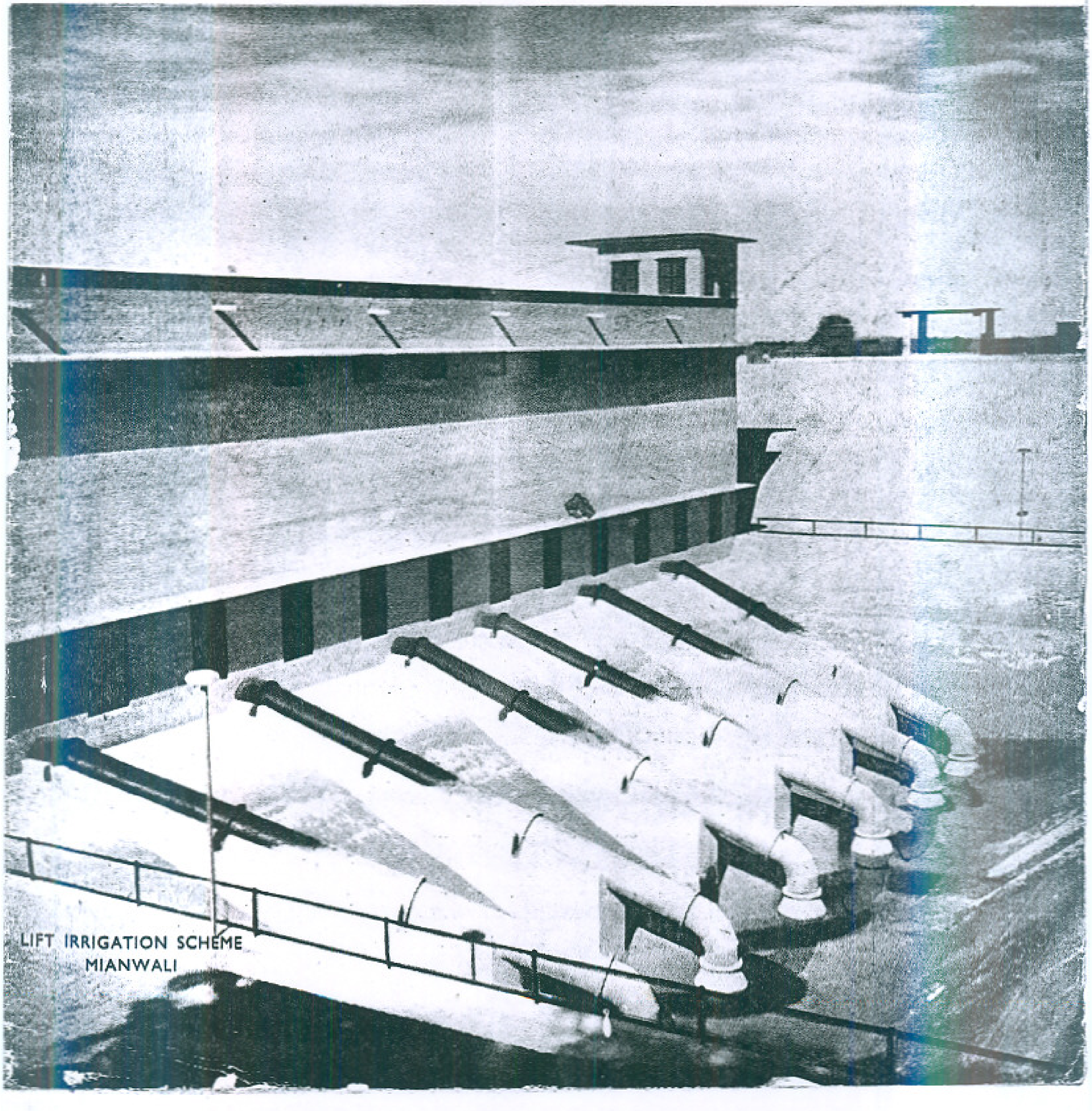
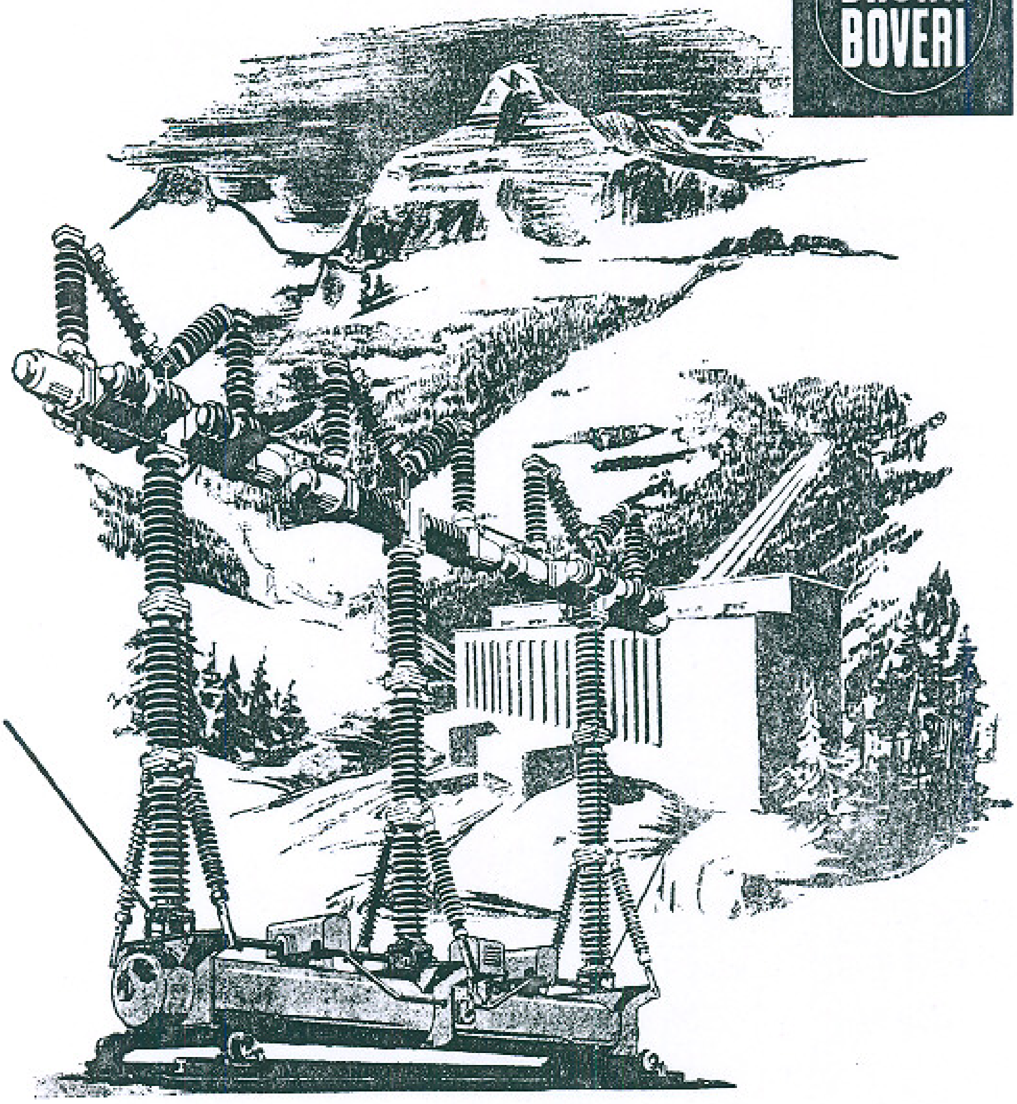
Engineering NEWS

VOL. 9, NO. 4

QUARTERLY JOURNAL OF THE WEST PAKISTAN ENGINEERING CONGRESS



LIFT IRRIGATION SCHEME
MIANWALI



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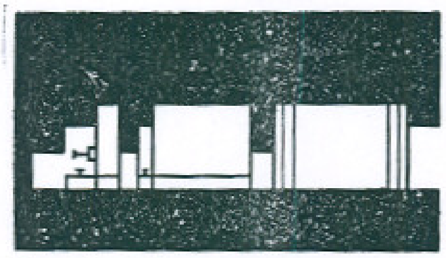
In this issue

AEG

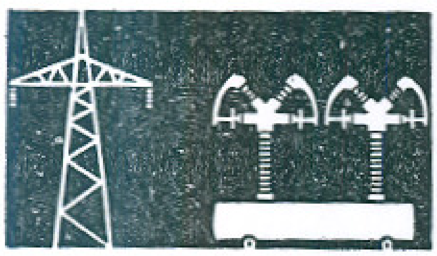
Electrical Plant and Equipment of all Kinds

Erection
Manufacture
Design

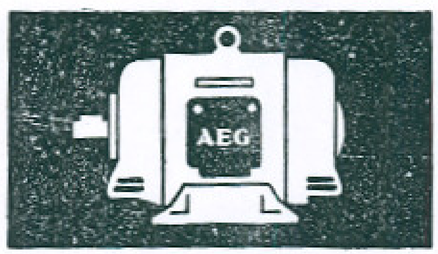


Power Generation

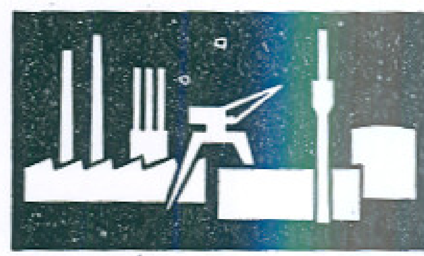
Nuclear Power Plant



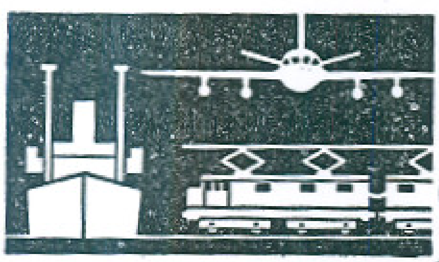
Power Transmission and Distribution



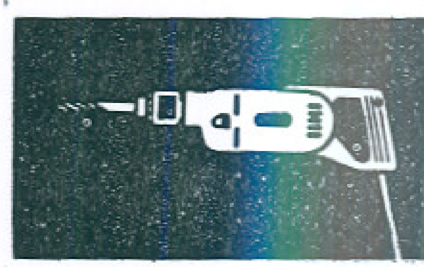
Energy Utilization Equipment



Industrial Plant



Electric Traction Engineering
Marine Engineering
Airfield Equipment



Electric tools

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F.A.O. Seminar on Waterlogging and Salinity

Hardly a year after the Symposium on Waterlogging and Salinity held in October 1964, the views of many in this country on the solution of the problem appear to have been radically changed. This is a result of the F.A.O. Seminar held here in November last.

The Symposium held on the occasion of the Golden Jubilee of the West Pakistan Engineering Congress was also an international get together in which Engineers and Scientists of many countries participated. Although some foreigners, particularly those from across the border, sounded a discordant note, the Jubilee Symposium was dominated by one class of thinkers. All the fourteen papers selected for the Symposium advocated one method of drainage, *viz.*, installation of tubewells, as the only solution of the problem. The opinion was unanimously expressed that the country was proceeding on the right line. Therefore no one should doubt the efficacy of technique, particularly when it had the support of Kennedy's Scientists whose report had just been received. No one in Pakistan could be in a better position to undertsand the problem and suggest its solution than the eminent scientists selected by the late Mr. Kennedy. No wonder, therefore, that the Symposium endorsed the recommendations of the Kennedy Scientists, who had already made thorough investigation.

It is said Pakistan has always been helped by God whenever she was in trouble. Fortunately this F.A.O. Seminar under the role of a scientific discussion was a God-send help. There appeared to be no justifications for another Symposium only a year after, holding a similar meeting. Nobody could see its usefulness. All possible suggestions and lines of approach about the drainage of the Indus Plains had already been discussed. Even the Engineering Congress executives were sceptical about the usefulness of another Seminar soon after the Jubilee Symposium. Nevertheless, the Seminar did take place. For full twelve days, Scientists of fourteen countries, including experts on waterlogging and salinity problems, scientists of the home country from the Departments of Agriculture, Forest, Fisheries, and various consultants expressed their views and took active part in the deliberations. Never before in this country had 78 experts assembled and exchanged views. Never before had such thorough discussion of the problem been held. Every one who had something to say got a chance to do so. The Netherlands is a territory in which fertility depends on efficient drainage. Vabden Berg, Director of the Institute of Land and Water Management, not only made a clear analysis of the problem, but as moderator, also recommended the most appropriate measures of drainage. Dr. V. Kovda, Director, Natural Resources, Unesco, a world famous authority on soils, their management and amelioriation, with valuable experience of 33 years of laboratory and field techniques, discoursed on the chemistry of soils and waters. As moderator for the optimum depth of groundwater, his exposition was most informative and instructive.

Dr. C. A. Bower, Director, U. S. Salinity Laboratory, moderator for salt balance, recommended measures for the proper control of salinity. Dr. R. M. Hagan, Professor of Irrigation, California, although joining late in the discussion, very ably dealt with Irrigation methods. Dr. M. Fireman, Van't Leven and Prof. A. F. Pillsbury, all scientists with deep insight into the subject, expatiated on the various aspects of the problem. In this Seminar none endorsed the solution which was so readily accepted in the last Symposium emphatically.

In the words of Prof. Pillsbury, "Vertical drainage, pumping from wells, has been highly successful in the upper part of the flood plains. But it is not really a drainage method. It is, rather, a means of creating a more adequate irrigation supply that, incidentally, can have excellent drainage benefits. The pumping that must be maintained, the rate of flow per unit lift, make vertical drainage completely inefficient for drainage alone. Many vertical drainage schemes were started in the South-Western part of the United States beginning in the early 1920's. Today, to the best of my knowledge, not a single "drainage" well is operating where the water is not used to help irrigate overlying land, or is used to satisfy downstream water rights. It might be added that, wherever saline waters are being pumped, extreme corrosion and incrustation problems with the well and pump appear to be inevitable". After this, the usefuness of tubewells in drainage should be reviewed.

The problem of salinity and alkalinity exists all over the world. Russia, the Netherlands, Egypt, Iraq and America had serious land problems, but by the concerted efforts of engineers, soil scientists and host of others, they have brought the problems under control. Not a single country has tried tubewells as the only means of solving soil problems.

West Pakistan is a vast country. Its 66 millions of culturable acres, extending along the Indus and its tributaries, constitute a huge area of great climatic soil and meteorological variation. Conditions change from place to place. Then how can tubewells in the Punjab, in Khairpur, in the delta area, and everywhere, be the only solution?

This Symposium clearly and convincingly brought home to each and every participant that pumping of groundwater and lowering of the watertable is not the only solution of the problem. Least of all is the pumping of deep lying, highly saline water from the Doabs in the Punjab, and the sea water of the delta area and putting it back on the land or in the canals or rivers to spoil whatever good exist. Indeed, it makes matters worse. The implications of such action are too terrible to contemplate.

Many countries are facing a similar problem, but none had adopted tubewell as the only measures being tried in this country. It is not being tried even in the countries of the scientists who advocate it as the only efficient one.

F.A.O. Seminar has suggested to us fresh lines of approach to the problem. The F.A.O. authorities are ready compiling all the statements and papers and this document when completed and distributed by F.A.O. authorities will perhaps be more valuable than the Revelle Report. It is, however, definite that its findings and conclusions will be very different from those arrived at by the Revelle Scientists. This was apparent from most of the contributions to the Seminar, some of which we have summarised in this issue.

Mianwali Lift Irrigation Scheme

By **M. ASLAM KHAN,**
Superintending Engineer, Irrigation Thal Circle, Mianwali.

Introduction

Before elaborating on the salient features of the Irrigation Schemes completed recently, the writer would like to give a brief history of the conditions prevailing in Mianwali District prior to introduction of irrigation system.

The mighty Indus River after debauching from the Kalabagh gorge entered the plains of Mianwali District. It used to flow waste without utilization of its water for irrigation purposes. The residents along the banks of the River resorted to irrigation of their lands known as Belas within the River bed. The lands along the banks were irrigated from the River over-spills. This practice is still manifest in most of the riverain areas which have not been provided with the modern irrigation system. Similarly people have also been using river water during the winter for irrigation of small tract of lands through kacha diversion bunds. These primitive methods, which are still in vogue at many places, could not satisfy the needs of the people.

Construction of a Barrage on the Indus

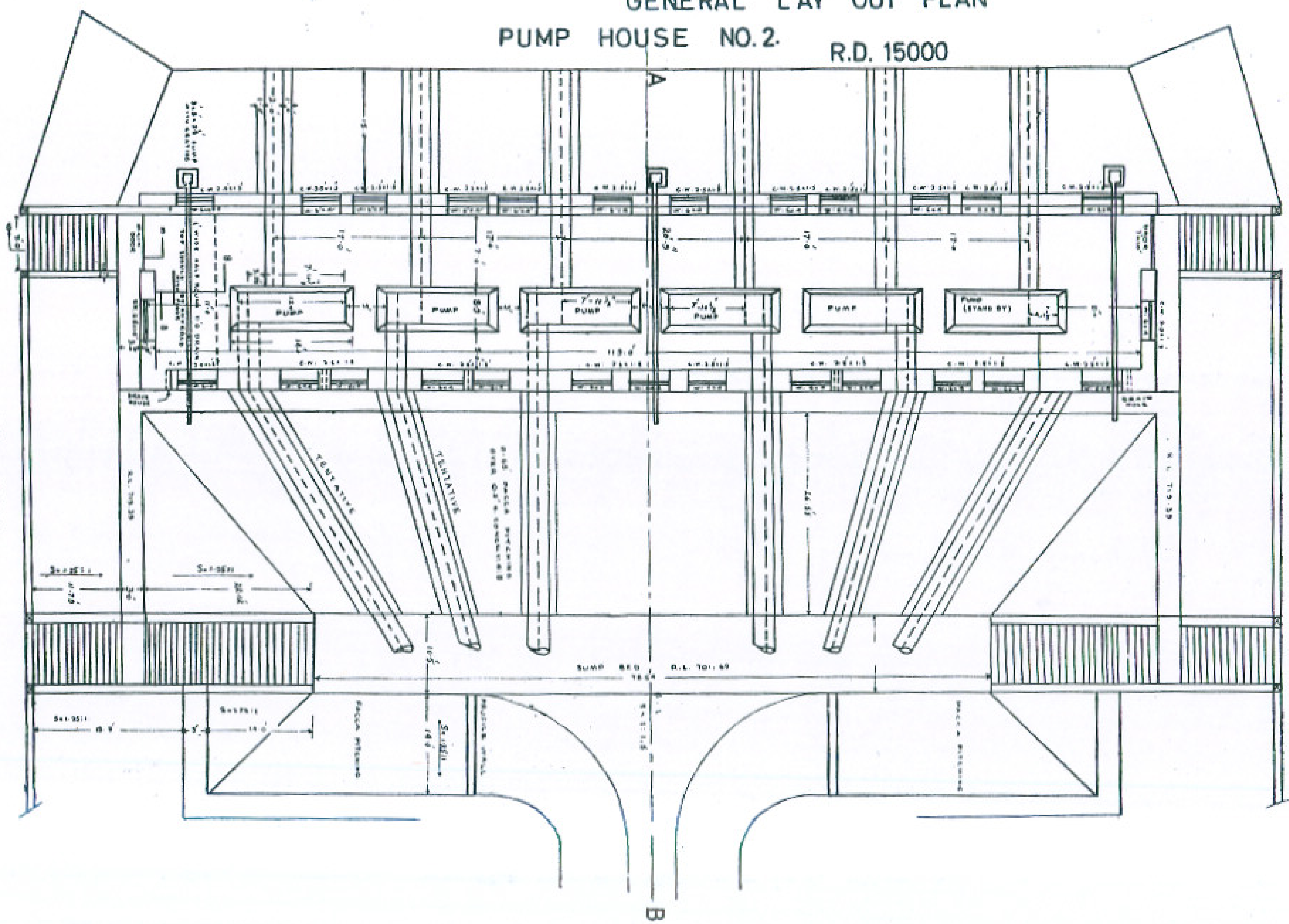
In the year 1872 Government of India seriously considered the construction of a Barrage on the Indus in the gorge, upstream of the Kalabagh Town. The investigations however did not prove promising and gave unfavourable results. The main reasons for rejection of the scheme were :—

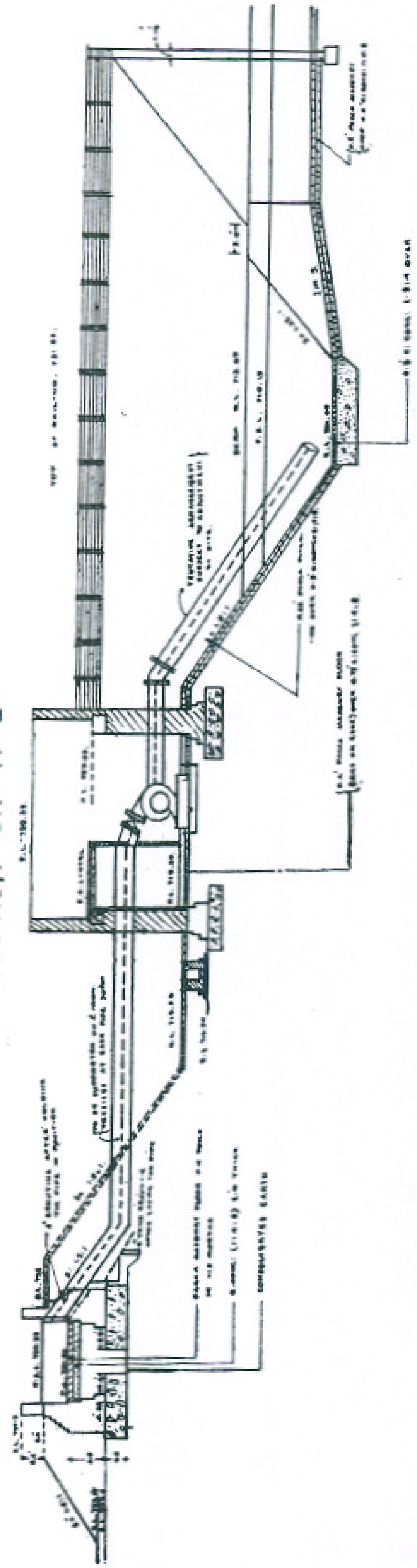
1. The canal taken off from the left of the barrage had to cross through steep hills, involving deep cuttings and tunnellings through the unstable hills.
2. Such a canal aligned along the toe of salt range extending right up to Khushab would have to cross innumerable drainage crossings. The subsequent maintenance of these would be a source of recurring expenditure.

Namal Dam

In view of the above difficulties, the scheme was dropped. Nothing was done for Mianwali District till 1913 when the construction of Namal Dam was started. It was completed in 1917 at a cost of Rs. 3,67,000. The main wall of the Dam consists of dressed limestone masonry in lime mortar. The maximum height of the Dam was 105′ from the bays

MIANWALI LIFT IRRIGATION SCHEME
GENERAL LAY OUT PLAN
PUMP HOUSE NO. 2. R.D. 15000





and overall length was 320′. Its original storage capacity at 1160 reduced level near the crest was 13109 acre feet. This has however after 43 years reduced itself to 5694 acre feet due to gradual silting up of the bed.

About 19000 acres of land in Mianwali Tehsil on the western side of salt range are being irrigated by the Namal Canal. It flows through the gorge of the hill range and irrgates the lands of Isakhel village extending right up to Mianwali town. This canal has been operated and maintained by the Civil Department, till 1952 when it was transferred to the Irrigation Department.

