basin, the Taiwan Provincial Water Conservancy Bureau.

*) Flood Forecasting and Warning Imrpovement Project in Tan-shui River Basin, Taipei, Taiwan, Republic of China, Japanuary 1969.

**) The Technical Cooperation Plan of the Government of Japan, Application by the Government of the Republic of China.

The Government of the Republic of China hoped that the said survey would be put in practice before January 1971. However, due to the time required for the appointment of experts and preparation of survey equipment, the survey in the Republic was carried out during the period from June to July 1971, with cooperation offered by the Government of the Republic of China, Taipei City Authorities, and the Water Conservancy Bureau.

1.2 Terms of Reference

Terms of reference to the survey team were set forth in the Application of Technical Assistance (Form A. 1) forwarded to the Japanese Government from the Government of the Republic of China.

In this application, the hydrologists were requested to study and determine an adequate method or methods for flood forecasting and warning in Tan-shui river basin. To be more precise, they were expected to make studies on the following subjects.

(1) Analysis and study of basic hydrological data

(2) Correlations between storm rainfall and river stage or correlations of river stages among upstream and downstream stations

(3) Runoff characteristics of various storm rainfall patterns

The tele-communication experts, on the other hand, were requested to study and determine the flood forecasting and warning network of the Tan-shui river basin as well as all the necessary facilities and specifications (including field reconnaissances and experiments).

1.3 Formation of Survey Team

The survey team was composed of four hydrologists and three tele-communication experts. The names, assignments and present posts of these seven experts are shown below.

Name	Assignment	Post
Takumi NISHIHARA	Leader, senior hydrologist	Deputy Director, River Planning Division, River Bureau
Kazuhiko TAKAYAMA	Acting Leader, senior tele-communication expert	Chief, Telecommunication Section, Kanto Regional Construction Bureau
Sukehisa AOKI	Senior Hydrologist	Senior Research Engineer, Section of Hydrology, Public Works Research Institute

Name	Assignment	Post
Hiroshi MIYAI	Senior Hydrologist	Supervisor, Office for Integrated Operation of Dams in the Yodo River, Kinki Regional Construction Bureau
Tadahiko NAKAO	Hydrologist	Engineer, Tone Karyu Work Office, Kanto Regional Construction Bureau
Yoshio TAKAHASHI	Tele-communication expert	Engineer, Minister's Secretariate, Ministry of Construction
Masaru YUTANI	ditto	Engineer, Water Resources Development Public Corporation

Duties to which each team member was assigned during the survey are described below.

Name of Team Member	Duties
Takumi NISHIHARA	Overall control, rainfall analysis and selection of station sites
Sukehisa AOKI	Arrangement of observed data, and analysis and study of forecasting method of flood runoff in the upper reaches
Hiroshi MIYAI	Arrangement of observed data, and analysis and study of forecasting method of inundation and flood wave propagation in the lower reaches
Tadahiko NAKAO	Establishment of flood forecasting calculation system and design of observation facilities
Kazuhiko TAKAYAMA	General control of tele-communication sector, and estimation of construction and maintenenance cost of forecasting facilities
Yoshio TAKAHASHI	Study of communication and telemeter system, and preparation of specifications and design drawings of communication equipment
Masaru YUTANI	Planning and design of telemeter system and study of maintenance of communication equipment

1.4 Plan of Survey

The survey was conducted by dividing the team into two parties, i.e. the party of hydrologists and that of tele-communication experts. *

The hydrologists arrived at Taipei on May 14 and returned to Japan on June 14, whereas the tele-communication experts arrived in the city on June 1 and left for Japan on July 1.

The survey itineraries of the two parties are shown in Table 1.1 and Table 1.2, respectively.

Table 1.1 Survey Itinerary of Hydrologists

Date		Description	Remarks
May	14	Departure from Haneda Airport and arrival at Taipei	
	15	Courtesy call on the Director of Water Conservancy Bureau and consultation with him on the survey itinerary and other subjects	
	16		
	17	Morning: Consultation about survey work Afternoon: Survey of Taipei Bridge Water Stage Station	
	18	Survey of the Keelung river (at Wu-tu and Chung-cheng Bridge)	
	19	Survey of the Hsin-tien Creek at Wu-lai	
	20	Visit to the Shih-men Reservoir, and survey of water stage stations at San-hsueh and Ta-hsi	
	21	Hydrological analysis: Collection of basic data	
	22	Ditto	
	23		
	24	Hydrological analysis: Collection of basic data	
	25	Ditto	
	26	Hydrological analysis: Runoff analysis	

* The team was divided into two parties due to the substantial time required for the customs clearance of the radio equipment indispensable for the survey by tele-communication experts.
In planning this arrangement, it was hoped that radio communication experts would join the hydrologists immediately after the customs clearance of survey equipment was completed.

Date		Description	Remarks
May	27	Hydrological analysis: Runoff analysis	
	28	Ditto	
	29	Inspection of Hua-lien Radar Station of the Weather Bureau	
	30		
	31	Hydrological analysis: Case study of floods	
June	1	Ditto	
		Arrival of the tele-communication experts, and consultation about survey work	
	2	Hydrological analysis: Case study of floods	
	3	Inspection of the Ming-te Reservoir	
	4	Inspection of Sun-Moon Lake	
	5	Survey of rivers in the vicinity of Tainan city	
	6		
	7	Inspection of Kao-shuing Radar Station of the Weather Bureau	
	8	Ditto	
		Discussion with Dr. Takenouchi (former consultant to the ECAFE and the WMO and professor of the Self-Defense College) on the flood forecasting facilities	
	10	Hydrological analysis: Case study of floods	
	11	Ditto	
		Preparation of interim report	
	12	Interim Report meeting at 1st assembly hall of the Water Conservancy Bureau	
	13		
	14	Departure for Japan	

Table 1.2 Survey Itinerary of Tele-communication Experts

Date		Description	Remarks
June	1	Departure from Haneda Airport and arrival at Taipei; consultation with the hydrologists about the survey work	
	2	Courtesy call on government offices concerned.	
	3 : 7	Same as the itinerary given in Table 1.1	
	8	Preliminary design of telemeter communication system Preparation and arrangement of radio-wave propagation test	
	9	Preliminary design of telemeter communication system Preparation and arrangement of radio-wave propagation test Field reconnaissance at Shi-tzu-tou and Chung-shan Bridge	
	10	Field reconnaissance at Chung-cheng bridge and Hsin-hai Bridge Field reconnaissance and propagation test at Taipei Bridge	
	11	Field reconnaissance and propagation test at Wu-tu	
	12	Interim report meeting of hydrologists. Noise measurement and arrangement of data	
	13		
	14	Noise measurement and service condition investigation of communication equipment of the Water Conservancy Bureau	
	15	Field reconnaissance and propagation test at Chu-chie; Review of communication system of Shih-men Reservoir Administration Bureau	
	16	Field reconnaissance at Hsiao-liao	
	17 18	Field reconnaissance and propagation test at Tah-tun-san	
	19	Field reconnaissance at Tun-hou and Fu-san	
	20		
	21	Field reconnaissance and propagation test at Mt. Ta-ping and Shih-men	

Date		Description	Remarks
June	22	Field reconnaissance at Ta-pao	
	23	Review of communication system of the Weather Bureau	
	24	Field reconnaissance at Chi-tan	
	25 26	Inspection of Hua-lien Radar Station of the Weather Bureau	
	27		
	28	Arrangement of data	
	29	Preparation of interim report	
	30	Interim report meeting	
July	1	Return to Japan	

1.5 Acknowledgements

All the members of the survey team wish to express their deep gratitude to many government officials of China for the assistance extended during the survey. In particular, they wish to express sincere thanks to the water Resources Committee of the Ministry of Economic Affairs and Water Conservancy Bureau for the valuable advices and data provided and to Mr. Tao-lung Wang, the Director, Mr. Hsueh-su Yang, Deputy Director, Mr. Yung-ting Hu, Deputy Chief Engineer, Mr. Chen-chi Chen, the Director of the Planning Division, Mr. Wang-chen Kuo, the Chief of Hydrology Section, Mr. Chen-hsiang Lin, the Chief of the 1st Regional Hydrologic Station, and other members of Water Conservancy Bureau for the untiring cooperation extended to them. They are also much indebted to the counter-part engineers headed by Mr. Hsing-ming Cheng, an engineer of the Bureau, for their assistance to the team in the execution of survey.

The team members also wish to record here their deep appreciation of the co-operation and assistance given by the officials of the Weather Bureau and each office of the Water Conservancy Bureau during the team's inspection of Hua-lien and Kao-shiung Radar Stations.

Finally, all team members wish to note that the survey work was immensely helped by kind cooperation extended by Mr. Yoshio Nakata, the counsellor of the Japanese Embassy in the Republic of China.

CHAPTER II CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

Conclusions reached by the survey on the flood forecasting and warning system in the Tan-shui basin are as summarized below.

1. Since the flood runoff of the Tan-shui flows directly into the flat and lowlying Taipei basin from the steep mountainous districts, flooding occurs with little time lag, and the time from the peak of rainfall to the peak of flood is as short as 6 to 11 hrs. Unless the numerical forecast of rainfall is available, flood warning cannot be given any more than 5 hrs in advance.

2. Granted that the warning can be given so short a period in advance, it would still provide sufficient time for the people to evacuate or take preventive measures against the inundation of properties, particularly for the inhabitants of cities like San-chung which is attacked by floods once in several years.

3. Flood forecasting and warning is to be given on the basis of the estimated depth and area of inundation in San-chung city and other districts. The depth and area of inundation can be obtained from the water stage at Taipei Bridge and Shih-tzu-tou to be estimated from the discharge of the Keelung, Hsin-tien Creek and Ta-han Creek which can be calculated from rainfall and the tidal level at the estuary.

4. The flood runoff can be obtained using the river channel unit graph method which incorporates Hayami's theory of the basic equation of unstady flow and also using the storage function method resorting to Kimura's theory, and the depth of inundation in the lower reaches is estimated by a hydraulic calculation making use of the equation of continuity.

   It was revealed that the runoff calculation can be worked out with good accuracy.

5. To obtain data required for the above calculation, it is necessary to establish 11 telemetering rain gauge stations and 8 telemetering water stage stations. Each rain gauge is to cover an average basin area of 260 km^2. This telemeter network calls for the construction of 2 relay stations on mountain summits and establishment of a new tele-communication system of 60 MHz band. It may be added that some of the existing station buildings could be made use of in the establishment of the new telemeter network.

6. Calculation of flood runoff and the depth of inundation is to be carried out by means of two portable electronic computers and some nomogrammes. The speed and procedures of calculation envisaged in this report will guarantee the high efficiency and quick operation required for the flood forecasting and warning.

2.2 Recommendations

The following recommendations are made regarding the establishment of the flood forecasting and warning system in the Tan-shui river basin.

1. It is recommended that the construction of telemeter facilities proposed in Chapter 7 be prompted in order that the basic data may be quickly collected for the forecasting work.

2. It is essential to establish a flood forecasting and warning center for the purpose of calculating water stages and discharges, analyzing hydrological data, issuing flood forecasting and warning, and transmitting the warning to pertinent organizations or the general public.

   It is recommended that such offices be so designed that they may be suited for the future installation of a high speed digital electronic computer.

3. It is advisable that a meteorological rader be installed at a suitable site in the Tan-shui basin so as to attain a higher accuracy in observing rainfall.

4. To assure that the flood warning will be quickly brought to the attention of the general public, it is recommended that the necessary broadcasting facilities, alarm sirens, automobiles equipped with loud speakers, etc. be provided.

5. It is necessary that amendments and revisions be effected to the fundamental legislation in order to clearly delineate the scope of responsibilities and competence of respective administrative organs partaking in the flood forecasting and warning.

6. The runoff analysis of the Keelung river is extremely difficult because no discharge observation is carried out at the Chung-shan Bridge Water Stage Station located in downstream of the river. A suitable site and suitable observation method should therefore be selected to obtain the river's discharge.

7. The tidal level at Yu-che-kou serves as a fundamental data for analyzing the inundation in lower reaches. It is therefore recommended that the hourly observation data of tidal level at this point be put to harmonic analysis for the establishment of an equation applicable for an easy tide level estimation at any desired time.

8. Water gauges in the downstream area of the Tan-shui are subjected to subsidence due to the heavy land subsidence recently observed in the said area. Measures currently taken by the Water Conservancy Bureau to cope with this situation is to adjust the datum level by shifting the gauge height according to the degree of subsidence. It is hoped that the measures be replaced, for easier consolidation of data, by the method of measuring the gauge elevation without changing its relative height and effecting correction to the water stage data obtained.

9. The Shih-men Reservoir is primarily intended for supplying irrigation water and is controlled not by the Water Conservancy Bureau but by the Shih-men Reservoir Administration Bureau. In planning a system of flood forecasting, due consideration should be given to the assurance of closer coordination between the two organs.

10. A field test concerning Mt. Li-tung telemeter system should be conducted at a suitable time in future since it was not included in the survey.

11. The numerical estimation of rainfall is indispensable for a flood warning with sufficient time allowance. Studies on this subject should be accelerated with efforts also directed towards propelling the study of storm rainfall patterns in the Tan-shui river basin.

12. It is necessary to study the maintenance and operation system of telemeter facilities to assure smooth functioning of the telemeter system.

13. In addition to the telemeter facilities, a network of communication between respective work offices and regional hydrologic stations should be planned in future.

CHAPTER III EXISTING STATE OF THE TAN-SHUI

3.1 General Description of Basin

The Tan-shui is the third largest river in Taiwan flowing in the northernmost part of the island and having a mainstream length of 158.7 km. The northeastern and northwestern parts of its 2,726 km^2 wide basin are severed from the coast by Mt. Ta-tun and Mt. Kuan-yin respectively, whereas the southeastern part is separated from the Lan-yang basin by Mt. A-yu and Mt. Hung-yeh and the southwestern part is delineated by Mt. Pin-tien and Mt. Ta-pa-Kuang.

One of the characteristics of this rever basin is that its flat and lowlying area rises immediately to the surrounding steep mountainous districts. For this topographical feature, the basin where Taipei is situated has never been free from the threat of flood, and the narrow channel width in the lower reaches observed at Kuan-tu has always intensified this threat.

The Government is exerting much efforts for the flood control of the Tan-shui because Taipei, the largest city and the political and economic centre of Taiwan, is located in this basin. However, the Tan-shui's flood control project has been set afoot only recently. *

The flood produced by Typhoon Gloria of 1963 inundated an area of about 21,000 ha embracing Taipei and caused heavy damages, and even after this, the basin has been subjected to flood damages once in every several years.

The Shih-men Reservoir having a large storage capacity of 316 million m^3 is found in the upper reaches of the Ta-han Creek, one of the three tributaries of the Tan-shui. The Shih-men Reservoir, however, is primarily intended for irrigation and cannot therefore be expected to exhibit any appreciable flood control effect. **

Fundamental data of each tributary of the Tan-shui, such as the river length, area of basin, etc. are shown in Table 3.1

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* Taiwan Provincial Water Conservancy Bureau: Revised Master Plan for Tan-shui Basin Flood Prevention Project, pp. 2-3, publication No. 44 of Water Conservancy Bureau.

** Refer to Section 2, Chapter 3.

Fig. 3.1 The Tan-shui River Basin

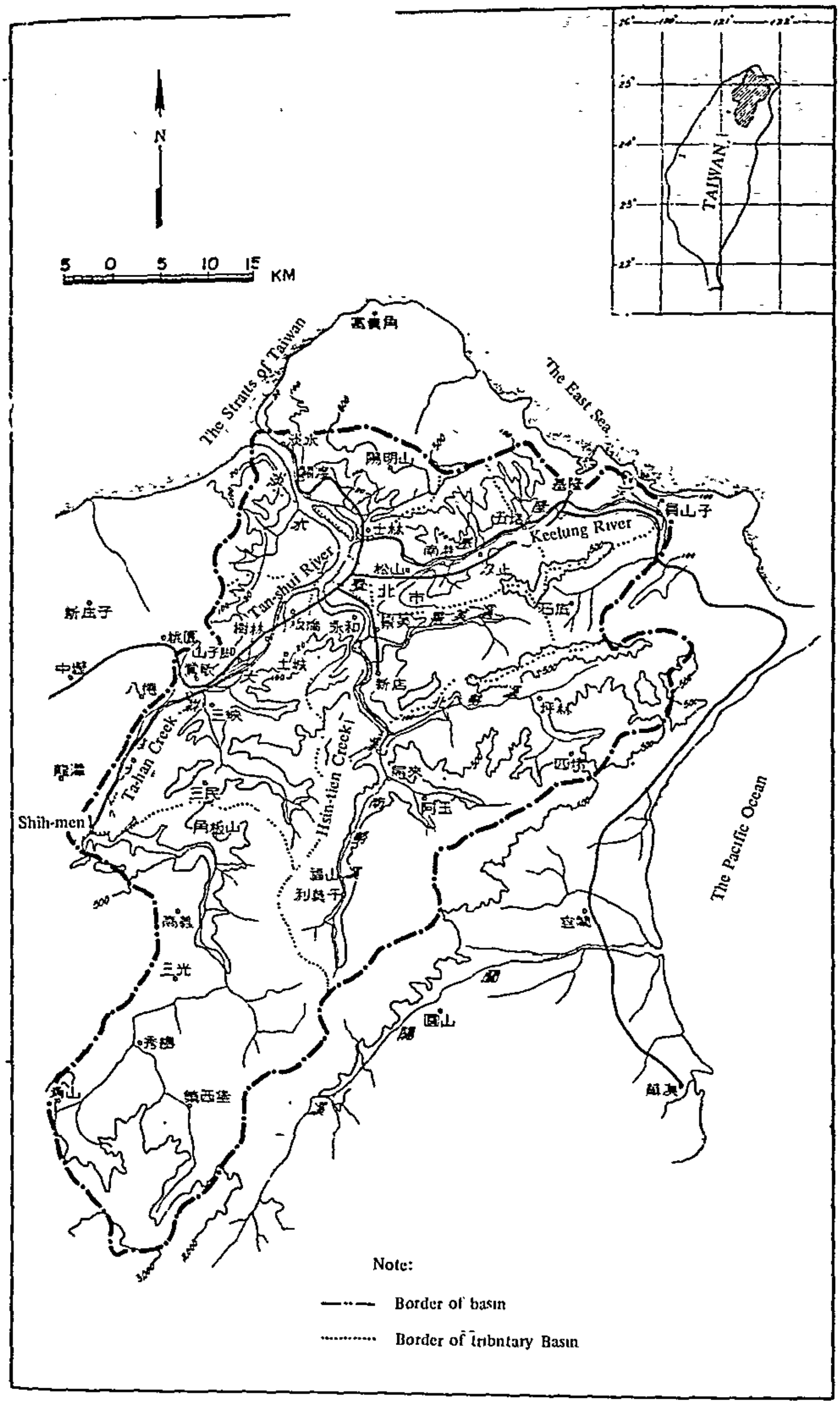


Table 3.1 Fundamental Data of Tan-shui Tributaries

Tributary	Location	Basin Area	Mean Elevation in the basin	Length	Mean Gradient of Water Course
Ta-han Creek	Shih-men	758.89 $^{km^2}$	1,430 ^{m}	90.5 ^{km}	0.0246
	Chiang-tzu-tsui	1,162.69	1,026	135.0	0.0151
Hsin-tien Creek	Chu-chie	645.65	673	50.9	0.0240
	Wan-hua	909.54	566	82.0	0.0136
Keelung River	Wu-tu	208.31	258	46.3	0.0104
	Chung-shan Bridge	401.07	186	74.9	0.0048
	Kuan-tu	490.77	209	89.4	0.0047
Tan-shui River	Taipei Bridge	2,083.22	808	139.4	0.0115
	Kuan-tu	2,687.77	661	149.2	0.0088
	Estuary	2,725.82	653	158.7	0.0082

3.2 Shih-men Reservoir*

The Ta-han Creek, the Tan-shui's mainstream, rises in Mt. Hsu-eh range. It flows through steep mountainous district in the upper reaches, and enters the flatland area after it passes through Shih-men, Tao-yuan prefecture. At Shih-men, mountains rise to a large height on either bank of the river as the name suggests;** providing an ideal site for dam construction. The Shih-men Dam is a multi-purpose dam constructed at this site for irrigation, power generation, flood control, municipal water supply and sight-seeing. The dam is about 52 km from Taipei, and water discharged from the reservoir reaches the city in about five hours.

For the Shih-men Dam Construction Project, a preliminary survey was carried out around 1948 by the Water Conservancy Bureau, which was ensued by the establishment of the Construction Commission within the Central Government which undertook the construction work as one of the national projects and completed it in 1963.

The dam was constructed primarily for the implementation of an agricultural irrigation plan which was intended to increase agricultural production by large scale reclamation of the highland area extending in and around Tao-yuan Prefecture. It may be added that the dam construction work was accelerated by the drought damage inflicted upon the Tan-shui basin in two successive years, 1953 and 1954.

Table 3.2 shows the economic benefits in various aspects estimated to be derived from the Shih-men Dam Project. As is clear in this table, the greater part (57%) of the dam's benefit goes to irrigation and a very small fraction of the total economic

* T. Chu : Shih-men Reservoir, Shih-men Reservoir Construction Commission, 1965.

** Shih-men means a "Stone gate" literally.

Table 3.2 Economic Benefit of Shih-men Dam (Estimate)

Purpose	Annual Economic Benefit in Value	Ratio	Remarks
Irrigation	N.T.$ 174,400,000	57.3 %	Figures indicate conservative estimates
Power Generation	92,720,000	30.5	
Flood Control	14,400,000	4.7	
City Water Supply	22,700,000	7.5	Future increment is not included
Total	304,220,000	100.0	

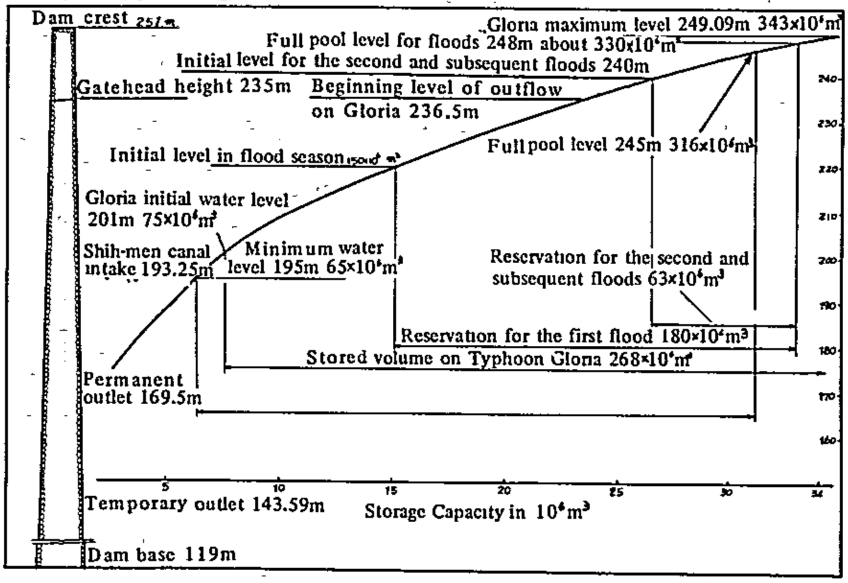
benefit is allocated for flood control. It may therefore be considered that the construction of the dam was done basically for the irrigation.

Dimensions of the reservoir and dam facilities are shown in Table 3.3, and allocation of storage capacity to each purpose is shown in Fig. 3.2.

Table 3.3 Dimensions of Reservoir and Dam Facilities

Catchment Area	763.4 km^2
Reservoir Surface Area	8.15 km^2
Total Storage Capacity of Reservoir	316×10^6 m^3
Effective Storage Capacity	251×10^6 m^3
Type of Dam	Core wall type fill dam
Height of Dam Body	133 m
Crest Length	360 m
Spillway	Crest gate - 6
Gate	Radial Gate, 10.5 m(H) x 14 m(W)
Bed Height	El. 235 m
Design Flood Discharge	8,450 m^3/sec
Maximum Flood Discharge	11,400 m^3/sec
Elevation of Power Plant Intake	169.5 m
Maximum Intake	25 m^3/sec
Elevation of Intake of Shih-men Main Canal	193.25 m
Maximum Intake	10 m^3/sec

Fig. 3.2



As seen above, no conduit pipe is installed through the dam body, and this is because the dam is of fill type. As the crest gates are the only facilities for flood control, water cannot be discharged when the reservoir water level is lower than the gate bed height. And so the dam cannot be expected to exhibit very efficient flood control performance including preliminary drainage of stored water. The flood control function of the dam is further limited by the fact that no sufficient water can be discharged unless the water level rises to a substantial extent.

The dam operation at the time of flood is carried out according to a plan prepared by the working group in the Shih-men Reservoir Control Office and approved by the Department of Economic Affairs. Under the current system, it is required that the discharge volume is reported every hour to the Water Conservancy Bureau.

The water level of the Shih-men Reservoir is required to be maintained within the upper and lower limits established for the whole year. In the beginning of the flood season of each year, the water level of the reservoir is required to be descended to 220 m. The flood controll capacity at this time including the surcharge is 180 x $10^6 m^3$ (235 mm if divided by the basin area of 753 km^2), so that it is clear that the dam displays an appreciable flood control effect in the early flood season. For the second and subsequent floods, however, the dam's flood controll capacity declines to 63 x $10^6 m^3$ or about one-third of the initial capacity because the water level is descended only to 240 m. This shows that the priority in the dam operation is for the supply of irrigation water than the flood control.

When a flood actually takes place, the dam is operated on the basis of the inflow into the reservoir calculated from the velocity of the rise of the water level in the reservoir because the telemetering system covering rain and water gauge stations in the upper and lower reaches has not yet been established.

A calculation disclosed that the dam operation at Shih-men is more or less like the constant rate control, though this appears to give place to free overflow method with the increase of water stage. *

Typhoon Gloria attacked the basin in April 1963 soon after the dam was completed bringing about an average rainfall of 1, 375 mm in the upstream area of Shih-men. The resultant flood water inflicted heavy inundation damage in the downstream Taipei basin, and this was partly imputed to the improper dam operation at Shih-men. The Shih-men Reservoir Construction Commission, however, disproved the charge giving the following two reasons.

a) It is a matter of impossibility to give an accurate forecast of a flood. Preliminary drainage immediately before the flood was not practicable in the case of Typhoon Gloria because the water level had been below the crest gate bed height. The irrigation and power outlets have total discharge capacity of only $35m^3/s$.

b) An attempt to close the gate for flood control would have resulted in rapid increase of water stage and water would have overflowed the dam body. Since the dam is of the fill type, this would have caused the dam corruption, causing heavier damage in the downstream area than was actually suffered.

A flood routing calculation done by the team revealed that the above two reasons given by the Commission could be generally justified. To put in more detail, the flood water brought about by Typhoon Gloria happened to be the maximum probable flood for which the spillway had been designed. The spillway therefore discharged this flood to downstream, so that it was quite likely that the safe-keeping of the dam body was all that the Commission could do.

The relationship between the reservoir level and dam discharge was also studied to find out what control effect was displayed by the Shih-men Reservoir against floods which were not so intensive as those caused by Typhoon Gloria, using calculated inflow hydrographs in the upper reaches of Chung-cheng Bridge on the Hsin-tien Creek which was considered to be similar in characteristic to Shih-men Reservoir Basin. **

The inflow hydrographs were prepared from the data of storm runoff of Typhoon Elsie which had a short duration and that of Typhoon Elaine which had a long duration, with values on the abscissa multiplied by constants to make the maximum values equivalent for comparison. Two methods of operation were reviewed, one being the free overflow with the gates full opened and the other the currently practised gate operation.

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* Flood control by dam operation generally resorts to the following methods.
a) Free overflow method.
b) Peak cut method in which outflow that is larger than a fixed value is cut, and water less than that value is discharged.
c) Method in which water is released at a specific rate to inflow.
d) Method in which water is discharged according to the downstream river stages.

** This method was resorted to due to the absence of flood hydrographs of the Shi-men Reservoir basin. Use of the inflow hydrographs in the upper reaches of Chung-cheng Bridge is considered acceptable because the constants of storage functions in the two areas are very similar to each other.

As will be clear from the calculation results shown in Table 3.4 and Fig. 3.3, currently adopted operation ensures very efficient flood control if the peak inflow is small, but that it displays even a smaller control effect than can be expected of natural overflow if the peak inflow is large or the flood duration is long. This is because the flood water is stored while the inflow is small and the reservoir loses its control function in the neighbourhood of peak inflow. In case of free overflow, the peak flood can be reduced by an approximately constant degree.

Table 3.4 Trial Calculation of Flood Control Capacity of Shih-men Reservoir

Initial Reservoir Water Level: 236 m

Peak Inflow Q_i m^3/s	Pattern of Hydrograph	Natural Discharge Method			Present Dam Operation		
		Peak Outflow Q_o m^3/s	Q_o/Q_i %	Time lag hr	Peak Outflow Q_o m^3/s	Q_o/Q_i %	Time lag hr
10,000	Elaine	7,000	70	1	9,400	94	0
	Elsie	7,200	72	4	7,400	74	3
7,500	Elaine	5,300	69	0	6,700	89	0
	Elsie	5,400	72	4	4,700	62	3
5,000	Elaine	3,600	72	1	3,500	70	0
	Elsie	3,600	72	4	2,500	50	3
2,500	Elaine	1,700	68	1	1,300	52	0
	Elsie	1,700	68	4	1,200	48	3

It entails danger to draw too many conclusions from the simple calculation mentioned above, but the following may be safely said about the presently adopted operation.

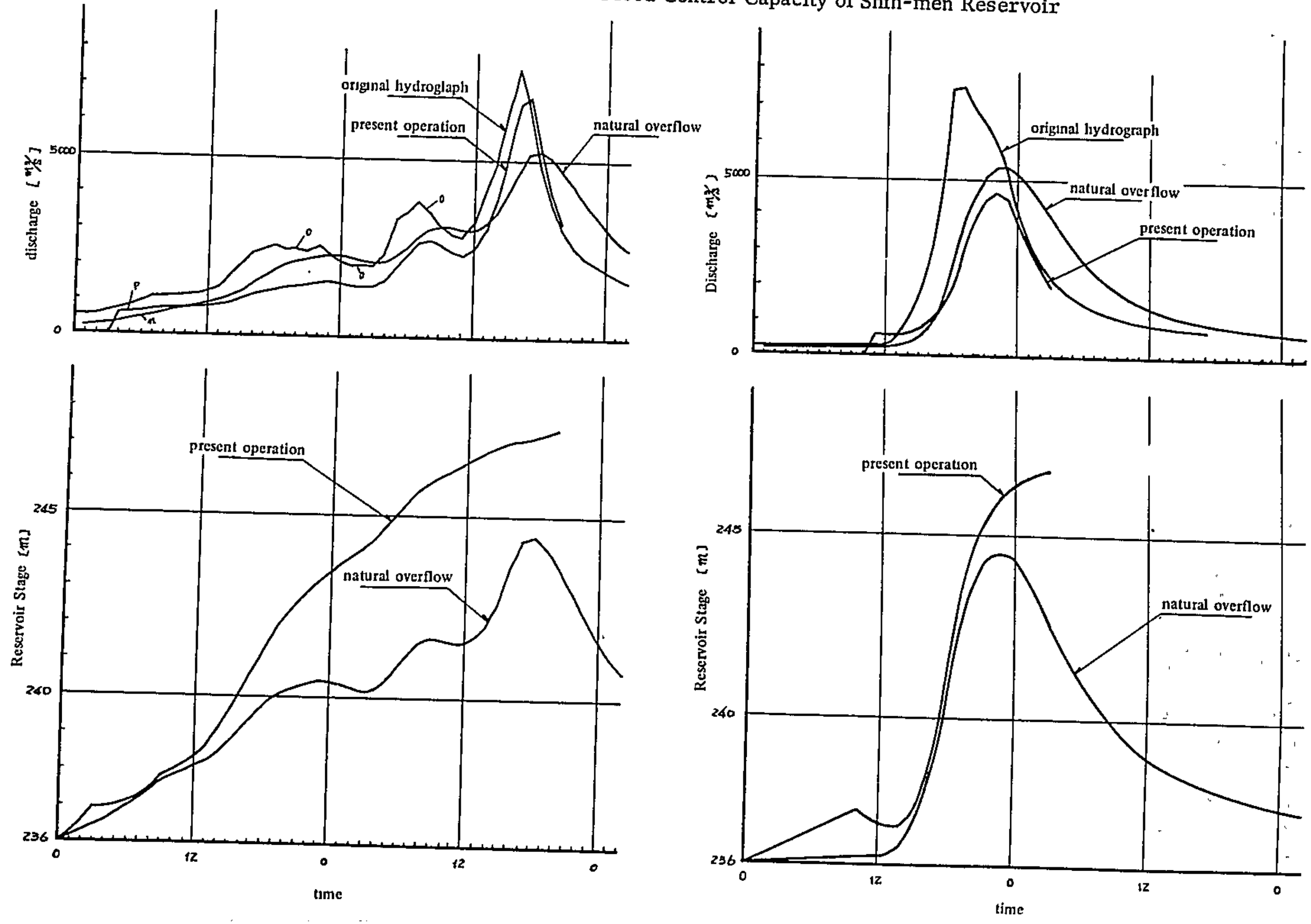
a) The dam operation method presently adopted is largely affected by the irrigation function of the Shih-men Dam.

b) In case of smaller floods, the gate operation serves for storing large quantities of water and exhibits effective flood control performance.

c) In case of floods of large magnitude, large quantities of water is stored in the beginning of flood, leaving no surplus flood control capacity and allowing the inflow to be released without regulating. This trend is conspicuous when the flood duration is long.

The above observation made clear that the flood forecasting and warning system should be planned with due account taken of the fact that the Shih-men Reservoir, though large in size, has a limited flood control capacity and is virtually in capable of regulating discharge by gate operation near the flood peak if the flood is large.

Fig. 3.2 Trial Calculation of Flood Control Capacity of Shih-men Reservoir



3.3 Inundations

Table 3.5 shows the causes of major inundations that happened in the Tan-shui basin in recent years.

Table 3.5 Causes of Major Inundations in Tan-shui Basin

Cause	Date of Occurrence	Cause	Date of Occurrence
Typhoon Wilda	1959 . 7 . 6	Typhoon Gilda	1967 .11 . 18-19
Typhoon Pamela	1961 . 9 . 12	Typhoon Elaine	1968 . 9 . 30-10
Typhoon Opal	1962 . 8 . 6	Typhoon Betty	1969 . 8 . 8
Typhoon Amy	1962 . 9 . 5	Tropical Depression	1969 . 9 . 11-12
Typhoon Gloria	1963 . 9 . 10-12	Typhoon Elsie	1969 . 9 . 26-28
Typhoon Cora	1966 . 9 . 6- 7	Typhoon Flossie	1969 .10 . 2- 5
Tropical Depression	1966 . 9 . 13-17	Typhoon Fran	1970 . 9 . 6- 7
Typhoon Carla	1967 .10 . 18-20		

It is clear from this table that the Tan-shui causes large inundations once a year due mostly to typhoons. Values of maximum discharge and highest water stage observed at major downstream water stage gauges on the Tan-shui at time of large inundations that took place over the last three years are shown in Table 3.6, together with values observed during Typhoon Gloria which caused the heaviest flood ever known. Values of water stage shown in Table 3.6 are expressed in elevation and differ from the reading of water gauges or automatic recording water gauges. These values are based on the datum level shown in Table 3.7. However, the readings of water gauges and automatic recording water gauges are directly shown as elevations of water stage for Typhoon Gloria because surveyed values of datum levels were not available.

On the basis of the basin's topographical map, a brief account is given below on the topography and inundation condition in the downstream area subjected to frequent attacks of floods.

The downstream area of the Tan-shui which is often inflicted with severe inundation can be broadly divided into five districts, i.e., Kuan-tu district (west bank downstream district of the Keelung including Shih-pai district), Chung-chou-li district (district embracing She-tzu district and delineated by the Keelung, the Tan-shui and Chien-tan Embankment), Ta-chih Sung-shan district (district extending upstream from the Chun-shan Bridge along the Keelung), Li-chou district (district embracing San-chung city and extending along the west bank of the Ta-han Creek and the Tan-shui) and Chiang-tzu-tsui district (deltaic district delineated by the Ta-han Creek and the Hsin-tien Creek near the confluence of the two rivers). *

* In the following sections, flood forecasting and warning in the five districts will be studied, but inundations caused by inside waters in Taipei city which is surrounded by an embankment of El. 6.5 - 7.0 m will not be discussed.

Table 3.6 Maximum Discharge and Highest Water Stage

Location / Typhoon	Maximum Discharge and Its Occurrence Time: Maximum Discharge (m^3/sec)						Time of Occurrence (Date and Time)						Highest Water Stage and Its Time: Highest Water Stage (El m)						Time of Occurrence (Date and Time)					
	Hsin-hai Bridge	Chung-cheng Bridge	Kuang-fu Bridge	Taipei Bridge	Chung-shan Bridge	Shih-tzu-tou	Hsin-hai Bridge	Chung-cheng Bridge	Kuang-fu Bridge	Taipei Bridge	Chung-shan Bridge	Shih-tzu-tou	Hsin-hai Bridge	Chung-cheng Bridge	Kuang-fu Bridge	Taipei Bridge	Chung-shan Bridge	Shih-tzu-tou	Hsin hai Bridge	Chung-cheng Bridge	Kuang-fu Bridge	Taipei Bridge	Chung-shan Bridge	Shih-tzu-tou
Elaine (Sep-Oct 1968)	1,770	3,860		5,170			1st 0.5 hrs	1st 1 hrs		1st 1 hrs			4.99	7.70	5.66	3.86	4.34	2.59	1st 0.5 hrs	1st 1 hrs	1st 1.5 hrs	1st 1 hrs	1st 4.5 hrs	1st 1 hrs
Betty (Aug 1969)	1,320	853		2,020			8th 15 hrs	8th 16 hrs		8th 16 hrs			3.75	3.08		2.57	1.78		8th 15 hrs	8th 16 hrs		8th 16 hrs	8th 17.5hrs	
Tropical Depression (Sep 1969)	936	2,520		3,550			12th 0 hrs	11th 21 hrs		12th 1 hrs			4.13	5.83	4.39	3.55	3.72		12th 0 hrs	11th 21 hrs	11th 21 hrs	12th o hrs	12th 1 hrs	
Elsie (Sep 1969)	4,300	6,040		7,460			27th 7 hrs	27th 4 hrs		27th 6-7 hrs			6.59	8.30	6.50	4.83	3.66	3.17	27th 7 hrs	27th 4 hrs	27th 4.3hrs	27th 5 hrs	27th 6 hrs	27th 6-7 hrs
Flossie (Oct 1969)	First Peak 2,220	4,530		First Peak 6,450			3rd 6 hrs	3rd 5 hrs		3rd 5 hrs			5.51	6.85	5.49	4.35		2.80	3rd 6 hrs	3rd 5 hrs	3rd 6 hrs	3rd 6 hrs		3rd 22-23hrs
	Second Peak 2,040	4,650		Second Peak 6,300			4th 5-6hrs	4th 7 hrs		4th 6 hrs			5.49	7.05	5.70	4.61	4.88	3.00	4th 5-6hrs	4th 7 hrs	4th 7 hrs	4th 6-7hrs	4th 9 hrs	4th 8 hrs
Fran (Sep 1970)	1,770	3,950		4,780			7th 2 hrs	7th 1 hrs		7th 12 hrs			4.75	6.42	4.75	3.57	2.95	2.50	7th 2 hrs	7th 1 hrs	7th 1 hrs	7th 2 hrs	7th 3-4hrs	7th 3 hrs
Gloria (Sep 1963)		6,300		14,900				11th 17 hrs		11th 20 hrs			higher than 8.30	9.26		6.70	6.08	5.36		11th 17 hrs		11th 21 hrs	11th 22 hrs	11th 24 hrs-12th 1 hrs

Table 3.7 Datum levels of Water Stage Gauges

Unit: m

Name of Typhoon	Hsin-hai Bridge	Chung-cheng Bridge	Kuang-fu Bridge	Taipei Bridge	Chung-shan Bridge	Shih-tzu-tou
Elaine (1968)	-0.51 (Estimated value)	-0.95 (Estimated value)	-0.64 (Estimated value)	-1.17 (Estimated value)	-0.56 (Estimated value)	-0.04 (Estimated value)
Betty (1969)	-0.51	-0.95		-1.17	-0.56	
Tropical Depression (1969)	-0.51	-0.95	0	-1.17	-0.56	0
Elsie (1969)	-0.51	-0.95	0	-1.17	-0.56	0
Flossie(1969)	-0.51	-0.95	0	-1.17	-0.56	0
Fran (1970)	-0.56	-1.02	-0.10	-1.41	-0.67	+0.08

Note: As regards the datum level of the water stage gauge at Chung-cheng Bridge, surveying conducted in 1969 disclosed a value of -0.924 m for staff gauge I (5.19-6.10 m) and -0.975 m for staff gauge II(6.10-9.00 m). Averaging these two values, 0.95 was adopted in this table. Surveying likewise conducted in 1970 produced -1.006 m and -1.029 m; these two values were averaged and -1.02 m was adopted in this table.

Kuan-tu tide gate is equipped with a total of 14 flap gates having a diameter of 2 m, and 3 m wide gate operated manually for navigation of small boats. The 1964 surveying disclosed that the tide gate had an elevation of 4.07 m on the top. The height of Kuan-tu tide embankment varies by place and ranges from 2.5 to 4.0 m in elevation. It is accordingly estimated that the inundation of this district starts when the downstream water stage of the Keelung rises beyond an elevation of about 2.5 m.

Chung-shan-li district ranges from 1.5 to 4 m in elevation but most of the district has an elevation of 3 m or less.

Ta-chih/Sun-shan district has an elevation ranging from 3 to 5 m and Chiang-tzu-tsui district from 2 to 7 m. The greater part of the two districts has an elevation of below 5.5 m.

Li-chou district, ranging from 0.5 to 5 m in elevation, is mostly covered with land lying below El. 2 m. The area extending along the Wen-tze, a small tributary flowing through Li-chou district, becomes inundated in rising tide because it has a very low elevation and no tide gate is constructed.

To explain the inundation condition in the Kuan-tu, Chung-chou-li and Li-chou districts, it is helpful to place it in proper perspective with the water stage at Shih-tzu-tou taken as the basis. To be more precise, flood water starts intruding into Chung-chou-li district when the water stage at Shih-tzu-tou reaches approximately El. 2 m, and when this rises beyond El. 2.5, the greater part of Kuan-tu district becomes inundated. As the water stage further increases to El. 3.5 m, practically whole of Li-chou district including San-chung city and the greater part of Chung-chou-li district are submerged under flood water.

*As we can see in Table 3.6, flood levels as high as El. 2.5m took place four times in only three years from 1968 to 1970.

**According to Table 3.6, the maximum water stage was El. 3.17m at Shi-tzu-tou at the time of Typhoon Elsie, but it rose up to 5.36m at the time of Typhoon Gloria.

The area extending on the left bank side of the Tan-shui and embracing San-chung city, which constitutes part of Li-chou district, is devoid of any embankments and has an extremely small ground surface elevation (less than 5 m). Hence, flood water of the Tan-shui often flows into the left bank side area of Li-chou district. This overflow condition will be better understood if explained on the basis of the water stage at the Taipei Bridge. Flood water overflows the left bank into Li-chou district at a point downstream of the Taipei Bridge when the water stage reaches about El. 3.2 m at the bridge, and overflows the entire left bank of the Tan-shui extending from the confluence of the Ta-han Creek and the Hsien-tien Creek when the water stage at the bridge rises to about 4 m. * When this latter situation is developed, Li-chou district is subjected not only to the intrusion of backwater created by the narrow river width near Shih-tzu-tou but also to the overflow of flood water of the Tan-shui. The water stage at the Taipei Bridge recorded a maximum of 6.7 m during the flood caused by Typhoon Gloria, and this means that the resultant overflow depth was as large as 2.7 m.

Chiang-tzu-tsui district has no embankments and is situated near the confluence of the Ta-han Creek and the Hsin-tien Creek. By reason of this unfavourable condition, the district suffers inundation whichever of the two rivers may overflow. The flood forecasting and warning for this district should therefore be planned on the basis of the water stage near the confluence.

In Ta-chih/Sung-shan district, the low-lying area stretching along the Keelung is vulnerable to inundation. When the water stage rises to about 4 m at the Chung-shan Bridge, flood water covers an extensive area in the district. It is therefore advisable that the water stage at the Chung-shan Bridge be taken as the basis for planning the flood forecasting and warning in the district.

Fig. 3.4 shows the topography of the downstream area of the Tan-shui. **

3.4 Flood Control Plan

Flood control of the Tan-shui involves substantial difficulties because the topography of the river basin is such that steep mountainous districts are directly connected to the densely populated flat area. Prominent among these difficulties is the problem of narrowing the gap between the flood discharge capacity and the design flood discharge at the Taipei Bridge. Many plans proposed to bring solution for this problem can be classified into the following three groups.***

1) A plan in which flood water of the Ta-han Creek, the largest tributary of the Tan-shui, is to be directly brought into the Straits of Taiwan from the upper reaches, or diverted into the Wen-tzu river by shifting the channel in San-chung city located opposite to Taipei, or controlled by a flood control dam constructed downstream of the Shih-men Dam.

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* It is considered that when the discharge at the Taipei Bridge reaches 6,500 m^3/sec, the flood water starts to overflow the left bank. According to the stage-discharge curve prepared by PWCB, the water stage corresponding to the said discharge is 5.5 m. Using the data shown in Table 3.7, this value can be converted to El. 4.1 m (approximate value) which shows a fair conformity to the value obtained from the topographical map.

** For a detailed explanation, refer to chapt. 5

*** This classification differs from authorized one by the Government of China.

2) A plan which envisages the control of the Hsin-tien Creek by a flood control dam constructed at a suitable upstream site such as Chu-chie.

3) A plan to improve the existing river channel to augment the discharge capacity.

These three plans were put to a detailed comparative study including model tests by the Government, whereby the conclusion was reached in 1965 that "diverting into the Wen-tzu river through a flood by-pass in San-chung city" envisaged under Plan 1) above would be most suited for the purpose. With further prudent studies made on this plan and technical opinions obtained from the Corps of Engineers of U.S. Army, the Integrated Planning Committee on Water Resources, Ministry of Economic Affairs prepared the "Report of the Study on the Flood Prevention Plan in Taipei District" for submission to the Government. In this report, the Committee states that the best plausible plan is to effect some minor changes to the alignment of the flood by-pass envisaged under the above-mentioned diversion plan so that the channel deviation will be started at a place downstream of the originally proposed point.* Fig. 3.5 shows the outline of this plan which is quite unique in that the planned by-pass cuts through San-chung city and the area along its either bank is proposed to be designated as " "Class 1 Restriction Area" where strict restrictions will be imposed on building construction.

The design flood discharge at an annual occurrence probability of 1/200, on which the plan is based, is taken at 25,000 m^3/sec for Taipei Bridge, 23,500 m^3/sec for Chiang-tzu-tsui (Ta-han Creek), 10,800 m^3/sec for Wan-hua (Hsin-tien Creek), and 4,000 m^3/sec for Kuan-tu (Keelung river). Of the total flow of 25,000 m^3/sec at the Taipei Bridge, 11,000 m^3/sec is planned to be diverted into the flood by-pass.

The by-pass is planned to have a width of about 650 m and an elevation of 3.0 m at its inlet.

At time of a flood, the low-lying land extending on the downstream left bank side will be inundated if the discharge at Kuan-tu exceeds 2,600 m^3/sec. The by-pass area covers an acreage of 585 ha within which any construction work or transfiguration of the existing topography will be categorically banned. According to the plan, however, inundation of this area takes place only when the water stage at the Taipei Bridge rises beyond 5.0 m, and since this high water stage is considered to occur no oftener than once in about three years, the area may be used for crop cultivation or as a playground.

All the other districts, to be protected by embankments, will have a total area of about 17,400 ha.

3.5 Hydrological Observation Facilities

Of all the stations established within the Tan-shui basin for observation of rainfall, water stage and discharge, those which are considered instrumental in the forecasting and warning of flood runoff are listed in Tables 3.8 and 3.9 together with their locations.

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* This plan is called the "Flood Way Plan No. 2."

Table 3.8 Rain Gauge Stations in Tan-shui Basin

Name of River	Name of Station	Station No.	Commencement of Ordinary Rainfall Observation	Commencement of Automatic Rainfall Recording	Observation Equipment and Instrument	Elevation of Station (m)	Supervising Agency	Communication Method	Other Observation Items
	Chen-hsi-pao	1	Jul 1954	Oct 1958	Siphon	1550	SRCO		7,10,17,1
	Pai-shih	3	Jul 1954	Apr 1959	Stevens	1630	"		
	An-pu	5	Jun 1954	May 1959	Siphon	1450	"		
	Hsiu-luan	6	Jun 1954	Apr 1958	"	840	"		
	Yu-feng	7	Jun 1954	Jun 1964	"	770	"	Radio Telephone	
	Ka-la-he	88	Jul 1956	Jan 1958	"	1160	"		
	San-kuang	9	Jun 1954	Jan 1958	"	630	"		1,7,14,17
	Pa-chun	12	Jul 1954	Jan 1966	"	1220	"	Radio Telephone	
	Kao-i	15	Jun 1954	Jun 1964	"	606	"	"	
	Hsia-yun	114	Jan 1965	Apr 1965	"	351	"	"	
Ta-han Creek	Fu-hsing	17	Jun 1954	Aug 1958	"	423	"		7,8,9
	Shui-liu-tung	18	Aug 1948	-		340	PWCB		
	Chang-hsing	110	Jun 1963	Jul 1964	Siphon	350	SRCO		
	Shih-men	22	Jan 1926	Jan 1958	"	169	"	Radio Telephone	
	Ta-hsi	24	Aug 1948	-		118	Tao-yuan Irr.		
	Chueh-tzu	27	Jul 1938	-		125	"		
	Ta-pao (1)	29	Aug 1954	-		242	SRCO		
	Ta-pao (2)	125	-	Dec 1967	Tele-meter	580	PWCB	Tele-meter	
	San-hsia	30	Jan 1950	-		33			
	Ta-liao	31	Aug 1954	-		150	SRCO		
	Shu-lin	32	Sep 1950	-		15	Tao-yuan Irr.		
	Pan-chiao	34	Aug 1948	-		8	"		6
	Hu-shan	37	Nov 1953	Jan 1954	Tamaya	420	TPC		1,10,7
	Tung-hou	121	Jan 1968	Jan 1968	Siphon	600	"	Tele-meter	
	A-yu	38	Jan 1951	Jan 1964	Tamaya	215	"		
	Hsin-hsien	39	Jan 1951	Jan 1964	"	221	"		
	Wu-lai	41	Jan 1951	-		204	"		
Hsin-tien Creek	Hsiao-liao	126	-	Dec 1967	Tele-meter	600	PWCB	Tele-meter	
	Kuei-shan	42	Jan 1951	-		152	TPC		
	Kan-kou	50	Nov 1952	Aug 1953	Tamaya	120	"		1,3,7,10,16
	Ping-lin	127	-	Sep 1969	Tele-meter	920	TWB		
	Tsu-keng	55	Jan 1951	-		57	TPC		
	Hsin-tien	56	Dec 1948	-		23	Liu-kung Irr.		
	Shih-ting	124	Jul 1968	-	Tamaya	95	PWCB		
	Huo-shao-liao	69	Apr 1955	Apr 1955	U.S.A.	380	"		
Keelung river	Jui-fang	71	Nov 1962	-		90	"		
	Keelung	73	Jul 1901	Jan 1939		60	TWB	Telegram	4,7,8,9
	Wu-tu	106	Jan 1963	Jun 1965	Tamaya	16	PWCB	Radio Telephone	
	Taipei (1)	64	Jan 1953	Jan 1953	Stevens QAC	8	"	Telephone	
	Taipei (2)	65	Jan 1897	Jan 1918	Siphon	8	TWB	"	
	Yang-ming-shan	92	Apr 1957	-		430	PWCB		
Tan-shui river	Ta-tun-shan	79	Apr 1952	Apr 1952	Siphon	1098	TWB		
	Chu-tzu-hu	80	Jan 1931	Jan 1931	"	600	"	Telephone	
	An-pu	81	Jul 1946	Jul 1946	"	836	"	"	1,4,10,14,17
	Shung-chun-tou	82	Jan 1948	-		76	PWCB	"	
	Tan-shui	83	Jan 1903	Jan 1903	Siphon	19	TWB	Telegram	

Note: Numbers given in the column of "Other Observation Items" have the following meanings.
1 - Evapo-pan. 3 - atomospheric pressure. 4 - barometer.
7 - Readings of wet and dry bulb theremometer. 8 - Highest temperature.
9 - Lowest temperature. 10 - Reading of maximum and minimum theremometer.
14 - Wind direction. 15 - Anemometer record.

Table 3.9 Water Stage and Discharge Observation Stations in Tanshui Basin

Name of River and Tributary		Name of Station	Basin Area (km^2)	Commencement of Ordinary Water Stage Observation	Commencement of Automatic Water Stage Recording	Commencement of Discharge Observation	Observation Equipment and Instrument	Supervising Agency	Communication method
Ta-han Creek		Shihmen Reservoir	758.85					SRAB	Radio telephone
		Ta-hsi	799.7		Aug 1960		Richard	PWCB	
		Yuan-shan	850.9			Jun 1959		SRAB	
		San-hsueh	861.0			Jan 1970	Needle type gauge	PWCB	
Hsin-tien Creek		Hsin-hai Bridge	1156.0		Jun 1962		Richard	"	Radio telephone
	Pei-shih creek	Ping-lin	114.5	Jul 1958				"	
		Kan-kou	258.0			Oct 1942	Otto	TPC	
	Nan-shih creek	Hu-shan	160.4			Oct 1942	K type	"	
		Hsin-hsien	187.8			Apr 1965		"	
	A-yu creek	Hsiao-i	24.2			Apr 1965	Otto	"	
	Ching-mei creek	Mu-cha	102.3		Dec 1968		Richard	PWCB	
		Ching-mei	115.0				Otto	"	
		Chu-chih	645.65			Jul 1970	Stevens	"	Radio telephone
	Hsin-tien creek	Hsiu-lang				Jan 1970	Needle type gauge	"	
		Hsin-tien	716.8	Sep 1953				"	
		Shui-yuan-ti	874.8	Aug 1962				"	
		Chung-cheng Bridge	876.85				K type	"	Radio telephone
		Kuang-fu Bridge			Jun 1966		"	"	
Keelung River		Wu-tu	208.31			Sep 1962	Stevens	"	Radio telephone
		Chung-shan Bridge	401.07		Aug 1964		K type	"	"
Tan-shui River		Taipei Bridge	2083.22		Sep 1964	Sep 1964	K type	PWCB	
		Ta-lung-tung	2110.3		Jan 1966	Jan 1966	Stevens	"	
		Shih-tzu-tou			Jun 1962		K type	"	
		Tu-ti-kung-pi	2689.0		Mar 1966		Richard	"	
		Yu-che-kou	2725.82				Pressure type	"	

Fig. 3.4 Topography of the Lower Reaches of the Tan-shui River

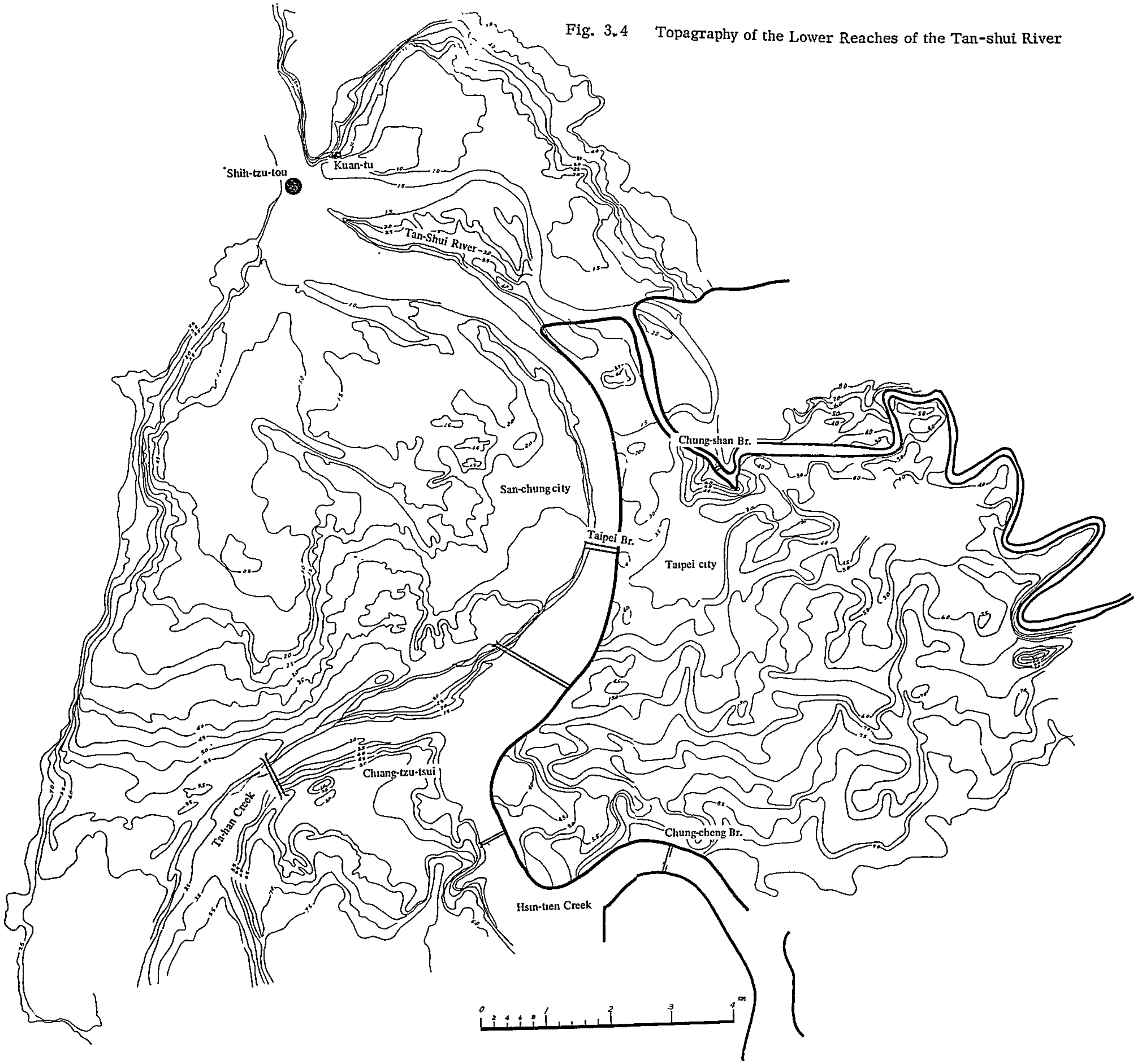


Fig. 3.5 Flood Contral Plan

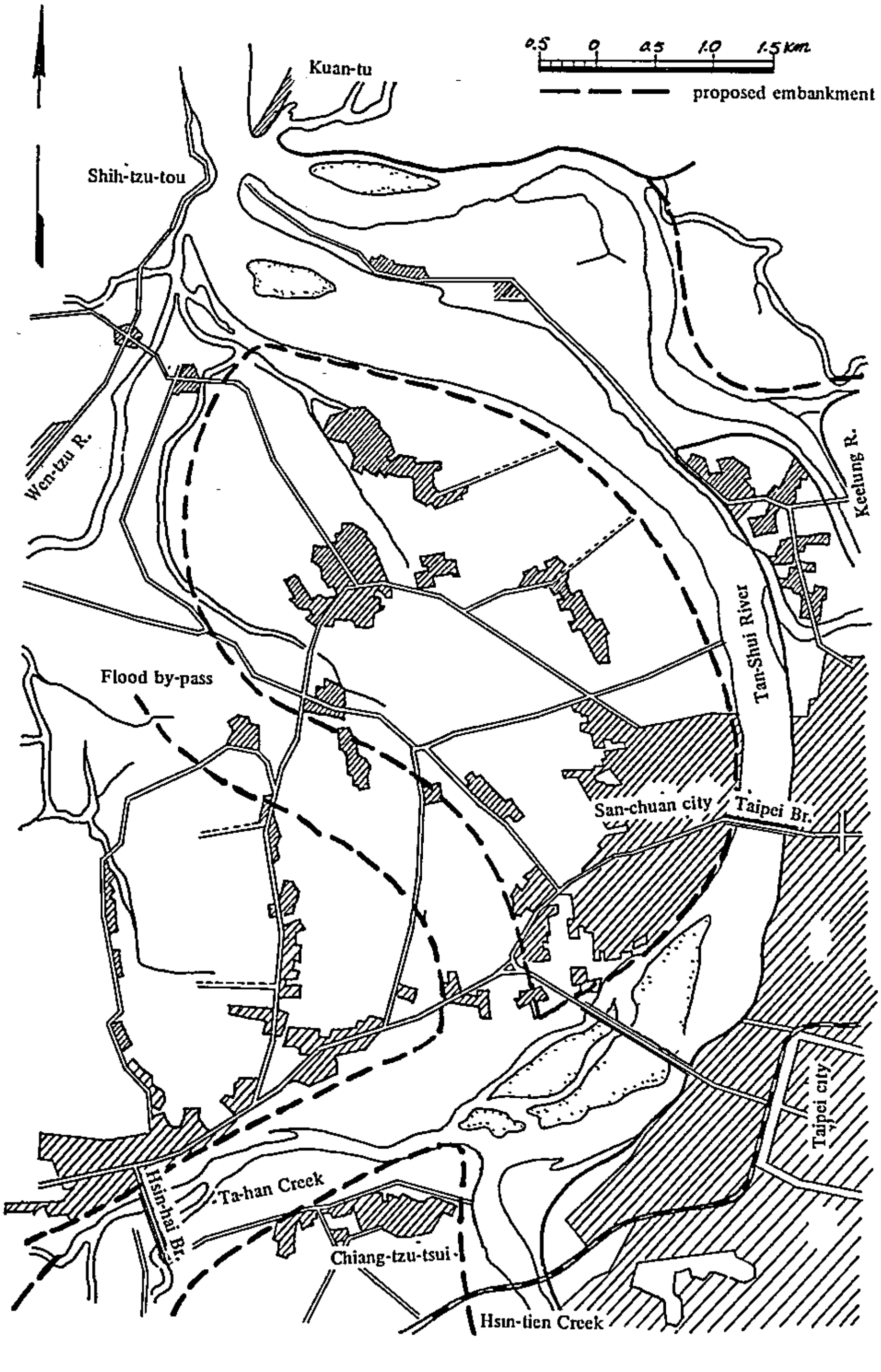
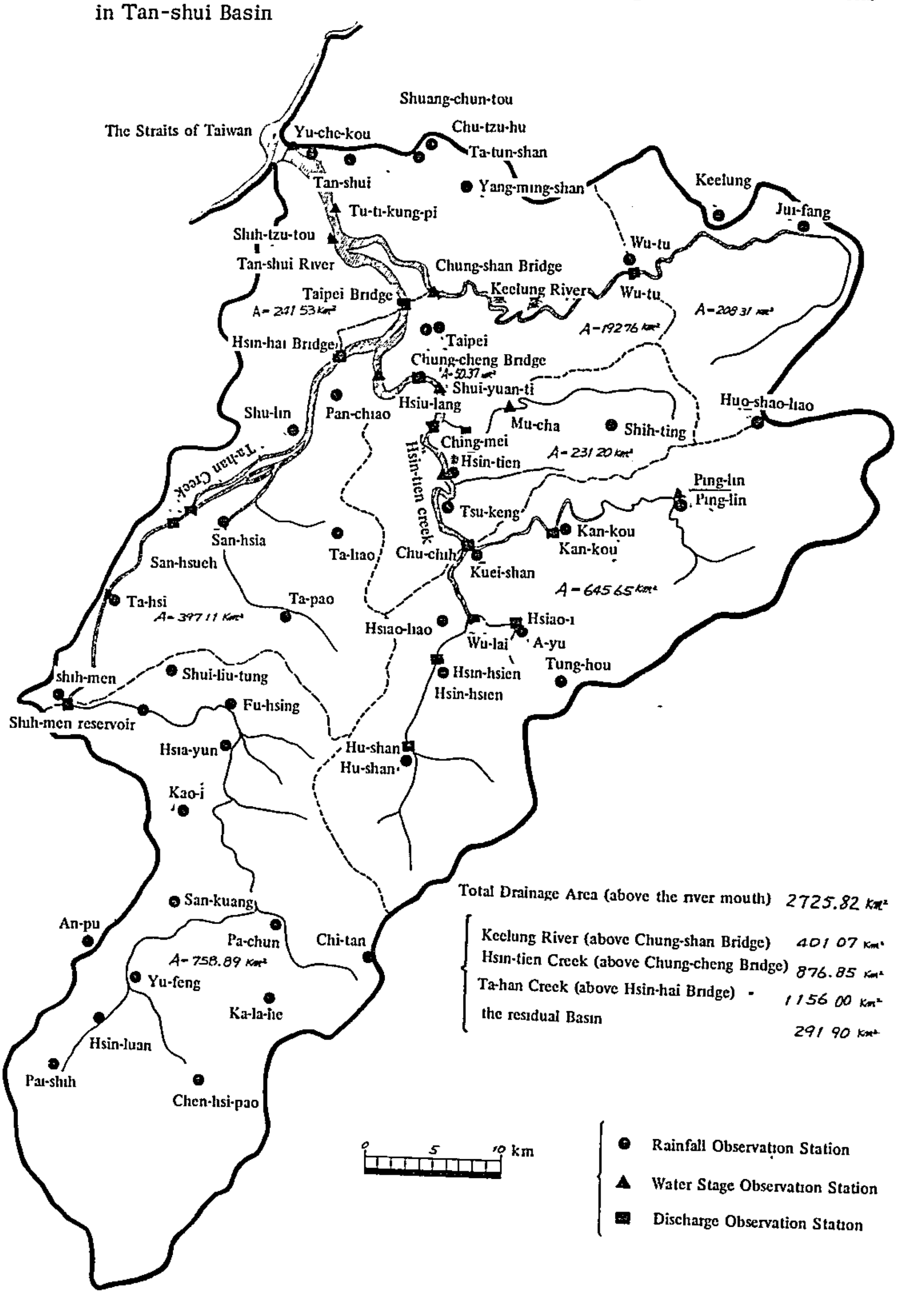


Fig.– 3.6 The Locations of Rainfall, Water Stage and Discharge Observation Stations in Tan-shui Basin



3.6 Existing State of Communication Facilities

PWCB, WB and Shih-men Reservoir Administration Bureau have their own and respective communication systems in the Tan-shui basin. The configuration of these systems is shown in Fig. 3.7.

