BASIC DESIGN STUDY REPORT

ON

THE PROJECT FOR ESTABLISHMENT

OF

METEOROLOGICAL RADAR NETWORK

IN

THE ISLAMIC REPUBLIC OF PAKISTAN

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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Preface

In response to the request of the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a Basic Design Study on the Project for the Establishment of a Meteorological Radar Network and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Pakistan a survey team headed by Mr. Haruo Suzuki (Deputy Director, Grant Aid Planning and Survey Department, JICA) from October 25 to November 21, 1988.

The team exchanged views with the officials concerned from the Government of Pakistan and conducted a field survey (in Karachi, Islamabad, Lahore, Sargodha and Cherat areas). After the return of the team to Japan, further studies were made and a mission headed by Mr. Yuichi Sakoda (Assistant to Director, Observations Division, Observations Department, Japan Meteorological Agency) was sent to Pakistan from 2nd to 11th March, 1989 to discuss the draft report, on the basis of which the present report has been prepared.

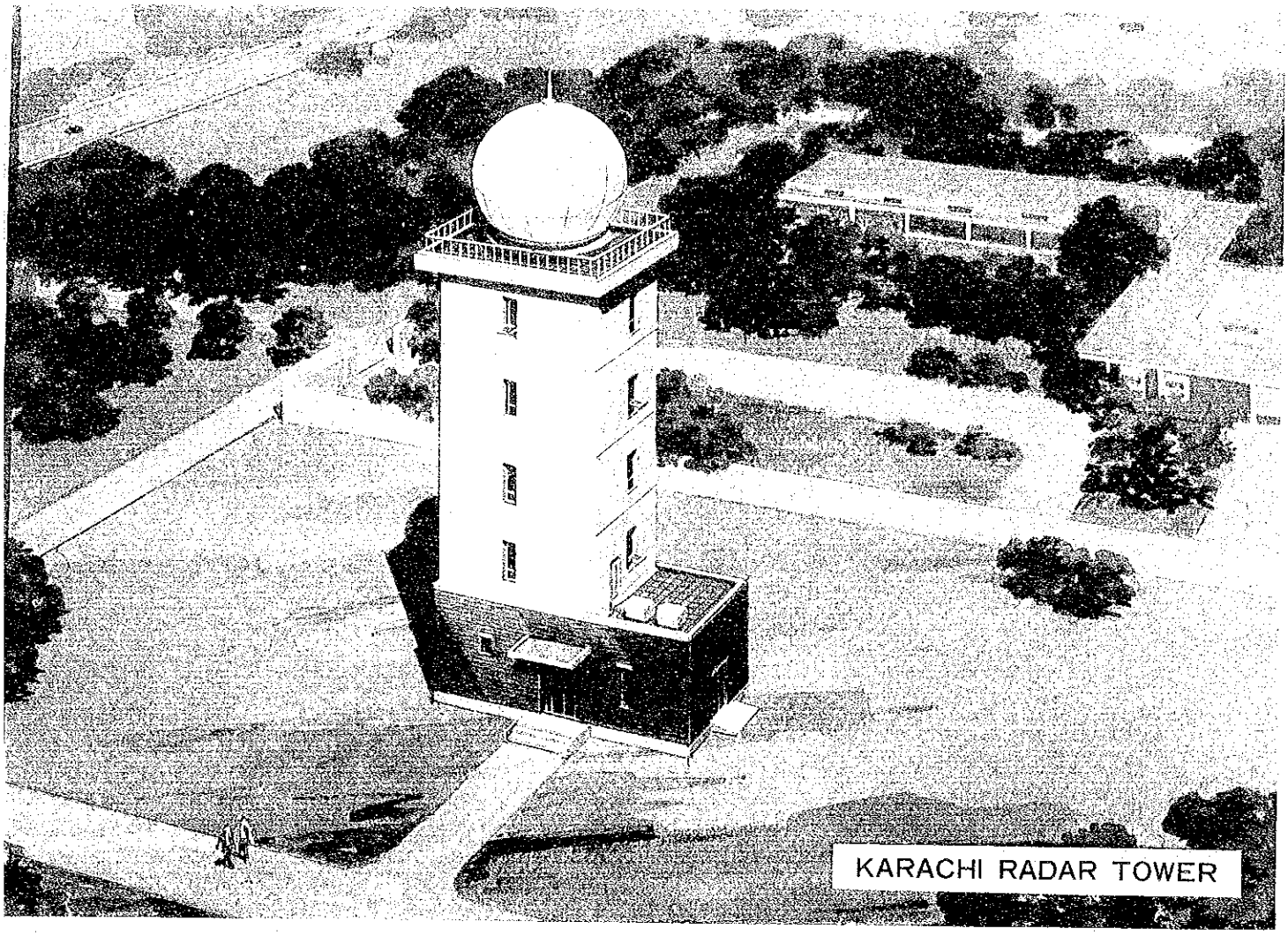
I hope that this report will be of service in the development of the Project and will contribute to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned from the Government of the Islamic Republic of Pakistan for the cooperation and support extended to the team.

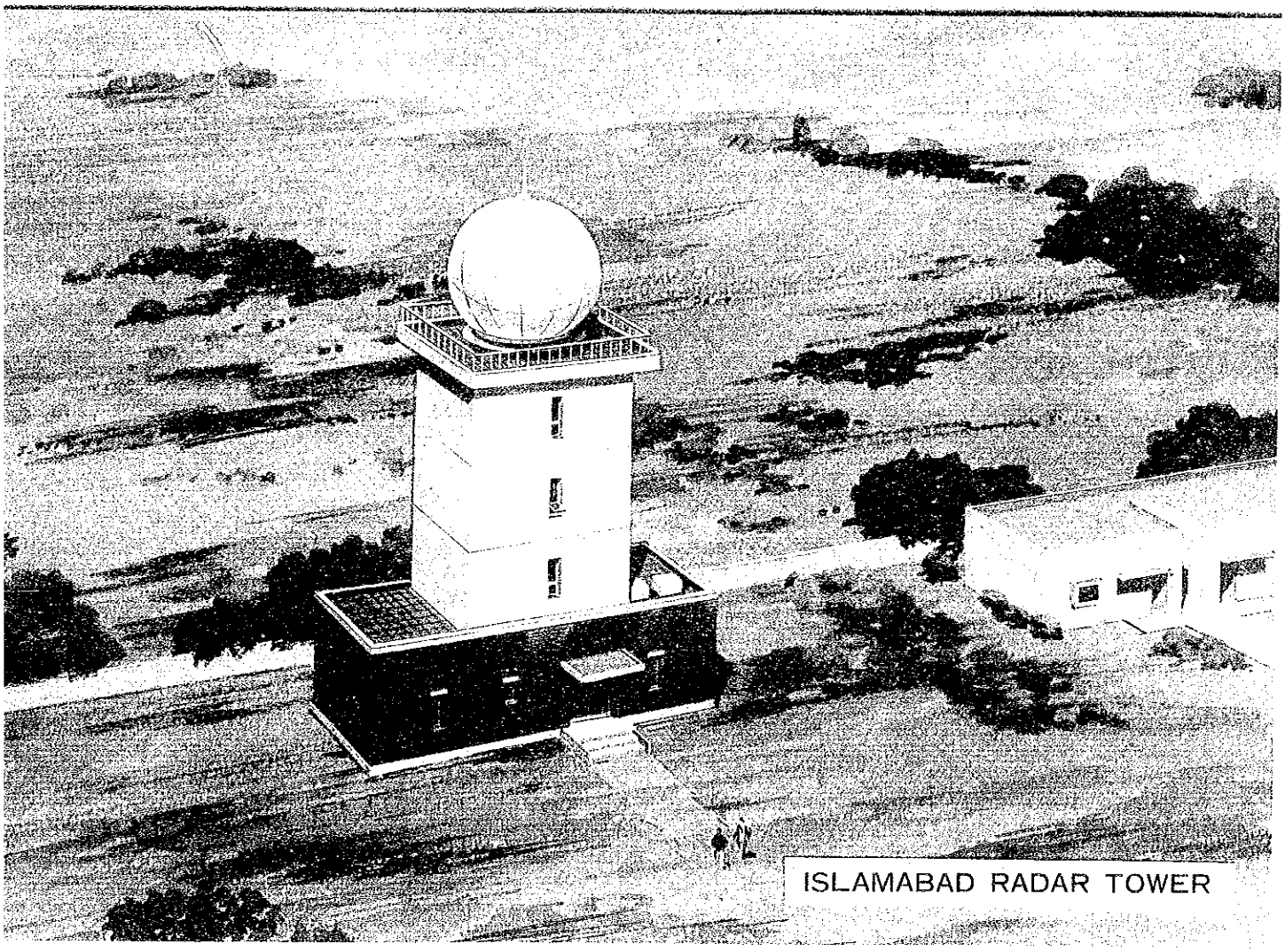
March 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency



KARACHI RADAR TOWER



ISLAMABAD RADAR TOWER

Summary

Summary

With the exception of the mountainous regions in the north, almost all of the Islamic Republic of Pakistan down to the Arabian Sea in the south belongs to the sub-tropical climatic zone. On the plains, the local torrential rains accompanying the cumulonimbus clouds that develop in the inter-tropical convergence zone during as well as before and after the monsoon season cause loss of human life and economic damage almost every year. The land is also visited by cyclones travelling north from the Arabian Sea during the post-monsoon season.

In particular, torrential rains that accompany cumulonimbus cloud clusters cause significant damage to agricultural produce in the granary regions, as well as considerable loss of life and economic damage due to floods and other disastrous phenomena in urban areas. The take-off and landing of aircraft and other operations of aviation, which have undergone a remarkable development in recent years, are also seriously hampered by these meteorological phenomena.

To prevent these meteorological disasters, the Pakistan Meteorological Department has been continuously carrying out meteorological observations, using weather surveillance radars, which provide the most effective means of meteorological observation over wide areas and which have been installed at five locations within the country. Most of these radars, however, were installed over twenty years ago and their capacities have been greatly curtailed with the result that appropriate weather forecasts cannot be issued. It has become a matter of urgency to establish a national meteorological observation system with a weather surveillance radar network capable of monitoring the distribution of areas of heavy rainfall.

Under these circumstances, with a view to minimising meteorological disasters in the regions around Karachi and Islamabad which, as well as being the political and economic centres of the country, are surrounded by crop-producing regions and occupy important positions in aerial transportation, the Pakistani Government adopted a "Project for the Establishment of a Meteorological Radar Network in the Islamic Republic of Pakistan" with replacement and installation of radars as its main point and made a request to the Japanese Government for a grant aid for this project.

In response, the Japanese Government decided to carry out a study for the basic design and the Japan International Cooperation Agency sent a study team to Pakistan during the period from 25th October to 21st November 1988 headed by Haruo Suzuki, the deputy director of the Grant Aid Planning and Survey

Department. The team ascertained and confirmed the background of the project and the details of the request, discussed the project with the officials of the Government of Pakistan concerned and made a study of the project sites. The results of the study were reviewed and analysed after the team's return to Japan and the basic design of the materials and the facilities were drawn from this on the most suitable scale. These analyses were summarised in a draft final report of the studies for basic design. A team headed by Yuichi Sakoda (Assistant to Director, Observations Division, Observation Department, Japan Meteorological Agency) was sent to Pakistan to explain these results during the period from 2nd to 12th March 1989.

The summary of the project compiled in the above report is as follows.

(1) Radars

The individual occurrences of heavy rains accompanying cumulonimbus cloud clusters, which are the most frequent causes of meteorological disasters in Pakistan, are concentrated in small areas ranging from several kilometres to several tens of kilometres and their maximum duration is about three hours. The radars will be capable of accurately detecting such meteorological phenomena. The frequency of the radars is in the C-Band (wavelength: approximately 5 cm) and their detectable range approximately 400 km (transmission output: 250 kW).

(2) Installation of Data Processors

Taking into account the benefit to the users, the radar systems have been designed to be capable of calculating hourly cumulative amounts of rainfall.

(3) Installation of Monitor Displays in the Forecaster's Rooms

In order to make effective use of the radars, monitor displays will be installed in the forecaster's rooms at the meteorological centres both at Karachi and Islamabad, so to enable the forecasters to directly monitor the radar images in real time and to make use of them in providing weather forecasts.

A monitor display will also be installed at the aeronautical meteorological observatory of the Karachi International Airport which is located about 5 km away, within view of the radar site and radar images will be transmitted

through a radio device enabling them to be used to ensure the safety of air traffic.

(4) Installation of Automatic Voltage Regulators

To protect the radar equipment from the voltage fluctuations of the commercial power supply in Pakistan.

(5) Installation of Stand-By Generators

To enable observations to be carried out without being affected by the conditions of the commercial power supply in Pakistan.

(6) Construction of Radar Towers

New radar towers will be built for the installation of the radars at Karachi, because of the unsuitability of the existing steel tower from the point of view of its structure and its strength and at Islamabad because of lack of facilities on which the radar can be installed.

Radars and facilities to be installed at Karachi and at Islamabad are as follows.

1. Radar

(1) Radome (Diameter: 7 m)
(2) Antenna (Diameter: 4 m)
(3) Transmitter/Receiver (C-band, 250 kW, Maximum Detectable Range: 400 km)
(4) Antenna Control Unit
(5) Dehydrator
(6) Main Indicator
(7) Digital Video Integrator Processor
(8) Data Processor
(9) Monitor Display
(10) Modem (2,400 bps)
(11) UHF-Band Radio Equipment (Karachi only)
(12) Colour Display
(13) Uninterruptible Power Supply Unit

(14) Automatic Voltage Regulator
(15) Distribution Board

2. Emergency Power Supply

(1) Stand-By Generator (Rated Output: 60 kVA)
(2) Generator Control Board
(3) Starting Battery
(4) Service Tank (420 ℓ)

3. Air Conditioner

4. Spare Parts

5. Radar Tower

(1) Karachi : 19.6 m, 5 storeys
(2) Islamabad : 16.1 m, 4 storeys

The total cost of the works for which the Government of Pakistan is responsible is estimated at Rs. 5,000,000.

In the implementation of the project, a total of 17.5 months needs to be considered after the Exchange of Notes (E/N). This consists of 3.5 months for detailed design, 1.5 months for the tendering, 8 months for the production of the radars, 8 months for the construction of the radar towers (simultaneous with the production of the radars), 1 month for the transportation of the radars from Japan to the sites and 3.5 months for installation, adjustment and handing over.

The maintenance costs for the radars at the two sites are estimated at Rs. 1,400,000 a year which is equivalent to about 2% of the amount set aside for ordinary expenses in the present budget of the PMD and is thought to be easily affordable.

The following benefits are expected to result from the execution of the present project.

(1) Benefits to Meteorological Services

Within 300 km radii or so of Karachi and Islamabad, it will be possible to carry out a constant quantitative observation on the rainfalls at 2.5 km resolutions, which will result in substantial improvements in the observation capacities that form the basis of meteorological services. The occurrence and the movement of local torrential rains accompanying cumulonimbus cloud clusters can be constantly observed in detail at 2.5 km resolutions making it possible to issue accurate warnings for the prevention of meteorological disasters.

(2) Reduction in Urban Disasters

In the prevention of floods on medium and minor rivers due to heavy rains which are typical of urban disasters, the radars will enable fairly accurate forecasts to be made and this will enhance the accuracy of warnings given to disaster prevention organizations and to the public.

