# 東南アジア諸国における
# 洪水防禦パイロットスタディー

—1982年度洪水防禦コース報告書—

1983. 3. 10.

建設省河川局・土木研究所
国　際　協　力　事　業　団
筑波インターナショナルセンター

# 東南アジア諸国における
# 洪水防禦パイロットスタディー

—1982年度洪水防禦コース報告書—



1983. 3. 10.

建設省河川局・土木研究所
国際協力事業団
筑波インターナショナルセンター

# ま　え　が　き

国連台風委員会の長期計画に基づく総合的な水害防禦技術（構造物のみでなく非構造物対応を含めたもの）に関する国際的な研修コースが設立されて１９７９年１０月にその第１回研修が開れたが，今年は第３回目に当る。

本研修の参加国は，東はイランから西は韓国まで含まれていて各国河川の置かれている状況は自然的にも社会的にも大きく異っている。従って，各国共通の対策は少なく，各国特有に対処されねばならない課題がほとんどである。共通項としてあるのは治水対策を堤防・ダム等の構造物のみに絞るのではなく，土地利用，洪水予報等を含めて検討しようという点である。研修の成果である研修員の報告も本レポートに含まれているが，研修員が所持してきた資料の状況にもより，その内容に大きな差があるのは仕方のないことであろう。しかし，若干でも各国の新しい情報が含まれ，今後の各国の河川の認識について寄与するところがあると考えるので，ここにその報告を公表する次第である。

なお，その他として，本研修参加国中中国について，その河川（揚子江）における洪水防禦についての研修員報告書全文を翻訳掲載した。

# 目　　次

## 1 研修コース設立の背景

東南アジアにおいて，総合的な水害防禦に関する技術開発の問題に関心が高くなったことについては，国連アジア太平洋経済社会委員会（ESCAP）に所属する台風委員会の活動について述べることが分り易いと思われる。

台風委員会は，１９６８年に東南アジアの台風常襲地帯に位置する７ケ国が集まって，台風の発生のメカニズム，進路の予測，台風によってもたらされる被害の軽減を図る等を目的とし研究と調査など情報交換を主体とする国際機構をつくり上げたことに端を発している。活動は年１回の委員会において，その年の各国の台風に関する諸活動を報告しあい，討議を通じ啓発するとともに地域的なセミナーなどの開催を行ってきた。台風委員会への加盟国は１９８３年２月現在香港，韓国，マレーシア，フィリピン，タイ，ラオス，ベトナム，クメール，中国，日本の１０カ国である。

１９７８年に委員会発足１０年を迎え，これまでの委員会活動の成果を明らかにし，さらに台風に関する加盟国の抱えている問題点を把握し，今後の活動方針を探る意味で７ケ国を訪問し問題点を討議するレビューミッションが企画され，実行された。

レビューミッションの報告書は，１９７８年１０月の台風委員会に提出され了承された。この報告書では今後の台風委員会の水文部門を重点とする活動として，これまで１０年間の洪水予防警報システムに関するめざましい発展をふまえ，構造物対応に非構造物対応を加えた総合的な水害防禦対策を実施することの必要性が強調されている。

台風委員会は，この問題の重要性を認め，水文部門における今後の活動の主要な柱とすることとしたが，まず手はじめに各国それぞれ試験流域を設定し総合的な水害防禦の技術的な検討を始めることとした。河川改修や治水ダムの建設などいわゆるハードな治水対策は，各国での行政活動そのものであり，これらの問題まで組み込むことは，台風委員会の性格上あまり適当でないという判断があり非構造物対応の課題を中心とすることとし，また，代表流域で事例的に研究された手法は他の流域にも適用可能であり技術開発のやり易い方法として採択されたものと考えられる。

発展途上国に対する集団研修やセミナーの開催なども台風委員会の重要な活動の一つであり，日本で従来から実施している河川工学コース研修も台風委員会の活動の一環である。１９７８年の台風委員会では，総合的な水害防禦対策に関する調査・研究活動を提供するに当り，この新しい問題に関する研修の実施についても要望が出され，日本政府がこれに対応することを約束したわけである。これが１９７９年に初めて本集団研修コースが発足した経緯である。コースは河川コースと同様ＪＩＣＡベースで行われ，参加国は台風委員会加盟国に限らず，広く門戸が開放された。

# 研修参加者名簿

| No. | Country (国名) | Name (名前) | Age (年令) | Present Post & Place of Employment (現職・所属先) | Educational Record (最終学歴) | Mailing Address (本国の住所) |
|---|---|---|---|---|---|---|
| 1 | China | Mr. Wan Quan Lin | 34 | Engineer,<br>Yangtze River Water Conservancy and Electric Power Research Institute | 1963–'68<br>Wuhan Institute of Hydraulic and Electric Engineering | No. 74, Huiji Road, Wuhan, Hubel Province, Peoples Republic of China |
| 2 | Thailand | Mr. Sa-Cha Wattanasarnvechakul | 28 | Civil Engineer,<br>Surveying and Planning Section of Water Channel Maintenance Bangkok Meptropolitan Administration | 1972–'75<br>Chiengmai University<br>Civil Engineering | 43/16 Beside Soil Lad Prao 82, Lad Pfao Raod, Bangkapi, Bangkok, Thailand |
| 3 | Thailand | Mrs. Watcharee Virapun | 30 | Meteorologist,<br>Hydrometeorological Section, Department of Meteorology, Ministry of Communication | 1970–'74<br>Chiengmai Univeristy<br>Mathematics | 834, Prachautit, Road, Hui-Khwang, Bangkok 10310, Thailand |
| 4 | Philippines | Mr. Emilio B. Alvarez | 35 | Meteorologist,<br>Meteorological Agency<br>P. A. G. A. S. A. | 1963–'73<br>National University<br>Civil Engineering | 880 Tandan Sora Street, Area 5, Diliman Quezon City, Philippines |
| 5 | Malaysia | Mr. Zulkefli Bin Yassan | 25 | Engineer,<br>Drainage and Irrigation Department Barat Laut Selangor Project, Sg. Besar, Selangor, Malaysia | 1977–'80<br>Newcastle Univeristy Upon Tyne, England<br>Civil Engineering | 421 Taman Sri Setia, Jalan Padang Tembak, Teluk Intan, Perak, Malaysia |

研修プログラム

| | 曜 | 課　　　　題 | 講　師 | 場所 |
|---|---|---|---|---|
| 8／9 | 月 | 建設省表敬・移動（東京－筑波） | | |
| 10 | 火 | 土研表敬：セミナーコース紹介<br>台風委員会とパイロットリバー | 富永・山本<br>竹村 | PWRI |
| 11 | 水 | 治水と文化（外国人の治水計画への影響<br>特・河に関わる災害の防止） | 山本<br>植原 | 〃 |
| 12 | 木 | カントリレポート発表 | 山本・末次 | 〃 |
| 13 | 金 | 特・沖積地形論と水害地形分類図 | 赤鍋 | 〃 |
| 16 | 月 | 特・水害地形分類図の作成手法 | 〃 | 〃 |
| 17 | 火 | 特・同上演習 | 〃 | 〃 |
| 18 | 水 | 見学：国土地理院・防災センター・土研 | 末次 | |
| 19 | 木 | 日本の川の特徴と洪水防禦手法 | 山本 | PWRI |
| 20 | 金 | 日本の砂防と流域管理 | 渡辺 | 〃 |
| 23 | 土 | 水文観測手法と洪水防禦への応用<br>レーダー雨量計 | 吉野<br>大倉 | 〃 |
| 24 | 火 | 特・利根川流域の開発と治水 | 大熊 | 〃 |
| 25<br>26<br>27 | 水<br>木<br>金 | 見学・利根川及び荒川流域（同行・末次・本間） | 工事事務所 | |
| 30 | 月 | 流域特性と流出予測 | 佐合・寺川<br>（水文研） | PWRI |
| 31 | 火 | 氾濫解析手法と洪水危険地図 | 吉川 | 〃 |
| 9／1 | 水 | 特・東南アジアの河川の洪水予報と防禦 | 木下 | 〃 |
| 2 | 木 | 特・洪水防禦計画調査の問題点 | 土屋 | TIC |
| 3 | 金 | 鶴見川総合治水計画（説明と映画） | 宇塚 | 〃 |
| 6 | 月 | 見学・鶴見川（同行・末次） | 京浜<br>工事事務所 | 関東地建 |
| 7 | 火 | 特・アジアの河川の水害地形分類図<br>都市化流域での流出抑制手法 | 大矢<br>末次 | TIC |
| 8<br>9<br>10 | 水<br>木<br>金 | 淀川の予備報システム<br>見学・淀川及び寝屋川（同行・末次）<br>見学・京都・・・日本文化の理解の為 | 福田・中尾<br>山口 | 近畿地建 |
| 13 | 月 | 耐水化工法（堤防・建築物）<br>水防工法 | 石川・本間<br>山本 | PWRI |
| 14 | 火 | パイロット河川の洪水防禦計画の検討 | 山本・末次 | 〃 |
| 16 | 木 | 今後の調査課題とその手法の検討と討議 | 〃 | 〃 |
| 17 | 金 | 報告書作成 | 〃 | 〃 |
| 20 | 月 | 同　上 | 〃 | 〃 |
| 21 | 火 | エヴァリュエーション・閉講式 | 竹村・芦田・山本・本間・末次 | |

# 4．研　修　員　報　告

Name: Wan Quan Lin
Country: The People's Republic of China
Organization: The Yangtze Water Conservancy and Hydroelectric Power Research Institute
Position: Engineer

## 1. Natural Conditions and Flood Control

China lies in the east of Asia. She has a total area of approximately 9,600,000 sq.km. It's territory extends over regions of high, mid and low latitude.

There are numerous rivers in China. Of these, over 1,500 have watershed areas larger than 1,000 sq.km and the Yangtze river, the Yellow river, the Haihe, the Huaihe, the Zhujiang, the Liaohe and the Shonghua river are by far the largest ones. Tremendous water resources are provided by these rivers with a total runoff of 2,700 million cu.m for normal year and a water power potential of 580 million kw.

China is a vast country. Annual climate variability is frequently matched by seasonal variability. The climate is wet in summer, frequented by rain due to Southwesterly monsoons, and dry in winter under the influence of cold currents from the northwest. The total of precipitation in the normal year amounts to 6,032 billion cu.meter, averaging 630 mm of rainfall per annum. But the precipitation varies widely not only with respect to geographical location, but also in different seasons in a year and from year to year. The total precipitation in a normal year along the coast in the Southeast is more than 1,600 mm, which decreases gradually in the northwestward direction, until it becomes even less than 200 mm in the northwest. The rainfall in flood season (July, August and September) usually comprises over 50% of that in the whole year, giving rise to frequent flood and inundation. Meanwhile, the typhoons from the northwest Pacific Ocean affect the climate and rainstorms to a great extent.

According to statistics in the 31 years from 1949 to 1979, there occurred 882 typhoons in the west Pacific Ocean (including the south china sea), of which 210 landed over the coast area of this country, average 7 times in a year. There were as much as 11 typhoons landing in 1961, and only 3 times in 1950. The passing typhoons often bring about serious consequences and heavy losses in the near areas. About 35% of typhoons coming ashore in our country more deep into the inland, sometimes giving rise to extraordinarily large storms.

Before liberation, according to historical records, there occurred 1,029 major floods with serious consequence in china during the 2,155 years from 206 B.C. to 1949, almostly averaging once every two years. Only a few projects were built on the upper reaches to control the floods and dykes were small and not capable of defending the flood water for lack of proper maintenance on the middle reaches; whereas on the lower reaches, the discharge capacities were inadequate, as a result, flood disaster happened frequently.

Since the foundation of new china, a number of hydraulic engineering projects have been built by the chinese people. At the same time, a tremendous amount of work has been done in renovating dykes, in excavating the river channels, in constructing defences and storage reservoirs on the upper reaches, in setting up diversion works for defending flood on the middle reaches and in enlarging the capacity to discharge floods on the lower reaches of the river. Up to now, the total storage capacity of reservoirs has reached 408.1 billion $m^3$, and the length of dykes has increased from 42,000 km shortly after liberation to 165,000 km. The completion of all these projects signifies the dominant role played in flood projection, in draining away the surplus water from water logged areas and in combatting drought over the years. Moreover, immense benifits have been drawn in power generation, navigation, aquatic products and so forth.

