TABLE OF CONTENTS
(Cont'd)

Page No.

The Peaking Role of Thermal Plant 176
Thermal Fuel Supply 177
Additions to the Power System during the Fourth Plan Period (1970-75) 178
Utilization of Tarbela Potential and the EHV System 180
Kunhar and Raising Mangla for Power 180
Nuclear Generation 181
Use of Indigenous Coal for Electricity Generation 181
System Development After 1980 182
The Bank Group's Proposed Power Program 182
Distribution 183
Financial Requirements 183
Tariffs and Accounts 186

IX. ORGANIZATION AND IMPLEMENTATION 188

Institutional Framework of Water and Power Development 188
"Implementation Capacity" 192
Project Planning and Construction 193
Management and Operation of System and Projects 195
Promotion of Farm Inputs 199

X. PROPOSED PROGRAMS AND PAKISTAN'S PLANS..... 204

Agriculture and The Development Plans 205
Sectoral Growth Rates 209
Investment Requirements of Proposed Programs 210
Public Sector Financial Requirements 213
Private Investment 218
The Growth of Agricultural Employment 221

GLOSSARY 223

MAPS — Following Page No.

1. Indus Basin - Location of Canals and Links 16
2. Development Plan for the Indus River System 30
3. Program 1965 to 1975 Project Areas 118
4. Tarbela and Kalabagh 154
5. Main Power Stations and Principal Transmission Lines ... 186

TABLE OF CONTENTS
(Cont'd)

FIGURES	Following Page No.
1. Historical Usage of Available Surface Water in the Indus River Basin of West Pakistan	10
2. Mean Monthly Discharge: Indus, Jhelum and Chenab Rivers	40
3. Derived Average Yields for Reference Years	62
4. Cotton Yield Projections	68
5. Projected Usage of Available Surface Water in the Indus River Basin of West Pakistan	114
6. Revised IACA Program for Irrigation Development	110
7. Average Annual Yield and Efficiency of Storage Capacity on the Indus and Jhelum Rivers	124
8. IACA's Estimate of the Total Mean-Year Demand for Stored Water on the Jhelum and Indus Rivers	128
9. Tarbela Project - Water Course Requirements and Supplies by Sources	134
10. Comparison of Tarbela With or Without Systemwide Interconnection with Cheapest Alternative Programs	168
11. Projection of the Economic Value of Natural Gas at Well Head	170
12. The Absorption of Hydro-Energy	172
13. West Pakistan: Alternative Development Patterns with 4 1/2% Per Annum Growth in Agriculture	208

The following is a brief table of contents of the other volumes of the Study. A detailed table of contents precedes the text of each of the respective volumes.

TABLE OF CONTENTS
(Cont'd)

Page No.

VOLUME II: Program for the Development of Irrigation and Agriculture in West Pakistan

Chapters:

	Introduction	1
I.	Past and Present Performance of Agricultural Sector	3
II.	Agricultural Development Potential	25
III.	Development of Water Resources	73
IV.	Priority Development Projects	121
V.	Program for Irrigation Development	167
VI.	Agricultural Inputs and Supporting Services	208
VII.	Financial Requirements of the Development Program	249
VIII.	Comparison of Supply and Demand	262
IX.	Conclusions and Recommendations	291

Annexes:

2.1 Watercourse Studies
2.2 IACA Agricultural Zones and Estimated Production
2.3 Factors Affecting Cropping Intensities
3.1 IACA Estimates of Cost of Groundwater Mining
3.2 Sequential Analysis
3.3 Priorities for Groundwater Development
4.1 Report on Project Content of Water Development Program
6.1 IACA Estimates of Area Covered by Fertilizer Applications
6.2 Prospects for Supply, Distribution and Use of Fertilizer in West Pakistan
6.3 The Program for Artificial Insemination in West Pakistan as Proposed by IACA
7.1 Indicative Estimate of Public Investment Expenditures for Water Development during Third and Fourth Plan Periods
8.1 Definition of Developmental Activities Employed in GPV Projections
8.2 IACA Projections of Growth of Agricultural Production
8.3 Bank Group's Projections of Growth of Agricultural Production
8.4 Assumptions Used in Estimating Gross Value Added
8.5 IACA's Derivation of Elasticity-Coefficients of Demand for Agricultural Products
9.1 Terms of Reference, Memoranda to Consultants and Guidelines for the Study

TABLE OF CONTENTS
(Cont'd)

Page No.

VOLUME III: Program for Development of Surface Water Storage

Chapters:

I. Introduction 1
II. Surface Water Hydrology 3
III. Historical Use of Surface Water 12
IV. The IACA Approach 17
V. Identification of Dam Sites and Comparison of Projects . 29
VI. Factors in the Operation of Surface Water Storage Reservoirs 63
VII. The Sequence of Projects for Developing Surface Water Storage 81
VIII. Program for Investigations 95
IX. Financial Requirements and Cost Comparisons 105
X. Findings and Conclusions 112

Appendix: Terms of Reference and Guidelines for Dam Site Consultant

Annexes:

1. Tarbela Project
2. Kalabagh Project
3. Gariala Project
4. Skardu Project
5. Ambahar Project
6. Kunhar Project
7. Mangla/Raised Mangla Project
8. Chasma Project
9. Sehwan/Manchar and Chotiari Projects

VOLUME IV: Program for the Development of Power

Chapters:

I. Introduction 1
II. The Existing Situation 11
III. Past Growth 18
IV. Forecasts of Energy Requirements and Power Demands 29
V. The Power Supply Program 1966-1985 62
VI. Evaluation of Stone & Webster Program 82
VII. The Bank Group's Adjusted Power Program 106
VIII. The Distribution Problem 131
IX. Tariffs and Organization 137
X. The Financial Requirements of the Power Development Program 145
XI. Conclusions 152

TABLE OF CONTENTS
(Cont'd)

Annexes:

1. Load Forecasting
2. The Industrial Load Forecast
3. The Residential Load Forecast
4. The Overall Energy Situation -- Supply and Demand
5. The Price of Thermal Fuel
6. Hydroelectric Projects and Reservoir Operation
7. The Power Aspects of the Tarbela Project
8. The Development of Mangla's Power Potential
9. Energy Transmission: EHV Interconnection and Gas Pipelines
10. The Power System Simulation Model
11. Guidelines and Terms of Reference

ECONOMIC ANNEX

Part I. Programming Methods Used in The Study

Part II. A Linear Programming Analysis of Irrigation Development Potentialities in The Indus Basin

Part III. Proposed Programs and Economic Growth

PREFACE

In November 1963 the World Bank was assigned the task of organizing a comprehensive investigation of the water resources of West Pakistan. The chief purpose of the investigation, which became known as the Indus Special Study, was to develop a program for the optimum exploitation, for agricultural and power purposes, of the water resources that would be available to Pakistan after implementation of the Indus Waters Treaty of 1960. This report, in four volumes and their annexes, summarizes the conclusions that were reached in the course of the Study and outlines recommended development programs in the fields of agriculture, irrigation, surface water storage and electric power for the next ten to twenty years.

Dr. Pieter Lieftinck -- an Executive Director of the World Bank and former Finance Minister of The Netherlands -- accepted an invitation from the President of the Bank in January 1964, to head the Study. Several senior members of the Bank's technical staff were also assigned to assist Dr. Lieftinck in the organization and execution of the Study. This nucleus is referred to collectively in this report as the Bank Group.

To provide the various skills required for the complex and detailed field work involved in the Study, the Bank Group obtained the services of a number of consulting firms. For the irrigation and agriculture aspects of the Study, three firms of international repute agreed, at the request of the Bank, to assume joint responsibility and to form, for this purpose, an Irrigation and Agriculture Consultants Association (IACA); the member firms were Sir Alexander Gibb & Partners and Hunting Technical Services Limited, both of the U.K., and International Land Development Consultants (ILACO) of The Netherlands. To handle questions concerning dam sites, Chas. T. Main International, Inc., a U.S. firm, was retained. For power aspects of the Study, the Bank retained the services of Stone & Webster Overseas Consultants Inc., also from the United States. In addition to their role in IACA, Sir Alexander Gibb & Partners were responsible for overall coordination among the consultants.

The Agreement between the President of the World Bank and the President of Pakistan which instituted the Study divided it into two distinct phases. In the first phase attention was concentrated on a proposal to build a large multi-purpose dam and reservoir on the Indus at Tarbela. This project was widely considered to be of high priority but it was also a center of controversy, and so the Bank Group had agreed to provide an interim report on the Tarbela Project separately. Draft reports on this project were prepared by the consultants by mid-November 1964; in early December a Pakistan delegation visited Washington to discuss the consultants' findings; and in February 1965, Dr. Lieftinck submitted the Bank Group's report on the Tarbela Project to the President of the Bank who transmitted it to the Pakistan Government.

Immediately after completing their initial Tarbela studies the consultants moved into the second phase of the Study which was to result in comprehensive reports on the development of the water and power resources of West Pakistan. It was originally intended that discussion drafts of these comprehensive reports would be completed by early 1966, i.e. within two years of the Study's commencement. However, unavoidable delays were encountered and drafts of the reports were submitted at various times through 1966.

It was recognized from the beginning of the Study that the time element and the scope of the problems made imperative the closest possible cooperation between the Bank Group, the Pakistan authorities and the consultants. All phases of the work, including such matters as the consultants' terms of reference, were therefore discussed in detail with the Pakistan authorities. To ensure a regular exchange of views and to guide the investigations along the most fruitful lines, certain tripartite committees were established: a Coordinating Committee in the sphere of irrigation and agriculture, which met on eight occasions; a Dam Sites Committee which also met on eight occasions; and an informal Power Consultative Committee which met twice. Although these committees had only an advisory role, they served to ensure that Pakistan and the Bank Group remained in agreement with the consultants on the scope of the work and the detailed methodology. The consultants' terms of reference were supplemented from time to time through the provision of additional written guidelines and other instructions from the Bank Group.

The final reports of the consultants were submitted simultaneously to the Bank and to Pakistan between May and November, 1966. One report, in 23 volumes, prepared by IACA, covers the irrigation and agriculture aspects of the Study. Another report, in six volumes, prepared by Chas. T. Main, covers surface water storage. And the third report, in two volumes, prepared by Stone & Webster, covers the power aspects of the Study. In addition Sir Alexander Gibb & Partners, as coordinators among the consultants submitted two reports, one, entitled "Summaries of Reports by Consultants on Irrigation and Agriculture, Electric Power and Surface Water Storage", and a second, updating the information presented earlier on Tarbela. At the request of the Pakistan authorities and the Bank Group, Sir Alexander Gibb & Partners also undertook, with the assistance of Harza Engineering Company International, of Chicago, a sequential analysis of the power and irrigation programs recommended by the consultants. This analysis resulted in a special report entitled, "Sequential Analysis of a Programme for Irrigation and Power Development in West Pakistan".

These reports, together with their supporting annexes, provided a basis for discussion between the Bank Group and the Pakistan authorities in November 1966. Discussions were held with the Government of Pakistan in Rawalpindi and with the Government of West Pakistan and affiliated agencies in Lahore. Senior members of all the consultant firms which had shared in the Study participated in these meetings.

Following the discussions in Pakistan in November 1966, the Bank Group prepared drafts of this four-volume document, which represents the conclusion of the Study. The report is based on the work and findings of the consultants, on suggestions made by the Pakistan authorities and on studies carried out by the Bank Group itself. Preparation of the report had to be compressed into a short space of time. Drafts of the three main volumes -- on irrigation and agriculture, surface water storage, and power -- were sent to Pakistan in March 1967. A final round of discussions between the Bank Group and the Pakistan authorities was held in Lahore and Islamabad in mid-April on the basis of these drafts. Thus throughout the Study the Bank Group has had the benefit of frequent contact with the Pakistan authorities, who made many helpful suggestions and comments.

At the last round of meetings in Islamabad in April 1967, Dr. Lieftinck stated that the main purpose of the Bank Group's report was to assist the Pakistan authorities in achieving the maximum feasible rate of economic development. The Study had been concerned with collecting as much basic data as possible and analyzing it with a view to clarifying the potential for growth and identifying priorites, particularly for the Third and Fourth Plan periods. Dr. Lieftinck said he hoped that the report would serve as a useful background document to the Pakistan Government in taking decisions about future development and to the World Bank in assessing Pakistan's progress and plans. The report was in no sense intended to be binding, either for Pakistan or for the World Bank, which would, he felt sure, continue to reassess Pakistan's need for assistance on a year-to-year basis.

The report now presented consists of four volumes, of which this general volume is the first. Volume II presents in detail the recommended program for the development of irrigation and agriculture in West Pakistan. Volume III covers dam sites and puts forward a tentative schedule for their development. Volume IV discusses the prospective growth of demand for electric power and proposes a plan for the development of resources to meet that demand. Each of these three volumes has a number of supporting annexes, discussing individual projects or topics in greater detail. An Economic Annex to the Report presents some of the economic work undertaken in the course of the Study.