The PWCB has two rainfall telemetering stations, one at Hsiao-liao and the other at Ta-pao. The timer-triggered transmitter installed at either place sends out observed values by the one-way pulse-count system at a frequency of 49.9 MHz and a transmitting output power of 1 W. At other telemetering stations of the PWCB, established at Wu-tu, Chung-shan Bridge, Taipei Bridge, Chung-chen Bridige, Hsin-hai Bridge and Chu-chie, antenna facilities alone are installed so that observation staffs dispatched to these stations at time of a flood may be allowed to transmit the observed values by means of a radio equipment (39.5 MHz, 30 W or 5 W).

The Weather Bureau has a rainfall telemetering system connecting the automatically operated relay station at Mt. A-yu and two observation stations (one at Pin-lin and the other at Kui-shan island located outside the basin) from which observed values are transmitted at a frequency of 402 MHz and 405 MHz and a transmitting output power of 0.3 W by the timer-triggered pulse-count system.

The Shih-men Reservoir Administration Bureau has four observation stations (Hsia-yun, Kao-i, Yu-feng and Pa-chun) and two relay stations (Mt. Ta-ping and Mt. La-hao). When a flood develops, staffs sent to the observation stations transmit the observed values using a radio equipment (35.3 MHz or 35.47 MHz, 60 W). From the relay stations, the observed values are relayed verbally by its staffs.

A 35.23 MHz 60 W press talk telephone network is established between the Shi-men Reservoir Control Office and PWCB for fixed time communication between the two. However, since this system does not permit direct telephone communication, inter-communication between the two places resorts to the verbal relaying at Mt. Ta-ping.

Above is the outline of the existing telecommunication systems for flood forecasting and warning in Tan-shui basin. In planning the forecasting and warning facilities, attention must be directed to the following drawbacks of the existing telecommunication system.

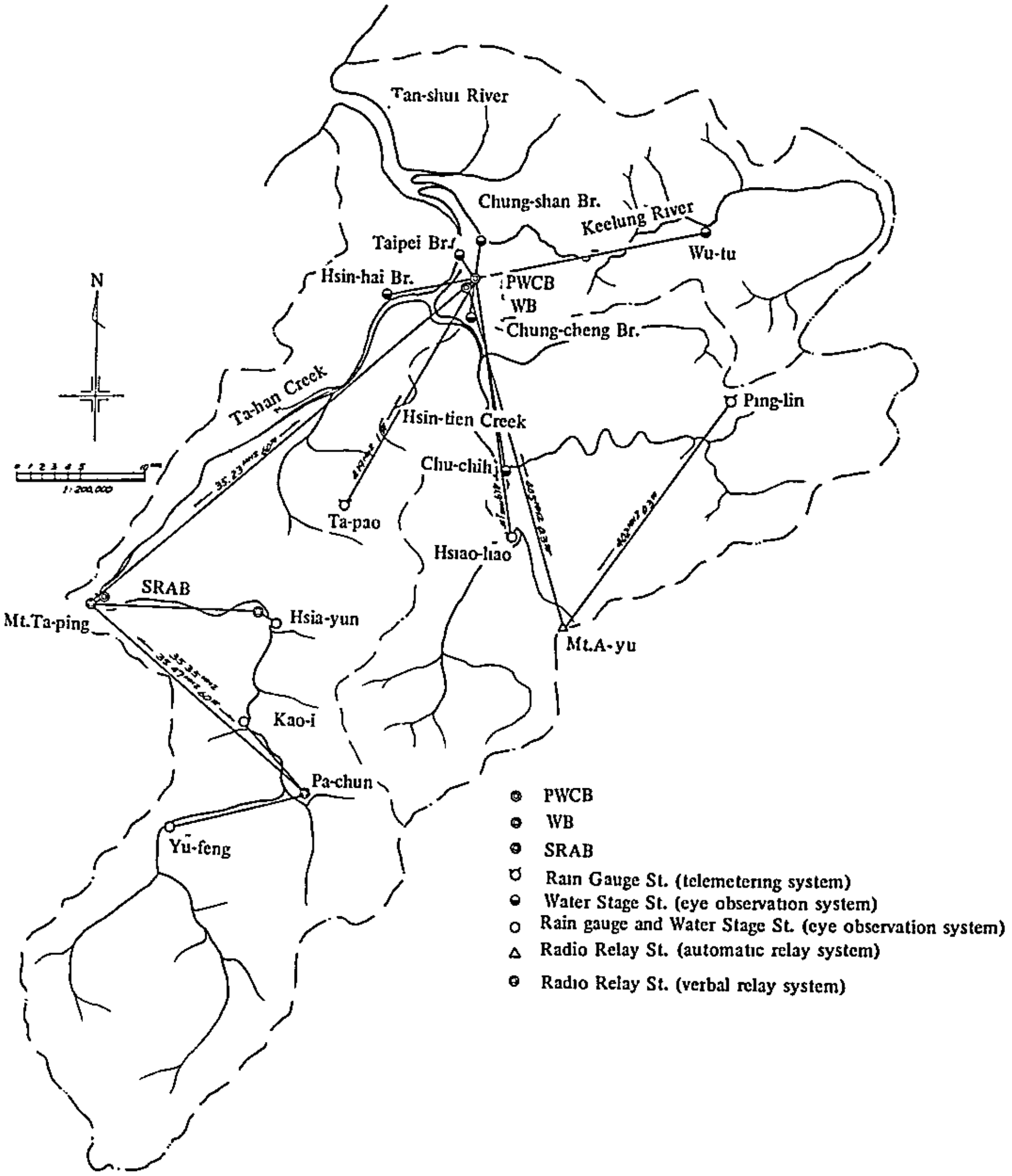
(1) Noise in the 30 MHz band is extremely large in Taipei city and therefore, it is not possible to ensure system stability.

(2) As compared with the automatic system, the eye observation and verbal relay system is lower in both efficiency and reliability.

(3) The telemetering system of the pulse count method is not only more vulnerable to interference and other disturbances but also less reliable than the digital coding system.

(4) Stations located at places geographically difficult of access are liable to be given deficient maintenance and inspection service.

Fig. 3.7 Existing telecommunication systems for flood forecasting and warning in the Tan-shui River Basin



(5) In the Tan-shui basin, both the temperature and humidity are high and heavy rainfall and many thunders are also observed.

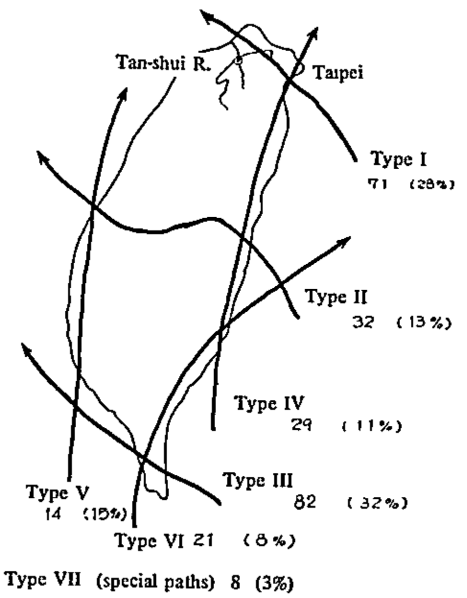
(6) Since the communication systems are not integrated and the communication method not standardized, not only the equipment interchangeability is made difficult but also accurate and quick exchange of necessary data between stations is made impossible.

4.1 Rainfall in the Tan-shui Basin

Almost all floods in the Tan-shui basin are caused by the rainfall due to typhoons. The relationship between typhoons and rainfall must therefore be clarified in planning the flood forecasting and warning system for the basin.

In Taiwan, paths of typhoons attacking the island are divided into seven as illustrated in Fig. 4.1, and studies have been made on the relationship between rainfall and typhoons approaching the island along each of the seven paths. * The Water Conservancy Bureau prepared maps showing the paths of all typhoons that attacked Taiwan in any substantial degree since 1903 and the isohyetal lines of total rainfalls brought about by such typhoons. An analytical study conducted on the basis of these maps revealed that most dangerous typhoons for the Tan-shui basin approach the island through Path I shown in Fig. 4.1. Table 4.1 shows the paths of several typhoons that caused flood damages in the basin in recent years. As will be clear in the table, typhoons not taking path I also brought about floods of substantial magnitude, indicating that the relationship between the path of typhoon and rainfall is rather complicated.

Fig. 4.1 Classification of Typhoon Paths 1891~1966 (PWCB)



* Ming-Tung Hsu : Distribution of Storm Rainfall in Taiwan District, Report on Rainfall, the Taiwan Provincial Weather Bureau, 1969, pp. 1~19.

Table 4.1 Typhoons which Caused Floods

Typhoon	Type of path	Water Stage at Taipei Br. (m)
Gloria	I	6.70
Cora	I	
Carla	III	
Gilda	II	
Elaine	III	3.86
Betty	I	2.57
Elsie	II	4 83
Flossie	IV	4.61
Fran	I	3.57

Note: Water stages are from Table-3.6.

Fig. 4.2 shows isohyetal lines of total rainfalls recorded by some of the typhoons that attacked the basin recently. Though the distribution of total rainfall may vary to some extent by the course of typhoons, the size of the basin would not make it practicable to associate the distribution of total rainfall with flood forecasting.

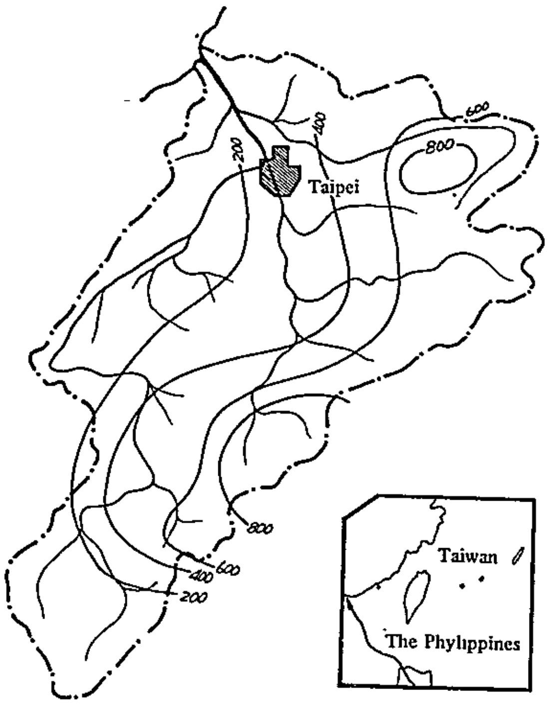
Fig. 4.3 shows isohyetal lines prepared with a time interval of six hours for storm rainfall of Typhoon Gloria.

By comparing these figures with changes of the location of typhoons, the relationship between the shifting of the area of intensive rainfall and the position of typhoon can be brought to light and it can also be disclosed the changes in the inter-relationship presents a pattern peculiar to the Tan-shui Basin.*

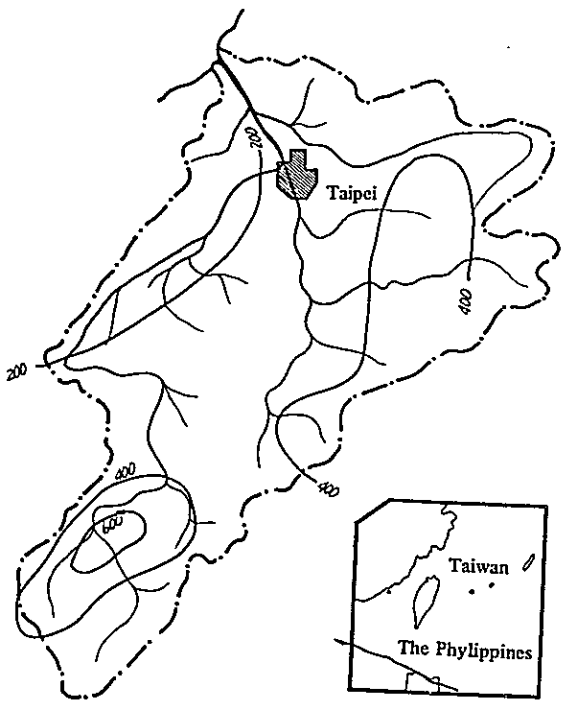
* A powerful step forward should be taken for reinforcing analytical studies of this sort because they provide useful data required in the actual flood forecasting and warning work. Further, it is desirable that a meteorological radar for rainfall forecasting be installed within the basin or at a suitable site outside the basin.

Fig. 4.2 Total Rainfall Caused by Typhoons (mm)

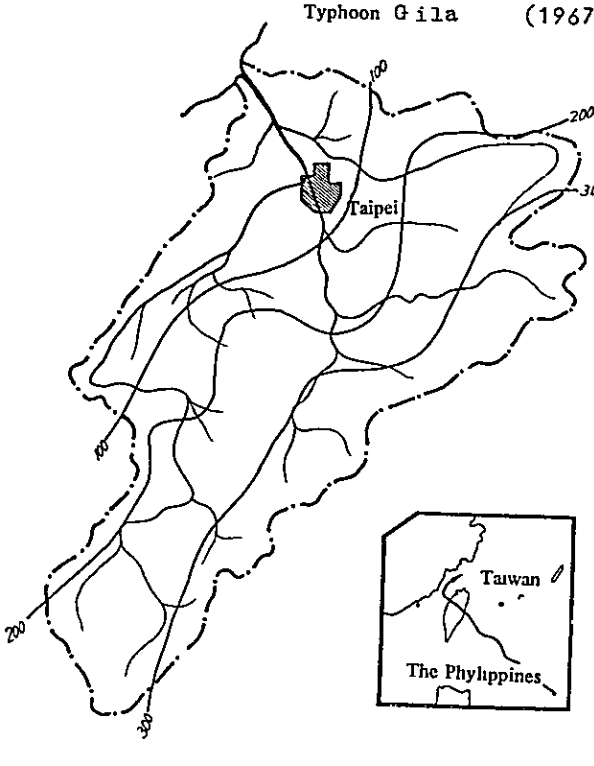
Typhoon Elaine (1968)



Typhoon Carla (1967)



Typhoon Gila (1967)



Typhoon Gloria (1963)

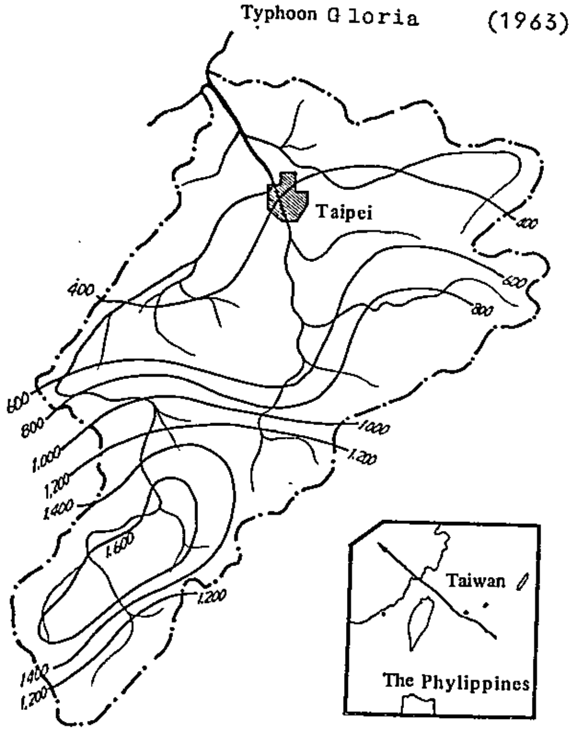
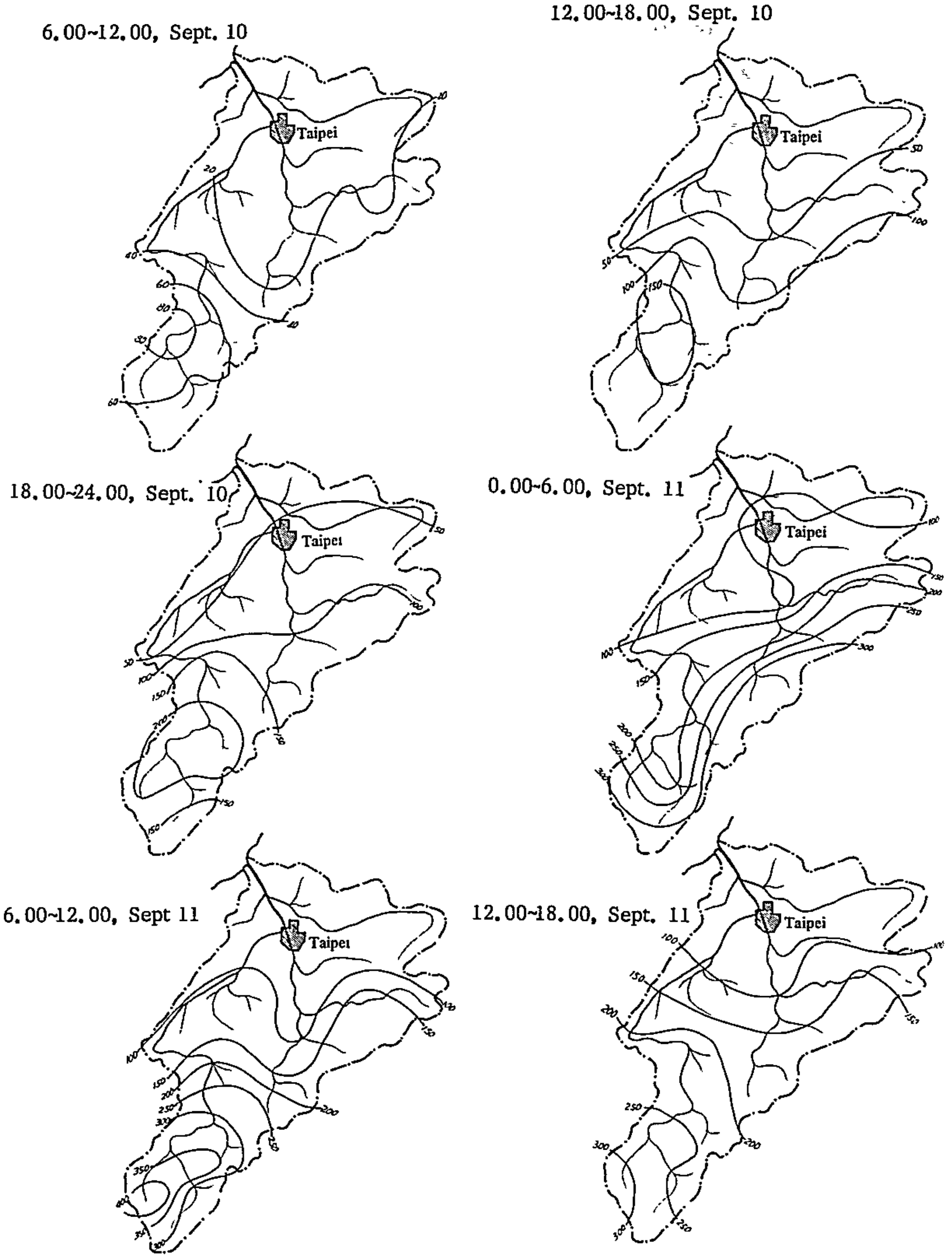


Fig. 4.3 Hourly Distribution of Rainfall (mm) (Typhoon Gloria)



4.2 Location of Rain Gauges

The rain gauges for flood forecasting and warning should be equipped with telemeter or radio equipment because they are required to be capable of transmitting data within a short time.

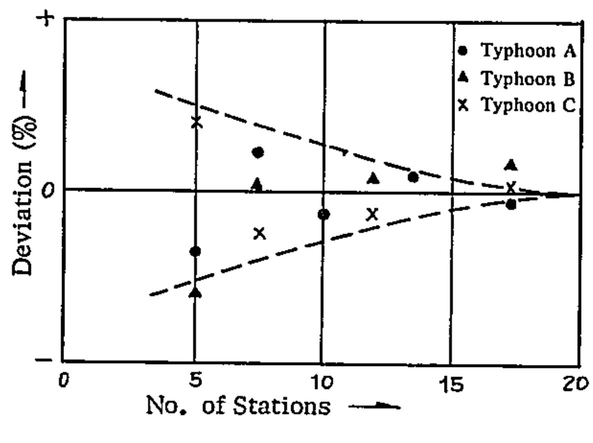
Their number and locations should be so determined as will accurately represent the rainfall in the basin. Selection of locations allowing easy maintenance and operation is also quite important in the Tan-shui basin which is surrounded by steep mountains.

As shown in Table 3.8, Chapter 3, there are a total of 46 rain gauges in the Tan-shui basin, of which 9 are capable of transmitting data by telemeter or radio equipment, 30 are recording rain gauges and 16 are ordinary rain gauges.

Needless to say, increase in the number of rain gauges leads to more accurate rainfall observation in the basin if they are properly distributed, but it also invites increased cost. Therefore, the number of rain gauges should be determined on the basis of the comparison between the cost for maintaining one station and the improvement of rainfall observation accuracy attainable by the operation of that station. This problem may not be solved readily if tackled in a straight forward manner.

If the relationship between the number of rain gauge and the accuracy of rainfall observation alone is to be sought, a diagrammatical method shown in Fig. 4.4 can be employed. In this method, the true value of the average rainfall over the basin is assumed to be the value obtained from Thiessen poligons or a isohyetal map prepared on the basis of rainfall data collected from all the stations in the basin, then the difference between the basin's average rainfall obtained by decreasing the number of stations successively and the true average value is graphically shown. Since this difference varies considerably by respective rainfalls and also by the selection of stations, it is of trial selections of stations.

Fig. 4.4 Relation betw. Accuracy and No. of Stations



However, application of the above method for preparation of hyetographs is generally impracticable because of the deficient number of stations in the basin. The method is therefore applicable only for total or daily rainfalls.

As for the Tan-shui River, though the number of rainfall stations is enough, observed data during floods are not adequate and this fact makes it not possible to apply this method.

Taking, therefore, the result of rainfall analysis as a basis, a system shown in Fig. 4.5* is presented and is reviewed to find out how accurately it can produce the rainfall distribution for major floods that took place in the past.

Table 4.2 shows the coverage and its percentage of each station calculated from Tiessen polygons shown in Fig. 4.5. Fig. 4.6 shows a comparison of the time distributions of rainfalls of each tributary calculated by the said coverage percentage and those got by all the stations available. **

Table 4.3 shows the coefficient of correlation between the two comparing average total rainfalls in the basin. Since the coefficient is within the range from 0.85 to 0.99 it may be said that rainfalls can be well represented by this system. ***

As regards the calculated values of flood runoff involving errors arising from the divergence of the observed average rainfall from the true value, detailed description will be given in Chapter 6.

Table-4.2 Coverage of Rainfall Stations

Upper figures: Covered area Lower figures: Coverage

Station	Tan-shui R	Ta-han C.		Hsin-tien C.	Keelung R	
	Downstream of Confluence	Upstream of Shie-men	Shie-men Re ~ Hsin-hai Br	Upstream of Chung-chen Br	Chung-shan Br Wu tu	Upstream of Wu tu
Pai-shih	2344 0.098	2344 0.310				
Yu-feng	166.4 0.070	166.4 0.220				
Chi tan	2247 0.094	2073 0.274		174 0.020		
Shih-men	1676 0.070	893 0.118	78.3 0.193			
Hu-shan	230.2 0.096	242 0.032	15.0 0.037	1910 0.220		
Ta-pao	340.8 0.143	348 0.046	268.7 0.662	373 0.043		
Taipei	165.9 0.069		43.9 0.108	66.0 0.076	56.0 0.371	
Mt.Ta-tung	245.8 0.103			245.8 0.283		
Ping-lin	3021 0.126			2848 0.328		173 0.083
Wu tu	306.0 0.128			26.1 0.030	88.9 0.589	1910 0.917
Chu tzu hu	6.1 0.003				6.1 0.040	
Total	2,390.0 1000	756.4 1000	405.9 1000	868.4 1000	1510 1000	208.3 1000

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* ECAFE/WMO Typhoon Mission recommended to install rain gauges with transceivers at Pai-shih, Pa-chun, Hsiao-liao, Ping-lin and Huo-shao-liao (Report of the ECAFE/WMO Preparatory Mission on Typhoons, May 1967).

** Since the numbers of rainfalls and tributaries available for comparison were rather limited, Fig. 4.6 was prepared for those rainfalls which meet the purpose of checking the influence on the calculated values of runoff.

*** Where the coefficient is r, $r^2 \times 100\%$ in the dispersion of rainfall is determined by the correlation of the two, and it may be considered that $(1 - r^2) \times 100\%$ arises by chance.

Table-4.3 Accuracy of Average Rainfall over Basins Based on Telemetered Stations

Basin	Flood No.	Duration of Calcuration		Coefficient of correlation
		from	to	
Keelung R. (Upstream of Wu-tu)	№ 8	10.00, 26th	23.00, 27th	0.9877
〃	№ 10	10.00, 5th	15.00, 7th	0.8552
Ta-han C. Shih-men Re. Hsin-hai Br.	№ 5	15.00, 27th	1.00, 1st	0.9898
〃	№ 9	12.00, 1st	9.00, 6th	0.9969
Hsin-tien C. (Upstream of Chun-chen Br.)	№ 5	12.00, 27th	1.00, 1st	0.9125

Fig. 4.5 Thiessen Diagram of Tan-shui River

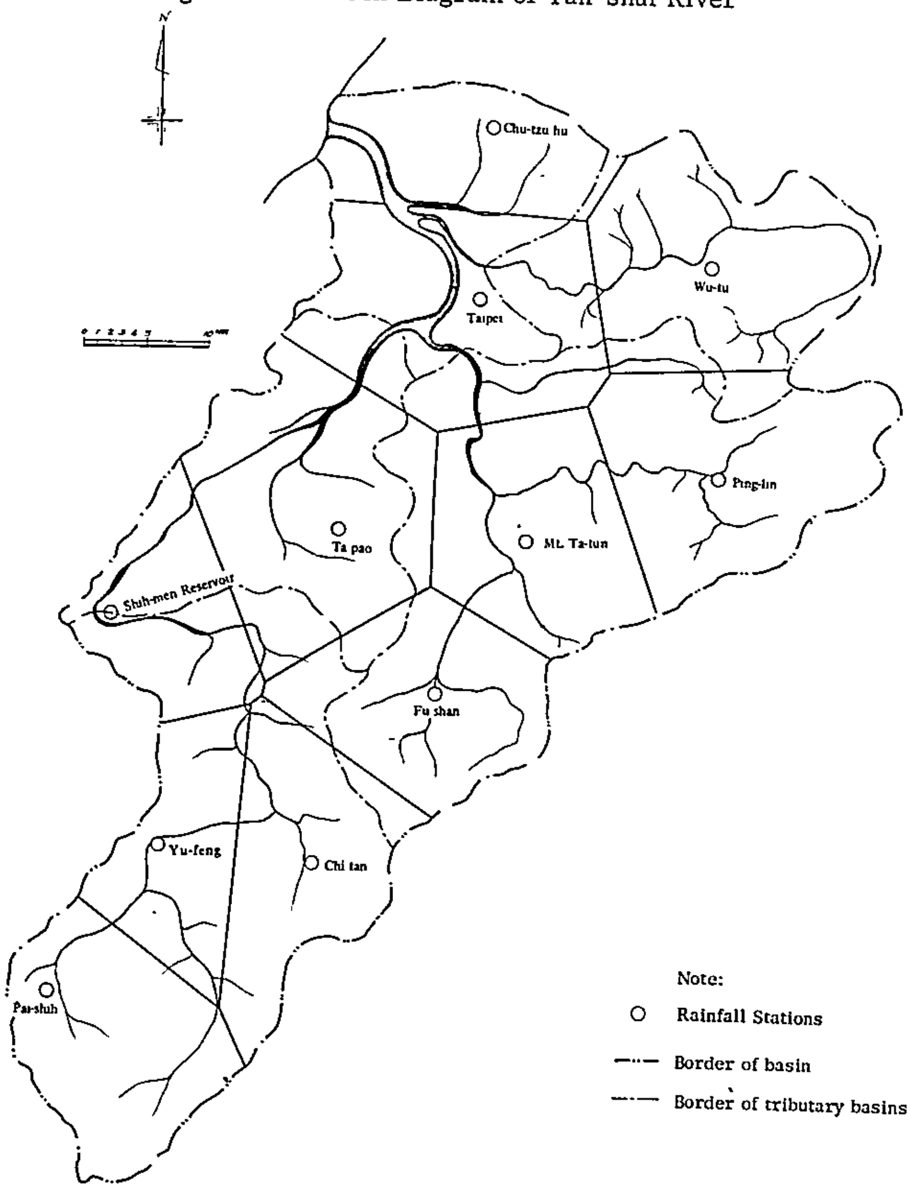
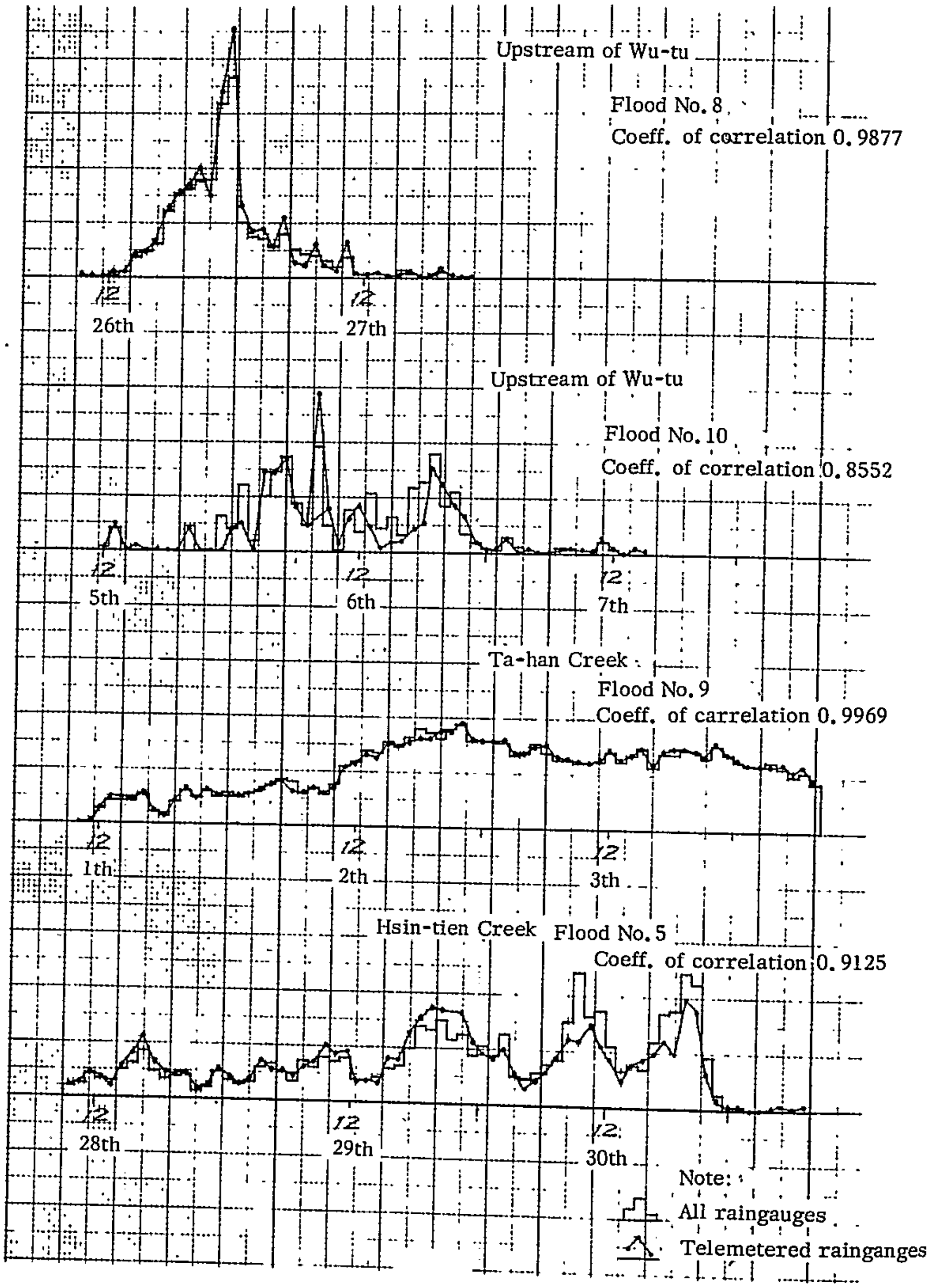


Fig. 4.6 Comparison of Average Rainfall



CHAPTER V ANALYSIS OF FLOOD

5.1 Flood Data

In the Tan-shui river basin, observation of storm rainfall, water stage and discharge was conducted at time of floods even before the World War II. As shown in Tables 3.8 and 3.9, however, a full scale hydrological observation network came into being in 1950's for rainfall and 1960's for water stage and discharge.

As basic analytical data required for the establishment of the flood forecasting and warning system plan, observation data of the 11 floods (including the one caused by Typhoon Gloria of 1963) recorded up to 1970 are available as shown in Table 5.1.*

Table 5.1 11 Floods in Tan-shui Basin for Analysis

Flood No.	Name of Flood	Time of Occurrence	Average Total Rainfull in the Basin	At Time of Flood Peak at Taipei Bridge	
				Water Stage (m)	Discharge (m^3/sec)
0	Gloria	Sep. 1963	823	(6.67)	14850
1	Cora	Sep. 1966	267	(3.62)	2220
2	Tropical Depression	Sep. 1966	408	(4.04)	2810
3	Carla	Oct. 1967	467	(3.83)	2740
4	Gilda	Nov. 1967	148	(4.00)	4100
5	Elaine	Sep. 1968	641	(5.03)	5170
6	Betty	Aug. 1969	214	2.57	2020
7	Tropical Depression	Sep. 1969	596	3.54	3550
8	Elsie	Sep. 1969	386	4.81	7460
9	Flossie	Sep. 1969	866	4.33	6450
10	Fran	Sep. 1970	417	3.81	4780

Note: Values of water stage are expressed in datum elevation of Taiwan. Values in parentheses, however, indicate the readings of water gauges because the datum levels were not clear.

* By virture of substantial efforts exerted by the parties concerned, the hydrological data at time of floods such as rainfall, water stage and discharge are observed with relatively good accuracy, in order by item and kept in strict custody. An item-wise study revealed, however, that these data, despite of the labour devoted to their collection, were not fully utilized for the flood survey in the basin and as a consequence, a data arranging system did not appear to have been established to meet the need for flood runoff analysis, inundation surveying, etc.

5.1.1 Rainfall Data

As shown in Table 3.8, there are a total of 46 rain gauges in the basin, of which 41 are established in tributary basins (4 at Keelung and An-pu etc. located outside the Tan-shui Basin inclusive). Thus, rain gauges are installed at a density of one to approximately 60 km^2. However, the number of rain gauges which provided rainfall data for the flood runoff analysis (i.e., the rain gauges by which PWCB can obtain rainfall data at all times) is only 15 even after 1969, so that each of them covers an area of approximately 162 km^2.

According to the survey conducted by the U.S. Weather Bureau in 1960* , Taiwan ranks among the top ranking areas in the density of rain gauges. But the rainfall observation network should be expanded for flood forecasting and warning.

In any event, it is clear that the number of rain gauges in the Tan-shui river basin is never sufficient, and it is a matter of controlling importance to establish a system under which the rainfall data recorded by the existing stations falling under the jurisdiction of PWCB and other agencies (such as SRAB, TPC, WB and agricultural irrigation associations) can be made available rapidly and accurately.

The hourly rainfall data recorded for each flood by respective rain gauges do not appear to be systematically put in order. For example, if any one station keeps on recording no rainfall at all while all the neighbouring stations have rainfall records, or if it records a sudden heavy rainfall at a particular time, it is desirable that the failure of observation equipment be checked from the recording paper so that such abnormal records may be taken as "ineffective" or "failure of observation".

5.1.2 Water Stage Data

There is nothing particular to be pointed out about the water stage gauges because they were established with a suitable spacing on each tributary. It may as well be mentioned, however, that one of the problems encountered by the team during the present survey was that the datum level of the water stage values recorded by recording or non-recording observation was available only for the values observed after 1969.

In the vicinity of Taipei city, the ground subsidence makes it difficult to maintain each staff gauge on the right level. Since the water stage at time of a flood must generally be converted to absolute elevation, it is an imperative to establish a system under which the flood level transition and the datum level of staff gauges can be safely and permanently preserved. At present, different methods are employed by respective control offices** in the maintenance of the staff gauges against the ground subisidence. An integrated system is therefore hoped to be put into practice under which the staff gauges can be kept at fixed points and the datum level in each period can be confirmed by surveying and kept on record.

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* V.T. Chow et al: "Handbook of Applied Hydrology (Sect. 9)", McGraw & Hill, 1964.

** The 1st Regional Hydrologic Station and the 12th Regional Construction Office

5.1.3 Discharge Data

Discharge observation stations which give the data of respective floods for analysis of flood discharge and inundation are located at five places, i.e., Taipei Bridge (Tan-shui river), Hsin-hai Bridge (Ta-han Creek), Shin-men Reservoir (Ta-han Creek), Chungcheng Bridge (Hsin-tien Creek) and Wu-tu (Keelung river). The four stations excluding the Shin-men Reservoir provide flood discharge data prepared from the observed water stage using the stage-discharge curve. It is to be noted, however, that the following general condition should be taken into account in utilizing these discharge data.

i All the four stations are subjected to the influence of downstream inundation at time of a flood. (Wu-tu is influenced only when the Keelung's downstream water stage is high).

ii Conversion from stage to discharge is carried out by applying curves varying by floods. There is a case where a loop stage-discharge curve is applied during one flood period.

iii In case of floods having a long duration, the discharge values observed in the latter stage of the flood seem to be somewhat larger than the true values.

From a detailed study of the discharge data (which gives the relationship between water stage and discharge) recorded during floods which occurred after 1969, the relationship between the water stage and discharge at respective stations is recognized as follows.

i) Hsin-hai Bridge on Ta-han Creek

Because of the evident backwater effect ensued from the inundation and submergence of the downstream areas, the discharge value observed is a function of water stages both at this station and at downstream points. By expressing the discharge at the Hsin-hai Bridge as a function of two elements, i.e., the water stage at this bridge and the water stage difference in the Hsin-hai Bridge~Taipei Bridge section, the discharge data recorded after 1969 can be graphically presented without inconsistency as shown in Fig. 5.1.

Fig. 5.1 Stage-discharge curve at Hsin-hai Bridge

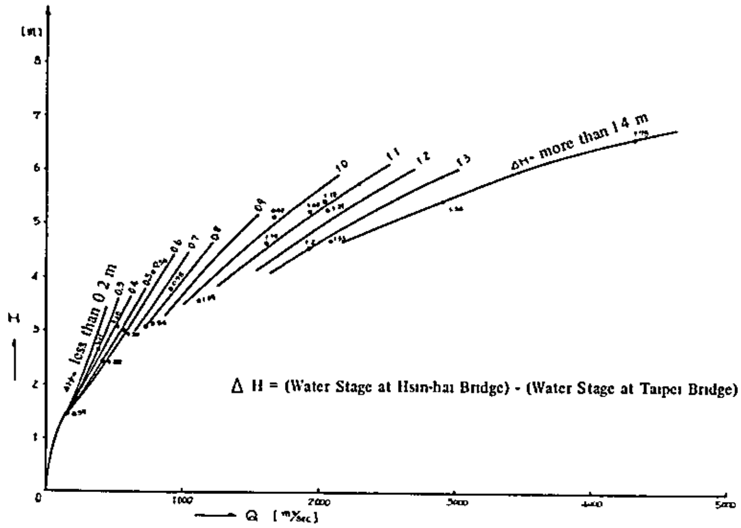


Fig. 5.2. Stage-discharge curve at Chung-cheng Bridge

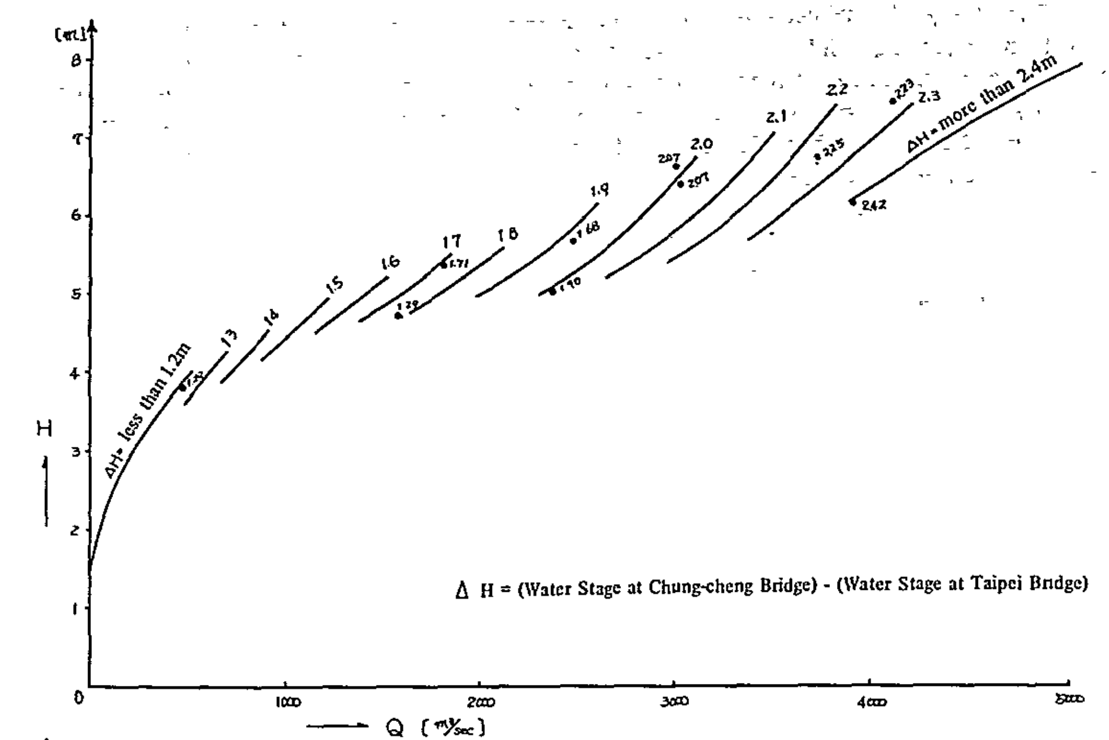
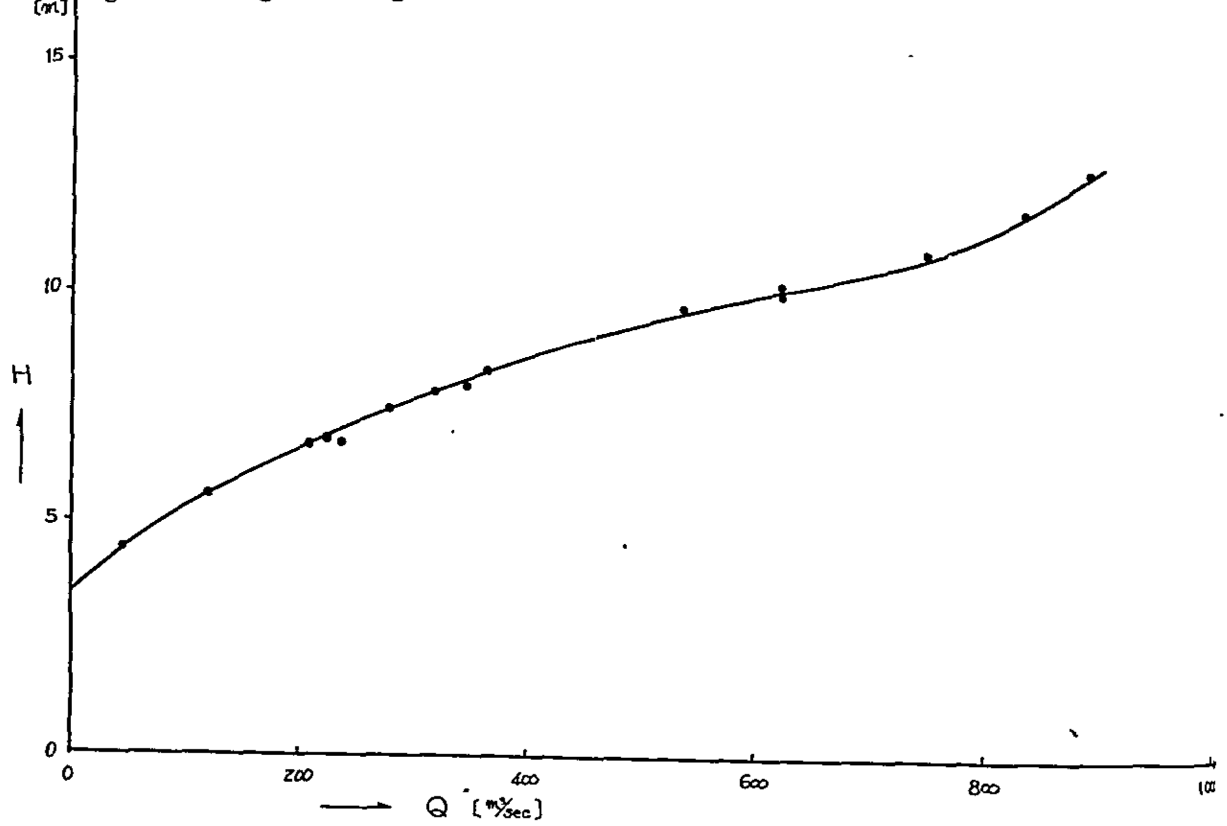


Fig. 5.3. Stage-discharge curve at Wu-tu



ii) Chung-cheng Bridge on Hsin-tien Creek

This station is likewise affected by backwater from downstream.

By expressing the discharge at the Chung-cheng Bridge as a function of the two elements, i.e., the water stage at this bridge and the water stage difference in the Chung-cheng Bridge ~ Taipei Bridge section, the discharge data recorded after 1969 can be graphically presented without noticeable inconsistency as shown in Fig. 5.2.

iii) Wu-tu on Keelung River

The discharge data recorded after 1969 can be approximately expressed as a single function of the water stage as shown in Fig. 5.3. However, it is recognized that when the discharge is large, the discharge increase is smaller than expected by the rise of water stage. Therefore, the ralation curve should be prepared and restudied especially for discharges exceeding 800 m^3/sec. with precise observations. Discharge observation is also to be conducted in the vicinity of the Chung-shan Bridge to get necessary data for analysis.

5.2 Time Lag of Flood Runoff

Table 5.2 shows the time lag of flood runoff (time elapsing between the heaviest rainfall in the basin and the peak discharge in tributaries) and travelling time of flood peak (peak time difference between the upstream and downstream sections of tributaries). Averages of time lag and travelling time of the aforementioned 11 floods are illustrated in Fig. 5.4.

Fig. 5.4 Time Lag and Time of Concentration of Flood Runoff (Average Peak Time Difference in Hours of All Floods)

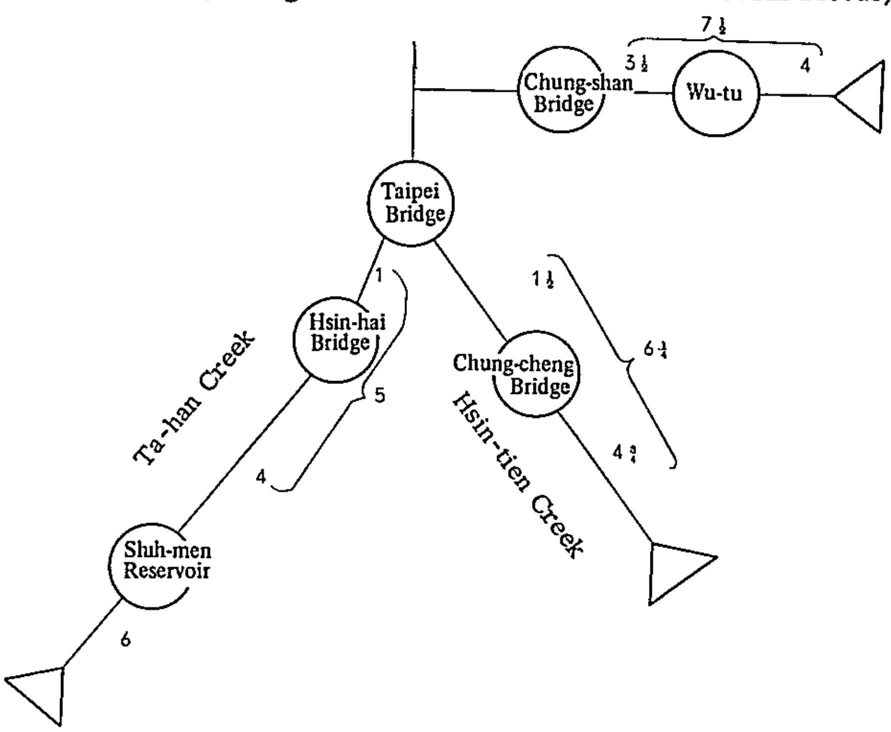


Table 5.2 Time Lag and Travelling Time of 11 Floods

Flood No.	Section	Ta-han Creek			Hsin-tien Creek		Keeling River	
		Upstream of Shih-men Reservoir → Shi-men Reservoir	Shih-men Reservoir → Hsin-hai Bridge	Hsin-hai Bridge → Taipei Bridge	Upstream of Chung-cheng Bridge → Chung-cheng Bridge	Chung-cheng Bridge → Taipei Bridge	Upstream of Wu-tu → Wu-tu	Wu-tu → Chung-shang Bridge
	River Channel Length		37.1	6.8		10.4		33.3 (km)
	Name of Flood							
0	Gloria	6			8	3	5	
1	Cora		4	1	4	0.5	3	2
2	Tropical Depression				5	2	3	4
3	Carla			1.5	4	2	4.5	4.5
4	Gilda		5	1	4	1	4	3
5	Elaine		4	1	4	1	4.1	4.8
6	Betty		4	1	3	1	6	3
7	Tropical Depression			1	5	4	3.8	4.2
8	Elsie		2.5	0.5	4	1.5	2.5	3.5
9	Flossie		4	1	4	0	2.4	3.1
10	Fran		3.5	0.5	7	1	4.3	3.3
	Average	(6)	4	1	4-3/4	1-1/2	4	3-1/2

Using Table 5. 2 and Fig. 5. 4, it is possible to roughly estimate, from the peak time of rainfall in the basin, the time at which the flood discharge will reach its peak in the downstream sections. However, because the rainfall after peak rainfall must be taken into account in estimating the peak flood discharge in downstream sections, it is not possible to estimate it from the peak discharge in the upstream. *

5. 3 Rainfall Loss

The effective rainfall is defined as the difference between total rainfall within a flood period and base flow. The difference between the total rainfall and effective rainfall is defined to be the rainfall loss. The values of total rainfall, effective rainfall loss of respective floods in the three tributary basins of the Tan-shui are as shown below.

Table 5. 3 can be graphically reproduced as shown in Fig. 5. 5 (a) - (c). A study of this figure made: it possible to say that the rainfall loss in the basin at time of a flood was characterized by the following trends.

i The relationship between the total rainfall and the total runoff is invariably subjected to considerable dispersion. The rainfall loss tends to increase with the increase of rainfall which produces floods. However, the coeffident of runoff rises with the increase of rainfall.

ii The rainfall loss in the three tributary basins presents an almost identical trend though the loss in the upstream area of Wu-tu appears to be slightly smaller than in the upstream area of the Chung-cheng Bridge.

iii The total runoff brought about by Typhoon Flossie (Flood No. 9) is considerably larger than the total rainfall. This is considered assignable to two reasons: Typhoon Elsie attacked the island immediately before Typhoon Flossie for one thing, and the flood runoff caused by Typhoon Flossie had a long duration (about 4 days) and as a consequence, discharge observation was not conducted with good accuracy in the latter half of the period. **
The dotted line in Fig. 5. 5 indicates the average trend presented in each basin. ***

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* This will be described in detail in Section 4 of this chapter (Outline of Storage Function Method) and in Chapter 6.

** See Section 5. 1.

*** If this trend is employed to calculate the runoff by means of the storage function method to be later described, it will serve for the estimation of firstly runoff ratio (fi) and saturation limit of rainfall (R_{sa}).

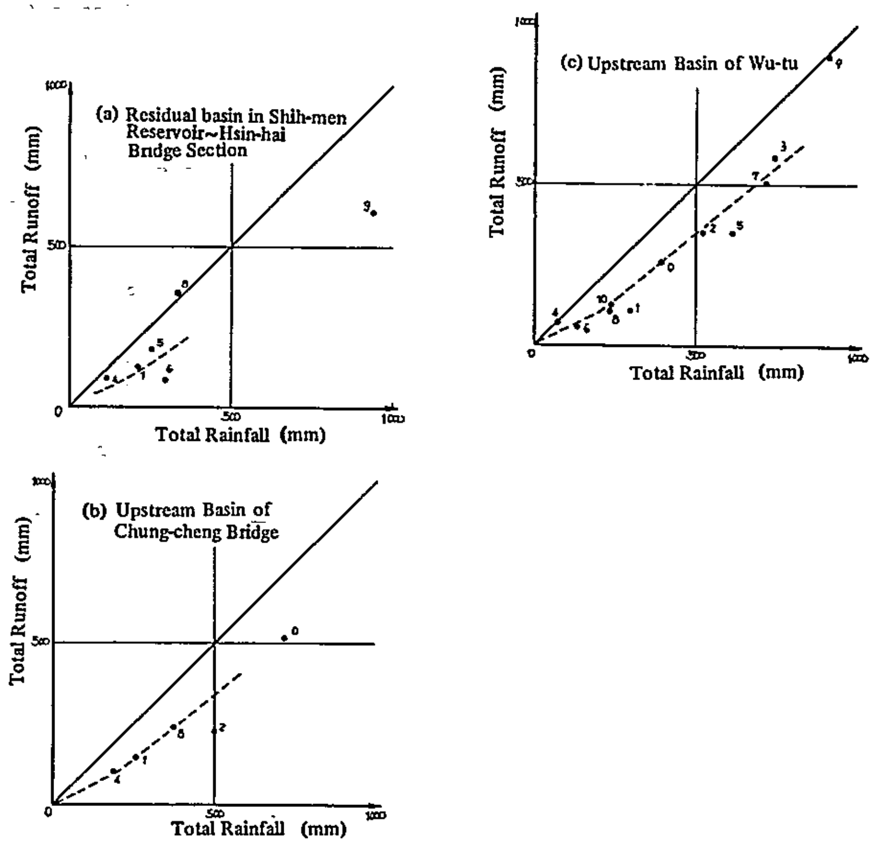
Table 5.3 Total Rainfall, Total Runoff and Rainfall Loss in Each Tributary Basin of 11 Floods

Flood No.	Name of Flood	Upstream of Shih-men Reservoir			Shih-men Reservoir Hsin-hai Bridge			Upstream of Chung-cheng Bridge			Upstream of Wu-tu		
		Total Rain-fall	Total Runoff	Rain-fall Loss	Total Rain-fall	Total Runoff	Rain-fall Loss	Total Rain-fall	Total Runoff	Rain-fall Loss	Total Rain-fall	Total Runoff	Total Rain-fall
0	Gloria	1346	961	385	483			718	517	201	396	263	133
1	Cora	287			211	128	83	260	151	119	294	101	193
2	Tropical Depression	342			259			499	330	169	519	446	73
3	Carla	412			311			560			748	582	166
4	Gilda	154			118	96	22	190	108	82	73	71	2
5	Elaine	972			255	180	75	543			613	346	267
6	Betty	212			293	93	200	209			136	57	79
7	Tropical Depression	510			563			642			714	505	209
8	Elsie	509			338	357	?	373	241	132	232	107	125
9	Flossie	744			939	603	336	858			919	899	20
10	Fran	561			503			346			237	121	116

Note: 1) In the runoff calculation, the base flow is supposed to be constant during the time of flood.

2) Some of the columns were left unfilled because the effective rainfall was not calculated by the deficiency of discharge data.

Fig. 5.5 Total Storm Rainfall and Total Runoff (Total Effective Rainfall) in Each Tributary Basins of the Tan-shui



5.4 Runoff in Upstream Basin

5.4.1 Runoff in Upstream Basin

As described before, the topography of the Tan-shui basin is such that a flat and low basin is connected directly to mountains. The water stage and discharge at time of a flood in the Tan-shui basin cannot be estimated without taking the downstream-end conditions into account. It is therefore advisable to divide the entire basin into the upper and lower basins and apply a method of calculating the flood discharge from rainfall to the former and employ a hydraulic method for calculation of flood discharge and water stage by giving inflow data from upstream and downstream-end conditions to the latter.

Following are methods currently employed in estimating flood runoff from rainfall.

a. Unit graph method
b. Tank model method (Sugawara·Maruyama's Method)*
c. Storage function method.
d. Characteristic curve method (Equivalent roughness method**, in which the flow of rainwater down the basin's slop is traced by the basic equation of unsteady flow).

Though all these methods have their own merits and demerits, the team reached after a detailed study, a conclusion that the so-called storage function method is most suited for the planned flood forecasting and warning for reasons given below, and determined to employ it in the calculation of flood runoff in the Tan-shui river basin.

a. The calculation by this method calls for a small number of constants which can all be obtained from the past rainfall and discharge data.

b. The non-linear characteristics of flood runoff can be introduced.

c. The runoff in the basin at a given time can be obtained from the rainfall in the basin at that time and from the discharge observed before that time. Therefore, any discrepancy between the forecast value and observed value can be readily corrected.

5.4.2 Outline of Storage Function Method

Flood routing introducing the basin storage as a parameter first attempted by Horton (1937), was studied by many hydrologists. Among them, Muskingum method (1938) in which a storage coefficient was assumed to be constant and Clark's study (1945) on the relationship between the storage method and the unit graph method is eminent. The storage function method, developed after this past series of studies was proposed in 1969 by Dr. Toshimitsu Kimura, the then chief of the Section of Hydrology, Public Works Research Institute, Ministry of Construction, Japan. Since full elucidation of the theoy and practice of calculation employing this method are given in his report*** and other papers, **** a brief introduction of the method will be given below.

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* Masami Sugawara: "On the Flood Forecasting of the Tenryu and the Kumano (in Japanese)", Statistical Research Institute, 1963.

** Tomitaro Sueishi: "On the Runoff Analysis by the Method of Characteristics (in Japanese)", Bulletin No. 29, Dec. 1955, JSCE

*** Toshimitsu Kimura: "Flood Runoff Routing by Storage Function Method (in Japanese)", Public Work Research Institute, Ministry of Construction, Aug. 1961.

