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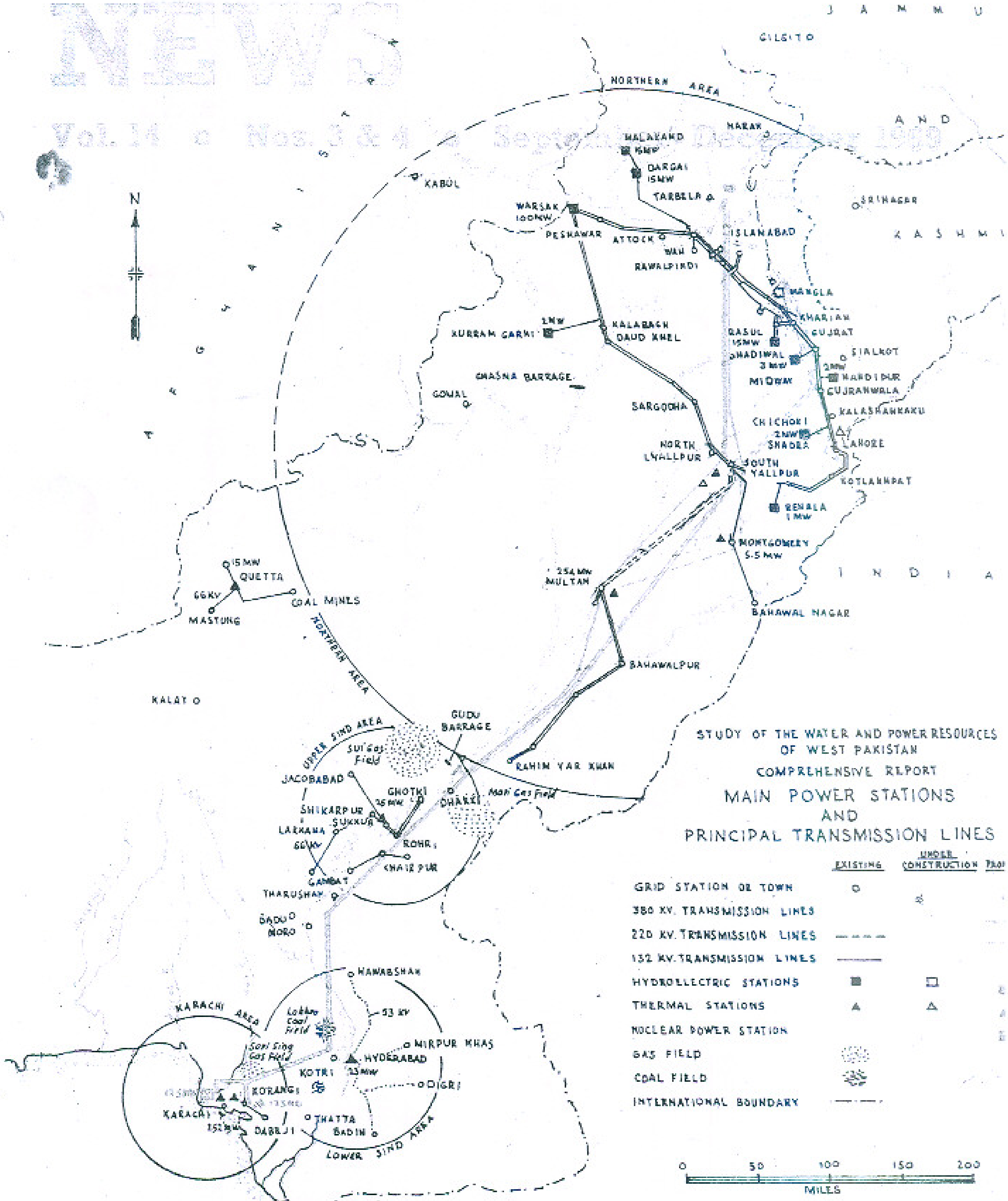

QUARTERLY JOURNAL OF THE WEST PAKISTAN ENGINEERING CONGRESS

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FOURTEENTH YEAR OF PUBLICATION

ENGINEERING NEWS

Quarterly Journal of the West Pakistan Engineering Congress

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In this issue

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ENGINEERS' DEMAND

This year at the time of annual convention of the Institute of Engineers, Mr. Ahmad Hassan repeated the demands of the Engineers. After Independence, particularly during the last one and a half decade, a single class of Services has continued to dominate and replace the technical personnels from all positions of policy decisions. This was not so even during the rule of the foreign colonial power, when technical services, like that of engineers, doctors, educationists etc. were headed by experts of the trade and every specialist could aspire to head the department at some stage, plan the policies and guide its working.

After independence the technically trained persons were to play a greater role to utilize the resources of the country. This was particularly true for the engineering services which had to undertake the largest responsibilities for development of the country's resources. At present these services utilize nearly 75 percent of the total development expenditure.

In normal circumstances, the policies of development should have been set by persons with long association and background of the technical subjects but in this country technical decisions are made by one class of public administrators who have the least background and training in the subject. The so-called members of civil services with superfluous knowledge and no specialisation are like illiterate quacks treating the complicated deceases.

Interesting enough whenever the engineers pointed out their difficulties from the platform of the Engineering Congress, they always received cold shoulders. Invariably they were advised to improve their integrity which was considered most questionable. Generally, it was the head of State who was made to say such words which brought insult to injury to the members of the profession. This was obvious so long as the members of a particular service drafted the reply for the President.

At present due to the policies of these administrators the financial position of the country is also not very optimistic. It is very easy to call in foreigners, place the country problems before them and beg for help. Naturally in this world of economic exploitation of developing nations, the self-interest of those who undertake the help of a country is foremost.

This has been the policy on a very large scale, loans after loans have been negotiated and these have now resulted in the huge drain on the meagre foreign exchange earnings which goes out in the form of interest on loans.

This technique of development by foreigner with negotiated loans, naturally outset the experts of the country, impair their confidence, place them in a second rate position and create in them a sense of inferiority.

The policies of the present-day economical exploiters are no different from the East India Company. Had our own engineers been the decision-makers the progress would have been more economical, more balanced, cheaper and perhaps with much less reliance on heavy loans.

This is not the grouse of the engineers alone. It is true for other technical services also which had been treated on the same lines. This is one main cause of dissatisfaction everywhere now in the country.

Mr. Ahmad Hasan in his address has put forth the demands of the Engineering profession.

1. All posts of central and provincial secretaries dealing with technical engineering subjects be manned by engineers.
2. Heads of the autonomous bodies engaged on technical work should be from amongst the engineers.
3. There should be one class of services for engineers and the present classification of temporary class II, Junior class I, Senior class I, be abolished.
4. More job opportunities may be created for qualified engineering graduates of the Universities and only qualified engineers be employed on the technical jobs.
5. The facility of in-service Technical Training as adopted for other services may also be made available to the engineers in the form of an Engineering Academy.

It is expected that with the changing conditions, the usurpation of the rights of the engineers will again be restored in the interest of the progress and prosperity of the country.

Deliberations of the Congress Executive Committee

(*Mar.* 1968 *to Dec.* 1969)

The 50th Annual session of the West Pakistan Engineering Congress was held in March 1968, when the new Executive Committee was elected headed by Sh. Ahmed Hasan as President. The Committee included five Vice-Presidents and twenty-seven members.

At the first meeting of the new Council held on March 15, 1968, Mr. Surfraz K. Malik was elected as Honorary Secretary, Mr. Ashfaq Ahmed Qureshi as Honorary Joint Secretary, and Mr. Mazhar Ali, Honorary Publicity Secretary. The three vacancies among the Executive Councillors caused by the election of office-bearers were filled by nominations of Mr. A. R. Qureshi, Mr. Alim-ud-Din and Mr. Manzur Hussain Bukhari.

Dr. Nazir Ahmed was again nominated as Honorary Editor of the Engineering News. The Council consisted of the following persons.

1. Sh. Ahmad Hassan, S.Q.A.
2. Sh. Muhammad Akram, S.K.
3. Mr. Muhammad Anwar Qureshi.
4. Mr. Mazhar -ud-Din.
5. Mr. Sayyid Hamid.
6. Mian Saeed Ahmed, T. Pk.
7. Mr. M. A. Waheed.
8. Mr. A. R. Qureshi.
9. Mian Alim-ud-Din, S.Q.A., S.K.
10. Mr. A. W. F. Sheikh.
11. Sardar Allah Bakhsh.
12. Rana Allah Dad Khan.
13. Mr. A. A. Siddiqui.
14. Mirza Abdul Latif.
15. Mr. Ashfaq Ahmad Qureshi.
16. Syed Fayyaz Ali Shah.
17. Syed Faiz Omar.
18. Mr. Haroon Rashid Toosy.
19. Mr. S.I. R. Sheikh.
20. Mr. Iqbal A. Shahab.
21. Mr. Jamil Asghar Khan.
22. Ch. Muhammad Hussain.
23. Dr. Mubashir Hassan.
24. Mian Muhammad Shafi.
25. Ch. Mazhar Ali.
26. Mr. M. R. Goheer.
27. Mr. M. R. Vehra.
28. Mr. Manzur Abbas Akbar.
29. Mr. Mazhar-ul-Haque.
30. Mr. Manzur Hussain Bokhari.
31. Ch. Muhammad Khurshid.
32. S. Monawar Ali Shah.

The President of West Pakistan Engineering Congress
1968—69

33. Mr. Mohammad Akbar Khan.
34. Syed Nazir Ahmed Shah.
35. Dr. Nazir Ahmad.
36. Mr. Sarwar Jan Khan.
37. Mr. S. H. Mahmud.
38. Syed Mohammad Ayub.

The Council holds a meeting generally every month. Its nineteenth meeting was held in December 1969, due to a gap of three months on account of the political situation, and ban on meetings of all sorts. The agenda of the committee constituted the under-mentioned nine items.

1. Confirmation of minutes of the last meeting.
2. (*a*) The collection and selection of technical papers for the next session.

   (*b*) Collection of papers for the annual symposium, and

   (*c*) Programme for visit to the engineering works.
3. Building of headquarters for the Congress.
4. Progress of recoveries of arrears of subscription due from the Congress members.
5. Progress of the Engineering News.
6. Recruitment of new members.
7. Absorption of temporary engineers in permanent cadres.
8. Establishment of an Engineering Service Academy.
9. Preparation of memorandum and other allied subjects connected with the wellbeing of the profession as a whole.

The executive committee has now remained in session for the last twenty months, during which ninteen meetings had been held and progress on the various items of agenda had been maintained.

COLLECTION OF PAPERS FOR PROCEEDINGS & SYMPOSIUM

During the first few meetings of the committee, requests were sent to all departments to encourage their officers to submit technical papers for the next session which was proposed to be held in March, 1969. By the end of the year 1968, several papers had been selected and approved for publication.

A symposium was also proposed on Water Resources Development. It was to cover a glaxy of subjects like Water Resources Planning and Developing, Irrigation and Drainage, Hydroelectric Power and Flood Control. The break-up of the subjects was as under :—

1. Water Resource Planning and Development

(*a*) Water resources and their studies, hydrological and geo-hydrological investigations, organizations, techniques and technical equipment, economics of field surveys.

(*b*) Economic aspects of integrated utilization water resources.

2. Irrigation and Drainage

(*a*) Surface and underground drainage. Experience gained from vertical and horizontal drains economy and costs etc.

(*b*) Reclamation of waterlogged and saline areas, methods, techniques and economic aspects,

(*c*) Water distribution, conveyance and field losses.

(*d*) Cropping patterns and consumptive use, water requirements, field efficiencies, increase in yields etc.

(e) Project costs and benefits, their methods of analysis and application.

3. Hydroelectric Power

(a) Operation of reservoir for integrated and multipurpose uses of water, operation difficulties, various techniques and use of computers etc.

4. Flood Control

(a) Collection of hydrologic data, methods and techniques used and field surveys etc.

(b) Sediment problems, field observations and implementation analysis of data.

(c) Analysis of hydrologic data, empirical and semi-empirical formulae, their uses and probable max. flood, average flows.

VISIT TO ENGINEERING WORKS

Three proposals continued to be examined with regard to visit to Engineering Works. The first related to a visit to engineering works in Iran, second to East Pakistan and the third pertained to visit in West Pakistan. After a considerable preliminary correspondance between Central Government and Mr. Azim-ud-Din of A.C.E. and Iranian Engineers, it was finally dropped except for a visit of ten senior Engineers of the various departments.

Necessary processing for a visit to East Pakistan also continued but finally it was decided that a visit to Chashma Barrage, Tarbela and Northern areas of Swat etc., will be conveniently possible.

HOLDING OF ANNUAL SESSION

The Congress usually holds its annual session in March of every year. This year the session was planned as usual when political situation deteriorated and Martial Law had to be declared. Even the monthly meetings could not be held. In July, 1969, permission to hold monthly meetings was received, and the committee decided to approach Justice A. R. Cornelius to agree to open the session proposed to be held in October, 1969, but unfortunately due to non availability of the Justice, and shortage of time, it was decided to hold the session in March, 1970, and request the Governor to open the Congress.

The proceedings as well as papers of the symposium were, however, printed and circulated to members.

BUILDING THE HEADQUARTERS OF THE CONGRESS

For building permanent headquarters of the Congress, plans of the proposed construction were got ready after several modifications and suggestions. It was also decided to co-operate with the Institute of Engineers so as to have similarity of construction of the two organisations. Dr. Mubashar and Sh. Muhammad Akram remained very active during the preparation of the plans. The final approved plans are now to be entrusted to Mr. Mohd. Akram for finalisation.

The campaign for collection of funds for the construction of the headquarters has been instituted. Rana Allah Dad has been of great help in collecting the donations.

ESTABLISHMENT OF ENGINEERING SERVICE ACADEMY

The establishment of an Engineering Service Academy has made much progress.

In the earlier stages a working paper on the proposed Academy by Mr. S. I. H. Shah was circulated among members. Mr. Monawar Ali Shah also put forth proposals which WAPDA had floated for setting up an Academy for WAPDA officers. Attempts were made to include the proposal in the agenda of the Governors' Conference. The latest position is that this item is included in the 4th Plan and a PC-1 is being prepared for submission to Government for approval and sanction.

ABSORPTION OF TEMPORARY ENGINEERS IN PERMANENT CADRE

Very active consideration with regard to the absorption of temporary engineers in permanent cadre have been continued during these two years. Secretaries, Irrigation and Power Department and C. & W. Department have been constantly reminded to finalise the filling of the vacant posts and the absorption of temporary engineers in permanent cadre. As a result of persistent perusal of the matter, a considerable success has been achieved.

The committee has also been very active with regard to the position of engineers in future set-up of the Government. Memorandum has been prepared. Actually a Sub-Committee of M/s Mazhar Ali, Mohammad Shafi, Saadat Ali, Sh. Muhammad Akram etc., was constituted to pursue the matter on the memorandum already sent by the Congress.

COLLECTION OF SUBSCRIPTION

One of the most difficult problems faced by the committee had related to the collection of subscription from members. Several times the defaulting members were reminded of the urgency of clearing the subscription. This item has always been kept on the agenda and the collection received every month had been brought to the attention of the members of the executive committee.

ENGINEERING NEWS: CREATION OF NEW MEMBERS ETC

The progress of publication of the Engineering News, approval of new members of the Congress, consideration of life members and such other items have continued to be discussed every month and suitable decisions made regularly.

No doubt the executive committee has remained in session for a considerably long time but it was due to the circumstances rather than the wilful prolongation of the session. The political situation, Martial Law and such other happenings stood in the way of holding the session. We do hope that the 51st session will be held in March, 1970 as presently proposed.

Abstracts of Papers of the Symposium on Water Resources Development

For 51st Annual Session

The Executive Committee of West Pakistan Engineering Congress decided to get the papers received, for the Symposium on Water Resources Development, printed. The booklet containing the papers of the Symposium have since been circulated to the members. In this issue we have printed brief abstracts of the six papers.

