# 6. Measurement and Maintenance of Hydrological Instruments

## 6.1 General

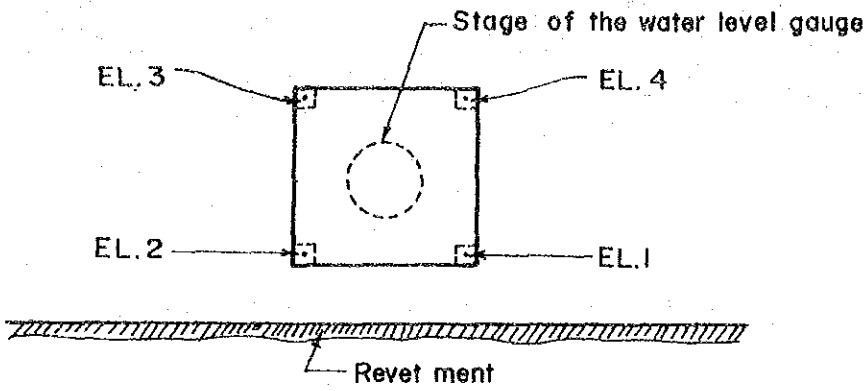
Two new automatic recording rain gauges and twelve new water level gauges have been installed to collect reliable data for understanding the hydrologic phenomenon which will be essential for the analysis.

Data collection has started at the beginning of August. After the Study Team returned to Japan, the measurement and maintenance have been performed by DDS.

## 6.2 Location and Specification

Location Map of gauging stations is shown in Fig. F.41. Top evaluation of the foundation for water level gauge is presented in Table F. 16.
The specification of each gauge is as follows:

Table F.16 Top Elevation of The Foundation for Water Level Gauge

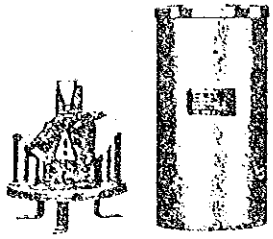



PLAN

| Station | EL. 1 | EL. 2 | EL. 3 | EL. 4 |
|---|---|---|---|---|
| (A) | 37.163 | 37.155 | 37.159 | 37.160 |
| (B) | 36.868 | 36.863 | 36.859 | 36.860 |
| (C) | 36.988 | 36.996 | 36.995 | 36.986 |
| (D) | 36.740 | 36.756 | 36.752 | 36.743 |
| (E) | 36.858 | 36.858 | 36.856 | 36.849 |
| (F) | 36.399 | 36.398 | 36.397 | 36.402 |
| (G) | 36.539 | 36.537 | 36.536 | 36.532 |
| (H) | 35.832 | 35.830 | 35.830 | 35.823 |
| (I) | 36.237 | 36.234 | 36.238 | 36.226 |
| (J) | 36.302 | 36.302 | 36.305 | 36.301 |
| (K) | 36.335 | 36.339 | 36.337 | 36.331 |

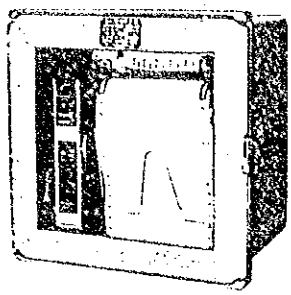
Note : Meam sea level is EL. 35.030 m

(1) Automatic Recording RAin Gauge



B- 020

Transmitter



B- 350

Recorder

Transmitter Specifications

| Catalog No. | Sensitivity | Heater | Application |
|---|---|---|---|
| B-020 | 1.0 mm | | Rain gauge |

Recorder Specifications

| Catalog No. | B-330,340 & 350 |
|---|---|
| Type | Electromagnetic-type |
| Recording points | 1 |
| Recording system | Zero reset at 100 counts (repeat recording) |
| Recording period | 3 months |
| Chart drive | Transistor clock (B-350) |
| Power supply | 12 V DC, 180 mA |
| Dimensions (mm) | 480(W) x 310(H) x 400(D) |
| Weight (approx.) | 17 kg. |

(2) Automatic Recording Water Level Gauge

(a) Richal-type water level gauge

These instruments can measure and record the water level of rivers, dams, tidal ebb and flood over extended periods. Extremely accurate recording is possible at all times whether at normal or flood levels.

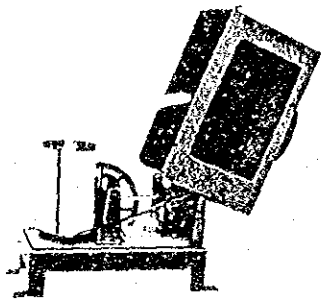


Figure Richal-type Water Level Gauge

Specifications

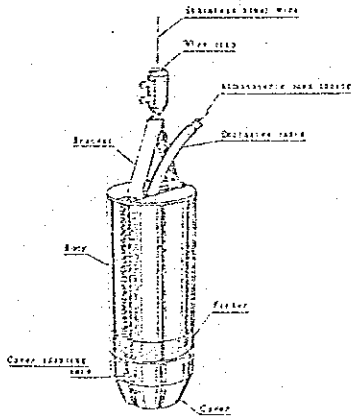
| | | |
|---|---|---|
| Type | : | Richal-type |
| Float diameter | : | 180 mm |
| Measuring range (special order) | : | 0 to 3 |
| Sensitivity | : | Less than $\pm$ 2 cm |
| Accuracy | : | Within $\pm$ 2 cm |
| Recording system | : | Reciprocating motion type |
| Chart dirve | : | Spring clock |
| Recording period | : | 1 day or 7 days |
| Dimensions (mm) | : | 335(W) x 145(H) x 250(D) |
| Weight (approx.) | : | 4.2 kg. |

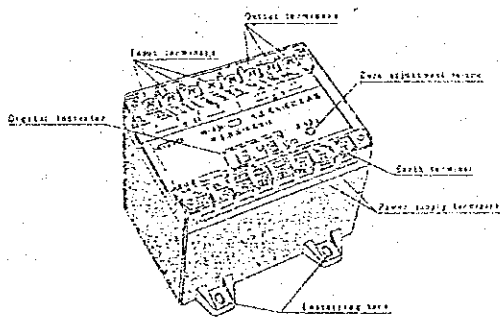
(b) Water pressure-type water level gauge

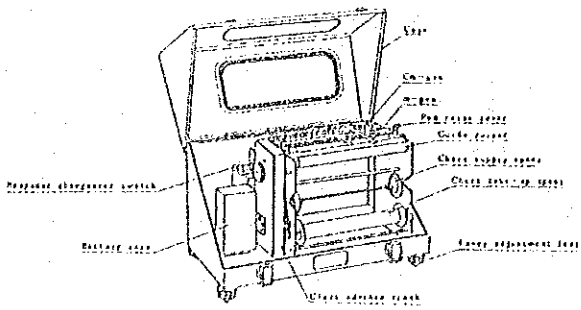
NAKAASA Model W-431 Water Level Gauge is used for measuring water level of Dam, River, Reservoir, Deep Well and others. For measurement, convert water pressure to electric signal and performed high accurate and excellent stability of water level measurement with small size.

Also, can be assured long period of water level measurement by using battery if a power supply for the area of commercial electricity is not available.

NAKAASA Model M-143 Analog Recorder is placed at the observation room away from the measuring point of water level and input water level datas converted to the DC voltage and continously recording for long periods by 2 Pens linear tracing.







## SPECIFICATIONS OF SENSOR AND CONVERTER

(1) Measuring range : 0 to 10, 20 30 or 50m.
(Range are described on Test Certificate)

(2) Output signal : 0 to 5V DC.

(3) Linearity & hysteresis : Within $\pm$ 0.1 % of full scale.

(4) Temperature compensation range : 1 Sensor ; -2 to +30°C.
2 Converter ; 0 to +50°C.

(5) Zero point & sensitivity variation : Within $\pm$ 0.3 % at sensor temperature -2 to +30°C (including converter).

(6) Indication : 4 digits digital display, Unit ; 0.01 m.

(7) Level shift : Within $\pm$ 15 % (Portion for shift, measuring range is smaller against full scale).

(8) Power supply : 10.8 to 16.7V DC.

(9) Power consumption : Approximately 25 mA.

(10) Exclusive cable : 50 m. 4 conductor shelded cable with atmospheric open tubing.

(11) Dimensions : 1 Sensor ; 38 x 140 mm.
2 Converter ; 115(W) x 117(H) x 127(D) mm.

(12) Weight : 1 Sensor ; 50 g. (without cable)
2 Converter ; 50 g.

## SPECIFICATIONS OF RECORDER

(1) System : Self balance type.

(2) Drive motor : Brushless DC servo type.

(3) Measuring range : 0 to 10, 20 or 50 meters.
(Range are described on Test Cirtificate)

(4) Input signal : 0 to 5V DC.

(5) Accuracy : Within $\pm$0.1 % of full scale.

(6) Recording system : 2-pen linear tracing system.

(7) Response
1 Continuous operation : 30 sec/100 cm.
2 Intermittent operation : Approximately 4 min./100 cm.

(8) Recording pen : Felt cartridge pen.

(9) Recording chart : Roll type chart, Effective width 200 mm.

(10) Chart speed : 6 mm/h.

(11) Chart drive : Quartz clock mechanism.

(12) Recording period : 3 months.

(13) Power supply : 10.8 to 16.7V DC.

(14) Power consumption
1 When balancing : Approximately 25 mA.
2 When pen running : Approximately 30 mA average intermittent operation.

(15) Environmental condition
1 Temperature : -10 to +50°C
1 Relative humidity : 90 % or less.

(16) Dimensions : 470(W) x 285(H) x 250(D) mm.

(17) Weight : Approximately 18 kg.

## 6.3 Maintenance and Measurement

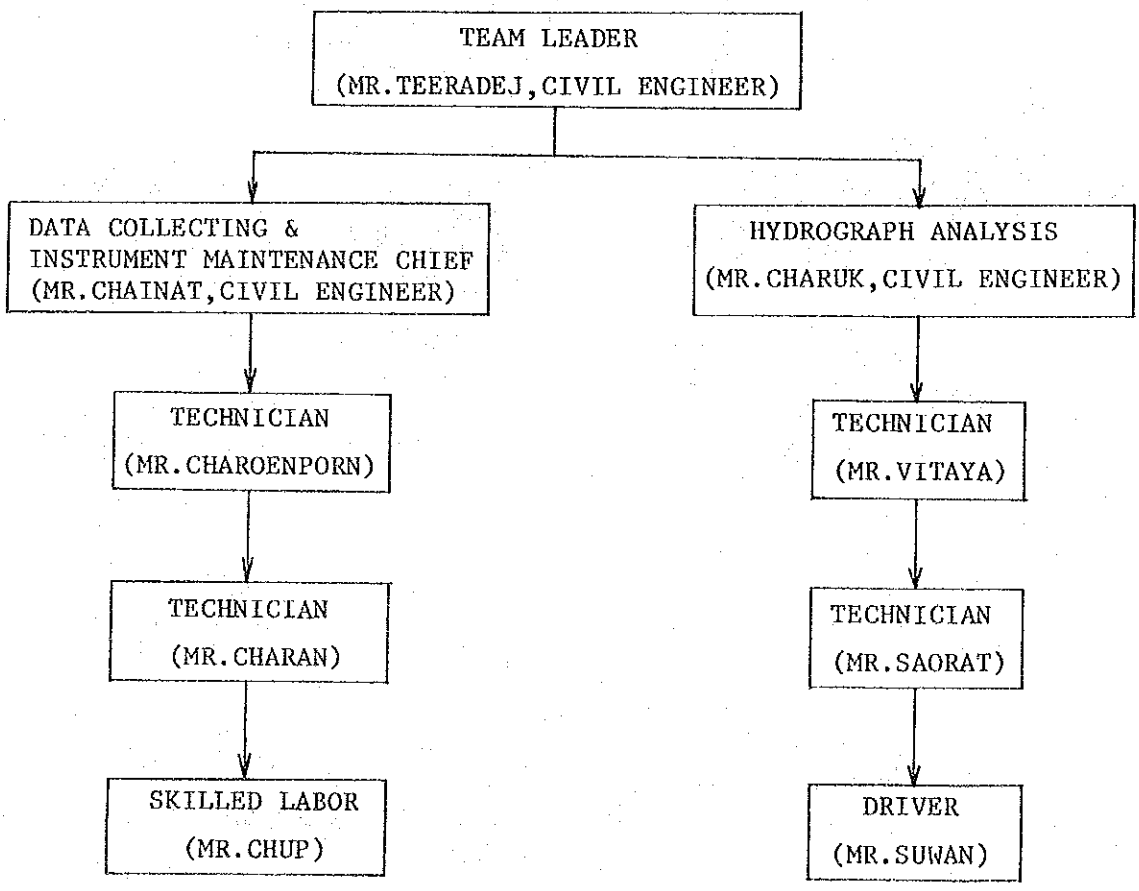
### 6.3.1 Organization for Maintenance and Measurement Team of DDS

The maintenance and measurement has been carried out by the members of Designing Section which is under the Technical Division of DDS. The team for this words consist of two groups. One is the Data Collecting and Instrument Maintenance group and the others is Data Measurement group.

The organization chart for the maintenance and measurement works is as follows:

Organization chart for the Maintenance and Measurement Works.

ORGANIZATION
OF
DATA COLLECTING, INSTRUMENT MAINTENANCE & HYDROGRAPH ANALYSIS TEAM



### 6.3.2 Maintenance Works

(1) Maintenance Items and Contents

The summary of the maintenance items and contents show in Table F.18 to Table F.20 and Details are indicated in the instruction manuals which was submitted to DDS by the study team.

(2) Maintenance Schedule

The interval of maintenance for each gauge is shown in Table F.17.

Table F.17 The Interval of Maintenance

| Item / Gauge | Usual Maintenance | Chart Installation | Number of gauge |
|---|---|---|---|
| Rain Gauge | 2 weeks | 1.month | 2 sets |
| Richal-type Water Level Gauge | 1 week | 1 week | 11 sets |
| Water-Pressure type Water Level Gauge | 2 weeks | 3 months | 1 set |

Since the fourteen gauges are located in distance and the interval of maintenance of three kinds of instruments is different, the maintenance can be carried out more efficiently by four gauges group such as A- B- C- D , E- F- G- H , J- K- L and I- 1- 2 . Table F.21 shows the maintenance schedule from August to December in 1983.

Table F.18 Maintenance Items and Contents of Automatic Rain Gauge

| Item | Contents | Interval | Reference Page of instruction manuals |
|---|---|---|---|
| Cleaning the rainfall inlet | Wash away dust on the wire net in the rainfall inlet | 2 months | Page 13 |
| Cleaning the filter | Remove sand deposits in the filter | 2 months | Page 13 |
| Check the connecting terminals | Remove dusts, rust, etc., of the connecting terminals unit | 2 months | Page 13 |
| Exchange the chart paper | | 1 month | Page 8 |
| Ink refil | Check the amount of ink contained in recording per reservoir | 2 weeks | Page 11 |
| Cleaning the pen | | 1 month | Page 14 |
| Check the pen balance | Always rebalance the pen after removal, cleaning or replacement by rotating the counterweight | 1 month | Page 10 |
| Check the battery for clock | | 6 months | Page 15 |
| Check the voltage of the battery | Check the power supply of the battery by using the check switch | 2 weeks | Page 11 |

Table F.19 Maintenance Items and Contents of Water Pressure-type Water Level Guage

| Item | Contents | Interval | Reference Page of instruction manuals |
|---|---|---|---|
| Adjustment of pen position | Adjustment between the pen tip position and actual water level | 2 weeks | Page 8 |
| Replacement of chart paper | | 3 months | Page 5 |
| Replacement of recording pen | | 3 months | Page 6 |
| Time setting | | 2 weeks | Page 7 |
| Clock operation | Check the rotating step of the pulse motor axle | 2 weeks | Page 9 |
| Zero adjustment of pen | Check the cm-pen and m-pen zero points | 2 weeks | Page 7 |
| Battery check | Check the power supply of the battery by using the check switch | | |

Table F.20 Maintenance Item and Contents of Richal-type Water Level Gauge

| Item | Contents | Interval | Reference Page of instruction manuals |
|---|---|---|---|
| Adjustment of pen position | Adjustment between the pen tip position and actual water level. | 1 week | Page 7 |
| Replacement of chart paper | | 1 week | Page 4 |
| Ink refil | Check the amount of ink contained in recording pen reservoir. | 1 week | Page 5 |
| Pen tip cleaning | Cleaning of pen tip by using a needle or similar instruments. | 1 month | Page 6 |
| Clock winding | Carefully winding up clock by using key. | 1 week | Page 5 |

Table F.21 Maintenance Schedule for Rain Gauge and Water Level Gauge (1983)

| August | | | September | | | October | | | November | | | December | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mon. | | 1 | Thu. | (E)(F)(G)(H) | 1 | Sat. | Holiday. | 1 | Tue. | (J)(K)(L) | 1 | Thu. | |
| 2 | Tue. | (G)(J)(K)(L) | 2 | Fri | (1)(2) | 2 | Sun. | Holiday. | 2 | Wed | (A)(B)(C)(D) | 2 | Fri. | |
| 3 | Wed. | (A)(B)(C) | 3 | Sat. | Holiday. | 3 | Mon. | | 3 | Thu. | (E)(F)(G)(H) | 3 | Sat. | Holiday. |
| 4 | Thu. | (D)(E)(F) | 4 | Sun. | Holiday. | 4 | Tue. | (J)(K)(L) | 4 | Fri. | | 4 | Sun. | Holiday. |
| 5 | Fri. | | 5 | Mon | | 5 | Wed | (A)(B)(C)(D) | 5 | Sat. | Holiday. | 5 | Mon. | National Holiday. |
| 6 | Sat. | Holiday. | 6 | Tue | (J)(K)(L) | 6 | Thu. | (E)(F)(G)(H) | 6 | Sun. | Holiday. | 6 | Tue | (J)(K)(L) |
| 7 | Sun. | Holiday. | 7 | Wed | (A)(B)(C)(D) | 7 | Fri | | 7 | Mon | | 7 | Wed | (A)(B)(C)(D) |
| 8 | Mon | | 8 | Thu. | (E)(F)(G)(H) | 8 | Sat. | Holiday. | 8 | Tue. | (J)(K)(L) | 8 | Thu. | (E)(F)(G)(H) |
| 9 | Tue. | (G)(J)(K)(L) | 9 | Fri. | | 9 | Sun. | Holiday. | 9 | Wed. | (A)(B)(C)(D) | 9 | Fri. | (1)(2) |
| 10 | Wed | (A)(B)(C) | 10 | Sat. | Holiday. | 10 | Mon. | | 10 | Thu. | (E)(F)(G)(H) | 10 | Sat. | Holiday. |
| 11 | Thu. | (D)(E)(F) | 11 | Sun. | Holiday. | 11 | Tue. | (J)(K)(L) | 11 | Fri. | (1)(2) | 11 | Sun. | Holiday. |
| 12 | Fri. | National Holiday. | 12 | Mon | | 12 | Wed | (A)(B)(C)(D) | 12 | Sat. | Holiday. | 12 | Mon. | |
| 13 | Sat. | Holiday. | 13 | Tue. | (J)(K)(L) | 13 | Thu. | (E)(F)(G)(H) | 13 | Sun. | Holiday. | 13 | Tue. | (J)(K)(L) |
| 14 | Sun. | Holiday. | 14 | Wed. | (A)(B)(C)(D) | 14 | Fri. | (1)(2) | 14 | Mon. | | 14 | Wed | (A)(B)(C)(D) |
| 15 | Mon | | 15 | Thu. | (E)(F)(G)(H) | 15 | Sat. | Holiday. | 15 | Tue. | (J)(K)(L) | 15 | Thu. | (E)(F)(G)(H) |
| 16 | Tue. | (G)(J)(K)(L) | 16 | Fri. | (1)(2) | 16 | Sun. | Holiday. | 16 | Wed. | (A)(B)(C)(D) | 16 | Fri. | |
| 17 | Wed. | (A)(B)(C) | 17 | Sat. | Holiday. | 17 | Mon. | | 17 | Thu. | (E)(F)(G)(H) | 17 | Sat. | Holiday. |
| 18 | Thu. | (D)(E)(F) | 18 | Sun. | Holiday. | 18 | Tue. | (J)(K)(L) | 18 | Fri. | | 18 | Sun. | Holiday. |
| 19 | Fri. | (1)(2) | 19 | Mon. | | 19 | Wed | (A)(B)(C)(D) | 19 | Sat. | Holiday. | 19 | Mon. | |
| 20 | Sat. | Holiday. | 20 | Tue. | (J)(K)(L) | 20 | Thu. | (E)(F)(G)(H) | 20 | Sun. | Holiday. | 20 | Tue. | (J)(K)(L) |
| 21 | Sun. | Holiday. | 21 | Wed | (A)(B)(C)(D) | 21 | Fri. | | 21 | Mon. | | 21 | Wed. | (A)(B)(C)(D) |
| 22 | Mon. | | 22 | Thu. | (E)(F)(G)(H) | 22 | Sat. | Holiday. | 22 | Tue. | (J)(K)(L) | 22 | Thu. | (E)(F)(G)(H) |
| 23 | Tue. | (J)(K)(L) | 23 | Fri. | | 23 | Sun. | Holiday. | 23 | Wed | (A)(B)(C)(D) | 23 | Fri. | (1)(2) |
| 24 | Wed. | (A)(B)(C)(D) | 24 | Sat. | Holiday. | 24 | Mon. | | 24 | Thu. | (E)(F)(G)(H) | 24 | Sat. | Holiday. |
| 25 | Thu. | (E)(F)(G)(H) | 25 | Sun. | Holiday. | 25 | Tue. | (J)(K)(L) | 25 | Fri. | (1)(2) | 25 | Sun. | Holiday. |
| 26 | Fri. | | 26 | Mon. | | 26 | Wed | (A)(B)(C)(D) | 26 | Sat. | Holiday. | 26 | Mon. | |
| 27 | Sat. | Holiday. | 27 | Tue. | (J)(K)(L) | 27 | Thu. | (E)(F)(G)(H) | 27 | Sun. | Holiday. | 27 | Tue | (J)(K)(L) |
| 28 | Sun. | Holiday. | 28 | Wed. | (A)(B)(C)(D) | 28 | Fri. | (1)(2) | 28 | Mon. | | 28 | Wed | (A)(B)(C)(D) |
| 29 | Mon. | | 29 | Thu. | (E)(F)(G)(H) | 29 | Sat. | Holiday. | 29 | Tue. | (J)(K)(L) | 29 | Thu. | (E)(F)(G)(H) |
| 30 | Tue. | (J)(K)(L) | 30 | Fri. | (1)(2) | 30 | Sun. | Holiday. | 30 | Wed. | (A)(B)(C)(D) | 30 | Fri | |
| 31 | Wed | (A)(B)(C)(D) | | | | 31 | | | | | (E)(F)(G)(H) | 31 | Sat. | Holiday. |

### 6.3.3 Measurement Works

After collecting the data of water stage and rainfall by the data collecting and maintenance group, the measurement of data is to be carried out immediately by the hydrological analysis group.

### 6.3.4 Report

In case of malfunction or disroder of instruments, DDS is to inform it to JICA Head Quarter through JICA Bangkok Office after consulting wish JICA expert of DDS.

## 7. Water Flow Measurement

The water flow rate in the existing klongs at the boundary of the study area was observed in 1983's rainy season. The location of the measuring points and date are shown in Fig. 4.11. The method of the water flow measurment are described as follows.

(1) Measuring the width of the klong

(2) Measuring the depth of the klong at 5 meter interval and setting the HIROI's current meter at 60 percent of the total depth.

(3) Recording the time for 10 times signal of the current meter.

(4) Calculating the velocity with the following formulas.

$$V = 0.1135\ N + 0.015 \quad (m/sec)$$

$$N = \frac{10 \times M}{T} \qquad (10)$$

M : No. of Signal

T : Time (sec)

(5) Calculating the areal cross section at each 5 meter.

(6) Multiply the velocity and the areal cross section.

The results of the water flow measurement are discribed in Figs. F.42 to F.46.

## 8. Existing Discharge Capacity of Main Klong

### 8.1. General

Flooding occurs due to various factors. One of the influencing factors is the discharge capacities of the main Klongs. If the main klongs have the discharge capacity so as to drain the stormwater adequately, flooding will not occur. However, existing capacities of the main klongs are far from that required due to flat Study Area. Consequently, flooding takes place frequently.

Therefore, existing capacities of the main klongs have been examined in order to determine how much stormwater they carry away and which sections are the bottlenecks.
For this estimate, uniform flow method and non-uniform flow method were used based on the topographical survey result which is described in Appendix A.

As the Klong Phra Khanong collects a considerable portion of stormwater in the Study Area, the capacity of downstream Kong Phra Khanong governs the capacity of the entire Study Area. According to the estimation, it has only 50 to 80 $m^3$/sec which is equivalent to 9 to 14 mm/day precipitations in the Study Area of 501 $km^2$.

Similarly, the discharge capacities of other main klongs, namely; Klongs Ton, Saen Saep and Lat Phrao were estimated as about 20 $m^3$/sec respectively.

The bottlenecks are found as follows: (Refer to Figs. 5.7 to 5.10 , main report.)

- At km 4 from the mouth of Klong Phra Khanong (Widening)
- At km 8 from the mouth of Klong Phra Khanong (Dredging)

- At km 5 from the mouth of Klong Ton (Widening)
- At km 9 from the mouth of Klong Ton (Dredging)
- At km 9 from the mouth of Klong Saen Saep (Dredging)
- At km 14 from the mouth of Klong Saen Saep (Widening)
- At km 22 from the mouth of Klong Saen Saep (Widening)

As the capacities in the above-mentioned sections are lower than that of adjacent sections, widening or dredging will increase capacities considerably though they do not meet the designed capacity.

## 8.2 Method of Estimation

### (1) Basic Equation of Non-Uniform Flow

Equation of Bernoulli is expressed as follows:

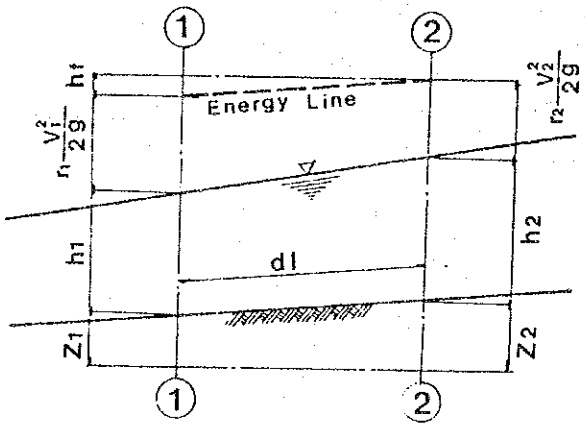
$$Z_1 + h_1 + \beta_1 \cdot \frac{V_1^2}{2g} + hf = Z_2 + h_2 + \beta_2 \cdot \frac{V_2^2}{2g}$$

which is transformed as follows:

$$hf = (Z_2 + h_2 + \beta_2 \cdot \frac{V_2^2}{2g}) - (Z_1 + h_1 + \beta_1 \cdot \frac{V_1^2}{2g}) \quad \ldots\ldots(1)$$

where;

$Z_1$, $Z_2$ ; Elevations in sections 1 and 2 respectively
$h_1$, $h_2$ ; Depths in sections 1 and 2 respectively
$v_1$, $v_2$ ; Velocities in sections 1 and 2 respectively
$\beta_1$, $\beta_2$ ; coefficient of Velocity
g ; Gravitational Acceleration



Friction head (hf) is expressed as follows by Manning's Formula :

$$hf = \frac{1}{2}\left(\frac{N_1^2 \cdot V_1^2}{R_1^{4/3}} + \frac{N_2^2 \cdot V_2^2}{R_2^{4/3}}\right) \cdot dl \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Hence, from equations (1) and (2), the following is obtained.

$$\left(Z_2 + h_2 + \beta_2 \frac{V_2^2}{2g}\right) - \left(Z_1 + h_1 + \beta_1 \frac{V_1^2}{2g}\right) = \frac{1}{2}\left(\frac{N_1^2 \cdot V_1^2}{R_1^{4/3}} + \frac{N_2^2 \cdot V_2^2}{R_2^{4/3}}\right) dl \quad \cdots\cdots\cdots\cdots\cdots\cdots (3)$$

(2) Calculation of Non-Uniform Flow

Using equation (3), calculation is conducted.

1) First, Q is assumed.
2) $h_1$ is also assumed.
3) $V_1$ and $R_1$ can be calculated based on the cross section surveyed by the Study Team, as $V_1$ and $R_1$ are functions of $h_1$.
4) $Z_1$, $\beta_1$ (1.0) and $N_1$ (0.035) is given.
5) Similary, the above-mentioned figures in section 2 are calculated assuming $h_2$ value.
6) Figures in section 2 will be obtained by try and error method so that left column figures become right figures.
7) Similarly, using the obtained $h_2$ value as $h_1$ value for the calculation of the second step, new $h_2$ is obtained.
8) Calculation is repeated to reach the upstream section.
9) Hence, water surface elevation (h) is obtained under the condition of Q.
10) Various water surface elevations are calculated depending on Q value.

The results are shown in 5.10, main report.