**** Hydrological Research Association, Ministry of Construction: "Exercise in Runoff Calculation No. 2", All Japan Association of Construction Engineers, May 1971

As for the storage function, the flood runoff is assumed to be a surface flow and by applying Manning's formula, the intra-basin storage (S) is expressed as the exponential function of its runoff (Q) as in the following equation of motion.

$$S_l = KQ_l^p \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5.1)$$

where, K, p : Constant varying by basin. *

The runoff in a basin is calculated by combined application of the above equation and the following equation of continuity.

$$(1/3.6) f\, r_{ave} A - Q_l = dS_l/dt \quad \ldots\ldots\ldots\ldots\ldots \quad (5.2)$$

where, f : Inflow coefficient**

r_{ave}: Average rainfall in the basin

$Q_l(t) = Q(t + T_l)$: Direct runoff in the basin calculated with time lag taken into account

S_l : Apparent intra-basin storage volume

T_l : Time lag

To calculate the effective rainfall, the inflow coefficient (f) is caused to change in time series. In other words, $f = f_1$ (firstly runoff ratio) in the early stage of flood, but when additional rainfall exceeds R_{sa} (saturation limit of rainfall), f = 1. ***

The base flow is assumed to have a constant value equivalent to the initial discharge, and added to the runoff obtained from equations (5.1) and (5.2).

Since these two equations reject algebraic solution when $p \neq 1$, it is the common practice to resort to diagrammatical/semi-diagrammatical method or polygonal line approximation method for approximate calculation.

The detailed explanation of the calculation will be given in Chapter 6.

5.4.3 Routing of Channel Flood Discharge

Fruitful discussions were presented in the past by many hydraulic

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* p = 1 represents the linear storage. Non-linear characteristic is given when $p \neq 1$.

** Inflow coefficient is equal to that of runoff in other methods, cf. Kimura op. cit.

*** This calculation method is a simplification of Sherman's, i.e. his cumulative loss curve is represented by two polygonal lines (one having a gradient of $1 - f_1$ and the other zero).

experts on the propagation of flood flow in channel (unsteady flow). Among many valuable discussions, the team decided to apply the unit graph method based on Hayami's theory* for flood routing required in the flood forecasting and warning of the Tan-shui river. In this method, the upstream discharge is considered to diffuse and travel down the channel, and the calculation can be worked out in much the same way as in the ordinary unit graph method.

Theoretically, the channel unit graph can be obtained with respect to the upstream and downstream water stages of the channel in view and can be given as the function of the channel length, discharge, diffusion coefficient, etc. as expressed by the following equation.

$$\frac{h - h_n}{h_o} = 1 - \frac{2}{\sqrt{\pi}}\int_0^{x/2\sqrt{kt}} \exp\left[V_w x/2k - X^2 - (V_w x/4kX)^2\right] dX$$

where, h : Water depth at a point which is distance x downstream of the upstream end.

h_n : Water depth at the same point before the flood wave reaches.

h_o : Water depth at the upstream end.

t : Time

$V_w = 1.5\ V$, V being the average flow velocity

k : Diffusion coefficient

X : Integration parameter

Though the travel of the flood flow down the channel cannot be accurately reproduced by linear expression, it was determined to employ the channel unit graph method since it involves no intricate calculation nor trial calculation and therefore best meets the purpose of flood forecasting and warning in which calculations must be worked out rapidly. The basic equation is shown below.

$$Q_o(t) = \int_0^{\infty} Q_i(t - \tau)\,K(\tau)\,d\tau$$

where, Q_i : Discharge at the upstream end

Q_o : Discharge at the downstream end

$K(\tau)$: Distribution ratio in unit graph

* Shoichiro Hayami: "On the propagation of flood waves", Kyoto Univ., Disaster Prevention Research Institute, Bulletin 1, Dec., 1951. An explanatory article of this paper is carried in V. T. Chow's Open Channel Hydraulics (Chapt. 20, Sec. 3), McGraw-Hill, 1959.

5.4.4 Flood Runoff in Shih-men Reservoir Basin of Ta-han Creek

The Shih-men Reservoir, whose historical background of construction and flood control effect have already been described in Section 3.2, has a mountainous basin covering an area of 758.89 km^2.

Though the data of intra-basin rainfall and runoff (inflow into the reservoir) which were required for the analysis of runoff were not made available owing to the circumstances on the part of the Shih-men Reservoir Control Office, It was possible to obtain the inflow data from the reservoir's operation diagram at the time of Typhoon Gloria which was contained in "Shih-men Reservoir" written by Chu-Ting and published by the Shih-men Reservoir Construction Commission. Inflow data of other floods, however, could not be obtained.

Table 5.4 Constants of Storage Function in Ta-han Creek Basin Upstream of the Shin-men Reservoir

Flood No.	Name of Flood	T_1 (hrs)	K	P	f_1	Rsa (mm)	Q_i (m3/s)	s mm/hr
0	Gloria	2	80	0.45	0.7	200	10	2.9

The deviation of observed and calculated runoff from the early stage of flood upto three hours after the flood peak is obtained to be 2.9 mm/hr (s in the table), where the calculated runoff was obtained using the above tabulated storage function, and the deviation is the square root of the value obtained by dividing the sum of squares of difference at each time by the number of data. *

5.4.5 Flood Runoff in Shih-men Reservoir ~ Hsin-hai Bridge Section of Ta-han Creek

The discharge at the Hsin-hai Bridge is expressed by the sum of the discharged water which travels down the Ta-han Creek from the Shih-men Reservoir to the bridge and the runoff from the residual basin (Shih-men Reservoir ~ Hsin-hai Bridge section). The area of the residual basin is 397.11 km^2 and the length of the channel is 37.1 km. Data of residual basin rainfall, outflow from the Shin-men Reservoir and at the Hsin-hai Bridge, which were required for the runoff analysis, were given for the aforementioned 11 floods (inclusive of those floods for which complete data were not available).

The flow travelling the channel from the Shih-men Reservoir to the Hsin-hai Bridge was calculated by the unit graph method as described before, and the runoff of the residual basin by the storage function method. The unit graph distribution ratios and the constants of storage function were simultaneously analyzed by trial calculation. The five floods shown in Table 5.5 were selected for the analysis since they provide more accurate data than other floods on the residual basin rainfall, outflow from the Shih-men Reservoir, and discharge at the Hsin-hai Bridge. Table 5.5 shows the distribution ratios and constants which were considered most adequate from the trial calculation.

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* This value shows the fitness of calculation, though it can not be compared with those in other tribntaries directly. For comparison, the figure must be made dimensionless deviding it, for instance, by the peak discharge of the flood.

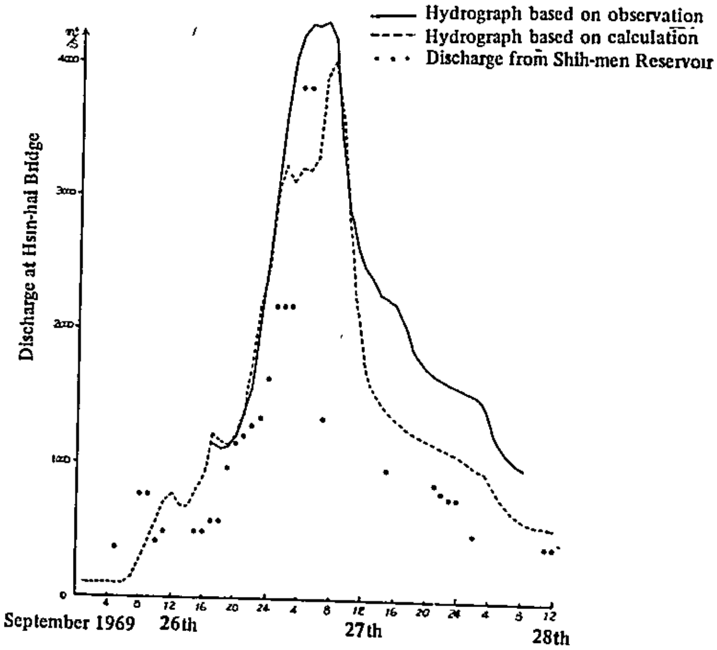
Fig. 5.6 shows a comparison of discharge hydrographs at the Hsin-hai Bridge prepared by calculation and observation for Typhoon Elsie.

Table 5.5 Trial Calculation of Constants of Storage Function of Residual Basin and Channel Unit Graph Distribution Ratios in Shih-men Reservoir ~ Hsin-hai Bridge Section of Ta-han Creek

Flood No.	Name of Flood	T_1 (hrs)	K	P	f_1	Rsa (mm)	Q_i (m^3/s)	s (mm/hr)
4	Gilda	2	50	0.3	0.5	50	20	0.52
5	Elaine	2	50	0.3	0.5	100	100	1.01
8	Elsie	2	50	0.3	0.5	200	100	2.03
9	Flossie	2	50	0.3	0.5	50	100	0.82
Most Probable Value		2	50	0.3	0.5	(100)		

	0	1	2	3	4	5	6	7 (hrs)
Channel Unit Graph Distribution Ratio	0.0	0.0	0.10	0.40	0.25	0.15	0.10	0.0

Fig. 5.6 Comparison of Discharge Hydrographs at Hsin-hai Bridge Prepared by Observation and Calculation of Typhoon Elsie



Application of the said storage function and the channel unit graph for actual flood forecasting and warning calls for the deciding a set of distribution ratios and constants A study was therefore made on the ratios and constants of those floods which presented a fairly food conformity in Table 5.5, whereby the following values were adopted as channel unit graph distribution ratios between the Shin-men Reservoir ans the Hsin-hai Bridge and the constants of residual basin storage function.

$S = 50\,(q - q_1)^{0.3}$, $T_1 = 2$ hrs

$K(\tau) = 0.0,\ 0.0,\ 0.10,\ 0.40,\ 0.25,\ 0.15,\ 0.10,\ 0.0$

(after lapse of 0 ~ 7 hrs)

5.4.6 Flood Runoff in Chung-cheng Bridge Basin of Hsin-tien Creek

This basin covers an area of 876.85km² of which the greater part constitutes mountainous districts. The intra-basin rainfall and the discharge at the Chung-cheng Bridge needed for the runoff analysis were available for all the 11 floods. *

The five floods shown in Table 5.6 were selected for the analysis of storage function constants of this basin because they offered more accurate data than other floods on the intra-basin rainfall and the discharge at the Cung-cheng Bridge. The set of constants which was calculated to be most suitable for each flood are shown in the said table (Table 5.6).

Table 5.6 Trial Calculation of Constants of Storage Function in Hsin-tien Creek Basin Upstream of Chung-cheng Bridge

Flood No.	Name of Flood	T_1 (hrs)	K	P	f_1	Rsa (mm)	Qi (m^3/s)	s (mm/hr)
1	Cora	3	90	0.2	0.5	10	125	0.54
2	Tropical Depression	2	60	0.2	0.5	30	100	1.61
5	Elaine	4	130	0.2	0.5	300	200	1.12
8	Elsie	3	110	0.2	0.5	50	200	2.66
9	Flossie	4	100	0.2	0.5	10	200	2.37
Most Probable Value		3	110	0.2	0.5	(200)		

Of the above five floods, Typhoon Cora was taken for discharge hydrograph comparison shown in Fig. 5.7 in which the observed and calculated values were compared.

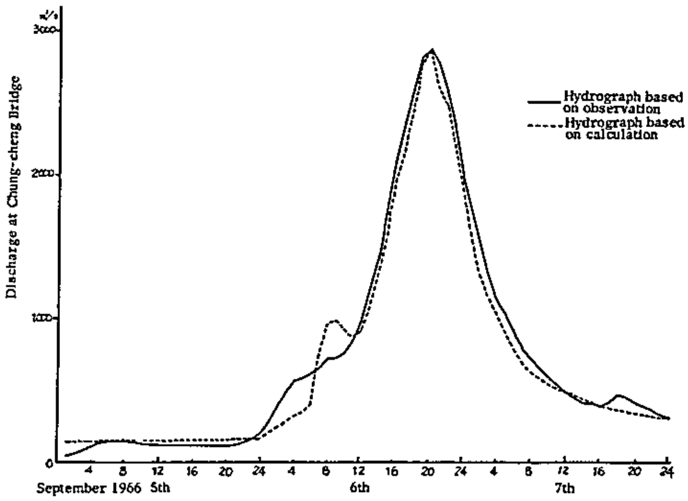
As a result of a study of constants of those floods which presented a fairly good conformity, it was concluded that the storage function applicable to the Chung-cheng Basin of the Hsin-tien Creek would be as given below. **

$$s=110\ (q-qi)^{0.2},\quad T_1=3hrs$$

* Sufficient discharge data were not available on six of these 11 floods.

** From the viewpoint of the applicable area of the storage function (generally 10 - 500 km²) and the flood forecasting and warning purposes, it is not advisable that the Hsin-tien Creek basin spreading upstream of the Chung-cheng Bridge is treated as a single basin . It is preferable that the basin is divided into the upstream and downstream basins at the recently established Chu-chie Station so that the flood forecasting and warning for the downstream area may be carried out using the flood discharge at Chu-chie in much the same manner as adopted for the Ta-han Creek basin described in the preceding section. Discharge data at Chu-chie were not available during the present survey. It is hoped that a method similar to the one applied to the Ta-han Creek (for which discharge from the Shin-men Reservoir is used) will be employed in the analysis (channel flow and residual basin runoff) in future.

Fig. 5.7 Comparison of Discharge Hydrographs at Chung-cheng Bridge based on Observation and Calculation of Typhoon Cora



5.4.7 Flood Runoff in Wu-tu Basin of Keelung River

The 208.31 km^2 wide Wu-tu basin is mostly mountainous. The intra-basin rainfall and the discharge at Wu-tu required for the runoff analysis were available for all the 11 floods.

The five floods shown in Table 5.7 were selected for the analysis of storage function constants of this basin because they provided more accurate data than other floods on both the rainfall and discharge. The most suitable set of constants calculated for each flood are also shown in this table (Table 5.7).

Of the above five floods, Typhoon Fran was taken for discharge hydrograph comparison shown in Fig. 5.8 in which the observed and calculated values were compared.

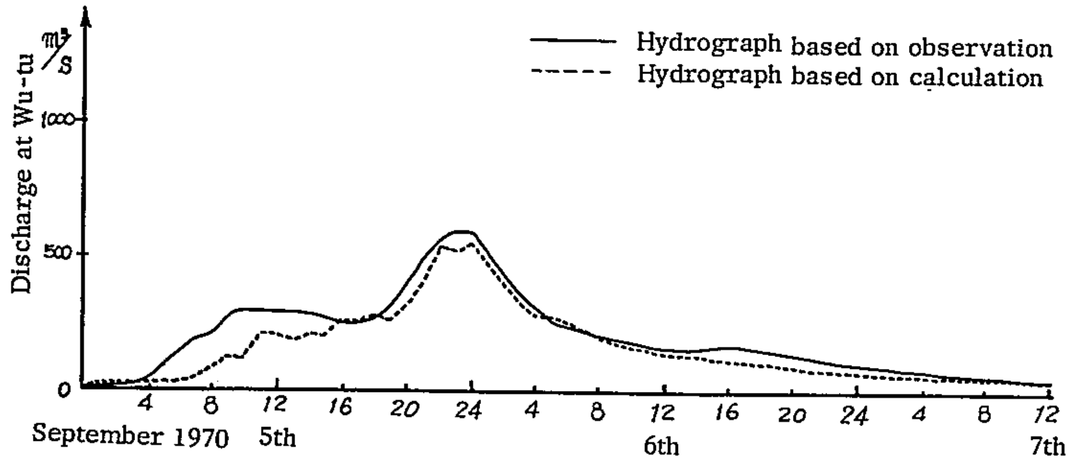
A study of the constants of those floods which showed a fairly good conformity disclosed that the storage function applicable to the Wu-tu basin of the Keelung river would be as given below.

$S = 65\ (q - q_i)^{0.3}$, $T_1 = 3$ hrs

Table 5.7 Trial Calculation of Storage Function in Keelung River Basin Upstream of Wu-tu

Flood No.	Name of Flood	T_1 (hrs)	K	P	f_1	Rsa (mm)	Qi (m^3/s)	s (mm/hr)
3	Carla	2	40	0.3	0.5	10	10	3.00
5	Elaine	3	70	0.3	0.5	300	20	2.95
8	Elsie	1	70	0.3	0.5	10	20	1.06
9	Flossie	3	70	0.3	0.5	70	20	1.93
10	Fran	3	60	0.3	0.5	50	20	1.00
Most Probable Value		3	65	0.3	0.5	(100)		

Fig. 5.8 Comparison of Discharge Hydrographs at Wu-tu based on Observation and Calculation of Typhoon Fran



5.4.8 Flood Runoff in Wu-tu ~ Chung-shan Bridge Section in Keelung River

The discharge at the Chung-shan Bridge is expressed by the sum of the discharge at Wu-tu which travells down the Keelung river and the runoff from the residual basin (Wu-tu~Chung-shan Bridge section).

The area of the residual basin is 192.76 km^2 and the channel length is 33.3 km. The residual basin rainfall and the discharge at Wu-tu, which were required for the runoff analysis, were given for all the 11 floods. No discharge observation is conducted at the Chung-shan Bridge, but the water stage data at this point were given for all the 11 floods.

As in the case of the Ta-han Creek, the flood discharge travelling down the channel from Wu-tu to the Chung-shan Bridge was calculated by the unit graph method, whereas the runoff of the residual basin obtained by the storage function method. Further, the unit graph distribution ratios and the constants of storage function were simultaneously analyzed by calculation so as to make the calculated runoff correspond to the water stage observed at the Chung-shan Bridge.

The five floods (Flood Nos. 3, 5, 8, 9 and 10) were selected for runoff analysis because they provided more sufficient data than other floods on the residual basin rainfall, discharge at Wu-tu and the water stage at the Chung-shan Bridge. The most suitable sets of distribution ratios and constants obtained by calculation are shown in Table 5.8.

Table 5.8 Trial Calculation of Constants of Storage Function of Residual Basin and Channel Unit Graph Distribution Ratios in Wu-tu ~ Chung-shan Bridge Section of Keelung River

Constants of Storage Fuction	T_1 (hrs)	K	P	f_1	Rsa (mm)	Qi (m^3/s)	s (mm/hr)	
Most Probable Value	2	35	0.5	0.5	(100)			
Channel Unit Graph Distribution Ratio	0	1	2	3	4	5	6	7 (hrs)
	0.0	0.0	0.10	0.60	0.20	0.10	0.0	0.0

From the above calculation, it was concluded that the most suitable sets of channel unit graph distribution ratios and constants of residual basin storages function in the Wu-tu ~ Chung-shan Bridge section would be as given below.

$S = 35\,(q - q_i)^{0.5}$, $T_1 = 2$ hrs

$K(\tau) = 0.0,\ 0.0,\ 0.10,\ 0.60,\ 0.20,\ 0.10,\ 0.0,\ 0.0$

(after lapse of 0 ~ 7 hrs)

5.4.9 Conclusions

Table 5.9 and 5.10 show the results of analysis conducted for the five tributary basins.

Table 5.9 The Most Probable Values of Constants and Ratios

Constants of Storage Function	T_1 (hrs)	K	P	f_1	Rsa (mm)	Q (mm/hr)
Ta-han Creek Upstream of Shih-men R.	2	80	0.45	0.7	(200)	
Ta-han Creek Shih-men R.~Hsin-hai Br.	2	50	0.3	0.5	(100)	
Hsin-tien Creek Upptream of Chung cheng Br.	3	110	0.2	0.5	(200)	
Kellung River Upstream of Wu-tu	3	65	0.3	0.5	(100)	
Keelung River Wu-tu~Chung-Shan Br.	2	35	0.5	0.5	(100)	

Channel Unit Graph Distribution Ratio	0	1	2	3	4	5	6	7
Shih-men Reservoir~Hsin-hai Bridge	0.0	0.0	0.10	0.40	0.25	0.15	0.10	0.0
Wi-tu~Chung-shan Bridge	0.0	0.0	0.10	0.60	0.20	0.10	0.0	0.0

Table 5.10 The Tendency of Constants Concerning Effective Rainfall

Basin	f_1	f_{sa}	Rsa (mm)
Upstream of Shih-men R.	0.7		
Shih-men R. ~ Hsin-hai Br.	0.5	0.8~0.9	200
Upstream of Chung-cheng Br.	0.5	0.8~0.9	200
Upatream of Wu-tu	0.5	0.8~0.9	200
Wu-tu~Chung-shan Br.			

The team considers that the values shown in these tables which were all obtained by an analytical study conducted on the basis of the rainfall and discharge data provided by PWCB, are generally acceptable. It is to be added, however, that some of these data were found inaccurate (inaccuracy of rainfall distribution in a basin, non-conformity between observed discharge values, etc.), but the team had no choice but to use them without making any corrections. It is therefore hoped that the errors involved in the analysis will be reduced in future when highly accurate data become available by the improvement of the observation network and observation system.

It may as well be mentioned here that some analytical studies have been made successfully on the flood runoff of the Tan-shui by Taiwan's river engineers who mostly resorted to the unit graph method. *

5.5 Propagation of Flood Waves in Downstream Area

5.5.1 Water Stage-discharge Relations for Water Stage Observation Points

As briefly explained in Chapter 3 on the condition of inundation, the lower Tan-shui basin embraces five districts which are subjected to a very high occurrence frequency of flood inundation. The planned flood forecasting and warning improvement will therefore be focussed on these five districts.

As a prerequisite to such forecasting and warning improvement scheme, it necessary to select sufficient and necessary number of water stage observation points. The water stage observation points selected as a result of various prudent studies are as follows.

a. Hsin-hai Bridge (Pan-hsin Bridge)
b. Kuang-fu Bridge
c. Taipei Bridge
d. Chung-shan Bridge
e. Shih-tzu-tou

The description in this section will be devoted to the estimation of water stage at the above five stations from the discharge at the Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge predicted by the method introduced in the preceding section. As to the relationship between the water stage at these observation points and the flood area, duration of inundation, depth of flood water, etc., studies will be made in the following section.

As can be readily imagined from the topography and other conditions, the propagation of flood waves in the lower Tan-shui basin involves extremely complicated hydraulic phenomena. It is necessary to integrate the fundamental equations of unsteady flow taking the tidal fluctuation of water levels at the estuary and the inflow from the upstream as boundary conditions, if a strict analysis be done.

As described in Chapter 3, however, it is known that when the water stage at the Taipei Bridge rises beyond a certain level, an enormous side-overflow over the left bank takes place, and when the water stage at Shih-zu-tou likewise rises beyond a certain level, Li-chou and Chung-chou-li districts and river channels combinedly form a large submerged area. Since the motion of water presents very conspicuous changes in each stage of such flooding, it not only entails substantial difficulties but is also not quite suited for the immediate need of flood forecasting and warning to build

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* To cite and example, "3 hours unit hydrographs at various points on the main and branch streams of the Tan-shui" is contained in "Annex 1 - Hydrological Study" of the "Report on the Flood Prevention Project in Taipei District".

In addition, runoff analysis in the Tan-shui's tributary basins is being carried out by the unit graph method by Cheng-Hsing-ming et al. under the control of PWCB.

a hydraulically strict model for simulation of the inundation condition. Though the importance of scrupulous hydraulic study is never to be overlooked, the propagation of flood waves in the downstream area of the Tan-shui should be studied with greater importance attached to the flood forecasting purpose.

As mentioned already, the water stage at the Hsin-hai Bridge and Chung-chen Bridge is largely influenced by those in the downstream section. This means that the estimation of water stage at the two bridges calls also for the estimation of downstream water stages. The downstream water stage, however, is affected by a number of elements such as the tide level, overflow into the left bank side area of the Tan-shui, magnitude of flow increment from the Keelung and so on. If all these elements are to be taken into consideration, estimate of the downstream water stage will involve a tedious calculation. Therefore, in consideration of the required accuracy of water stage forecasting and the importance of flood areas represented by the above two points and also for the purpose of saving the time and labour needed for the farecasting at these points, all the downstream conditions were disregarded and it was determined that the water stage at these points could be got uniqnely from the stage-discharge curve.

The stage-discharge curve at the Hsin-hai Bridge is as shown in Fig. 5.9. This curve represents the average of the stage discharge curves of the past six floods. It is to be noted that due to the considerable curve fluctuation observed in each flood, an error of about ±0.5 m cannot be avoided in obtaining the water stage at a given discharge.

For the flood forecasting for the Chiang-tzu-tsui district, it is considered expedient to estimate the water stage at the Kuang-fu Bridge rather than at the Chung-cheng Bridge because the former is closer to the area to be covered by the forecasting service. For this reason, the runoff in the Chung-cheng Bridge ~ Kuang-fu Bridge section was disregarded and the water stage-discharge curve at the Kuang-fu Bridge was prepared from the discharge at the Chung-cheng Bridge and from the water stage at the Kuang-fu Bridge as shown in Fig. 5.10. As this curve also represents average of the past seven floods, an error of about ±0.5 m cannot be avoided. *

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* Besides this method, another method resorting to the water stage correlation between the Chung-cheng Bridge and the Kuang-fu Bridge could be employed in estimating the water stage at the Kuang-fu Bridge. Study of the past flood records reveals that the water stage at the Kuang-fu Bridge at a given time and that at the Chung-cheng Bridge observed 0.5 hours earlier show a strong linear correlation. To employ this correlation in estimating the water stage at the Kuang-fu Bridge the discharge at the Chung-cheng Bridge must be converted to water stage. As a result of a study, however, the team discovered that an error of ±0.6 m was inevitable if the water stage was to be obtained from the discharge using the stage-discharge curve at the Chung-cheng Bridge. Estimation of the water stage at the Kuang-fu Bridge by the above correlation method, therefore, produces an error of about ±0.7 m. In other words, use of the stage-discharge curve described above is much simpler and provides somewhat higher accuracy as well.

Fig. 5.9 Water Stage Estimation Curve at Hsin-hai Bridge

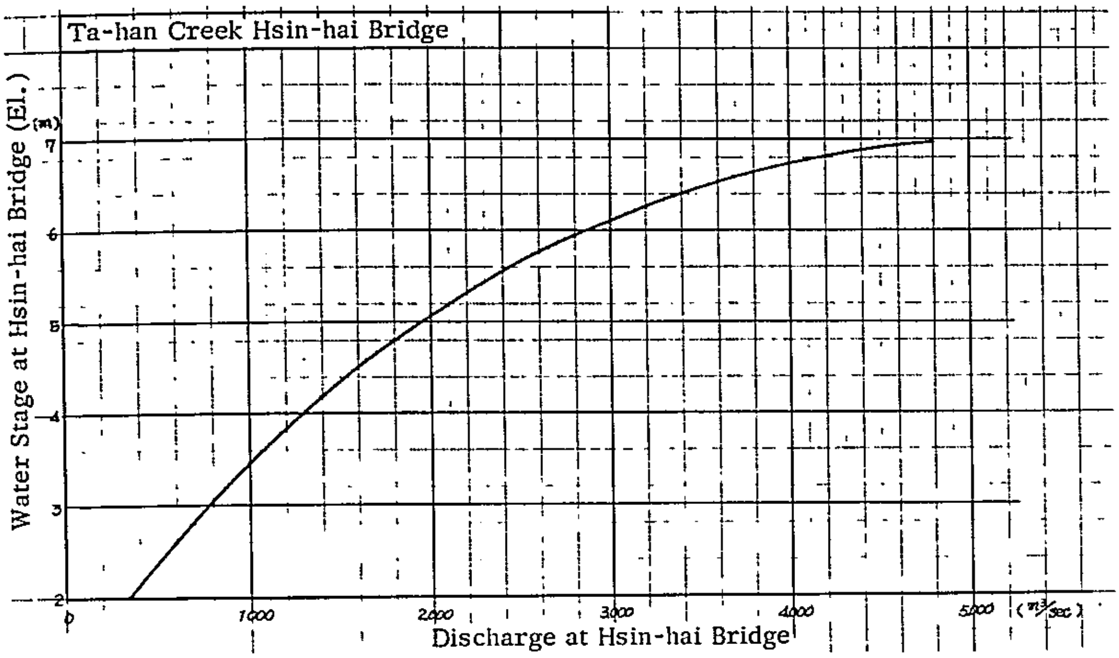
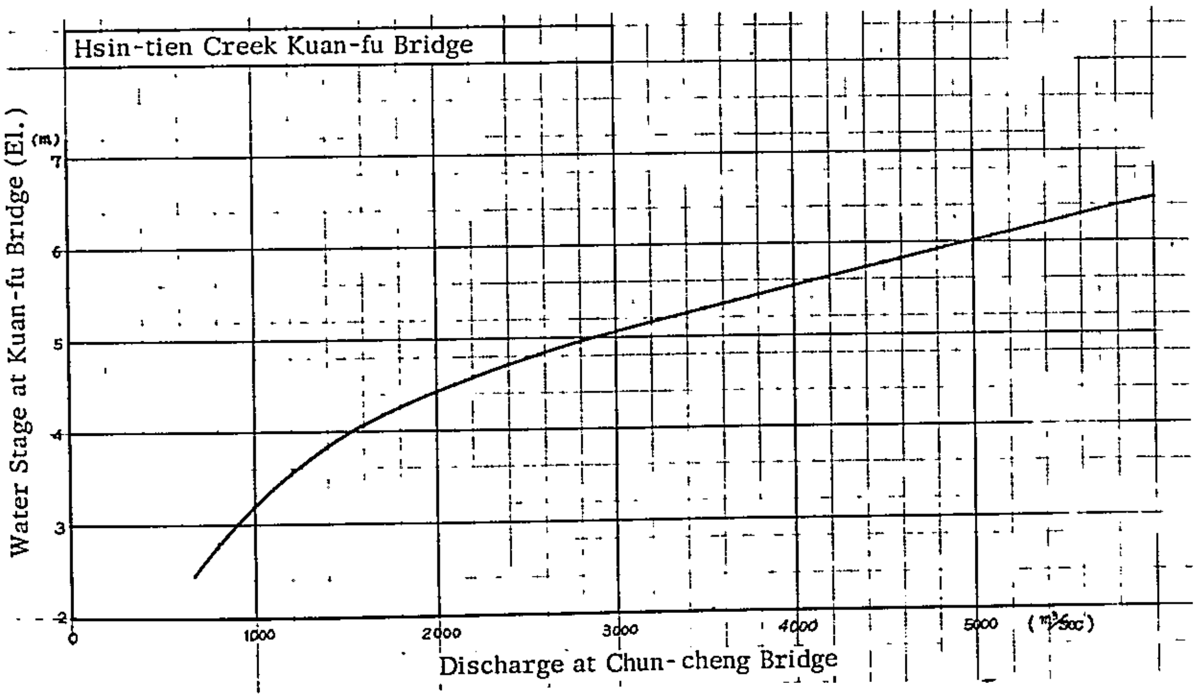


Fig. 5.10 Water Stage Estimation Curve at Kuan-fu Bridge



Effect of downstream water stages observed at the Hsin-hai Bridge and the Kuang-fu Bridge is also found at the Taipei Bridge. This effect was disregarded also in the analysis at the Taipei Bridge. It is difficult to estimate the discharge at the Taipei Bridge because, as described already, overflow into the left bank side area develops when the water stage rises beyond a certain limit at this bridge. For this reason, the stage-discharge curve at the Taipei Bridge was prepared using the total discharge at the Hsin-hai Bridge and Chung-cheng Bridge at a given time and the water stage at the Taipei Bridge at the same time. Due to the large fluctuation by flood, this curve, shown in Fig. 5.11, will incur an error of about ±0.5 m if it is used in estimating the water stage from the discharge.

The said curve indicates that the water stage at the Taipei Bridge rises to El. 3.2 m when the total discharge of Ta-han Creek and Hsin-tien Creek comes to record 2,400 m^3/sec to 2,600 m^3/sec, and to El. 4 m when this total discharge shows a value of 4,000 m^3/sec to 4,200 m^3/sec. When the said total discharge attains a value of this magnitude, overflow into San-chung city becomes inevitable.

Application of the aforementioned stage-discharge curves produces the result that the maximum discharge at the Chung-cheng Bridge and the highest water stage at the Kuang-fu Bridge occur at the same time, and that the maximum total discharge of the Hsin-hai Bridge and Chung-cheng Bridge and the highest water stage at the Taipei Bridge also occur at the same time a' pri. o'ri. This needs further study because both the magnitude and occurrence time of the gighest water stage are very important for flood forecasting.

Table 5.11 was prepared from the past observation records to indicate the occurrence time of highest water stage, maximum discharge, etc. This table indicates, for one thing, that the highest water stage at the Kuang-fu Bridge takes place within an hour before the maximum discharge is observed at the Chung-cheng Bridge, and for another, even if the maximum discharge at the Chung-cheng Bridge and the highest water stage at the Kuang-fu Bridge are assumed to occur at the same time, there will be a difference of only several centimetres between the said highest water stage and the true highest water stage at the Kuang-fu Bridge, so that the difference bears no significance for practical purpose.

The table also indicates that there is a maximum time difference of 3 hours between the occurrence of the maximum total discharge value obtained by observation at both the Hsin-hai Bridge and the Chung-cheng Bridge and the occurrence of the highest water stage at the Taipei Bridge. Assuming, however, that the water stage at the Taipei Bridge observed at exactly the same time when the maximum value of total discharge occurs is the highest water stage, there will be created a maximum difference of only 0.28 m from the true highest water stage and this causes a difference of only a few centimetres in almost all floods.

From the discussion heretofore advanced and from the accuracy of the stage-discharge curves mentioned above, it can be concluded that it entails no practical problems to assume that the maximum discharge at the Chung-cheng Bridge and the highest water stage at the Kuang-fu Bridge occur at the same time and that the total maximum discharge at both the Chung-cheng Bridge and the Hsin-hai Bridge takes place at the same time as the highest water stage at the Taipei Bridge.

Fig. 5.11 Water Stage Estimation Curve at Taipei Bridge

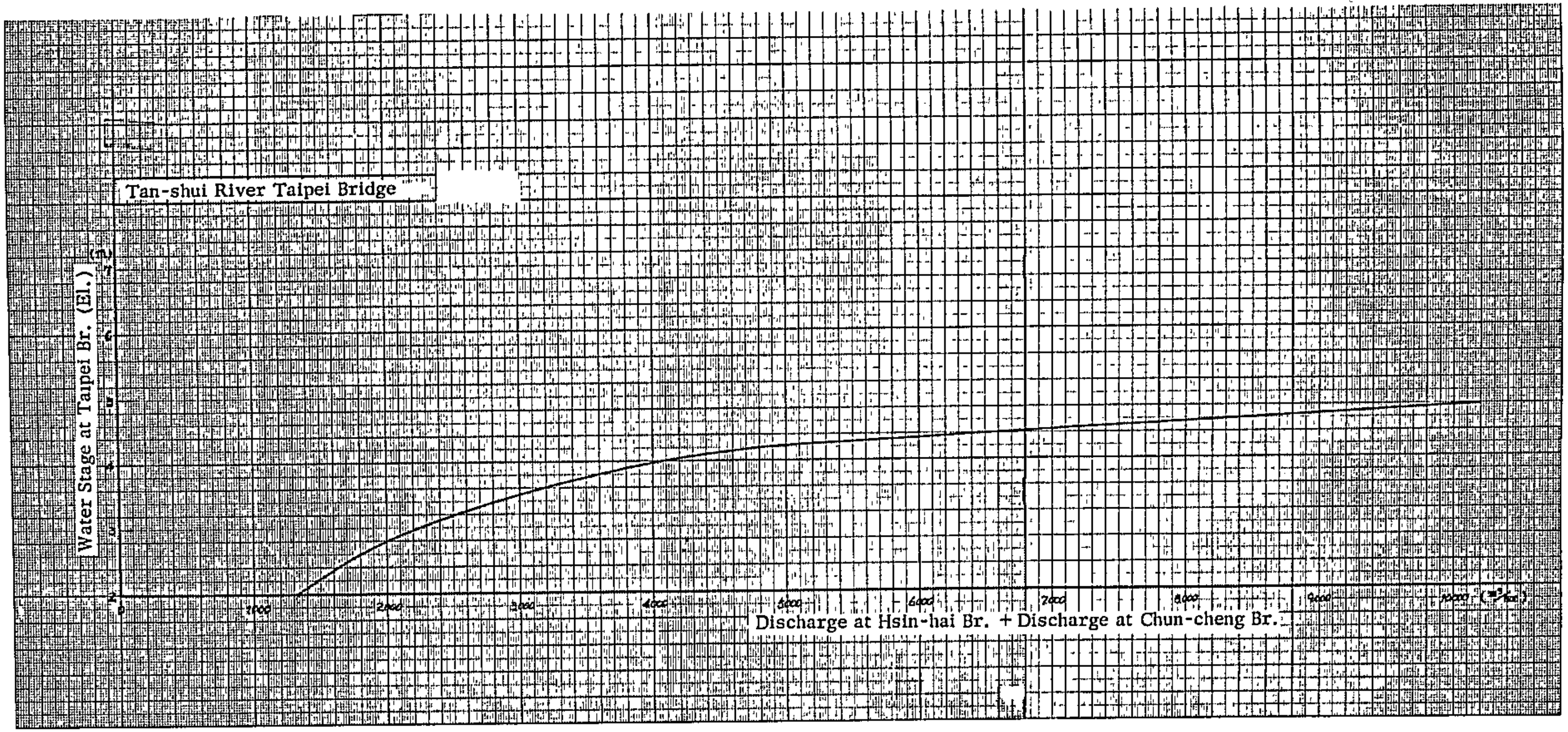


Table 5.11 Occurrence Times of Highest Water Stage and Maximum Discharge

Location / Name of Flood	Occurrence Time of Maximum Discharge at Chung-cheng Bridge	Occurrence Time of Highest Water Stage at Kuang-Fu Bridge	Difference between Water Stage at Kuang-fu Bridge at Time of Maximum Discharge at Chung-cheng Bridge and Highest Water Stage at Kuang-fu Bridge	Occurrence Time of Maximum Total Discharge of Hsin-hai and Chung-cheng Bridges	Occurrence Time of Highest Water Stage at Taipei Bridge	Difference between Water Stage at Taipei Bridge at Time of Maximum Total Discharge and Highest Water Stage at Taipei Bridge
Cara	6th, 20:00 hrs	6th, 21:00 hrs	-0.02 (Water Stage at 20:00 hrs is lower than at 21:00 hrs)	6th, 20:00 hrs	6th, 20:00 hrs & 21:00 hrs	0
Tropical Depression (1966)	14th, 9:00 hrs					
Carla	19th, 9:00 hrs	19th, 10:00 hrs	-0.02	19th, 9:00 hrs	19th, 11:00 hrs	-0.06
Gilda	18th, 15:00 hrs			18th, 15:00 hrs	18th, 16:00 hrs	-0.09
Elaine	1st, 1:00 hrs	1st, 1:30 hrs	0	1st, 1:00 hrs	1st, 1:00 hrs	0
Betty	8th, 16:00 hrs			8th, 15:00 hrs	8th, 16:00 hrs	?(Water stage data at 15:00 hrs is unknown)
Tropical Depression (1969)	11th, 21:00 hrs	11th, 21:00 hrs	0	11th, 21:00 hrs	11th, 24:00 hrs	-0.28
Elsie	27th, 4:00 hrs	27th, 4:20 hrs	0	27th, 4:00 hrs	27th, 5:00 hrs	-0.05
Flossie	3rd, 5:00 hrs 4th, 7:00 hrs	3rd, 6:00 hrs; 4th, 7:00 hrs	-0.01 0	3rd, 5:00 hrs; 4th, 7:00 hrs	3rd, 6:00 hrs; 4th, 7:00 hrs	-0.02 0
Fran	7th, 1:00 hrs	7th, 1:00 hrs	0	7th, 1:00 hrs	7th, 3:00 hrs	-0.07

5.5.2 Estimation of Flood Water Level in Submerged Area

The flood runoff passing down the Ta-han Creek and the Hsin-tien Creek flows into the Tan-shui, and augmented by the flood runoff from the Keelung, flows to Shih-tzu-tou while overflowing, in part, the left bank and rushing over, also in part, the right bank into Chung-chou-li and She-tzu district. On arriving at Shih-tzu-tou, the flood flow is impeded by the estuary tidal effect and the narrow river width so that it forms an extensive submerged area upstream of Shih-tzu-tou.

The motion of flood water in the Shih-tzu-tou ~ Yu-che-kou section is affected by the estuary tide level. For simplicity's sake, however, the flow is assumed to be a steady flow within a period of about an hour. By so assuming, it becomes possible to determine the discharge capacity in this section uniquely by the water stage at the upstream and down stream points.

Any flood runoff in excess of the discharge capacity of this section is logged in the upstream area of Shih-tzu-tou, raises the water stage in that area, and expands the submerged area towards upstream. If the water stage in the submerged area rises, the discharge into the estuary increases, and as the flood inflow from upstream into the submerged area continues to surpass the discharge to the estuary, the rise of water stage in the submerged area is accelerated. Conversely, if the flood inflow into the submerged area decreases and continues to fall short of the discharge capacity, then the water stage in the submerged area gradually declines accompanied by the shrinkage of the flooded area.

Forecasting of the water stage in the submerged area upstream of Shih-tzu-tou carries a great weight in flood forecasting and warning for the lower Tan-shui basin. A method of forecasting this water stage is described below on the assumption that the following data, i.e. hydrograph of inflow into the upstream area of Shih-tzu-tou Q (t), tide level at Yu-che-kou Station Hy (t), flood discharge capacity of the channel between Shih-tzu-tou and Yu-che-kou per unit time V_{out} (Hs, Hy) which can be determined uniquely from Hy (t) and Hs (t), and stage-capacity curve in the submerged area are available.

Since the inflow hydrograph is required to include the total quantity of water flowing into the submerged area, the discharge observed at all the three points, i.e., Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge, should be summed up. The sum of all the discharge values at the three points is obtained, for simplicity's sake, on the assumption that the discharges passing down all the three tributaries flow into the submerged area simultaneously and no time difference of their confluence will be taken into account.

The stage-capacity curve of the submerged area (V) can be readily obtained from the topographic map as the function of Hs (water stage at Shih-tzu-tou) by assuming that the water stage in the submerged area is horizontal and equivalent to Hs (t). This curve will be referred to as V = V (Hs).

As regards the discharge capacity (V_{out}), a chart can be prepared for different combinations of the water stage at Yu-che-kou, H_y (t), and that at Shih-tzu-tou, Hs (t), if the computation of backwater curves are worked out in advance. This chart* is attached to this report as an annex.

When the water stage at time t at Shih-tzu-tou, H (t), is given, the water stage at time t+1, Hs (t+1), can be obtained by the method described below.

Firstly, the volume of water in the submerged area at time t, Vt, can be obtained by substituting V(Hs) for Hs(t) in the volume curve V=V (Hs). Then, the water stage at Shih-tzu-tou is assumed to change to Hs(t+1) at time t+1. By taking Hs (t+1) as a suitable value, the volume of water at time (t+1) at time t+1, i.e., Vt+1, can be obtained.

The mean water stage at Shin-tzu-tou and Yu-che-kou between time t and time t+1 can be expressed by Hs (t~t+1)=(1/2) Hs(t)+Hs(t+1) and Hy (t~t+1)=(1/2) [Hy (t)+Hy (t+1)], respectively. By using the discharge capacity chart, therefore, the volume of water flowing out of the submerged area between time t and time t 1, i.e., Vout Hs[(t~t+1), Hy(t~t+1)], can be readily obtained.

Since the inflow into the submerged area during the same time is already given as Q (t) by the hydrograph, the volume of inflow per hour can be obtained from the following equation.

Vin (t~t+1)=(1/2)[Q (t)+Q (t+1)]×3, 600

* The chart was prepared by following process.

1. Estimation of coefficient of roughness between Yu-che-kou and Shih-tzu-tou section.

In working out the computation of backwater curves, the Manning equation was employed to express the frictional energy loss.

The geometric elements of the section were prepared from the longitudinal and cross section al data of the river.

The coefficient was estimated from the data of the water stage in the cases of Typhoon Elsie and Typhoon Flossie.

The coefficient of roughness obtained by such operation varies fairly by flood. In the Yu-che-kou~Shih-tzu-tou section, a value of 0.017 was obtained for Elsie and 0.019 for Flossie. Accordingly, these values were applyed to the estimation of water stage at Shih-tzu-tou in the cases of many other floods, and 0.019 was finally adopted as the most suitable value of the coefficient of roughness.

2. The water stage at Shih-tzu-tou was obtained by the computation of backwater curves, which was worked out by varying the water stage at Yu-che-kou at intervals of 0.5m from 0.5m up to a stage of 3.0 m and also by varying the discharge at the same place at intervals of 500 m^3/sec. from 0 up to 15,000 m^3/sec.

3. The chart prepared by process 2. above was converted to a chart which was to be used to obtain the discharge from the water stage at Yu-che-kou and Shih-tzu-tou. These computation were carried out by an electronic computer. For the simplicity of the flood warning the discharge is expressed as the water volume per hour.

If the assumed water stage at Shih-tzu-tou at time t + 1 is correct, then the following equation must be established with respect to the above-mentioned water volumes.

$$V_{in}\ (t \sim t+1) + V_t = V_{out}\,[H_s(t \sim t+1),\ H_y(t \sim t+1)] + V_{t+1} \cdot \cdot \cdot \cdot \cdot$$

. . . . (equation of continuity)

If the left side of the above equation fails to become equivalent to the right side, the water stage at time t + 1 at Shih-tzu-tou, H_s (t + 1), which was assumed at first, proves to be incorrect and so the calculation is to be made again. When this calculation succeeds in finding a new value of H_s (t + 1), which makes the two sides equivalent, this value is taken as the correct water stage at time t + 1 at Shih-tzu-tou, and calculation is to be continued for the water stage at time t + 2. If this trial and error calculation is continued for each hour, it will give the water stage at Shin-tzu-tou at each hour, i.e., the water stage in the submerged area at each hour. Completion of this series of calculation makes it possible to obtain the flood area from the topographical map by the assumption of horizontal inundation. These estimations of water stage at Shih-tzu-tou serve for warning the flood condition in Li-chou district*, Kuan-tu district and Chung-chou-li district.

In the actual flood forecasting service, the above-mentioned trial and error calculation is very troublesome and labour-taking. Accordingly, it is advisable to simplify the calculation though with some sacrifice of accuracy. The trial and error calculation is dispensed with by the following approximation.

$$H_s\ (t \sim t+1) \fallingdotseq H_s\ (t)$$

$$H_y\ (t \sim t+1) \fallingdotseq H_y\ (t)$$

$$V_{in}\ (t \sim t+1) \fallingdotseq V_{in}\ (t) = Q\ (t) \times 3,600$$

Therefore, the above equation of continuity is simplifyed as follows.

$$V_{t+1} = V_{in}\ (t) + V_t - V_{out}\,[H_s\ (t),\ H_y\ (t)]$$

By this arrangement, it becomes possible to estimate easily the value at time t+1 from the value at time t. If the water volume in the submerged area at time t + 1 is given, the water stage at Shih-tzu-tou at that time, H_s (t + 1), can be readily obtained by conversely applying the stage-capacity curve [$V = V(H_s)$].

5.5.3 Initial Stage Conditions

A cautionary comment must be made here on the initial calculation condition. As will be clear from the above explanation, at time t = 0 when the calculation is to be initiated, the water stage at Shih-tzu-tou, H_s (0), is not available. This means that the water stage an hour later, $H_s(1)$, and $H_s(0)$ must be both set as an assumptive value. Results of many calculations of this sort indicate, however, that the error involved in the assumed values of $H_s(0)$ loses its effect almost as the calculation proceeds

* Flooding over the left bank of the Tan-shui must be taken into account in forecasting the inundation condition of Li-chou district.

for some hours ahead. Therefore, the following method will suffice for obtaining the initial value of water stage.

By expressing the water stage at Yu-che-kou at time of starting calculation by H_y and the total upstream discharge by Q, and by assuming that Q has been flowing down the channel for many hours in the past enough to maintain the water stage at Shih-tzu-tou in a steady state, the water stage at Shih-tzu-tou at the time can be readily obtained from the aforementioned chart showing the value of Vout (Hs, Hy). Hs thus obtained may well be taken as the initial water stage value.

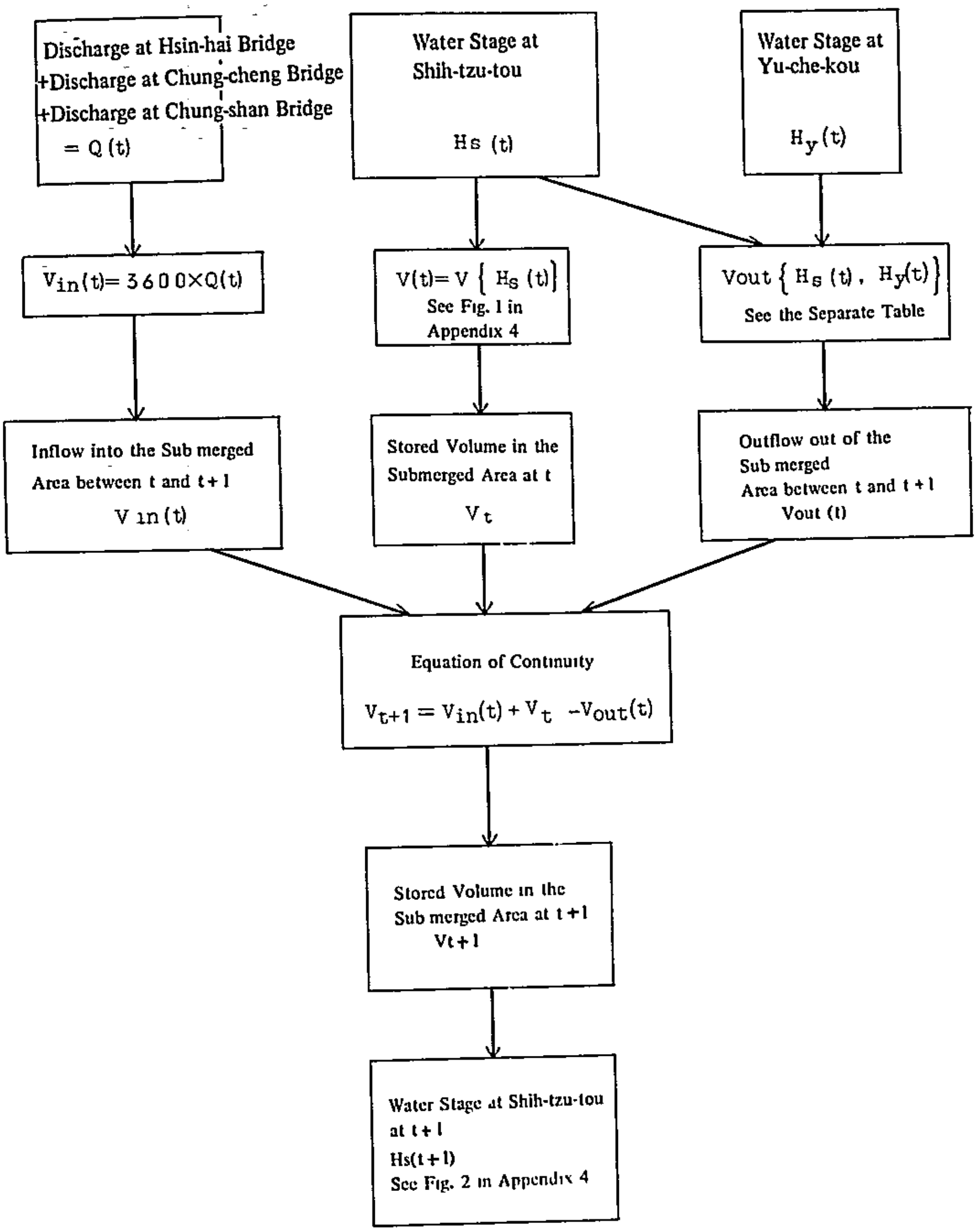
If a telemetering water stage gauge is established at Shih-tzu-tou, the problem raised above can be completely dispelled, because the initial value can be determined easily by the constant availability of latest observation values. Establishment of the said gauge will improve the accuracy of calculation because whenever calculation is to be commenced, the observed value at that time can be directly employed as the initial value.

Question may be raised as to the time at which the calculation is to be initiated before the telemeter is installed at Shih-tzu-tou. Some explanation will be given below to answer this question.

The initial calculation time may be set at the time when horizontal flood water logging begins to take place upstream of Shih-tzu-tou, and such horizontal inundation may be considered to start when the total discharge of Hsin-hai, Chung-cheng and Chung-shan goes beyond approximately 2, 500 m^3/sec.

An illustration of the simplified calculation method of water stage at Shih-tzu-tou is shown in Fig. 5.12. The stage-capacity curve [$V = V(H_S)$] and the flood discharge capacity in the Shih-tzu-tou ~ Yu-che-kou section [$V_{out}(H_S, H_y)$] are attached to this report as annexes. An example of calculation is given in Section 6.4.

Fig. 5.12 Simplified Method for Calculation of Water Stage at Shih-tzu-tou



5.5.4 Downstream End Conditions

Review of the recording paper indicates that the water stage at Yu-che-kou, which is to be utilized as downstream end data, is affected by the flood discharge to some extent. This effect, however, is disregarded here and the water stage is assumed to be equivalent to the tidal level, because the said arrangement makes it possible to prepare an annual tide table from the harmonic analysis of past data and to forecast the water stage at any given time. However, due to the lack of data required for the analysis, the following method will have to be adopted for some time to come.

Waves recorded over the past 24 hours* are extracted from the recording paper at Yu-che-kou Station immediately before the occurrence of flood and repetitively transferred in parallel in the direction of time axis to obtain the future water stage. **

Next comes the forecasting method of the water stage at the Chung-shan Bridge. Though the estimated discharge is to be obtained from the runoff calculation based on rainfall, the water stage at this point cannot be obtained from a stage-discharge curve due to the absence of observed flood discharge. Therefore we computed many backwater curves, of the Keelung for the Shih-tzu-tou~Chung-shan Bridge section so as to be able to prepare a graph which is instrumental in obtaining the water stage at Chung-shan Bridge. In this graph, the discharge of the Keelung is plotted on the abscissa and the water stage at the Chung-shan Bridge (in elevation) on the ordinate, with the water stage at Shih-tzu-tou taken as the parameter, so that the water stage at the Chung-shan Bridge can be estimated if the estimated discharge of the Keelung and the estimated water stage at Shih-tzu-tou are given. The value of Manning roughness coefficient, n, which was employed in the computation of the backwater carves is as given below. ***

n = 0.026 for Keelung's cross section of					1 ~ 7
n = 0.022	"	"	"	"	7 ~ 14
n = 0.063	"	"	"	"	14 ~ 16

* 24 hours back to the time when the water stage recorded at the end of the paper is given.

** For a little stricter forecasting, one may cite the method of forecasting the water stage by means of a harmonic analysis. In this method, a period of about 24 hours and another of about 12 hours may safely be taken as dominant periods because the water stage within three to four days ahead is what is desired to be forecasted. Therefore, the data to be analyzed should cover a period of about 10 days, and values read therefrom at intervals of two hours may be used to obtain Fourier's coefficient. Once accustomed to it, this method entails no particular difficulty.

*** In determining the roughness coefficient of the Keelung river, the water stage values were taken from Figs. III-9~13 contained in "Report of the Study on Flood Prevention Project in Taipei District, Annex 2 - Hydraulic Model Test", General Planning Committee of Water Resources, Ministry of Economics, 1970, and calculation of coefficient of roughness was carried out using the cross section provided in Taiwan.

To verify the validity of this method, the water stage at the Chung-shan Bridge as obtained from this graph using the observed value of water stage at Shih-tzu-tou and also using the value of discharge at the Chung-shan Bridge was compared with the observed water stage, and this comparison made clear an error of about ±0.3m.

5.5.5 Accuracy Verification

Finally, the validity of the calculation method for forecasting the water stage at Shih-tzu-tou will be studied. Data available for this study are the observed discharge values at the Hsin-hai Bridge and Chung-cheng Bridge (obtained from the observed water stage values using the stage-discharge curve), observed water stage at Yu-che-kou, discharge at the Chung-shan Bridge estimated from rainfall, the discharge capacity chart attached to the report, and stage-volume curve. Fig. 5-13, 14, 15, and 16 show the results of calculation worked out for the past four floods.

Different results are given for a single observed value, as explained in the remarks, by making estimation for different hours ahead. Estimating the water stage at T hours ahead means calculating the water stage on the basis of data observed before the present time. By comparing the estimated value with the observed value, therefore, the accuracy of estimation can be masured.

5.6 Flood Inundation in Downstream Area

Figs. 5.17~5.21 were respectively prepared to show the areas inundated by flood brought about Typhoon Gloria (September 1963), Typhoon Elaine (September ~ October, 1968), Typhoon Elsie (September 1969), Typhoon Flossie (October 1969) and Typhoon Fran (September 1970). Analysis of inundation in downstream area will be made using these figures and Table 5.12 ~ 5.16 which show the results of field investigation conducted in these areas at time of flood.

For flood forecasting service planned for the future, it is essential that a unified theory is established that can be applied for substantially integrated explanation of the inundation condition represented in the above figures and tables.

In the preceding sections, discussion has been focussed on the method of forecasting the discharge at the Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge from rainfall data and also dealt with the method of forecasting the water stage at key stations.

If these methods are capable of forecasting, with no error at all, the water stage at the selected key observation points, such values should prove instrumental for full explanation of the actual inundation condition. The analysis will therefore be focussed on this point, and all the floods will be reviewed one by one. To put in other words, this analysis is an attempt to find a way to explain the inundation condition on the basis of the correct water stage at certain time at each station. *

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* Since the validity of basic idea alone is to be checked, observed discharge data alone should be used so as to remove the errors involved in estimated values of discharge and water stage.

Fig. 5.13 Accuracy Verification of the Forecasted Water Stage at Shih-tzu-tou (E laine)

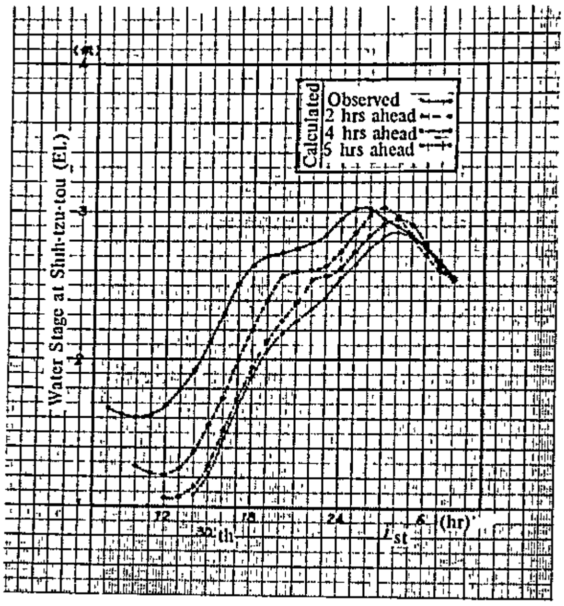


Fig. 5.14 Accuracy Verification of the Forecasted Water Stage at Shih-tzu-tou (E lsie)

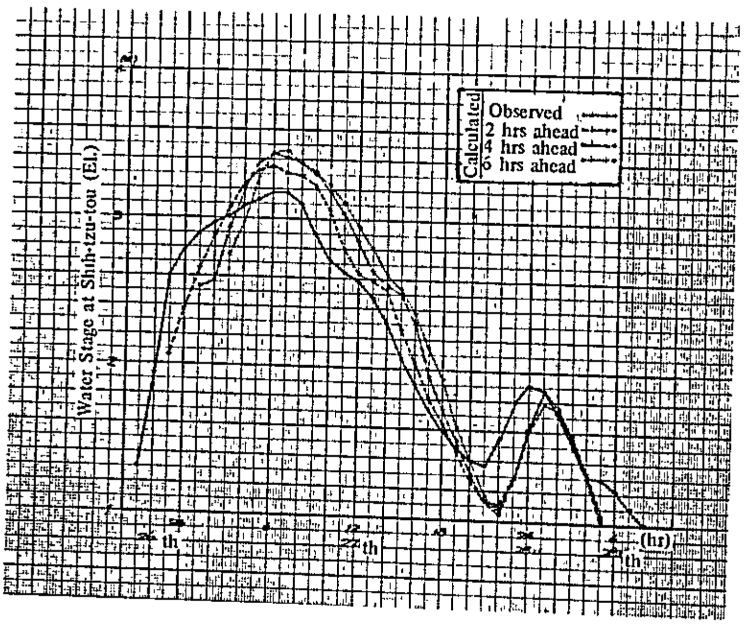


Fig. 5.15 Accuracy Verification of the Forecasted Water Stage at Shih-tzu-tou (Flossie)

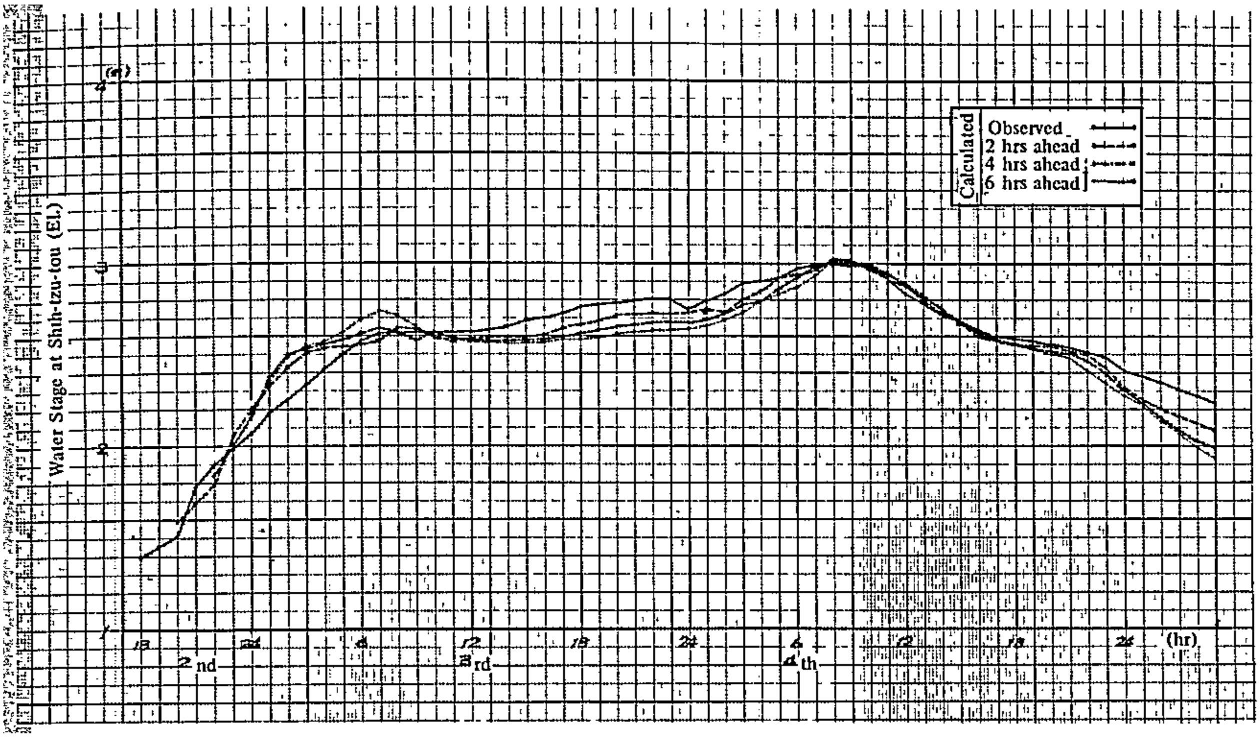


Fig. 5.16 Accuracy Verification of the Forecasted Water Stage at Shih-tzu-tou (Fran)

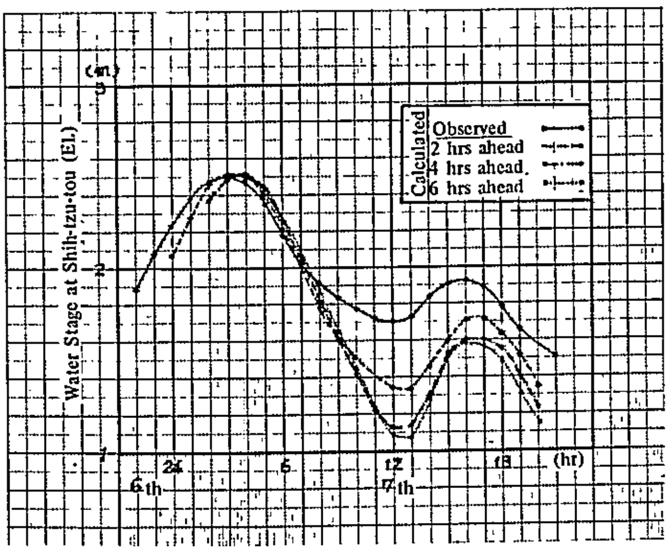


Table 5.12 Inundation Caused by Flood of Typhoon Gloria

District	Inundated Area	Flood Water Depth	Duration of Inundation
	ha	m	hr
o She-tzu, Kuan-tu	2,411	less than 3.90	unknown
o San-chung, Li-chou, Hsin-chuang	4,406	less than 3.50	"
o Chiang-tzu-tsui, Shu-lin	1,645	less than 2.90	"
o Yung-he, Chung-he	1,189	less than 0.80	"
o Shih-lin, Chung-shan-ward, Sung-shan	1,515	less than 2.70	"
o Mu-cha	490	unknown	"

Table 5.13 Inundation Caused by Flood of Typhoon Elaine

District	Inundated Area	Flood Water Depth	Duration of Inundation
	ha	m	hr
o Sung-shan, Chung-shan Ward	427	unknown	unknown
o Pei-tou, Shih-lin	1,218	"	"
o Li-chou, Wu-ku, Tai-shan, San-chung, Hsin-chuang	2,784	"	"
o Pan-chiao	83	"	"
o Mu-cha	223	"	"

Table 5.14 Inundation Caused by Flood of Typhoon Elsie

District	Inundated Area	Flood Water Depth	Duration of Inundation
	ha	m	hr
o San-chung, Hsin-chuang	1,890	0.20 ~ 2.40	15 ~ 40
o Li-chou, Wu-ku, Tai-shan	1,696	0.30 ~ 2.40	40 ~ 70
o Pan-chiao, Chiang-tzu-tsui	570	0.30 ~ 1.85	4 ~ 10
o She-tzu, Kuan-tu	1,297	0.50 ~ 2.00	30 ~ 55
o Mu-cha, Kou-tzu-kou,	109	0.50 ~ 1.00	2 ~ 6
o Sung-shan, Ta-chih	681	0.30 ~ 1.90	15 ~ 36

Table 5.15 Inundation Caused by Flood of Typhoon Flossie

District	Inundated Area	Flood Water Depth	Duration of Inundation
	ha	m	hr
o San-chung, Hsin-chuang	1,740	0.10 ~ 2.50	54 ~ 88
o Li-chow, Wu-ku, Tai-shan	1,700	0.35 ~ 2.50	88 ~ 105
o Pan-chiao, Chiang-tzu-tsui	310	0.29 ~ 1.26	24 ~ 50
o She-tzu, Kuan-tu	1,126	0.60 ~ 2.20	55 ~ 70
o Mu-cha, Kou-tzu-kou	82	0.10 ~ 0.50	5 ~ 14
o Sung-shan, Ta-chih	1,840	0.10 ~ 3.00	18 ~ 70

Table 5.16 Inundation Caused by Flood of Typhoon Fran

District	Inundated Area	Flood Water Depth	Duration of Inundation
	ha	m	hr
o San-chung, Hsin-chuang	1,889	0.10 ~ 1.50	12 ~ 36
o Li-chow, Wu-ku, Tai-shan	1,790	0.10 ~ 1.80	36 ~ 72
o Pan-chiao, Chiang-tzu-tsui	278	0.10 ~ 0.80	12 ~ 36
o She-tzu, Kuan-tu	790	0.20 ~ 1.80	2 ~ 48
o Mu-cha, Kou-tzu-kou	27	0.20 ~ 0.70	12 ~ 24
o Sung-shan, Ta-chih	51	0.10 ~ 0.60	6 ~ 24

Needless to say, such an approach is not allowable in making an overall review and verification of the flood forecasting method (including the runoff calculation from rainfall) which we propose. In the study of such an overall review, which will be described in Chapter 6, the available data are confined to the rainfall and water stage data recorded at some fixed points before the time of such review, and all the other data must be obtained by calculation.