PAPER No. 89

Planning Development of Pakistan Water Resources

By Sarfraz Khan Malik

Water is the most natural vital resource. On its planned development depends the agricultural and to a great extent the industrial production of Pakistan. Without abundant water and hydro/power, industrial and agricultural production which contributes mainly to the gross national product cannot make progress.

Pakistan has started integral uses of its water resources. In 1955 the Irrigated areas in the country were 22.7 million acres. During the first plan period up to 1960, the irrigated areas stood at 24 million acres. Another 2.57 million acres were improved through drainage, flood control and increased irrigation supplies.

In the second plan, 1960 to 65, West Pakistan WAPDA started development of ground water for its scarp schemes. Increased surface diversions outside the Indus Basin Works accounted for increase of another 1.5 million acres. Private tubewells provided additional 5 million acres feet to irrigate 3 million acres.

East Pakistan also prepared a Master plan for water and power development and a large number of irrigation and flood control projects were found technically sound and economically feasible. Schemes completed during the period included the Karnafuli multi-purposes project, the Faridpur Drainage Scheme and the Low lift pumping irrigation Scheme.

The third five-year plan of Pakistan began in July, 1965 with a sudden drop in foreign assistance and unforeseen stresses and strains on the country's internal resources. The economy faced the challenge of preserving the growth rate of the plan despite the reduced financial resources. To obtain the projected growth rates with lower levels of investment, the priorities in the water and power sector of the economy were revised in favour of quick yielding projects, although the agricultural growth rate remained stunted during 1966-67 giving a rise of only 1.4% per annum as compared to the third plan target of 5 percent. The agricultural economic made a remarkable recovery during the year 1967-68 when the growth rate by major crops went up to 10 per cent. The development of water resources was assigned a high priority in the third plan and nearly 14 per cent of the total public sector resources of Pakistan amounting to 4199 million rupees were allocated for the water sector. Out of this, 1960 million was intended for projects in East Pakistan, 2181 million for West Pakistan and the rest for agencies under the Central Government.

The Schemes completed in East Pakistan by June 1968 were:—

1. Dacca-Demra-Narayanganj project for irrigating 15000 acres and flood protection of 12,740 acres at a cost of Rs. 21.5 million.
2. Brahmaputra right bank flood protection project included construction of 135 miles long embankment to protect 672,700 acres from floods at a cost of Rs. 69.7 million.
3. Providing 362 electric driven tubewells, 60 electrical low lift pumps and 689 diesel low lift pumps to irrigate 186,800 acres in the districts of Dinajpur, Rangpur, Bogra and Rajshahi.
4. Improvement of old Dakatia and little Fenny river in Noakhali and Comilla Districts Phase I. The scheme was to solve drainage problem of 242 square miles.
5. Dreading of the Gumti river in the district of Comilla has been completed at a cost of Rs. 11.9 million.
6. A comprehensive drainage Scheme has been completed at a cost of Rs. 41.1 million for the Faridpur District.
7. Teesta sub-project to boost up food production in 33,000 acres of Rangpur district was also completed. The on-going projects included the Coastal Embankment project Phase I, under which 2600 miles of embankment have to be completed at an estimated cost of Rs. 1145 million. By June 1968 about 1617 miles of embankment were completed.

The Ganges-Kobadak project, Kushtia unit was nearing completion to irrigate 120,000 acres at a cost of Rs. 509.4 million.

The above mentioned projects are being implemented in East Pakistan by Water and Power authority. Two other organisations like East Pakistan Agricultural Development Authority and Pakistan Academy for Rural Development are also implementing low lift pumping schemes and installing tubewells.

In West Pakistan out of an allocation of Rs. 2181 million, 52 percent were to be spent on drainage, reclamation and tubewells, 22.7 percent on irrigation and 3 percent on flood regulation up to 1968. Tanda Dam was completed, and work was in progress on Khanpur and Hub dams. A few Schemes of small dams were also completed.

In connection with activities on Scarps, 3475 tubewells had been installed of which 1470 were electrified by June 1968.

Indus Basin works continued to proceed according to plan. Mangla Dam was completed in 1967, a year ahead of the schedule.

The World Bank commitments of $895.0 million have further been increased by $315.0 million under a supplemental agreement of 1964 wherein Pakistan undertook to meet the full rupee cost of the completed works from her over resources.

The paper concludes with a suggestion for a concentrated effort by engineers, research workers, planners, financiers and land and water management workers to overcome the flood protection plan of East Pakistan and waterlogging-salinity problem of West Pakistan.

The research for optimum utilization and economic planning of our remaining water resources would be urgently needed.

PAPER No. 90

Planning Irrigation Requirements

By Sh. Mohammad Afzal

An optimum growth of plants need a required amount of water of suitable quality at a proper time. The process of irrigation needs storage of water in the root zone of plants for their evapo-transpiration requirements. In this connection it becomes imperative to know the moisture holding capacity of a soil, its permeability, structure, texture, composition, organic and inorganic content etc. The next problem is a knowledge of accurate appraisal of transpiration process, and the climatic factors such as heat, humidity, sunshine, etc.

Of primary importance are the soil factors such as its physical and chemical properties and the soil moisture, varying percentages of which in a given soil are named as hygroscopic moisture field capacity moisture, capillary water and gravitational water.

The water consumed by a plant through transpiration and evaporation from the adjacent soil and free water surface is termed the total consumptive use. It is influenced by many climatic, soil and plant factors. Innumerable formulae have been put forth to determine free water surface evaporation, the pioneer in this field was Dalton whose relation is still the basic one.

Evapo-transipration has been estimated by various methods, the most commonly used formulae are of Lowry Johnson, Blaney Criddle and of Hargreaves, etc.

Considerable information is given in the paper based upon calculations put forth by Blaney and Criddle in their report on Irrigation requirements for West Pakistan (1957).

Blaney Criddle divided West Pakistan into six climatic zones and worked out the monthly consumptive use.[1]

The authors have found that the "The Major cause of low production seems to be an insufficient quantity of irrigation water applied on the fields. This has resulted in an inefficient use of available water in terms of productivity. This is readily borne out by a comparison of historic deliveries in West Pakistan with those made for similar crops under similar conditions in those countries where production is more than double that of Pakistan. In general it may be said that water deliveries in West Pakistan are about half of what is considered necessary in other parts of the world, where climatic conditions are similar for optimum production."

The report further states:

"Low yields are not the only results of water application inadequate to meet the consumptive requirements, inadequate waterings have also adversely affected plant growth by contributing to the salinization of top soil."

The author's analysis shows that the water development of West Pakistan has lagged far behind the development of land. The dependable surface water supply is said to be about 110 maf of which the diversion by 1967-68 amounted to 85 maf. To fulfil our national goal, we must develop about 60 maf of additional water.

(*i*) There is a need for developing storage reservoirs to increase the number of full supply days in a year.

(*ii*) Increase in canal capacities appears to be essential in view of the increasing intensities of irrigation on most canal systems in West Pakistan.

(*iii*) Water allowances sanctioned at present should be enhanced to provide adequate water supply to the farmers for optimum production of food and fibre.

(*iv*) Conservation of fresh water resources of West Pakistan by resorting to lining and/or piped water supply system deserves top priority. In addition, the need of education to the farmer for improved water management practices must not be overlooked.

Discussing the extent and frequency of irrigation water application, the author has explained the wastage of water by the present technique of irrigation, causing evaporation from free water surface, seepage and deep drainage and nonuniform spreading of soil moisture. He has explained the methods to actually estimate the depth and frequency of irrigation.

In arid and semi-arid climatic conditions, the crop yields are likely to be affected due to salt imbalance in the root zone soil. This is true especially if adequate irrigation water is not supplied to wash down the harmful salts. Drainage of excessive water applications must receive due consideration. Unfavourable salt content in soils may be corrected and the land may be kept in perpetual beneficial use by the process of leaching. Excessive salt content reduces the permeability of soil so that flow of moisture in the root zone is obstructed. Irrigation with high T.D.S. water (such as ground water) will necessitate a certain percentage of irrigation water to be leached through the root zone to maintain soil salinity at a favourable level.

Common method to determine leaching requirement are put forth.

In the end the author concludes that the so-called water allowances, sanctioned from time to time, are inadequate and need immediate revision in the light of information available today. The irrigation engineer has yet to play a vital role to improve the general economy of Pakistan. Providing adequate irrigation supplies to over 28 million irrigated acres in West Pakistan appears to be a gigantic task but is by no means an impossible one. With the completion of the Indus Basin Project, we would have accomplished solution of a major part of the formidable problem. Substantial development of water resources is coming up in the shape of thousands of tubewells installed all over irrigated area of West Pakistan. The engineer at the same time should divert his attention to the much neglected aspect of water conservation. This involves more efficient canal water distribution and control of the enormous losses of valuable fresh water supplies by seepage, evaporation and evapo-transpiration through noxous weeds. Research should be launched with a view to achieving these objectives at a competitive cost.

The paper includes essential data in the form of appendix to work out consumptive use and also all the latest references.

PAPER No. 91

Drainage Surplus Experiments in Irrigated Areas

By P. J. Drury

In this paper the constituent elements of the water balance are discussed with special reference to conditions in the Lower Indus Area. Criteria for establishing the drainable surplus are considered, especially in regard to irrigation efficiencies and evaporation losses. Experimental data are quoted in support of the adopted assumptions. A typical calculation of the drainable surplus is presented for areas to be drained by tubewells and the special problems of tile drainage areas are examined.

Under optimum conditions the water supplied to an irrigated area must always be in excess of that necessary to mature a crop. Part of the excess water is evaporated or transpired from non-crop areas and part passes below the root zone and joins the groundwater is called the drainable surplus. To prevent the water table from rising and eventually affecting crop growth the drainable surplus must be removed. The determination of drainable surplus is therefore of prime importance and this paper considers the criteria and the method of calculation which were used to determine drainable surplus in the Southern Zone.

The drainage surplus is estimated by incoming and outgoing water. The incoming water is subjected to field losses, watercourse and field channel losses, farm losses, canal losses besides the consideration of rainfall and down valley flow.

Inattention to the distribution of irrigation water is the prime cause of low field efficiencies which at present is generally 60 percent. The future development for higher cropping intensities, better levelling of fields, improved maintenance of field bunds and improved water management practices can raise the field efficiency to 70 or 75 percent.

Watercourse and field channel losses are primarily due to evaporation, evapo-transpiration and seepage.

An average of 10 percent of the watercourse head discharges is taken to represent the watercourse and field channel losses of which 50 percent is the seepage reaching the water table and the rest is the evaporation and evapo-transpiration loss. Seepage occurs through the wetted area of the bed and sides of a channel and a minor loss is as a result of evaporation from water surface. The seepage flow may be absorbed by unsaturated surrounding media, evaporated from bare soil of the channel banks and adjacent areas, or transpired by non-crop vegetation growing in these areas. Common estimate of loss in terms of cusecs per million square feet of wetted surface is 5 cusecs for the Southern Zone of which 94 percent is seepage and 6 percent is evaporation from an average watercourse of 10,000 feet in length, 9 inches water depth, 3 feet water surface width and 2.5 cusecs discharge.

Form losses are a combination of field losses and watercourse losses. The term field efficiency is defined as the ratio of the amount of water beneficially used by a crop in a field to the amount of water supplied for it at the watercourse head. The paper gives the results of farm efficiency determined by various workers.

In this connection canal losses are also important. The earlier workers like Buckley, Champhekar have assumed it to be 8 cusecs per m. sq. ft. and in non-perennial channels this factor has been increased to 12 cuecs per m. sq. ft. Results of large number of tests conducted by Hunting for Southern areas are given in the paper which range from 3 to 6 cusecs per m. sq. ft. of surface. It was further determined that about six percent was lost as evaporation from water surface, another six percent by evapo-transpiration of canal bank vegetation and nearly 88 percent passed to the ground water.

Rainfall has some contribution to the field moisture in the Southern regions. The down valley flow contribution is taken as negligible.

For estimating outgoing water, the loss of water from fallow and never cultivated land has to be taken into account. Assuming water table at 7 feet depth and half the never cultivated area assumed to be covered with vegetation, for which the evapo-transpiration ratio was taken as 24 inches and evaporation from bare soil equal to 56 inches giving an average of 14.8 inches per year. This correspondded to about 0.2 percent of the free water surface evaporation taken equal to 80 inches per year.

Evaporation and evapo-transpiration from cutlivated lands is in addition.

Using all these sources of incoming and outgoing waters, the author has worked out drainable surplus for a typical tubewell development unit. Calculations have also been put forth for tile drains at field level.

In this paper much of the data used has been actually collected during investigations in the Southern regions.

PAPER No. 92

Study of Waterlogging Problems of West Pakistan with Electric Analogue Computers

By Maqsood Ali Shah Gilani

In the present paper the electric analogue computers, their construction and applications have been discussed. Studies have been made to analyze the problems related to waterlogging in three different areas of West Pakistan. The effects of pumping in the Upper Rechna and Lower Thal Doab Project areas for the lowering of groundwater levels have been computed on respective analogue models of the two areas. The drawdown contour maps after 20 years of continuous pumping have been prepared from computer solution for non-equilibrium state. Some of the representative graphs for transient groundwater level changes have also been shown.

On the Chaj Doab analogue model, analyses have been made for the steady state conditions that prevailed prior to the canal irrigation period and the non-steady conditions for the canal irrigation period from the year 1900 to 1960. The rise in groundwater levels, the rate of infiltration from the main canals and their distributaries, net recharge rate to groundwater reservoir and the rate of evapo-transpiration have been determined. The close agreement between the results of the analogue computer studies and the actually observed field data of groundwater levels in Chaj Doab is noteworthy.

The above studies indicate that the use of electric analogue computer can go a long way in analyzing the development projects for waterlogging problems.

Two systems are said to be analogous if their response to similar input stress is similar in form. Voltage and amperage in an electric circuit correspond faithfully to the head and volume rate of flow in the groundwater reservoir. Darcy law in groundwater flow and Ohm's electric current flow are perfectly analogous. These base principles are utilized in building electric analogue models.

Using this technique, studies have been carried out on Chaj Doab for steady state and non-steady state under certain assumed conditions. The assumptions for steady state conditions were:

1. The rivers were fully penetrating streams and were the recharge boundaries to the groundwater system.

2. Evapo-transpiration was the principal discharge source to maintain equilibrium conditions. The term evapo-transpiration as used here is in fact the actual evapo-transpiration minus the areal recharge due to precipitation which was considered to be a very minor source of recharge.

3. Recharge by underflow from the Upper reaches was considered negligible.

Several assumptions had to be made for non steady flow.

These studies have been carried out for Upper Rechna and Lower Thal Doab also.

In this paper the following conclusions are put forth:

1. During the pre-irrigation period of steady state conditions in Chaj Doab, rivers were the major source of recharge to the ground water and to keep the hydraulic dynamic equilibrium, the major discharge of ground water was by evapo-transpiration. The evapo-transpiration losses were greatest adjacent to the rivers where the water table was closest to the land surface. The configuration of the water table in Chaj Doab was controlled by the pattern of a evapo-transpiration losses and the geometry of the Doab.

2. Seepage from the canal irrigation system is the source of rise in groundwater levels in Chaj Doab and is the principal cause of subsurface drainage problems in the area. The seepage from the canals is a major component of groundwater recharge. It is found that seepage from the canals is a function of the size and discharge in the canals.

3. The decline in groundwater levels after 50 years project operation of Upper Rechna Doab area will range from less than 10 feet in proximity to the line-sources of recharge to over 50 feet in areas remote from the rivers and the main canals. It has been found that about 85 per cent of the dewatering will occur within the first 20 years. The equilibrium conditions will be attained in proximity to the line-source within 5 years and over most of the project area within 20 years. For practical purposes, equilibrium will be established over the entire project area within 40 to 50 years. Only in the areas of maximum drawdown will the unsteady flow conditions persist after 50 years and then the annual rate of decline will be insignificant.