(3) Benefits to Flood Prevention

The runoff into dams and main rivers can be calculated from the areal precipitation on river basins by using the functions for calculating cumulative rainfall. These values can then be converted into equivalent rise in the water-levels allowing effective control of dams and forecasting of floods on the main rivers which will contribute towards reduction in loss of human life and economic damage.

(4) Benefits to Operation of Flights

Heavy rains and gusts accompanying cumulonimbus cloud clusters greatly affect the take-off and landing of aircraft and their safe operation. Disruption of flights can also result in significant economic losses from the point of view of consumption of fuel. With the installation of a weather surveillance radar at Karachi, it will be possible to monitor radar images in real time at Karachi International Airport which is the main gateway to Pakistan by air. This will enable flight operators to ensure the safety of operation plans and the air-traffic controllers to give appropriate instructions as to whether to hold in the air or to land at another airport. This will result in an improvement of the safety of air-flights and in a reduction of

economic losses such as large consumption of fuel.

(5) Reduction in Agricultural Disasters

The plains within the observation ranges of the weather surveillance radars are the breadbaskets of Pakistan. In preventing disasters due to heavy rain on the plains, the accuracy of forecasts for damages due to inundation of agricultural land is enhanced, by making it possible to observe the areal distribution of rainfall and the amount of precipitation, using the functions for calculating cumulative rainfall. By providing proper drainage systems, damages to agricultural products due to inundation can be minimised leading to an increase in agricultural production.

This project will contribute to the development and improvement of the meteorological services in Pakistan, resulting in considerable benefits in preventing disasters and decreasing the damage caused by adverse weather conditions. It is of great significance that the project is to be implemented under the Japan Grant Aid Scheme and it is expected that the greatest effect will be achieved through the full implementation of this project. Since the Government of Pakistan fully recognises the importance of this project and has established a structure for its implementation and operation, an early implementation of the project is hoped for.

In addition, it is also desired that technical cooperation for training of Pakistani radar engineers be included together with cooperation through grant of aid in the implementation of the project in order to ensure that the project be all the more effective.

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Chapter 1 Introduction

The Islamic Republic of Pakistan is located between the latitudes of 23° and 37° North and between the longitudes of 61° and 76° East. Its area of 796,095km² is approximately twice as large as that of Japan.

According to the 1981 census, the population of Pakistan was 84,253,000 and the annual population growth for the past few years has been approximately 3%. More than 70% of the population live in rural areas.

The main industries are agriculture, forestry and fisheries which account for 23.8% of the GDP and they are followed by the manufacturing industry that accounts for 17.5%. Agriculture is the largest of the primary industries but the importance of the livestock industry has been increasing in recent years. The wholesale and retail industries occupy an important position and generate a total income second to that generated by the manufacturing industry. The per capita income of $ 370 is the highest among the southwestern Asian countries and is 1.37 times that of India and 2.31 times that of Bangladesh.

The climate in Pakistan varies from a middle latitude climate to a tropical climate. In winter, low pressures associated with fronts pass over the northern parts. These lows are frequently accompanied by thunderstorms and gusts throughout the country. In the hot weather season, heat waves frequently occur and cyclones sometimes strike Pakistan. During the monsoon season, local torrential rain occurs in the mountainous areas, due to the effect of monsoons blowing in from the sea and heavy rain from cumulonimbus clusters (Cb-clusters) in the Inter-Tropical Convergence Zone (ITCZ). Especially in July and August, rain bursts occur in specific areas due to the effect of the ITCZ and monsoon depression resulting in floods and landslides which have done great damage to lives and agricultural products in the past.

Modern air transportation is greatly affected by the weather and, therefore, utilisation of meteorological information for aviation becomes essential. Heavy rains, gusts and poor visibility accompanying Cb-clusters often occur around Karachi and Islamabad Airports, which are located on the main international air routes, and frequently jeopardise landings and take-offs.

Weather surveillance radars provide the most effective means of quickly detecting movements of Cb-clusters that cause rain bursts and gusts. The

number of the existing radars, however, is insufficient to cover the whole country and they are too old to fulfill their functions. As the Pakistan Meteorological Department depends on cloud images which are received twice daily from the NOAA polar-orbiting meteorological satellites as the second best alternative, they cannot detect rapid changes in patterns of heavy rain.

The Government of Pakistan adopted a modernisation plan for the Pakistan Meteorological Department and made a request to the Government of Japan for a grant aid for the renewal of the radar at Karachi and installation of a new radar at Islamabad which form a part of this plan. In response to the request the Government of Japan decided to carry out a study on the basic design in this respect. The Japan International Cooperation Agency sent a study team headed by Mr. Haruo Suzuki, the deputy director of the Grant Aid Planning and Survey Department during a period of 28 days from 25th October 1988. The study team has confirmed the feasibility of the project and the substance of the request and has made a survey of the sites for the radars and their surroundings as well as conditions of construction, electricity and transportation.

After the implementation of the site study, effects of the project and its validity as an object of the Japanese grant aid scheme were examined and the basic design for the weather surveillance radars most suitable for the purpose was carried out in Japan and the results were compiled in a draft final report.

The second study team headed by Mr. Y. Sakoda, Japan Meteorological Agency, was sent to Pakistan from 2nd to 12th March 1989 to explain and discuss the contents with the parties concerned of the Government of the Islamic Republic of Pakistan.

The present report was compiled by making the necessary corrections to the draft report on the basis of results of the above.

The composition of these teams, the itinerary of the study and the minutes of the discussions are given in the Appendix.

Chapter 2 Background of the Project

Chapter 2 Background of the Project

2-1 Social and Natural Environment of Pakistan

2-1-1 Social Environment

(1) Territory

Pakistan is located between the latitudes of 23° and 37° North and between longitudes of 61° and 76° East and extends 1,500 km northeast from the 800 km coastline of the Arabian Sea. Pakistan is bordered by Iran to the west, Afghanistan to the northwest and north, China to the northeast and India to the east and southeast.

Excepting Kashmir, whose sovereignty is disputed with India, Pakistan is composed of four provinces, Federally Administered Tribal Areas and the Islamabad Federal Capital Area as shown in Figure 2-1-1. The provincial capitals are Lahore, Karachi, Peshawar and Quetta. The sizes of the provinces and special areas are shown in Table 2-1-1. The total area of 796,095 km² is approximately twice that of Japan.

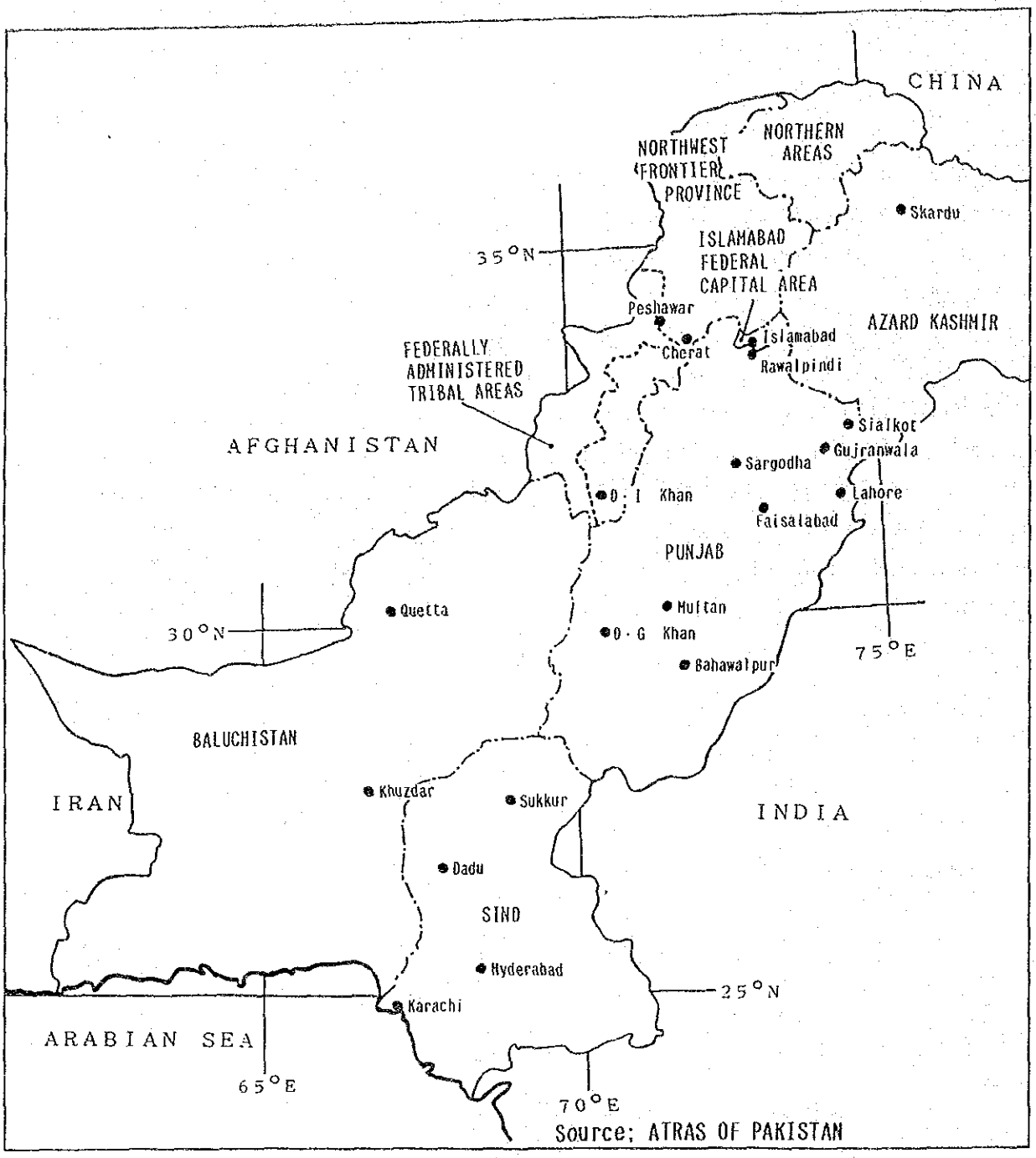


Fig.2-1-1 MAP OF PAKISTAN

Table 2-1-1 Sizes of Provinces

Provinces	Area(km²)	Parcentage share
Punjab	206,251	25.9
Sind	140,914	17.7
Northwest Frontier	74,521	9.4
Baluchistan	347,910	43.6
Federally Administered Tribal Areas	27,219	3.6
Total	796,095	100.0

Including Federal Capital Area(907km²)in Punjab

Source: Pakistan Statistical Yearbook 1982

(2) Population

According to a census taken in 1981, the total population of Pakistan was the ninth largest in the world at 84,253,000. The distribution of population in each province is shown in Table 2-1-2. However, these figures do not include approximately 3 million refugees from Afghanistan and the population of the Northern Areas and Azad Kashmir (estimated at 2 million). If we consider cities and towns having a population of over 5,000 as urban areas, 28.3 % of the total population live in urban areas. While Sind has the largest urban population (43.4%), 85% of the population of Baluchistan and the Northwest Frontier Province as well as 73% of that of the Punjab are rural. Population of the main cities is shown in Table 2-1-3. There are eight cities that have a population of over half a million, including Karachi, the largest city which has a population of 5.2 million.

The overall population density is 105 per km^2. The highest is that of the Punjab (230) and the lowest that of Baluchistan (12).

Table 2-1-2 Distribution of Population (1981 Census)

Provinces	Population in thousand			Percentage Share	Population Density per km²
	Total	Male	Female		
Punjab	47,292	24,860	22,432	56.2	230
Sind	19,029	9,999	9,030	22.6	135
Northwest Frontier	11,061	5,761	3,300	13.0	148
Baluchistan	4,332	2,284	2,048	5.1	12
Federally Administered Tribal Areas	2,199	1,143	1,056	2.6	80
Federal Capital Area	340	185	155	0.4	375
Total	84,253			100.0	105

Source; Pakistan Economic Survey 1983-1984

Table 2-1-3 Population in Major Cities
(In thousand, 1981 Census)

Karachi	5,208
Lahore	2,953
Faisalabad	1,104
Rawalpindi	795
Hyderabad	752
Multan	732
Gujranwala	601
Peshawar	506
Sialkot	302
Sargodha	291
Quetta	286
Islamabad	204

Source; Statistical Pocket Book of pakistan 1984

(3) Industry

① Agriculture, Forestry and Fisheries

Pakistani society is based on an agrarian economy. Agriculture (including forestry and fisheries) is the principal economic field, employing 51% of the work force in 1985 and accounting for 23.7% of the GDP in 1986/87. Wheat, rice and cotton are the typical products. Besides these, a large amount of sugar cane, beans and maize are also produced.

A large proportion of the agricultural land is concentrated in the Punjab and Sind and much of the agricultural land south of 32° North Latitude is under irrigation. Irrigated land takes up over 70% of all agricultural land and this proportion is the highest in Asia. The harvest, however, largely depends on weather conditions.

Of the total 40 million acres of arable land, 25 million acres are affected by inundation.

② Mining

The main mineral resources of Pakistan are natural gas and limestone. Both, however, merely satisfy domestic demand.

③ Manufacturing Industry

The manufacturing industry accounted for 17.7% of the GDP in 1986/ 87. A large proportion of this, however, was taken up by food processing, dependent on agriculture for its materials, and the textile industry (mainly cotton).

(4) Transportation

The transportation system by land consists of 8,800 km of railway and 110,000 km of road. Over a half of the roads are paved and road conditions are generally good. Because of the large land area, domestic flight routes are well developed and the volume of traffic is showing an increase of approximately 10% per annum. In 1987, internal air transportation corresponded to 2% of the total amount of domestic transportation.

(5) Electricity

Pakistan's capacity for generating electricity was 4,795 MW at the end of 1983. Hydroelectricity took up 53% of the total output, thermal power 44% and nuclear power 3%. Hydroelectricity takes up a large proportion, but the dams are used for both electricity generation and irrigation and the discharge of water for the purpose of irrigation takes priority over that for the generation of electricity. It becomes necessary to limit the generation of electricity when the water level of a dam is low.

(6) Trade

Pakistani trade has constantly shown a deficit since the 1960's. The government is attempting to reduce the deficit by setting various restrictions on imports with decrees on import policy.

In the decree for 1983/84, a basic change was made from the positive list (list of importable goods) method to the negative list (list of forbidden goods) method. The decrees on imports used to be published every year, but since 1987/88, they have become effective for a longer term of three years. The list is revised every year, but no fundamental changes are to be made.

Goods subject to restriction are divided into 4 categories as shown below:

1. Forbidden goods (goods whose importation is forbidden except in special circumstances)
2. Negative List Goods (goods whose importation is not permitted except in special circumstances)
3. Restricted Goods

(1) Goods which can only be imported by public bodies
(2) Goods which can only be imported by industrial consumers
(3) Importation by the actual users
(4) Importation under certain conditions
(5) Importation from specific exporters
(6) Consumer goods with restrictions on quantity

4. Importable Goods (goods not listed in 1 to 3 above)

Import license is required for all imports.

2-1-2 Natural Environment

(1) Topography

As shown in Figure 2-1-2, the topography of Pakistan is divided into two major areas, namely, mountainous regions in the north and west and the plain of the Indus Basin. There are also plateaux, one extending in the west in Baluchistan and the Pothwar Plateau between the mountains and the plain.

The mountainous regions in the north comprise of some of the highest mountains in the world such as those in the Himalayas, the Karakoram and the Hindu Kush, where there are peaks that exceed 8,000 m above sea level.