First of all the flood forecasting method will be studied with the flood of Typhoon Flossie. This flood lasted for as long as six days, i.e., from October 2 to 7, 1969.*

At 15:00 hrs of October 2, the water stage at Shih-tzu-tou was El. 1 m. The lowland area in Li-chou district extending along the Wen-tzu river was already partially submerged, but the other two districts, Kuan-tu and Chung-chou-li had no shbmerged areas.

At 24:00 hrs of October 2, the water stage at Shih-tzu-tou rose to El. 2.07 m and some parts of Chung-chou-li district were submerged.

At 5:00 hrs of October 3, the water stage further rose to El. 2.50 m. From about this time, river water began to overflow the lower parts of the Kuan-tu tide embankment, so that Kuan-tu district started to be subjected to inundation.

At 8:00 hrs of October 4, the water stage at Shih-tzu-tou reached the highest value of 3.00 m, and this was ensued by gradual decline of water stage which recorded 2.51 m at 22:00 hrs of the 4th, 2.00 m at 10:00 hrs of the 5th, 1.50 m at 24:00 hrs of the 5th, and 1.01 m at 11:00 hrs of the 6th.

The area delineated by broken line in Fig. 5.21 is the inundated area estimated from the topographical map by assuming that horizontal inundation takes place when the water stage at Shin-tzu-tou reaches the highest of 3.00 m. The actual inundated area in Kuan-tu and Chung-chou-li districts (delineated by dot-and-dash line) fairly well conforms to the estimated inundated area, which indicates that the inundation in these two districts can be explained by the notion of horizontal inundation having a water stage equivalent to the stage at Shih-tzu-tou. In Li-chou district, however, the actual inundated area embracing San-chung city along the Tan-shui shows substantial divergence from the estimated inundated area.

The topographical map indicates that there stretches a hill range through the area extending from the Hsin-hai Bridge to Shih-tzu-tou along the left bank of the Tan-shui. The height of the range increases towards upstream, and lowland is found on the west side of this range in any part of the area. When the water stage of the Tan-shui rises beyond the height of the range, then flood water will flow into Li-chou district. The thick line in Fig. 5.22 indicates the elevation of the said range in the longitudinal direction of the Tan-shui. Therefore, if the flow profile of the Tan-shui (Ta-han Creek upstream of the confluence) at each selected hour is filled in Fig. 5.22, it will become possible to forecast where the water will overflow the left bank. In this figure, a few flow profile during Typhoon Flossie are indicated by thin line.**

* See Figs. 5.15 and 5.20.

** It is assumed that the water stage at the confluence of the Ta-han Creek and the Hsin-tien Creek (the point between Stations 31 and 32 approximately 21.8 km upstream from the estuary) is the arithmetic average of water stages observed at the Hsin-hai Bridge, Kuang-fu Bridge and Taipei Bridge.

Fig. 5.17 Submerged Area Caused by Flood of Typhoon Gloria

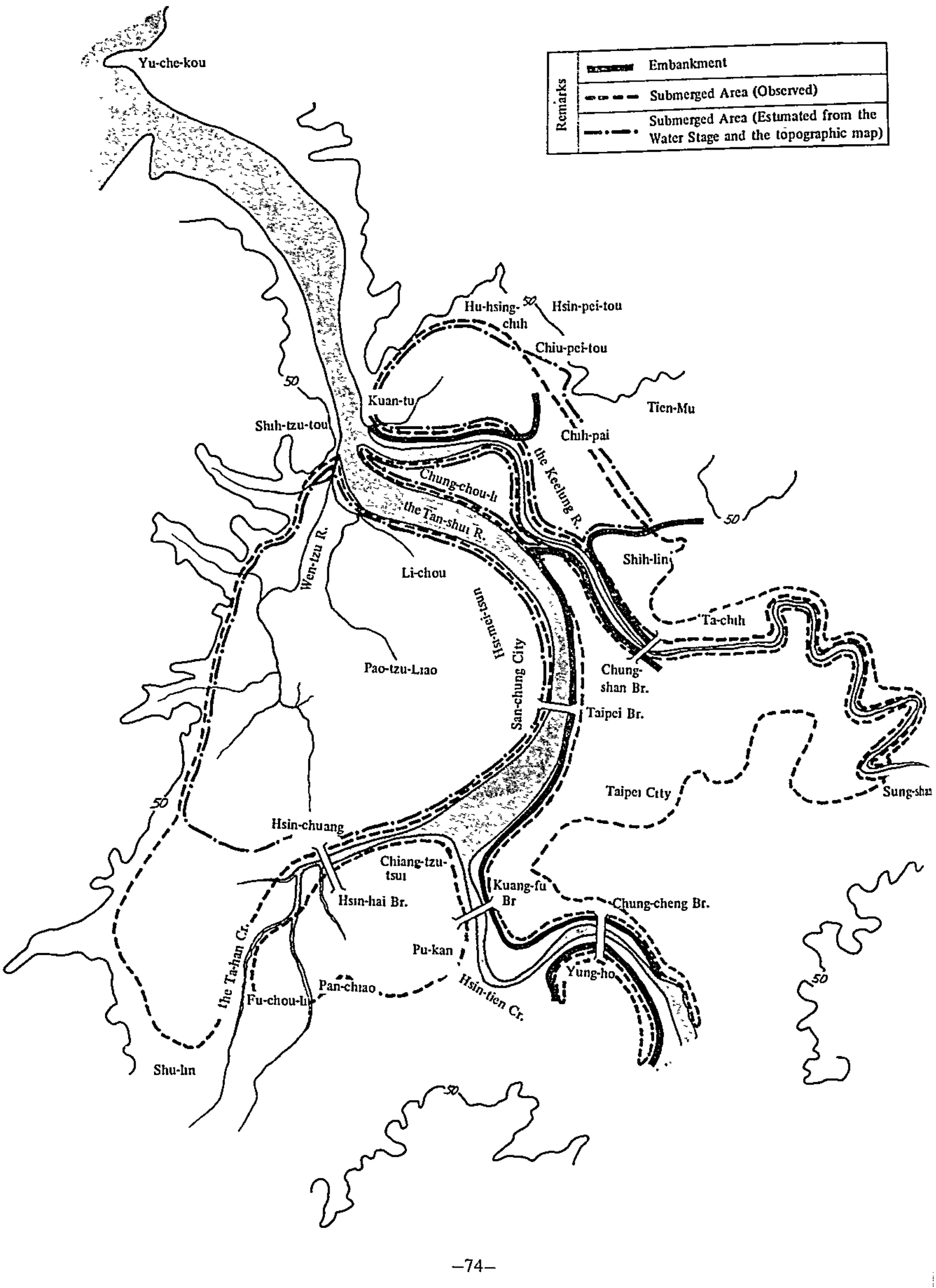


Fig. 5.18 Submerged Area Caused by Flood of Typhoon Elaine

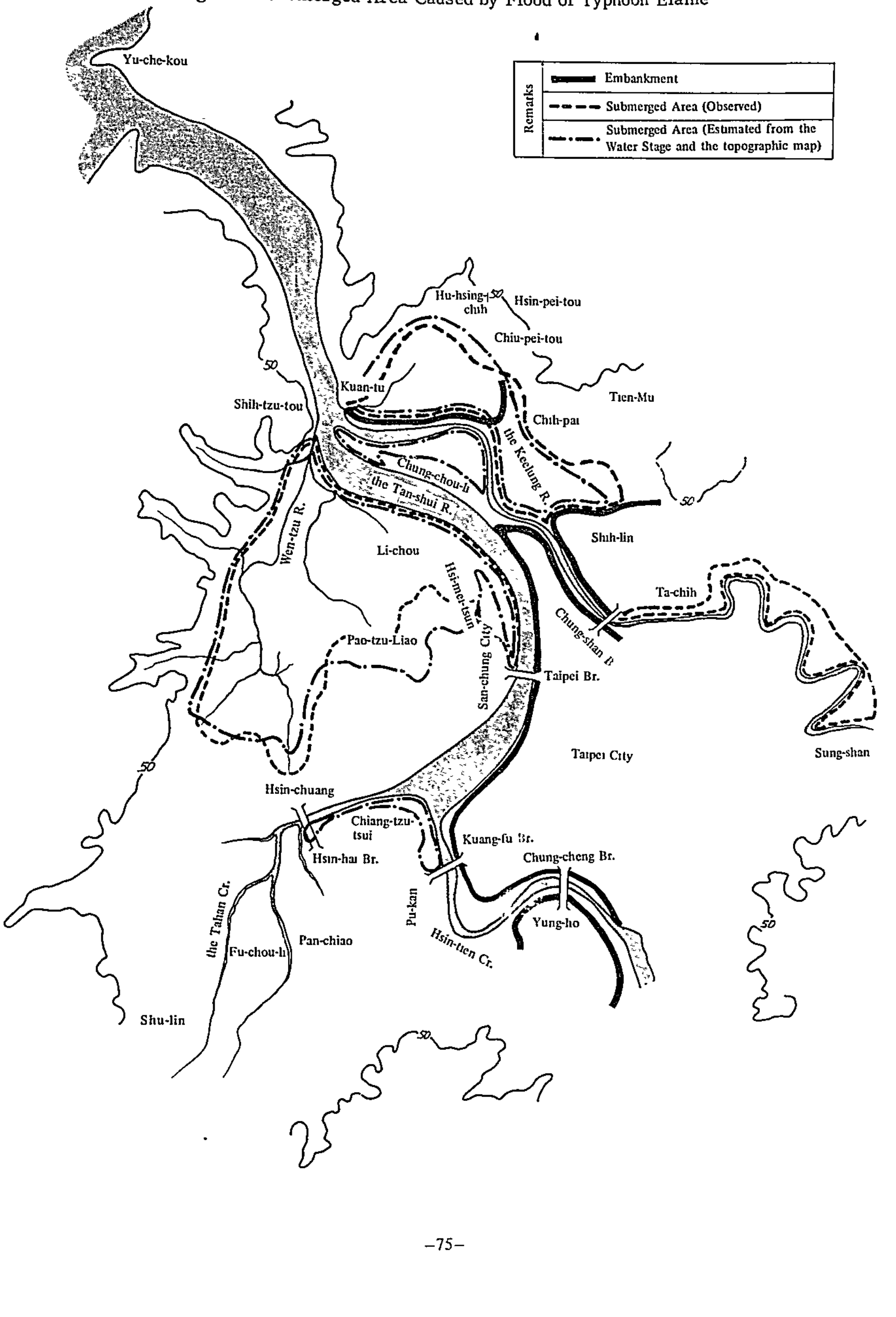


Fig. 5. 19 Submerged Area Caused by Flood of Typhoon Elsie

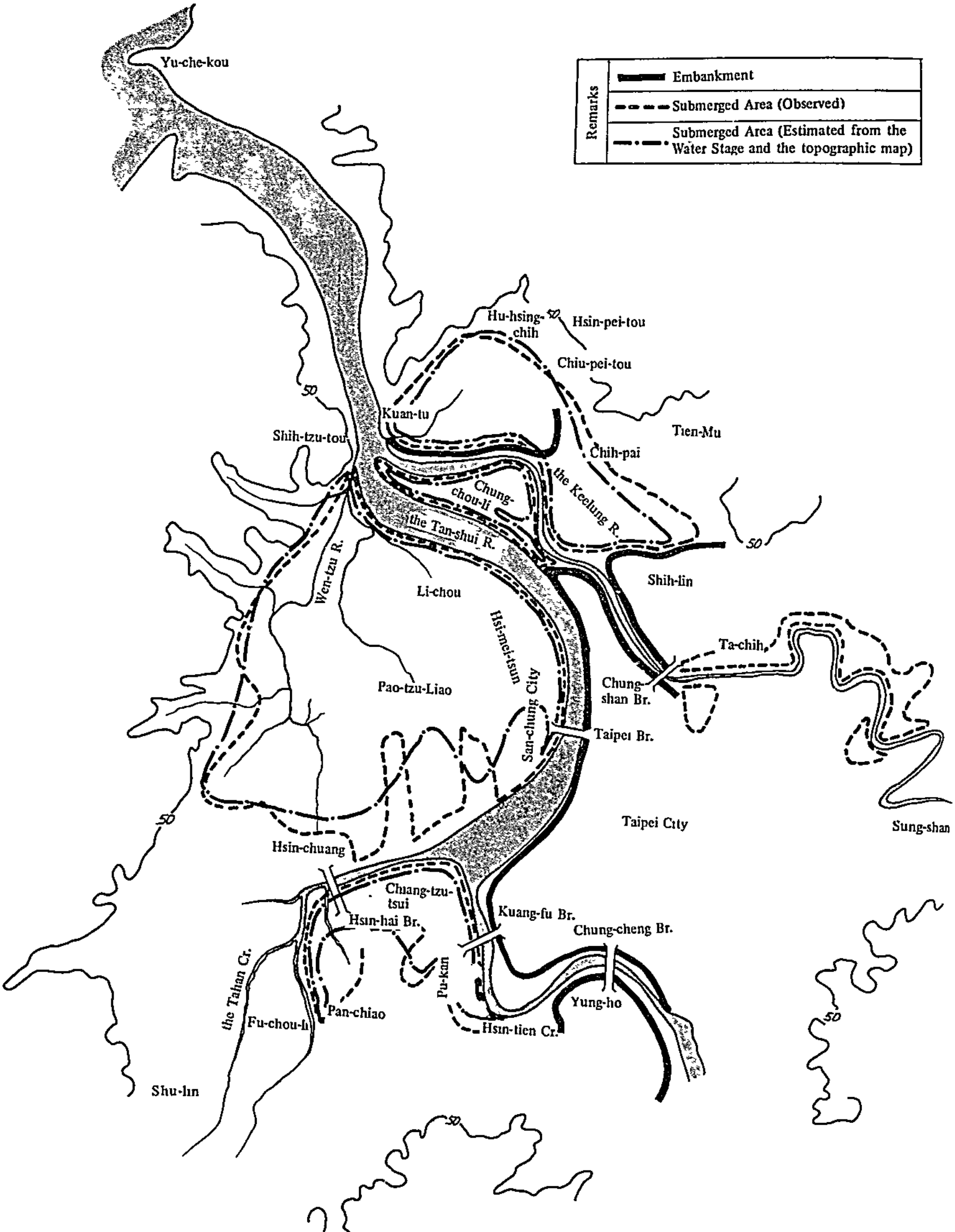


Fig. 5.20 Submerged Area Caused by Flood of Typhoon Flossie

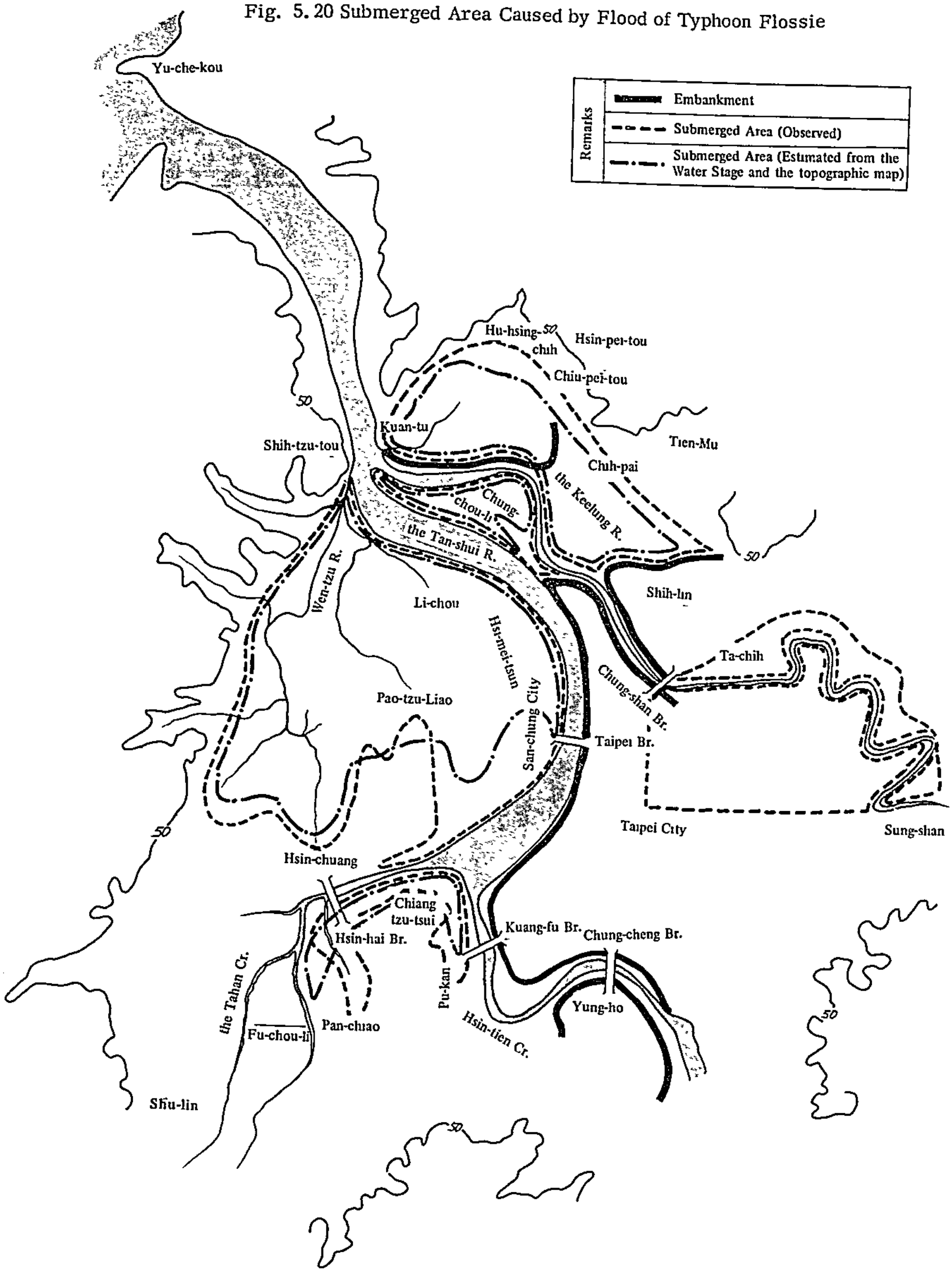


Fig. 5. 21 Submerged Area Caused by Flood of Typhoon Fran

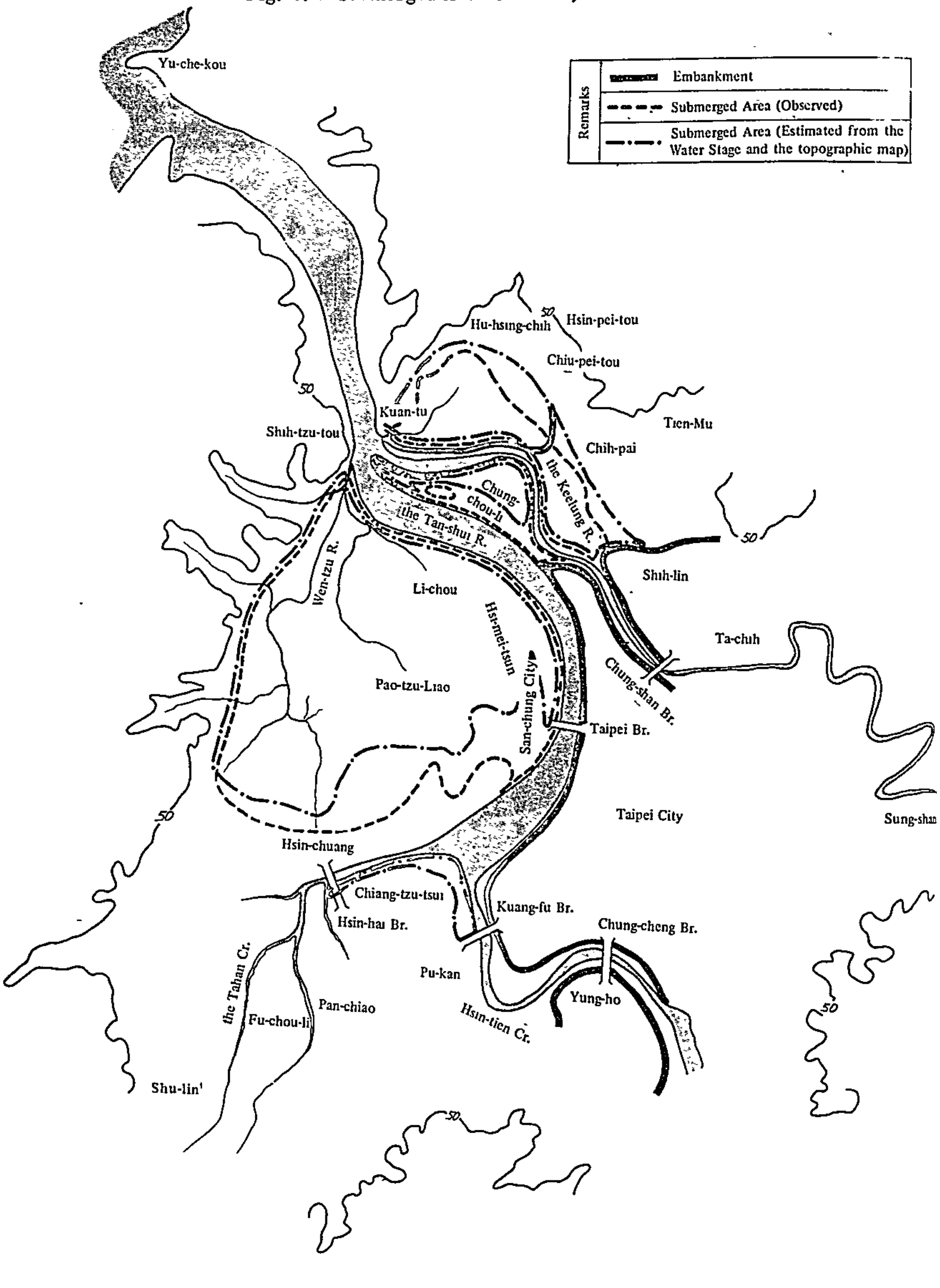
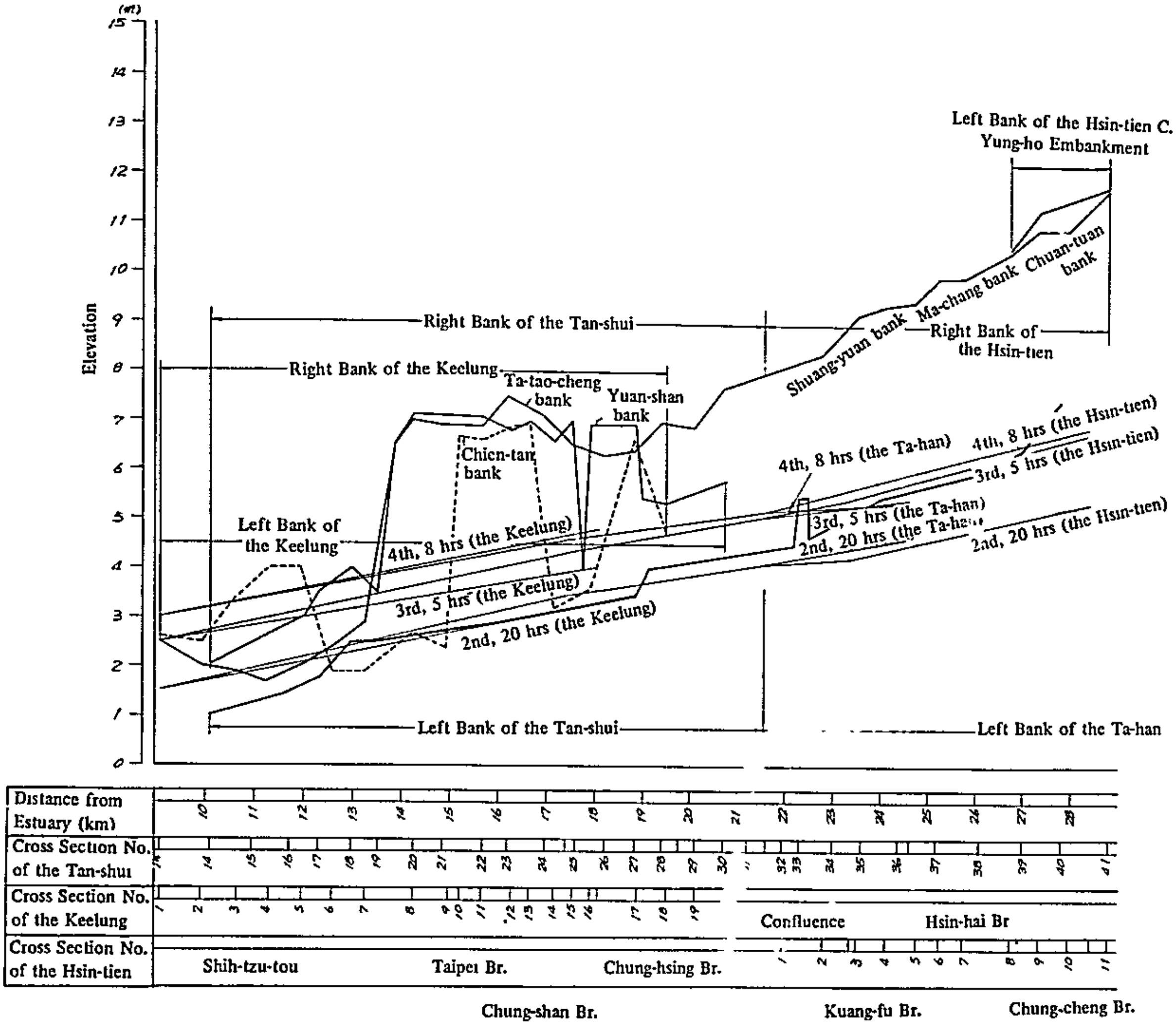


Fig. 5. 22 Flow Profiles in Case of Flood Flossie



From this Fig. 5. 22, it is inferred that the entire left bank side area downstream of Station No. 27 (downstream of a point about 1. 4 km upstream of Taipei Bridge) was flooded at 20:00 hrs of the 2nd, and that the entire left bank side area downstream of Station 35 (about 1 km downstream of the Hsin-hai Bridge) was also flooded at about 5:00 hrs of the 3rd and 8:00 hrs of the 4th (with the exception of the highland area around San-chung). This overflow condition is indicated by arrows in Fig. 5. 20.

When Fig. 5. 23 is thus re-studied, it becomes clear that the aforementioned disagreement between the actual inundated area and the estimated largest inundated area delineated by the assumption of horizontal inundation can be solved if the estimated inundated area is overlaid by the area to be inundated by the side-overflow from the Tan-shui and the Ta-han Creek.

Fig. 5.22 can be also utilized in flood forecasting for the right bank side area of the Tan-shui, i.e., Chung-chou=li district and city area of Taipei. * From Fig. 5.22 it is clear that while Chung-chou-li district becomes submerged excepting a small part having an elevation of higher than 4 m, Taipei city is protected against the intrusion of flood water by the embankment which has an elevation of 6.5 to 7.0 m. Though flood forecasting for Taipei city may not be necessary until the water stage at the Taipei Bridge threatens to rise beyond El. 6.3 m, flooding of water from the Keelung in the north and the Hsin-tien Creek in the south which surround the city must be taken into due consideration (Refer to Section 6.2 for detailed description on this subject).

The duration of inundation shown in Table 5.15 is 88 - 105 hrs in Li-chou district, 55 - 70 hrs in Kuan-tu district and 55 - 70 hrs in Chung-chou-li district. ** The inundation duration estimated for the same three districts on the basis of the water stage data observed at Shin-tzu-tou and assumption of horizontal inundation shows a fairly good agreement with the values shown in Table 5.15. In Li-chou district, the estimated duration is 92 hrs (suppose the inundated area is defined from 1 to 3 m in elevation, the inundation duration is the time required for the water stage at Shih-tzu-tou to be higher than 1 meter in elevation), and is 78 hrs in Kuan-tu district (it is assumed that river water starts overflowing the Kuan-tu tide embankment when the water stage at Shin-tzu-tou rises beyond 2.5 m, and inundation comes to an end when the said water stage declines to 1 m). For Chung-chou-li district, a period of 76 hrs is estimated (assuming that the inundated area has an elevation ranging from 1.5 to 3 m). As above-mentioned, the actual inundation duration and the inundation duration estimated from the water stage at Shih-tzu-tou are confirmed to agree with each other.

The depth of flood water shown also in Table 5.15 for the three districts is 2.5 m in Li-chou, 2.2 m in Chung-chou-li and 2.2 m in Kuan-tu. The depth estimated from the lowest ground elevation and the highest Shih-tzu-tou's water stage (3.0 m) which were adopted for estimating the inundation duration, is 2.0 m in Li-chou, 1.5 m in Chung-chou-li and 2.0 m in Kuan-tu. The error in the value estimated for Chung-chou-li district is outstanding, and this may be attributed, among others, to the fact that the Tan-shui's water surface gradient was not taken into account. As for the Chiang-tzu-tsui district, unlike the downstream area, the flood inundation is influenced by the flood flow from Ta-han Creek and Hsin-tian Creek, and so it would be reasonable to take the average of the values obseved at the Hsin-hai Bridge, Kuang-fu Bridge and Taipei Bridge as the water stage to be forecast.

The inundation condition in Ta-chih/Sung-shan district cannot be readily explained because the topographic map indicates that contour lines in the district are quite complicated. There will be no alternative but to make a rough estimation of the inundation from the water stage at the Chung-shan Bridge and from the assumption of horixontal inundation.

The above explanation of the inundation condition in the lower Tan-shui basin, in which the flood of Typhoon Flossie alone is taken up, can also be given for other typhoons though omitted in this report.

* In Fig. 5.22 Chung-chou-li district extends downstream of a point halfway between Stations 19 and 20 (about 14 km from the estuary), whereas Taipei's city area is found upstream of this point.

** The district delineation in Table 5.15 differs from that adopted in this report.

CHAPTER VI FLOOD FORECASTING AND WARNING SYSTEM

6.1 Purpose and Methods of Flood Forecasting

Flood forecasting and warning is intended to warning the administrative organs concerned or the inhabitants in the basin by giving river water stages or discharges which are estimated when climatic condition and other factors point to the occurrence of a flood. It is aimed at giving necessary information to flood defense organizations prevention of an inundation, and providing the inhabitants with the information required for their evacuation and protection of properties at the stage when an inundation is impending.

To fulfill the above purposes, detailed information should be offered with sufficient time allowance to administrative organs or the inhabitants, and this in turn demands that a most effective flood forecasting and warning system be set up according to the scale of the river, topography and configuration of the basin in view.

Studies made in the foregoing pages indicate that the flooding of the Tan-shui is limited to the flat and lowland area upstream of Shih-tzu-tou which spreads around San-chung city opposite to Taipei, the neighbourhood of the confluence with the Ta-han Creek, and the downstream area of the Keelung. It appears that flood forecasting and warning need only to cover these three areas only.

For the first of above three areas, flood water level, area of inundation and time of occurrence of inundation may be included in the forecast. For the remaining two areas, however, whether and when an inundation occurs would be thė only information that is to be given.

As described in the interim report*, the forecasting will be made by estimation of the flood runoff,from the three tributary basins using the data obtained from the telemetering rain gauges (Ref. Section 4. 2),and by estimating the inundation condition in the upstream area of Shih-tzu-tou from these runoff data and estuary tidal level. In estimating the condition of inundation in this area, calculations are to be worked out using the data of water stages at the key observation stations described in Section 5. 5. Information to be forecast will be obtained by calculations by means of the charts attached to this report, river profiles, topographic maps (contour maps) as well as with the aid of a portable electronic computer, and will be transmitted and announced through TV, radios and loudspeakers.

6.2 Method of Flood Forecasting

6.2.1 Method of Flood Runoff Forecasting in Upstream Tributary Basins

i) Basin Runoff Forecasting by Storage Function Method

It has already been described that the diagrammatical method, semi-diagrammatical method and polygonal line approximation method can be employed in calculating the basin runoff by means of the storage function. The following

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* Refer to Appendix 1.

description is intended to elucidate the semi-diagrammatical method applied with the aid of an electronic computer.

By multiplying both equations (5.1) and (5.2) by 3.6/A, the following difference equation can be established for time t ~ t + Δt if f = 1.

$$R_{t+\Delta t - T_1} - \frac{Q_t + Q_{t+\Delta t}}{2} = \frac{S_{t+\Delta t} - S_t}{2} \quad \ldots \quad (6.1)$$

where,

$R_{t+\Delta t - T_1}$	:	Rainfall intensity at time $t - T_1 \sim t + \Delta t - T_1$ (mm/hr).
Q_t, $Q_{t+\Delta t}$	:	Runoff height at time t and t + Δt (mm/hr).
S_t, $S_{t+\Delta t}$	:	Basin storage volume at time t and t + Δt (mm).
Δt	:	Time interval of calculations (hr).

The above equationccan be rearranged as follows.

$$(S_t/\Delta t + Q_t/2) + R_{t+\Delta t - T_1} - Q_t = S_{t+\Delta t}/\Delta t + Q_{t+\Delta t}/2 \quad \ldots \quad (6.2)$$

If the values of K and p of the storage function are given, S and $S_{t+\Delta t}$ can be expressed by the function of Q_t and $Q_{t+\Delta t}$ respectively. Hence, all the left side terms of the above equation are known at time t, and $Q_{t+\Delta t}$ on the right side alone remains unknown. If the storage function is expressed by $S_{t+\Delta t} = KQ^p_{t+\Delta t}$, the above equation cannot be analytically solved except when p = 0.5 or 1 and therefore, graphical solution is expedient.

For this purpose, a curve is to be prepared with Q (mm/hr) plotted on the abscissa and $S/\Delta t + Q/2 = KQ^p/\Delta t + Q/2$ (mm/hr) plotted on the ordinate. If the known value of the left side of equation (6.2) at time t is calculated and given to take the place of the ordinate ($S_{t+\Delta t}/\Delta t + Q_{t+\Delta t}/2$), then the abscissa will be represented by $Q_{t+\Delta t}$.

For better understanding of the above process, an exercise is given below.

(Exercise 1)

Question: A storage function in a basin having an area of 120 km^2 is known to be $S = 40\,Q^{0.35}$ and T_1 = 2 hrs by analysis. A rainfall of 15 mm was observed from 8:00 to 9:00 hrs on a certain day in the said basin, and the discharge at the basin's downstream end at 9:00 hrs was 350 m^3/sec. Estimate the runoff at 10:00 hrs and 11:00 hrs with the base flow of 20 m^3/sec.
Disregard the rainfall loss, and Δt = 1 hr.

Solution: At first, a curve representing $(Q, 40Q^{0.35}/1 + Q/2)$ is to be prepared.

Q (mm/hr)	$40Q^{0.35}/1+Q/2$
0	0
0.5	31.60
1.0	40.50
2.0	51.98
5.0	72.83
10.0	94.64
20.0	124.11
30.0	146.88

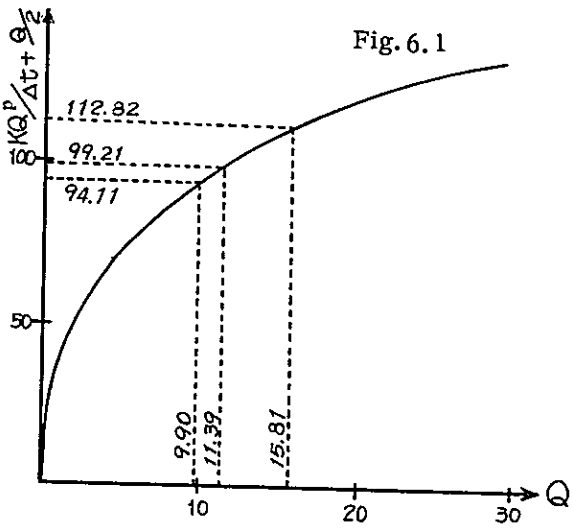

Fig. 6.1

Then, the discharge at 9:00 hrs is to be converted to runoff as shown below.

$$Q_9 = (350 - 20) \times 3.6/120 = 9.90 \text{ (mm/hr)}$$

The value of the 1st term of left side of equation 6.2 is to be obtained as calculated below.

$$\left(\frac{40Q_9^{0.35}}{1} + \frac{Q_9}{2}\right) = 40 \times 9.90^{0.35} + 9.90/2 = 94.11 \text{ (mm/hr)}$$

This value can also be obtained from the Fig. 6.1.

$$\left(\frac{40Q_9^{0.35}}{1} + \frac{Q_9}{2}\right) + R_{9+1-2} - Q_9 = 94.11 + 15 - 9.90 = 99.21 \text{ (mm/hr)}$$

From the figure, $Q_{10} = 11.39$ mm/hr is to be obtained as the abscissa (Q_{10}) corresponding to the ordinate 99.21 $\left(= \frac{40Q_{10}^{0.35}}{1} + \frac{Q_{10}}{2}\right)$.

Similar calculation is to be made to obtain the runoff at 11:00 hrs as shown below using the value of Q_{10}.

$$\left(\frac{40Q_{10}^{0.35}}{1} + \frac{Q_{10}}{2}\right) + R_{10+1-2} - Q_{10} = 99.21 + 25 - 11.39 = 112.82 \text{ (mm/hr)}$$

From the figure again, $Q_{11} = 15.81$ mm/hr is to be obtained as being corresponding to $\frac{40Q_{11}^{0.35}}{1} + \frac{Q_{11}}{2} = 112.82$.

The following values obtained by conversion from Q_{10} and Q_{11} are the estimated discharge values to be obtained.

$$Q_{10} \times \frac{120}{3.6} + 20 = 11.39 \times \frac{120}{3.6} + 20 = 400 \ (m^3/sec)$$

$$Q_{11} \times \frac{120}{3.6} + 20 = 15.81 \times \frac{120}{3.6} + 20 = 547 \ (m^3/sec)$$

Values of Q_{10}, Q_{11} .... can be obtained with ease from the table shown below.

Time	mm/hr	
	94.11	. . . $KQ_9^p / \Delta t + Q_9 /2$ (to be calculated from the observed value)
9	- 9.90	. . . Q_9 (observed value)
	+15	. . . Rainfall intensity from 9 - T_L hrs to 10 - T_L hrs (R_{9+1-T_L}).
	99.21	. . . $(KQ_9^p / \Delta t + Q_9 /2) + R_{9+1-T_1} - Q_9 = KQ_{10}^p / \Delta t + Q_{10} /2$
10	-11.39	. . . Q_{10} (to be obtained from the figure)
	+25	. . . Rainfall intensity from 10 - T_L hrs (R_{10+1-T_L})
	112.82	. . . $(KQ_{10}^p / \Delta t + Q_{10}/2) + R_{10+1-T_L} - Q_{10} = KQ_{10}^p / \Delta t + Q_{11} /2$
11	-15.81	. . . Q_{11} (to be obtained from the figure)
	+	. . . Rainfall intensity from 11 - T_L hrs to 12 - T_L hrs ($R_{11+1-T1}$)

In the above calculation, the figure is used to obtain the value of Q_{t+1} that satisfies $KQ_{t+1}^p + Q_{t+1}/2 = C$. If a portable electronic computer having the programming function, the above-explained calculation can be easily worked out.

When S is expressed by the P = 1 power of Q in equation (6.2), the following equation is established to make S = KQ.

$$Q_{t+\Delta t} = \{R_{t+\Delta t-T_1} + (K/\Delta t - 1/2)Q_t\} / (K/\Delta t + 1/2) \quad \ldots\ldots \quad (6.3)$$

If p = 0.5 (i.e., $S = KQ^{0.5}$), on the other hand, the following equation can be established.

$$Q_{t+\Delta t} = 2 \left[\{M + (\frac{K}{\Delta t})^2\} - \sqrt{\{M + (\frac{K}{\Delta t})^2\}^2 - M^2} \right] \quad \ldots \quad (6.4)$$

where, $M = R_{t+\Delta t} - T_1 - \frac{Q_t}{2} + \frac{KQ_t^{0.5}}{\Delta t}$

ii) Flood Routing Calculation by Channel Unit Graph Method

By exactly the same method as employed in the calculation of flood runoff in a basin, the discharge at the downstream end of the channel at each time can be obtained if the discharge at each time at the upstream end of the channel at each time is given. *

The discharge value can be obtained by the application of the following equation which is established from equation (5. 3).

$$Q_o\,(t) = \sum_{\tau=0}^{\infty} Q_i\ (t-\tau)\cdot K(\tau)\,\Delta\tau \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6.5)$$

where,

Q_i : Discharge at upstream end
Q_o : Discharge at downstream end
$K(\tau)$: Unit graph distribution ratio

The calculation is simple enough to dispense with any further explanation by an exercise.

Constants required in working out the above calculation are already available from the analysis described in Section 5. 4 and are shown in the Table 5. 9.

iii) Estimation of Effective Rainfall in each tributary basin

The total rainfall, total runoff and total rainfall loss are shown in Table 5. 3 for each tributary basin and for each of the past floods, and their average pattern is shown by the solid line in Fig. 5. 5. The average pattern of effective rainfall in each tributary basin of the Tan-shui, iif expressed by the constants of storage function method, will be as shown in Table 5. 10. **

* This discharge value is to be added to the residual basin runoff to obtain the calculated discharge at the downstream end.
** In the storage function method, the runoff ratios (f_1 and f_{sa}) is to be multiplied by the basin area A. However, since this makes the workload of runoff calculation double-fold, the team resorted to the expedient of multiplying f_1 and f_{sa} by the hourly rainfall in this report. In other words, it is assumed that the effective rainfall, r_e, can be approximately expressed as follows.

If $\sum_{t=0}^{t} r_{ave}\cdot\Delta t \leq R_{sa}$, $r_e = (f_{sa} - f_1)\cdot r_{ave}$

If $\sum_{t=0}^{t} r_{ave}\cdot\Delta t > R_{sa}$, $r_e = f_{sa}\cdot r_{ave}$

iv) Forecasting of Flood Runoff at Chung-cheng Bridge

The method of forecasting the flood runoff at the Chung-cheng Bridge is illustrated in the attached Flow Chart No. 3(1). If the flood runoff at this point up to T hours later is to be forecast at time t using the storage function, the following data are necessary.

(1) Discharge at the bridge at time t (Q_t, shown in the upper left part of the chart). *

(2) Hourly average basin rainfall from time $t-T_l$ to time $t-T_l+T$ (R_{t-T_l+1}, ... , R_{t-T_l+T}, shown in the upper left part of the chart).

The basin rainfall need not be forecast if $T \leqq T_l$, but should be forecast for duration $T - T_l$ if $T > T_l$.

If data of (1) and (2) mentioned above are obtained by observation or by forecasting, they are to be applied to the equation of storage function (See Table 6. 1 and lower half of the chart). This process is already explained in "Exercise 1".

v) Forecasting of Flood Runoff at Hsin-hai Bridge

The method of forecasting the flood runoff at the Hsin-hai Bridge is illustrated in the attached Flow Chart No. 3(2). If the runoff at this point up to T hours later is wanted to be forecast at time t by using the channel unit graph and the storage function of the residual basin, the following data are necessary.

(1) Discharge at the bridge at time t (Q_t, shown in the upper central part of the chart).**

(2) Outflow from the Shimen Reservoir up to time t (Q_{Dt}, shown in the upper right part of the chart).

(3) Hourly average rainfall in the residual basin from time $t - T_l$ to time $t - T_l + T$ (R_{t-T_l+1}, ..., R_{t-T_l+T}; shown in the upper left part of the chart).

The rainfall in the residual basin need not be forecast if $T \leqq T_l$, but should be forecast for the duration $T - T_l$ if $T > T_l$.

Forecasting of the outflow from the Shih-men Reservoir down the channel is feasible if $T \leqq \tau_l$ (τ_l : lapse of time after which the unit graph distribution ratio ceases to be zero for the first time, in the case of the Shih-men Reservoir ~ Hsin-hai Bridge Section, τ_l = 2 hrs), and if $T > \tau_l$, the outflow from the reservoir must be forecast by some means or other.

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* Obtainable from Fig. 5. 2.

** Obtainable from Fig. 5. 1.

When data of (1) to (3) are obtained, the following steps must be taken.

(1) The outflow from the Shih-men Reservoir [Q_{Dt}] obtained by information or forecasting) is to multiplied by the channel unit graph distribution ratio so as to obtain the travelling discharge at the Hsin-hai Bridge at each forecasting time [Q'_D (t)].

(2) The travelling discharge at the bridge at the present time (t) obtained by the step (1) above (Q'_{Dt}) is to be deducted from the discharge observed at present (Q_t), and the difference is to be taken as the runoff of the residual basin(Q_{Rt}).

(3) The runoff of the residual basin at present (t) (Q_{Rt}) obtained by step (2) above and the observed or forecast value of average residual basin rainfall are to be applied to the equation of storage function to estimate the runoff of the residual basin [Q_R (t)].

(4) The sum of Q_R(t) obtained in step (3) and Q'_D (t) obtained in step (1) is to be adopted as the forecast discharge at the Hsin-hai Bridge.

vi) Forecasting of Flood Runoff at Chung-shan Bridge

The method of forecasting the flood runoff at the Chung-shan Bridge is illustrated in the attached Flow Chart No. 3(3). If the discharge at this point until T hours later is to be estimated at time t by using the channel unit graph and the storage function, the data mentioned below are necessary.

(1) Discharge at Wu-tu until time $t - \tau_1 + T$ [Q_I (t)] (τ_1 :Lapse of time after which the channel unit graph distribution ratio ceases to be zero for the first time. In the Wu-tu ~ Chung-shan Bridge section, τ_1 = 2 hrs) (shown in the left part of the chart).

(2) If $T>\tau_1$, it is necessary to forecast the discharge at Wu-tu from time t = 1 to time $t - \tau_1 + T$, and therefore, it becomes necessary to obtain the average intra-basin rainfall from time $t - T_{11} + 1$ to $t - \tau_1 - T_{11} + T$, ($R_t - T_{11} + 1$, ..., $R_t - \tau_1 - T_{11} + T$). If, again, $T > \tau_1 + T_{11}$, rainfall for the duration $T - (\tau_1 + T_{11})$ must be forecast (shown in the upper left part of the chart).

(T_{11} : time lag of the storage function of upstream basin of Wu-tu).

(3) Hourly average rainfall in the Wu-tu ~ Chung-shan Bridge section between time $t - T_{12}$ and time $t - T_{12} + T$, ($R_t + T_{12} + 1$, ..., $R_t - T_{12} + T$). If $T>T_{12}$, then the forecasting must cover the duration $T - T_{12}$ (Shown in the right part of the chart). (T_{12} : time lag of the storage function of the Wu-tu~ Chung-shan Bridge section).

If data of (1) to (3) above are obtained, the following stpes must be taken.

---

* Obtainable from Table 5.9.

(1) If $T > \tau_1$, the discharge at Wu-tu at the present time t (Q_{1t}) and the average rainfall in the area upstream of Wu-tu (observed or calculated value) are to be applied into the equation of storage function in order to forecast the discharge at this point until time $t - \tau_1 + T[Q_1(t)]$.

(2) The discharge at Wu-tu $[Q_1(t)]$ is to be multiplied by the channel unit graph distribution ratio* so as to obtain the travelling discharge at the Chung-shan Bridge at each forecasting time $[Q_1'(t)]$.

(3) The average rainfall in the Wu-tu ~ Chung-shan Bridge section is to be applied into the equation of storage function of this section in order to estimate the runoff of the residual basin $[Q_2(t)]$.

(4) The sum of $Q_1'(t)$ obtained in step (2) and $Q_2(t)$ obtained in step (3) is adopted as the forecast discharge at the Chung-shan Bridge.

6.2.2 Method of Water Stage Forecasting and Flood Forecasting at the Key Water Stage Forecasting Stations

Water stage is to be forecast at the key water stage forecasting stations using the discharge values at Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge, which are estimated in the preceding section.

As described in Section 5.5, the following five are the key water stage forecasting stations.

(1) Hsin-hai Bridge
(2) Kuang-fu Bridge
(3) Taipei Bridge
(4) Chung-shan Bridge
(5) Shih-tzu-tou

Since the method of calculating the forecast water stage at these five points is already elucidated in Section 5.5, description in this section will centre on the process of the calculation.

The water stage at the Hsin-hai Bridge is to be forecast from the stage-discharge curve shown in Fig. 5.9 and that at the Kuang-fu Bridge from the curve shown in Fig. 5.10. Note that the discharge at Chung-cheng Bridge is plotted on the abscissa in Fig. 5.10.

The water stage at the Taipei Bridge is to be forecasted from the curve shown in Fig. 5.11. In this figure, the total discharge at Hsin-hai and Chung-cheng (time difference disregarded) is plotted on the abscissa.

The method of forecasting the water stage at Shih-tzu-tou is illustrated in Fig. 5.12. For details of this method, refer to the description given in Section 5.5 or to the exercise included in Section 6.4.

All the data required for calculation are prepared in the tables (Appendix 4). Table 1 is intended to be used in obtaining the stored water volume (V) in the submerged area from the water stage at Shih-tzu-tou (Hs), and Table 2 in obtaining the water stage at Shih-tzu-tou (Hs) from the stored water volume (V). A separate table is prepared which can be used in obtaining the discharge capacity between Shih-tzu-tou and Yu-che-kou $[V_{out}(Hs, Hy)]$. Hy in these tables indicated the water stage at Yu-che-kou.

* Obtainable from Table 5.9

Fig. 3 of Appendix 4 is to be used to obtain the water stage at the Chung-shan Bridge from the water stage at Shih-tzu-tou mentioned above and from the forecast discharge at the Chung-shan Bridge obtained in the preceding section. In this figure, the absissa represents the discharge at the Chung-shan Bridge, parameter the water stage at Shih-tzu-tou, and ordinate the water stage at the Chung-shan Bridge to be obtained.

The water stage at the key stations can be forecast by the use of the above data, but the flood forecasting and warning based on such water stage further calls for the availability of a topographical map and a longitudinal river profile. A map with a contour line interval of 0.5 m included in the report Fig. 3.3 may satisfy the need of topographical map. In the river profile shown in Fig. 5.22, the height of both bank and ground surface are filled in the longitudinal direction of rivers. By entering the forecast water stage value at respective key stations in this figure and also by filling in the flow profile created by connecting the water stage values by direct lines, it can be easily estimated when and where and what depth of inundations or overflows will occur.

Since both the topographical map and the figure of the longitudinal river profile will be frequently used, their original drawings for tracing must be prepared. In areas subjected to heavy land subsidence, surveying should be conducted every year so that they can be both kept up to date.

The method of utilizing each of the above-mentioned data is illustrated below.

Forecast water stage at Shih-tzu-tou →	Topographical map →	Flood forecasting for Li-chou and Kuan-tu districts
Forecast water stage at Taipei Bridge →	Topographical map →	Flood forecasting for San-chung city
Forecast water stage at Hsin-hai Bridge →	Topographical map →	Flood forecasting for Hsin-chuang and Pan-chiao districts
Forecast water stage at Chung-shan Bridge →	Topographical map →	Flood forecasting for Ta-chih/Sung-shan districts
Forecast water stage at Kuang-fu Bridge →	Topographical map →	Flood forecasting for Pu-kan district
Forecast water stage at the confluence of Ta-han Creek and Hsin-tien Creek (average of water stage values at Hsin-hai, Kuang-fu and Taipei Bridges) →	Longitudinal River profile →	Flood forecasting for Taipei city, San-chung city, Erh-chung and Chung-chou-li district

6.3 Validity of Proposed Flood Forecasting Method

A flood runoff model was built in Section 5.4 with the view to forecasting the runoff in a basin from rainfall. In this model building, all the rainfall data available were employed for as accurate an estimation as possible of the intra-basin average rainfall. In the actual forecasting work, however, the rainfall data available are limited to those transmitted from telemeter stations.

In Section 5. 5, a model was also proposed for forecasting the water stage at Shih-tzu-tou. To make this model as accurate as possible, the discharge values at the Hsinhai Bridge and the Chung-cheng Bridge and the water stage values at Yu-che-kou employed were all observed values, but the discharge at the Chung-shan Bridge had to be estimated because of the absence of observed value. In the actual forecasting service, however, there will be no alternative but to resort to calculated estimated values. *

Thus, various studies made in the preceding sections aimed primarily at model building and therefore, the amount of information assumed therein is based on conditions quite divergent from the actual availability of information. In this section, therefore, studies will be made on the accuracy of the proposed forecasting method when it is put in practice with a limited amount of information.

The rain gauges are limited to the telemetering stations selected in Section 4. 2 and the intra-basin flood runoff calculated from the data transmitted from them is as shown in Fig. 6. 2.

This figure indicates that there occur substantially large errors when the number of telemetering rain gauges is limited.

This calculation should be made for each tributary to estimate the water stage at Shih-tzu-tou for an overall checking of accuracy, but this cannot be done chiefly due to the lack of past data in the upstream area of the Ta-han Creek. In the actual flood forecasting work, it is to be noted that large errors could occur if these factors are not taken into due account.

6. 4 Exercise in Flood Forecasting Calculation

In order to elucidate how the flood runoff and the inundation of downstream area to be forecast when a flood actually takes place and a flood warning need to be given, an exercise is given below.

a. Calculation of Upstream Flood Runoff

Average intra-basin rainfall and river water stage shown in Table 6. 1 were observed in the Tan-shui's three tributary basins up to 18:00 hours of a certain day of a cirtain month. The hourly flood discharge at the Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge until 5 hours thereafter (23:00 hrs) will be estimated using the said data. Further, assuming that the values shown in parentheses of the said table were observed at 19:00 hrs of the same day, the flood discharge until 5 hours later (i. e., up to 24:00 hrs) will be estimated. Both flood discharge forecasting can be done successfully by following the method described in Section 6. 2.

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* If a telemeter station is established at Shih-tzu-tou, observed water stage data can be made use of .

Fig. 6.2 Difference between Calculated Discharge and Observed Discharge

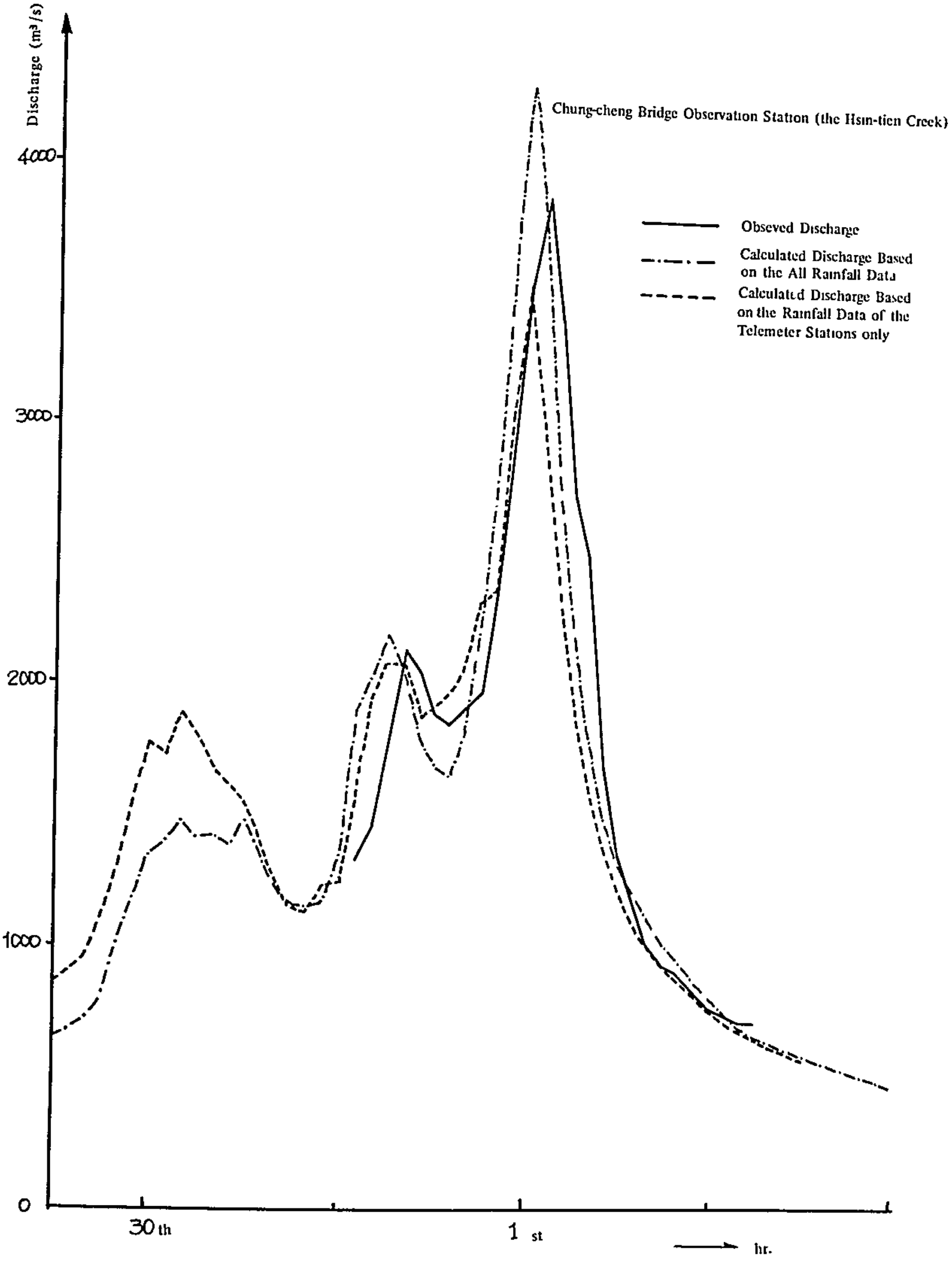


Table 6.1 Observed Average Rainfall of Each Basin and Water Stage Observed at Each Station

Time	Basin's Average Rainfall				Outflow from Shih-men Reservoir	Observed Water Stage			
	Shih-men Reservoir ~ Hsin-hai Bridge	Upstream of Chung-cheng Bridge	Upstream of Wu-tu	Wu-tu ~ Chung-cheng Bridge Section		Hsin-hai Bridge (EL.)	Chung-cheng Bridge (EL.)	Wu-tu (EL.)	Taipei Bridge (EL.)
	mm	mm	mm	mm	m³/s	m	m	m	m
Up to 0:00 hrs	13.8	56.2	111.8	64.7					
1	3.7	6.1	10.5	5.2	51			5.86	1.07
2	3.2	6.5	13.0	8.3				6.04	1.31
3	0.8	5.7	11.0	7.5				6.36	1.35
4	1.0	7.1	13.0	8.9				6.72	1.29
5	2.7	9.0	12.0	7.7				7.02	1.17
6	2.6	8.4	12.5	8.9				7.35	1.05
7	2.3	7.5	14.5	9.8				7.68	0.93
8	3.9	10.0	11.3	8.1				8.06	0.88
9	6.4	8.3	12.8	9.1				8.38	0.90
10	4.9	6.8	7.5	9.4	81			8.86	0.96
11	6.1	9.7	7.5	10.5	413			9.38	1.10
12	3.1	6.4	7.5	9.2	500			10.06	1.30
13	5.2	8.0	8.0	9.2	600			10.50	1.48
14	6.6	11.1	14.0	11.3	672			10.55	1.68
15	7.6	17.6	24.5	11.6	1080			10.46	2.03
16	5.0	11.8	14.0	10.2	1100			10.30	2.33
17	10.9	15.2	20.0	11.6	1200		4.50	10.23	2.48
18	12.8	17.7	20.5	11.6	1250	4.13	4.87	10.37	3.01
19	(12.3)	(19.4)	(21.0)	(11.5)	(1150)	(4.44)	(5.13)	(10.76)	(3.27)

The discharge at the Hsin-hai Bridge can be obtained from Table 6. 2 and its explanatory note. The discharge at the Chung-cheng Bridge can be obtained from Table 6. 3 and its explanatory note, whereas the discharge at the Chung-shan Bridge can be obtained from Table 6. 4 and its explanatory note pending the completion of a stage-discharge curve at Chung-shan or a neighbouring point in future. Completion of this curve will make it possible to obtain the discharge at the Chung-shan Bridge in much the same manner as applied for the Chung-cheng Bridge. The explanation about these tables is perhaps of no use.

b. Calculation of Downstream Water Stage of Flood

The discharge of the Ta-han Creek, Hsin-tien Creek and Keelung River at the Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge respectively can be estimated as above-mentioned. Using these discharge values we are to start from the forecasting operation to estimate when, where and what depth of inundations or overflows will occur in the lower reaches.
It is convenient for the estimation to tabulate the data just like Table 6. 5. The method of the estimation will be explained below.