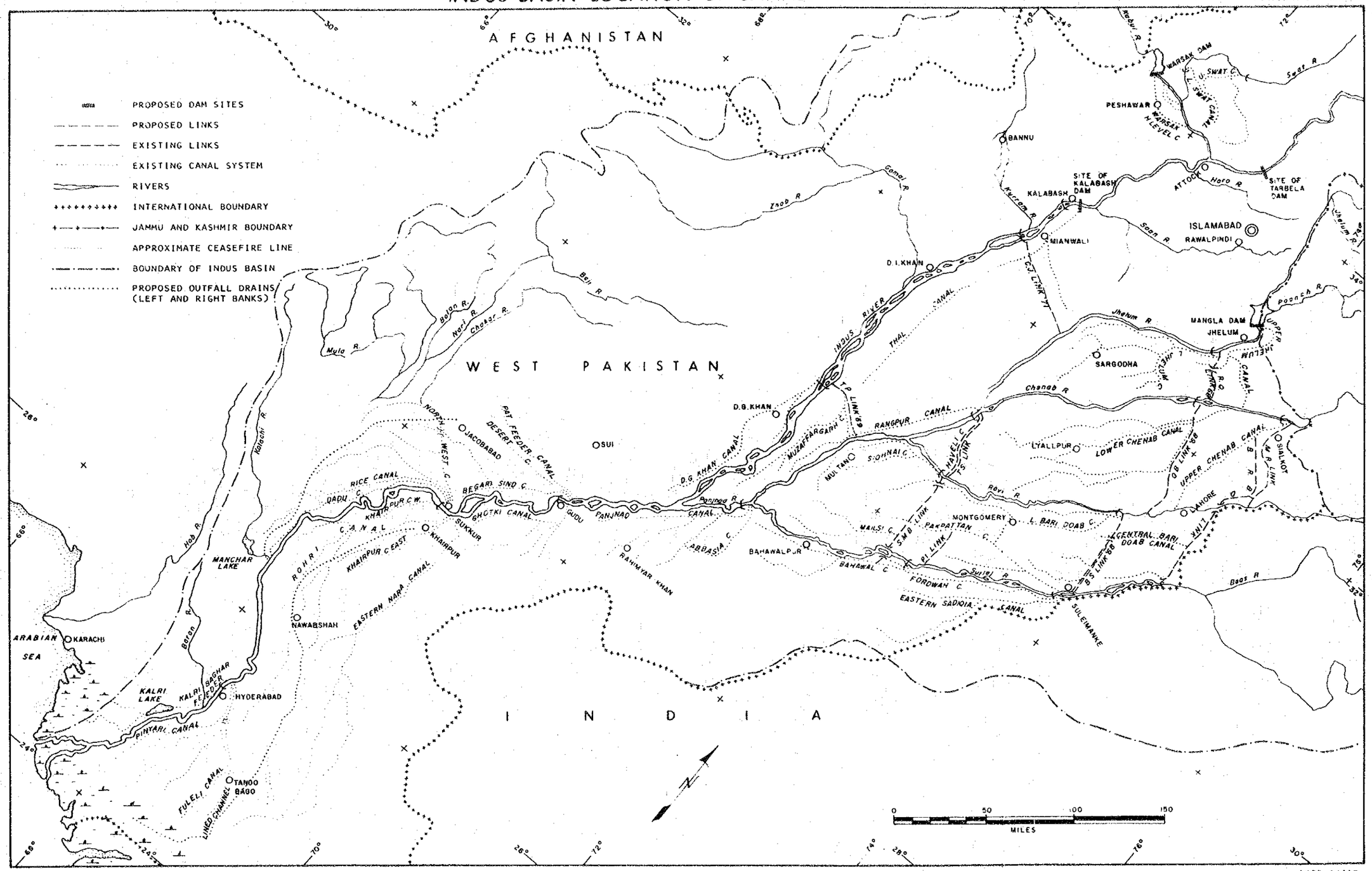
The Bank Group's work was carried out under the personal responsibility of Dr. Lieftinck. Under him the Bank Group consisted of A. Robert Sadove as Deputy Head of the Study; Thomas C. Creyke in charge of Irrigation and Agriculture; General Herbert D. Vogel in charge of Dam Site Engineering; and A. D. Spottswood in charge of Electric Power. From the beginning Willi A. Wapenhans was principal assistant to Mr. Creyke in supervising the work and preparing the reports on Irrigation and Agriculture. Christopher Willoughby assisted Mr. Sadove in the preparation of Volume I of the report and was primarily responsible for the background work on electric power; he drew heavily on the assistance of Dr. Henry D. Jacoby of the Harvard Water Program

who prepared a simulation model of the West Pakistan power system. Heinz Vergin assisted Mr. Sadove in the economic aspects of the Study and carried out the linear programming analysis of investment in irrigation and agriculture with direction from Professor Robert Dorfman of Harvard University. E. P. Delaney and K. B. Norris, on assignment in Washington from Sir Alexander Gibb & Partners, assisted considerably with engineering aspects of the Study. To assist in the preparation of Volume II an agricultural group was established, consisting of James B. Hendry, Harold Manning and Kyaw Myint, all of the Bank's staff. Added to this group for a period of several months at Bank headquarters were key members of the Irrigation and Agriculture consultant groups, including W. R. Rangeley, James Turtle and Roger White, of Sir Alexander Gibb & Partners, Thomas Jewitt of Hunting Technical Services, and Pieter Mulder of International Land Development Consultants. Other Bank staff members who made substantial contributions to the work of the Bank Group are: Firouz Afrouz, Stanley P. Johnson, Gary G. Luhman and Miss Huda S. Qubein. Thomas B. Winston assisted with editing at the later stages of the Study. Each of these staff members contributed many months to the Study, but the report could never have been completed without the valuable cooperation of many other people in the Bank, particularly those responsible for the task of accurately reproducing large volumes of written material.

STUDY OF THE WATER AND POWER RESOURCES OF WEST PAKISTAN
COMPREHENSIVE REPORT

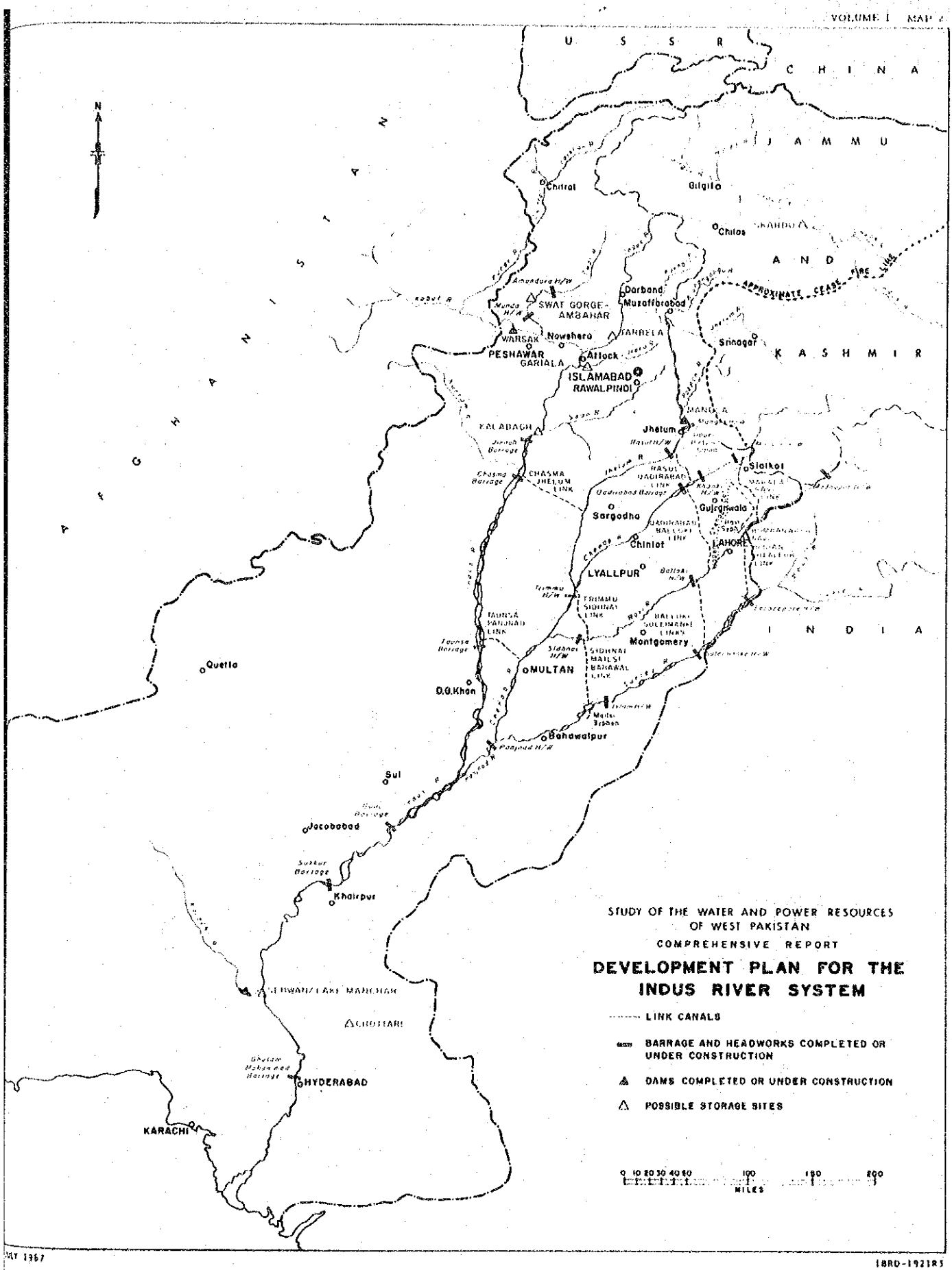
INDUS BASIN - LOCATION OF CANALS AND LINKS