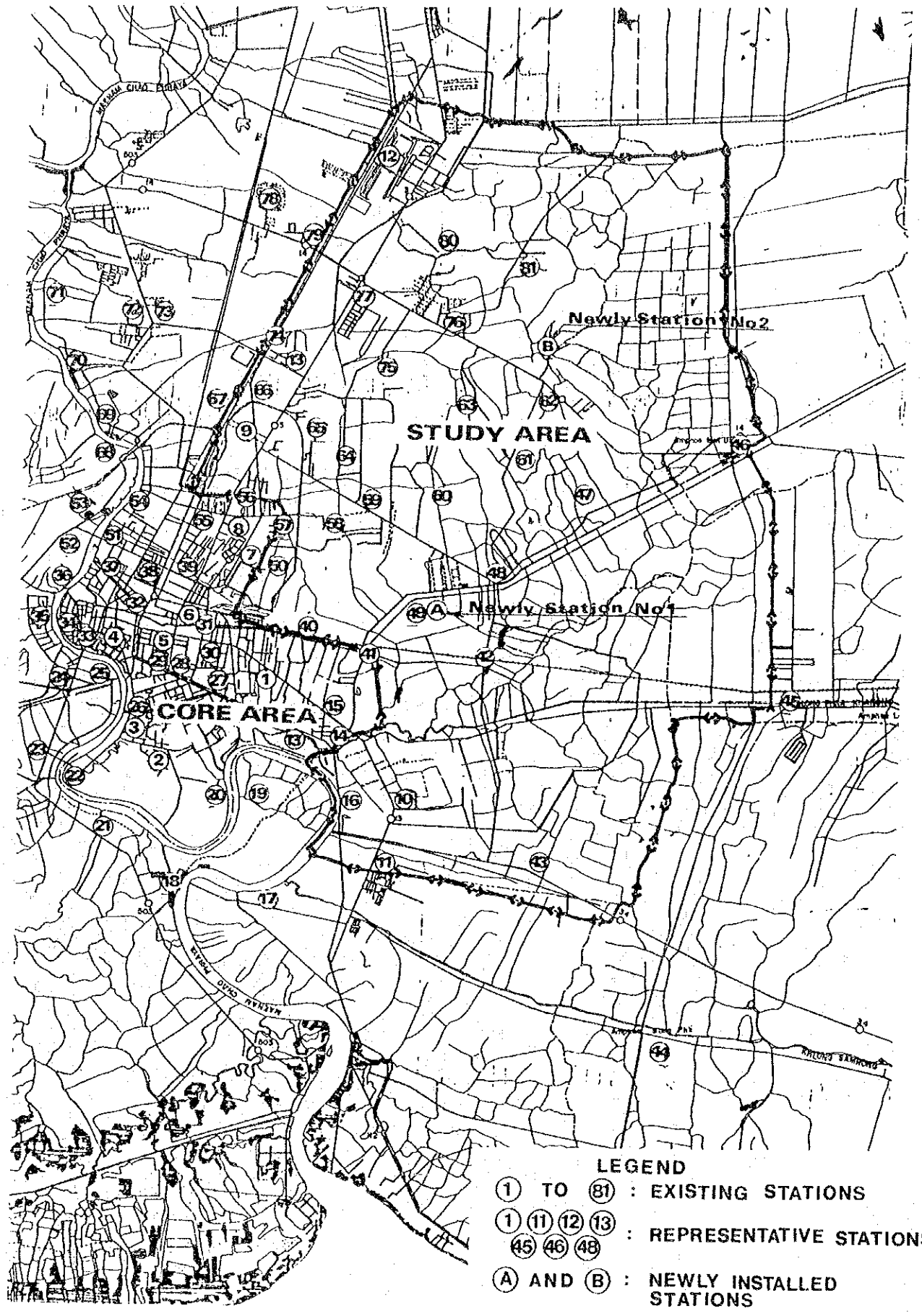
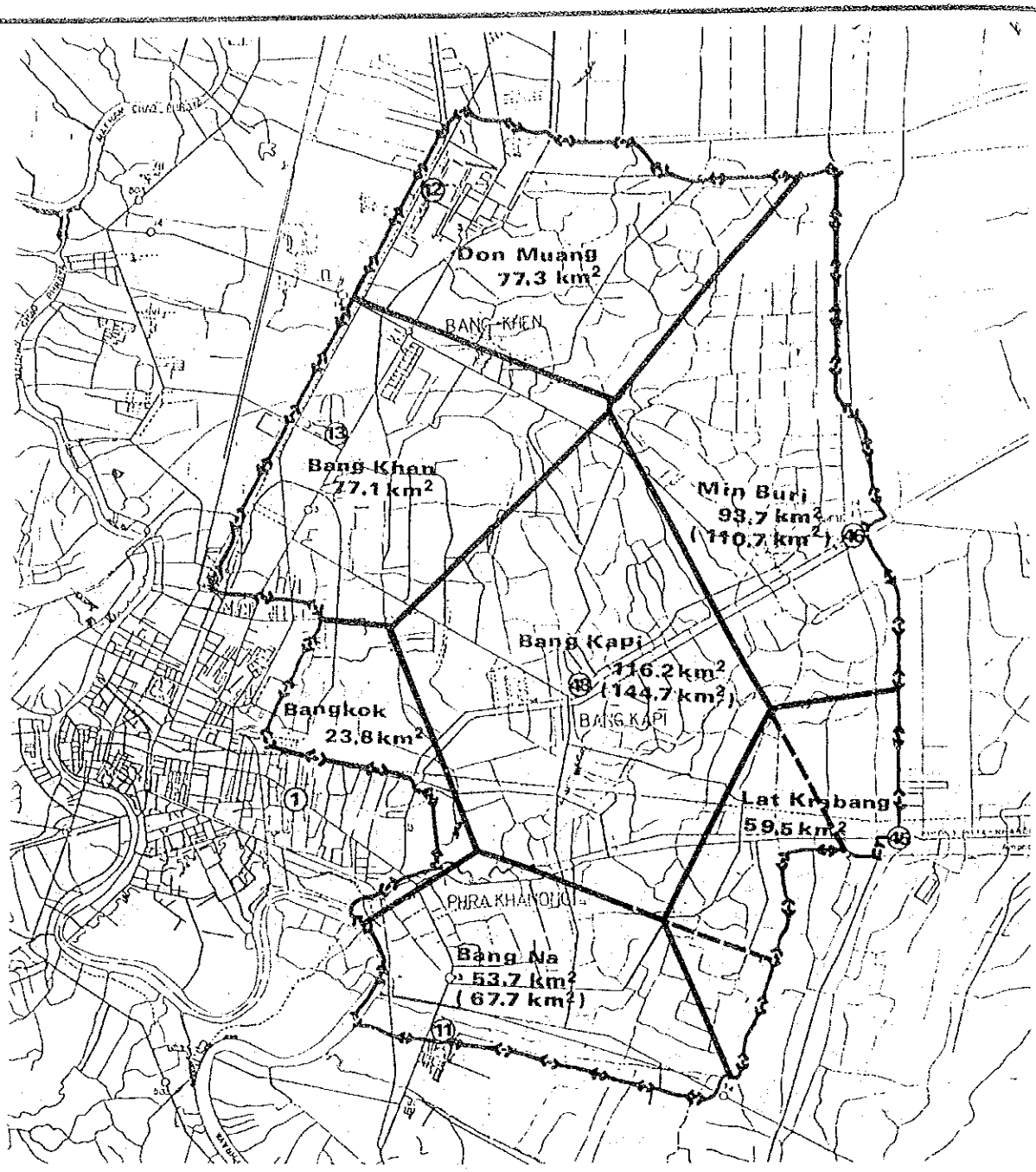



FIG. F. 1 Location of Existing and Newly Installed Rain Gauge Stations in and around the Study Area

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



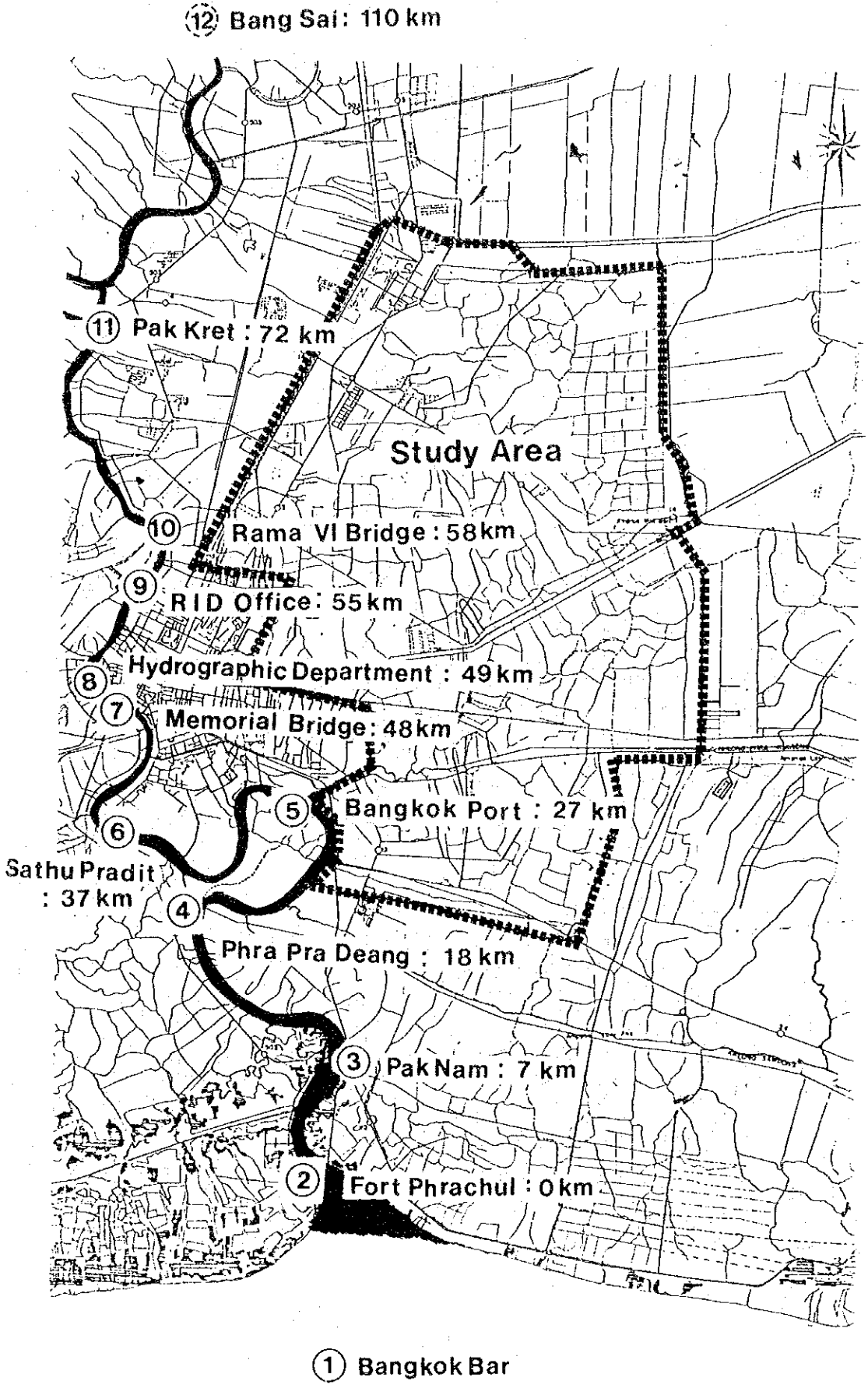

Thiessen Polygon

**Table of Controlled Area for Each Representative Station**

| Item \ Station | | DonMuang | BangKhen | Bangkok | BangNa | BangKapi | MinBuri | LatKrabang | Total |
|---|---|---|---|---|---|---|---|---|---|
| Case 1 | Area ($km^2$) | 77.0 | 77.1 | 23.8 | 53.7 | 116.2 | 93.7 | 59.5 | 500.1 |
| | Thiessen coefficient | 0.1537 | 0.1539 | 0.0475 | 0.1072 | 0.2319 | 0.1870 | 0.1188 | 1.000 |
| Case 2 | Area ($km^2$) | 77.0 | 77.1 | 23.8 | 67.7 | 144.7 | 110.7 | - | 500.1 |
| | Thiessen coefficient | 0.1537 | 0.1539 | 0.0475 | 0.1351 | 0.2888 | 0.2210 | - | 1.000 |

FIG. F. 2 Representative Rain Gauge Stations and Thieesen Polygon in the Study Area

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




| FIG. F. 3 | Location of Existing Water Level Gauge Stations in the Lower Chao Phraya River |
|---|---|

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

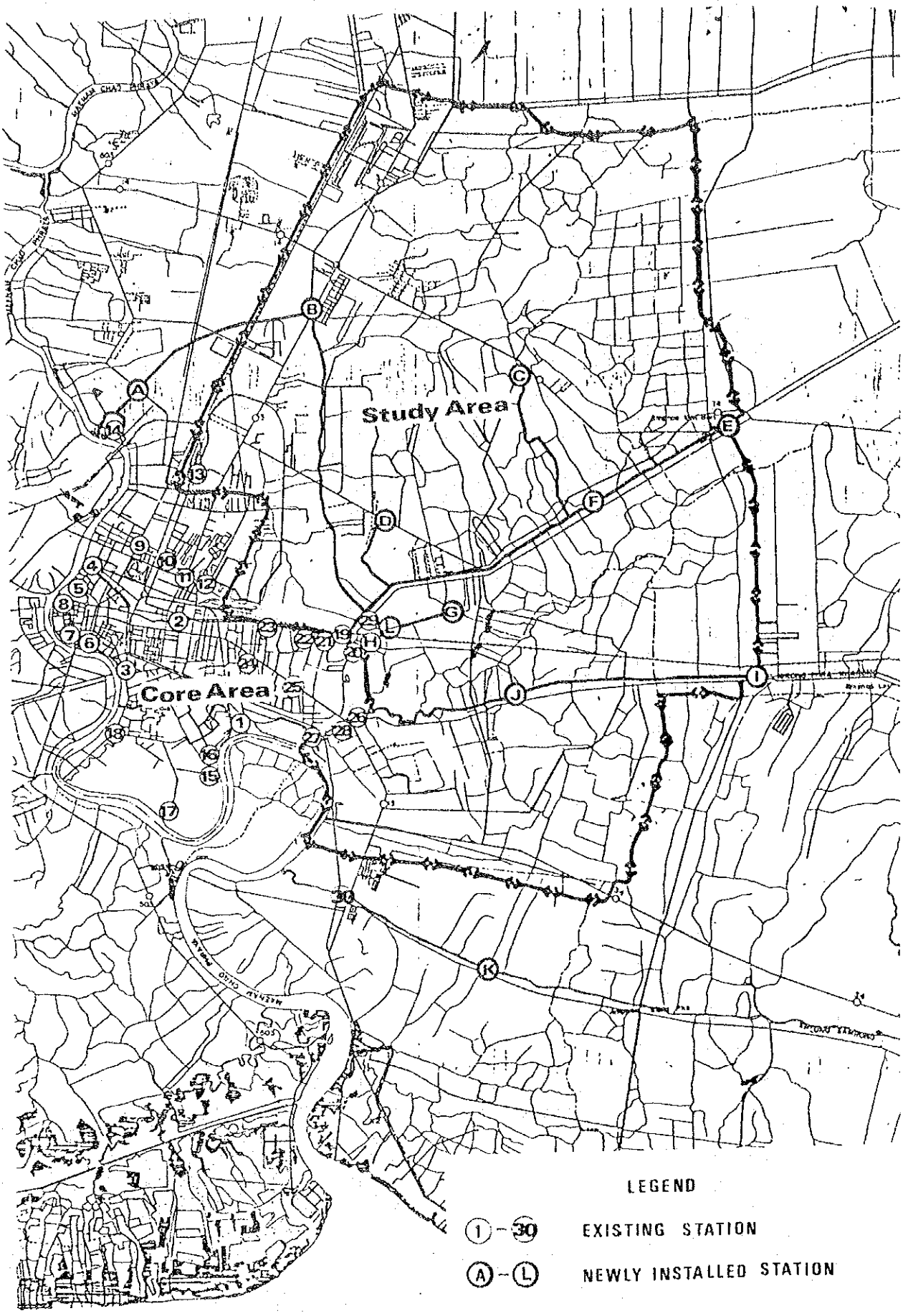



FIG. F. 4 Location of Existing and Newly Installed Water Level Gauge Stations in the Main Klongs

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

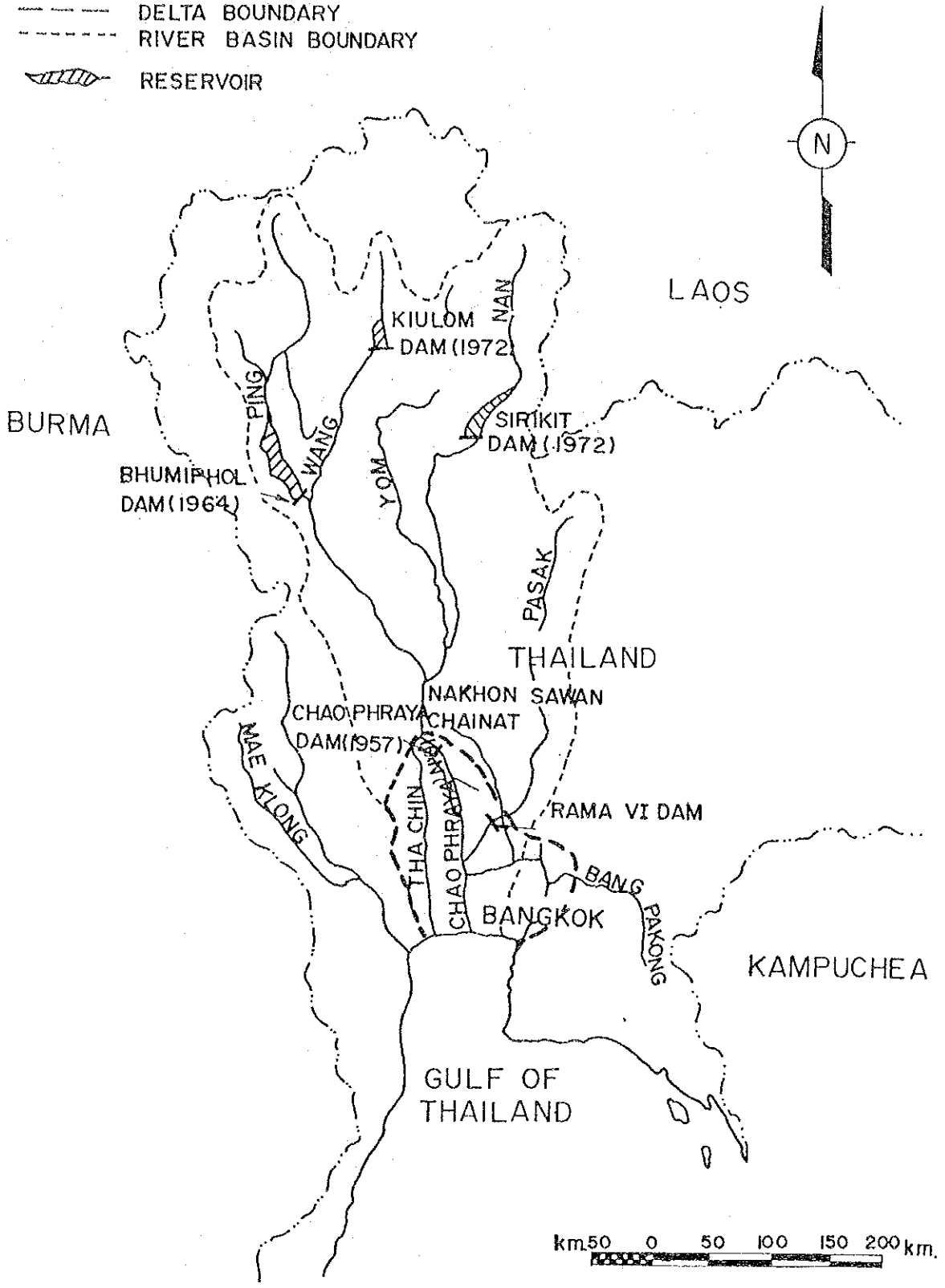
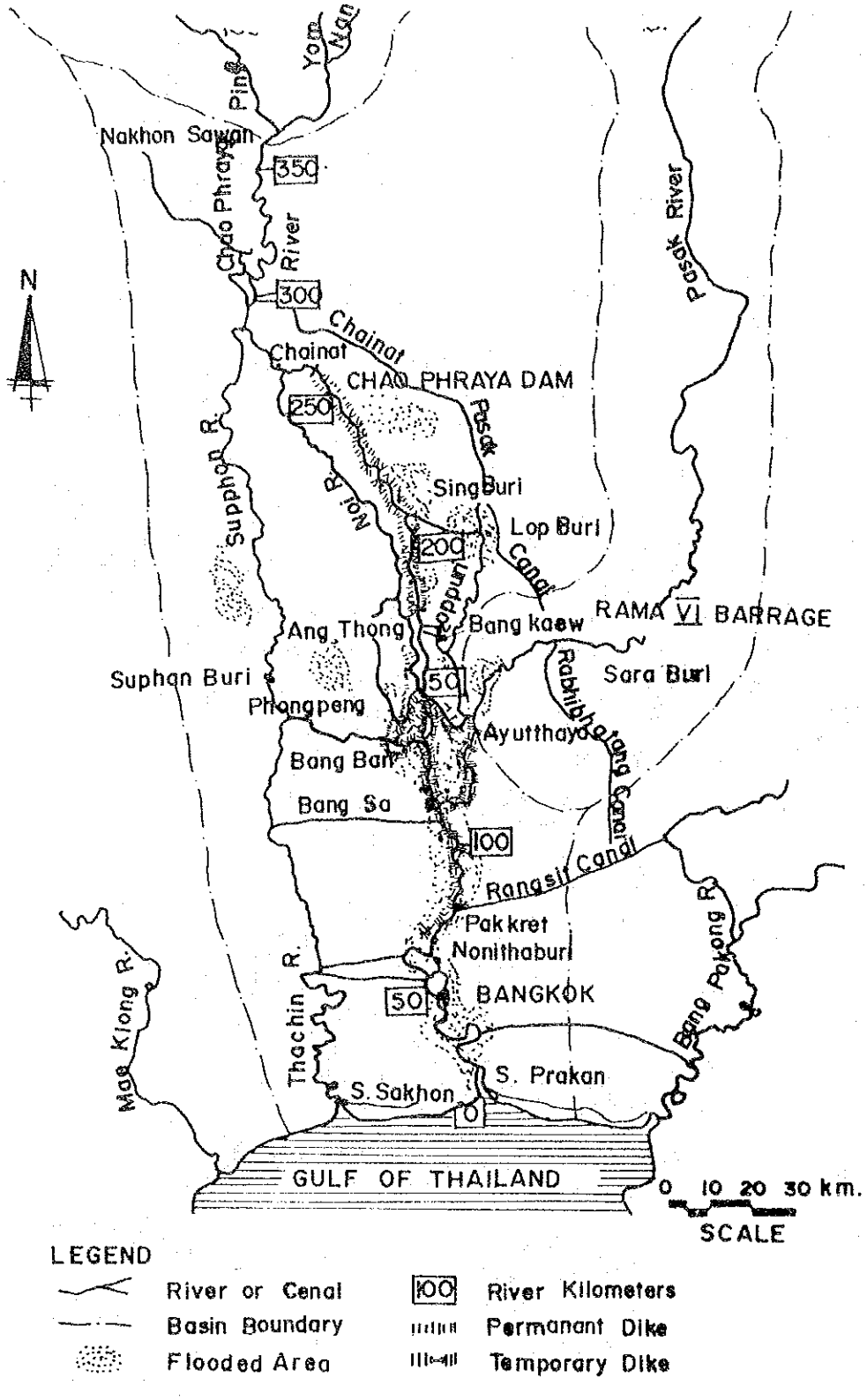



FIG. F. 5 **Chao Phraya River Basin**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




| FIG. F. 6 | Map of Inundation of Chao Phraya and Its Diking System |
|---|---|

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

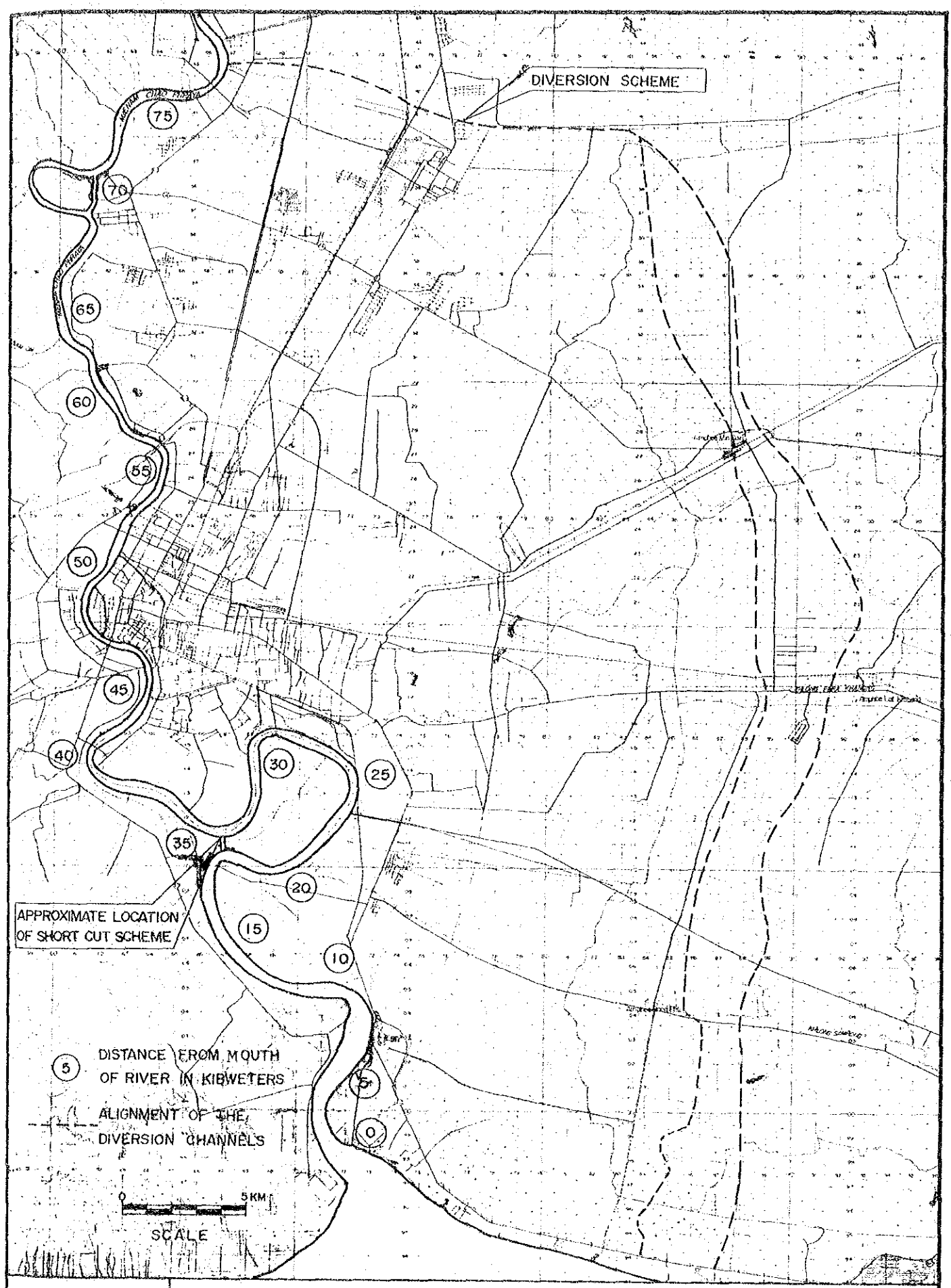
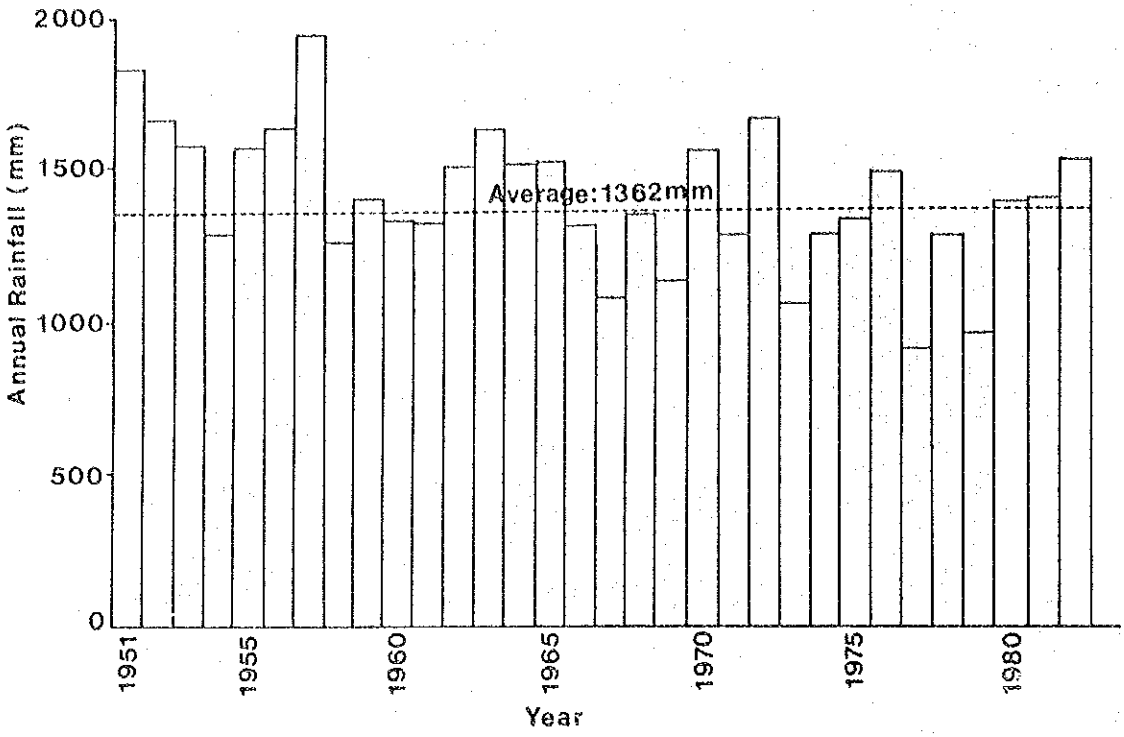
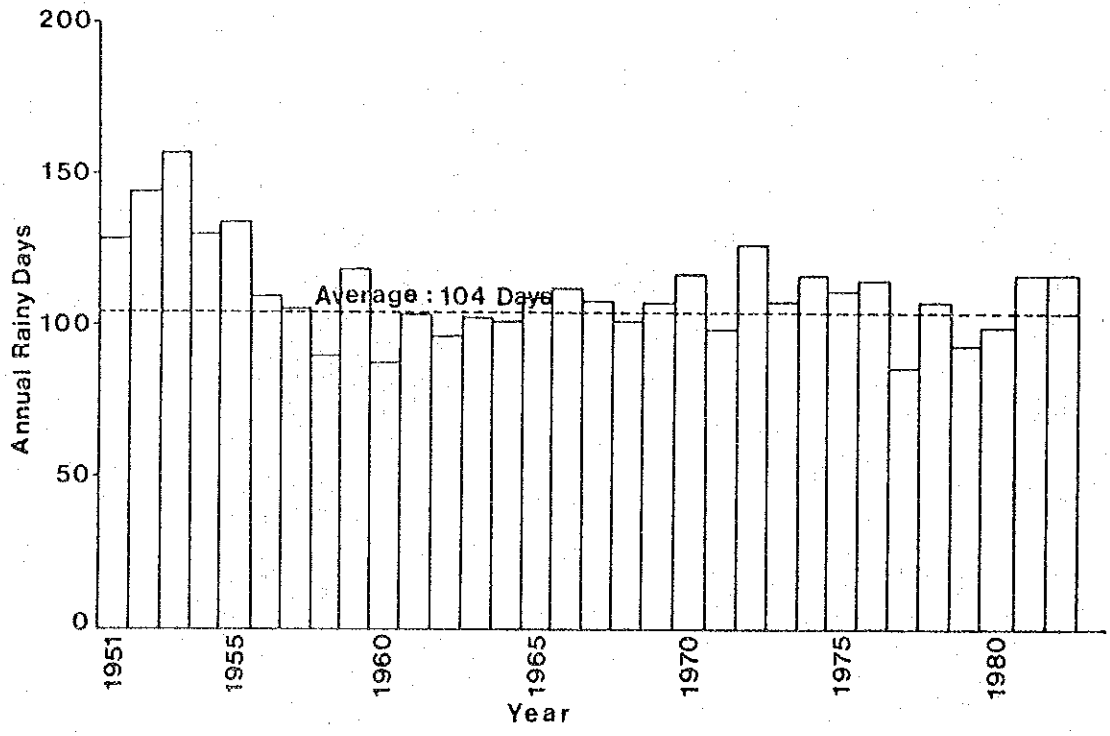