4. On the Lower Thal Doab Model, the drawdown after a period of 20 years of continuous pumping has been observed to range from 5 feet to 25 feet and 5 feet to 15 feet for the transmissibility values of 440,000 gpd/ft. and 800,000 gpd/ft. respectively. Low drawdown has been observed in proximity to the rivers and the unpumped central area of mineralized groundwater.

The pumping in the project area will have an influence on the groundwater levels in this unpumped area and adjacent Upper Thal Doab. It is concluded that for a reasonably assumed value of transmissibility of the aquifer, the lowering of water table will be less than 25 feet anywhere in the project area after 20 years of continuous pumping.

PAPER No. 93

The Economics of Land Reclamation in the former Sind

By C. E. Finney

The paper is divided into three main sections. The methods and techniques of reclamation, and the technical data obtained from the L.I.P. investigations, are discussed first. This is followed by a discussion on the economies of small-scale reclamation, after which the economic aspects of intensive and extensive large-scale irrigation development are examined. Particular attention is given to this question, because it is of such importance for the successful exploitation of the province's agricultural resources.

The simplest and most effective method of reclaiming saline and saline-alkali soils is that of leaching, which is the normal method used in Sind. Large quantities of water are applied to the land, and as this water infiltrates, the salts in the soil through which it passes go into solution and are carried down by the percolating water.

The research undertaken under Lower Indus Project lead to the main results about the time required to reach normal yield levels.

To achieve these results, efficient soil drainage is essential. If the water table is high the reclamation is not lasting.

Croping increases water penetration and mobilizes calcium from the calcium carbonate of the soil.

For perennially-irrigated areas a rice-berseem rotation is best, although where alkalinity is disproportionately high, an initial planting and green manuring of Sesbania may be necessary. The great advantage of rice is that it is reasonably salt-tolerant and can withstand large applications of water and the presence of standing water. Berseem is the most suitable rabi crop because it also has relatively high water requirements. In all cases a heavy preliminary leaching is advisable.

With heavy leaching the soils can become sodium affected, leading to a reduction in soil premeability and making reclamation considerably more difficult. Special measures, such as the application of gypsum, become necessary to displace the sodium and improve the soil structure.

Based upon these consideration, the auther has worked out the economics of small scale reclamation and has shown that reclamation is economically possible.

Normally, canal water is used for reclamation, but with return of this magnitude, the use of private tubewell water to reclaim additional land could be highly attractive, in spite of the fact that such waters are considerably more costly.

In the paper, calculations of the cost of reclamation with private tubewells show that this is reasonably profitable, and that the investment made through pumping the necessary water, should be fully recovered within a year of reclamation being completed.

The author has also considered the economies of large-scale reclamation. He has concluded that it is far more economical to intensify cultivation on the area already developed than to extend the cultivated area by a large-scale reclamation.

PAPER No. 94

Some Problems of Ground Water Resources of West Pakistan

By Dr. Nazir Ahmad

As a result of nearly 90 years of efforts, it is now possible to divert about 83.5 maf. of surface water at the canal head. Out of this about 41 maf. is utilized by crops.

It is being planned to pump by 1970 about 27 to 30 maf. from groundwater. Presently about 20 maf. groundwater is being pumped which includes about 10 maf. pumped by farmer, 6 maf. by WAPDA and the rest by Irrigation & Public Health Departments. By 1968, nearly 60,000 tubewells installed by farmers are in operation. WAPDA is installing 9138 tubewells in their ongoing schemes. Scarp schemes approved so far include the installation of 14236 tubewells having pumpage capacity of 34.71 maf. although the proposed utilization is up to 19.36 maf.

This vast resource of groundwater has been slowly building up during the formation of the Indus plans by deposition of the alluvium which took nearly 5.5. m. years to fill up the depression below the salt range by depositing nearly 400,000 acres ft. of sediment every year.

Sediment deposit included about 0.02 per cent salts which got readjusted by subsequent flow.

The accumulation of saline water is a result of washing of the formations. These salts are drawn from waters of the rivers. It is argued that these salts are not the remnants of sea water which have been washed down to much deeper depths under the pressure of fresh water.

The waters with high order of salinity are heavier and thus sink deeper. This fact is confirmed by the existence of saline water in the centre of each doab. Some pockets of saline water also exist. These were formed by the obstruction to flow by the clay formations. This saline water is out of earlier accumulation of salts which have not been washed off. This condition is very obvious in Bari Doab where fresh and saline water exist in quite a complicated manner.

The saline water in the doabs has always remained under an enveloping pressure of fresh water. This pressure is a result of seepage from rivers which have kept the saline water enclosed and enveloped by fresh water. This saline water cannot find its way from underneath the rivers, the seepage of which forms a high water pressure zone.

As a result of intensive pumping from the fresh water zones and increase of irrigation practices on the area containing saline groundwater, the age-old balance of fresh water pressure enveloping the saline water is bound to be upset resulting in redistribution of saline water into the good water zones.

The Scarp schemes need special considerations. In practically all these schemes either the saline water is to be pumped out and spread on land or a reverse pressure gradient may be expected to be established. It will cause saline water to flow into good water quality areas.

In the five Scarp Schemes of the Punjab, where annually 3 million tons of salts used to be spread with 18,000 cusecs of irrigation water, now with the pumping of 21,000 cusecs from the groundwater, additional 21 million tons of salts will be pumped out.

It thus calls for urgent action to revise our conception of pumping groundwater. Our present seepage order is about 50,000 cusecs which will increase to about 70,000 cusecs. Steps can be taken to recover a part of this huge volume of water, by keeping the hydrological conditions similar to those as exist now. Simple but proper planning can be helpful to attain this condition otherwise we will not only spoil our land but also our reserves of fresh groundwater.

Controlled Fall

(A NEW DEVICE)

By

PIR MOHAMAD IBRAHIM QURESHI

INTRODUCTION

Irrigation Department of West Pakistan, in order to economise in the cost of construction, devised a system of flumed falls for its hydraulic structures across the rivers and canals. Such structures are narrowed down in width at the fall. The ratio of the narrowed section to the full width is called the fluming ratio. The smaller the fluming ratio, the greater was the economy in the construction of works and their superstructures.

However, the economy in the construction of the flume was to a great extent offset by the long down-stream protection which had to be provided to withstand the concentration of flow in the centre and the erosion of the sides due to back rollers. These rollers (whirls) caused destruction to the banks immediately down-stream of the pacca structures. They also concentrated heavy discharge in the central portion of the canal which caused deep scour holes down-stream of the structures. Figures 1 and 2 of a fall illustrate the phenomena.

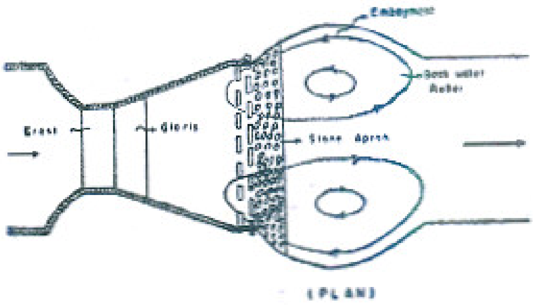


Fig. 1

Fig. 2

To avoid the damage to the sides and the bed, long down-stream pacca splays and floor are provided. In spite of these costly measures the maintenance costs of works remain high as increase in the length of down-stream splays do not offer a complete remedy. The maintenance of the fall structures in the alluvium remains a problem.

Various measures were tried to overcome the intensive damages. These were:—

1. Provision of a big stilling basin.

2. Construction of Baffle walls.
3. Provision of Multiple rows of friction blocks.
4. Spreading the floor.
5. Providing Guide vanes.

All these measures were costly and of limited success. Search for an inexpensive device, which (for a low fluming ratio) would achieve a uniform distribution of the discharge in a short length down-stream and secure a fall without any back-water whirls, continued.

By 1948 the writer had discovered "three Laws of Liquid Flow" as given below:—

Law I

Resistance to the flow of a liquid offered by a Constraining Surface is proportionate to the Dynamic Pressure exerted by the liquid. This pressure is equal to the product of the area of the surface, density of the liquid, and half the square of the velocity of the filament next to the surface.

Law II

Resistance to the flow of a filament of a liquid offered by a filamental surface is proportionate to the Interfilamental Dynamic Pressure exerted by the liquid. This pressure is the product of the area of the surface, density of the liquid, intensity of the Eddy Strain, discharge up to free surface passing over a unit of the Constraining Surface and the gradient of the depth-velocity Curve at the filament to the Constraining Surface.

Law III

Energy of flow per unit area of Rough Constraining Surface continuously diverted to generate Penetrating Eddy Strain in the liquid is inverse of the product of the Relative Intensity of Stream Lining, Stream Lining Coefficient of the Constraining Surface and a function of the temperature of the liquid.

Law IV

In 1952 the fourth Law of Liquid Flow, which relates to falling liquids, was discovered by him. This law states "A liquid falling to an accelerated flow takes the direction normal to the down-stream edge of the curve of the crest".

With the discovery of this Law the writer realised that it could be utilised in the narrowing down of the gullet of a fall to a much greater extent without causing harmful concentration of flow and back-water whirls on the down-stream sides of a fall.

The adoption of the device resulting from the use of this Law, would cause very substantial saving not only in the construction but also in the maintenance of canal falls and river barrages. Savings of crores of rupees would result in the construction of barrages across the rivers. The device was got patented by the writer in the following countries:—

1. U.K. in 1953 through Messrs. F. J. Cleveland and Company, London.
2. Pakistan in May 1953, through Messrs Sheikh Brothers, Karachi.
3. India in April 1953, through Messrs Depending and Depending, Calcutta.
4. Iraq in January 1954, through F. J. Cleveland and Company, London.
5. Application for the patent was made in April, 1952, in U.S.A. through Messrs. F. J. Cleveland and Company, London.

FOURTH LAW OF (FALLING) LIQUIDS

The following brief description of water falling from a fall is offered in support of the law :—

(*a*) Figure 3 shows a tank full of water with open flume outlets on its four sides. The water will issue in all the four directions. The falling water has no inherent tendency for a particular direction. There is obviously something in the construction of the outlet which fixes the direction of the falling water.

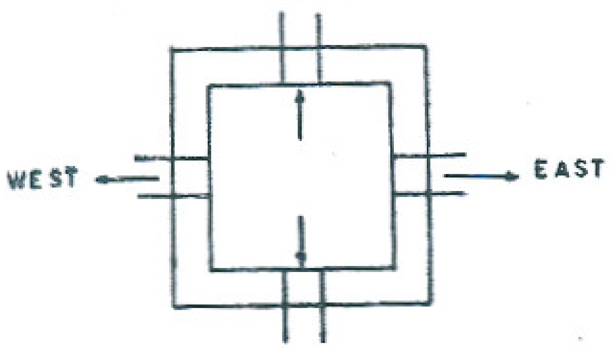


Fig. 3

(*b*) Similar is the position in case of a group of outlets at the tail end of a channel. The directions of flow of water are fixed by the construction of cluster-components of the fall. (*See* Figure 4).

(*c*) If we construct two open flume outlets in a side of the tank (fig. 5) so that they are absolutely similar excepting that the down-stream edge of the crest of a flume, is parallel to the side and the other at 45 degrees to it, the direction of falling water in each outlet will be normal to the down-stream edge of the crests.

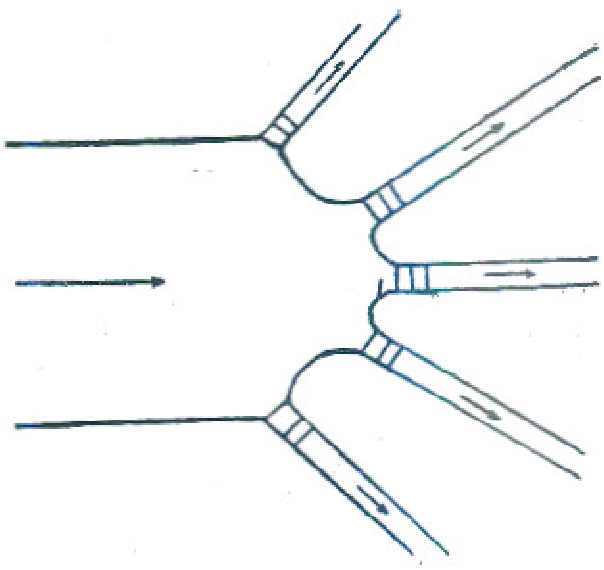


Fig. 4

The above explains the principle of the Fourth Law of (Falling) Liquid:—

"Liquid falling to an accelerated flow takes a direction normal to the crest (down-stream edge) of the fall".

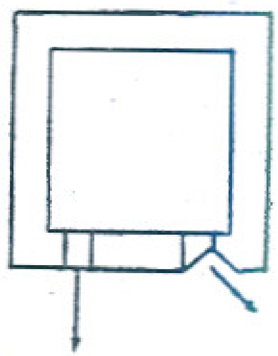


Fig. 5

With the help of this law the direction of the falling water can be controlled. See Figure 6 in which direction of flow changes at A.

DIRECTION OF FALLING WATER LEAVING THE CREST-EDGE

(*a*) Along the Glacis

A flowing mass of water takes the steepest line of drop. The water from the crest of a fall will move in the direction normal to the crest-edge if that direction happens to be the steepest line of flow. (*See* Figure 6 in which the steepest line of fall is along AB).

(*b*) At the End of Down-stream Splays

The direction of water in a stream of a uniform turbulent flow is then controlled by means of rows of friction blocks, located down-stream of the splays. The direction of the blocks is kept at right angle to the direction of the desired flow. (*See* C in Figure 6).

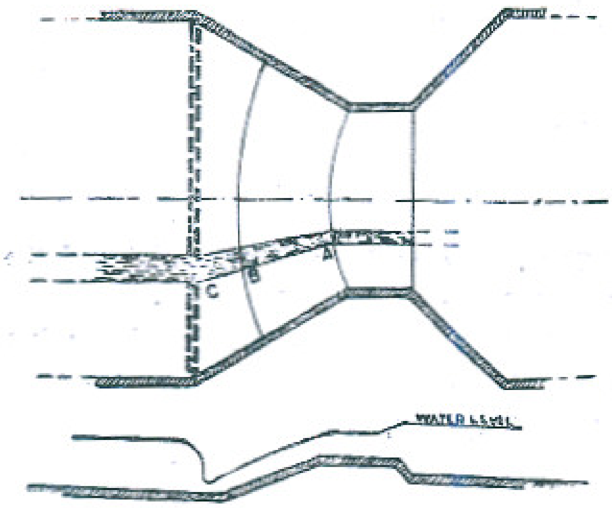


Fig. 6

By a combination of the Principles mentioned above a complete control over the direction of flowing water can be achieved at A, B, C in Figure 6. The application of these principles results in the designs of canal-falls and river barrages which are economical both in their construction and maintenance.

MATHEMATICAL TREATMENT

The hydraulic principles involved in controlling the directions and intensities of falling water are enumerated below:—

A. Direction

(*i*) To control the direction of falling water, the curvature of the down-stream edge of the crest should be so designed that the direction normal to the curvature at any point is the desired direction of flow.

(*ii*) To keep the flow along the glacis in the desired direction, the slope along it should be steepest in that direction. This can be achieved by keeping uniform lengths of glacis along the desired lines of flow.

(*iii*) After the extra energy of the fall has been destroyed by the standing wave or in any other manner, the flow becomes uniformly turbulent (*i.e.* it is no more accelerated), the direction of flow can be altered by placing rows of friction-blocks at right angle to the direction of flow in the down-stream channel. The friction-blocks should be located at the end of splays where the full bed width of the down-stream channel is attained.