VOLUME I MAP I



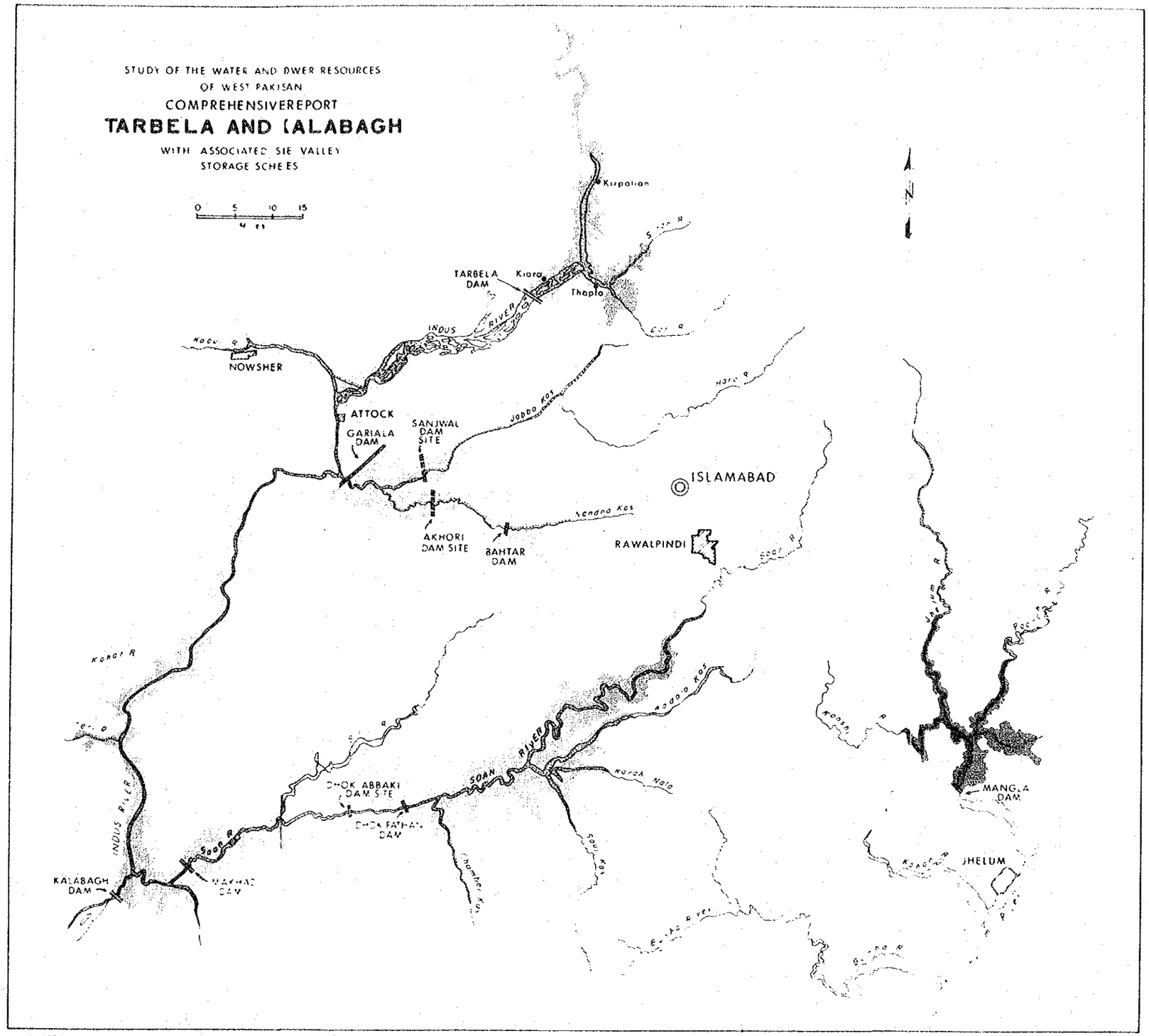
JULY 1967

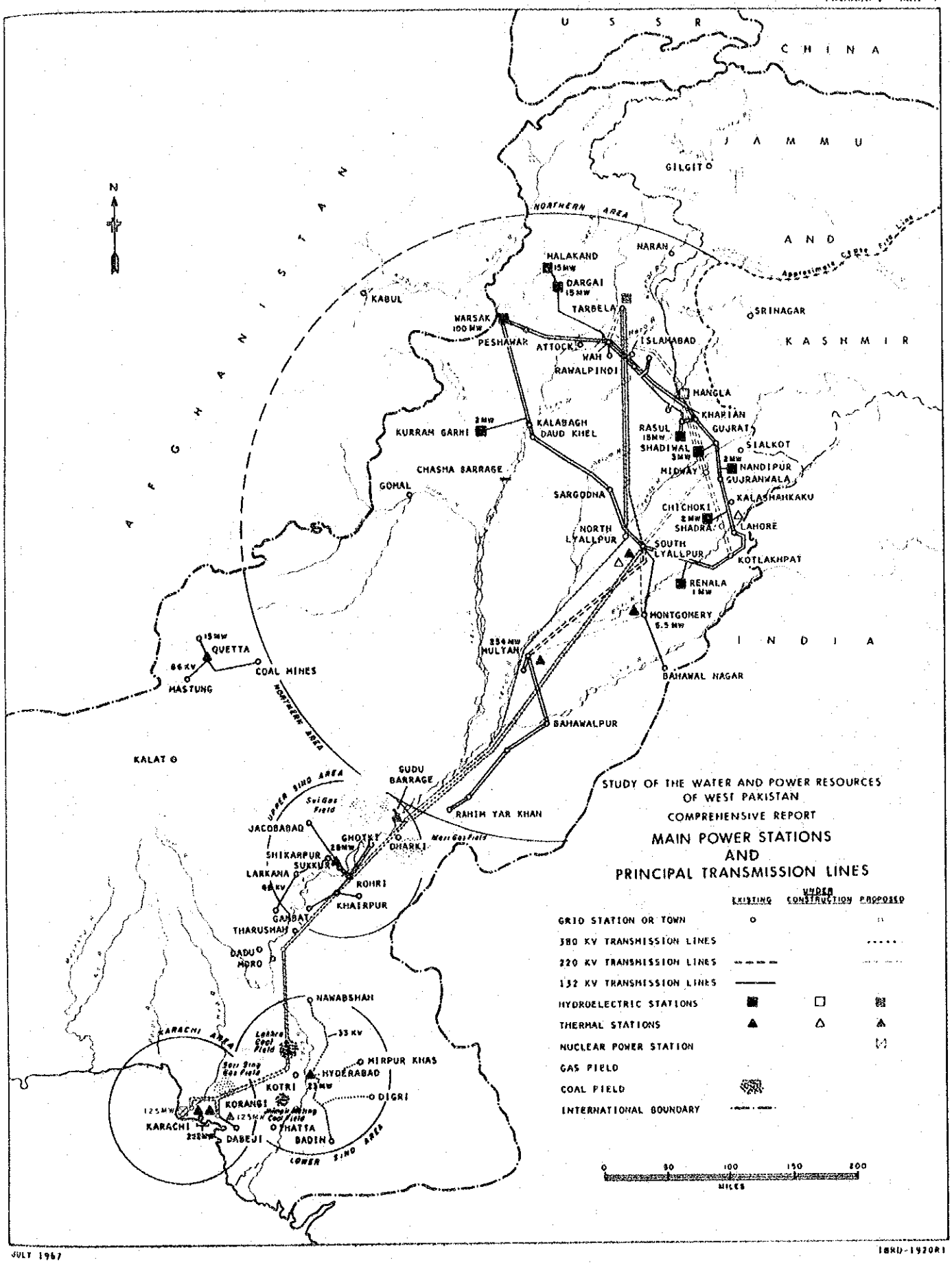
IBRD-1331R



JULY 1967

IBRD-1921R5


STUDY OF THE WATER AND PWER RESOURCES
OF WEST PAKISAN
COMPREHENSIVEREPORT
TARBELA AND KALABAGH
WITH ASSOCIATED SIE VALLEY
STORAGE SCHEES
0 5 10 15
N
Kirpalian
TARBELA DAM
Kiara
Thapla
INDUS RIVER
NOWSHER
ATTOCK
GARIALA DAM
SANJWAL DAM SITE
ISLAMABAD
AKHORI DAM SITE
BAHTAR DAM
RAWALPINDI
KALABAGH DAM
DHOK ABBAKI DAM SITE
DHOK PATHAN DAM
SOAN RIVER
MANGLA DAM
JHELUM
JULY 1967



JULY 1967

IBRD-1920R1

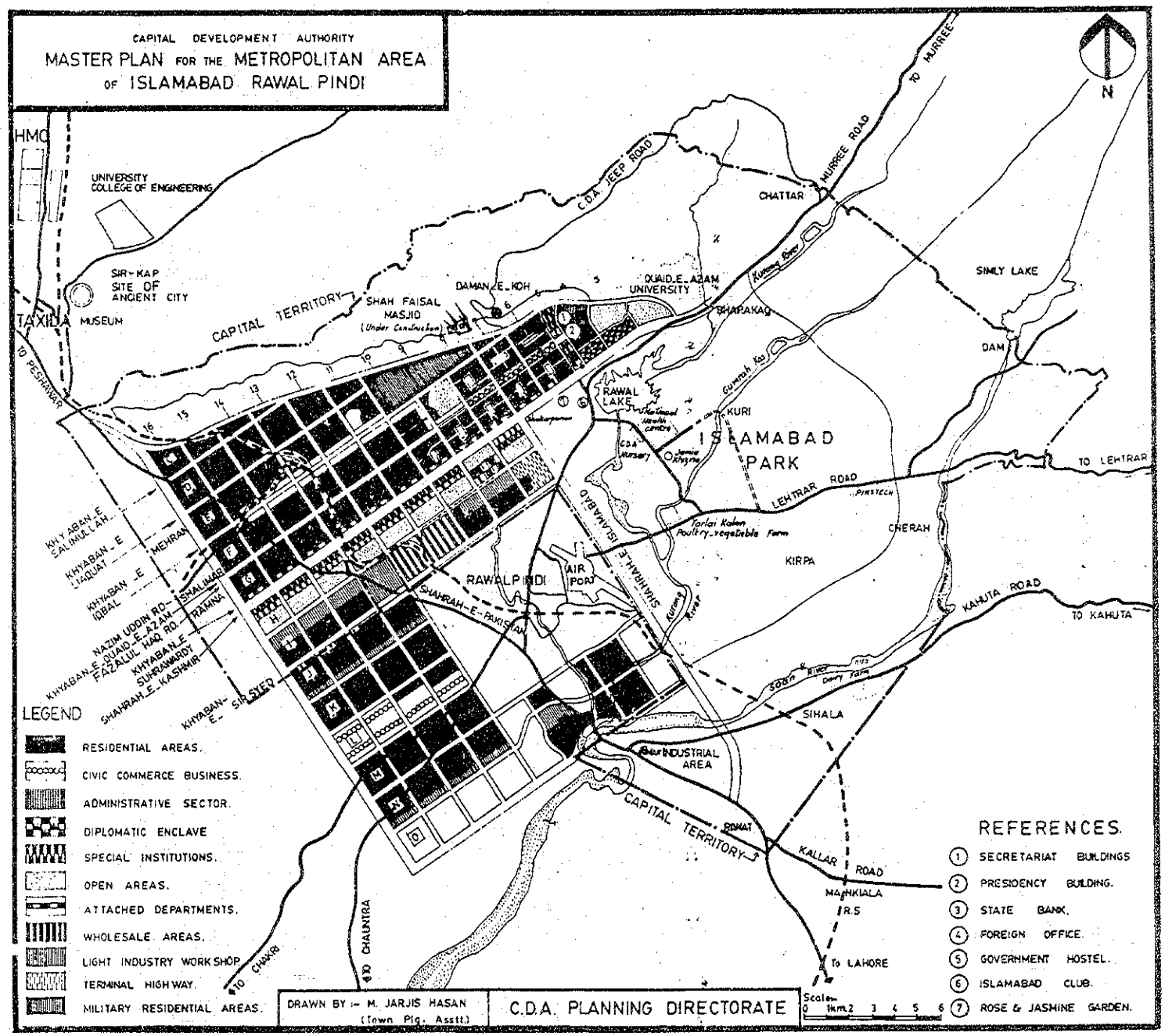
THE MASTER PLAN

The Master Plan for the Metropolitan area of Islamabad and Rawalpindi has been prepared on the principle of "Dynapolis" which means a dynamic city where the city centre grows in direct proportion to the growth of residential functions.

Four highways with a right of way of 365.8 metres from the framework within which a grid of squares, each measuring 3.1 square kilometres has been planned. Two of these highways namely Shahrah-e-Islamabad and Shahrah-e-Kashmir link Islamabad with the rest of the country through Shahrah-e-Pakistan, both with Lahore, Peshawar and Kashmir. Master Plan covers an area of 1165.50 square kilometres. The area enclosed by the Master Plan can be divided into four parts.

i)	Rawalpindi	259.00	Square kilometres
ii)	Islamabad proper including Institutional & Industrial area	220.15	Square kilometres
iii)	Islamabad Park (Semi-Urban)	220.15	Square kilometres
iv)	Islamabad Rural Area	466.20	Square kilometres
	Total:	1165.50	Square kilometres
v)	Region (Specified area of Islamabad)	3626.00	Square Kilometres

The area mentioned at ii, iii, and iv above has been named as Federal Capital area and has been declared as Islamabad district w.e.f. 6th January, 1981.


CAPITAL DEVELOPMENT AUTHORITY
MASTER PLAN FOR THE METROPOLITAN AREA OF ISLAMABAD RAWAL PINDI
N
HMC
UNIVERSITY COLLEGE OF ENGINEERING
SIR-KAP SITE OF ANCIENT CITY
TAXILA MUSEUM
TO PESHAWAR
CAPITAL TERRITORY
SHAH FAISAL MASJID (Under Construction)
DAMAN-E-KOH
C.D.A. JEEP ROAD
QUAID-E-AZAM UNIVERSITY
CHATTAR
MURREE ROAD
TO MURREE
SHAPAKAG
SIMLY LAKE
DAM
RAWAL LAKE
KURI
ISLAMABAD PARK
LEHTRAR ROAD
TO LEHTRAR
CHERAH
KIRPA
KAHUTA ROAD
TO KAHUTA
RAWALPINDI
AIR PORT
ISLAMABAD
SHAHRAH-E-PAKISTAN
SHAHRAH-E-FAISAL
KHYABAN-E-SALIMULLAH
KHYABAN-E-LIAQUAT
KHYABAN-E-IQBAL
MEHRAN
SHALIMAR
RAMNA
NAZIM UDDIN RD.
KHYABAN-E-QUAID-E-AZAM
FAZALUL HAQ RD.
KHYABAN-E-SUHRAWARDY
SHAHRAH-E-KASHMIR
KHYABAN-E-SIR SYED
TO CHAKRI
TO CHALINTRA
SOAN RIVER
SIHALA
INDUSTRIAL AREA
CAPITAL TERRITORY
KALLAR ROAD
MANKIALA
R.S
To LAHORE
LEGEND
RESIDENTIAL AREAS.
CIVIC COMMERCE BUSINESS.
ADMINISTRATIVE SECTOR.
DIPLOMATIC ENCLAVE
SPECIAL INSTITUTIONS.
OPEN AREAS.
ATTACHED DEPARTMENTS.
WHOLESALE AREAS.
LIGHT INDUSTRY WORK SHOP.
TERMINAL HIGH WAY.
MILITARY RESIDENTIAL AREAS.
DRAWN BY :- M. JARJIS HASAN (Town Plg. Asstt.)
C.D.A. PLANNING DIRECTORATE
Scale:- 0 1km 2 3 4 5 6
REFERENCES.
1 SECRETARIAT BUILDINGS
2 PRESIDENCY BUILDING.
3 STATE BANK.
4 FOREIGN OFFICE.
5 GOVERNMENT HOSTEL.
6 ISLAMABAD CLUB.
7 ROSE & JASMINE GARDEN.