Column (1) is to be filled with time. Since the discharge is estimated (punctually) at each hour, the water stage at each hour should be estimated. The value at 19:00 hrs is known in the exercise, and the value at each hour until 24:00 hrs is to be estimated.

Columns (2), (3) and (4) are to be filled with the estimated discharge at the Hsin-hai Bridge, Chung-cheng Bridge and Chung-shan Bridge, respectively.

Column (5) is to be filled with the discharge at the Taipei Bridge. This value is the sum of the discharge at the Hsin-hai Bridge filled in Column (2) and that at the Chung-cheng Bridge in Column (3). In this summing up, no time difference is to be taken into account. At 20:00 hrs, for example, the value should be 4, 386 (= 1, 939 + 2, 447) m^3/sec.

Column (6) is to be filled with the water stage at the Taipei Bridge which can be obtained directly from Column (5) using Fig. 5. 11 because the water stage and discharge at this point are approximately represented by a unique function. From this value, the overflow from around the Taipei Bridge into San-chung city district can be directly forecast.

Column (7) is to be filled with the estimated water stage at the Hsin-hai Bridge. Though a single stage-discharge curve at this point cannot always be established, the water stage is obtained from the discharge at this point filled in Column (2) using Fig. 5. 9.

At 20:00 hrs, for example, discharge estimated at Shin-hai Bridge is 1, 939m^3/sec, so it is possible to obtain a value of 5. 00m.

From the water stage thus obtained, the inundation of Fu-chou-li and neighbouring area can be forecast.

Column (8) is to be filled with the estimated water stage at the Kuan-fu Bridge. Estimation of the water stage at this bridge and not at the Chung-cheng Bridge is justified because there exists a water stage correlation between the two bridges as explained in Chapter 5, and the former bridge is closer to the area actually subjected to inundation. The water stage at this point can be readily obtained from the discharge at the Chung-cheng Bridge given in Column (3) and Fig. 5.10.

Column (9) is to be filled with the estimated water stage near the confluence of the Ta-han Creek and the Hsin-tien Creek. Since no water gauges have yet been installed near the confluence, the average of the water stage values at the Taipei Bridge, Hsin-hai Bridge and Kuang-fu- Bridge is to be adopted. From this average value, it will be possible to forecast the overflow into Erh-chung and Chiang-tzu-tsui districts.

Column (10) is to be filled with the inflow volume into the submerged area which is to be obtained by multiplying the sum of values filled in Columns (2), (3) and (4) by 3,600 sec (= 1 hr). In this case, time difference is to be disregarded.

At 20:00 hrs, for example, the inflow will be calculated as follows.

$$(1,939 + 2,447 + 1,256) \times 3,600 = 20,310,000 \text{ m}^3$$

Column (11) is to be filled with the water stage at Yu-che-kou which is to be estimated in advance by harmonic analysis or other means.

Column (12) is to be filled with the water stage at Shih-tzu-tou. For 19:00 hrs, the observed value of 1.36 m is to be entered, under which the value estimated for each hour is to be filled.

Column (13) is to be filled with the hourly volume of water flowing out of the submerged area down the channel. From the water stage of 0.32 m at Yu-che-kou and 1.36 m at Shih-tzu-tou at 19:hrs, an hourly outflow volume of $1,290 \times 10^4 m^3$ can be obtained using the table of the separate appendix or Fig. 2 in the appendix 4.

Column (14) is to be filled with the storage volume in the submerge area. Since the water stage at Shih-tzu-tou is known to be 1.36 m at 19:00 hrs, a storage volume of $6,989 \times 10^4 m^3$ can be obtained from the stage-storage volume curve or the Table shown in Appendix 4.

Using the following relationship (an equation of continuity), the stored volume at 20:00 hrs is obtained.

Stored volume = Stored volume at the previous hour + Inflow - Outflow

Accordingly, a value of $7,447 \times 10^4 m^3$ can be obtained as calculated below.

$$6,989 + 1,748 - 1,290 = 7,447 \ (10^4 m^3)$$

The water stage values at each subsequent hour can be forecasted in the same manner.

The water stage at Shih-tzu-tou can be obtained from the stored volume calculated above and filled in Column (14) by employing Table 2 or Fig. 1 in Appendix 4.

Column (15) is to be filled with the estimated water stage at the Chung-shan Bridge. Since the water stage at this point is strongly affected by that at Shin-tzu-tou, it is to be estimated from the water stage at Shih-tzu-tou and the observed or estimated discharge of the Keelung by means of Fig. 3 in Appendix 4.

The above estimation consists mostly of simple elementary arithemetic operations and reading of nomograms or tables. Estimation for five hours ahead will require no more than 10 minutes if carried out by a skilled operator.

Table 6.2 Method of Forecasting the Discharge at Hsin hai Bridge of Tahan Creek up to 5 hours later

Present Time	Effective Rainfall in the Residual Basin of Shih-men Reservoir ~ Hsin-hai Bridge Section (f_1 = 0.50, Rsa = 100 mm)											
	Average Rainfall in the Residual Basin				Accumulative Rainfall				Effective Rainfall			
	Observed Value	Estimated Value at an Hour Later	Estimated Value at 2 Hours Later	Estimated Value at 3 Hours Later	Observed Value	Accumulative Rainfall at an Hour Later	Accumulative Rainfall at 2 Hours Later	Accumulative Rainfall at 3 Hours Letter	Calculated from Observed Values	Value at an Hour Later	Value at 2 Hours Later	Value at 3 Hours Later
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
10	4.9				45.3				2.5			
11	6.1				51.4				3.1			
12	3.1				54.5				1.6			
13	5.2				59.7				2.6			
14	6.6				66.3				3 3			
15	7.6				73.9				3.8			
16	5.0				78.9				2.5			
17	10.9				89.8				5 5			
18	12.8	9.6	9.6	9.6	102.6	112.2	121.8	131.4	12.8	9 6	9.6	9.6
19	12.3	12.0	12.0	12.0	114.9	126.9	138.9	150.9	12.3	12.0	12.0	12.0
20												
21												
22												
23												
24												
	Thiessen's method employed.	Rainfall at each hour to be estimated from radar data and weather map.			Cumulative total of (1)	(5) + (2) x Δt	(6) + (3) x Δt	(7) + (4) x Δt	If (5), (6), (7), (8) > Rsa: (9) = (1), (10) = (2), (11) = (3), (12) = (4)	If (5), (6), (7), (8) ≦ Rsa: (9) = (1) x f_1, (10) = (2) x f_1, (11) = (3) x f_1, (12) = (4) x f_1		

Present Time	Observed Discharge at Hsin-hai Bridge (obtained from stage-discharge curve)			Flood Routing in Shih-men Reservoir ~ Hsinhai Bridge Section by Channel Unit Graph Method (Unit graph: 0, 0, 0 1, 0.4, 0 25, 0.15, 0.1, 0)									
				Outflow from Shih-men Reservoir				Travelling Discharge					
	Water Stage at Hsin-hai Bridge	Water Stage at Taipei Bridge	Observed Discharge at Hsin-hai Bridge	Informed Value	Estimated Value at an Hour Later	Estimated Value at 2 Hours Later	Estimated Value at 3 Hours Later	Value at Present Time	Discharge at an Hour Later	Discharge at 2 Hours Later	Predicted Discharge at 3 Hours Later	Predicted Discharge at 4 Hours Later	Predicted Discharge at 5 Hours Later
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
10		0.96		81									
11		1.10		413									
12		1.30		500									
13		1.48		600									
14		1.68		672									
15		2.03		1080									
16		2.33		1100									
17		2.48		1200									
18	4.13	3.01	1430	1250	1300	1400	1500	850	991	1109	1203	1263	1343
19	4.44	3 27	1650	1150	1100	1100	1100	991	1109	1188	1173	1145	1123
20													
21													
22													
23													
24													
	Elevation above the standard sea level		To be obtained from (13) and (13) - (14), using H-Q curve.	To be in informed from Shih-men Reservoir Control Office	To predict the outflow from the Shih-men Reservoir.			To be calculated from (16) - (19), using the unit graph (use of a portable electronic computer will be helpful). (21) = 1200x0.1+1100x0 4+1080x0.25 +672x0.15+600x0.1 = 991 (24) = 1400x0.1+1300x0.4+1250x0.25 +1200x0.15+1100x0.1 = 1263					

Estimation of the Residual Basin Runoff and Discharge at Hsin-hai Bridge
(A = 397.11 km², T1 = 2 hrs, S = 50 (q - q)$^{0.3}$, Qi = 20 m³/s)

Present Time		1 Hour Later				2 Hours Later				3 Hours Later				4 Hours Later				5 Hours Later			
The Residual Basin Runoff	The Residual Basin Runoff Hight	Effective Rainfall at an Hour Earlier	Estimated Runoff Hight	Estimated Discharge	Discharge at Hsin-hai Bridge	Effective Rainfall at Present Time	Estimated Runoff Hight	Estimated Runoff	Discharge at Hsin-hai Bridge	Effective Rainfall at an Hour Later	Estimated Runoff Hight	Estimated Discharge	Discharge at Hsin-hai Bridge	Effective Rainfall at 2 Hours Later	Estimated Runoff Height	Estimated Discharge	Discharge at Hsin-hai Bridge	Effective Rainfall at 3 Hours Later	Estimated Runoff Hight	Estimated Discharge	Discharge at Hsin-hai Bridge
(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)
580	5.08	5.5	5.16	589	1580	12.8	6.75	765	1874	9.6	7.41	837	2040	9.6	7.94	896	2159	9.6	8.36	942	2285
659	5.79	12.8	7.34	830	1939	12.3	8.58	966	2154	12.0	9.50	1068	2241	12.0	10.21	1146	2291	12.0	10.74	1205	2328
(15) - (20)	((26) -Qi) x 3.6/397.11	Column (9)		(29) x 397.11/3.6 + Qi	(30) + (21)	Column (9)		(33) x 397.11/3.6 +Qi	(34) + (22)	Column (10)		(37) x 397.11/3.6 +Qi	(38) + (23)	Column (11)		(41) x 397.11/3.6 +Qi	(42) + (24)	Column (12)		(45) x 397 11/3 6 +Qi	(46) + (25)

(29), (33), (37), (41), (45) : To be obtained by iterative calculation of the storage function using the semi-diagrammatical method or a portable electronic computer from respective effective rainfalls, r_t, ((28), (32), (36), (40), (44)) and from the residual basin runoff height at an hour earlier, q_{t-1} ((27), (29), (33), (37), (41)). Refer to Exercise 1.

Table 6.3 Method of Forecasting the Discharge at Chungcheng Bridge of Hsintien Creek up to 5 Hours Later

Present Time	Effective Rainfall in Area Upstream of Chung-cheng Bridge (f_1 = 0.50, Rsa = 200 mm)									Observed Discharge at (Obtained from stage-		Chung-cheng Bridge discharge curve)	
	Basin's Average Rainfall			Accumulative Rainfall			Effective Rainfall						
	Observed Value	Estimated Value at an Hour Later	Estimated Value at 2 Hours Later	Observed	Value at an Hour Later	Value at two Hours Later	Calculated from Observed Values	Value at an Hour Later	Value at 2 Hours Later	Water Stage at Chung-cheng Bridge	Water Stage at Tai-pei Bridge	Observed Discharge at Chung-cheng b Bridge	Runoff Height at Chung-cehng Bridge
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	6.8			131.6			3.4				0.96		
11	9.7			141.3			4.8				1.10		
12	6.4			147.7			3.2				1.30		
13	8.0			155.7			4.0				1.48		
14	11.1			166.8			5.6				1.68		
15	17.6			184.4			8.8				2.30		
16	11.8			196.2			5.9				2.33		
17	15.2			211.4			15.2			4.50	2.48	1250	4.93
18	17.7	16.5	16.5	229.1	245.6	262.1	17.7	16.5	16.5	4.87	3.01	1850	7.39
19	19.4	18.6	18.6	248.5	267.1	285.7	19.4	18.6	18.6	5.13	3.27	2050	8.21
20													
21													
22													
23													
24													
	Thiessen's method employed.	Rainfall at each hour to be estimated from radar data and weather map.		Cumulative total of (1)	(4) + (2) x Δt	(5) + (3) x Δt	If (4),(5),(6) > Rsa, (7),(8),(9) = (1),(2),(3); If (4),(5),(6) ≦ Rsa, (7),(8),(9) = (1),(2),(3) x f_1			Elevation above the standard sea level		To be obtained from (10) and (10)-(11) using H-Q curve.	$(12-Q_i) \times \frac{3.6}{876.85}$

Estimation of Discharge at Chung-cheng Bridge
(A = 876.85 km^2, T_1 = 3 hrs, $S = 110(q-q_i)^{0.2}$, Q_i = 50 m^3/s)

1 Hour Later			2 Hours Later			3 Hours Later			4 Hours Later			5 Hours Later		
Effective Rainfall at 2 Hours Later	Estimated Runoff Height	Estimated Discharge	Effective Rainfall at an Hour Earlier	Estimated Runoff Height	Estimated Discharge	Effective Rainfall at Present Time	Estimated Runoff Height	Estimated Discharge	Effective Rainfall at an Hour Later	Estimated Runoff Height	Estimated Discharge	Effective Rainfall at 2 Hours Later	Estimated Runoff Height	Estimated Discharge
(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
5.9	7.09	1777	15.2	8.82	2198	17.7	11.3	2737	16.5	12.57	3112	16.5	13.76	3402
15.2	9.84	2447	17.7	11.93	2956	19.4	14.18	3504	18.6	15.64	3859	18.6	16.67	4110
Column (7)		(15) x $\frac{876.85}{3.6}$ + Q_i	Column (7)		(18) x $\frac{876.85}{3.6}$ + Q_i	Column (7)		(21) x $\frac{876.85}{3.6}$ + Q_i	Column (8)		(24) x $\frac{876.85}{3.6}$ + Q_i	Column (9)		(27) x $\frac{876.85}{3.6}$ + Q_i

(15), (18), (21), (24), (27): To be obtained by iterative calculation of the storage function employing the semi-diagrammatical method or a portable electronic computer from respective effective rainfall values, r_t, (14, 17, 20, 23, 26) and from the runoff height at an hour earlier, q_{t-1}, (13, 15, 18, 21, 24).
Refer to Exercise 1.

Table 6 4 Method of Forecasting the Discharge at Wu-tu and Chung-san Bridge of Keelung River up to 5 Hours Later (Provisional Method)

Present Time	Effective Rainfall in the Basin upstream of Wu-tu: Observed Average Rainfall of Basin ①	Accumulative Rainfall of Basin ②	Effective Rainfall ③	Observed Discharge at Wu-tu (to be obtained from stage-discharge curve): Water Stage at Wu-tu ④	Discharge at Wu-tu ⑤	Runoff Height at Wu-tu ⑥	Estimation of Discharge at Wu-tu (A=208.31 km^2, Tl = 3 hrs. $S=65(q-q_i)^{0.3}$, Qi=10 m^3/s) — 1 Hour Later: Effective Rainfall at 2 Hours Earlier ⑦	Estimated Runoff Height ⑧	Estimated Discharge ⑨	2 Hours Later: Effective Rainfall at an Hour Earlier ⑩	Estimated Runoff Height ⑪	Estimated Discharge ⑫	3 Hours Later: Effective Rainfall at Present Time ⑬	Estimated Runoff Height ⑭	Estimated Discharge ⑮
10	7 5	229.9	7.5	8 86	440	7.43									
11	7 5	237.4	7.5	9.38	516	8.74									
12	7 5	244.9	7 5	10.06	644	10.96									
13	8 0	252.9	8.0	10.50	726	12.37									
14	14.0	266.9	14.0	10.55	734	12.51									
15	24.5	291 4	24.5	10.46	716	12.20									
16	14.0	305 4	14.0	10.30	692	11 79									
17	20.0	325.4	20.0	10.23	680	11 58									
18	20.5	345.9	20.5	10.37	706	12 03	14.0	12.54	736	20.0	14.59	854	20 5	16.34	955
19	21 0	366.9	21.0	10.76	758	12.93	20.0	14 90	872	20.5	16.58	969	21.0	17 98	1050
20															
21															
22															
23															
24															
	Thiessen's method employed.	Cumulative total of ①.	If ②> Rsa, ③=①; If ②≤Rsa, ③=①x f_1	Elevation above the standard sea level.	To be obtained from ④, using the stage-discharge curve	(⑤-Qi) x $\frac{3.6}{208.31}$	Column ③		⑧x $\frac{208.31}{3.6}$+Qi	Column ③		⑪ x $\frac{208.31}{3.6}$ +Qi	Column ③		⑭ x $\frac{208.31}{3.6}$ +Qi

⑧,⑪,⑭ : To be obtained by iterative calculation of the storage function from respective effective rainfall values, r_t(⑦,⑩,⑬) and from the runoff height at an hour earlier, q_{t-1} (⑥,⑧,⑪)

Present Time	Flood Routing in Wu-tu – Chung-shan Bridge Section by Channel unit Graph Method (Unit graph 0,0,0 1,0.6,0 2,0.1,0,0) — Discharge at Wu-tu: At Present Time ⑯	At an Hour Later ⑰	At 2 Hours Later ⑱	At 3 Hours Later ⑲	At 4 Hours Later ⑳	At 5 Hours Later ㉑	Effective Residual Basin Rainfall in Wu-tu – Chung-san Bridge Section (f_1 = 0 50, Rsa = 100 mm) — Average Residual Basin Rainfall: Observed Value ㉒	Value at an Hour Later ㉓	Value at 2 Hours Later ㉔	Value at 3 Hours Later ㉕	Accumulative Rainfall: Observed Value ㉖	Value at an Hour Later ㉗	Value at 2 Hours Later ㉘	Value at 3 Hours Later ㉙	Effective Rainfall: Calculated from Observed Value ㉚	Value at an Hour Later ㉛	Value at 2 Hours Later ㉜	Value at 3 Hours Later ㉝
10							9 4				147 6				9.4			
11							10.5				158.1				10 5			
12							9.2				167.3				9.2			
13							9.2				176.5				9 2			
14							11 3				187.8				11.3			
15							11.6				199 4				11.6			
16							10 2				209.6				10 2			
17							11.6				211 2				11.6			
18	718	700	689	702	736	826	11 6	11 1	11.1	11.1	232.8	243.9	255.0	266.1	11.6	11.1	11.1	11.1
19	700	689	705	751	842	937	11.5	11 6	11 6	11 6	244.3	255.9	267.5	279 1	11.5	11.6	11.6	11.1
20																		
21																		
22																		
23																		
24																		
							Thiessen's method employed.	Value at each hour to be estimated from radar data and weather map			Accumulative total value of ㉒.	㉖+㉓x Δt	㉗+㉔x Δt	㉘+㉕x Δt				

⑯–㉑: To be calculated from ⑤,⑨,⑫ and ⑮ using the unit graph method (use of a portable electronic computer will be helpful). Example of calculation ⑰ = 680x0 1+692x0 6+716x0.2+734x0 1=700
⑳ = 854x0.1+736x0.6+706x0.2+680x0.1=736

㉚–㉝: If ㉖,㉗,㉘,㉙ > Rsa, ㉚,㉛,㉜,㉝ = ㉒,㉓,㉔,㉕; If ㉖,㉗,㉘,㉙ ≤ Rsa, ㉚,㉛,㉜,㉝ = ㉒,㉓,㉔,㉕ x f_1

Estimation of Residual Basin Runoff and Discharge at Chung-shan Bridge
(A = 192.76 km^2, Tl = 2 hrs, $S = 35(q-qi)^{0.5}$, Qi = 10 m^3/s)

Estimated Residual Basin Runoff Height at Present Time ㉞	1 Hour Later: Effective Rainfall at an Hour Earlier ㉟	Estimated Runoff Height ㊱	Estimated Discharge ㊲	Discharge at Chung-shan Bridge ㊳	2 Hours Later: Effective Rainfall at Present Time ㊴	Estimated Runoff Height ㊵	Estimated Discharge ㊶	Discharge at Chung-shan Bridge ㊷	3 Hours Later: Effective Rainfall at an Hour Later ㊸	Estimated Runoff Height ㊹	Estimated Discharge ㊺	Discharge at Chung-shan Bridge ㊻	4 Hours Later: Effective Rainfall at 2 Hours Later ㊼	Estimated Runoff Height ㊽	Estimated Discharge ㊾	Discharge at Chung-shan Bridge ㊿	5 Hours Later: Effective Rainfall at 3 Hours Later (51)	Estimated Runoff Height (52)	Estimated Discharge (53)	Discharge at Chung-shan Bridge (54)
*8.74																				
8.84																				
9 10																				
9 12																				
9.13																				
9.48																				
9.83																				
9 89	11.6	10.17	555	1255	11.6	10.41	567	1256	11.1	10 53	574	1276	11.1	10.63	579	1315	11.1	10.71	583	1409
10 17	11.6	10.41	567	1256	11.5	10.59	577	1282	11.6	10 76	586	1337	11.6	10.90	594	1436	11.6	11.02	600	1537
To be obtained by iterative calculation of storage function from the value of ㉚ at 2 hours earlier and from the value of ㉞ at an hour earlier.	Column ㉚		㊱ x $\frac{192.76}{3.6}$ + Qi	㊲ + ⑰	Column ㉚		㊵ x $\frac{192.76}{3.6}$ + Qi	㊶ + ⑱	Column ㉛		㊹ x $\frac{192.76}{3.6}$ + Qi	㊺ + ⑲	Column ㉜		㊽ x $\frac{192.76}{3.6}$ +Qi	㊾ + ⑳	Column ㉝		(52) x $\frac{192.76}{3.6}$ +Qi	(53) + ㉑

㊱,㊵,㊹,㊽. To be obtained by iterative calculation of storage function by the semi-diagrammatical method or a portable electronic computer from respective effective rainfall values, r_t(㉟,㊴,㊸,㊼,(51)) and from respective residual value (52) : runoff heights at an hour earlier, q_{t-1} (㉞,㊱,㊵,㊹,㊽). Refer to Exercise 1.

Table 6. 5 Example of Calculation of Downstream Water Stage

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮
Time	Discharge at Hsin-hai Br.	Discharge at Chung-cheng Br.	Discharge at Chung-shan Br.	②+③ Discharge at Taipei Br.	Water Stage at Taipei Br. (From ⑤ and Fig. 5.11)	Water Stage at Hsin-hai Br. (From ②,⑥ and Fig. 5.9)	Water Stage at Kuang-fu Br. (From ③ and Fig. 5. 10)	(⑥+⑦+⑧) / 3 Water Stage at Confluence	(②+③+④) ×3600 Inflow Volume	Water Stage at Yu-che-kou	Water Stage at Shih-tzu-tou (From ⑭ and Fig 2 in Appendix 4)	Outflow Volume (from ⑪, ⑫ and Separate Appendix Table)	⑭+⑩-⑬ Total Stored Volume	Water Stage at Chung-shan Br. (From ④,⑫ and Fig. 3 in Appendix 4)
	CMS	CMS	CMS	CMS	m	m	m	m	$\times 10^4 m^3$	m	m	$\times 10^4 m^3$	$\times 10^4 m^3$	m
19	1650	2050	1255						1748	0.32	1.36	1290	6989	
20	1939	2447	1256	4386	408	500	4.66	458	2031	019	1.54	1490	7447	3.40
21	2154	2956	1282	5110	4.24	5.24	5.04	484	2301	0.12	1.68	1620	7988	3.45
22	2241	3504	1337	5745	430	5.36	5.28	498	2550	015	1.87	1770	8669	3.60
23	2291	3859	1436	6150	434	542	5.48	508	2731	0.30	2.09	1940	9449	3.93
24	2328	4110	1537	6438	436	546	5.60	514	2871	050	226		10240	416

CHAPTER VII FLOOD FORECASTING AND WARNING FACILITIES

7.1 Hydrological Observation Stations

7.1.1 Policy for Establishing Flood Forecasting and Warning Facilities

As described in Chapter 3, there are nine rain gauge stations and seven water stage stations in the Tan-shui basin, all provided with either telemeter or radio communication equipment.

Both the rain gauge station and water stage stations which will be required for the flood forecasting and warning of the Tan-shui, for which detailed explanation is given in Chapter 3 and Chapter 5 respectively, should all be furnished with telemeter equipment. To attain the maximum effect from the minimum budgetary appropriation, the whole construction period is divided into two stages. In the initial stage of construction, efforts are to be exerted to make best use of the existing facilities.

The water stage station at Chu-chih is not required for the forecasting method described in this report. However, its completion will make it possible to revise the forecasting method and employ the same method for both the Hsin-tien Creek and Keelung river, and this will assure the forecasting service of a higher accuracy.

7.1.2 Rain Gauge Station

Rain gauge stations required for collection of data to be used for flood forecast are listed in Table 7-1.

At Shih-men and Wu-tu, radio units and a water stage station will be established. Converters etc. will be installed at water stage stations.

As a telemetering unit is already installed at Ta-pao, the station building will be used as it is.

Taipei Station is to be established within the Flood Forecasting Centre, and no particular facilities are required for accommodation.

At Pai-shih, Yu-feng, Chi-tan, Hu-shan, Ping-lin, and Chu-tzu-hu, coltages with a floor area of 1.75 m x 1.85 m will be constructed to accommodate equipment and instruments. For construction materials for cottages, hollow concrete blocks or bricks which are easily obtained in this region will be used.

Table 7.1 List of Rain Gauge Stations to be Telemetered

No.	Name	Location	Basin	Remarks
1	Shih-men	Shih-men	Upper basin of Ta-han Creek	First stage
2	Fu-shan	SSE of Taipei	Upper basin of Hsin-tien Creek	"
3	Wu-tu	Wu-tu	Upper basin of keelung River	"
4	Taipei	Taipei	Tan-shui River	"
5	Hsiao-liao	S of Taipei	Hsin-tien Creek	First stage only
6	Chi-tan	SE of Shih-men	Upper basin of Shih-men	First stage
7	Ta-pao	SW of Taipei	Residual basin of Ta-han Creek	Second stage
8	Pai-shih	S of Shih-men	Upper basin of Shih-men	"
9	Yu-feng	SSE of Shih-men	"	"
10	Pin-lin	SE of Taipei	Upper basin of Hsin-tien Creek	"
11	Ta-tung-shan	S of Taipei	Hsin-tien Creek	To be transferred from Hsiao-liao
12	Chu-tzu-hu	N of Taipei	Keelung River	Second stage

At Hsiao-liao, the existing building at the present site will be used for the first stage, however, at the second stage the rainfall station will be transferred to Mt. Ta-tung relay station.

Appendix 5 shows an example of layout, structure and size of observation station.

7.1.3 Water Stage Stations

Water stage stations required for collection of data to be used for flood forecast are listed in Table 7.2.

Table 7.2 List of Water Stage Stations to be Telemetered

No.	Name	Location	Basin	Remarks
1	Shih-men	Shih-men	Upper basin of Ta-han Creek	Newly constructed at first stage
2	Hsin-hai Br.	W of Taipei	Ta-han Creek	Newly constructed at second stage
3	Chu-chih	Chu-chih	Upper basin of Hsin-tien Creek	First stage
4	Chung-cheng Br.	Taipei	Hsin-tien Creek	Second stage
5	Taipei Br.	Taipei	Tan-shui River	First stage
6	Wu-tu	Wu-tu	Upper basin of Keelung River	"
7	Chung-shan Br.	Taipei	Keelung River	Second stage
8	Shih-tzu-tou	N of Taipei	Tan-shui River	Remodelled at second stage

Shih-men station measures the water level of the after bay downstream of Shih-men dam. It will be equipped with a cottage with a floor area of about 1.75 m x 1.85 m to accommodate radio equipment, and it is advisable to install a well of an inside diameter of about 60 cm.

Hsin-hai Bridge station has no facilities at present, and will be equipped with facilities similar to those of Shih-men station. Unlike Shih-men station, this station might be suffered from water level changes due to an alteration of the river bed in the future, level of lateral tube etc. must be carefully studied.

Shih-tzu-tou station will be remodelled because it became obsolete and the cottage on the observing well has not a sufficient space.

Chu-chih station has not a space sufficient to accommodate radio equipment, and construction of a new cottage of about 1.75 m x 1.85 m should be considered.

Other stations have sufficient spaces and can be used as they are.

Water gauges will be changed to such ones as can be used in the telemetering system. To facilitate the replacement of spare parts, it is advisable to use gauges of the same type. Appendix 5 shows an example of layout and size of station.

7.1.4 Discharge Station

In the flood forecasting and warning system proposed presently, discharge is not directly measured to be used directly for forecasting but will be calculated by means of stage-discharge curve with values of water levels at one or two points. As the relation between the water stage and the discharge may change due to an alteration of the river bed etc., flow must be observed as often as possible and in a constant accuracy at every flood, and stage-discharge curve must be corrected. Discharge stations required for this purpose are listed in Table 7.3.

Table 7.3 List of Discharge Stations

No.	Name	Location	Basin	Remarks
1	Hsin-hai Br.	W of Taipei	Ta-han Creek	
2	Chung-cheng Br.	Taipei	Hsin-tien Creek	
3	Taipei Br.	Taipei	Tan-shui River	
4	Wu-tu	Wu-tu	Keelung River	
5	Chung-shan Br.	Taipei	Keelung River	Not exist at present

The stations will be located at places where bridges are existing.

In Keelung River basin, discharge value at Wu-tu is available, however, it is not available at Chung-shan Bridge, and this made the analyzing work very difficult. It is hoped that the flow observation will be initiated at a suitable place.

A float for measurement of the current velocity should be set at a proper length according to the depth of water. For example, it is considered that a float of one meter is not long enough to be used at Wu-tu.

7.2 Plan of Telemeter Communication Facilities

7.2.1 Tele-communication System and Design of Circuits

In planning the communication circuits for flood forecasting and warning system in the Tan-shui river basin, maps and profile maps of the downstream basin were used to study carefully in detail the topography, profile, distance etc., and also study of the outline of communication circuit system and design of circuits were made on the desk. During the desk work, the objectives were to satisfy the following conditions:

Condition 1. Radio channel should be secured in VHF band to stabilize the communication.

Condition 2. Proper site should be selected for the sake of convenience of maintenance after construction and installation.

Condition 3. Location of station building must be selected in consideration of convenience of observation and natural conditions such as effects by lightning, strong wind, etc.

Condition 4. Number of relay stations should be minimized for a higher reliability.

As a result, the networks are composed of the following three systems:

Tele-communication System No. 1.

A system to communicate directly with Taipei (to be called Taipei System)

Tele-communication System No. 2.

Stations along the upstream of the Hsin-tien Creek, not included in System No. 1 and communicating through Mt. Ta-tu relay station (to be called Mt. Ta-tu System)

Tele-communication System No. 3.

Stations along the upstream of the Ta-han Creek, not included in Systems No. 1 and No. 2 and communicating through Mt. Li-tung relay station (to be called Mt. Li-tung System)

Field survey and propagation test were conducted based on the desk plan. The propagation test was carried out according to the method illustrated in Fig. 7.1 and the propagation loss was measured. * The result of the test are the sum of free space loss and additional loss shown in the table of system design (Fig. 7.4). The test was conducted at Taipei Bridge, Wu-tu, Chu-chih, Mt. Ta-tu, Shih-men, Mt. Ta-ping and Ta-pao. As to propagation loss at other places, calculated values were used.

Since city noise is considered very large within Taipei city, an antenna was installed on the roof of PWCB's building and external noise power was measured by the method shown in Fig. 7.2. The measured values are important in the system design particularly with respect to S/N ratio.

The installation plan of the telemeter system prepared on the basis of the above tests and measurements is shown in Fig. 7.3. (Rain Gauge and Water Stage Telemeter System for Flood Forecasting in the Tan-shui River Basin). The network system and the profiles are shown in Appendix 6 and 7, respectively.

Two waves in 60 MHz (54 MHz - 68 MHz) having a frequency difference of about 1.5 MHz were assumed, and the "Technical Standard for Radio Stations" of the Radio Regulatory Bureau, Ministry of Posts and Telecommunications of Japan, was employed in the design of the system.

As regards the S/N ratio and channel reliability,** the network was so designed as will satisfy the following conditions.

---

* Covering the entire system with the field survey was not practicable because of the limited time allowed for the survey. The field survey was therefore conducted for the Taipei system and Mt. Ta-tu system, and the propagation test was conducted for those stations which are planned to constructed in the initial stage and are likely to present propagation problems.

** Ratio of time in which undisturbed communication is assured.

a. The S/N ratio under normal condition in a section of the tele-communication line, as calculated by the following equation, exceeds 30 dB.

$$S/N = Pt-(Lp+Lf)+G_{At}+G_{Ar}-Prn+I$$

where,

- S/N : Signal to noise ratio
- Pt : Antenna power (dBm)
- Lp : Propagation loss (dB)
- Lf : Feeder loss (dB)
- G_{At} : Isotropic gain of transmitting antenna (dB)
- G_{Ar} : Insotropic gain of receiving antenna (dB)
- Prn : Receiving noise power (dBm)
  Prn, receiving noise power is the sum of the receiver internal noise power (Prni) and external noise power (Prne), to be calculated
- I : S/N improvement factor (dB)

S/N improvement factor for each section is as follows:

$$I=10 \log \frac{3\, fd^2 \cdot B}{2fm}$$

- fd : Maximum frequency deviation
- B : Equivalent noise bandwidth of receiver
- fm : Maximum modulation frequency

b. Annual channel reliability in a span should exceed 95% when the propagation conditions alone are considered. The reliability is determined by whether the antenna power P_t satisfies the following equations.

$$A + M(dB) > P_t > A$$
$$A(dBm) = (L_p + L_f + L_F) - G_{At} - G_{Ar} + P_{th}$$

where,

- M : to be normally 10 dB
- L_F : Fading loss (dB) (to be 0.1 dB per km)
- P_{th} : Threshold level (dBm) ($P_{th} = C_f \cdot P_{rn} = 9\text{ dB} + P_{rn}$)

The construction of tele-communication facilities is to be carried out over two stages. Towards the end of the initial construction stage, both the existing and newly installed facilities will be functioning as shown in the Network design (Fig. 7.4).

It is economically advisable to construct the Taipei system and Mt. Ta-tu system in the initial stage, and other systems in the second stage. However, since Chi-tan station and Shih-men station should be constructed in the initial stage, it is planned that communication equipment will be installed on the summit of Mt. Ta-ping where the relay station of SRAB is now located so as to constitute Mt. Ta-pin system for operation until the completion of the second stage construction. *

* By the transfer of the equipment from Mt. Ta-ping to Mt. Li-tung during the second stage, the stations at Chi-tan and Shih-men can be readily incorporated into Mt. Li-tung system.

For Mt. Li-tung system, detailed investigation should be carried out in future to carry out its construction in the second stage for completion of the entire telemeter system.

7.2.2 Telemetering System

Though there are many methods available for telemetering system, it is advisable, in consideration of its characteristics as flood forecasting and warning system, to adopt the standard system employed by Ministry of Construction of Japan that has given satisfactory results with stabilized transmission.

For reference, the standard specifications for telemetering and warning prepared by Ministry of Construction are attached in the appendix of this report.

The Ministry has established also standard specifications for common-call telemetering and warning system, however, it is not described in this report because the system is not applied to the Tan-shui River.

7.2.3 Composition of Tele-communication Equipment

The facilities of the project can be classified by function as follows.

(1)	Control Station	Taipei (including rain gauge station)
(2)	Radio Relay Stations	Mt. Ta-tu (including rain gauge station) Mt. Li-tung, Mt. Ta-ping
(3)	Rain Gauge Stations	Chu-tzu-hu, Ta-pao, Ping-lin, Hu-shan, Chi-tan, Yu-feng and Pai-shih
(4)	Water Stage Stations	Chung-shan Bridge, Chung-cheng Bridge, Hsin-hai Bridge, Shih-tzu-tou, Chu-chih, and Taipei Bridge
(5)	Rain Gauge and Water Stage Stations	Wu-tu, Shih-men
(6)	Monitoring Station	

The control station will be a flood forecasting and warning center to be capable of receiving, recording and indicating the observed data, conducting various calculation based on the data, giving communication and instruction to relevant organizations, grasping meteorological conditions and monitoring the operation and performance of equipment and instruments at stations.

The block diagram of the telemetering system is shown in Fig. 7.5

Relay station will be capable of automatic tele-communication between the control station and observation stations.

Observation stations will measure and record rainfall and water stage and also automatically transmit data according to instructions from the control station.

The monitoring station will have no control function but will be capable of receiving automatically the data of the flood forecasting and warning center. The monitoring station is not included in the present project, however, as for power supply for the stations, the control station will be equipped with on-interruption automatic stand-by power supply system by means of motor-generator as well as commercial power supply. Other stations will be equipped with battery floating charging system by solar cell, so that equipment and instruments could be normally operated under any circumstances.

7.3 Organization of Flood Forecasting-Warning System

A flood forecasting-warning system should include the following four function:

1. Observation and collection of data
2. Estimate of the scale and time of floods
3. Announcement of flood forecasting and warning
4. Guidance in anti-flood activities, evacuation and other activities for prevention of damage and loss etc.

The flood forecasting-warning system will be effective if the above four works are smoothly conducted. For this purpose, establishment of the following system will be necessary.

7.3.1 Establishment of Flood Forecasting -Warning Center

The main purpose of flood forecasting activity is to collect data in a centralized way, estimate the scale of the flood and announce flood warning. In short, a flood forecasting center must be established to conduct the works described in the above Items No. 2 and No. 3.

The Center will receive the data about rainfall and water level directly from observation stations which are to be newly equipped with telemeter system. The Center will also obtain meteorological data and information on typhoon from the weather bureau and also hydraulic and hydrological data as much as possible from other organizations concerned.

After analysis of those data and information, the Center will work at conjecture of an occurrence of a flood, its scale and the anticipated time to come, and dispatch and announce forecast and warning to organizations concerned and the inhabitants.

The Flood Forecasting Center should require a minimum number of staff members as follows:

a. Director of the Center (one)

The director should be capable of conducting flood forecasting and warning and be responsible for the activities. Accordingly, he must be a hydrological experts or a river engineer with a very high academic background and practical experience.

b. Chief Forecasting Officer (one)

This Officer will analyse meteorological data, hydrological data and hydraulic data and also draw up a craft for flood forecasting. He must be a hydrologist or a river engineer with high-level technical knohow, and must be capable of acting for the director during a flood of long period.

c. Meteorologist (one)

The meteorologist should be capable of analyzing meteorological data obtained from the telemeter system and other data from the weather bureau for the use of forecast of flood.

d. Hydrologist (one)

The hydrologist will forecast a flood by use of obtained hydrological and hydraulic data.

e. Assistants (three)

The assistants will be in charge of treatment of data and conducting the announcement of the forecasting and warning.

Other than the above-mentioned main staff, some technical assistants and driver should be required.

When there is no flood, the Center should be engaged in improving the accuracy of flood forecasting and these system. One telecommunication engineer and some technical assistants are required for maintenance and repair of the telemeter system to be newly introduced. These engineers should repair immediately equipment and instruments in trouble as well as make regular inspection tours around observation stations and relay stations. A few jeeps must be prepared for such purposes.

It is necessary to collect accurate data as much as possible during a flood for the purpose of improving flood forecasting-warning system. However, this task is to be undertaken by the regional construction office or regional hydrological station of the PWCB.

7.3.2 Kinds and Content of Flood Forecast and Warning and Informating System

When a flood forecast is announced, the following steps must be taken:

a) refuge of inhabitants
b) flood fighting
c) to secure and maintain public service systems such as traffic on roads, power supply, communication etc., and
d) to maintain the public peace and order by police, military police and military forces.

As these measures must be taken step by step, it is advisable to classify a flood forecast into three steps, namely flood warning, flood alarm and flood information.

The flood warning is to inform the inhabitants and the parties concerned of the scale and scope of a possible flood for the purpose of giving warning about necessary preparations against flood.

The flood alarm is to give warning to the inhabitants and the parties concerned with the scale and scope and the time of the flood to come so that those people take measures to counter the coming flood.

The flood information is to inform the people of the present conditions and a forecast for the future so that the people take proper measures to counter the flood.

The communication media and routes for transmission of those flood warning, alarm and information to the people and organizations concernd should be reviewed sufficiently.

7.3.3 Others

The duty of the Flood Forecast Center is to analyze information based on data obtained from PWCB and WB and give the information as a flood warning or alarm to the public in general. This work is closely related with the works that have been conducted by WB and PWCB, and these three organizations should cooperate in maintenance of the telemeter system and arrangement for reinforcement of the personnel for a flood.

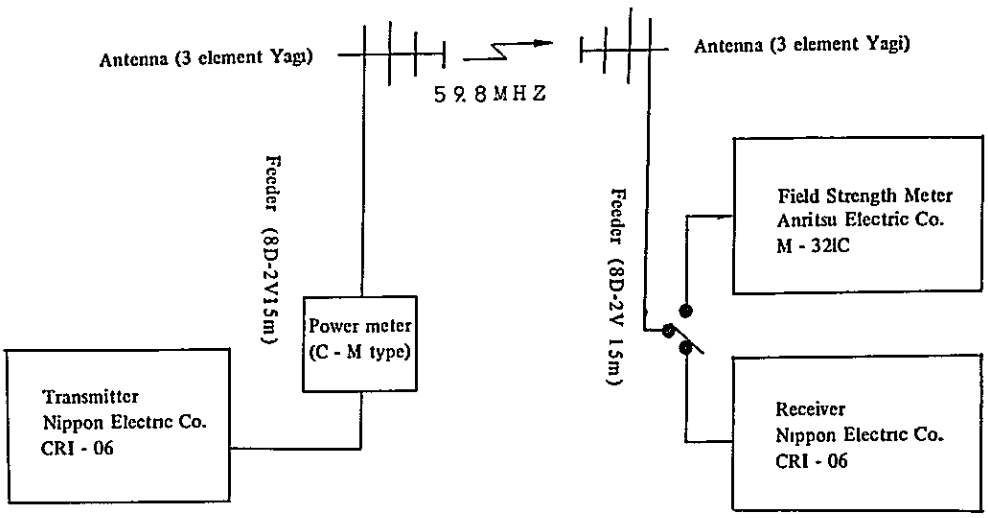
As SKAB has the duty to observe the outflow in the area that is a quarter of the Tan-shui basin, a close contact must be usually maintained with the Flood Forecast Center.

Therefore, works must be allotted in details to these four organizations so that flood forecast activity can be conducted sufficiently in cooperation.

It is necessary to organize a system of cooperation in transmission of flood information, for example, by means of assigning a duty to broadcast flood information to radio and television stations because broadcasting networks can be the main means of transmitting flood information, or making arrangements for use of other communication means such as military broadcasting networks etc.

In view of the importance in flood forecast, it is necessary to establish laws and regulations for flood defense with definition of the responsibility and the authority for those duties and works.

Fig. 7.1 Method of Span Loss Measurement



$$Lp = X + r + Lft + Lfr - G_{At} - G_{Ar} - P$$

Lp : Span loss (dB)

X : Coefficient for relation between receiving power and receiving Open-terminal voltage X = 113 dB

r : Receiving input voltage by Field Strength Meter (dBμ)

Lft : Transmitting Feeder loss Lft = 0.7 dB

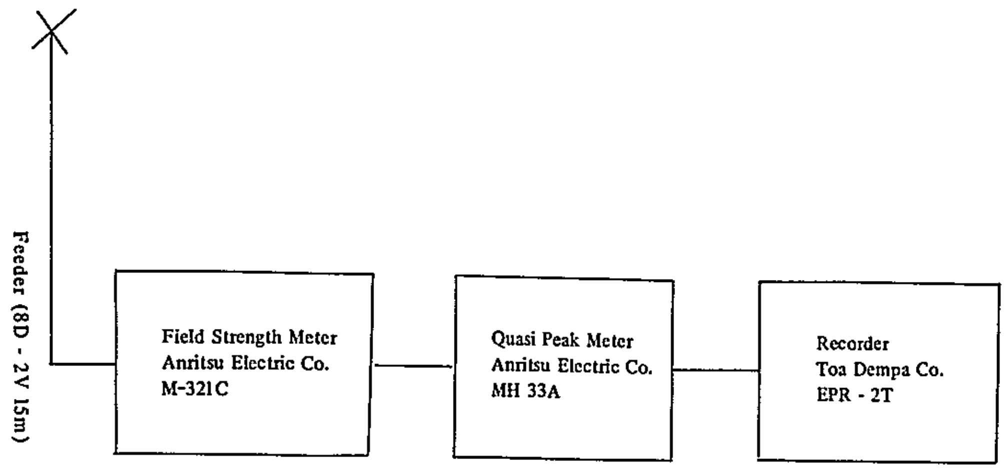
Lfr : Receiving Feeder loss Lft = 0.7 dB

G_{At}: Transmitting Antenna Gain G_{At} = 8 dB (Gis)

G_{Ar}: Receiving Antenna Gain G_{At} = 8 dB (Gis)

P : Indicated Power by CM-type Power Meter (dBm)

Fig. 7.2 Measuring Method of City Noise



Note:

Measured noise level was 31.2 dBμ(5%), 26.7 dBμ(50%).
For this data, we take - 99 dBm for receiving noise power in Taipei station.
Also we presume - 110 dBm for it in the other stations.

Fig. 7.3 Plan for the Rain Gauge and Water Stage Telemetering System for Flood Forecasting in the Tan-shui River Basin

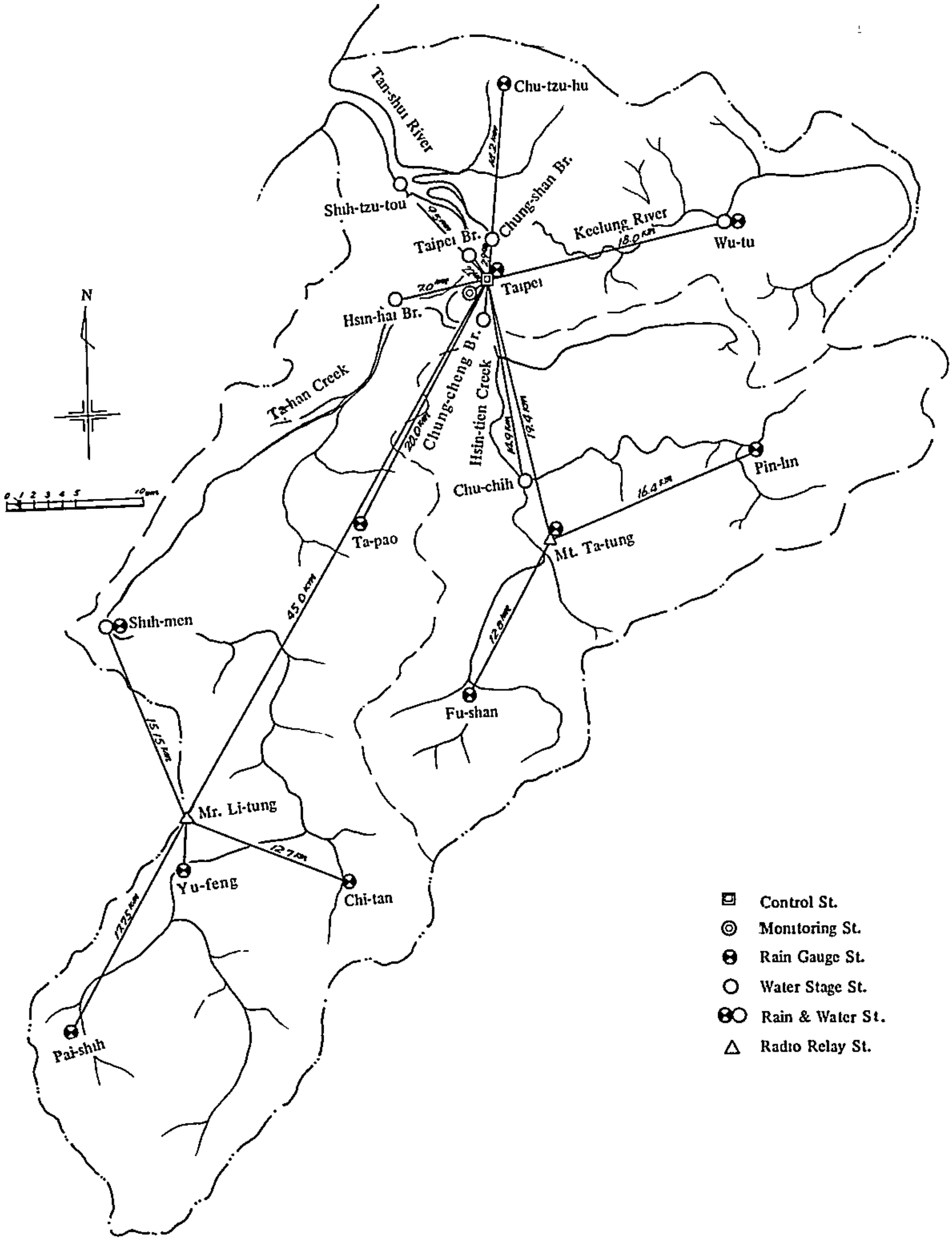


Fig. 7.4 Network at the 1st stage plan

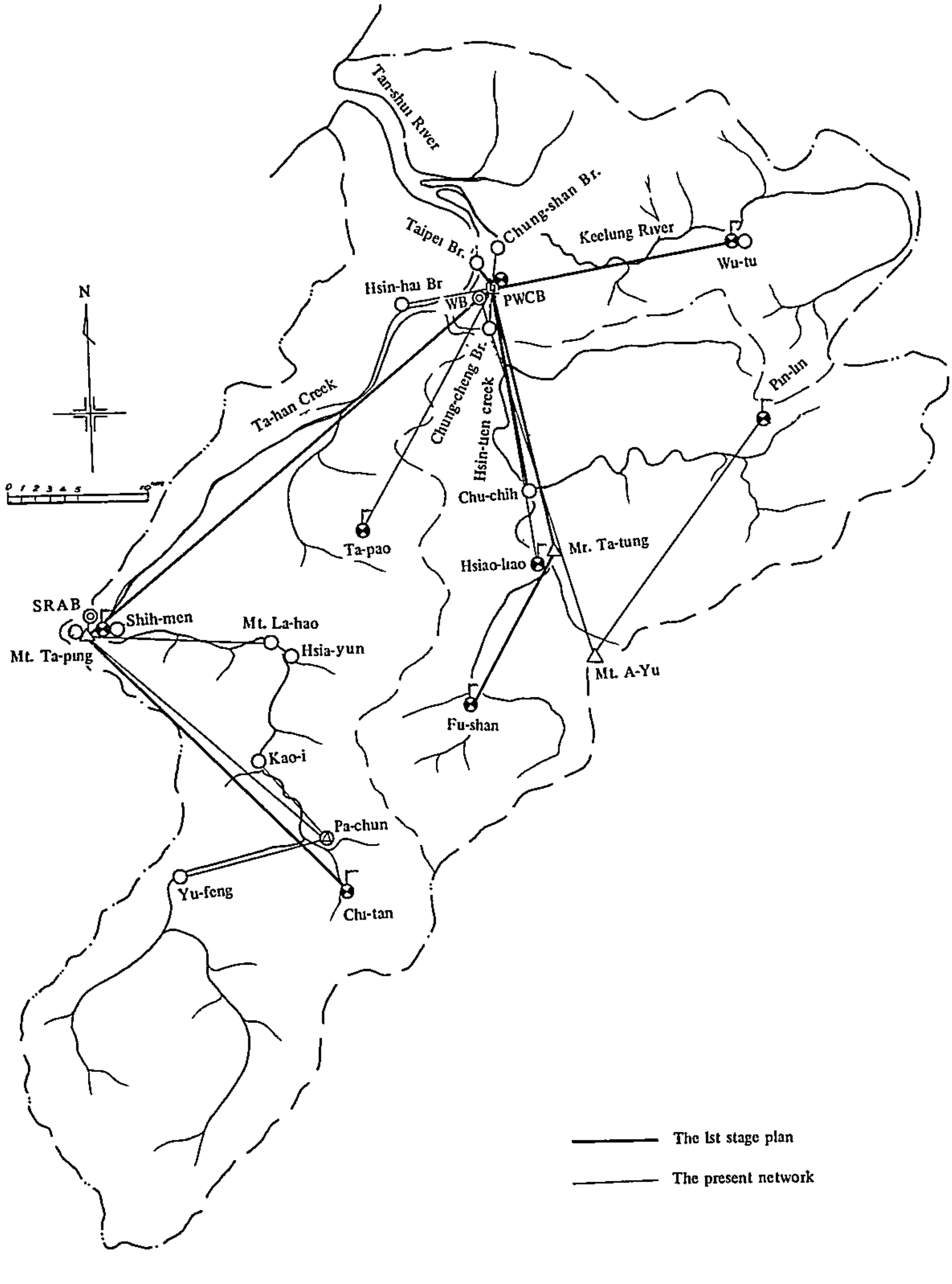


Fig. 7.5 (1) Block Diagram of the Telemetering System

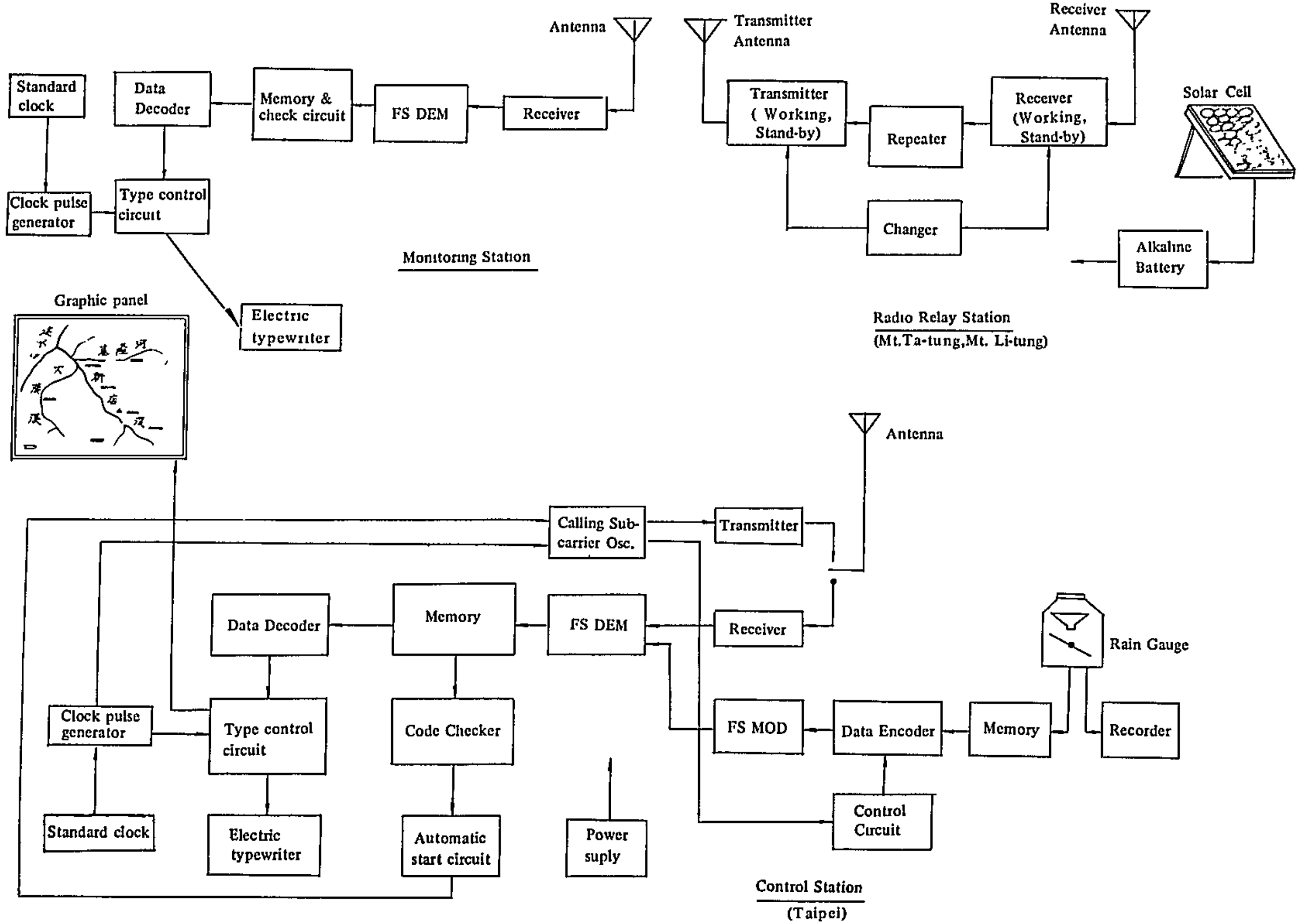


Fig. 7.5 (2) Block Diagram of the Telemetering System

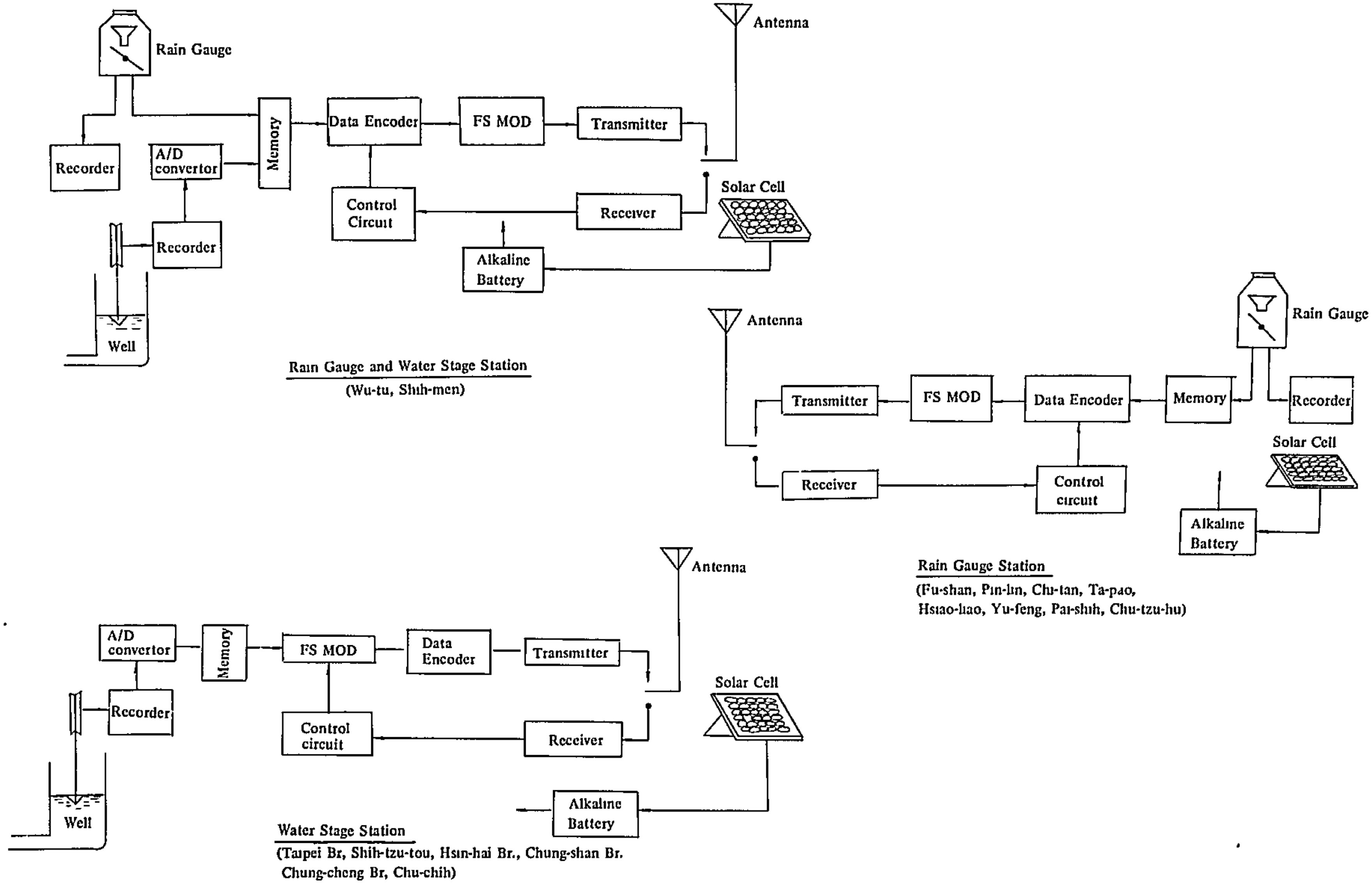


Table 7.4 (1) Circuit Design Sheet (Taipei System)

Classification \ Station	Unit	Taipei(R) Taipei Bridge(T)	Taipei(R) Chung-shan Bridge(T)	Taipei(R) Chung-cheng Bridge(T)	Taipei(R) Hsin-hai Bridge(T)	Taipei(R) Shih-tzu-tou (T)	Taipei(R) Wu-tu(T)	Taipei(R) Chu-Chih (T)	Taipei(R) Chu-tzu -hu (T)	Taipei(R) Ta-pao(T)
Antenna power	dbm	40	40	40	40	40	40	40	40	40
Free space loss	db	75	78	78	85	88	93	92	91	94
Additional loss	"	20	20	20	20	20	41	34	20	16
Feeder loss	"	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Antenna gain (transmitting)	"	8	8	8	8	8	9	9	8	8
" (receiving)	"	-6	-6	-5	-6	-6	6	4	-6	4
T-R joint loss	"									
Receiving power	dbm	-54.5	-57.5	-46.5	-64.5	-67.5	-80.5	-74.5	-70.5	-59.5
Receiving noise power	"	-99	-99	-99	-99	-99	-99	-99	-99	-99
Carrier S/N C/N	db	44.5	41.5	52.5	34.5	31.5	18.5	24.5	28.5	39.5
S/N improvement factor	"	12	12	12	12	12	12	12	12	12
S/N under normal condition	"	40 <	40 <	40 <	40 <	40 <	30.5	36.5	40 <	40 <
Fading loss	"	0.5	0.5	0.5	1	1	2	1.5	1.5	2
S/N in each span with fading	"	40 <	40 <	40 <	40 <	40 <	28.5	35	39	40 <
Total S/N	"									
Threshold level	dbm	-90	-90	-90	-90	-90	-90	-90	-90	-90
Fading margin to threshold level	db	35.5	32.5	43.5	25.5	22.5	9.5	15.5	19.5	30.5
Margin to threshold level with fading	"	35	32	43	24.5	21.5	7.5	14	18	28.5
Special Remarks										

Table 7.4 (2) Circuit Design Sheet (Mt. Ta-tung System)

Classification	Station / Unit	Mt.Ta-tung(T) Tai-pei(R)	Mt.Ta-tung(R) Ping-lin(T)	Mt.Ta-tung(R) Hu-shan(T)
Antenna power	dbm	37	40	40
Free space loss	db	94	92.5	90.5
Additional loss	"	9	39.5	41.5
Feeder loss	"	1.5	1	1
Antenna gain(transmitting)	"	-5	8	8
" (receiving)	"	3	5	5
T-R joint loss	"			
Receiving power	dbm	-69.5	-80	-80
Receiving noise power	"	-99	-110	-110
Carrier S/N C/N	db	29.5	30	30
S/N improvement factor	"	12	12	12
S/N under normal condition	"	40<	40<	40<
Fading loss	"	2	2	1.5
S/N in each span with fading	"	39.5	40	40<
Total S/N	"			
Threshold level	dbm	-90	-101	-101
Fading margin to threshold level	db	20.5	21	21
Margin to threshold level with fading	"	18.5	19	19.5
Special Remarks				

Table 7.4 (3) Circuit Design Sheet (Mt. Ta-ping System)

Classification \ Station	Unit	Mt.Ta-ping(T) Tai-pei(R)	Mt.Ta-ping(R) Shih-men(T)	Mt.Ta-ping(R) Chi-tan(T)
Antenna power	dbm	40	40	40
Free space loss	db	100	70	97
Additional loss	"	13	10	46
Feeder loss	"	1.5	1	1
Antenna gain(transmitting)	"	2	8	8
" (receiving)	"	0	2	7
T-R joint loss	"			
Receiving power	dbm	-72.5	-31	-89
Receiving noise power	"	-99	-110	-110
Carrier S/N C/N	db	26.5	79	21
S/N improvement factor	"	12	12	12
S/N under normal condition	"	38.5	40 <	33
Fading loss	"	4	0.5	3
S/N in each span with fading	"	34.5	40 <	30
Total S/N	"			
Threshold level	dbm	-90	-101	-101
Fading margin to threshold level	db	17.5	70	12
Margin to threshold level with fading	"	13.5	31	9
Special Remarks				

Table 7.4(4) Circuit Design Sheet (Mr. Li-tung System)

Classification \ Station	Unit	Mt.Li-tung(T) Tai-pei(R)	Mt.Li-tung(R) Yu-feng(T)	Mt.Li-tung(R) Pai-shih(T)	Mt. Li-tung(R) Shih-men(T)	Mt.Li-tung(R) Chi-tan(T)
Antenna power	dbm	37	40	40	40	40
Free space loss	db	101.5	82	93.5	92	90.5
Additional loss	"	10	40	20	40	36.5
Feeder loss	"	1.5	1	1	1	1
Antenna Gain(transmitting)	"	2	8	8	8	8
" (receiving)	"	4	-6	-6	5	5
T-R joint loss	"					
Receiving power	dbm	-70	-81	-72.5	-80	-75
Receiving noise power	"	-99	-110	-110	-110	-110
Carrier S/N C/N	db	29	29	37.5	30	35
S/N improvement factor	"	12	12	12	12	12
S/N under normal condition	"	40 <	40 <	40 <	40 <	40 <
Fading loss	"	4.5	0.5	2	1.5	1.5
S/N in each span with fading	"	36.5	40 <	40 <	40 <	40 <
Total S/N	"					
Threshold level	dbm	-90	-101	-101	-101	-101
Fading margin to threshold level	db	20	20	28.5	21	26
Margin to threshold level with fading	"	15.5	19.5	26.5	19.5	24.5
Special remarks						

CHAPTER 8 CONSTRUCTION COSTS & MAINTENANCE EXPENSES FOR FLOOD FORECASTING & WARNING

8.1 Construction Costs

The total expenses required for construction of the project will be ¥161,000,000.