FIG. F. 7 **Plan of Alignment of Diversion Channels — AIT Study —**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




Annual Rainfall

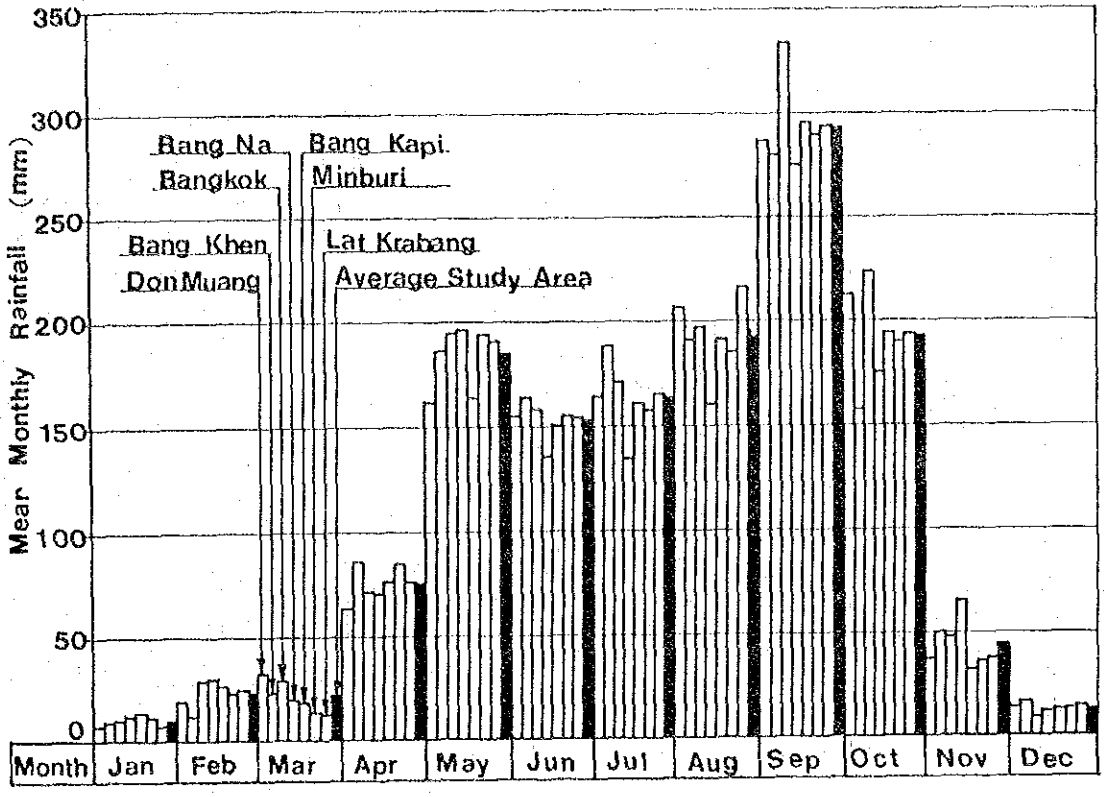



Annual Rainy Days

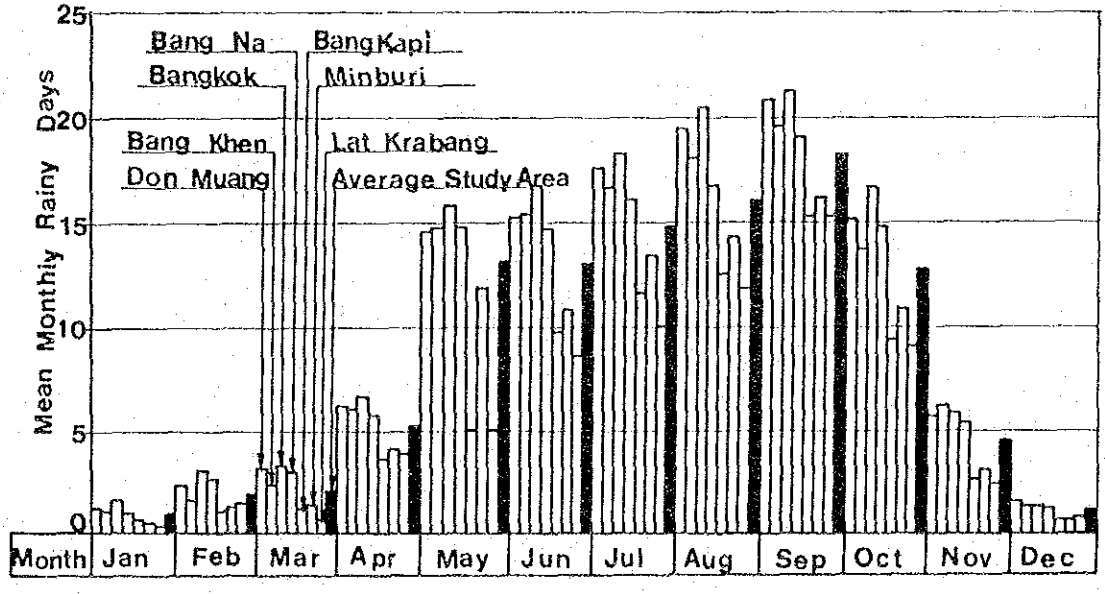
**Source :** Meteorological Department

FIG. **F. 8** **Annual Rainfall and Rainy Days in the Study Area between 1951 and 1982**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




Annual Montly Rainfall

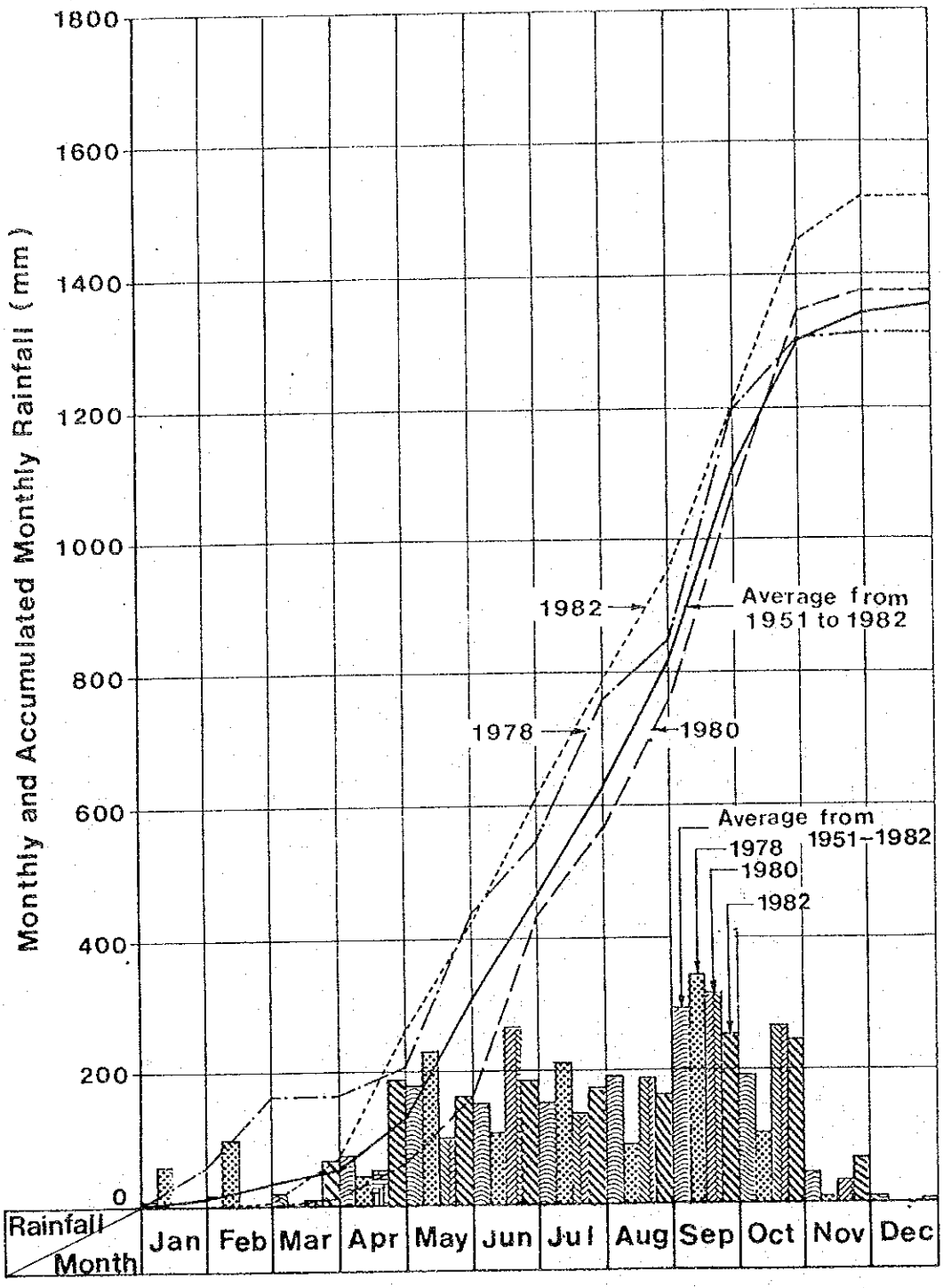



Annual Rainy Days

Source : Meteorological Department

| FIG. F. 9 | Annual Montly Rainfall and Rainy Days in the Study Area between 1951 and 1982 |
|---|---|

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

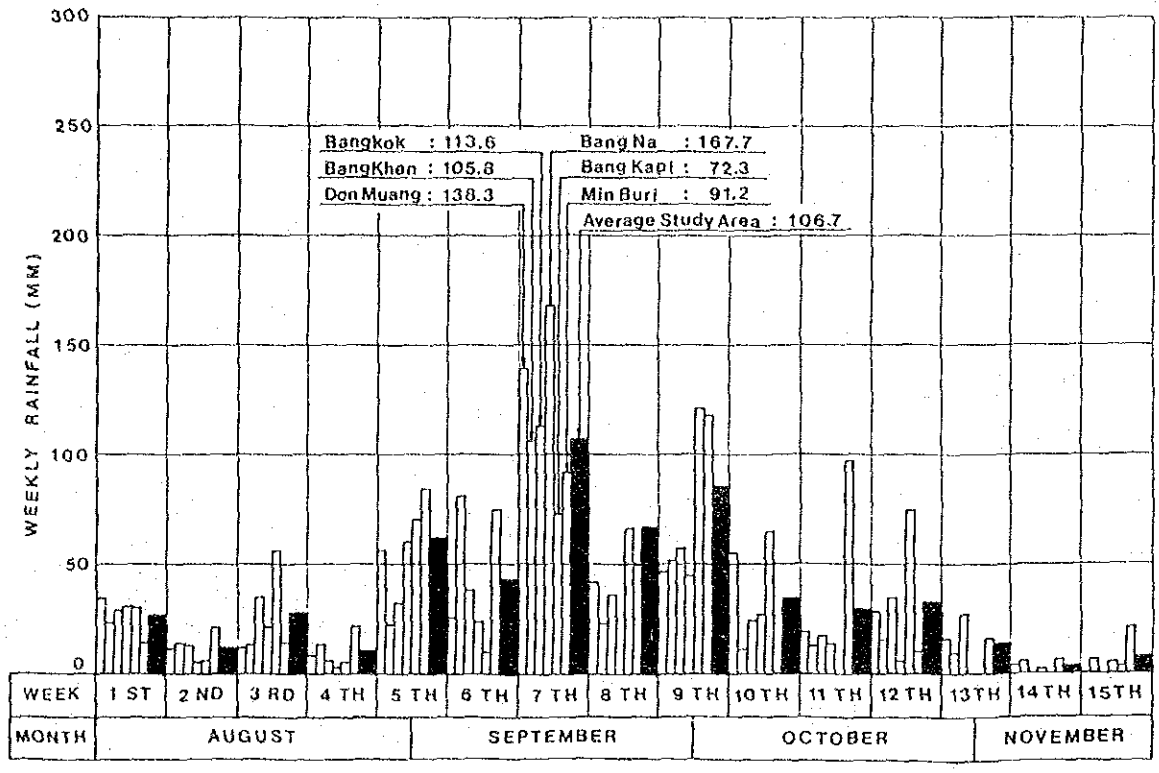



Unit : mm/month

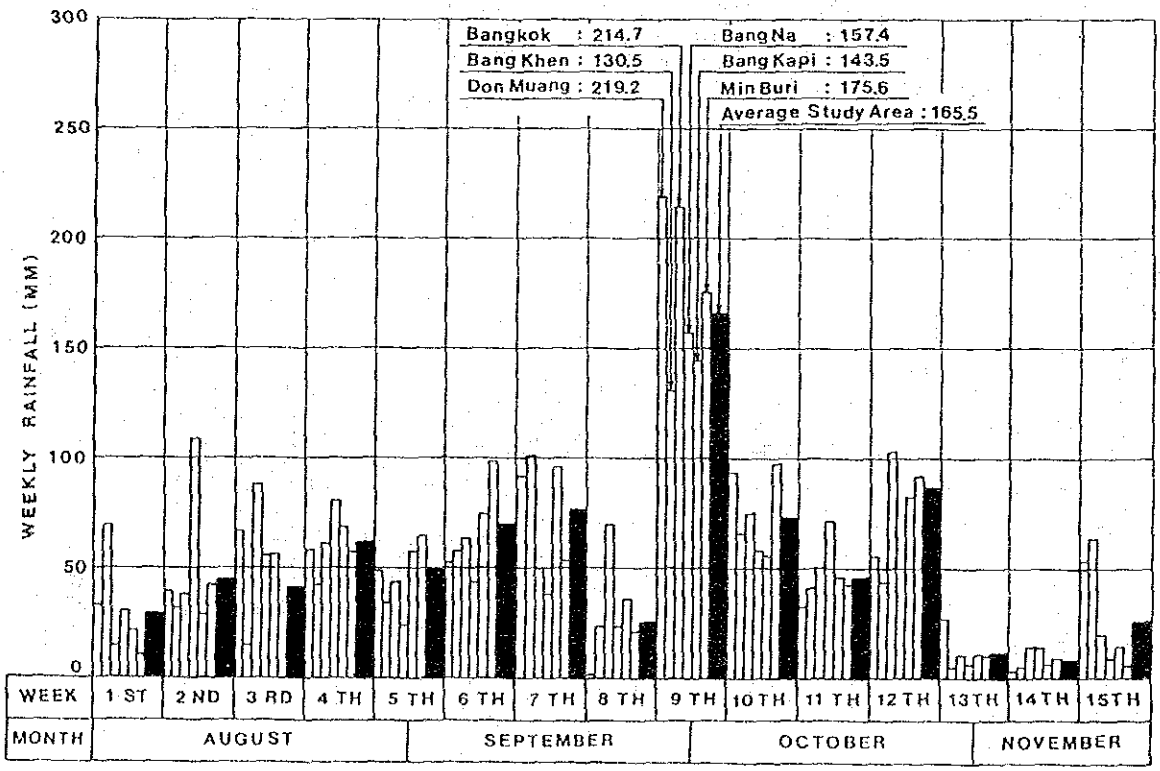
| Year | Jan | Feb. | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average from 1951 - 1982 | 9.7 | 23.2 | 20.9 | 75.0 | 184.0 | 153.3 | 163.4 | 192.4 | 293.5 | 192.2 | 43.8 | 13.3 | 1365 |
| 1978 | 60.0 | 103.8 | 0 | 43.8 | 229.1 | 110.1 | 212.6 | 90.0 | 321.4 | 119.2 | 9.5 | 0 | 1319 |
| 1980 | 0 | 0 | 11.2 | 50.8 | 100.9 | 269.5 | 137.5 | 191.5 | 318.9 | 274.3 | 32.9 | 0 | 1388 |
| 1982 | 0 | 2.6 | 70.1 | 189.0 | 164.4 | 184.2 | 175.0 | 166.7 | 252.9 | 246.6 | 65.1 | 1.7 | 1517 |

FIG. F.10 **Monthly & Accumulated Monthly Rainfall in the Stady Area for Recent Flood Year, 1978, 1980 and 1982**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




1978

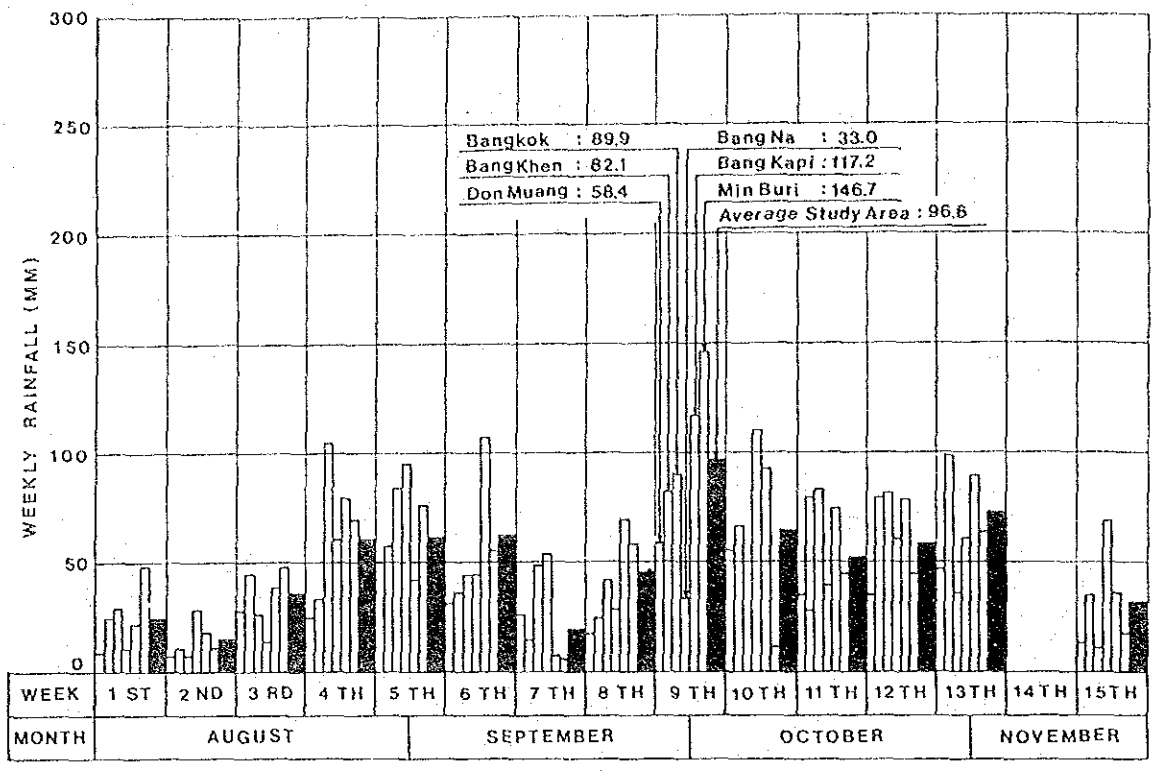



1980

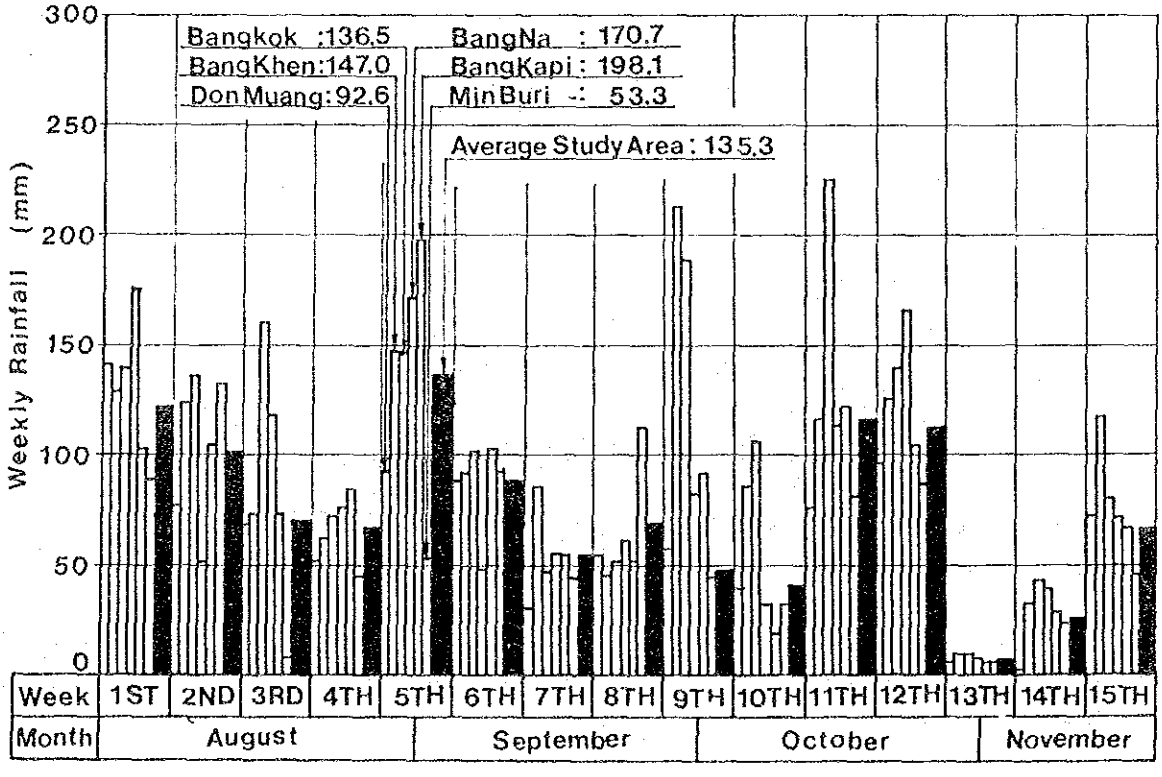
Source : Meteorological Department

FIG. F.11 **Weekly Rainfall in the Study Area between Aug. and Sep. in 1978 & 1980**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




1982

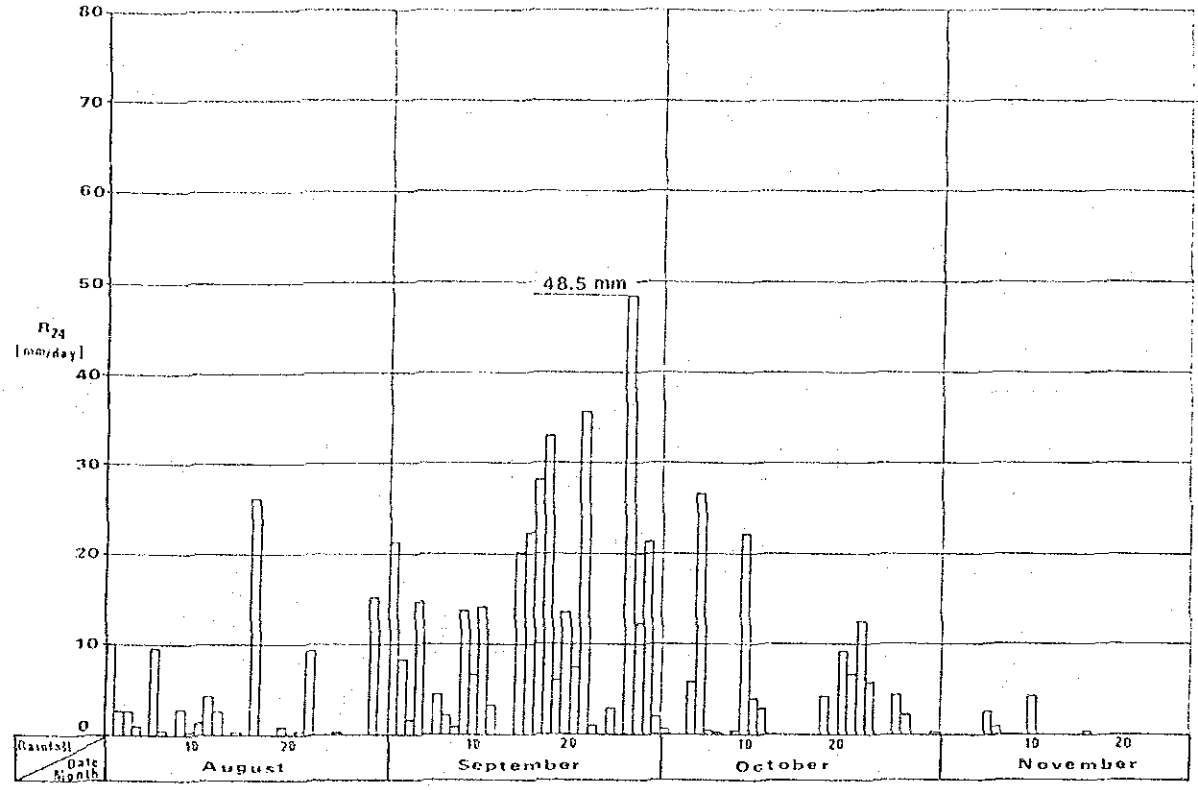



1983

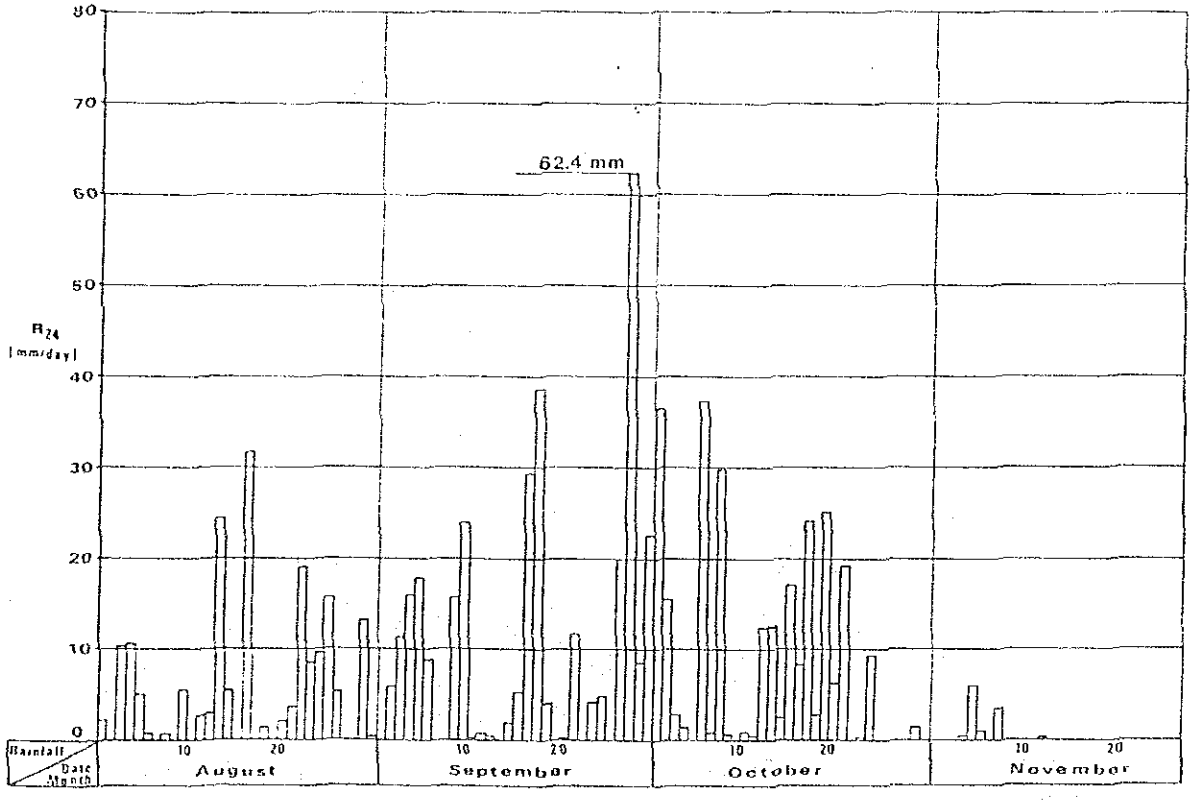
Source : Meteorological Department

FIG. F.12 **Weekly Rainfall in the Study Area between Aug. and Sep. in 1982 & 1983**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




