

Report
on visit to
U.S.A., Italy
and Yugoslavia

1957

Kanwar Sain



GOVERNMENT OF INDIA

Ministry of Irrigation & Power

Central Water & Power Commission

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foreword

Great strides have been made in different parts of the world in the techniques of design and construction of river valley projects. A knowledge of these modern trends and practices can well be considered as a technical basis for economic development of our water resources.

Apart from receiving assistance and advice from many foreign countries in connection with water utilization projects, many of our engineers have visited other countries to acquaint themselves with the latest trends of developmental practices. It is not only necessary but essential for such engineers to disseminate their experiences and impressions for the benefit of other professional engineers in the field.

Shri Kanwar Sain, who has had opportunities to personally witness the engineering advances and to intimately discuss engineering problems with eminent engineers in almost all parts of the world, has already made an excellent and invaluable contribution in this field. In this volume, he vividly describes the projects visited by him in U.S.A., Italy and Yugoslavia in 1957, highlighting his most important observations. The important discussions and conclusions arrived at at the Third Congress of I. C. I. D. and World Power Conference are also brought out.

No doubt the information contained in this volume coupled with ideas of new techniques in engineering and allied aspects mentioned therein would be of great interest and value to our engineers in the execution of river valley projects. The conclusions and recommendations are of much significance.

All concerned with our country's efforts for economic exploitation of water potential and all engineers of the profession will be highly grateful to Shri Kanwar Sain for this very valuable service.

H. Mohd. Ibrahim

(Hafiz Mohd. Ibrahim)
Minister of Irrigation & Power
Government of India.

With the advance of scientific and technological research and development, many new techniques and practices have come into vogue in design and construction of dams and other river valley schemes. In our endeavour to build up various development projects in the country, particularly water utilisation projects, it is obligatory to keep abreast of the latest developments and techniques to effect economic construction. It is, therefore, essential to compare and contrast the trends in engineering construction and development prevalent in our country with those of other countries. Visits to foreign countries and participation in International Conferences afford opportunities to get an insight into the latest techniques and also to discuss most important engineering problems with eminent engineers.

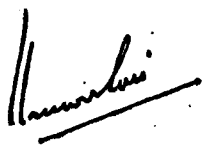
During the last decade, I have had occasions to visit many countries of the world, and already reports on my visits to river valley projects in China, U. S. S. R. and some countries in Europe have been published for information of professional engineers.

Being in the habit of preserving diary notes of discussions and jotting down most important points and special features of projects visited — though hastily recorded for want of time — yet I feel it is my duty to record and disseminate these to the benefit of my fellow engineers.

During May and June, 1957, besides attending Third Congress of the International Commission on Irrigation and Drainage, some projects and engineering organisations in U.S.A. were visited. Later some visits were made in Italy by the kind courtesy of Electro-consult, before attending the World Power Conference in Yugoslavia which was further followed by tours to river valley projects in that country.

In this report, my impressions, both general and technical, have been recorded since it would be of considerable value to the members of the engineering profession who have not had the opportunity to visit these projects. Salient details and special features of the projects are also given together with the latest techniques in planning, design and construction. I would like to draw attention to the conclusions and recommendations made, which, I hope, will be of much interest in planning our future water utilisation projects.

I express my sincere thanks to the various engineers and administrators who spared no pains to take me round their projects, research laboratories and private engineering organizations. My special thanks are due to Shri J.S. Jain, Technical Attache to the Embassy of India, Washington, for his excellent forethought in preparing the ground for my visits and discussions in U.S.A., without which I could not have covered so much in such a short time. My thanks are also due to my Technical Secretary, Shri K. Krishnamurthy for his valuable assistance in the preparation of this report.



(KANWAR SAIN)
Chairman
C.W. & P. Commission

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The tour

To attend the Third Congress of the International Commission on Irrigation and Drainage held in San Francisco (U. S. A.) from April 29 to May 4, the Government of India deputed me to lead a delegation of which the other three members were :

- (1) Shri U. N. Mahida, I.S.E., Chief Engineer, Bombay — *alternate leader*.
- (2) Shri Yadava Mohan, I.S.E., Chief (Natural Resources), Planning Commission.
- (3) Shri Baleshwar Nath, Secretary, Indian National Committee for I.C.I.D.

After the conferences, some of the river valley projects in the Central and Imperial Valleys of California were visited from May 5 to May 17. Besides these, I toured the United States for about a month visiting some of the important projects under execution in the country and visiting the offices of the Bureau of Reclamation, Army Corps of Engineers, Soil Conservation authorities and other engineering organisations. This tour facilitated discussions and exchange of ideas in connection with the latest progress and trends in planning, design and construction of river valley projects. Flood Control aspects were discussed with the engineers of the U. S. Army Corps.

My visits in the United States were followed by visits in Italy to some of the arch, buttress and dome-shaped dams, and also some medium and high-head underground power stations. These visits were made particularly in view of considerable economy being

effected in that country by the choice of arch and buttress type dams in preference to gravity structures.

The Eleventh Sectional Meeting of the World Power Conference was held at Belgrade from June 5 to June 11, 1957. Important topics like 'Utilisation of Nuclear Power', 'Power as a Factor of Development of Underdeveloped Countries', 'Integrated Utilisation of Water Resources' were to come up for discussion. In view of this, the Government of India deputed a delegation of two members to attend this conference. The members were Dr. H. J. Bhabha, Secretary, Department of Atomic Energy, as leader and myself. Shri B. Seshadri, Secretary, Indian National Committee, also attended the conference.

During my stay in Yugoslavia, I had the opportunity, in addition to attending the conference and discussions on some aspects with the Yugoslavian and other engineers who had assembled, to visit some of the river valley projects which were of importance particularly with reference to foundation treatment in structures.

During these seven weeks of going round the Globe (I went *via* Japan and came *via* Europe)—*Figure 1*, a large number of people were met at the World Conferences and Engineering Organisations. Appendix A gives the itinerary. A number of talks and discussions were held with some very prominent persons from all countries on matters in which we, in India, are interested.

In this brief report, I would like to record my general impressions and important observations with particular reference to river valley development. Though

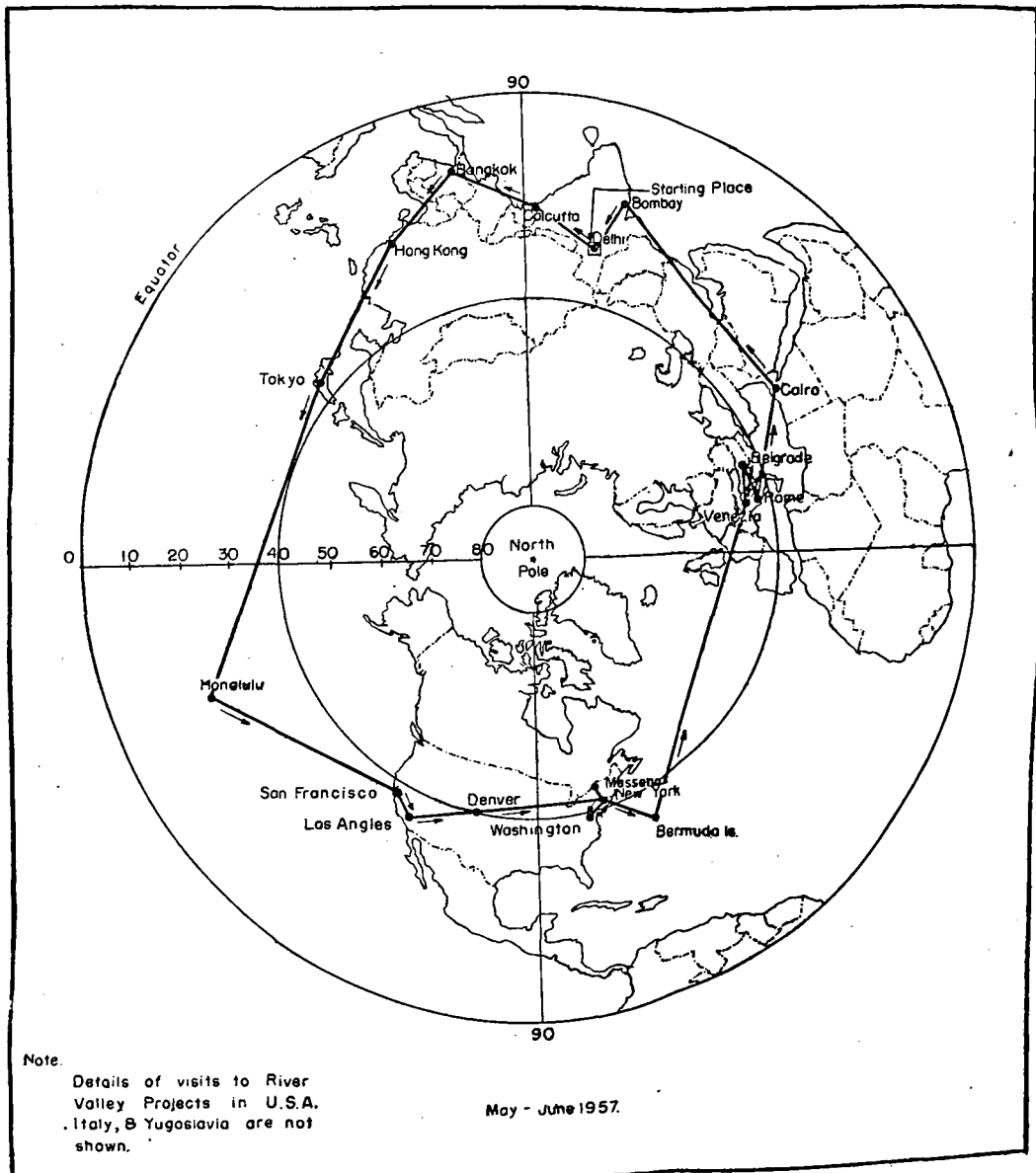


Fig. 1 — Map of the World Showing Travel Route

it is not feasible to give full technical details in a report like this, technical aspects and special features of some of the important projects visited by me are included.

In 1955, the International Arid Lands Symposium and Conference meetings were held in New Mexico under the auspices of the American Association for the Advancement of Science. I was invited by the Planning Committee of the A.A.A.S. to be Chairman of one of the Sessions of the Symposium on "Better Use of Present Resources". This International Scientific Meeting — the first held in the United States — devoted solely to problems of arid zone research. Following the three-day Session at the University of New Mexico, the experts went on a field trip to obtain a first hand knowledge of the arid zones. Those specially invited for the purpose met at Socorro to make recommendations for further work to deal with arid lands. The conclusions arrived at this symposium and the deliberations at the conferences are of great value to the development of arid lands in India, including the State of Rajasthan. Though there were very many important conclusions arrived at, one of my important observations in connection with saving of water is mentioned in this report.

2

General impressions

Resurrection after War

One thing which impressed me in the countries, visited this year and last year, was that there is unceasing activity and very heavy programmes of construction; construction in all directions — highways, buildings, river valley projects, ports and the like. Belgrade, the capital of Yugoslavia, we were told, changed hands perhaps 60 times during the last few hundred years. Because Yugoslavia is just in the centre of Europe, she suffered from attacks from the East and from the West and perhaps very seldom there has been any settled life in Yugoslavia. It is a pretty and very picturesque country. It has lot of natural resources, but these could not be developed because there was no settled government. We were told that a large portion of the population of Yugoslavia was killed during the last War. Yet when one sees that country now, when one sees these ruined cities being rebuilt, the factories renovated, big highways being constructed in the countryside, and the people moving about again, almost forgetful of the War, one feels amazed to see the tempo of development.

Every time I have had an opportunity of going out, visiting some country or the other every year, my general impression is that life is fuller and the pace at which these countries are progressing is more accelerated. This struck me as somewhat paradoxical, because of persistent reports and alarms of explosions of atomic weapons. In the face of all this possible destruction,

General Impressions

this very heavy activity in the life of these countries, sometimes does look perplexing and paradoxical. With the men of my own profession, with the men of my own vocation of life, I have had some fairly intimate talks, not only on professional matters, but also on what is happening in the World today. And my impression is that in no continent, including America and Europe, people want War. They dread War. Even in America, which has not actually seen the disastrous effects of War which faced Europe and some countries in Asia, they do not want War.

Rising Standards of Living

Another impression which I may mention is that the living standards in all these countries are going up and up, year after year. I have no doubt that we are making some progress. Of course, it is a positive progress, it is the progress of which we can legitimately feel a little proud. But, when we compare it with these other countries, we cannot help awakening to the fact that we have yet a lot to do and achieve. The gap, which now exists between the living standards in India and some other countries in the East and the countries of Europe and America, has to be reduced by fast development. We sometimes might have felt that in the past colonialism helped the Western countries to build those standards. Today, those countries definitely realise that the age of colonialism has passed and they are fast adjusting themselves to this reality.

Key to Progress

What is helping these countries to build up higher standards is, no doubt, the use of scientific and

modern techniques in agricultural development, higher industrial output and sound pre-planning. The prosperity of the country devolves round the potential increase and achievements in agricultural and industrial production to meet the growing demands of the expanding population, by systematically exploiting the natural resources. One of the reasons for high productivity in America and elsewhere is the importance attached to pre-planning. Particularly in water resources development sound planning is essential since water utilisation has considerable influence almost on every aspect of national economy.

3

Third congress of international commission on irrigation and drainage

The Third Congress

In this once-every-three-years Conference sponsored by the I.C.I.D., about 41 countries were represented by nearly 450 delegates. The Indian Delegation was joined in U.S.A. by Shri N. D. Gulhati, Chief Engineer and Joint Secretary, Ministry of Irrigation and Power, and Shri J. S. Jain, Technical Attache, Indian Embassy in Washington.

President's Message

The Session opened with a striking message of greetings from Mr. Dwight Eisenhower, President of the United States of America, which read as below :

“Please give my greetings to the Third Congress of the International Commission on Irrigation and Drainage and special welcome to your delegates attending from abroad.

• “Progress in the development of land and water resources is progress towards the peaceful betterment of mankind. It is, therefore, encouraging to see so many nations of the world represented at this Congress exchanging information and ideas.

“Each advancement in the science of irrigation and drainage is a contribution to the welfare of all people. I wish you a successful meeting in the furtherance of your basic objectives.”

Technical Problems

After the inaugural session, technical sessions started and lasted for four days. The four technical problems¹ dealt with by the Commission were :

1. Canal Lining

Scope of the subject — Purpose and practical aspects, particularly materials, technical and economic aspects, maintenance and related problems.

2. Soil-Water Relationship in Irrigation

Scope of the subject — Movement of moisture in irrigated soils, special methods for the preservation of soil structure and fertility and the effects of soil fertility on duty of irrigation water. Economical use of irrigation water.

3. Hydraulic Structures on Irrigation and Drainage Systems

Scope of the subject — Particularly those relating to regulation and safety, distribution and measurement of water, prevention of silting (exclusive of canals, conduits and river works).

4. Inter-relation between Irrigation and Drainage

A leading part was taken by the Indian Delegation in the discussions on the above important subjects. Nine interesting papers² had been submitted by India for discussion. The question of Soil-Water Relationship in Irrigation was introduced by Shri Baleshwar Nath, who also presented a general report giving a gist of 29 papers received from various parts of the World. Interesting and valuable discussions followed thereafter. Shri Mahida stressed the need for proper soil classi-

fication as the basic requirement for working out sound irrigation projects.

On the question of canal lining, a good number of countries who had vast experience, made the discussions very interesting and valuable. The Japanese National Committee's paper³ discussed the materials used in Japan to prevent erosion of banks and other losses from canals. The list included clay linings, sodding, willow branch hurdles, stone masonry and concrete lining, and bamboo baskets filled with pebbles. The report brought out the economic and structural advantages of precast concrete blocks over quarry rock masonry. The behaviour of bituminous concrete lining and lining for protection of the banks from erosion was brought out in a French paper⁴. Technical aspects of the use of asphalt to line irrigation canals were detailed in a paper by U.K.⁵ Soviet Russia presented a paper⁶ on soil stabilisation in irrigation construction. Use of natural and man-made materials to line irrigation canals and to curtail waste of water was presented in the papers by U.S.A.⁷

A very comprehensive report on canal linings in India was presented by the writer. The paper brought out specifically the measures taken by Indian Engineers to minimise canal losses by lining.

The importance of saving water in canals and also the economics of canal lining were discussed. Important extracts from the paper are given in Appendix B.

Discussions on other problems evoked considerable amount of interest and the papers presented by prominent persons all over the world covered the complexity of the problems and the techniques of tackling them according to local conditions.

Findings of The World Congress

The deliberations in the conferences led to the following conclusions :

I. Canal Lining

It is becoming increasingly important to reduce transit losses in irrigation canals. Lining of canals, in addition to accomplishing this objective, is also expected to improve hydraulic conditions thus permitting more economical designs, to stabilize and improve the safety of canals, to reduce maintenance costs and to reduce damage to adjacent lands and the threat of health problems.

Much has been learned from experience in all irrigated countries. New types of linings are being developed. Established types are being improved. Future progress will depend, in a large measure, on the ability to make reliable evaluations of work that has been done. These evaluations must come from a study of lined canals in use and effort should be made to bring to light the experience and knowledge of those who have responsibility for the operation and maintenance of such canals.

A problem as broad as the lining of irrigation canals, involving the conservation of needed world water resources, deserves continuing consideration by the International Commission on Irrigation and Drainage. To further the good work that has been done in the Third Congress it is felt that the question should be taken up for discussion again in the Fifth

Congress with particular attention to maintenance and design considerations. Specific phases of this problem that might be examined further are :

- (a) Maintenance problems, standards and costs for various types of linings, preferably covering long periods of use.
- (b) Seepage losses — how the volume can be determined and sources located.
- (c) Friction losses — the changes, if any, that occur with long periods of use and remedial measures.

Answers to these questions would be helpful to the managers of existing works, to the designing engineer, to the estimator who seeks basic information for comparative analyses, and to the administrator who must treat with the broad economic problems.

2. Soil-Water Relationship in Irrigation

The wide range of subjects covered by the reports received under this question indicates clearly the diverse ways in which this question is important to the development of agriculture by irrigation. So far only limited attention has been paid to it. Its importance, however, is fully recognized now and correlated research and field investigations are in progress in different parts of the world.

Papers presented indicate the methods adopted for classification of land and of soils, systematic mapping, etc. More work is necessary with regard to studies of soil-moisture relationships

under varying soil characteristics. The results to be obtained from these studies are of great importance to the economic use of available water resources. Further work is also necessary to determine the adjustments that should be made in agro-technical processes with a view to ensure optimum utilisation of available water and land resources.

The need for further studies of water consumptive values for systematic single or diversified cropping on different soils and under different climatic conditions was stressed as also of some common terminology and basic units.

The studies already made and the technique adopted in different countries have been described in the reports received and should be of great interest in further work to be undertaken.

3. Hydraulic Structures on Irrigation and Drainage Systems

The papers presented to the Congress and the discussions have brought out clearly the great diversity in the types of hydraulic structures used in irrigation and drainage networks. A useful description has been furnished on many engineering devices which are simple, practical and carefully adapted to the conditions they have to cater for.

Emphasis has been laid on the need for silt regulation, for devices for the safety of structures, for measurement of discharges and volumes

and on the overall need that all hydraulic structures on irrigation and drainage networks should be designed to suit the governing principles of operation of the networks. The desirability of developing systems of irrigation on demand, and of payment on a volume basis have been brought out. The needs of farmers and the requirements of regulation must be coordinated. The desirability of the use of local material and equipment and of pre-fabricated structures has been brought out.

4 Inter-relation between Irrigation and Drainage

The papers presented to the Congress and the discussions have amply brought out the complexity of the problem, varying local conditions requiring varying considerations and treatment. It is, however, fairly well-established that, with continuous application of irrigation water and without simultaneous provision for efficient drainage, a rise of the sub-soil water table is inevitable and this leads in most cases to a deterioration of agricultural lands.

A close relation exists between irrigation and drainage. The necessity of drainage is not questioned. Some experts feel that irrigation and drainage projects should be carried out in parallel while others recommend that drainage works should be undertaken a few years after the introduction of irrigation and after some knowledge has been obtained of the requirements of drainage in each area. It is agreed,

however, that at least the main drains should be incorporated in every irrigation project from the start.

Studies have been described showing the attempts made in finding out all about the relation between irrigation and drainage in order to recommend necessary remedial measures and to forecast future behaviour under modern technique of irrigation and drainage. Soil surveys have been carried out, physical and chemical properties of the soils determined, qualitative and quantitative studies have been made on the behaviour of the sub-soil water table and various means have been devised to lower the underground water table through open or covered drains or by pumping. Useful data have been furnished about experiments and techniques followed in various parts of the world, specific cases have been illustrated and reclamation practices described.

The use of canals for the dual purpose of irrigation and drainage in certain special cases has been cited.

Economic considerations have hardly been touched in this Congress.

A subject as broad as this, involving such a large variety of problems, deserves continuing consideration by the Commission. To further the understanding reached at this Congress it is felt that the question should be taken up again in future Congresses in a more defined form.

Flood Control in the Purview of I.C.I.D.

In view of the growing importance of the flood problems in national economy and the urgent necessity of pooling and exchanging knowledge and experience gained in tackling flood problems in different countries of the world, the writer put up a suggestion in 1956, to include flood control within the activities of the I.C.I.D. There was a good response to this proposal by member countries, and this matter was discussed at the Eighth Meeting of the Executive Council of I.C.I.D. on 29th May, 1957, at San Francisco. The Commission accepted this suggestion and flood control has since been included. A copy of my note on the subject is included as Appendix C.

The Conference Concludes

The Conference concluded with a vote of thanks, by the leader of the Indian Delegation in his capacity as Vice-President of the I.C.I.D., to the host country and other members and member countries who took part in the proceedings.

India continues to occupy an important place, with the election of Shri N. D. Gulhati as one of the Vice-Presidents of the I.C.I.D. Shri Yadava Mohan was elected as Secretary-General.

4

Inter-society conference on irrigation and drainage

The First United States Inter-Society Conference on Irrigation and Drainage was held on 29th and 30th April, 1957, at San Francisco preceding the Third Congress of I. C. I. D. This was sponsored by the American Society of Civil Engineers (I & D Division), the American Society of Agricultural Engineers (Soil and Water Division), and the Soil Science Society of America, in cooperation with the U.S. National Committee of I. C. I. D.

Can Man Develop a Permanent Irrigation Agriculture ?

Answer to this question was the theme of the Conference. Specialists in irrigation and allied subjects contributed valuable papers and took part in the discussions. Approaches to the conflicting problems of water demands were presented in a leading paper⁸. The ever-increasing importance of team work and co-ordination amongst engineers, agronomists and men of other branches was brought out in another paper⁹. 'Can evaporation be reduced' was discussed in one of the papers¹⁰. All the papers presented covered the following aspects :

1. Water in a Permanent Irrigated Agriculture

Influence of climate on irrigated agriculture.
Watershed management in relation to water yield.

Inter-Society Conference on Irrigation & Drainage

- (a) Water yield control through forest management in snow-pack watersheds.
- (b) Water yields as influenced by vegetation management on watersheds below snowline.
- (c) Importance of Phreatophytes in water supply.

Factors affecting the useful life of reservoirs.
Continued utilisation of ground water storage basins.

Can evaporation losses be reduced ?

Problems of maintaining a satisfactory water quality.

2. Crops in a Permanent Irrigated Agriculture

Selection of crops for water-deficient areas.

Cropping practices for maximizing water use efficiency.

Plant diseases, insects, and weeds as affected by irrigation.

3. Soils in a Permanent Irrigated Agriculture

Soil classification in relation to the irrigability of land areas.

Effect of irrigation on soil fertility and profitable development.

Maintenance of favourable soil structure and adequate water infiltration rates.

Salinity and alkalinity hazards.

Hydraulics of irrigation water application as affected by soil and other factors.

Drainage in relation to a permanent irrigated agriculture.

4. Man in a Permanent Irrigated Agriculture

Conflicting demands for water — some approaches to the problem.

Irrigation organisations and water laws as factors in a permanent agriculture.

Inter-State and international water compacts.

Man's changing food habits and their impact on irrigated agriculture.

Health problems as affected by irrigated agriculture.

Man's opportunities to assure the permanence of irrigated agriculture — a summary.

The question of the possibility of having a permanent irrigated agriculture has been put to me several times by many people. Politicians sometimes questioned the fate of irrigation systems being built, as they felt doubtful of the land being able to stand continuous irrigation. It is a very important subject and this was dealt with by various experts in the Conference. The conclusion at the end of the Conference was that it is possible to develop permanent irrigated agriculture, provided scientific and economic utilisation of water with effective drainage is assured.

In under-developed countries of Asia, this problem has become increasingly important with the growing gap between the increase in population and increase in agricultural production. In India, we are in an era of economic water utilisation to bring more land under irrigation to increase agricultural production, to increase the growth of raw materials necessary for industries, and to generate low-cost hydro power much needed for industrial development. Water utilisation schemes

Inter-Society Conference on Irrigation & Drainage

cost much to the National Exchequer, and give rise to many technical and economic problems. The problem of insufficient drainage has already created water-logging problems in Northern India.

Control, conservation, distribution and scientific and economic utilisation of water, and drainage embraces many fields of activities and warrants the cooperation of engineers, scientists, agriculturists, revenue authorities, local population etc. Let us take a water utilisation project. Ministries or departments dealing with irrigation and power, agriculture and food, transport, industries, planning, scientific, agricultural and engineering research, meteorology, geology, soil conservation in the various States and the Centre, must all have a say in the matter. Perfect coordination amongst many of these agencies is necessary in planning and executing a project to derive optimum benefits of the region as a whole, and for balanced development of water potential.

It is here, I would like to stress the importance and utility of organising inter-society conferences and discussions on engineering and allied aspects. The deliberations will go a long way in promoting effective and economic utilisation of water resources, thus contributing to a stable and thriving economy.

5

Saving water in storage reservoirs and irrigation canals

The problem of saving water has been engaging the attention of engineers all over the world and of late various methods are being adopted and experiments conducted for reducing losses caused by evaporation and absorption.

In view of the growing importance of reducing transit losses in canals which is closely interlinked with the conservation of the costly storage waters, the subject has been receiving continued attention of the International Commission on Irrigation and Drainage.

During my visit to U. S. A., I discussed with American Engineers and engineers from other countries the details of experiments conducted to reduce evaporation and methods of canal lining to save water. These are briefly indicated in this chapter.

Necessity of Saving Water

A brief idea about the water losses which occur due to evaporation and seepage clearly depicts the magnitude of the problem.

In India, there are about 66,400 miles of canals taking off from rivers and reservoirs, carrying more than 400,000 cusecs of water. Considerable quantity of water is lost due to absorption in canals and also due to evaporation in reservoirs. The canal losses due to seepage, leakage and evaporation occurring between the headworks and the fields have been estimated to vary within a very wide range from 10 to 50% of the

Saving Water in Storage Reservoirs & Irrigation Canals

supplies entering at the head. Absorption losses in distributaries, minors and water courses are equal to or often larger than the quantity lost in main canals and branches.

Kennedy showed as far back as 1881, that out of every 100 cubic feet of water entering at the head nearly 47 cubic feet were lost in transit. Observations on the Ganges Canal showed that the losses amounted to 44%. Values very near to these figures were obtained in 1907 in case of canals in Khandesh in Bombay.

These show that the extent of water losses in the irrigation canals is huge and demands early steps to conserve water by reducing these losses, for the benefit of developing additional areas.

Even assuming a loss of 25% to be saved it amounts to a saving of 100,000 cusecs of water. With a duty of 100 acres for half of this discharge, and 200 acres for the other half, the water that can be saved by reducing these losses will be able to irrigate 15 million acres of land. For the sake of comparison, it may be mentioned that this will be equivalent to irrigation benefits from four Bhakra Dam Projects.