Now, the standards set for river regulation in our country is to cope with floods recurring once in 50 years for the 7 main rivers mentioned above, with an eye on provisional measure to tackle the problem of defending extraordinarily large floods.

Our principles of flood control are as follows: "Pay due attention to both the upper and lower courses and take measures both in retaining and discharge flood waters".

As regard the management of the work of flood protection, our policy is "Prevention is better than cure and it is more important than rush repairs."

## 2. Organizations Concerning to the Water Administration

The work of flood prevention has a most important bearing on the life and property of the people, the progress of reconstruction work, and the entire national economy and hence, our government has attached great importance to it. The Water Conservency and Electric Power Ministry was set up by the central government. The Ministry is responsible for the work of water administration. The similar departments were also set up in province, areas and countries. In addition the organizations of valley extent were set up. These organizations are responsible for planning, designing, constructing and so on.

The "central flood protection command" was set up by our central government to assume responsibility of direction and dispatching all the work of flood protection in the country. Flood protection commands at different levels were established in the province, areas and countries to be in charge of the organization and directing of the work of flood prevention in the regions for which they are to hold responsibility.

### 3. Outline of Flood Protection on the Yangtze

There are numerous rivers in China, wherefore, the flood protection projects have a very wide distribution. According to the features of rivers, as planned, the aims of the regulation and flood protection projects are quite different.

The outline of flood protection on the Yangtze is as follows:

The Yangtze originates from the Qinhai-Tibet plateau and flow into the East China sea at Shanghai, with a total length of 6,300 km, the total drainage area is 1.8 million km$^2$. The mean annual runoff into the sea is about 1,000 billion cubic meter. The total drop is about 5,400 meter, and the hydroelectric potential is about 268 million kw. The main stream of the Yangtze above Yichang is named as the upper reach, with a total length of more than 4,500 km, and a drainage area of 1.0 million km$^2$. The middle reach is the stretch from Yichang to Hukou, having a total length of more than 900 km. Below Hukou the stretch is called the lower reach, with a length of more than 800 km. The total drainage area of the middle and lower reaches is 800 thousand km$^2$.

The topographic features of the basin are as follows: the mountainous region covers 65.6% of the total area of the basin, the hilly land 24.0% and the plain together with lake 10.4%. The mean value of annual precipitation of the whole basin is about 1,100 mm, with a large portion of basin exceeding 1,000 mm. Mean annual runoff at the Yichang and Datung Hydrological Station is 451 and 915 billion cu.m. respectively (corresponding mean annual discharge 14,300 and 29,000 m$^3$/s respectively).

According to 1978 statistics the total population of the Yangtze basin is of 342 million, the area of cultivated land is about 374 million mu (about 25 million hectares). The grain yield amounts to about 70% of the country's total. The forestry and mineral resources are also very rich. Communications in most part of the basin are good. The value of industrial output amounts to about 40% of the national total. Therefore the Yangtze basin occupies a very important position in the national economic development. But considerable portion of the basin, especially its fertile and prosperous plain areas are still seriously menaced by flood. This makes flood control in the basin an important and the most pressing matter to be dealt with at present.

The districts most seriously menaced by flood are mainly the plain areas and low terrace land in the middle and lower reaches of the main stream and tributary streams of the Yangtze.

In respect of flood control in the middle and lower reaches of the Yangtze, the situation of the Jingjiang section from Zhicheng to Chenglingji is most critical and important (referring the map of water system and bank protection on the middle reach of the Yangtze).

The runoff of the Jingjiang sections comes mainly from the main stream of the Yangtze above Yichang. The flood discharge in the general year is about 5,000 $m^3/s$, arriving at 66,800 $m^3/s$ in 1954.

Because the Yangtze basin is affected by the subtropical anticyclone in the west Pacific Ocean and is supplied with water steam on the Bengal bay of Indian ocean, which forms the flood season from April to September in normal year. The precipitation is rich on the upper and middle reaches of the Yangtze areas, averaging 1,000–1,200 mm. per annum, arriving at 1,600 mm. of the largest precipitation. The rainfall in the flood season usually comprises more than 75% of that in the whole year, giving rise to frequent and serious flood in the middle and lower reaches of the Yangtze.

According to historical records, there occurred more than 200 times floods during the past 2,000 years, averaging approximately once ten years. Before liberation, the banks on the middle and lower reaches of the Yangtze almost had no flood protection work, and dykes were small and not capable of defending the flood water with a lot of hiding defects.

Taking the 1931 flood water, for example, the peak discharge at Yichang gaging station was 63,600 $m^3/s$, the flood broke the dykes on the Jingjiang section, the total inundated area of cultivated land amounted to more than 50 million mu (3.3 million hectares) and the population affected nearly 30 million persons. Among that 145 thousand were drowned. At the same time Wuhan city was inundated by flood for about 3 months. The flood at Wuhan in 1935 killed 142 thousand people after flooding 22.64 mu of farmland with 10.03 million inhabitants in the affected area.

Since the foundation of new China, our government has paid great attention to the flood protection on the Jingjiang section. The capacity of the Jingjiang flood protection was entirely changed. The guiding principles were decided to "take account of both storing and releasing, with releasing putting first."

The 1954 flood was even more higher and larger than the 1931 flood, but owing to the fact that dykes were strengthened and rose to a certain extent, some diversion project, such as the Jingjiang Diversion Project etc. were completed, especially the broad mass of the people along the river were mobilized to fight against the flood, the damage was greatly alleviated, a lot of large and medium cities and the vast farmland were defended.

In July 1981, the extraordinary torrential rain in the historical record was brought about, curring over wide areas on the upper reach of the Yangtze. The areas that the precipitation intensity in the three days was more than 50 mm were about 340 thousand sq.km, the areas of the precipitation more than 100 mm were about 120 thousand $km^2$. The largest precipitation was 439.6 mm. It was 60 mm more than the 1956 precipitation in the three days. The peak discharge at Yichang gaging station was 71,000 $m^3/s$ or 4,200 $m^3/s$ more than the 1954 peak discharge. The reasons were mainly as follows:

(1) the trough moved quickly toward the east and further deepended at high altitude.
(2) a strong cold air current in the north area moved over Sichuan province.
(3) the subtropical anticyclone of the west Pacific Ocean was strong and stable.
(4) the southwest vortex appeared at the three thousand meter high altitude.
(5) the Indian trough was at the skew north direction and was strong.

Our government, from the central to the local, and the commands at different level made arrangements immediately and widely. The departments of meteorology, hydrology, communication and so on, coordinated each other. A mighty force of dyke defenders headed by officials was gathered on the banks along the middle and lower reaches of the Yangtze. Eventually, the main embankments bore the peak discharge safely.

## 4. The Flood Prevention Project and Work on the Yangtze

### (1) Dyke

In the past thirty years, we have done a large amount of renovation and consolidation work, completing 78 million $m^3$ of earthwork and 5.97 million $m^3$ stonework. At present, the elevation of the Dyke crest is over 1.0 m, higher than the maximum water level in record. The cross-section of the Dyke is crest width 8–30 m, inside slope 1 : 3 and 1 : 5, and outside slope 1 : 3.

### (2) Flood Diversion and Detention Basin

As early as 1952, the Jingjiang Flood Diversion Basin was constructed. It was started in March 1952 and was completed in July of the same year and it took 75 days. The project is composed of the following principal features.

(a) Flood Diversion Sluice
The sluice is built of reinforced concrete, with a total length of 1.054 m. The designed discharge capacity of the sluice is 8,000 c.m.s.

(b) Embankments or Dykes
The total length of the Embankments or Dykes surrounding the flood diversion districts is 208 km.

(c) Areas of Refuge
For temporary relocation of inhabitants during flood diversion, the areas and platforms of refuge with a total area of 20.6 $km^2$ were constructed in the detention basin.

(d) Drainage Installations
In order to drain both the waterlog caused by local rainfall and the flood water in the basin during diversion in flood year two outlet sluices and one electrical pumping station were constructed. The total drainage capacity is 700 c.m.s.

In 1954, a major flood of a 100 years frequency of the Yangtze occurred, the sluice was operated for three times for diverting the excess flood water in order to ensure safety of the Jingjiang Dyke. Through flood diversion the maximum water level of Shashi city was lower by about 1.0 m. The effect of the project on flood control also proved to be very significant.

In 1956 the Dujiatai Flood Diversion Project of the Hanjiang was constructed and then others were completed one after another.

(3) Artificial Cutoffs

The lower reach of Jingjiang is a typical meandering channel, and a results in the lower flood capacity, water way shifts seriously on the plain. Natural cutoff often occurred, due to existence of cavities in the banks.

In the early founding of new china a research of systematic artificial cutoffs at the lower reach of Jingjiang was carried out. After detailed contrast, a scheme of systematic cutoff was drawn up. Then, two artificial cutoffs (i.e., Zhongzouzi and Shangchewan) were completed, respectively, in 1966 and in 1968.

Since the completion of the cutoffs, diversion of water flow through them has been satisfactory under varying flow conditions in different hydrological years, especially under some high flood and remarkable benifits have been achieved. As for flood control, after cutoffs the flood level of the upper river stretch is dropped, as a result, the flood hazards to areas along the river banks of upper reach of Jingjiang are minimized to varying degrees. After completion of the cutoffs and revetment, the river regime remains stable and the miserable past of serious caving of the levee and collapsing of the farmland has changed into the bright present favourable to the promotion of agriculture production.

(4) Reservoirs and the Three Gorges Project

As for flood control reservoir, we have built the Danjiangkou Reservoir on the Hanjiang River, the Zhaxi Reservoir on the Zishui River etc. These reservoirs are now playing an important role in flood control.

Now the three Gorges project has been actively in planning but is only in its final preparation stages. After its completion, the project will have 37 billion $m^3$ flood control capacity. The scheme will resolve major flood control problems in the middle and lower reaches of the Yangtze, especially the project will play a decisive role in safety of the Jingjiang dyke.

## 5. Flood Forecasting System and Forecasting Mission

The flood prevention projects including flood control works completed have been playing a decisive role in flood control. The perfect flood forecasting system and the exact forecast have also been playing an important role in flood control.

Before 1949, there were no hydrological forecasting work and no specialized personnel in this field other than a few reporting station along the Yangtze.

After 1949, under the leadership of Ministry of Water Conservancy the Hydrology Bureau was set up in Oct. 1952. The Hydrological Department and Hydrological Bureau which serve the Yangtze Valley Planning Office were also set up one after another, and are responsible for the forecasting the hydrology and meteorology on the Yangtze.