1978

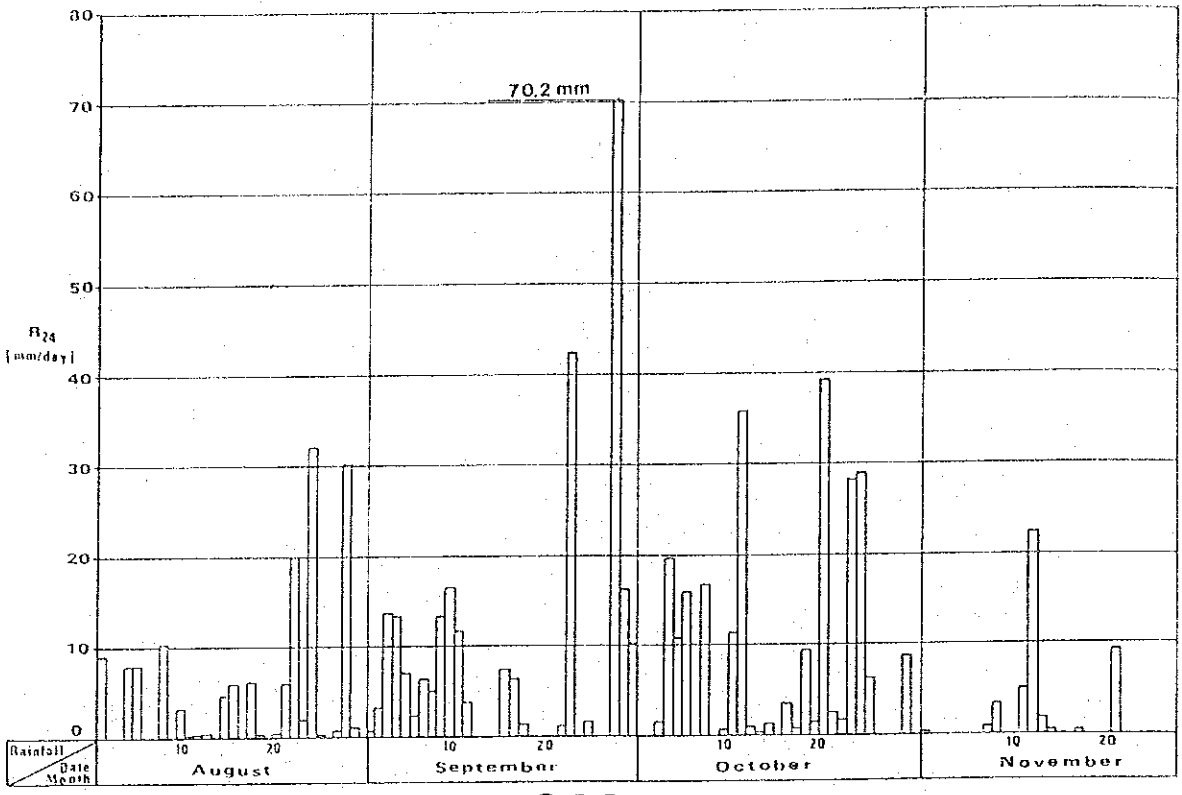



1980

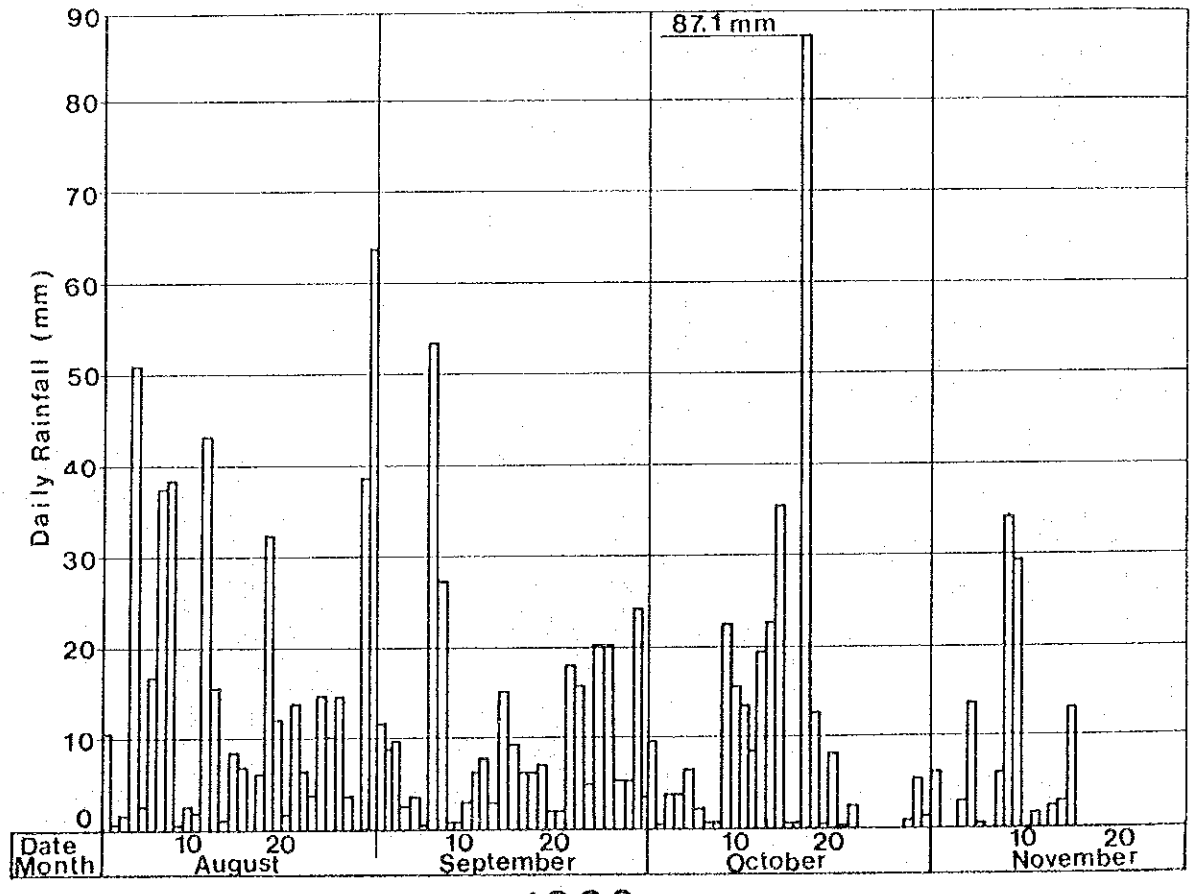
Source : Meteorological Department

FIG. F.13 Average Areal Daily Rainfall in the Study Area between Aug. & Nov. in 1978 & 1980

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




1982

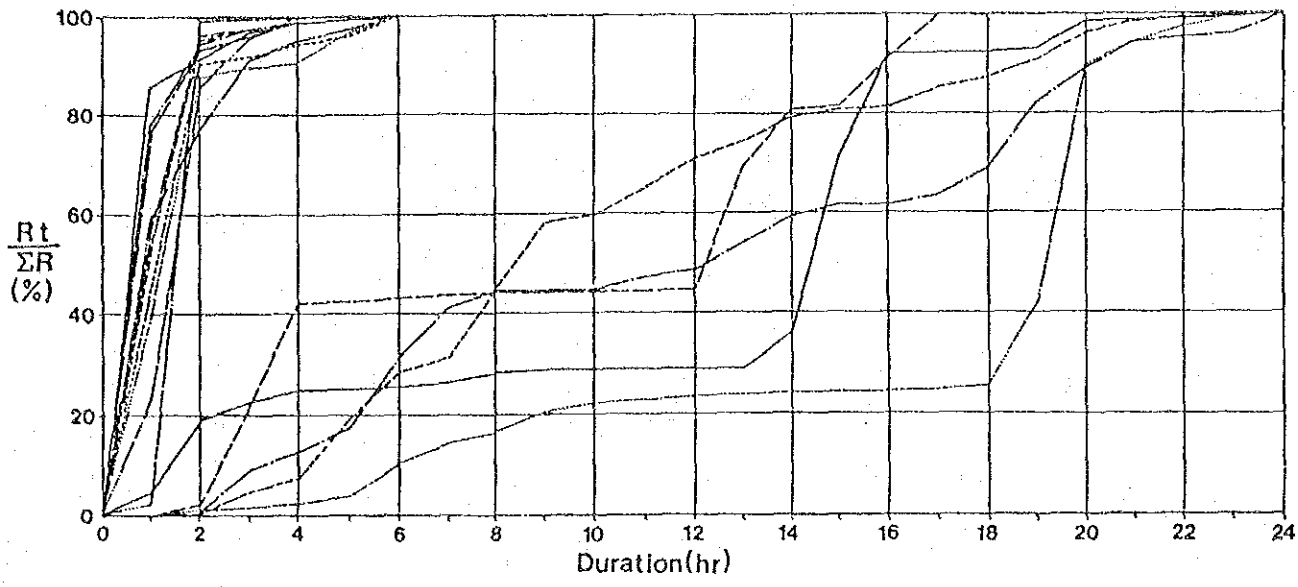



1983

Source : Meteorological Department

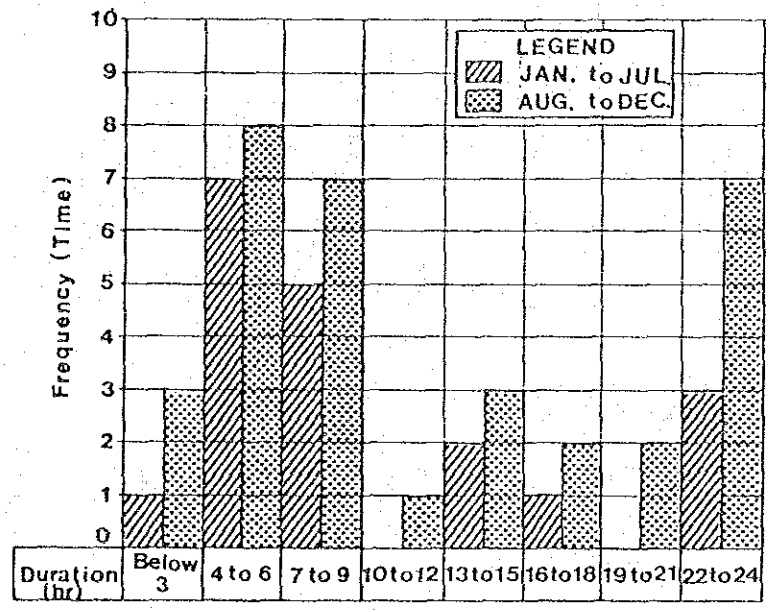
FIG. F. 14 **Average Areal Daily Rainfall in the Study Area between Aug. & Nov. in 1982 & 1983**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




Time Distribution Diagram for Duration of Daily Rainfall above 90 mm/day

Note; Daily rainfall data (15 samples) above 90 mm/day were recorded at the Bangkok Station between 1951 and 1982.

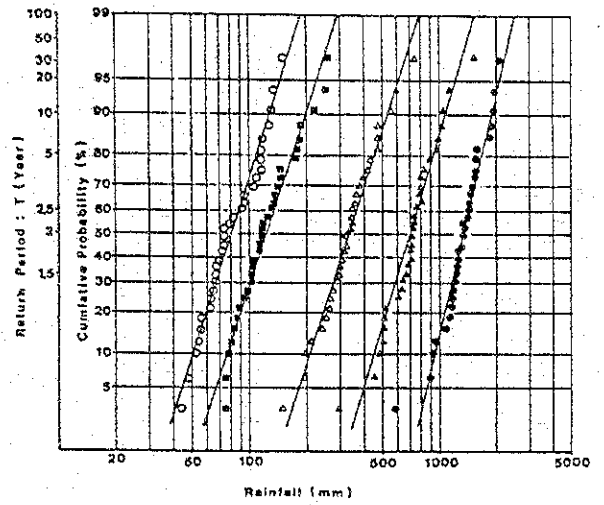



Frequency Diagram for Duration of Daily Rainfall above 60 mm/day

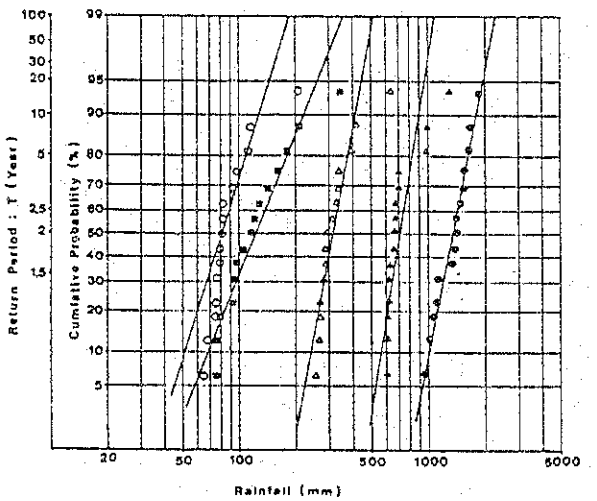
Note ; Daily rainfall data ( 52 samples ) above 60 mm/day recorded at the Bangkok Station between 1951 and 1982 were used.

| FIG. F.15 | Time Distribution and Frequency of Daily Rainfall |
|---|---|

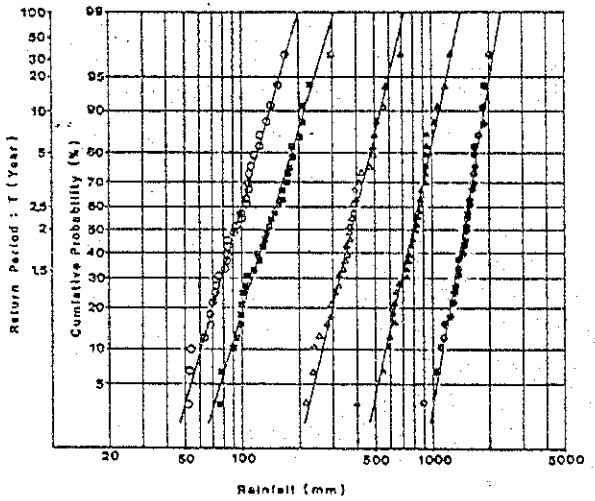
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



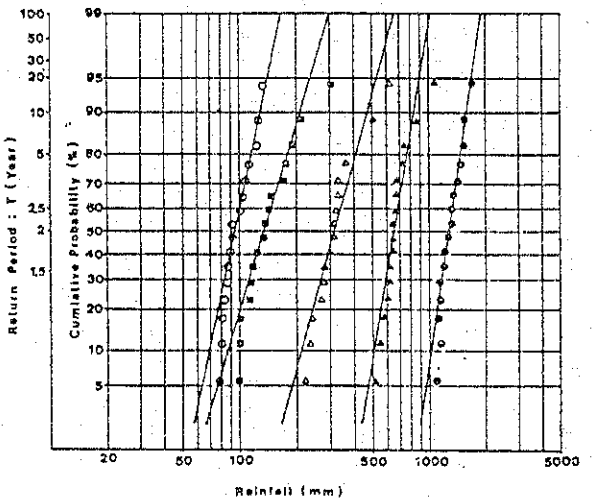

Don Muang




BangKhen




Bangkok




BangNa

Legend

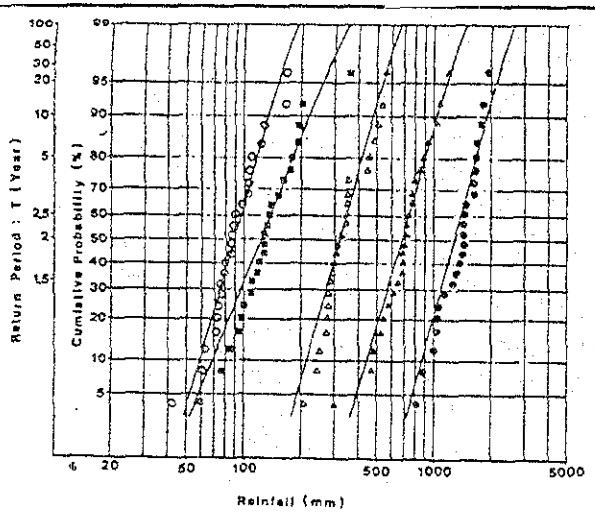
- ○ : Probable Daily Rainfall
- ■ : Probable 3-Days Rainfall
- △ : Probable Monthly Rainfall
- ▲ : Probable 3-Months Rainfall
- ● : Probable Yealy Rainfall

Unit : mm

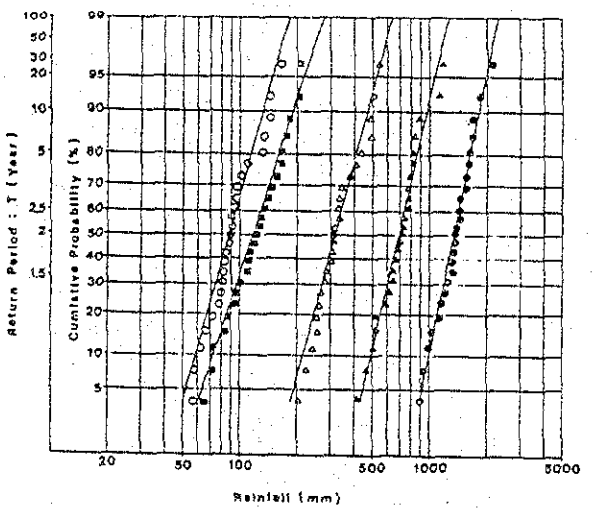
| Item | Return Period \ Station | Don Muang | Bang Khen | Bangkok | Bang Na |
|---|---|---|---|---|---|
| Daily Rainfall Probability | 2 Year | 80.5 | 80.3 | 91.0 | 94.0 |
| | 5 | 108.5 | 108.2 | 120.2 | 114.9 |
| | 7 | 117.6 | 117.5 | 129.4 | 121.3 |
| | 10 | 126.9 | 126.5 | 138.7 | 127.7 |
| | 20 | 144.3 | 143.9 | 156.0 | 139.3 |
| | 30 | 154.3 | 153.9 | 165.9 | 145.7 |
| | 50 | 166.9 | 166.3 | 178.2 | 153.6 |
| | 100 | 183.9 | 183.3 | 194.7 | 163.9 |
| 3-Days Rainfall Probability | 2 | 121.8 | 122.2 | 137.4 | 133.8 |
| | 5 | 165.3 | 179.3 | 184.2 | 178.6 |
| | 7 | 179.5 | 198.7 | 199.3 | 193.0 |
| | 10 | 194.0 | 219.0 | 214.7 | 207.7 |
| | 20 | 221.4 | 258.4 | 243.7 | 235.3 |
| | 30 | 237.1 | 281.6 | 260.3 | 251.1 |
| | 50 | 256.8 | 311.2 | 281.0 | 270.7 |
| | 100 | 283.5 | 352.3 | 309.0 | 297.3 |
| Monthly Rainfall Probability | 2 | 329.8 | 314.9 | 368.5 | 315.7 |
| | 5 | 446.8 | 376.0 | 468.9 | 409.6 |
| | 7 | 484.7 | 394.3 | 500.2 | 439.2 |
| | 10 | 523.6 | 412.5 | 531.9 | 469.4 |
| | 20 | 596.9 | 445.3 | 590.2 | 525.2 |
| | 30 | 639.0 | 463.4 | 623.0 | 556.9 |
| | 50 | 671.7 | 485.3 | 663.4 | 596.1 |
| | 100 | 763.2 | 514.0 | 717.3 | 648.6 |
| 3-Months Rainfall Probability | 2 | 714.7 | 706.6 | 786.4 | 657.0 |
| | 5 | 943.1 | 826.2 | 976.8 | 767.4 |
| | 7 | 1016.0 | 861.5 | 1035.3 | 800.0 |
| | 10 | 1090.3 | 896.5 | 1094.1 | 832.2 |
| | 20 | 1229.0 | 959.1 | 1201.4 | 889.9 |
| | 30 | 1308.0 | 993.4 | 1261.4 | 921.5 |
| | 50 | 1406.2 | 1034.7 | 1334.9 | 959.6 |
| | 70 | 1538.5 | 1088.5 | 1432.1 | 1009.1 |
| Yearly Rainfall Probability | 2 | 1319.0 | 1337.9 | 1451.0 | 1271.1 |
| | 5 | 1653.9 | 1614.2 | 1711.2 | 1453.5 |
| | 7 | 1757.3 | 1697.6 | 1788.6 | 1506.8 |
| | 10 | 1861.5 | 1780.7 | 1865.3 | 1559.1 |
| | 20 | 2052.4 | 1930.9 | 2002.8 | 1652.1 |
| | 30 | 2159.5 | 2014.1 | 2078.4 | 1702.6 |
| | 50 | 2290.8 | 2115.3 | 2169.8 | 1763.3 |
| | 70 | 2456.2 | 2248.1 | 2289.1 | 1841.7 |

FIG. F.16 **Probability of Daily, 3-Day, Monthly, 3-Month and Yearly Rainfall in the Study Area**

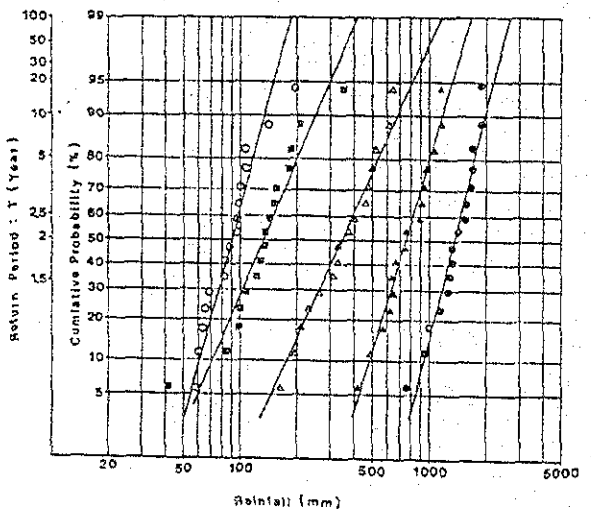
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



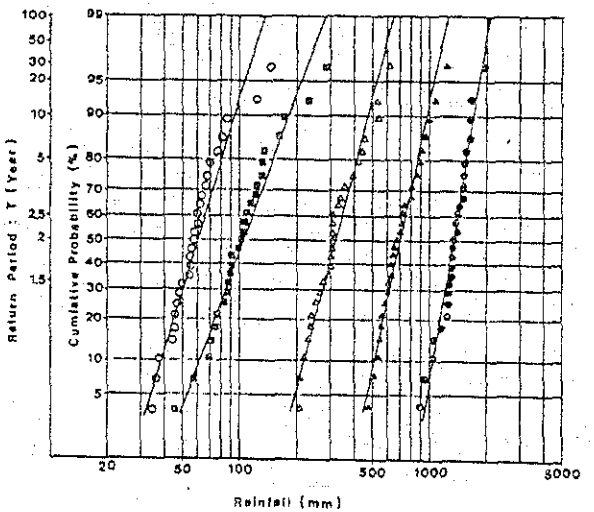

BangKapi




MinBuri




LatKrabang




Average Study Area

Unit : mm

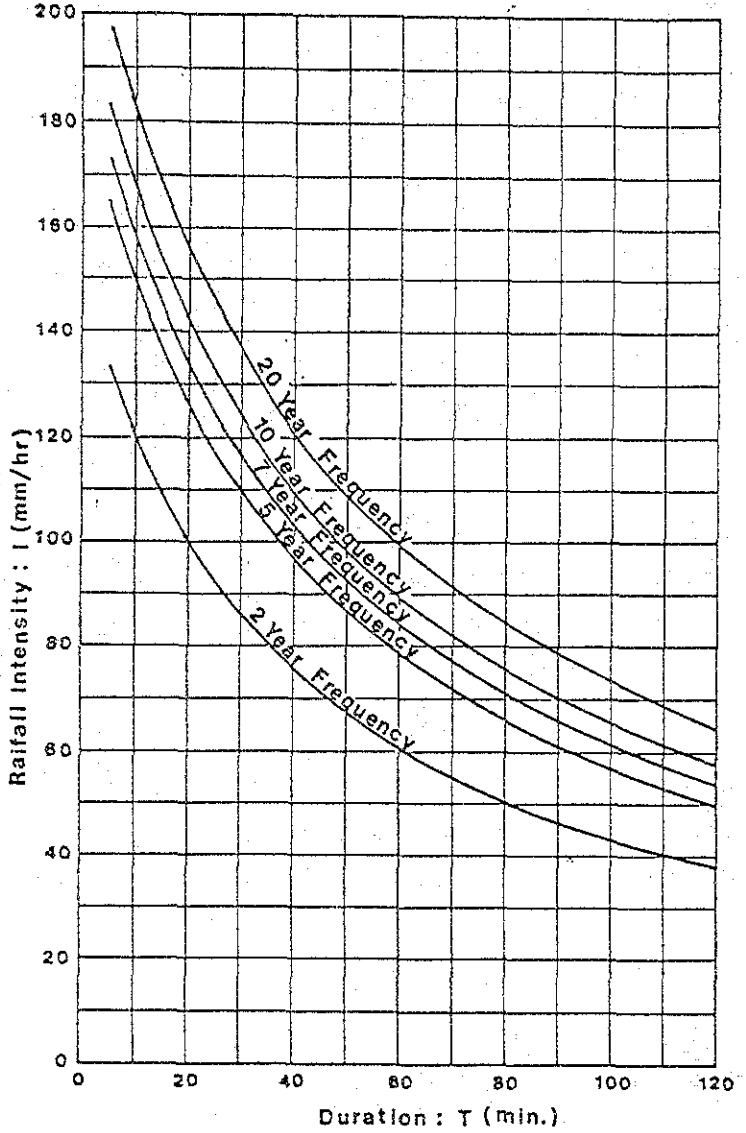
| Item | Return Period | Bangkapi | Min Buri | Lat Krabang | Average Study Area |
|---|---|---|---|---|---|
| Daily Rainfall Probability | 2 Year | 88.2 | 91.3 | 89.6 | 60.1 |
| | 5 | 115.4 | 117.3 | 116.3 | 80.8 |
| | 7 | 124.0 | 125.8 | 124.7 | 87.4 |
| | 10 | 132.8 | 134.1 | 133.3 | 94.2 |
| | 20 | 149.1 | 149.5 | 149.1 | 107.0 |
| | 30 | 158.3 | 158.3 | 158.1 | 114.3 |
| | 50 | 169.8 | 169.1 | 169.3 | 123.5 |
| | 100 | 185.2 | 183.5 | 184.2 | 135.9 |
| 3-Days Rainfall Probability | 2 | 122.2 | 118.8 | 132.8 | 105.9 |
| | 5 | 178.4 | 161.6 | 201.0 | 150.4 |
| | 7 | 197.5 | 175.5 | 224.7 | 165.2 |
| | 10 | 217.5 | 189.8 | 249.7 | 180.6 |
| | 20 | 256.0 | 216.7 | 298.6 | 210.1 |
| | 30 | 278.7 | 232.2 | 327.8 | 227.3 |
| | 50 | 307.7 | 251.6 | 365.3 | 249.0 |
| | 100 | 347.8 | 278.0 | 417.9 | 279.0 |
| Monthly Rainfall Probability | 2 | 318.1 | 319.3 | 344.2 | 324.0 |
| | 5 | 411.4 | 408.1 | 509.1 | 417.3 |
| | 7 | 440.7 | 435.9 | 565.5 | 446.6 |
| | 10 | 470.5 | 464.0 | 624.8 | 476.3 |
| | 20 | 525.7 | 515.8 | 739.8 | 531.3 |
| | 30 | 557.0 | 545.0 | 807.8 | 562.4 |
| | 50 | 595.6 | 581.1 | 894.7 | 600.8 |
| | 100 | 647.4 | 629.2 | 1015.8 | 652.2 |
| 3-Months Rainfall Probability | 2 | 680.8 | 683.5 | 753.7 | 707.3 |
| | 5 | 901.1 | 852.8 | 999.0 | 872.4 |
| | 7 | 971.4 | 905.0 | 1077.4 | 922.8 |
| | 10 | 1043.2 | 957.4 | 1157.5 | 973.4 |
| | 20 | 1177.3 | 1053.4 | 1307.2 | 1065.7 |
| | 30 | 1253.8 | 1107.1 | 1392.6 | 1117.1 |
| | 50 | 1348.9 | 1172.9 | 1498.8 | 1179.9 |
| | 70 | 1477.3 | 1260.2 | 1642.2 | 1263.0 |
| Yearly Rainfall Probability | 2 | 1286.9 | 1324.3 | 1347.3 | 1355.2 |
| | 5 | 1652.3 | 1612.9 | 1709.3 | 1583.8 |
| | 7 | 1766.8 | 1700.5 | 1821.9 | 1651.4 |
| | 10 | 1882.8 | 1788.0 | 1935.7 | 1718.2 |
| | 20 | 2097.2 | 1946.7 | 2145.0 | 1837.7 |
| | 30 | 2218.4 | 2035.0 | 2262.8 | 1903.2 |
| | 50 | 2367.9 | 2142.3 | 2407.8 | 1982.3 |
| | 70 | 2567.8 | 2283.8 | 2601.0 | 2085.0 |