The mountainous region in the west is sandwiched between the western side of the Indus and the Afghan border. The mountains are relatively low compared to those in the north and include ranges such as the Safed Koh Range, the Toba Kakar Range and the Sulaiman Range.

The plain in the Indus Basin is an alluvial plain created by the Indus which rises in northwestern Tibet and confluent rivers that join it from the east such as the Jhelum, Chenab, Ravi and Sutlej. This area is the granary of Pakistan under large-scale irrigation.

The plateau in Baluchistan extends between the Iranian border and the southern part of the western mountains. It is a dry region at relatively high altitudes (500 m to 1,500 m) comprising of much barren land and made up of rocky and sandy deserts.

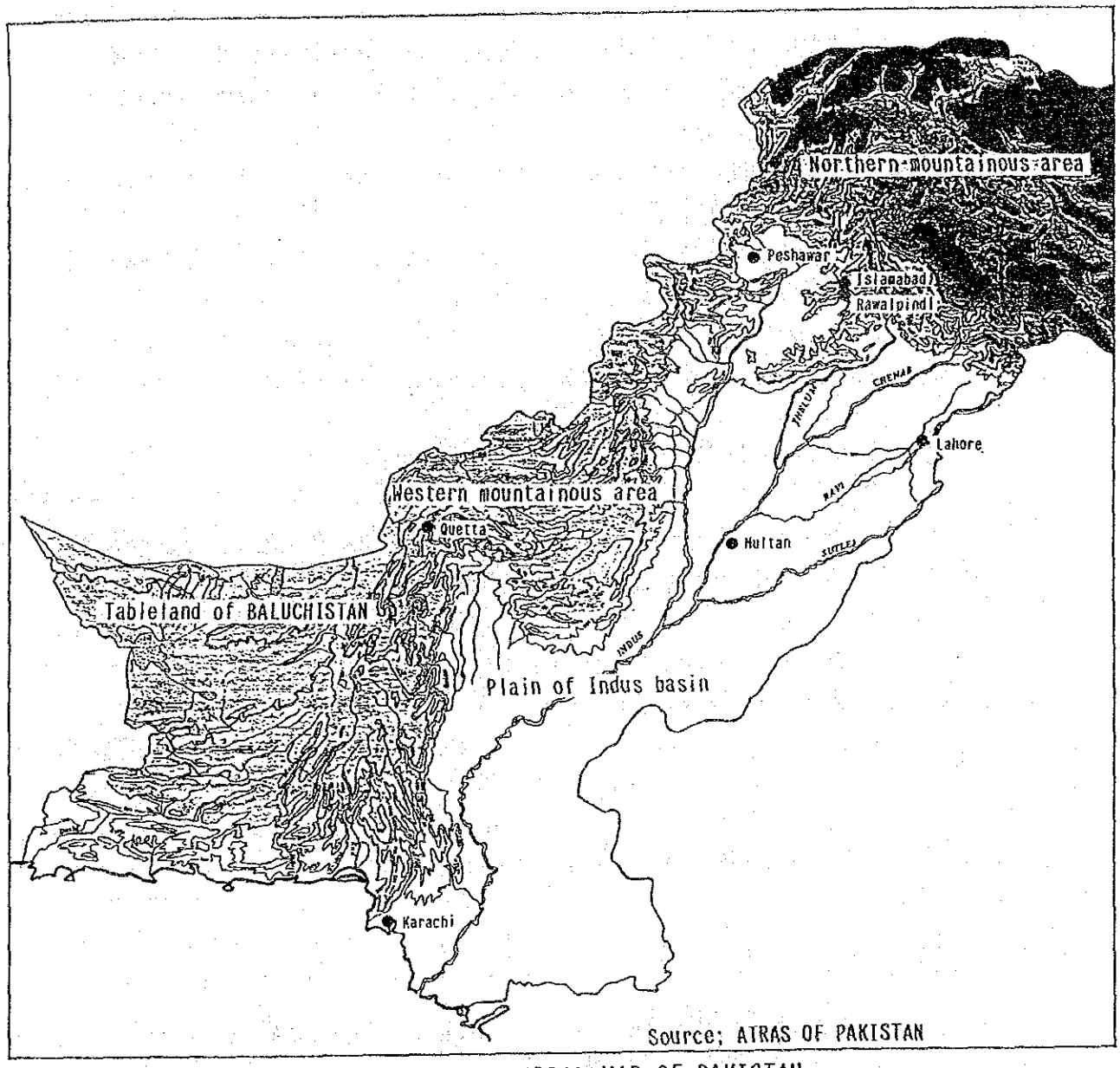


Fig.2-1-2 TOPOGRAPHICAL MAP OF PAKISTAN

(2) Climate

Excluding the northern mountainous region, the climate on the plains of Pakistan is, in general, sub-tropical in winter and tropical in summer. In summer, temperatures are very high followed by heavy rainfall from monsoon systems. In the northern parts of Pakistan, temperatures are low in winter with adequate rainfall. Due to the vast extension from north to south combined with its varying topography, there is great variation in climate according to regions and altitudes.

As seen from Figure 2-1-3 showing monthly rainfalls and mean temperatures, the climate of Pakistan is divided into four seasons; namely, the winter season (December to March), the hot weather season (April to June), the monsoon season (July to September) and the post-monsoon season (October to November).

① Winter Season (December to March)

In winter, high pressure systems develop over India and Pakistan, bringing continuous sunny weather, with northerly winds and low humidity to the whole area of Pakistan. The further inland one goes, the greater the range of diurnal air temperature becomes. Quite often, extra-tropical cyclones (called Western Disturbances) accompanied by fronts, pass over the northern part of Pakistan bringing rain and snow to the northern mountains and the Northwest Frontier Province, while causing rain in the Punjab, Baluchistan, and to some extent to parts of Sind Province. Although the rainfall in the plain is limited, it is vital to the agricultural produce.

② Hot Weather Season (April to June)

As the elevation angle of the sun at midday increases, temperature rises rapidly throughout the country and the maximum temperature begins to daily exceed 35° C.

Thermal depressions are formed over the Indian Subcontinent by this high temperature. Moist winds begin to blow in from the sea and, where these winds clash with dry hot winds from inland areas, there results an intense convective instability and Cumulonimbus clouds develop in turn, generating strong gusts, hail and thunderstorms and causing damage to agricultural products in the rural areas in the northern part of Pakistan.

The number of the western disturbances passing through begins to

decrease but still brings some rain to the northern mountains.

③ Monsoon Season (July to September)

From late June, the ITCZ accompanied by heavy rain rapidly moves north. Moist air begins to blow into Pakistan from the Arabian Sea and the Bay of Bengal, and southwesterly monsoons are formed. As a result, huge Cb and Cb-clusters develop in the ITCZ causing heavy rainfalls in the northern mountains and severe thunderstorms, hail and gusts on the plain.

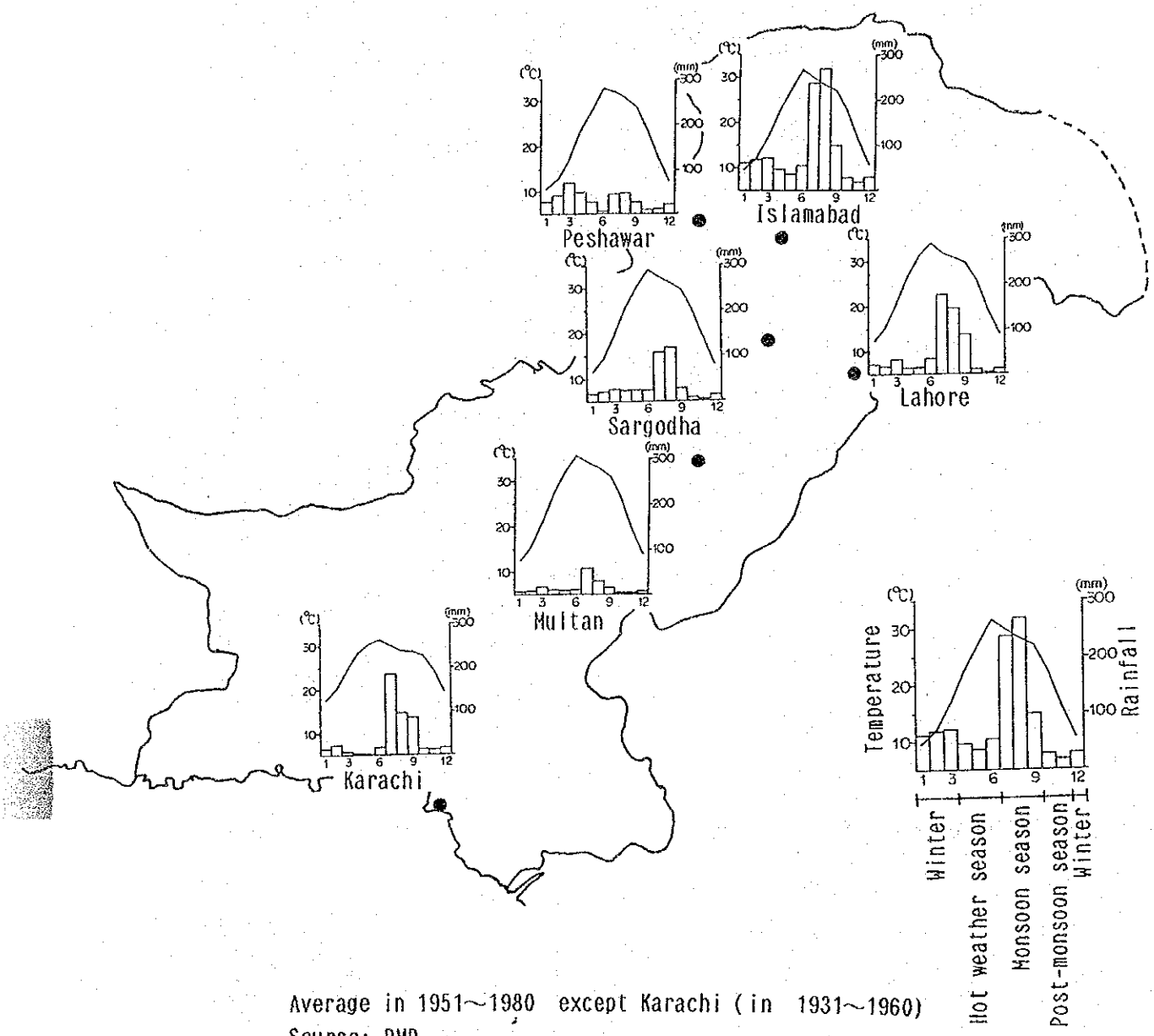
Cb-clusters in the ITCZ sometimes develop into weak tropical depressions but they rarely develop into cyclones as they usually move inland.

④ Post-Monsoon Season (October to November)

In the post-monsoon season, the ITCZ shifts to the south and the effects of monsoons lessen, resulting in fine weather with mild winds and the most pleasant time of the year. There are occasions, however, when the ITCZ extends from the Arabian Sea into the southern parts of the Indian Subcontinent and the ITCZ develops over the Arabian Sea. Monsoon depressions, sometimes, form in the Bay of Bengal and move northwestwards affecting Pakistan. They are the sources of moderate to heavy rainfall, resulting in loss of life and damage to property.

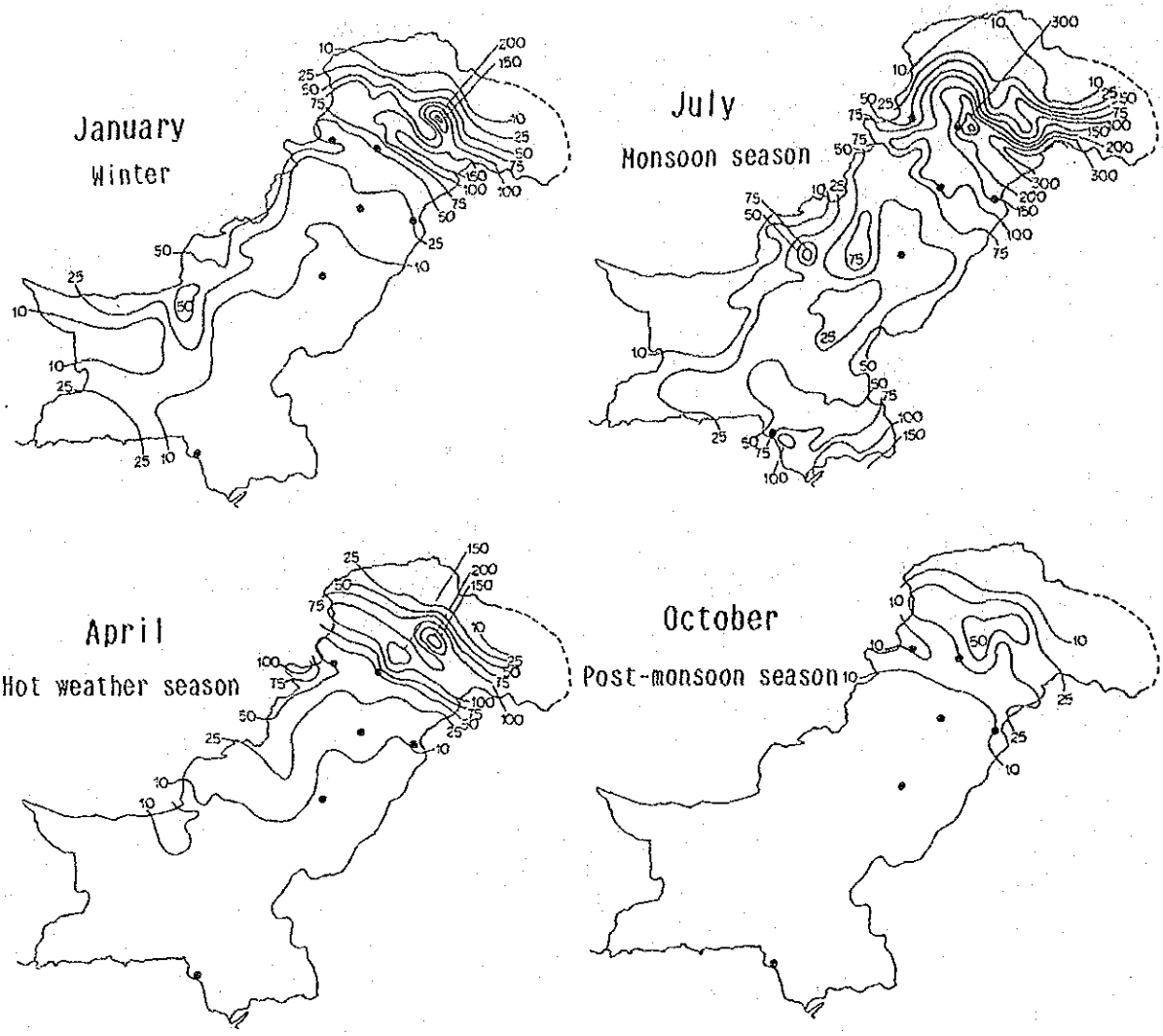
The monthly rainfall distribution in January, April, July and November is shown in Figure 2-1-4. Throughout the seasons, there is much rainfall in the northern mountainous region, reaching a maximum of over 200 mm in the monsoon season and over 100 mm even in winter and the hot weather season. On the plain in the Indus Basin, on the other hand, there is less rainfall throughout the year and in the area south of the 32nd parallel (south of Sargodha), the rainfall remains between 25 mm and 75 mm even in the monsoon season and below 10 mm during the other seasons. The distribution of the daily maximum rainfall (1931 to 1961), shown in Figure 2-1-5 bespeaks a different story. The maximum daily rainfalls are greater in the northern mountainous regions, but there is no radical variation between the mountainous region and the plain, as seen from the distribution of monthly rainfalls. It can be seen that there is a fair amount of rainfall also on the plain, indicating that there are few days of rainfall, but the intensity is

heavy. Along the southwestern coast (around Pasni) in the hot weather season, for example, in the central parts of the plain (around Multan) in the monsoon season and around Karachi in the post-monsoon season, the high daily maximum rainfalls are recorded instead of the low mean monthly rainfalls, indicating that it rarely rains in these areas but, when it does rain, heavy rainfalls are observed in short periods of time. The reason for high daily rainfalls in coastal areas lies in the effect of cyclones and tropical depressions and the reason for the high daily rainfalls lies in the effect of Cb-clusters developed along ITCZ.