Types of Losses

The losses are mainly due to :

- (a) Evaporation in reservoirs.
- (b) Absorption and transmission losses in canals.

Any water resource planning aimed at economic utilisation of water should consider these aspects.

A. Evaporation In Reservoirs

Several methods of reducing evaporation losses from reservoirs are known. The project planners and designers are aware of reducing evaporation losses by

keeping the water surface area to the minimum possible, by proper operational procedures either of a single reservoir or a network of reservoirs, by evolving efficient water management plans, by dyking of shallow areas, by skimming warm surface of water to reduce the surface temperature and by oil films.

In the past few years, the use of oil films to suppress evaporation has received considerable attention. Increasing importance is being given to the possible use of a monomolecular film. The early work of Rideal (1925), Langmuir and D. B. Langmuir (1927), Langmuir and Schaefer (1943), and other investigators indicated that certain monomolecular films were effective in suppressing evaporation and suggested that the substance most likely to be useful was hexadecanol.

(i) Experiments in Australia

Recently experiments were afoot in Australia by the Commonwealth Scientific and Industrial Organisation. Evaporation control tests have been in progress at Stephens Creek Reservoir, Broken Hill, in Australia. The C.S.I.R.O. since then are engaged on a coordinated programme of research both in the laboratory and in the field.

In September-October 1956, a delegation under the leadership of Professor M.S. Thacker visited Australia. Dr. R. C. Hoon, Director, Central Water and Power Commission was one of the members. During his visit, Dr. R. C. Hoon studied the details of the technique applied in the Stephens Creek Reservoir. The experiments were conducted with Cetyl alcohol. *Figures 2 and 3* show two forms of raft used by C.S.I.R.O. for dispensing Cetyl alcohol in small-sized storage reservoirs. The details of the techniques of dispensing

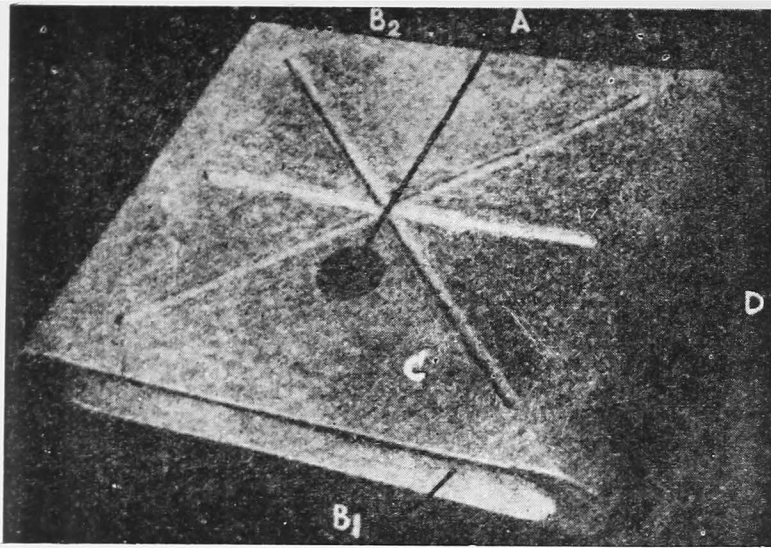


Fig. 2 — Form of Raft for Dispensing Cetyl Alcohol in Small-sized Storage Reservoirs — used by C.S.I.R.O.

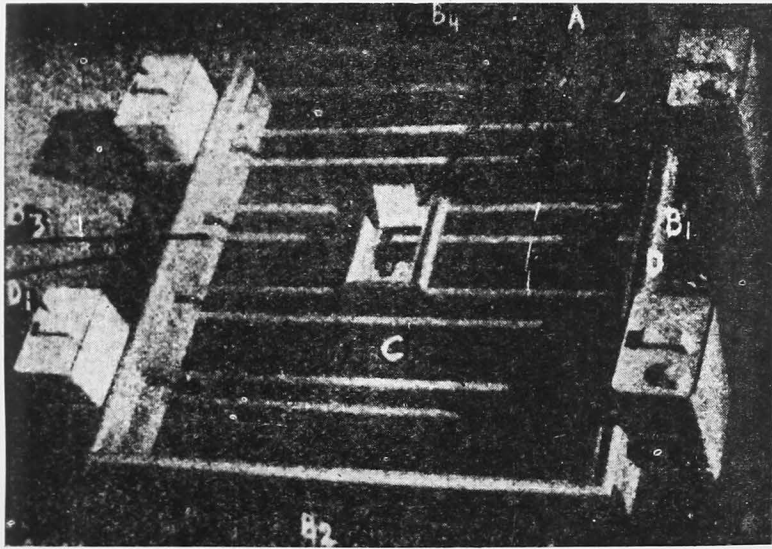


Fig. 3 — Another Form of Raft
A = Trapdoor or filling plug ;
B₁ to B₄ = Sides made of gauze ;
C = Top and Bottom screens ;
D to D₁ = Anchoring bolts.

Cetyl alcohol in the form of solution at that reservoir were studied by Dr. Hoon.

From the latest report from Australia, it is noticed that the experiments which are being conducted there are successful. The Cetyl alcohol used in the experiments at Broken Hill is said to be a commercial mixture obtained from Price's (Bromborough). Typical composition is :

Myristyl alcohol	10	per cent
Cetyl alcohol	45	„
Stearyl alcohol	40	„
Unsaturated alcohols	5	„

It is listed in Price's Technical Bulletin (1956) under reference A. 31.

Figure 4 gives a plan of the floating rafts used at Stephens Creek Reservoir.

However, the C.S.I.R.O. have mentioned that further work is required before actual recommendations could be made as to the use of Cetyl alcohol.

(ii) Experiments in India

Small scale experiments are being carried out in this country by Irrigation Development Division, Pona. These experiments indicated a reduction in the rate of evaporation to an extent of 34 per cent by use of the Cetyl alcohol monolayer. Also small scale experiments and studies are being made at the National Physical Laboratory, New Delhi.

It has now been decided that full scale experiments should be organised in India under the direction of the C.W. & P.C. Experiments are being organised to be carried out at three selected reservoirs — one in

Saving Water in Storage Reservoirs & Irrigation Canals

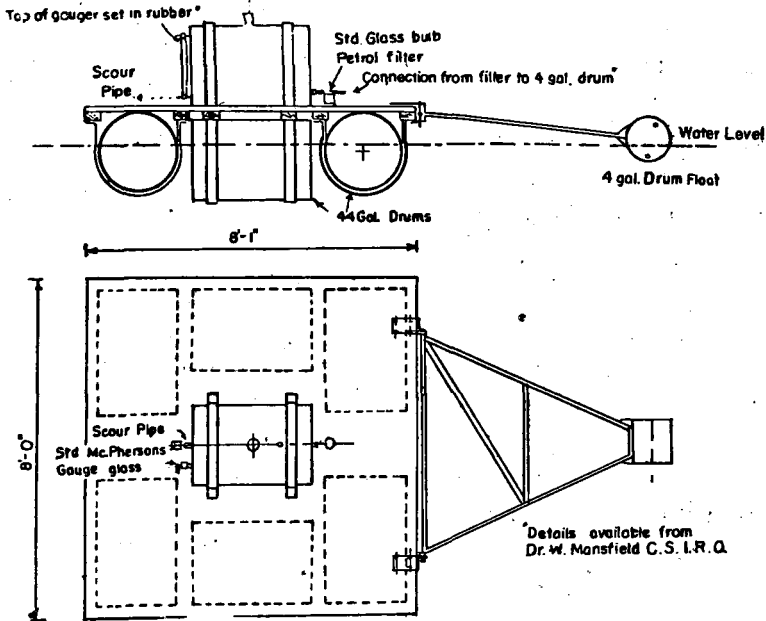


Fig. 4 — Plan Showing Type of Floating Rafts used for Dispensing Cetyl Alcohol Solution at the Stephens Creek Reservoir

Madras, one in Mysore and one in Punjab — on lines similar to those followed in Australia, under the direction of Dr. R. C. Hoon.

(iii) Experience in U. S. A.

During my visits in the United States of America, I discussed the question of reduction of evaporation by the application of Cetyl alcohol with some American experts. Some trials have already been made with Cetyl alcohol on the reservoir used for water supply to the city of Oklahoma. Full scale studies are afoot for experiments on Lake Hefner which has a water surface area of about 2,400 acres.

Systematic efforts are being made now jointly by the United States Bureau of Reclamation and the

city of Oklahoma to conduct experiments. The experiments are being conducted in two phases. The first would be a study of the effect of the treatment on the water quality and the second would be full scale evaporation reduction studies at the lake. Therefore, the first phase is being conducted at the Kids Lake which is an arm of Lake Hefner and is located a few hundred feet away from the big Lake. This location has been decided upon to avoid any possible harmful effect of hexadecanol on water since Lake Hefner supplies water to the city of Oklahoma.

The alcohol used is hexadecanol, the chemical composition of which is as below :

Tetradecanol	1.1 per cent
Hexadecanol	90.6 „
Octadecanol	7.3 „
Unsaturated	1.0 „
Melting point	52° C + 1° C.

During discussions it was further revealed that hexadecanol appeared to have no effect on changing the water quality including taste, odour, colour, toxicity and other chemical qualities. It is, however, too early to arrive at any definite conclusions before large scale experiments are conducted.

(iv) What is Hexadecanol ?

Hexadecanol, which is a by-product from whale oil, is practically the same as Cetyl alcohol. The theory of applying hexadecanol is very interesting. Hexadecanol is one of the long-chain molecules called "polar" which means that such a molecule which is a thin long structure like an eel or snake has one end allergic to

Saving Water in Storage Reservoirs & Irrigation Canals

water while the other end likes it. Therefore, when water surface covered with this chemical is looked through a super-powerful microscope, there can be seen a thick forest of these molecules, only 6,10,000,000ths of an inch long, but all standing crowded together with their water loving ends in the water and their water hating ends lifted out of it. Evaporation occurs when individual molecules of water absorb so much energy from the heat of the sun that they can get up 'flying speed' and take off from the surface; but when they are underneath a complete carpet of hexadecanol, they batter at it in vain. These monolayers over the surface of water are known to offer an effective resistance to vapour transfer, about 1600 times greater than that of a free water surface. The cost of operation is not much. In Oklahoma city, for example, water delivered to taps or individual installations cost an average of \$61 per acre foot of water, while the cost of maintaining hexadecanol cover is estimated at not much more than \$1.6 per acre foot.

B. Absorption and Transmission Losses

(i) Absorption Losses in India

The absorption losses in canals contribute a good share of the total water losses. Much has been done in India for reducing these losses.

In the writer's paper on 'Canal Lining' the extent of losses by absorption in Bari Doab Canal, and losses in other parts of India are indicated.* The canal losses can be reduced by 75 per cent or even more by lining. In some cases the reduction may be as large as 95 per cent

*Relevant extracts are given in Appendix B.

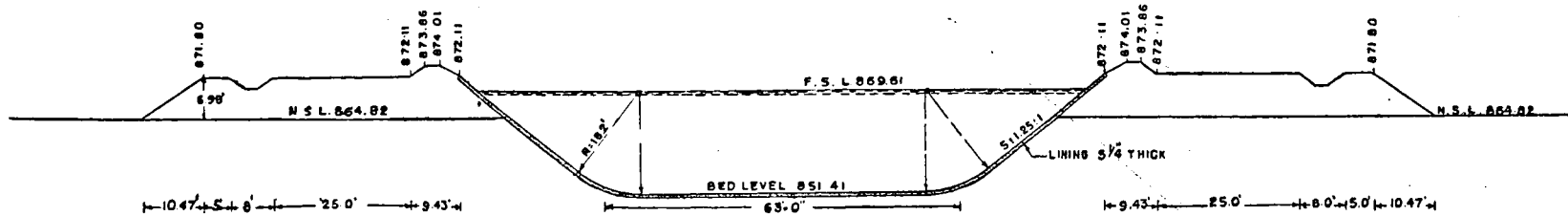
of the total seepage losses. Different methods of lining, results obtained and cost of lining have also been indicated in the paper.

The selection of canal lining has to be ideally determined by an economic evaluation of various types of linings, structurally suited to site conditions. Cost of materials and installation, maintenance and operation of the lining, and canal sections are concerned. Cement concrete linings though most desirable are expensive. Linings constructed out of earth material are cheap but not always durable. Brick and stone linings stand somewhere in between the two extremes mentioned above.

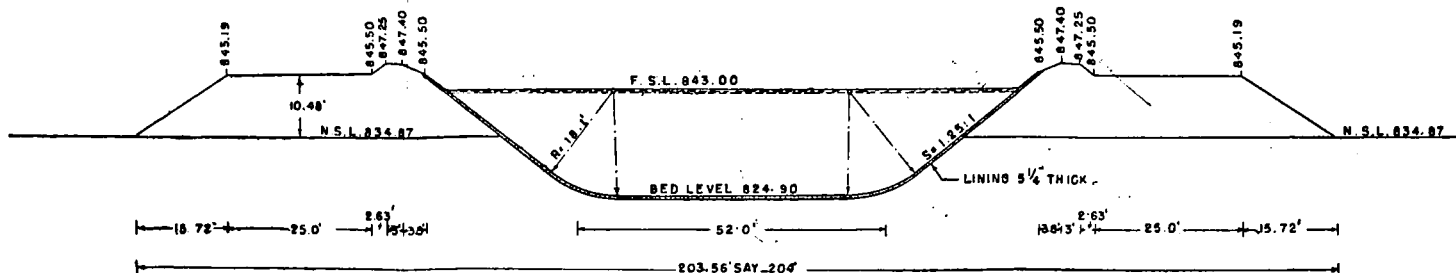
(ii) *Canal Lining in U. S. A.*

Canal lining is gaining more and more importance in the United States. Twenty-five million square yards have been lined with concrete or asphalt since 1952 in 750 miles of canals, thus saving 700,000 acre ft. of water annually. Lining has been adopted there not only to save water for irrigation purposes but the Army Corps of Engineers were using lining as a flood control measure. Just near Los Angeles there are some hill torrents which experience heavy floods without notice. Notice is just perhaps a couple of hours, if any at all, and the velocities in these torrents range from 25 ft. to 50 ft. per second. Lining has been adopted to prevent bank erosion.

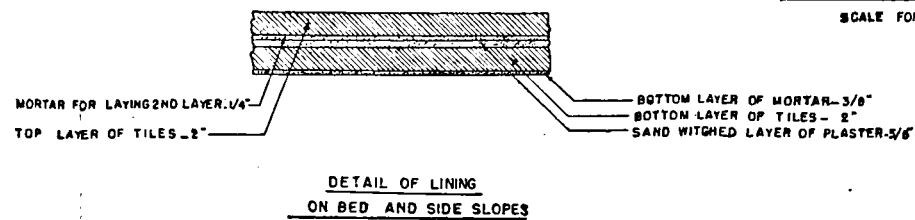
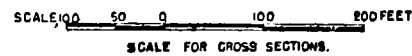
I had discussions with many experts, who had assembled in U.S.A. for the Conference from different parts of the world, on the question of reducing the seepage losses and also on the economics of various methods of lining. It was considered by all of them that the method of sandwiched brick-tile lining indicated



CROSS SECTION AT R.D. 16,000
Q = 12228 CUSECS



CROSS SECTION AT R.D. 210,000
Q = 7224 CUSECS



DETAIL OF LINING
ON BED AND SIDE SLOPES

Fig. 5 — Bhakra Main Line Canal — Typical Cross-sections at R. D. 1,60,000 and 2,10,000

by me was considered to be one of the best methods for Indian conditions to economically and effectively reduce canal losses. *Figure 5* gives typical cross-section of Bhakra Main Line Canal and details of linings.

(iii) Steps taken at Elephant Butte Reservoir in U.S.A.

I had the opportunity to see the extensive work done in the delta area of the Elephant Butte Reservoir to save water as much as possible, when I was in U.S.A. in 1955 to attend the Arid Lands Symposium sponsored by the American Association for the Advancement of Science¹¹. Examination of conditions in the irrigated areas below the reservoir during the past few years indicates the measures taken by a highly developed area to meet a critical and prolonged period of water shortage. Discharge of Rio Grande River at the head of the reservoir averaged to 1.0 million acre feet annually during the 60 years period from 1895 to 1954. During the period 1943 to 1954 actual annual discharge averaged to 50 per cent of the 60-year average. During the 5 years preceding 1955 there has been an acute shortage of water and the average yield worked out to only 380,000 acre feet which was about 40 per cent of the 60-year average. It is very interesting to note that this situation of water shortages had been met by rationing and careful use of the available water supplies, *i.e.*, by drilling numerous irrigation wells for purposes of supplementing deficient surface water supplies with ground water, and by institution of litigation for the purpose of making the Rio Grande Compact an effective instrument in apportioning river flow between areas above and below the Elephant Butte Reservoir.

When I visited the Project in 1955, I noticed extensive channelisation to reduce water losses by

absorption and evaporation. The Bureau of Reclamation had started this large scale water salvage programme in the Rio Grande Valley, upstream of Elephant Butte Reservoir in 1951. The work was begun by the construction of 7.7 miles of pilot channels through a large swampy area. Further work covered construction of a low-flow channel and a cleared floodway, 31 miles in length, varying in width from 1,000 to 1,400 feet. Material removed in the construction of the low-flow channel was placed on the river side to form a spoil bank levee parallel to the new channel. A 50-foot brush fringe was left on the floodway side of this levee as a protective measure against erosion. Gravelled access roads along each side of the channel provide a means for patrol and maintenance. The low-flow channel was designed to carry the entire flow of the river about 80 per cent of the time. Discharges exceeding the capacity of the low-flow channel are directed down the floodway. Velocities in the channel average about 4 feet per second, thus permitting the conveyance of most of the sediment. The overall water salvage resulting from this work is estimated to be 45,000 acre feet per year. *Figure 6* shows graphically the increase in water salvage as channelisation progressed during 1951 to 1954.

The low-flow channel and floodway are currently being extended upstream for a distance of approximately 40 miles. This extension will cost in the neighbourhood of \$3,900,000 and will result in the salvage of an estimated additional 40,000 acre feet of water annually.

This is a very interesting and valuable example for saving water in the arid tracts in India and for making the best use of available supplies. As Chairman of the Session on 'Better Use of Present Resources' I brought out clearly the improvements necessary in saving water

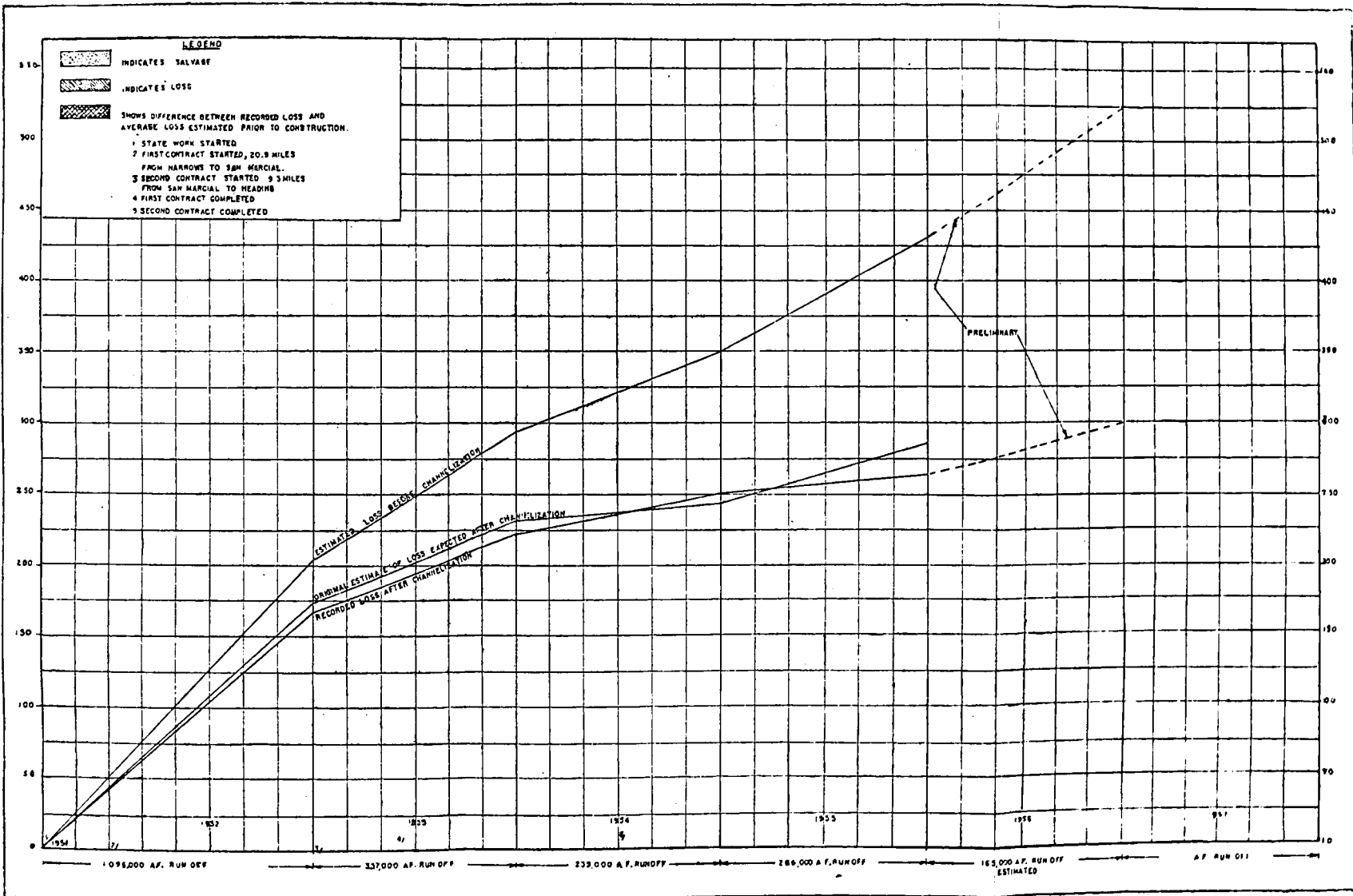


Fig. 6 -- Channel Rectification above Elephant Butte Reservoir -- Mass Curves -- Rio Grande Losses and Water Salvage

and also the importance of arid lands for increasing agricultural production by irrigation¹².

Summing Up

Many engineers in U.S.A. were not very optimistic about the results that are being obtained at present in using monomolecular films for reducing evaporation in reservoirs.

Small scale experiments have been undertaken in India on the lines of the work done in Australia. It is, however, too early to say how far the application of hexadecanol for reducing evaporation losses in India will be effective in practice. In India, the surface areas of many of the storage reservoirs are huge. The important problem consists in dispensing hexadecanol over the water surface and also in maintaining the thin film. Wave action and rain often break the thin alcoholic film on the water surface. The pressure of the film and the area covered are interlinked. If the pressure is less it will not reduce evaporation. With the results of experiments that are now being launched upon, in India and elsewhere, the utility of hexadecanol or other monomolecular films in small reservoirs and tanks may become practicable.

In the case of canals, evaporation is comparatively of less importance. Most of the losses occur as absorption into the soil. Various types of linings have been tried. While concrete linings are perhaps most durable, they are at the same time most expensive. Asphalt linings will not have the same life in the tropical conditions in India. The economy and suitability of plastic linings to reduce seepage losses are yet to be established. Experiments for this purpose have been taken in hand in the Central Water and Power Commission. Under

the available conditions of labour and materials in India, sandwiched type of brick lining first adopted in Haveli Canal in 1937-38 is still the most economical. The cost of lining in the Rajasthan Canal, construction of which has just been started, will be a very important factor in the cost of the whole project. Detailed studies are being made to find the most economical and best type of lining.

Here is an extract from "Economic Methods of Controlling Evaporation of Water" by Mr. K. L. Southerland in 'Research' May 1957, Vol. 10, Number 5, which is of interest.

"Whilst there is considerable work yet to be done in fully elucidating some of the practical problems, Mansfield has developed at least two economic methods of treating water surfaces. The hexadecanol is non-toxic in any amount to humans and animals and under no circumstances has it been observed that oxygen transfer in water has been adversely affected.

"There is, at present, no guarantee that the process as developed in Australia will be applicable everywhere else in the world. For example, in some localities biological destruction of the monolayer may be sufficiently great to render the process uneconomic or surface contamination of water may interfere with its effective action.

"One important conclusion has emerged — it is of no value to save water from evaporation if the water is left to seep away."

Sprinkler irrigation

Sprinkler Irrigation Round the World

In U.S.A. sprinkler irrigation is widely prevalent. It now extends to six million acres. Except for growing rice and some other cereals, the farmers have found that on many occasions sprinkler irrigation proved comparatively economical and not a luxury. The cultural practices and high standards of living have also affected in switching to sprinkler methods.

Sprinkler irrigation has proved particularly of importance in irrigating vegetable crops. In California it has been widely practised for growing tomatoes, potatoes, onions, cucumbers, cabbage, cauliflower, peas and some root crops. The practice is not widespread in the case of growing head lettuce, carrots, watermelons and various vegetable seed crops, etc. This method is considered as a last resort in the case of tall crops such as beans, sweet corn, etc., during advanced stages of growth.

Sprinkler irrigation is comparatively costly. The initial cost of equipment is high. Based on certain modest assumptions, the total annual costs for operating a sprinkler system would be about \$32.5 per acre of land. This includes the fixed costs, labour and power charges and is exclusive of the cost of water. Calculations, in another case to irrigate a farm of 160 acres, show that the cost of operation (excluding cost of water) amounts to \$15.65 per acre feet. These figures indicate that sprinkler system is expensive both in initial cost and in operation cost and application of this method depends

mainly on individual income, availability of requisite equipment and allied factors.

In Italy sprinkler irrigation has gained importance since the last few years and it is being used to the extent possible subject to local needs and conditions.

In Australia the practice of sprinkler irrigation has increased considerably during the past few years. Among the reasons for its increased application are :

- (a) Spray irrigation permits greater control of water applied than surface irrigation methods.
- (b) Preliminary preparation of land by grading and furrowing is obviated.
- (c) Irrigation of uneven land, which is otherwise not possible by gravity flow of water, is made possible.
- (d) The loss of land used up for construction of surface water courses and the labour entailed in the maintenance of the latter are obviated.
- (e) The requirement for increased productivity method of farming receives a fillip with need for irrigation fulfilled.

The system of spray irrigation is used in Australia for irrigating pasture lands, orchards and vegetable crops but not for crops like wheat, sugarcane, etc. Pasture lands and orchards are mostly developed in valleys, which made it difficult to allow flow irrigation. The spray irrigation has fitted well in their farm economics as the products from their pasture lands, orchards and vegetable farms, namely, milk and milk products, wool, fruits and vegetable fetch very good price.

Suitability of a Sprinkler System

Sprinkler irrigation is conditioned by topography of the area to be irrigated, source of water supply, soil characteristics, rainfall, etc. This method is mainly meant to distribute water uniformly and to maintain an adequate and constant supply of soil moisture in a major portion of the root zones of the crops. The amount of water to be supplied is also regulated by both the type of the crops and the soil.

This system is desirable in any one of the following situations :

- (a) New land is to be developed for irrigation.
- (b) The topography is rolling or rough.
- (c) Soil conditions vary.
- (d) The present method of irrigation involves certain difficulties resulting in inefficient irrigation.
- (e) The crops to be grown require frequent light irrigations.
- (f) Problems of seed germination have been encountered.
- (g) The flow of the water is not large enough to permit efficient irrigation by surface methods.

By and large, sprinkler irrigation system is mostly adaptable in cases of rough land with irregular features where surface irrigation method becomes more costly and complicated.

Advantages

When the land is rolling and rough it avoids costly preparation of land by grading and levelling.