Legend

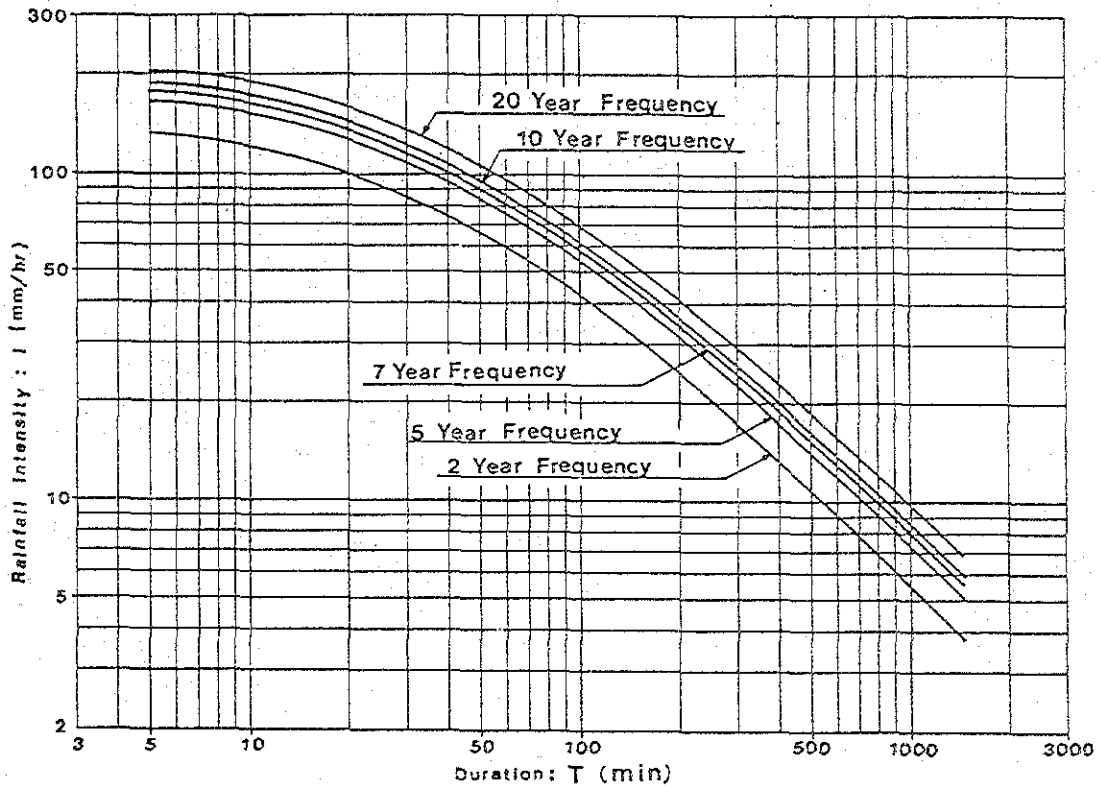
- ○ : Probable Daily Rainfall
- ■ : Probable 3-Days Rainfall
- △ : Probable Monthly Rainfall
- ▲ : Probable 3-Months Rainfall
- ● : Probable Yealy Rainfall

FIG. F. 17 **Probability of Daily, 3-Day, Monthly, 3-Month and Yearly Rainfall in the Study Area**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




Case A'




Case B'

Rainfall Intensity–Duration Formula

2 Year Probability : $i = \frac{5,690}{t + 37}$

5 " " : $i = \frac{7,600}{t + 40}$

7 " " : $i = \frac{8,230}{t + 41}$

10 " " : $i = \frac{8,850}{t + 42}$

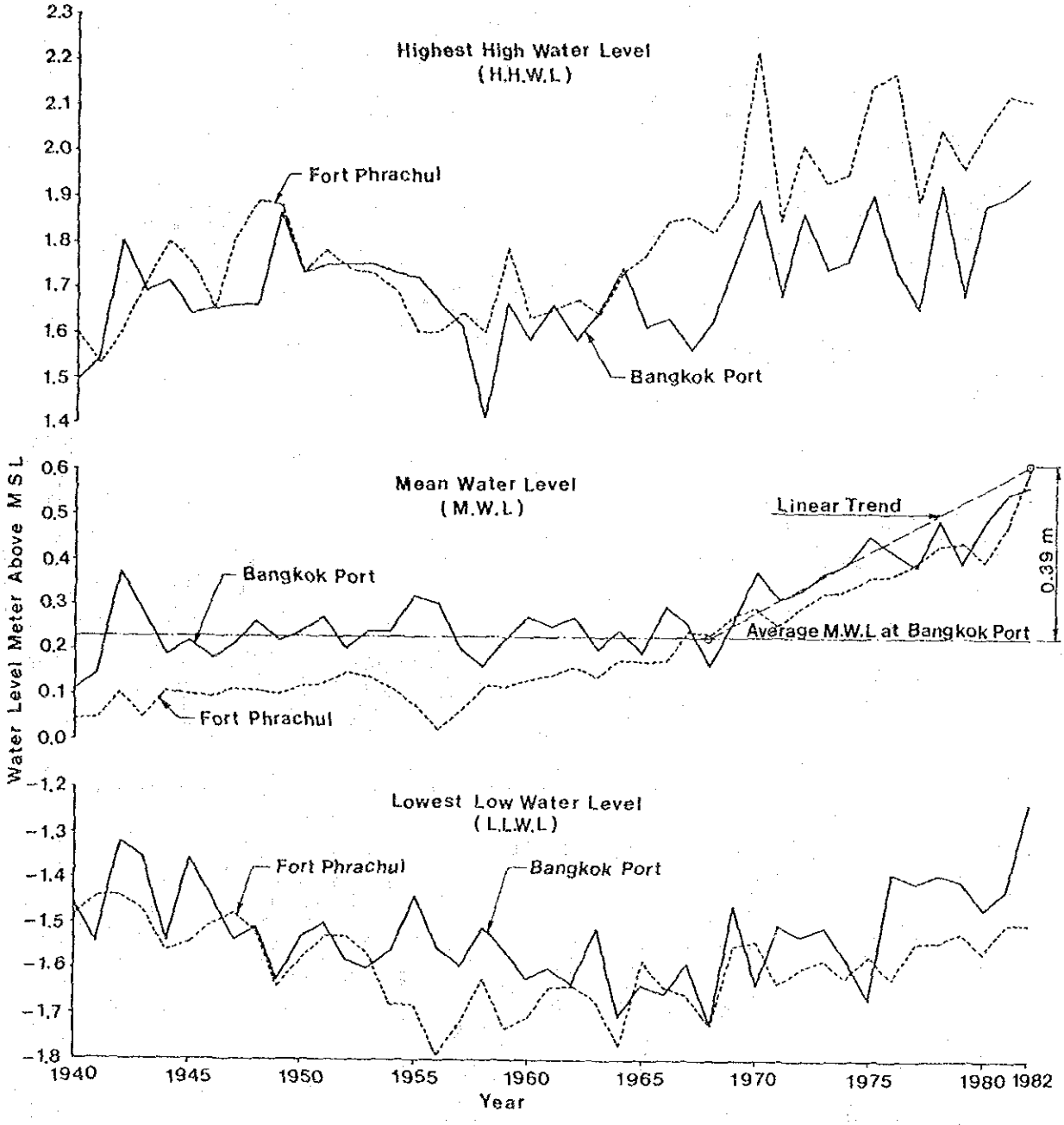
20 " " : $i = \frac{10,040}{t + 44}$

Note : 1. Case A' is used for the case when the time of concentration is within 2 hours.

2. For case B', the time of concentration is between 2 hours and 24 hours

FIG. F. 18 Rainfall Intensity – Duration Curves

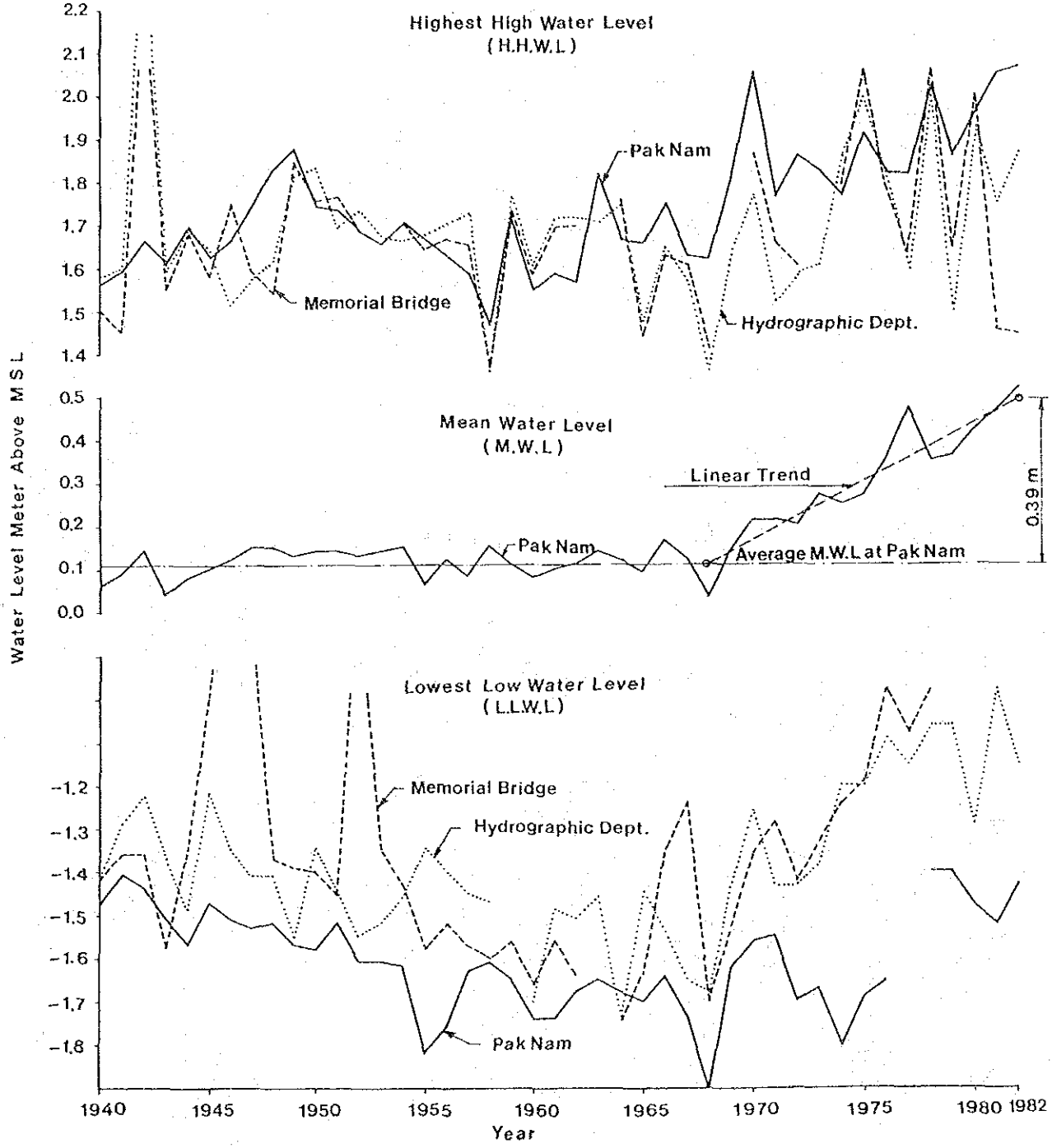
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




Source: Port Authority of Thailand

| FIG. F. 19 | Annual H.H.W.L, M.W.L, L.L.W.L and Effect of Land Subsidence on Water Level of Chao Phraya River |
|---|---|

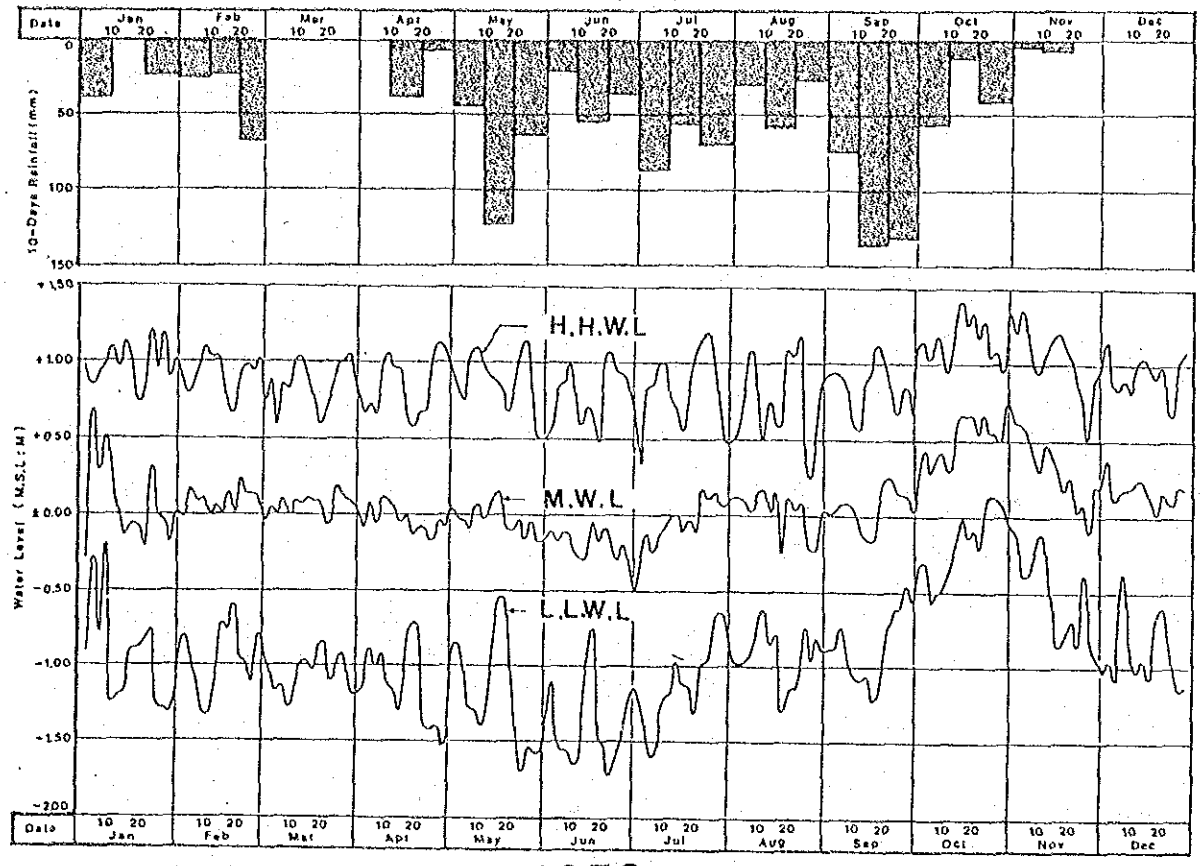
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



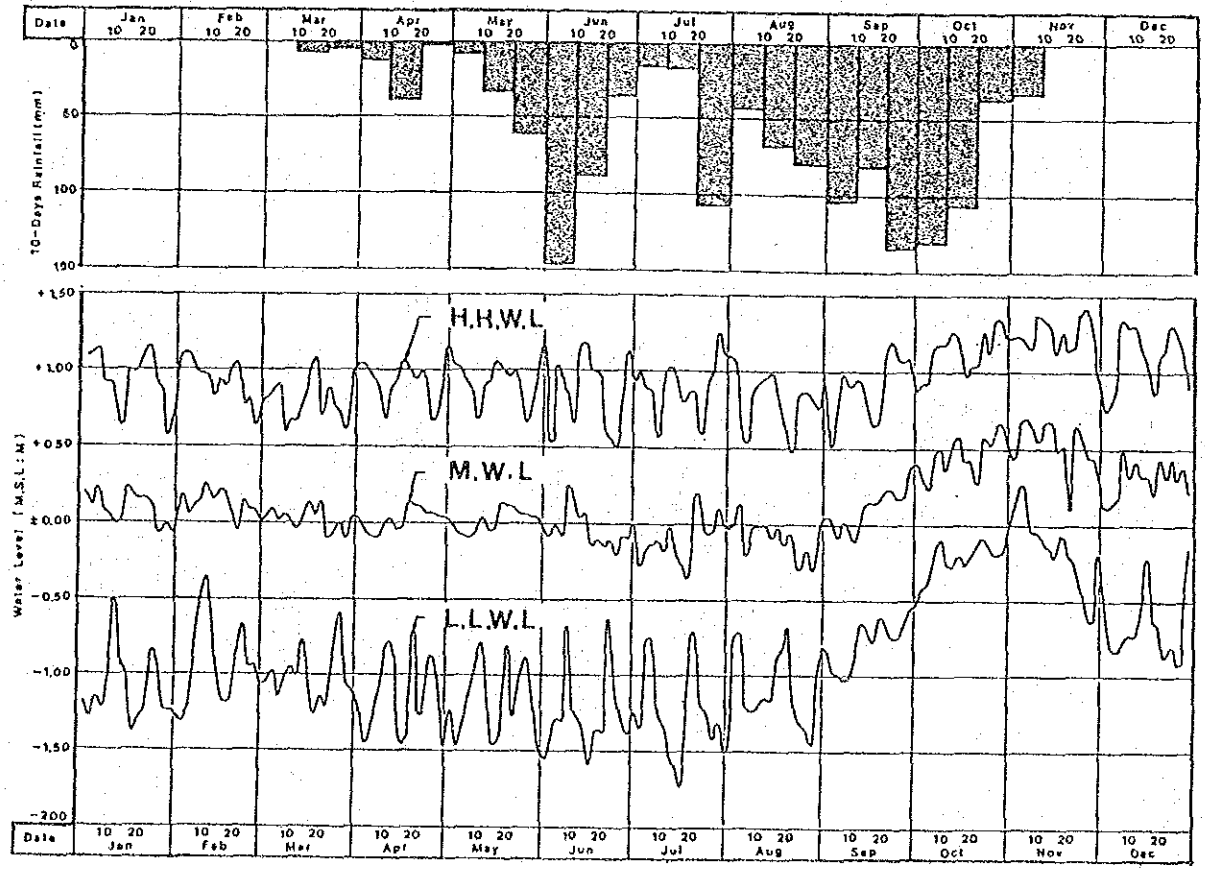

Source: Port Authority of Thailand, Hydrographic Dept. and RID

FIG. F. 20 Annual H.H.W.L, M.W.L, L.L.W.L and Effect of Land Subsidence on Water Level of Chao Phraya River

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




1978

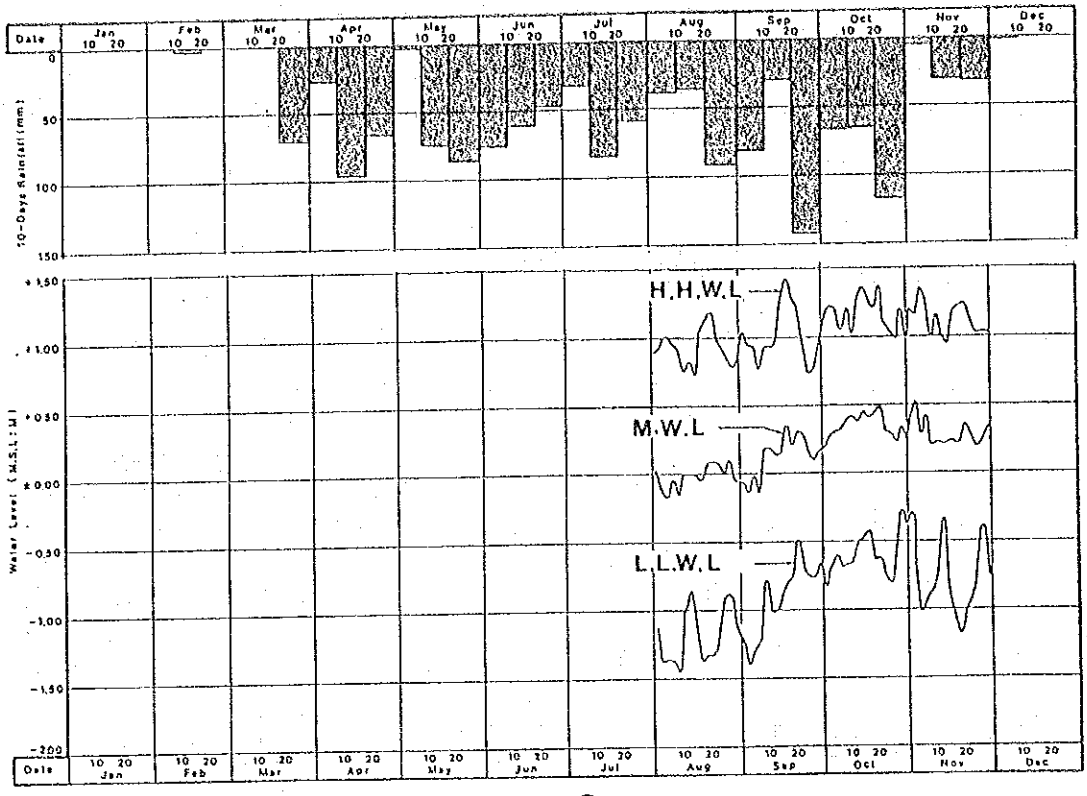



1980

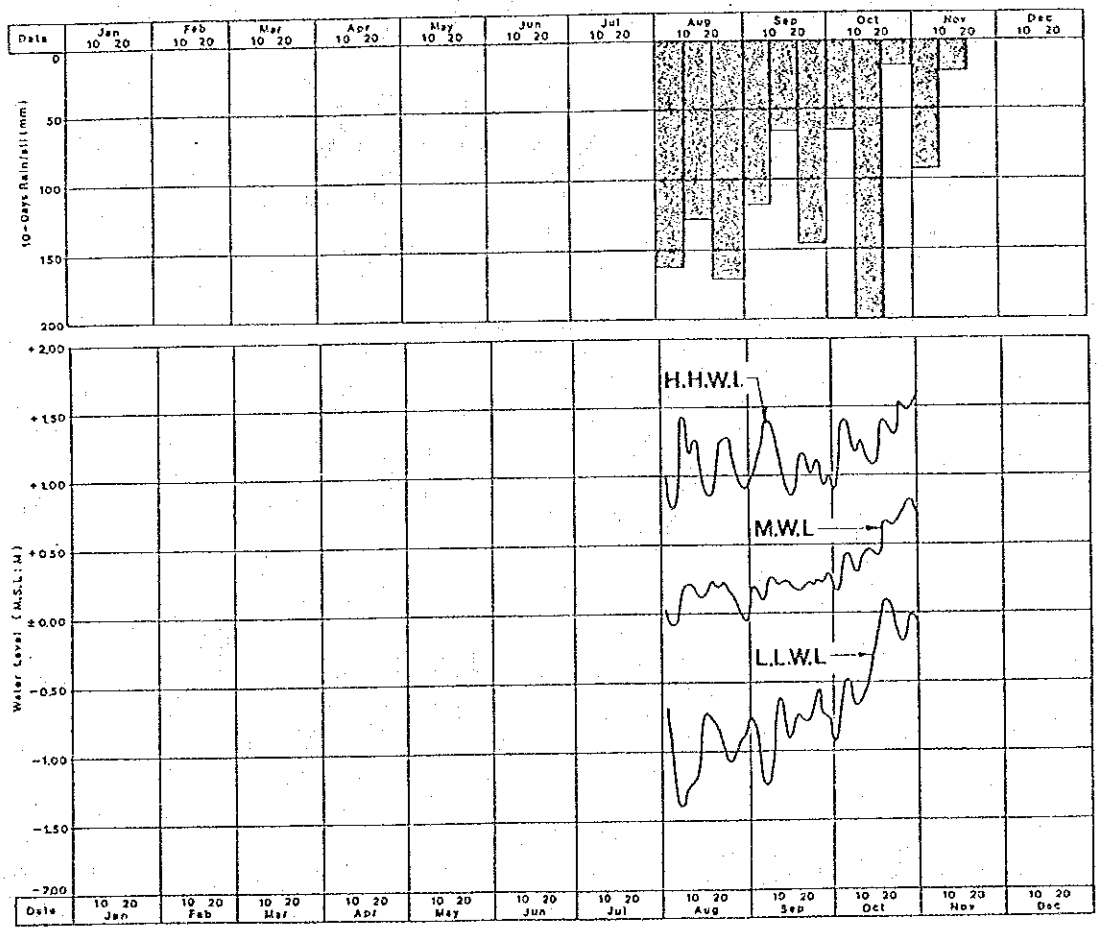
Source : Meteorological Department and P.A.T

FIG. F. 21 **Seasonal Changes of Rainfall in the Study Area and Water Level at Bangkok Port in 1978 & 1980**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




1982

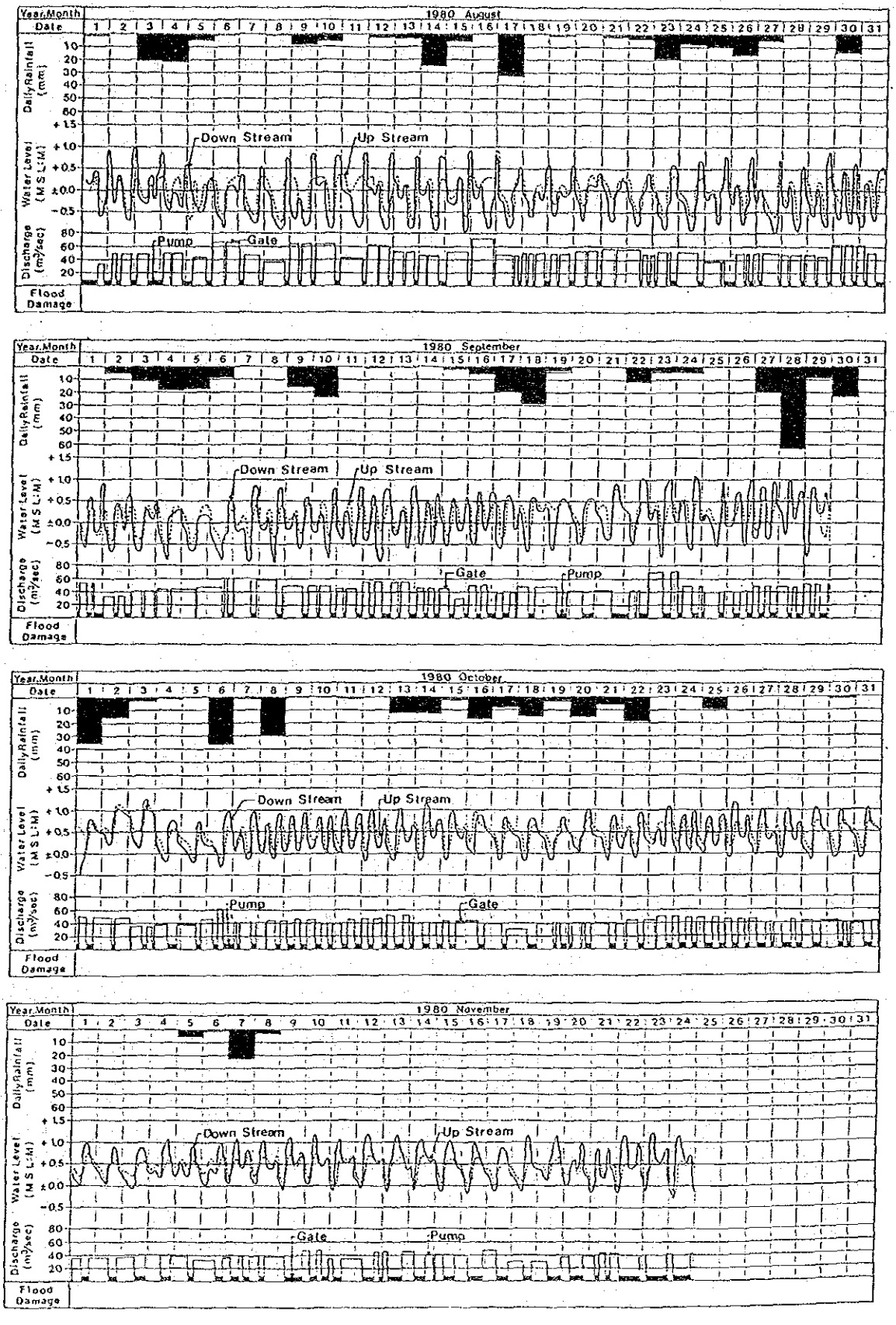



1983

Source : Meteorological Department and P.A.T

FIG. F. 22 Seasonal Changes of Rainfall in the Study Area and Water Level at Bangkok Port in 1982 & 1983

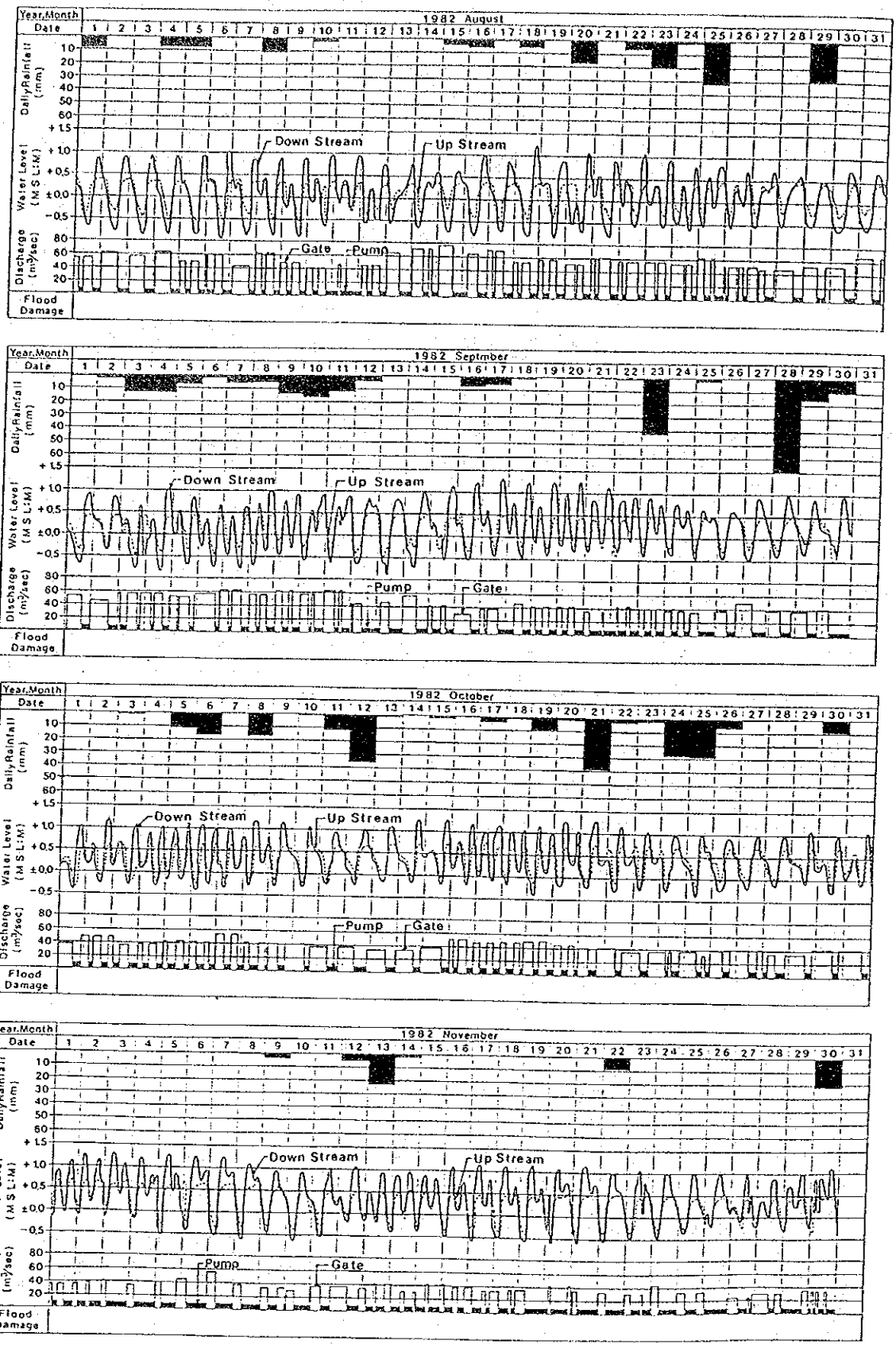
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