B. Intensity of Discharge

It is not only sufficient to control the direction of flow in the down-stream channel but it is also necessary to control the intensity of discharge at the end of the splays. The intensity of discharge per foot width, falling at an angle to the direction of flow in the gullet, is given by:—

$$q = C\,(H + h_a \cos\theta)^{3/2}$$

where

q = Discharge falling per foot width of the crest of a fall.

C = A coefficient.

H = Depth of fluid on the crest of the fall.

h_a=Head due to velocity of approach of the upstream channel.

and θ =The angle which the stream falling at the crest edge is desired to take with the direction of flow of upstream channel.

2. Figure 7 gives the sketch of a fall with a curved crest and a curved toe of glacis. The notations used in the mathematical calculations are also listed below:—

B =Width of the down-stream channel.

d =Width of the constricted fall (Gullet).

L =Length down-stream of the crest edge necessary to accommodate glacis and standing wave-rush.

— —The distance of the point at which the stream is not required to change its direction as measured from the down-stream end of the contracted width of the gullet.

E —Length of the down-stream splays as measured in the direction of flow from the point from which A is measured.

0 —The angle through which a stream falling from the edge of the crest is required to change direction.

G —The horizontal length of glacis of the fall.

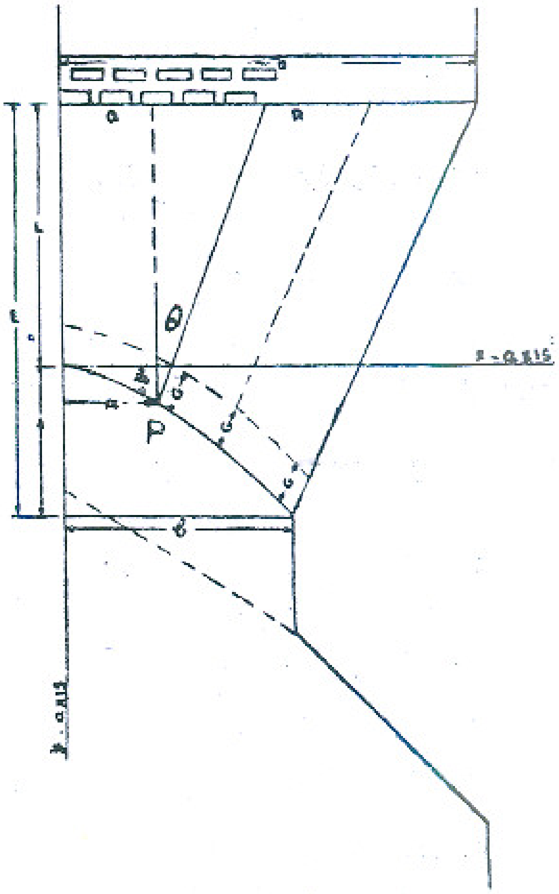


Fig. 7

MATHEMATICAL ANALYSIS

3. Assuming that the intensity of the discharge throughout the width of the gullet of a fall and downstream of the channel is uniform, the design for controlling the direction and the discharge intensity of the falling liquid is given below.

A. CONTROLLING DIRECTION OF FLOW:—

(*a*) **Mathematical Treatment**

(*i*) In order to make the water leaving the fall-crest follow the desired direction, the tangent to the curve of the crest at each point should be normal to that direction.

To write it mathematically, at a point P (*x y*) on the curve of the crest (*See* Fig. 7):—

$$\frac{\partial y}{\partial x} = \tan\theta \ \textit{i.e.}\ \frac{QR}{PQ}$$

or $\frac{\partial y}{\partial x}=\frac{(B-b)\frac{x}{b}}{L+y}$

or $(L+y)\partial y=(B-b)\frac{x}{b}\partial x.$

or $Ly+\frac{y^2}{2}=\frac{(B-b)}{2b}x^2+C.$

It is known that when $x=0$, y is also equal to zero, therefore C is equal to zero.

$\therefore\ Ly+\frac{y^2}{2}=\frac{(B-b)}{2b}x^2,$

or $(L+y)^2=\frac{B-b}{b}x^2+L^2,$

or $y=\sqrt{\frac{B-b}{b}x^2+L^2}-L$ ..(1)

As when $x=b$, $y=A$

$\therefore\ A=\sqrt{(B-b)b+L^2}-L,$ ..(1*a*)

or $A+L=\sqrt{(B-b)b+L^2}$

i.e. $E=\sqrt{(B-b)b+L^2}$ ..(2)

or $L^2=E^2-(B-b)b,$

or $L=\sqrt{E^2-(B-b)b}$ ..(3)

The value of L is always positive as a certain length down-stream of the fall has to be provided for stilling.

For this condition from (2) we have

E not less than $\sqrt{(B-b)b}$ ..(4)

(*ii*) In order to guide the liquid falling over the glacis to flow in the desired direction (normal to the crest-edge) the slope of glacis along that direction should be the steepest. This is secured if the horizontal length (G) along the desired flow line at each point on crest-edge (as shown by A and B in Figure 6) is the same—as perpendicular to the line is the shortest between the point and the line.

(*iii*) At the end of splays in the full width of the channel, two rows of friction blocks are placed to make the uniformly turbulent flow follow the desired course. (*See* point C in Figure 6).

(*b*) Practical Way to Solve the Problem of Controlling the Direction of Flow

(*i*) Fix the splays according to the relation (4) *i.e.*, the value of L should be sufficient to accommodate the glacis and kill the extra energy.

(*ii*) Find out the value of L and A from (3) and (1*a*).

(*iii*) Mark lengths L and A on the line, on which flow does not change directions. Assume this down-stream end of A (*i.e.* 0) as zero point of x and y axes.

(*iv*) Through O, mark x and y axes at right angle and parallel to the direction of up-stream flow.

(*v*) Assume values of x between zero and the value of b and find y from (1). Plot these values of x and y to draw the curve of the down-stream edge of the crest.

(*vi*) Draw the desired flow lines through the calculated points and along each of the lines set out a length equal to (G). This would fix the curve of the toe of the glacis.

(*c*) Example Showing the Influence of Direction of Flow on the Shape of Curve

Suppose a channel of 80' width has a fall with 50% fluming ratio. Suppose a 10' length of down-stream of the central toe of the glacis is required to form the standing wave on the pacca floor.

Suppose the horizontal length of the glacis is 3'. The design of this structure according to the fourth law is as under:—

Here $L=10+3=13$

and $B=2b$

From the relation (1)

$$y=\sqrt{\frac{B-b}{b}x^2+L^2}-L$$

or $$y=\sqrt{x^2+169}-13$$

The above relations gives the following corresponding values of x and y to enable the curve of the crest to be drawn (See Fig. 8):—

x	y
0	0.00
5	0.93
10	3.40
15	6.65
20	10.85

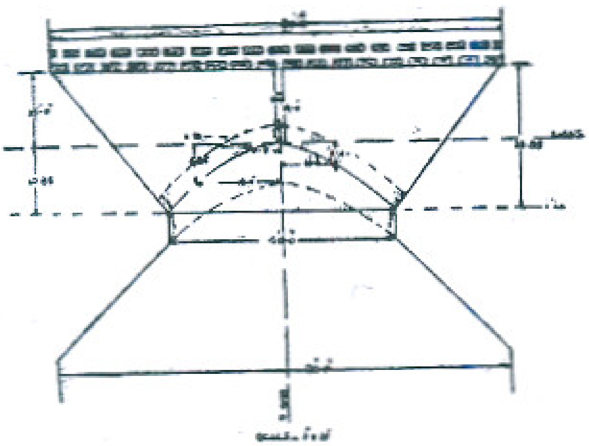


Fig. 8

B. DISCHARGE INTENSITY

The crest edge when plotted would be a curve. The steeper the downstream side splays, the greater the curvature. The value of ∂s corresponding to ∂x increases as we proceed from the centre to the side. This would affect the intensity of discharge unless the depth over the crest is corrected. In case of a fall with very steep down-stream splays, this is not fully compensated by the reduction in the velocity of approach. To adjust this, the levels along the crest-edge have to be fixed and a transition from the gullet to the edge of the crest provided. The method of calculating the transition depth d is given below:—

(*a*) Mathematical Treatment

$$\partial s=\sqrt{\partial x^2+\partial y^2} \quad \text{or} \quad \frac{\partial s}{\partial x}=\sqrt{1+\left(\frac{\partial y}{\partial x}\right)^2}$$

if d = height (or rise) of the edge of the curved crest at P above the centre of the curve at O. (*See* figure 7).

Therefore

$$C\partial x(H+h_a)^{3/2}=C\partial s\ (H+h_a\cos\theta-d)^{3/2},$$

$$\text{or}\quad \frac{\partial x}{\partial s}=\left(\frac{H-d+h_a\cos\theta}{H+h_a}\right)^{3/2}$$

$$\text{or}\quad \sqrt{\frac{1}{1+\left(\frac{\partial y}{\partial x}\right)^2}}=\left(\frac{H-d+h_a\cos\theta}{H+h_a}\right)^{3/2}$$

$$\text{or}\quad d=H+h_a\cos\theta-\frac{H+h_a}{\sqrt[3]{1+\left(\frac{\partial y}{\partial x}\right)^2}}$$

$$=H+h_a\cos\theta-\frac{H+h_a}{\sqrt[3]{1+\frac{(B-b)^2\frac{x^2}{b^2}}{(L+y)^2}}}$$

$$=H+h_a\cos\theta-\frac{(H+h_a)(L+y)^{2/3}b^{2/3}}{\sqrt[3]{(L+y)^2b^2+(B-b)^2x^2}}$$

$$=H+\frac{h_a(L+y)b}{\sqrt{(L+y)^2b^2+(B-b)^2x^2}}$$

$$-\frac{(H+h_a)(L+y)^{2/3}b^{2/3}}{\sqrt[3]{(L+y)^2b^2+(B-b)^2x^2}} \qquad \ldots.(5)$$

(*b*) Influence of the distribution of discharge and splays on the crest levels

In the example given under Controlling Direction of flow, if H (Prevailing)=4 and $h_a=0.07$, the values of d at various points as calculated (*See* enclosed Table I of Calculations) from relation (5) will be as below:—

x	d
0	0.000
5	0.155
10	0.396
14	0.555
20	0.646

Note.—If H and *ha* in a channel fluctuates then the prevailing value of H and *ha* will have to be adopted in calculating the above elevation.

The calculations for the crest-edge above 0 (the centre of the crest) for 50% fluming with different side splays give different values of *d*. The rise (*d*) at the extreme end of the crest of the fall with different splays are listed below for the example given above.

Draw-stream splays	Maximum rise (*d*) at the end-crest in feet
1 in 1.25	0.600
1 in 1.50	0.440
1 in 2.00	0.290
1 in 3.00	0.120
1 in 4.00	0.038

The rise is also affected by the fluming ratio. Lower the fluming-ratio, the lesser the rise (*d*), other things being the same.

Table I of the Calculations

Note.—Splay is 23.185 in 20 or 1.1975 in 1

x	L+y *i.e.* $\sqrt{\frac{B-b}{b}x^2+L^2}$	y=(2)—L	$\frac{x\frac{(B-b)}{b}}{L+y}$	$\sqrt{1+(4)^2}$	$\frac{L+y}{\sqrt{(L+y)^2+x^2}}$	$h_a(6)$	4+(7)	$\frac{H+ha}{(8)}$	(8)—(9)
1	2	3	4	5	6	7	8	9	10
5	13.93	0.93	0.359	1.0412	0.988	0.0692	4.0692	3.9138	0.1554
10	16.40	3.40	0.610	1.1111	0.854	0.0598	4.0598	3.6635	0.3963
15	19.85	6.85	0.756	1.1625	0.798	0.0559	4.0559	3.5011	0.5548
20	23.85	10.85	0.839	1.1942	0.766	0.0536	4.6536	3.4080	0.6456

Note.—(2), (4), (6) (7), (8), (9) denote Col. 2, Col. 4, Col. 6, Col. 7, Col. 8 and Col. 9, respectively.

OTHER USES OF THE NEW DEVICE

(a) The Device is a Departure from Existing Designs

The device described in this paper aims at producing controlled flow of a fluid stream. When added to a fall it gives full control over the direction and distribution of the discharge downstream. It may be used in the design of falls and weirs, canals, barrages in rivers, curves in canals etc.

Economy in the construction of a fall at present is generally obtained by constricting the waterway. This is achieved by providing curved up-stream approaches and diverging splays down-stream. But the down-stream splays do not completely stop the backwater rollers.

The existing designs of falls have serious defects. The water passing over the crest tends to go straight ahead instead of distributing itself evenly across the down-stream splayed out section. This results in greater intensity of flow in the centre as compared to the sides. This solution is worsened by the creation of backwater rollers. In earthen channels of erodable material, it not only results in costly construction of down-stream splays and floors but also necessitates their expensive maintenance.

As a result, big scour holes in the bed and embayments on the sides are formed. To counteract this, devices such as friction blocks and baffle walls, either at the end of the glacis or splays are generally provided. These, however, can dissipate only a small portion of the energy of the central concentrated jet. Dissipation of a major portion of the energy will need devices costly to construct and maintain.

The new device described here, provides a remedy by uniform distribution of flow down-stream of a fall. The new device which is inexpensive to construct and maintain neutralises effectively the concentration of energy below a canal fall. This is achieved by providing down-stream crest-edge and the toe of glacis to lie on predetermined curvatures so that the flow intensity (down-stream) is uniformly distributed, thus minimising the possibility of scour holes due to the concentration of flow.

Friction blocks placed at the end of the down-stream splays help to change the direction of (the uniform turbulent) flow and make it normal to the channel downstream.

(a) (i) Description of the Device and its Advantages

Figure 9 shows the plan and cross-section of a fall embodying the device. The crest is located in a constricted width of the channel both for the sake of economy and for metering the supply. The edge of the crest is designed to produce a uniform intensity of flow downstream of it and also at the end of the splays

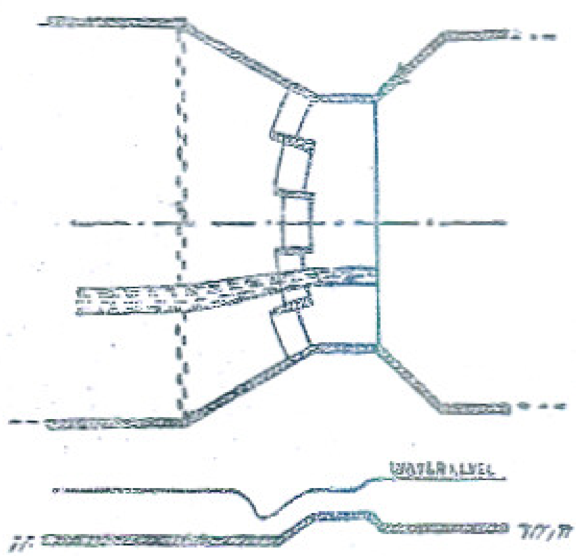


Fig. 9

where the full channel width is secured. At that location one or two rows of friction blocks are provided for changing the direction of flow to make it normal to the channel. This results in the proper distribution of discharge at the end of the splays and the toe of glacis. In this way, the backwater whirls are eliminated and the possibility of scour holes in the erodable channel is obviated. The length of splays and floor are reduced, thus bringing down the construction cost of the weirs and falls.

(*ii*) Model Test Confirms the Efficiency of the Device

A fall of the Irrigation Department of West Pakistan which had back-rollers and a scour hole down-stream was selected and provided with properly designed curvatures both on the down-stream edge of the crest and glacis. The results achieved fully demonstrated the utility of the device. The floats dropped in the model followed exactly the predetermined courses and there were no back-rollers on sides and no concentration of flow in the centre. (*See* Figure 10).