Good water control is possible in some areas especially in pervious soils liable to large seepage and in areas of low rainfall. This method of irrigation avoids waste of water by deep percolation.

In areas likely to be water-logged where the sub-soil water table is high, sprinkling method has a decided advantage in applying the proper depth of water to wet the soil to the desired extent without raising the water table.

In some cases this method may help in eliminating construction of water courses and other ditches necessary for surface irrigation. Seepage and evaporation losses in water courses are also reduced or eliminated. It is most suitable to adopt this method when shallow-rooted crops cannot efficiently be irrigated by surface methods. Sprinkler system can be designed to operate effectively with a small rate of flow and particularly in small fields with limited water supply.

With modern techniques of irrigation and the use of fertilizers, the method of sprinkler irrigation helps to distribute water uniformly without causing any possible injury to the crops. Excessive leaching of soil nutrients which occurs where water is wastefully applied by surface methods sometimes can be prevented by using sprinklers.

Disadvantages

Besides some positive advantages which have been mentioned earlier there are other decided disadvantages. The techniques of applying this method require hard work and constant attention by the farmers. In heavy soils, the methods are not suitable.

One important limitation is by the prevailing winds. Results of experiments show that wind in excess

of six miles have a decided influence on water distribution. In fact with the spacing of laterals used with some sprinklers, the water reaching the soil in parts of the area between sprinklers is only about 15 per cent of the amount the system was designed to apply. Experiments on wind have also proved that with increase in wind speed the efficiency of sprinklers is much reduced. A plot of the uniformity coefficient for 30 ft. sprinkler spacing by 30 ft., 40 ft., 50 ft. and 60 ft. lateral spacing — when the sprinklers operated at 30 pounds per square inch is shown in *Figure 7**. The uniformity coefficient is expressed as a percentage on a scale of 0 per cent to 100 per cent with 100 per cent indicating absolutely

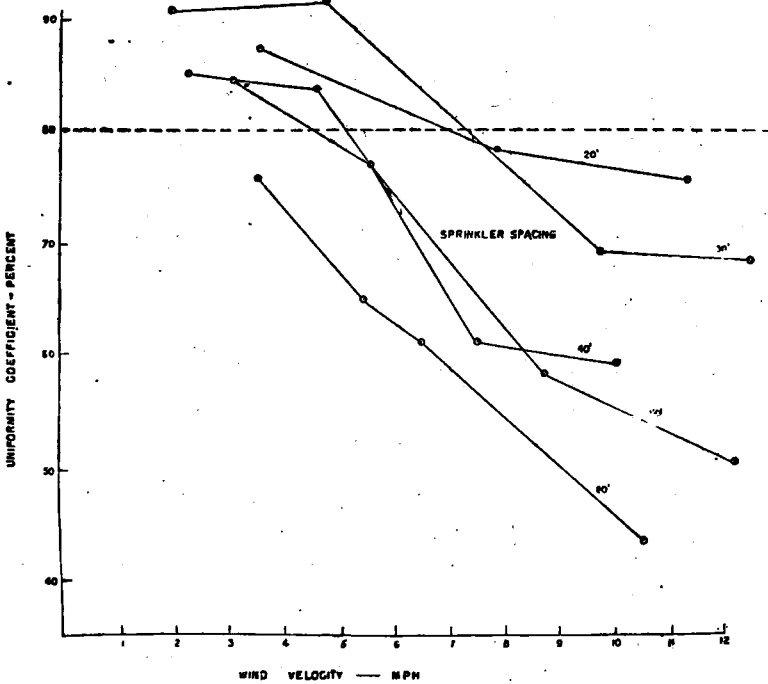


Fig. 7 — Sprinkler Spacing Tests at 30 lbs. per sq. in. — Relation Between Wind Velocity and Uniformity Coefficient.

* From California Agriculture, Vol. II, No. 4, April, 1957, Page 30.

uniform distribution over the entire area covered by the water discharging from the sprinklers. A uniformity coefficient of 80 per cent is generally considered to be the lower limit of acceptable distribution. The uniformity coefficient falls down from 80 per cent to 50 per cent with the increase in the speed of the wind from six miles per hour to twelve miles per hour. There is little effect at low wind velocities.

Water loss is more by evaporation while sprinkling than with surface flooding methods. There are two sources of evaporation loss, *i.e.*, from the water drops or spray moving in air and from the wetted soil and foliage surfaces. The net loss by evaporation varies between 5 to 40 per cent.

Sprinkling may help the germination of a larger number of seeds much earlier than the germination of the crops themselves. Under certain climatic conditions diseases may also be encouraged by sprinkling.

Where large heads of water are available for short periods of time which is the case normally in land served by irrigation projects it is impracticable to apply water by sprinkler irrigation.

Availability of the water supply may also create some problems with sprinkling. With a rotation in water supply, water is delivered in large quantities and in such cases it would require excessive sprinkling equipment which might be difficult to manage.

Sprinkling systems are costly compared to other methods of irrigation and it is necessary to give consideration to the initial cost, depreciation and maintenance and repairs before adopting such system.

Sprinkler Irrigation in India

Sprinkling systems require pressures ranging from 5 to 120 pounds per sq. inch depending upon the type of the system. Pressures of 30 to 60 lb. per sq. inch are most efficient in areas where sprinklers are used for irrigating vegetable crops. One pound per sq. inch is equivalent to lifting water 2.31 ft. in height. Therefore, if a pressure of 50 pounds per sq. inch must be developed by the pump, the rate of power consumption would be the same for operating a sprinkler system as would be required for lifting water 115.5 feet. This means a lot of power consumption.

Irrigation has been practised since several centuries in India, and this country is one of the pioneers in irrigation engineering. Statistics show that India's irrigated area in 1956 was about 67.5 million acres.

Several techniques of irrigation have been in vogue in India and sprinkler irrigation has not been adopted so far, presumably due to natural and local conditions.

The cost of storage and distribution of water to irrigate one acre is not much in this country. Cost figures are available for all the projects. There are some projects in the recent past with abnormal cost of irrigation. The average cost of irrigation from diversion weirs, some completed in the recent past, works out to about Rs. 164 per acre omitting some projects which cost much more. On a similar basis from storage reservoirs of irrigation projects the cost is about Rs. 334 per acre, and from storage reservoirs of multipurpose projects, the average rate is more than Rs. 400 per acre. For the sake of information the figures pertaining to some multipurpose projects are as follow :

	Cost of irrigation
	per acre
Hirakud Dam Project	Rs. 564
Bhadra Reservoir	Rs. 764
Tungabhadra Project :	
Low Level Canal	Rs. 728
Left Bank Canal	Rs. 510
D.V.C. Projects	Rs. 246
Chambal	Rs. 314
Bhakra-Nangal Project	Rs. 348
Nagarjunasagar	Rs. 384

In India the time is not yet ripe to use sprinkler irrigation because of its high cost and non-availability of necessary equipment at reasonable price. Moreover the method demands education of cultivators to adopt the new techniques in sprinkler irrigation.

A country like India with under-developed economy cannot change over easily from cheaper methods of surface irrigation to costlier sprinkler irrigation except in a few special localities. The smallness in holdings by cultivators also do not favour such a change. The existing financial resources will have to be spent on easier methods of increasing agricultural production than spending on costly equipment required in sprinkler irrigation. A combination of all these reasons has not favoured sprinkler irrigation in India.

One important prerequisite for adopting sprinkler irrigation is the availability of cheap electric power at the fields. This has to come mainly from hydro-electric projects. Transmission and distribution of power to the various localities and fields at present is not a feasible proposition. Of a greater need is the

Sprinkler Irrigation

problem of rural electrification, which is engaging the attention of planners at this stage. So power cannot be easily made available for sprinkler irrigation.

One-Ditch System in U.S.A.

The one-ditch system for irrigation and drainage is another interesting practice in U.S.A. During summer water is kept 3 feet below ground level in the channel and is pumped on to the land. The cost of operation, including lifting water by 3 feet, was only of the order of \$1.5 per acre annually, including the power for lifting and the cost of construction of these ditches.

7

United States of America

Sacramento River Flood Control Project

The Sacramento River

The Central Valley of California is a land of great promise and achievements. The major hydrographic system of the Central Valley is that of the Sacramento and San Joaquin Rivers and their tributaries. Two-thirds of the Central Valley's abundant water resources originate in the Sacramento Valley with its drainage area of 26,500 sq. miles, though it contains only one-third of the agricultural lands. The river is frequently flooded in late winter and spring, causing heavy damages and allowing a great percentage of valuable water resources to waste.

Levees to Mitigate Flood Menace

Levees were first constructed along Sacramento River in 1870 and they have been existing since then. Just after 1870, in the beginning, during excessive gold mining operations, a lot of silt and debris from mining operations was thrown in the river bed with the result, that the river bed rose more than 20 feet. To avoid this, laws were passed by the State in 1910, promulgating that all these gold digging and mining organizations, before proceeding with mining operations, should construct debris dams, sediment catching dams, just on small tributaries where they were working. As a result of this law, and as a result of those debris dams, some of which I saw, the river bed scoured back 10 to 15 feet. This behaviour of river regimes is interesting in

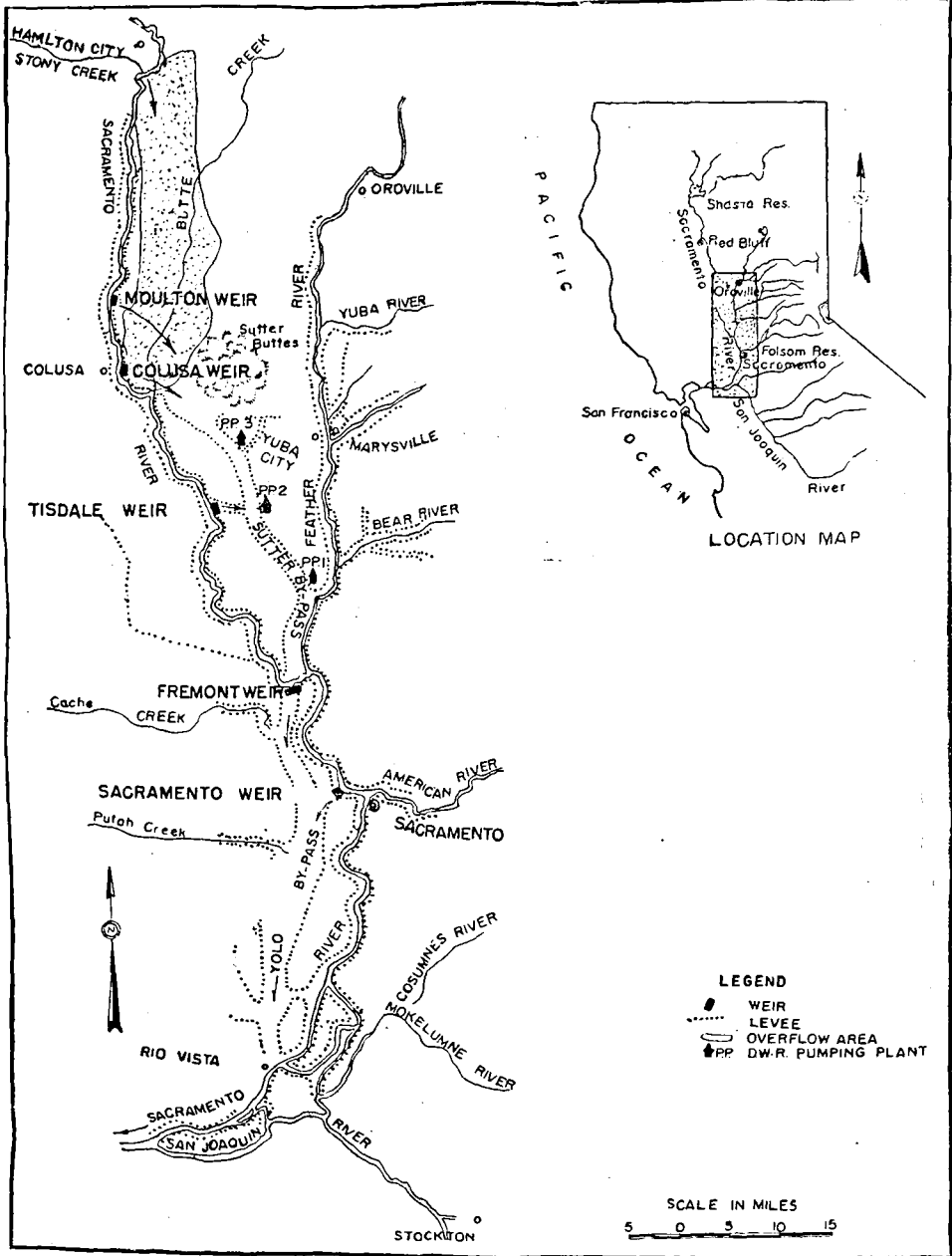


Fig. 8 — Sacramento River Flood Control Project — Levees, Overflow Area and Location of Structures

connection with the problems we are dealing in connection with flood control. They were also dredging with the help of suction dredges to maintain a navigation channel of about 30 feet depth.

In the past 50 years another interesting phenomenon experienced in the valley was salt water intrusion from the sea. This has occurred five times in the past half a century and has since been checked by the construction of the Shasta Dam and other storage dams in the Central Valley.

A Flood Control Scheme Conceived

The Sacramento River Flood Control Project was conceived to carry the flood waters of the northern portion of California's Central Valley safely across the valley floor to Suisun Bay, an arm of San Francisco Bay. It is a comprehensive system of leveed river and by-pass channels, together with appurtenant weirs, drainage pumping plants, and control structures along Sacramento River and the lower reaches of its principal tributaries. *Figure 8* depicts major features of the project. The physical works of the project include approximately 980 miles of levees; 440 miles of channels and canals; and seven by-passes 95 miles in length and 1,01,000 acres in area. When all these works are completed, the project will provide protection from floods to about 8,00,000 acres of highly productive agricultural lands, and to the cities of Marysville, Yuba, Sacramento and numerous smaller communities.

These flood control works are of great interest in the present context of flood problems in our country. In the operation of the Sacramento Project, approximately 100 stream gauging stations are maintained, eight automatic short-wave radio water stage transmitters are operated, as well as three other automatic telemetering devices which report water stage elevations.

As the river channels are of insufficient size to safely carry the peak flood runoff, excess waters flow over the left bank of the Sacramento River at the northerly limit of the project into the as yet unreclaimed Butte Basin, denoted by the shaded area in *Figure 8*. Also, in addition, excess flow leaves the river over Moulton and Colusa Weirs and is carried in the Sutter By-pass to the confluence of the Feather and the Sacramento Rivers. At this point the combined flow is divided between the river channel and the Yolo By-pass by means of the Fremont Weir. The Sacramento Weir also diverts excess water into Yolo By-pass. The design capacity of the river to the west of Sacramento is about 1,10,000 cusec. The maximum flood in the river is 5,00,000 to 6,00,000 cusec with a frequency of once in 50 to 100 years. The excess flood, which is much more than the carrying capacity of the river, is passed in large floodways. In fact the design capacity of the Yolo By-pass is of the order of about 4,90,000 cusec.

Federal-State-Local Undertaking

The project is a joint Federal-State-Local Undertaking. Presently it is being financed by the U. S. Army Corps of Engineers. The State of California through the Reclamation Board provides the funds for the necessary right-of way acquisition and provides the assurances that the project works will be satisfactorily maintained.

The State of California, Department of Water Resources, exercises supervisory powers over the operation and maintenance of the project and also physically maintains 134 miles of levees, all by-pass channels, three major pumping plants, and the five major flood control weirs. The maintenance of the remainder of the physical

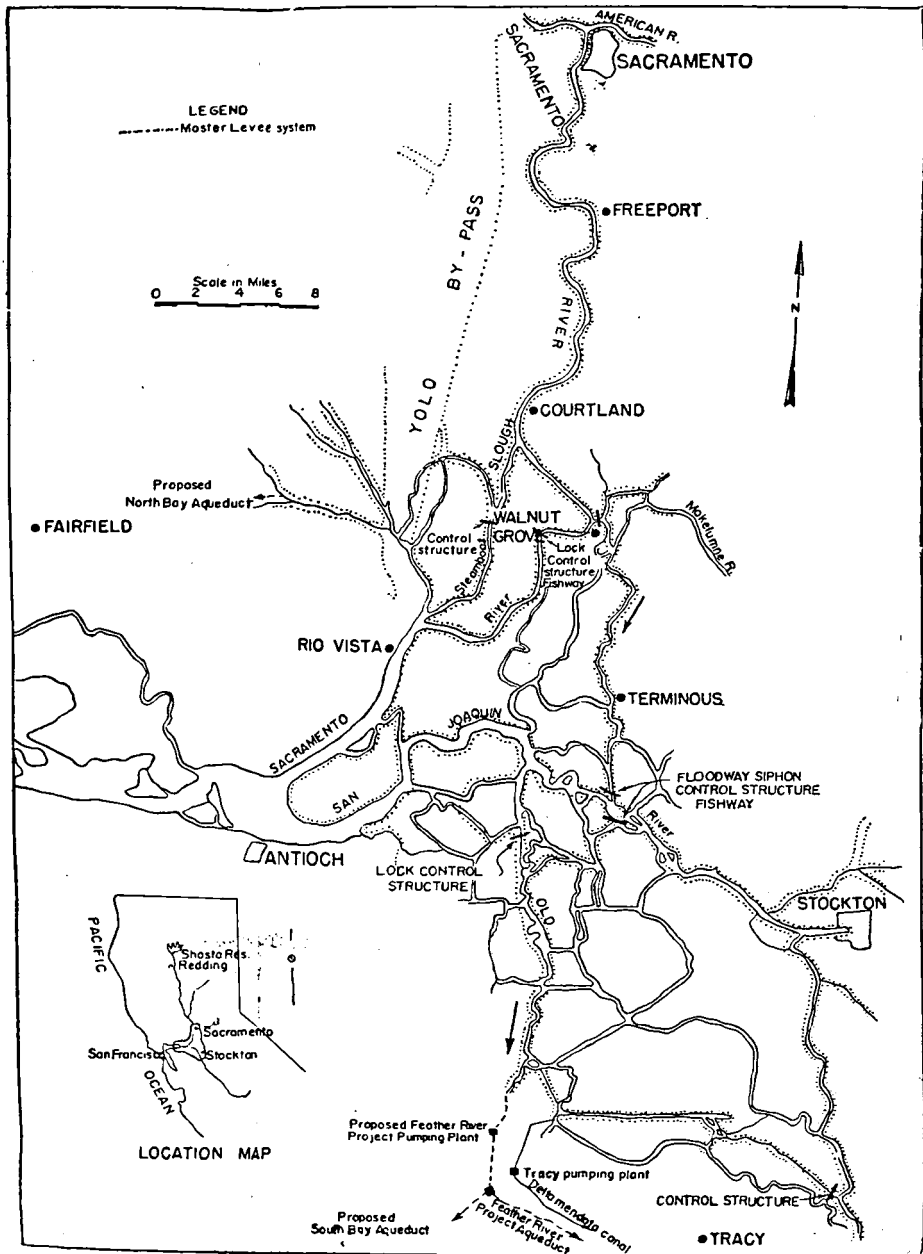


Fig 9 — Sacramento — San Joaquin Delta Area — The Biomed Plan Features.

works is the responsibility of local government agencies. An additional 95 miles of levees are physically maintained by the Department of Water Resources with funds received by assessments from the so-called maintenance areas. Maintenance areas are created by the Reclamation Board when it is found that local interests are not providing satisfactory maintenance, or upon request of the local governing agency.

Already authorities concerned have contributed about 140 million dollars and the construction of the project, which has been progressing since the turn of the century is nearing completion.

Sacramento-San Joaquin Delta

The delta, a roughly triangular-shaped area of approximately 5,30,000 acres, is the terminus of the Sacramento and San Joaquin Rivers. These two river systems drain an area of over 43,000 square miles of the Central Valley.

The delta, consisting of approximately 85 highly productive islands and tracts that are protected by approximately 1,100 miles of levees, plays a key role in the California Water Plan which will be explained later. The flood flows from the Sacramento and San Joaquin river systems must be conveyed safely through the delta. Interior land surfaces of the islands and tracts vary from sea level to as much as 15 feet below sea level. The preponderance of peat and other deleterious materials in the delta make the construction and maintenance of adequate levees very difficult.

A plan proposed for the delta area, known as the Biemond Plan, is depicted in *Figure 9*. It is proposed therein to construct a master levee system not only to confine flood flows but also to permit the transfer of

water from the Sacramento River to pumping plants at the southerly limit of the delta. To prevent degradation of the Sacramento River water during low-flow periods, control structures would be constructed. The water would flow south in a confined channel and be siphoned under the San Joaquin River in four 32-foot diameter pipes. The central structures would be gated so as to permit the utilisation of the confined channels for the passage of flood flows. Barge locks and fishways are integral facilities in the overall Biernond Plan.

The State of California, Department of Water Resources, proposes to complete studies on this Plan by 1959.

The California Water Plan

Most of the countries are today busy in promoting projects for harnessing water much needed for agricultural and industrial prosperity. With the rise in population all over the world coupled with rise in the standards of living, demands for water facilities have increased. Water demands by industries are constantly increasing. To meet the water shortages, to conserve and distribute the surplus waters in some regions, to mitigate the floods etc., California is faced with the task of drawing out a comprehensive water plan for systematic development.

Many of the different uses of water are mutually conflicting. Efforts of the planning, constructing and operating agencies must be coordinated in team work to minimise their conflicts. In this Chapter, the concepts of planning and some brief details of the water plan are given.

California's Need and Water Problems

The urgency of California's need and water problems can be best illustrated by indicating the rapid growth of the population. In 1940, California had a population of 6.9 million which increased to 10.6 million in 1950. In 1955, it had increased another 23 per cent and the population reached 14 million in 1957. Obviously with this growing population, the use of water both for domestic and other development purposes increased significantly and resulted in seasonal and permanent shortage of developed water in the State. With the expanding population, agricultural development had a fillip and was side by side supplemented with rapid growth of industries - all these demanding water facilities.

The estimated seasonal shortage of developed water in the State of California is as below :

1950	2.7 m. a. ft.
1955	4.0 m. a. ft.
1965 (estimated)	10.0 m. a. ft.

The above facts depict the need of California and the necessity for solving the present and future needs.

The water problems of California are :

1. Unprecedented expansion is the need for water for consumptive demands comprising those for agricultural, industrial and municipal purposes and non-consumptive uses including those for flood control, hydroelectric power, recreation, and fish and wild life.

2. Unbalanced distribution of its water resources and water requirements. The major sources of water are in Northern California whereas the major urban areas and productive agricultural lands are to the south in which occurs only 30 per cent of the total natural runoff. Great distances and rugged mountains separate the water

available areas from areas of demand. About 70 per cent of the total stream flow occurs north of the latitude of Sacramento, but 77 per cent of the present use of water, and 80 per cent of the forecast ultimate use lie south of that line.

3. Large variations of runoff within the season and from year to year, and periodic droughts.

4. Periodic floods from rivers and streams throughout the State particularly in the valleys and flood plains where most of the 14 million population live, resulting in major damage to property and loss of life.

5. Limitation of land in the ultimate development of the State.

6. Deficiencies in surface and ground water development from lack of drainage and from improper disposal of wastes and over-draws of ground water storage, thus reducing the quality of fresh water supplies.

7. Serious problem of adequate drainage associated with irrigated agriculture. Extensive drainage system and proper disposal of drain waters of high mineral content are important factors in maintaining soil fertility and ground water quality.

8. Provision of peaking energy by extensive development of hydroelectric power.

Thus California is faced with critical problems, on the one side to tackle floods and on the other side to meet the requirements of areas of water deficiency.

How the Plan was Prepared ?

The first broad investigation of the irrigation problem of California was made in the later part of the 19th Century by a Board of Commissioners authorised by Congress and appointed by the President. Later on,

the two Federal agencies, *i.e.*, the U. S. Bureau of Reclamation who deal with water plans in the Western States of U.S.A. and the U.S. Army Corps of Engineers who deal with the flood problems, conducted comprehensive studies of the development of water resources on various streams in California. Many dams have also been constructed by these agencies.

Later, to evolve a complete state-wide plan (except for one small river, there are no inter-state rivers in California) for ultimate water supply development, the state-wide Water Resources Investigation was initiated by the State Water Resources Board in 1947. The Board was authorised by the State Legislature.

The State Water Code incorporated the pertinent sections which constitute the basis for a water development plan, thus accepting the necessity of a comprehensive plan for the use of the available waters in the interests of the people all over the State. The Code also declared that the people of the State have a primary interest in the control and conservation of flood waters, prevention of damage by flood waters, erosion problems, and in the determination of the manner in which flood waters shall be stored and used in the general public interest. It further declared that the State should engage in the study and coordination of all water development projects undertaken by counties, cities, State agencies, public districts and the United States, or any of its department or agency in order to ensure a balanced allocation and appropriation of water by necessary legislature. The state-wide water resources investigations have thus been conceived and developed as a fundamental comprehensive survey designed to serve as a basis for logical and orderly pattern of development of the State water resources.

Brief Aspects of Study

The study comprises of three stages :

1. Inventory of data on sources, qualities and characteristics of water.
2. Present and ultimate requirements of water.
3. A comprehensive master plan for the control, protection, conservation, distribution and utilisation of available water to meet present and future needs for all beneficial uses and purposes in all areas of the State to the maximum feasible extent.

These have been published already as Water Resources Board Bulletins¹³. The Appendices volumes of the California Water Plan are, however, not available as these are still under print.

In studying the water problems and in the preparation of the California Water Plan the State was divided into seven major hydrographic areas and planning groups

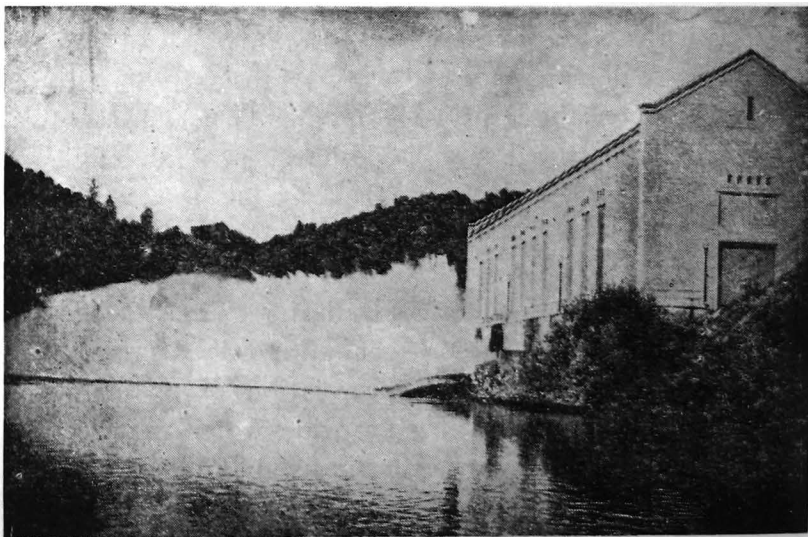


Fig. 10 — Electric Power Plant on Mokelumne River

and each area was studied separately in all its aspects. Further, while considering each region it was sub-divided into different areas to study the present and further needs of water and water deficiency. In this way the whole State is covered in a comprehensive and scientific manner resulting in the formulation of the California Water Plan. In this study the method of implementation of the Plan and the necessary legal measures to be taken have also been indicated.