Source : RID

FIG. F. 23 Operation Record at Prakhanong Flood Gate and Pump between August and November in 1980

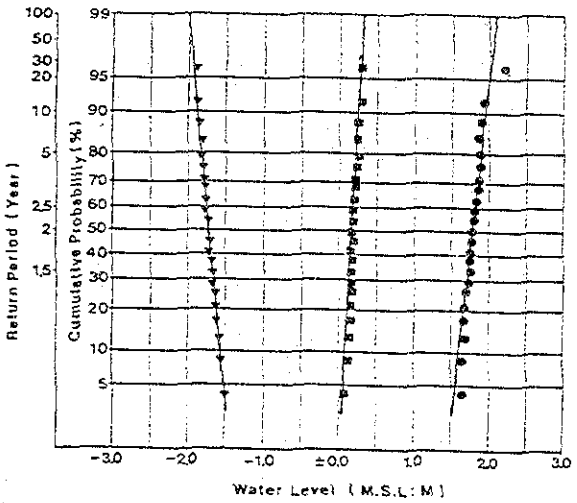
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



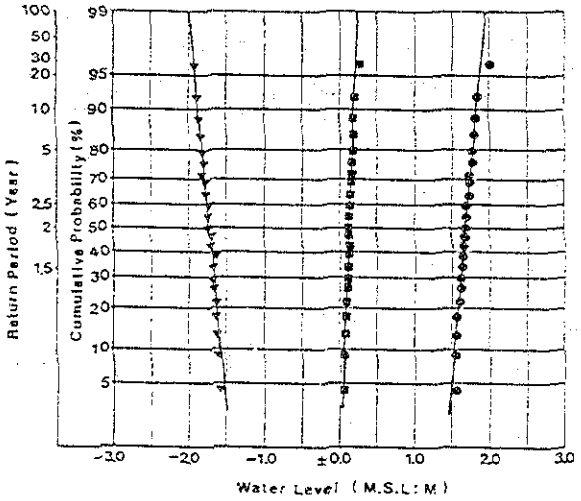

Source : R I D

FIG. F. 24 Operation Record at Prakhanong Flood Gate and Pump between August and November in 1982

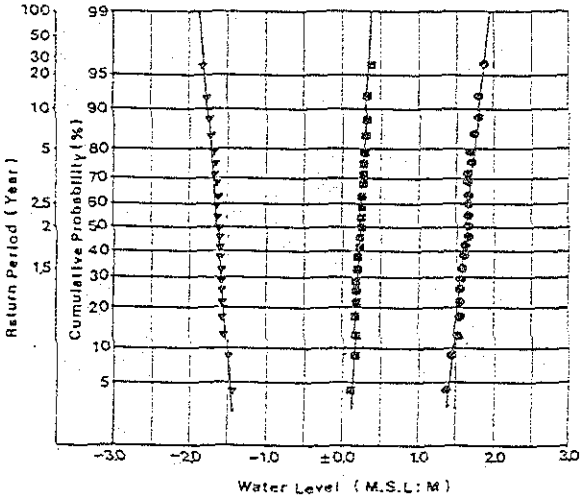
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



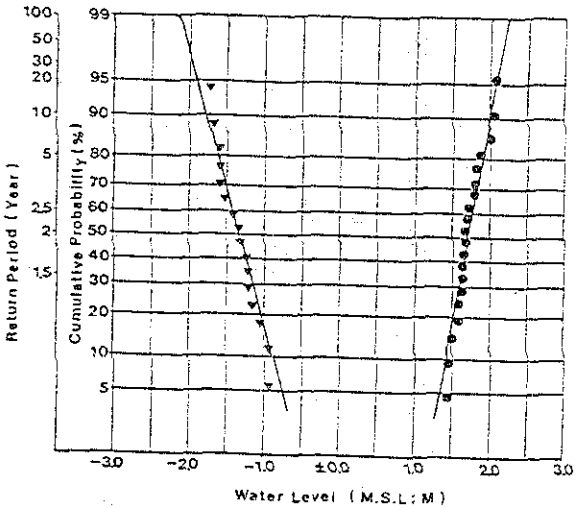

Fort Phrachul



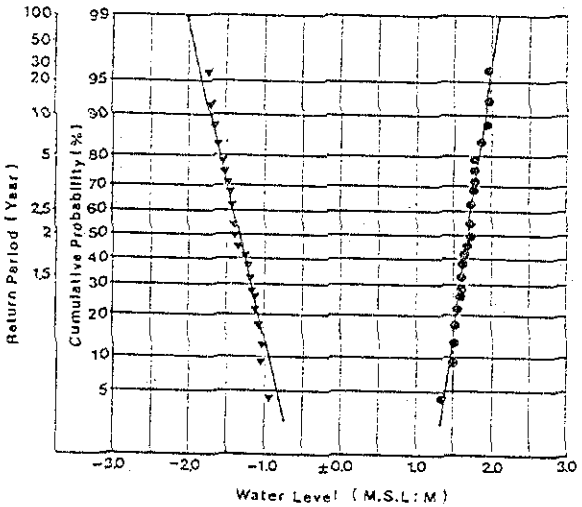

Pak Num




Bangkok Port




Memorial Bridge




Hydrographic Dep

| Item | Year | Port Phrachul | Pak Num | Bangkok Port | Memorial Bridge | Hydrographic Dep. |
|---|---|---|---|---|---|---|
| Highest High Water Level (H.H.W.L.) | 2 | 1.78 | 1.67 | 1.61 | 1.68 | 1.67 |
| | 5 | 1.89 | 1.77 | 1.72 | 1.86 | 1.83 |
| | 10 | 1.95 | 1.82 | 1.77 | 1.96 | 1.91 |
| | 20 | 2.00 | 1.86 | 1.82 | 2.04 | 1.99 |
| | 30 | 2.02 | 1.88 | 1.85 | 2.09 | 2.03 |
| | 50 | 2.06 | 1.91 | 1.88 | 2.14 | 2.08 |
| | 100 | 2.10 | 1.95 | 1.92 | 2.21 | 2.14 |
| Mean Water Level (M.W.L.) | 2 | 0.18 | 0.12 | 0.22 | | |
| | 5 | 0.22 | 0.16 | 0.27 | | |
| | 10 | 0.25 | 0.18 | 0.30 | | |
| | 20 | 0.27 | 0.19 | 0.32 | | |
| | 30 | 0.28 | 0.20 | 0.34 | | |
| | 50 | 0.29 | 0.21 | 0.35 | | |
| | 100 | 0.30 | 0.23 | 0.37 | | |
| Lowest Low Water Level (L.L.W.L.) | 2 | -1.72 | -1.74 | -1.64 | -1.36 | -1.34 |
| | 5 | -1.81 | -1.84 | -1.73 | -1.63 | -1.57 |
| | 10 | -1.87 | -1.89 | -1.77 | -1.79 | -1.70 |
| | 20 | -1.91 | -1.93 | -1.81 | -1.93 | -1.82 |
| | 30 | -1.93 | -1.96 | -1.83 | -2.01 | -1.88 |
| | 50 | -1.96 | -1.98 | -1.85 | -2.11 | -1.96 |
| | 100 | -1.99 | -2.02 | -1.88 | -2.24 | -2.06 |

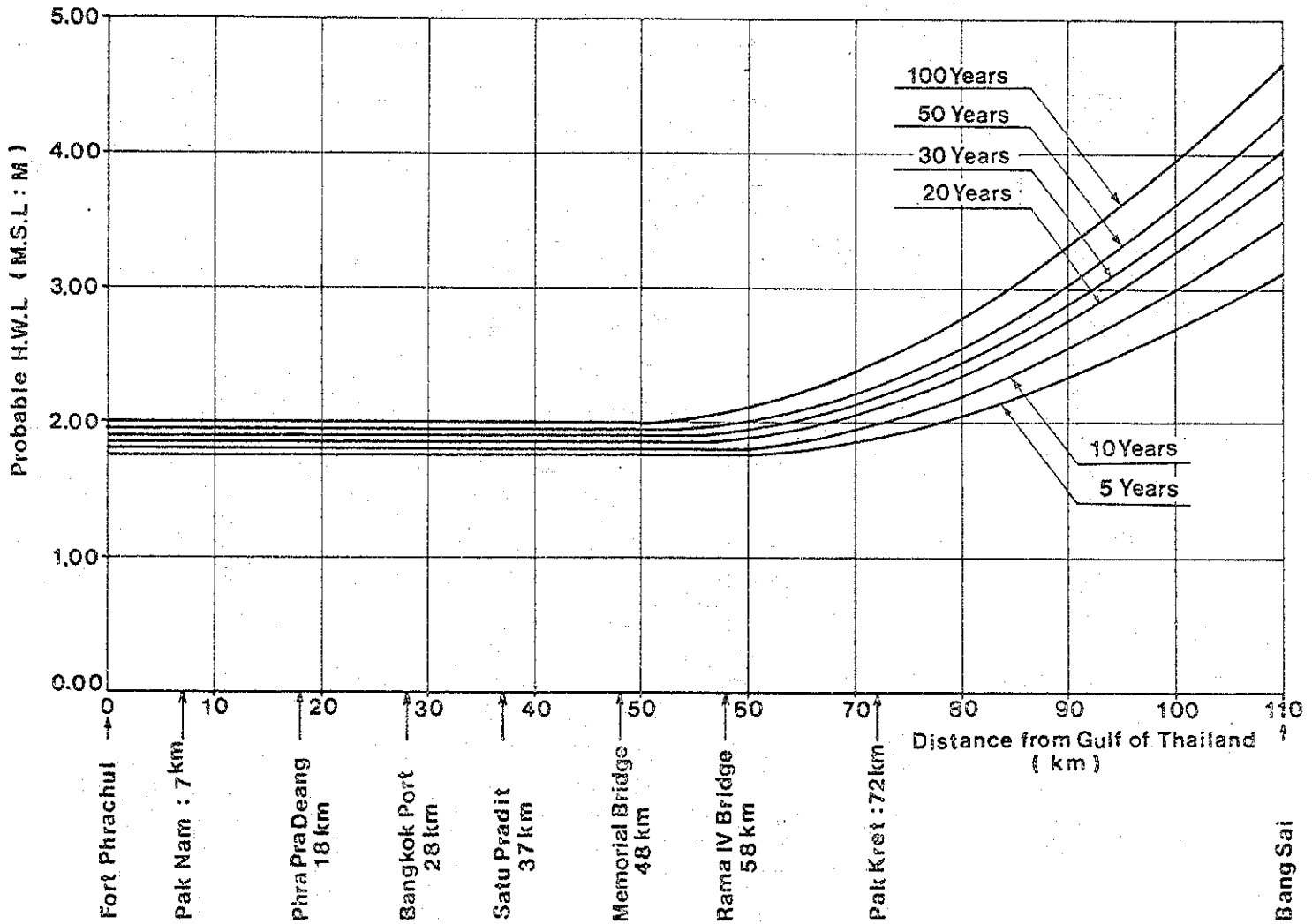
Unit : Meter above MSL

Legend

- : Highest High Water Level
- : Mean Water Level
- : Lowest Low Water Level

FIG. F. 25 Probable Yearly Water Level of Chao Phraya River

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




| FIG. F. 26 | Probable Flood Water Level of Chao Phraya River |
|---|---|
| FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK | |

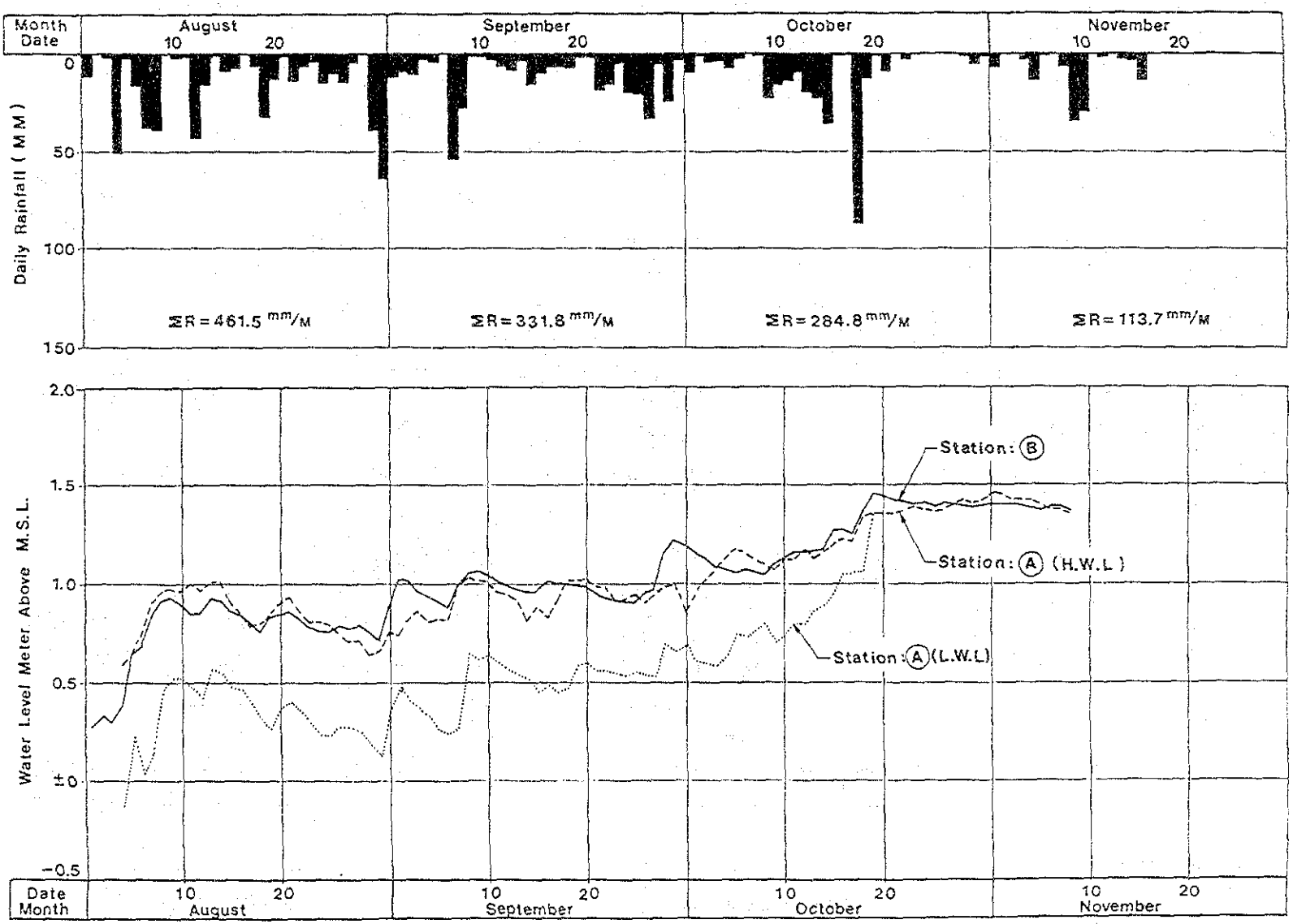



FIG. F. 27 **Average Areal Daily Rainfall in the Study Area & Water Level of Klong Bang Khen between Aug. and Nov. in 1983**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

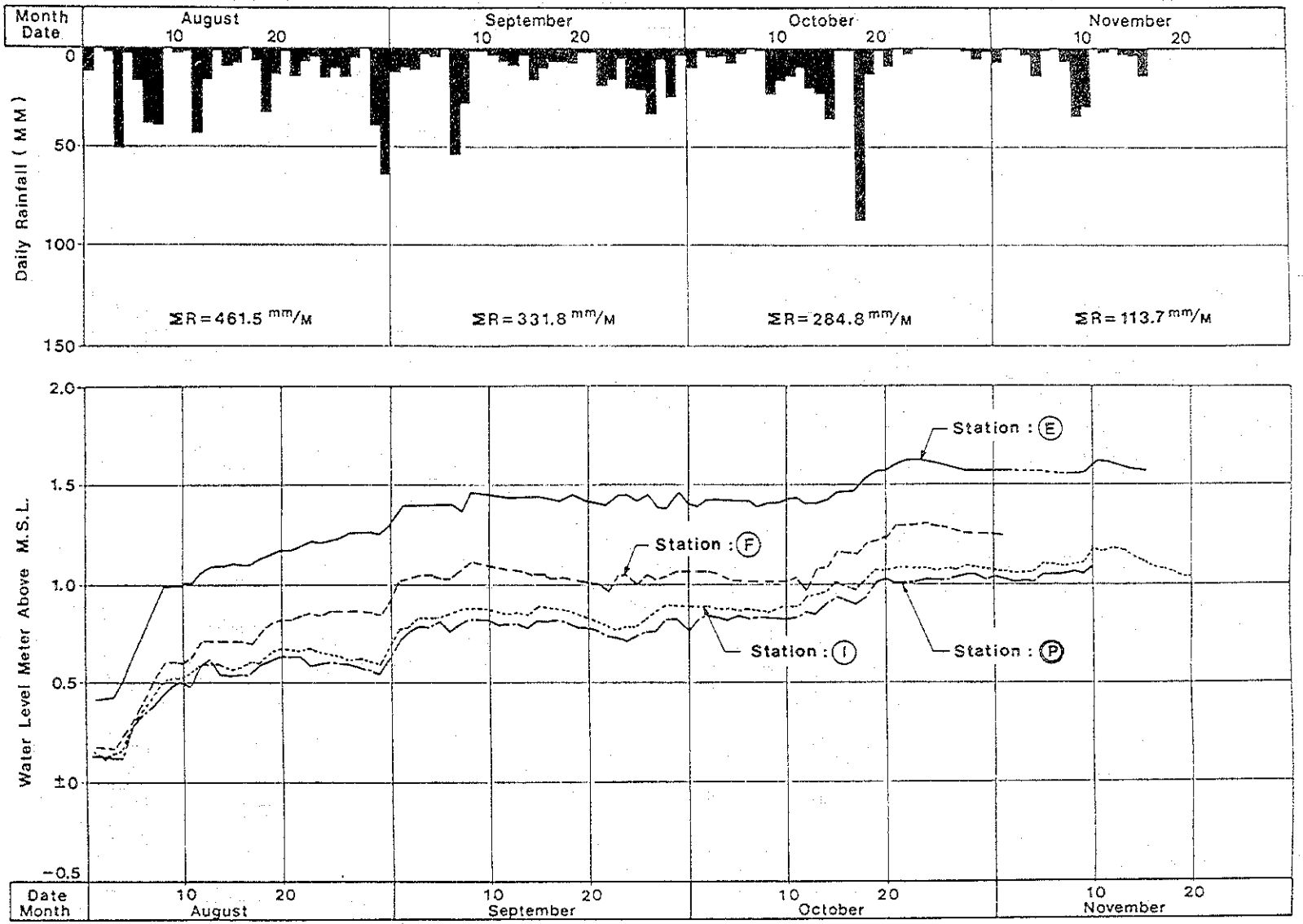



FIG. F. 28 **Average Areal Daily Rainfall in the Study Area & Water Level of Klong Saen Saep between Aug. and Nov. in 1983**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

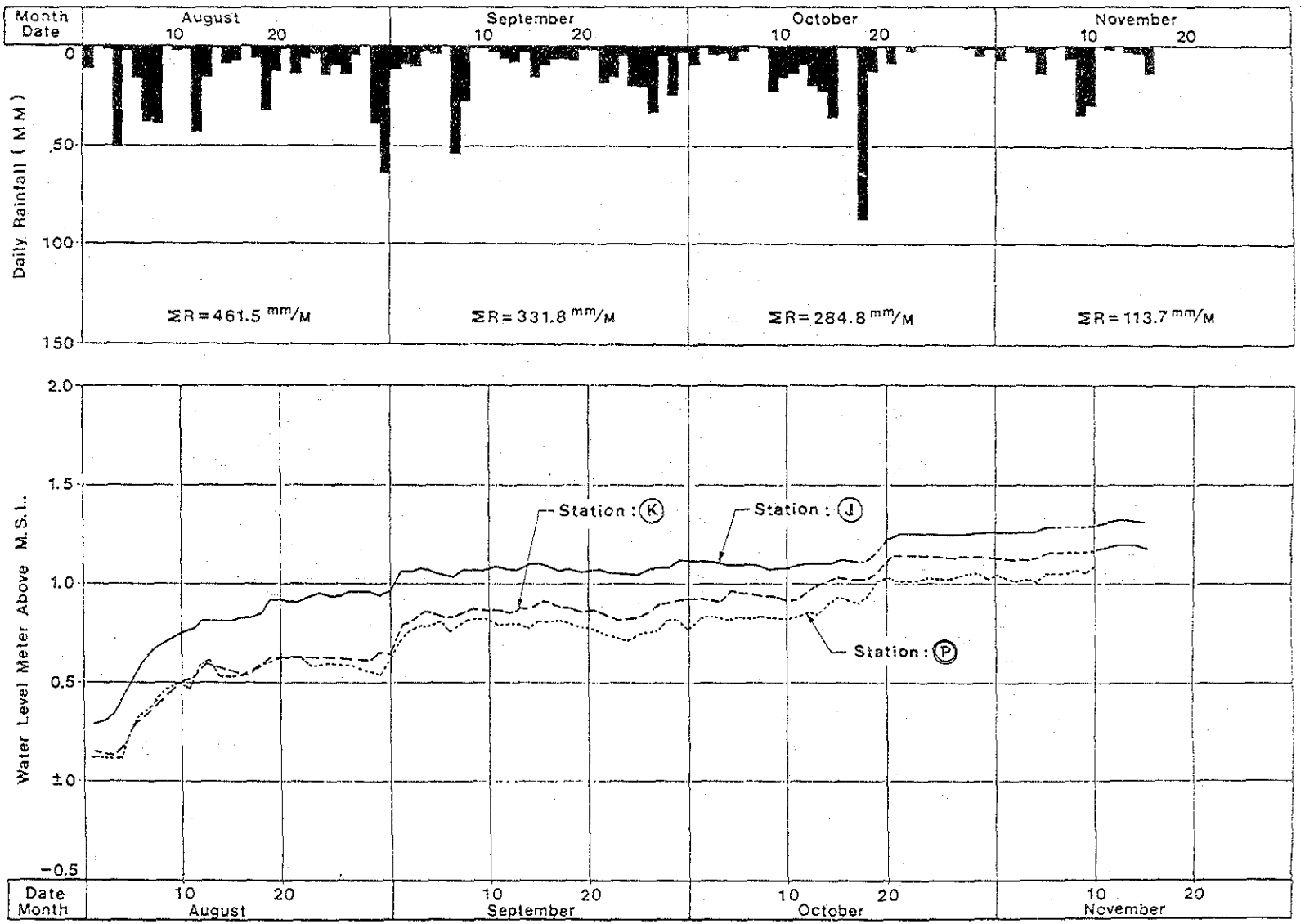



FIG. F. 29 Average Areal Daily Rainfall in the Study Area & Water Level of Klong Prakhanong between Aug. and Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

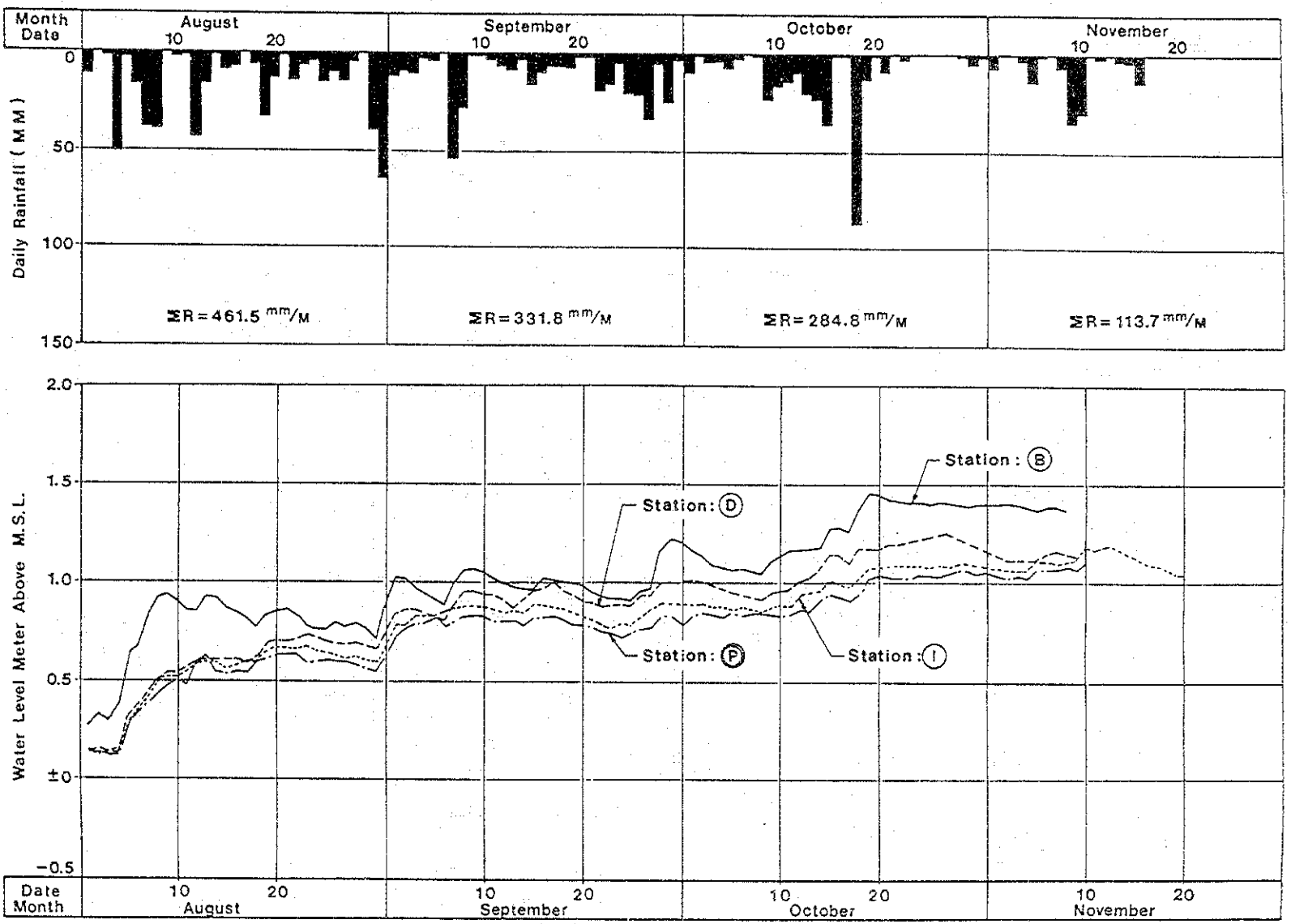



FIG. F. 30 Average Areal Daily Rainfall in the Study Area & Water Level of Klong Lat Phrao between Aug. and Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

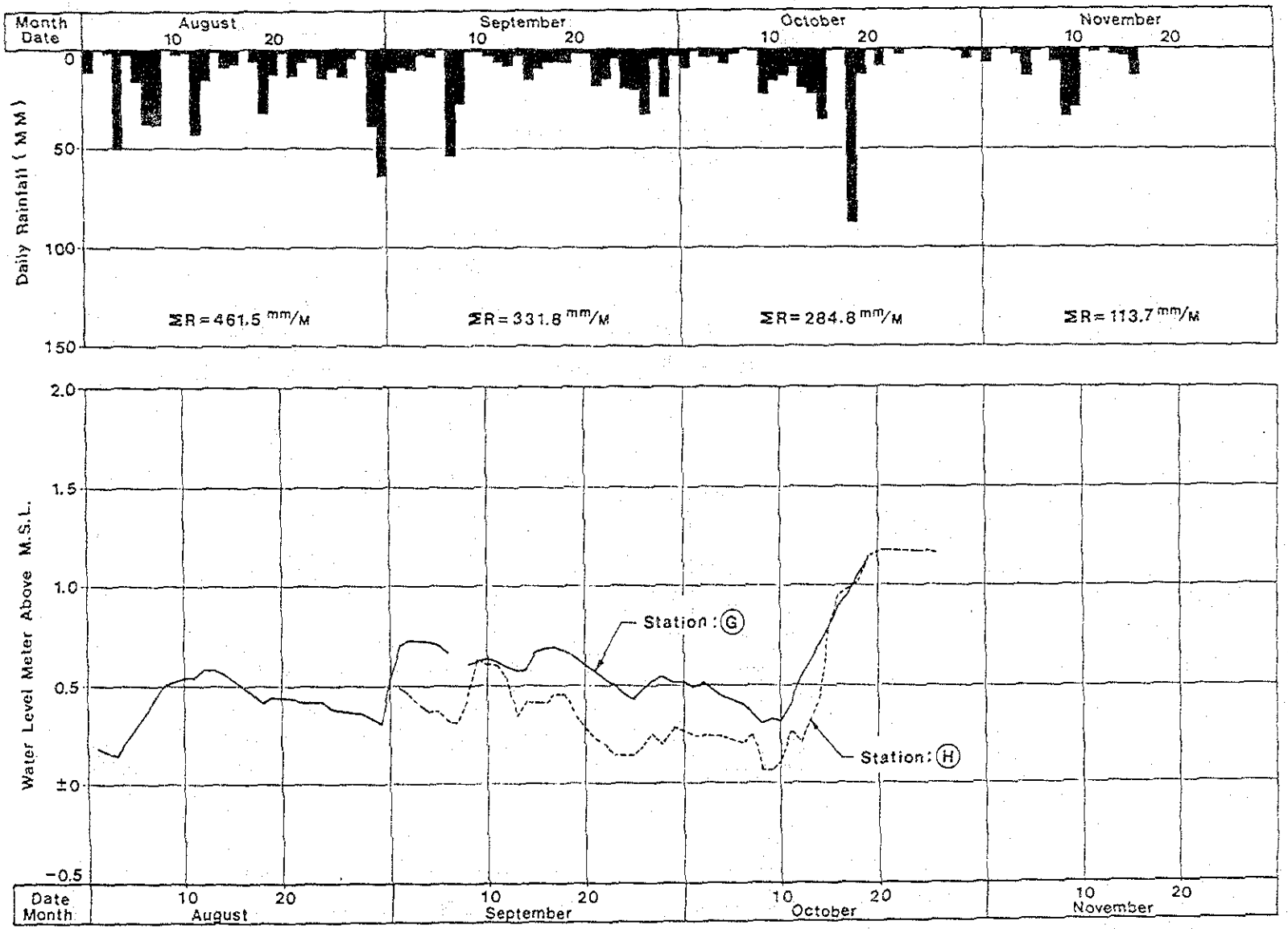



FIG. F. 31 Average Areal Daily Rainfall in the Study Area & Water Level of Klong Ka Cha between Aug. and Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