Thal Project

After the implementation of Namal Dam Scheme, the Government again thought of constructing a Barrage on River Indus. Finally the Government of India in 1939 ordered the construction of the Barrage now called the Jinnah Barrage at its present site. The canal system and other allied works were sanctioned under Grow More Food.

After independence the completion of this Project was further accelerated to receive large influx of refugees from India and for settling them down into various Chaks under this scheme. This task has since been successfully done. The canal system under Thal Irrigation Circle is functioning and developing ahead of schedule. The salient features of the Thal Project are as below:—

(*a*) Cost of the Project Rs. 15,45,14,000
Gross area 21,71,604 acres
Gross commanded area .. 18,55,285 acres
Ultimate annual permissible by 1968 .. 11,67,000 acres

(*b*) The total length of the channels of the project is :—

Main Canal and Branches	.. 229.17 miles
Major Disty.	.. 908.66 miles
Minors	.. 920.40 miles

At present the entire supply of 6000 cusecs is being utilized by the cultivators. In order to cover the seepage losses and to increase irrigation during Kharif, the capacity of the canal is being raised to 75000 cusecs during the next two years. This extra supply will be utilized during Kharif only.

Lift Schemes (General)

After the implementation of Thal Canal Project a large tract of lands was, however, left without irrigation facilities. This land extended from Kalabagh to Khushab, in between the irrigation boundaries of the Irrigation System and the Salt Range. This area extends right to the foot of the Salt Range and possesses fairly steep slope. This area of terraces and long tracts is about 3 lac acres. It has no means of artificial irrigation, except the natural scanty rainfall, which comes down the Salt Ranges and the steep slope floods the land and deposits land wash on to the terraces. The people of these lands seeing their neighbours enjoying the privilege of irrigation facilities, has been requesting the Government for similar means of irrigation for their lands. The Government in order to help these people and to ameliorate their lot has embarked on the ambitious Lift Irrigation Schemes to provide them with regular ensured Irrigation facilities. The first two Schemes known as Gulmiri Lift Irrigation Scheme and Samandwala Lift Irrigation Scheme were started in 1953 and completed in a couple of years. Similarly Daudkhel Lift Irrigation Scheme was also completed for irrigating the area near Daudkhel village and Sikandarabad colony town.

The water for these three schemes is lifted from the Thal Main Line Canal. The other features of the three schemes already under operation are as under:—

Gulmiri Lift Irrigation Scheme:—

Gross area	.. 5465 acres
Gross commanded area	5235 acres
Discharge	.. 20. cusecs
Lift	.. 9 feet.
Length of channel	.. 6.4 miles
Estimated cost of original scheme	.. Rs. 3,05,100

The scheme is functioning since 1954.

Samandwala Lift Irrigation Scheme

Gross area	.. 12,175 acres
Gross commanded area	10.000 acres
Discharge	.. 40 cusecs
Lift	.. 25 feet
Estimated cost of original scheme	.. Rs. 4,65,327
Length of Channels	.. 13.0 miles

The scheme is in operation since 1954. Originally both these schemes had Diesel driven pumps; these are now being operated by Electric motors.

Daudkhel Lift Irrigation Scheme

Gross area		.. 4905 acres
Gross commanded area		4210 acres
Discharge		.. 16 cusecs
Lift	1st stage	.. 25 feet
	2nd stage	.. 25 feet
Length of channels		.. 6.7 miles.

The scheme was commissioned in 1962.

Estimated cost	.. Rs. 3,70,000

Mianwali Lift Irrigation Scheme

This is the 4th scheme in the series of this programme. Under this scheme 200 cusecs of water were lifted from R. D. 92 of Main Line Upper. The total lift is 60 feet and in the first stage the full discharge is lifted 35 feet through a Pump House A. The water is taken across a reinforced concrete aqueduct and through a lined Feeder Channel to a distance of 7800 feet from where 100 cusecs discharge is distributed proportionately into two Channels, 1-R and 1-L. The remaining 100 cusecs is further lifted another 25 feet and distributed proportionately into two Channels, 2-R and 2-L. The total Gross area under this Scheme is 53340 acres and the Gross commanded area is 52145 acres with the permissible intensity of 79% area, the net area of 40,000 acres will be brought under cultivation. All the irrigation channels of this scheme except the three miles long Feeder Channel connecting Pump House A with Pump House B, runs in cutting. As the slope of the country is fairly steep, therefore the irrigation is being done on one side only, *viz.*, on the right side from the channels known as 1-R and 2-R and on the left side from the channels known as 1-L and 2-L.

Mianwali Lift Irrigation Scheme is the largest scheme successfully implemented by the Irrigation Department of West Pakistan. It has been constructed in much less than the schedule time at a cost of half million rupees which is less than the original estimated cost.

Picnic Spot Round Pump House A

Pump House 'A' has an overall length of 139 feet, width 24 feet and height up to the top of roof 32 feet. It was located after clearing the sandy spoil banks on the left of Main Thal Canal. The loose sand after construction of the sumps and the main reservoir was likely to be blown into the sumps and then picked up with the water after suction through the main suction pipes. The sand dunes around the sump was cut into terraces and pitched with the 3rd class bricks dismantled from pillars constructed for centring of concrete work. Other spoil banks around this Pump House were levelled to form different terraces. Fruit and shady trees were planted in geometrical order all round. Flower beds and flower trees were planted in the colony area of both the Pump Houses A and B. It has not only improved the general appearance round these Pump Houses and colonies but has also converted it into a beauty spot and National Parks. All the spoils of the material left over after the construction were collected and dumped into a huge heap and converted into a rock garden with beautiful cactus and other plants now covering with profusion.

The salient features of the scheme are :—

A. General Data

1. Capital cost	.. 5.60 million
2. Actual Expenditure	.. 52 lacs
3. Annual maintenance charges	.. 0.75 million
4. Cost benefit ratio	.. 2 : 8 : 1
5. *Area*—	
(*a*) Gross area	.. 53340 acres
(*b*) Gross commanded area	.. 52145 „
(*c*) Culturable commanded area	.. 80790 „
(*d*) Permissible irrigation	.. 39594 „
6. Pumping levy per acre on matured area	.. Rs. 20.68
7. *Length of Channels*—	
(*a*) Feeder channel	.. 3.00 miles
(*b*) Irrigation channel	.. 49.26 miles

B. Data of Pumping Stations

Particulars	Station 'A'	Station 'B'
Cost of Pump House ..	Rs. 3,50,000	Rs. 2,00,000
(*a*) Lift ..	35 feet	25 feet
(*b*) A.F.S. Discharge ..	200 cusecs	100 cusecs
(*c*) No. of Pumps ..	6	6
(*d*) Capacity of each pump ..	50 cusecs	20 cusecs
(*e*) Horsepower of each motor ..	295 H. P.	85 H. P.
(*f*) Energy to run each motor ..	284 K. W.	63 K. W.
Consumption per day per motor ..	5280 Units	1522 Units
Cost of energy per day per motor ..	Rs. 422	Rs. 91.76
Delivery Pipe ..	24 inches	20 inches
Suction Pipe ..	30 inches	20 inches

Welcome Address

By **A. RASHID KAZI,**

S.S.E.I. Secretary Irrigation and Power.

Mianwali Lift Irrigation Scheme was opened by Malik Amir Mohammad Khan, the Governor of West Pakistan on 9th December 1964.

Mr. A. R. Kazi, Secretary Irrigation and Power, was to deliver this address which due to the illness of the author was presented by Mr. Nazir Ali, Deputy Secretary. The address ran as follows :—

Mr. Governor, Distinguished Guests and Gentlemen,—

It is a great privilege and honour for me to welcome the Governor of West Pakistan on the auspicious occasion of the inauguration of Mianwali Lift Irrigation Scheme.

2. Sir, I am extremely grateful to you for acceding to our humble request to spare a part of your time to be here today. It is true that compared to the gigantic projects underway all over West Pakistan, Mianwali Lift Irrigation Scheme is a small undertaking. But, permit me to express, Sir, that for the inhabitants of this area, as in other backward regions and pockets of the Province, such small schemes have a special significance and they justifiably merit your gracious patronage.

3. Pakistan is still a developing nation with varied needs for a balanced growth. In the vast expanse of this Province, bigger in size than many countries of the world, the disparity in the standards of living and per capita income is so very much marked, from area to area and region to region. This has been mainly due to natural causes. In many cases the schemes do not prove economical for execution due to high costs to develop a small potential yet these areas have to be helped. The Constitution of Pakistan provides for and the Government aims at removal of disparities in the shortest possible time. It is in this context that this Lift Irrigation Scheme, being inaugurated today, will go a long way to alleviate the suffering and backwardness of the agriculturists in this area of scanty rainfall.

4. In passing I may kindly be permitted to remark on the growing tendency towards urbanization. In spite of it, the agricultural population, spread all over the nooks and

corners of the Province, will neither reduce in size nor in importance. It will continue to grow, toiling to provide food for the increasing mouths and fibre for the industries. That by itself is inadequate. There has to be a parallel development in all fields besides irrigation, including industry, to guard against stagnation in the rural areas in a monotony of activities producing more food.

5. Sir, we are aware of your most thoughtful considerations for the tillers of the soil, particularly those in the backward regions. All owe you their profound gratitude for encouraging the implementation of the hundreds of the smaller schemes simultaneous with large projects. The impact of these small schemes, on the locals, is immense as well as direct. It is of crucial importance that we carry the people in the villages of these areas with us in our efforts to build a real welfare state. From a purely agricultural rural economy we may as well attempt a gradual shift towards a technological society embracing all fields for better production and balanced development.

The Scheme

The history of the development of Mianwali Lift Irrigation Scheme is linked with the history of Kalabagh Barrage itself. It was as far back as 1872 that Engineers first thought of constructing a diversion in the gorge above Kalabagh town. The economics of that project, involving difficult cutting through a rugged terrain, delayed execution of any work until 1936, when emerged the final project for the construction of headworks as now located, with the Thal Canal system serving the Districts of Mianwali, Shahpur and Muzaffargarh.

The project, however, left out of command, vast areas of extremely fertile lands on the left bank of Indus. The Namal Dam completed in 1917 had provided irrigation facilities for only 23,000 acres of the high-lying-area. After Independence serious considerations were given to the lifting of water from Thal Canal by utilizing electric power, then expected to be available from the newly sponsored Mianwali Hydel Scheme. The latter, however, did not materialize. The use of diesel driven pumps for such Lift Schemes estimated for in 1951 proved uneconomical. A revised scheme was then prepared in 1953 for lifting water for only two small areas, Gulmiri and Samandwala. These two started operating on diesel engines and have only recently been changed over to electric power. The Samandwala scheme was in fact the first stage development of a larger project to cover what now embraces the Mianwali Lift Irrigation Scheme. The latter came to be approved only in 1962 for gross command of 52145 acres. Out of this gross command, 40,000 acres are to be cultivated annually 13,000 in Kharif and 27,000 in Rabi.

The Mianwali Lift Irrigation Scheme is the second largest of its kind in West Pakistan, the one bigger than it, *viz.*, the Warsak Lift Channel, is still not complete. This Mianwali Scheme provides for lifting 200 cusecs of water from R. D. 92 of Thal Main Line Upper to a height of 35 ft. at the first stage lift, and 100 cusecs of it by another 25 feet down the canal. The main pumping station close to which we are sitting, is fitted with six pumps of 50 cusecs capacity each for a gross head of 50 ft. The second Lift Station will also have a set of six pumps but of only 20 cusecs capacity each. Only four pumps will be operating at one time at the first pumping station, the remaining two acting as stand by while five sets will be operating at the second station, where one pump will remain as a stand-by. The pumps are electric-driven with power from the West Pakistan Grid.

The project was estimated to cost Rs. 56.5 lacs in all and the expenditure as booked to date to be less than Rs. 52.00 lacs. The area proposed to be served by the scheme is very fertile and has good natural surface drainage. The development is expected to be quick as no colonization is required. The cost benefit ratio of the project was estimated at 1:2.8 but actual benefits are likely to be better and the rate of development much faster as the land is extremely rich and perhaps very suitable for long staple cotton. The rate of recovery from the zamindars for this Lift Irrigation is not yet finally approved by the Government but it is not likely to be heavier than similar Lift Schemes elsewhere.

Development of Thal

It is my privilege to mention, with a feeling of satisfaction, that irrigation on the Thal Canal has already developed beyond the designed figures, for its present capacity of 6,000 cusecs during the Kharif and varying supplies in winter according to the availabilities in the river. Against the target project figures of 8,49,000 acres to end of 1962-63 the actual cultivation has been 8,87,000 acres.

Today every cusec of the water allocation on Thal stands committed and is utilised for maximum benefits, in contrast with many other projects where development has not reached the designed figures over decades.

The Irrigation Department has since got approved estimates for raising the capacity of Thal Canal to 7,500 cusecs, and may finally be raised to 10,000 cusecs.

Surveys are also complete for Irrigation supplies to some parts of Mohar Thal from Mohajir Branch.

Riverain Areas

Sir, under your guidance, the Irrigation Department started surveys for tubewells on the riverain areas too, which are since long deprived of adequate monsoon floodings. Fifteen such tubewells have been installed not far from here. The facilities will be extended to other riverain areas for which aerial photography has been arranged for quick and correct planning by the Irrigation Officer. Simultaneously ground surveys are being started. These riverain areas are extremely rich and will add greatly to the agricultural produce of the country in a short time. Not the entire sailaba areas need to be covered by a network of tubewells alone. Some of it can be helped by extending the existing channels wherever feasible but without depriving the old commands of their rights on water supply.

Sir, you are aware that the equitable distribution of water on all the canal systems of West Pakistan has already became complex and difficult, particularly since the loss of three eastern rivers. The pressure on land, increase in the number of holdings on watercourses, occasioned by the land reforms and settlement of refugees, and the awakening amongst the public for their water right, all necessitate a rigorous watch from head to tail of channels in an ageing canal system. The preparation and revision of legally correct share lists which are many times more than previously experienced, has alone increased the work-load of all ranks in the denuded strength of the Irrigation Department. The scientific remodelling of silted canals in changing regimes calls for a combination of a sound technical knowledge and experience for its correct application. The maintenance is no more a routine and often requires pooled and co-ordinated thinking of a strong body of Irrigation Engineers. The officers in the Irrigation Department are conscious of this responsibility and are watchful that with the growing attention to large eye catching projects the maintenance of our Irrigation System, the largest in the world, does not get neglected either for lack of funds or lack of an appreciation of its true importance.

Before I conclude I would like to think the officers of the Electricity Department and the Railways for their co-ordination and helping Irrigation officers to put this scheme into commission in a very short period of twenty-one months.

All the work of design and execution of Mianwali Lift Scheme was done under the general guidance of Ch. Fazl-ur-Rehman, P.S.E.I., Chief Engineer, Irrigation, Sargodha Zone. In the execution of the project, Mr. Nasir Sultan Ali Khan, the then Superintending Engineer, gave the job a good start. Mr. Mohammad Aslam Khan, who succeeded Mr. Nasir Sultan Ali Khan, put in sincere efforts for speedy completion of the scheme. The design of the Pumping Station and the canal system was ably handled by Mr. Sarfaraz Malik assisted by Mr. Abdur Rashid, Assistant Design Engineer and Ch. Ghulam Rasul, Chief Draftsman. The Civil Works were supervised by M/s F. H. Zaidi and Abdul Wassy Khan, Executive Engineers and later by Kh. Mohammad Afzal with their Sub-Divisional Officers, Messrs Niamat Ali and Mohammad Hanif, whose efforts are worth a mention.

The mechanical installation of the pumps and other equipment was carried out under the supervision of Mr. I. H. Ansari, Superintending Engineer, Tubewell Circle. His Overseer Chowdhary Ghulam Yasin handled the erection of the machinery from the beginning to end. They all have done a good job. I would request the Governor to kindly present "Sanads" to the three overseers and one Chief Draftsman, whose contribution has been greatly appreciated by all.

In the end I would request the worthy Governor to kindly switch on the Pumping Station and inaugurate the Scheme.

"PAKISTAN PAINDABAD"

Mailsi Siphon Completed

On December 12, 1964, Mr. Ghulam Ishaq Khan, Chairman, Wapda, congratulated the Mailsi plan contractors on the completion of Mailsi Syphon, a major structure on the Sutlej River for covering the workers of the Trimmu, Sidhnai Mailsi Link to the Balwal Link. It is the first major construction project completed under the Indus Basin settlement plan. In this article we have given the settlement features of the work for the information of the readers.

Introduction

Mailsi Syphon is a major river structure of the Trimmu-Sidhnai-Mailsi-Bahawal system for crossing the Sutlej river. This is the final link undertaken for construction under the Indus Basin Project. The link taking of from Trimmu flows into Sidhnai on the River Ravi. Another link connects Sidhnai with Marale. Crossing the Sutlej to feed the Bahawal canal system.

The maximum discharge of the link at the crossing is 5200 cusecs. It is located about 8 miles south of Mailsi town and 30 miles downstream of the existing Islam Barrage. In the original scheme a barrage was proposed for crossing the river. Detailed investigations, however, revealed certain undesirable features in the barrage scheme. The primary concern was in respect of the high pond level of 434.5 which was 5.5 feet higher than the estimated maximum high flood level of 429.0 at the site of the crossing. The normal practice in the Indus Basin is to provide a pond level for the barrage which is lower than the maximum high flood level at the site before the construction of the barrage. Departure from this practice in the case of Mailsi barrage could lead to serious problems of accretion of river level upstream, heavy pond losses and the consequential water-logging of the adjoining areas.

The above considerations led to the investigation of the following alternative :

(1) An Aqueduct.

(2) Syphon without gates.

(3) Gated Syphon.

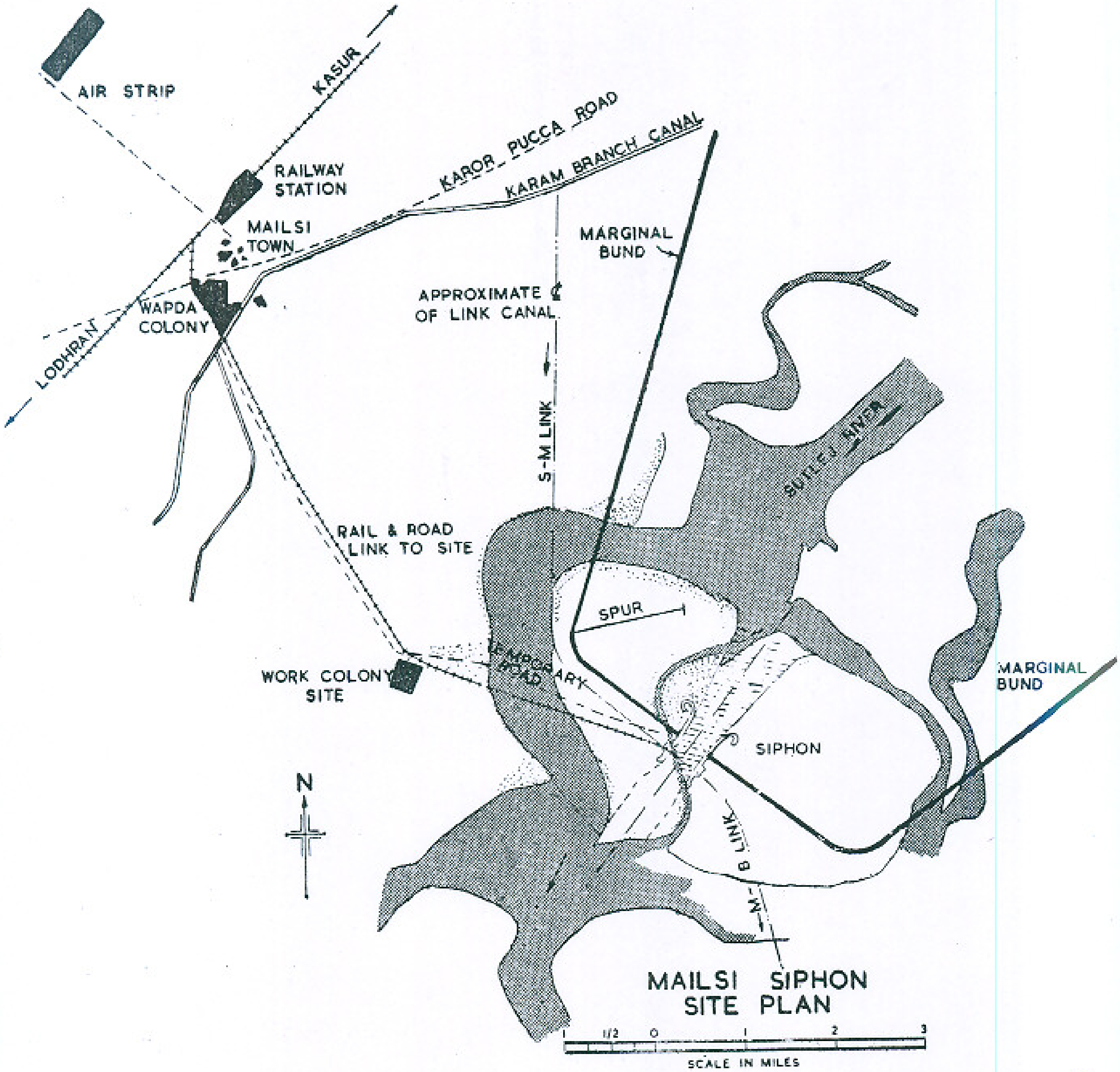
Aqueduct

This proposal had many disadvantages compared to the other alternatives. Due to limitations of the level the minimum clearance between the bottom of the aqueduct flume and the maximum high flood level in the river was only 2.5 feet. With the accertion of the river bed level in the future this clearance would have further reduced and if the water level reached or exceeded the bottom level of the flume, the structure was likely to be damaged. Further the length and height of banks in the canal was greater than for the barrage or the syphon alternatives and would have resulted in additional cost. In view of these disadvantages this alternative was dropped.

Syphon without gates

This alternative visualised a reinforced concrete syphon with five barrels with the top of the barrels at the existing bed of the river and being the shape of weir to discharge modularity the river floods. Solid concrete and flexible concrete block aprons would be provided in the same way as for a barrage. Such a design proved to be most economical in cost, but had the following disadvantage:

(*a*) There were no means of regulating the river and controlling the approach



MAILSI SIPHON SITE PLAN

conditions which had resulted in heavy concentration of river flows in certain portions of waterway resulting in objectionable scour.

(*b*) There was no bridge crossing to faciliate inspection of link from the downstream and of the syphon to the Bahawal Canal.