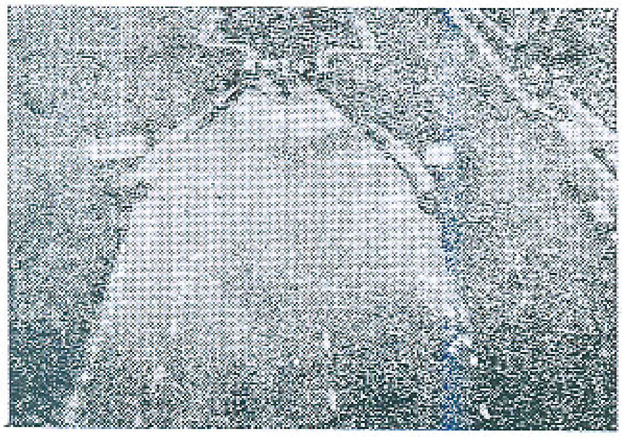


Fig. 10. A fall in running condition

A photograph taken after shutting down the flow in the model shows almost complete absence of scour hole or side embayments. (*See* Figure 11).

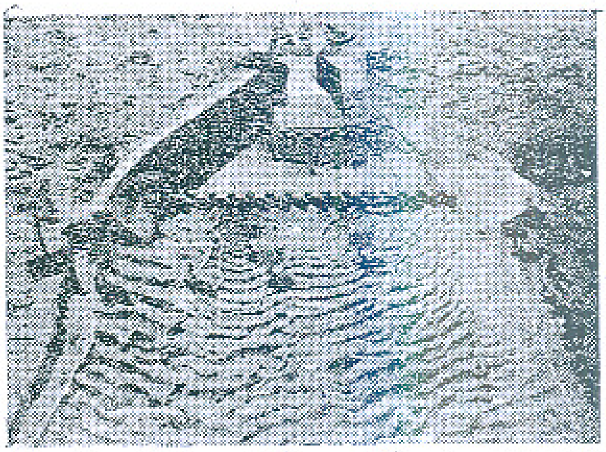


Fig. 11. Bed conditions after operating the fall

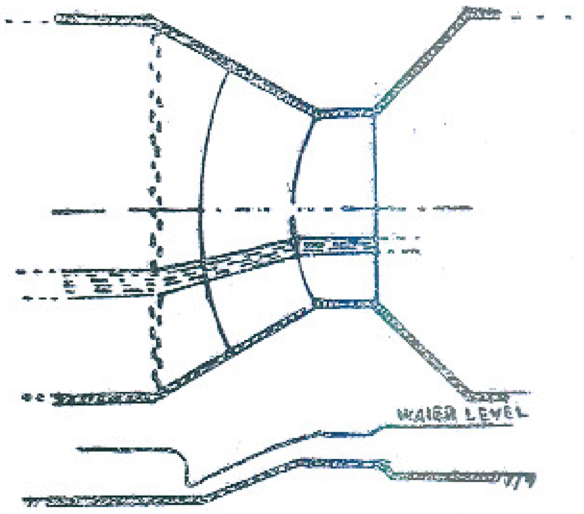


Fig. 12
A Five-span Fall

(*Note*.—The figure shows only the down-stream portions of piers).

(*c*) Multiple Span for Barrage Design.

The plan and section of a five-span controlled fall designed on the same principle are shown in Figure 12. The piers between the spans are located along the flow lines. The introduction of piers in the case of a wide flume and dividing the down-stream edge of the curved crest into segments, reduces the length (A in Figure 7) of the crest protruding far into the down-stream channel. The length of the downstream protection is also reduced to the minimum.

A good example of a multi-span fall is a barrage on a river. It is possible by the use of the device to reduce the length of a barrage without increasing the intensity of discharge on the non-erodable floor.

(*d*) Use of the Device to Replace Curves in Canals.

Where a channel curves, silting takes place on the inner side and scouring on the outer side, such curved reaches require costly maintenance. A curved channel also cuts up the irrigation fields in awkward shapes. The device could be used to replace the lengthy curves by abrupt turns provided a fall can be introduced at the apex of the curve. (*See* Figure 13).

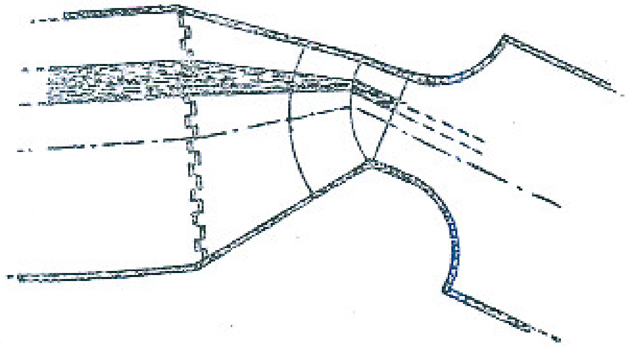


Fig. 13. The use of device on a curved channel

(*e*) Use of the Device in High Falls

In case of high falls, where the destruction of extra energy is required, this can also be achieved through the help of the device. The discharge can be divided into two equal streams one passing over the other to collide at exit in opposite directions in a vertical plain. With the help of device, the various segments of the discharge in each stream

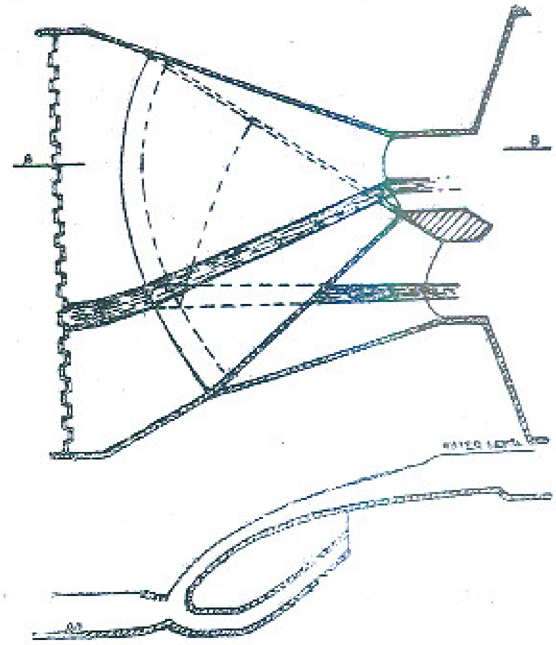


Fig. 14. A two-span fall

could be made to collide with discharge of an equal order in the other stream. The arrangement is shown in Figure 14.

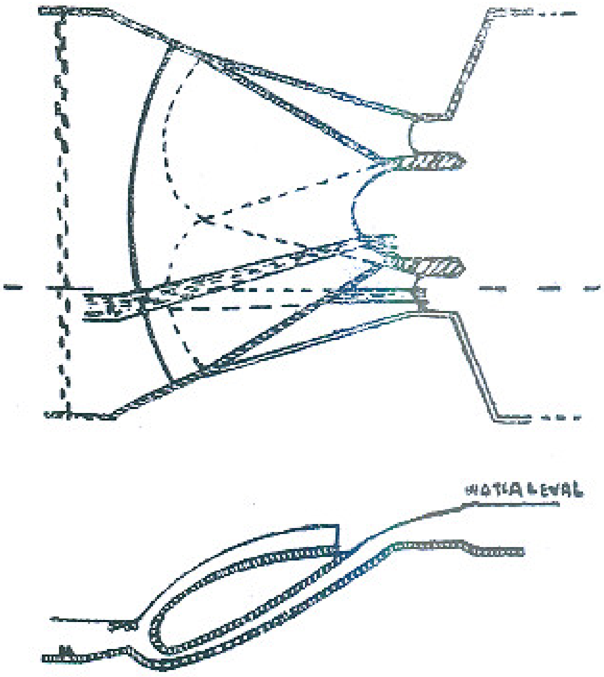


Fig. 15

Figure 15 shows a construction similar to the one shown in Figure 14, except that a more symmetrical arrangement is obtained by the use of three, or multiples of three spans.

SUMMARY

1. Since this device, even with steep splays and considerable fluming, can secure uniform discharge downstream of a fall in erodable channel, it eliminates the back rollers at the sides of the channel and reduces to the minimum the depth of the scour hole, thereby reducing considerably the costs of construction and maintenance of the fall.
2. With the help of this device, the fluming can be increased (to the extent of lowering the crest level to the upstream bed levels of the channel) because of the perfect control over the direction and intensity of flow which it secures.
3. The surplus and harmful energy of water can be destroyed by dividing the stream into two or more portions with the ultimate aim of colliding jets of one with equal and opposite jets of the other stream throughout the width of the downstream channel.
4. Curves in the irrigation channels are expensive to maintain. Moreover, these cut up the irrigation fields into irregular shapes. The use of the device will replace a long curve by an abrupt turn provided a fall can be introduced at the apex of the curve.

Tubewells for Dewatering of Foundations

NAZIR AHMAD

In this article the technique of tubewells for dewatering of foundation is put forth. Simple methods are explained, which can be applied to shallow and deep foundations alike. Before explaining the tubewell technique, historical development of dewatering by open pit pumping with and without cassion and the dewatering of clays by Electro Osmosis is also explained. The tubewell technique described in this paper, started to be utilized in 1954, has been found very successful for dewatering of the Indus alluvial formations.

Necessity for Dewatering

Engineering structures have often to be laid deep in the formation. Such structures are tall buildings, hydroelectric stations or irrigation structures. Very often the sites are such at which the ground water exists fairly close to the surfaces and the foundation of the structure has to be laid several feet below the ground water level.

No structure can be built in water or in slush of saturated soil. Water has to be removed from the formation and the bed has to be dried out without causing any physical changes in the formation. This removal of water from a formation is termed dewatering. There are cases where several feet of saturated formation has to be dried out and kept under this condition for several months.

Early Methods of Dewaterting

The simplest method adopted by engineers in the early stages had been to enclose the area to be dewatered within embankments. Generally two or three times the width to be dewatered was enclosed and in the area excavation was carried out till the water table appeared. At this level one or two deep trenches were made at suitable points and water was pumped out from these. (Figure 1)

The removal of water from the depression affected the ground water level in the area on which foundation was to be laid. This system was full of many defects. It could dewater to shallow depths often less than five feet. Even for this shallow depth, the seepage of water flattened the side slopes of the trench so that sand continued to flow in constantly and its removal from under the water was a problem.

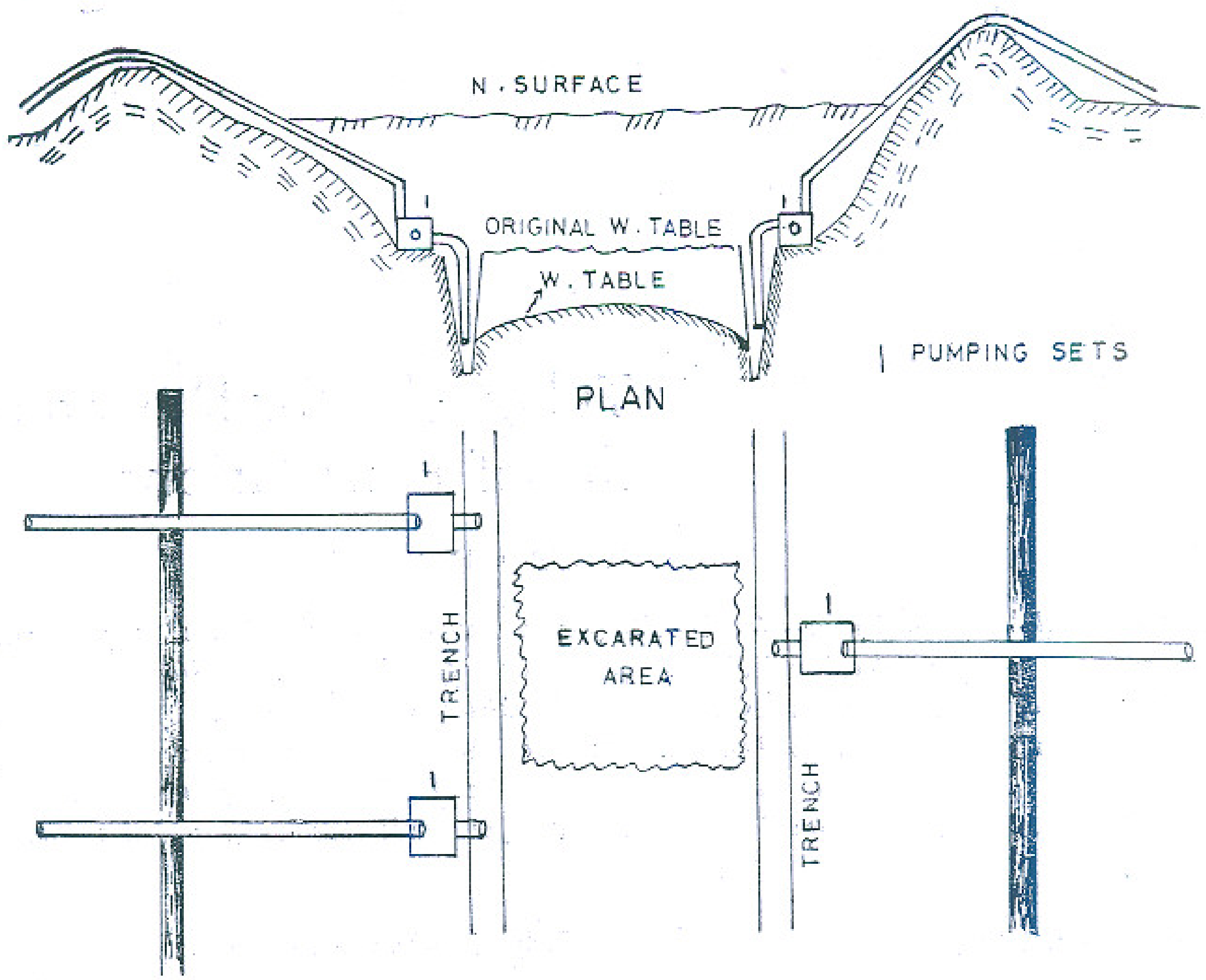


FIG. 1
DEWATERING BY OPEN TRENCH

A solution to this trouble was the development of a system of Cassion which consisted of a brick walled rectangular stucture about 10 feet square. It was sunk 7 to 10 feet into the formation which was to be dewatered. Several such Cassions were erected generally 50 to 100 feet apart. (See figure 2). One wall of the Cassion was kept open to allow water to flow in. After removing sand from within the Cassion, water was pumped out. In this deep sink, the ground water flowed in to be removed by pumping. No doubt the walls protected the inflow of sand from sides but the flowing water brought in sand which flowed either into the Cassion or blocked the inlet. Persistent removal of sand out of the Cassion was thus a headache for the engineers.

This method of dewatering also removed the finer particles. The top formation thus became spongy and compaction was disturbed. The foundation was never completely dry. Its loss of original natural compaction brought in very serious consequences. At certain sites if under a thin layer of sand existed an extensive layer of clay, dewatering at top resulted in an uplift pressure on clay which if thin, heaved up and thus caused serious problems of construction.