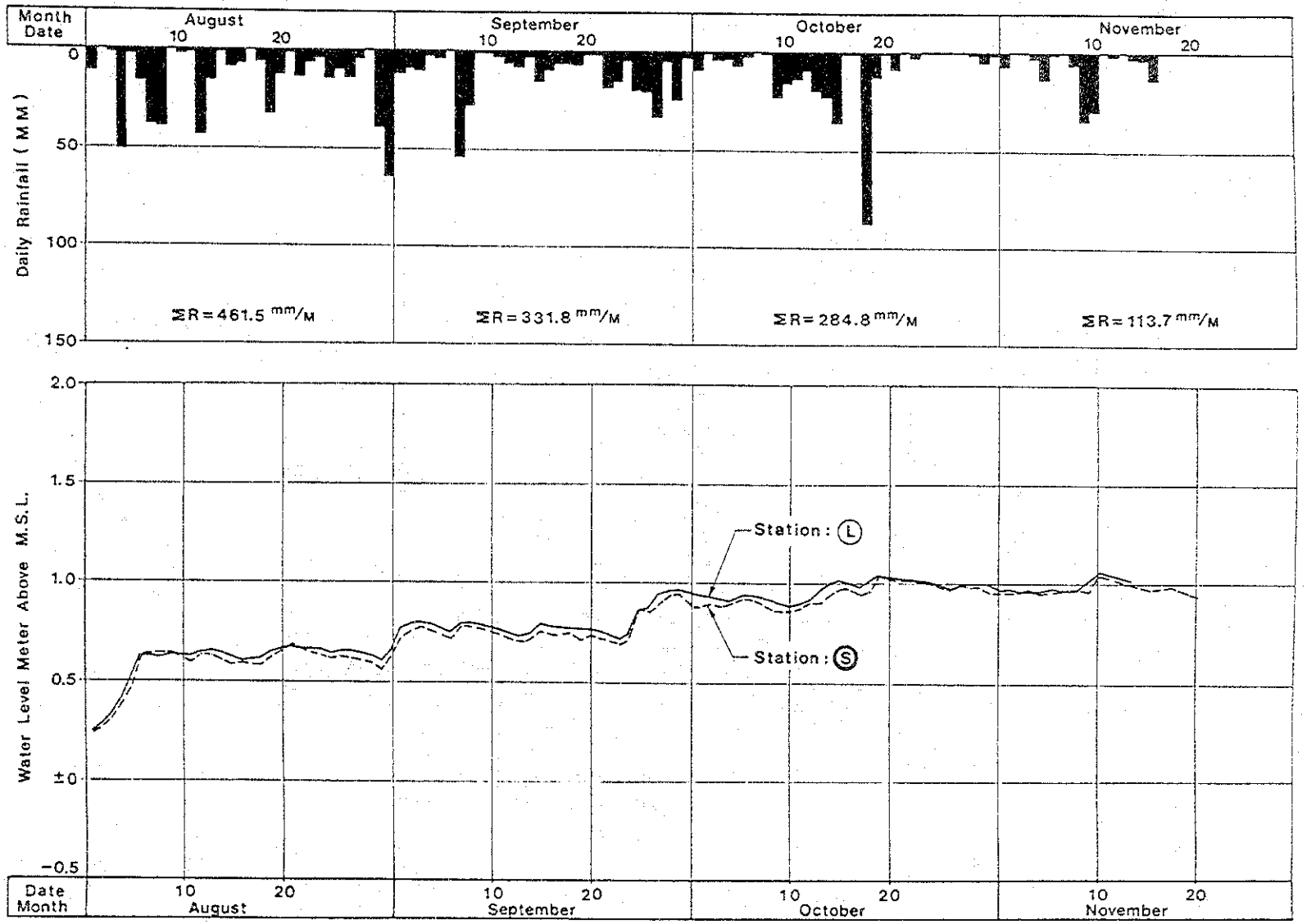



FIG. F . 32 **Average Areal Daily Rainfall in the Study Area & Water Level of Klong Sam Rong between Aug. and Nov. in 1983**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

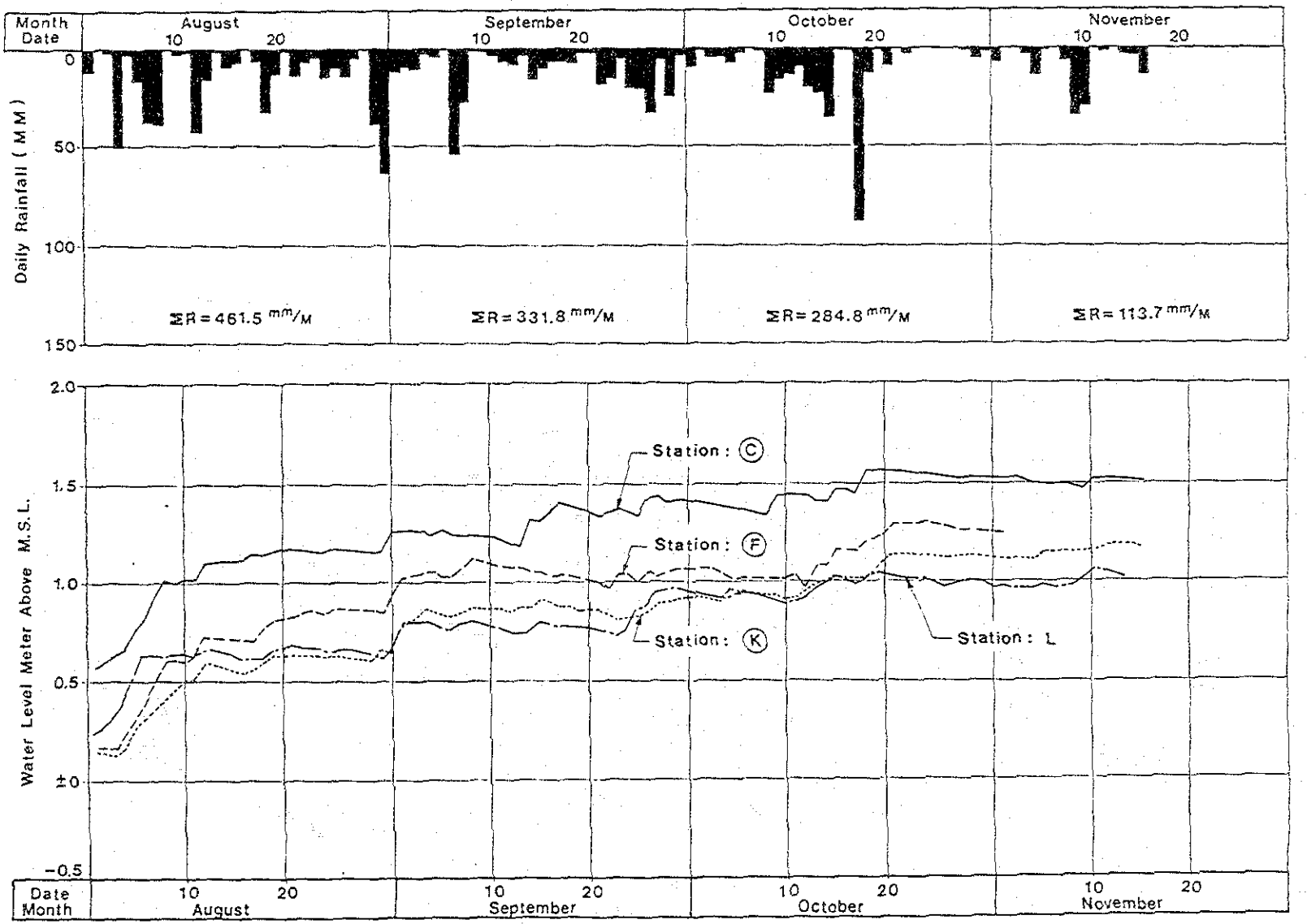



FIG. F. 33 Average Areal Daily Rainfall in the Study Area & Water Level of K. LamChan & San Na between Aug. & Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

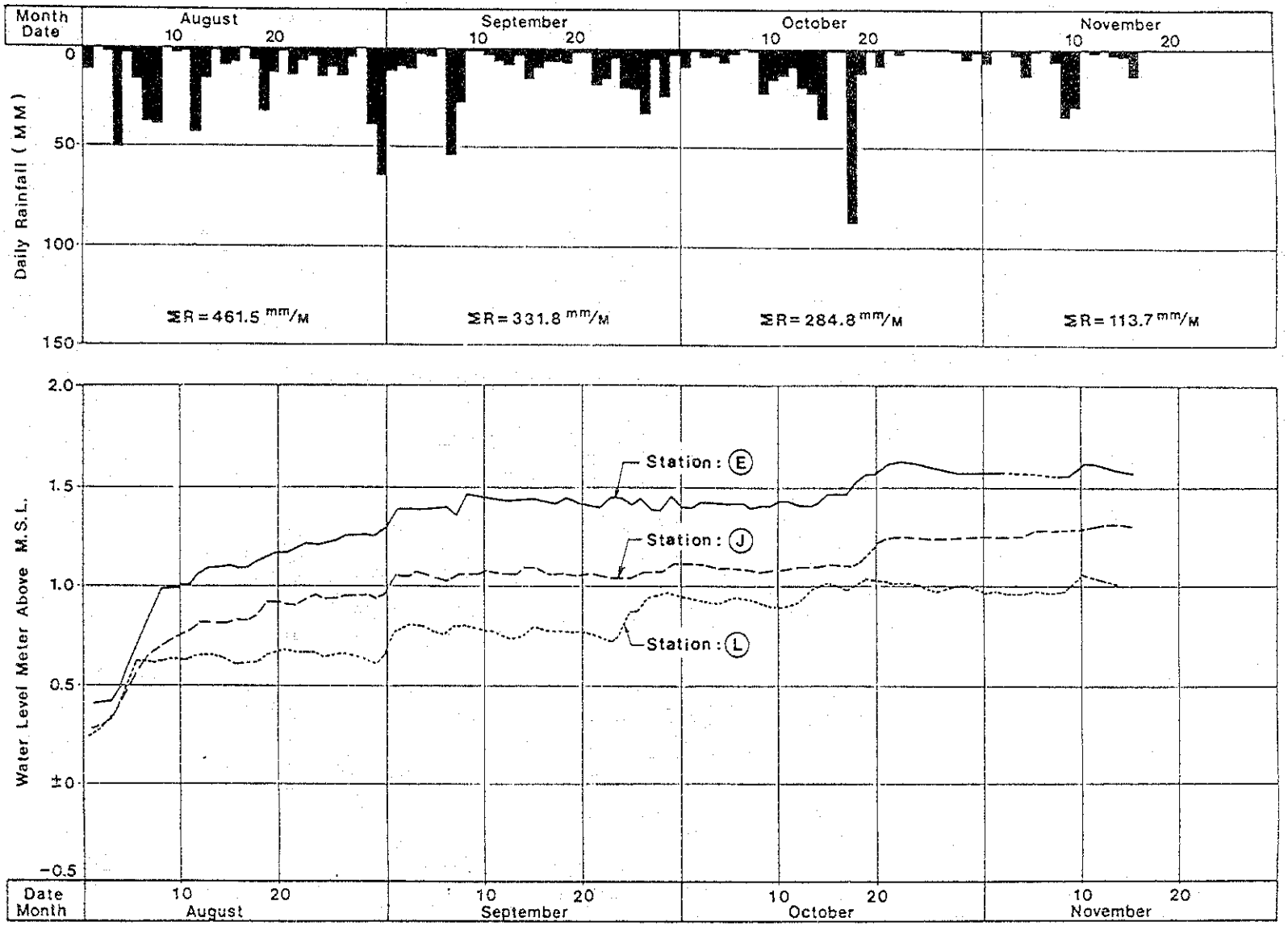



FIG. F.34 Average Areal Daily Rainfall in the Study Area & Water Level of K. Song Ton Nun & Chuat Lat between Aug. & Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

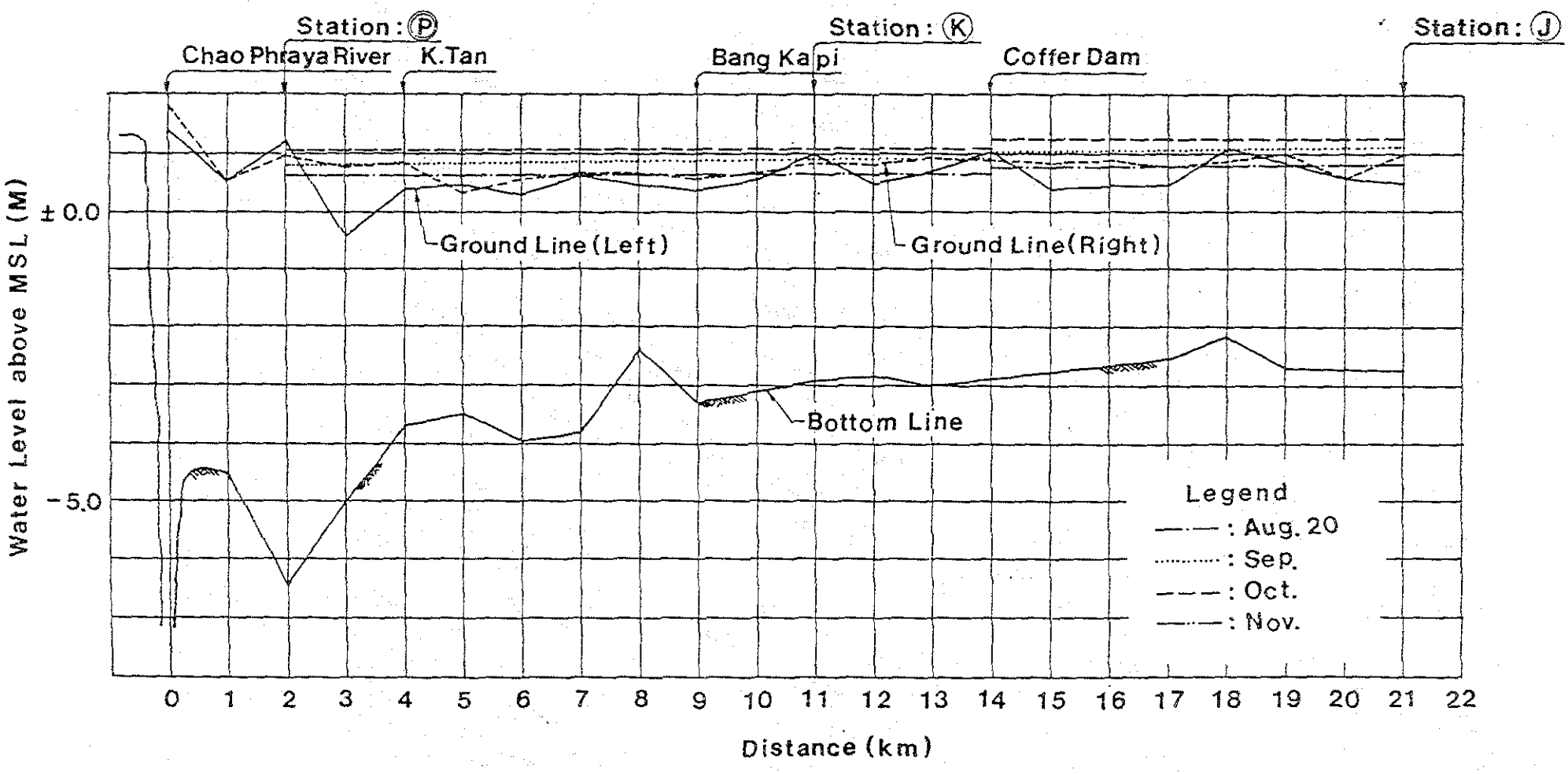



FIG. F.35 Profile of Observed Water Level in Klong Prakhanong between Aug. and Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

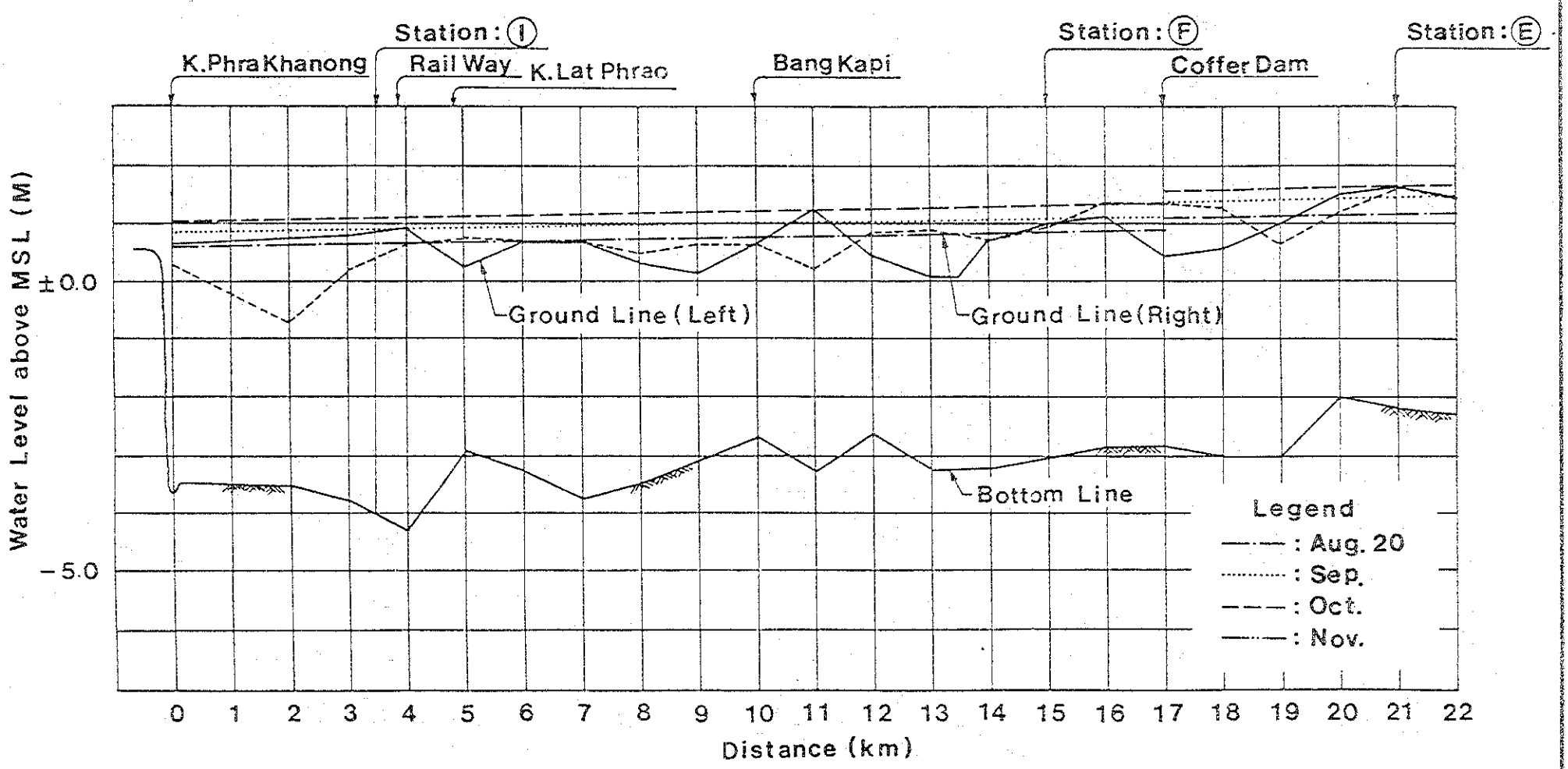



FIG. F.36 Profile of Observed Water Level in Klong Saen Saep between Aug. and Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

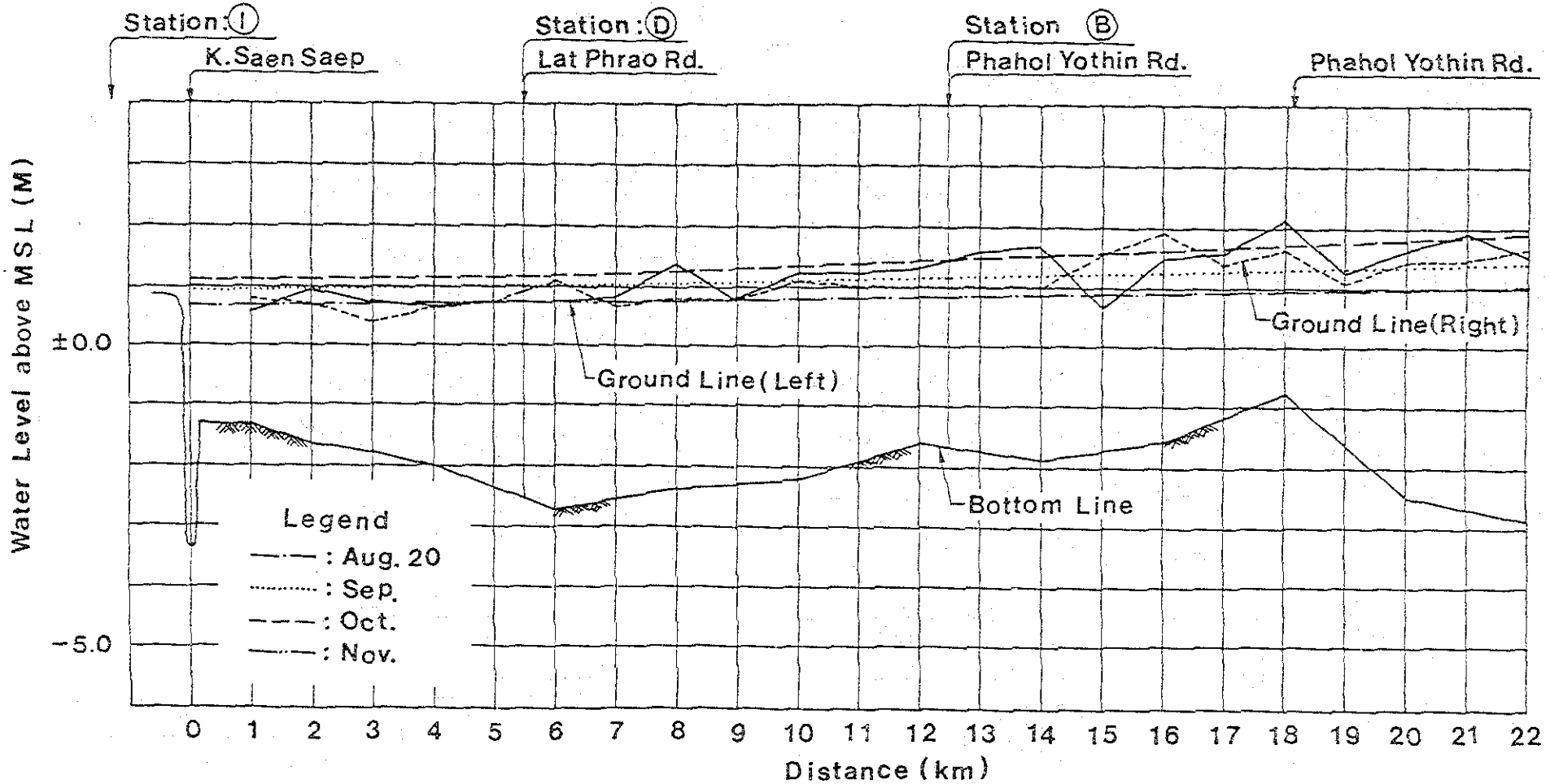
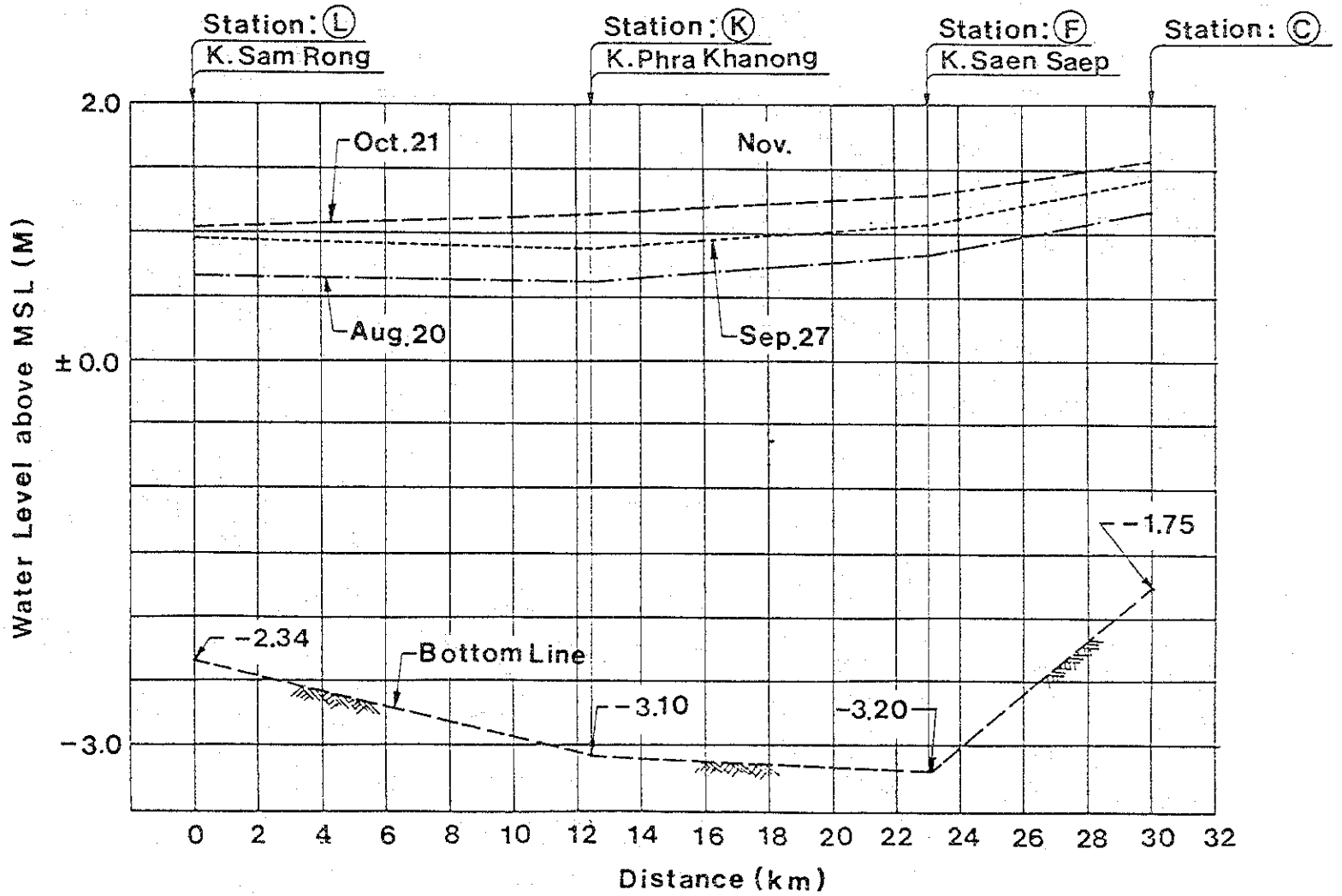
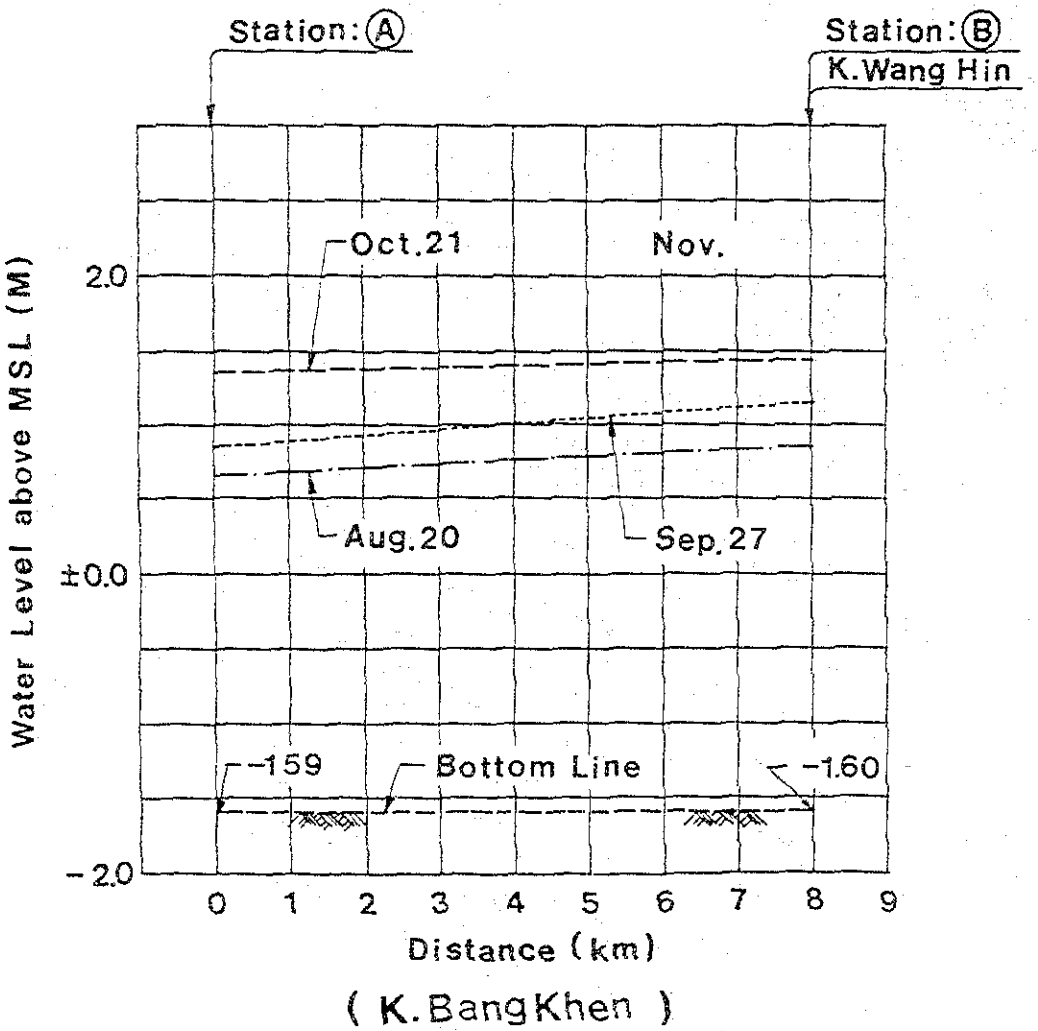