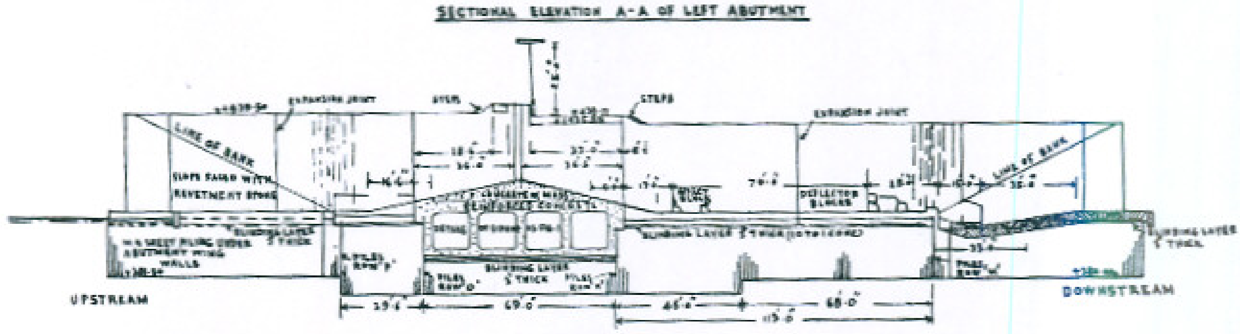
Gated Syphon

In this alternative the main disadvantages in the simple syphon crossing were eliminated by providing:—

(*i*) Gates as in the case of a barrage to a lower height, in order to prevent undue concentration of river flows and to correct the approach conditions

MAILSI SIPHON

SECTIONAL ELEVATION A-A OF LEFT ABUTMENT



whenever necessary.

(*ii*) The provision of a bridge both for the operation of the gates as well as to provide access to the other side of the river.

The gated syphon alternative had all the advantages of a barrage in respect of efficient discharging of floods, and this scheme was finally adopted for crossing the Trimmu-Sidhnai-Mailsi-Bahawal system across the Sutlej river.

Structure

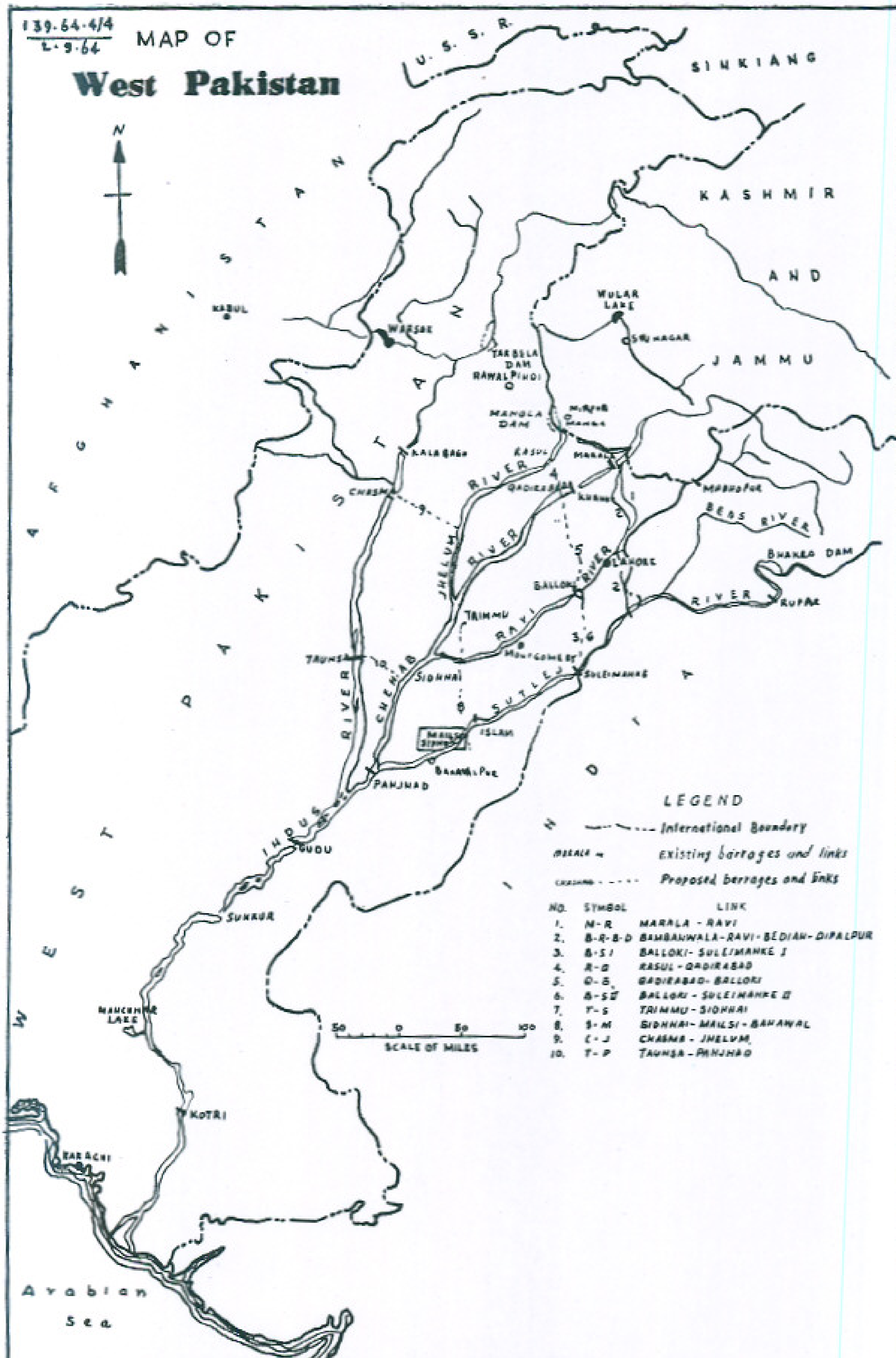
The main structure consists of four, 13′—6″ square. The total length of the barrels is 1874 feet. On top of the barrels are 23 concrete piers at 67 feet centres. Between the piers are steel gates which will control the flow of the river Sutlej over the top of the weir and syphon barrels.

The piers also carrry two prestressed concrete bridges, each spanning 60 feet. One bridge is a narrow service bridge for operating the gates, the other is a 33 feet wide road bridge. The Macalloy system of prestressing is used.

At the north end of the syphon, flow through the barrels is controlled by steel sluice gates.

In the river channels upstream of the wier heavily reinforced concrete tunnels each over the syphon barrels is a blockwork apron 57 feet wide, and a narrow concrete floor 29 feet wide. Downstream of the weir is a concrete floor 112 feet wide and a block work apron 77 feet wide.

Parallel to the syphon barrels and perpendicular to the river are four rows of steel sheet piles. These rows of piles are bedded into the concrete structures which are on two of them, and act as cut-offs to the flow of water through the sub-soil below the structure. The sheet piles also reduce the uplift pressure due to the river water.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MAP OF
West Pakistan
N
U.S.S.R.
SINKIANG
KASHMIR
AND
JAMMU
AFGHANISTAN
WEST PAKISTAN
INDIA
KABUL
WULAR LAKE
SRINAGAR
TARBELA DAM
RAWALPINDI
MANGLA DAM
KALABAGH
RASUL
MARALA
CHASMA
QADIRABAD
LAHORE
BALLOKI
TRIMMU
MONTGOMERY
TAUNSA
SIDHNAI
SULEIMANKE
ISLAM
BAHAWALPUR
PANJNAD
GUDU
SUKKUR
MANCHHAR LAKE
KOTRI
KARACHI
BEAS RIVER
BHAKRA DAM
RUPAR
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
INDUS RIVER
Arabian Sea
SCALE OF MILES
50 0 50 100
LEGEND
International Boundary
Existing barrages and links
Proposed barrages and links
NO. SYMBOL LINK
1. M-R MARALA - RAVI
2. B-R-B-D BAMBANWALA-RAVI-BEDIAN-DIPALPUR
3. B-S I BALLOKI- SULEIMANKE I
4. R-Q RASUL - QADIRABAD
5. Q-B QADIRABAD- BALLOKI
6. B-S II BALLOKI - SULEIMANKE II
7. T-S TRIMMU - SIDHNAI
8. S-M SIDHNAI- MAILSI - BAHAWAL
9. C-J CHASMA - JHELUM
10. T-P TAUNSA - PANJNAD

Loads and Capacities

The syphon barrels are designed to take a maximum flow from the link canal of 5200 cusecs. The velocity of flow through the barrels at this capacity is 7.22 feet sec. The loss in head over the length of the syphon is about 2 feet.

The weir is designed to take a maximum flow in the river Sutlej of 429,000 cusecs, which is 2000 more than the maximum flood ever recorded in 1955 at the Islam Barrage, 30 miles upstream.

The road bridge is designed to take the Ministry of Transport (U.K.) standard loading for highway bridges, *i.e.* a distributed load of 220 lbs/sq. ft., and centrally placed knife-edge load of 2,700 lbs. perlin. ft. It is also designed to take a Class 70 military loading.

The ground under the syphon barrels, and under the abutments, has to be densified to take a load of 3 tons/sq. ft. This was done by the "Vibroflotations" process. A steel cylinder is forced into the ground by water jets and an internal vibrator. A crater is formed around the cylinder by vibration, and this crater is filled with coarse granular material. The surrounding ground is compacted by the vibrations. These craters, or probes, have been placed at 6′—6″ centres. The ground under the downstream floor has to be densified to less than 2 tons/sq. ft., and this is being carried out by exacavation, and the recompaction of suitable filling in their layers with mechanical plant.

River Control and Diversion

The permanent flow of the river over the weir is controlled by the 24 steel gates. These gates are necessary to prevent excessive accretion or excessive scour at any one point upstream or downstream of the weir. The gates will be manipulated to achieve an even river bed in the vicinity of the weir.

The flow towards and away from the weir is diverted by two guide banks, 3580 feet long. The sloping surfaces of these banks in contact with the flowing water are armoured with tightly packed pitching stone. At the toe of guide banks are wide loose stone aprons to protect them against scour.

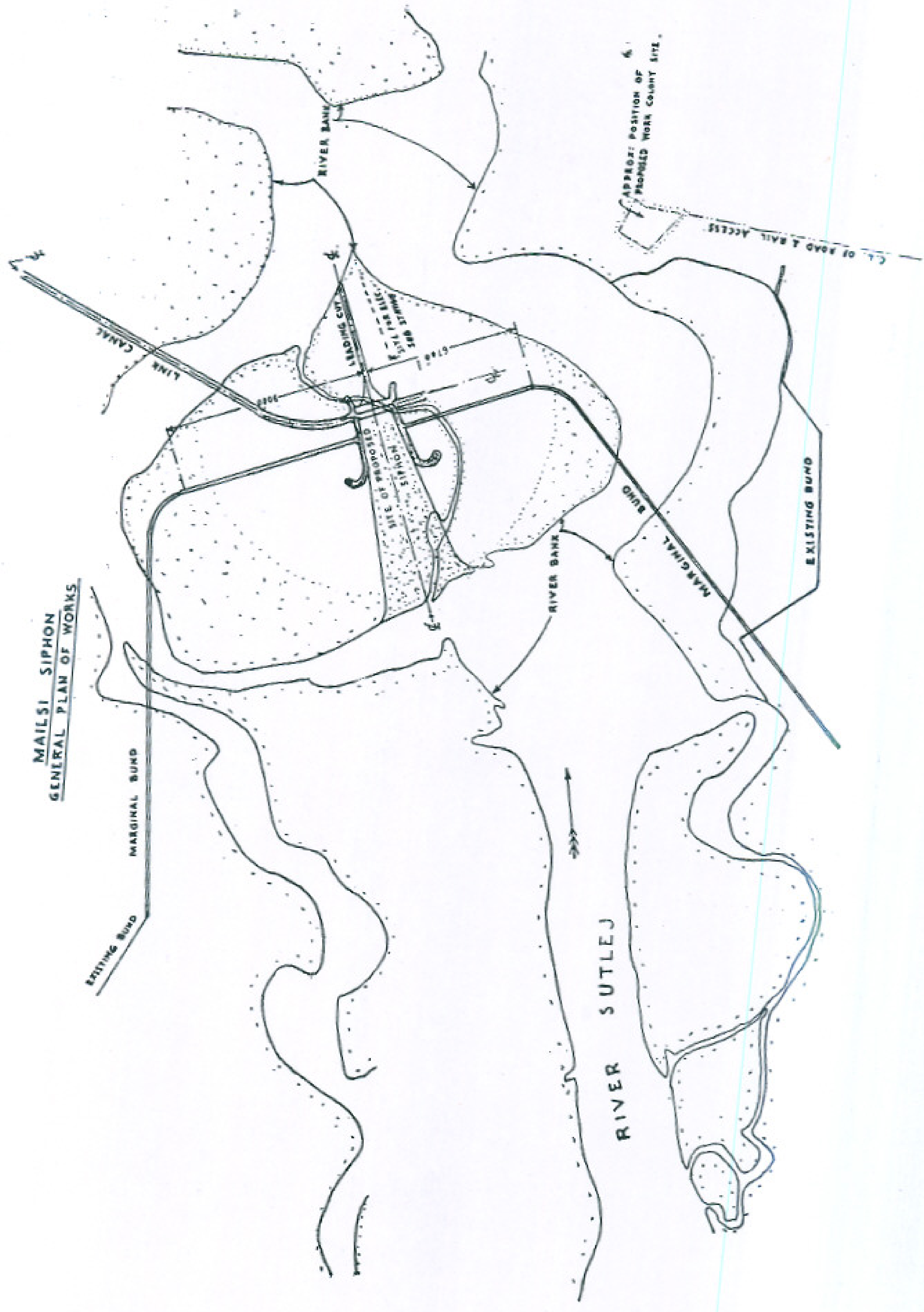
The whole possible flood zone of the river is enclosed by earth marginal bunds, which extend upstream of the syphon for about 15 miles on either side of the river. An armoured spur about 5700 feet long, juts out from the right marginal bund, and helps to direct the main current of the river away from the unprotected bund towards the upstream tips of the guide banks.

The syphon is being constructed in the dry, on an island in the river. The main right channel of this has been blocked by the right marginal bund, and the river during the construction period, has been diverted across the island, but around the left side of the works-area. This was done by digging a narrow leading out, about 100 feet wide, and about 3½ miles long, along the line of the required diversion. The early floods widened and deepened this cut, until its capacity was sufficient for the later large floods. The works area was meanwhile protected by the permanent guide banks and by temporary earth coffer_dams.

Technical Data

Weir—

Design discharge	429,000 cs.
Flood of Record	427,000 cs.
H.F.L. upstream	434.82
H.F.L. downstream	430.50
Length between abutments.	1601 ft.


MAILSI SIPHON
GENERAL PLAN OF WORKS
LINK CANAL
LEADING CUT
SITE OF PROPOSED SIPHON
SITE FOR ELEC. SUB STATION
RIVER BANK
RIVER BANK
MARGINAL BUND
EXISTING BUND
MARGINAL BUND
EXISTING BUND
APPROX: POSITION OF PROPOSED WORK COLONY SITE.
C.L. OF ROAD & RAIL ACCESS
RIVER SUTLEJ

No. of openings	24 spans at 60 ft. each.
Crest Level	415.50
Height of gate	7.0 ft.
Top of gate level	422.50

Syphon—

Length of horizontal portion.	1668 ft.
Length of inclined portion u/s	106 ft.
Length of inclined portion d/s	100 ft.
No. of barrels	4
Size of barrels	13.5×13.5 ft.
Max. discharge in the barrels.	5200 cs.
Max. velocity in the barrels.	722 ft/sec.
Head loss in the syphon	1.99 ft.

Guide Bank—

Length upstream	3580 ft.
Length downstream	830 ft.
Type	Diverging.

Marginal Bunds—

Right Marginal Bund	84,000 ft. long.
Left Marginal Bund	67,000 ft. long.

(*Continued from page* 31)

In view of the huge costs involved WAPDA has constituted a Board of eminent engineers and soil mechanicians. The Chairman of the Board is Dr. Casagrande, the other member is Dr. Slichter and the second member is Mr. Peterson. The Board is scheduled to meet in London on 26th Oct. 1964 and will pay a visit to the Site on 27th October, 1964. They are expected to give their findings during the middle of November, 1964. We expect that the Board will give some independent views and may modify the proposed remedial measures. However in case the Board upholds the proposals of the Consulting Engineers, we will at least be satisfied with the additional expenditure on these remedial measures.

The suggestions of Board are eagerly awaited.

Mangla Dam Problem

By **RAMIZ AHMAD MALIK,**
Director, Mangla Dam Project, West Pakistan, WAPDA.

In this interesting article the author has traced the history of the investigation of Mangla Dam and some of the problems which have been brought to light very recently. Mr. Ramiz has been associated with Mangla from the time it was conceived and investigations were started. Nobody is more informed about the stages through which the investigation, the design and the construction of the Dam has passed through. This informative article is partly based upon a lecture which he delivered to Engineers in Lahore recently.

Preliminary Investigation at Dam Site

The idea of damming Jhelum River near Mangla was conceived by S. S. Kirmani in 1952. In September, of the same year Mr. Roice J. Tipton visited the site as part of his General Survey of the water resources of West Pakistan.

On the advice of Mr. Tipton, the Government of Pakistan established an Organization known as Dams Investigation Circle for investigating possible dam sites in West Pakistan. A Consulting Board was also appointed by the Government of Pakistan in early 1953 to advise Dams Investigation Circle. This Board consisted of Mr. Raymond A. Hill, an eminent American Engineer, Mr. Roger Rhoades, a Geologist and Mr. Thomas M. Leps. The investigations for the Mangla Dam site principally consisted of aerial photography of the reservoir area and explorations to determine depths to bedrocks and their nature and the amount and character of available material for Embankment Fill. A total of 126 test pits were dug to an aggregate depth of 2835 feet, 12 diamond drill holes were put down to an average depth of 136 feet and three adits were excavated in characteristic formation. Geologic mapping was done by the officers of Geological Survey of Pakistan. The investigation and laboratory tests were so programmed that a feasibility report could be prepared by the Board during May, 1954.

The salient features of the report were that a storage of 4.1 million acre feet capacity could be had with the top of dam at R.L. 1200 and water conservation level of R. L. 1178. This gave a dam 365 feet high above the bedrock in the deeper section. A spillway of 1 million cusecs capacity was considered sufficient. *Four* 26 feet diameter tunnels were proposed for diversion of the river, and for installing power units each of 75,000 kilowats capacity. The annual rate of siltation was estimated equal to 40,000 acre feet.

The recommendation of Mr. Hill and Company were based on the investigations of over a year only. In 1957 Binnie and Partners were appointed as Consulting Engineers and they carried out detailed Investigations for about 3 years before the project was put to tender. These detailed investigations confirmed that the lay-out structure proposed by Mr. Hill was sound and practically feasible. The annual silting rate of 40,000 acres feet was also confirmed. There has been only one material change whereas Mr. Hill proposed bowing of materials from upstream and downstream if the dam site, Binnie and Partners thought that the excavated materials both sandstone and clay could be used as fill materials. (Now I discuss some of the design considerations for the Main Structures of the Project.)

A good Omen

A Helicopter of the Agriculture Department, Government of Pakistan had been hired for reconnaissance. It operated from Irrigation Rest House, Mangla. Two Geologists first went for reconnaissance and came back to the Rest House. In the second trip Mr. Hill accompanied the Pilot. They, however, did not return for several hours. After about 5 hours the Pilot and Mr. Hill walked into the Rest House saying 'here we come minus the Helicopter'. The Pilot told the story of the accident. After reconnaissance when they were coming back and flying along the river, they suddenly heard some noise in the gear box and the Helicopter started falling rapidly. Landing on the sandy ground was not advisable due to expected immense impact and hence they dropped the Helicopter in the river stream. After getting a dip in the river both the Pilot and Mr. Hill released themselves from the belts and started swimming. The Pilot landed in shallow water and waded to the river bank safely. Mr. Hill fell in the deeper water and was carried by the strong current of the river. However after some distance he touched the shallow water with deep channels on both sides. The local people came to his rescue and brought him to the shore with the help of inflated goat-skin. They took a boat and rowed down to the Rest House. Some people took it as a happy omen that sooner or later this project was going to go through as machinery pieces had gone to its foundations right from the start.

Azim-ud-Din puts an alternative

On receipt of the Feasibility Report from Messrs. Tipton and Hill the Government of Pakistan seriously started work on the project. A construction Circle for the construction of roads and buildings was sanctioned in March, 1955. In the meantime Mr. Azim-ud-Din now head of Associated Consulting Engineers and who at that time was Chief Engineer, Central Engineering Authority gave an alternate proposal for the Mangla Dam Project. He proposed a concrete dam of about 120 feet on the Jhelum River near Kamalpur and another dam on Poonch River just upstream of its confluence with the Jhelum River. The water from the Jhelum River was proposed to be diverted to the reservoir in Poonch River through tunnels.

It was claimed that this scheme would give almost the same irrigation yield, and the reservoir on Poonch River would have much longer life because only a small protion of silt of Jhelum River would enter this storage. The Government of Pakistan immediately stopped construction of preliminary works at Mangla and desired investigations of the proposals. About a year was spent on investigation of this alternative. It was, however, found that the bed level of Jhelum River had been assumed 100 feet higher than the actual. This increased the height of the dam to 220 feet. Another six months' work proved the proposal to be much more expensive. Thus after a delay of one and a half year the Government of Pakistan then gave the clearance for going ahead with the preliminary works at Mangla.

Binnie and Partners appointed Consultants

During December, 1957, Messrs. Binnie, Deacon and Gourley (Now Binnie and Partners)—an English Firm, were appointed as the Consulting Engineers for detailed investigations and design of the Project. The idea of changing the Consulting Engineers was to have a second opinion on the Project. In December, 1958 Binnie and Partners gave an interim report confirming that the Project was feasible.

Recommendations of the Review Board

The Government of Pakistan again appointed a Board of 3 eminent engineers to review the designs of Binnie and Partners. The Board gave their findings during October, 1959. They accepted the designs of the Consulting Engineers and proposed two significant changes. They objected to the safety of the proposal Mirpur Dyke where the depth of rock was over 1,000 feet. The silt on which the dyke was to be founded on saturation would act like jelly and could be destroyed by an earthquake even of an ordinary intensity. The Board, therefore, recommended the omission Mirpur Dyke and in its stead a dam constructed on Jari Nullah about 4 miles upstream of the Mirpur Dyke. Binnie and Partners were not sure of the stability of the rock during tunnel excavations. They, therefore, proposed an experimental tunnel costing a sum of Rs. 1 crore. It was proposed that it would ultimately frame a part of one of the main tunnels. The Board did not agree to this recommendation and suggested its omission. The Board also laid down certain criteria for the Spillway and the Tunnels. The subsequent designs of the Project for various structures were made in the light of the recommendations of the Board.

Conservation Level

Messrs. Tipton and Hill proposed a Conservation Level of 1178 which gives a gross storage of 4.1 M.A.F. Messrs. Binnie and Partners, however, considered it economically practicable to increase the Conservation Level to 1202. As Mangla is the only suitable site for Storage on this river, it was considered necessary to exploit it to the maximum. No doubt full exploitation of the Jhelum River, a storage capacity of about 32 M.A.F. is necessary. This needs an impounding level of about 1420 and a dam height of nearly 550 feet above the river bed level. However, limitations imposed by Jari Dam and Sukian Dyke made the consideration of a dam of this height impracticable. The maximum Conservation Level which is considered feasible at Mangla is 1252. For Stage I Conservation Level of 1202 has been adopted.

Spillway Capacity

The Board of Consultants stipulated the following criteria for the Spillway Capacity:

(*i*) It should be able to discharge all floods of record without significant surcharge above the Conservation Level.

(*ii*) The Main Spillway Capacity combined with the fuse plug discharge capacity should be able to cope with the maximum probable flood.

(*iii*) The fuse plugs in the event of a malfunction of the spillway, should be eashed out when the water level in the reservoir starts raising above the Conservation Level.

Subsequent investigations, however, showed that suitable site did not exist where fuse plugs could be located and operated without any serious danger to the Dyke. Besides, if these fuse plugs did operate, some considerable damage to property and possible life was bound to occur. Considerations were, therefore, given to an "Emergency Spillway" which would come into operation at water level not very far above the Conservation Level.