The breakdown is as follows: Expenses for facilities to accommodate equipment and instruments etc. --- ¥72,100,000; Expenses for equipments, and their installation and adjustment --- ¥76,700,000, and Expenses for technical training and guidance ---¥12,200,000.

The total expenses are also divided as follows: ¥58,200,000 for the first stage project, and ¥102,800,000 for the second stage project. The breakdown is as follows: expenses for facilities to accommodate equipment and instruments etc. --- ¥9,800,000 for the first stage and ¥62,300,000 for the second stage; Expenses for equipment, installation and adjustment --- ¥40,500,000 for the first stage and ¥36,200,000 for the second stage; and Expenses for technical training and guidance --- ¥7,900,000 for the first stage and ¥4,300,000 for the second stage.

The above estimation includes all the expenses for construction such as design, manufacture, transport, and installation and adjustment etc., satisfying the conditions of the specifications and design drawings attached in Appendices 8 and 9. *

Details of the estimates are shown in Table 8.1. The prices of equipment and instruments are F.O.B. prices estimated based on the actual prices of purchase by the Ministry of Construction.

Expenses for installation and adjustment and also maintenance expenses described later seem to be rather expensive. However, after local training of engineers is implemented, the expenses will be considerably decreased.

* This does not include the import tax.

Table 8.1 Expenses of Flood Forecasting and Warning System

Item	Standard	Quantity	Unit Price	Amount	Remarks	
1. Housing Facilities, etc.			Yen	Yen		
Well		4	1,800,000	7,200,000	¥3,600,000 for the 1st stage 3,600,000 for the 2nd stage	
Station House	Type A	2	720,000	1,440,000	720,000 for the 1st stage 720,000 for the 2nd stage	
Station House	Type B	8	600,000	4,800,000	2,400,000 for the 1st stage 2,400,000 for the 2nd stage	
Antenna Tower		19	160,000	3,040,000	1,280,000 for the 1st stage 1,760,000 for the 2nd stage	
Lightning Unit		2	1,800,000	3,600,000	1,800,000 for the 1st stage 1,800,000 for the 2nd stage	
Forecast Center Building	1,000 m^2	1		50,000,000	50,000,000 for the 2nd stage	
Forecast Center Tower	30 m high	1		2,000,000	2,000,000 for the 2nd stage	
Total				72,080,000	9,800,000 for the 1st stage 62,280,000 for the 2nd stage	
2. Equipment, installation & Adjustment						
Equipment	F.O.B.	1		52,000,000	27,600,000 for the 1st stage 24,900,000 for the 2nd stage	As shown in Table 8.2
Accerories & Spare Parts	"	1		8,300,000	5,600,000 for the 1st stage 2,700,000 for the 2nd stage	As shown in Table 8.3
Installation & Adjustment		1		13,300,000	6,000,000 for the 1st stage 7,300,000 for the 2nd stage	
In land Transportation		1		600,000	300,000 for the 1st stage 300,000 for the 2nd stage	
Marine Transportation		1		2,000,000	1,000,000 for the 1st stage 1,000,000 for the 2nd stage	
Total				76,700,000	40,500,000 for the 1st stage 36,200,000 for the 2nd stage	
3. Technical Training & Guidance						
Training		1		4,400,000	2,640,000 for the 1st stage 1,760,000 for the 2nd stage	2 hydrologists for 2 months 3 telecommunication engineers for 3 months
Guidance		1		7,900,000	5,260,000 for the 1st stage 2,640,000 for the 2nd stage	1 hydrologist for one year 2 telecommunication engineers for one year
Total				12,200,000	7,900,000 for the 1st stage 4,300,000 for the 2nd stage	
Grand Total				160,980,000	58,200,000 for the 1st stage 102,780,000 for the 2nd stage	

Table 8.2 Equipment & Instruments

Item	Standard	Quantity	Unit Price (1,000 yen)	Amount (1,000 yen)	Taipei (C) (R)	Taipei Bridge (W)	Chung-shan Br. (w)	Chung-cheng Br. (w)	Hsin-hai Br. (w)	Shih-tzu-tou (w)	Chu-chih (w)	Wu-tu (R)(w)	Chu-tzu-hu (R)	Ta-pao (R)	Mt. Ta-tung (Relay)(R)	Ping-lin (R)	Fu-shan (R)	Mt. Li-tung (Relay)	Shih-men (R) (w)	Yu-feng (R)	Pai-shih (R)	Chi-tan (R)	Mt. Ta-ping (Relay)
Antenna	Control St.	1	192	192	192																		
	Relay St.	2	293	586											293			293					
	Observing St.	15	102	1,530		102	102	102	102	102	102	102	102	102		102	102		102	102	102	102	
Radio Eq.		5	291	1,455	291										582			582					
Telemetry Terminal Eq.		1	4,815	4,815	4,815																		
Typewriter		1	647	647	647																		
Control Desk		1	970	970	970																		
Graphic panel		1	5,870	5,870	5,870																		
Telemetry Equipment	Double	2	733	1,466								733							733				
Telemetry Equipment & Reapeter Equipment	Single	13	694	9,022		694	694	694	694	694	694		694	694		694	694			694	694	694	
		1	1,105	1,105											1,105								
Reapeter Equipment		1	687	687											{687 / 418			687					
Rainfall measuring Equipment		11	219	2,409	219							219	219	219	219	219	219		219	219	219	219	
Rain-gauge Recorder		11	187	2,057	187							187	187	187	187	187	187		187	187	187	187	
Water Stage measuring Equipment		8	38	304		38	38	38	38	38	38	38							38				
Water-Stage Recorder		8	489	3,912		489	489	489	489	489	489	489							489				
Power Supply Unit	Control St.	1	466	466	466																		
Solar cell	Relay St.	2	1,245	2,490											1,245			1,245					
"	Observing St.	15	518	7,770		518	518	518	518	518	518	518	518	518		518	518		518	518	518	518	
Battery	Relay St.	2	410	820											410			410					
"	Observing St.	15	162	2,430		162	162	162	162	162	162	162	162	162		162	162		162	162	162	162	
Lightning Arrester		18	83	1,494	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	
Total				52,497	13,740	2,086	2,086	2,086	2,086	2,086	2,086	2,531	1,965	1,965	4,124	1,965	1,965	3,300	2,531	1,965	1,965	1,965	
Total for 1st stage				27,634	7,870	2,086					2,086	2,531			3,330		1,965	(3,300)	2,531			1,965	3,300

Note: 1. [W] means water stage obs. stations.
[R] means rainfall obs. stations.
2. Figures underlined are for the 1st stage.

Table 8.3 Accessories and Spare Parts

Item	Quantity	Unit Price (1,000 yen)	Amount (1,000 yen)	Name of Station: Taipei (C) (R)	Taipei Bridge (W)	Chung-shan Br. (W)	Chung-cheng Br. (W)	Hsin-hai Br. (W)	Shih-tzu -tou (W)	Chu-chih (W)	Wu-tu (R)(W)	Chu-tzu -hu (R)	Ta-pao (R)	Mt. Ta-tung (Relay)(R)	Ping-lin (R)	Fu-shan (R)	Mt. Li-tung (Relay)	Shih-men (R)(W)	Yu-feng (R)	Pai-shih (R)	Chi-tan (R)	Mt. Ta-ping (Relay)
Circuit Diagram, Instruction Manual, Test-sheet Tool, Connector, Cords, Fuses, Lamps, Recording-papers. Spare parts box etc.																						
Control St.	1	136	136	136																		
Relay St.	2	110	220											110			110					
Observing St.	15	64	960		64	64	64	64	64	64	64	64	64		64	64		64	64	64	64	
Spare Radio Unit	2	291	582	291													291					
Spare Unit Control St.	1	840	840	840																		
Relay St.	1	420	420											420								
Observing St.	5	140	700		140	140						140				140		140				
Circuit-tester	18	21	378	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
Power meter (Terminal)	18	28	504	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	
Power meter (C-M type)	1	135	135	135																		
Radio-tester	1	550	550	550																		
Synchro-scope	1	932	932	932																		
Frequency-counter	1	497	497	497																		
Telemeter-checker	1	504	504	504																		
Portable Generator	3	76	228	76										76			76					
Table Electronic Computer	1	700	700	700																		
Total			8,286	4,710	253	253	113	113	113	113	113	253	113	655	113	253	526	253	113	113	113	
Total for 1st stage			5,462	3,794	253					113	113			655		253	(235)	113			113	235

Note: 1. [W] means water stage obs. stations.
[R] means rainfall obs. stations.
2. Figures underlined are for the 1st stage.

8.2 Maintenance Expenses

The annual total expenses for maintenance of the facilities are estimated as shown in Table 8.4.

Table 8.4 Expenditure for Annual Maintenance

Item	Quantity	Amount	Remarks
Traffic fare	1	yen 400,000	For month by inspections, 12 times
Parts, other supplies	1	180,000	10,000 yen/a station one year
Regular inspection	1	2,220,000	Once a year (by 2 engineers from the work shop for a month)
Total		2,800,000	

8.3 Maintenance of Facilities

Maintenance of facilities should be conducted, in conformity to the following standards, for the purposes of maintaining the equipment and instruments in the best condition and operating those with the best performance.

A. Regular Inspection

Daily Inspection: Each station is called from the control station to inspect the performance of equipment and instruments of the station.

Monthly Inspection: Inspection of power supply, telemeter unit, radio unit, antenna system etc. of the control station, relay stations and observation stations.

Before and after the flood season, however, levels of each sections and S/N ratio must be measured. Inspection must be conducted twice a month when rain fall is expected for a long period.

Annual Inspection: Detailed inspection and adjustment once a year by skilled engineers.

B. Action After Inspection

After inspection, if a measured value is under the standard, it must be corrected to the standard value by means of adjustment or repairing. Details and results of inspection must be recorded in the inspection book. For reference, a sample of inspection book is shown in Appendix 13.

Appendix 1

ON THE FLOOD WARNING AND FORECASTING IN THE TAN-SHNI RIVER

Interim Report

June 12 1971

Survey Team Organized by the Government of Japan

Appendix 1

This is to report what has been made clear concerning the hydrological aspects in the flood forecasting and warning in the Tan-shui river during the hydrologists' stay in Taipi.

The contents of this report may subject to change both by opinions of tele telecommunication experts and by results of further investigation which will be done in their home country.

The final report will be submitted by the end of 1971.

1. The Objective of Flood Forecasting and Warning

When a flood occurs in the Tan-shui river, mostly the lower reaches of the Keeling river and the area of San-chuan city situated on the left bank side of the Tan-shui, and according to the scale of flood, the upper reaches of the Keelung and the area close to the confluence of the Ta-han and the Hsin-tren creeks are inundated.

The main objective of the forecasting and warning, therefore, must be to make inhabitents of the region know whether the inundation will occur or not, and if it will be expected, when and how will be.

To achieve this objective, the forecasting and warning will be issued estimating the scale of inundation in the areas from the water stage at the Taipei bridge.

2. Outline of Forecasting Procedures

1) The principle

Calculations are executed deviding the basin into two parts, i.e., the upper reaches and the lower reaches which is affected by the inundation.

In the former, the so-called Storage Function Method, and in the latter a hydraulical method which takes into consideration both the effect of tidal change at the estuary and that of inundation can be applied.

2) Deviding of the basin

The river basin will be devided as follows:

Upper reaches

Ta-han creek	Upper reaches of Shih-men reservoir
	Reaches bet. Shih-men reservair and Hsin-hai Bridge

Lower reaches

Reaches between the lower ends of the above three tributeries and the estuary.

3) Caluculation of the flood discharge

Calculations of flood discharge for each sub basin will be done along the following procedure.

(i) Upper reaches of Shih-men reservoir

The inflow to the reservoir is calculated from rainfall in the basin by the Storage Function Method.

(ii) Reaches between Shih-men reservoir and Hsin-hai bridge

The discharge at Hsin-hai bridge is calculated adding the discharge from the reservoir, after deforming, to the calculated runoff in the resisudal area by the Storage Function Method.

(iii) The basin of Hsin-tien creek

The discharge at Chung-cheng bridge is calculated from rainfall by the Storage Function Method.

(iv) The basin of Keelung river

The discharge at Chung-shan bridge is calculated from rainfall by the Storage Function Method.

(v) The lower reaches of Tan-shui river

Firstly, the water stage at Shih-tzu-tou from discharges at Hsin-hai, Chung-shan and Chung-cheng bridges taking the tidal level at the estuary into consideration.

From the above result, the area and the water depth of inundation, and water stages at these points including that at Taipei bridge are estimated being based the correlation among them.

3. Facilities for Flood Forecasting and Warning

Facilities for flood forecasting and warning will be planned along the following line.

1) The principle

Facilities will be constructed in two stages: the first stage will be concentrated on indispensable facilities and the second one will deal with the complete system.

The first stage should be implemented as early as passible.

2) The location of observation stations

The location of observation stations is selected as shown in Fig. 1*

3) Telecommunication systems

Transmitting of observed data will be done by 60 MHz band telemetering systems. However, existing transmitting facilities will be used for the time being.

Communication between Shih-men Dam and the Flood Forecasting and Warning Centre will depend on a existing system.

4) The Flood Forecasting and Warning Centre

The Flood Forecasting and Warning Centre will be situated in Taipei city. In planning the system, introduction of a high speed digital electronic computer in the near future, must be considered.

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* Omitted in this report.

Appendix 2

ON THE FLOOD WARNING AND FORECASTING IN THE TAN-SHUI RIVER
(RAINFALL AND WATER STAGE TELEMETERING SYSTEM)

Interrim Report

June 30 1971

Survey Team Orgamized by the Government of Japan

F o r e w o r d

This Interim Report is submitted to the Provincial Walter Conservancy Bureau, and contains the facts found by the three telecommunications experts during the field survey in compliance with the interim report made by the Japanese Government's hydrological experts.

Some of the details may be subject to change by further investigation and study in the future.

As mentioned in the interim report prepared by the hydrological experts, the final report will be submitted by the end of December 1971.

1. Objective of Establishing the Telemetering System

The system should be established for the purposes of flood forecasting in Tan-shui river as early as possible, collecting and analyzing rainfall and water stage data of each basin in a quick and accurate way, and notifying the inhabitants with the time and the extent of the flood.

2. Outline of Telemetering System

(1) Existing System

The route available at present for data collection is shown in the Attached Drawing-1. (omitted)*

(2) Newly Planned Telemetering System

The Attached Drawing-2 (omitted) shows a network to transmit most securely the data from raingauge and water stage station pointed out by the hydrological experts. **

(3) Following points must be particularly taken into consideration (especially concerning the environments, except general technical conditions).

1) Maintenance must be easier after establishment.
2) Sufficient countermeasure must be taken to lightning.
3) It must be capable of withstanding high temperature and high humidity.
4) It must withstand strong wind.

3. Rain Gauge and Water Stage Telemetering System

(1) The telemetering system newly planned is shown in Attached Sheet-3.

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* Reference should be made to the Drawing-3. 7 in Chapter 3 of this report.

** Reference should be made to the Drawing-7. 3 in Chapter 7 of this report, however, some change was made to the network due to change in measuring points.

(2) Reasons for Adopting this System

1) It is not easily affected by external effects such as noise, etc.
2) It is possible to call the station at any time.
3) It is available for telephone talks as occasion demands.
4) It is a firmly established system based on its actual records over ten years in Japan.
5) It is suitable for propagation in mountainous areas.

4. Outline of Facilities

Outline of the planned system is shown in Attached Drawing-4* (omitted).

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* Reference should be made to Fig. 7.3 in Chapter 7 of this report.

ATTACHED SHEET-3.

1. It is effective to use a frequency between 60 MHz and 150 MHz. (in consideration of city noises and propagation over mountains)

2. Power supply will be always floating charging system. (By a commercial source or a solar battery; and it must be durable for a long period in consideration of service interruption or rate of sunshine.)

3. Antenna power will be up to 10W. Relay stations will be of auxiliary unit switching system, and observatories will use interchangeable panels.

4. Two observation systems will be available; regular observation (four-step system by selecting any one of every 12, 3 or one hours and every 30, 15 or 10 minutes) and occasional observation by calling from the control station as occasion demands.

5. For maintenance, telephone channels must be available between the control station and observation stations, and between the control station or observation stations and relay stations.

6. Recording will be done automatically by tabulating system by means of electric typewriters, to be available for indication on the graphic panel.

7. The system of sub-carrier FS system will be employed to secure stabilized transmission of data, and binary coded decimal system for the purpose of easy connection with the central processing unit of an electronic computer.

8. As for the external conditions, followings must be taken into consideration:

   (1) For countermeasure to humidity, the transmitting unit should be enclosed type.

   (2) For countermeasure to high temperature, the transmitting unit should be installed indoors and totally solid type.

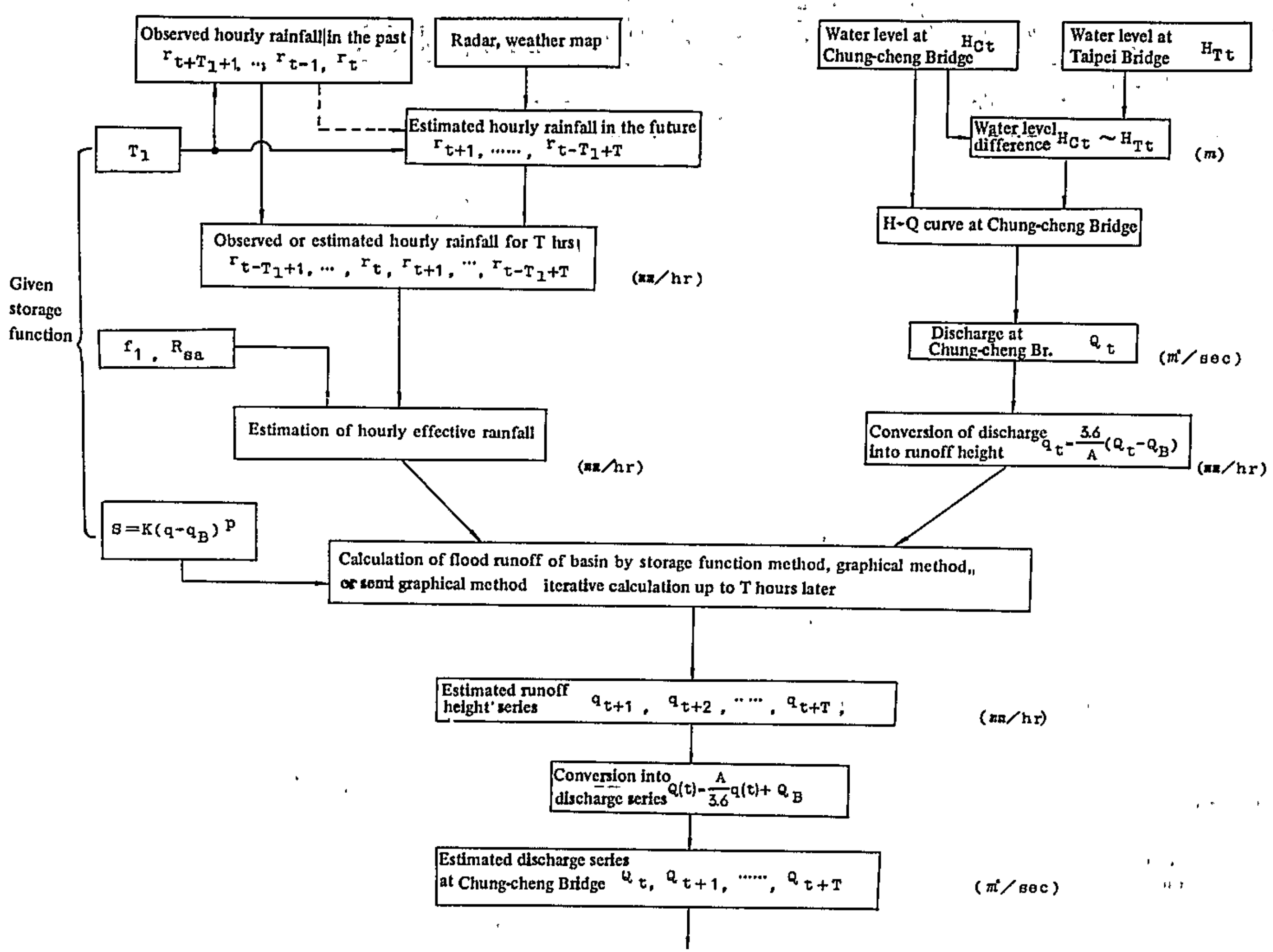
   (3) For countermeasure to lightning, consideration must be given to the topography for installation of station buildings, and due attention must be paid to lightning conductors, arresters and grounding.

Appendix 3

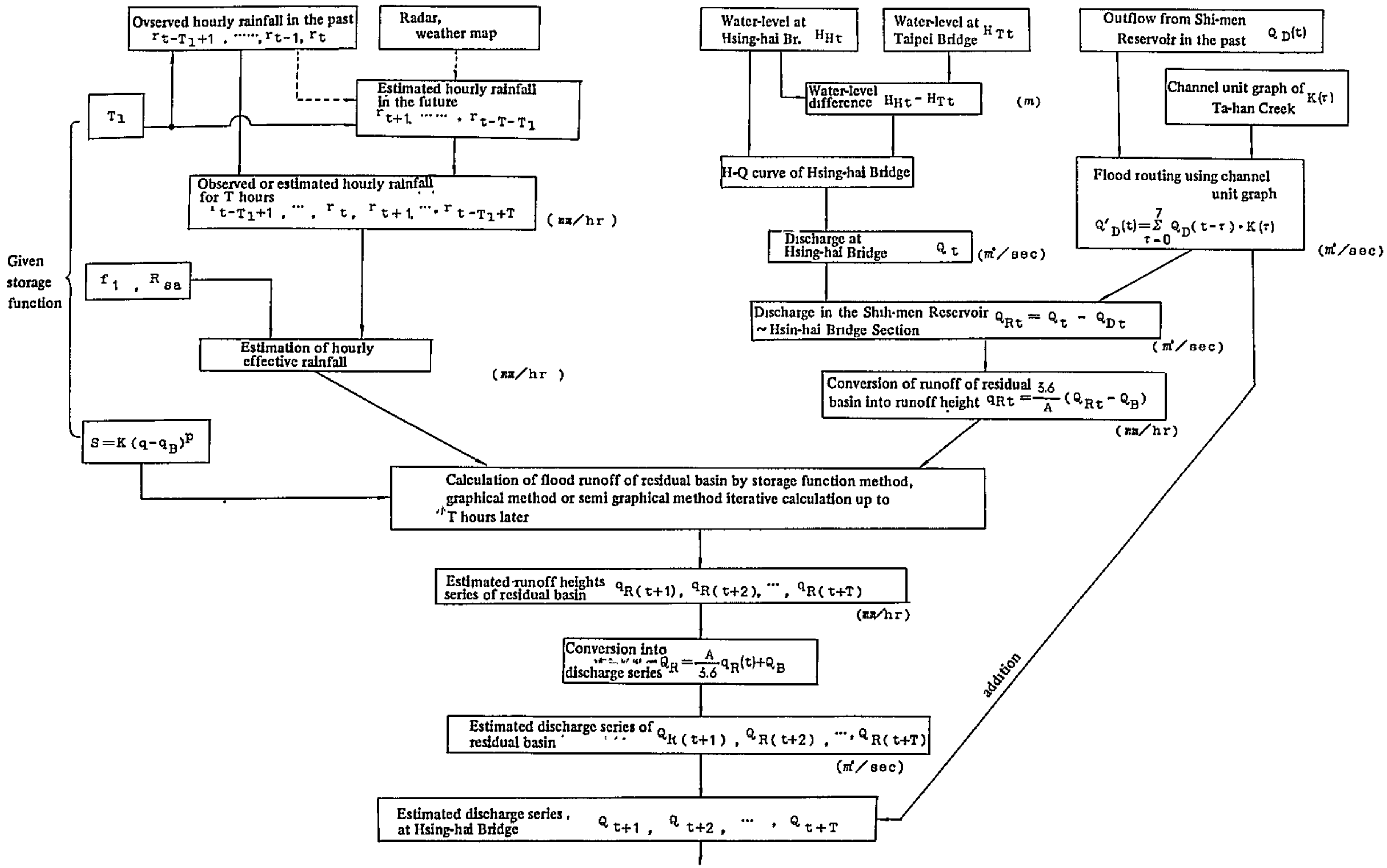
FLOW CHARTS OF RUNOFF ESTIMATION IN UPSTREAM TRIBUTARY BASINS

1. Chung-cheng Bridge of Hsin-tien Creek
2. Hsin-hai Bridge of Ta-han Creek
3. Chung-shan Bridge of Keelung River

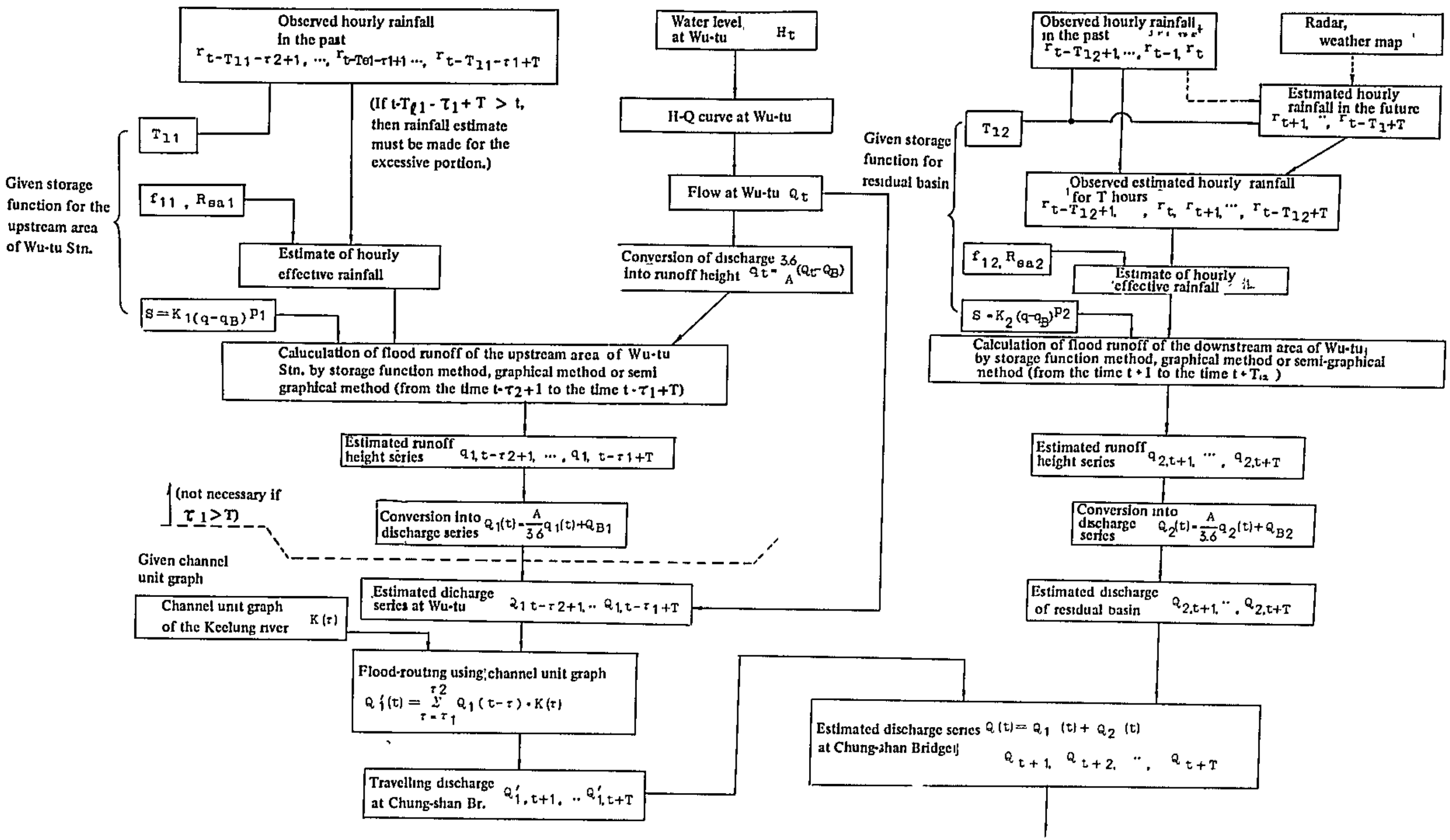
Appendix 3 (1) Flood Runoff Estimating System at Chung-cheng Bridge of Hsin-tien Creek (An estimate up to T hours later)



Appendix 3 (2) Flood Runoff Estimating System at Hsin-hai Bridge of Ta-han Creek
(An estimate up to T hours later)



Appendix 3 (3) Flood Runoff Estimating System at Chung-shan Bridge of Keelung River (An Estimate up to T hours later)



Appendix 4

TABLES AND NOMOGRAMS FOR CALCULATING THE DOWNSTREAM INUNDATION

Annexed Table 1

Relation betw. Water Stage at Shih-tzu-ton and Water Volume Stored in the Submerged Area

Water Stage: Taiwan Datum Level, in m
Water Volume: 10^3 m^3

Water Stage	0.	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.99
0.	38030	38260	38500	38730	38970	39200	39430	39670	39900	40140
0.10	40370	40610	40800	41070	41310	41540	41780	42010	42250	42480
0.20	42710	42950	43180	43420	43650	43890	44120	44350	44590	44820
0.30	45060	45290	45520	45760	45990	46230	46460	46700	46930	47160
0.40	47400	47630	47870	48180	48340	48570	48800	49040	49270	49510
0.50	49740	49980	50210	50440	50680	50910	51150	51380	51610	51850
0.60	52080	52320	52550	52790	53020	53250	53490	53720	53960	54190
0.70	54430	54660	54890	55130	55360	55600	55830	56070	56300	56530
0.80	56770	57000	57240	57470	57710	57940	58170	58410	58640	58880
0.90	59110	59340	59580	59810	60050	60280	60520	60750	60980	61220
1.00	61450	61690	61920	62160	62390	62620	62860	63090	63330	63560
1.10	63800	64030	64260	64500	64730	64970	65200	65440	65670	65900
1.20	66140	66370	66610	66840	67070	67310	67540	67780	60010	68250
1.30	68480	68710	68950	69180	69420	69650	69890	70120	70350	70590
1.40	70820	71060	71290	71530	71760	71990	72230	72460	72700	72930
1.50	73160	73520	73880	74240	74600	74950	75310	75670	76030	76390
1 60	76740	77100	77460	77820	78170	78530	78890	79250	79610	79960
1.70	80320	80680	81040	81390	81750	82110	82470	82830	83180	83540
1.80	83900	84260	84610	84970	85330	85690	86050	86400	86760	87120
1.90	87480	87830	88190	88550	88910	89270	89620	89980	90340	90700
2.00	91050	91490	91950	92370	92810	93250	93680	94120	94560	95000
2.10	95440	95870	96310	96750	97190	97630	98060	98500	98940	99380
2.20	99820	100250	100690	101130	101570	102010	102440	102880	10332	103760
2.30	104200	104630	105070	105510	105950	106390	106830	107260	107700	108140
2.40	108580	109020	109450	109890	110330	110770	111210	111640	112080	112520
2.50	112960	114680	116400	118120	119840	121560	123280	125000	126730	128450
2 6.0	130170	130790	131410	132030	132650	133270	133890	134520	135140	135760
2.70	136380	137000	137620	138240	138860	139480	140110	140730	141350	141970
2 80	142590	143210	143830	144450	145080	145700	146320	146940	147560	148180
2.90	148800	149420	150050	150670	151290	151910	152530	153150	153770	154390
3 00	155010	155720	156420	157120	157820	158530	159230	159930	160630	161330
3 10	162040	162740	163440	164140	164850	165550	166250	166950	167650	168360
3.20	169060	169760	170460	171170	171870	172570	173270	173970	174680	175380
3.30	176080	176780	177490	178190	178890	179590	180290	181000	181700	182400
3.4.0	183100	183810	184510	185210	185910	186610	187320	188020	188720	189420
3.50	190120	190830	191530	192230	192930	193640	194340	195040	195740	196440
3.60	197150	197850	198550	199250	199960	200660	201360	202060	202760	203470
3.70	204170	204870	205570	206280	206980	207680	208380	209080	209790	210490
3 80	211190	211890	212600	213300	2140u0	214700	215400	216110	216810	217510
3 90	218210	218920	219620	220320	221020	221720	222430	223130	223830	224530
4.00	225230	225940	226640	227340	228040	228750	229450	230150	230850	231550
4.10	232260	232960	233660	234360	235070	235770	236470	237170	237870	238580
4 20	239280	239980	240680	241390	242090	242790	243490	244190	244900	245600
4 30	246300	247000	247710	248410	249110	242810	250510	251220	251920	252620
4.40	253320	254030	254730	255430	256130	256830	257540	258420	258940	259640
4 50	260340	261050	261750	262450	263150	263860	264560	265260	265960	266660
4 60	267370	268070	268770	269450	270180	270880	271580	272280	272980	273690
4.70	274390	275090	275790	276500	277200	277900	278600	279300	280010	280710
4 80	281410	282110	282820	283520	284220	284920	285620	286330	287030	287730
4.90	288430	289140	289840	290540	291240	291940	292650	293350	294050	294750

Annexed Table 2

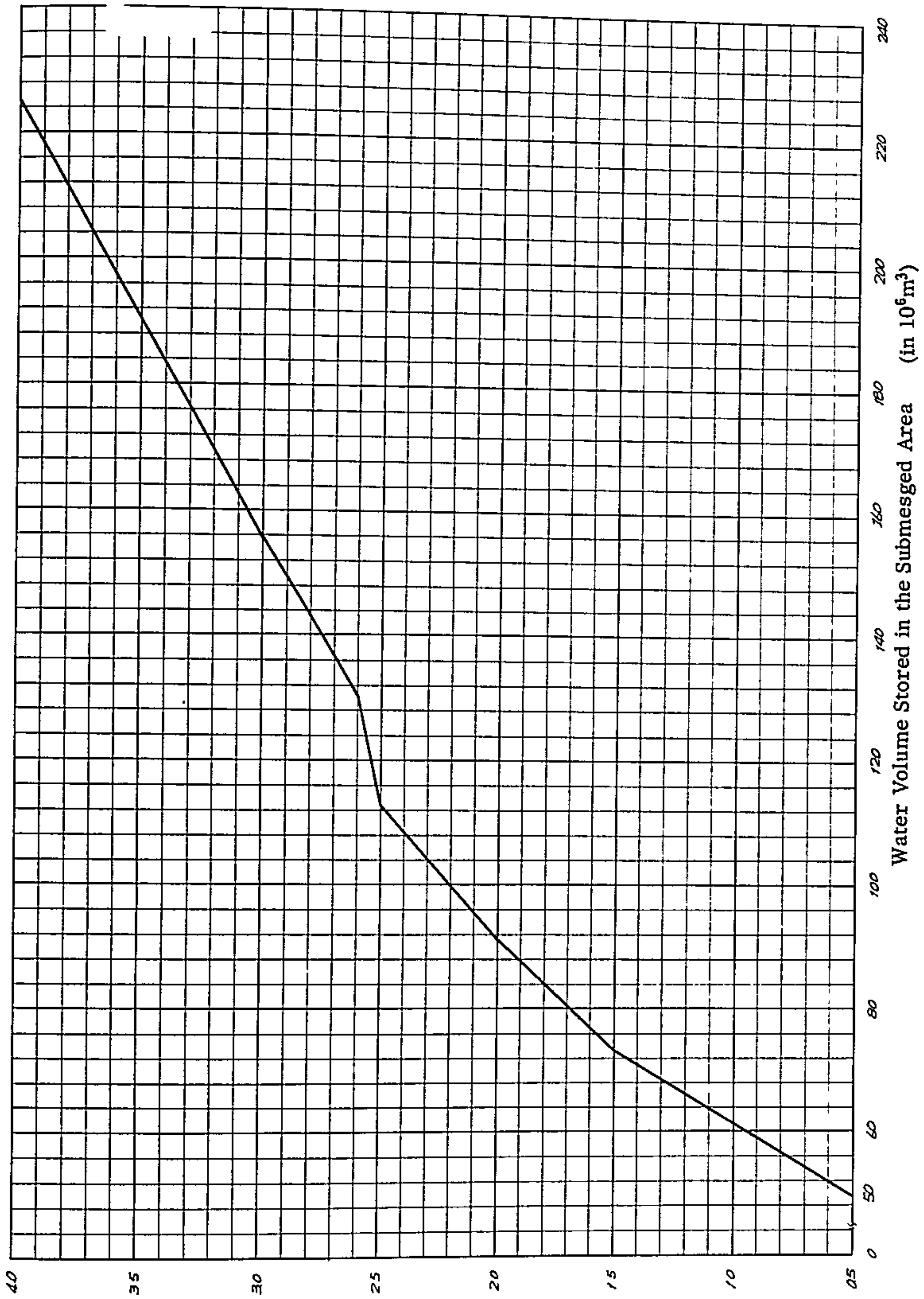
Relation betw. Water Volume Stored in the Submerged Area and Water Stage at Shih-tzu-ton

Water Volume: 103 m³
Water Stage:
Taiwan Datum Level, in m

Water Volume	0.	500000.	1000000.	1500000	2000000.	2500000	3000000.	3500000.	4000000.	4500000.
30000000.	-0.34	-0.32	-0.30	-0.28	-0.26	-0.24	-0.21	-0.19	-0.17	-0.15
35000000	-0.13	-0.11	-0.09	-0.07	-0.04	-0.02	-0.00	0.02	0.04	0.06
40000000	0.08	0.11	0.13	0.15	0.17	0.19	0.21	0.23	0.25	0.28
45000000.	0.30	0.32	0.34	0.36	0.38	0.40	0.43	0.45	0.47	0.49
50000000	0.51	0.53	0.55	0.57	0.60	0.62	0.64	0.66	0.68	0.70
55000000	0.72	0.75	0.77	0.79	0.81	0.83	0.85	0.87	0.90	0.92
60000000.	0.94	0.96	0.98	1.00	1.02	1.04	1.07	1.09	1.11	1.13
65000000	1.15	1.17	1.19	1.22.	1.24	1.26	1.28	1.30	1.32	1.34
70000000.	1.36	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.52	1.54
75000000	1.55	1.57	1.58	1.59	1.61	1.62	1.64	1.65	1.66	1.68
80000000	1.69	1.70	1.72	1.73	1.75	1.76	1.77	1.79	1.80	1.82
85000000.	1.83	1.84	1.86	1.87	1.89	1.90	1.99	1.93	1.94	1.96
90000000	1.97	1.98	2.00	2.01	2.02	2.03	2.04	2.06	2.07	2.08
95000000	2.09	2.10	2.11	2.12	2.14	2.15	2.16	2.17	2.18	2.19
100000000.	2.20	2.22	2.23	2.24	2.25	2.26	2.27	2.28	2.30	2.31
105000000.	2.32	2.33	2.34	2.35	2.36	2.38	2.39	2.40	2.41	2.42
110000000	2.43	2.44	2.46	2.47	2.48	2.49	2.50	2.50	2.54	2.51
115000000	2.51	2.51	2.52	2.52	2.52	2.53	2.53	2.53	2.54	2.54
120000000.	2.54	2.54	2.55	2.55	2.55	2.56	2.56	2.56	2.56	2.57
125000000.	2.57	2.57	2.58	2.58	2.58	2.58	2.59	2.59	2.59	2.60
130000000	2.60	2.61	2.61	2.62	2.63	2.64	2.65	2.65	2.66	2.67
135000000	2.68	2.69	2.69	2.70	2.71	2.72	2.73	2.73	2.74	2.75
140000000.	2.76	2.77	2.77	2.78	2.79	2.80	2.81	2.81	2.82	2.83
145000000	2.84	2.85	2.85	2.86	2.87	2.88	2.89	2.90	2.90	2.91
150000000	2.92	2.93	2.94	2.94	2.95	2.96	2.97	2.98	2.98	2.99
155000000.	3.00	3.01	3.01	3.02	3.03	3.04	3.04	3.05	3.06	3.06
160000000.	3.07	3.08	3.09	3.09	3.10	3.11	3.11	3.12	3.13	3.14
165000000.	3.14	3.15	3.16	3.16	3.17	3.18	3.18	3.19	3.20	3.21
170000000	3.21	3.22	3.23	3.23	3.24	3.25	3.26	3.26	3.27	3.28
175000000.	3.28	3.29	3.30	3.31	3.31	3.32	3.33	3.33	3.34	3.35
180000000.	3.36	3.36	3.37	3.38	3.38	3.39	3.40	3.41	3.41	3.42
185000000	3.43	3.43	3.44	3.45	3.46	3.46	3.47	3.48	3.48	3.49
190000000.	3.50	3.51	3.51	3.52	3.53	3.53	3.54	3.55	3.56	3.56
195000000.	3.57	3.58	3.58	3.59	3.60	3.60	3.61	3.62	3.63	3.63
200000000.	3.64	3.65	3.65	3.66	3.67	3.68	3.68	3.69	3.70	3.70
205000000.	3.71	3.72	3.73	3.73	3.74	3.75	3.75	3.76	3.77	3.78
210000000	3.78	3.79	3.80	3.80	3.81	3.82	3.83	3.83	3.84	3.85
215000000.	3.85	3.86	3.87	3.88	3.88	3.89	3.90	3.90	3.91	3.92
220000000.	3.93	3.93	3.94	3.95	3.95	3.96	3.97	3.98	3.98	3.99
225000000.	4.00	4.00	4.01	4.02	4.03	4.03	4.04	4.05	4.05	4.06
230000000	4.07	4.07	4.08	4.09	4.10	4.10	4.11	4.12	4.12	4.13
235000000	4.14	4.15	4.15	4.16	4.17	4.17	4.18	4.19	4.20	4.20
240000000	4.21	4.22	4.22	4.23	4.24	4.25	4.25	4.26	4.27	4.27
245000000	4.28	4.29	4.30	4.30	4.31	4.32	4.32	4.33	4.34	4.35
250000000.	4.35	4.36	4.57	4.37	4.38	4.39	4.40	4.40	4.41	4.42
255000000	4.42	4.43	4.44	4.45	4.45	4.46	4.47	4.47	4.48	4.49
260000000.	4.50	4.50	4.51	4.52	4.52	4.53	4.54	4.54	4.55	4.56
265000000.	4.57	4.57	4.58	4.59	4.59	4.60	4.61	4.62	4.62	4.63
270000000	4.64	4.64	4.65	4.66	4.67	4.67	4.68	4.69	4.69	4.70
275000000	4.71	4.72	4.72	4.73	4.74	4.74	4.75	4.76	4.77	4.77
280000000	4.78	4.79	4.79	4.80	4.81	4.82	4.82	4.83	4.84	4.84
285000000	4.85	4.86	4.87	4.87	4.88	4.89	4.89	4.90	4.91	4.92
290000000.	4.92	4.93	4.94	3.94	4.95	4.96	4.96	4.97	4.98	4.99
295000000	4.99	5.00	5.01	5.01	5.02	5.03	5.04	5.04	5.05	5.06
300000000	5.06	5.07	5.08	5.09	5.09	5.10	5.11	5.11	5.12	5.13

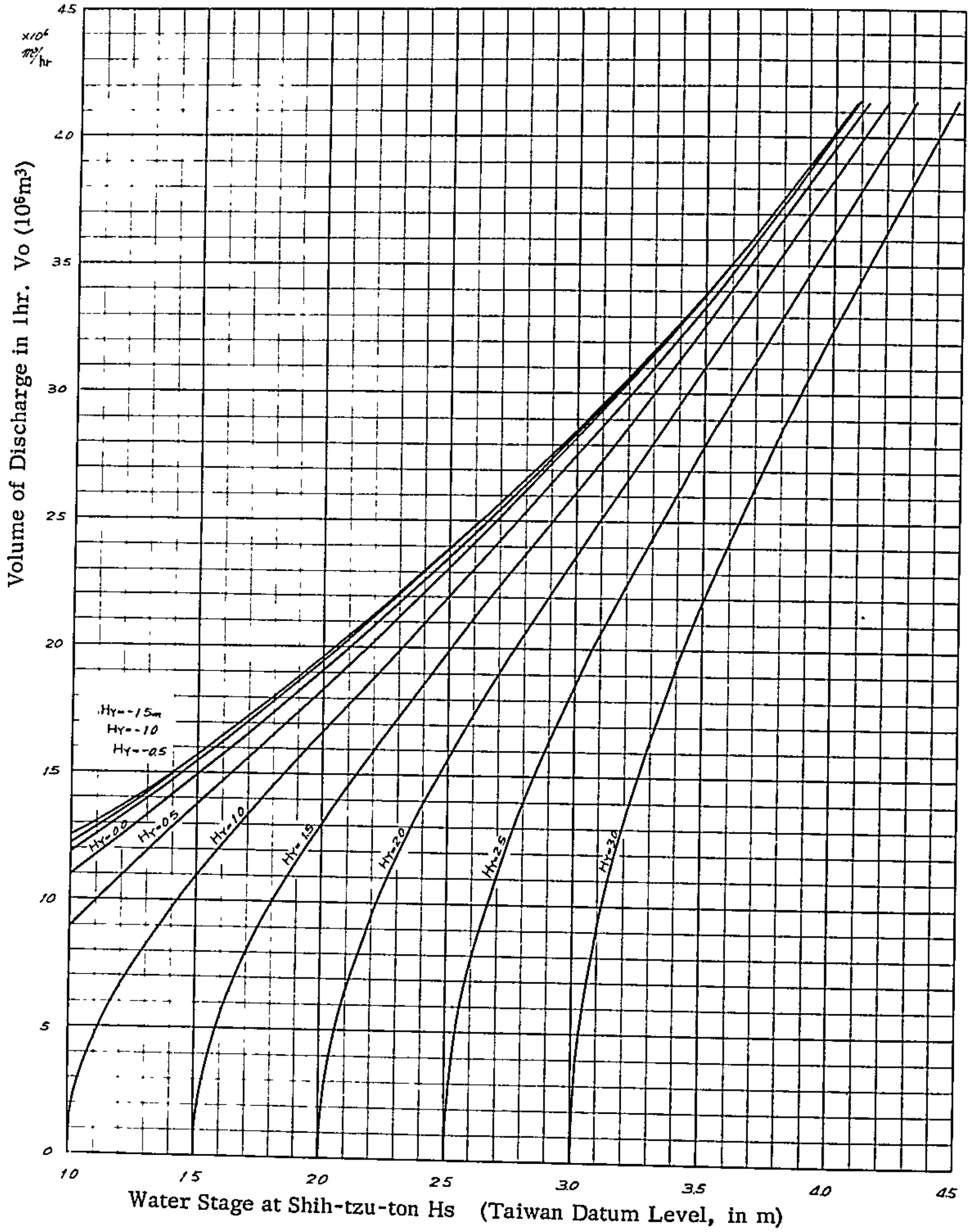
Annexed Figure 1

Relation betw. Water Volume Stored in the Submerged Area and Water Stage at Shih-tzu-ton



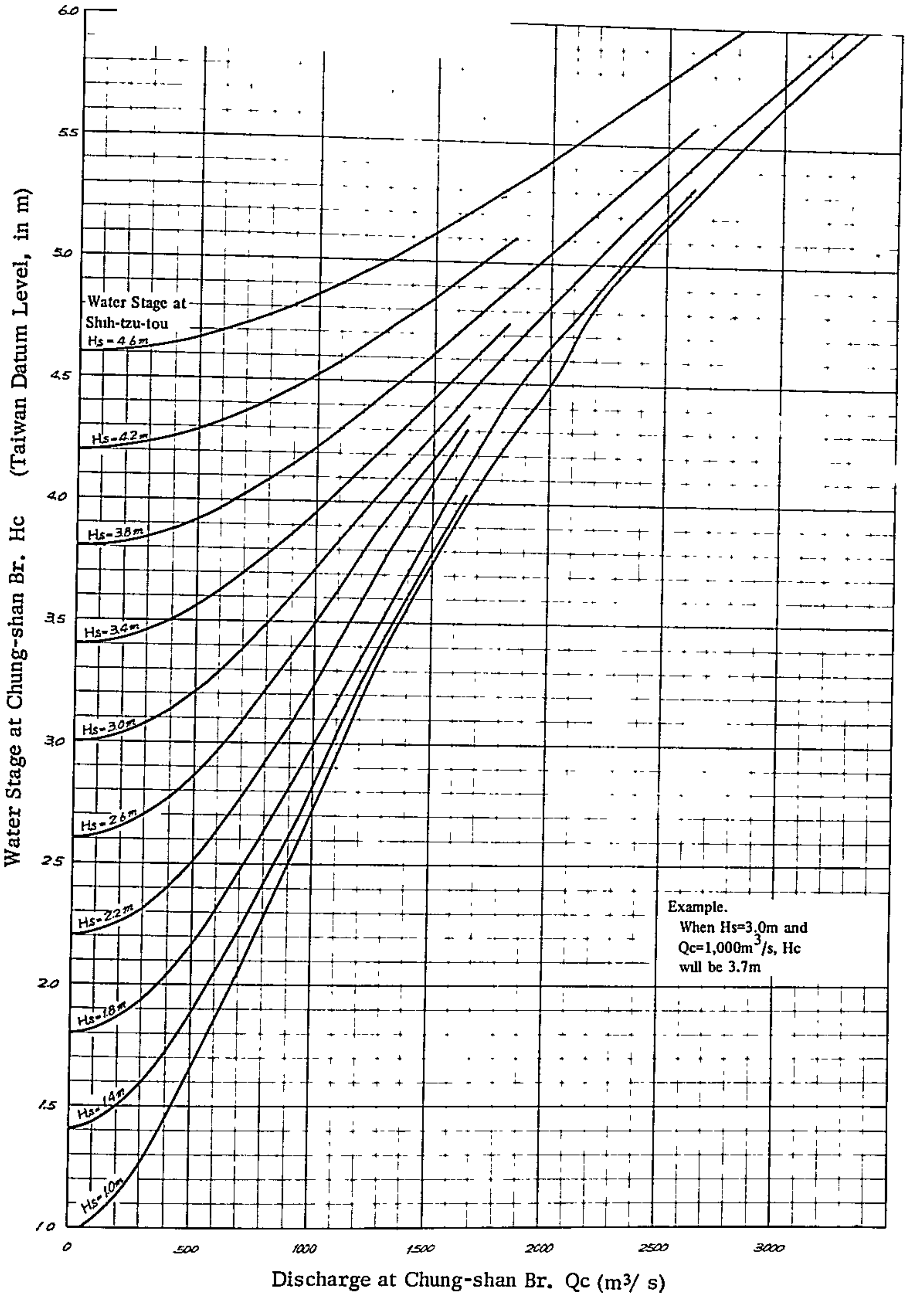
Annexed Figure 2

Nomogram for Calculating Volume of Discharge from the Submerged Area



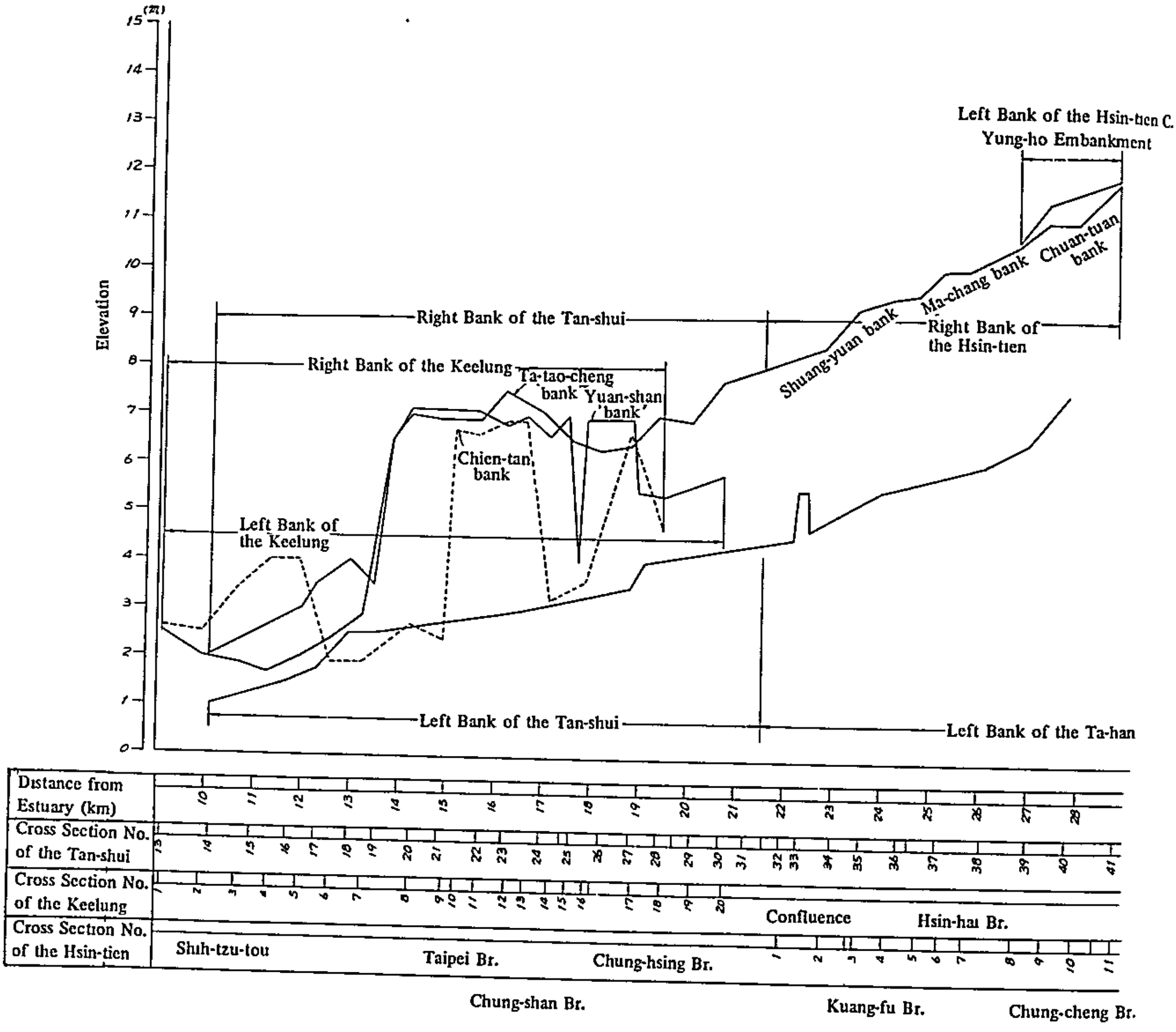
Annexed Figure 3

Nomogram for Calculating Water Stage at Chung-shan Br.