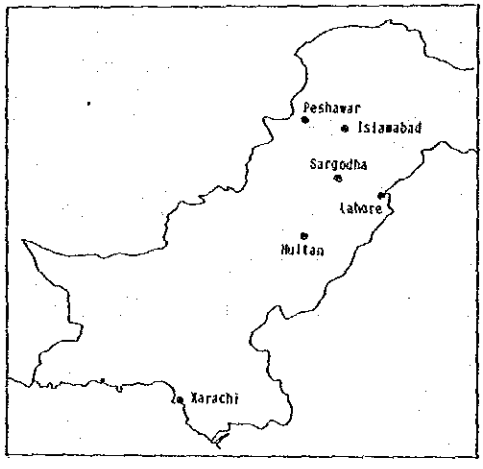
Average in 1951~1980 except Karachi (in 1931~1960)
Source; PMD

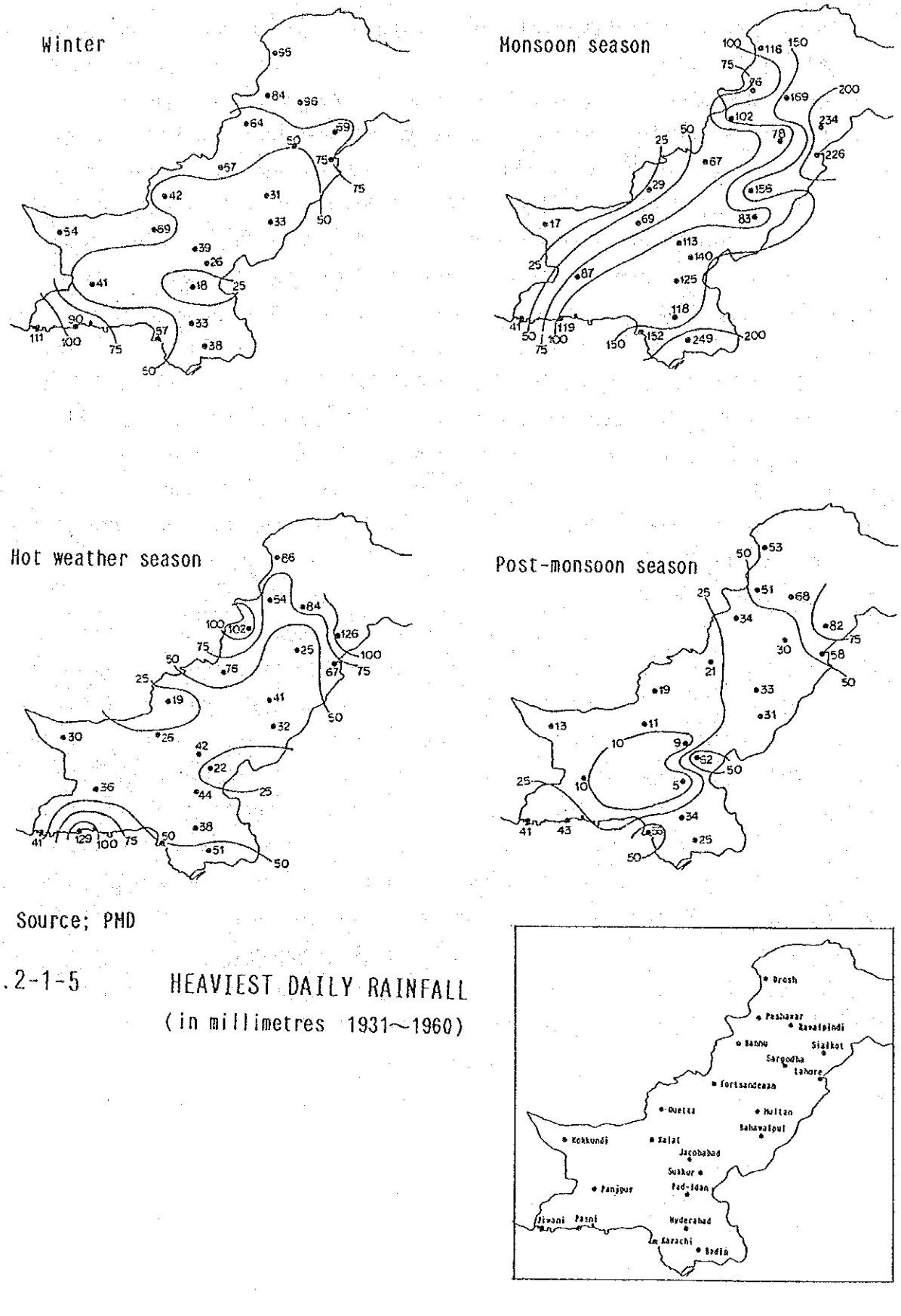
Fig.2-1-3 MEAN MONTHLY TENPERATURE AND MEAN MONTHLY RAINFALL



Source; ATRAS OF PAKISTAN

Fig.2-1-4 MEAN MONTHLY RAINFALL
(in millimetres)





Source; PMD

Fig.2-1-5 HEAVIEST DAILY RAINFALL
(in millimetres 1931~1960)

(3) Meteorological Disasters

Disasters resulting from meteorological phenomena often occur during the monsoon season in Pakistan. This is because Cb-clusters and tropical depressions along the ITCZ cause local torrential rains, hail storms and gales as well as floods and inundation of farmland, destruction of houses, disconnection of power lines, landslides and disintegration of road flanks, often resulting in a great loss of life. Damage caused by floods in the Punjab during the period 1973-1986 are shown in Table 2-1-4. Deaths due to floods are recorded nearly every year and more than 400 deaths were recorded in 1973 and 1976. Great damage is also done to farmland, houses and livestock. Damages to agricultural produce by inundation due to heavy rain were also recorded in 1987, much damage being done to wheat and other products, and a damage total of $ 1 million was recorded. In 1988, large-scale floods were caused in the Punjab due to heavy rain in India resulting in 250 deaths and extensive damage to agricultural produce. Because of this, the Government of Pakistan has greatly reduced its budget in other areas for procurement of funds for disaster relief and the initial budget of the PMD was also reduced by 11%.

The volume of traffic on internal flights has increased every year in Pakistan, but transportation by air is greatly affected by meteorological conditions, such as the occurrence of Cb-clusters. The number of times when alterations had to be made to landing locations because of bad weather, according to the 1988 data of the Pakistan International Airlines (PIA), is shown in Table 2-1-5. On twenty days within a month, alternative landings spots were chosen at one or another of the airports due to thunderstorms or bad weather. In the case of 14th August in particular, a plane that could not land in Lahore because of a thunderstorm tried to land in Delhi but failed to do so because of bad weather there and finally landed in Islamabad.

Major meteorological disasters that have occurred throughout Pakistan since 1972 according to data compiled by the PMD are listed below.

Table 2-1-4 Damage caused by floods in Punjab 1973~1986

Year	Area of crops affected(acres)	Person died	Hauses damaged	Hauses washed away	Cattle head lost
1973	2,871,924	449	802,020	unknown	41,734
1975	678,979	25	63,885	unknown	1,062
1976	2,145,635	408	676,509	515,659	27,555
1977	146,801	32	13,807	2,204	95
1978	905,082	129	278,408	214,897	4,003
1979	1,200	1	56	13	1
1980	163,810	61	15,444	11,281	79
1981	299,549	82	41,259	30,047	302
1982	41,535	1	3,376	1,438	4
1983	25,107	—	586	136	13
1984	145,403	7	8,324	3,912	66
1985	12,885	23	2,953	255	16
1986	574,562	37	24,387	55,178	2,169

Source; Flood Forecast and Warning Centre PMD

Table 2-1-5 Alterations in landing place due to bad weather (Augst 1988)

Date	Airport	Number of cases
1	Karachi, Turbat, Panjgur	3
2	Pasni, Lahore, Lahore, Quetta	4
3	Turbat, Quetta, Skardu	3
4	Sui, Quetta	2
5	Lahore, Karachi, Karachi, Karachi	4
6	—	—
7	Khuzdar, Karachi, Karachi	3
8	Sukkur	1
9	Faisalabad, Islamabad	2
10	Guadar	1
11	Faisalabad	1
12	Chitral	1
13	—	—
14	Lahore	1
15	—	—
16	—	—
17	Chitral	1
18	Skardu	1
19	Islamabad	1
20	Islamabad	1
21	—	—
22	—	—
23	—	—
24	Lahore	1
25	—	—
26	Lahore, Lahore	2
27	Lahore, Zhob	2
28	—	—
29	—	—
30	Peshawar, Chitral	2
31	—	—

Source; Pakistan International Airlines

1972 : A hail storm with a heavy downpour of rain occurred in Quetta on 26 June. It was estimated that wind velocity was over 25 m/s and rainfall was 38 mm within 20 minutes. The roads in the city were covered with knee-deep water and there were deaths of children, damage to buildings and damage to both power and communication lines. There were at least nine deaths and loss of 269 head of livestock. The total damage were estimated at Rs 2,500 million.

1973 : Heavy rain occurred in the first week of August resulting in floods in the central and northern Punjab spreading to the southern Punjab and Sind towards the end of the month. These floods were of an unprecedented scale and caused considerable damage. Approximately 500 lives were lost together with a large number of livestock. Damage totalled Rs 2,500 million in the Punjab with inundation of 10 million acres of land, 10,000 villages being affected and 8 million people losing their houses, and Rs 1,000 million in Sind with inundation of 2 million acres of land, 24,000 villages affected and 800,000 people losing their houses.

1974 : On 8th June, Bahawalpur (Punjab) was struck by a dust storm accompanied by thunder and a wind velocity of over 25 m/s was recorded. Four people were killed and twenty injured. In several towns and villages roofs were blown away and a large number of trees felled.

1975 : Floods occurred during the monsoon season. Twenty-five people were killed, 1062 head of cattle lost, 2.4 million acres inundated and over 60,000 houses affected in the Punjab while forty-nine people were killed, 578 head of cattle lost, 4.1 million acres inundated and 130,000 houses affected in Sind.

1976 : Heavy rain at the end of July resulted in floods in the northern and southern Punjab, Northwest Frontier Province and Sind. Twenty-five people were killed in Sind including five in Karachi.
Heavy rain in the north during August also caused unprecedented floods in the Punjab and Sind. Two hundred and forty people were killed in Punjab, forty-two in Sind and eight in Northwest Frontier Province. Fifty people were found to be missing and 12,700 villages were

affected.

Floods due to a heavy rain occurred again in September in Baluchistan and Sind. Six hundred villages were inundated and 50,000 people affected in Sind. Bolan Dam was washed away and Dadu City (in western Sind) was isolated.

1977 : Heavy rain occurred in the southeast of the country at the end of June. A total rainfall of 240 mm was recorded within two days on 29th and 30th in Karachi resulting in floods that caused 300 deaths and 2000 people to lose their houses. Damage was also caused to livestock and agricultural produce in the low lying areas of Sind.

Heavy rain occurred again on 11th and 12th July in Karachi with a total rainfall of 90 mm resulting in a certain amount of damage.

Also in July, heavy rain due to a monsoon in the Mardan district in the Northwest Frontier Province resulted in floods, although it lasted only for a short period and floods occurred also in parts of the northern Punjab. One hundred and thirty people were killed in the Northwest Frontier Province, two were missing in Sind and 7,000 houses were affected.

1978 : Heavy rain due to monsoon depressions fell on 14th July in Sind and a rainfall of 76 mm was recorded within five hours on the morning of 15th in Karachi. Five people were killed, twenty injured and 2000 forced to take refuge. A rainfall of 203 mm was recorded in ten hours between 14th and 15th in Sukkur (in northern Sind) and four people were killed.

Another depression hit Sind on 17 August, and a rainfall of 127 mm was recorded that night in Karachi. Forty-nine people were killed and many injured. The same depression proceeded west to cause heavy rain in Las-Bela District (west of Karachi) resulting in the deaths of seventy-eight people and loss of 1,000 head of cattle.

1980 : A heavy rain fell on Lahore on 30th and 31st July. 333 mm of rain fell in 24 hours (a record since 1930) and damage was caused to many older houses.

1982 : A developed disturbance struck Quetta on 5th August causing a rainfall of 44mm in a short period of time. Thirty people were killed,

200 houses destroyed, many trees felled by strong winds and roofs blown off houses.

A Heavy rain due to a monsoon depression fell on Karachi on 15th August resulting in eleven deaths and damages to numerous houses.

1983 : A dust storm accompanied by rain fell upon Rawalpindi (in the northern Punjab) on 2nd July causing five deaths and extensive damage to livestock and trees.

About thirty people went missing and numerous houses were destroyed by a heavy rain at Khamango in the vicinity of Skardu (in Kashmir) on 13th August. Heavy rain at D.I.Khan (in the southern part of Northwest Frontier Province) and the surrounding area resulted in six deaths and destruction of 300 houses.

Heavy rain fell on Hyderabad (in Sind) on 4th and 19th August resulting in two deaths and considerable damages to the communication system.

1984 : There was a heat wave in the northern and central parts of the country resulting in five deaths and damage to 150 cattle in areas of the Punjab such as Multan, Lahore and D.G.Khan.

In August, two depressions advanced from the Bay of Bengal into northern and central India bringing heavy rain. Floods resulted in thirty-one deaths in Karachi, five deaths in Khuzdar (in Baluchistan) and eleven deaths in Peshawar as well as the destruction of many houses.

1985 : A heavy rain accompanied by a hail storm hit Karachi on 1st April. Four people were killed and flight, electrical and telephone services were disrupted.

Heavy rain on 8th July caused fourteen deaths in Islamabad and Rawalpindi and heavy rain on 18th and 19th resulted in nine deaths in Karachi.

Heavy rain fell on Hyderabad in August resulting in two deaths and considerable damage was caused to cotton plants at Nawabshah in central Sind.

A rainfall of 157 mm within 24 hours was recorded on 10th October during heavy rain at Lahore.

1986 : 31st May - Twenty-one people were killed and 250 injured in a dust

storm accompanied by a wind of 31 m/s.

4th June - Four people were killed and thirteen injured in gales at Faisalabad.

10th and 11th July - Several people were killed in violent sandstorms in Multan and Peshawar.

29th July - Five people were killed at Sukkur during heavy rains accompanied by gusts in Sind.

3rd and 10th August - Eight people were killed at Karachi in heavy rains.