POLICY PAPER FOR CONSIDERATION OF THE BOARD

Subject: OUTLINE PERSPECTIVE DEVELOPMENT PROGRAMME 1985 - 1998

While the work on the review of the Master Plan shall begin shortly and may take some time to complete and generate a final short term as well as long term programme for the development of Islamabad it is important that an interim frame of reference is prepared to provide a direction to the city development in the meanwhile.

2. Table-1 below shows the population projection during the forth coming Five Year Plan.

Table-1 POPULATION PROJECTIONS

Years		Population(000)
1983		205
	6th Plan	
1988		318
	7th Plan	
1993		460
	8th Plan	
1998		609

Planning Wing CDA

Contd:- 2.

3. To cater for the housing needs of the population increase the following bench marks are worked out:-

Table-2. DEVELOPMENT TARGETS

YEAR	HOUSING UNIT	COMMERCIAL ESTABLISHMENT	INDUSTRIAL ESTABLISHMENT
1983	35,000	2,000	205
1988	53,000	3,200	350
1993	83,000	4,600	470
1998	121,000	6,000	700

Planning Wing, CDA.

Contd:- 3.

4. The targets so fixed necessiates development of following sectors in the urban area:

Table-3 SCHEDULE OF URBAN DEVELOPMENT PLAN- 1983-1997

6th Five Year Plan (1983) - 1988

a) Residential Sectors:

E-9 E-10

F-11 G-11

D-11

b) Industrial Sectors

I-10, I-11

c) Institutional Sectors

H-11

7th Five Year Plan 1988-1993

a) Residential Sectors

G-12, F-12

D-12, E-12

G-13, D-13

b) Industrial Sectors

I-12 I-14

c) Institutional Sectors.

H-10, H-12, H-13, F-9

8th Five Year Plan 1993-1998

a) Residential Sectors:

E-13 F-13

G-14 F-14

E-14 D-14

b) Industrial Sectors

I-15.

c) Institutional Sector.

H-14.

Contd:- 4.

4. So far land is acquired till 11th series and urban development targets shall lag behind the schedule if forward planning is not made for land acquisition. This is worked out in Table-4; below:-

Table-4 SCHEDULE OF LAND ACQUISITION

YEAR	S E C T O R S
1986	D-12, E-12, H-12.
1987	F-12, G-12, H-13.
1988	D-13, E-13, F-13.
1989	G-13, D-14, H-14.
1990	E-14, F-14, G-14.
1991	D-15, E-15, H-15.
1992	F-15, G-15, D-16.
1993	E-16, F-16, G-16. H-16.

Planning Wing, CDA.

5. The interim plan is submitted for approval of the Board so that it is circulated for forward planning at all levels.

COUNTER MEASURES FOR LEAKAGES AND WASTAGE :

Short Terms Measures :

The conduction mains and delivery mains are being given occassional shut downs to repair the lines in order to avoid losses. Recently a shut down from 5th to 7th Feb: 1986 was given to 1st 36" dia PRCC line from Simly Filtration Plant to 5 M.G Service Reservoir at Islamabad. Similarly, 21" dia PRCC rising main & from Central Sump of National Park Area to 5 - 7 M.G Service Reservoirs was shut down during January, 1986 and leakages were repaired. 24" dia PRCC delivery main from 5 MG Service Reservoir to Sectors E-7,E-8,F-7 and F-8 is being repaired during day time while the supplies are being made during nights.

2- The repairs requiring shut downs are carried out generally during winter when the water demand is minimum. However, repairs to the distribution net-work are carried out continuously round the year to keep the losses to the minimum.

3- There are permanent repairs gangs employed on the job. The efforts are intensified during winter when shut downs can be arranged without causing much inconvience to the consumers due to low demand during this time of the year.

4- In order to avoid wastage at consumers end, new connections are being provided only with installation of water meters. However, most of the old connections are either without water meters or the meters have gone defective. Arrangements are being made to replace/install water meters on such connections under long term measures. Where water meters are found repairable, the same are being repaired in a small workshop maintained by Water Meter Division of CDA.

Long Terms Measures :

Where lines have not been found to be repairable, proposals have been made to replace them. PC-I for the same is now under consideration ~~to~~ with the Planning Division, of the Government of Pakistan. The PC-I includes provision of water meters on the old connections which are either without meters or the meters have gone defective.

2- While approval of the PC-I is awaited, CDA has undertaken some of the immediate works financing the same out of its own resources. Substantial improvement is expected before the year 1986 is out.

3- The water meter repair and testing facilities available in the water meter repair shop are not adequate. In order to establish a proper repair shop, request has been made to obtain services of experts from Japan to study the existing conditions and to suggest details for establishment of a full scale repair and testing workshop. A copy of the request is attached herewith.

15/2/86

(A. Q. Homani)
Director Water Supply

資料19－1

WEST PAKISTAN

WATER AND POWER DEVELOPMENT AUTHORITY

SEDIMENT APPRAISAL
OF
WEST PAKISTAN RIVERS
1960—1966

SURFACE WATER HYDROLOGY PROJECT

LAHORE—FEB., 1969

資料19－2

PAKISTAN

WATER AND POWER DEVELOPMENT AUTHORITY
HYDROLOGY & SYSTEM ANALYSIS ORGANIZATION

SEDIMENT APPRAISAL OF PAKISTAN RIVERS 1960 – 1975

SURFACE WATER HYDROLOGY PROJECT (SWHP)
WAPDA, LAHORE
PAKISTAN

MAY – 1980

P R E F A C E

This report is published by Surface Water Hydrology project and has been prepared by Technical Co-ordination Section under the guidance of Syed Amjad Hussain, Project Director, Surface Water Hydrology Project WAPDA. The sediment observation stations were operated by the Surface Water Hydrology Project and field samples were collected and analysed by personnel of the Project.

The first publication on sediment appraisal was printed in Jan'1967. Subsequently three more publications were issued including data of additional stations for specified periods during Feb'1969, (1960-66), September 1970 (1960-68) and Jan'1975 (1960-1972). This publication incorporates sediment records of all additional stations which came under operation of Surface Water Hydrology Project during the period 1972-75, and also updates data of all station of the 1975 issue.

The first publication on sediment appraisal gave detailed descriptions about sediment characteristics of the sub-basins; field techniques and equipments, laboratory analysis and office procedure which is not included in this report.

Suspended sediment transport computations were made using sediment rating, flow duration curves method. In the present publication, it was considered worth while to omit exhibits for individual stations; firstly because the agencies using data are concerned with the final results only and secondly the procedures used for the computations of suspended sediment transport are well established.

TABLE OF CONTENTS

Section		Page
	DEFINITION OF TERMS AND ABBREVIATION	
I.	INTRODUCTION	
	Purpose and scope of report	1
	Necessity of sediment study	2
	Pre - WAPDA Activities	3
	WAPDA Activities	4
	Authority and Personnel	6
	SEDIMENT TRANSPORT CHARACTERISTICS OF INDIVIDUAL STREAM:	
	(Arranged in downstream orders)	
1.	Shyok River at Yugo	7
2.	Indus River near Kachura	9
3.	Gilgit River at Gilgit	11
4.	Hunza River at Dainyor Bridge	13
5.	Gilgit River at Alam Bridge	15
6.	Indus River at Partab Bridge	17
7.	Astore River at Doyian	19
8.	Indus River at Darasin	21
9.	Indus River at Besham Qila	23
10.	Gorband River near Karora	25
11.	Brandu River near Daggar	27
12.	Indus River near Darband	29

		Page
13.	Siran River near Phulra	31
14.	Siran River at Thapla	33
15.	Chitral River at Chitral	35
16.	Kabul River at Warsak	37
17.	Swat River near Kalam	39
18.	Swat River at Chakdara	41
19.	Bara River at Jhansi Post	43
20.	Kabul River at Nowshera	45
21.	Kalpani River near Risalpur	47
22.	Indus River at Mendori (Attock)	49
23.	Haro River near Khanpur	51
24.	Chablat Kas near Hasan Abdal	53
25.	Haro River at Sanjwal	55
26.	Haro River at Gariala	57
27.	Kohat Toi at Jarma Weir	59
28.	Soan River at Chirah	61
29.	Ling River near Kahuta	63
30.	Soan River near Rawalpindi.	65
31.	Wadala Kas at Panin	67
32.	Sil River near Chahan	69
33.	Soan River at Dhok Pathan	71
34.	Ghambir Nallah at Danda Shah Bilawal	73
35.	Indus River at Mussan	75
36.	Kurram River at Thal	77
37.	Tochi River at Tangi Post	79
38.	Tank Zam near Jandola	81
39.	Gomal River at Khajuri Kach	83
40.	Gomal River at Kot Murtaza	85

41.	Chenab River at Alexandria Bridge	87
42.	Jhelum River at Chanari	8[illegible]
43.	Kishanganga at Muzaffarabad	91
44.	Kunhar River at Garan	93
45.	Kunhar River at Khanian	95
46.	Kunhar River near Rathi Habib Ullah	97
47.	Jhelum River at Kohala	99
48.	Jhelum River at Karot	101
49.	Bishan Daur Kas near Missa	103
50.	Kanshi River near Palote	105
51.	Kanshi River near Jhangi	107
52.	Poonch River near Kotli	109
53.	Jhelum River upstream from Mangla Headworks	111
54.	Khast River at Chapuer Rift	113
55.	Beji River at Guatti Bridge	115
56.	Nari River near Sibi (at Nari Bank)	117
57.	Chakkar River at Talli Tangi	119
58.	Bolan River at [illegible] Bridge	121
59.	Mula River at Hailang	123
60.	Lehri River at Gork Tangi	125
61.	Indus River near Sehwan	127
62.	Gaj Nai near Jubble	129
63.	Hub River at Bund Murad Khan	131
64.	Windor Dhora near Goth Aman	133
65.	Kud River near Mai Gondrani	135
66.	Purali River near Sinchi Bent	137
67.	Dasht River near Mirani Dam	139

LIST OF THE CLOSED STATIONS

Sr.No.	Station	Closed Year	Page
1.	Gilgit River At Gilgit	1973	11
2.	Indus River near Darband	1974	29
3.	Siran River at Thapla	1974	33
4.	Kabul River at Warsak	1971	37
5.	Kalpani River near Risalpur	1969	47
6.	Chablat Kas near Hassan Abdal	1965	53
7.	Kohat Toi at Jarma Weir	1968	59
8.	Ling River near Kahuta	1971	63
9.	Tochi River at Tangi Post	1969	79
10.	Tank Zam near Jandola	1968	81
11.	Gomal River at Khajuri Kach	1968	83
12.	Chenab River at Alexandria Bridge	1968	87
13.	Kunhar River at Khanian	1969	95
14.	Bishan Daur Kas near Misga	1972	103
15.	Kan[illegible] River near Jhangi	1967	107
16.	Haji River at Chatti Bridge	1967	115
17.	Nari River near Sibi	1971	117
18.	Chakkar River at Talli Tangi	1968	119
19.	Bolan River at Kundlani Bridge	1971	121
20.	Mula River at Naulang	1966	123
21.	Lehri River at [illegible] Tangi	1966	125
22.	Gaj Nai near Jubbla	1971	129

DEFINITION OF TERMS AND ABBREVIATIONS

Acre foot or Acre foot	:	Abbreviated as A-ft; quantity of water required to cover an acre of area to a depth of one foot.
Bed load	:	Sediment quantity which moves in almost continuous contact with the stream bed (i.e. within bed layer).
Bed Layer	:	A flow layer two grain diameter thick, immediately above the bed. The thickness of bed layer varies with the particle size.
Bed material	:	The sediment mixture which composes the moving bed.
Bed material load	:	That part of the sediment load which consists of grain sizes represented in the bed and equals the sediment transport capability of the flow.
Bed load equation	:	General relationships between bed-load rate, flow condition and composition of bed material.
Catchment area	:	The total drainage area upstream from a river station.
Check dam	:	A small structure of rock, mud, or concrete, etc; constructed to check erosion and catch sediment.
Cusec	:	Rate of flow of a stream whose cross sectional area is one square foot and whose velocity is one foot per second.
Drainage area	:	The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide i.e. the rim of a drainage basin.