Annexed Figure 4

Longitmdinal Profile of Embankment and Ground Height



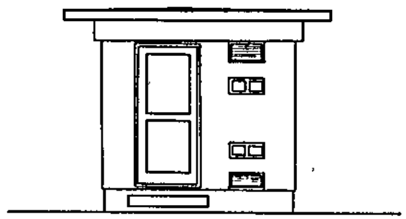
Appendix 5

EXAMPLES OF INSTALATIONS

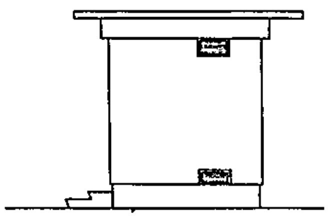
1. Station House (Relay Station)
2. " (Observation Station)
3. Water Stage Station
4. Tele Polo (Relay Station & Observation Station)
5. " (Control Station)
6. Lightning Arresting Facilities (Relay Station)
7. Photographs

1. Station House (Relay Station)

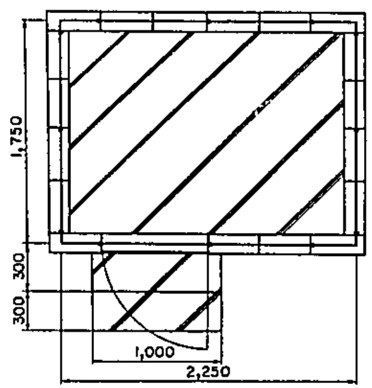
ELEVATION

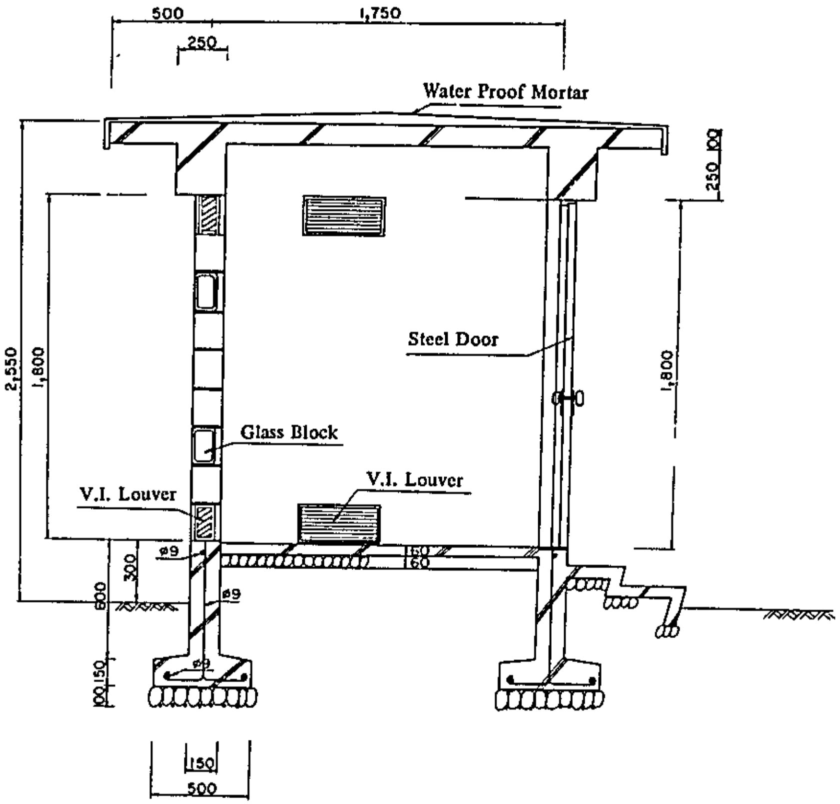


SIDE



PLAN



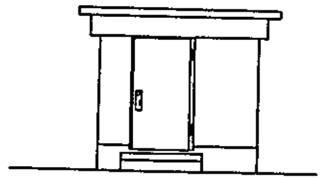


DETAIL

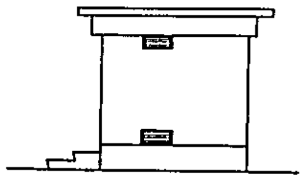
unit mm

2. Station House (Observation Station)

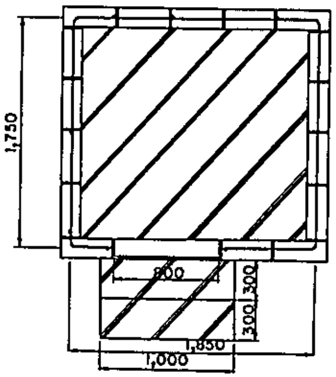
ELEVATION

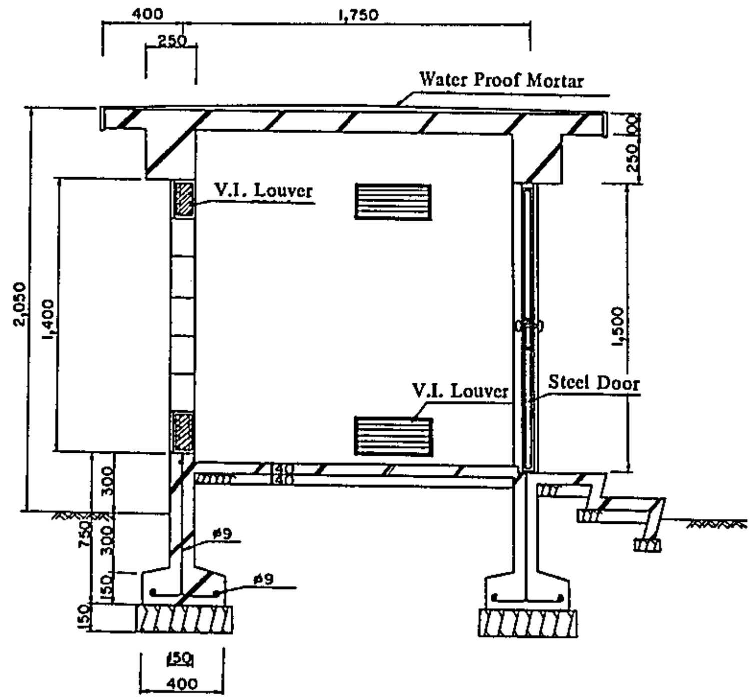


ELEVATION (SIDE)



PLAN



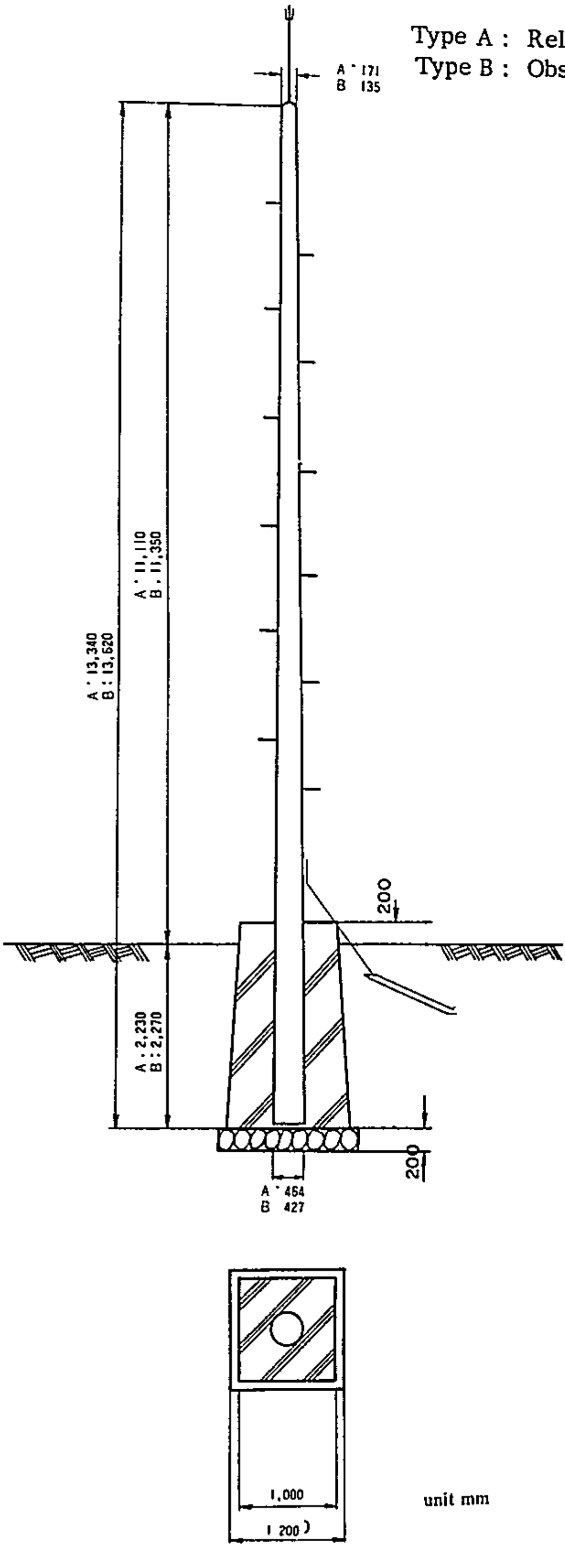


DETAIL

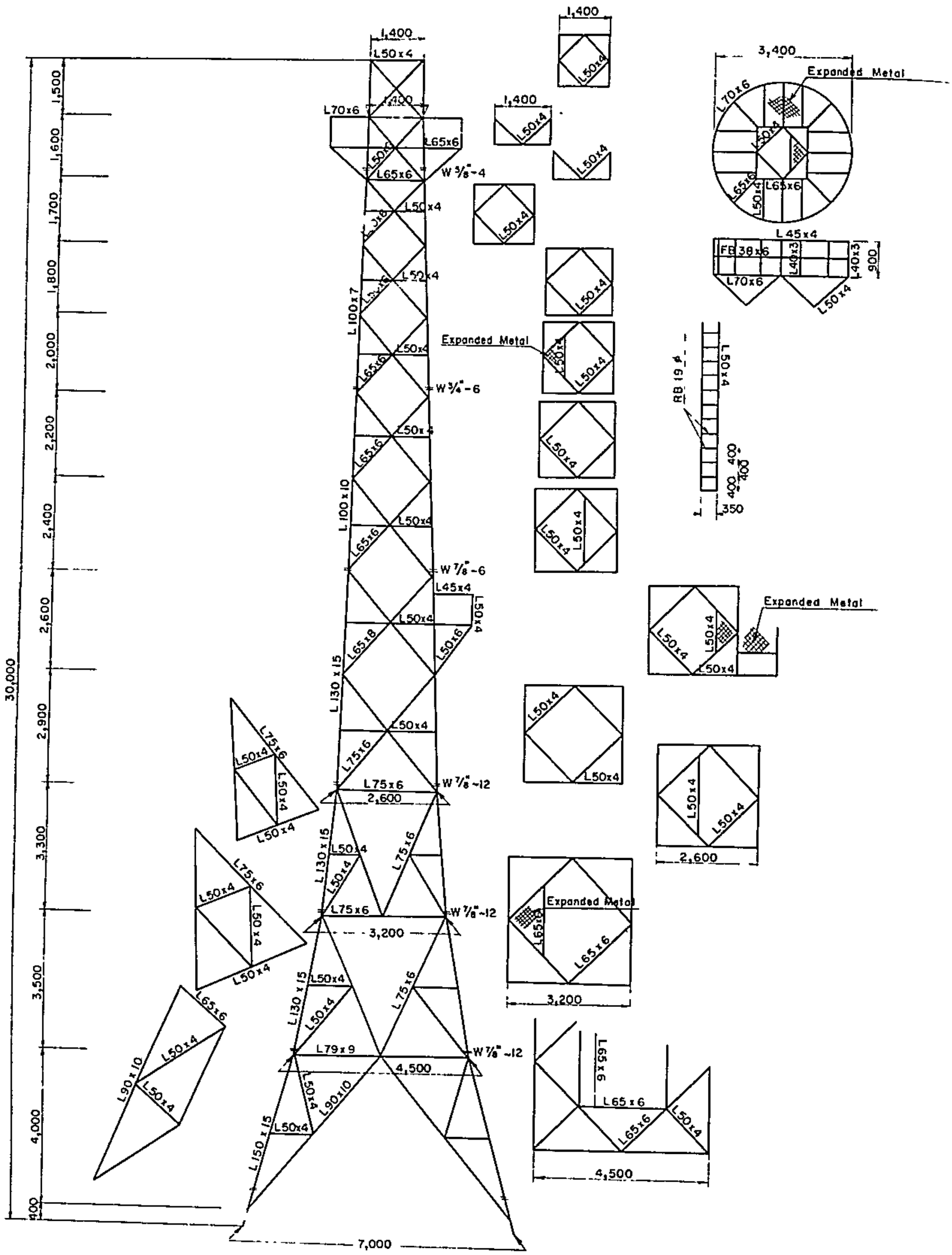
unit mm

4. Tele Pole (Relay Station and Observation Station)

Type A : Relay Station
Type B : Observation Station

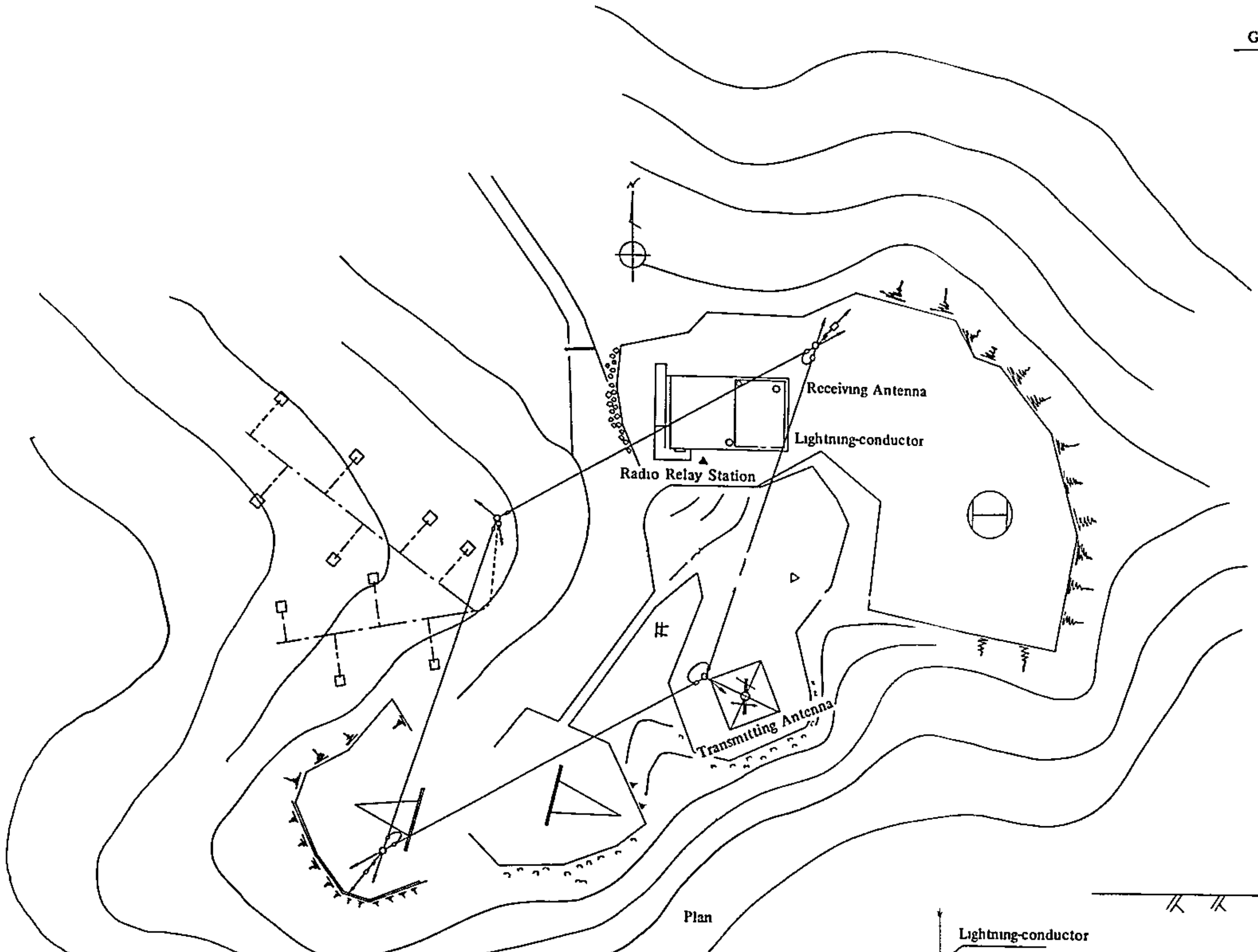


5. Tele Pole (Control Station)

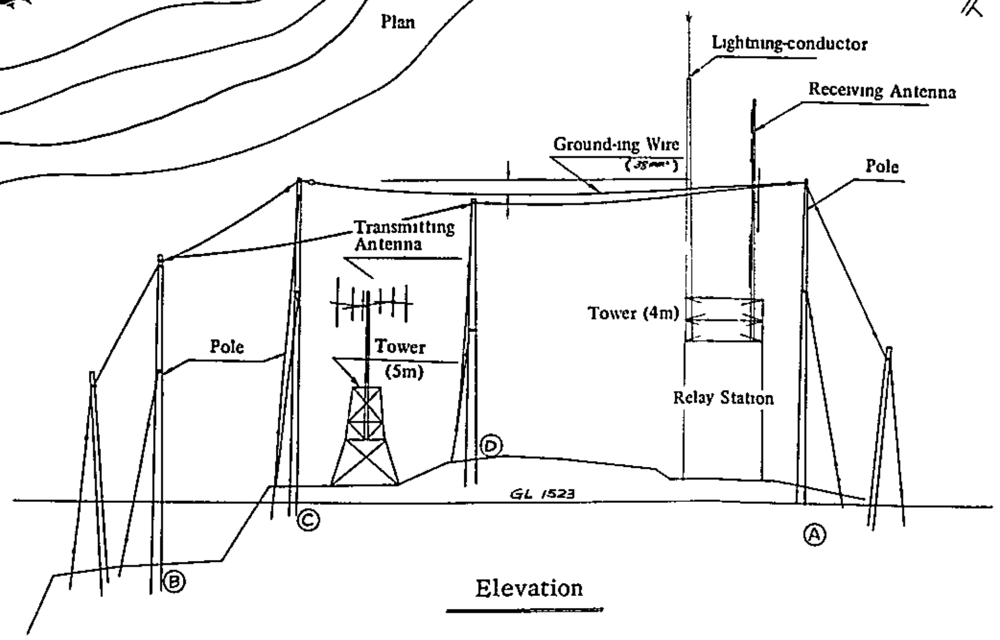


unit mm

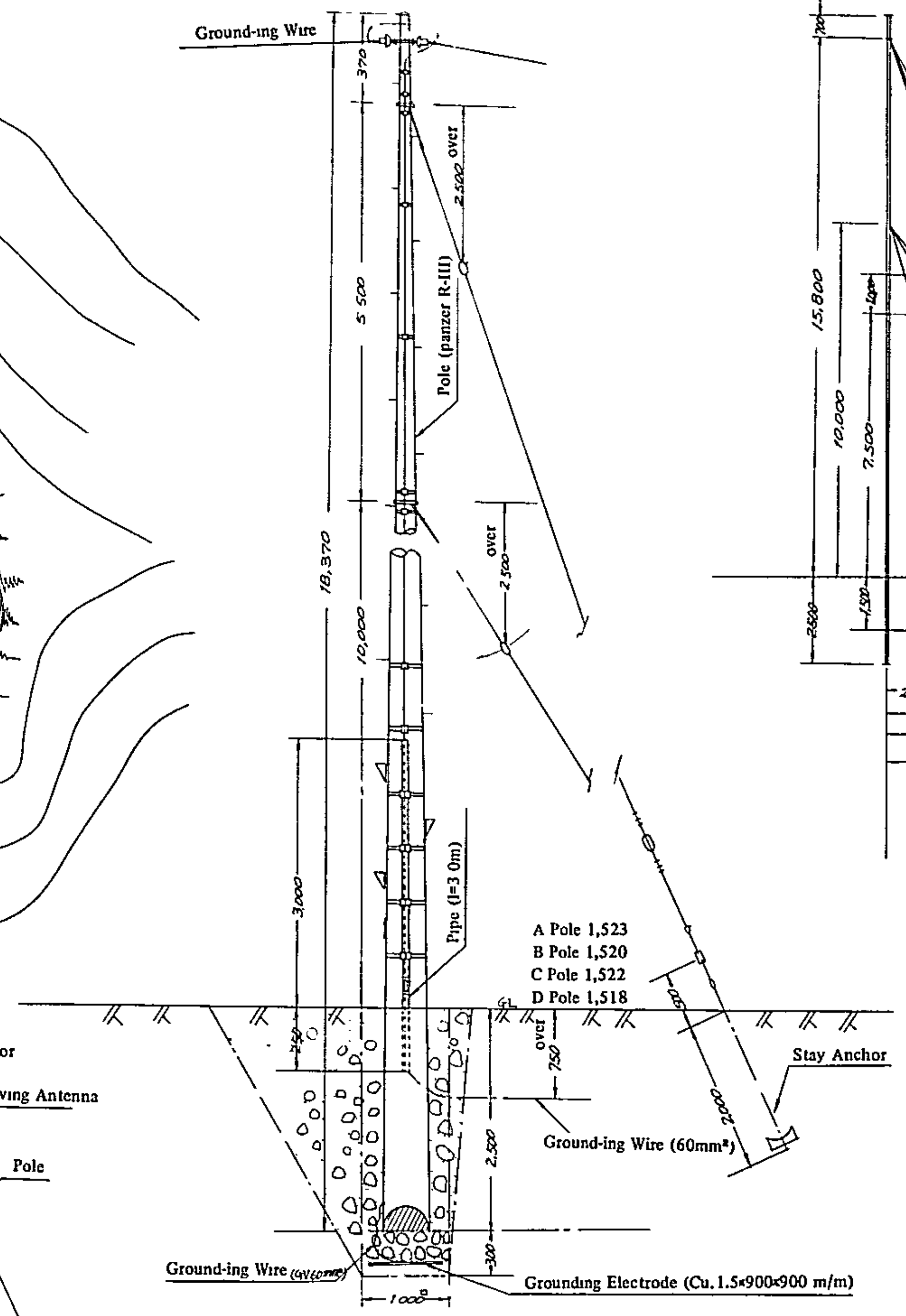
Appendix 5. 6 Lightning Arresting Facilities (An example at Arashima Radio Relay Relay St. in Japan)

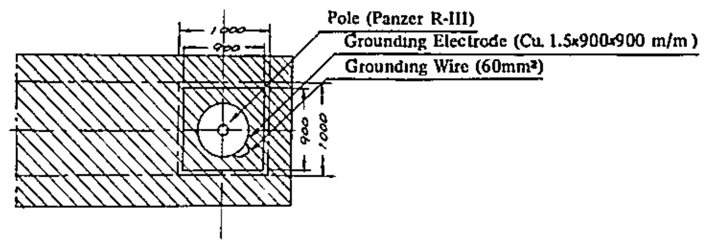


Plan

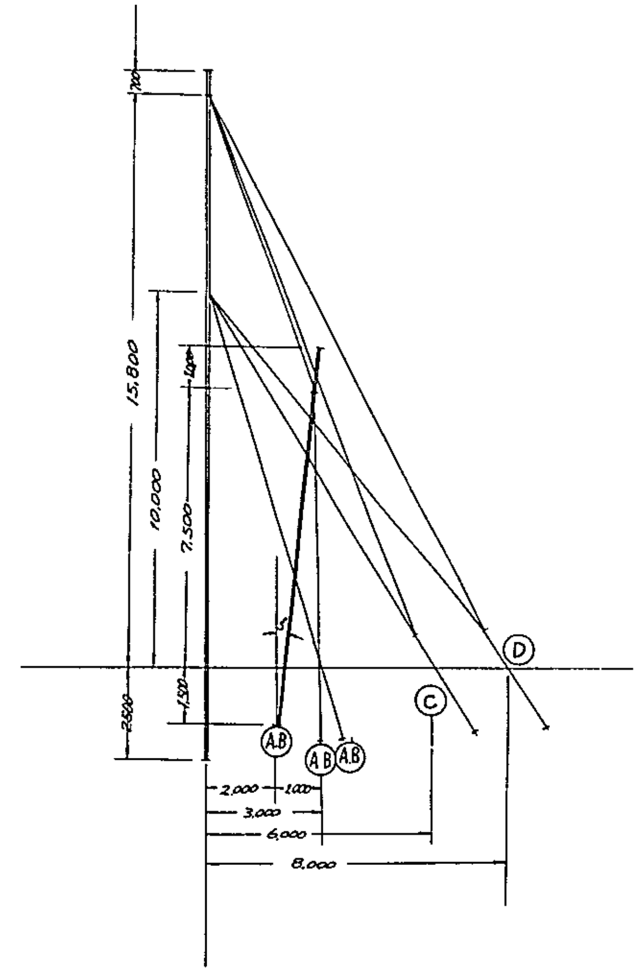


Elevation



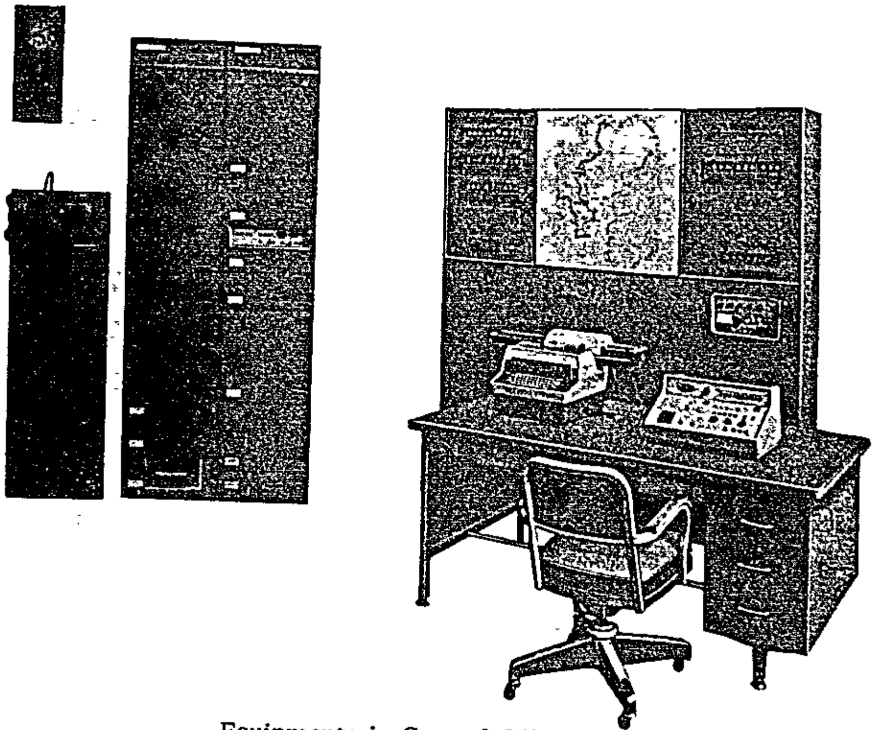


Plan and Elevation
(POLE)

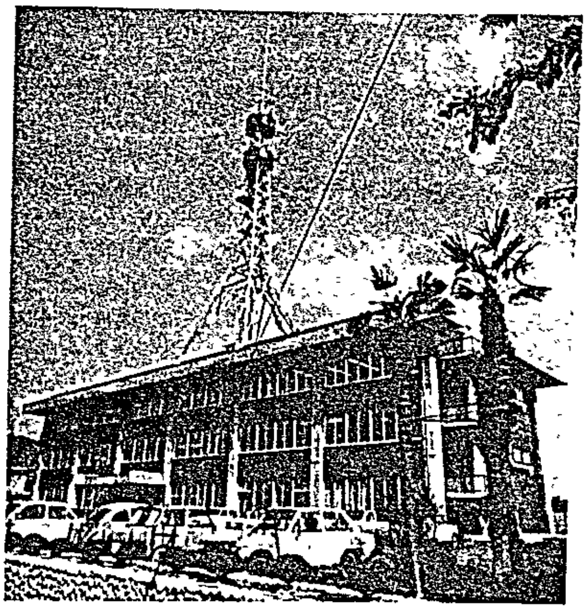


Elevation (STAY)

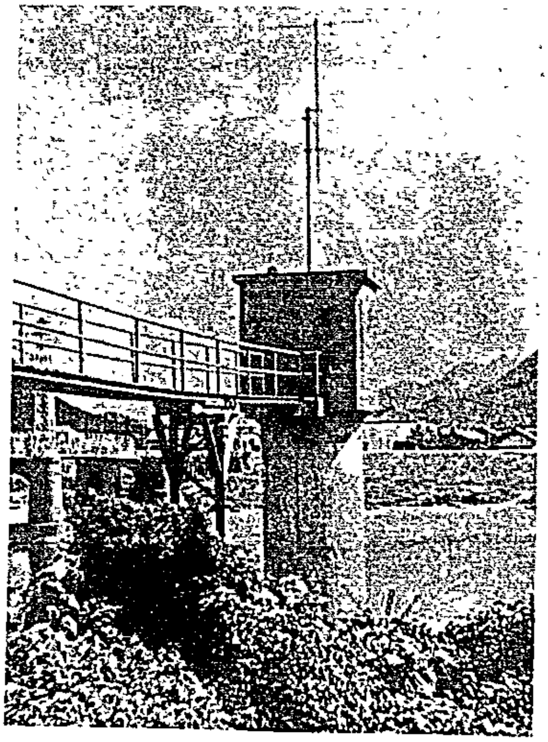
7. Photographs



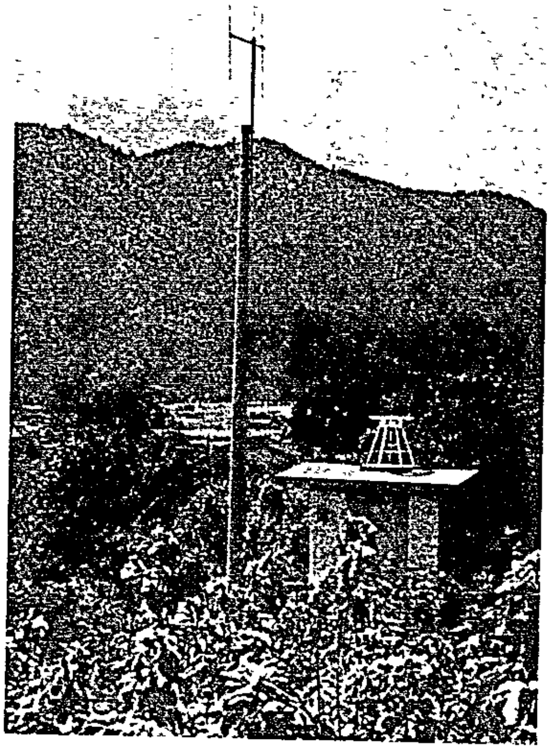
Equipments in Control Office



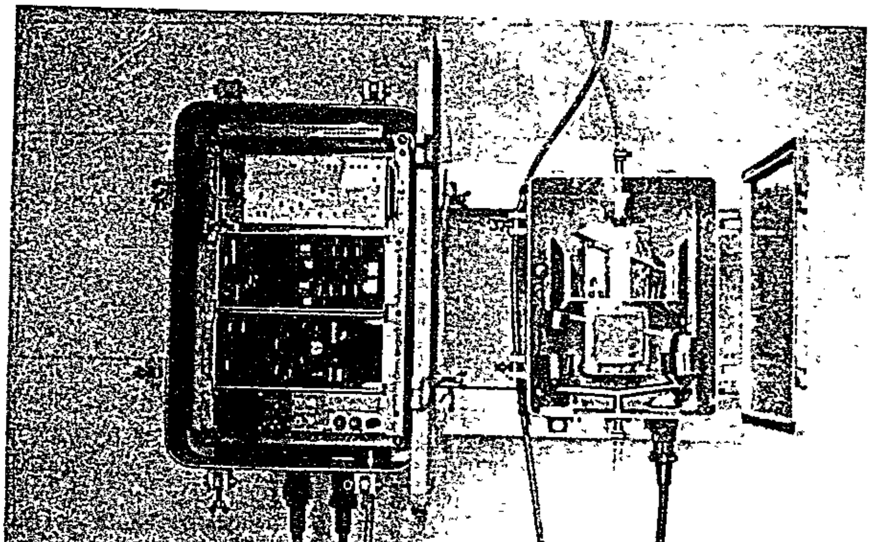
Control Office



Water Stage Station

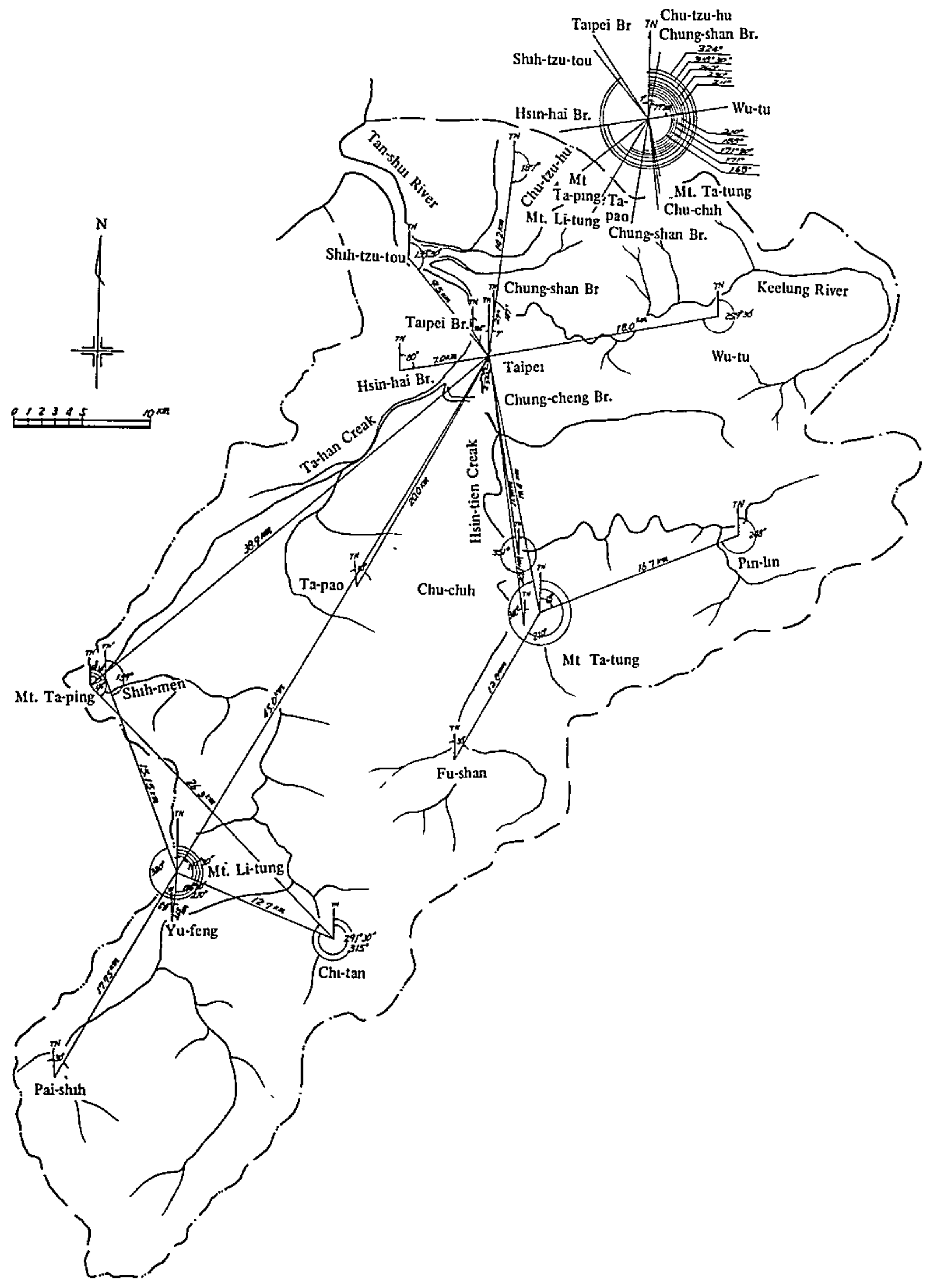


Rain Gauge Station



Equipments in Rain Gauge Station

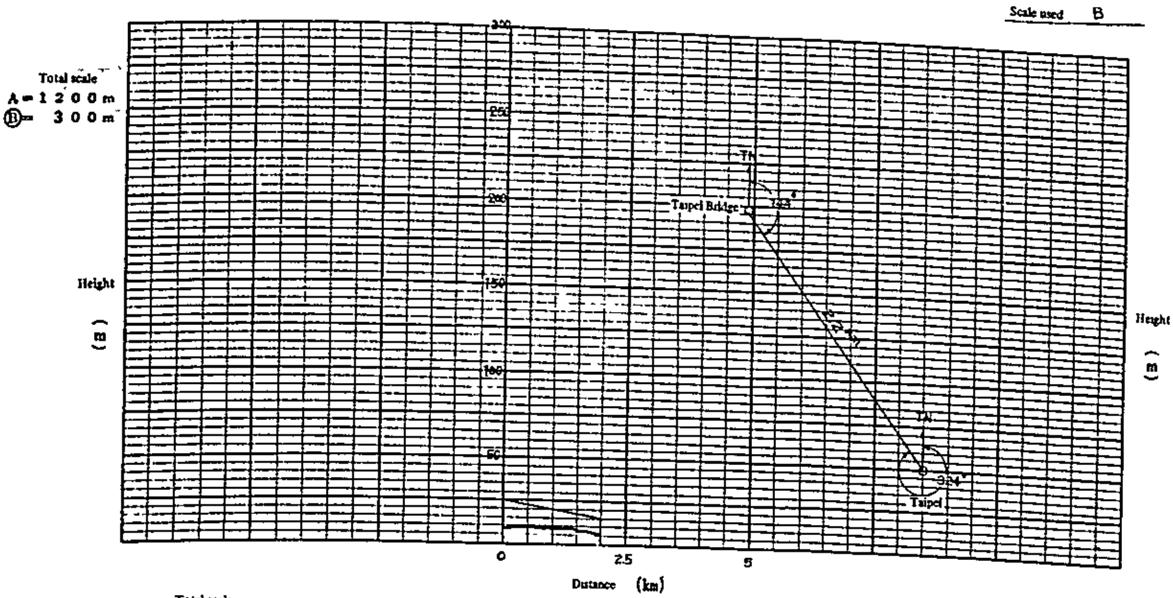
Appendix 6 Proposed Plan of Tele-communication Systems in the Tan-shui River Basin



Appendix 7

PROFILE MAPS

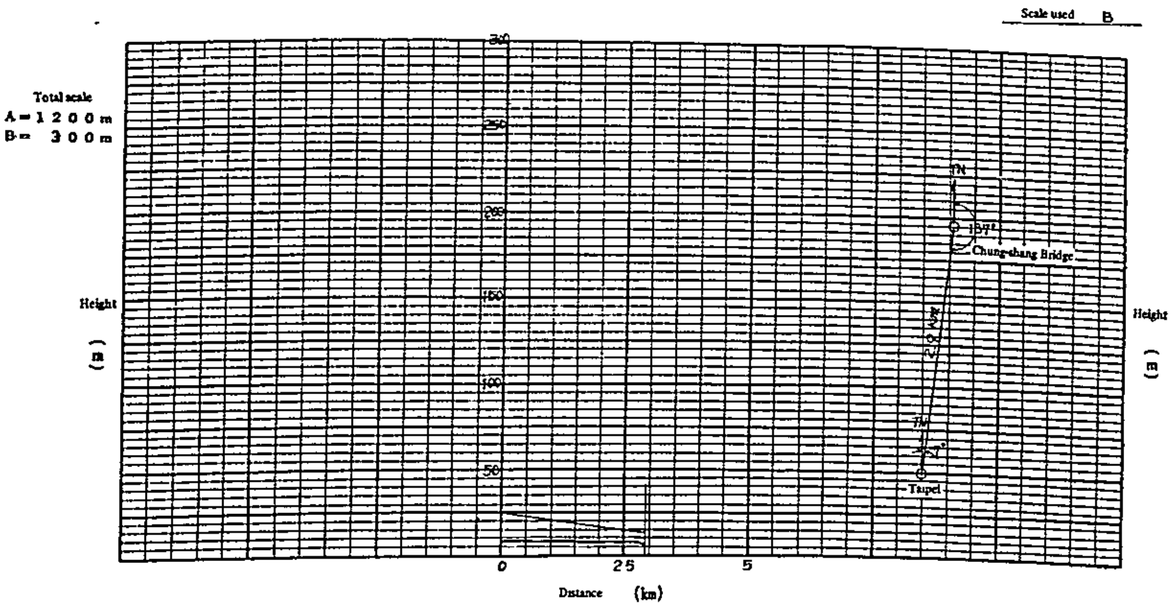
Profile MAp (k=4/3)



Total scale
A = 4 0 km
B = 2 0 km

Taipei		Taipei Bridge
Above sea-level 8 m		Above sea-level 5 m
Height of Antenna above ground level 17 m	2.2 km	Height of Antenna above ground-level 10 m
E 121° 30′ 49″		E 121° 30′ 17″
N 25° 02′ 52″		N 25° 03′ 49″

Profile Map (k=4/3)

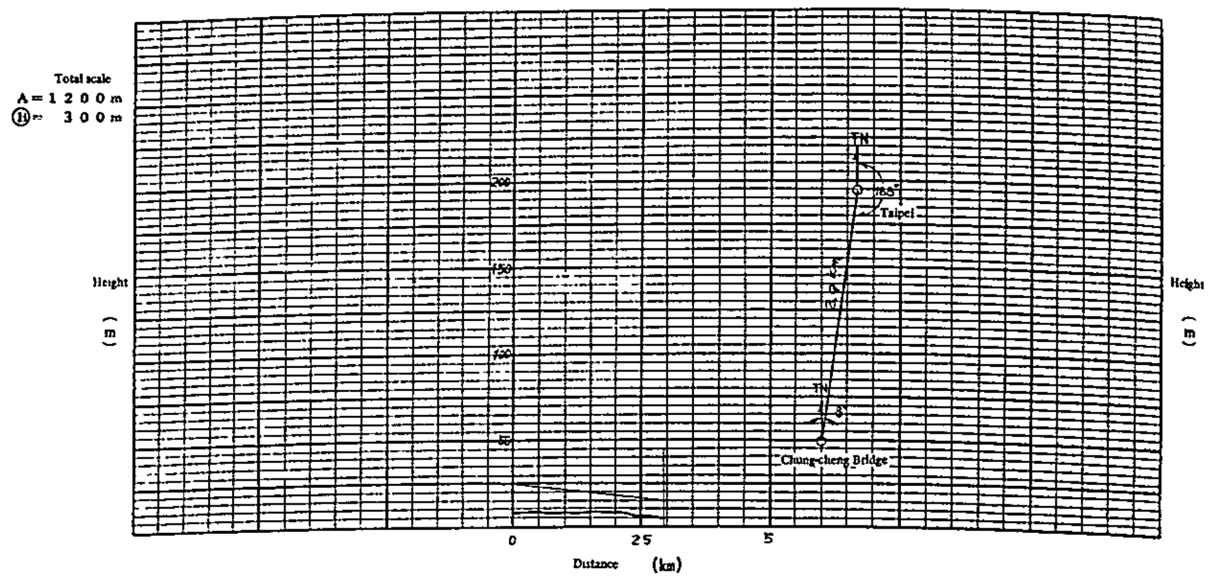


Total scale
A = 4 0 km
B = 2 0 km

Taipei		Chung-shang Bridge
Above sea-level 8 m		Above sea-level 5 m
Height of Antenna above ground-level 17 m	2.9 km	Height of Antenna above ground-level 10 m
E 121° 30′ 49″		E 121° 31′ 01″
N 25° 02′ 52″		N 25° 04′ 21″

Profile Map (k=4/3)

Scale used B

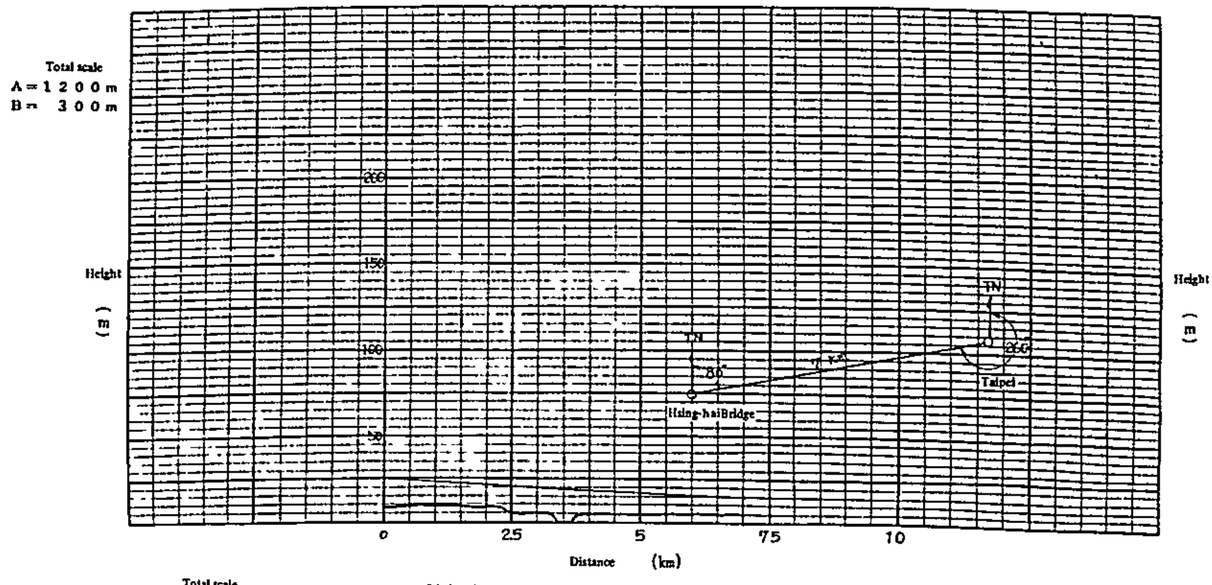


Total scale
A = 4 0 km
(B) = 2 0 km

Taipei		Chung-Cheng Bridge
Above sea-level 8 m		Above sea-level 5 m
Height of Antenna above ground-level 17 m	2.9 km	Height of Antenna above ground-level 10 m
E 121° 30′ 49″		E 121° 30′ 35″
N 25° 02′ 52″		N 25° 01′ 17″

Profile Map (k=4/3)

Scale used B

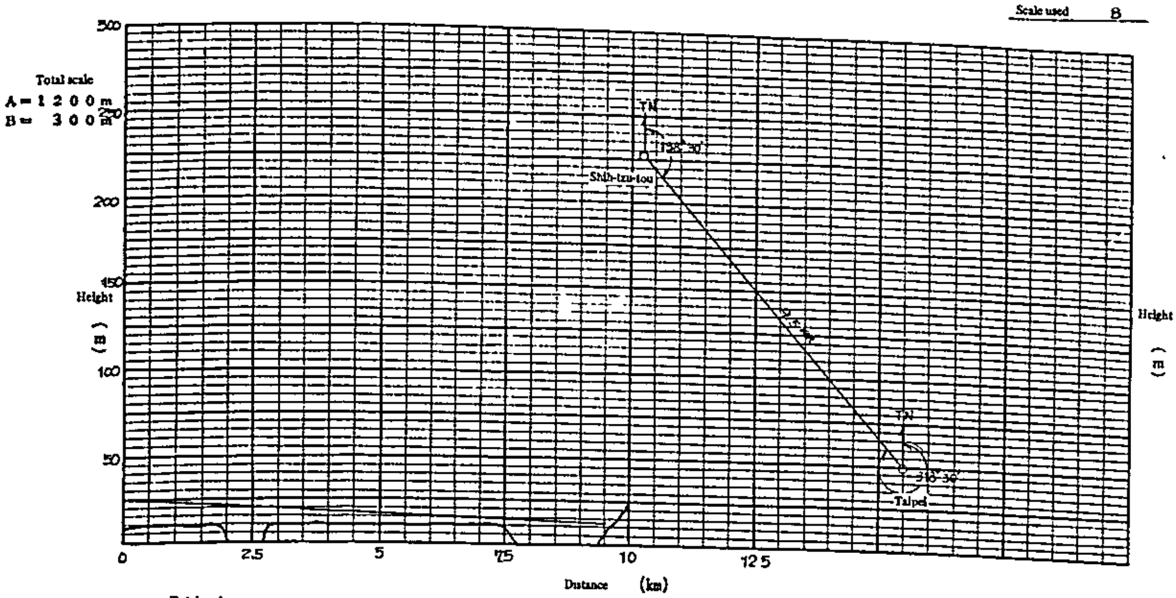


Total scale
A = 4 0 km
(B) = 2 0 km

Taipei		Hsing-hai Bridge
Above sea-level 8 m		Above sea-level 5 m
Height of Antenna above ground-level 17 m	7.0 km	Height of Antenna above ground-level 10 m
E 121° 30′ 49″		E 121° 26′ 40″
N 25° 02′ 52″		N 25° 02′ 07″

Profile Map (k=4/3)

Scale used B

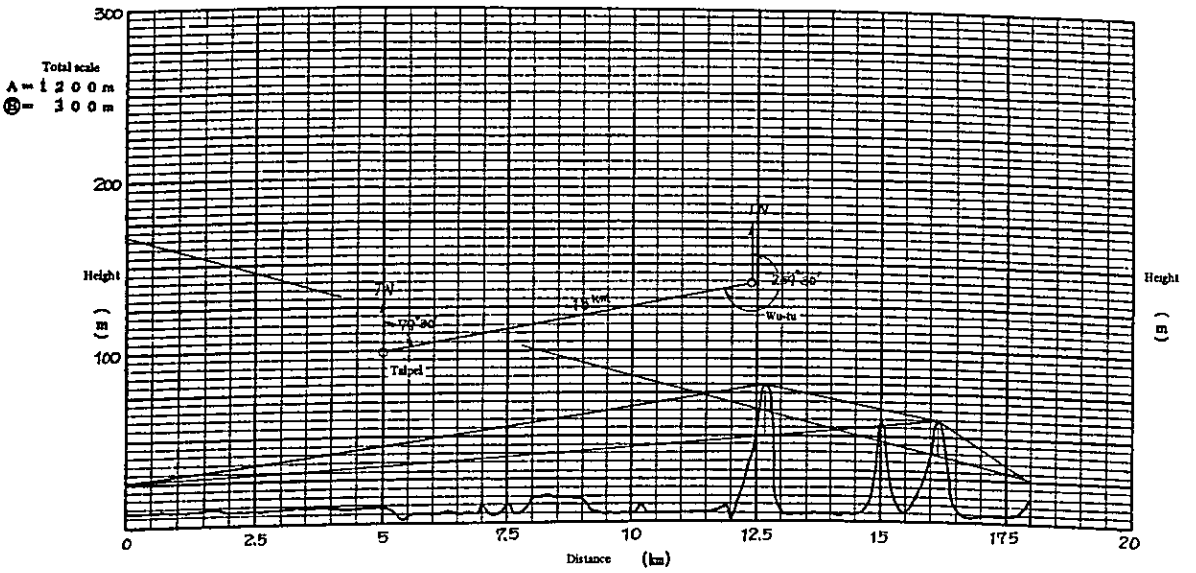


Total scale
A = 40km
Ⓑ = 20km

Taipei		Shih-tzu-tou
Above sea-level 8 m		Above sea-level 5 m
Height of Antenna above ground-level 17 m	9.5 km	Height of Antenna above ground-level 10 m
E 121° 30' 49"		E 121° 26' 59"
N 25° 02' 52"		N 25° 06' 47"

Profile Map (k=4/3)

Scale used B



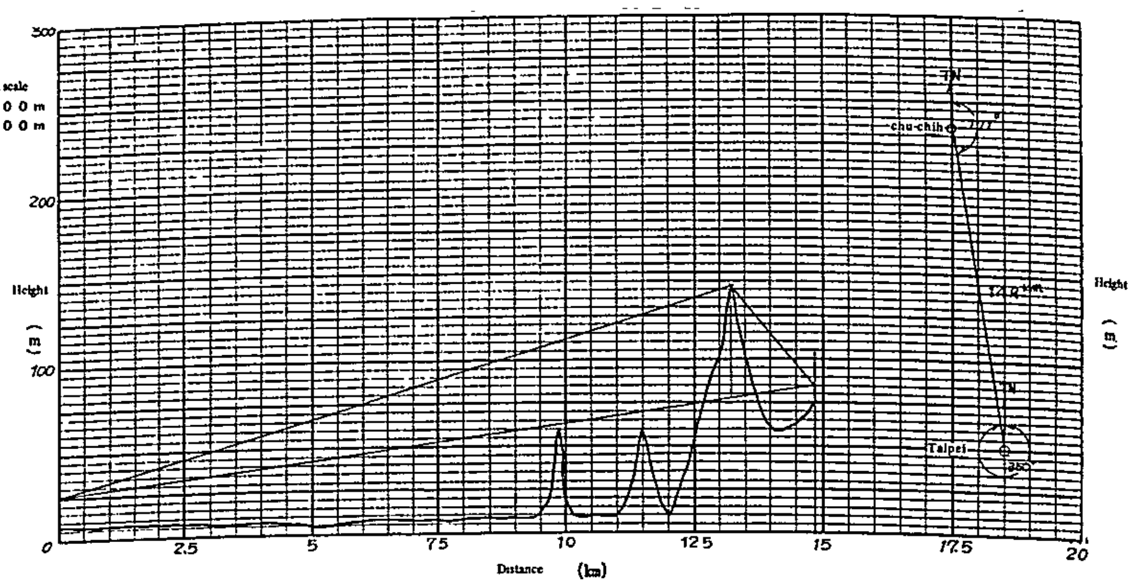
Total scale
A = 40km
Ⓑ = 20km

Taipei		Wu-tu
Above sea-level 8 m		Above sea-level 16 m
Height of Antenna above ground-level 17 m	18 km	Height of Antenna above ground-level 10 m
E 121° 31'		E 121° 41' 19"
N 25° 02'		N 24° 04' 51"

Profile Map (k=4/3)

Scale used B

Total scale
A = 1 2 0 0 m
Ⓑ = 3 0 0 m



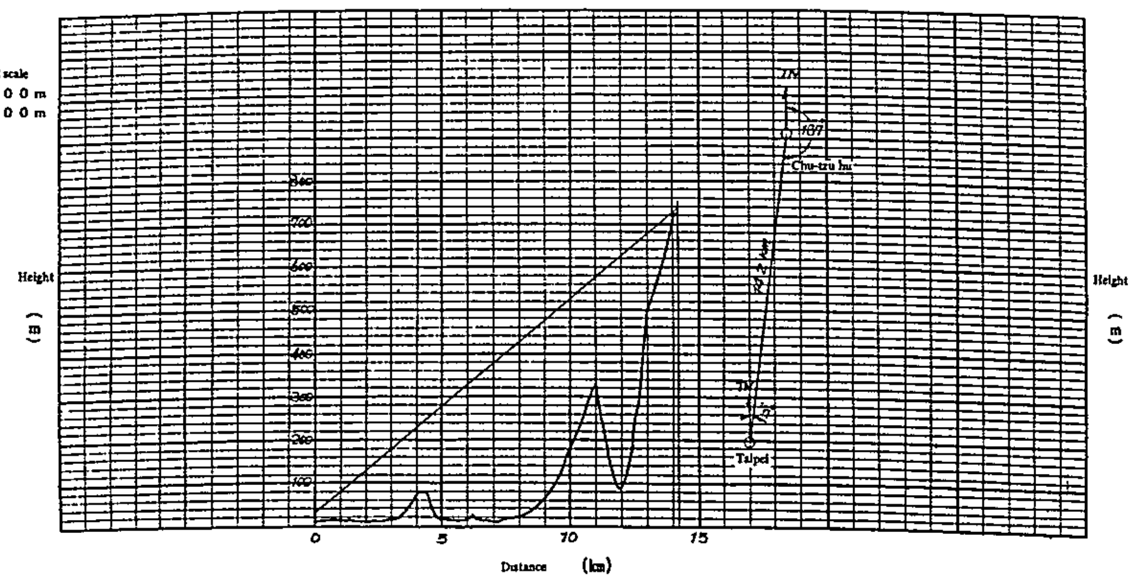
Total scale
A = 4 0 km
Ⓑ = 2 0 km

Taipei		Chu-chih
Above sea-level 8 m	14.9 km	Above sea-level 7.5 m
Height of Antenna above ground-level 17 m		Height of Antenna above ground-level 10 m
E 121° 31′		E 121° 32′ 22″
N 25° 02′		N 24° 55′ 09″

Profile Map (k=4/3)

Scale used A

Total scale
A = 1 2 0 0 m
B = 3 0 0 m



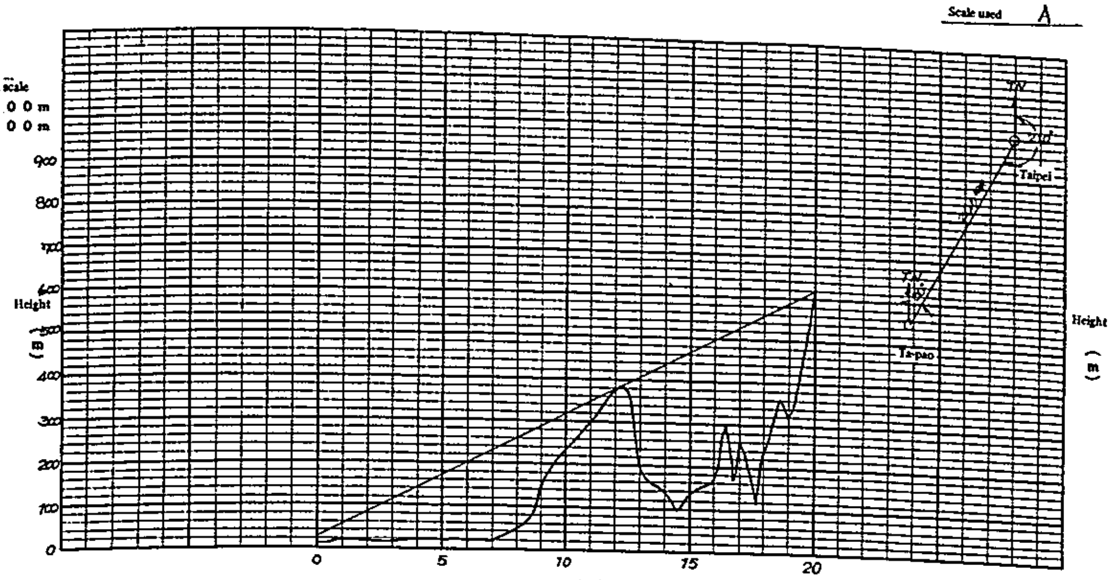
Total scale
Ⓐ = 4 0 km
B = 2 0 km

Taipei		Chu-tzu-hu
Above sea-level 8 m	14.2 km	Above sea-level 717 m
Height of Antenna above ground-level 17 m		Height of Antenna above ground-level 10 m
E 121° 30′ 49″		E 121° 31′ 42″
N. 25° 02′ 52″		N 25° 14′ 21″

Profile Map (k=4/3)

Scale used A

Total scale
Ⓐ= 1 2 0 0 m
B = 3 0 0 m



Total scale
Ⓐ= 4 0 km
B = 2 0 km

Taipei

Above sea-level 8 m
Height of Antenna above ground-level 17 m

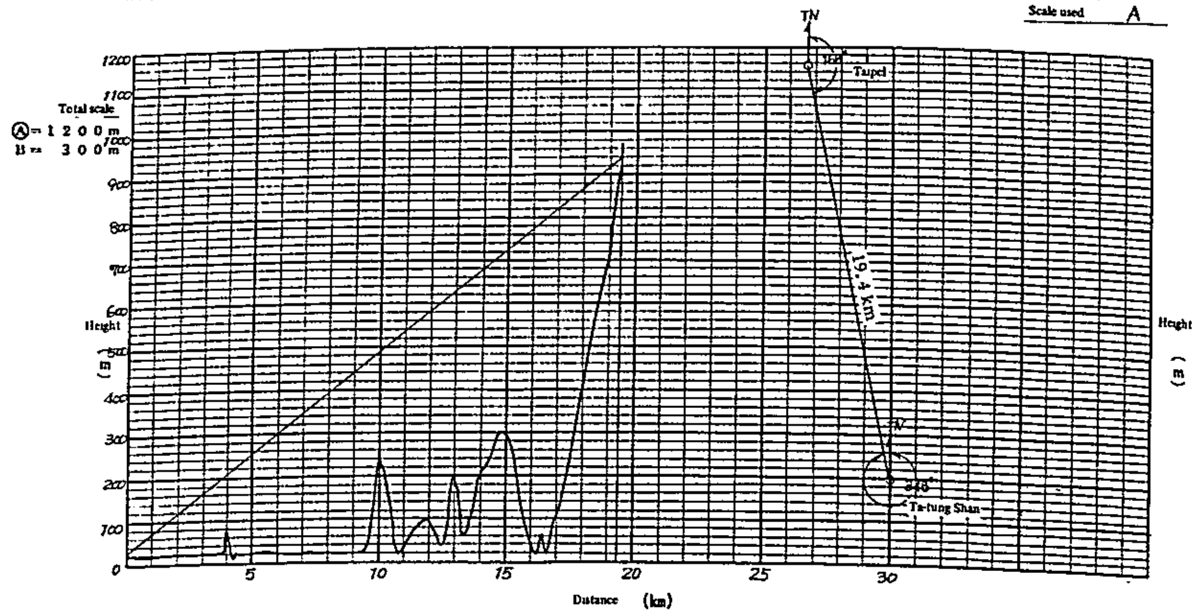
20 0 km

Ta-pao

Above sea-level 600 m
Height of Antenna above ground-level m
E 121° 24' 59"
N 24° 66' 01"

Profile Map (k=4/3)

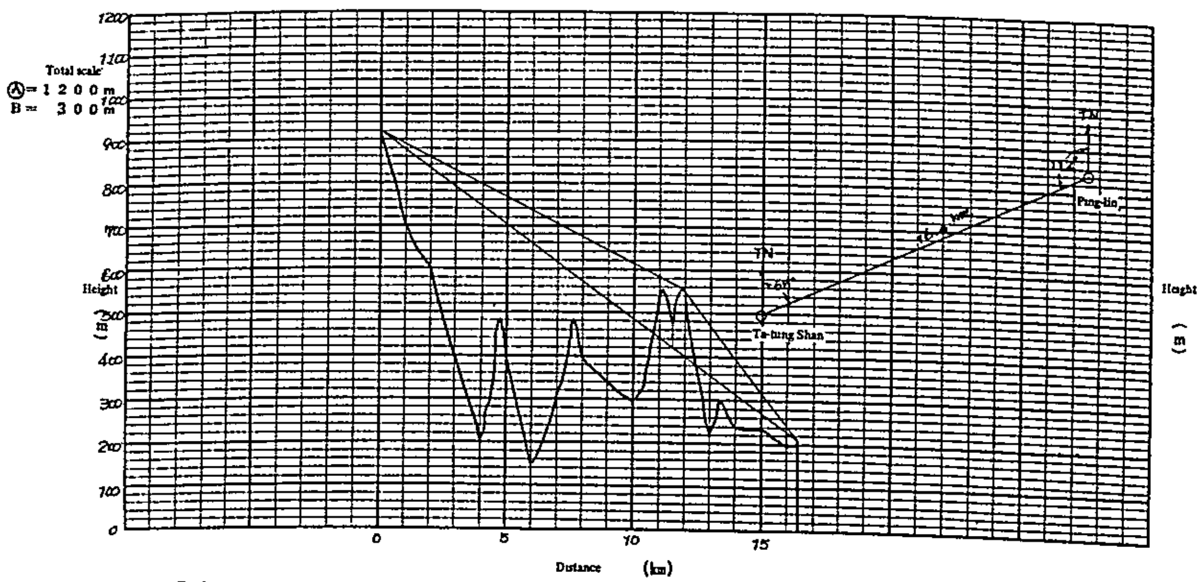
Scale used A



Taipei		Ta-tung Shan
Above sea-level 8 m		Above sea-level 916 m
Height of Antenna above ground-level 17 m	19.4 km	Height of Antenna above ground-level 10 m
E 121° 31′		E 121° 42′ 29″
N 25° 02′		N 24° 56′ 02″

Profile Map (k=4/3)