The main spillway was to be so designed as to pass the flood of record without any significant surcharge above the Conservation Level.

The Main Spillway and the Emergency Spillway both together should be able to pass the maximum probable flood. In case the Main Spillway were completely inoperable, the Emergency Spillway should be able to pass the flood of record.

Data of the last seventy years of floods are available on the Jhelum River. The maximum flood occurred in August, 1929 when the estimated peak flow was 1.1 million cusecs. Another highest flood on record is that of July, 1959. It had a peak flow of 827,000 cusecs. The total volume of this flood exceeded that of 1929.

On the basis of this information the Spillway capacity was initially set at 1.1 million cusecs with reservoir level at 1202. It was, however, realized that even if this capacity were reduced substantially, the flood of 1929 could be passed with only a very small rise above 1202. It was, therefore, decided to reduce the Spillway Capacity to 90,000 cusecs at Conservation Level. A spillway of this capacity involved a rise in reservoir level of about 1.0 foot above 1202 while passing of a flood of 1.1 million cusecs.

The Crest of the Emergency Spillway was set at 1202 but to prevent the waves washing down the Spillway, the rest is proposed to be protected by a bund of erodible material to a level of 1206. The Emergency Spillway would discharge to Bara Kas which would not be able to pass a discharge of more than 2,30,000 cusecs without erosion of the nullah.

Thus taking the capacity of the Main Spillway as 90,000 cusecs with crest level at 1202 it would be able to pass in conjunction with the Emergency Spillway, the maximum probable flood with a reservoir level of 1228.

Free Board

The effect of wave wash has been worked out theoretically as well as by conducting hydraulic model tests at Walingford Laboratories in England. The longest fetch of the reservoir at the Main Dam lies in a NWE-SSW direction and is 14 miles long. With a wind velocity of 35 mile's per hour a wave height of about 6.0 ft. was expected. Thus the level of embankment was fixed at 1234.

Tunnels

Originally the Consulting Engineers proposed 6 tunnels of 28 feet dia. for the diversion of the river during construction of the Dam and later to serve as power tunnels, for the hydro-electric units. Later on they changed the scheme to 5 tunnels of 30 feet dia. Thus diameter of the tunnels was fixed keeping in view the geology of site. In no other countries tunnels larger than of 30 feet dia. have been excavated in similar rocks. In choosing the size and number of tunnels it was kept in view that the flood of record can be passed through the tunnels by constructing a diversion dam to a practical height which was taken as 1080. Also the velocity of water in the tunnels was not to exceed 70 ft./sec.

Period for height of diversion Dam

Flood routing studies were carried out to determine the height of the diversion dam so that the floods which occur can be safely passed through the tunnels. The four months during which the floods can occur are- December, February, March and July. Flood routing studies showed that after diversion of the river during September, the diversion dam must be raised to 930 elevation before 1st November, 980 elevation before 1st February, 1070 elevation before 1st March and 1080 before 1st June of next year. Raising of the diversion dam to these heights was considered the most critical aspect of construction and in order to provide incentive to the Contractor a total bonus of Rs. 1 crore has been allowed for if the Contractor raises the diversion dam to these elevations on the dates mentioned above.

Slurry Trench Cut off

Underneath the diversion dam the Consulting Engineers proposed a cut off by slurry trench method. Taking advantage of this provision the Contractor constructed two more slurry trenches to cordon off the core trench of the Main Dam. The overburden in the flood plain of the river is very pervious having a permeability ranging from 0.1 to 2 centimeter per second. The slurry trench reduced this permeability to 1×10^{-6} cm/sec. thus providing a very effective cut off. The slurry trench method consisted of excavating a trench with the help of dragline and keeping it full with a slurry made from bentonite having a high liquid limit. Continuing the excavation of the trench more and more slurry is added. The presence of slurry and its pressure in the trench, keeps out the underground water and at the same time the walls stand vertically. In this way a depth of excavation up to 80 ft. has been successfully done.

Hydraulic Jumps in the Tunnels

The river is to be diverted through 30 ft. diameter during the beginning of flow period of 1955. Hydraulic model of the tunnels were tested at Nandiour and at Lahore. During tests it was revealed that hydraulic jumps occur in the tunnels under a considerable range of flows. Pressure changes also occurred in the tunnels when the jumps were jumped. It was found that up to a discharge of 25,000 cusecs in the river pressing 5,000 cusecs per tunnel, there were no hydraulic jumps. For the discharge ranging from 8,000 to 12,000 cusecs per tunnel, hydraulic jumps started occurring, the air entrained in the tunnel coalesced into large bubbles causing blow-back through jumps. For a discharge of 15,000 cusecs, besides the blow-back some air bubbles travelled downstream also and blew out at the exit. No blow-backs were noticed at a discharge of 17,000 cusecs—all the air was carried downstream. The blow-outs occurred at the exit of the tunnels. Recording of pressures gave a high intensity. The positive pressure was as high as 120 feet of water. The negative pressures were of the order of 80 feet of water. It was known that the tunnels could stand positive pressures but the negative pressures were beyond the cavitation range. With a negative pressure of more 30 feet cavitation and chipping of the concrete takes place. In case of high velocity flow during a flood the possibility of excessive cavitation and failure of the tunnel lining existed. If a damage occurred during the diversion period, it would not be possible to repair the damage until the end of the river diversion. By that time the damage might be far-reaching and extremely serious. The blow-out particularly in tunnel No. 1 may give rise to vibration and which may jeopardise the construction of Power Station and installation of turbines and equipment. Several remedial measures were considered to control the function of the hydraulic jumps in the tunnels. Some of these were as under:

(*i*) Lower the invert level of the tunnels at the intakes.

(*ii*) Provide air vents in the roofs of the tunnels.

(*iii*) Control the discharge through individual tunnels by operation of upstream gates.

(*iv*) Control the pressure in the tunnels by operation tail gates.

(*v*) Provision of a gated weir in the tail escape channel.

(*vi*) Provision of a weir with needles in the tail escape channel.

(*vii*) Provision of Fabridam in the tail escape channel.

(*viii*) A protective lining or treatment of the tunnel soffits against cavitation damage.

(*i*) Lowering diversion intakes

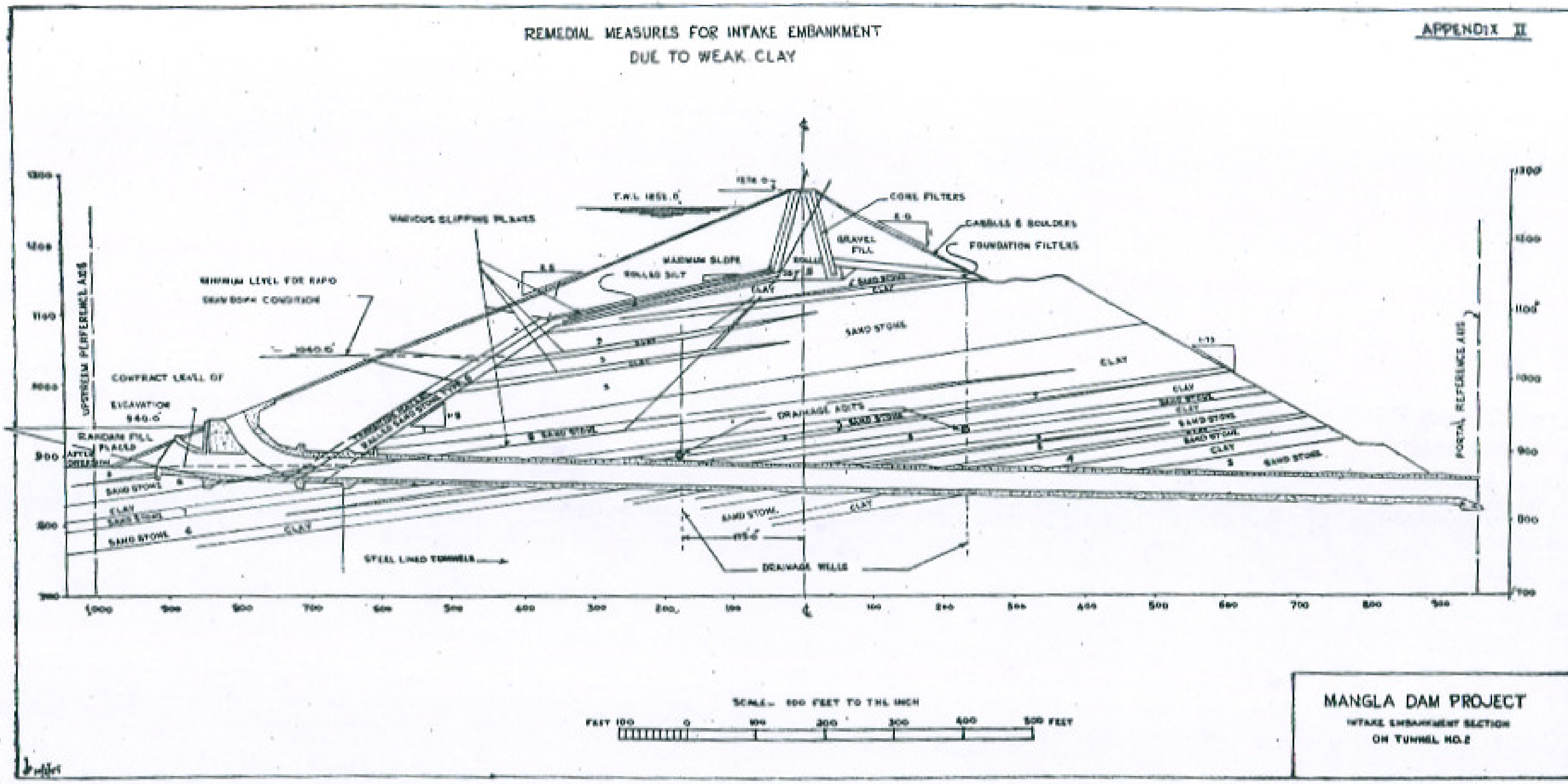
This, combined with a low weir upstream to maintain river levels and prevent gravel being drawn into the tunnels, would slightly reduce the hydraulic jumps but would not eliminate them. This solution was discarded.

(*ii*) Provision of air vents in the roofs of the tunnels

An air vent in the roofs of the tunnels was proposed by constructing a small tunnel parallel to and above the existing one. It was located close to the point of function of the jump. This measure showed that blow backs were eliminated but the construction of vents and air tunnels would be very costly and possibly not feasible due to overbreak and nature of the rock.

(*iii*) Provision of Upstream gate

The regulation of flow through the tunnels by low-ring or raising of gates was considered. It was proposed that when the river flow rose to 25,000 cusecs, four of the five tunnels would be closed. Flow in the remaining fifth tunnel would quickly rise to 25,000 cusecs at which discharge it would flow full and the hydraulic jumps would not occur. As flood rose higher, the remaining tunnels would be opened in turn, in each case at a discharge when the tunnel flowed full. This process was to be reversed with a falling flood. It was, however, realized that there would always be the possibility of human error and mechanical breakdown. Should it be found impossible to open one of the gates on a rising flood, the diversion


REMEDIAL MEASURES FOR INTAKE EMBANKMENT
DUE TO WEAK CLAY
APPENDIX II
T.W.L 1252.0'
CORE FILTERS
COBBLES & BOULDERS
FOUNDATION FILTERS
GRAVEL FILL
VARIOUS SLIPPING PLANES
MAXIMUM SLOPE
ROLLED SILT
MINIMUM LEVEL FOR RAPID DRAWDOWN CONDITION
1040.0'
CONTRACT LEVEL OF EXCAVATION 940.0'
RANDOM FILL PLACED
UPSTREAM REFERENCE AXIS
PORTAL REFERENCE AXIS
SAND STONE
CLAY
DRAINAGE ADITS
STEEL LINED TUNNELS
DRAINAGE WELLS
SCALE – 100 FEET TO THE INCH
FEET 100 0 100 200 300 400 500 FEET
MANGLA DAM PROJECT
INTAKE EMBANKMENT SECTION
ON TUNNEL NO.2

arrangements might be jammed with the possibility of the diversion dam being overtopped. This solution was, therefore, also given up.

(*iv*) Control of pressures by operation of tail gates

This solution was also similar to that providing the upstream gates. It was also dropped with the possibility of human error and mechanical breakdown. In the event of a gate jamming or failure of operating equipment, the tunnel discharge capacity would be reduced resulting in increased risk of the closure dam being overtopped.

(*v*) Provision of a gated weir in the tail escape channel.

A gated weir in the tail escape channel would control the tailrace levels but the design, calling of tenders, manufacture and delivery of gates would have taken too long and gates would have been a costly solution.

(*vi*) Provision of a weir with needles in the tail escape channel.

The weir with needles in the tail escape channel would control tailrace levels. The needles would be hinged at their lower ends to enable them to be released quickly by the removal of pins during a rising flood. They could be lifted from a bridge by winches to riase the tailrace level and so the jumps would not occur. This solution was also considered to be very costly.

(*vii*) Provision of a Fabridam in the tail escape channel.

This scheme consists of the provision of inflatable bags, known as Fabridams in the tail escape channel.

These would be kept inflated during most of the diversion period and their height would be such that the jumps could be eliminated. The bags would be deflated during floods exceeding 130,000 cusecs so that the full flood discharge capacity of the tunnels would be maintained.

(*viii*) A proctive lining or treatment of the tunnel soffits against caviation damage.

This solution would be very costly but a spray coating of epoxy resin can reduce cavitation damage to concrete.

After consideration of the above mentioned proposals the Fabridam scheme was thought over to have the following advantages:

1. It costs less.
2. The controls are smipler and it could be raised in much less time.
3. Manufacturing and supply period much less.

Hydraulic model tests have shown that a Fabridam 10 feet high could reduce the cavitation pressures to safe limits and was thus suitable for controlling hydraulic jumps in the tunnels.

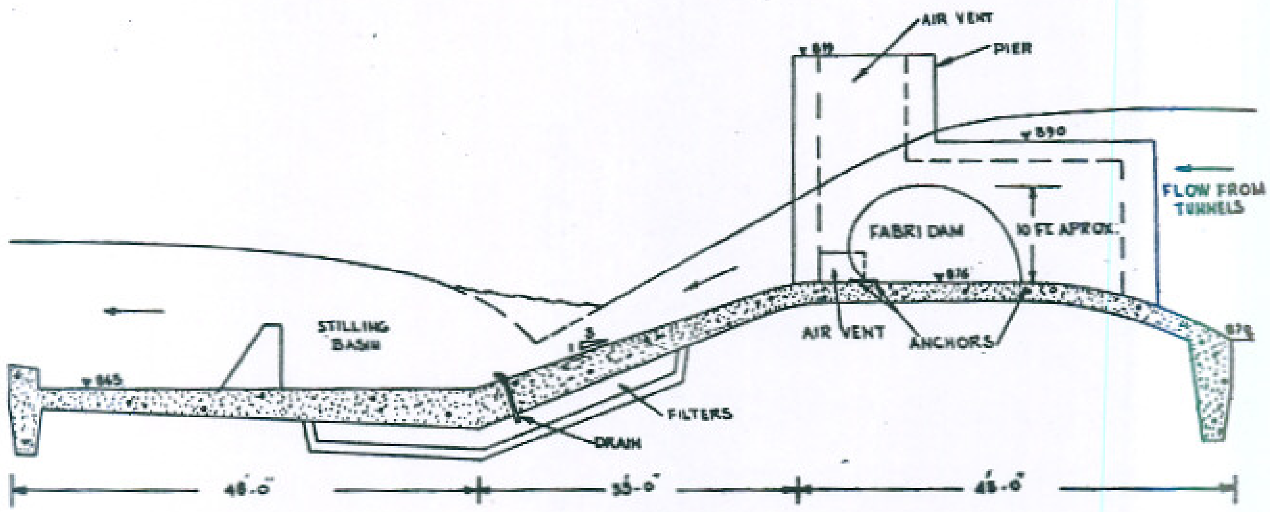
The Fabridam would consist of rubber bags which would go to the height of 10 feet above the crest under working conditions. It would be inflated by pumping in water and would be deflated by releasing the water. The inflation time would be about 1 to 2 hours and the deflation time $\frac{3}{4}$ to $1\frac{1}{4}$ hours. This scheme is estimated to cost about Rs. 4.25 million.

Design of Structures due to discovery of weak clays.

The Consulting Engineers have recently discovered that sheared and fractured clays occur near the top and bottom of some clay beds parallel to the bedding clays. The shearing angle of these weak clays varies from 18 degrees to 24 degrees. Previously the Consulting Engineers designed the struc-

FABRIDAM IN TAILRACE

SCALE:-10FT. TO 1 INCH



tures for a shear angle of 30 to 32 degrees. These weak clays give a lower factor of safety and therefore some remedial measures are essential. The first remedial measure is for the Intake Embankment for the portion of the Main Dam lying over the tunnels. This is most vital part of the Main Dam. Any mishap to this portion would be disastrous for the Power House.

Following remedial measures have been proposed for it:

1. Steel lining of the remaining portion of the Tunnels Nos. 1, 2 & 3.
2. Providing a blanket on the upstream face of the Embankment.
3. Providing a drainage gallery with drainage wells both up and down.
4. Loading the toe of Embankment with gravels.
5. Increasing the slip of the Embankment to the east of the Tunnels so as to prevent any slips.

All these measures are going to cost something like Rs. 25 million. The worst of all is that for steel lining of the tunnels, will reduce the diameters of the tunnels from 30 feet to 26 feet.

Besides the Main Spillway and Emergency Spillway are also to be redesigned and therefore the cost is going to be tremendous.

(*Continued on page* 22)

Silt Trouble in Jamrao Canal: ex-Nara Canal of Sukkur Barrage.

By **AHMAD HASSAN**
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Silt trouble in many irrigation channels is a result of improper regulations. The silting of Mithrao, Khipro and Nara canals is an example. The author, Mr. Ahmad Hassan, Irrigation Adviser to A.D.C., is a keen observer with vast background of regulation of canal supplies. With a simple change in regulation he has succeeded in eliminating the silt trouble from this canal system. His method can be adopted with advantages in other similar cases.

Nara Canal and its Branches

The Nara Canal was built in 1895. It was an inundation canal running in the bed of old Nara River. On the construction of the Sukkur Barrage in 1931, it was connected to the Barrage by excavating an 8 mile long channel, called the new Nara Cut. The canal thus became a perennial channel from 1932. The authorised full supply discharge of the canal provided in the Project is 13,602 cusecs.

The first offtake is at mile 115 where Jamrao canal with a perennial discharge of 3442 cusecs branches off upstream of a fall built in 1895. This fall is called the Jamrao Weir.

At mile 145 is situated the Makhi Weir. At this regulator three canals take-off:—

(*i*) The perennial Mithrao Canal, discharge 2,475 cusecs.

(*ii*) The perennial Khipro canal, discharge 1,005 cusecs and

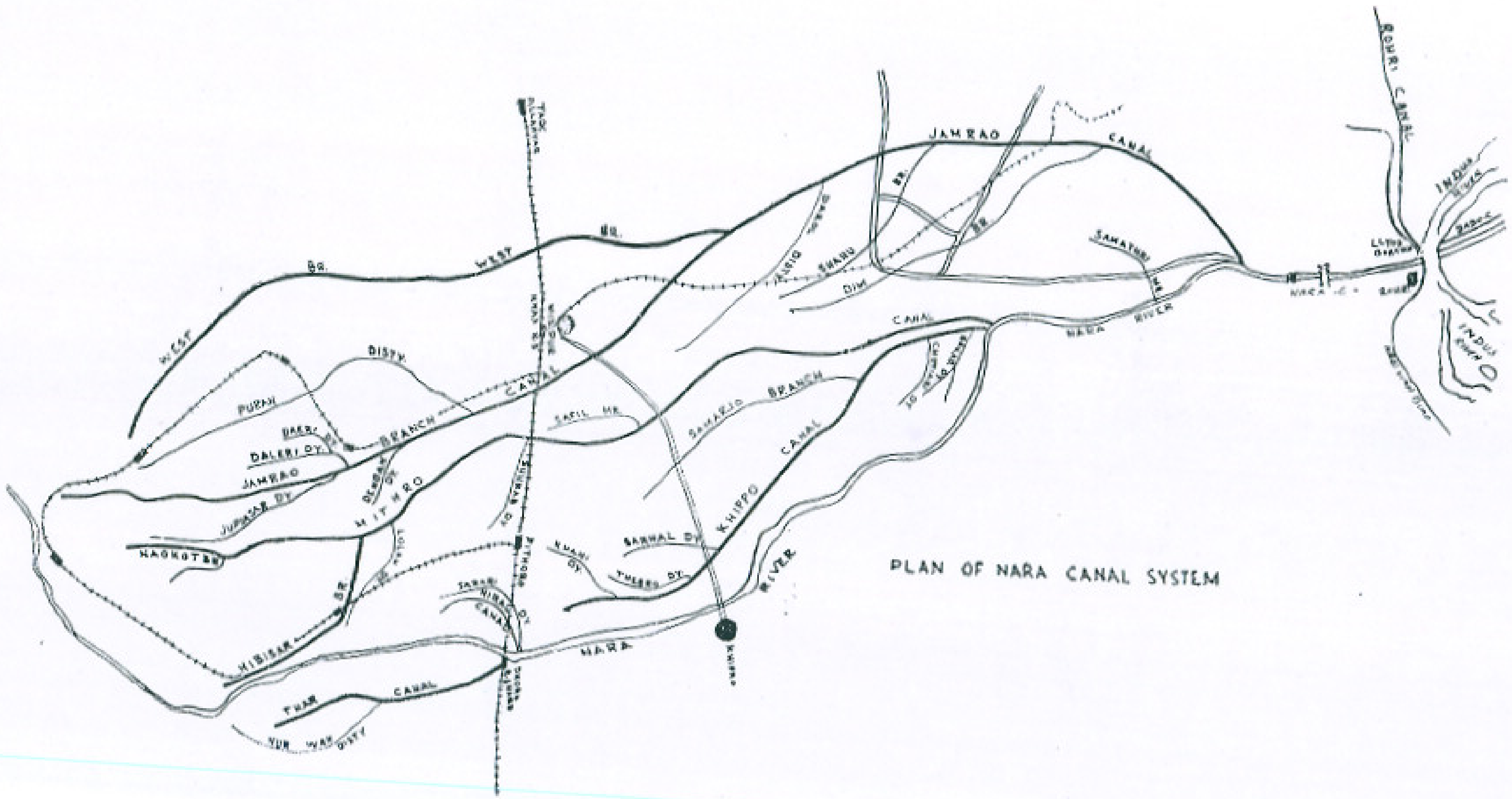
(*iii*) The non-perennial Nara Canal below Makhi Weir, discharge 2,887 cusecs.

The Nara Canal thus draws less discharge during Rabi (winter season) than during Kharif (summer season).

Silt Trouble Starts

On becoming a weir controlled canal, the Nara ran with its authorised discharge for a couple of years but later on its withdrawals decreased. Since the middle thirties it is getting only about 11,000 cusecs because of the serious silt trouble. It started in all its off-takes, especially in the Jamrao Canal.