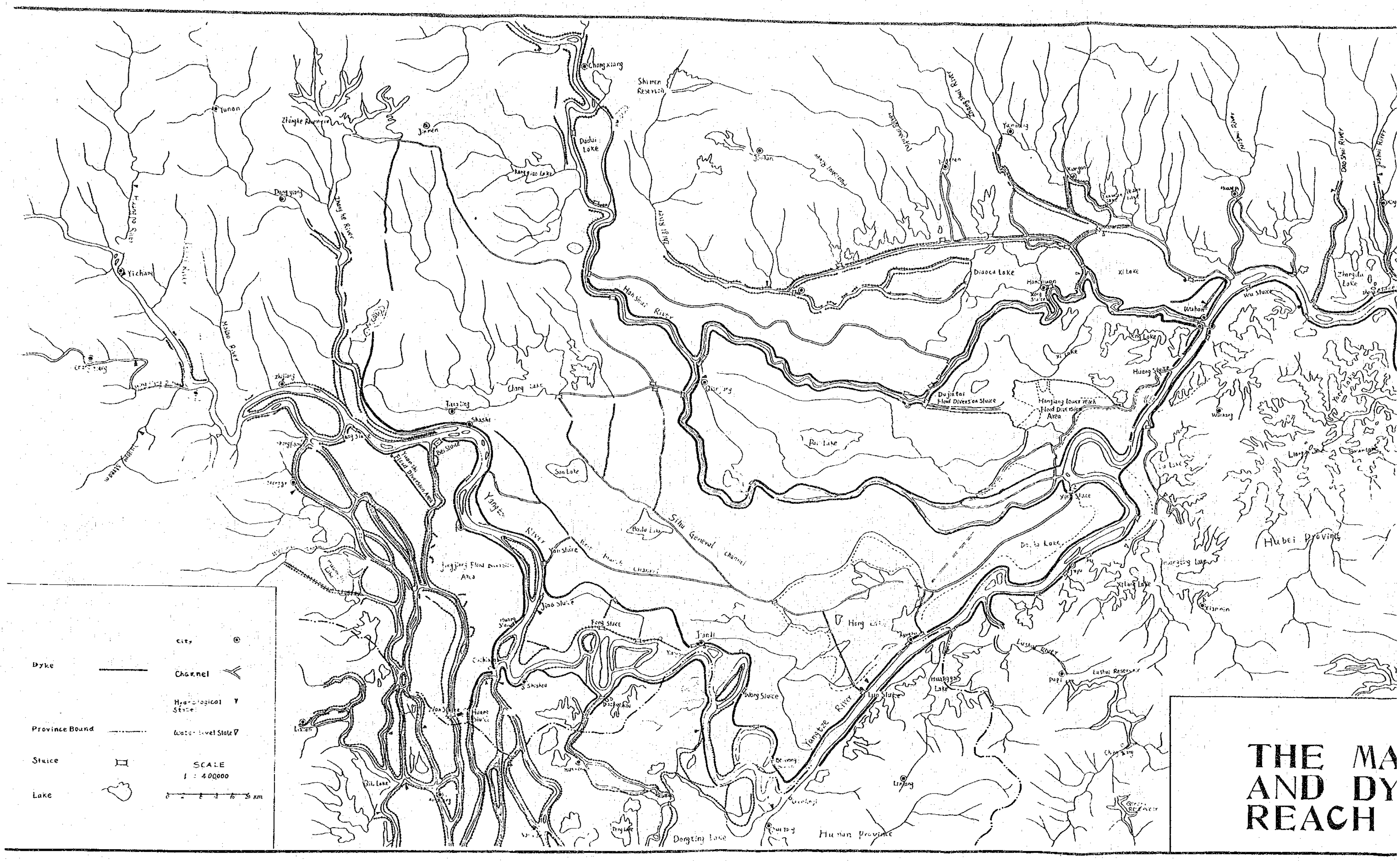
Under the Leadership of Hydrology Bureau of the Y.V.P.O., some central stations were set up. They are the Chongqin central station, the Yichang, the Hankou, the Nanjing and so on. Each central station contains: the hydrological station, the water level measuring station and the river surveying team. At the same time, the Hydrology Bureau of the Y.V.P.O. still have the hydrological forecasting section and the meteorological forecasting section.

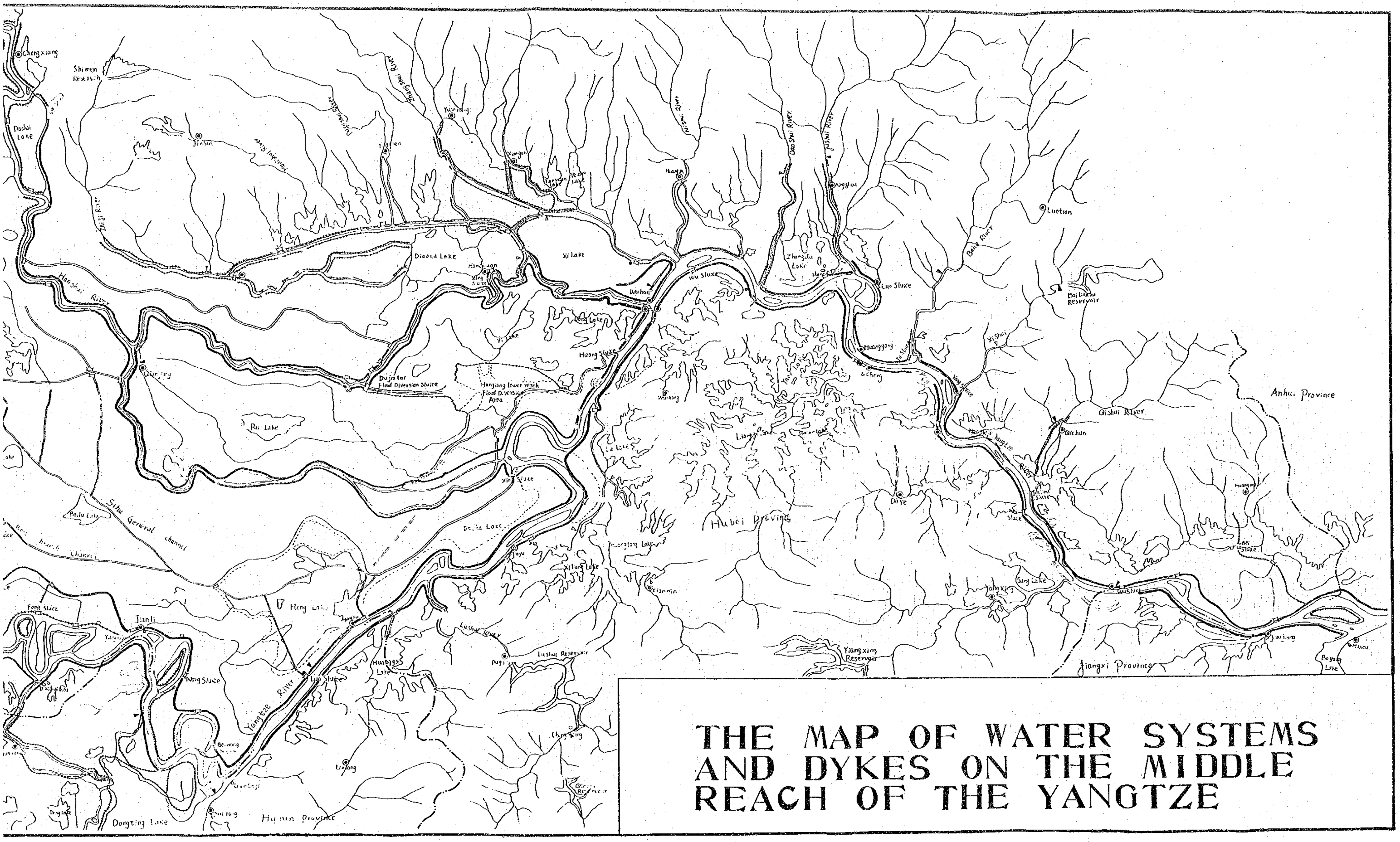
In the early stage of founding new China, on the basis of learning the flood forecasting method from foreign countries the forecasting scheme with the method of corresponding stages and flood routing were worked out in the main stream of the Yangtze. As accurate judgement and accurate flood forecasting were made for the need of operating the sluice gate of the Jingjiang flood diversion zone, a best result was achieved in 1954.

The flood forecasting was required to tackle the problem not only in predicting the highest stage and discharge hydrograph for natural conditions, but also in guiding the rational operating schedule for those retarding basins and flood storage areas along the Yangtze. The optimum operating schedule of the reservoir and lakes in series was thus developed and was applied to estimate the regulating effect and the rising process of flood regulated at the downstream section, the bank of Jingjiang and the important cities were safeguarded.

The forecasting service by combining meteorological forecasting and hydrological forecasting proved to be successful by offering informations that extraordinary large flood would appear in the middle and lower reaches of the Yangtze. In the coming 5 days, when the peak discharge at the Yichang gaging station was 71,000 $m^3/s$ in July 1981, the forecasting service could already forecast it exactly and forecast error was only 1.5%. The feature of the peak discharge in Sichuan province and the effect of the peak discharge on the middle and lower reaches were rationalized and forecasted. As a result, our government could take a series of correct measures and won the victory of the struggle agains the flood.

Although tremendous successes have been achieved in the past 31 years in the struggle of flood prevention, there are still many rivers and streams which lack adequate controls in the time of major flood, and where dangerous situation due to human activities may arise even in the case of medium or minor floods. There still remains the long term task of ensuring the safety of all rivers with respect to flood prevention in future.


Chongxiang
Shimen Reservoir
Yunan
Zhanghe Reservoir
Jinmen
Dahui Lake
Dangyang
Zhang He River
Yichang
Mabo River
Zhijiang
Shashi
Chang Lake
Yan Stuice
Han Shui River
Qianjiang
Diaoca Lake
Xi Lake
Wahan
Wu Sluice
Dujiatai Flood Diversion Sluice
Hanjiang Lower Reach Flood Diversion Area
Huang Sluice
Pai Lake
San Lake
Yangtze River
Jingjiang Flood Diversion Area
Sihu General Channel
Jiao Sluice
Fang Sluice
Jianli
Hong Lake
Wong Sluice
Luo Sluice
Yangtze River
Lushui River
Lushui Reservoir
Hubei Province
Dongting Lake
Hunan Province
Lixian
City
Dyke
Channel
Province Bound
Water Level State
Sluice
Lake
SCALE
1 : 400000
km
THE MA
AND DY
REACH




# THE MAP OF WATER SYSTEMS AND DYKES ON THE MIDDLE REACH OF THE YANGTZE

Name: Sa-cha Wattanasarnvechakul
Country: Thailand
Organization: The Bureau of Drainage and Sewage
Position: Civil Engineer 4

## DESCRIPTION OF THE AREA

The physical aspects of the surrounding area of a municipality have a considerable effect on the sewage, drainage and flood protection facilities with which it is to be provided. Topography dictates the balance between flowing by gravity or constructing pumping stations, and the possible subjection of the area to periodic flooding. Geology affects the conditions of construction for the majority of these facilities which are built below the surface of the ground. Climate directly affects the design of drainage facilities and exerts a control over the periods of the year in which construction programs can more readily be carrried out.

## TOPOGRAPHY

The deltaic area upon which Bangkok Metropolitan was built was formed by the Chao Phya River. The delta is somewhat triangular in shape with a 120 kilometer (75 mile) base along the Gulf of Thailand and a length extending to the north about 200 kilometers (124 miles) to Chainat as shown in Figure 1. This area is extremely flat, extensively irrigated and very rich agriculturally. It is surrounded by low rugged mountains which are an extension of the Himalaya range.

The center of Bangkok Metropolitan is about 50 river kilometers (31 miles) north of the Gulf of Thailand. The municipalities of Bangkok Metropolitan presently occupy a total of 303 square kilometers (118 square miles). Ground elevations at Bangkok are a maximum of about 2 meters (6.6 feet) above mean sea level and at Chainat the elevation is only 15 meters (49 feet) above mean sea level.

## GEOLOGY

### Geologic History

The mountains surrounding the Chao Phya Plain were formed during the late or Post Miocene orogeny. The present Chao Phya river basin was possibly the result of the development of structural basins in the late Tertiary epoch followed by heavy alluvial depositions during the Quarternary epoch. These first deposits, consisting of layers of fine gravel, sand, and sandy clay, are now located at a depth of 300 meters (984 feet) or more below the surface. A thick layer of grey, relatively homogeneous clay was later deposited after the major movement of the earth's crust had stopped.

The delta steadily advanced into the Gulf waters to the south. About 500 years ago the present site of Bangkok was at the shore of the Gulf of Thailand. Recent flood control and irrigation projects have caused most of the silt to precipitate before it reaches the Gulf but the southward growth of the delta, although slow, is continuing.

### Type of Soil

Subsurface conditions in Bangkok are relatively uniform. Borings to a depth of 20 meters (66 feet) indicate that there are basically two types of clay, one soft and one stiff. The soft clay is on the upper level. The change from soft to stiff occurs at an average depth of 13.5 meters (44 feet) which varied from 11 to 17 meters (36 to 55 feet). During the dry season, however, the top one or two meters of the natural ground surface is relatively stiff brown clay.