In the study, basin characteristics, meteorological and hydrological features, existing works both for conservation, flood control and hydroelectric power, areas of water deficiency, areas of ground water and sea water intrusion etc., have been considered. A few of the existing works—the electric power plant on Mokelumne River, and the Tracy Pumping Plant can be seen in *Figures 10 and 11*. The study is designed to supplement the

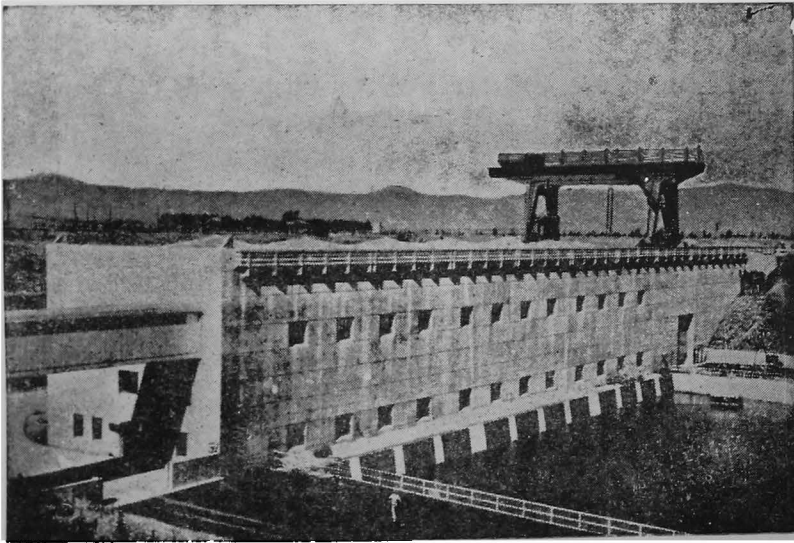


Fig. 11 — Tracy Pumping Plant — Capacity 4,600 cusec :
lift 196 feet

existing water resource development works and does not interfere with the existing rights of the use of water.

In making such a study, the State of California is fortunate since most of its river-streams take origin and flow completely within the State itself. Thus there is no inter-state water dispute. The most important river systems in the State are those of the Sacramento and San Joaquin Rivers, and of the Trinity River. The annual rainfall varies from 10" to 110" within the State. The region is subjected to cyclic meteorological changes resulting in wet and drought periods. The cyclic changes have also varied both in length and intensity during the past. One of the main features of this intensive study which has resulted in a Master Plan of this type is transportation of water from Northern California to Southern California through aqueducts. *Figure 12* shows the hydrographic areas and gives a pictorial presentation of transfer of water under the California Water Plan.

Concepts of the California Water Plan*

"1. The California Water Plan is a master plan to guide and coordinate the activities of all agencies in the planning, construction, and operation of works required for the control, development, protection conservation, distribution and utilization of California's water resources for the benefit of all areas of the State and for all beneficial purposes (*Figure 13*).

2. *As a Master Plan - the California Water Plan :*

- (a) Evaluates the water supply available to California, and describes the places and characteristics of its occurrence ;

*Extracted from Bulletin No. 3 — The California Water Plan published by the Department of Water Resources, California, U.S.A.

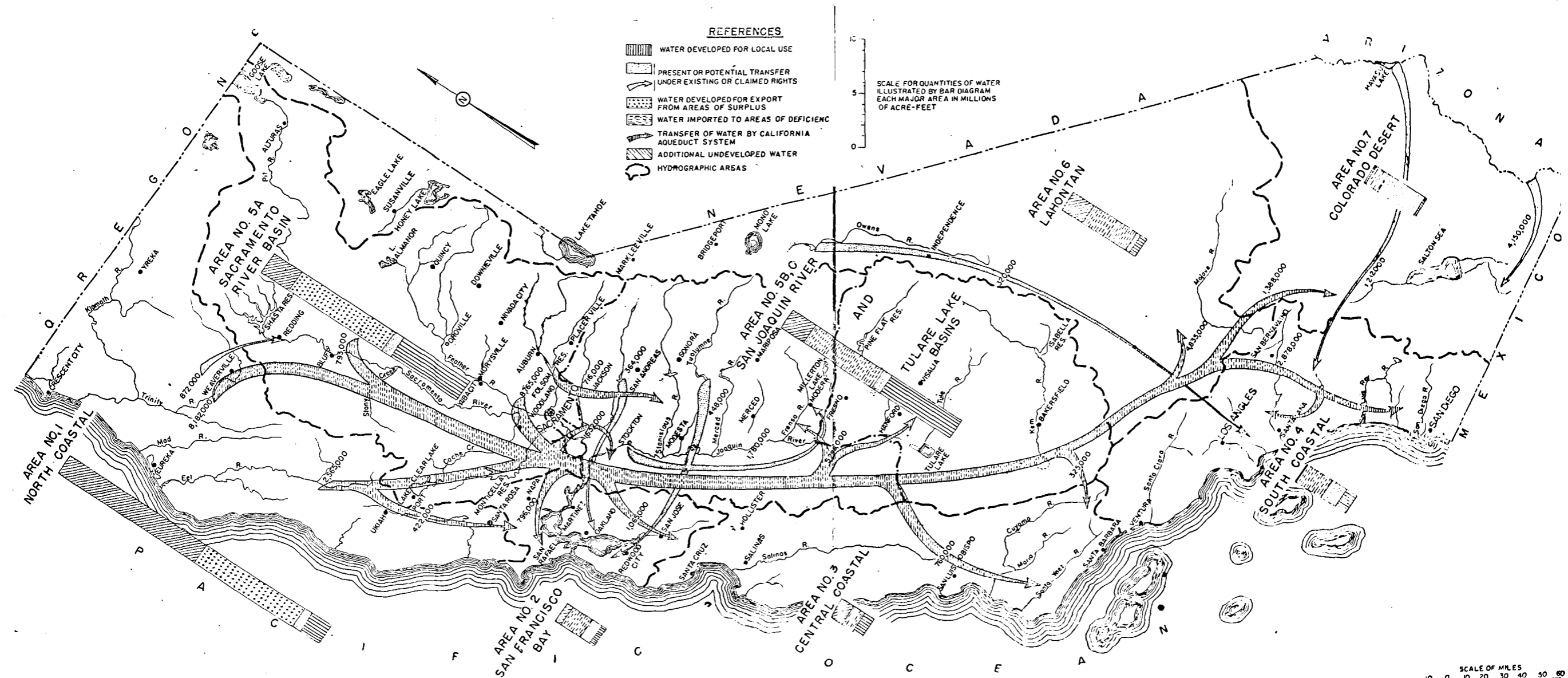


Fig. 12 — Map of California — Hydrographic Regions ; Ultimate Development and Transfer of Water under the California Water Plan

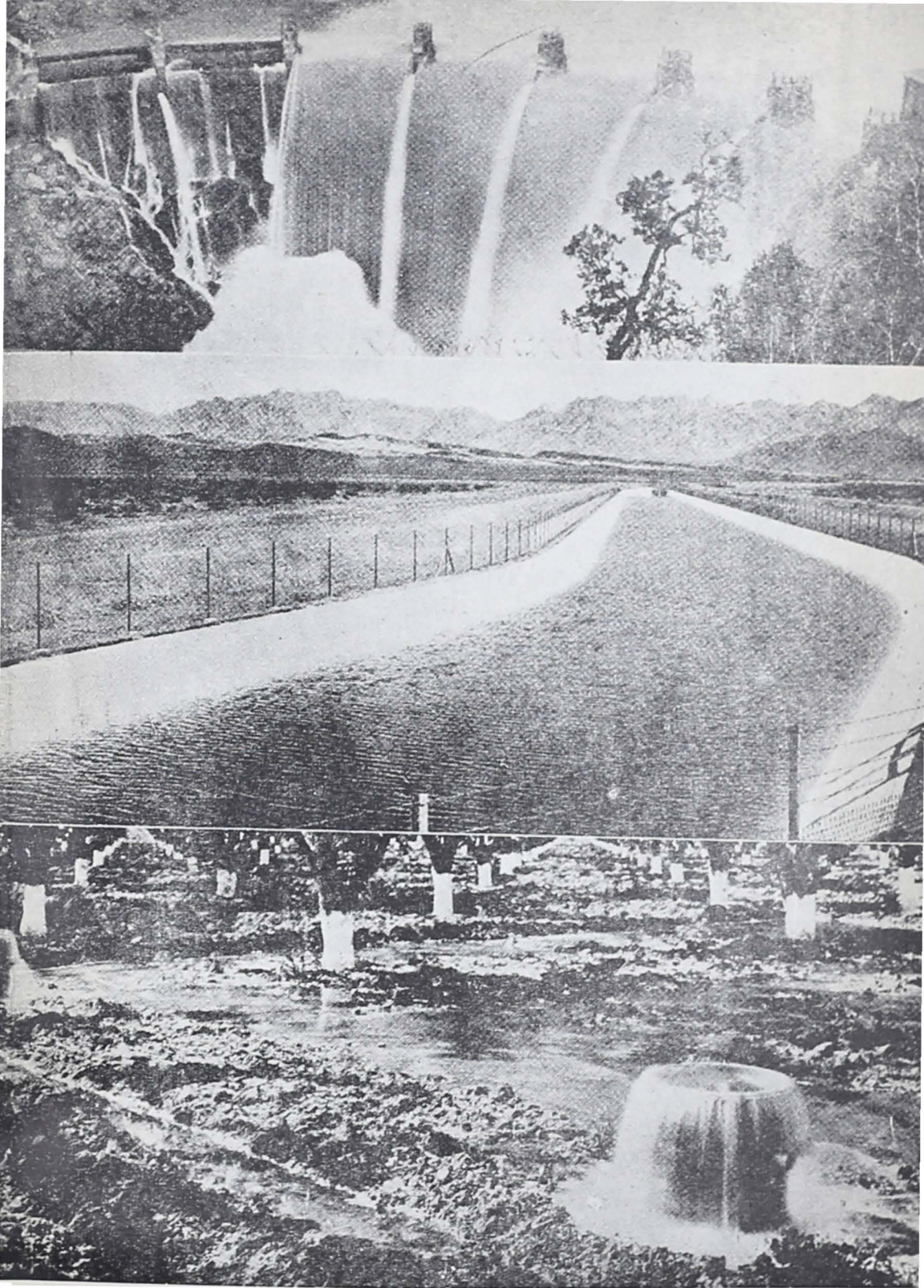


Fig. 13 — The California Water Plan "...for the Control, Development, Protection, Conservation, Distribution and Utilization of California's Water Resources".

- (b) Estimates the water requirements, both present and future, for all beneficial purposes for each area of the State, as those requirements can be foreseen ;
- (c) Points out the watersheds where present estimates indicate surplus waters exist over and above future needs for local development, gives estimates of such surpluses, indicates the areas of deficiency and gives the estimated deficiency for each such area ;
- (d) Describes existing and prospective water problems in each area of the State ;
- (e) Describes the uses to which the remaining unappropriated waters of the State should be put for maximum benefit to the people of all areas of the State ;
- (f) Suggests the means by which the waters of the State could be distributed for the benefit and use of all the people in all areas ;
- (g) Proposes objectives toward which future development of the water resources should be directed in all areas of the State, and suggests broad patterns for guidance toward these objectives ;
- (h) Defines these objectives in terms of potential physical accomplishments which may be used to measure the merits of projects proposed for construction by any agency ; and
- (i) Demonstrates that the waters available to California, including the State's rights in and to the waters of the Colorado River, are not

only adequate for full future development of the land and other resources, but also that physical accomplishment of these objectives is possible.

3. The California Water Plan is conceived as :

- (a) A comprehensive plan which will meet the requirements of water at some unspecified but distant time in the future when the land and other resources of California have essentially reached a state of complete development ; and
- (b) A flexible pattern, susceptible of orderly development by logical progressive stages as the growing demands of the State may dictate, into which future definite projects may be integrated in an orderly fashion, and which may be substantially altered and improved in accordance with advances in technology and changes in conditions which cannot be fully foreseen today.

4. The California Water Plan is designed to include or supplement, rather than to supersede, existing water resource development works. It also incorporates certain of the planned works now proposed or authorized by public and private agencies and individuals. Of special significance in this respect is the authorised Feather River Project, which is the initial unit for construction under the Plan, and on which construction started in May 1957.

5. Although the California Water Plan is capable of accomplishment from an engineering standpoint, its component features have widely variant relationships to present concepts of economic and financial feasibility.

It is realized that certain of the works would be extremely costly under present value criteria. Such works are for the indefinite future, and their need may never materialise. However, the economics of the distant future cannot be foreseen, and the planning effort is deemed necessary at this time in order that provision may be made for such developments, if and when they become needed and justified.

6. The California Water Plan gives full consideration to the use of water for agricultural, domestic and industrial purposes ; to hydroelectric power development ; to flood control and protection ; to drainage ; to salinity control ; to protection of the quality of water ; and to the interests of fish, wild life and recreation.

7. Under the California Water Plan, water would not be taken from those who will need it ; rather, it would provide for the needs of areas of inherent deficiency by transfer only of excess or surplus water from areas of abundance. Legislative acceptance of the Plan, and firm provisions for its progressive implementation as successive component projects become feasible, would tend towards elimination of sectional concern as to future availability of necessary water supplies.

8. The California Water Plan is neither an inflexible regulation nor a construction proposal as it is presented herein. It does not purport to include all possible water development projects in the State. Rather it serves to demonstrate that the full satisfaction of ultimate water requirements in all parts of the State is physically possible of accomplishment. Therefore, the omission of any project from description in this bulletin does not preclude its future integration into the Plan.”

What the Plan Involves in Terms of Physical Accomplishments

- (a) About 376 new reservoirs throughout the State with a total gross storage capacity of about 77 m. a. ft. are to be added to the 20 m. a. ft. of storage capacity in existing reservoirs. Out of this 282 would be conservation reservoirs, 30 would be operated primarily for power generation, 60 would serve as regulatory diversion reservoirs, and 4 would be operated solely for flood control ;
- (b) New hydroelectric power generating facilities in connection with the water development works, with a total installed power capacity of about 7,800,000 kilowatts and a seasonal energy production of about 34 billion kilowatt-hours ;
- (c) Pumping installations with an aggregate installed capacity of about 12,300,000 kilowatts, and a seasonal energy requirements of about 49 billion kilowatt-hours.

Costs

Construction of all features of the California Water Plan, which would be accomplished over a long period of time, would involve a total capital expenditure of some \$ 11,800 million, based upon 1955 price levels and economic conditions. Of this total amount, the cost of developments to meet local water requirements would aggregate to some \$ 2,800,000,000 and the California Aqueduct System would cost about \$ 9,000,000,000. Of this latter amount, about \$ 4,400,000,000 would be required to develop and convey agricultural water to the high desert areas of southern California. Development of

the demand for this water service cannot be foreseen at the present time.

The preparation of the California Water Plan has taken 10 years of intensive study by the State Water Resources Board. In Bulletin No. 3 they have described a vast system of integrated works, both local and inter-basin, which serves to demonstrate that the objectives of the Plan are physically possible of accomplishment within the limits of available water resources. The full natural seasonal runoff of streams in California amounts to 71 m. a. ft. on the average and is sufficient to provide for the full satisfaction of ultimate water requirements for all areas of the State which has been estimated to be in the order of 51 m. a. ft. The existing and potential areas of intensive water surveys total to about 23.6 million acres of which approximately 20 million acres are classified as suitable for irrigated agriculture. It is expected under the ultimate development the majority of the remaining 77.3 million acres of land will be settled and will have only very minor requirements of water.

Any water development plan is bound to be complicated and no rigid proposals can be framed at the planning stage. Ultimate development of land and other resources may have to be achieved by works differing in many respects from those described in the Water Plan, but the essential factors will remain the same. The works as indicated in the California Water Plan are considered to be as realistic as can be foreseen at present.

Summing up

I am sure that this Water Plan will be a very useful and valuable guide in the preparation of Water Plans in India and other countries of the World.

Though the basic problems differ from country to country, but the main principles and criterion for the formulation of any water plan remain the same.

At a time when India is on the threshold to prosperity and is striving hard for a stable and thriving economy, engineers have a unique role to play in suggesting ways and means of utilising the natural resources of the country, particularly land and water. We have to take stock of the past achievements and also study the extent of present land utilisation including increase in agricultural production due to major and minor river valley projects. We have to increase agricultural production, particularly food stuffs by all possible means. With the proposed industrial development the importance of tapping hydroelectric resources needs no emphasis. There have been plans for water utilisation and several river valley projects have come up or are underway. But it is necessary to think ahead and formulate long range integrated plans for water utilisation* and transfer of water, with engineering and economic analysis, keeping in view the present and future needs, and national policies of the country.

Feather River Project

The Feather River (catchment area 3,600 sq. miles and mean annual flow 4.5 m. a. ft.) is the most important tributary of the Sacramento River, and the Project is a part of the California Water Plan. The primary purpose of this project is to regulate the erratic flows in the river, to prevent flood damage, to conserve water for utilisation, and to transfer surplus water to deficient areas.

*Master Plans for Integrated Water Utilisation by Shri Kanwar Sain, Journal of the Institution of Engineers (India), March, 1958.

One of the dams contemplated on this river — the Oroville Dam — will be about 730 ft. high and will involve 4 million cubic yards of excavation and 14 million cubic yards of concrete. The reservoir will have a storage capacity of 3.5 m. a. ft. A dependable power generating capacity of 410,000 kW would be made available. *Figure 14* gives a profile of the Oroville Dam looking upstream and *Figure 15* gives the maximum section. *Figure 16* gives a section through the power plant.

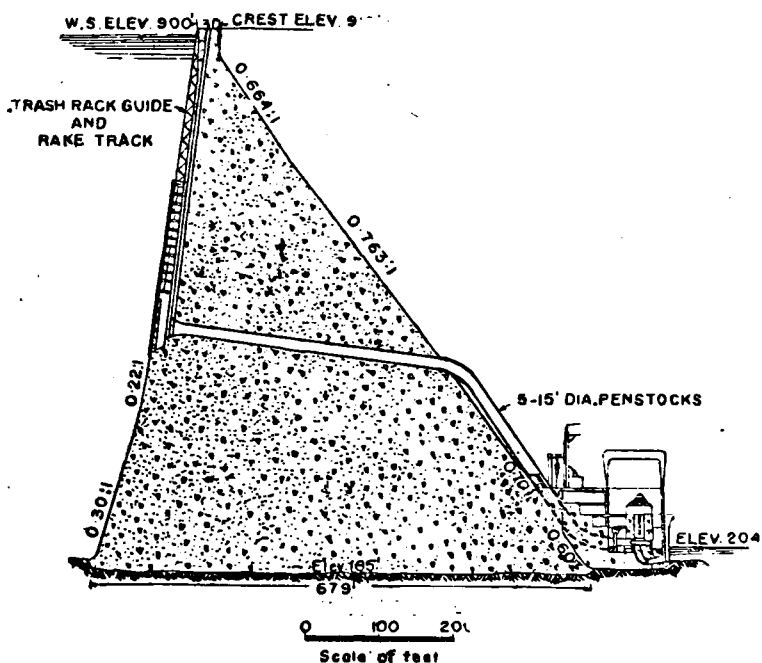


Fig. 15 — Oroville Dam — Maximum Section

I was told that in the proposals they have prepared, the cost of re-locating the railway and highway for the high dam will cost as much as the cost of the Shasta Dam.

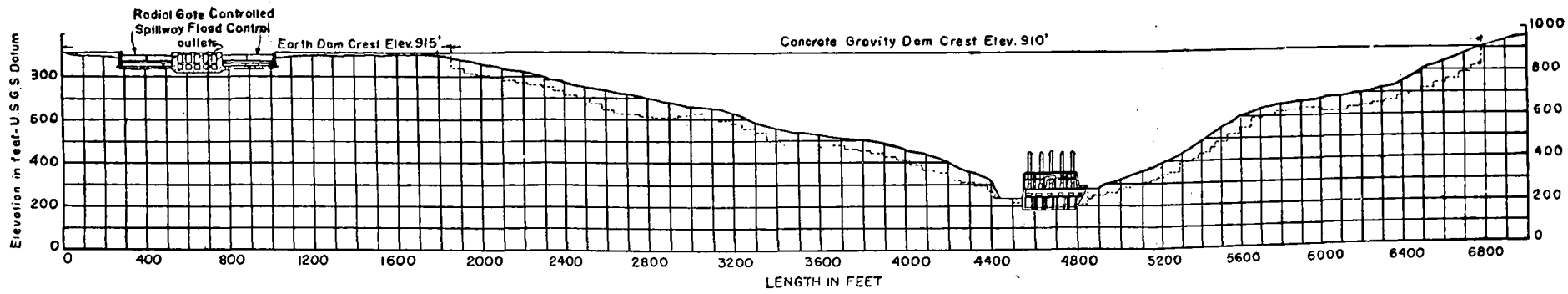


Fig. 14 — Feather River Valley Project — Profile of Oroville Dam Looking Upstream

This project, based on initial studies, will :

1. Provide a firm water supply for 322,000 acres of irrigable land in the Feather River Service Area. The supply of 970,000 acre feet annually would be adequate to meet all future needs of the area ;

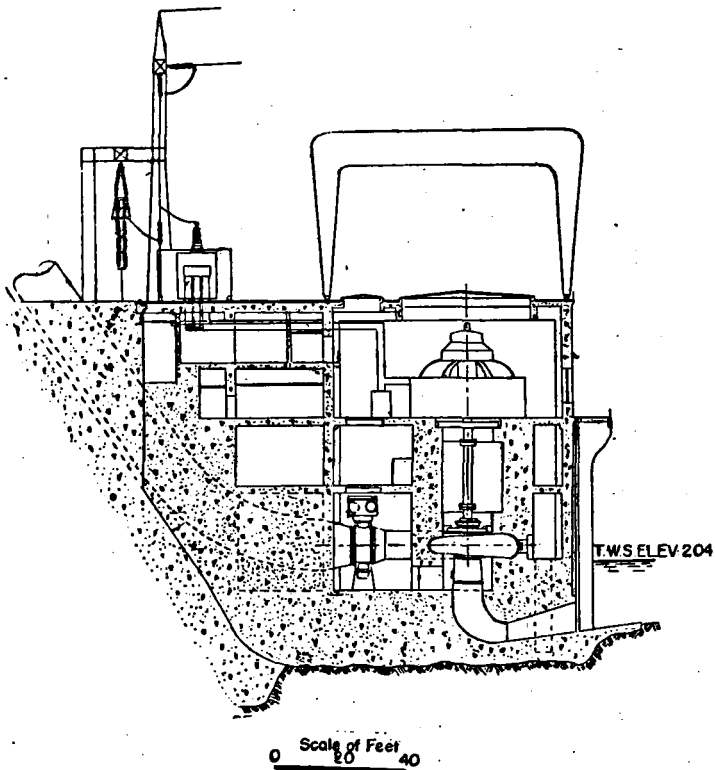


Fig. 16 — Oroville Dam — Section through Power Plant

2. Reduce flood flows below the dam which have reached a recorded maximum of 230,000 second feet to between 50,000 and 100,000 second feet, giving flood protection to an area with a market value of \$ 340,000,000 ;

3. Make available a dependable power generating capacity of 410,000 kilowatts and generate an average of $1\frac{3}{4}$ billion-kilowatt hours of electric power annually ;

4. Supply 240,000 acre feet of water annually through the South Bay Aqueduct to areas in Santa Clara, Aameda and San Benito counties ;

5. Supply 2,100,000 acre feet of water annually to areas in Fresno, Kings and Kern counties on the west and south sides of the San Joaquin valley ;

6. Supply 1,800,000 acre feet of water annually to areas south of the Tehachapi Mountains.

Shasta Dam

This multipurpose structure, which is a key unit of the Central Valley Project, is located on the Sacramento River. In the California Water Plan proposals, Shasta Reservoir is considered to be a feature of the California Aqueduct System.

I visited Shasta Dam first in 1939, when it was just in the construction stage and the Bureau of Reclamation Engineers were worried about the nature of the poor foundations. The rock was rather sheared and shattered and very heavy grouting operations were contemplated at that time. As I happened to be in the vicinity, I took this opportunity of seeing this second highest dam in the world at that time (602 ft. high), particularly to see how the extensive grouting which has been done at that time was behaving. This was of great importance in view of what we are doing at Bhakra Dam at present where we are facing similar foundation problems. I was very happy to see that there is not much seepage in the foundation and very little grouting has been necessary

after completion of the dam. That gives some assurances on the effectiveness of the grouting done at the time of construction.

Trinity Earth Dam

Another interesting project visited, and which definitely was of great interest, was the Trinity Dam. The Trinity River utilisation and diversion is a major feature of the Central Valley Project. It is designed to provide irrigation, power, recreation and fish and wild life conservation. Surplus water from the Trinity River Basin will be stored, regulated and diverted through a system of dams, reservoirs, power plants, tunnels and conduits into water deficient areas of the Central Valley Basin.

The Trinity River Division features are located in Trinity and Shasta counties of California. The Trinity River at Lewiston is 1,500 feet above and 20 miles west of the Sacramento River at Keswick Dam.

Plan

The Trinity River supplies will be stored in the Trinity Reservoir with a capacity of 2.5 m. a. ft. Releases from this reservoir will be utilised by a 96,000 kilowatt power plant and re-regulated in Lewiston Reservoir (Capacity 14,600 acre feet, Height of Dam 70 feet) about seven miles downstream Lewiston Dam will contain outlets to release adequate water to meet the downstream requirements of the Trinity River Basin, including those of the important Trinity River Fishery. Water not needed in the Trinity River Basin will be diverted through the Clear Creek Tunnel to the 130,000 kW Clear Creek Power Plant and into the 250,000 acre ft. Whiskeytown Reservoir (Height of

earth dam 278 ft.) on Clear Creek, a tributary of the Sacramento River. From this point the water from Trinity River and surplus flows from Clear Creek will flow through the Spring Creek tunnel to the Spring Creek Power Plant and into Keswick Reservoir on the Sacramento River. By proper distribution of the available supplies about 1.42 m. a. ft. of water per year would be provided to serve lands in Shasta county, ultimate requirements of the Sacramento Canals Unit, lands in the Delta-Mendota Canal Service area and other areas of the Central Valley Projects.

Figure 17 gives a plan of the Trinity River utilisation.

The Trinity Dam

The Trinity Dam is a multipurpose major structure. The dam is proposed to be built in earth and will be 465 ft. above river stream bed which is 50 ft. above the proposed foundation level. It is an earth-, sand-, gravel-and cobble - fill dam of just the same type as we have at Hirakud.

The project was first submitted to the Congress in 1953 and authorised in 1955 at a cost of about 225 million dollars. The estimates have been revised after the receipt of bids to 246 million dollars.

Description of the work involved in the Trinity Dam is given below :

- (a) *General* :—The principal features in the construction of the Trinity Dam include an earth-fill dam embankment, a tunnel spillway, tunnel outlet works, tunnel auxiliary outlet works and excavation in areas downstream from structures.