(v)

Drainage basin	:	A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.
Erodibility	:	Rate of erosion of the soil cover in a drainage basin; it is expressed in acre-feet square mile per year or tons per square mile per year.
Fall velocity	:	The average rate of fall that a particle would finally attain if falling alone in quiescent distilled water of infinite extent and at a known temperature. The standard fall velocity is the fall velocity at 24°C.
Fall diameter	:	The diameter of a sphere that has a specific gravity of 2.65 and has the same standard fall velocity as the particle.
Ft.	:	Foot or feet.
Flow-duration curve	:	Accumulative frequency curve that shows the percent of time that specified discharges are equalled or exceeded.
I.R.I.	:	Irrigation Research Institute.
In.	:	Inches.
Kas	:	A small river generally but not always perennial in flow.
Measured load	:	Suspended sediment load which can be measured in a vertical of river section with the available sediment samplers.
M.S.L.	:	Mean sea level.
maf.	:	Million acre-feet.
Nallah	:	Intermittent stream.
Potwar	:	A deeply eroded plateau comprising a part of the Punjab uplands in north-central West Pakistan.

ppm	:	Parts per million (by weight).
%	:	Percent.
P and I	:	Planning and Investigation Directorate, WAPDA.
Range lands	:	This refers to large, naturally vegetated, mostly unfenced lands of low rainfall areas that are grazed by domestic livestock and game animals.
Reforestation	:	To re-plant or to improve forested areas.
Sediment	:	The fragmental material transported by, suspended in or deposited by water or air or accumulated in beds by other natural agents without regard to the size of the individual particle or group of particles; classes of sediment having sizes above 0.0625 mm, between 0.0625 mm and 0.0055 mm and smaller than 0.0055 mm in diameter are termed as sand, silt and clay respectively.
Sediment concentration	:	Ratio of the weight of the sediment in water sediment mexture to the total weight of the mixture. It is ordinarily expressed in percent for high values and in ppm by weight for low values.
Sediment discharge	:	Dry weight of sediment transported at a particular section of a stream per unit of time. It is generally stated in tons/day which is the weight of sediment in tons transported at a particular section of the stream in 24 hours. The ton is a short ton of 2000 lbs; throughout this report.
Sediment rating curve	:	This is a correlation curve between water discharge and suspended sediment loads in tons per day.
Sediment hydrograph	:	Diagram showing the variation of sediment concentration or sediment discharge with respect to time.

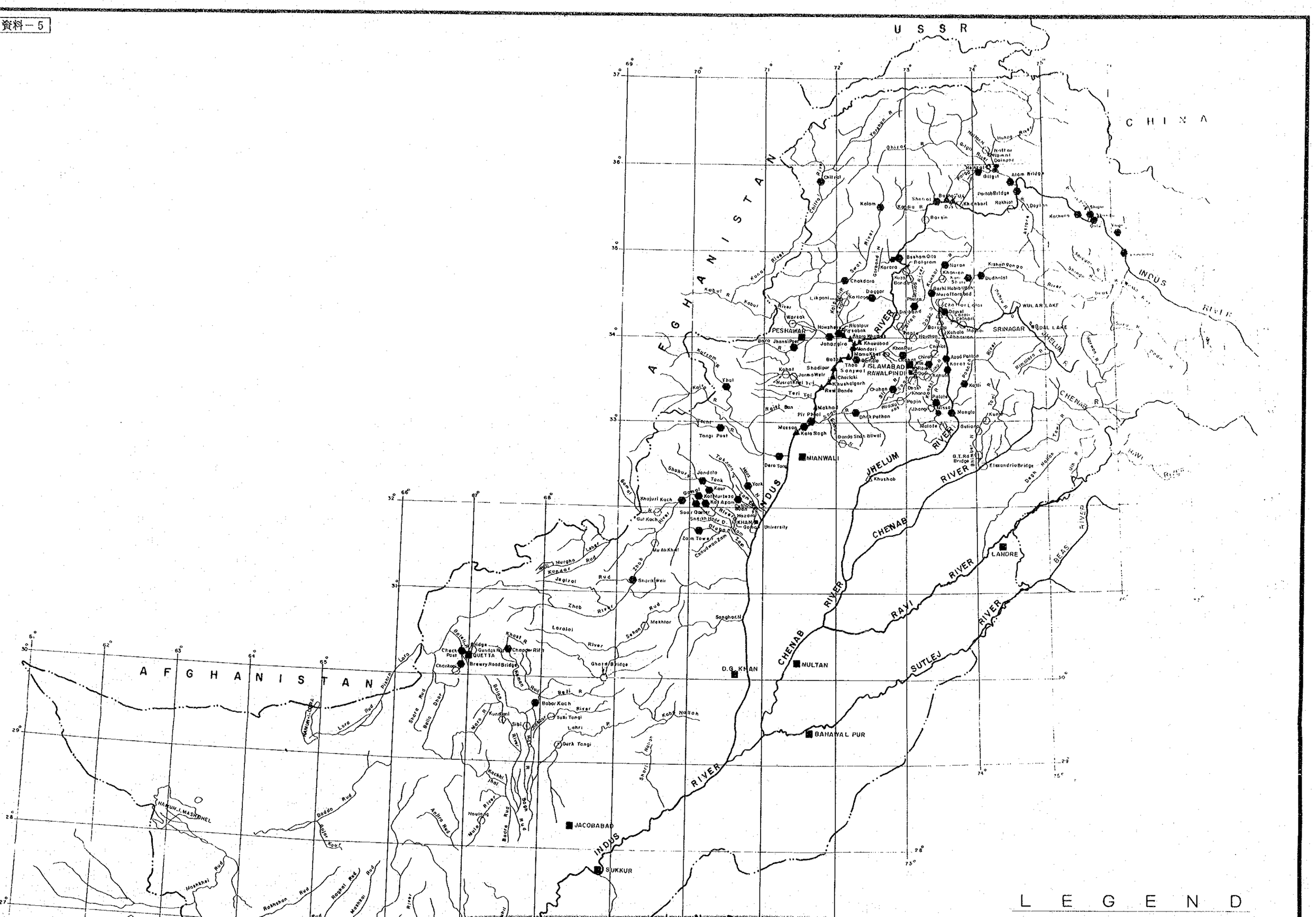
Sediment yield	:	Total quantity of sediment accumulated in a specified period of time. Normally it is expressed by weight or by volume per year.
Sediment load	:	Same as sediment discharge.
Suspended sediment	:	The sediment which remains in suspension in flowing water for a considerable period of time without contact with the stream bed.
Suspended load	:	Rate of sediment particles continuously supported by water and moving outside the bed layer.
Saltation load	:	Sediment which moves in a series of low flow ending at the stream bed.
Sq.mi.	:	Square miles.
Short ton.	:	Quantity of water or sediment weighing 2,000 pounds.
S.W.C.	:	Surface Water Circle.
S.W.H.	:	Surface Water Hydrology Project.
Torrents	:	Rapidly growing streams, particularly the flood flow of small or intermittent streams.
Total sediment load	:	This equals: Bed load + Suspended load or bed material load + wash load or measured load + unmeasured load.
Time integration	:	Method of sampling to secure an increment of sample from every portion of a vertical line in the river measuring section.
WAPDA	:	Water and Power Development Authority.
WASID	:	Water and Soils Investigation Division, WAPDA (defunct).

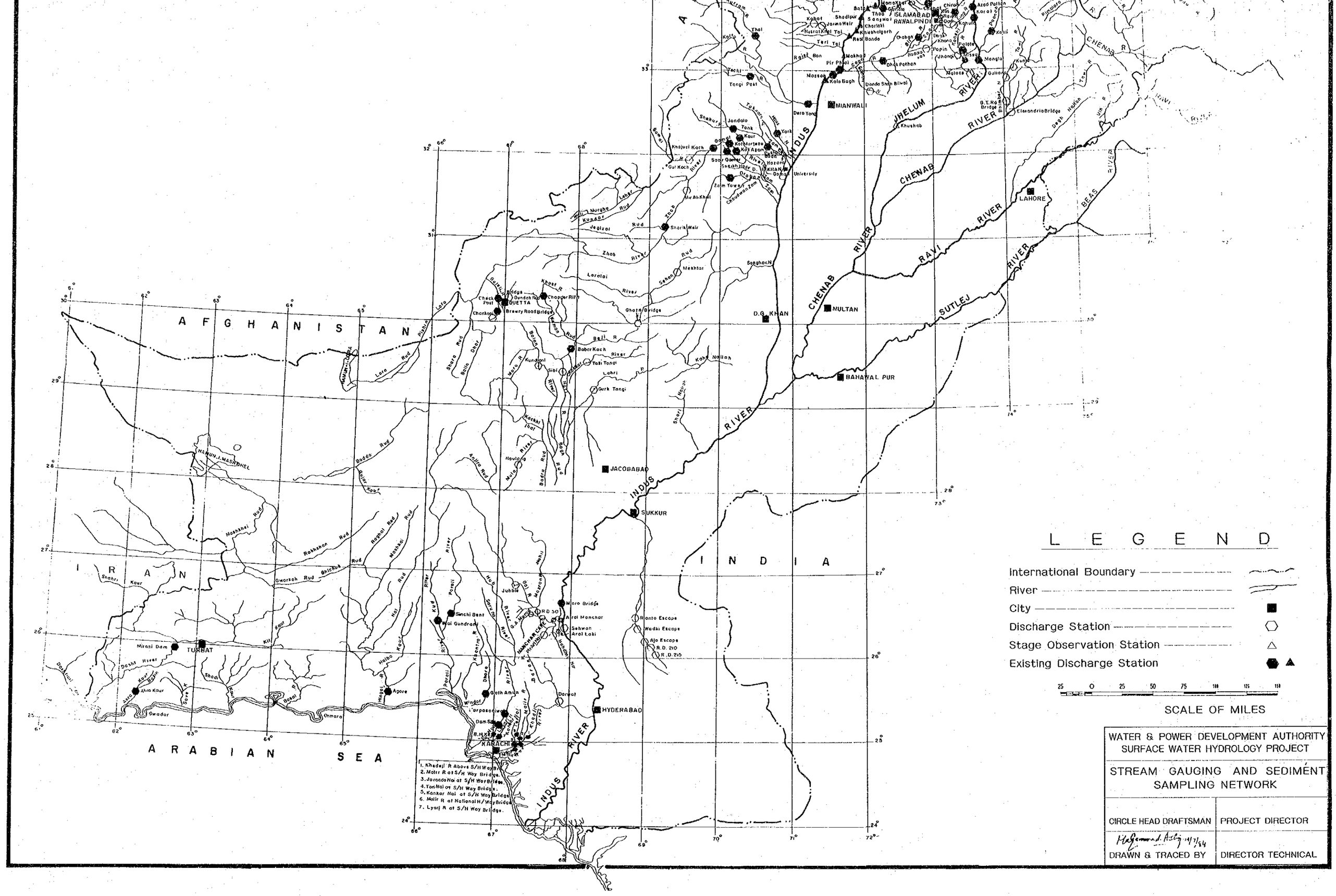
(viii)