Other sub-surface explorations indicate that below 20 meters the clay is increasingly mixed with sand or gravel. Alternate layers of sand, clay or mixtures of sand and clay exist at depths in excess of 300 meters (984 feet) as indicated by one boring in the Bangkok area which failed to encounter consolidated rock. During oil exploration testing about 65 kilometers (40 miles) north of Bangkok granite was reportedly encountered at a depth of 365 meters (1,200 feet).

### Ground-Water

The ground-water level in Bangkok is very close to the surface during the wet season. Even during an extreme dry season the ground-water is rarely more than a meter below the surface. The average elevation of the ground-water table varies approximately from 35.5 to 36.0. The mean sea level is 35.0 and the mean water level in the Chao Phya River at Bangkok is about 35.3.

## CLIMATE

Thailand has three different seasons: The "Cold Season", which includes November, December and January; the "Hot Season", extending from February through May, and the "Wet Season", covering the other five months of June through October. The relatively dry period extends from November through April with practically no rainfall in December and January.

The mountains around Bangkok dissipate the forces of the typhoons or cyclones that create such havoc in the South China Sea and the Bay of Bengal. While gentle breezes of more than 1.5 kilometers per hour prevail about two thirds of the time these breezes seldom exceed 12 kilometers per hour. Maximum winds up to 122 kilometers per hour (76 mph) have been recorded, however. The prevailling winds are either from the north or the south.

Table summarizes the climatic conditions in Bangkok, including temperature, relative humidity, evaporation, days of rain and rainfall, and wind velocities. (see next page)

### Hydrology

Thailand's climate is tropical. Generally the cool season is from late-October to mid-February, the hot season from mid-February to mid-May and the rainy season from mid-May to mid-October. The Central Plain (including Bangkok) rarely has temperatures below 21°C or above 38°C. Humidity in the rainy season is high.

The heaviest rainfall normally occurs during August to September as the result of heavy monsoon rains and the torrential rainfall caused by tropical storms and depressions. As a consequence, flash flooding usually takes place towards the end of the wet season when heavy rainfall is more frequent.

Tropical storms, depressions and a few typhoons which weaken into storms or depressions, move into Thailand every year. The statistics of 28 years (1947–1974) showed that the storms moved into Thailand at an average rate of 3.7 storms per year. As shown in Table below, the historical storms occurred more frequently during the months of September to November, with the maximum frequency recorded is the month of October.

Table: Climatic Conditions in Bangkok

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature, °C | | | | | | | | | | | | |
| High | 33.3 | 33.9 | 35.0 | 36.1 | 35.0 | 33.9 | 33.3 | 33.3 | 32.8 | 32.8 | 31.7 | 31.7 |
| Low | 18.9 | 21.1 | 22.8 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 23.9 | 23.9 | 21.6 | 19.4 |
| Avg. | 26.2 | 28.0 | 29.3 | 30.1 | 29.7 | 29.0 | 28.5 | 28.4 | 28.1 | 27.7 | 26.9 | 25.6 |
| Temperature, °F | | | | | | | | | | | | |
| High | 92 | 93 | 95 | 97 | 95 | 93 | 92 | 92 | 91 | 91 | 89 | 89 |
| Low | 66 | 70 | 73 | 76 | 76 | 76 | 76 | 76 | 75 | 75 | 71 | 67 |
| Avg. | 79 | 82 | 85 | 86 | 85 | 84 | 83 | 83 | 82 | 82 | 80 | 78 |
| Relative Humidity, | | | | | | | | | | | | |
| percent | 71.4 | 74.1 | 73.6 | 74.3 | 78.6 | 79.4 | 79.4 | 80.1 | 82.1 | 82.7 | 79.3 | 73.5 |
| Evaporation, | | | | | | | | | | | | |
| millimeters | 185 | 169 | 195 | 170 | 140 | 141 | 130 | 119 | 100 | 125 | 153 | 182 |
| inches | 7.3 | 6.7 | 7.7 | 6.7 | 5.5 | 5.6 | 5.1 | 4.7 | 3.9 | 4.9 | 6.0 | 7.2 |
| Days of Rain, | | | | | | | | | | | | |
| per month | 1 | 3 | 4 | 6 | 17 | 18 | 19 | 19 | 21 | 17 | 7 | 3 |
| Average Rainfall,[1] | | | | | | | | | | | | |
| millimeters | 8 | 31 | 35 | 84 | 179 | 163 | 176 | 187 | 313 | 245 | 53 | 6 |
| inches | 0.3 | 1.2 | 1.4 | 3.3 | 7.1 | 6.4 | 6.9 | 7.4 | 12.3 | 9.7 | 2.1 | 0.3 |
| Wind Velocities, | | | | | | | | | | | | |
| Max., km/hr | 47 | 61 | 58 | 97 | 122 | 76 | 76 | 72 | 83 | 72 | 54 | 50 |
| Avg., km/hr | 7 | 13 | 13 | 11.5 | 8.5 | 7 | 6.5 | 7 | 7 | 6.5 | 6 | 3.5 |

1 Mean annual rainfall = 1,482 millimeters (58.4 inches). Period of record = (1937 to 1966).

**Table: Monthly Distribution of Tropical Storm Occurrence in Thailand**

| Month | Number of Storms |
|---|---|
| January | 0 |
| February | 0 |
| March | 0 |
| April | 1 |
| May | 1 |
| June | 4 |
| July | 7 |
| August | 10 |
| September | 24 |
| October | 29 |
| November | 20 |
| December | 7 |
| Total | 103 |

Period: 1947–1974
Source: Meteorological Department

The rainfall is unevenly distributed in time as well as in space. Generally, heavy rainfall occurs on the western flanks of the mountain ranges or on the coasts.

Convective and orographic rains cause most of the rainfall during the wet season. More widespread rainfall of longer duration can be caused by occasional tropical cyclonic disturbances, which are lassified according to wind speed as tropical storms or depressions.

The average annual rainfall in the Chao Phya and Mae Klong river basins varies from just below 1,000 mm on the western side of the Chao Phya river basin to more than 2,000 mm in the north western rim of the MAE Klong river basin. About 85% of the annual rainfall occurs during the months of May to October, with some variation in the monthly pattern from north to south.

In Bangkok Metropolitan Area, high intensity rainfall is a bigger problem than flooding caused by overflow from the Chao Phya River. If the rainfall intensity exceeds 30 mm/hour, the existing internal drainage system fails, resulting in wide-spread flooding and damage to roads, traffic, etc.

The Chao Phya river basin comprises most of the mountainous areas and valleys in Northern Thailand and Central Valley. It extends from the Thai-Burma border in the north down to the Gulf of Thailand in the south, with the whole catchment area of roughly 177,550 $km^2$, or about 31% of the total area of the Kingdom. In the Central Valley an alluvial plain has been formed by the Chao Phya river system. South of Chainat the alluvial plain is called the "Bangkok Plain", which is (for the greater part) the real delta of the Chao Phya River. Here the river overflows its banks regularly and the Bangkok Metropolitan Area and other adjacent areas are frequently inundated.

Stream flow records or the Chao Phya River and the Klongs (canals) in the project area will be studied in order to establish flood hydrographs. The increase in roofed and paved areas increases to a great extent the surface run-off. The flooding situation is further aggravated by building of encroachments such as shanties on the klongs like parts of the Klong Toey. This had considerably reduced the carrying capacity of the channel in recent years. The potential flooding problem is expected to become more serious in the long term due to continuing land subsidence throughout Bangkok (due to consolidation of the soil groundwater levels are falling).

### Hydraulics

The Caho Phya River is a seasonal river. The river stage usually starts to rise in May following the onset of the wet season and reaches its highest water levels in September-October. In the wet season a high discharge of 4,000 $m^3/s$ was measured near Chainat and in the dry season a low discharge of 50 $m^3/s$.

After the storage dams were built on the Ping and Nan rivers of the Chao Phya River system, navigation programmes were developed in the river reaches below the dam. At present, the minimum release downstream of the Chao Phya dam of 75 $m^3/s$ can maintain a minimum draft of 1.40 m throughout the Chao Phya river reaches.

Salinity intrusion in the southern portion of the Central Plain has been detrimental to the extensive orchard and vegetable area along the Chao Phya river for a long time, especially when the flow is low. The extent of salinity intrusion can be controlled and the area protected can be increased with increased flows. At present a minimum flow of about 80 $m^3/s$ is released for salinity control in the Chao Phya river. However, about 20 $m^3/s$ is assumed to be used for water supply in the vicinity of the Bangkok Metropolitan Area.

Some 2,000 public and private production wells have been constructed for human consumption and sanitation in the Bangkok Metropolitan Area and adjacent areas. In the Bangkok

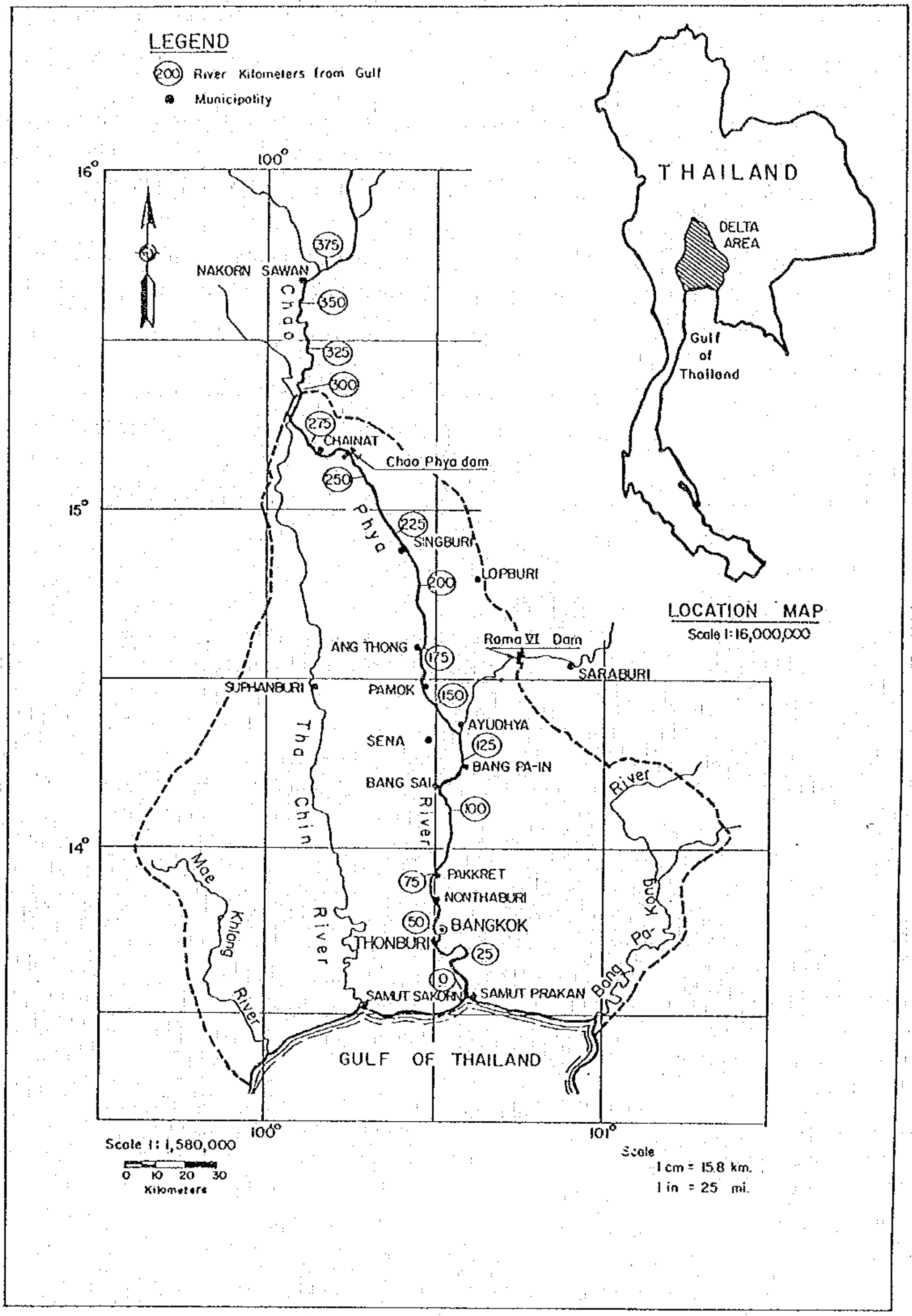



**Fig. 1. Chao Phya River Delta**

Metropolitant Area, one third of the total public water supply, some 92 million gallons per day, comes from aquifers.