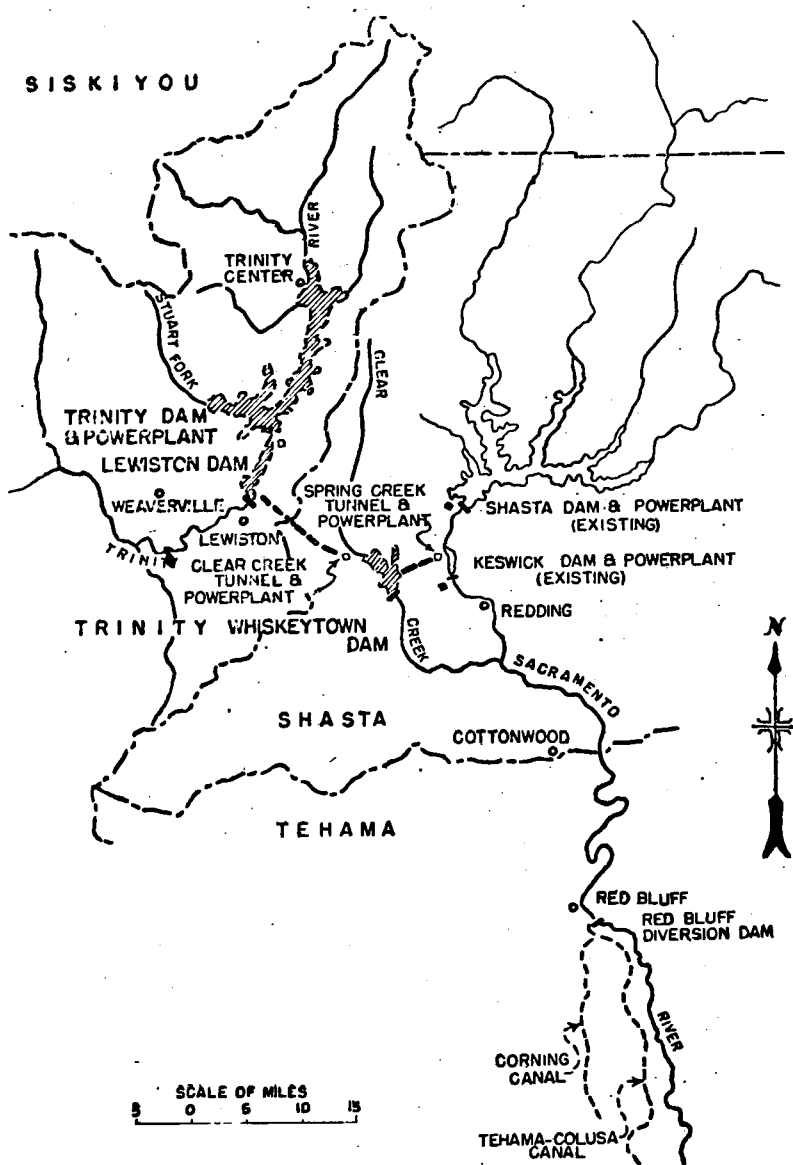


Fig. 17 — Trinity River Development — General Plan

- (b) *Dam Embankment* — The dam embankment will be approximately 2,450 feet long at the crest and approximately 505 feet high from foundation, approximately 2,600 feet wide, to 40-foot wide crest. The foundation will be grouted along the lines of the 2 grout caps. The embankment will consist of an earth-fill, zones 1 and 2, core supported and protected by embankment zone 3 and rock-fill zone 4. The upstream slope of zone 3 will be protected by a 3-foot layer of rip-rap and the downstream slope of zone 3 will be protected by a 24-inch layer of rock surfacing. The crest of the dam embankment will be covered by a 6-inch layer of selected surfacing. *Figure 18* gives a section of the dam and lines of grouting.
- (c) *Spillway* — The spillway consists of an uncontrolled morning glory concrete crest structure, concrete-lined 20-foot diameter inclined shaft and tunnel, and a concrete chute. The capacity of the spillway is 24,000 cusec.
- (d) *Outlet Works* — The outlet works consist of a concrete tower intake structure with diversion inlet, a concrete-lined 28-foot diameter tunnel with gate structure and shaft for a 10-foot by 20-foot fixed-wheel gate, a 28-foot diameter concrete conduit, a diversion chute, a concrete control house for two 84-inch ring-follower gates, and two 84-inch hollow-jet valves, a concrete

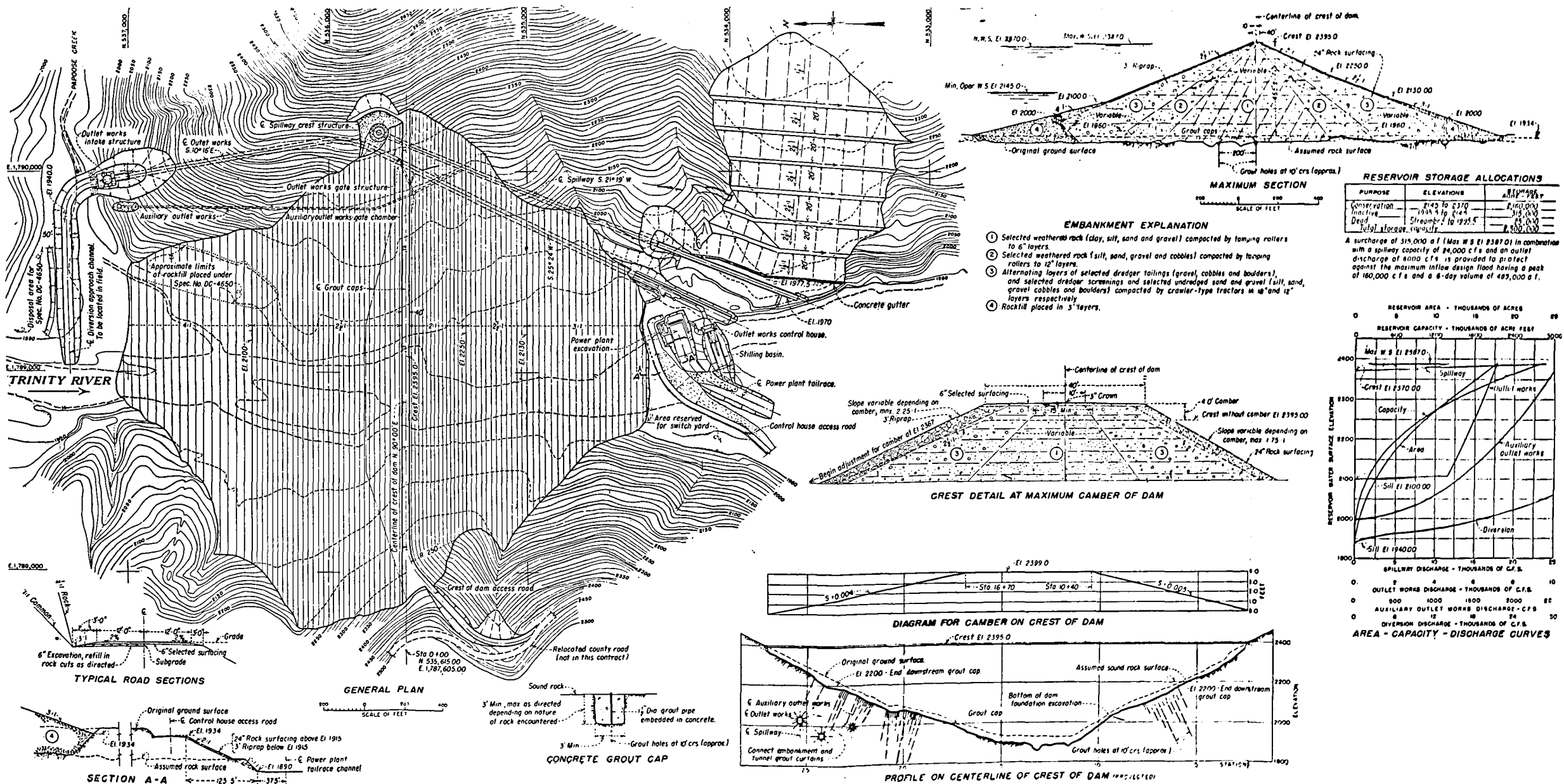


Fig. 18 — Trinity Dam — General Plan and Sections

stilling basin, and an outlet channel. A 16-foot diameter steel penstock will extend from the outlet-works gate structure to the power plant manifold and 11' 3" diameter steel outlet pipe will extend from the power plant manifold to the outlet-works control house manifold. The capacity of the outlets is 4,970 cusec.

- (e) *Auxiliary Outlet Works* — The auxiliary works consist of a concrete intake structure, a 7-foot diameter concrete conduit, a concrete-lined 7-foot diameter tunnel to the gate chamber for a 84-inch ring-follower gate and a 84-inch jet-flow gate, and a concrete lined 8-foot ovate tunnel from the gate chamber to the spillway tunnel. *Figure 18* gives the general plan and some other sections.

Figure 19 gives a section through the spillway.

Discussions with U.S.B.R.

During my tour in the U.S.A., I had discussions with the U.S.B.R. engineers, who are responsible for most of the investigations, suitability of construction materials, designs and specifications etc., of this Trinity Dam. The pre-construction testing of all materials was done at the Central Laboratory of the U.S.B.R. at Denver. The reasons were simple. This was partly due to specialised nature of the problem and partly due to the close contact of construction engineers with the design men, as the earth dam was designed by U.S.B.R. at Denver. All these tests were done in the laboratory so that the design and laboratory staff also could

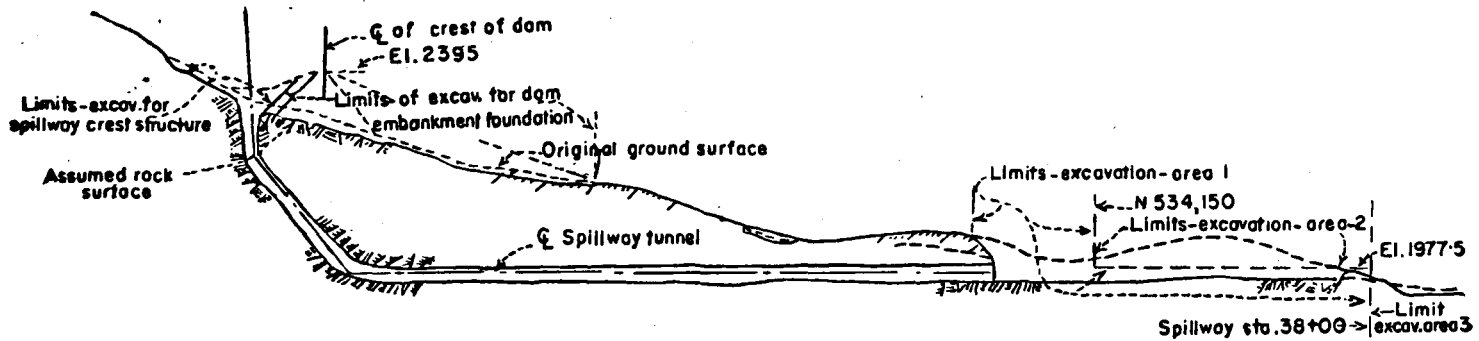


Fig. 19 — Trinity Dam Section through Spillway

exchange ideas and have discussions before these factors were incorporated in the design.

It appears that the engineers were first thinking of constructing the dam in concrete, but they found that the earth dam would be much cheaper.

Testing of Embankment Materials

All tests are conducted according to U.S.B.R. Earth Manual except in cases of triaxial shear, large-scale compaction, large-scale percolation, unconfined compression and sheepsfoot compaction.

Triaxial, consolidation and other tests were in progress when I visited the laboratory at Denver. They were trying large samples of 9" diameter \times 22½" length for triaxial shear tests. The test specimens were placed at optimum moisture content and variable densities below proctor density. Each specimen was then consolidated with lateral pressure to the proctor density of the soil before beginning the tests. They have developed some sort of techniques in conducting the various tests. Permeability tests were also in progress.

They have used 'Swedish' Slip Circle' method for testing the stability. The factor of safety allowed is about 1.5 though with high pore pressure it is expected to reduce to 1.2. The dry bulk density of the earth material is 110-130 pounds.

Specifications of the Trinity Dam, Earth Laboratory Reports giving the results of laboratory testing of embankment materials have been published by the U.S.B.R. and will be of much use.

Summing up

Our future dams in India wherever possible, could certainly be constructed in rolled fill zoned earth.

fact our State contemplating such dams might send our younger engineers to the Trinity Dam. Work has already started and in a few months, the work at this dam, which will contain 33 million cubic yards of earth, will reach the most interesting stage for our engineers to see and observe.

Cheesman Masonry Dam

This is one of the oldest masonry structures in the United States. Originally, a combined rock-fill dam with steel plate in front was constructed at this site in 1898. In 1900 a heavy rainstorm occurred as a result of which the flood waters overtopped the dam and washed it away. The present masonry dam was constructed in 1908 and is now maintained by the Water Board of Denver State.

This dam was purposely visited in view of our decision to build the Nagarjunasagar Dam in masonry. The Cheesman Dam was built in the same way as we build our masonry dams in India today. In construction, rock has been used in big pieces with thick joints in ashlar masonry. Concrete, however, was not used in those days, apparently due to fear of development of cracks.

The dam is behaving all right after 50 years of service. Though there was some seepage on the downstream face I was told by Mr. Gross of the Denver Water Board that there had been no material leakage or seepage since the construction of the dam. Due to snow and weathering some lime had been washed out of the joints and there were some wet spots. There was no anxiety, however, on this point.

The Nagarjunasagar Dam in Andhra, now under construction, will be ultimately 360 ft. high and is being

constructed in masonry. A question arose whether the dam should be constructed in masonry or concrete. Two uncertainties were felt in this connection. The first was the ultimate stress which masonry can stand as compared with concrete. Concrete is a material about which we know what it can do and how it behaves. We did not have similar information in respect of masonry. The second was whether the pace of progress in concrete and masonry can be the same. Concreting, of course, we know, is highly mechanised. Batching, mixing and pouring plants have been designed in other countries. In masonry, such mechanisation is very limited. After discussing the merits and demerits of the alternatives, we came to the conclusion that if special care is taken to see that the joints are made secure, either by vibration or by good workmanship and supervision, stone masonry could be trusted to take 20 tons per sq. ft. Wherever the stresses were higher, we thought we should use concrete. As the Nagarjunasagar Dam is quite long, we thought that even if it takes 7 or 8 years, by which time the canals will be ready, we may not lose any time if we constructed the dam in masonry. Of course, masonry will be definitely cheaper as compared to the cost of concrete.

Masonry Blocks Tests at Denver

To know more about the strength of masonry it was decided to make some experiments at the U.S.B.R. laboratories. They were requested to make 36" blocks of masonry according to our specifications and test them in their 5-million lb. compression testing machine. That is the only machine existing in the world where blocks of that size could be tested. The Bureau has been at it for the last almost 18 months, and I took the

opportunity of seeing these tests when I passed through Denver.

Tests conducted on 3-ft. rubble masonry cubes at Denver indicated that, by mixing one part of cement with three parts of sand for cementing the stones, masonry develops an average strength of 3,360 lb. per sq. in. in 90 days. By reducing the cement mortar mix to 1 to 4, the strength was found to be 2,720 lb. per sq. in. The Bureau has taken a film of the various processes and of how the block breaks. These tests show that if the masonry is well done, and the joints are taken care of, it can be expected to take the same stresses as concrete. This finding is of great importance to us in India because in certain regions of the country we can definitely build masonry structures cheaper than concrete structures.

The results obtained so far are incorporated in the following table. *Figures 20 and 21* give the comparison of mortar strength *versus* rubble masonry strength.

Glen Canyon Dam

Glen Canyon Dam is situated on the Colorado River in the U. S. A., about 370 miles upstream from Hoover Dam.

Description of Work

- (a) *General* — The principal features involved in the construction of Glen Canyon Dam and power plant are a concrete arch dam across the Colorado River, two tunnel-type spillways, a power plant, and service roads and parking areas.
- (b) *Dam* — The dam will be an arch-type concrete dam approximately 700 feet

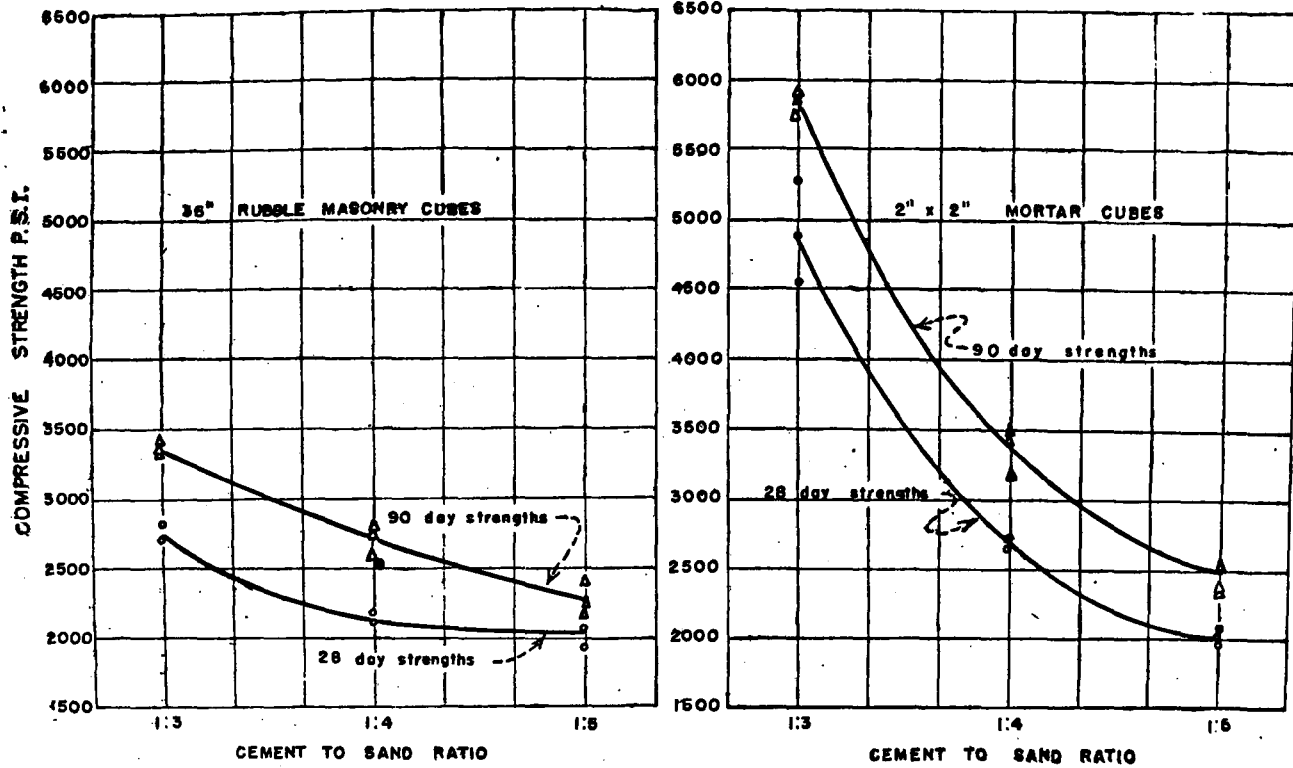


Fig. 20 — Comparison of Mortar Strength to Masonry Strength

high at the maximum section and approximately 1,500 feet long at the crest. The foundation will be drilled and pressure-grouted, and foundation drainage will be provided through holes drilled into the rock.

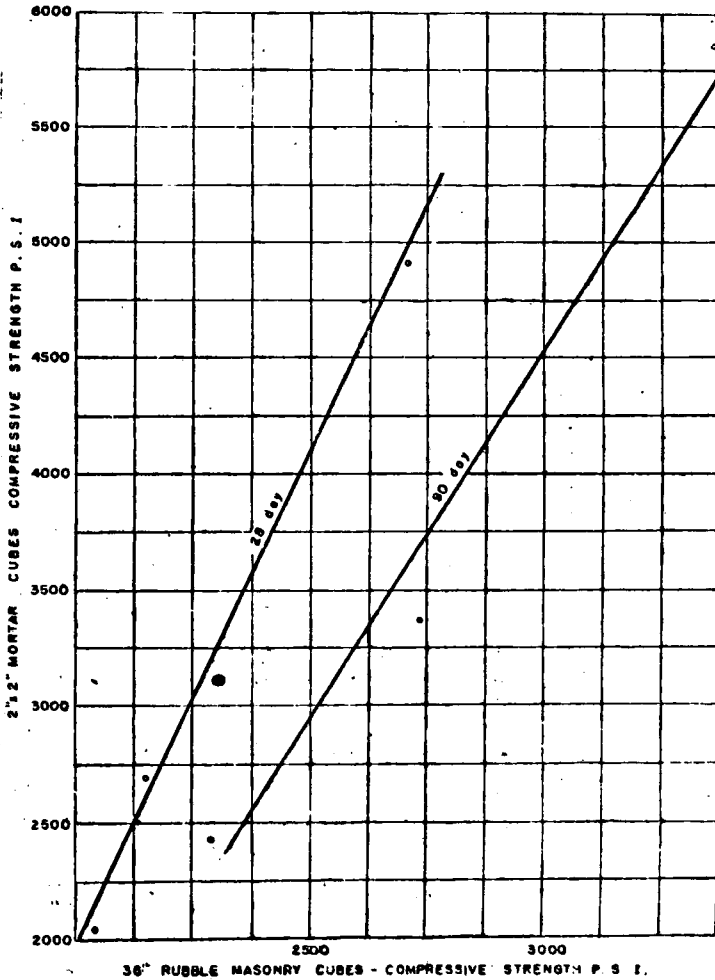


Fig. 21 — Mortar Strength vs. Rubble Masonry Strength

The concrete in the dam will be divided into blocks by means of vertical transverse and longitudinal contraction joints. Eight 15-foot 6-inch diameter penstocks and four 96-inch diameter outlet pipes will be embedded in the concrete of the dam. An outlet valve house will be located downstream of the power plant on the left abutment. Galleries and shafts will provide access to points in the interior of the dam, and two elevators will provide access to the galleries from the top of the dam.

- (c) *Spillway* — There will be a spillway intake structure with two 40 feet by 52.5 feet radial gates and a lined spillway tunnel on each abutment of the dam. The downstream portions of the spillway tunnels will be used during construction as diversion tunnels.
- (d) *Power Plant* — The power house structure will be approximately 665 ft. by 127 ft. with an attached machine shop, 104 ft. by 200 ft. upstream on the left abutment. There will be 8 generating units each of 112,500 kW capacity. Each unit will receive water through a 15-ft. steel penstock embedded in the dam and spanning the distance between the toe of the dam and the power house on concrete piers.

The reservoir will have a capacity of 28 million acre feet and this giant water conservation dam will enrich the sparsely populated Western United States.

This is being constructed by the Bureau of Reclamation. The construction of the dam was started in April 1957. Total cost of construction without transmission facilities is estimated at \$ 300 million.

Figures 22 and 23 give the plan and sections of the dam.

Rising Construction Costs

It is interesting to note that construction costs have approximately trippled in the past 26 years since the construction of the Hoover Dam. The table below gives the comparison of prices prevalent in 1931 and 1957.

Building Costs for Hoover and Glen Canyon Dams Compared

Typical Major Pay Items	Unit price by low bidder, per cubic yard*	
	Hoover Dam (1931)	Glen Canyon Dam (1957)
Mass concrete in dam (does not include cost of cement).	\$ 2·70	\$ 10·25
Excavation, common, for dam and power plant foundations.	2·20	1·95
Excavation, all classes, in diversion tunnels.	8·50	20·00
Excavation, all classes, in open cut for spillways.	2·60	4·00
Excavation, rock, for dam foundation.	4·40	3·25
Concrete in lining of diversion tunnels.	11·00	36·50

*1957 index is 295 with 1931 as base.

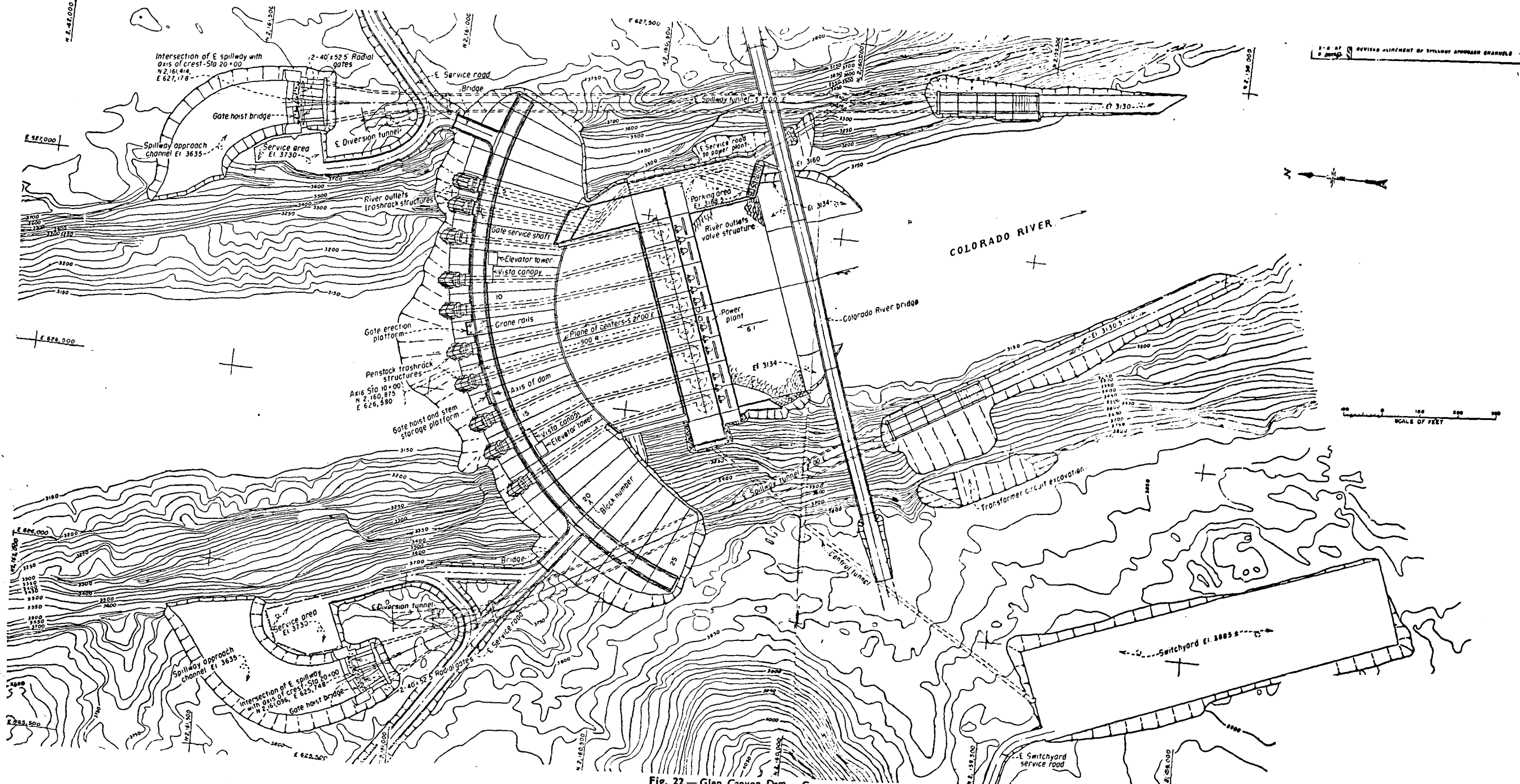


Fig. 22 - Glen Canyon Dam - General Plan

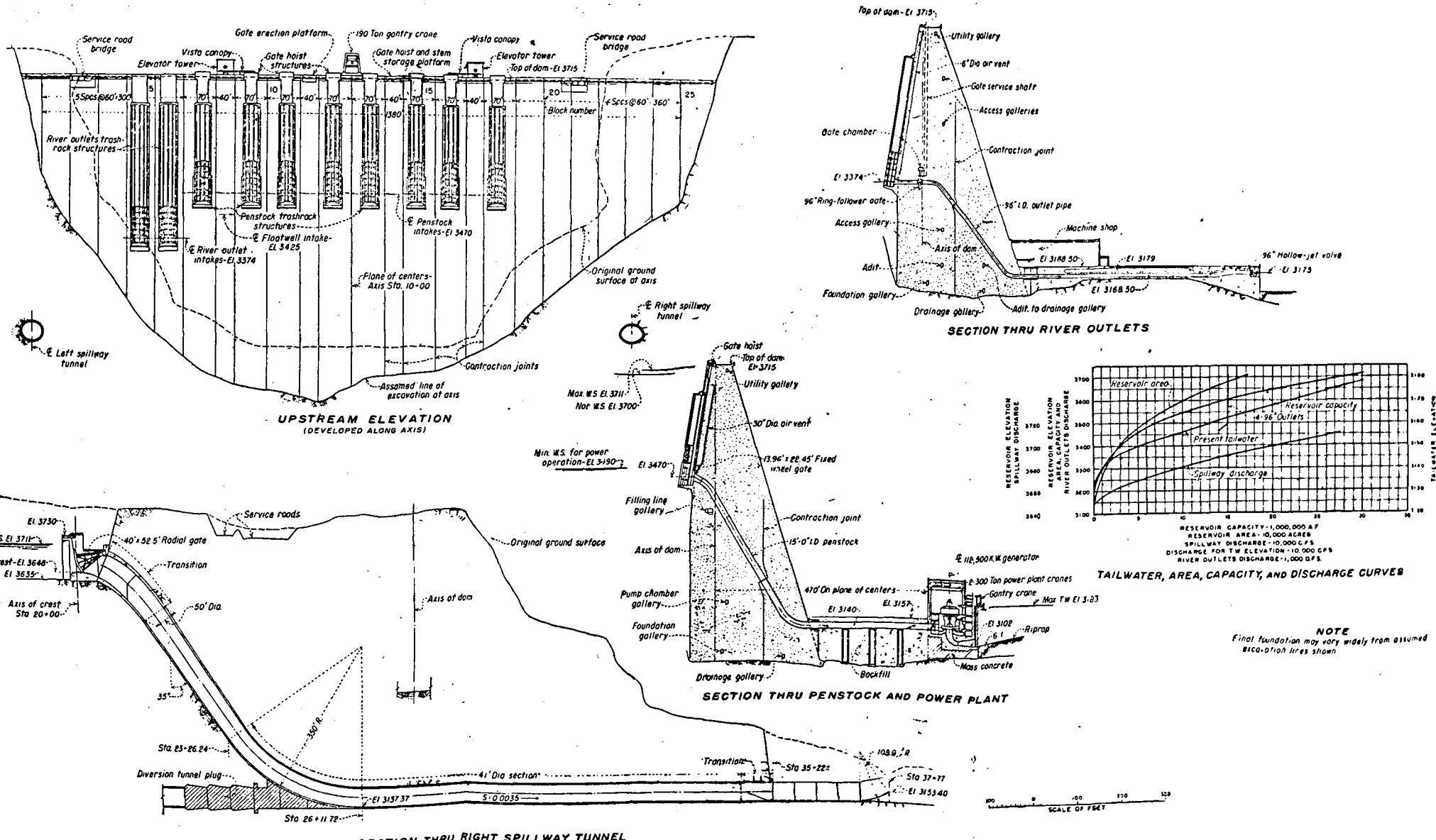


Fig. 23 — Glen Canyon Dam and Power Plant — Elevation and Sections

Rates for common labour have increased from about \$ 0.5 per hour to \$ 2.25 per hour and for skilled labour from \$ 0.75 to \$ 3.45 per hour. Cement prices increased from \$ 1.40 to \$ 3.50 a barrel, and steel from \$ 33 a ton to \$ 115 a ton.