The sanctioned surface slopes of Nara



Plan showing Jamrao Canal System of Sukhur Barrage

Canal as per L-section of the Project are as below:—

Nara Canal (Perennial)

Mile	Discharge (cusecs)	Slope
0— 0	13602	1/13000-New cut.
0— 8	13441	1/13000
8— 16	13280	1/11000
16— 33	12938	1/6100
33— 58	12434	1/6000
58— 88	11830	1/5400
88—115	11288	

Jamrao Weir at mile 115 to Makhi Weir at mile 145:

Mile	Discharge (Cusecs)	Slope
115+145	7888	1/5081

Makhi Weir D/s Nara (Non-Perennial)

R.D.	Discharge (cusecs)	Slope
0-115000	2887	1/6500
115-215000	2716	1/10600
215-365000	2427	1/13800
Below-365000	2090	1/13000

The steep gradients downstream of mile 33 were adopted because of those obtaining in the inundation canal and are more or less stable due to innumerable bends and stiff clay berms overgrown with thick jungle. The flatter slopes in the head reach compare favourably with the perennial Rohri Canal which takes off a little downstream from the same pocket of the Barrage. The Rohri Canal with an authorised discharge of about 10,500 cusecs was constructed to a slope of 1/10700 in the head reach but has retrograded its bed and adjusted to a slope of nearly 1/20,000.

Silt in Jamrao Canal

Soon after the construction of Sukkur Barrage and the running of Nara as a perennial canal, the Jamrao Canal, taking off at mile 115 started giving serious silt trouble which caused a lot of concern. Investigations were carried out by various officers but the real cause of the trouble could not be established. The silt deposits in the head reach went on increasing so much so that the water level at head rose above the designed by over 8 feet. Jamrao Canal was not able to get full supply discharge with the result that serious shortages were experienced all over its system.

Hydraulic surveys carried out show that the water levels at all the cross regulators on this canal are much higher than the original design. This has happened due to excessive heading up at the cross regulators to feed the off-taking channels. It may be stated that in spite of much higher water levels at the cross regulators, the cut offs (working heads) of the off-taking distributaries are mostly nil or very small. This shows that the water levels in the off-taking channels have gradually risen during the last many years to command larger areas, thus requiring raising of pond levels at the cross regulators.

It is not possible now to lower the water levels of the off-taking channels without creating serious repercussions. The areas cannot be thrown out of command after having been irrigated by flow for many years.

The behaviour of Jamrao Canal in the head reach is most peculiar. Carrying a perennial discharge of 3442 cusecs it has adopted very steep gradient in the head reach which is 1/5000 in the first 17 miles. The slope gradually gets flatter in the middle reaches till the discharge of the channel is reduced to about 2000 cusecs when it starts steeping again. The designed and existing surface slopes alongwith full supply discharges are given below:

R.D.	Discharge cusecs	Designed slope	Existing slopes
0—	3442	1/5835	1/5000
87—	2830	1/8672	1/1000
163—	2428	1/13480	1/1000
241—	2113	1/21100	1/14600
291—	1180	1/9047	1/10400
342—	963	1/15545	1/10500
385—	879	1/11700	1/9200
407—	762	1/17490	1/8200
443—	424	1/14263	1/9912

In order to investigate the causes of heavy silting up, extensive research was carried out. A lot of data were collected but the analysis of it did not give any satisfactory explanation for the serious silting trouble. At one stage, it was thought that this heavy silt in Jamrao Canal was due to blowing in of sand from the surrounding Tibbas. If one flies over the Nara Canal, he will find that the blowing sand could not be a contributing factor. Many other channels passing through much worse terrains in the Indus plain do not have such serious silting problems.

Cause of silt trouble, Defective Regulation at Jamaro Weir

The author visited the canal in 1958 and after studying its woking, discovered that the defective regulation at Jamrao Weir was responsible for the heavy silt deposits in the head reach of Jamrao Canal.

The discharge above Jamrao Weir during summer season is about 11000 Cs. and less than 8,000 Cusecs in winter.

As for regulation at Jamrao Weir, a fixed pond level was maintained all the year round even during winter when the discharge was reduced to about 2/3rd. This causes gradual silting up so that the silt deposits about 3 ft. in depth just upstream of the Jamrao weir. It diminishes gradually to nil in a length of a few miles following generally the backwater curve.

The silt deposits in the winter season. It gets flushed into the Jamrao and the Nara Canals downstream of Jamrao weir, with the increased summer supplies.

To overcome this difficulty, it was decided by the author in 1958-59 to maintain a variable pond level according to the discharge intensity. A gauge discharge relationship, as given below, was worked out and regulation was adopted accordingly.

JAMRAO WEIR

Total discharge approaching the weir	Pond level
cusecs	.. R.L.
7,000	.. 112.0
7,700	.. 113.0
8,800	.. 114.0
10,000 and above	.. 115.0

It may be pointed out that as the Jamrao Canal had already silted to such an extent that it could not be fed during Rabi with a pond of less than 112 ft. It was decided to adopt this as the winter pond level and raise the summer pond level to R.L. 115.0

Silting Characteristics of Perennial Canals

In most of the perennial canals of the Indus Basin, silt deposits take place in their head reaches during the summer season, when the river waters are highly silt charged. These deposits are picked up gradually and carried away by the clear waters during winter season, bringing the bed to its original levels.

In addition to the normal silt coming from the river during summer season, the heavy silt deposits in the pond area of Jamrao weir were flushed into the Jamrao and the Nara Canals downstream of the weir. These heavy doses of silt have proved much beyond the capcity of these canals to wash away during the winter.

Elimination of Silt trouble by Proper regulation

The Jamrao weir was remodelled in 1959-60 and a regulation with fluctuating pond was adopted. Because of insufficient height of the Canal banks, the pond at Jamrao weir could only be realised by stages to a maximum of:—

113.0 ft. during Kharif 1961.
113.8 ft. during Kharif 1962.
114.0 ft. during Kharif 1963.

Before the adoption of this system of regulation, the Jamrao Canal could not pass more than 2900 cusecs, with its head gauge of 17.3. As a result of new method of regulation, the silt in the head reach started scouring out and the chronic shortage trouble on the Jamrao Canal has been overcome. During Kharif 1963, the canal was able to pass 3310 cusecs with gauge height of 16 ft. only. This was 1.3 ft. lower than the period of silted bed and yet could pass a discharge for 400 cusecs more.

It is anticipated that, with the gradual scouring out of the bed, the water levels at the head of the Jamrao canal will continue to lower till more reasonable slopes are attained. It would thus be possible to lower correspondingly the pond levels during summer as well as during winter. The following programme is proposed for the future years.

Discharge	Pond levels, R.L.					
	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68
7000	112.0	111.0	110.5	110.0	109.5	109.0
7700	113.0	112.0	111.5	111.0	110.5	110.0
8800	114.0	113.0	112.5	112.0	111.5	111.0
10000 above	115.0	114.0	113.5	113.0	112.5	112.0

By 1967 the canal would be fed with a winter pond level of 109.0 and the maximum summer pond level of 112.0. The raising of pond to 115.0 during Kharif is thus a temporary measure.

The heavy silt deposits on being scoured out from the head reach of Jamrao Canal will gradually move down in the form of silt bars, raising up the water levels correspondingly until these will get dissipated and disposed of into the distributaries and the outlets.

Silt Trouble Below Jamrao Canal

Besides the Jamrao Canal, the heavy silt deposits washed downstream of the Jamrao weir have caused steep gradient in the Nara Canal. The existing gradient between Jamrao and Makhi weirs, a distance of 30 miles, is 1/5000. This is much too steep for a perennial canal having a Kharif discharge of about 7800 cusecs and Rabi discharge of about 4000 cusecs. The three canals below Makhi weir:

(*i*) the Mithrao perennial passing 2475 cusecs;

(*ii*) the Khipro perennial passing 1005 cusecs;

(*iii*) and the Nara non-perennial, passing 2887 cusecs, all have very steep slopes as depicted below.

R.D.	Discharge (cusecs)	Designed slope	Existing slope in 1958
(*i*) **Mithrao Canal**			
0-18000	2475	1/9000	1/5600
18-65000	2400	1/9000	1/11900
65-136000	2250	1/12000	1/14600
136-175000	2060	1/12000	1/14000
175-251700	1465	1/12000	..
(*ii*) **Khipro Canal**			
0-15000	1005	1/10000	1/3300
15-70000	910	1/10000	1/7700
70-91000	606	1/9500	1/9500
191-137000	509	1/9500	1/11000
137-176000	417	1/9500	1/10000
176-195000	250	1/9500	1/8000
195-248000	220	1/9500	1/9200
D/S-248000	167	..	..
(*iii*) **Nara Downstream Makhi Weir (Non-Perennial).**			
0-115000	2887	1/7000	1/6500
115-215000	2716	1/10000	1/10600
215-365000	2427	1/13000	1/13800
D/S of 365000 to 510 tail.	2090	1/13000	1/13824

To overcome the silt trouble in all the three canals, a modified regulation at Makhi weir was also adopted to fluctuate the pond levels corresponding to the discharges reaching there so as to reduce the deposit of silt in the pond area and getting it flushed out in the Kharif season.

It may be pointed out that the Nara Canal system unlike any other canal system in West Pakistan is non-perennial, with 1/3rd the total head discharge. The silt is collected in the pond areas and is then washed down. The quantities being much more than what the canals can deal with; thereby creating exceedingly steep slopes in their head reaches.

Silt Deposition in Barrages

The situation upstream of river barrages with regards to silt deposition is similar. The soundings taken in the pond between the months of October and April when the winter pond is maintained, show the difference. But in the case of a barrage, however, most of the silt deposited in winter gets flushed downstream of the river as soon as escapage through the Barrage increases with the rise in the river. The divide also controls silt entry into the canals. The case with Nara Canal is different. Here all the silt collected upstream of the Jamrao Weir and Makhi Weir has to find its way into the canals.

A similar deposition of silt takes place in all other canals of West Pakistan where excessive heading up is practised during low supplies, to feed the high level channels. When the silt is flushed out of the pond area, it gets deposited downstream of the canal, The canal starts widening itself by eroding its berms, to compensate for the rise in bed levels. Thus the serious silt troubles, on many of our canals are not entirely due to the sediment load that comes from the rivers but it is from the silt which is made to settle down upstream of the regulators by indiscriminate heading up and then flusing it down. The regulators where heading up is practised act as silt manufacturing devices and are in fact responsible for a lot of silt trouble on our canals. For the proper functioning of a canal system, the regulation at the cross regulators should be done extremely judiciously. The regime of a main or a branch canal should not be upset for the sake of feeding a high level channels. This effects the entire canal system.

FAO Regional Seminar on Water-logging and Salinity of W. Pakistan

A seminar on water-logging and salinity in West Pakistan was organized in Lahore under the United Nations expanded programme of Technical Assistance from 16th November, 1964 to 28th November, 1964. It was the largest symposium ever held in the country in which 78 experts drawn from various discipline at home and abroad participated in the deliberation. Never before in the history of West Pakistan such a seminar has ever been held, in this country with participation of so many experts on the subject.

Food and Agriculture Organization (F.A.O.) Rome, in co-operation with the Government of Pakistan, Ministry of Agriculture and Works has been entrusted to prepare the proceedings which will be another scientific document as valuable as the Revelle Report. In this volume we have reproduced brief information for the readers pending the issue of the proceedings.

The Programme

The seminar opened on the 16th November, 1964. The venue of the meetings was the Educational Auditorium on the Mall. In the morning at the time of registration, the participants were given folders containing a summary of the basic report which was earlier prepared by the working group of Pakistani experts and other informative documents connected with the seminar.

The seminar was formally opened by Mr. Rana Abdul Hamid, Minister for Agriculture, followed by a few remarks by Sayyed Hamid, the Director of the Seminar and by Mr. Webster the Associate Director of the Seminar representing F.A.O. organizations.

The working Session was held on the next two days on 17th and 18th of November when in four Sessions of 12 hours from 8.30 to 12.30 and 14.30 to 16.30 each day, various aspects of the basic report on Water-logging and Salinity in West Pakistan were introduced and so was the country reports presented by the foreign delegates. Some special papers on the problem in general were also put forth.

The next six days from 19 November to 24 November were spent on visits to Laboratories of WASID, Land Reclamation and Irrigation Research Institute. The working of Salinity Control Project No. 1 was seen, and so were the Lyallpur University, Saline and Alkaline areas of Montgomery and Ghulam Mohammad Barrage were also visited.

The discussion of the problem was again started on 25 November. It was completed on the afternoon of 17. During this period a visit to Chakanwali Reclamation Farm was also arranged. November 28 was the day for concluding the seminar and for departure of the delegates.

The Participants

The participants included 11 experts from seven countries of the near East, 4 consultants from F.A.O., 2 delegates from UNESCO and 2 delegates were from I.B.R.D. F.A.O. Organization had brought in 7 experts and other helpers, United States Aid Department sent in 4 officials. From Pakistan there were 21 participants and 27 observers which included 11 ex-patriate consultants of Wapda working in this country. The names and addresses of all the 78 participants are given here:

Foreign Participants

AFGHANISTAN

Mr. Abdul Mahboob
Irrigation Engineer,
Ministry of Agriculture.
Mr. Abdul Ghaffar Shuja
General Director, Irrigation,
Helman Valley Authority.

JORDAN

Mr. Khalil Hamdoukh
Irrigation Agronomist,
East Ghor Canal Authority.
Mr. Ibrahim Attour
Head of Hydrology Division,
Central Water Authority, Amman.

KUWAIT

Mr. Sam' Izzat Banna
Soil and Crop Specialist,
Agricultural Section,
Ministry of Public Works.
Mr. Wajeeh Saleem Farawana
Chief Chemist, Government Research Station, Ministry of Public Works.

LIBYA

Mr. Abdul Hamid Sef-el-Nasser
Geologist, Technical Department,
Ministry of Planning.

SOMALIA

Mr. Mohammad Hersi Bahal
Head of Agricultural and Horticultural Service, Ministry of Agriculture.

SYRIA

Mr. Baha Dabbous
Head of Irrigation and Drainage Section,
Ministry of Agriculture.
Mr. M. Walid Dardari
Engineer, Design Office,
Major Projects.

SAUDI ARABIA

Mr. Abdul Mannan Turjoman
Director, Plant Production Department,
Ministry of Agriculture.

Consultants

Dr. Charles A. Bower
Director, U. S. Salinity Laboratory,
Agricultural Extension Service,
University of California, U.S.A.
Dr. Robert M. Hagan
Professor, Irrigation, Davis, California.
Dr. Milton Fireman
University of California Extension Service.
Dr. C. Van den Berg
Director, Institute of Land and Water Management, Netherland.

Sitting L to R: Mr. Sarwar Jan Khan, Dr. M. S. Qureshi, Mian Muzaffar Ahmad, Pir Muhammad Ibrahim Qureshi, Mr. Thomas Maddock, *US-Aid*. Mr. J. A. Van't Leven *F.A.O.* Miss A. Hulse. *F.A.O.* Professor A. Pillsbury, *F.A.O.* Mr. I. McCallum Webster, *FAO-Associate Director of Seminar*, Mr. Sayyid Hamid, T.Pk., *Director of Seminar*, Professor V. Kovda, *Unesco*, Dr. Milton Fireman, *U.S.A.* Professor C. Van den Berg, *Netherlands*, Dr. Charles A. Bower, *U.S.A.* Baha Dabbous. *Syria*, Mr. Abdul Ghaffar Shuja, *Afghanistan*, Mr. Abdullah Arar, *F.A.O.* Mr. Herbert E. Skibitzke, *US-Aid*, Dr. Robbert M. Hagan. *U.S.A.*

Standing 1st Row : Mr. Fateh Khan Bandial, Mr. Sa'adat Ali, Mr. S. B. Hasan, Mr. Anwar-ul-Haque, Mr. Shah Mohammad, M. Manzoor Ahmad T.Q.A., Mr. G. B. Laghari, Mr. Ahmad Hasan, Mr. Anis Ahmad, Mr. M. A. Lateef, Dr. Muhammad Iqbal, Mian Shamim Ahmad, Ch Mohammad Shaffi Gill, Mr. Ghulam Muhammad, Mr. Mumtaz Ali, Mr. W. V. Swarzanski, *US-Aid* Mr. Muhammad Hersi Bahal, *Somalia*, Mr. Abdul Mahboob, *Afghanistan* Mr. Abdul Mannan Turjoman *Saudi Arabia*, Mr. S. M. Said.

Standing 2nd Row : Mr. W. H. Ellis, *Ibrd*, Mr. M. de Forges, *FAO/Unesco*, Ch. Fazal Illahi, Dr. Nazir Ahmad, Mr. M. A. Hafeez, Mr. G.D. Farooqi, Mr. Khalil Ahmad Soomro, Mr. Khalil Hamdouth *Jordan*, Ch. Mohammad Hussain. Mr. M. Badr-ud-Din, Mr. Ibrahim Attour *Jordan*, Mr. M. Shakoor, Major Edward *Ibrd*, Mr. P. Kirpich *Ibrd*, Mr. Sami Izzat Banna, *Kuwait*. Mr. Wajeeh Saleem Farwana, *Kuwait*, Mr. M. H. Bhatti, Dr. C. B. Harstos, Mr. A. R. K. Javeed.

UNESCO Officials

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U.S. A.I.D.

Mr. Thomas Maddock
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Mr. Herbert E. Skibitzke
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Mr. G. D. Bennet
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Agricultural Economist,
Harza Engineering Co.,
International, Sunny View, Lahore.

Mr. G. R. Hoffman
Chief Project Engineer,
Hunting Technical Services Ltd.,
5-H Gulberg, Lahore.

Dr. G. A. Stiven
Senior Soil Chemist,
Hunting Technical Services Ltd., Sukkur

RANA ABDUL HAMID
Central Minister for Agriculture and Works inaugurates Seminar on Water-logging and Salinity

On the afternoon of 16th November, Rana Abdul Hameed, Minister for Agriculture and Works, Government of Pakistan, inaugurated the Seminar on Water-logging and Salinity. The inaugural address was followed by introduction by I. McCallum Webster, Associate Director of the Seminar and representing F.A.O., Rome. Below we have reproduced both the addresses in full:

Rana Abdul Hameed said, "It is both a pleasure and a privilege to welcome you all on behalf of the Government of Pakistan to this Seminar on Water-logging and Salinity which has been convened in co-operation with the Food and Agriculture Organization of the United Nations.

This Seminar has a special significance for Pakistan. Water-logging and Salinity are universal problems, wherever irrigated agriculture is practised, but perhaps these problems are nowhere quite so serious or involved as in West Pakistan where the very basis of the economy is irrigated agriculture. The incidence of Water-logging and Salinity in West Pakistan has assumed such serious proportions and circumscribed agricultural production to such an extent that it has become one of the foremost problems facing the country. Realising the urgent need to increase food and fibre production for a rapidly increasing population, and to raise the standards of living of the people, a large majority of whom depend on agriculture for a living, Pakistan Government has been actively engaged in trying to solve this basic problem facing its agriculture. Our past experience has indicated that the solution of this problem in all its related aspects is not a straightforward matter and we have to take fuller advantage of advanced scientific knowledge and experience in other countries. It was with this object that the Pakistan Government initiated the idea of holding a Seminar on Water-logging and Salinity here, and requested the Food and Agriculture Organization to extend its assistance. I am extremely grateful to the Food and Agriculture Organization for the active interest which they have taken and for their whole-hearted co-operation which has made it possible to convene this Seminar.

I am very happy to note that we have with us a number of internationally renowned experts who have so kindly agreed to attend this Seminar at the request of the FAO, and I am sure that their presence here would be of significant importance. We are also fortunate to have with us participants from a number of Near East countries where conditions are somewhat similar to those in West Pakistan and I am confident that they would be able to make valuable contributions by extending the benefits of their experience.

As I have said earlier, the agriculture of West Pakistan is dependent almost entirely upon irrigation. The early irrigation developments consisted of inundation canals which depended for their flow on the rise of river levels during the flood season. The most significant development of irrigation in the Indus Plains has, however, come about during the last 100 years, and particularly during the last 60 years. This was made possible with the construction of Barrages on the rivers which raised the water levels so that irrigation command could be extended to large tracts of land. There are now 14 of these Barrages commanding areas from half a million to 7½ million acres individually. The canals off-taking from these barrages have an aggregate carrying capacity of 245,000 cusecs and a total length of 40,000 miles. For a more effective distribution of the irrigation supplies a system of transfer channels has been incorporated in the irrigation system and thereby the dependable natural river flows have been almost fully committed. This vast irrigation system—extending 800 miles from the foot hills of the Himalayas to the Arabian Sea and covering 33 million acres is the life-line of the agricultural economy of West Pakistan.

The system which has been constructed with huge capital outlays in West Pakistan, had the development of agriculture as their primary aim. Yet the agriculture which is based on them is far from developed—in fact in some respects it is still primitive. Despite the favourable climatic conditions and soils which are admirably suited for irrigation agricultuse, the level of agricultural production on the irrigated areas is among the lowest in the world. The low level of production has placed a great restraint on economic development particularly in the face of a large and rapidly increasing population. In the past the Government has been making sizeable efforts to increase agricultural production by extending cultivated areas, improving technology, facilitating increase in farm inputs and rationalizing the over-all institutional set-up but the increases in agricultural production have not yet reached the optimum levels.

Our irrigation system was built on the concept of bringing the maximum area of land under irrigation with the minimum possible use of water. The two-fold requirement of water for consumptive use of crops and for salt balance in the soil was not met. The water allowances as at present allowed are far too inadequate to meet the needs of thec rops and soils. Low river flows during the winter cropping season, and inadequate canal capacities during the summer cropping season, generally limit irrigation water application to less than those required to sustain optimum plant growth. In this environment, it is natural to expect problems of soil salinity but the situation has been greatly aggravated by attendant water-logging which has been brought about by the construction of the irrigation systems. Water tables which were 60 to 100 feet deep in the pre-irrigation period have now risen to within 5 to 10 feet of the ground surface and in the absence of any sub-surface drainage, waterlogging and salinity has affected millions of acres of once fertile lands. In a gross area of 42 million acres which includes the principal irrigated lands it is estimated that about 25 per cent of the areas is predominantly poorly drained or waterlogged. More than 10 per cent of the land is predominantly severely saline and saline patches are common over more than 25 per cent of the cultivated lands. Regular surveys of the lands affected by salinity have brought out that there is a progressive deterioration of lands and on an average about 100,000 acres of cultivated lands are going out of cultivation or are being severely salinized every year.

These are the main problems of our irrigated agriculture and unless they are solved, we cannot expect to realize substantial benefits from improvements in other phases of our agriculture. What is needed foremost, is to establish a happy relationship between crops, soils and water, which with other adjuncts will make it possible to achieve a large and rapid increase in agricultural productivity.

Pakistan Government has been fully conscious of these problems and is determined to solve them as expeditiously and as well as is possible. This is evident from the personal interest which our President, Field Marshal Mohammad Ayub Khan, has been taking in these problems. Realizing the gravity of the situation, the President in 1961 had the problem reviewed and called for an immediate appraisal of the magnitude of resources which would have to be mobilized to undertake a programme of Waterlogging and Salinity Control. The personal interest of the President was also responsible for the active assistance from the United States Government, which constituted a Panel of experts on Waterlogging and Salinity and whose profound comprehensive and broad-based study has thrown more light on these problems and has provided useful guidelines.