FIG. F. 37 Profile of Observed Water Level in Klong Lat Phrao between Aug. and Nov. in 1983

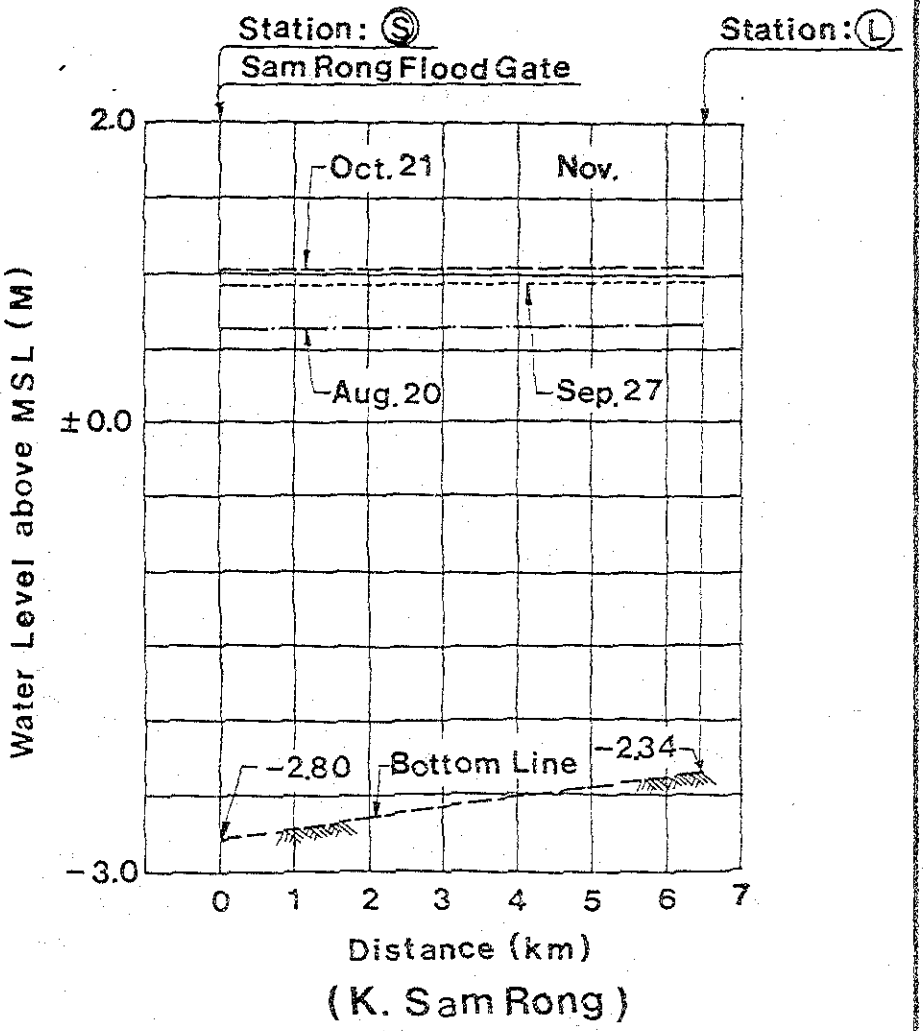
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




| FIG. F. 38 | Profile of Observed Water Level in Klong LamChan, SanNa & Palat Phiang between Aug. and Nov. in 1983 |
|---|---|
| FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK | |



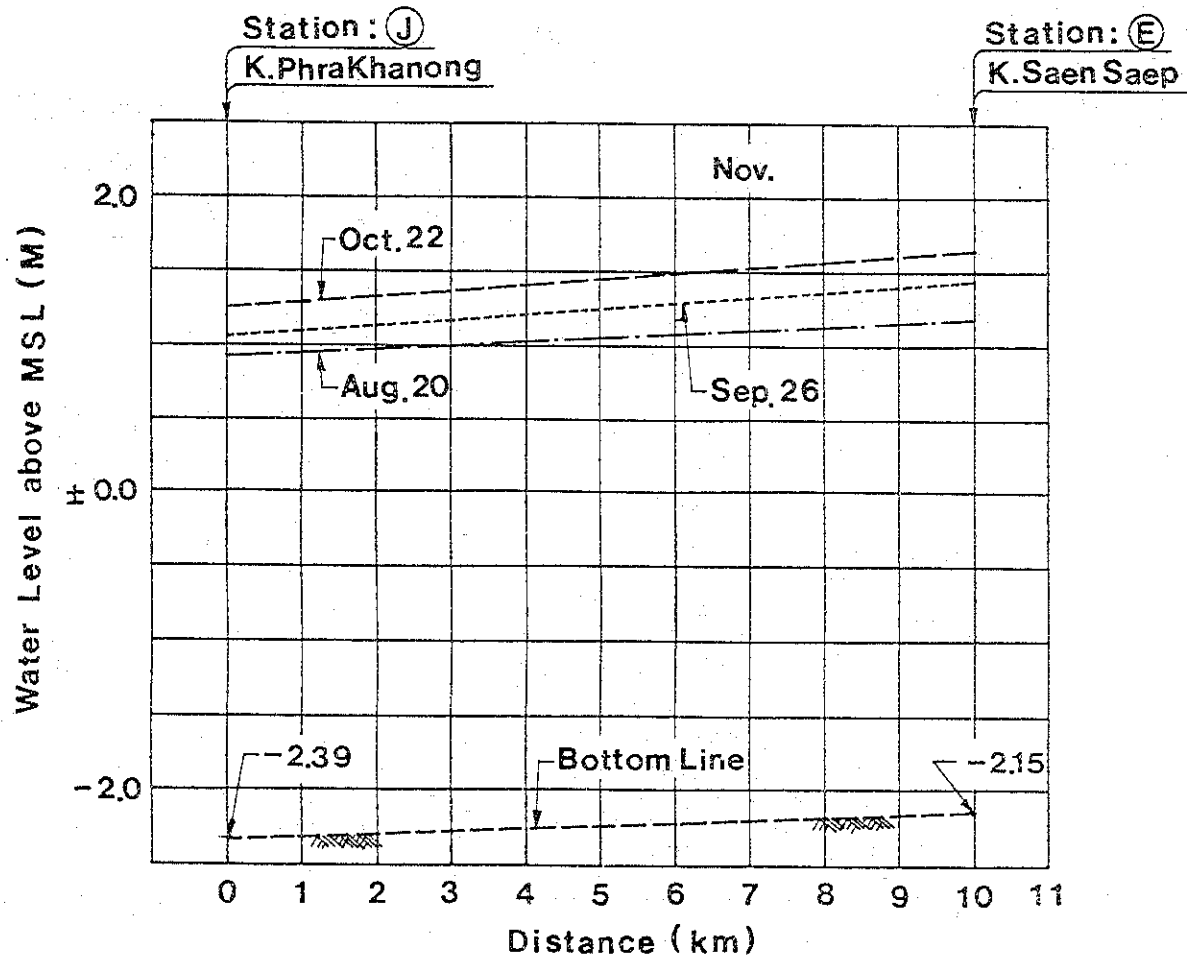

( K.Bang Khen )




( K. Sam Rong )

FIG. F. 39 Profile of Observed Water Level in Klong Bang Khen & Sam Rong between Aug. and Nov. in 1983

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK




| FIG. F.40 | Profile of Observed Water Level in Klong Song Ton Nun between Aug. and Nov. in 1983 |
|---|---|

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

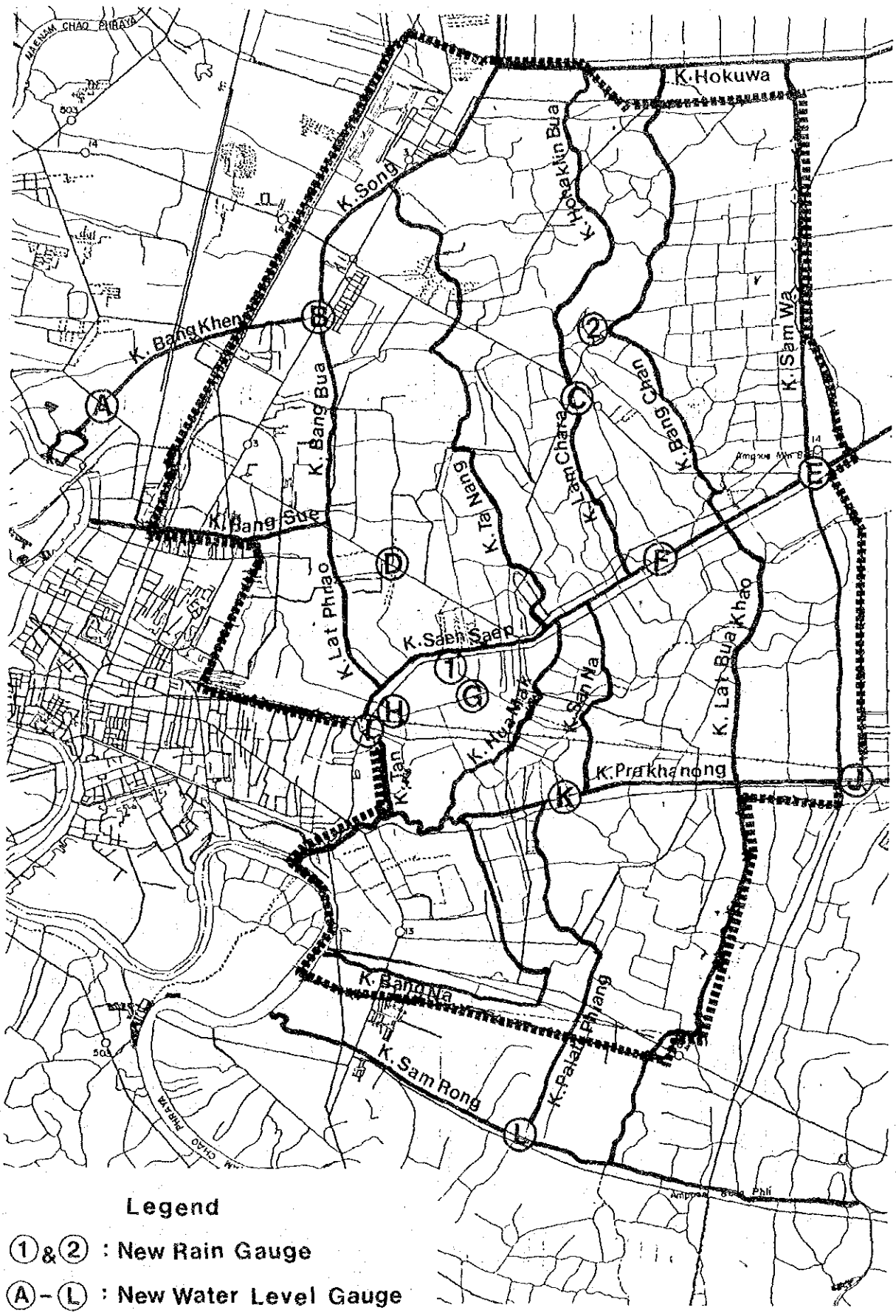
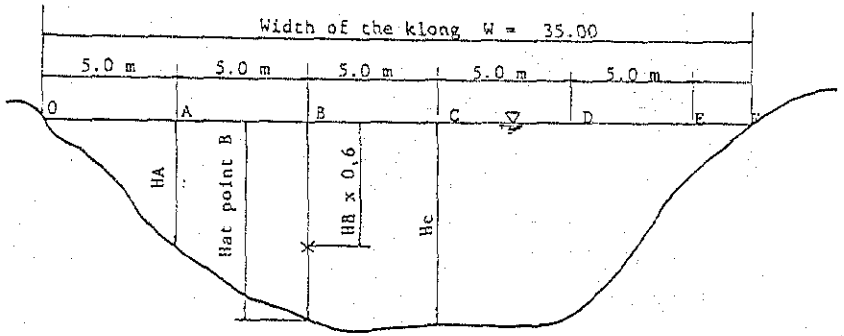



FIG. F.41 Location of New Gauging Stations

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Water Flow Measurement

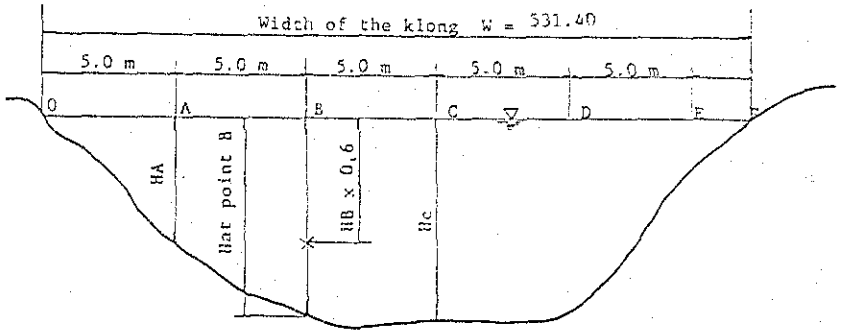
Location : Klong Phra Khanong Station K
Date : Oct.4, 1983 16:30
Flow Direction : East to West




| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 2.30 | .229 | 18.3 | 4.2 |
| B | 3.10 | .326 | 15.5 | 5.1 |
| C | 3.50 | .361 | 17.5 | 6.3 |
| D | 3.75 | .414 | 18.8 | 7.8 |
| E | 3.45 | .322 | 17.3 | 5.6 |
| F | 2.00 | .265 | 16.8 | 4.5 |
| G | | | 104.2 $m^2$ | 33.5 m3/s |
| H | | | | |

Water Flow Measurement

Location : Klong Snen Seap at MINBURI (E)
Date : SEP. 26, 1983 11:00 - 11:30
Flow Direction : East to West



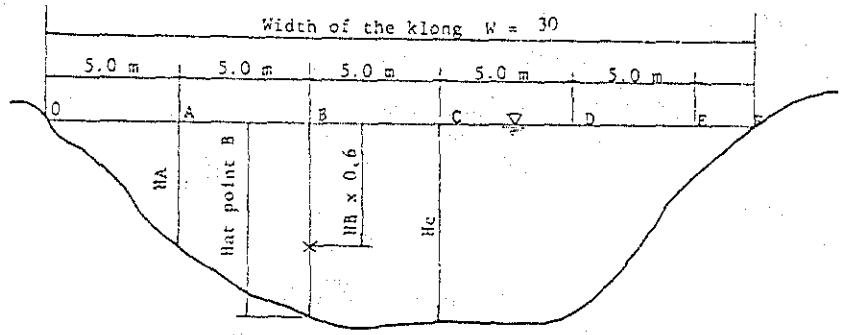

| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 2.10 | 0.08 | 15.9 | 1.3 |
| B | 2.24 | 0.12 | 11.2 | 1.3 |
| C | 3.40 | 0.18 | 17.0 | 3.1 |
| D | 2.90 | 0.22 | 14.5 | 3.2 |
| E | 2.08 | 0.17 | 19.5 | 3.3 |
| F | | | 78.1 $m^2$ | 12.2 $m^3/s$ |
| G | | | | |
| H | | | | |

FIG. F.42 **Water Flow Measurment ( No 1 )**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Water Flow Measurement

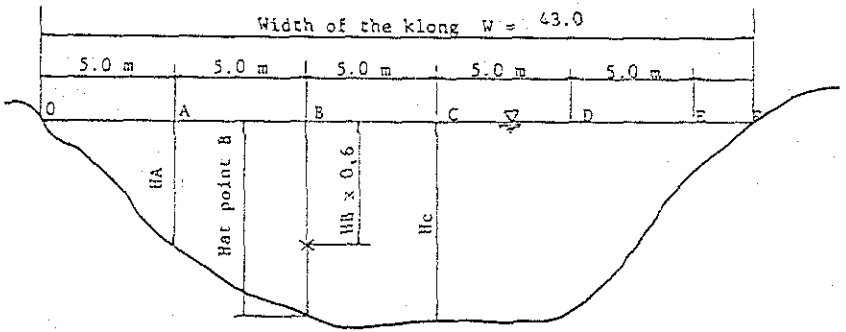
Location : Klong Saen Seap at station F
Date : Oct. 20 1983 15:30
Flow Direction : East to West




| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 3 | 0.134 | 24.0 | 3.2 |
| B | 4.2 | 0.182 | 21.0 | 3.8 |
| C | 4.9 | 0.230 | 24.5 | 5.6 |
| D | 3.5 | 0.26 | 17.5 | 4.6 |
| E | 2.4 | 0.285 | 12.0 | 3.4 |
| F | 1.4 | 0.100 | 5.5 | 0.6 |
| G | | | 104.5 $m^2$ | 21.2 $m^3/s$ |
| H | | | | |

Water Flow Measurement

Location : Klong Song
Date : Nov. 2, 1983 12:00
Flow Direction : North to South



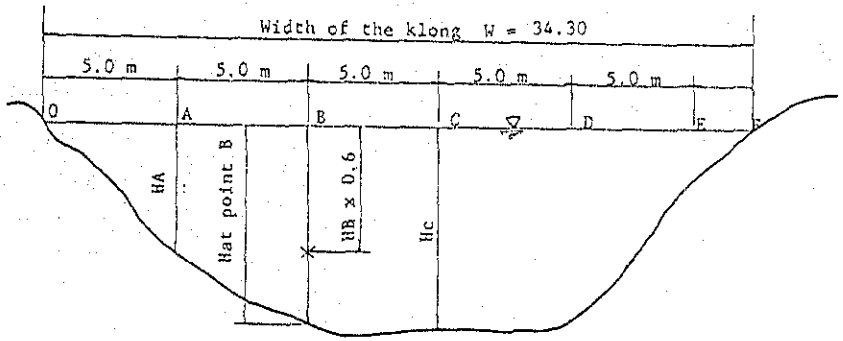

| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 1.90 | 0.05 | 10.0 | 0.5 |
| B | 2.30 | 0.15 | 11.5 | 1.7 |
| C | 4.15 | 0.15 | 20.8 | 3.1 |
| D | 4.80 | 0.14 | 24.0 | 3.4 |
| E | 2.90 | 0.19 | 14.5 | 2.8 |
| F | 2.10 | 0.18 | 10.5 | 1.9 |
| G | 1.80 | 0.09 | 12.1 | 1.1 |
| H | | | 103.4 $m^2$ | 14.5 $m^3/s$ |

FIG. F.43 **Water Flow Measurment ( No 2 )**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Water Flow Measurement

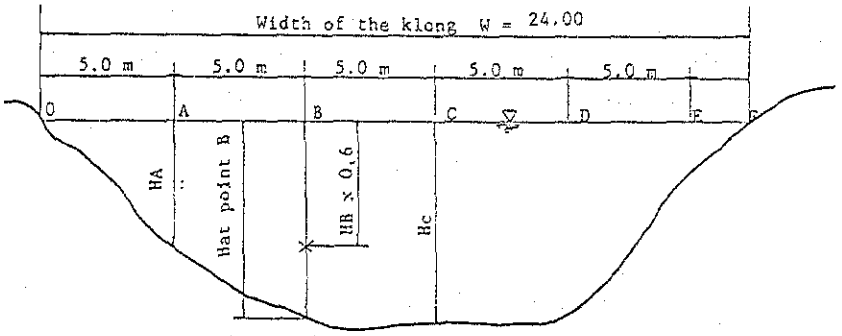
Location : Klong Sam
Date : Nov. 2, 1983 13:30
Flow Direction : North to South




| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 1.90 | 0.03 | 10.0 | 0.3 |
| B | 2.30 | 0.08 | 11.5 | 0.9 |
| C | 2.45 | 0.10 | 12.3 | 1.2 |
| D | 2.50 | 0.14 | 12.5 | 1.8 |
| E | 2.30 | 0.13 | 11.5 | 1.5 |
| F | 1.75 | 0.06 | 8.8 | 0.5 |
| G | | | 66.6 $m^2$ | 6.2 $m^3/s$ |
| H | | | | |

Water Flow Measurement

Location : Klong Si
Date : Nov.2, 1983 15:00
Flow Direction : North to South



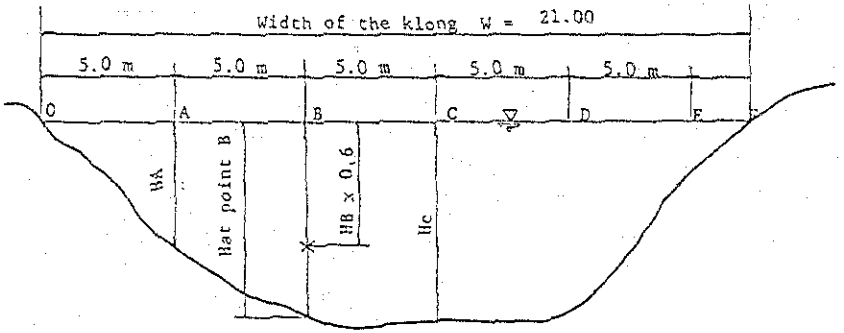

| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 1.50 | 0.08 | 8.9 | 0.7 |
| B | 2.60 | 0.20 | 13.0 | 2.6 |
| C | 2.90 | 0.19 | 14.5 | 2.8 |
| D | 1.90 | 0.07 | 9.8 | 0.7 |
| E | | | 46.2 $m^2$ | 6.8 $m^3/s$ |
| F | | | | |
| G | | | | |
| H | | | | |

FIG. F.44 Water Flow Measurment ( No 3 )

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Water Flow Measurement

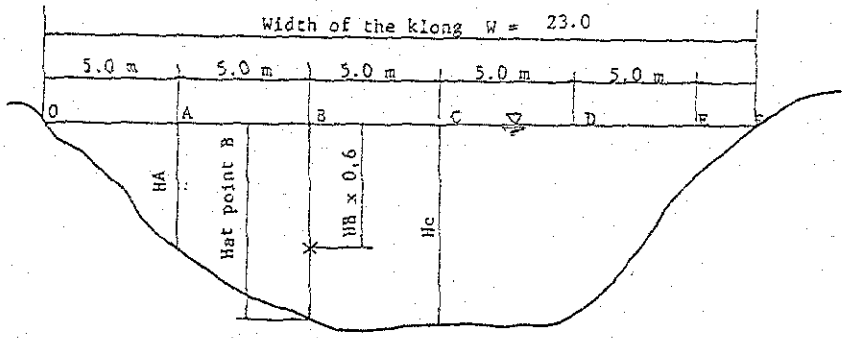
Location : Klong Na.
Date : Nov. 2, 1983 15:30
Flow Direction : North to South




| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 2.30 | 0.07 | 12.5 | 0.9 |
| B | 3.10 | 0.49 | 15.5 | 7.6 |
| C | 2.70 | 0.37 | 15.4 | 5.7 |
| D | | | 43.4 $m^2$ | 14.2 $m^3/s$ |
| E | | | | |
| F | | | | |
| G | | | | |
| H | | | | |

Water Flow Measurement

Location : Klong Hok
Date : Nov. 3, 1983 11:50
Flow Direction : North to South



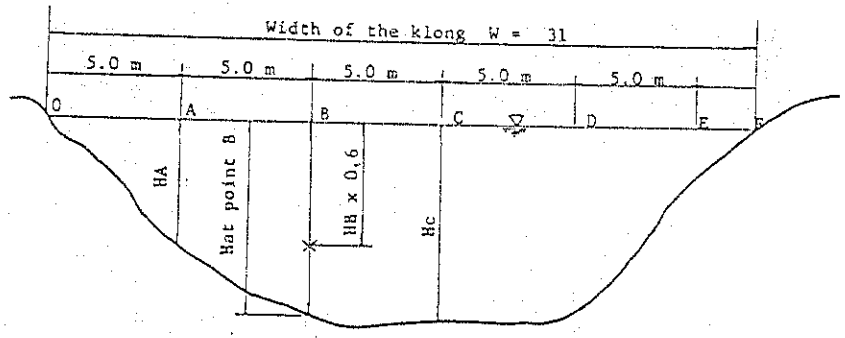

| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 1.30 | 0.26 | 9.4 | 2.4 |
| B | 3.60 | 0.31 | 18.0 | 5.6 |
| C | 2.80 | 0.29 | 19.2 | 5.6 |
| D | | | 46.6 $m^2$ | 13.6 $m^3/s$ |
| E | | | | |
| F | | | | |
| G | | | | |
| H | | | | |

FIG. F.45 Water Flow Measurment ( No 4 )

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Water Flow Measurement

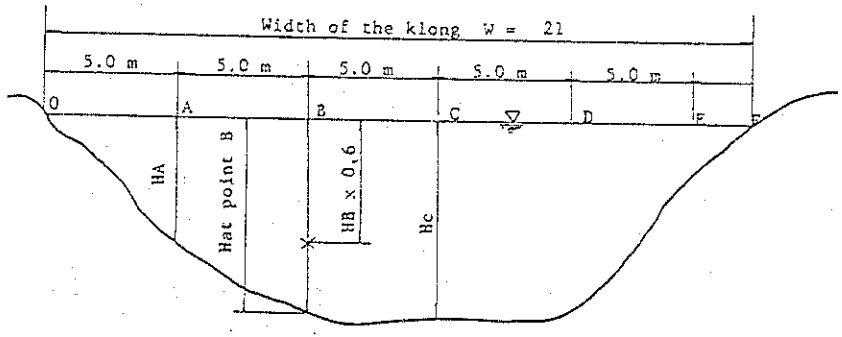
Location : Klong Chet
Date : Nov. 3, 1983 12:15
Flow Direction : North to South




| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 1.70 | 0.12 | 9.0 | 1.1 |
| B | 2.10 | 0.18 | 10.5 | 1.9 |
| C | 2.70 | 0.20 | 13.5 | 2.7 |
| D | 2.40 | 0.17 | 12.0 | 2.0 |
| E | 1.50 | 0.09 | 9.4 | 0.8 |
| F | | | 54.4 $m^2$ | 8.5 $m^3/s$ |
| G | | | | |
| H | | | | |

Water Flow Measurement

Location : Klong Hok WA (in front of the District Office)
Date : Nov. 3, 1983
Flow Direction : West to East




| Point | Depth H(m) | Velocity (m/s) | Areal Cross Section ($m^2$) | Quantity (m3/sec) |
|---|---|---|---|---|
| A | 3.40 | 0.09 | 25.5 | 2.3 |
| B | 3.80 | 0.07 | 19.0 | 1.3 |
| C | 2.80 | 0.06 | 23.8 | 1.4 |
| D | | | 68.3 $m^2$ | 5.0 $m^3/s$ |
| E | | | | |
| F | | | | |
| G | | | | |
| H | | | | |

FIG. F.46 Water Flow Measurment ( No 5 )

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

# APPENDIX G

## Runoff Analysis for Model Area

## Appendix G Runoff Study in Model Area

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## Appendix G Runoff Analysis for Model Area

### 1. General

Eastern suburban Bangkok is a typical, low flat area of the Chao Phraya alluvium. Recent urbanization of Bangkok has gradually expanded towards the eastern area, furthermore, land subsidence has also been experienced so that floods have become a serious problem in this area. For the purpose of planning the flood protection and drainage of this area, it is required that a comprehensive hydrological study be executed taking future land use into consideration.

However, urban floods are affected by complex factors which are interconnected and are not constant either in time and place. The quantitative analysis of each factor is therefore difficult. The major factors are shown as follows:

1) Land subsidence
2) Land Use
3) Topographical/geographical characteristics
4) Rainfall
5) Inflow from outer area
6) Capacity of drainage facility
7) Others

In order to grasp the geographical characteristics relating to runoff discharge in the Study Area, we selected a Model Area and carried out the necessary investigation and study.

Firstly, the installation of the hydrological observation equipment which measures water level, rainfall and pump discharge were made and then the observations were recorded.

## 2. Existing Status of Model Area

As is shown in Figure G-1, the selected model area adjoins the eastern end of the urbanized core area of Bangkok. This model area has recently incurred rapid development and urbanization, therefore the present urbanized situation of the model area may show a trend of the future urbanization of the Study Area.

The model area was enclosed by the existing road and railway and at the boundary, the klongs which are connected to the outside of the area, was closed by a cofferdam with gate. Therefore, this area was considered as a suitable district as a model area in view of the easiness of making the necessary hydrological observations.

According to the flood damage survey, this model area did not suffer serious damage from the 1982 flood by virtue of the polder system. Following are the descriptions of the various factors governing the model area's regime.

### 1) Topography

The model area, which covers some 8.8 square kilometers, is rather like a parallelogram in shape with about 4 kilometers base along the east-west direction and about 3 kilometers height to the south-north direction. This area is extremely flat and low with ground elevations i.e, a maximum of about 1.1 meters and averaging about 0.7 meters above mean sea level as is shown in Figures G-2. The roads and railway surrounding the model area are embanked with top elevations between 1.0 and 1.8 meters above mean sea level.

### 2) Land Use

Model area is one of the most urbanized areas within the Study Area as shown in Figure G-3 and Table G-1. Built up space constitutes more than 70% in the model area.