This will be one of the highest dams of the world and it will take approximately 3½ years of continuous work as envisaged in the project.

The concrete in the interior or major part of the dam will contain approximately two bags of cement and one bag of pozzolan per cubic yard. At Hoover Dam four bags of portland cement were used per cubic yard.

A Consulting Board of engineers and geologists renders advice on the construction of the dam. The dam is expected to be completed in 1963.

The St. Lawrence Seaway and Power Project

The Biggest Single Venture in the World

The 1000-million Dollar St. Lawrence Seaway and Power Project is technically an excellent example of twentieth century engineering feat in solving diverse problems with a single master plan. The project is a cooperative venture between the United States and Canada, a supreme model of cooperation between two neighbouring countries. This is the biggest single engineering venture being handled today in the world. After nearly 50 to 60 years of continuous efforts to utilise the water potential of the St. Lawrence River, work on this project started in April 1954. It is expected to be completed by 1959.

The River

The St. Lawrence River takes its origin from Lake Ontario and connects the Great Lakes with the Atlantic

Ocean. Water comes from a drainage area of about 300,000 sq. miles which includes 95,000 sq. miles surface area of the five Great Lakes. One-third of 31.2" annual rainfall forms the runoff.

With the Great Lakes as the storage reservoir, the flow in the St. Lawrence River is almost constant. The average annual flow is about 236,000 cusec. Based on the record of 1860 to 1954, the dependable flow is 244,000 cusec.

Two Aspects of the Project

These are :

- (i) Opening navigation facilities from the Atlantic Ocean to the Great Lakes for ocean-going ships with a draft of 27 ft. This will enable ships from any port of the world to travel nearly 2,700 miles into the North American Continent.
- (ii) Development of 1.88 million kW of hydro power.

The Project Features

The project mainly consists of :

- (i) Excavation of navigation channels and construction of locks.
- (ii) Iroquois Dam.
- (iii) Long Sault Dam.
- (iv) Barnhart Power Dam and Power House.

Figure 24 indicates the plan of development and the location of the structures.

Navigation

In the giant steps which the St. Lawrence River System takes from the level of Lake Superior down the

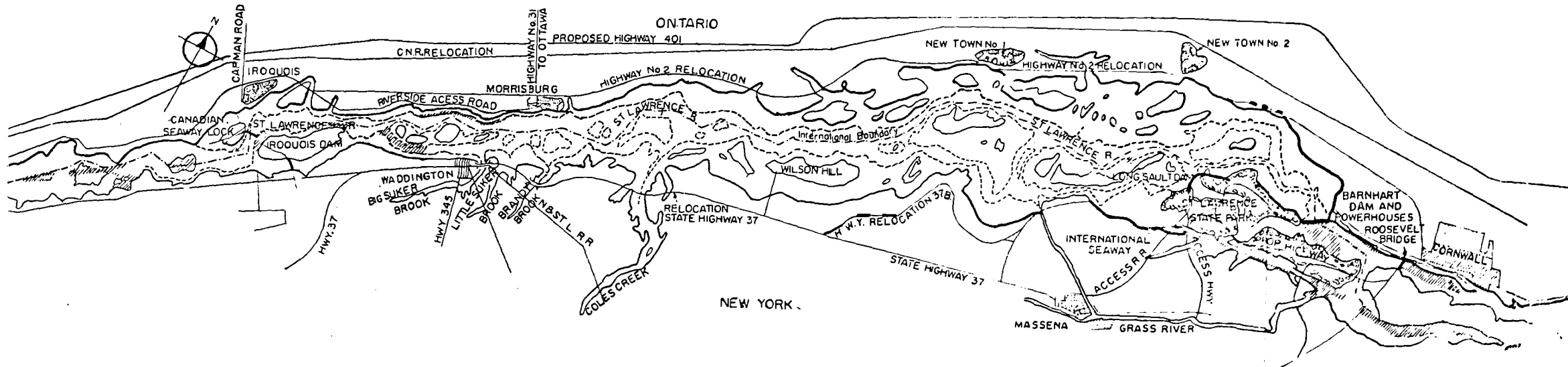


Fig. 24 — St. Lawrence Seaway and Power Project — Plan and Locations of Structures

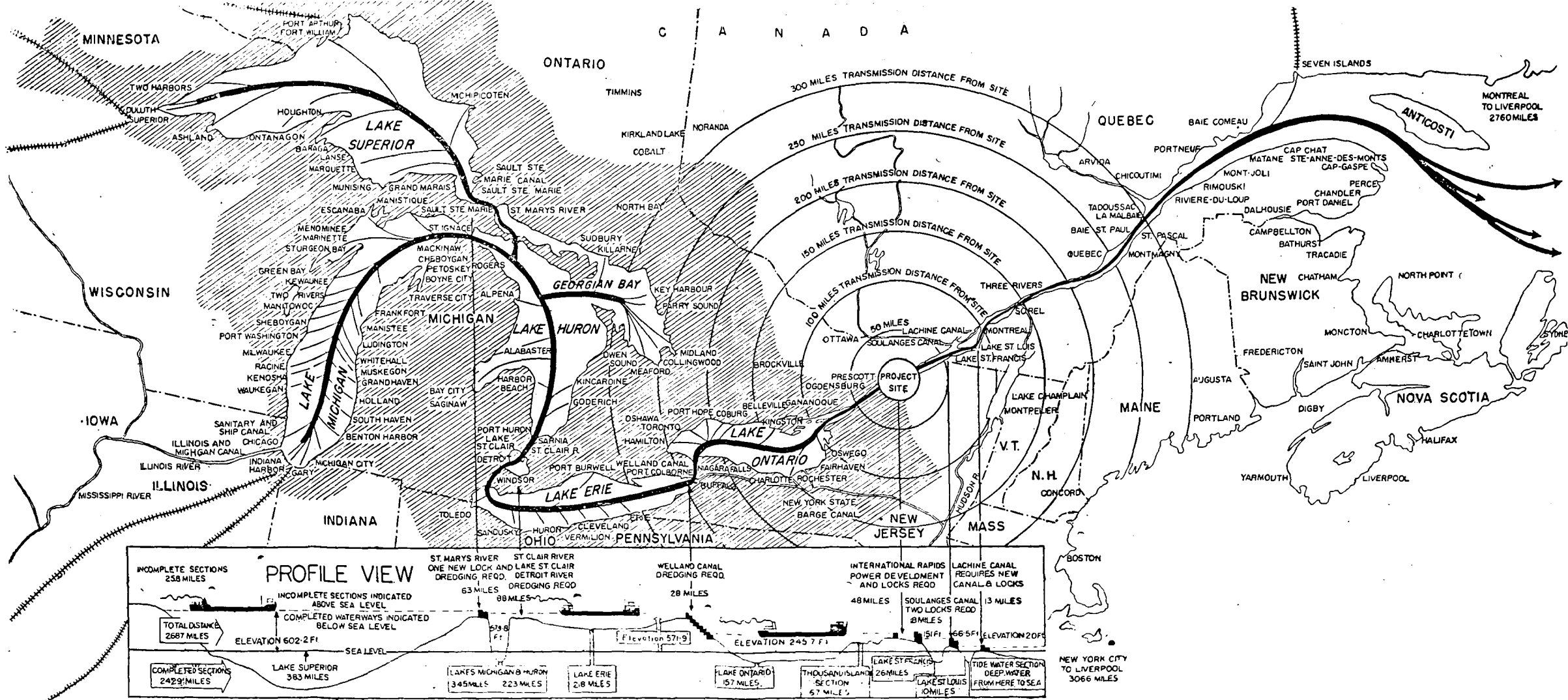


Fig. 29 — St. Lawrence Seaway — Map and Profile

Atlantic, there is a drop of 602 ft. *Figure 25* gives a profile view and indicates the complete and incomplete sections, which are included in the scheme.

The navigation aspect involves an estimated total excavation of about 66 million cubic yards both dry and wet. Locks have been provided to negotiate the difference in elevation and typical dimensions are given below :

Project channel depth.	27 feet
Minimum channel width in river.	450 feet
Bottom width of canals.	442 feet
Lock dimensions and data width.	80 feet
Length between upper and lower service gates.	860 feet
Usable length.	768 feet
Minimum depth over sills.	30 feet
Maximum lift.	49 feet
Service gate.	Miter type
Emergency gate (Upper lock).	Vertical lift
Height of lower Miter gates.	85 feet

Excavation is mostly done by draglines with buckets of 10 to 15 cubic yards capacity, excavators and trucks. When I visited the project, a 650-ton dragline known familiarly as 'The Gentleman' was digging the 10-mile Long Sault Canal — *Figure 26* — involving an excavation of 16.63 million cubic yards. The international section is about 48 miles and millions of cubic yards of dirt has to be removed for making the navigation channel.

The navigation aspect of the scheme is estimated to cost \$350 million. Actual development is from Lake Erie up to east of Montreal.



Fig. 26 — 'The Gentleman' — 15 cu. yd.

Iroquois Dam

The Iroquois Dam is mainly to control and regulate the outflow from Lake Ontario and assist in controlling the speed of flow to form an ice cover in winter. The dam is a buttress gravity structure on rock foundations, consisting of a series of piers and sluiceways. The 32 openings between piers are controlled by 32 fixed roller, 52' × 48' vertical lift gates operated by two 350-ton travelling gantry cranes. In operation the head differential will not exceed 5 ft.

Height of roadway above foundation	67 feet
Effective length of spillway	1600 feet
Number of spillway sections	32
Elevation of spillway sill	200 feet
Elevation of top of spillway gates	248 feet
Elevation of roadway	260 feet
Excavation (dry)	2,726,000 cubic yards
Earth (wet)	1,240,000 cubic yards
Rock	66,000 cubic yards
Concrete	194,920 cubic yards
Reinforcing steel	6,672,000 pounds
Structural steel in spillway	7,860,000 pounds
Fixed wheel gates	9,600,000 pounds
Two 350-ton gantry cranes	1,300,000 pounds

Work started on this dam towards the end of 1955 and is expected to be completed by March 1958.



Dragline — digging the Long Sault Canal

The dam is being constructed in two parts in order to allow the riverflow to pass.

Figure 27 gives the downstream elevation and a section of the dam.

Long Sault Dam

The Long Sault Spillway Dam will control the flow of water into the Barnhart Island power pool and thence into the power dam.

The Long Sault Dam is located just below the foot of Long Sault Island, four miles above the power dam. One end of the dam is on the New York mainland and the other on Barnhart Island. The structure will be entirely within the United States.

The dam is a concrete-gravity curved-axis spillway structure with thirty 50-foot wide vertical lift gates. Eighteen of the 30 gates will be operated by fixed hoists of 175-ton capacity each; the remaining 12 will be operated by travelling cranes on the deck.

Construction started in August 1954 when excavation began for the coffer dams. First concrete was placed on October 10, 1955. Completion date is set for the end of 1958.

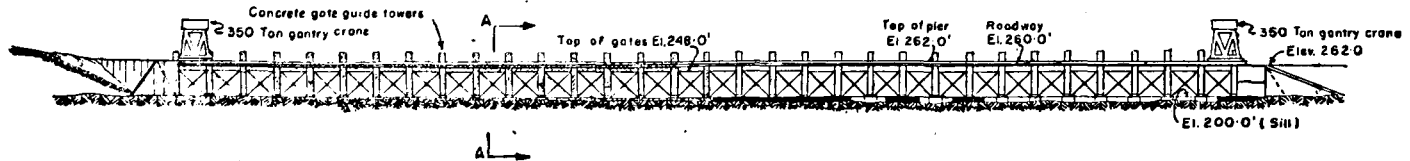
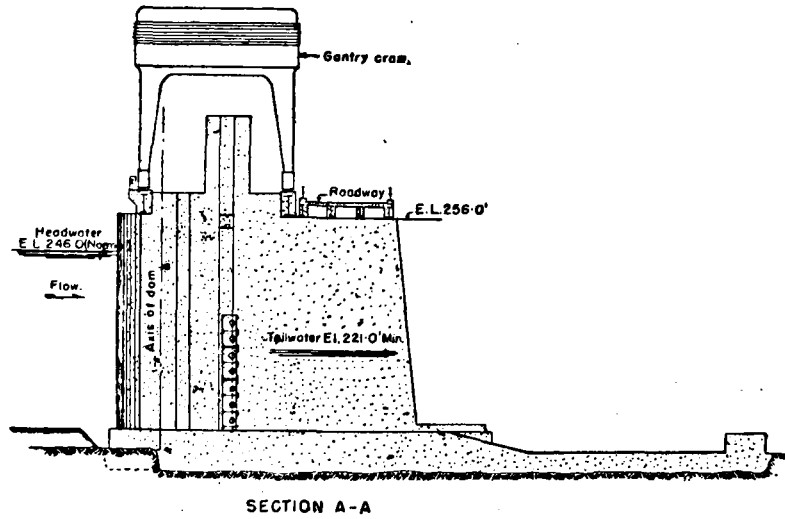
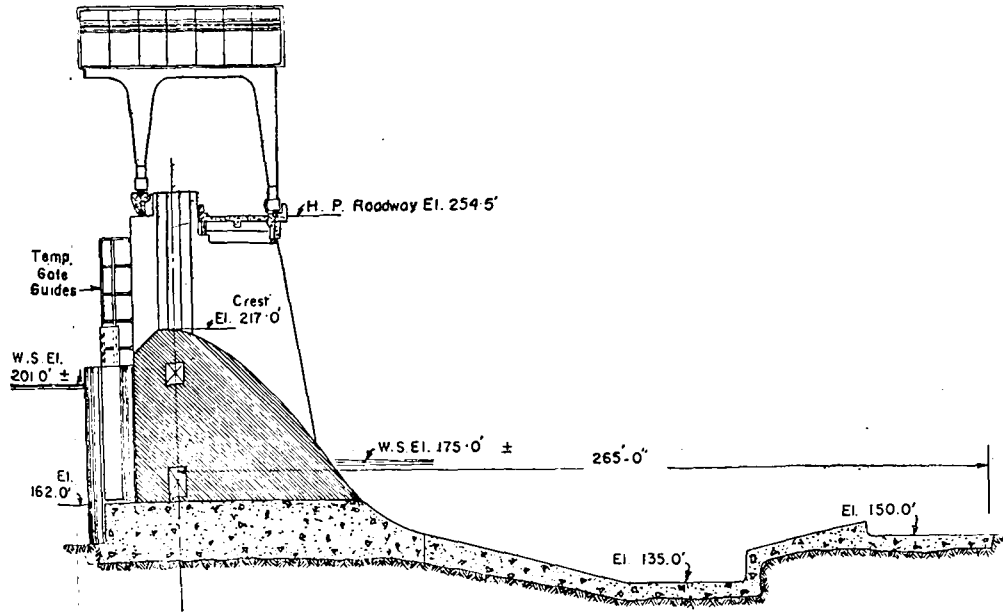
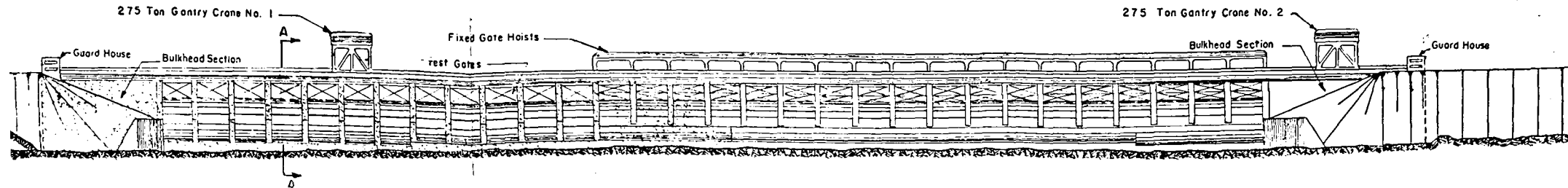


Fig. 27 - Iroquois Dam — Downstream Elevation and Section



SECTION A-A



DOWNSTREAM ELEVATION

Fig. 28 — Long Sault Dam — Downstream Elevation and Section

To meet the requirements of the river diversion programme, the dam is being constructed in four stages. Three channels are involved in the diversion, the Barnhart Island North Channel and the Long Sault North and South Channels.

Construction became complicated in view of the necessity of maintaining almost constant depth in the navigation channels.

Height of dam above foundation	114 feet
Length	2,960 feet
Length of spillway	1,800 feet
Number of spillway sections	30
Type of spillway gates	Vertical lift
Size of spillway gates	52 feet by 30 feet
Gantry cranes (2 each) capacity	275 tons
Excavation :	
Earth	7.5 million cubic yards
Borrow	150,000 cubic yards
Rock	280,000 cubic yards
Concrete	750,000 cubic yards
Cement	564,000 cubic yards
Reinforcing steel	9,313,000 pounds
Structural steel	4.2 million pounds

Figure 28 gives the downstream elevation and a section of the dam.

Steel sheet pile coffer dams protect construction of the structure. *Figure 29* shows a view of typical coffer dams constructed in these projects.

Power Dam

The St. Lawrence Power Dam is the power house structure at Barnhart Island, with an overall length of

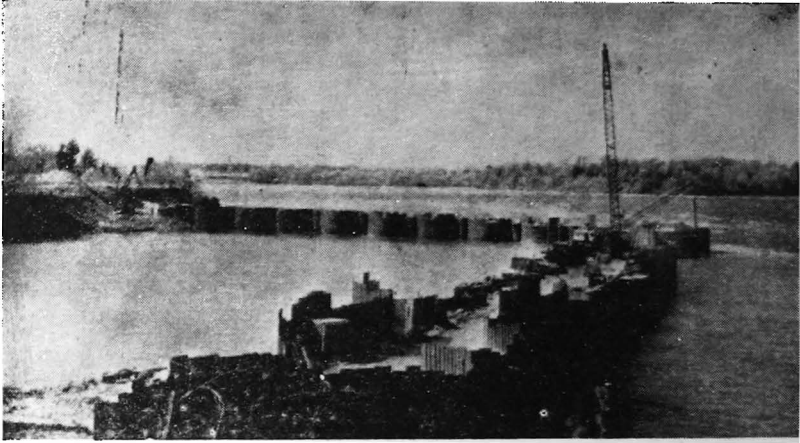


Fig. 29 — A View of Typical Cellular Cofferdam

3300 ft. The longest coffer dam, with the Canadian-American Power House link can be seen in *Figure 30*. It rests on dolomite interbedded with thin strata of shale, limestone, sandstone, and gypsum. This foundation required a lot of grouting to seal underground channels. The power dam spans the channel between the eastern end of the Island in the U.S. with the Canadian Shore.

All power from the St. Lawrence Power Project will be developed at this power dam. The power house will have 32 units of 57,000 kW each. The international imaginary boundary between Canada and U.S.A. runs along the centre of the power house and thus 16 units will be in the U.S.A. and 16 units in Canada. All the power units have a semi-outdoor type, with removable individual covers over the generators. The water head is about 80 ft.

Construction work which started in 1954, was in full progress when I visited the site. Steel sheet pile interlocked cellular coffer dam protected the construction site. The power dam involves nearly 4 million



Fig 30 — The Longest Cofferd Dam with the Canadian-American Power House Link

cubic yards of excavation and about 2 million cubic yards of concrete. *Figures 31 and 32* give a couple of views of construction work in progress.

On the U.S.A. side, the practice is to stop concreting during winter, while Canadians pour concrete all through the winter when many times the temperature varies between 30 to 50 degrees below 0°F. The capacity of concreting plants of the U.S. side is larger and hence they make up the progress.

The U.S. engineers were using steel shuttering and concreting was done in 5-ft. lifts. The Canadians use wooden shuttering and have 20-ft. lifts. The Canadians use wood forms for draft tubes, while U.S. gives preference for steel forms—*Figure 33*.

The scroll cases are cast in concrete — both walls and roof.

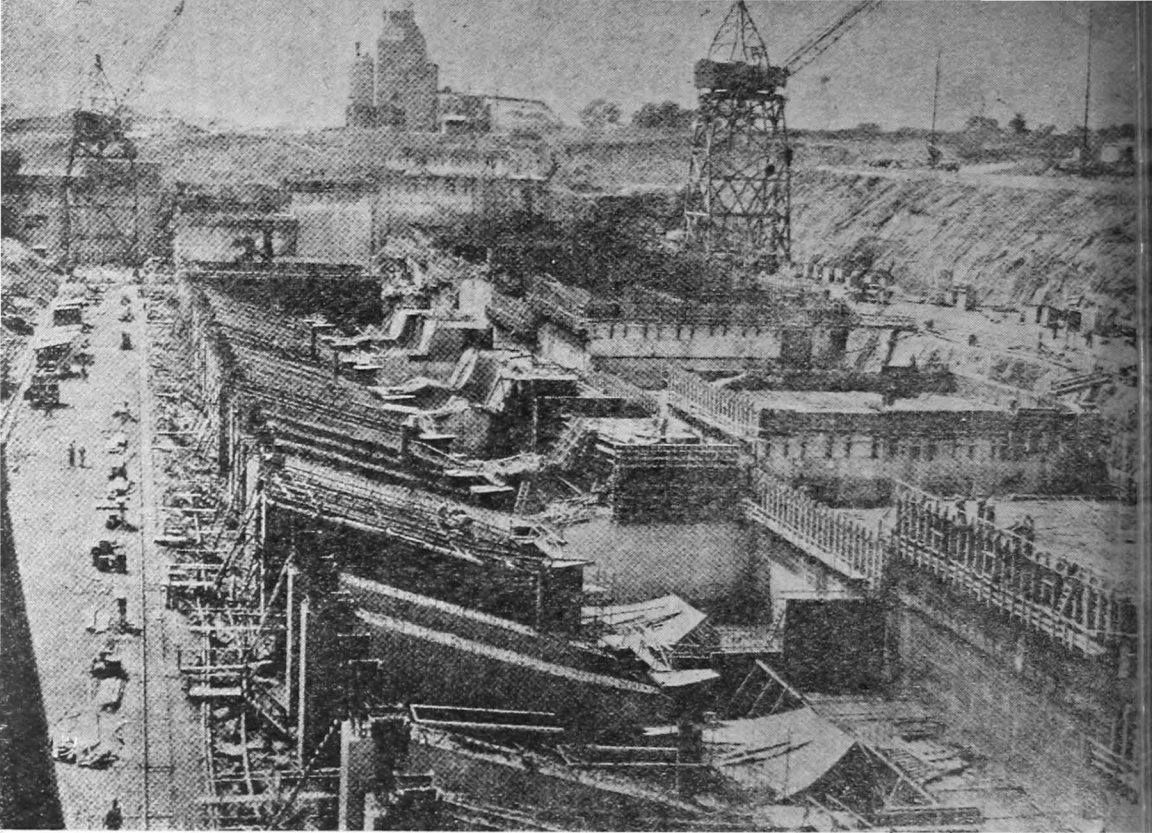
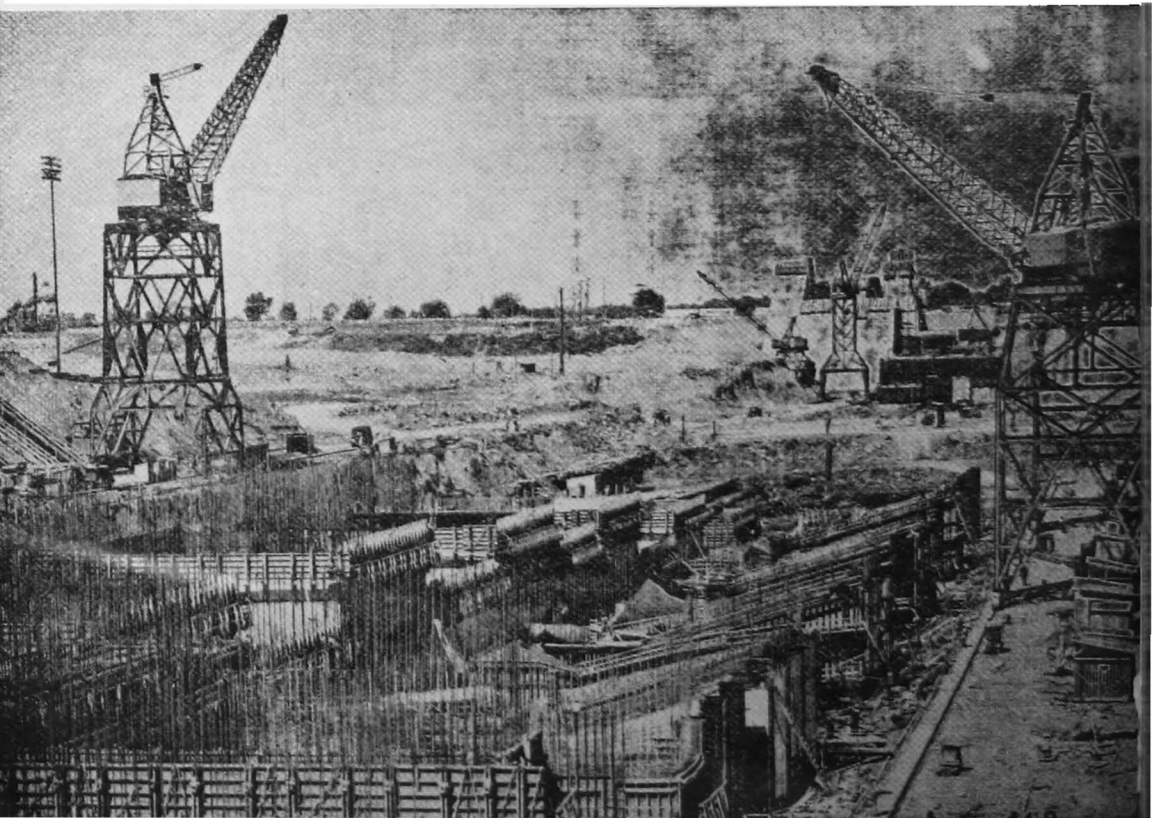