Parts of the city are already protected against floods by partially completed polders. Emergency measures including sand bags, temporary cofferdams and mobile pumping units are also used when floods arise, as in the significant floods of October, 1978 and 1980.

Dredging of the Chao Phya River up to Nakhon Sawan by Inland Waterways Project of which the design has been completed by BCOM, might affect the hydrological and hydraulic aspects of Bangkok flood control and drainage project.

The general topography of the area is flat. The lowest and highest land elevations do not differ more than about one metre. The area is laced with canals (known as klongs) which were built for transport and defence purposes when Bangkok was founded two hundred years ago. During the monsoon season, rainfall and high water levels in the Chao Phya River cause flooding to depths of 70 cm on the roads.

The factor which most importantly affects consideration of sewage, drainage and flood protection systems for Bangkok Metropolis is the Chao Phya River, together with the canals in the area which are connected to the river.

## THE RIVER

The Chao Phya River drains an area of about 177,000 square Kilometers (68.500 square miles) (see Figure 2.) In the delta area south of Ayudhya, where Bangkok is located, the land is very flat. The main stream normally flows in a well defined channel below Ayudhya. When the river is in flood it inundates adjacent lands, with the water moving slowly toward the Gulf of Thailand. A small rise of the flood level extends the waters over extremely large areas. Fortunately the flood waters rise gradually and do not normally reach great depths.

The overall slope of the Chao Phya River is about 5.5 centimeters per kilometer (3.5 inches per mile). Below Bangkok the slope is at its minimum of about 2 centimeters per kilometer. At Bangkok the river has a minimum width of 180 meters (590 feet), with depths of as much as 20 meters (66 feet) or more. Downstream the width increases to 500 meters (1,640 feet) at river kilometer 10 (distance from the Gulf), and to more than 1,000 meters near its month.

The Royal Navy Yard is located at river kilometer 23. Additional smaller anchorage areas for commercial and naval vessels are at river kilometers 6, 31, 38 and 50. As a general rule,

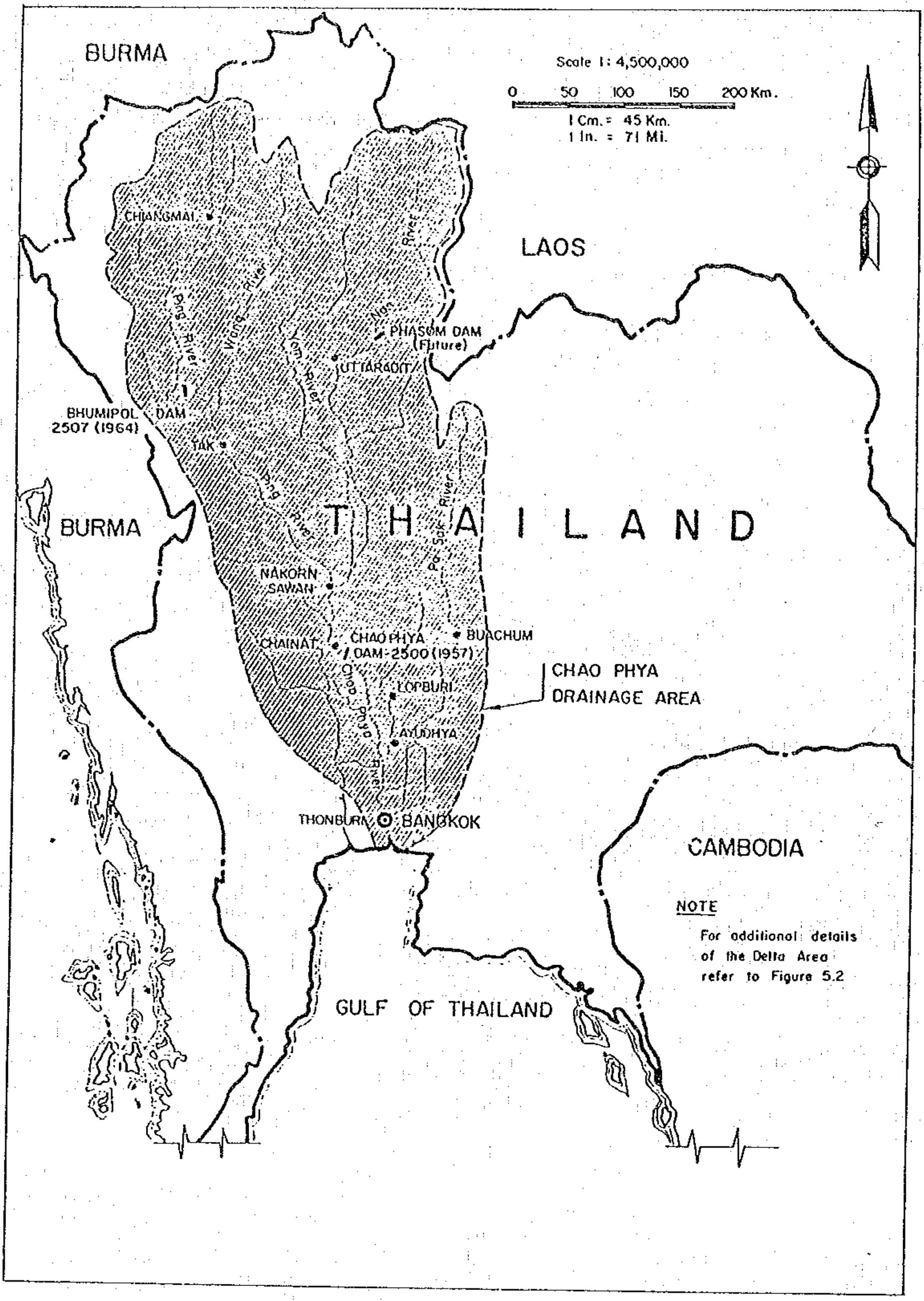
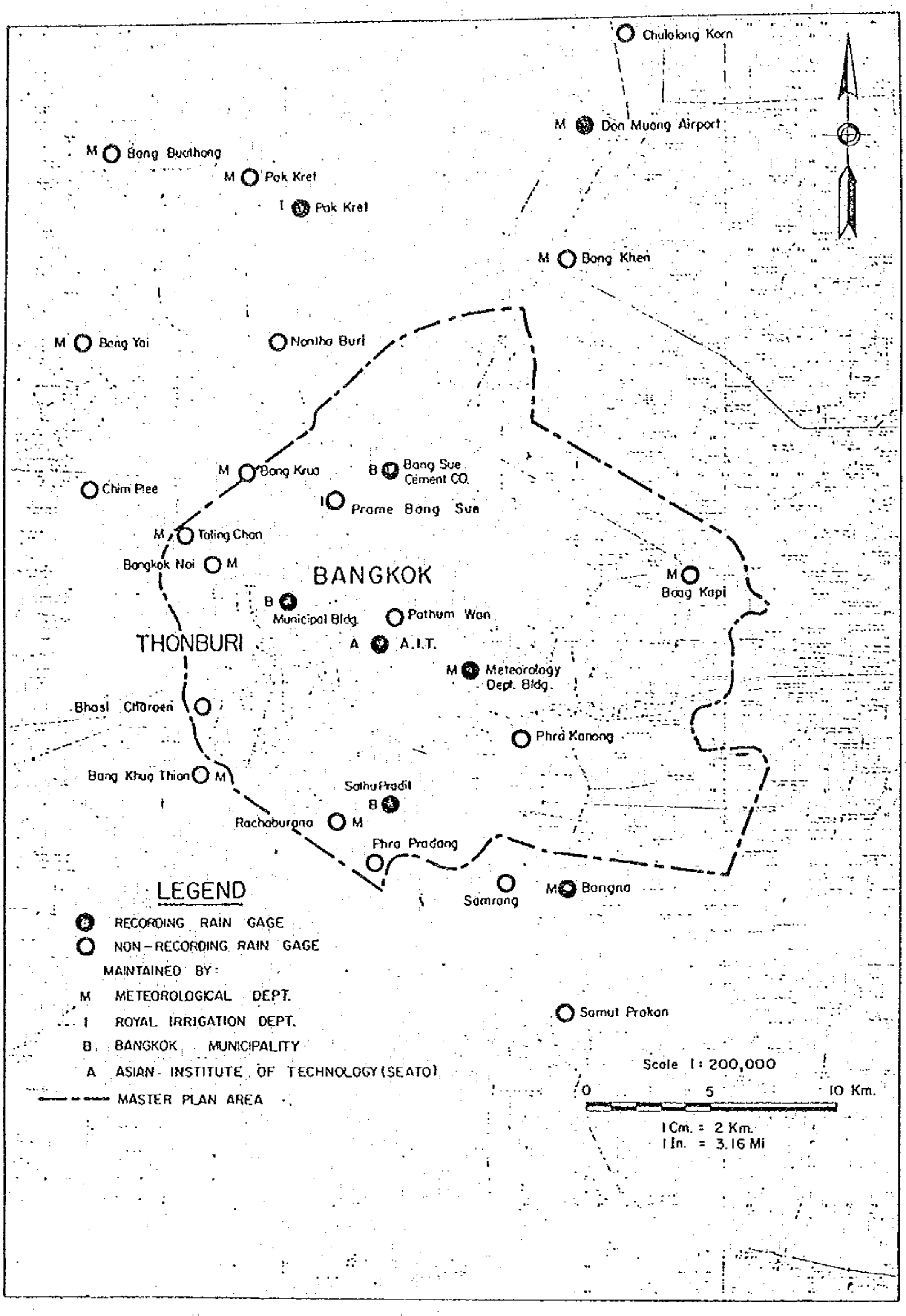



Fig. 2. Chao Phya Drainage Area




Rain Gage Locations Bangkok and Thonburi Area the river traffic above the Bangkok Port consists of river barges, small sea craft and river boats. Navigation of smaller sea going vessels is possible up to the Chao Phya Irrigation Dam and Lock at river kilometer 269 while other motorized river boats ply up to river kilometer 550. Some of these vessels also enter the larger canals.

## RIVER FLOWS

Until recently, during the period from January to July, the average river discharge at Bangkok was somewhat less than 100 CMS (3,530 cfs) with a minimum of 25 to 50 CMS around April. The discharge normally exceeds 1,000 CMS during the period from August to December with a maximum of 3,000 to 4,000 CMS in October. A typical discharge hydrograph is shown in Figure 3.

Records maintained at Ayudhya show that during the 126 year period from 1831 to 1957 there were 21 years of moderate drought, 35 years of severe drought and 5 years of extreme drought. They also show that 11 years had moderate floods, 4 years had severe floods and 2 had extreme floods.

## THE KLONGS (THE CANALS)

In the lower reaches of the delta the land is traversed by many klongs. Some of these klongs are natural but by far the majority are man-made. In the earlier days several of the klongs around Bangkok were constructed for defensive purposes. Later, others were added for navigation, drainage and irrigation needs. Additional klongs were dug to furnish fill material for road construction or to provide outlets for ubran storm-water runoff, as the city continued in its rapid growth the utilization of these klongs also changed. In the last decade many of the klongs have been converted into highways. Klongs which were originally constructed for irrigation purposes now often receive combined storm water and waste water to the point where many klongs in the central municipal area have become severely polluted and offensive. Navigation and the movement of farm products by water has decreased considerably in recent years within the fully developed parts of the city.

Before 1900 most of the homes were built next to the klongs because the basic means of transportation was by boat. Outside the larger urban areas the practice of locating houses adjacent to klongs it still widespread throughout the delta.