1987 : At Lahore and in the northern part of the Punjab, temperatures in May were the lowest recorded for the past 122 years and the rainfall the second highest. Maximum temperatures in May were 10° C to 20° C below the average and the rainfall in the northern Punjab and the Northwest Frontier Province were 3 to 12 times as large as that of the average year. (A monthly rainfall of 98 mm was recorded at Lahore where the average rainfall for May is 8 mm) Extensive damage was caused by the heavy rain and the accompanying hail and dust storms to wheat just before harvest (affecting 15 % of the total acreage). The damage was estimated at US $ 1 million. Loss of life was also reported.

There was less rain than usual during the monsoon season with a shortfall of 30 to 50 % on the plains in the Punjab and 85 % in the Northwest Frontier Province and the harvest of produce such as sugarcane and rice were affected.

1988 : Heavy rain fell in the northern part of Bihar Province in India on the upper reaches of the Sutlej River and emergency discharges were made from a dam on the river resulting in floods on the Pakistani side. In the Punjab, two hundred and fifty people were killed, about 30,000 head of cattle lost, 3.46 million acres inundated, 4038 villages affected and approximately 550,000 houses destroyed or washed away.

2-1-3 Necessity of Meteorological Services

There has been remarkable progress in the manufacturing industry in Pakistan since her independence, but agriculture is still a major industry and more than 70 % of the population live in rural areas. The main agricultural region is the plains in the Indus Basin and large-scale irrigation agriculture has been developed on these plains. Water for irrigation is taken from the Indus and several tributaries which join it from the east. Dams (such as Tarbela Dam on the Indus and Mangla Dam on the Jhelum river) have been constructed in the northern mountainous region to make effective use of heavy rainfall water from the mountains. When the ITCZ moves north on to these plains during the monsoon season, however, a heavy rain of short duration suddenly occurs, though in limited areas, resulting from Cb-clusters formed along the ITCZ. This rain, besides being intense, can be accompanied by hail and thunder and sudden rain often results causing inundation of farmland and damage to agricultural produce, extensive damage and loss of human life, livestock and homes caused by floods and gusts. The area along the Arabian Sea is subject floods and storms due to cyclones even outside the monsoon season.

Meteorological damage to the transportation system cannot be ignored. In Pakistan with its large area, the importance of aircraft transportation has been increasing in recent years. Although aviation is greatly affected by violent rain, strong down draughts and poor visibility accompanying a cumulonimbus, no accident due to bad weather has been reported so far. Emergency landings, however, in alternative airports have sometimes had to be made in order to ensure safety in aircraft operations.

As these disasters and troubles due to meteorological phenomena occur frequently in Pakistan, meteorological information is vital and meteorological services become a necessity. With the meteorological service, observations are made at the observatories located throughout the country and the observational data are collected and analysed to detect disturbances. The movements of the disturbances are predicted in order to make weather forecasts and, when damages is expected, warnings are issued and distributed to the public. In carrying out meteorological services, it is first necessary to collect meteorological observational data from various parts of the country. This can be said of any country and any area in the world, but this is particularly important in countries like Pakistan where meteorological disasters occur frequently.

To provide accurate predictions and warnings by collecting observational

data, it is necessary to detect accurately meteorological disturbances that cause natural disasters. In the case of typical heavy rains in Pakistan, it is necessary to carry out constant observations of conditions rainfall caused by Cb-clusters generated along the ITCZ, since these heavy rains from Cb-clusters are normally concentrated in a small area ranging from several kilometres to several tens of kilometres while, at the same time, they develop and decay within short periods of about an hour to 2 hours and can occur at any point. Since the monsoon depression during the South West Monsoon season is responsible for heavy to very heavy rainfall in Pakistan, the constant observations of meteorological conditions of these rainfalls are also necessary.

Density of the network for basic surface observations and upper air observations is not high enough to detect the movement of the meteorological phenomena. Movement of a Cb-cluster can be effectively detected by weather surveillance radars which are capable of making spatially detailed observations and by cloud image observation through meteorological satellites. For the cloud image observation, the Soviet Union is to launch a geostationary satellite under the WWW Plan of the WMO but the launching of the satellite has been delayed. The Pakistan Meteorological Department is unable to obtain adequate cloud images at present. Satellite information is limited to that received from the NOAA polar-orbiting satellites and only information transmitted twice a day can be used. As there are long intervals between observation times, it is impossible to detect the development and weakening of Cb-clusters. As clouds are observed from the high altitude, heavy rain is not directly observed but the potential of heavy rain is detected from the cloud image from the satellite.

Weather surveillance radars are the most effective means of carrying out continuous observations of rainfall over wide areas in a short time period. Radars transmit radio waves and estimate the amount of rainfall and its extent from the radio waves reflected back by the rain drops. By continuous transmission of the radio waves, it is possible to detect the areas of rainfall expanding and shrinking with time. Weather surveillance radars are the most effective means of observation in Pakistan where local torrential rain caused by monsoon depression or Cb-clusters frequently occur.

The existing radars in Pakistan, however, do not cover the whole country and, as they are getting old, the area of coverage of each radar is small and their capability for detecting rainfall is inadequate. There is an urgent need, therefore, for the meteorological services in Pakistan to establish a weather

surveillance radar network, to carry out the collection of observational data from this network, to make forecasts through accurate analysis of the data and disseminate quickly forecasts to the authorities concerned as well as to the public.

2-2 Meteorological Services in Pakistan

2-2-1 Present Situation of the Meteorological Services

(1) Organization of the Pakistan Meteorological Department

The Pakistan Meteorological Department(PMD) is the government organization responsible for carrying out meteorological services. The PMD carries out various meteorological observations in order to prevent natural disasters caused by meteorological and seismological phenomena, ensure safety of the transportation system, contribute to increase in agricultural productivity and provide the public with adequate weather forecasts. The PMD collects and analyses observational data and provides the public with meteorological information.

The PMD had made serious efforts to improve the meteorological service in the following areas.

- Establishment of a network for meteorological, seismological and agrometeorological observation;
- Establishment of a meteorological telecommunications network for prompt transmission of information;
- Improvement of meteorological analyses;
- Education and training of the personnel necessary to carry out the works mentioned above.

The PMD is making efforts to employ new observation methods, communication techniques and analysis methods for these purposes. Given below are the present organization, details of operation, personnel and budget of the PMD.

1) Organization

The organization of the PMD is shown in Figure 2-1-1. Forecast and Climate Division, Maintenance Division, Administration Division and Planning and Development Division belong to the Karachi Headquarters under the Director-General.

The country is divided into two regions, i.e., the southern (Sind, Baluchistan) region and the northern (Punjab, Northwest Frontier Province) regions, and these regions are under the supervision of the Southern

Meteorological Regional Centre at Karachi and the Northern Meteorological Regional Centre at Lahore, respectively. In Islamabad, the National Agrometeorological Centre covers the Federal Capital Area. The PMD has the Flood Forecasting and Warning Centre at Lahore, the Geophysical Centre at Quetta and the Upper Atmospheric Research Station at Peshawar.

Located at the headquarters in Karachi are the Institute of Meteorology and Geophysics, the Main Analysis Centre and the Climatological Data-Processing Centre. Under the Maintenance Division there are the National Telecommunication Centre and the Meteorological Workshop.

The meteorological regional centres control the observatories and the meteorological stations at airports in their respective regions. The National Agrometeorological Centre is responsible for issuing weather forecasts for the Federal Capital Area and provides agrometeorological information.

The Flood Forecasting and Warning Centre at Lahore carries out analysis of hydrological data and issues forecasts and warnings related to each river.

Meteorological service for aviation is carried out by meteorological stations at airports and these stations provide meteorological information as required.

The PMD has one weather surveillance radar at the Southern Meteorological Regional Centre at Karachi, three at the Northern Meteorological Regional Centre at Lahore and one at the Flood Forecasts and Warning Centre at Lahore.

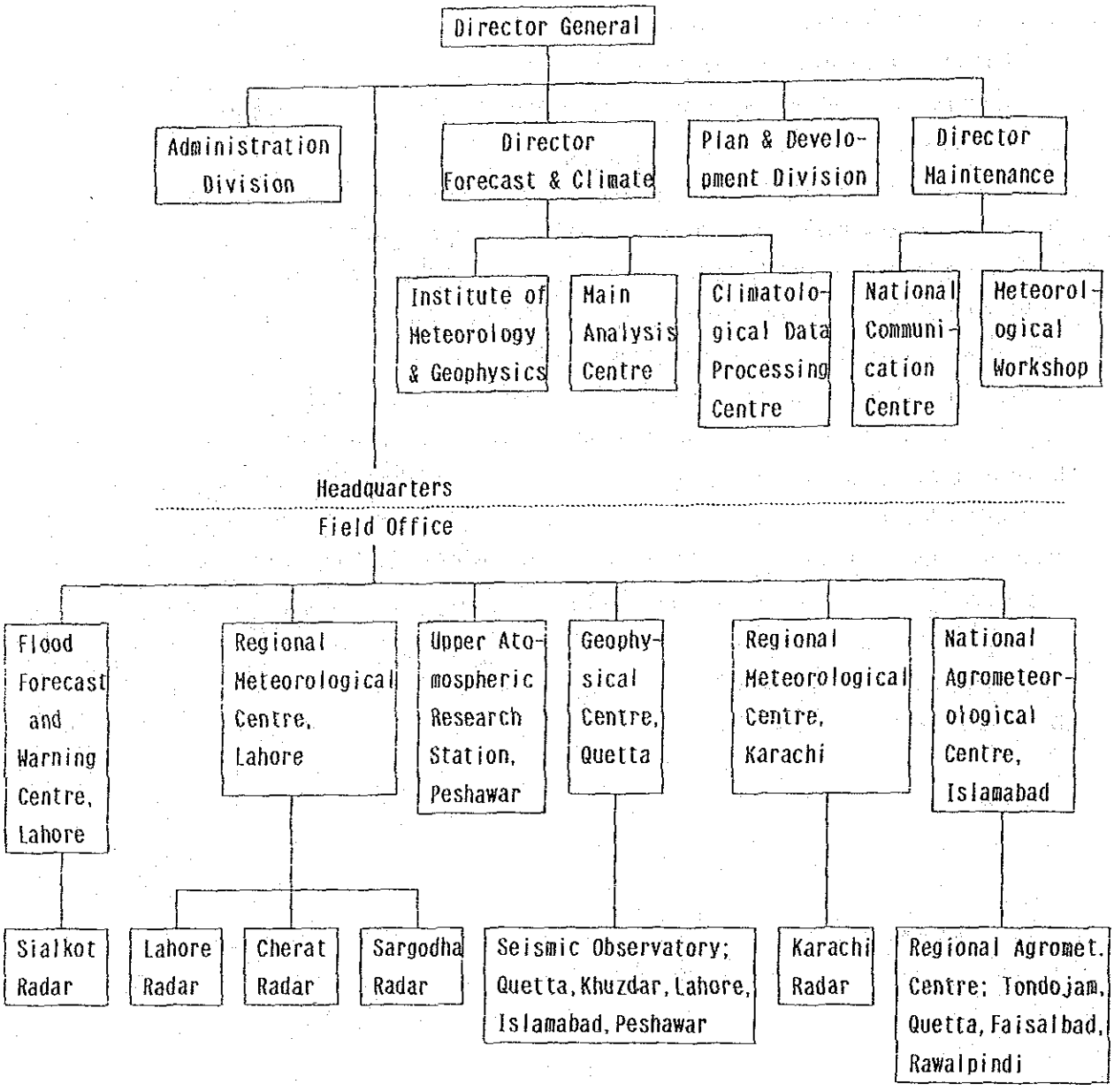


Fig. 2-2-1 Organization Chart of Pakistan Meteorological Department

2) Services of PMD

The services of the PMD include meteorological observations, analyses and provision of meteorological information as well as meteorological telecommunications. Details in this respect are given below.

a) Observations

① Surface
② Upper Air
③ Seismology
④ Astronomy
⑤ Solar radiation
⑥ Atmospheric Ozone
⑦ Geomagnetism
⑧ Air Pollution

b) Meteorological Analysis and Provision of Meteorological Information

① Issue of General Weather Forecasts to the Public;
② Issue of Forecasts and Warningsconcerning Aeronautical Meteorology;
③ Issue of Forecasts and Warnings concerning Marine Meteorology;
④ Issue of Forecasts and Warnings concerning Floods;
⑤ Provision of Information and Data on Earthquakes;
⑥ Observation of Atmospheric Pollution;
⑦ Provisionof AgrometeorologicalInformationand Warnings
⑧ Provision of Astronomical Information
- Times of Sunrise and Sunset
- Times for Prayer
- Twilight Times
- Solar and Lunar Eclipses

⑨ Provision of Other Meteorological Information;
- Planning and Development
- Urban Planning
- Design of Roads, Bridges, Airports, Power Generating Stations and Air conditioning
- Meteorological and Seismological Data for Court Cases, Insurance Claims, Inquests and Official Publications of Local Authorities

c) Meteorological Telecommunications

d) Research in the Following Areas

① Meteorology
② Climatology
③ Hydrology
④ Oceanography
⑤ Aerophysics
⑥ Environmental Pollution
⑦ Geophysics
⑧ Agrometeorology

e) Training in Meteorology and Geophysics

① Training of the PMD Staff
② Training of Staff of Other Organisations
③ Training of Foreigners

f) Maintenance, Production and Calibration of Meteorological Instruments

3) Personnel

The number of the staff of the PMD was 2233 as of November 1988, consisting of 980 meteorologists under the Director-General, 490 electronic and mechanical engineers in the Maintenance Division, 106 administrative staff in the Administration Division and 657 workers engaged in auxiliary work. The composition of thestaff are shown in Table 2-2-1.

Table 2-2-1 Personnel of Pakistan Meteorological Department

Meteorologist

Name	Posts
1,Director-General	1
2,Director	7
3,Dy.Director & Senior Meteorologist	18
4,Meteorologist	52
5,Asst.Meteorologist	128
6,Professional Asst.	88
7,System Analyst	1
8,Met.Assistant	171
9,Asst.(Technical)	53
10,Sr.Observer	358
11,Observer	103
Total	980

Administrator

Name	Posts
1,Chief Admin.Officer	1
2,Dy.Ch.Admin.Officer	2
3,Admin.Officer	5
4,Security Officer	1
5,Superintendent	7
6,Stenographer	10
7,Stenotypist	10
8,Asst.(Clerical)	20
9,Upper Dy.Clerk	27
10,Lower Dy.Clerk	23
Total	106

Electronic and Mechanical Engineer

Name	Posts
1,Director	1
2,Sr.Elec.Enginneer	2
3,Electronic Engineer	13
4,Workshop Engineer	1
5,Asst.Elec.Engineer	11
6,Asst.Mech.Engineer	2
7,Electronic Asst.	73
8,Technical Asst.	1
9.Sr.Radio Mechanic.	1
10,Mechanical Asst.	3
11,Overseer	1
12,Teleprinter Superv.	25
13,Telept.Operator	166
14,Radio Mechanic	60
15,Chief Mechanic	6
16,Mechanic Grade I	32
17,Mechanic Grade II	48
18,Mechanic Grade III	2
19,Tracer	1
20,Wireman	1
21,Electrician	1
22,Draftsman	5
23,Driver	30
24,Duplicating Machine Operator	3
25,Feroprinter	1
Total	490

Worker

Name	Posts
1,Laboratory Attendant	15
2,Daftary	14
3,Naib Qasid (Hessenger)	230
4,Balloon-Maker	147
5,Chowkidar (Guard)	136
6,Coolie (Porter)	19
7,Cleaner (Car washer)	2
8,Sweeper	57
9,Mali (Gardener)	34
10,Farrash (Interior Cleaner)	3
Total	657

Source; PMD

4) Budget

The fiscal year of the Government of Pakistan runs from July to June of the following year. The PMD begins the preparation of budgetary requests in January and after internal adjustments the budget is approved by the Ministry of Finance and submitted to Parliament. The new budget comes into effect in July.