Fig. 31 (above) — American Half of Power House work begins to rise from rock bottom

Fig. 32 (below) — Power House begins to take shape — Canada work shown in background



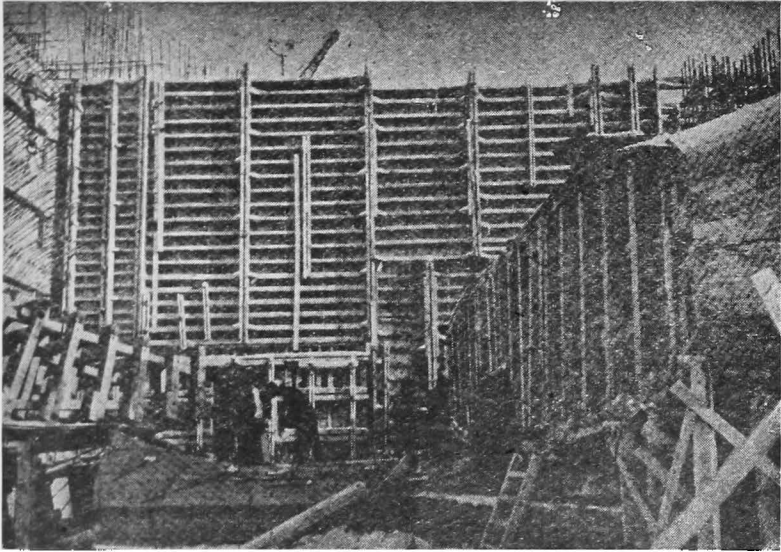
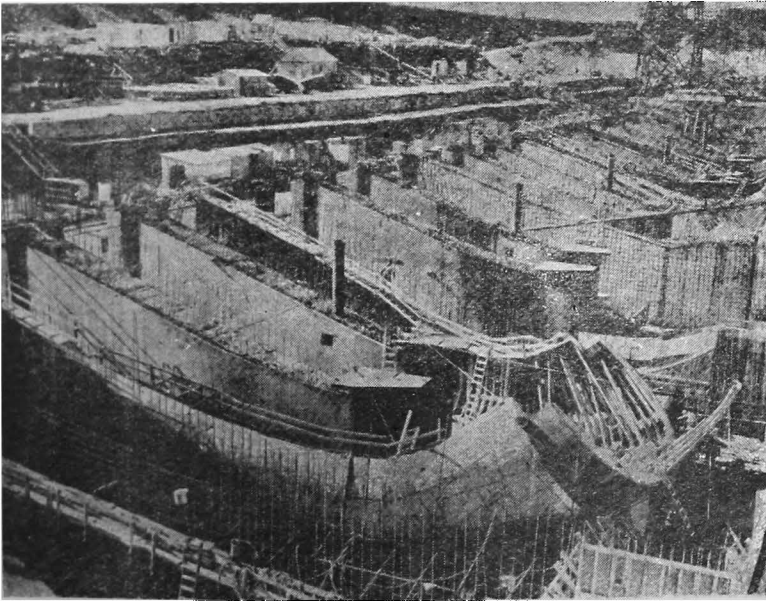


Fig. 33 — Canadians use wood forms for draft tubes (above), while U.S. preference (below) is for steel forms where they can be utilized four or more times



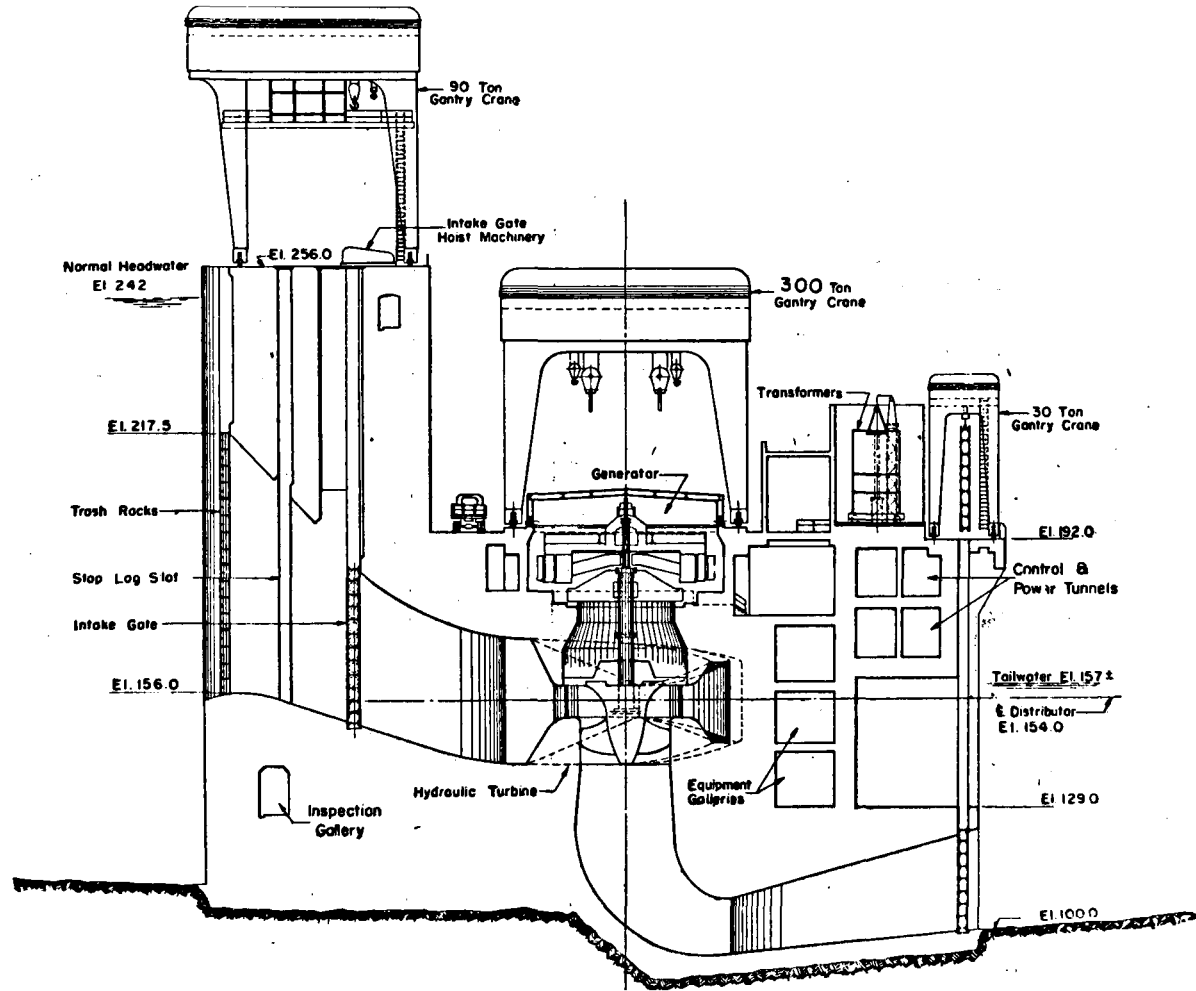


Fig. 34 — Section through Power Unit (U.S.A.)

Figures 34 and 35 give sections through the power units in the U.S.A. and Canada respectively.

General

For this project land has been acquired all round the reservoir up to 6 ft. vertical clearance above the high flood level. Houses were being moved as such—*Figure 36*—by huge house moving machines. New townships were under way and the houses were bodily fixed in the new surroundings.

Work on all aspects of the project was going on fast with modern mechanised methods and techniques. The construction, through specially complicated in view of keeping alive the existing navigation, in keeping lake levels without any infringement to the rights of shipping companies, etc., was going on in a well-planned coordinated way.

This huge project is expected to be completed in 1959. There were already some signs of exceeding the estimated cost of \$ 1,000 million. There was some controversy in the press. The authorities responsible for constructing, operating and maintaining the navigation works in Canada and the U.S.A. are respectively the St. Lawrence Seaway Authority and the St. Lawrence Development Corporation. Power is looked after by the Hydroelectric Power Commission of Ontario on the Canadian side and the Power Authority of the city of New York on the side of the U.S.A.

In the construction on this project, extensive facilities are provided for visitors interested in the construction of the project. Details of planning and other technical details, *e.g.*, construction features, laboratory reports on construction materials, specifications pertaining to this entire project, some of which are available, will be valuable references.

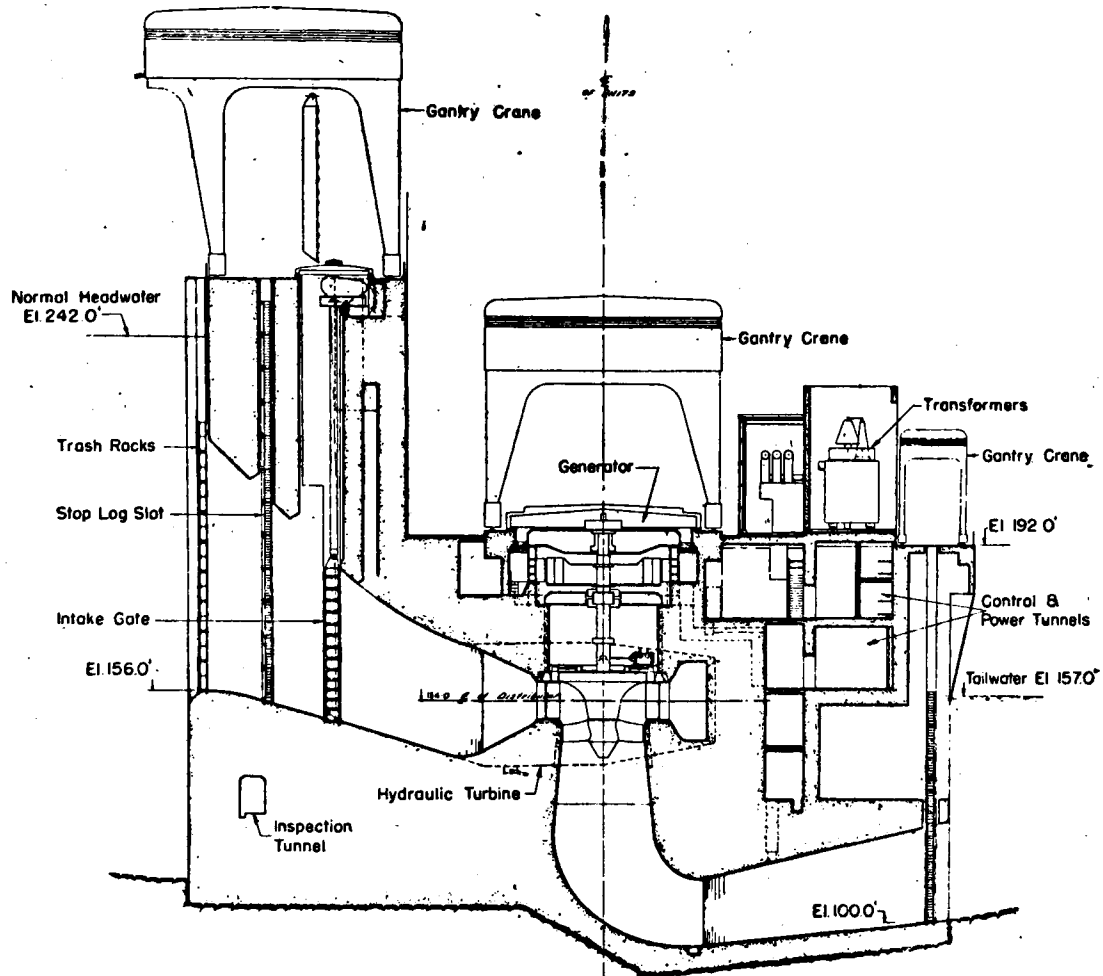


Fig. 35 — Section through Power Unit (Canada)

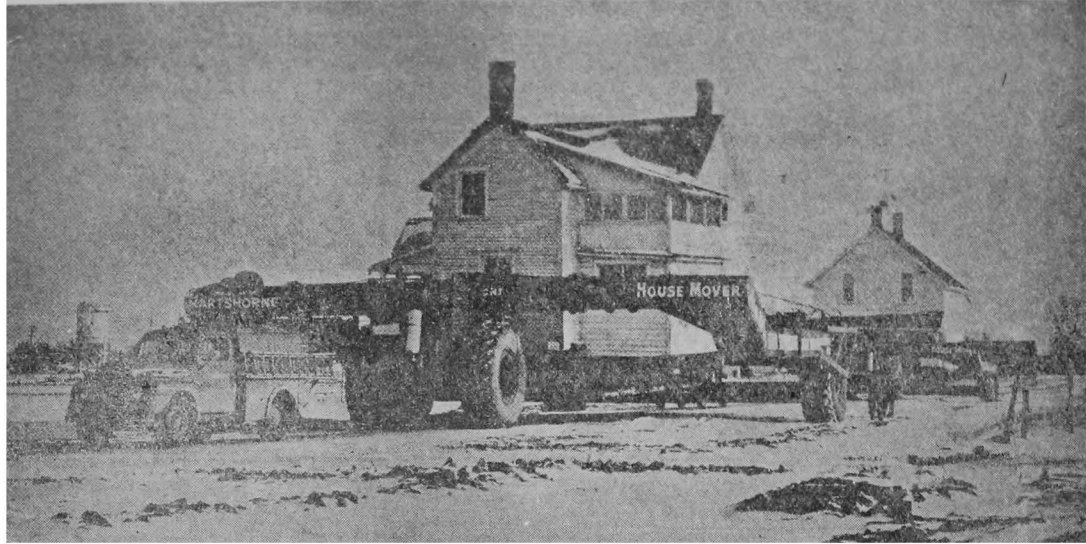


Fig. 36 — Two houses on the move to New Iroquois Town site. The larger house-moving machine in the foreground is capable of lifting weight up to 4,00,000 lb.

After completing visits in the U.S.A., I spent a few days in Italy before proceeding to Yugoslavia for attending the World Power Conference. During these few days I was almost on the move visiting some of the river valley projects including some underground power stations, both high and low head. My impressions in brief are given in this chapter.

I.S.M.E.S.— Experimental Institute for Models and Structures

In Italy, one thing which impressed me was the Experimental Institute at Bergamo near Milan. The Institute known as I.S.M.E.S. — Experimental Institute for Models and Structures has done remarkable work in conducting model experiments and has built up a reputation which has made other countries seek their advice on important structures. The Institute operates in the following research fields.

- (a) Characteristics of materials, particularly of those necessary for the construction of models;
- (b) Design, construction and casting of models, and their tests;
- (c) Tests on structural elements, and tests of whole constructions (dams, bridges, buildings); and
- (d) Measuring instruments.

In this laboratory, they make large scale models with scales $1/30$ to $1/100$, of arch gravity dams, spherical dams, in concrete itself and test for

temperature stresses and stresses due to dead load water load, uplift, etc. They have a large number of points in which they measure the stresses. Some of the tests were under progress during my visit. The engineers there have realised the growing importance of model experiments, these being the natural connections between intuition and theory and also between theory and construction. *Figure 37* shows a model of a dam in testing.

Effect of Earthquakes on Dams

In this laboratory effects of earthquakes of various intensities on dams were also being tested. They had one dam under test during my visit, but they had not come to any definite conclusion. The results of experiments at this laboratory give an opportunity for designers to improve designs. The designers have the support of sound model experiments and studies to justify increase or decrease of sections. I was told in the case of one dam (Piave Dam) that the experiments conducted resulted in a saving of about 20 per cent in the total quantity of materials, which was confirmed when construction on the dam was completed. In several cases these models and field tests permitted savings over 10 per cent in the use of concrete.

Here is a laboratory which we can some time make use of in testing the effect of earthquakes on some of our dams.

Visit to Dams

The Italian Engineers have made great strides in design and construction of arch, buttress and dome-shaped dams. I had occasion to see about half a dozen of them — some completed and some under construction. Though at the beginning of the 20th Century dams in Italy were generally of gravity type, there has

been a marked shift in the recent years to adopt arch dams to effect overall economy.

Geoveretto Dam

This is a buttress type dam with a maximum height of 91 metres and a crest length of 378 metres

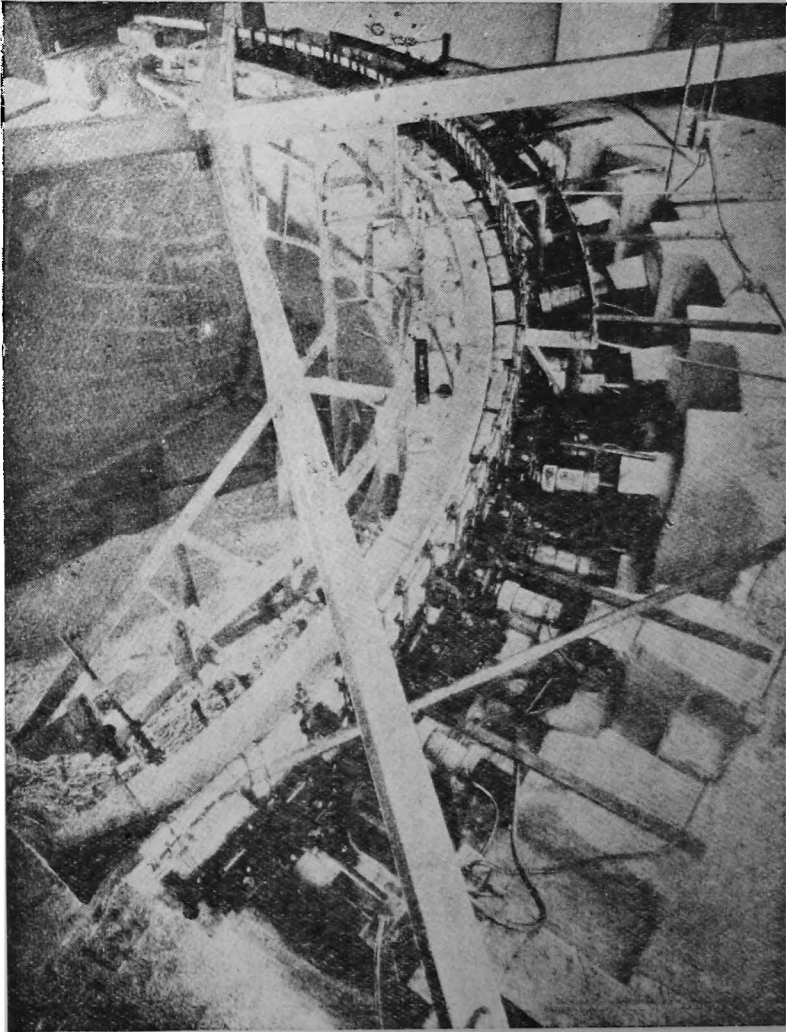


Fig. 37 — Concrete Model Testing of an Arch Dam
in Progress (I.S.M.E.S.)

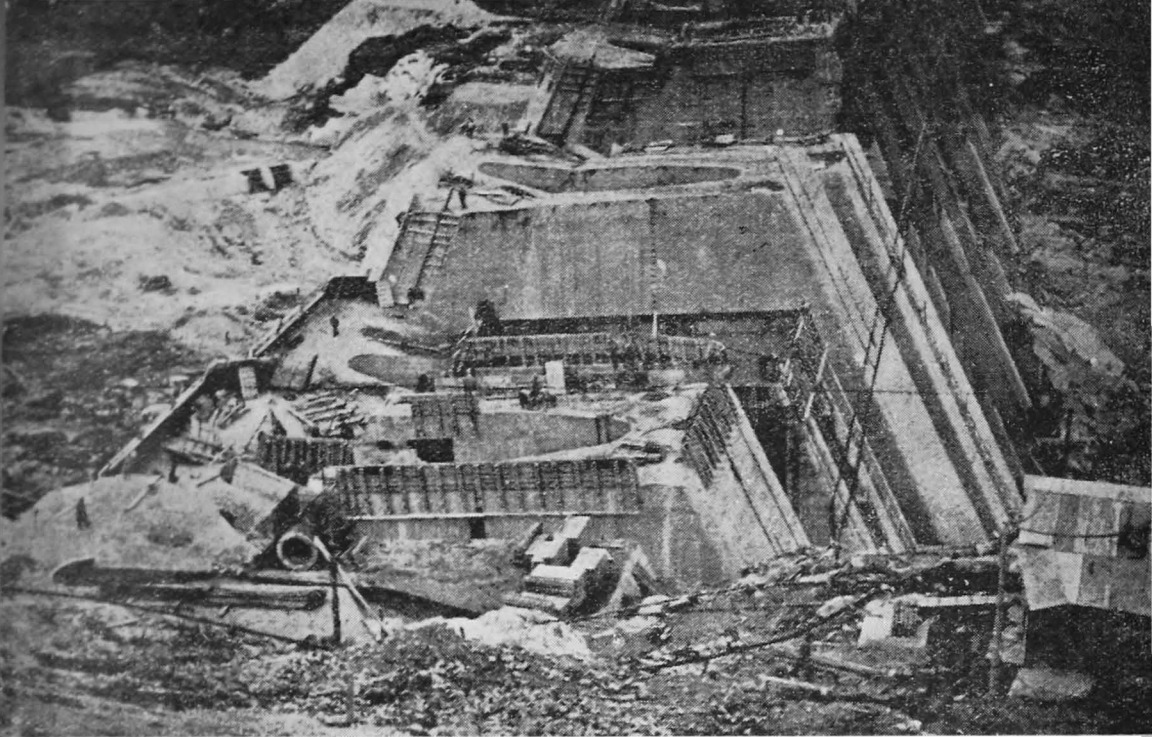
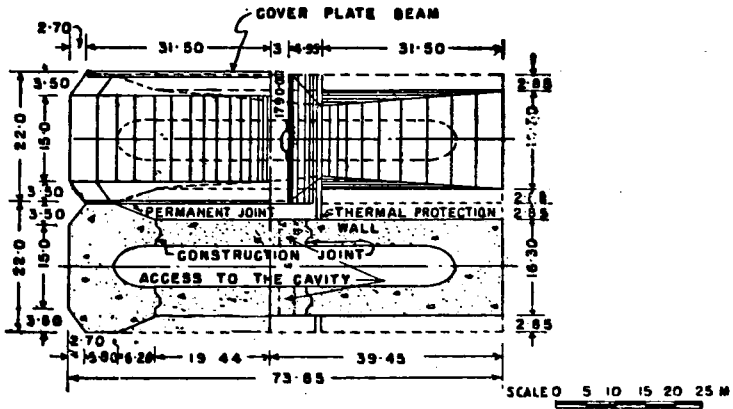
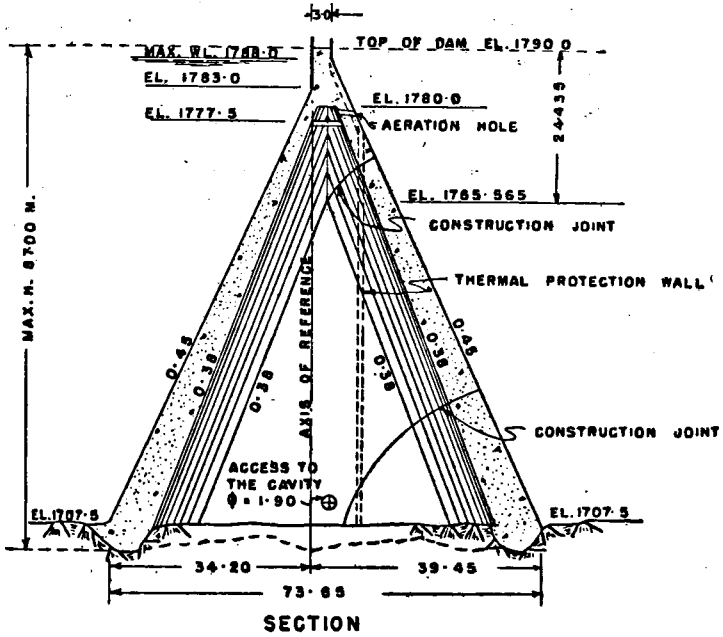


Fig. 38 — Construction Progresses at Bissina Dam

Before making the choice to construct this as a buttress type dam, the engineers had made a thorough comparative study of requirement of materials and costs involved between a straight gravity dam and a buttress dam. This revealed that the concrete required in a buttress dam was only two-thirds of that required by a gravity structure. The principal stresses worked out to 33 tons per sq. ft. as compared to 21 tons per sq. ft. in the case of a simple gravity type. I was informed that a net saving of 25 to 30 per cent in the total cost of the dam was reported by making this choice.

Bissina Dam

This is a hollow buttress type dam now under construction. The maximum height is 85 metres with a crest length of 560 metres. The volume of concrete is 430,000 cubic metres. The quantity of construction materials in this dam is said to have been reduced to



Sectional Plan
 Fig. 39 — Bissina Dam

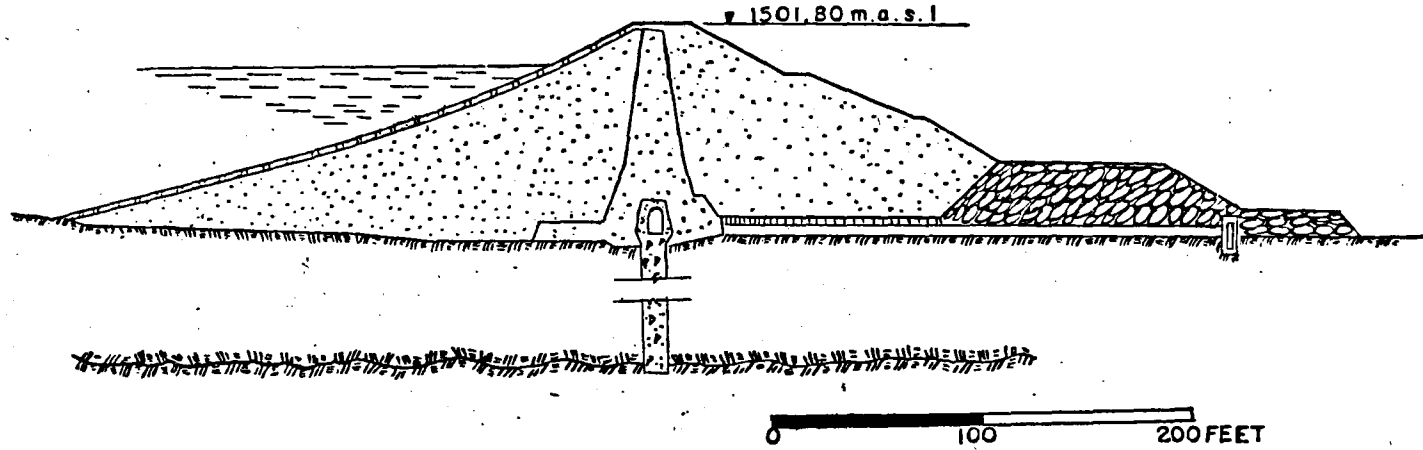


Fig. 40—S. Valentino Dam—Section

65 per cent of that required in a straight gravity dam. A view of the dam is given in *Figure 38*. Sectional plan and section are indicated in *Figure 39*.