The major irrigation and navigation Klongs are well developed in and around Bangkok Metropolitan. Many of the major klongs have navigation locks or regulators built for

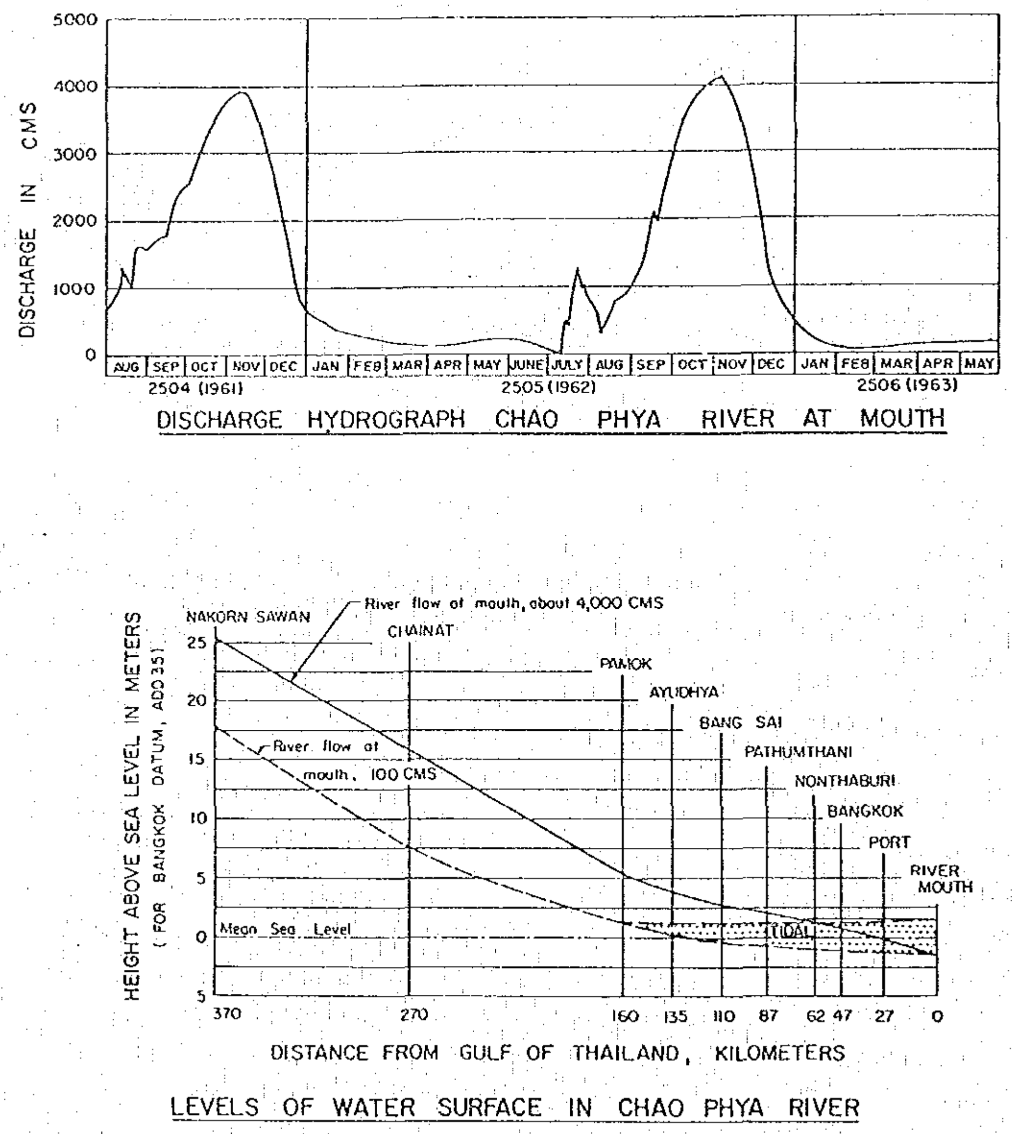



Fig. 3. Discharge Hydrograph and Water Surface of Chao Phya River

the purpose of controlling irrigation water levels. The policy of conservation of irrigation water towards the end of the flood season results in high water levels in the klongs which adversely affects the requirements for better and faster drainage of the urban lands.

The primary responsibility for maintenance of the major existing klongs is delegated to the Royal Irrigation Department. The smaller klongs within the city limits are maintained by the Municipality.

In 1966 the Road and Sewage Improvement Committee of the Ministry of Interior recommended that a number of the existing klongs be kept open and maintained for the purposes of navigation, irrigation and drainage. The more important of these klongs are shown on Figure 4.

An increasingly important use for the klongs in the city has been their use as a major source of water to fight fires. As the area has become more densely populated, the municipal water distribution system growth has not kept pace and now the needs for water supply alone, not considering fire requirements, cannot be met.

The klongs should continue as a source of supply for fire-fighting water in addition to serving as the most economical means of removing storm water. In addition to these practical functions the klongs are an important part of the historical culture of Bangkok.

## EFFECT OF TIDES

Tidal phenomena in the Gulf of Thailand are very complicated. The mean tidal range at Bangkok Bar (the mouth of the Chao Phya River) varies from 1.9 to 2.6 meters (6.2 to 8.5 feet) with a cyclical period of six months. The maximum ranges usually occur during June and December and the minimum about March and September. The large tidal ranges are usually diurnal (one cycle per day) in character while the smaller ranges tend to be more semi-diurnal (two cycles per day) in character. If a cycle is defined only as the period between low waters lower than mean sea level, the average tidal cycle throughout the year varies from about 18 to 24 hours.

Over a 10 year period, observations at Bangkok Bar indicate that highest high water was 2.0 meters (6.6 feet) above mean sea level and lowest low water was 2.3 meters (7.6 feet) below mean sea level. Over a 51 year period from 1914 to 1965 observations of water surface elevations at Memorial Bridge in Bangkok (river kilometer 47) indicate that the highest level reached elevation 37.45 (2.42 meters above mean sea level) in October 1942 and the lowest level reached elevation 33.40 (1.63 meters below mean sea level) in July 1965.