The PMD budget is divided into two parts, i.e. ordinary expenses and development funds. The budgets for the past five years divided into ordinary expenses and development funds are shown in Table 2-2-2. While the ordinary expenditure has been held in check, the development fund has been decreasing every year and this has jeopardised the planning of development. These development funds include yearly amounts from the total budgets of projects approved by the government, such as PC-1. Foreign aid is also included, though it is separate from government budgets.

In the budget for this year, the original figure demanded for the development fund was curtailed by 11 % from the beginning to make up for the emergency expenditure for the flood that struck the Punjab in September 1988.

Details of the budget for this year (1988 - 1989) are shown in Table 2-2-3. 70 % of the ordinary expenditure is apportioned to items such as labour and 5 % to the purchase of equipment. The combined total of funds for the purchase of equipment from the ordinary expenses and the development funds amount to only Rs 3,956,000 (approx. ¥ 27,700,000) and it is difficult for these budgets to purchase expensive equipment such as weather surveillance radars.

Table 2-2-2 Badget of PMD for the past five years

Year	Current (Rs)	Growth(%)	Development(Rs)	Growth(%)
1984-85	51,400,000		15,240,000	
1985-86	53,930,000	4.9	15,050,000	-1.2
1986-87	60,000,000	11.3	15,490,000	2.9
1987-88	58,879,000	-1.9	8,180,000	-47.2
1988-89	60,351,000	2.5	7,098,000	-13.2

Source; PMD

Table 2-2-3 Budget of PMD for the year 1988-1989

Items	Current (Rs1000)	Development (Rs1000)	Remarks
1.Establishment Charge	42,072	113	Wages
2 Purchase of Durable Goods	2,956	1,000	Procurement of Radiosonde Equipment and so on
3.Construction Work	228	4,110	Addi.work & New Building
4.Repair & Maintenance of Durable Goods	513	—	Equipment & Building
5.Commodities & Services	13,775	—	Telephone, Power, Water supply & Consumables for operation
6.Others	807	—	
7.Aid Expert Fellowship	—	1,875	UNDP

Source; PMD

(2) Observation Duties

As explained in 2-2-1 1) the observational duties of the PMD cover wide areas of meteorology, seismology and hydrology. Observatories of the PMD are listed in Table 2-2-4.

As shown in Figure 2-2-2, observatories for making surface observation and upper air observation are distributed throughout the country. In addition, weather surveillance radars are located at Karachi and four other places in areas having a large amount of the annual rainfall in the north. Wind finding radars are located at five places along the main internal flight route connecting Karachi and Islamabad and receivers for automatic picture transmission (APT) from NOAA are located at the four major airports in the country.

For observational instruments, radiosondes are purchased every year, but many of the radars and surface observational instruments have been in use more than twenty years. The shortage of expendable items and parts results in the reduction of the observation cycles.

As regards the observational technology, training for meteorological engineers is being carried out at Karachi in accordance with the WMO standards.

Table 2-2-4 Observatories in the possesion of the PMD

Observatories	Number of stations	Number of observations per day	Remarks
1. Surface weather stations	59	8	Pressure, Temperature, Humidity, Wind, Cloud, etc
2. Pilot Balloon observatories	28	4	
3. Aerometeorological stations	35		Including 32 Airport observatories for civil aviation
4. Radiosonde/Rawinsonde stations	6	2	In generall, it is difficult to observe twice per day owing to a shortage of supply of expendable parts
5. Wind Finding Rader stations	5	1	X-band, 12GMT
6. Weather Surveillance Rader stations	5	8	Hourly, in rough weather
7. Weather Satellite Ground Receiving stations(APT)	4	4	
8. Seismological stations	6		Quetta etc
9. Geomagnetic stations	2		Quetta, Gilgit
10. Solar Radiation stations	7		Lahore etc
11. Ozone Measuring station	1		Quetta
12. Agrometeorological stations	5		Islamabad etc
13. Remote Recording Meteorological Instrument stations	10		
14. Voluntary Observing Fleet	16		
15. Air Pollution stations	1		Chitral

Source; PMD

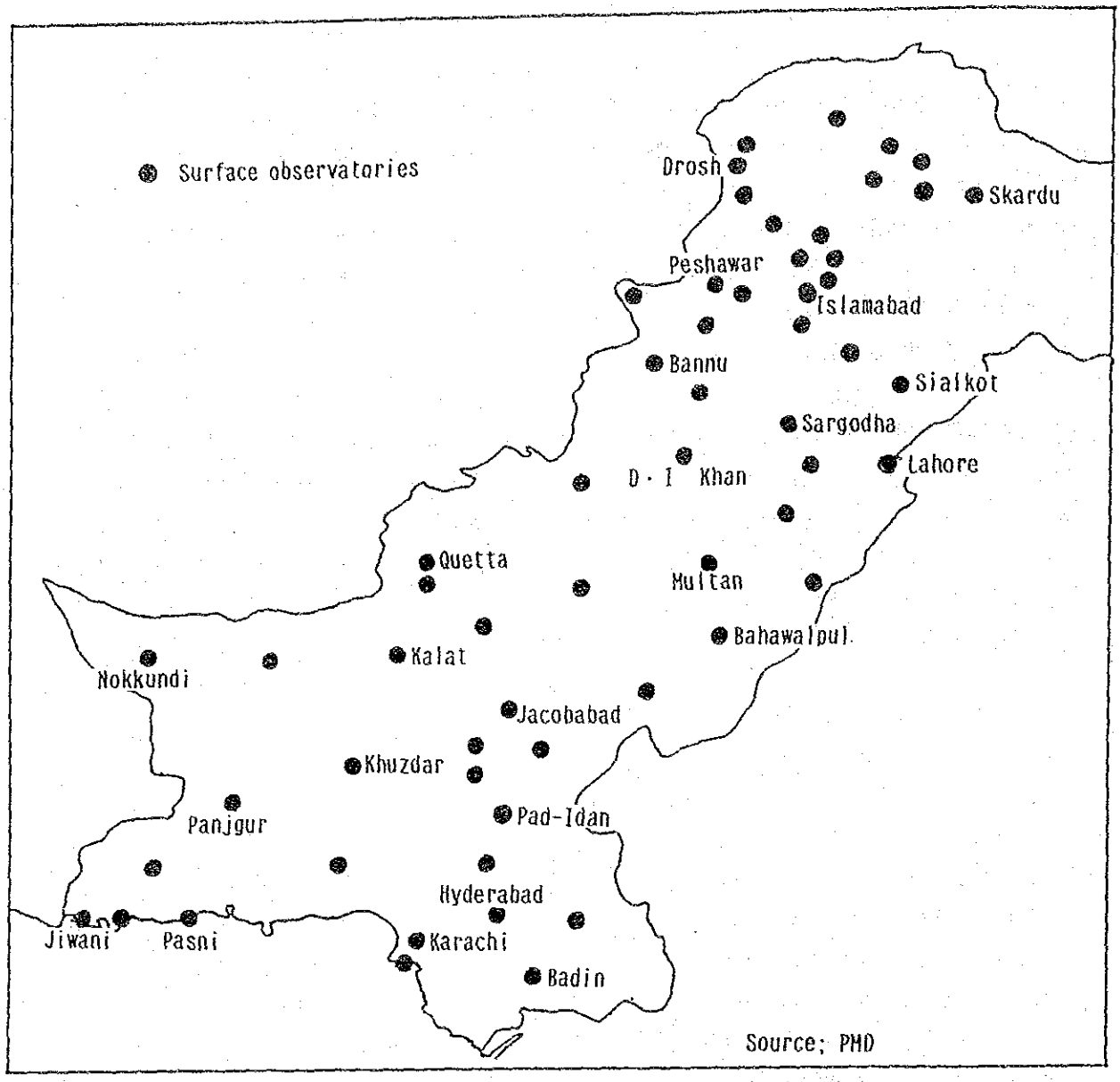


Fig. 2-2-2 (1) DISTRIBUTION OF OBSERVATORIES (Surface)

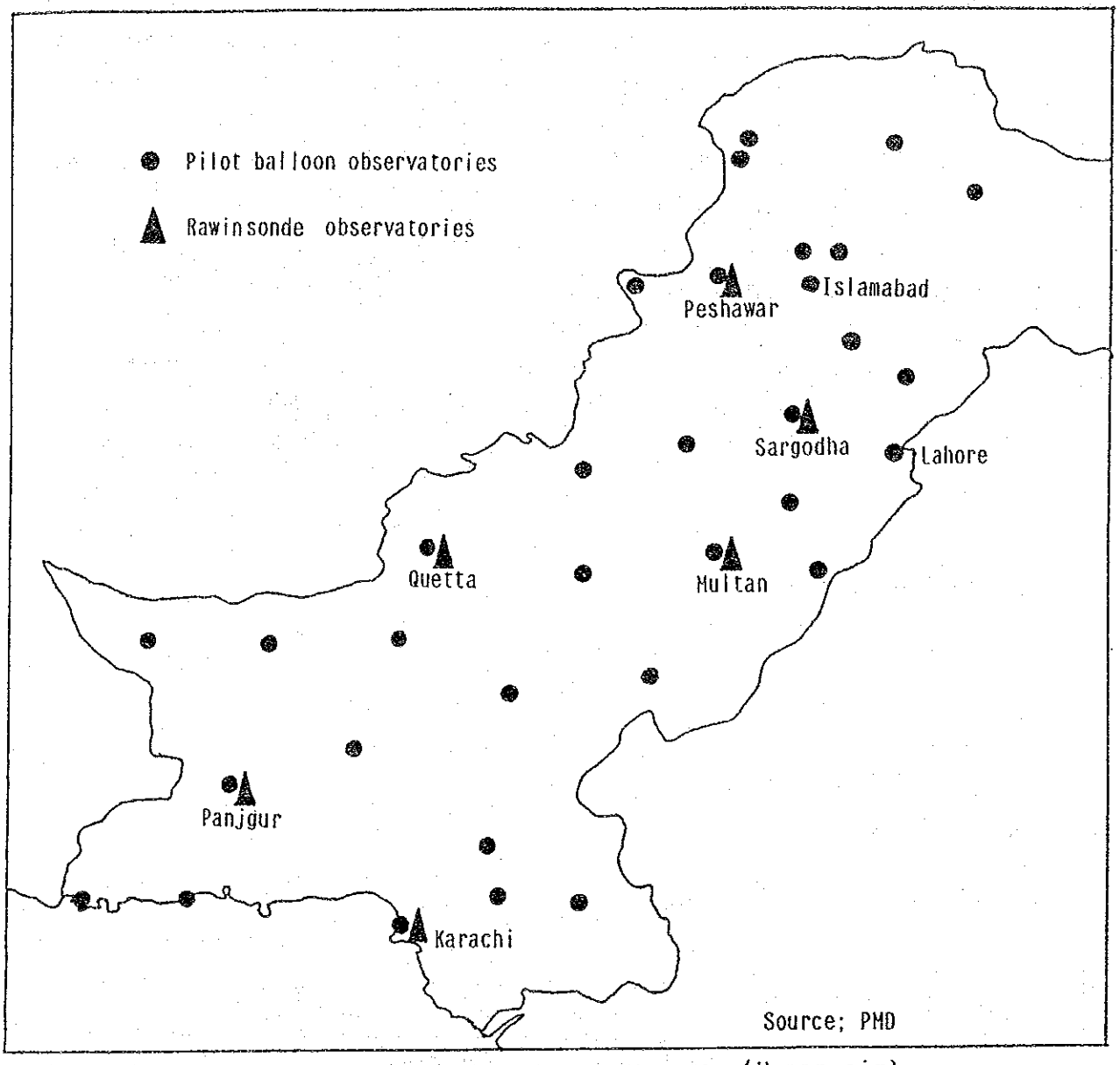


Fig. 2-2-2 (2) DISTRIBUTION OF OBSERVATORIES (Upper air)

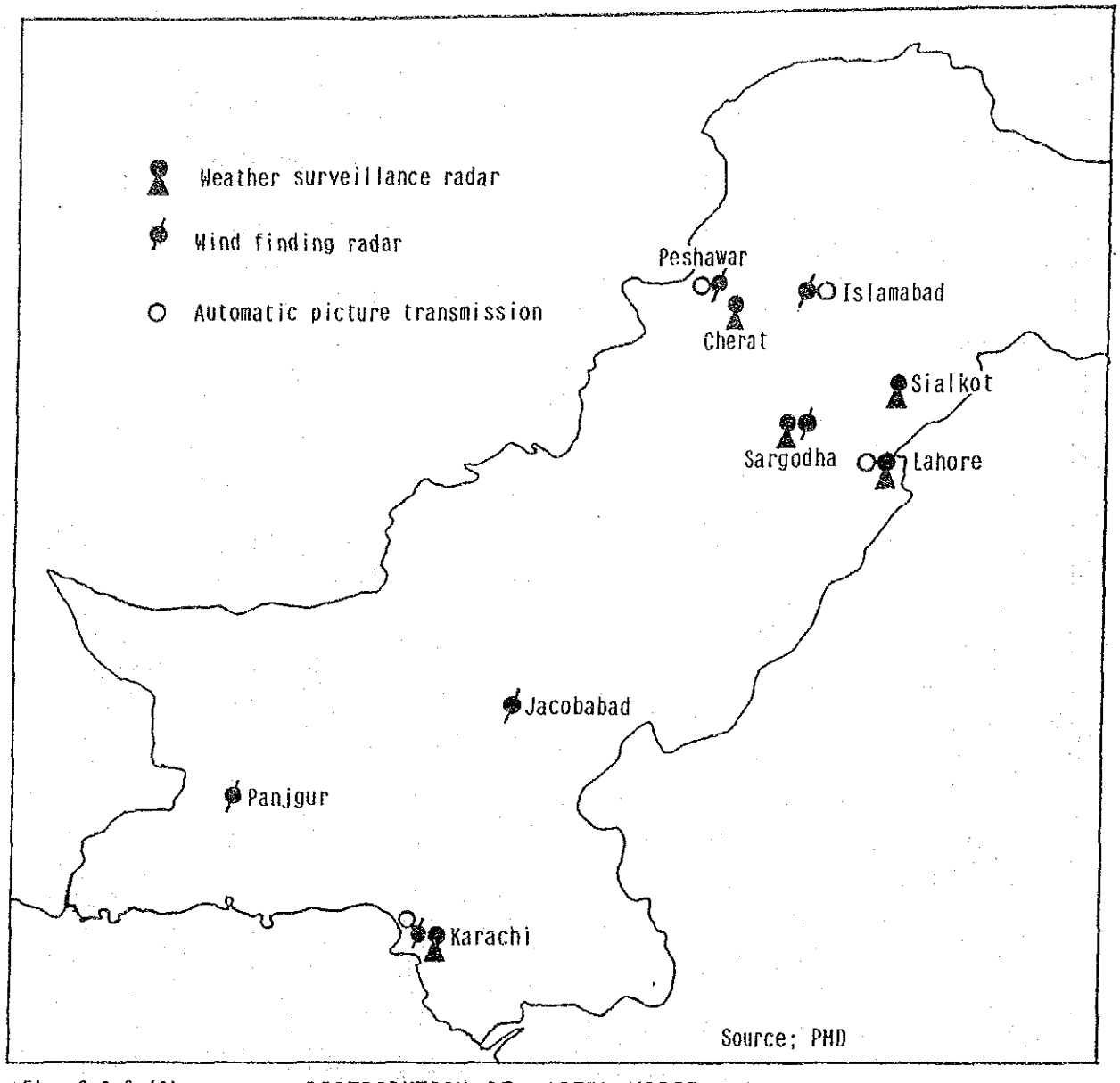


Fig. 2-2-2 (3) DISTRIBUTION OF OBSERVATORIES

(Weather surveillance radar, Wind finding radar, Automatic picture transmission)

(3) Dissemination of Data

The equipment used by the PMD at present for communication of meteorological data are shown in Table 2-2-5 and the network for dissemination of meteorological data in Figure 2-2-3 and Figure 2-2-4.