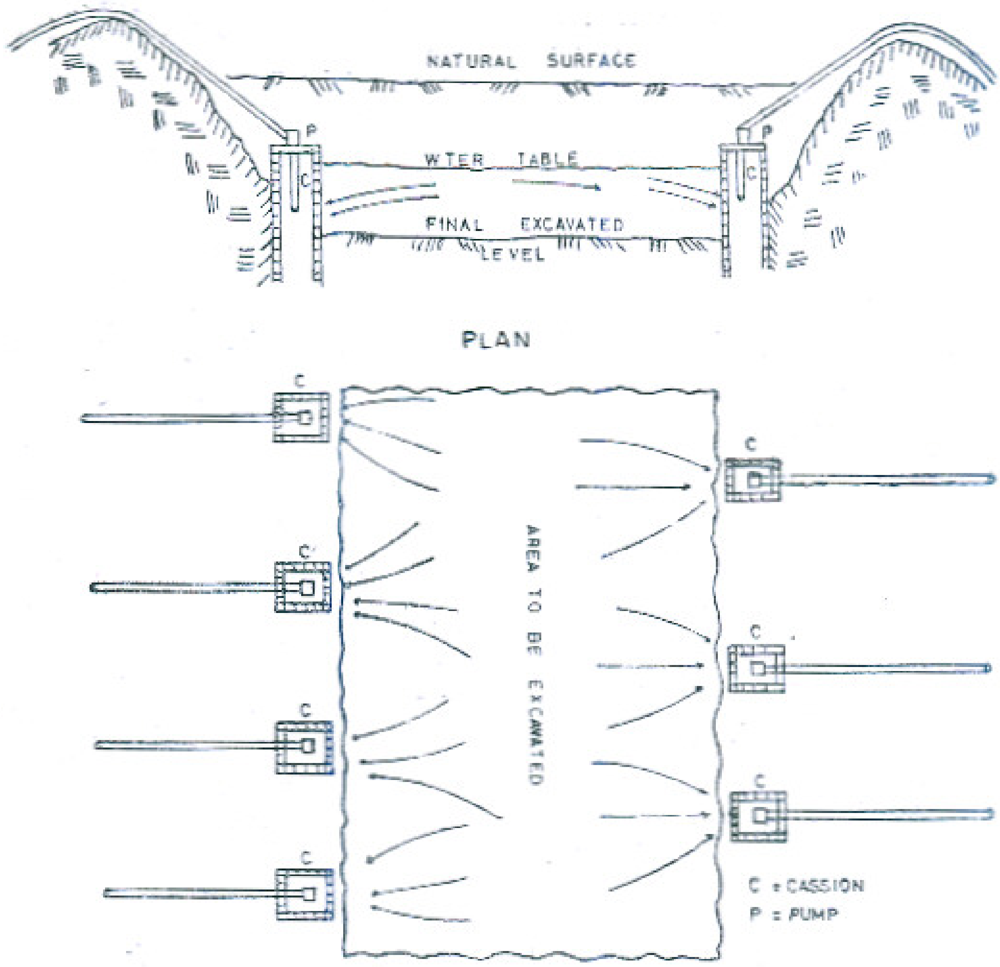


FIG.2: DEWATERING BY PUMPING THROUGH CASSIONS

If deep dewatering, just as for hydei structures, was needed, this technique was never successful as it was impossible to maintain steep slopes. The flat slope extended to long distances. Due to the existence of slush, it was impossible to use machines. Even donkeys were found to be sinking in the formation.

For these defects and the impossibility of deep dewatering, the Irrigation engineers developed a system of well foundation which were sunk into the formation without dewatering.

With the development of reinforced cement concrete and the necessity of deep excavations, several feet below water table, dewatering system had to be developed.

Many techniques for dewatering have been perfected during recent years. The most common are called the well points, and the deep tubewell technique. These two methods are not applicable at all sites. There are formations which cannot be dewatered by these methods. For such formations the vacuum technique and an Electro Osmosis method have been used.

Well Points

For temporary lowering of ground water, the technique of pumping called the well points has been commonly used. The method consist of installing small diameter pipes fitted with a small strainer which permits the flow of water into the pipe from adjacent soil formations. These pipes are 18 to 20 feet in length with 3 to 5 feet length of strainer at their bottom. These are jetted or driven into the soil formation. Such pipes are installed very close together depending upon the type of soil formation, its permeability and the lowering of ground water required. Often a spacing of 3 to 12 feet is adopted in between two well points. The area to be dewatered is enclosed by well points all round. The tops of the well points are connected together through elbows, universal joints and sluice valves to a header pipe which carries the water pumped from the well points. Leonards[1] had prepared nomograms to fix the spacing of well points for different types of soil formation. Two of his nomograms for uniform clean sand and for startified sand are shown in figures 3 and 4.

Pumping is carried out by means of reciprocating pumps. Great care is to be taken to keep all joints air tight otherwise suction will not be successful.

Due to high order of interference of the well points and suction from a reciprocating pump, a system of well points can lower the water table by 3 to 12 feet only depending upon the site conditions and the sources of infiltration etc. Due to the low order of dewatering attained, very often several stages of well points have to be installed, if dewatering level is deep such as in case for hydel projects. A typical case of dewatering

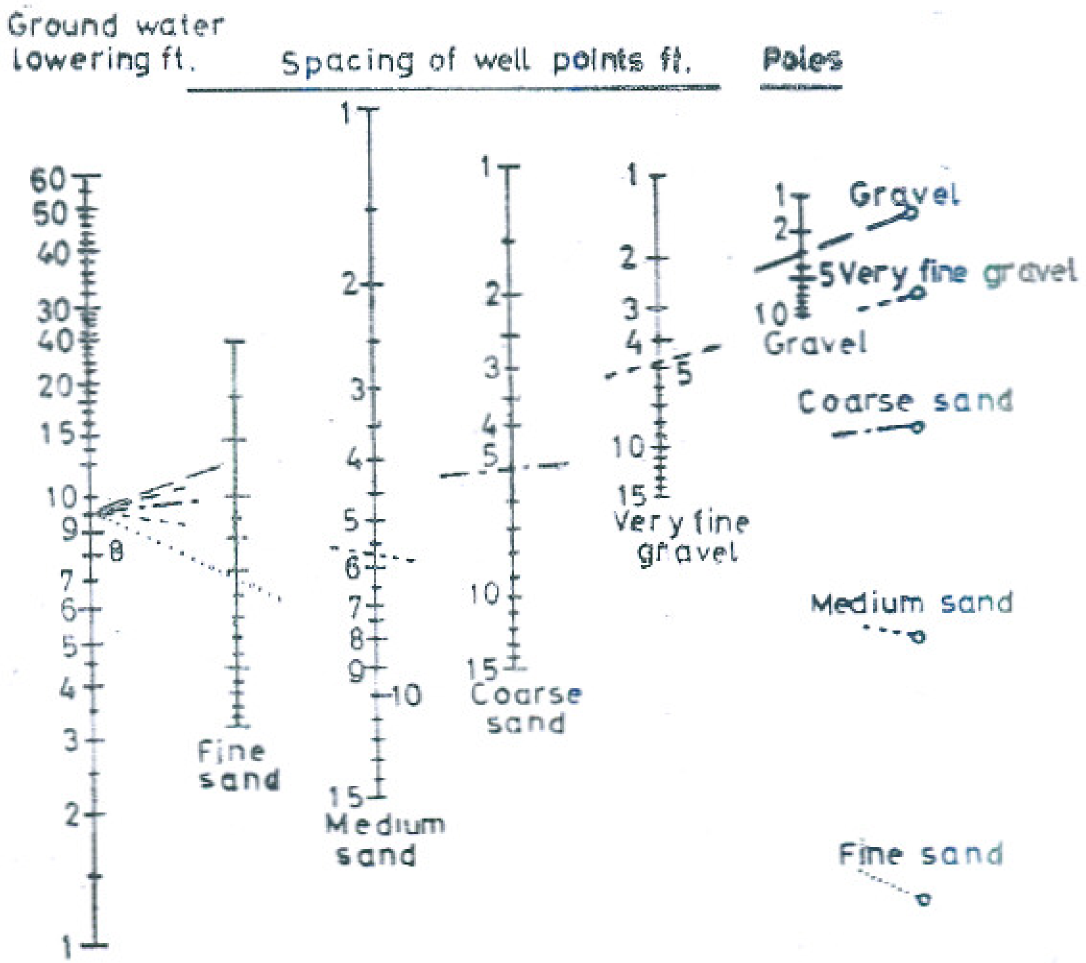


Fig. 3. Nomogram for determining spacing of well points.

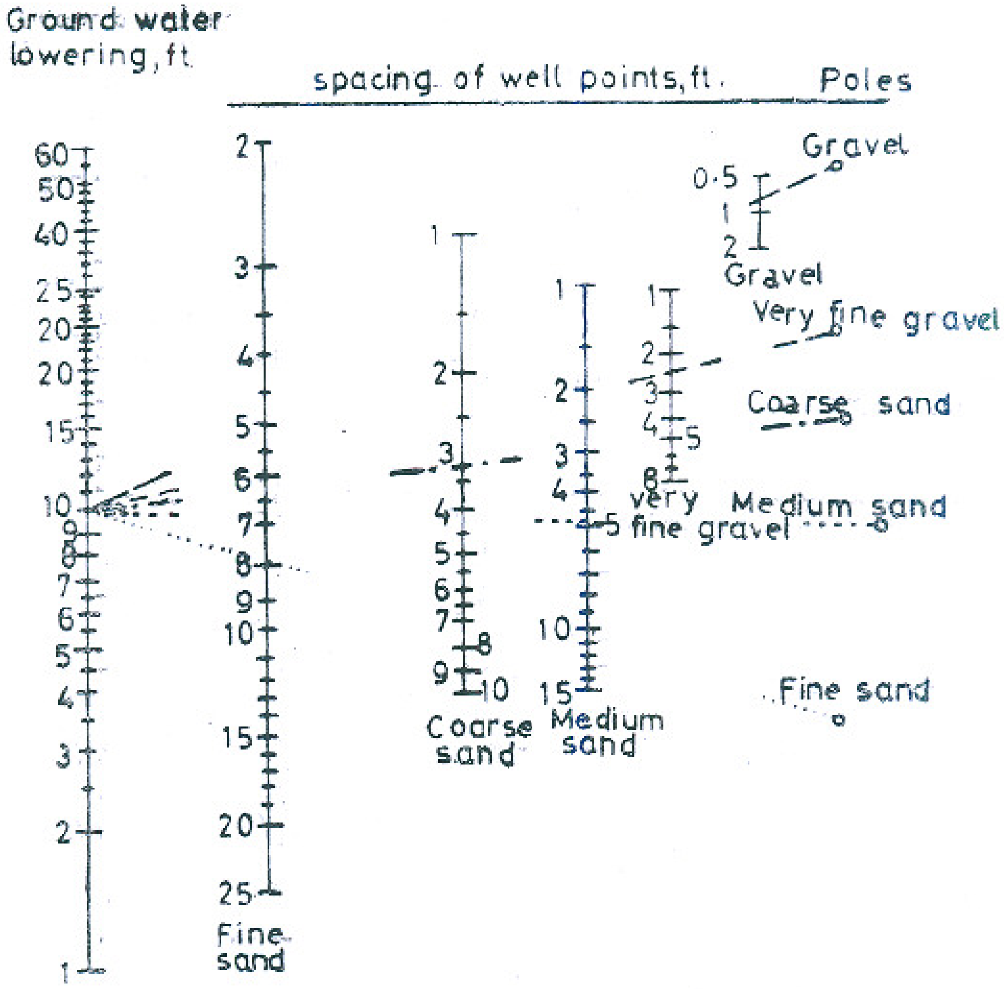


Fig. 4. Nomogram for determining spacing of well points.

for Shadiwal Hydel Station is an example, where four stages of well points were adopted.[2] The formation at site is shown in Fig. 5. Below ten feet of top soil crust there existed about 70 feet of clean predominantly medium grade of sand. The power house was to be located about 550 feet away from the Upper Jhelum Canal carrying a discharge of about 8000 cusecs. Its full supply level was at R. L. 749 and bed at R. L. 741.41. The ground water existed at the bed level of the canal *i.e.*, at R. L. 741. 7. The raft of the Hydel Station was to be laid at R. L. 707 and the proposed dewatering level was at R. L. 701.0 nearly 40 feet below the level of the existing ground water. The company entrusted with site exploration reported a permeability coefficient of 0.0063 ft. per second. It was towards a high side. The dewatering was proposed to be carried out by well points. One helpful feature of the site was the existence of fairly extensive ten feet thick low permeability clay at the bed of this canal which reduced the seepage considerably.

Well points consisted of $1\frac{1}{2}$ inches, 20 feet long pipes with 3 feet of bottom strainers. Four stages of well points had to be laid. The first stage enclosed an area of about 363×343 sq. ft. in which 538 well points were installed with their top at R. L. 734 and water table at R. L. 732.0. Working with four sets of pumps of 2000 gallons per minute capacity each, the water table

SOIL FORMATION AT SHADIWAL HYDEL SCHEME

CROSS SECTION

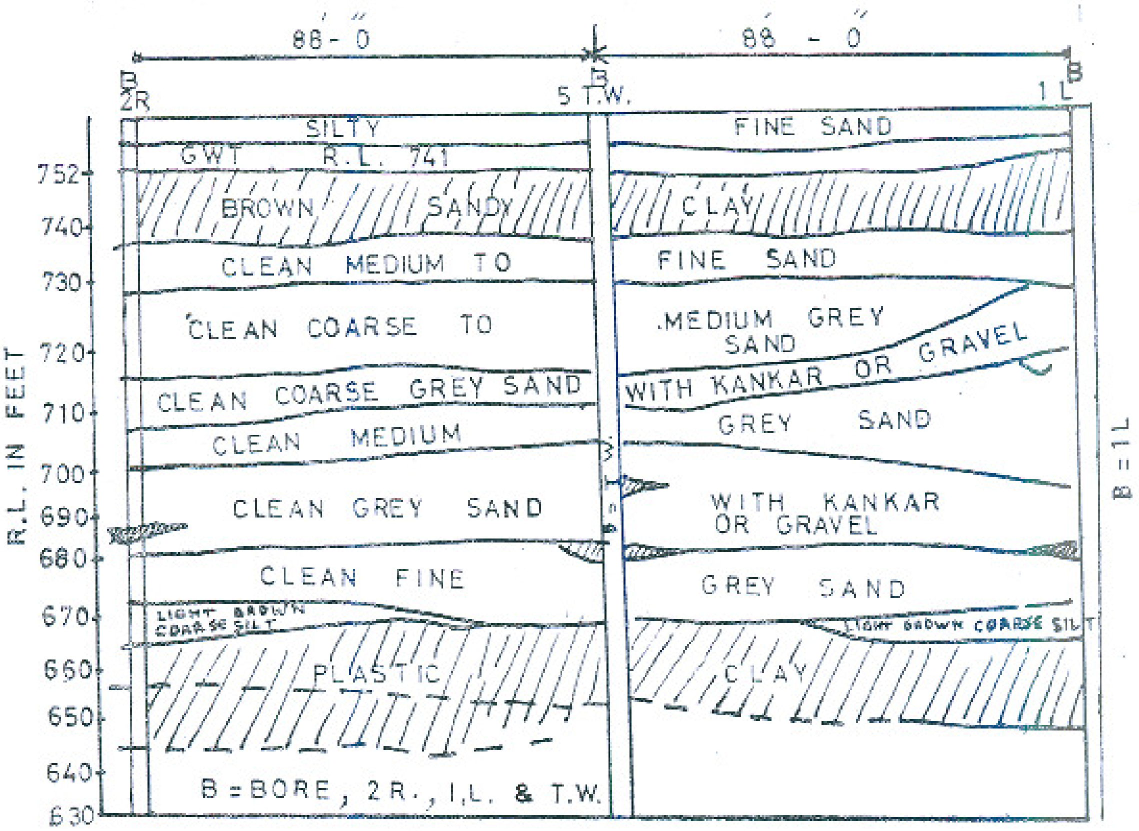


Fig. 5

was brought down to R. L. 729 *i.e.*, about 13 ft. below the initial level.

In the second stage another set of 330 well points covering an area of 317×302 sq. ft. was installed. Each well point was again at a distance of about 3 to 4 feet apart. Working with five sets of pumps of the above mentioned capacity, the water level was pulled down by another 13 feet, to R. L. 706 still above the desired level of dewatering.

The third stage of 416 well points enclosed an area of 297×222 sq. ft. The well points were very close together and working with six pumping sets, the water table was brought down by another 9.7 ft. from R. L. 706 to R. L. 696.3 feet. At this stage the topmost system of well points became dry and hence were closed.

A fourth stage of 82 well points enclosing an area of 206×191 sq. ft. was also set up. This, however, was less effective and it was not worked for a long time. It stabilized the water table at R. L. 695.8. The above stated information is given in table I.