資料－5
資料－7
資料－12
資料－20

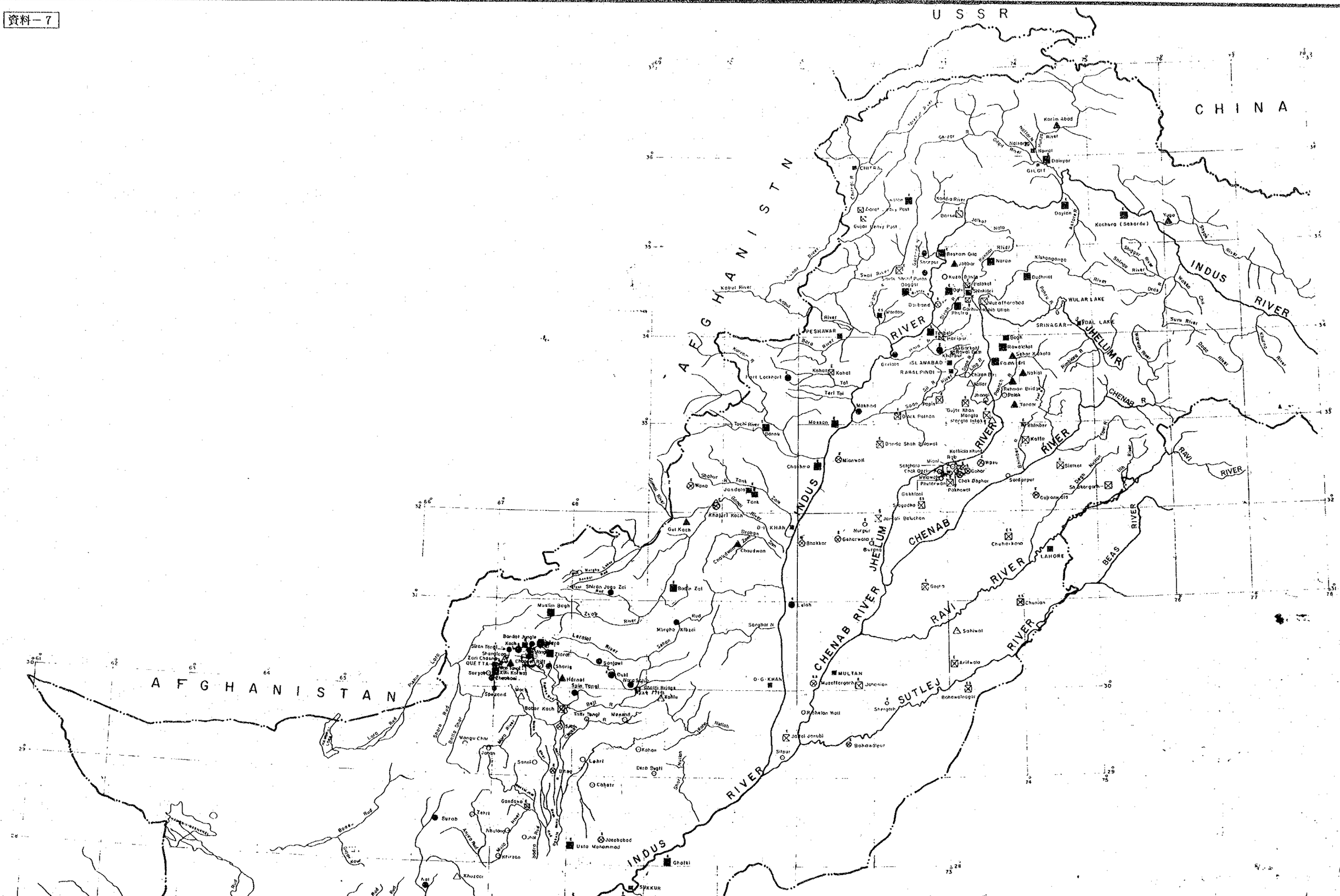
在中

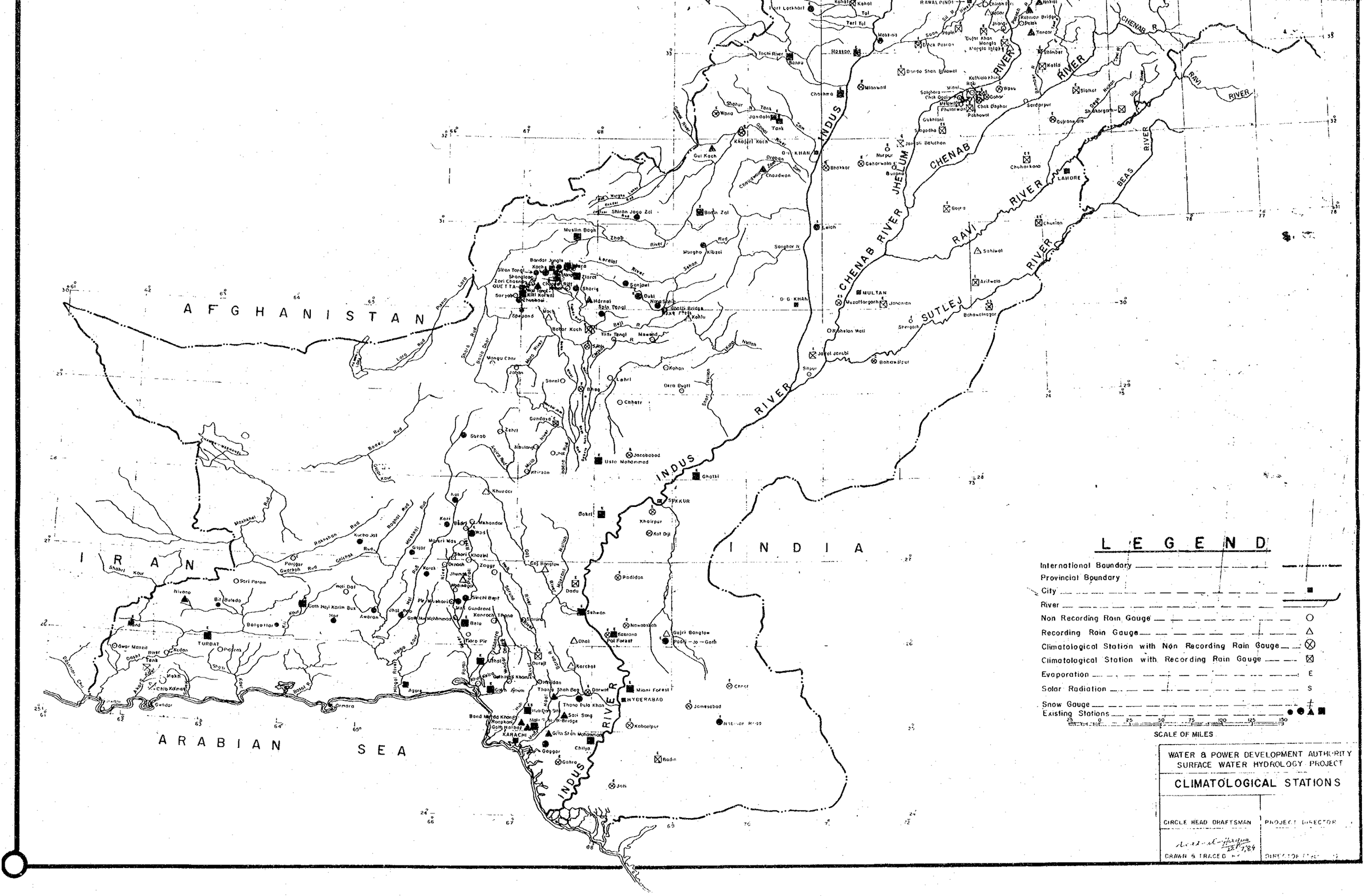
資料－5

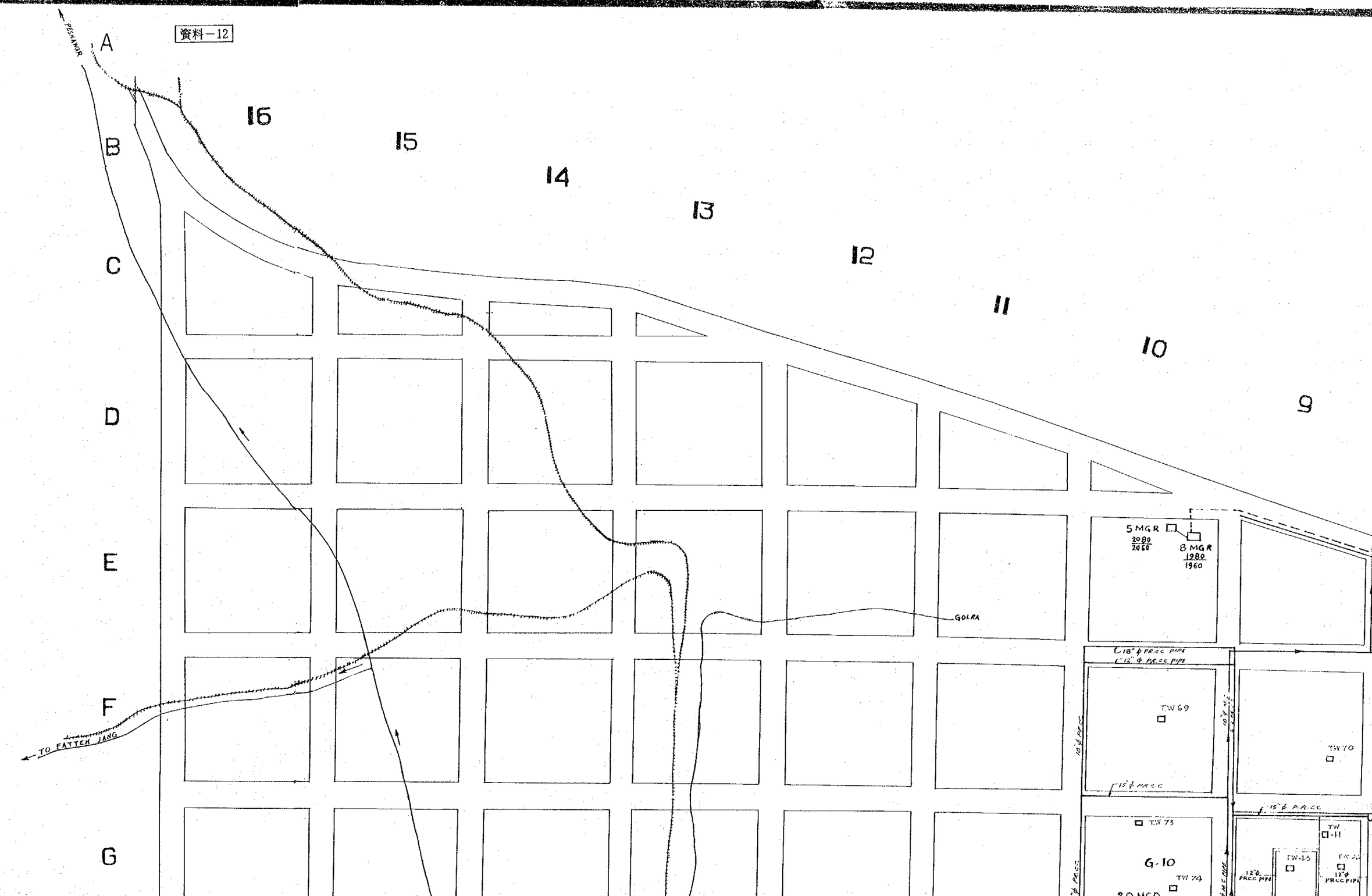

U S S R
C H I N A
A F G H A N I S T A N
A F G H A N I S T A N
INDUS RIVER
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
BEAS RIVER
PESHAWAR
ISLAMABAD
RAWALPINDI
SRINAGAR
WULAR LAKE
DAL LAKE
MIANWALI
LAHORE
MULTAN
D.G. KHAN
BAHAWAL PUR
JACOBABAD
SUKKUR
QUETTA
HAMUN-I-LORA
HAMUN-I-MASHKHEL
L E G E N D

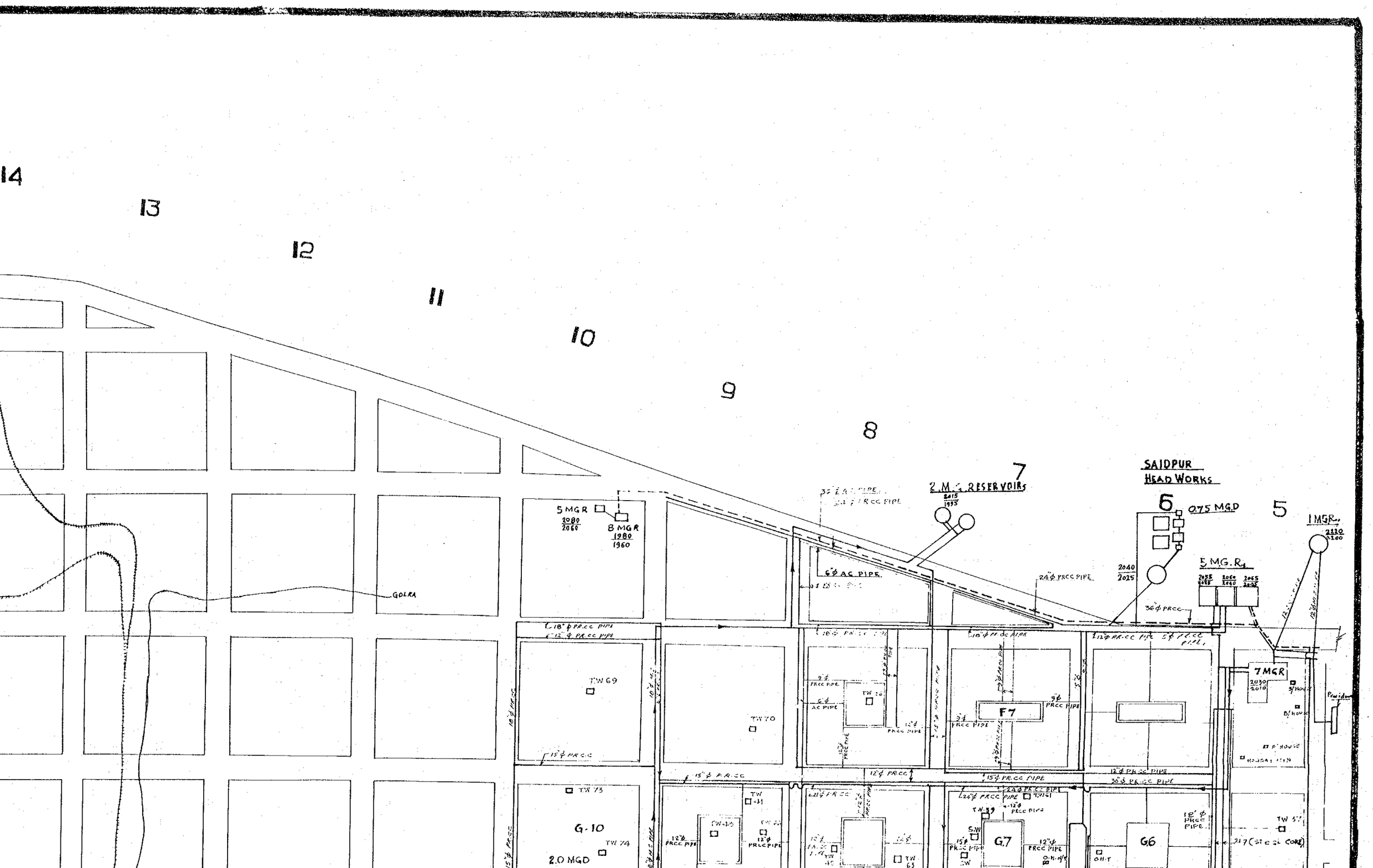

AFGHANISTAN
IRAN
INDIA
ARABIAN SEA
INDUS RIVER
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
BEAS RIVER
ISLAMABAD
RAWALPINDI
MIANWALI
LAHORE
MULTAN
D.G. KHAN
BAHAWAL PUR
JACOBABAD
SUKKUR
HYDERABAD
KARACHI
QUETTA
TURBAT
LEGEND
International Boundary
River
City
Discharge Station
Stage Observation Station
Existing Discharge Station
SCALE OF MILES
WATER & POWER DEVELOPMENT AUTHORITY
SURFACE WATER HYDROLOGY PROJECT
STREAM GAUGING AND SEDIMENT SAMPLING NETWORK
CIRCLE HEAD DRAFTSMAN
PROJECT DIRECTOR
DRAWN & TRACED BY
DIRECTOR TECHNICAL