During the last decade a great deal of spade work has been done to explore, survey and investigate the many factors relating to the main problems of irrigated agriculture so that feasible solutions could be implemented. With the active co-operation of the United States Government in 1954 for the first time a comprehensive programme of soils, salinity and geologic and hydrologic investigations was launched. In 1958, the Government established an autonomous body, the West Pakistan Water and Power Development Authority, for developing the Water and Power Resources of West Pakistan and in particular for making concerted efforts to overcome the menace of Water-logging and Salinity. Within the framework of overall and regional plans and based on the results of the investigations the Authority is formulating and implementing irrigation and drainage projects. For the efficient operation and maintenance of the reclamation projects, and for the integrated application of all the factors of production therein, the Government has established a high powered Land and Water Development Board. For the co-ordinated development of new irrigation project areas and for the general agricultural development in the Province, an autonomous Agricultural Development Corporation has also been created by the Government.

For the control of Water-logging and Salinity a number of measures have been adopted in the past, based on different philosophies and have produced varied results. Several approaches have been adopted to restrict canal seepage losses and other components of ground water recharge, leaching of saline soils has been attempted by allocating increased canal supplies to different areas; and techniques have been developed for the reclamation of alkali soils. All these measures merely touched upon isolated aspects of the problem in a small way, and at best proved to be palliatives. Subsurface drainage as a necessary adjunct of irrigation did not receive due attention quite recently when a Pilot Reclamation Project with vertical drainage was undertaken in a small irrigated area of 10,000 acres. This Project was the result of the active interest and co-operation of the Food and Agriculture Organization and I would like to take this opportunity to express to them my sincere appreciation for their whole-hearted efforts for the solution of the problems of agriculture of our country. This Project had a significant importance as it pointed the way to a unified approach for the solution of Water-logging and Salinity and improvement of irrigation. This Project was followed with three other small projects conceived on the same lines, and as the results proved to be encouraging a major reclamation project covering an area of one million acres was taken in hand by the West Pakistan Water and Power Development Authority, with financial assistance from the Government of the U.S.A. This Project has now been in operation for 3 years. By exploiting the large reservoir of ground water by means of 1800 tubewells the mixed tubewell and canal irrigation supplies have been almost doubled in the project area, which has led to a substantial increase in the cultivated area. As participants of the Seminar, you will have the opportunity to visit this project and to see things for yourselves. The Report of the Panel of experts set up by the President of the United States, headed by Dr. Revelle, had made a detailed study of this project and had recommended that to get the best results from this project, it was necessary to reorientate it towards maximising agricultural production in the area and with that view to link vertical drainage with use of additional water. There are a number of associated technical aspects of this programme which are under study.

There are, however, many areas where the ground-water could not be so utilized, and due to a wide variety of local conditions the problems of irrigation and drainage would require different approaches. Then there are problems of a regional nature, such as the allocation of surface supplies, conjunctive use of groundwater and disposal of saline effluents for which solutions may not be so easy to find. I understand that in other countries experience has shown that efficient horizontal drainage is an adequate remedy for the problem of salinity. You will hear the views of exponents of both vertical and horizontal drainage and I am looking forward to the result of your discussion which will help us to finalise our decisions. I must, however, emphasise that it seems to me that there can be no single remedy for a problem of such complexity and that while problems of each area have to be met, large investments will not be possible nor results commensurate with the efforts if they do not result in actual increase of the farmer's income.

I am sure that as participants of this Seminar, you would have an opportunity to appreciate the technical aspects of these problems and the field trips which have been planned would help you in getting a more intimate knowledge of the local conditions. I sincerely hope that your deliberations based on your expert knowledge and wide experience would yield fruitful results which would go a long way towards the solution of some of the problems of irrigated agriculture of this country.

With this hope, I wish you all a pleasant stay in this country and all success to your deliberations.

Mr. McCallum Webster stated:

It gives me great pleasure on behalf of the Director-General of the Food and Agriculture Organisation of the United Nations, to welcome you to this Seminar.

During the Sixth FAO Regional Conference for the Near East, held at Tel Amara Agricultural Research Station in Lebanon from 30 July to 8 August 1962, the following recommendation was adopted :—

The Conference recognising

—the inherent danger of waterlogging and soil salinisation in the region unless special measures are adopted to prevent its occurrence ;

—the especially difficult problem encountered in Pakistan and the considerable efforts made to combat the danger in that country;

request the Director-General of FAO to consider : making arrangements to hold in Pakistan a Seminar on Methods of Water Use and Management in Irrigation with particular reference to prevention of waterlogging and salinity as soon as possible.

The Government of Pakistan invited FAO to hold this Seminar in Lahore and accordingly invitations were extended to Member Countries of the FAO Near Eastern Region, and to a consultant specialising in this field. We are fortunate in having the participation of the United Nations Educational, Scientific and Cultural Organisation, who will be represented by Professor V. Kovda, Director of the Natural Sciences Department.

FAO's interest in these problems can be illustrated in many ways. As Executing Agency for the United Nations Special Fund FAO has recently, in co-operation with the Government of the United Arab Republic, completed a three year pilot project in drainage of irrigated land, using mechanical tile laying techniques. Studies are being made of drainage problems in another U. N. Special Fund Project in the Ghab Region of Syria, and experts have been sent to many of our Member Countries to assist in the improvement of irrigation and water management techniques.

The preparation of publication forms an important part of our work. Professor Kovda, Professor R. M. Hagan, Professor of Irrigation, University of California, and Dr. C. van den Berg, Director of the Institute for Land and Water Management, Wageningen, all of whom are attending this Seminar, are co-Editors of the FAO/Unesco Sourcebook on Irrigation and Drainage of Arid Lands in Relation to Salinity and Alkalinity. The aims of this Sourcebook, which is a joint FAO/Unesco undertaking, can be summarised as follows :—

(*a*) To provide a summary of modern scientific concepts in a form convenient for use by administrators, engineers, agronomists, hydro-technicians, soil scientists, and other specialists dealing with irrigation and drainage methods and practices in relation to salinity and alkalinity of arid lands.

(*b*) To review procedures for forecasting water requirements of crops and the irrigation and drainage needs for irrigation projects under various conditions, giving particular attention to the prevention of salinity and alkalinity problems.

(*c*) To discuss irrigation and drainage systems and management problems in relation to salinity and alkalinity.

(*d*) To assemble data required by the specialists concerned in the design and operation of irrigation and drainage works in the arid zone.

The Sourcebook is not meant to be a complex scientific treatise for research workers, but rather it is intended to show the numerous inter-relationships between irrigation, drainage and salinity problems and encourage an inter-disciplinary approach by those concerned with project planning and management. The Sourcebook, while maintaining a sound scientific level, will remain as practical as possible in order to meet the needs of specialists carrying out actual field work in newly developing countries.

Specialists of 23 countries have been officially approached to participate in the preparation of the Sourcebook. More than 70 scientists are involved as co-authors. The pioneering character of the Sourcebook involves the difficult task of comparing and synthesising knowledge and experience acquired under difficult conditions from many countries throughout the world. It has required the adoption of appropriate procedures for those cooperating in the project so as to reach a common point of view. However, if after exchanges of ideas between authors, co-authors and the Editors, differences of opinion about the text persits, the differing views will be included and attributed by name to those concerned.

The Editorial Board have held meetings in various countries. The Government of Pakistan has kindly extended an invitation to the Editorial Board to hold their next meeting in Lahore immediately after conclusion of this Seminar.

In addition to our co-operation with Unesco in preparation of this Sourcebook, FAO is taking an active part in cooperating with Unesco in the appropriate fields of study, within U.N. Hydrological Decade.

The importance of the problems of waterlogging and salinity and the close relationship of these problems with irrigation practices and the use of proper agricultural techniques, need no emphasis in a gathering of this nature, where all participants either come from countries where these problems occur, or have made a close scientific study of them. Waterlogging and Salinity are no new problems in the history of irrigation. In ancient times, as the archaeologists will tell you, numerous civilizations depended to a considerable extent on irrigated agriculture. It is interesting to speculate whether the problems of waterlogging and salinity occurring many centuries ago did not themselves contribute to the decline of agriculture and, in consequence, to the eclipse of these civilizations.

Turning now to modern times, the development of irrigation began to accelerate, about 100 years ago. Although the problems which we are here to discuss were known to exist it is only in very recent years that the full importance has been realised and that intensive scientific studies into the cause, effect and solution have been made.

We will have presented to you at this Seminar a summary of the Basic Report which has been prepared by an Advisory Committee constituted by the Ministry of Agriculture and Works, Government of Pakistan. Other papers will be presented dealing with scientific aspects of the subject and participants from Member Countries have been invited to make a statement on the problems in their own countries. As you will see from the Seminar Program, which you have received, an interesting series of field trips has been arranged by the Government of Pakistan. We hope that the Basic report, the papers to be presented, and the country reports to be submitted, will, together with the field trips, provide the basis for a full and free discussion, and exchange of views on this most interesting and important subject.

On behalf of the Director-General of FAO, I would like to thank the Government of Pakistan for the invitation to hold this Seminar in Lahore, and for the arrangements they have made as Host Country. We hope that all those participating will find this Seminar both of interest and of benefit.

INTRODUCING THE PROBLEM

On 17 and 18 November 1964, Pakistani participants of the Seminar introduced briefly various chapters of the basic report. It has earlier been summarised and circulated by F.A.O. The participants of co-operating countries also presented their country reports. The F.A.O. consultants presented four papers on the problems. In this volume two papers are briefly reproduced and excerpts from the rest two experts are put forth. Several Pakistani also took part in the general presentation. Their brief remarks are collected together.

TUESDAY, 17 NOVEMBER 1964
Morning Sessions

Basic Report

SYED HAMID, Director of Seminar, Chief Engineer Groundwater and Reclamation Division, Wapda, outlined the main features of the basic report and reviewed the Water-logging and Salinity problems of the Indus Basin. He said that the problem in Pakistan was not due to the shortage of Agricultural Land as about 66 million acres were available for cultivation, but it was a result of low annual precipitation, relatively high temperature and insufficiency of water. The major factors limiting the Agricultural production has thus been the shortage of water, existence of saline and saline-alkali soils, lack of drainage resulting in salinization of soil and water-logging and unsatisfactory agricultural practices and methods. Recent attempts to make the best use of available water, particularly from the underground and improve the irrigation practices to maintain a salt balance with at least 10% of drainage surplus, were reviewed. With the proper planning of ground water pumping and increase of recharge potential, water supply is expected to be adjusted to such a way as to produce over 200 per cent crops production which will be about 100% more than from the present land utilization. He also explained the measures being adopted to improve the economy, expand agriculture, improve the water resources and thus control the existing problem.

(*a*) Hydrology and Geology

M. A. LATIF, Superintending Hydrologist, Wasid Wapda, Lahore spoke on the geological investigations which were started in 1955 in the Upper Indus Plains. The exploratory drilling generally to a depth of 600 ft. and in special cases to a depth of 1500 ft. was carried out. About 1070 drill holes spread on an area of 4000 sq. miles, combined with electrical resistivity method and well logging technique to determine the geological features of the Indus Plains. The material of the Upper Indus Plains constitutes alluvium principally fine and medium grained sand, silt and clay. In spite of the heterogeneous composition of the alluvium, the medium forms a unified highly pervious acquifer in which the groundwater occurs essentially under watertable conditions. About 185 pumping tests were run to determine the permeability characteristics of the formation. The pumping tests extended to 4 or 6 days duration and it was found that the permeability coefficient varied between 0.001 to 0.006 ft. per second giving an average of 0.003 cusec per sq. ft. The specific yield of the material varied from 0.02 to 0.26 giving an average of 0.14 per cent. There was a considerable variation observed between the vertical and the lateral permeability coefficients.

(*b*) Soils

Mr. H. S. ZAIDI, Superintending Research Officer, Wasid Wapda talked about Soils Surveys which were started in 1955 and to date the whole of Upper Indus Plains including Bahawalpur area has been surveyed. The soil classification was based on U. S. Soil classification, modified according to the local conditions. The depth of exploration has been limited from 72″ to 120″. Five series of soil classification has been adopted depending mainly on the texture of the soil formation. Soil classification maps and soil salinity maps are being prepared. If there is neither alkali nor salinity at any depth, the soil profile is classified as normal. The saline profiles are characterised as saline and in presence of salinity and alkalinity in a soil profile is classified as saline alkali. The speaker also put forth the details of the tests which are being carried out for the classification of the soil.

(*c*) Water Chemistry

M. A. HAMID, Superintending Research Officer, Wasid Papda, Lahore, talk about the chemical analysis of shallow and deep waters of the Indus Plains. Since 1955 thousands of samples of groundwater have been analysed. The groundwater quality between 100 to 450 ft. except in Bahawalpur Regions is suitable with dissolved salt less than 1000 ppm in about 70% of the land in the four Doabs of Thal, Chaj, Rechna and Bari. Water close to the rivers is of good quality to still greater depths. Investigations have also been extended to determine the sodium and bi-carbonates hazards and other salts contents of the water which make it unsuitable for use on the land. He also talked about the study of changes in the quality of groundwater as a result of tube-well pumping.

(*d*) **History of Irrigation**

SARWAR JAN KHAN, Chief Engineer, Irrigation Peshawar Region, spoke on the history of Irrigation in the country. He said that even in the eighth century there were irrigated and non-irrigated areas. He referred to the memoirs of Baber in 1235 where mention was made about the irrigated and non-irrigated areas. During the 19th century extensive irrigation was practised in Sind which was ideally suited for diversions of water through inundation canals as the river Indus in this area flowed over a ridge. The author then put forth the history of present irrigation system which started with the Upper Bari Doab Canal in 1850. Mention was also made of the great Sukkur Barrage Project and subsequent canals including Ghulam Mohammad Barrage, Link Canals and the present canal system.

(*e*) **The Problem of Reclamation**

MR. MUHAMMAD HUSSAIN, Director, Land Reclamation, Lahore gave details of the existence of problems of Water-logging and Salinity. He mentioned the annual salinity surveys, the serial reconnaisance surveys and the soil surveys which has shown the extent of the problem in the Punjab and Bahawalpir Region. He also discussed the causes and effects of water-logging and salinity, briefly described the measures undertaken by his organization for amelioration of the salt effected lands. He put forth many facts and figures depicting the extent of the problem with special reference to alkali soils.

(*f*) **The Investigations**

M. BADR-UD-DIN, Project Director, Planning and Project Preparation put forth the programme of investigations. He repeated some of the information already given by Mr. Latif, Zaidi and Hamid. He mentioned the extensive programme of investigations of Wapda in the Upper Indus and Lower Indus Plains. He mentioned the Soils Survey, programme and the estimation of water both from surface and groundwater and the geological investigations of the formation which were underway. Seepage studies, corrosion and incrustation of tubewells, research on soils on agronomical factors and everything connected with soils was under study by Wapda.

(*g*) **Problems of Delta area of Ghulam Mohammad Barrage**

MR. AHMAD HASSAN, Chief Engineer and Irrigation Adviser, A.D.C., put forth that the problems of Irrigation of the delta area of Ghulam Mohammad Barrage with respect to the highly saline and alkaline nature of land and unsuitable high level of groundwater. The experience with pumping of saline ground-water by short life tubewells was put forth. He mentioned the difficulties of successful irrigation practices in the area and invited suggestions for effective measures.

(*h*) **Success of the Drainage Measures**

MR. SHAMIM AHMAD, Secretary, Land and Water Management Board traced the history of the measures undertaken to ameliorate the water-logged and saline land of the Indus Plain. He stated that lining of canals, elimination of unnecessary flow in the canals, winter closure of canals, construction of seepage drains have all been tried but without much success. Large scale tubewell pumping has recently been started in an area called Scarp No. 1. By pumping 2.79 million acres ft. of water in a year constituting 60% of the installed capacity of the tubewells, the high watertable has successfully been lowered 3.0 ft. in the first year, 5 ft. in the second year and another 3 ft. in the third year. At present the position of watertable ranges from 12 to 20 ft. below surface. The results of measures taken have been very encouraging. Irrigation of land has increased extensively. The salinity is disappearing and increased food supply is the result. Monitoring being maintained by Wasid has shown no appreciable change in the quality of groundwater. It appears that we have achieved everything which we were aiming at during the last century. It is hoped that these results will persist in the land where reclamation measures by tubewell pumping had been undertaken.

OTHER COUNTRIES' REPORTS

On this very day the representatives of Near East countries put forth their reports. Below we have given brief extracts from their presentations.

(*i*) Afghanistan

MR. ABDUL MAHBOOB, Irrigation Engineer, Ministry of Agriculture, stated that over half of 8 million hectares is irrigated. Dry farming of wheat and barley on mountain slopes is practised. Water supply is from surface streams, or shallow ground water from underground tunnels (Karezes). The main source is derived from Hindukush Mountains. When not used, most waters evaporate in inland basins. Karezes have been drying up because of watertable recession.

Irrigation water is usually obtained by temporary river diversion structures. Problems occur with sediment deposition, and the maintenance of the canals themselves.

Salinity and water-logging problems are not important now, but will become important with full development.

(*ii*) Jordan

MR. KHALIL HAMDOUKH, Irrigation Agronomist, East Ghor Canal Authority said that Jordan is a country of 10 million population, with only 1,000 sq. kilometers irrigated, and 7,000 sq. kilometers dry-farmed. Water supply remains a problem. The East Ghor Canal Authority will eventually irrigate 30,000 acres when a dam at Wadi Ziglab on the Yarmouk River is completed. Groundwater and spring water is being developed. The sub-surface drainage and salinity problems were summarized, along with studies underway and measures so far taken.

(*iii*) Kuwait

MR. SAMI IZZAT BANNA, Soil and Crop Specialist, Agricultural Section, Ministry of Public Works,—said that Kuwait is developing in all fields, social, economic, industrial, as well as agricultural. Agriculture will play an increasing role in the development of the country. The expansion of agriculture is limited by the harsh climatic conditions soil and hydrological seasons. In 1955 an experimental farm station was established to tackle and solve the agricultural problems.

Rainfall ranges from 1.6 to 9.5 inches, so there is no great water supply, limiting irrigation to small cases. There is some ground water, but quality is in the range of 2,000 to 4,000 ppm, total salts for most of it, which imposes a limitation on the uses that can be made of it. An electrodyalasis plant has been constructed to demineralize 4,000 ppm. brackish water to 500 ppm.

(*iv*) Syria

MR. BABA DABBOUS, Head of Irrigation

Drainage Section, Ministry of Agriculture, stated the extent of irrigation in Syria. The problems of rainfall distribution decreases from north to south and east to west from more than 1,000 mm. to less than 100 mm. Some land in the north is dry-farmed to wheat and barley. Problems of the irrigated areas include a rising water-table, salinization of the soil, which is effecting the economics. Drainage measures are required.

(*v*) **Somalia**

Mr. MOHAMMAD HERSI BAHAL, Head of Agricultural and Horticultural Service, Ministry of Agriculture said that Irrigation in Somalia is mainly confined to the southern part where two permanent river flows exist. In the northern part of the country no permanent flow exists and it is characterised by scanty rainfall. Irrigation has become a major activity for farmers living along the sides of Uehi Scebeb River and Jub River.

The development of improved irrigation is envisaged by the Government in the five-year plan.

About 10% of the 8 million hectares of cultivable land can be irrigated for the greater part of the year. The quality of the irrigation water is excellent. Up to the present, water-logging and salinity are not problems in Somalia.

Afternoon Session

In the afternoon Dr. C. A. Bower, Director, Salinity Laboratory spoke on salinity control in Irrigation Agricultural and Professor Arthur F. Pillsbury, Consultant F.A.O., put forth the principles, in the utilization of Flood Plains. We have extracted briefly both these papers below.

SALINITY CONTROL IN IRRIGATION AGRICULTURE

This was the subject of address by Dr. C. A. Bower, Director U. S. Salinity Laboratory.

Although irrigation agriculture is practised on only about one-tenth of the arable land in the world, it supplies perhaps as much as one-fifth of the total output of food and fiber, and is the mainstay of the agricultural economy of many arid countries. Moreover, additional development of irrigation agriculture is expected to meet a considerable part of the world's increasing agricultural needs.

The decline of several once-flourishing civilizations based on irrigation has led some to question the permanence of irrigation agriculture. From the standpoint of permanence, the main difference between non-irrigated and irrigated agriculture arises from salinity. Rainwater is essentially salt-free, but water for irrigation may contain several hundred pounds or even several tons of dissolved salt per acre-foot. Plants grown by irrigation absorb and transpire the water but leave nearly all of the salt behind in the soil, where it accumulates and eventually prevents plant growth unless removed. The accumulation of salt has caused the abandonment of much formerly productive soil and has undoubtedly contributed to the failure of some civilizations. But enough has been learned about the cause, prevention, and cure of salinity to say with some certainly that irrigation agriculture can be permanent. This paper outlines some of the principles, requirements, and practices that have been found to be essential or useful for the control of salinity in irrigation agriculture.

Salt Balance and Leaching Requirement

Originally the term salt balance was applied by Scofield to the tons per year of salt either removed or deposited in an irrigated area. Under conditions where it is possible to measure the amount of salt added to an area in irrigation water and the amount removed in drainage water with reasonable accuracy, Scofield's salt balance is a useful indicator of year-to-year trneds in salinity conditions in the area.

The principle of salt balance can also be applied to the root zone of crops. In this case, salt balance can be defined by the equation.

$$V_iC_i+S_m=V_dC_d+S_p+S_c \quad .. (1)$$

where V_i and V_d are volumes of irrigation and drainage waters, respectively, having corresponding salt concentrations C_i and C_d S_m is the amount of salt dissolved from soil minerals, S_p is the amount of added salt that precipitates in the soil, and S_c is the amount of salt removed in the harvested part of crops. Except where C_i is low, S_m, S_p, and S_c are usually small in relation to the other two quantities of salt ($V_i C_i$ and V_dC_d) and, in any case, S_m which is positive in equation (1) tends to cancel the two negative values S_p and S_c. By disregarding S_m, S_p, and W_c equation (1) reduces to

$$V_d/V_i=C_i/C_d \quad .. (2)$$

If D_d and D_i are volumes per unit of area or equivalent depths of drainage and irrigation waters, respectively, equation (2) may also be written

$$D_d/D_i=C_i/C_d \quad .. (3)$$

The leaching requirement (LR) has defined as the ratio of the equivalent depth of drainage water D_d/D_i, that is required to maintain a given soil solution concentration at the bottom of the root zone. Because the concentration of the soil solution at the bottom of the root zone equals the concentration of the drainage water, one may write

$$LR=D_d/D_i=C_i/C_d \quad ..(4)$$

Thus the leaching requirement may be calculated from knowledge of the concentration of the irrigation water and the permissible concentration of the drainage water. If, in addition to irrigation water, salt-free rainwater of depth D_r is involved, an adjusted concentration for applied water, C_i(adj), can be calculated by the equation

$$C_i(ad_j)=D_iC_i/D_i+D_r) \quad ..(5)$$

The permissible concentration of the drainage water depends upon the salt tolerance of the crop. The U. S. Salinity Laboratory reports the salt tolerance of crops in terms of relative yield over a range of values for the average electrical conductivity of the saturation extract of the soil in the root zone (EC_e), and, tentatively, employs the EC_e value corresponding to a relative yield of about 50 per cent as the permissible concentration of the drainage water for calculating the leaching requirement. While it might appear that such a procedure will permit yields only 50 per cent of maximum in actuality, the obtainable yields are in excess of 90 per cent of maximum for two reasons: (*a*) the soil water content at which the EC_e is measured is about three times the average field water content so that the concentration of the extracted soil solution is only about one-third that of the actual soil solution, and (*b*) the concentration of the soil solution normally increases with depth in the root one with the result that its average concentration is considerably less than that of the drainage water at the bottom of the root zone. In general, the EC_e values employed in the LR equation are about 4 mmhos/cm. for salt-sensitive crops, about 8 for moderately salt-tolerant crops, and 12 to 15 for highly tolerant crops.