Thus water table was brought down by 45 feet from the original level of R. L. 741.0. The raft area was 250×150 sq. ft., only so that some of the well points of the fourth stage had to be removed with the construction of the raft. A cross section and plan of the excavation is shown in fig. 6.

Well point technique is commonly used but it is very troublesome and costly for those who have to import all machinery. It needs constant vigilance of several workers to see that no leakage takes

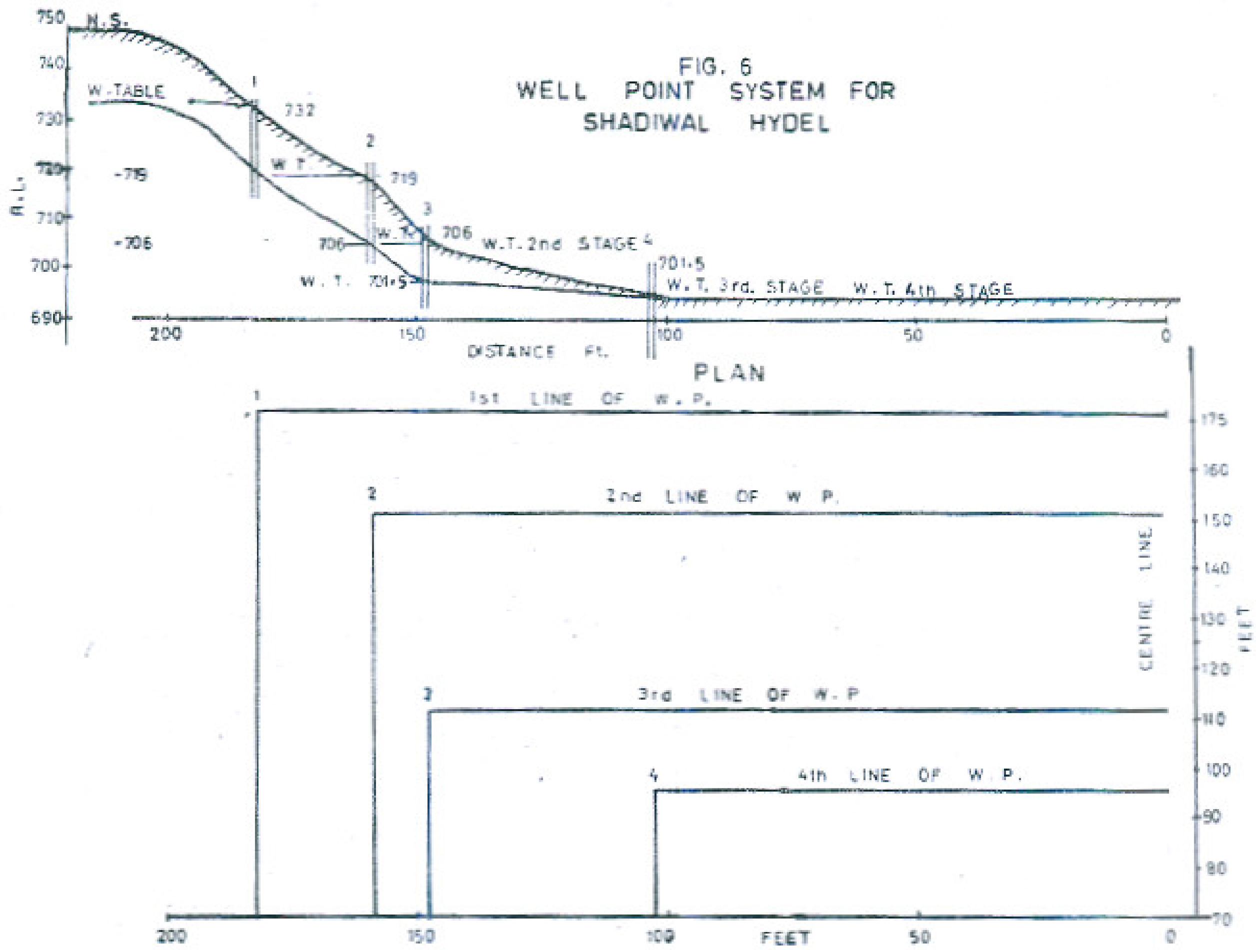


FIG. 6
WELL POINT SYSTEM FOR SHADIWAL HYDEL

TABLE I

Dewatering levels of Groundwater with varying stages of well point.

S. No.	Stages of well point (w.p.)	Top R.L. of well point	R. L. of W. Table at start	R. L. of W. Table after working the stage	Lowering attained by a stage, ft.	No of well points in a stage (beginning)	No. of well points in the stage, actual operating	Dimension of ring of the well points	Distance of W.P. from edge of foundation, ft.	No. of pump in operation.
1	2	3	4	5	6	7	8	9	10	11
1.	1st	734.0	732.0	719	13	528	538	363×343	94	4
2.	2nd	722	719	706	13	430	330	317×302	71	5
3.	3rd	709	706	696.3	9.7	400	416	297×222	31.0	6
4.	4th	701.5	696.3	695.8	0.5	..	82	206×191	15.5	6

place. The location of so many well points with system of header pipes, so close to the excavation often interferes with the working operation. For safety against mechanical failure, stand by pumping sets have also to be arranged. It has been noted as will be explained further that dewatering by deep tubewells is less costly, effective, care-free and has practically no interference with the working operations.

Vacuum Technique

At certain sites the formation is too fine to release water under the action of gravity. The instances are for clay loam, silty soil or organic silt. Terzaghi[3] and Peck have limited soil having effective grain size, D_{10} less than 0.05. mm., these cannot be drained out by gravity flow forces. The size of 0.05 mm., is the limit of silt. Similarly Glossop[4] and Skempton has stated that formation possessing 60% of clay and silt cannot be drained by natural flow. Actually for fine grained soils, the moisture is held by strong capillary forces and the release of water by gravity is quite insignificant. In table (2) are put forth different types of formation with their classification. Their pores space and release of moisture by gravity drainage is also given. It may be seen that clay hardly yield 3 to 5 percent moisture although its pores space is fairly high and a large percentage of these are full of water.

For such soils vacuum method is suggested which is very similar to well points but instead of a number of well points sucked by a reciprocating pump, each one is sucked individually. Boring up to 6 inches is carried out in the formation to be dewatered. A well point with a bottom strainer is installed in it. The well point is shrouded

TABLE No. 2

Pores space and water yield of different granular materials.

Classification	Percentage pore space	Percentage water yield
Gravel ..	25—35	25—30
Uniform sand ..	30—40	20—30
Sand ..	35—40	20—25
Sand mixed with gravel	20—35	15—20
Fine sand and very fine sand.	35—45	10—15
Silt ..	40—50	5—10
Clay ..	45—35	5—7
Heavy clay ..	50—70	3—5

and the casing pipe is pulled out. The top of the shrouding is sealed by a relatively impervious materials as shown in fig. 7.

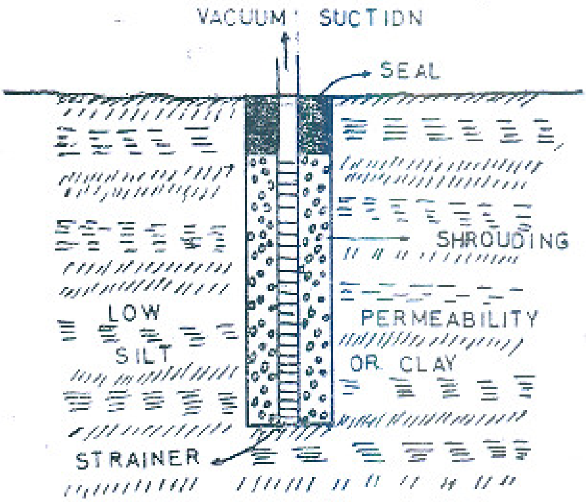


FIG. 7. VACUUM TECHNIQUE

When suction is applied, the atmospheric pressure which is about a ton per sq. ft. exerts pressure on the soil and water which flows through the shrouding into the pipe.

This method is very uncommon and has been used only on very special works particularly for stabilizing steep cut slopes for important excavations.

Electro-Osmosis

Freundlist[5] in 1926 put forth a theory that a soil particle envelops a water film around it. This film is made up of two components. One component of water is rigidly bonded with the soil particle and it has an excess of positive charge. It is thus anoic in nature. On this rigidly bonded water lies another film of water which is relatively free and is easily drained out. This film has an excess of negative charge and it is catonic in nature. When some external voltage is applied, the unbonded catonic water migrates towards the cathode.

Casagrande[6] is 1947 made use of this principle of Electro Osmosis to stabilize waterlogged fine grained soils.

A perforated pipe was lowered into the formation to be dewatered. In this pipe another one with an open bottom or having a small strainer was installed. This pipe was connected to a negative terminal and was thus made a cathode. At some distance away several rods were driven into the soil. These worked as anode when connected to a source of current. The current flowed from the anode to the cathode through the soil formation. It freed cathodic water which moved into the strainer. It was then sucked out. This process, however, needs a large order of current. For instance in one case, Casagrande utilized 70 KW direct current. It produced 150 volts and passed 1200 amperes. The formation which originally was yielding only 1 gallon per minute at a suction head of 170 ft. now gave 20 gallons per minute. Another similar instance[7] of the use of this method was at a site which was yielding 90 gallons is 24 hours from 20 well points. When subjected to a current of 180 volts passing 19 ampere per well point, the yield rose to 13000 gallons in 24 hours.

These are two instances of the technique of the use of Electro Osmosis for dewatering of heavy clay soils.

This method has not been used so extensively in America as in Europe.

In West Pakistan we do not have this type of problem. The clays of the Indus Plains are relatively pervious. Generally, these overlie layers of sand. If the sandy formation is pumped out, the soil drains out by vertical gravity drainage but the progress is very slow and it takes days to drain out.

Clays generally do not get completely saturated. Their 50 to 70 percent pores are seldom full of water. Generally these contain 32 to 40 percent moisture only. If about 10 percent of this moisture is drained out, the soil attains field capacity moisture and becomes more unsaturated. Ten percent moisture can be released by gravity drainage, when it is facilitated by pumping of the bottom formation.

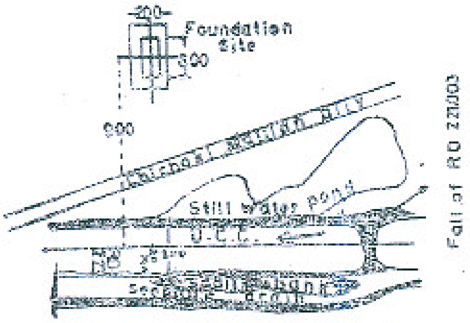
In spite of the drainability of clays of the Indus plains, their dewatering offers a tedious problem.

Dewatering by Tubewells

Another method of dewatering is by deep tubewells. This was introduced in West Pakistan in 1956 for dewatering of Chichoki Mallian Hydel Foundation. Previously all dewatering for constructing irrigation structures used to be done by open pumping or through cassion and pit excavations. The technique of dewatering by tubewells was attempted in 1946 while constructing Rasul Power Station but the method did not have the desired effect. Actually the study remained within the four walls of the Irrigation Research Institute where three-dimensional Electrical Analogy Experiments were performed to study the spacing and number of tubewells for an effective dewatering.

Major construction like Taunsa Barrage and Ravi Syphon in 1948-49 were constructed even after independence by using the old open sump pumping.

Dewatering by tubewells was introduced for the first time during the construction of Chichoki Mallian Hydel Project in 1956. The area where the station was to be constructed was waterlogged with water table within 3.0 feet of surface. A big canal called Upper Chanab Canal passing a discharge of 5000 cusecs existed at a distance of 800 feet from the site of dewatering. The width of canal was about 200 feet and its full supply water depth was 10.0 feet. A plan in fig. 8 shows the site.

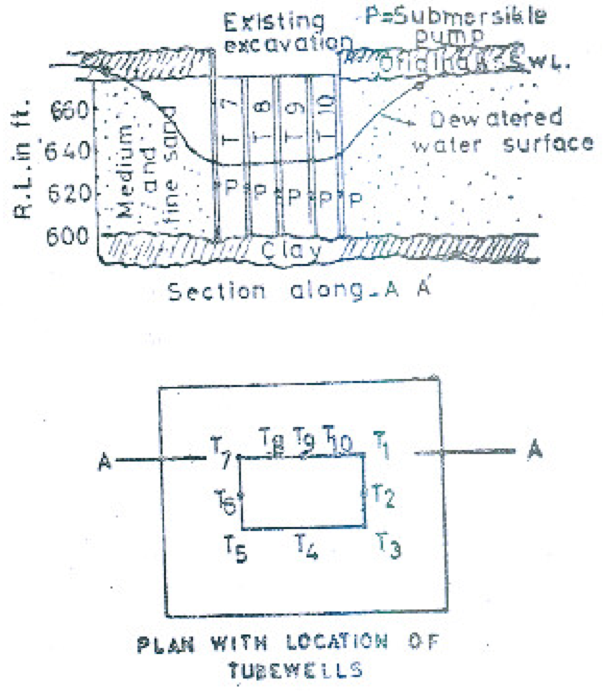


CHICHOKI MALLIAN HYDEL SITE PLAN

Fig. 8

The site was about 2000 feet down stream of 10.25 feet Joyanwala fall so that during the construction of the canal its bed was excavated and relatively low permeability top soil had been removed. The result was that the bed now constituted fine sand, with high order of seepage from the canal. This was the reason that the water table at the site of excavation existed more or less at the full supply level of the canal.

The area to be dewatered was 400×300 sq. ft. and water table was to be taken down by 40 ft. to R. L. 648 from the original level of R. L. 688. After a preliminary study of the site a system of twelve tubewells to dewater the area was suggested. It completely dried the formation within three weeks of pumping as shown in fig. 9.



Dewatering of Chichoki Mallian Hydel Site

Fig. 9

This technique was found so successful that all future construction, big or small including reconstruction of Ravi Syphon after flood damages, Gujranwala Hydel Project, repair to Panjnad Headworks, Guddu Barrage etc. were all dewatered by tubewells. In fact, all constructions by Irrigation Department after 1956 had used this technique. This method has become a very successful device for dewatering of Indus Formations which are most suited to this technique of dewatering.

SITE EXPLORATION ESSENTIAL FOR SUCCESSFUL DEWATERING

Basic information with regard to the nature of the formation, its gradation, permeability, the sources of infiltration and in some cases load-bearing characteristics of the formation are essential for a successful dewatering scheme.

Site exploration has to be carried down to at least equal to the maximum width of the foundation. The formation samples are mechanically analysed to find the gradation curve and then to determine the existence and percentage of fine particles, Uniformity coefficient and Effective size etc.

The permeability is determined 'in situ' by actual pumping tests, and inflow from any adjacent source is also taken into account. No dewatering can be successfully planned without this basic information.

Characteristics of the Indus Formations

The Indus formations are generally alluvium deposits. These consist of alternate layers of clays and sands of different grades. Sand deposits predominate. It has a high Uniformity usually between 1.5 to 2. Being water transported, it has predominance of one grade. The sands are generally medium to fine grades. Coarse grades occur in the foot hill districts.

In majority of sites the top layer consists of soil of thickness varying between 5 to 15 feet. Other clay layers appear in the form of small lenses often 5 to 20 feet thick and the largest are a few sq. miles in dimension. Generally these are small lenses, with the result that the formation is connected as a whole so that dewatering at one place draws the sub-soil water from large areas.