The communication of meteorological data by the PMD is not satisfactory because of frequent outages of the power supply and poor quality of communication lines.

In concrete terms, the reception condition of radio communication is poor for collection of data from foreign countries. There are areas from which meteorological data cannot be collected, and hence the preparation and analysis of weather charts are critical. Furthermore, prompt dissemination of meteorological information between the observatories and the regional centres is hindered because teleprinters are getting old and the conditions of the telephone lines are very poor.

These conditions of the communication of meteorological data cause serious delays in the work of the PMD at the times of disasters.

Table 2-2-5 Equipment for meteorological data dissemination

Equipment	Circuit	Function		Purpose	Problems
		reception	transmission		
1, Teleprinter (50 bauds)	Public circuit	○	○	Data dissemination	Shortage of spare parts
2, SSB	HF	○	○	Data dissemination or stand-by equipment for others	Inadequate reception caused by noises
3, Radio Teletype (RTT)	HF	○		Data collection from the sorrounding countries	—ditto —
4, Weather FAX	HF	○		Reception of weather charts from Tashkent	—ditto —
5, Telephone	Public circuit	○	○	Data collection and transmission of warnings	Restriction of time for data dissemination
6, Telegram by post office			○	Data collection from observatories that have no equipment for data dissemination	Dilatory dissemination

Source; PMD

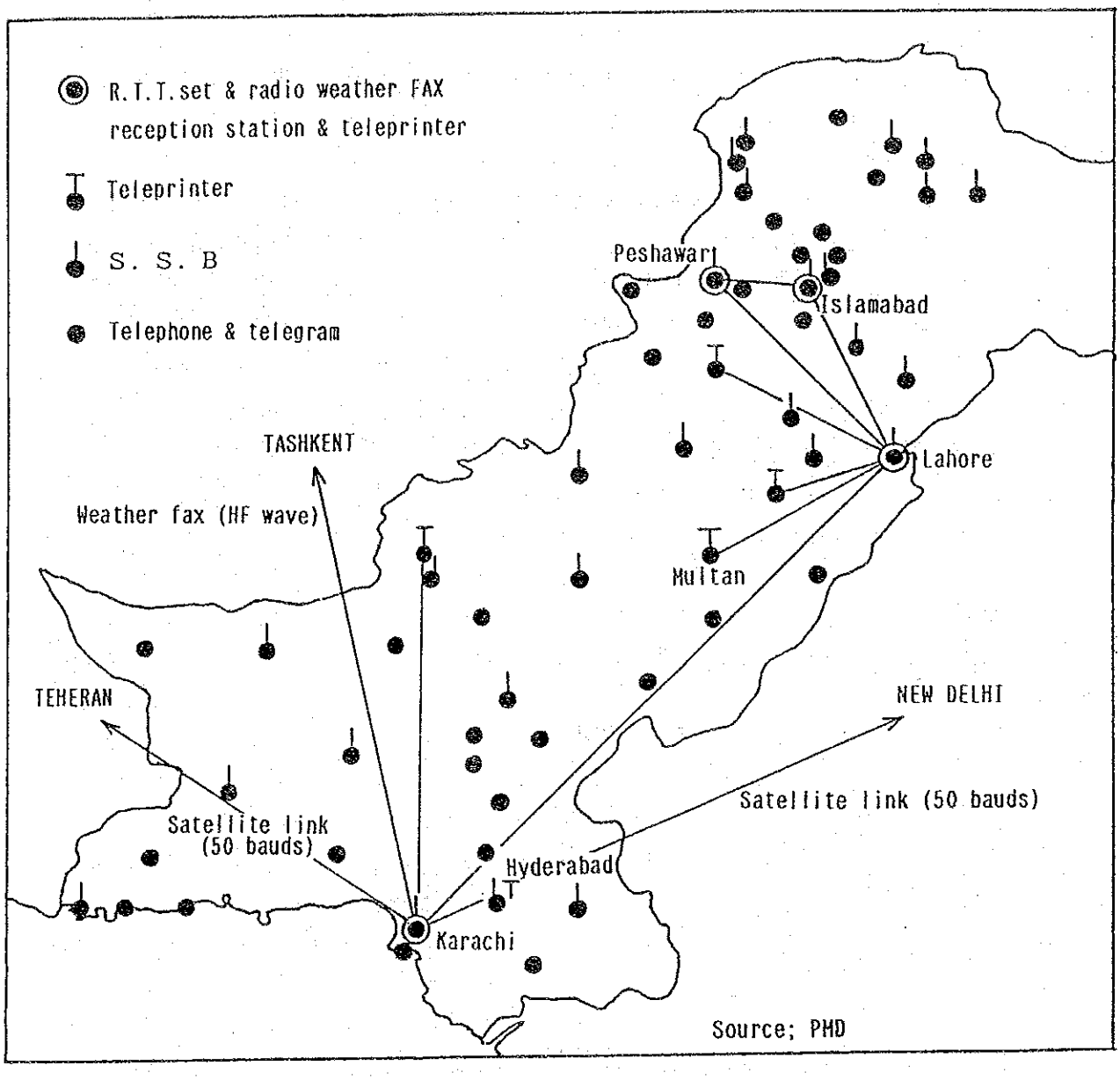


Fig. 2-2-3 METEOROLOGICAL DATA DISSEMINATION NETWORK

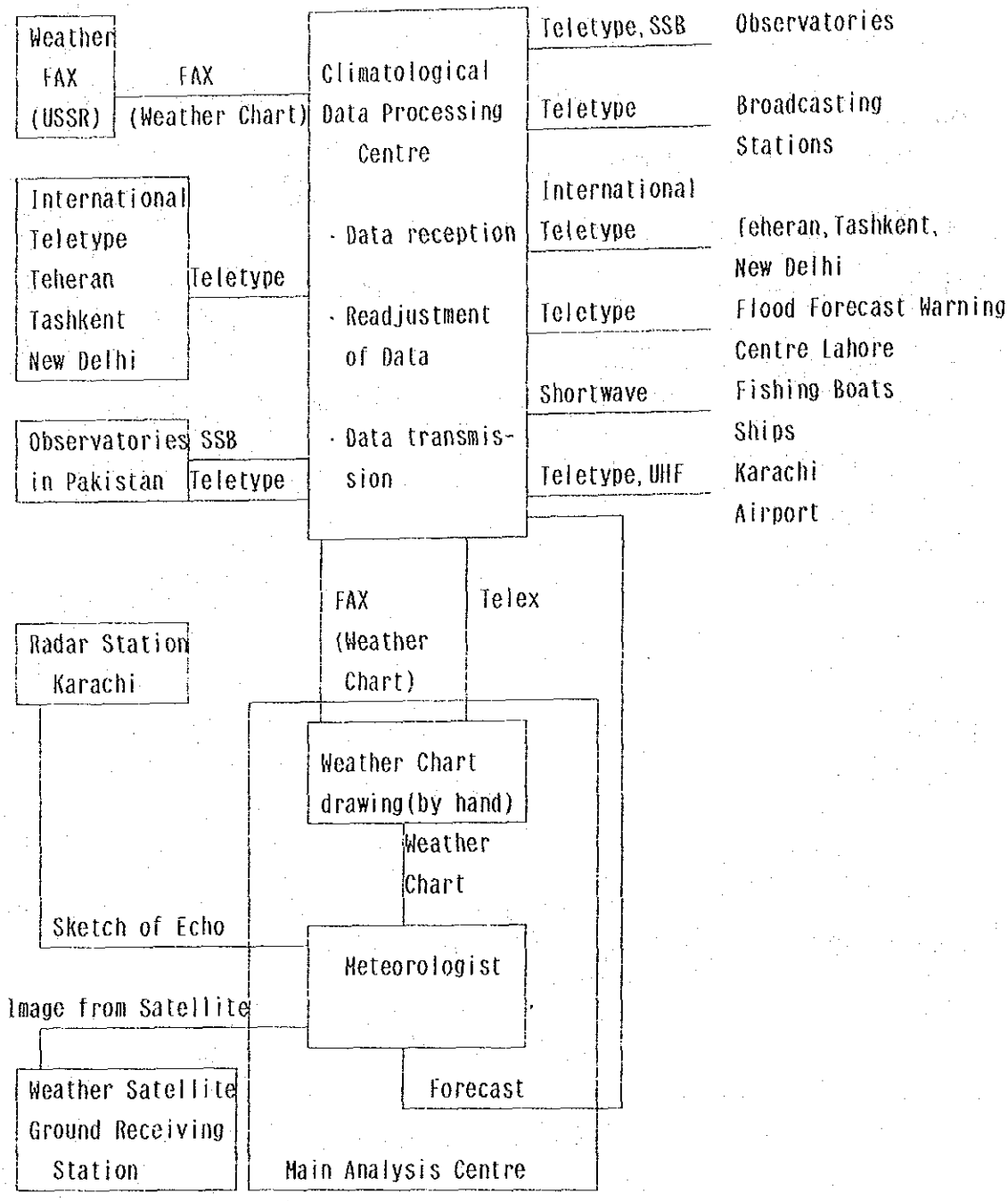


Fig.2-2-4 Meteorological Data Dissemination in Headquaters of PMD

(4) Analysis and Communication of Meteorological Information

Types of meteorological information disseminated by the PMD are shown in Table 2-2-6.

Forecasters at the PMD carry out weather analyses based on meteorological reports available by teletypewriters, weather charts transmitted through meteorological facsimile transmissions and NOAA data received as APT.

Unsatisfactory conditions of communications, however, inevitably result in blank areas on the weather charts. These blanks are filled with information obtained from meteorological facsimile weather charts prepared by other countries and cloud image pictures obtained from NOAA.

The forecasters at the PMD prepare 24-hour and weekly forecasts despite these disadvantages as shown in Figure 2-2-5 (1)～(3).

Furthermore, they issue warnings against violent weather conditions, such as a local torrential rain accompanying tropical depressions and Cb-clusters in the ITCZ. As heavy rains in Pakistan occur suddenly, it is difficult to predict dangerous signs of heavy rains based on information available from NOAA.

Although the meteorological services in Pakistan suffer from disadvantages mentioned above, efforts have been made to improve meteorological services in order to satisfy the increasing demand. Forecasts for the airports and the flight routes, for example, are prepared and disseminated to users and forecasts are also prepared for foggy areas on the Arabian Sea.

Agrometeorological information based on the analysis of meteorological observational data is also distributed to users.

Besides the types of forecasts and warnings mentioned above, the Flood Forecasting and Warning Centre makes use of hydrological methods to forecast the discharge of rivers. With a view to carrying out speedy collection of information and dissemination of warnings, the Centre has constructed a communication network as shown in Figure 2-2-5(4). This is an example of Pakistan's efforts in the work of preventing natural disasters. It is mentioned that prompt availability of meteorological data will lead to more effective operation.

Table 2-2-6 Items of Meteorological Information

Charge	Items	Transmitted Place	System of Communication
Main Analysis Centre (MAC) Karachi	24 hour forecast Weekly forecast Seasonal forecast	Government Organization —ditto — —ditto —	Telephone, Hand to hand Hand to hand —ditto —
Regional Meteorological Centre (RMC) Karachi, Lahore	24 hour forecast Agrometeorological Information Marine weather forecast	Organization for Disaster prevention Broadcasting station Agricultural Office Ships	Telephone, Hand to hand —ditto — —ditto — Broadcast, Telegram
Airport Meteorological Office	Aerometeorological Information	Airport Office	Meeting, Telephone, Hand to hand
Agrometeorological Centre Islamabad	Agrometeorological Infofmation	Agricultural Office Organization for Disaster prevention Broadcasting station	Broadcast, Telephone, Hand to hand —ditto — —ditto —
Flood Forecast and Warning Centre Lahore	Flood Forecast and Warning	Organization for Disaster prevention Broadcasting station	Broadcast, Telephone, Police radio Telephone, Police radio