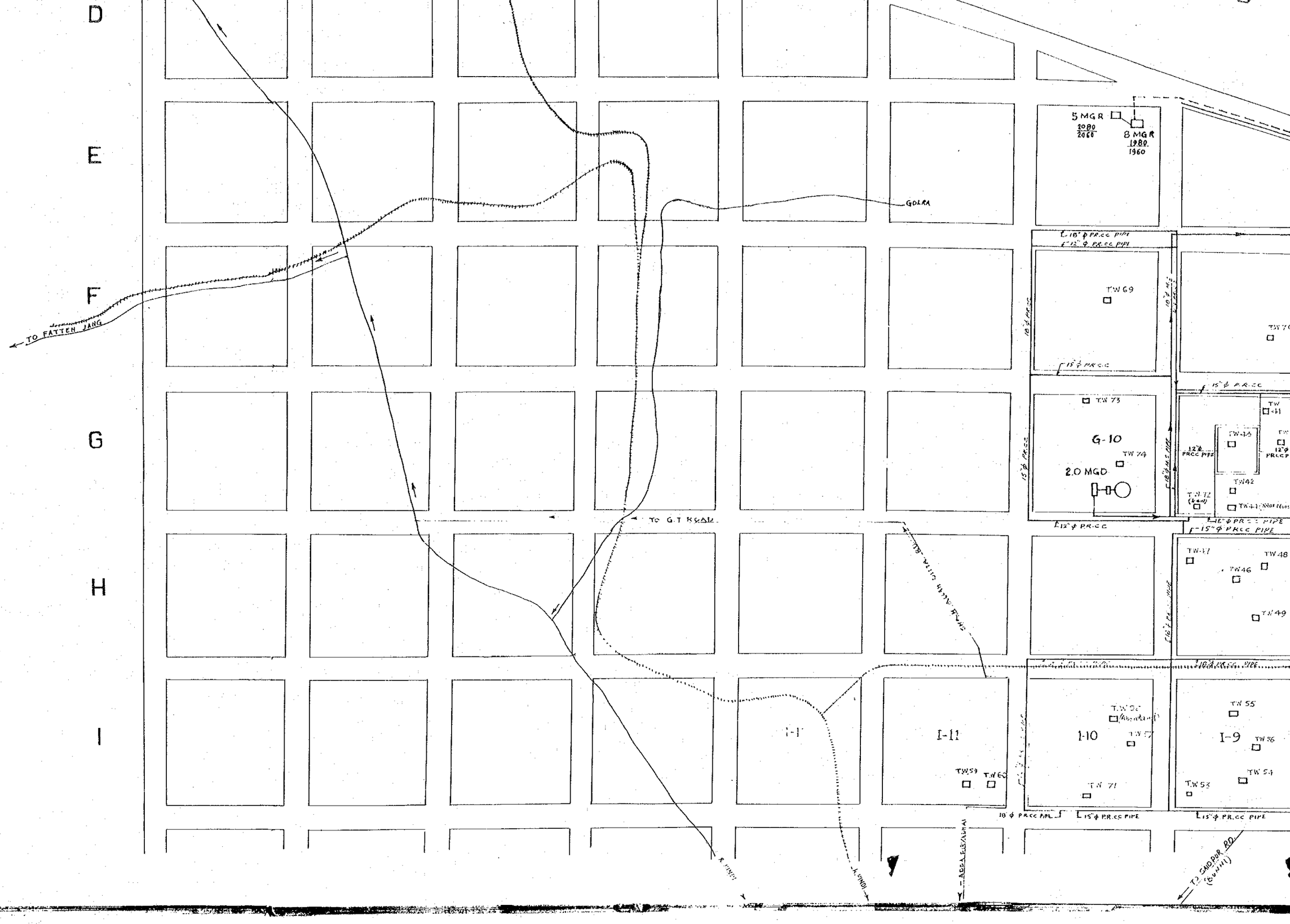
資料－7


USSR
CHINA
AFGHANISTAN
AFGHANISTAN
INDUS RIVER
JHELUM R
CHENAB R
RAVI RIVER
SUTLEJ RIVER
BEAS RIVER
CHENAB RIVER
JHELUM RIVER
INDUS RIVER
PESHAWAR
ISLAMABAD
RAWALPINDI
SRINAGAR
DAL LAKE
WULAR LAKE
LAHORE
MULTAN
SUKKUR
GILGIT
CHITRAL
Kabul River
Swat River
Kunar River
Panjkora R
Kurram R
Tochi River
Gomal River
Zhob River
Indus River
Jhelum River
Chenab River
Ravi River
Sutlej River
Beas River
Karim Abad
Dainyor
Kachura (Sakardu)
Yugo
Besham Qila
Naran
Dudhnial
Muzaffarabad
Rawalakot
Bagh
Rawalkot
Sahar Kakota
Fateh Jang
Nakial
Rahman Bridge
Tandar
Kotla
Sialkot
Sadarpur
Gujranwala
Chenab Bridge
Chunian
Sahiwal
Arifwala
Bahawalnagar
Bahawalpur
Jalal Janubi
Sitpur
Muzaffargarh
Jahanian
Shergarh
Bhakkar
Mianwali
Kalabagh
Dera Ismail Khan
Tank
Bannu
Kohat
Peshawar
Mardan
Swabi
Chakdara
Dir
Chitral
Gilgit
Skardu
Leh
Kargil
Zhob
Quetta
Sibi
Jacobabad
Ghotki
Khairpur
Larkana
Dadu
Hyderabad
Tando Adam
Mirpur Khas
Nawabshah
Sehwan
Khuzdar
Kalat
Surab
Nushki
Dalbandin
Pasni
Gwadar
Panjgur
Turbat
Kech
Pishin
Chaman
Spin Tangi
Sarjob
Zarghun
Ziarat
Sibi
Loralai
Muslim Bagh
Bodin Zai
Shikan Jaga Zai
Mirgha Kibzai
Sanjawi
Duki
Khanozai
Khuzdar
Kharan
Panjgur
Turbat
Gwadar
Pasni
Jiwani
Sonmiani
Hub
Karachi
Thatta
Badin
Mirpur Sakro
Umarkot
Nagar Parkar
Chhachro
Mithi
Diplo
Sanghar
Nawabshah
Tando Allahyar
Tando Muhammad Khan
Hyderabad
Mirpur Khas
Tando Adam
Sukkur
Rohri
Shikarpur
Larkana
Jacobabad
Dera Ghazi Khan
Muzaffargarh
Multan
Bahawalpur
Sadiqabad
Rahim Yar Khan
Khairpur
Sukkur
Ghotki
Dadu
Sehwan
Khuzdar
Kalat
Surab
Nushki
Dalbandin
Pasni
Gwadar
Panjgur
Turbat
Kech
Pishin
Chaman
Spin Tangi
Sarjob
Zarghun
Ziarat
Sibi
Loralai
Muslim Bagh
Bodin Zai
Shikan Jaga Zai
Mirgha Kibzai
Sanjawi
Duki
Khanozai
Khuzdar
Kharan
Panjgur
Turbat
Gwadar
Pasni
Jiwani
Sonmiani
Hub
Karachi
Thatta
Badin
Mirpur Sakro
Umarkot
Nagar Parkar
Chhachro
Mithi
Diplo
Sanghar
Nawabshah
Tando Allahyar
Tando Muhammad Khan
Hyderabad
Mirpur Khas
Tando Adam
Sukkur
Rohri
Shikarpur
Larkana
Jacobabad
Dera Ghazi Khan
Muzaffargarh
Multan
Bahawalpur
Sadiqabad
Rahim Yar Khan
Khairpur
Sukkur
Ghotki
Dadu
Sehwan

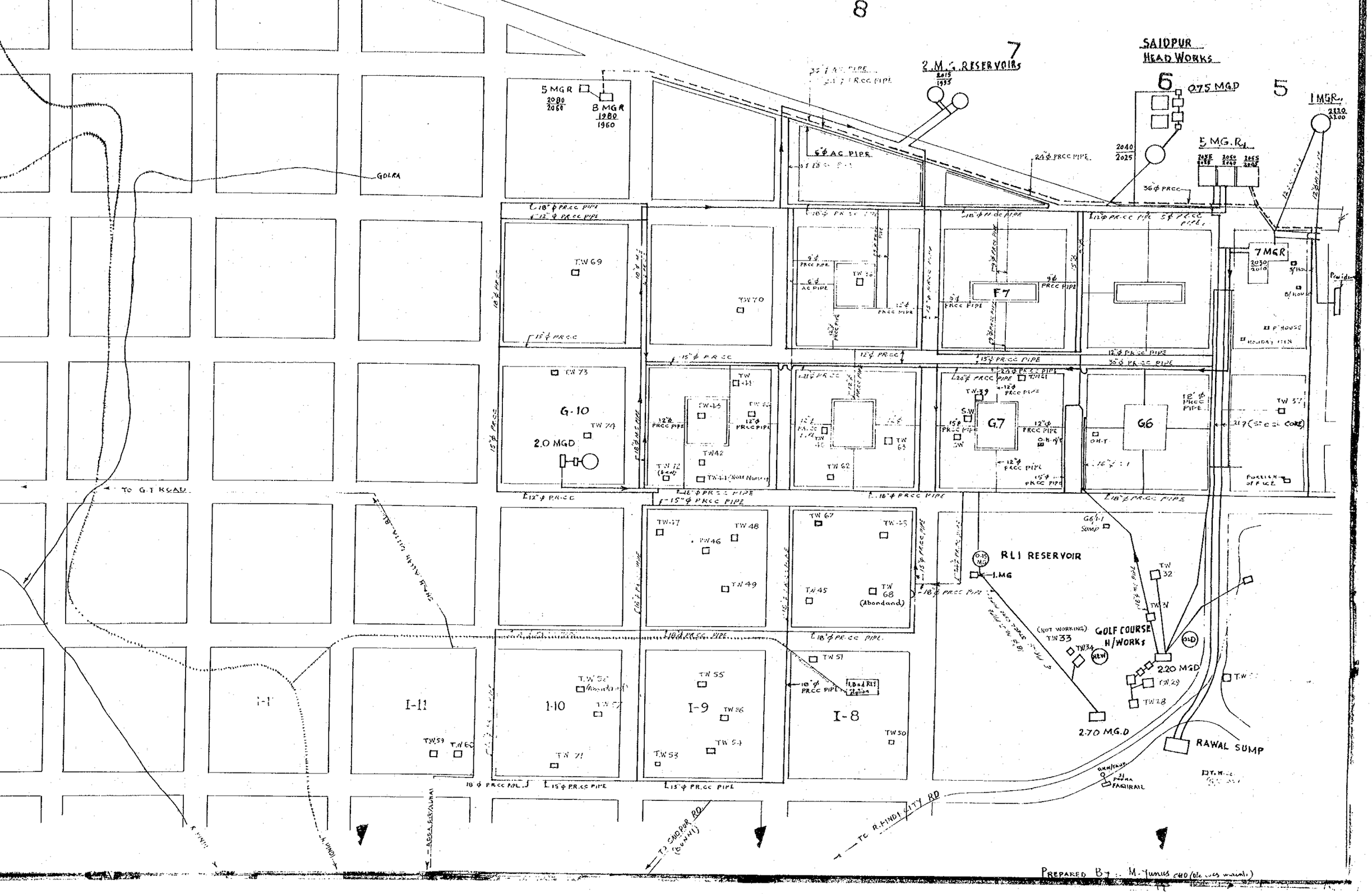

AFGHANISTAN
IRAN
INDIA
ARABIAN SEA
INDUS RIVER
CHENAB RIVER
JHELUM RIVER
RAVI RIVER
SUTLEJ RIVER
BEAS RIVER
QUETTA
D.I. KHAN
D.G. KHAN
MULTAN
LAHORE
HYDERABAD
KARACHI
SUKKUR
TURBAT
LEGEND
International Boundary
Provincial Boundary
City
River
Non Recording Rain Gauge
Recording Rain Gauge
Climatological Station with Non Recording Rain Gauge
Climatological Station with Recording Rain Gauge
Evaporation
Solar Radiation
Snow Gauge
Existing Stations
SCALE OF MILES
WATER & POWER DEVELOPMENT AUTHORITY
SURFACE WATER HYDROLOGY PROJECT
CLIMATOLOGICAL STATIONS
CIRCLE HEAD DRAFTSMAN
PROJECT DIRECTOR
DRAWN & TRACED BY