Sub-Soil Profile of Ravi Aquaduct Foundation in April 1950

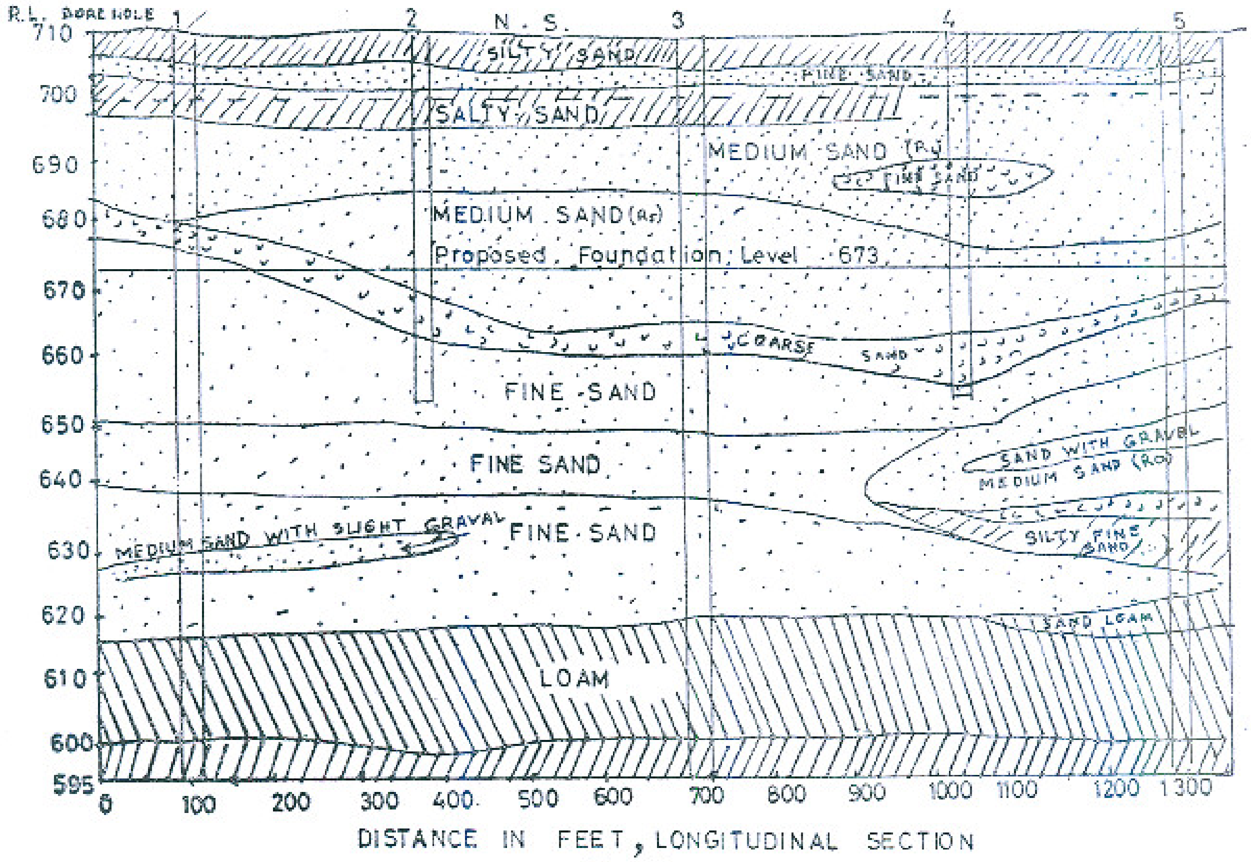


Fig. 10

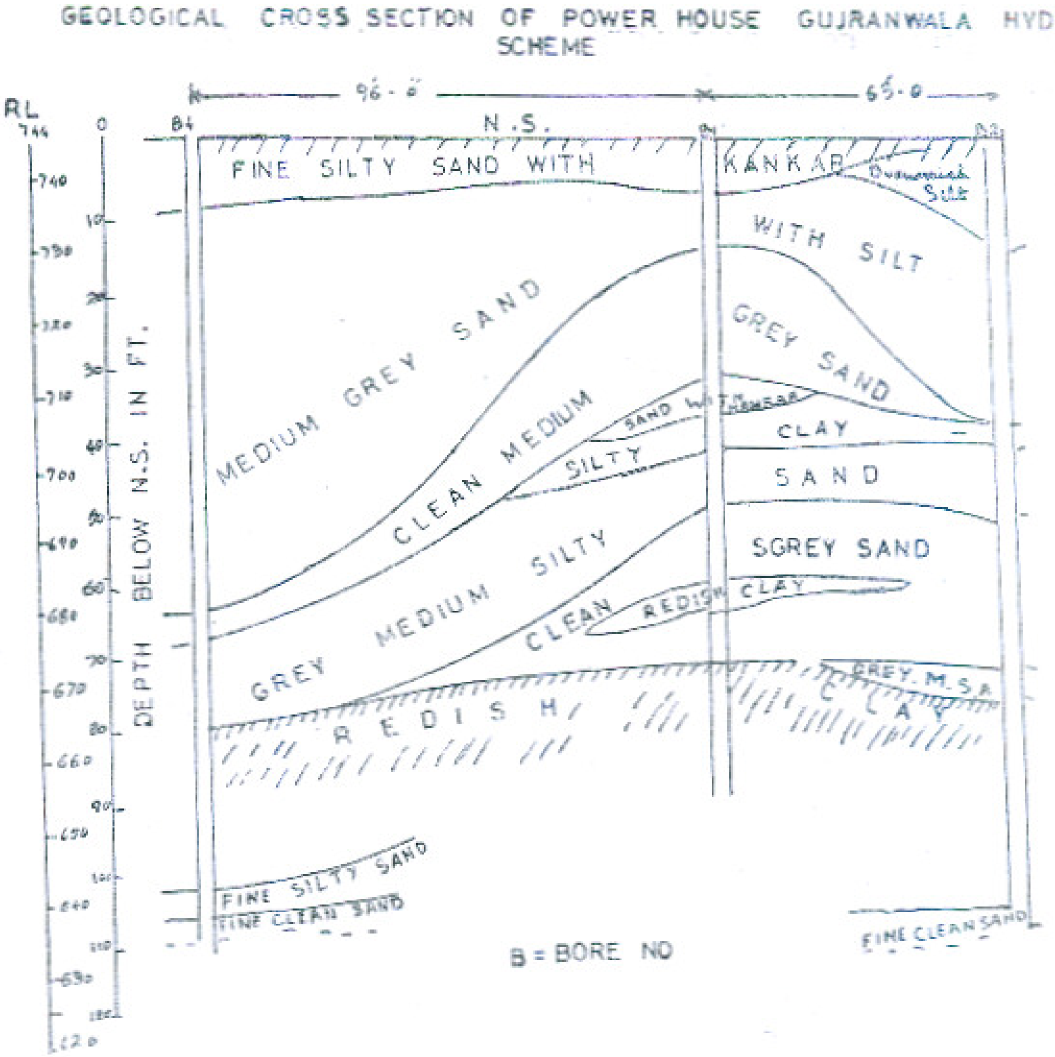


Fig. 11.
Geological Cross Section of Power-House, Gujranwala Hydel Scheme.

Very often in a depth of 100 feet one comes across a clay formation which is comparatively thick, often more than five feet and extends to a few thousand square feet.

In figures 10 & 11 the formation as it exists at Ravi Syphon, and Gujranwala Hydel sites are shown.[2] In all these cases comparatively thick clay appeared within 80 to 100 feet depth from surface.

The second most essential information pertains to the estimation of the order of inflow. For this purpose an estimate of permeability of the formation is most essential. For Indus formation some idea of permeability can be had from the gradation determined for the site during exploration. It has been found that permeability coefficient for the three grades of sand lies between the following range.

TABLE 3

Grade of the formation	Approx. diameter in m.m.	Permeability Coeff. ft. per second $\times 10^{-3}$
Coarse Grade of medium sand ..	0.4	20.0—6.0
Fine grade of medium sand ..	0.3	8.0—3.0
Fine sand ..	0.2	3.5—1.6

For the Indus plains on the basis of field tests an average value of permeability can be taken as 2.5 to 4×10^{-3} ft. per second for the top 300 feet depth. The lowest and the highest range of the permeability has been 1.0 to 5.3×10^{-3} ft. per second as shown in table 4.

TABLE 4

AREA	Sites or Doabs	Range of permeability	
		$\times 10^{-3}$ ft./sec.	Average V. $\times 10^{-3}$ ft./sec.
Indus Plain Punjab area	Rechna	2.5—5.3	3.8
	Chaj	1.8—3.4	2.8
	Thal	1.7—3.7	3.3
	Bari	1.0—3.0	2.6
	All doabs	1.2—3.9	2.6

Estimation of Inflow into the Excavation

If the site is such in which a thick impervious clay formation exist at a suitable depth as was the case for the three Hydel sites, Chichoki, Shadiwal and Gujranwala and the area to be dewatered is also not very extensive, say lying in a circle of about 500 feet in diameter, it can be dewatered by a system of tubewells located on the *perifree* of the area as shown in fig. 9. The bottom of the wells is located on clay which work as a seal for the bottom inflow. The sides inflow is intercepted by the tubewells located all round.

For the sake of calculations of the inflow we can assume a single well of diameter equal to the area to be encavated. Assuming the extent of the effectiveness of this big diameter single well to say about 2000 or 3000 ft., the discharge is worked out by the relation:

$$Q = \frac{2\pi k\ b\ (h_o - h_w)}{2.3 \log R/r_w}. \qquad (1)$$

where

Q= the expected discharge in cusecs.

K= the average permeability in ft. per second.

b= the thickness of water-bearing formation in ft.

R= the radius of influence assumed equal to 2 or 3 thousand feet.

r_w =the radius of the tubewell in ft. say equal to the size of the excavation.

h_o-h_w=the depression inside the tubewell in ft.

In the above formula, permeability is the main variable which can have considerable effect on the yield as it varies directly as the variation in K, yield can only be known if the K value is correct for the site. The extent of the effect of pumping is another uncertain factor but as it effect the yield by 1/log R, the variation from 2000 to 3000 ft. does not make a material effect. If a pervious source such as a leaky canal exist close by, the effect will extend to that distance only, whereas for extensive medium or when the source is relatively of low percolation, the limit of R extends to a great distance. For calculation we generally assume the value of R, in between 2 to 3 thousand feet only. Depression inside a well and its effective lowering of water table is the most uncertain factor. The actual depression inside a well as will be discussed further is much more than the limit of dewatering outside.

The thickness of water-bearing medium is simple to assume. It can be taken from the top of the original water table down to the level of clay layer.

Dewatering of an Extensive Site

There can be cases when the sites of dewatering are fairly extensive such as a barrage or a river structure. For instance Guddu Barrage was more than a mile in length, Ravi Syphon[2] about 1800 feet in length and Panjnad Headworks about 1000 feet. Width of these sites in comparison to the length was small. In such cases it is economical to dewater that portion of the foundation which is to be immediately laid.

The estimation of the inflow can be carried out by two methods. The first method is by plotting the flow lines, and using Darcy's relations. An example of such estimate for a portion of the Panjnad Headworks is put forth. It was damaged after the unprecedent flood of 1957. A length of about 840 ft. in 14 bays of the headworks on the upstream side was to be dewatered. The site had inflow sources both on the upstream and the downstream. The data for the site was as under :—

Length of the area to be dewatered. ..	1000 ft.
Width of floor upstream of central sheet pile. ..	175 ft.
Water level on the upstream side beyond the embankment. ..	R.L.325
Water head on the upstream side. ..	20 ft.
Water head on the downstream side.	9.0 ft.
Level of floor ..	R.L.320
Proposed dewatering level ..	R.L.316
Mean diameter of the sand formation at site. ..	About 0.18 m.
Assumed permeability of the area. ..	0.0005ft· per second.

Flow patterns as depicted in section in fig. 12 were plotted.

Inflow was estimated from the upstream and the downstream sides separately from each flow tube by using Darcy relation.

$$Q = \frac{h}{l} \times K \times A \qquad (2)$$

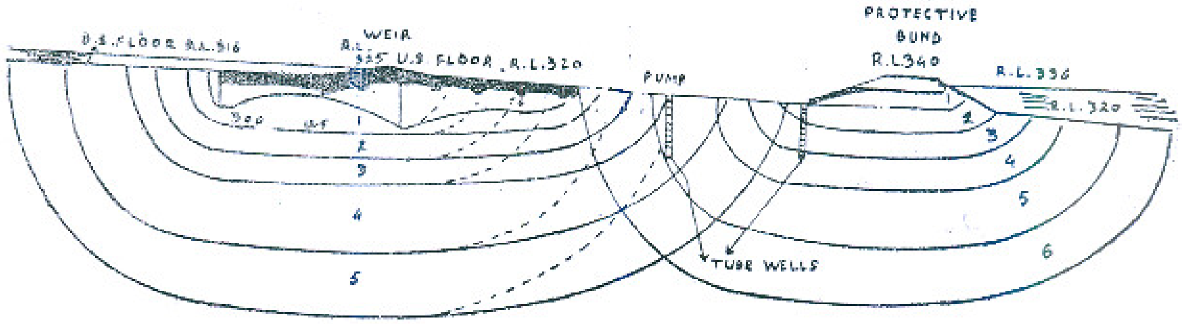
where A=1000×200 ft. being assumed effective depth.

K=0.0005 ft. per second.

h=20 ft.

L=the path of flow tube estimated from flow net and given as under in table 2.

DEWATERING OF DAMAGED FLOOR OF PANJNAD HEAD WORKS



FLOW LINES WITH FLOOR INTACT
DAMAGED

Fig. 12

TABLE 5

Stream Tube		Flow Path, L, in Feet.	Dis, Q in Cusecs
1.	..	110	1.845
2.	..	150	1.335
3.	..	220	0.950
4.	..	280	0.950
5.	..	370	1.050
6.	..	490	0.455
		Total ..	6.350

Similar inflow from the downstream sides was estimated for a water head of 9.0 ft.

Stream tube	L, with floor intact, ft.	L, with floor non-existing, ft.	Q, expected with damaged floor.	Q, expected with floor intact.
1.	320	240	0.315	0.415
2.	370	300	1.270	0.335
3.	420	350	0.240	0.285
4.	520	480	0.385	0.435
6.	640	580	0.315	0.345
		Total ..	1.525	1.815

Thus the inflow was expected equal to 8.2 cusecs for the pumping of which provision was to be made.

Another similar example is the dewatering of Ravi Syphon which was got damaged during the flood of 1957-58.

It was proposed to dewater the full length of 1800 feet and 350 feet wide. The dewatered level was fixed at R.L. 670 about 18 feet below the top level of the barrels of the syphon.

The working area was protected by embankment, 769 ft. up stream and 425 ft. downstream from the centre line of the barrels. A second line of embankment as a protection was also errected, 1329 feet upstream from the same reference point. The maximum free water level upstream and down-stream of the embankment was taken as R. L. 710 and R. L. 700 respectively so that dewatered level was to be 40 and 30 feet below the free water level on the two sides.

The expected percolation could be worked out by plotting flow net shown for Panjnad Headworks.

Another simple and approximate technique to estimate the yield was by dividing the area into circular tubewells each equal in diameter to the width of the strip to be dewatered. Due to a number of tubewells located together there is considerable interference between the adjacent wells. (see fig. 13).

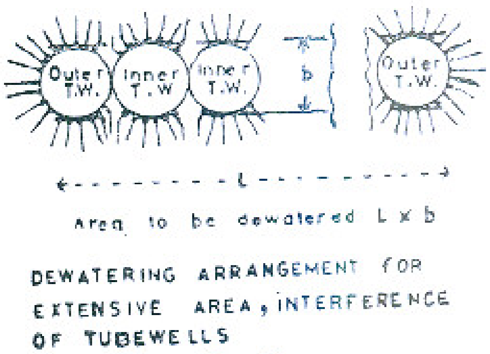


Fig. 13

Using the common tubewells formulae the discharge is estimated. Due to the numbers of tubewells working close together the interference as per figure 13 will reduce the yield of the inner tubewells by about 50 percent and those at sides by about 25 percent. This is a very approximate method on the basis of flow lines but the proper analytical solution as developed by Musket[8] and discussed by Todd[10] can be used to determine the interference and the fall in