The increase in salt concentration from that of the irrigation water to that of the drainage water is largely determined by losses of water by evapotranspiration. The depth of irrigation water entering the soil, D_i, is related to the depth lost by evapotranspiration, D_e, and the depth of drainage water, D_d, by the equation

$$D_i = D_e + D_d \qquad ..(6)$$

Substitution of equation (3) into equation (6) gives an equation in terms of depth of water lost by evapotranspiration and the concentrations of irrigation and drainage waters for calculating the depth of irrigation water required to satisfy both the evapotranspiration and leaching requirements, *viz*:

$$D_i = D_e \ (1 - C_i / C_d) \qquad ..(7)$$

Achieving the Leaching Requirement

Water Supply.—Much soil salination in irrigation developments throughout the world results from an inadequate water supply. Attempts are made to irrigate too much land in relation to the water supply. Under such conditions farmers tend to under-irrigate with the result that there is little, if any, net downward movement of water through the root zone to satisfy the leaching requirement. Other than obtaining an additional supply of water directly or indirectly by reducing water conveyance losses, there are essentially three ways to correct soil salination resulting from under-rrigation:

1. The total area irrigated may be reduced by an amount sufficient to provide enough water to meet the evapotranspiration and leaching requirements on the remaining area under the prevailing cropping pattern.

2. Crops having a lower evapotranspiration requirement because their growth period is shorter or occurs when the evapotranspiration potential is lower may be grown. Moreover, substitution of a crop having a low evapotranspiration requirement for one having a high requirement also reduces the leaching requirement providing the salt tolerances of the crops are equivalent.

3. The cropping pattern may be altered in the direction of growing more salt-tolerant plants that have a lower leaching requirement thereby decreasing the depth of irrigation water required.

Uniformity of water infiltration

In using equation (7) to calculate the depth of irrigation water required to satisfy the evapotranspiration and leaching requirements, uniform areal infiltration of water is tacitly assumed. Because of difficulties in obtaining uniform distribution of water and the marked differences in soil permeability over short distances in fields, this assumption is rarely valid.

Soil Permeability

One of the greatest deterrents to salinity control is insufficient soil permeability to permit the required leaching.

The low permeability of soils resulting from excess exchangeable sodium can be alleviated by any procedure such as application of chemical amendments that replaces the exchangeable sodium with calcium or magnesium. When it is not feasible to increase soil permeability, the irrigator may be able to control salinity by shifting to crops that have a lower leaching requiremnt.

Because of their adverse effect on soil permeability, waters from which excessive amounts or sodium are adsorbed by soils should not be employed for irrigation. The level of exchangeable sodium that can be tolerated, however, increases as the total salt concentration of the irrigation water increases.

Drainage

The water leaving the root zone (drainage water) carrying the salts necessary to maintain salt balance must continue to move either downward or laterally so as to prevent the development of a watertable near the bottom of the root zone. If a watertable approaches the bottom of the root zone, appreciable upward movement of the groundwater and salination of the root zone occurs between irrigations, and eventually the required leaching cannot be maintained. In some irrigation developments drainage water continues to move downward and laterally out of the area by natural means. More often it is necessary to provide facilities for removing the drainage water. The facilities may consist of a system of open ditches and or tile lines or wells. If a deep, permeable aquifer underlies the irrigated area drainage] by wells is usually advantageous. This is especially true if the ground water is of suitable quality for irrigation. Of course, owing to increasing contamination with drainage water, the pumped water eventually becomes too saline for irrigation unless there is also appreciable natural movement of the ground water, and therefore salt, out of the area. Usually, however, degradation of the quality of pumped ground water is sufficiently slow to permit use of the water for irrigation over a long period.

When pumped groundwater is no longer usable directly or by mixing with water of better quality, it must be conveyed out of the irrigated area. Open ditches and tile lines may also be used to drain root zones underlain by permeable materials and are mandatory where the substrata have low permeability. The permissible depth to the watertable for salinity control depends largely on the relation between the depth to watertable and rate of evaporation of water from the soil surface. This relation for two soils having different water-conducting properties was shown. Both curves show that the evaporation rate decreases markedly as the waterable is lowered to 150-200 cm. and that a further lowering reduces the rate only slightly. Thus, although evaporation continues at a slow rate at depths in excess of 800 cm., a practical and usually satisfactory depth to watertable is 150-200 cm. This view is confirmed by recent data of Collis-George and Evans showing the relation between the depth to watertable and the chloride concentration of surface soil adjacent to the Hawkesbury River in Australia.

The growing of crops having low evapotranspiration requirements and/or high salt tolerance has already been mentioned as a means of compensating for deficiencies of water supply and soil permeability otherwise needed to achieve the leaching requirement. Owing to method or intensity of irrigation, cropping season, and perhaps other factors, soil may tend to salinize during the growing of one crop and ro desalinize during the growing of another. Thus, it is possible achieve the leaching requirement over a period of time to manipulating the pattern of cropping.

Special Management Practices

The salt tolerance of most crops varies with stage of growth. Although some crops have their greatest tolerance in the germination and seedling stages most are least tolerant in these stages.

Design of Irrigation Projects in Relation to Salinity Control

Because salinity control is vital for successful and permanent irrigation agriculture, it should be a paramount consideration in the design of irrigation projects. Many of the salinity problems which exist today in irrigated areas throughout the world are the result of faulty design and could have been avoided. Five major design considerations from the stand-point of salinity control are as follows:—

1. Suitability of soils.
2. Efficiency of layout.
3. Allocation of water.
4. Provision for drainage.
5. Cropping intensity.
6. Literature Cited.

PRINCIPLE IN THE UTILIZATION OF FLOOD PLAINS

Prof. Arthur F. PILLSBURY

Prof. Arthur F. Pillsbury stated that much of the irrigated agriculture of the world is located on the flood plains of river basin systems. The fact that irrigation must be practised implies that the flood plain is arid, semi-arid, or at least lacking sufficient precipitation during the growing season.

The Watershed

The watershed is that portion of the river basin system where water supplies originate.

Basically, the land of the watersheds is upland, where the soil has been formed in place through the decomposition and mechanical grinding of rock materials.

The process of rock decomposition and grinding makes a granular material out of the rock that is readily transported by water as a liquid and/or as ice, down-stream to lower elevation. Thus, watersheds produce sediments as well as water.

As decomposition and grinding take place, soluble salts are dissolved into the water. The amount of salt produced on a watershed varies somewhat with the geology and topography, but has a significant relationship to the water production. Some rather incomplete data from a wide variety of streams in western United States indicates that on the average:—

$(SP)^2 = 2575$ WP, where

SP = Salt Production in kg/k^2/yr. and

WP = Water Production in m^3/k^2/yr.

The Valley

The valley is the upper part and sometimes the major part of the flood plain. It is where the greater part of the debris—the sediment—washed down from the watershed are deposited. The debris is, by and large, carried into the valley during flood, and the texture of the particles deposited is related to the velocity and depth of the flood flows, in accordance with Stoke's law.

When the streams overflow their banks, there is a rapid decrease in velocity and depth, causing deposition of the next coarsest material, usually sand, and the building of natural levees. The soil materials subsequently deposited through the valley are to a large extent of medium texture, making them rather ideal for irrigated agriculture.

The nature of deposition of soil material, the particles are rarely round, and there is a marked tendency for the long axis of irregularly shaped particles to come to rest more or less in a horizontal position. Coupled with this, the vagaries of floods are much that the material deposited varies grestly with time and place. Thus, stratification, irregular and discontinuous, is an inherent characteristic of the alluvial fill. Stratification means interfaces where there are rather abrupt vertical changes in texture. And interfaces, particularly where a finer textured soil overlies a coarser textured soil, means that vertical hydraulic conductivity is impeded. Put these factors all together, and we find the soil inevitable to be heterogeneous and anisotropic.

If K is the vertical hydraulic conductivity of a soil and K_h is the horizontal hydraulic conductivity, the ratio K_v/K_h is always less than one. K_v and K_h will, in general, both be highest at the upper end of the valley and lowest at the lower end. Also, the ratio K_v/K_h will, in general, be highest at the upper end of the valley and decrease towards the lower end.

The valley, as a whole can be expected to have a water supply derived from the surface flows entering at the upper end, and or groundwater derived from aquifers, ancient buried stream channels interlaced through the alluvial fill at all depths. By By and large, the valley has good drainage under natural conditions; salts are periodically leached, and flushed away from the surface, by floods; the groundwater maintains a gradient towards, and flows towards, the lower end. Conjunctive use of the surface water and groundwater maximises the available supply and creates storage capacity for replenishment during floods.

The Basin

The basin can be defined as the lower part of the flood plain where drainage is impeded. The basin has many characteristics of the valley except that drainage is impeded, the sediments are predominantly fine with clay predominating, and the rato of K_v/K_h is extremely low because of more thorough textural sorting. Basins have long been used for inundation farming, and usually at least parts are suitable for irrigation farming with suitable drainage.

Inventory

It is axiomatic that, for rational planning for flood plain utilization, there be a rather complete inventory of the natural resources available. Of these, those of an inflow-outflow nature are of prime importance because records for a fairly long period of time must be obtained before they become statistically meaningful. An inventory of the land itself must be completed before planning can be finalised, but this is a straightforward, relatively short time job.

Problems in Flood Plain Utilization

Pioneering.—Man has always pioneered, and such pioneering has led to the advance of civilization. The original civilisations arose on flood plains. Some have withered away and died, mostly because of waterlogging and salinity problems. Utilization of the Indus Plain in West Pakistan did give rise to one of those original civilizations, and the fact that there are still tremendous values associated with that development today is mute testimony to the fact that the pioneering is still basically sound after almost 5000 years of continuous utilization.

Water Supply

Basically, water is one of our most plentiful and cheapest resources. Under the pressures of population, however, we often have shortages and tend to spread available supplies too thin. Most basic problems on the flood plains stem from use of too little water, or rather spreading it out too thin, than from rather copious usage. This does not mean that we should use it carelessly, but where we use it at all, we must use it adequately to provide all evapotranspirational needs with extra because of the non-uniformity of soils, and extra for liberal leaching and flushing away of salts. It is a characteristic of irrigated agriculture that yields and quality tend to be depressed appreciably with slight deficiencies in availability of moisture for evapotranspiration.

Salt

Under a natural regime, evapotranspiration on the flood plain is small enough so that it does not hinder the carrying of all imported salt to the basin and often beyond. Groundwater gradients and flows are towards the basin. Therefore, salt balance is maintained through the valley and sometimes through the basin. Irrigation development greatly increases evapotranspirational use of water, and overloads natural surface and subsurface drainage capacity. Irrigation development, then implies the need for artificial measures for surface and subsurface drainage, beginning at the bottom of the flood plain, and working upstream through as much of the valley as necessary. The ultimate requirement, often not attained in short-range pioneering measures, is to obtain complete salt balance.

The attainment of salt balance is no easy task, and to the best of my limited knowledge is today actually being attained only where there is really a quite adequate—(ample, if you will)—water supply for the irrigated lands, plus appreciable waste. In the attainment of salt balance, the whole world has much ahead of it.

The ratio K_v/K_h has been mentioned, along with the fact that the ratio generally decreases with progress down-stream through the flood plain, along with decreases in both K_v and K_h. The complications of this generalisation have also been mentioned. The attainment of sub-surface drainage is a dynamic thing. If it is necessary only to pass a small amount of water through the plant root zone, slow rates of flow below the watertable might be adequate. But with a healthy irrigated agriculture the quantity of applied water over evaportanspiration needs is considerably in excess of the theoretical leaching requirement. The point is that while vertical drainage would effectively lower a watertable over most of an unirrigated flood plain, it must inevitably fail over much of the lower part of an irrigated flood plain because of the K_v/K_h ratio, and because of the need for rapid egress of ground water immediately below the plant root zone.

Vertical drainage, pumping from wells, has been highly successful in the upper part of the flood plains. But it is not really a drainage method. It is, rather, a means of creating a more adequate irrigation supply that, incidentally, can have excellent drainage benefits. The pumping that must be maintained, the rate of flow per unit lift, make vertical drainage completely inefficient for drainage alone. Many vertical drainage schemes were started in the south western part of the United States beginning in the early 1920. Today, to the best of my knowledge, not a single "drainage" well is operating where the water is not used to help irrigate the overlying land, or is used to satisfy down-stream water rights. It might be added that, wherever saline waters are being pumped, extreme corrosion and incrustation problems with the well and pump appear to be inevitable.

Waste Water Concentration

It might be well to remember that salinity occurs only because evapotranspiration removes too much of the water and essentially none of the salt. Concentration is due to evaporation from water and moist soil surfaces, but primarily transpiration by crop plants and phreatophytes.

The matter of desalinization techniques might be mentioned because they are, except

F.A.O. Seminar, Lahore 17 to 28 November, 1964.
Participants from Near East Countries.

along the edge of oceans, simply a means of (1) concentrating waste water so that less will have to be wasted (smaller conduits and less pumping) and still maintain salt balance; and (2) amplifying water supplies. With any once through system, about one-third of the water will come out sufficiently lowered in salt content to be of good quality, and about 2/3 will be more concentrated. The process can be repeated on the more concentrated 2/3, but will be even more expensive, and the 1/3 of this step will be more saline. Not even the first step is economically feasible now for irrigation agriculture.

Closed Basins

It is implicit with ground water pumping that there will be some evacuation of stored water. With heavy pumping in one area, a zone of depression in piezometric pressure is created that initiates flow from all directions into that zone, and at the lower end of the zone a reversal of gradients and flow is created. There is no longer a continuous down-stream gradient to maintain salt balance in the groundwater basin. This can mean, and has sometimes meant, in closed basins, that all the inflow of water is utilized and essentially all of the salt is simply circulated. Degradation, with the supply eventually becoming unusable, is the inevitable result.

Conclusions

It can be concluded from this review of principles that:—

(*a*) Rational long range development cannot be undertaken without a rather complete inventory of the resources, particularly of the inflow and outflow of water, sediments, and salt.

(*b*) It is usual and apparently necessary that pioneering efforts proceed on a short range basis in order to establish vallues that will make longer range plans feasible.

(*c*) Particularly in arid and semi-arid regions, the flood plain provides much of the prime agricultural land for the satisfaction of the world's needs for food and fiber.

(*d*) The flood plain has become prime agricultural land because of the periodic deposition of sediments during floods, and "flood control" measures are really short-range pioneering efforts. Long range plans must contemplate learning in some way to "live with floods" or to provide some means of insurance against the disastrous effects of floods.

(*e*) Successful irrigation agriculture on the flood plain requires a rather adequate and ample water supply for the area irrigated.

(*f*) Conjunctive use of surface and groundwater is usually essential to providing an adequate and ample water supply, and this implies a great deal of groundwater pumping, and the inevitable development of closed basins.

(*g*) Drainage, basically, implies the maintenance of salt balance over the entire part of the flood plain developed, or to be developed.

(*h*) By and large, and implying conjunctive use of surface and subsurface water supplies in arid and semi-arid regions, "horizontal drainage" is sub-surface drainage, and drainage effects of "vertical drainage" are of a temporary nature or are incidental to the enhancement of the water supply. This is related to the matter of the K_v/K_h ratio, and the efficiency of horizontal drainage in providing rapid egress of the soil water immediately after it passes through the root zone—the primary zone of concentration of salts.

WEDNESDAY, 18th NOVEMBER 1964

In both the Sessions of this day Mr. J. A. Van't Leven and Dr. Fireman put forth their views. They were followed by a brief discussion by six Pakistani participants. Their brief remarks are included in this section.

Morning Session

The morning session was occupied by four speakers, two were from F.A.O. and the rest two were from Pakistan.

MR. J. A. VAN'T LEVEN, Water Resources and Irrigation Branch, F.A.O. Rome, Italy, spoke on Waterlogging and Salinity. He presented a general review of the problems of waterlogging and salinity. He mentioned the relation existing between the mean ground water level during the growing season, soil salinity and the yield of the crops.

In irrigated areas with high water tables, abundant irrigation causes oxygen deficiency, starving of roots, and consequently decreased plant production by rising water tables. In areas with high water tables, drainage is necessary in a horizontal way by covered or open system, or in a vertical way by tubewells.

If deep drainage by gravity is impossible, the excess of water can be pumped out. In tidal areas sluices equipped with tidal gates, can provide a solution.

DR. MILTON FIREMAN, F.A.O. Consultant, spoke on some comments on the "Reclamation of Saline and Alkali Soils." He defined what he meant by "reclamation" as the amelioration of problem soils so as to provide for the economic production of the crops involved.

An Alkaline or sodic condition develops much more slowly than a salinity condition, and is correspondingly harder to cure. Possible methods of reclamation were reviewed, calling attention to the fact that only one, leaching, and with previous adequate drainage, was really effective.

For saline soils, a rule of thumb is that 80% of the salt can be removed to a unit depth of soil by a unit depth of application of leaching water.

The efficiency leaching, and difficulties in the various ways of replacing sodium in alkaline soils was discussed.

MR. AHMAD HASSAN, Chief Engineer and Adviser to A.D.C., spoke on Regionalisation of Irrigated areas of the Indus Valley for Drainage and Reclamation. A detailed sequence of construction and function of each canal system was described. The problem of the various units were reviewed and the solution summarised.

DR. NAZIR AHMAD put forth some Basic Conceptions for Solution of Waterlogging

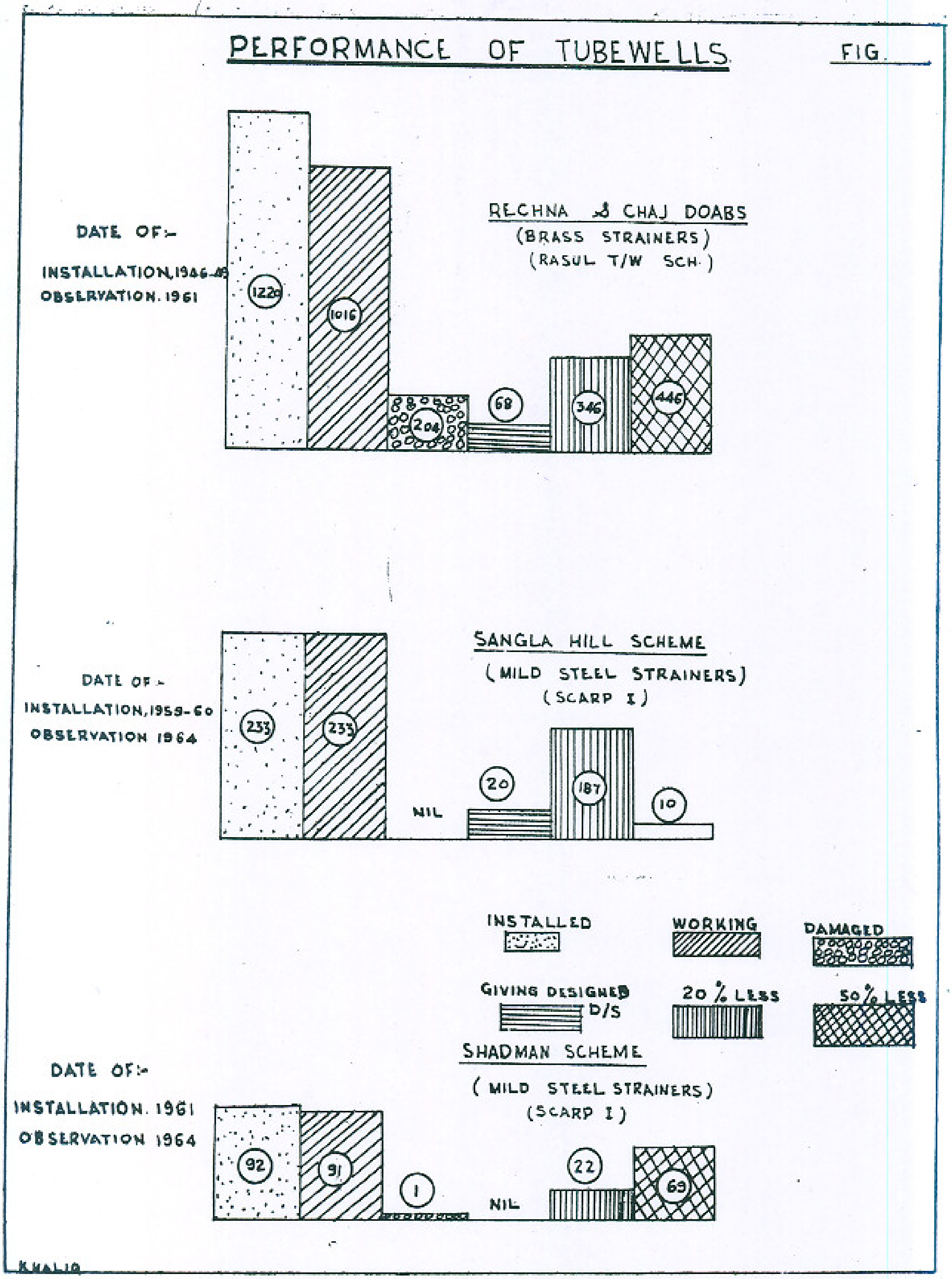
PERFORMANCE OF TUBEWELLS.
FIG.
DATE OF:-
INSTALLATION, 1946-49
OBSERVATION. 1961
RECHNA & CHAJ DOABS
(BRASS STRAINERS)
(RASUL T/W SCH.)
1220
1016
204
68
346
446
DATE OF:-
INSTALLATION, 1959-60
OBSERVATION 1964
SANGLA HILL SCHEME
(MILD STEEL STRAINERS)
(SCARP I)
233
233
NIL
20
187
10
INSTALLED
WORKING
DAMAGED
GIVING DESIGNED D/S
20 % LESS
50 % LESS
SHADMAN SCHEME
(MILD STEEL STRAINERS)
(SCARP I)
DATE OF:-
INSTALLATION. 1961
OBSERVATION 1964
92
91
1
NIL
22
69
KHALID

Fig. 1

and Salinity Problems. He presented the following conceptions:

High Water-table and its lowering by Tubewell

There is no doubt in the statement that the present level of high water table has been brought by the Irrigation canals, seepage from which has continued to add to the under ground porous formation. The addition of water, has been more than the outflow with the result that water continued to fill the formation and within the last 70 years, it has filled it to the brim. Now the proposed solution is to take down the water table in the Punjab and Bahawalpur Regions to the pre-irrigation position. It will be done by tubewell pumping and the pumped out water will be used on land where it will wash down the salts. This will solve both the problems of salinity and water-logging.

Thus our main tool is the tubewell. It is true that tubewell can draw a large amount of water and thus quickly drains the land and helps to maintain the water level at any desired level but unfortunately the tubewell installed in this area with all possible precautions have not performed satisfactorily for more than 10 years. Incrustation of strainers, corrosion of materials, have caused fall in discharge, increase of pumping level, increase of power input and sometimes failure or abandonment of this venture.