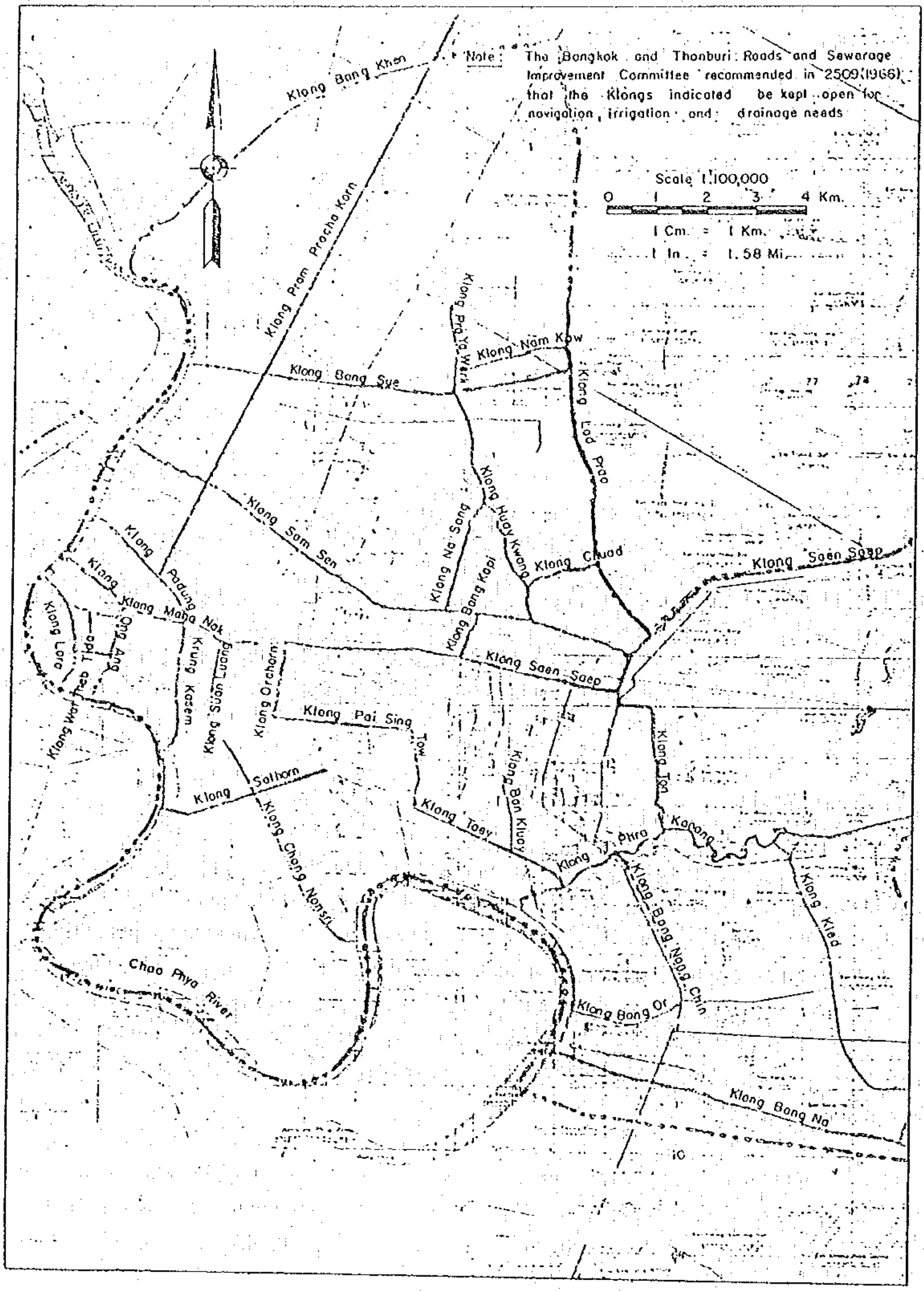



Fig. 4. Major Klongs Recommended for Retention by Government Agencies

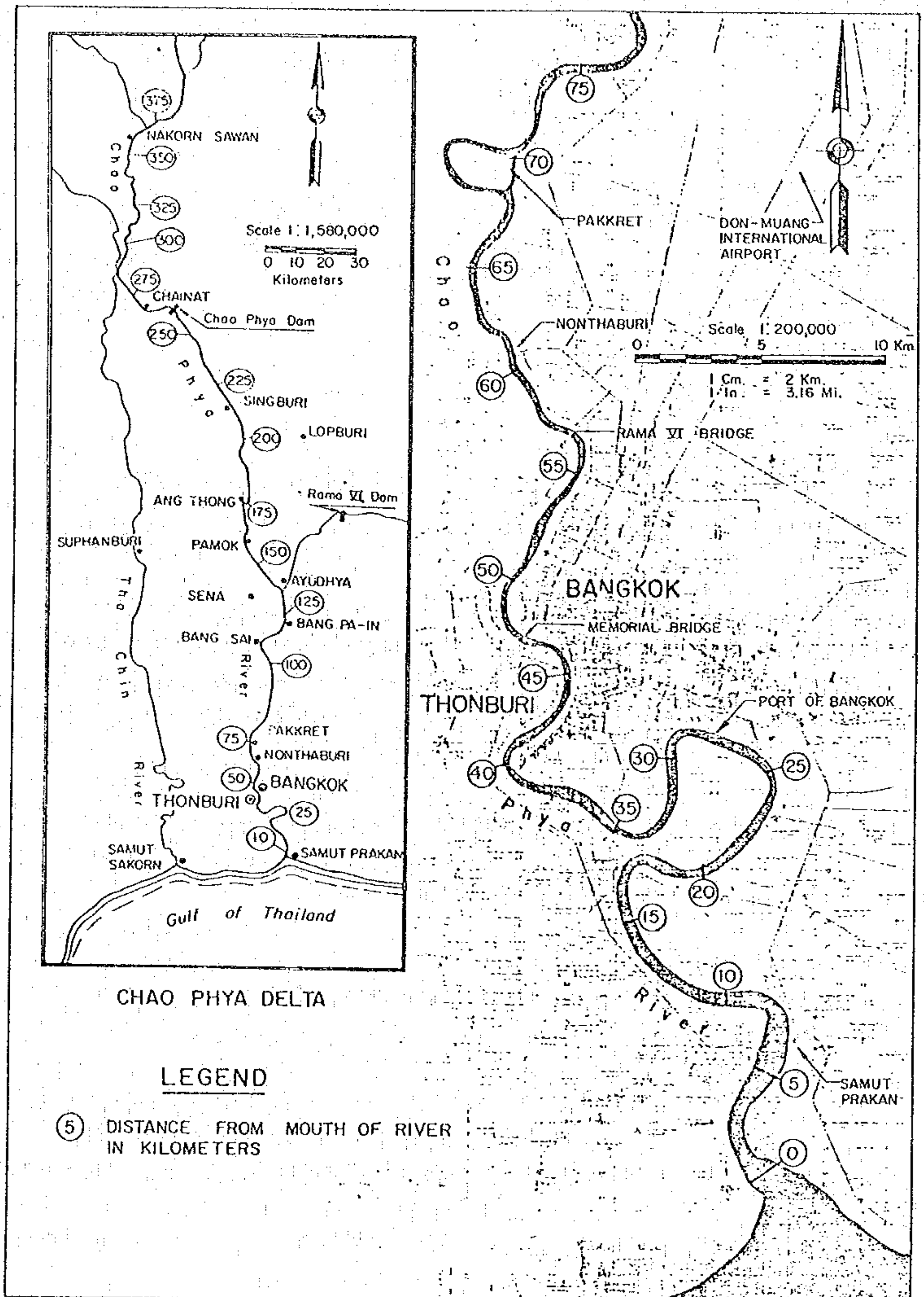



Fig. 5. Chao Phya River Stationing

The elevation of the water surface of the Chao Phya River and the extent of saline intrusion in the river are proportional to the river flow as well as the effects of the tides. For river flows as low as 100 CMS (3,500 cfs) the tide effects the elevation of the water surface as far north as Pamok at river kilometer 160. For a similar low flow the intrusion of salinity would be up to river kilometer 60. Under the condition of extremely low flows of 50 CMS and 20 CMS, the saline intrusion would extend to river kilometers 75 and 110, respectively. Conversely, if a minimum flow of 200 to 250 CMS can be maintained in the river the saline intrusion barrier would be moved down to Klong Toey at the Port of Bangkok, river Kilometer 27. These data are based on observations made by NEDECO[1] in a report to the Government of Thailand.

## LAND USE

The salient features of the plan are as follows: The old central section of Bangkok Metropolitan which is now densely populated would remain as mixed commercial and residential areas. Urban renewal projects are expected to improve living conditions and traffic condition but the population density of the entire area would not be materially affected even though some reductions in local areas are contemplated. Future development would be directed outward from the center along radial highways and waterways. The newly developed areas would be separate units, each having manufacturing, residential, commercial and institutional or service zones. In the new areas, commercial services would not stretch out along the main roads in small combined business and dwelling units. Commercial – retail areas would be confined to markets and shopping centers of the main highways with provision for off-street parking. Open green areas, recreational and agricultural, would be interspersed between the developed raidal areas.

The categories of proposed land use are as follows:

1. **Residential:**
   Residential areas are divided into three classes: low density, medium density and high density.
   These are described as follow:
   Low density covers single family houses, each on its own lot, with lawns between.
   Medium density covers the row houses and garden apartments or courts.
   High density includes high rise apartment developments and closely spaced low rise units.
   Each newly developed residential area would have shopping centers, schools and other essential service units.

---

1 "Siltation of the Bangkok Port Channel W, July 1965, Netherlands Engineering Consultants (NEDECO), The Hague, Holland.

2. **Commercial:**

Commercial areas are divided into two classes, high density and low density. The old central commercial ara between Klong Padung Krung Kasem and Klong Lord is really an area of mixed commercial – residential use. The population concentrations here are the highest in Bangkok Metropolitan with shop owners and their families living directly over or adjacent to their place of business. This area and a section of Pathum Wan (to the east of Klong Padung Krung Kasem) are classified as high density commercial. The recently developed commercial areas such as Bang Rak, centered on Silom Road, have a lighter density. Existing office building, hotels, and sotres in this area are in accord with modern practices. In future expansion, commercial zones would provide ample space for parking, sidewalks and rest areas. Sections such as these are classified as low density commercial.

3. **Manufacturing:**

The manufacturing category includes the sites of existing heavy and light industries and future sites along the river, main highways and railways. Three extensive new areas have been proposed for industrial development. Two are sited along the Chao Phya River to the south, and one along the railroad, to the east.

4. **Institutional:**

The institutional category covers most public buildings from schools and universities to the offices of international agencies and the Royal Palace. The government agencies usually provide housing for the civilian personnel as well as the military. A few of the more extensive of these housing areas have been zoned as residential for design purposes.

5. **Utilities:**

The utilities category covers the major public utilities installations such as the railway yards, the port area and water and waste-water facilities. Many utilities have been relocated since the original plan was submitted.

6. **Green Areas:**

Green areas are divided in two classes, recreation and agriculture. The recreation areas shown on the plan include about 15 square kilometers or four per cent of the entire area. In addition to the above, small playgrounds, playing fields and open spaces would be provided throughout the large residential areas. The agricultural areas are now devoted to agriculture and, principally because of their location, are likely to remain so for quite some time.

## PRESENT SITUATION

- Bangkok has a ground level which is an average of 1.0 metre above Mean Sea Level;
- During periods of very high discharges of the Chao Phya River and of high tide levels in the Gulf of Thailand extensive flooding of low lying areas in Bangkok occurs;
- High intensity rainfall and drainage problems occur during August through October;
- The Bhumipol and Sirikit Dams and the Chainat barrage provide some degree of flood control to Bangkok: accoridng to the Acres/RID paper, these dams cannot provide greater flood control benefits in Bangkok than are presently being achieved;
- Accoridng to the Acres/RID paper, there are no opportunities for new storage projects which would result in major increases in the degree of control of flows in the lower Chao Phya Basin;
- Plans for agricultural development and improved drainage of the so-called Central (Bangkok) Plain will result in an increase in high water discharges of the Chao Phya River near Bangkok. This increase will partly offset the flood control effect of the Bhumipol and Sirikit Dams and the Chainat Barrage;
- It is not anticipated that improvement of the flooding conditions in the areas to the north of Bangkok, if feasible, would substantially reduce flood problems in the Bangkok region.

**The Chao Phya River Basin**
**The Control of Water**

The Bhumiphol reservoir controls the outflow from a catchment area of 26,400 $km^2$ and the Sirikit reservoir from 13,200 $km^2$. The combined area is only 39,600 $km^2$ or about 36 percent of the area drained by the Chao Phya River at Nakhon Sawan and 22 percent of the area of the entire basin. There are no opportunities for new storage projects which would result in major increases in the degree of control of flows below the two major dams in the Chao Phya Basin.

**Project Relationship with Chao Phya Basin**
**Development Plans** •

The following line diagram amply indicates the complexity of the river network which drains the Chao Phya river basin.

In the north the landscape is characterized by north-south trending mountain ranges and highlands. In this area the Ping, Wang, Yom and Nan rivers are well defined and their streamflow time series are well documented. In recent years the Bhumipol, Kewlom and Sirikit dams on the Ping, Wang and Nan rivers have significantly reduced the potential for flooding in the lower Chao Phya basin due to heavy rainfall in their catchment areas. Further control of these northern rivers is scheduled which will modify the storm discharge patterns at their confluence at Nakorn Sawan, where the bankful capacity is only some 3,700 $m^3/s$. The Upper Ping river basin is currently under development for hydropower, irrigation and flood control, the latter being particularly important for Chiang Mai. When fully developed, this river network will significantly reduce flood potential at this northern capital. Development of the Koeng Sua Ten dam in the Yom basin is being studied, as is the Ping-Yom–Nan transbasin diversion scheme. When completed, these various projects will result in a high degree of control of these northern rivers.

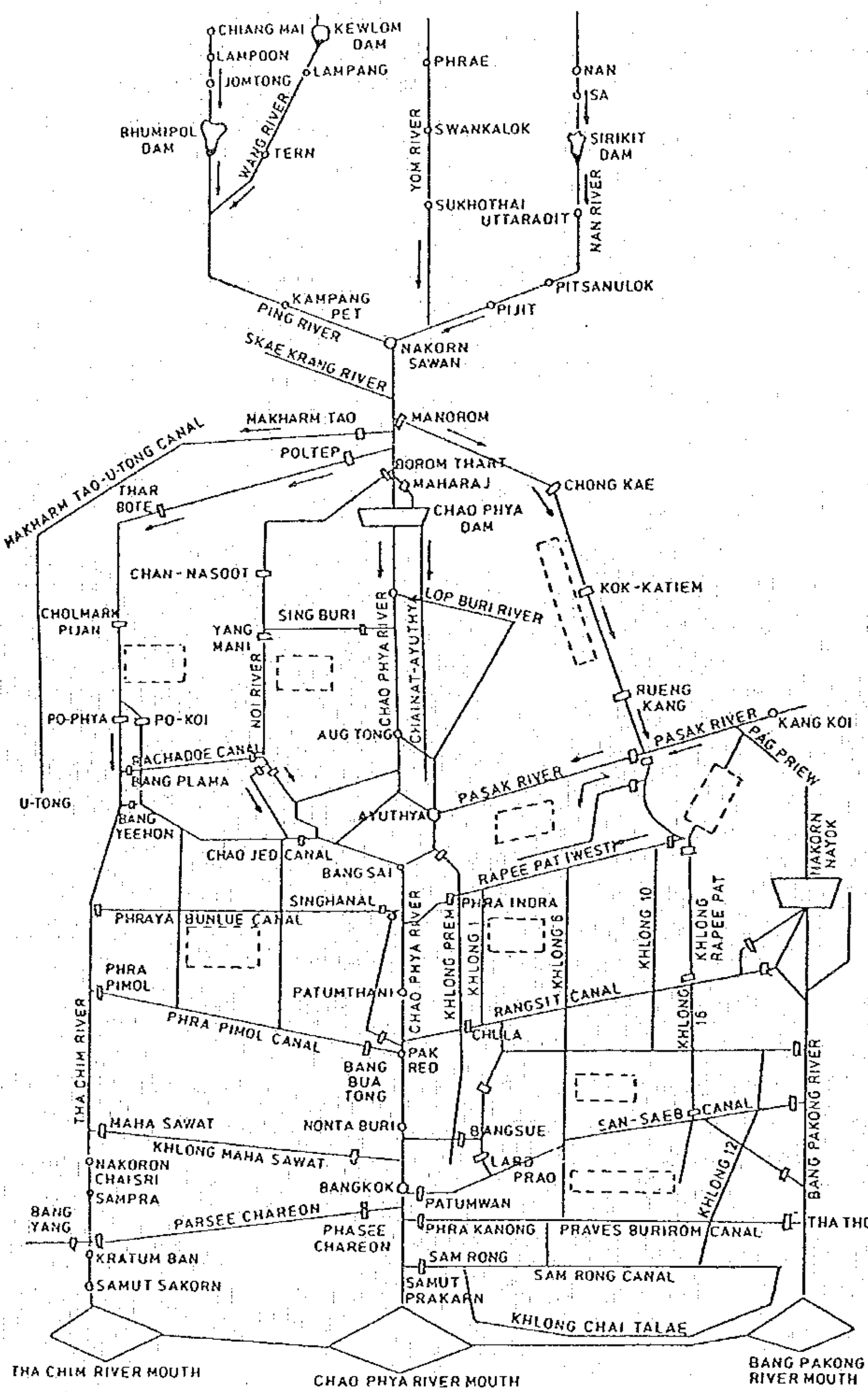
Further south, the Skai-Krang river discharges into the main stem of the Chao Phya just north of the Chainat Dam. It is at this point that the Chao Phya river discharges into the central plain of Thailand. The samll bankful capacity of the river at this point, 3,200 $m^3/s$, the flatness of the topography, and diversions into the irrigation service areas supplied from the Chainat Dam spreads the monsoon season flows over a wide area into a network of canals and natural drains. The Ta Chin river, to the west of the main stem, acts as a major branch of the Chao Phya river and carries significant excess flows past Bangkok to discharge into the Gulf at Samut Sakorn.