Source; PMD

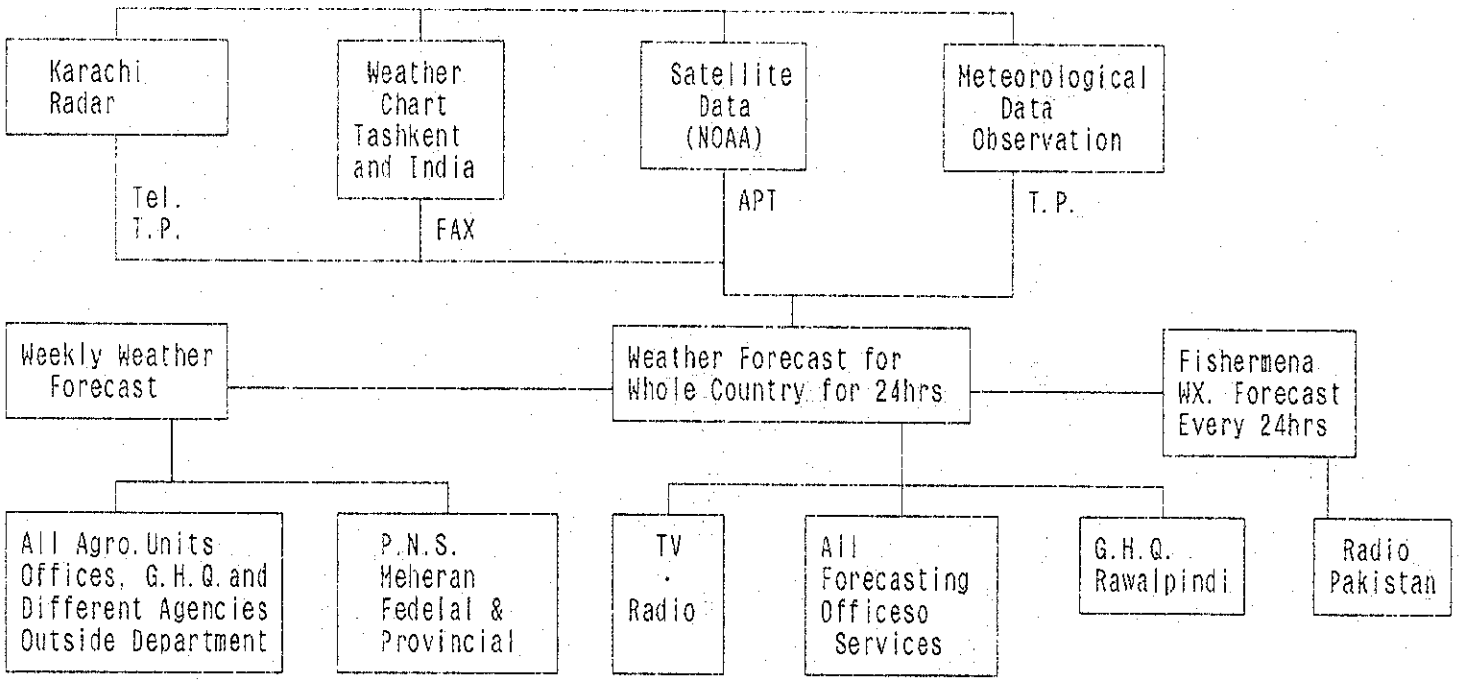


Fig.2-2-5(1) Dissemination of Meteorological Information of MAC Karachi

Tel. : Telephone
T.P. : Teleprinter

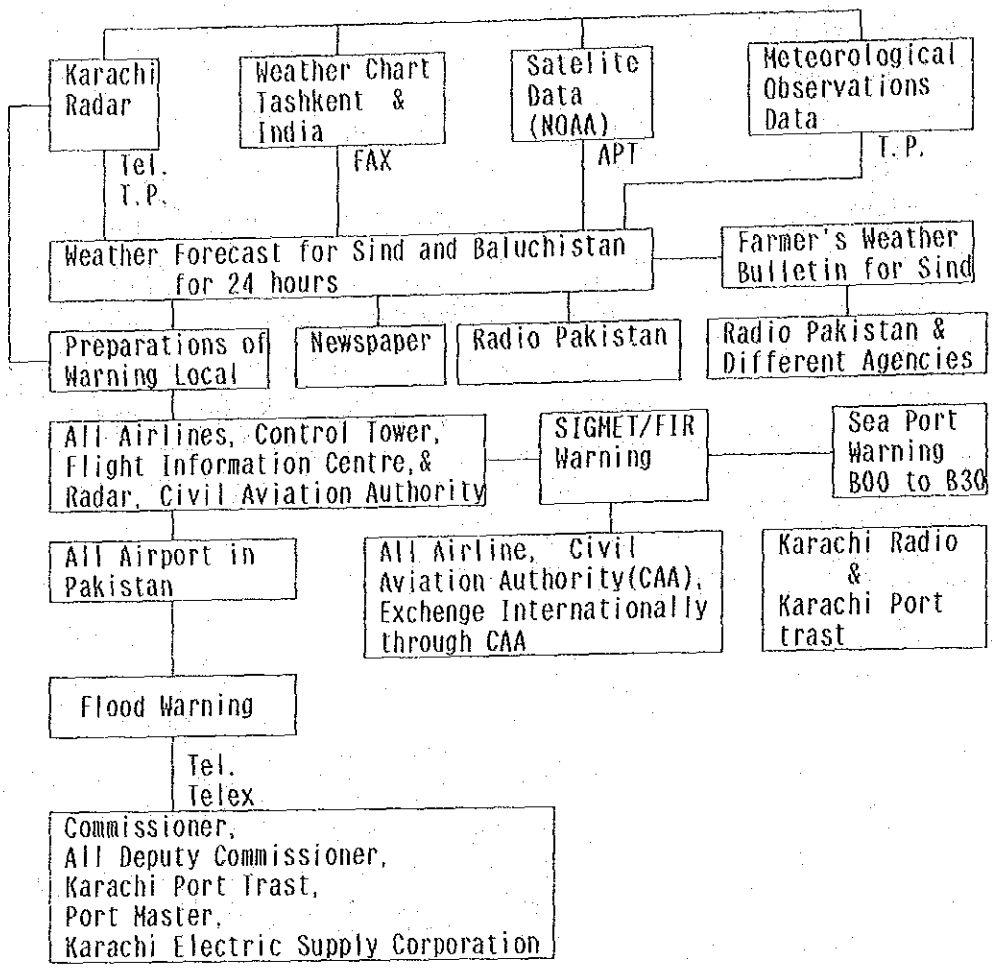


Fig. 2-2-5(2) Dissemination of meteorological Information of Meteorological Office at Karachi Airport

Tel. ;Telephone
T.P. ;Teleprinter

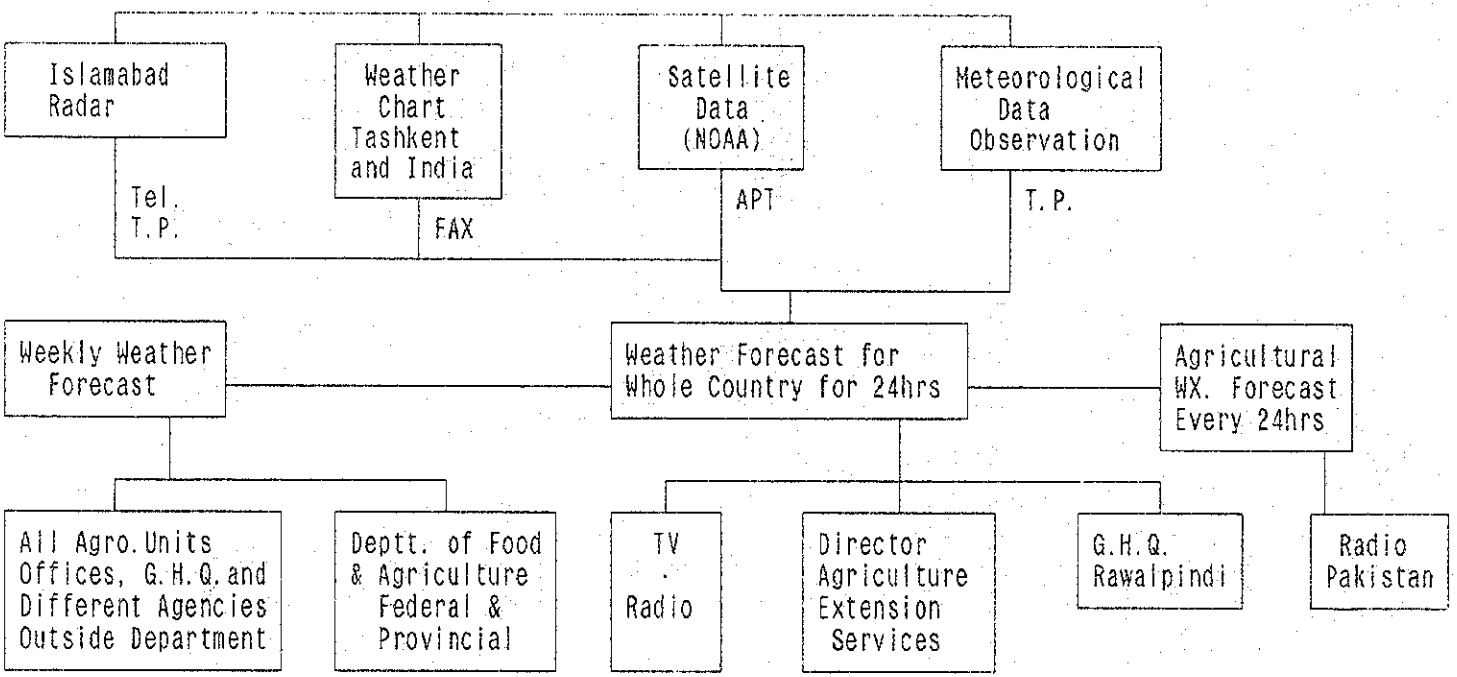


Fig. 2-2-5(3) Dissemination of Meteorological Information of MAC Islamabad

Tel. : Telephone
T.P. : Teleprinter

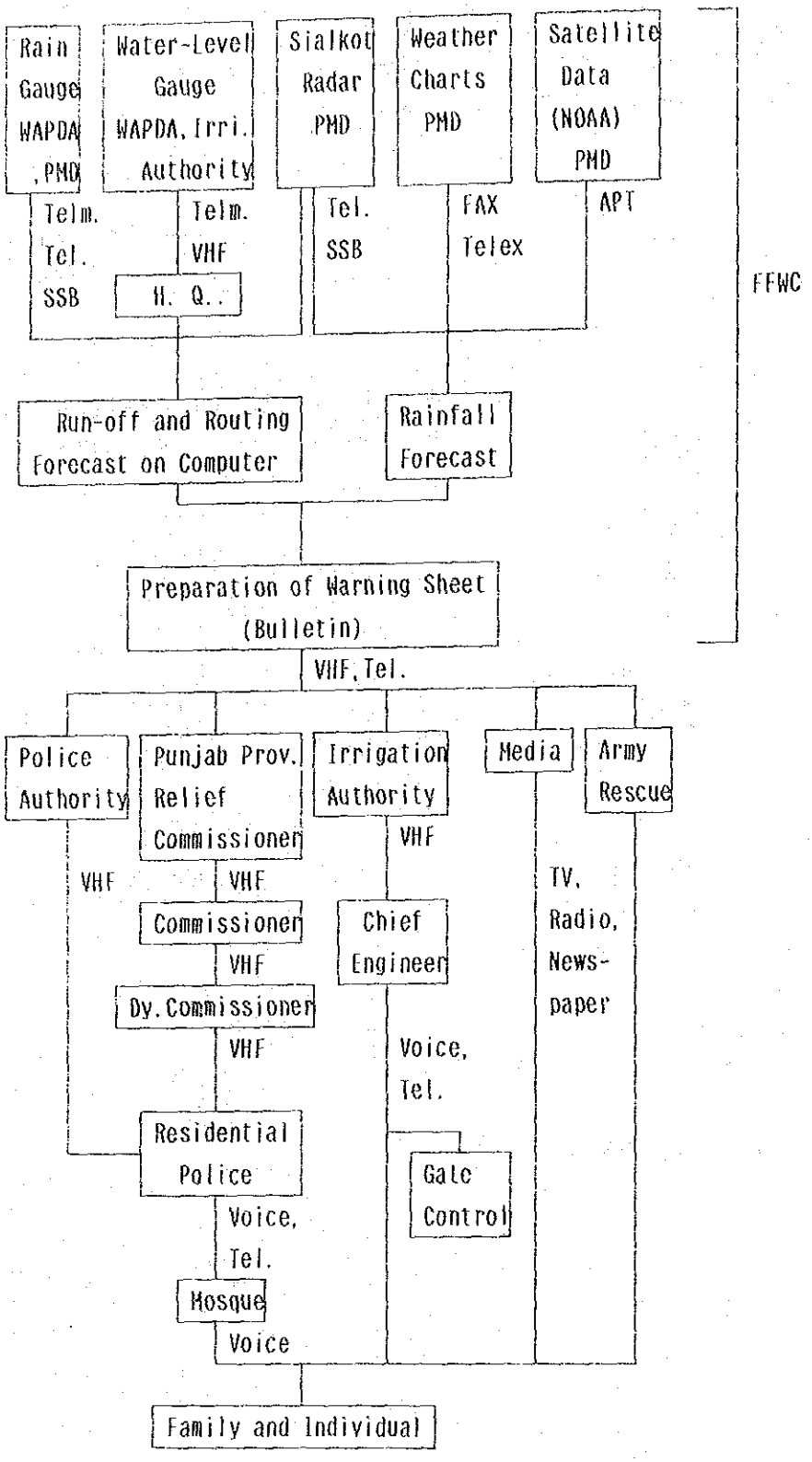


Fig.2-2-5(4) Dissemination of Meteorological Information of FFWC Lahore

WAPDA;Water and Power Development Authority
Tel. ;Telephone
Telm. ;Telemeter System

(5) Utilisation of Meteorological Information

The main users of meteorological information are shown in Table 2-2-7. Particularly for the prevention of disasters arising from flooding of rivers due to rain, the PMD has established a Flood Forecasting and Warning Centre at Lahore, to keep a 24 hour watch on the major rivers in Pakistan. In carrying out meteorological services for aviation, meteorological stations at airports (including minor local airports) provide meteorological information. As for meteorological service for agriculture, the Agrometeorological Centre at Islamabad distributes agrometeorological information to those engaged in the industry in the granary of the Punjab.

Thus, meteorological information is transmitted in order to contribute to the prevention of natural disasters, ensure safety of the transportation system and increase agricultural production.

(6) International Assistance

The PMD receives financial assistance from the USA including machines such as lathes for the meteorological workshop; the staff of the PMD is sent to study abroad under the UNDP as listed in Table 2-2-8. The PMD also receives technical and financial assistance from the WMO and the UNDP and there are at present two projects shown in Table 2-2-9, both of which are exempted from taxes by approval of the EAD.

The Flood Forecasting and Warning Centre at Lahore has also been established with the assistance of the UNDP.

Table 2-2-7 Users of Meteorological Information

Sphere	Users	Purpose
Disaster prevention	Police	Transmission of forecasts and warnings to people for refuge
	Irrigation Authority	Protection from floods
	Water Power Development Authority	Gate control of dams
	Relief Commissioner	Rescue activities from natural disasters
	Army Rescue	—ditto —
Transportation	Civil Aviation Authority	Securing safety of navigation
	Port Authority	—ditto —
Agriculture	Ministry of Food and Agriculture	Instruction to farmers for droughts or the harvesting season
	Government of Province	—ditto —.

Source; PMD

Table 2-2-8 Overseas Study under International Assistance

Year	Title	Place	Attendant	Period	Promoter
1984	Tropical Meteorology	U.S.A	1	2mon.	UNDP
	Meteorology	F.R.Germany	1	6	--ditto --
1985	Hydrology	U.S.A	1	3	--ditto --
1986	--ditto --	-ditto-	2	1,3	--ditto --
	Communications	India	2	4	--ditto --
1988	Agrometeorology	Kenya	3	6	--ditto --

Source; PMD

Table 2-2-9 Existing Project under International Assistance

Title	Period	Input	Promoter	Remarks
Establishment of Agrometeorological Centre in Pakistan	JUN1987 ~ DEC1990	US$467,000 Rs3,851,000	WMO/UNDP Pakistan Govt.	To study meteorological factors in relation to crop yield (at five sites)
Establishment of Computerrised Data Procesing Centre	JUN1987 ~ AUG1990	US$463,000 Rs1,861,000	WMO/UNDP Pakistan Govt.	To computerize all climate data at PMD Headquarter

Source; PMD

2-2-2 Problems in Meteorological Services

Meteorological services in Pakistan such as meteorological observations, collection and analyses of meteorological data and weather forecasts, are carried out by the PMD. In particular it has been playing an important role by issuing meteorological warnings for preventing disasters caused by the sudden occurrence of torrential heavy rain, due to meteorological phenomena such as Cb-clusters in the ITCZ (which are meteorological phenomena peculiar to Pakistan). Problems can be summarised as follows.

Meteorological instruments purchased with the aid of organizations such as the UNDP, have become aged and it is sometimes impossible to collect the required data. Especially in the observation of rainfall in wider areas, the weather surveillance radars in Pakistan are getting old and have lost their ability to detect such phenomena as a heavy rain. For this reason, the PMD makes use of cloud images received from NOAA several times a day, but is unable to carry out continuous, accurate observation of Cb-clusters which are accompanied by a heavy rain and gusts, creating a critical situation where it cannot ascertain the intensity, speed of movement as well as the growth and decay of these clusters.

The communication system is unsatisfactory and there are many problems in making reports to the central authorities, exchanging and collecting necessary data, because of unsatisfactory conditions of power supply and the low quality of public telephone lines.

Even if the PMD has technical expertise, it is often the case that the expertise cannot be put to effective use because of the lack of data and appropriate and speedy activities required to prevent natural disasters.

It is a matter of urgency in Pakistan, therefore, to improve the observational capability. Particularly for protecting the people from disasters resulting from heavy rain, it is necessary to establish a network of weather surveillance radars which contribute to the prevention and mitigation of natural disasters.