資料－12
PESHAWAR
A
B
C
D
E
F
G
16
15
14
13
12
11
10
9
GOLRA
TO FATTEH JANG
5 MGR
2080
2060
8 MGR
1980
1960
18" φ PRCC PIPE
12" φ PRCC PIPE
TW 69
TW 70
15" φ PRCC
TW 73
G-10
TW 74
TW
12" φ PRCC PIPE


14
13
12
11
10
9
8
7
6
5
SAIDPUR
HEAD WORKS
0.75 MGD
2 M.G. RESERVOIRS
5 MGR
8 MGR
1980
1960
2080
2060
GOLRA
6" ϕ AC PIPE
24" ϕ PRCC PIPE
36" ϕ PRCC
5 MG.R.
1 MGR.
7 MGR
2040
2025
TW 69
TW 70
TW 73
TW 74
G-10
2.0 MGD
F7
G7
G6
15" ϕ PRCC
12" ϕ PRCC PIPE
18" ϕ PRCC PIPE
24" ϕ PRCC PIPE
30" ϕ PRCC PIPE
6" ϕ AC PIPE
P. HOUSE
B/ HOUSE
S/ HOUSE
Pavilion


D
E
F
G
H
I
TO FATTEN JANG
GOLRA
TO G.T ROAD
5 MGR
2080
2060
8 MGR
1980
1960
18" ϕ PR.CC PIPE
12" ϕ PR.CC PIPE
TW 69
15" ϕ PR.CC
TW 73
G-10
TW 74
2.0 MGD
12" ϕ PRCC PIPE
TW 42
15" ϕ PRCC PIPE
TW 47
TW 48
TW 46
TW 49
I-11
I-10
I-9
TW 55
TW 56
TW 54
TW 53
TW 59
TW 60
TW 71
18" ϕ PRCC PIPE
15" ϕ PR.CC PIPE
TO SHOPUR RD.
(BUNNI)

spring

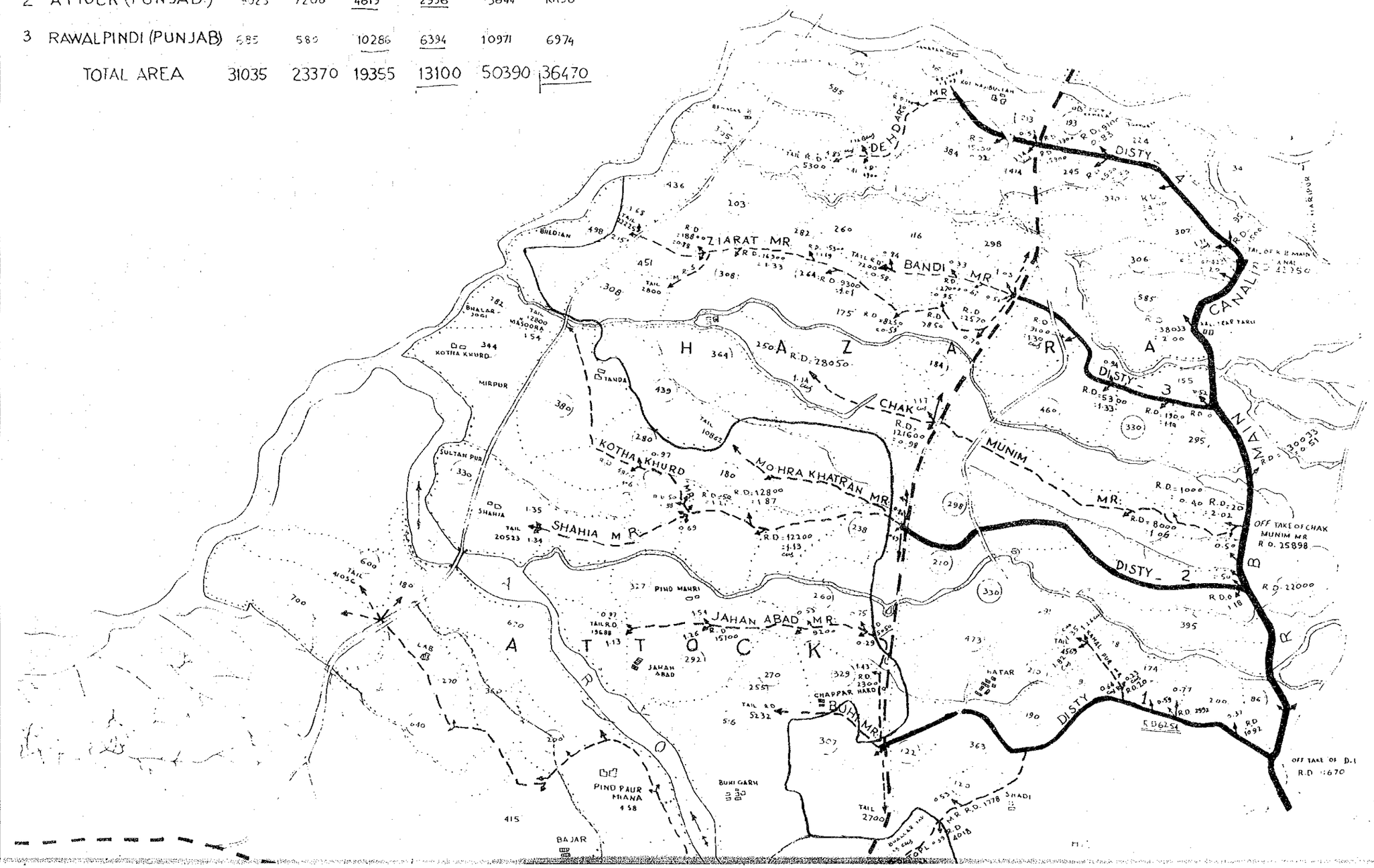


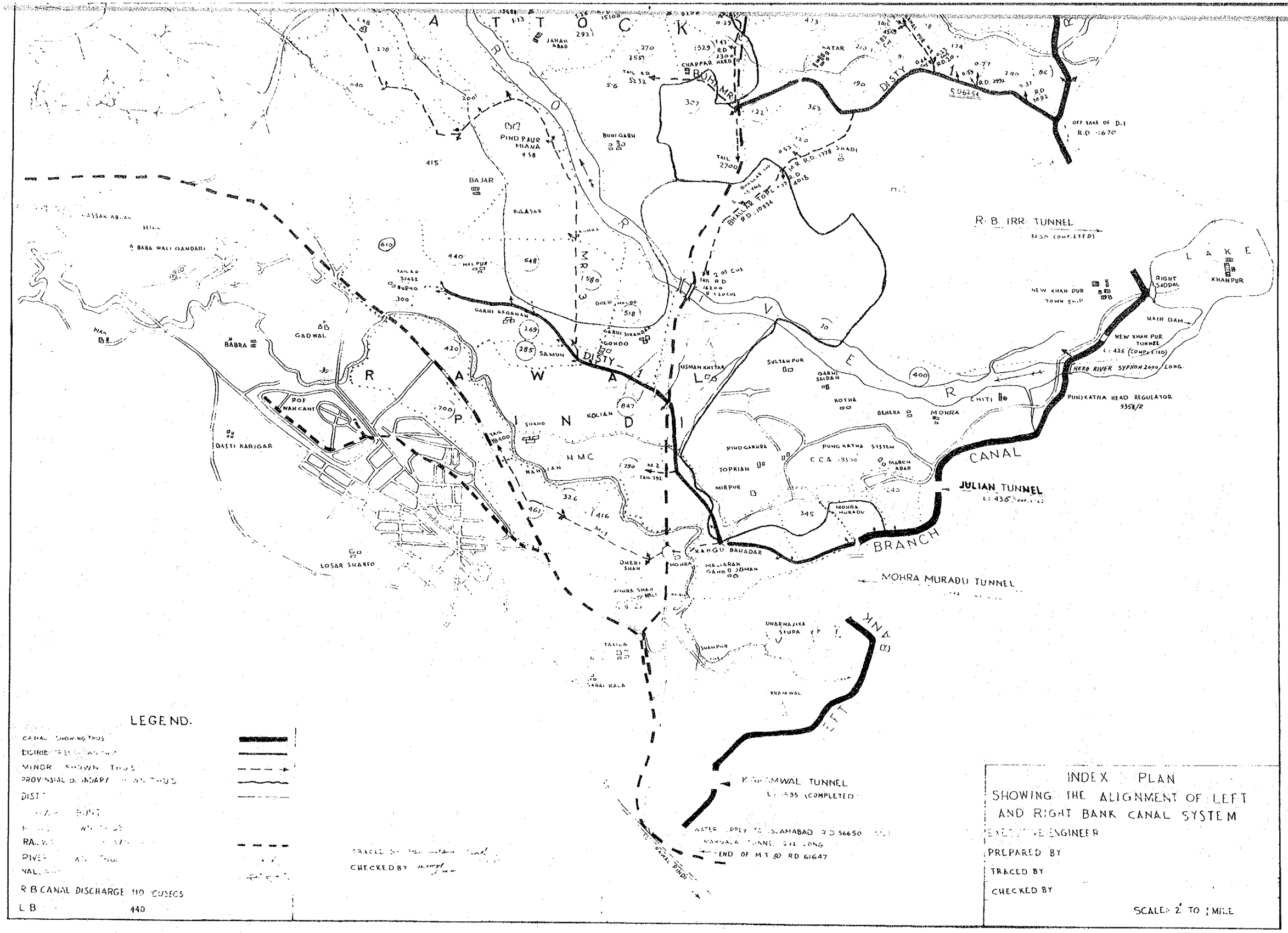
8
7
6
5
SAIDPUR HEAD WORKS
2 M.G. RESERVOIRS
0.75 MGD
5 MGR
8 MGR
1 MGR
5 M.G.R.
7 MGR
GOLRA
TO G.T ROAD
G-10
2.0 MGD
F7
G7
G6
RL1 RESERVOIR
1.MG
GOLF COURSE H/WORKS
2.20 MGD
2.70 M.G.D
RAWAL SUMP
I-11
I-10
I-9
I-8
TO SAIDPUR RD (BUNNI)
TO R.PINDI CITY RD
PREPARED BY :- M. Yunus CHD (Ole wes wainli)

spring

COMMAND STATEMENT OF RIGHT/LEFT BANK CANAL KHANPUR DAM.

S NO	NAME OF DISTRICT	R B CANAL		L. B. CANAL		TOTAL	
		G.C.A	C.C.A	G.C.A	C.C.A	G.C.A	C.C.A
1	HAZARA (N.W.F.P)	21325	15590	4450	3770	[illegible]	19360
2	ATTOCK (PUNJAB.)	6025	7200	4619	2936	13644	10136
3	RAWALPINDI (PUNJAB)	685	580	10286	6394	10971	6974
	TOTAL AREA	31035	23370	19355	13100	50390	36470





ATTOCK
RAWAL PINDI
RIVER
LAKE
BRANCH
CANAL
LEFT BANK
R.B. IRR. TUNNEL
3450 (COMPLETED)
JULIAN TUNNEL
MOHRA MURADU TUNNEL
KARAMWAL TUNNEL
PUNJKATHA HEAD REGULATOR
HERO RIVER SYPHON 2000 LONG.
NEW KHAN PUR TUNNEL
MAIN DAM
RIGHT SADDAL
KHANPUR
NEW KHAN PUR TOWN SHIP
OFF TAKE OF D-1
BUHI MR
CHAPPAR HARD
PIND PAUR MIANA
BUHI GARH
BAJAR
BULASAR
BABA WALI QANDARI
GADWAL
BABRA
POF WAH CANT
BASTI KARIGAR
LOSAR SHARFO
GARHI AFGANAN
SAMUN
GONDO
KOLIAN
HMC
USMAN KHTTAR
SULTAN PUR
GARHI SAIDAN
KOTHA
BEHERA
MOHRA
CHITI
PINDGAKHRA
TOPKIAN
MIRPUR
PUNGKATHA SYSTEM
MARCH ABAD
MOHRA MURADU
KANGU BAHADAR
MALIARAN GANO
DHARMAJIKA STUPA
SHAHPUR
KRAMWAL
TALILA
SARAI KALA
DISTY 1
MR 3
LEGEND.
CANAL SHOWING THUS
DISTRIBUTRIES SHOWN THUS
MINOR SHOWN THUS
PROVINSIAL BOUNDARY SHOWN THUS
DIST
RA
RIVER
NAL
R B CANAL DISCHARGE 110 CUSECS
L B 440
CHECKED BY
WATER SUPPLY TO ISLAMABAD R D 56650
END OF M T @ RD 61647
INDEX PLAN
SHOWING THE ALIGNMENT OF LEFT AND RIGHT BANK CANAL SYSTEM
EXECUTIVE ENGINEER
PREPARED BY
TRACED BY
CHECKED BY
SCALE: 2" TO 1 MILE

JICA