During the last forty years experiments have been conducted on the use of brass, wood, mild steel, prepacked gravel and coir string strainers but unfortunately, none has stood for a long time. Fig. 1 illustrates the performance of various types of tubewells, none has continued to yield over a long period, the designed discharge. Sooner or later strainer of inert materials have got incrusted. It has occurred on brass (Fig. 2) on wood and even on coir string strainer

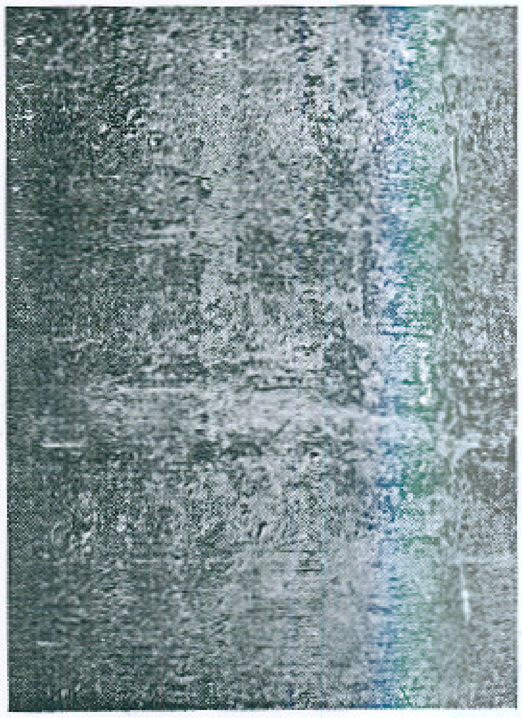

Fig. 2. Chocked Brass Strainer

(Fig. 3). Corrosive materials such as mild steel have shown another serious defects. Not only the presence of iron has helped in the incrustration but corrosion of slits have caused failure of tubewells (Fig. 4). Evidently this tool to fight waterlogging and salinity cannot be a lasting solution. True it has several advantages but those can be attained only if a tubewell is installed with the conception that it is to have a limited life and it shall have to be replaced frequently. Cheapness of design and installation to pump only good quality water are the other two necessities.

Suitable Position of Ground-Water Table

To fully exploit the groundwater mineral, it is being proposed to take down the water-table to a depth of 100 ft. or still deeper.

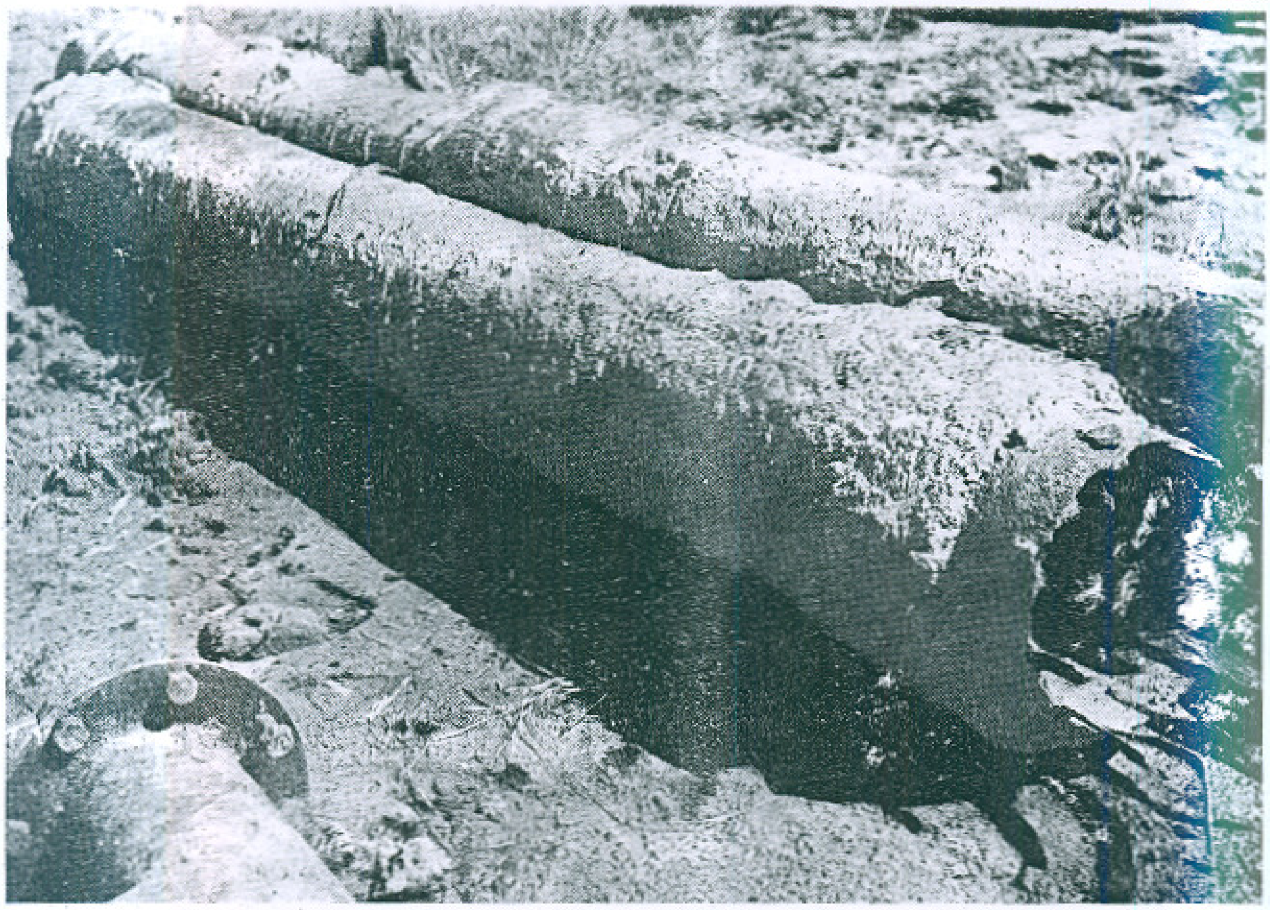

Fig. 3. COIR STRING STRAINER
Extracted after 3 years from Gaja Area Groundwater conductivity 20,000 m. mohs/cm.

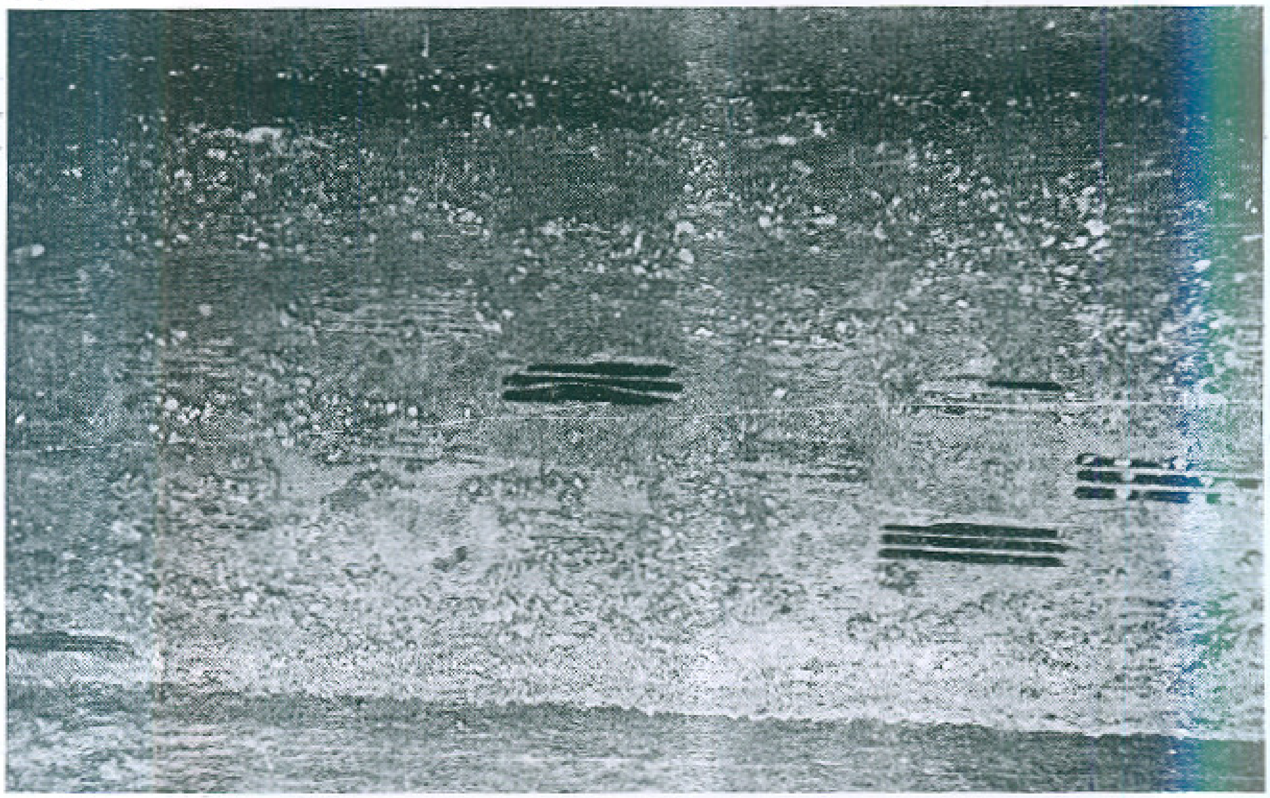

Fig. 4. MILD STEEL SLIT STRAINER
Extracted after 3 years from Shadman Scheme near Sheikhupura. Groundwater conductivity 600 m. mohs/cm.

This action will result in reduction of a very useful means of water supply to crops, the sub irrigation. It is well known that crops can draw moisture from the under ground to the extent of 50-70 per cent from water table at 3 to 4 ft., 40-50% with water table at 5 to 7 ft. and about 25-30% with water table at about 10 ft. Lowering of water table will reduce the amount of sub-irrigation and the requirements of the crops shall have to be met from surface irrigation.

Pumping Saline Ground-Water and Its Use on Land

In the Northern Regions in the Doabs after hundreds and thousands years of infiltration and seepage from rivers a reservoir of good quality water has been formed in certain areas. The sub-surface salts have generally been washed to sites which had deep ground water where it could flow due to steep gradient. Nature helped the country to remove its the sub surface salts and got these accumulated in small pockets. Now that salty water lies deep, 70 to 100 ft. below surface suppressed by good quality water floating on it.

Pumping out this saline water and use it on land even through diluted will leave large amount of salts in the soil profile. The present trouble of soil salinity has appeared after using water of 200 ppm. The expected behaviour of land after using water with higher mineral content not be satisfactory.

As an alternative skimming of top good quality water can give the desired effects. Deep pumping from saline ground water zone does not appear to be proper section where are alternation exists.

Pumping Saline Under ground Water from Sind

In the Southern region, the so called middle Indus Plain and the delta areas of G. M. Barrage, neither the rainfall nor the intensity of irrigation or the structure of the soil, were such as to create a reservoir of good quality water. In that region highly mineralised water existed close to the surface before the irrigation and even now. Pumping this water out and dispose it through rivers or drains will cause many problem of deterioration of land besides the frequent failure of tubewell working in fine sand and excession salts. Such areas definitely needs horizontal drains to build up top fresh water zone and the keep depressed the saline ground water.

Large amount of water is being lost from land kept fallow or by crops. A land lying fallow with water tableor by crops. A land lying fallow with water table at 3 to 4 ft. may loose half the amount of water as lost from free water surface. This loss is reduced to about 20% with water table at about 7 ft. and to about 5% with water table at 10 ft. Similarly crops consume more than 3 times, their actual requirements when the water table is at 3 to 4 ft. and about twice their requirements when the water table is at 7 ft. and nearly 1½ ro 1½ times their requirements even with water table at 10 ft. Thus under the present condition of high water table, we are losing about a large volume of water may be equal to 20,000 to 25,000 cusecs by wasteful means. An optimum depth of ground water table at which the crops will draw the maximum amount of their requirement from sub-ririgation and yet the wastage is minimised is a proper solution. This measure will save a lot of water going waste and will minimise use of water.

Optimum Depth of Water-table

Under the present conditions in the northern regions water-table exists quite close to the surface, 2.0 million acres have water-table within 5 ft., 1.2 million acres within 10 ft. and 7.7 m. acres within 15 ft.

The next speaker was MR. ABDUL HAMID who put forth Observation on Salinity and Alkalinity Hazard in Scrap I. He stated that water from 52% of the tubewells can be used for irrigation directly without dilution. The balance can be used with dilution since such dilution corrects both EC and SAR.

MIAN MUZAFFAR AHMAD made a few observation on Salinity and Waterlogging problems. He pointed out that nature has provided a drainage system through the medium of the rivers. Before canals were constructed, the rivers provided proper drainage. Roads, railroads, plus the confining levees in the former Sind, all contribute to impaired drainage.

In the Punjab rice is the only crops contributing to the water-table. Tubewells will increase degradation of water with progress downstream, and add to salinity of deep aquifers. While tubewells are necessary, farmers in the north are putting in their own.

In the former Sind, there must be drainage ditches to the sea in the low region between the mountains and the river. This will provide horizontal drainage and the removal of salts.

MR. MUHAMMAD SA'ADAT ALI spoke on the lowering of the watertable for combating Waterlogging and Salinity. He suggested the deepening and extension of horizontal drainage systems.

MR. MUHAMMAD HUSSAIN put forth Irrigation and Agricultural Practices for Salinity Control in West Pakistan. His studies on Irrigation practices were based upon :—

1. studies of Irrigation practices for increased production and salinity control;
2. increased production of cotton and maize under the available water supply with improved irrigation practices, and
3. application trials to meet peak demands of crops during periods of short supply.

To be Continued in the Next Issue.

International Hydrological Decade

(Detailed Programme)

In our September issue, we briefly mentioned about the proposed research programme of International Hydrological Decades. In the article we have given further details of proceedings and the type of investigations desired. This article is still abridged. The details can be seen in Vol. No. 57, November 1964 issue of International Union of Geodesy and Geophysics.

In accordance with the resolution adopted at the twelfth session of the General Conference of Unesco, an inter-governmental meeting of experts in scientific hydrology was held at Unesco house in Paris from 7 to 17th April, 1964. Representatives from 58 countries participated. All the United Nation Special agencies such as the United Nations and its Economic Commission for Africa, F.A.O., W.M.O., I.A.E.A., W.H.O., the International Council of scientific Unions (ICSU), the International Union of Geodesy and Geophysics (IUGG), the International Association of Scientific Hydrology (IASH), the International Union of Geological Sciences (IUGS), the International Association of Hydrogeologists (IAH), the International Geographical Union (IGU), the Union of International Engineering Organizations (UIEO), the International Association for Hydraulic Research (IAHR), the International Union for the Conservation of Nature and of Natural Resources (IUCN) and the International Commission on Irrigation and Drainage (ICID), were also represented.

The Conference selected three working groups for :

(*a*) Collection of basic data.

(*b*) Inventories and balances and

(*c*) Working group on research.

Major objectives of the International Hydrological Decade

The rapid advances made in industry and agriculture, the accelerating growth of human populations and the desire to secure higher standards of living, have resulted in increased use of water by man, to the extent that the availability of water has become a critical factor in the development of many regions of the world. The absolute necessity of increasing the degree of rational management of water as a vital element of the human environment is therefore recognized. For this it is essential that an adequate and reliable data should be available in each country, and that water use and management should be based on scientific principles established for all the branches of hydrology. In order that a progressive approach may be maintained as new problems arise, further scientific research in hydrology and extensions and improvements of basic data are also essential.

The overall objective of an international programme in the field of hydrology is to accelerate the study of water resources and the regime of waters with a view to their rational management in the interest of mankind, to make known the need for hydrological research and education in all countries, and to improve their ability to evaluate their resources and use them to the best advantage. That is, the programme which will focus on science but will give strong consideration to utilitarian factors.

The need for such an international programme is reinforced by the very nature of hydrological phenomena, which are related to the planetary circulation of the atmosphere and the distribution of land and sea and which in many cases involve consideration of very large areas. This implies that data should be properly collected from points on a network of observation stations which must be of adequate density and comparable standard in all countries. All countries have important problems relating to the estimation, conservation and rational management of their water resources, but there are many deficiencies in hydrological services in relation to data collection, data processing, research and water use which call for collaboration and mutual assistance between states.

The fact that problems of water resources development occur throughout the world, that deficiencies in hydrologic knowledge must be overcome quickly, that there is scarcity of hydrologists that highly specialized research workers may have to work outside their own countries, constitute additional reasons for an international co-ordinated approach.

Components of the Programme

The programme planned for the hydrological decade includes the following basic components :—

(*a*) Appraisal of the state of our knowledge of the hydrology of the world, and identification of the principal gaps in that knowledge;

(*b*) Standardisation of the instruments, observations, techniques and terminologies used for the collection compilation and reporting of data;

(*c*) Establishment of basic networks and improvement of existing networks, to provide fundamental data on hydrological systems varying in size from small watersheds to the world as a whole;

(*d*) Research on hydrological system in selected geological, geographical, topographical and climatic environments, constituting what may be called representative basins;

(*e*) Research on specific hydrological problems whose urgency and special nature call for a considerable effort at international level;

(*f*) Theoretical and practical training in hydrology and related subjects;

(*g*) Systematic exchange of information.

To be fully effective and to have the desirable coverage, the proposed long-term programme should be spread over a minimum period of ten years, from 1965 onwards, and it is for this reason that the undertaking has been named the "International Hydrological Decade".

Outline of the Programme

The subject of study are separated into the following main heads :—

(*i*) Water balance studies.

(*ii*) Quality of natural waters.

(*iii*) Erosion, stream bed evolution, transport and deposition of sediment.

(*iv*) Man's influence in hydrological phenomena.

1. Water Balance Studies

This is to include:—

(*a*) *Precipitation.*—A network of rain gauging stations taking daily reading must be kept in permanent operation. A special effort will be made to improve the instruments, and methods of measuring snow fall studies of long term fluctuation of precipitation, use of inclined rain gauges in mountain area and 24 hours precipitation recording may be adopted.

Preparation of maps and charts showing rainfall intensity-duration area-frequency data for all states where this is practicable, otherwise of maximum 24 hours rainfall maps for the low frequencies. The experimental basins and representative basins must be equipped with recording rain gauges. The data thus obtained may be used for the plotting of intensity-duration curves and intensity-duration-area-frequency maps.

(*b*) *Evaporation.*—Development of standard instrumentation for different categories of station from the simplest to the most complex for measuring evaporation.

In the observation programmes of the various types of station, the study of the conditioning factors should not be overlooked. The more important stations will have to be provided with equipment for the study of turbulent exchange of moisture in the lower atmosphere and for the all-round meteorological observation of solar radiation. This category of station should also study the factors operative in corrections in regard to screen and environmental effects, etc.

(*c*) *Surface water.*—Improvement in the standard of the data supplied by the networks should be aimed at obtaining correct observations, without gaps, on water levels, a better calibration of stations, particularly for floods and base flows, and also a greater density. One of the activities proposed is the selection, by each state, a certain number of stations to be known as Hydrological Decade Stations. The States would undertake to observe, in the case of these stations, certain standards of quality to be defined by WMO and most of which have, in fact, already been proposed by that organization.

(*d*) *Soil moisture.*—Promotion of studies of measuring instruments and measurement methods for the different types of research, coupled with an endeavour to standardize as far as possible, those methods and instruments and the presentation of the results obtained.

Promotion of soil moisture studies with special reference to the use of the moisture in the top layer of the soil, care being taken to ensure that the different methods which have to be standardized yield comparative results.

Promotion of laboratory and field research on the variations of soil moisture, on water movement at the air-soil interface and in the zone of certain in conjunction with the determination of infiltration and run off rates. Wide dissemination of the results is desirable.

Encouragement of the systematic study of the influence of soil physical properties on infiltration and on soil moisture retention.

Organization of meetings of experts on water consumption by plants, comparison of observation and exchange of information. Wide dissemination of the results is warranted.

(*e*) *Ground Water*.—Collection in each state of all the geological geophysical, geochemical and hydrogeological data obtained from wells and from other research work. Study of methods for automatic data classification and processing.

Promotion of the development of networks of observation wells to measure the levels of watertables in deep or shallow aquifers. The first stage might consist in making observations on the levels of water tables beneath existing wells. The flow rate of springs should also be regularly measured.

Development of representative and experimental basins, or other units, where co-ordinated hydrological and hydrogeological studies could yield quantitative data on the recharge of ground water systems. Wide dissemination of methods and results. Emphasis on the primary importance of the ground water balance resulting from recharge and discharge of the aquifer (both natural and artificial), knowledge of the balance is essential for any sound ground water resources development programme.

Publicizing of the methods used and results obtained in experimental artificial ground water recharge. Efforts should be made to obtain advice from the few specialists in this field.

Promotion of studies on methods and techniques for evaluating ground water reserves and resources and studies of their genesis and evolution in time.

Development of hydrological research methods in which "kanats" foggaras, rhetaras, etc. are used.

(*f*) *Snow and Ice*.—Improvement of the rain gauging, snow gauging and hydrological networks in the areas under snow and ice, and standardization of their measuring instruments. In the States concerned, at least one of their decade stations should be placed at the outlet of a basin strongly affected by snow and ice.

(*g*) *Specific aspects of water balance*.—Preparation of maps showing precipitation, evaporation, floods, run off and infiltration, sedimentation and erosion and also of hydrological maps. The preparation of all these maps will necessitate co-ordinated action on the part of the various disciplines concerned, and the proportion of hydrological maps will involve close collaboration with Unesco, FAO, IASH and IAH, which have already undertaken action in the field.

2. Quality of Natural Waters

Continuation and extension of the work already begun by IASH and other bodies towards establishing an initial network for measuring the temperature and analysing the quality of the waters of stream and rivers. The measurements in question should as far as possible include biological and bacteriological analysis; these latter categories of analysis should only be carried out when means permit. Various categories of stations should be planned, proceeding from the simplest category (analysis of a few elements) to the most complex, providing for biological and bacterial analysis. Efforts should be made to standardize methods of sampling, measurement and analysis, and also the presentation of results.

Modification of salinity of natural waters by human action (irrigation, drainage, excessive utilization and evaporation from the watertable), encouragement of use of radioactive tracers etc.

3. Erosion, stream bed and evolution, transport and deposition of sediments

Standardization of instruments and methods for measuring transport of suspended load. A network of measuring stations, co-ordinated with those for water quality study, should be set up, samples for analysis can be taken at the hydrometric stations themselves at the same time as the discharge is measured. It would be desirable to make a simultaneous study of the particle size of loads carried during high and low water periods and to ascertain the differences in the modes of transport of fine and coarse grained sediments. It would be useful to instal these stations at the outflow points of small, medium and large basins so as to permit valid comparisons between one network and another.

Inclusion in the programmes of certain small experimental and representative basins, of research into geomorphology, erosion and transport of the solid load with the use of erosion plots, sediment traps, measurements of suspended load and minute observations of river and deformations, after geological, pedological and geomorphological, surveys of the basin.

4. Man's Influence on Hydrological Phenomena

Establishment of a number of small experimental and representative basins with sediment traps and other equipment to make quantitative measurements of the consequence of the changes brought about by man in the vegetation cover and in the soil. Basins thus equipped would enable investigations to be carried out more quickly and accurately. Investigations should also be made on erosion plots.

Draft of articles

The three working groups has put forth their detailed recommendation on the basis of which the Unesco has drafted ten articles for the guidance of the Co-ordinating Council of the International Hydrological Decades.

Full detail of the programme is published in the International Union of Geodesy and Geophysics No. 57, November, 1964 and can be had from Unesco Office, Paris.

Vol. IX December 1964 No. 4

In this issue