A further major source of flooding, further south and entering the main stem of the river at Ayuthya, is the Pasak river. In 1978 exceptionally heavy monsoon rainfall centered over this basis and contributed signficiantly to the flood problem in Bangkok.

South of Ayuthya the terrain is very flat and the land is web of interconnecting canals and drains. Some of these run north-south such as Klong Prem, Klong No. 6 and Klong Rapepat, while others such as Klong Rangsit and Klong San Saep, intercept these and tend to drain back towards the main stem of the river. Klong San Saep, of course, runs right through Bangkok.

Bangkok is thus attacked not only from the main stem of the river but also from overland flow from the north, the north-east and the east.

Much can be done to reduce peak flood flows from the northern rivers. The Skai Krang river can be partially controlled and studies have already been undertaken to examine the potential for control of the Pasak River. These are long term developments and the Ping-




Chao Phya River Basin — River Network

Yom-Nan diversion scheme could reduce the beneficial effects of these storage schemes. Clearly, in the near term, Bangkok will not benefit from these schemes.

A more immediately beneficial scheme is that developed by RID by Royal Initiative. The conceptual guidelines for this project are:

- Improve discharge through a system of canals to the east of Bangkok to drain this area more effectively to the Gulf. Klong to be so improved are Klong Praya Surenth, Klong Moh Tack, Klong Song, Klong Lam Pak Ch, and Klong Tong Lang.

- Establish a green belt in the Klong Praya Surenth and Klong Sam Wa or Klong Sam Wa and Klong Pet area to facilitate construction of main drains now and in the future.

- Construct flood protection systems within the Bangkok area – the BMA Project.

- Construct flood retention areas within Bangkok as a means of strengthening the effectiveness of the flood prevention scheme. This work is reported to be in hand and will be considered under the Project studies for rural and semi-rural areas.

- Extend and open the waterways to the east of Bangkok at various highway and railway crossings.

- Klong cleaning in Huay Kwang, Prakanong and Bangkapi areas.

- Weed eradication in the canals east of Bangkok.

RID advise that the major work outside the Project area is to commence in 1982–83.

**Flood Control Benefits of the Major Reservoirs**

The Acres/RID paper shows that nearly all the flood reduction benefits which can be provided by the Bhumiphol and Sirikit reservoirs automatically result from operation of the reservoirs to meet downstream water needs. The Ping and Nan River reservoirs cannot provide greater flood control benefits in Bangkok than are presently being achieved.

**Flood Protection System**

The natural ground level in Bangkok varies from about elevation 0.5 m to 1.5 m

+ MSL. On the average this represents a height of one metre above mean sea level. Normal tidal range at Bangkok is slightly over one metre.

The concept of polders has been accepted in principle for Bangkok and a construction programme has been underway for some years. Parts of the city are already protected against floods by partially completed polders. Emergency measures including sand bags, temporary cofferdams and mobile pumping units are also used when floods arise, as in the significant floods of October, 1978 and 1980.

Permanent pumping stations have already been built for polders number 1 and 2 and many sections of the peripheral embankments, usually comprising permanent roads, are already built, but flooding is still a recurring and costly problem which is worsening.

**The River and Flood Stages**

The overall slope of the Chao Phya River is about 5.5 cm per km. Below Bangkok the slope is at its minimum of about 2 cm per km.

A serious flood was in 1952 when the river level rose to about 0.7 m above the roads in Bangkok. The maximum flood level reached at Memorial Bridge (river km 47) an elevation of 2.3 m + MSL. During that flood practically the entire area of Bangkok was under water for nearly one month.

Downtown districts and residential areas have been filled to elevations between 1.5 and 2.0 m + MSL. In general the built-up ground is just below the expected 100-year frequency river flood level but the natural ground is subject to annual flooding.

It must be pointed out that the expected river flood levels are subject to change. The Royal Irrigation Department reported in 1964 that the average flood levels in the Chao Phya River tend to increase every year by about 1.1 cm. This annual rise seemed to have been checked by the constructed upstream flood control and diversion structures. However, in recent years flooding appears to be on the increase.

**Economics**

The Government has attempted to quantify losses from some past floods. The localized flood of June 1979, which inundated about 5 $km^2$ for about 3 days are estimated to cost Baht 100 million. The more general and extensive flood of October 1975, which inundated several large areas of the city for up to two months, was estimated by the Government to cost about Baht 580 million.

## Water Transportation
### Venice of the East

Two hundred years ago, Bangkok was a quiet river-side-village situated near the mouth of Chao Phya River. King Rama I, the founder of the Capital took the advantage of the low lying topography and soft clay to excavate a crescent shaped canal linking Chao Phya River to form an oval moat surrounding the city. From then on, many canals were excavated to form a network of waterways throughout the city and the surrounding area. It reflects the Thai appreciation of the value of water and the dependency on it as a means of irrigation, flood control and transportation. An early map of the city, is evidence of this: it shows the area crisscrossed by canals. Because of this, the city was dubbed the "Venice of the East".

Being the tropical zone and on low-lying area, seasonal flooding of Bangkok is unavoidable. The old generation of Bangkokians built their houses on stilts to avoid the flood. But as commerce flourished, Bangkok grew, stilted houses gave way to modern buildings, canals to roads, but flooding remained. But this time, it caused great damage to the city not only in monetary terms but political as well.

### Existing Main Canals

The main canals which crisscross and form networks in the proposed project are:

1. Klong Lord, running from Chao Phya River to Sanam Luang with total length of about 1.8 km.

2. Klong Ong Ang and Klong Banglampoo, forming a creascent shaped route about 3.5 km across the area with opening at both ends to Chao Phya River.

3. Klong Pradung Krung Kasem, a crescent shaped canal of about 5.5 km in length with both ends opening to Chao Phya River.

4. Klong Mahanak running east-west about 1.3 km in length connecting Klong Banglampoo to Klong Pradung Krung Kasem.

5. Klong Saen Saep extends from Klong Mahanak eastward for about 9.5 km in the project area. This canal has a extensive conneciton with other canal networks in the surrounding area.

6. Klong Sam Sen running east from Chao Phya River with total length of about 5 km in the project area.

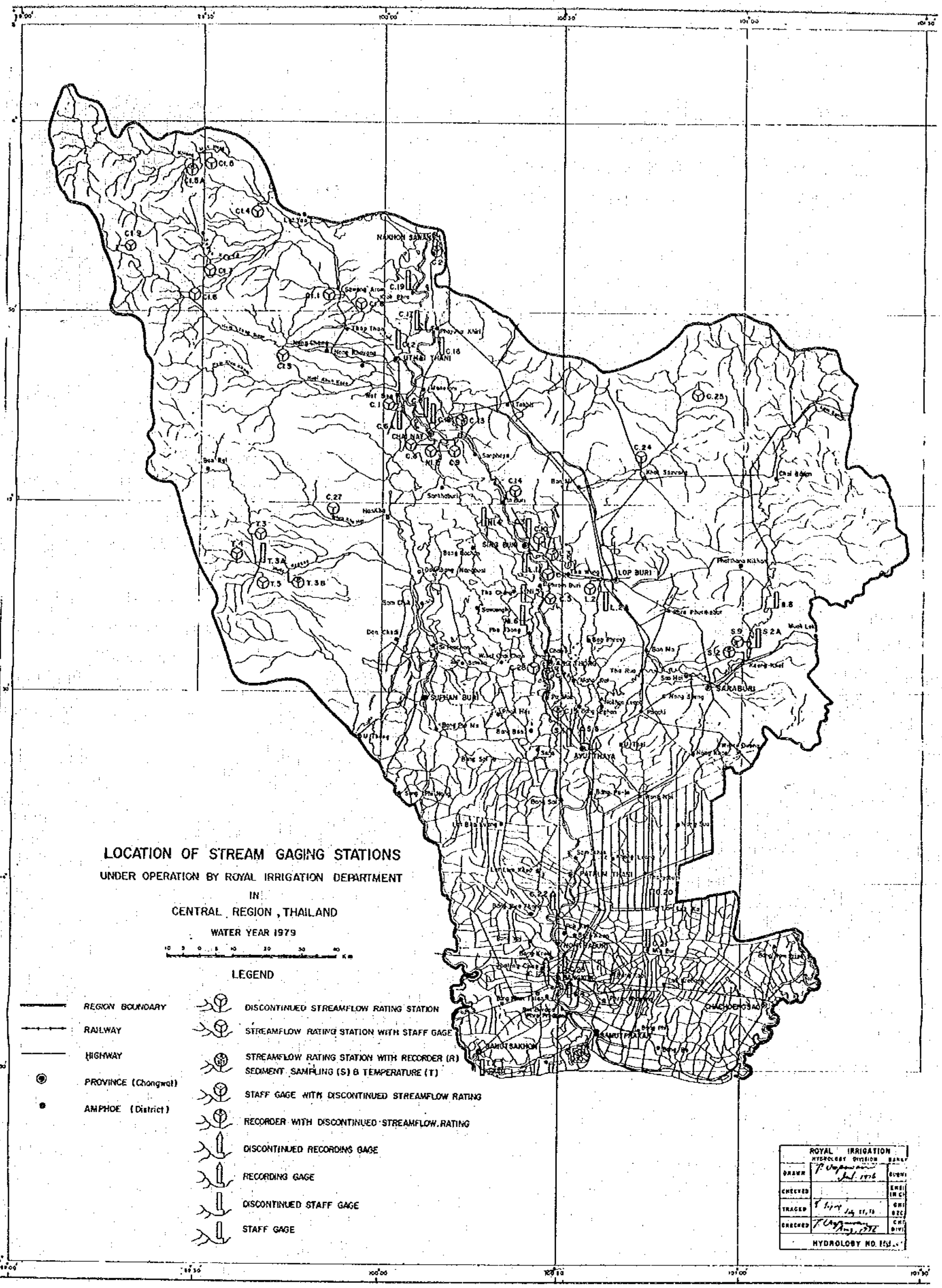
7. Klong Prem Prachakorn running north-south for about 5.6 km connecting Klong Prandung Krung Kasem to Klong Sam Sen and Klong Bangsue.

8. Klong Bangsue forming a north boundary of the area. This Klong starts from Chao Phya River and runs due west for about 1.8 km to join Klong Prem Prachakorn.

**Waterborne Transport and Navigation**

Canals in Bangkok have served at transportation channels for a long time. They allow the populace to be mobile, provide cheap transportation for minimum investment and without importing equipment.

In view of the fact that there are many canals in Bangkok, it is an advantage to utilize and incorporate them into the flood control programme. A series of dikes and gates can be built across the canals and flood water is removed by pumping during the flood season. However, it should be emphasised that several canals are being used for transportation as well. Therefore, it is important that particular attention should be paid to them.



LOCATION OF STREAM GAGING STATIONS
UNDER OPERATION BY ROYAL IRRIGATION DEPARTMENT
IN
CENTRAL REGION , THAILAND
WATER YEAR 1979
LEGEND
REGION BOUNDARY
RAILWAY
HIGHWAY
PROVINCE (Chongwat)
AMPHOE (District)
DISCONTINUED STREAMFLOW RATING STATION
STREAMFLOW RATING STATION WITH STAFF GAGE
STREAMFLOW RATING STATION WITH RECORDER (R)
SEDIMENT SAMPLING (S) & TEMPERATURE (T)
STAFF GAGE WITH DISCONTINUED STREAMFLOW RATING
RECORDER WITH DISCONTINUED STREAMFLOW RATING
DISCONTINUED RECORDING GAGE
RECORDING GAGE
DISCONTINUED STAFF GAGE
STAFF GAGE
ROYAL IRRIGATION
HYDROLOGY DIVISION
DRAWN
CHECKED
TRACED
CHECKED
HYDROLOGY NO.
NAKHON SAWAN
UTHAI THANI
CHAI NAT
SING BURI
LOP BURI
ANG THONG
SUPHAN BURI
SARABURI
AYUTTHAYA
PATHUM THANI
NONTHABURI
SAMUTSAKHON
SAMUTPRAKAN
CHACHOENGSAO