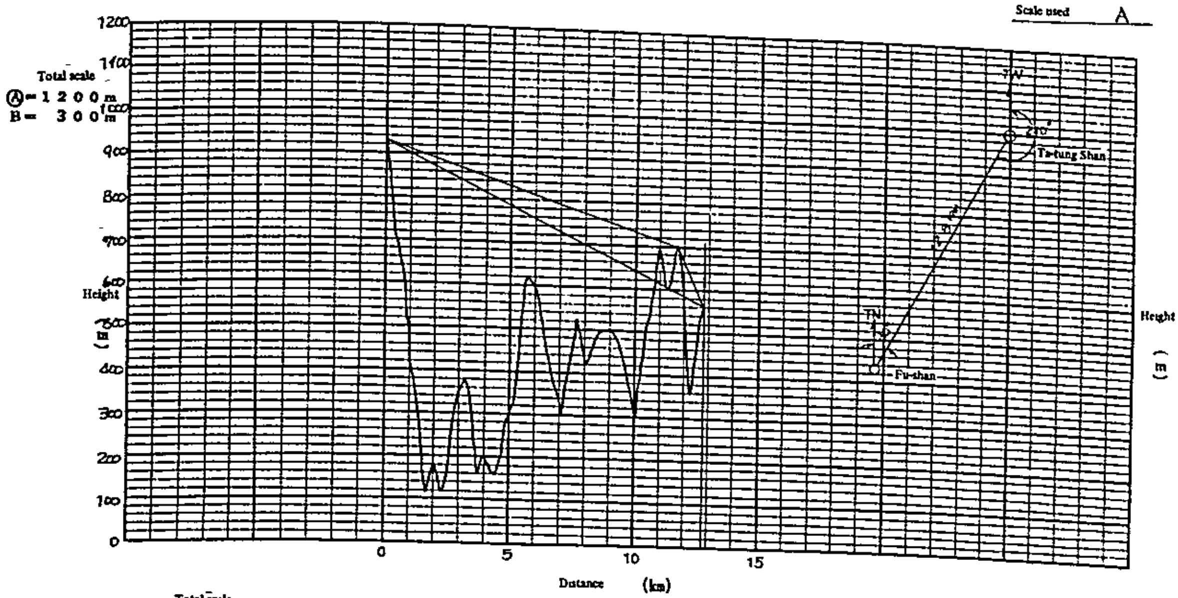
Scale used Ⓐ



Ta-tung Shan		Ping-lin
Above sea-level 916 m		Above sea-level 200 m
Height of Antenna above ground-level m	16.4 km	Height of Antenna above ground-level m
E 121° 33′ 09″		E 121° 42′ 29″
N 24° 52′ 40″		N 24° 56′ 02″

Profile Map (k=4/3)

Scale used A



Total scale
Ⓐ= 4 0 km
B= 2 0 km

Ta-tung Shan

Above sea-level 916 m

Height of Antenna above ground-level 10 m

12.8 km

Fu-shan

Above sea-level 580 m

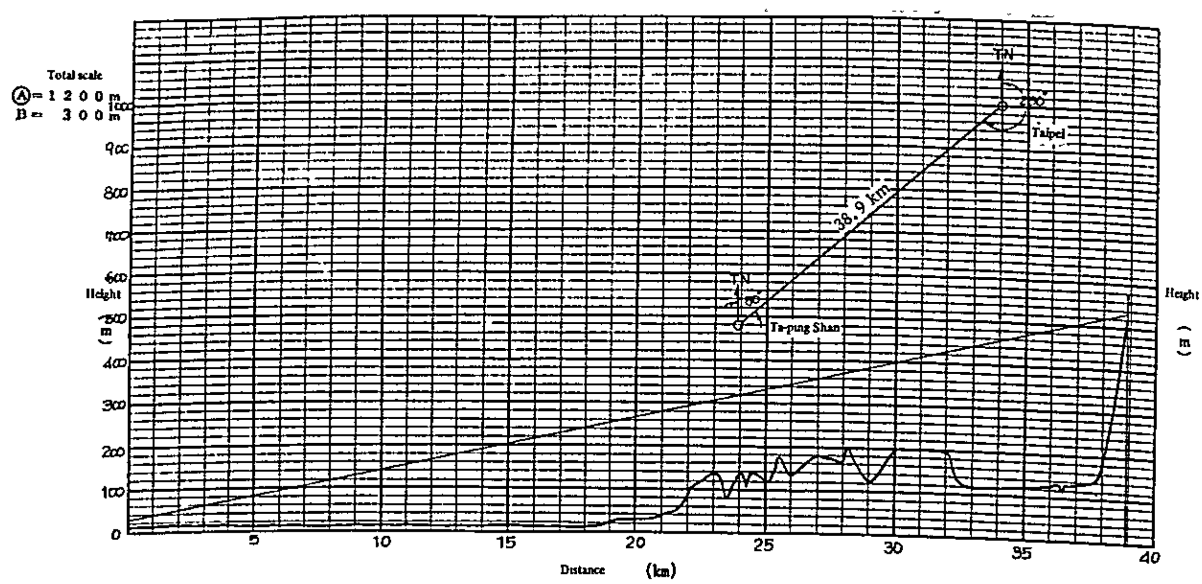
Height of Antenna above ground-level 10 m

E 121° 29' 31"

N 24° 46' 44"

Profile Map (k=4/3)

Scale used A



Taipei

Above sea-level 8 m
Height of Antenna above ground-level 17 m

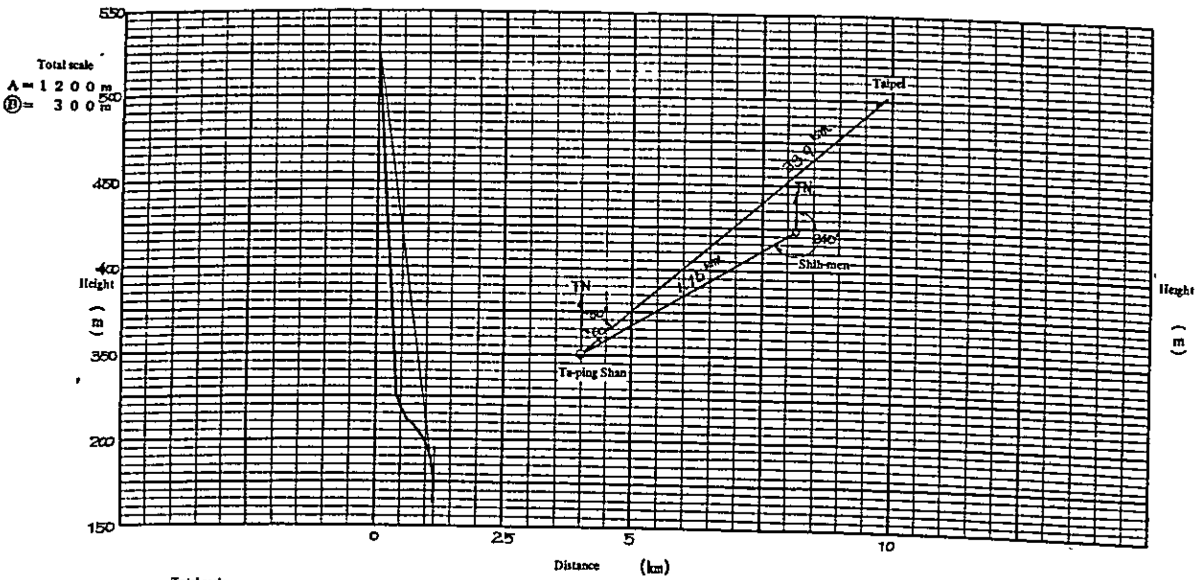
38.9 km

Ta-ping Shan

Above sea-level 520 m
Height of Antenna above ground-level 10 m
E 121° 13' 40"
N 24° 48' 49"

Profile Map (k=4/3)

Scale used B



Ta-ping Shan

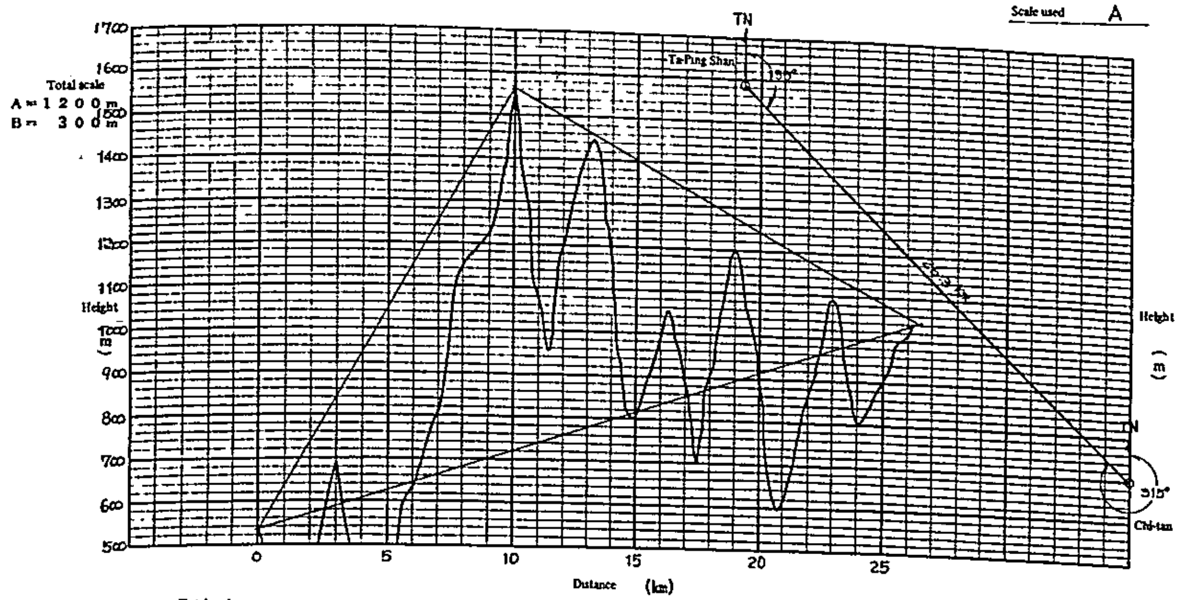
Above sea-level 520 m
Height of Antenna above ground-level 10 m
E 121° 13' 40"
N 24° 48' 49"

1.15 km

Shih-men Sub-dam

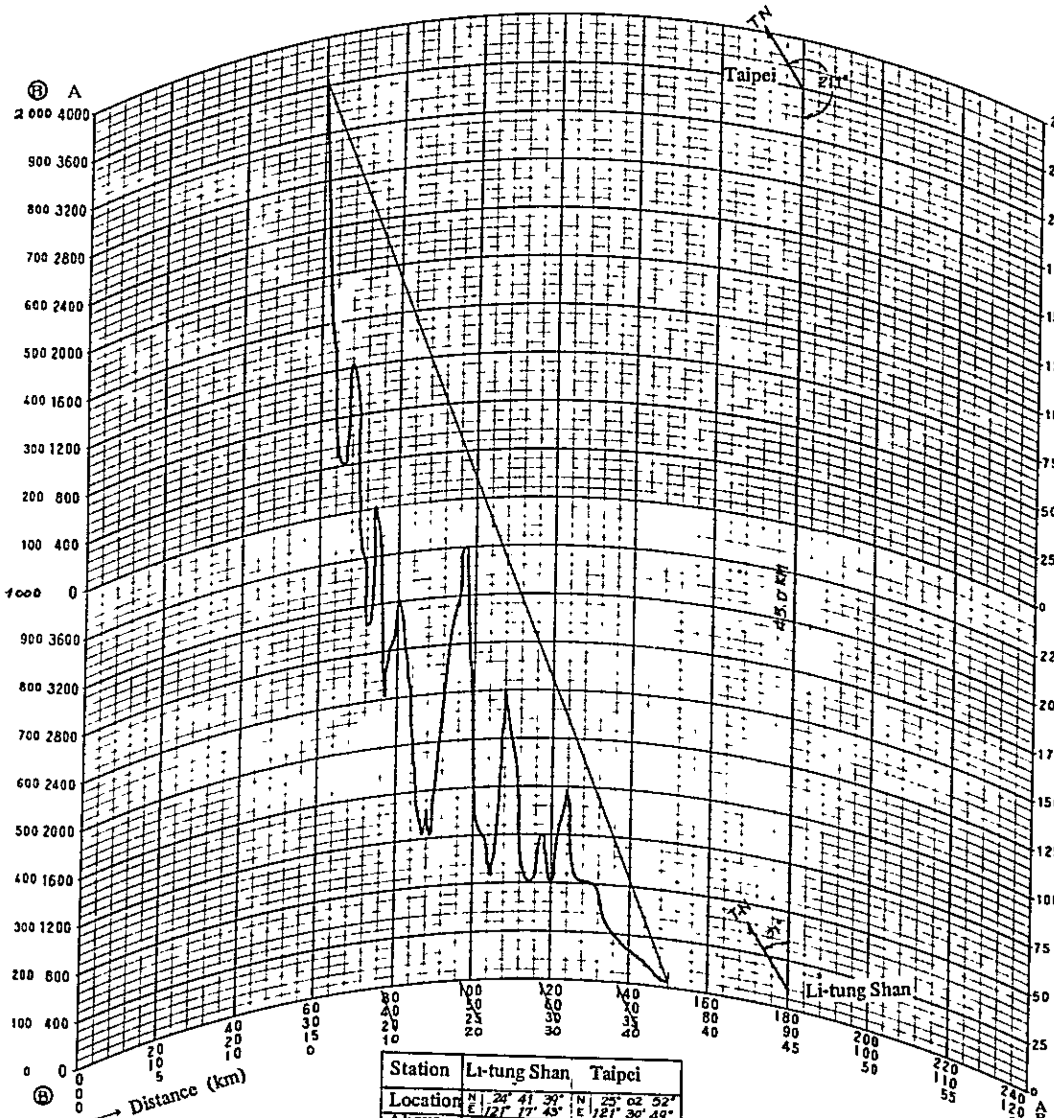
Above sea-level 160 m
Height of Antenna above ground-level 10 m
E 121° 14' 10"
N 24° 49' 09"

Profile Map (k=4/3)



Ta-ping Shan		Chi-tan
Above sea-level 520 m	26.3 km	Above sea-level 1040 m
Height of Antenna above ground-level 10 m		Height of Antenna above ground-level 10 m
		E 121° 24' 38"
		N 24° 38' 47"

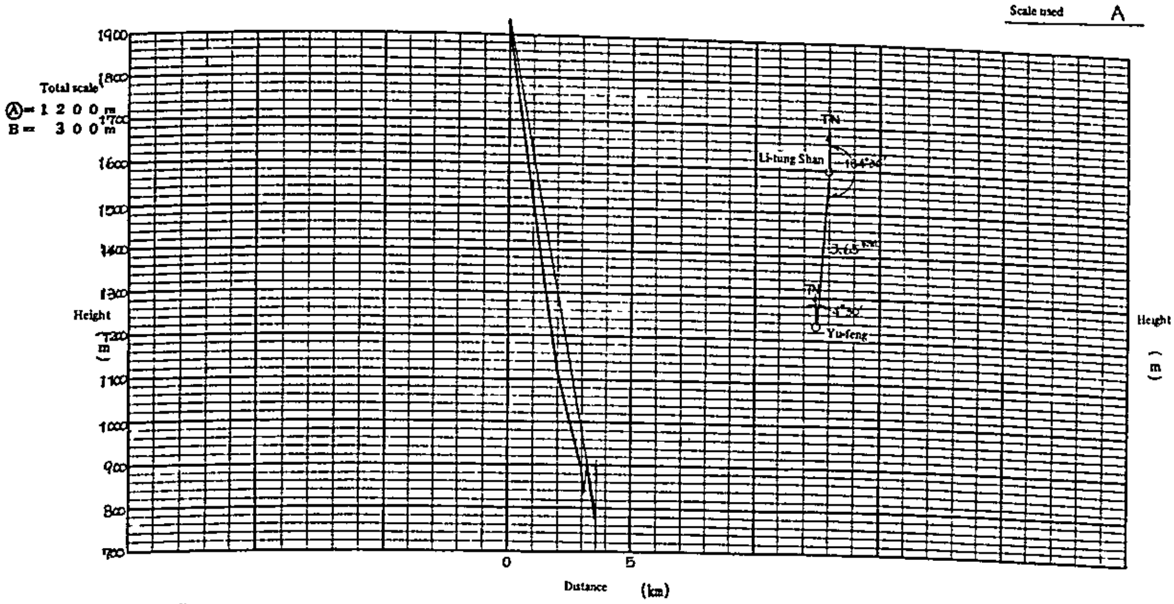
Profile Map



Station	Li-tung Shan	Taipei
Location	N 24° 41′ 39″ E 121° 17′ 43″	N 25° 02′ 52″ E 121° 30′ 49″
Above sea-level	1920 m	17 m
Distance	45 km	

Profile Map (k=4/3)

Scale used A

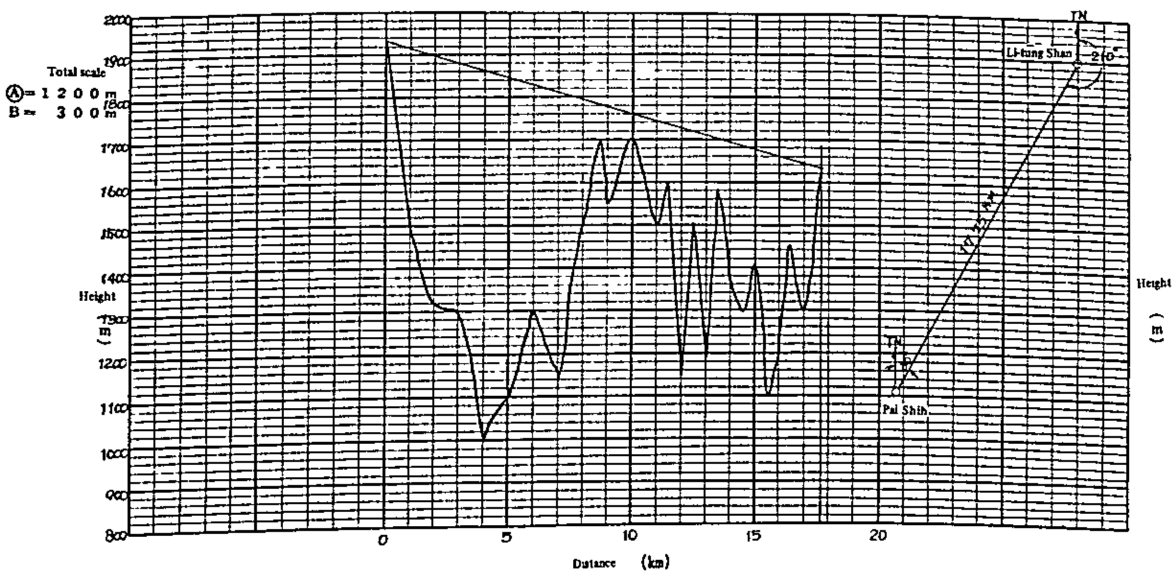


Total scale
Ⓐ= 4 0 km
B = 2 0 km

Li-tung Shan		Yu-feng
Above sea-level 1920 m	3.65 km	Above sea-level 780 m
Height of Antenna above ground-level 10 m		Height of Antenna above ground-level 10 m
		E 121° 17' 32"
		N 24° 39' 41"

Profile Map (k=4/3)

Scale used A

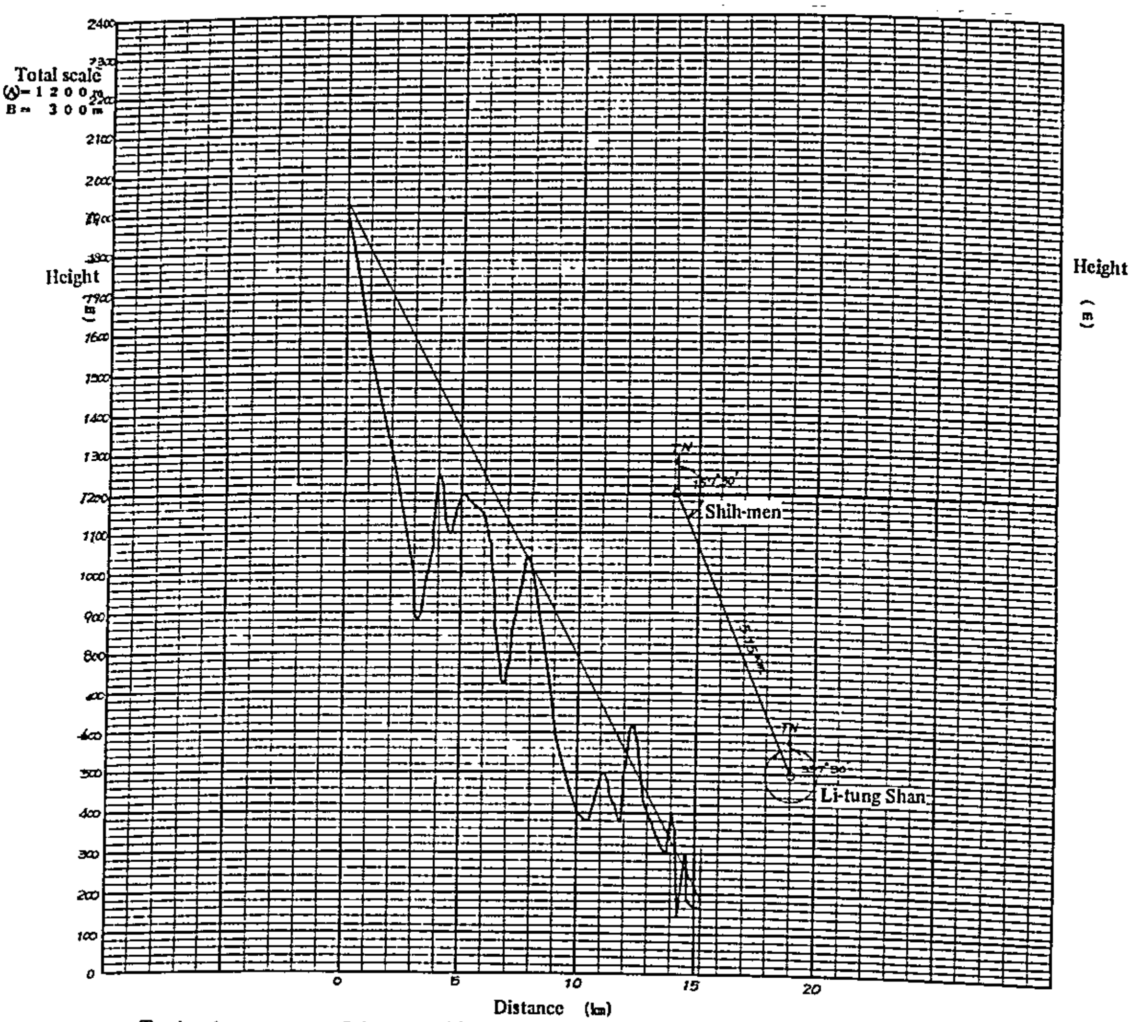


Total scale
Ⓐ= 4 0 km
B = 2 0 km

Li-tung Shan		Pai Shih 工
Above sea-level 1920 m	17.75 km	Above sea-level 1620 m
Height of Antenna above ground-level 10 m		Height of Antenna above ground-level 10 m
E 121° 17' 43"		E 121° 12' 48"
N 24° 41' 39"		N 24° 33' 16"

Profile Map (k=4/3)

Scale used A



Total scale
Ⓐ= 4 0 km
B = 2 0 km

Li-tung Shan

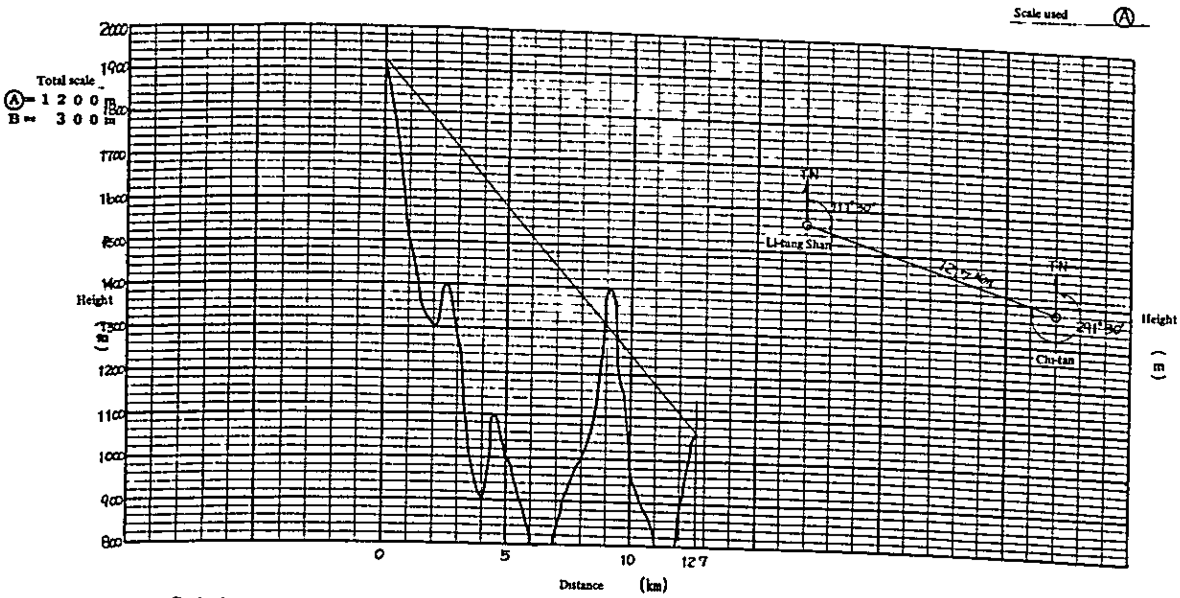
Above sea-level 1913 m
Height of Antenna above ground-level 10 m

15 15 km

Shih-men Sub-dam

Above sea-level 160 m
Height of Antenna above ground-level 10 m
E 121° 14' 10"
N 24° 49' 09"

Profile Map (k= 4/3)



Total scale
Ⓐ = 4 0 km
B = 2 0 km

Li-tung Shan		Chi-tan
Above sea-level 1920 m		Above sea-level 1050 m
Height of Antenna above ground-level 10 m	12.7 km	Height of Antenna above ground-level 10 m
		E 121° 24' 38"
		N 24° 38' 47"

Appendix 8

SPECIFICATIONS FOR STANDARDIZED TELEMETER AND WARNING SYSTEMS BY MINISTRY OF CONSTRUCTION, JAPAN

Specification for Telemeter and Warning System

Specification No. 11 for Standard Telemeter and Warning System
(Set forth on July 1st, 1964)

Application:

This Specification applies to the telemeter system for measurement on rain-fall amount and water-level and the discharge-warning system, to be installed by the Ministry of Construction. As for special functions and ancilliary units, not specified herein, are specified in the separate specification. But, the specification shall not supersede with those requirements as specified in the standard specification.

(Telemeter system):

The system for calling the observation stations from the master station shall be classified into following three kinds.

Kinds of call system:

(Automatic calling system)

With this calling system, the master station calls up all observation stations one by one in series according to the present time and order, then the function of the called observation stations start automatically and transmit their observation data in sequence.

(Manual calling system)

This is a calling system which starts manually at any time, and manually all observation stations are called one by one in a present order.

(Manual individual calling system)

This is a calling system which is manually controlled and selected any one of the observation stations.

The automatic calling system shall have an operational priority against the other two call systems under the normal condition. This however, does not apply to the calling systems in an emergency case and the priority control of the automatic calling system may be released.

Observation time interval:

In the case of automatic calling system, a time intervals of 3 steps of every 12 hours, 3 hours, 1 hour as standard and one of every 30, 15 or 10 minutes are selected optionally.

No. of times of recalling:

In the case where the observation station fails to respond or responds with error codes, the master station will automatically recall the station. This recalling can be made twice and if the observation station fail to respond or responds with error codes, the master station will send a visual and audible alarms to the station and then proceed to the next operation.

Recording system:

The master station shall prepare a page print type recorder by means of a motor-driven typewriter. The format shall be such that the observation time is printed on the left side of the recording paper and the observation data shall be printed in the column which are pre-designated to each observation station.

(An example of printed record is shown in the separate paper) It should be noted that there is no restriction to the recording system in a monitoring station.

(Discharge - Warning System):

The system for calling the discharge-warning station from the control station shall be only the manual individual call system.

Calling system:

(Manual individual call system)

By manual start, the master station calls one warning station which is selected at will.

Function of warning station:

The warning station shall perform the following three functions under control of the master station:

(Warning)

The warning station shall blow its siren in the pre-determined form. If the siren fails to blow due to mechanism, it will made an artificial sound simulated to the siren through its loudspeaker as well as to inform the control station of a siren failure.

(Check)

The warning station can check its siren for normal operation without blowing the siren.

(Broadcasting)

The warning station can start its loudspeaker to broadcast the voice anouncement transmitted from the master station and can stop the amplifier after broadcasting.

Check of warning station operation:

The master station can check the warning operations of its associated warning stations as follows:

(Warning)

When a warning station sounds its siren to give "a warning" under control of the master station, the sound of blowing siren are transmitted back to the master station for confirmation and it is checked by speaker in the master station. The warning station transmits back the sound of siren for approx. 10 sec.

(Check)

When the warning station performs "a check" under control of the master station, the former station shall also check the final power switch terminals for presence of the specified voltage and shall transmits the result of said check back to the latter station for confirmation.

Mode of siren blowing:

The mode of blowing of siren at a warning station shall be one mode as a rule. But, the station may be operated with a maximum of three modes of blowing can be designated in the case of operational circumstances.

The mode of the artificial sounding given through the loudspeaker shall conform to that specified above for the siren.

Display of special information:

Where the master station requires special display such as power supply voltage and normal water level in addition to ordinary data, it shall have the observation station transmit one special information together with other data during its observation time and shall display the information in a pre-determined manner.

Control of relay station operation:

Where the radio repeater is used in the transmission system, its start and stop shall be controlled from the master, warning or observation station.

But, the warning and observation stations are provided with the above control function upon demand.

(Signal system):

Transmitting of calling signal:

The calling signals for the observation and warning stations are sent in series using the standard reed selector frequency. The frequencies are classified as follows:

A B C

- C — Discharge-Warning Control Signal (No. 3 Signal)
- B — Station Calling Signal (No. 2 Signal)
- A — Group Calling Signal (No. 1 Signal)

The calling signal for the observation station is a series transmission of frequencies A and B.

The calling signal for the warning station is a series transmission of three frequencies A, B and C.

Group calling signal:

The group calling signal shall be 15 frequencies (A1 - A15) as shown in the table below. These signal frequencies shall be allocated to the telemeter from the lowest to higher frequency, and discharge-warning system shall be from the highest to lower. In case where telemeter and discharge-warning systems are installed as a combined system, some of the group calling signal frequencies may be used commonly on both systems.

Allocation of this group signal frequencies to the telemeter and discharge-warning systems shall be performed by the Ministry of Construction, since it concerns with the allocation of radio frequencies.

(Group Designation Signal Frequencies)

A1	487.5Hz	A6	562.5Hz	A11	637.5Hz
A2	502.5Hz	A7	577.5Hz	A12	652.5Hz
A3	517.5Hz	A8	592.5Hz	A13	667.5Hz
A4	532.5Hz	A9	607.5Hz	A14	682.5Hz
A5	547.5Hz	A10	622.5Hz	A15	697.5Hz

Station calling signal

The station calling signal shall be 5 frequencies (B1-B5) as shown in the table below. These 5 frequencies shall be allocated to the observation and warning stations separately.

It should be noted that frequencies B6 and B7 shall be used for the control signal frequencies to the relay station and, therefore, shall not be allocated as station calling signal frequencies.

(Station Calling Signal Frequencies)

B1	412.5Hz	B6	382.5Hz	Starting repeater
B2	427.5Hz	B7	397.5Hz	Stopping repeater
B3	442.5Hz			
B4	457.5Hz			
B5	472.5Hz			

Control signal of warning:

The control signal to the warning station shall be 10 frequencies (C1 - C10) as shown in the table below. These 10 frequencies C1 - C10 shall be allocated to the operation items of the warning station.

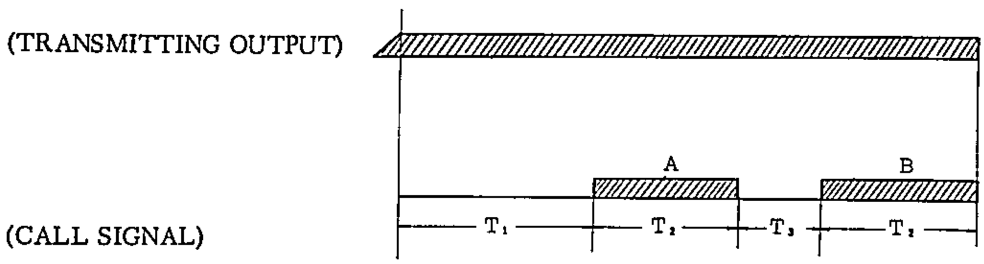
(Warning Control Signal Frequencies)

C1	712.5Hz	Blowing siren (Model 1)
C2	727.5Hz	Blowing siren (Model 2)
C3	742.5Hz	Blowing siren (Model 3)
C4	757.5Hz	Checking siren
C5	772.5Hz	Starting warning broadcasting
C6	787.5Hz	Stopping warning broadcasting
C7	802.5Hz	
C8	817.5Hz	
C9	832.5Hz	
C10	847.5Hz	

Transmitting time of call (control) signal:

The transmitting time of the call signal shall be as follows:

Composition of Call Control Signal for Observation and Relay Station

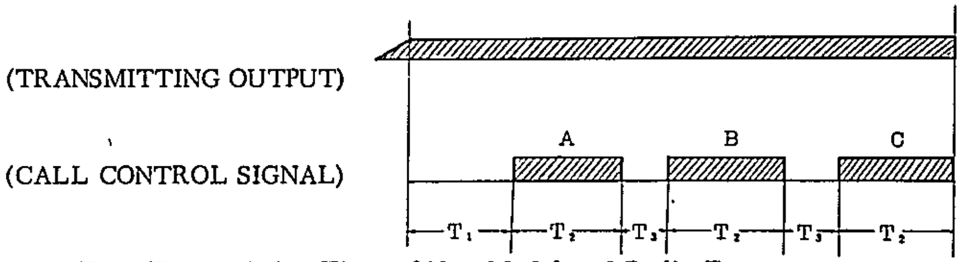


T_1 : Transmitting Time of Non-Modulated Radio Frequency: More Than 600 ms

T_2 : Signal Transmitting Time: 600 ± 100 ms

T_3 : Signalling Interval: 50 ± 25 ms

Composition of Warning Station Call Control Signal



T_1 : Transmitting Time of Non-Modulated Radio Frequency: More Than 600 ms

T_2 : Signal Transmitting Time: 600 $\pm$ 100 ms

T_3 : Signalling Interval: 50 $\pm$ 25 ms

Transmitting of control signal for relay station:

In case where the transmission system involves the radio relay station, the master station shall automatically send the relay-station-starting signal prior to starting of call and control operations and the relay-station-stopping signal upon completion of its operation.

The station shall employ individual indication signal frequencies B6 and B7 for the relay station and send them with the prefixed group signal.

(Response System):

Kinds and sequence of informations:

The kinds and sequence of the informations which should be transmitted by the observation station shall be as listed below. In this case, however, the observation station shall not omit its station number, although the number is not required for recording at the master station.

(1) Observation value
(2) Station number
(3) Special information

The observation value shall be the maximum of four digits (0000-9999) in binary-coded decimal system. If this is not necessary, the value may be given as three digits in binary-coded decimal system.

The station number shall be the maximum of two digits in binary-coded decimal system.

The special information shall be transmitted using one kind of signal when the master station requires to display a power supply voltage or warning of water-level. But it shall be omitted where there is no need of such special information.

Coding of information:

The observation value and station number shall be coded on the binary-coded decimal system with one parity bit suffixed to the binary digits.

The coincidence of decimal values to binary-coded decimals is as shown in the Table below.

Table of Decimal Values VS. Binary-code Decimals

DECIMALS	BINARY-CODED DECIMALS	DIGITAL CODE
0	0	00001
1	1	00010
2	10	00100
3	11	00111
4	100	01000
5	101	01011
6	110	01101
7	111	01110
8	1000	10000
9	1001	10011

The last digit of each information code is the parity bit, the total number of degit 1 shall be the odd number.

Transmission system of code:

The information code shall be transmitted on the FS type of transmission system with digits 1 and 0 converted to a dash and a dot respectively using a sub-carrier.

The sub-carrier shall be the carrier telegraph channel frequency of 2, 635 Hz. But, when it becomes necessary to allocate a frequency other than 2, 635 Hz because of radio interference and others, the frequencies listed in the table below shall be used in the sequence given.

(Sequence for Use of Sub-Carrier)

SEQUENCE	SUB-CARRIER
1	2 6 3 5 Hz
2	2 4 6 5 Hz
3	2 2 9 5 Hz
4	2 1 2 5 Hz
5	1 9 5 5 Hz

The width of frequency deviation in each channel shall be ±35 Hz and its tolerance shall be less than ±6 Hz.

The direction of the deviation shall be (+) for the mark and (-) for the space. The durations of the mark and space shall be as follows:

Dash mark (bit 1)	120 ms ± 20%
Dot mark (bit 0)	40 ms ± 20%
Inter-bit space	40 ms ± 20%
Inter-digit space	40 ms ± 20%

The information code shall be delivered from the observation station to the the master station with possibly short delay time provided immediately after reception of calling signal.

Example of Page Type Printing

DATE	TIME	NAME OF OBSERVATION STATION			
		STATION 00	STATION 000	STATION XX	STATION XXX
05 12	0900	235	651	211	407
	0921	251			
	1632	263	679	250	437
05 13	0900	264	685	250	437

Appendix 9

SPECIFICATIONS FOR EQUIPMENTS IN RAIN GAUGE AND WATER
STAGE TELEMETERING SYSTEMS FOR THE TAN-SHUI RIVER BASIN

1. General Provisions

1.1 This specification shall be applied to the rain gauge and water stage telemetering system intended for flood control perpose in the Tan-shui River Basin, and be in conformity to the items mentioned hereunder as well as durable for the use in abnormal environment .

1.2 The system shall conform to relevant laws and regulations.

1.3 Any item not specified in the specifications or in question shall be discussed and determined by the purchaser and the contractor.

1.4 Prior to manufacture of the system equipment, design drawings shall be submitted for approval.

1.5 On completion of manufacture, the equipment shall be subject to the final inspection of the purchaser.

1.6 In case any trouble occurs within one year from the completion of installation due to the manufacturer's poor workmanship and/or the inferior perts, the munufacturer shall repair or replace with new parts free of charge.

2. General Description

2.1 Circuit Systems

The circuit system of the telemetering system shall satisfy the requirements set forth in the attached plan for the rain gauge and water stage telemetering system for flood forecasting in the Tan-shui River Basin, propposed plan of telecommunication systems in the Tan-shui River Basin.

2.2 Composition of Equipment

Composition of the system equipment shall be as follows, and reference should be made to the attached table of composition:

(1) Control Station (Taipei Station)---antenna system, radio equipment, telemetry terminal equipment, control desk, graphic panel, power supply unit (rainfall measuring unit), spare parts and accessories.

(2) Radio Relay Station (Mt. Ta-tung Station) (Mt. Ta-ping Station, Mt. Li-tung Station)---antenna system, repeater equipment, power supply unit (telemetry equipment), (rainfall measuring unit), spare parts and accessories.

(3) Observation Station---antenna system, radio equipment and telemetry equipment rainfall or water stage measuring unit, spare parts and accessories.

2.3 Environmental Conditions

Environmental conditions for the system are as follows:

(1) The apparatuses to be installed outdoors shall operate normally at an ambient temperature of -10°C ~ +50°C and a relative humidity of 99%. The equipment must not be damaged at an instantaneous maximum wind velocity of 60m/sec.

(2) The apparatuses to be installed indoors shall satisfy the specifications at an ambient temperature of 0°C ~ +40°C and a relative humidity of 95%, and operate normally at an ambient temperature of -10°C ~ +50°C.

2.4 Power Supply

Power supply to be used for the system shall be as follows:

Control Station --- commercial power source (AC115V ± 10%, single phase 60 Hz

Relay Station & Observation Station --- battery floating charge system with solar cell

2.5 Working Conditions

(1) As for the control station, the observation shall be carried on during service interruption with a stand-by power supply, and the controlling clock shall operate normally even during a continuous 3-day interruption of service.

(2) As for observation station and relay station, observation shall be possible for at least once in every hour and be durable for 30 days without sunshine.

2.6 Composition of Observation Stations

Composition of observation stations of the system shall be as shown in the circuit system diagram. In consideration of possible requirements for increasing the number of stations in the future, it shall be easily possible to compose the system with 30 stations at maximum.

2.7 Structure

Structure of the system shall be as follows:

(1) The equipment shall be solid in construction and beautiful in appearance as well as durable for a long period use.

(2) Structure shall be simple for the convenience of operation use and maintenance of the system.

Equipment and part of stations having the same function shall be interchangeable so that any part can be easily replaced with a spare part in case of trouble. This must be applied also to common equipment and sections of stations of different function.

(3) The active circuit shall be designed in solid state, requiring small power.

(4) Each equipment shall be designed with due consideration to pervention of dust and moisture infiltration and damage by insects, birds and animals.

(5) Each major equipment shall be provided with electrostatic shield and connecting cables shall be provided with arresters for prevention of lightning where necessery.

3. Function & Capacity

3.1 Antenna System

(1) Antenna

(a) Model 3-element Yagi (folded) type
4-element Yagi (folded) type

(b) Frequency Each one antenna for transmission and reception within the frequency range of 54 - 68 MHz. Relay stations shall have frequencies antennes for exclusive uses for transmission and reception.

(c) Impedance 50 Ω

(d) Standing wave ratio below 1.5

(e) Gain 3-element Yagi type --- over 8 dB (isotropic gain)
4-element Yagi type --- over 9 dB (isotropic gain)

(f) Directivity characteristics

Bi-directional antennas shall be employed for the control station and relay stations, and the directivity characteristics shall satisfy the values in the attached circuit design.

(2) Feeders

(a) Type Radio-frequency coaxial cable

(b) Frequency According to the above-mentioned Item (1)

(c) Impedance 50 Ω

(d) Attenuation below 0.025 dB/m

(e) Dimensions To be equivalent to radio-frequency cable (AFZE50-4) manufactured by Dainichi-Nihon Densen Co., Ltd.

3.2 Radio Equipment

This equipment shall be capable of operating for transmission and reception of telemetry and telephone signals, satisfying the following functions:

(1) Transmitter

(a) Sending frequency shall be one within 54 - 68 MHz.

(b) Output power shall be 10W, and within ±20% under normal condition.

(c) Modulation shall be phase modulation.

(d) Frequency tolerance shall be below $\pm 10 \times 10^{-6}$

(e) Input required for 1 KHz 70% modulation shall be -4±3 dB.

(f) Frequency characteristics of modulation shall be as follows on the basis of 1 KHz 30% modulation:

0.3 KHz	- 10.5±3 dB
2 KHz	+ 4±3 dB
3 KHz	+ 6±3 dB
15	- 25 dB or less

(g) Modulation characteristics shall be linear at modulation frequency of 1 KHz up to phase deviation of 3.5 radians, and the deviation shall be less than ±2 dB.

(h) Maximum frequency deviation shall be ±5 KHz or less.

(i) Distortion factor shall be less than -20 dB at 1 KHz 70% modulation.

(j) Residual amplitude shall be less than 5% at 1KHz 100% modulation.

(k) Sending S/N shall be more than 40 dB at 1 KHz 70% modulation.

(l) Strength of spurious radiation shall be below 1 mW and lower than average power of carrier wave by more than 80 dB in the band and by more than 60 dB outside the band.

(m) Occupied frequency bandwidth shall be less than 16 KHz.

(n) Output circuit shall be unbalanced and capable of matching with a load with standing wave ratio of less than 2 when connected to a load through 50 Ω coaxial cable.

(2) Receiver

(a) Receiving frequency shall be one within 54 - 68 KHz.

(b) Receiving system shall be of super heterodyne.

(c) Frequency tolerance of local oscillator shall be less than $\pm 10 \times 10^{-6}$.

(d) Bandwidth shall be over 12 KHz at 6 dB down when measured by 20 dB noise quieting method.

(e) Selectivity shall be within 12.5 KHz from the center frequency at 70dB down when measured by 20dB noise quieting method.

(f) Spurious response shall be below -80 dB.

(g) Input power required for securing 20 dB noise supperssion shall be below 3 dB under normal condition.

(h) With an desired wave input power higher by 6 dB than input power necessary for suppressing noise to 20 dB, and by adding modulated disturbing wave apart more than 20 KHz from the receiving frequency, disturbing wave input power shall be over 80 dB when noise is suppressed to 20 dB.

(i) Without any desired wave and by adding disturbing waves of the same amplitude to produce inter- modulation which are apart 20 KHz and 40 KHz from the receiving frequency, disturbing wave input power to suppress noise at 20 dB shall be over 65 dB.

(j) The squelch circuit shall be adjustable for the input signals of 10-20 dB noise ation quieting. Singnals of more than 40 dB shall not be suppressed.

Input	S/N
0 dB	over 14 dB
10	24
30	40

(k) The squelch circuit shall be adjustable for the input signals of 10-20 dB noise ssion, quieting. Signals of more than 40 dB shall not be Suppressed.

(l) Modulation frequency characteristics shall be as follows on the basis of the 1 KHz 30% modulated wave:

0.3 KHz	$+6\pm3$ dB
2 KHz	-4 ± 3 dB
3 KHz	-8 ± 3 dB

(m) The maximum undistorted output of the audio-frequency output amplitude shall be a value which will not disturb usual telephone conversation.

(n) Input terminal shall be connected through 50 coaxial cable to the antenna, and a protective circuit must be installed against any excessive input.

(3) Repeater Equipment

(a) The repeater equipment has 2 pairs of redio unit: one in service is changed over to the other automatically in the event of failure and also can be changed over to the other periodically by the timer provided.

(b) It shall be capable of being monitored from the control station in it performance.

(c) Instructions for start and stop of transmitting working conditions shall be made in conformity to telemetry communication system.

(d) The repeater function is locked and unlocked by the instructions from the control station at the start and end of repeating operation.

(e) It shall not produce any mutual interference between transmission and reception.

Condition 1. Difference between sending frequency and receiving frequency --- about 1.5 MHz

Condition 2. Distance between antennas for transmission and reception --- about 20 meters to the right angle of directivity.

(4) Testing

The stand-by radio unit shall be automatically tested by means of the failure detection and switching circuit provided in the repeater equipment.

3.3 Telemetry Terminal Equipment, Telemetry Equipment

(a) Reference should be made to Telemetering transmission system in Chapter 7.
(b) Measured values shall be of three digits.
(c) Additional information shall indicate to the condition of the power supply.
(d) The telemetry terminal unit at Taipei Station shall be equipped with function of a test sham observation station for the purpose of testing the panels of rainfall observation station and other observation stations, as well as the function of supervisory control station.

3.4 Rainfall Measuring Unit

It shall be a tipping bucket rain gauge and details shall be as follows:

(a) Inlet diameter : 200 mm
(b) Tipping bucket : one tipping for every one milimeter rainfall
(c) Measuring range : 0 - 999 mm accumulated
(d) Accuracy : within ' 3%
(e) Recording Paper : 3 - month use
(f) The A/D converter shall indicate numerical figures which can be directly read.

3.5 Water stage Measuring Unit

It shall be a water level meter with float, and details shall be as follows:

(a) Measuring range : 0 - 999 cm
(b) Accuracy : within ±1 cm
(c) Automatic recorder : according to Model SUIKEN 62
(d) The A/D converter shall indicate numerical figures which can be directly read.

3.6 Control Desk

It shall be a control desk for the operation and supervision of the control station equipment, and details shall be as follows:

(1) Selection of observing method and observation station
(2) Indication of Station No., time, values and additional information under observation
(3) Recording by typewriter
(4) Display of the time (accuracy ± 5 sec./week)
(5) Supervision and inspection of working conditions of relay stations
(6) Telephone communications with other stations
(7) Indication of the operating conditions of the control station, and alarm for trouble

(8) Other necessary items

3.7 Graphic Panel

(a) Following data shall be automatically indicated on the indicator of the graphic panel:

(1) Measured data and time (in case of regular observation)
(2) Measured value of water stage
(3) Amount of hourly rainfall and accumulative rainfall by rain gauge stations
(4) When erroneous data are received, the panel holds previous values together with the sign indicating that the volues are previous ones.

(b) Automatic and manual display buttons being provided, optional values can be displayed by selecting the manual button.

(c) The graphic panel shall be self-supporting type; its shape and design shall be separately specified.

3.8 Power Supply Unit (for the use of relay stations and observation stations)

It shall be battery floating charging system with a solar cell, consisting of the followings:

(1) Solar cell (silicon type)
(2) Alkaline batteries (Ni-Cd pocket type, standard specification)
(3) Switchboard (with voltmeter, ammeter and protective circuit for load)
(4) Four electric capacity gauges, 2 for relay stations and another two for observation stations, shall be mounted to enable to measure electric capacity.

(5) As for calculation of capacity, reference should be made to the attached example for calculation of capacity for solar cell and other batteries .

3.9 Power Supply Unit (for the use of control station)

(1) As for power supply to the apparatuses, a protective circuit shall be installed to protect the apparatuses against abnormal rise of voltage.

(2) Power supply unit for the clock control section shall be a floating alkaline battery (Ni-Cd enclosed type, sintering system)

4. Spare Parts and Accessories

(a) Circuit diagram, instruction manual, test-sheet, 3 copies for each station
(b) Tools for maintenance, printed board connector, cords, one set for each station
(c) Tester or check meter, one unit for each station
(d) Terminating type power meter, one unit for each station
(e) Spare parts for telemetry equipment, telemetry terminal equipment and repeeter equipment, one sheet for each equipment for each station (One set for the control station and each relay station, and five sets for each observation station)

(f) Stand-by radio equipment, one unit for each type
(g) Consumable such as recording paper, etc., for one year use for each station
(h) Fuses, lamps, 300% of the working quantities for each station
(i) Portable engine-generator (power supply for maintenance work and charging), one unit for each relay station, and another for the observation stations
(j) Telemetry checker, one unit
(k) Synchroscope, one unit
(l) Wavemeter (frequency counter), one unit
(m) Tester for mobile radio equipment (Oscillator, level meter, signal generator, CM Power meter), one unit
(n) Spare parts box, one unit for each station
(o) Passing type Power meter, one unit

Appendix 9

Equipment Composition Table

Item	Standards	Unit	Quantity	Station Observation	Tai-pai (control) (rain)	Tai-pei Br. (water)	Chung-shan Br. Water	Chung-cheng Br. water	Hsin-hai Br. water	Shih-tzu-tou water	Chu-chih (water)	Wu-tu (rain)(water)	Chu-tzu-hu rain	Ta-Pao rain	Mt.Ta-tung (relay) rain	Ping-lin rain	Fu-shan (rain)	Mt.Li-tung relay	Shih-men (rain)(water)	Yu-feng rain	Pai-shih rain	Chi-tan (rain)	Mt.Ta-ping (relay)
Antennas	4-element Yagi		4		2		1	-			1	1											
"	3 element Yagi		21			1	1	1	1	1			1	1	4	1	1	4	1	1	1	1	
"	matching unit		5		1										2			2					
"	feeder		20		1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	
Radio equipment	60Mc 10W		20		1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	
Telemetry terminal equipment			1		1																		
Control Desk			1		1																		
Graphic panel			1		1																		
Telemetry equipment	for rain and water		2									1							1				
"	for rain or water		14			1	1	1	1	1	1		1	1	1	1	1			1	1	1	
Repeater equipment	(excluding radio unit)		2												1			1					
Rainfall measuring unit			11		1							1	1	1	1	1	1		1	1	1	1	
Water stage measuring equipment			8			1	1	1	1	1	1	1							1				
Power supply unit	for control station		1		1																		
"	for relay stations		2															1					
"	for observation stations		15			1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	
Spare parts, accessories	Refer to the other table		18		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Installation & adjustment	for observation stations		15			1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	
"	for relay stations		3												1			1					1
"	for the control station		1		1																		

NOTE: Stations marked with a circle for type of observation shall be constructed at the first stage of the project.

Appendix 9

Table 2

Spare parts and Accessories Composition Table

Item	Standards	Quantity	Station Observation	Tai-pei (control)(rain)	Tai-pei Br. (water)	Chung-shan Br water	Chung-cheng Br. water	Hsin-hai Br. water	Shih-tzu-tou water	Chu-chih (water)	Wu-tu (rain)(water)	Chu-tzu-hu rain	Ta-pao rain	Mt.Ta-tung (relay)rain	Ping-lin rain	Fu-shan (rain)	Mt.Li-tung relay	Shih-men (rain)(water)	Yu-feng rain	Pai-shih rain	Chi-tan (rain)	Mr.Ta-ping (relay)
Circuit diagram, instruction manual, test-sheet, tools for maintenance, connector, cords, fuses & lamps, recording papers, spare parts box, etc.	for the control station	1		1																		
	for relay stations	1															1					
	for relay-rain-rains station	1												1								
	for rain stations	7										1	1		1	1			1	1	1	
	for water-level stations	6			1	1	1	1	1	1												
	for rain-water stations	2									1							1				
Tester or check meter		18		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Spare Unit	for the control station	1		1																		
	for relay stations	1												1								
	for observation stations	5			1	1						1				1		1				
Terminating type Power meter		18		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Passing type Power meter		1		1																		
Portable generator		3												1			1	1				
Telemeter checker		1		1																		
Synchroscope		1		1																		
Frequency Counter		1		1																		
Mobile radio unit tester		1		1																		
Stand-by radio unit		2		1	1																	

Appendix 10

SPECIFICATIONS OF DATA PROCESSING EQUIPMENT

Appendix 10 Specifications of Data Processing Equipment

Type	SEIKŌ S301 desk computer*
Calculating Element	Integrated Circuit
Number of Figures	23 figures
Calculation time	addition and subtraction 30 ms multiplication and division 300 ms
Memories	6 core memories can be used as 12 memories
Printing facilities	
Type:	small line printer
Figures:	17 figures and 2 symbols (red and black)
Speed:	150 lines per minute
Method of Calculation	Floating decimals Fixed decimals system at the time of printing
Funtion keys	23 kinds
Programming	Up to 153 steps
Operation:	25 kinds (including 2 kinds jump messages) Constants can be inserted into the program IBM 80 colum cards can be used with built-in reader. The program can be printed out.
Room Temperature	$0^{o} - 40\ ^{o}C$
Power Source	100 – 115V 110W (50 – 60 Hz)
Size	B 42.4 x D48.7 x H17.7 cm
Weight	19.5 kg

* There are many kinds of large or small computers avairable for data processing. Among them we chose SEIKO S301 desk computer as it had a printing function. It had better use the same type when more than two computers are necessary, from the view point of maintenance and the easiness of handling. The recently spreading "mini-computer" which is small in size and with high performance will save much time for calculation. It is desire desirable to introduce a computer of this kind in order to carry out the whole calculation for flood forecasting in the Tan-shui automatically.

Appendix 11

NECESSARY CAPACITIES OF SOLAR CELL AND ALKALINE BATTERY

Observation Stations

Operating Conditions

No. of observation		24/day
During sending	3600 mA	10 sec/observation
During receiving	112 mA	2 sec/observation
During waiting	25 mA	
During testing	3600 mA	10 min/day
No. of station		18

Average current consumption I_L

$$I_L = (\text{current during waiting}) + \frac{(\text{sending time (sec) x current during sending})}{3600} +$$

$$\frac{\text{test period (sec) x current during sending}}{3600} +$$

$$\frac{\text{receiving time (sec) x current during receiving x No. of squelch opening } (n_1)}{3600} +$$

$$\frac{\text{sending time (sec) x current during receiving x No. of squelch opening } (n_2)}{3600}$$

n_1 : No. of squelch opening in response to the calls from the control station

n_2 : No. of squelch opening by data transmission from observation stations

$n_1 = n_2 = 10$

$$I_L = 25 + \frac{10 \times 3600}{3600} + \frac{10 \times 60 \times 3600}{3600 \times 24 \times 30} + \frac{2 \times 112 \times 10}{3600} + \frac{10 \times 112 \times 10}{3600}$$

$$= 39.57$$

No. of parallel module of solar cell N_p

$$N_p = \frac{I_L}{Iin} \eta c \cdot Fc$$

ηc : temperature correction coefficient

F_c : other correction coefficient

Iin is 10 mA provided that the annual sunshine hour is 1540 .

$\eta c = 1.11$ (over 0°C)

$F_c = 1.05$

If the above-mentioned coefficients are used for calculation,

$$N_p = \frac{39.6}{10} \times 1.11 \times 1.05 = 4.61 < 5$$

No. of series module Ns

In case of 12V, Ns = 4.

Output of solar cell P

$$P = 0.36 \times Ns \times Np = 0.36 \times 4 \times 5 = 7.20 \text{ (W)}$$

Capacity of alkaline battery AH

$$AH = \frac{\text{(average current consumption)} \times \text{(non-sunlight hours)}}{\text{(self discharge rate)} \times \text{(temperature change rate)} \times \text{(aging)} \times \text{(capacity change)}}$$

$$= \frac{0.0396 \times 24 \times 30}{0.97 \times 0.65 \times 0.9 \times 1.1} = 45.7\text{(AH)} < 60 \text{ (AH)}$$

where, no. of non-sunlight day is 30.

Results of calculation:

Output of solar cell : 7.20 watt
Capacity of alkaline battery: 60 AH

2. Relay Stations
Operating Conditions

No. of relaying = No. of observation stations in one system = 10/hour

Current during relaying	3600 + 250 = 3850 mA	12 sec/each time
During starting	112 mA	2 sec/each time
During waiting	25 mA	
No. of observation stations	20	

Average Current Consumption I_L

$$I_L = 25 + \frac{10 \times 12 \times 3850}{3600} + \frac{2 \times 112}{3600} = 148.5$$

No. of parallel module of solar cell Np

Iin is 10 mA provided that the total annual sunshine hour is 1540.

$\eta_c = 1.11$ (over 0° C)

$F_c = 1.05$

$$Np = \frac{148.5}{10} \times 1.11 \times 1.05 = 17.3 < 18$$

Ns = 4

Output of solar cell P

$$P = 0.36 \times Ns \times Np = 0.36 \times 4 \times 18 = 25.9\ (W)$$

Capacity of solar battery AH

$$AH = \frac{0.1485 \times 24 \times 30}{0.97 \times 0.65 \times 0.9 \times 1.1} = 169.7(AH) < 220(AH)$$

where, No. of non-sunlight day is 30.

Results of Calculation:

Output of solar cell: 25.9 watt
Capacity of alkaline battery: 220 AH

Appendix .12 Recording Paper (Sample)

Telemetering Observation on Tan-Shui River Basin

Date:

Date	Time	System Station	Ta-pao (rain)	Pai-shih (rain)	Yu-feng (rain)	Chi-tan (rain)	Shih-men (rain)	Shih-men (water)	Hsin-hai Br. (water)	Chu-chih (water)	Chung-cheng (water)	Tai-pei Br. (water)

Date	Time	Shih-tzu-tou (water)	Chung-shan Br. (water)	Wu-tu (water)	Wu-tu (rain)	Fu-shan (rain)	Mt.Ta-tung (rain)	Pin-lin (rain)	Tai-pei (rain)	Chu-tzu-hu (rain)

Appendix 14

THE FLOOD DEFENSE LAW (EXTRACTED)

APPENDIX 14

THE FLOOD DEFENSE LAW (Extracted)

Chapter 1. General Provisions

(Objective)

Article 1. The objective of this Law is to maintain public security by taking precautions against and preventing flood disasters and also minimize damage there of in the event of flood or high tide.

(Definition)

Article 2. "Flood Defense Administrating Organization" in this Law shall be municipalities of cities, towns and villages (including special districts; hereinafter the same.) that responsible for flood defense, by the provision in the next Article, or municipal associations which jointly execute the matters concerning flood defense (hereinafter called "flood defense executing association") or flood disaster prevention associations.

2. "Flood Defense Administrator" in this Law shall be the chief of a municipality which is a flood defense administrating organization, or the president of flood defense association or flood disaster prevention association.

3. "Fire-fighting Organization" in this Law shall be organizations for fire-fighting provided in Article 9 of Fire-fighting Organization Law (Law No. 236, 1947).

4. "Head of fire-fighting organization" in this Law shall be the chief fire-fighting officer in municipalities with fire-fighting headquarters, or the chief of fire squad of municipalities without fire-fighting headquarters.

5. "Flood Defense Plan" in this Law shall be those plans concerning supervision, precautions, communication, liaison, transport and operation of dam or flood gate or lock gate necessary for flood defense, activities of flood defense organization and fire-fighting organization for flood defense, cooperation and assistance between a flood defense organization and other organizations and maintenance and operation of tools, materials and facilities required for flood defense.

6. "Water gauge etc." in this Law shall be water level measuring equipment and facilities such as water gauge and tide guage etc.

7. "Flood Defense Warning" in this Law shall be the announcement of warning about the necessity of flood defense activities when there is a fear of disaster due to a flood or a high tide.

Chapter 3. Flood Defense Activities

(Inspection of River Etc.)

Article 9. The flood defense administrator, the chief of flood defense brigade or the chief of fire-fighting organization shall make inspection of rivers and banks along coasts in the area in charge at times, and whenever a danger to flood defense is found the officer shall request the administrators of that river or banks along coasts necessary actions.

(Flood Forecast)

Article 10. When the Director General of Meteorological Agency sees a fear of flood or a high tide from the meteorological situation, he shall report it to the Minister of Construction and governors of prefectures concerned, and if necessary, announce the situation to the public in general through information media such as broadcasting organizations, newspaper etc. (hereinafter called "information media")

2. When there is a fear of flood in rivers whose watersheds extends over more than two prefectures or which have large watercheds and floods in which would seriously affect the national economy the Minister of Construction in collaboration with the Director General of Meteorological Agency shall inform the governors of prefectures concerned of the situation by showing water levels and discharges, and if necessary, announce to the public through information media.

3. Rivers provided in the foregoing Paragraph shall be decided by the Minister of Construction in consultation with the Minister of Transport.

(Notification of Flood Warning)

Article 10-2. When notification as provided in Paragraph 1 or 2 of the foregoing Article was given to a governor of a prefecture concerned, he shall immediately distribute the information of which he was notified among flood defense administrators and water gauge superintendents (officers in charge of superintendence of water gauge etc., hereinafter the same) designated in the flood defense plan of the prefecture.

(Flood Defense Warning)

Article 10-4. Minister of Construction shall dispatch flood defense warning about rivers, lakes and coasts designated by him as those a floods or high tide in whose basin would seriously harm the national economy, and governors of prefectures shall do the same about rivers, lakes or coasts other than those designated by Minister of Construction and designated by them as those a flood or a high tide in whose basin would cause a considerable damage.

2. Minister of Construction shall when he dispatched a flood defense warning according to the provisions in the foregoing Paragraph, inform governors of prefectures concerned about the details of the warning.

3. Governors of prefectures shall, when he dispatched flood defense warning according to the provisions in the foregoing Paragraph 1 or when he was notified according to the provision of the previous Paragraph, immediately inform the details of the warning, according to the flood defense plans set up by prefectures to the flood defense administrators and other organizations relevant to flood defense.

(Flood Defense Communication)

Article 20. Every person shall be requested to cooperate in the fastest communication for urgent flood defense activities.

2. Minister of Construction, governors of prefectures, flood defense administrators, chiefs of flood defense squads, chiefs of fire-fighting squads or the persons given instruction by those officers shall be authorized to use with priority public telecommunication or may use exclusive communication facilities such as police communication facilities, those of metaorological offices, railways or electric companies communication facilities etc. for the purpose of conducting urgent communications necessary for flood defense activities.