S. Valentino Dam

Type	...	...	Earth dam
Maximum height	...	51	m
Crest length	...	467	m
Earth volume	...	600,000	m ³

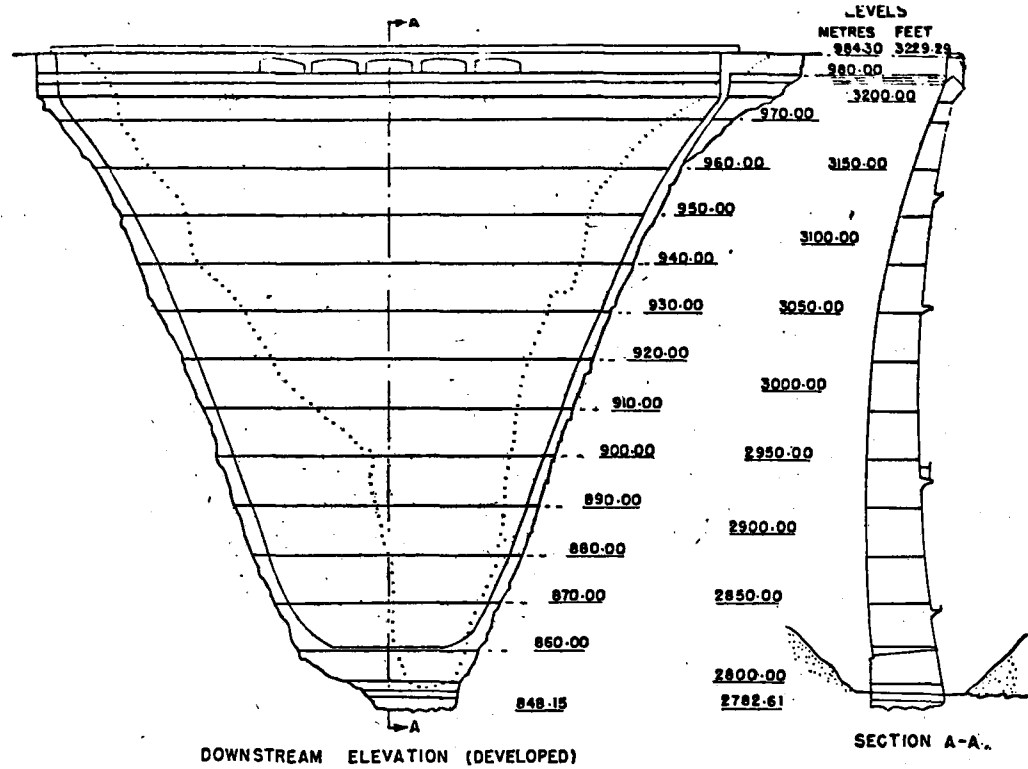
Figure 40 gives a cross-section of the dam.

Arch Dams

Several arch dams have been constructed in Italy during the last few years. Recently constructed are, Lumei, Pieve di Cadore and Val Gallina Dams.

By providing a symmetrical section, abnormal twisting stresses, which are prevalent in asymmetrical section, are avoided thus resulting in reduced thickness. Depending upon the type of profile, symmetry of the section is obtained by excavating a part of the abutment and providing reinforced plug to act monolithically with the abutment rock with a perimeter joint. The perimeter joint — *Figure 41* — is an important feature in recent Italian dams and divide the structure into two parts, the dam proper and the saddle which is fixed or clamped to the rock. The joint between the perimeter and the saddle is made watertight by means of several layers of asphaltic sheets and a staunching piece. This device not only prevented bending at the junction of the arch or dome with the abutment but also eliminated the cantilever action in the dam. The saddles and plugs were difficult for any analysis and models were therefore greatly used. *Figure 42* gives a view of Frera Dam

Fig. 41—Lumei Dam —
Perimetral Joint



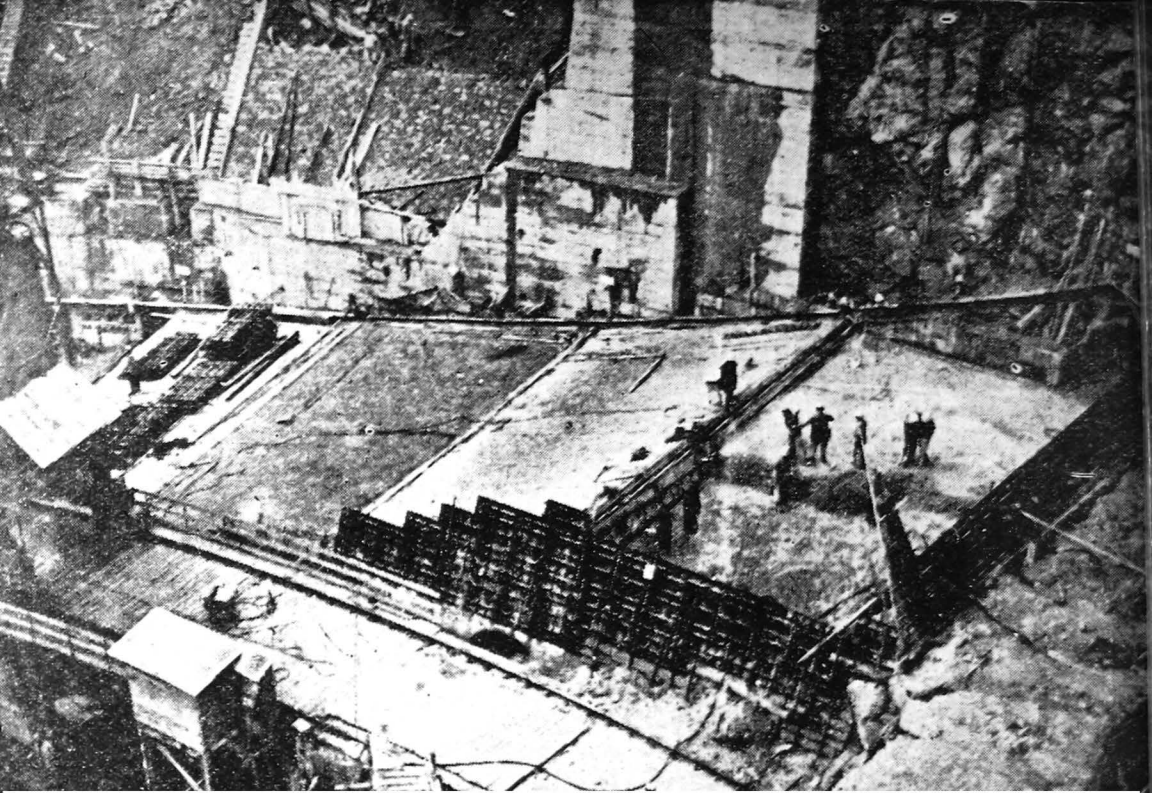


Fig. 42 — Frera Arch Dam—Perimetral Joint

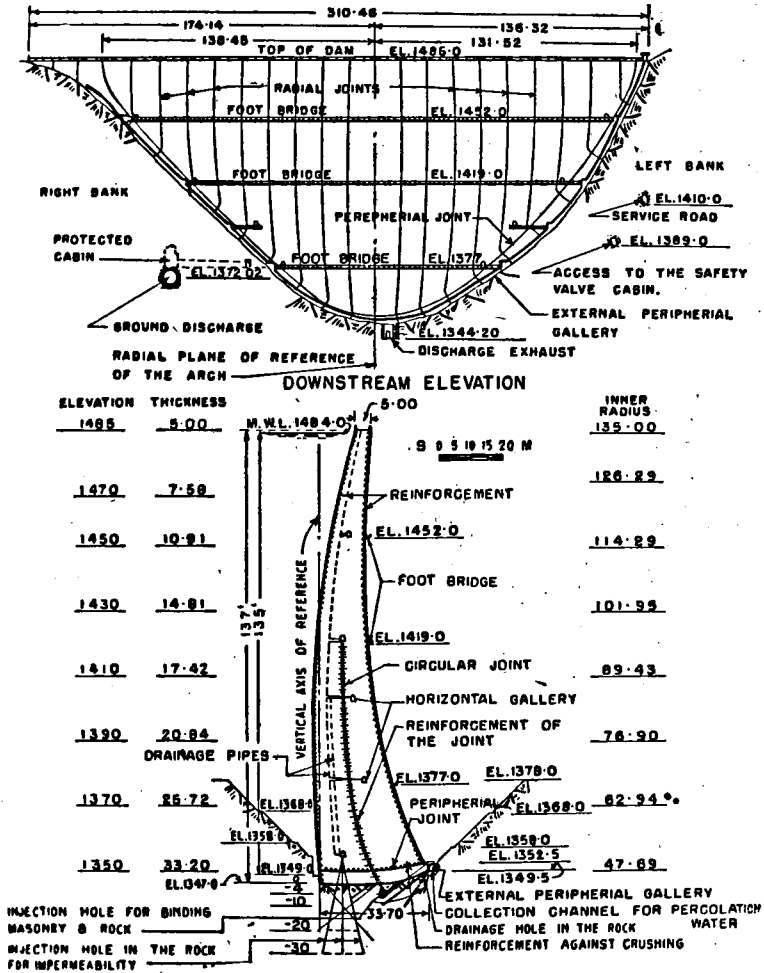
(Note the perimetral joint). *Figure 43* gives the maximum section of the dam and downstream elevation.

Another arch dam 800 feet high is under construction. The amount of saving effected in an arch dam in preference to straight gravity is also fairly considerable. For example an arch dam of 200 feet height requires about 40 per cent of construction materials of that of a straight gravity dam, thus resulting in large savings in the use of cement. The Italian Engineers also claim better factor of safety in arch and buttress type dams in addition to greater economy.

General

River diversion is not a problem in Italy on account of small mountain streams. Similarly the work is not fully mechanised due to smallness of schemes. Never-

theless the problems in Italy are so complex and the condition under which work has to be carried out are so different at each site that it is necessary to be very cautious in applying the procedure used for a



Maximum Section
Fig. 43 — Frera Arch Dam

previous one to similar jobs even though the earlier results have been favourable. Efforts are made constantly to reduce the quantity of concrete to the utmost minimum, of course not at the cost of stability and safety. The design features are generally verified by model tests. There had been very good agreement between theoretical and experimental results for thermal behaviour and for movement of the dam caused by external loads. There seems to be rapid improvement in the methods of design and construction. Perhaps this may be due to management by private enterprises.

In future, in India, it would be preferable to adopt arch or buttress type dams according to site conditions and suitability. So long as the flood discharges are taken care of by other means the buttress type structure can be used at any dam site wherever gravity type is suitable. If in India greater stress is given to these types of dams it will result in big savings in the use of cement as well as in the cost of overall construction of the projects.

Underground Power House of Ala

This is low head underground power house and the water is fed through a pressure tunnel. The details of the tunnel are as below :

Length	9260 m
Section	66 m ²
Diameter	9.54 m
Peak flow	200 m ³ per sec.

The surge tank is also underground with spillway arrangements. Facilities have been provided for keep-

ing out silt at the head of the offtake tunnel and for silt ejection at the end of the tunnel. The silt ejecting valves are normally worked once a week and have proved effective. These discharge into the tailrace.

Engineering Enterprises

There are several private engineering organisations specialised in designing, constructing and operating river valley projects, and hydroelectric installations. Mention may be made of the Electroconsult who offer consulting services in that country and is closely associated with the design and construction supervision of all types of dams and hydroelectric power stations. These organisations have wide experience in hydraulic and power engineering projects. I was told that the design and construction supervision costs of the companies average to about 6 per cent of the total cost of the project.

World Power Conference

The Eleventh Sectional Meeting of the World Power Conference was held in Belgrade, Yugoslavia, between June 4 to 11, 1957.

The delegation from the Government of India to the Sectional Meeting consisted of :

- (1) Dr. H. J. Bhabha, Secretary, Atomic Energy Directorate, Government of India.
- (2) Shri Kanwar Sain, Chairman, Central Water and Power Commission, Government of India, and President, Indian National Committee for the World Power Conference.

The meeting was also attended by Shri B. Seshadri, Secretary of the Indian National Committee for the World Power Conference, from the Institution of Engineers (India). Shri H.J. Bhabha was specially invited to preside over the technical session on 'Utilisation of Nuclear Power'.

The following are the objects of the World Power Conference, taken from the Preamble to the Constitution :

“The purpose of the World Power Conference is to consider how the sources of heat and power may be adjusted nationally and internationally.

“By considering the potential resources and all the means of production of energy in all their aspects.

“By comparing experiences in the development of scientific agriculture, irrigation, and transportation by land, air and water.

“By conferences of engineers, technical experts and fuel experts, and authorities on scientific and industrial research.

“By consultations of the consumers of fuel and power and the manufacturers of the instruments of production of power.

“By conferences on technical education to review the educational methods in different countries and to consider means by which the existing facilities may be improved.

“By discussions on the financial and economic aspects of industry, nationally and internationally.

“By conferences on the possibility of establishing a permanent World Bureau for the collection of data, the preparation of inventories of the world's resources, and the exchange of industrial and scientific information through appointed representatives in the various countries.”

The Theme of the Conference

It is significant that this conference mostly dealt with technical problems as indicated below :

A — Economic aspects.

B — Technical aspects.

B.1 — Integral utilisation of water resources.

B.2 — Integral utilisation of low quality solid fuels.

B.3 — Utilisation of nuclear power.

B.4—Power and agriculture.

B.5—Power for the metallurgical, chemical and other industries.

All the above technical problems are extremely important, particularly to depict the role of power in the underdeveloped countries. The group of papers discussed obviously were of vital importance to the human race.

There were not many papers, however, from the underdeveloped areas though a special session was devoted to discussion on "Power as a factor of development of underdeveloped countries". Many papers had been received from other countries. The proceedings of this conference highlighted the importance of the subject.

Yugoslavia itself had seen the horrors of war and had emerged from an underdeveloped economy and it was quite significant that the conference was held in Yugoslavia wherein direct contribution to the efforts made by the peoples of the underdeveloped countries in resolving a problem on which further development of world economy as a whole is largely contingent, were presented.

There were interesting discussions on the planning for power development, financing of power development projects, the relationship between power and agriculture, and planning for integrated utilisation of water resources. The writer submitted a paper on 'Integrated Utilisation of Water Resources' to this conference.

It was felt that water is essential for growing food and has great potential for generating hydro-power. The underdeveloped countries are vitally interested in

accelerating their progress and working for economic stability. The very fact that there is growing demand for additional irrigation of vast areas and for exploitation of water resources for generating cheap hydro-power for industrial development indicate the importance of water utilisation planning.

More than two-thirds of the world's area do not get sufficient rainfall and more than half of world's population do not get sufficient food. Obviously various methods for increasing production and planning for optimum utilisation of water has to be launched upon. Artificial rainfall may not help much in this context. Irrigation must have priority in arid and semi-arid regions. Careful planning to make the fullest use of water potential for power generation will result in economic power generation. The theme of the conference was particularly of immediate interest to all the countries in the march of development and also to countries already developed. In the underdeveloped countries there is already an awakening, and electricity is no longer considered a luxury but a necessity in every day life of the people.

Discussions at this conference clearly brought out, that in spite of the fact that underdeveloped countries usually have an abundance of labour, this does not remove the need for power for modern industries and agriculture.

The most important limiting factor as indicated in the discussions is of finance, both internal and external. Considerable proportions of the limited budgets of some, perhaps in most, of these countries is being spent on defence. If even a part of this expenditure could be diverted towards the development of power, the

standard of living and national income could be raised within a short period. It has been the experience in underdeveloped countries and particularly in India that the demand for power is always ahead of the power generation.

PERRICA DAM

I would like to mention only one dam which I visited. Brief features of this Perrica Dam are as below :

Height	...	...	60 metres
Crest length	...	...	490 metres
Crest width	...	...	6 metres with road
Width in the deepest section	...	...	204 metres
Storage capacity	...	...	550 million cubic metres
Free board	...	...	3 metres
Spillway capacity	...	...	560 cubic metres/sec automatic

Originally the engineers had thought of building this dam in concrete. The foundations are in limestone. The Yugoslav Engineers attach more importance to the coefficient of elasticity of the foundation material rather than the compression strength. In this case the Yugoslav Engineers found that the modulus of elasticity varied from 15,000 kg. per sq. metre to 25,000 kg. per sq. metre. Due to this, they decided that concrete would not be suitable, and they went in for a rockfill dam. In this dam limestone foundations have very big hollows underneath. From the surface one may find first class rock but 50 feet or 100 feet down the rock may be hollow. Instead of digging the whole foundation which was considered not feasible and economical, the engineers resorted to clay-cement grouting.

Grouting (clay cement)

The engineers have planned to drill about 100 miles of holes for this comparatively small dam and grout them. Grouting had almost been finished at the time of my visit.

Some of the grout holes are 209 metres deep (690 ft.) for a dam which will be 60 metres high. The grout material in this case is clay and cement. The composition is 75 per cent clay and 25 per cent cement. About 400 kilos of dry substance are injected in a linear metre of the grout hole. Before mixing, the clay is activated chemically and mechanically to prevent it from segregation. Sometimes bentonite is used with the following composition :

Clay	...	...	70 per cent
Cement	...	...	25 „
Bentonite activated chemically with Na_2CO_3	...	...	5 „

Sometimes when great losses occur bentonite up to 20 per cent is also used.

Pressures in the grout holes are as below :

	Depth in metres	Pressure
Outer rows	Under 5	5 atmospheres
	0—10	10 „
	10—20	15 „
	20—60	Increase to 40 atmosphere at the rate of 0.75 atmosphere per linear metre.
Middle rows	0—10	15 atmospheres
	10—20	25 „
	20—60	Increase to 60 atmospheres at the rate of one atmosphere per linear metre.

Properties of Material

Briefly the properties are :

Liquid limit	... ..	58 to 82 per cent
Index of plasticity	... ..	35 to 51
Optimum moisture content		21 per cent
Dry bulk density	... ..	1.66 tons per cubic metre
Permeability	... ..	$5 \text{ to } 8 \times 10^{-9}$ cubic metre/sec.

The dam is proposed to be built about 1 metre higher than designed to allow for any possible settlement. Upstream and downstream slopes have been kept at 1:1.4 and four berms have been provided in downstream side. An inspection gallery (3m × 3m) has been provided for grouting.

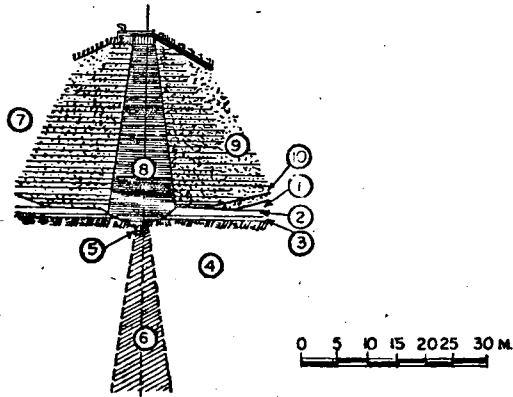
It has been programmed by the engineers to complete the work on this dam within 3 years. It is interesting to note that the working season is only 4 months and the rest of the 8 months is non-working season due to heavy rains. Work was in progress mostly by mechanical equipment and in the rockfill dam the progress was about 3,000 cubic metres with 16 hours of working every day. Clay is done in three shifts with a progress of about 400 cubic metres. During the idle season they overhaul all the equipment used in the project.

Earth Dams and Rockfill Dams Preferred

In Yugoslavia, earth dams and rockfill dams are preferred to concrete dams due to technical and economical reasons. The poor ground conditions, shortage of cement, floods of low intensity and difficult access to sites are some reasons for the choice of earth and rockfill dams. Earth dams are generally preferred to rockfill

dams in view of labour shortage and because mechanisation can be effectively applied. Besides, earth dams could be built in stages.

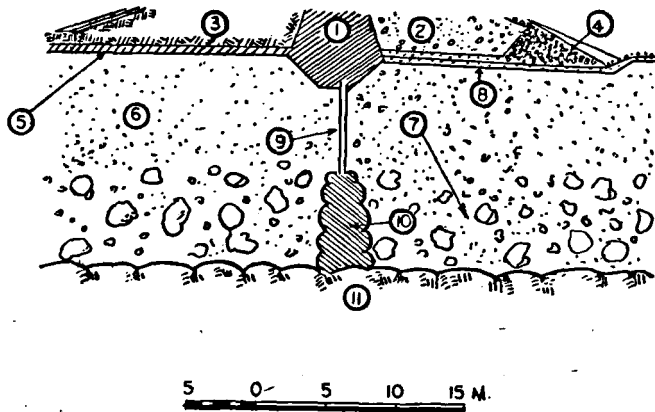
A speciality in Yugoslav Dams is the provision of control gallery at the contact point of ground and the impervious core — *Figure 44*. This gallery is placed along the dam up to a certain height with access from the downstream side. The gallery is built of porous concrete so that seepage could be measured. An added advantage is that grouting can be effectively carried out from this gallery. Incidentally the programme of grouting can be independent of the general plan of construction, thus expediting construction progress.



- | | |
|----------------------------------|-------------------------------------|
| 1. SANDY CLAY. | 6. GROUTING CURTAIN. |
| 2. SIETY SAND. | 7. UPSTREAM SEMI-PERVIOUS MATERIAL. |
| 3. GRAVEL. | 8. IMPERVIOUS CLAY CORE. |
| 4. ROCK (MICASHISTS) | 9. DOWNSTREAM SEMI-PERVIOUS MA- |
| 5. GROUTING AND CONTROL GALLERY. | 10. FILTER AND DRAIN LAYER. |

Fig. 44 — Control Gallery in Earth Dam

The impermeability of the structure is obtained generally by a central clay core and diaphragm or



- | | |
|--|---------------------------------|
| 1. CLAY CORE. | 7. ALLUVIAL GRAVEL WITH BLOCKS. |
| 2. GRAVEL. | 8. PROTECTING FILTER LAYER. |
| 3. GRAVEL. SOIL. | 9. TIMBER SHEET PILING. |
| 4. ROCK TOE. | 10. GROUTING CLAY CURTAIN. |
| 5. HORIZONTAL IMPERVIUS CLAY
BLANKET. | 11. ROCK (PALEOZOIC SHISTS) |
| 6. ALLUVIAL GRAVEL. | |

Fig. 45 — Typical Diaphragm Obtained by Timber Sheet Piling and Clay Groutings.

grouting. In a particular case the dam was situated at a place where large slip had occurred into the river bed. Two diaphragms were provided as a measure of safety — *Figure 45*. The vertical diaphragm consisted of timber sheet piling and clay grouting and the horizontal diaphragm consisted of horizontal clay blanket of about 1 metre thick extending about seven times the height of the dam on the upstream side.

In another case it was necessary to utilise lot of excavated material for the dam. Therefore in place of impervious core, the middle of the dam was filled with

material of determined granulations which was later on grouted with cement. ,

It is almost a universal practice that the whole of unused excavated foundation materials and the materials that are to be cleared from the site are dumped at the toes of the dam preferably on the upstream side.

Yugoslav Engineers have made special studies of the clay-cement grouting and were confident of the grout material. This is of great value particularly for Indian Engineers who are faced with poor foundation conditions in some of our structures where grouting can be adopted with advantage and also without sacrificing any lapse of time in construction

Private Enterprise in Yugoslavia

There are very many official engineering enterprises run on lines of private venture in the country, of which I visited the Electro Project Enterprise. This is a very big engineering concern with about 60 engineers headed by a director who is an electrical engineer. The staff consists of engineers, geologists, architects, etc. The director forms a technical council for every special problem facing the organisation. In 1945, when this organisation was established the work was fully centralised. With the passage of years, *i.e.*, in 1952 the functioning of the organisation was decentralised mainly due to the fact that centralisation got too big and clumsy. They could not also physically coordinate the work. Moreover, the much needed personal contact could not be had. This offers a very good example of decentralisation wherever possible.

Conclusions and recommendations

Based on discussions with many eminent engineers from different parts of the world during the international conferences, and as a result of visits to river valley projects and engineering organisations in the U.S.A. and some countries of Europe, certain conclusions and recommendations are briefly indicated below:

2.1. Potential achievements and increase in agricultural and industrial production to meet the growing demands of the expanding population by systematic exploitation of the natural resources contributes to the national prosperity.

2.2. The living standards in all the countries visited are going up year after year. What is helping these countries to build up rising standards is the use of scientific and modern techniques in developmental works.

2.3. Sound pre-planning, particularly in water utilisation, and the importance attached to this is one of the major reasons for high productivity in most of the countries.

3.1. Canal lining has become increasingly important to reduce transit losses in irrigation canals.

3.2. To economically utilise the costly stored waters, the I.C.I.D. decided to discuss the problem with particular emphasis on maintenance and design in the Fifth Congress. India should study these aspects and make a significant contribution.

3.3. To ensure optimum utilisation of available water and land resources studies in agro-technical processes should be made.

Conclusions and Recommendations

3.4. In connection with hydraulic structures on irrigation and drainage systems, emphasis was laid on the need for silt regulation, for devices for the safety of structures, for measurement of discharges, etc.

3.5. Payment of water charges on a volume basis was brought out. Coordination between the needs of farmers and the requirements of regulation was stressed.

3.6. Discussions on inter-relation between irrigation and drainage amply brought out the complexity of the problem. The close relation between these two should be studied. In all irrigation project proposals, provision should be made for main drains to avoid problems of water-logging at a later stage.

3.7. The proposal by the writer that flood control should also be dealt with by the I.C.I.D. was discussed in May 1957. As a result flood control has been included within the purview of the International Commission.

4.1. Discussions on "Can Man Develop a Permanent Irrigation Agriculture?" at the First Inter-Society Conference on Irrigation and Drainage covering variety of subjects including saving of water, selection of crops, types of soil and soil classification, revealed that it is possible to develop permanent irrigated agriculture provided scientific and economic utilisation of water with effective drainage is assured.

4.2. Control, conservation, distribution and economic utilisation of water and drainage embrace many fields of activities and warrants the cooperation of engineers, scientists, agriculturists, revenue authorities, local population, etc.

4.3. In India Inter-Society Conferences and discussions on engineering and allied aspects should be

organised. The concerned departments of the Central and State Governments should give a lead at the earliest possible.

5.1. Saving water in irrigation canals and storage reservoirs is of great importance to India and particularly in the arid and semi-arid tracts.

5.2. Canal losses due to seepage, leakage and evaporation occurring between headworks and the fields vary within a wide range of 10 to 50 per cent of the supplies entering at the head.

5.3. Prevention of 25 per cent losses in the 400,000 cusec of water which flow in the canals of India will be able to irrigate 15 million acres of additional land. This will be equivalent to irrigation benefits from four Bhakra Dam projects.

5.4. To reduce canal losses, lining is gaining more and more importance in U.S.A. Twenty-five million square yards have been lined with concrete or asphalt since 1952 thus saving 700,000 acre ft. of water annually.

5.5. Lining has been adopted in U.S.A. as a flood control measure also, particularly in the case of hill torrents where the velocities range from 25 to 50 ft. per second.

5.6. In some cases channels with discharge capacity of one lakh cusec have been lined for short distances to reduce erosion.

5.7. The idea of super-elevation in designing curved channels can be adopted with advantage wherever possible.

5.8. Discussions on the economics of various methods of lining with eminent engineers revealed that the method of sandwiched brick-tile lining indicated by the writer

Conclusions and Recommendations

was considered to be one of the best methods for Indian conditions.

5.9. Reducing evaporation losses from free water surface is gaining importance in many of the countries.

5.10. To reduce evaporation losses, experiments are in progress in some of the countries by the application of oil films.

5.11. Experiments in Australia by the C.S.I.R.O. have indicated that further work is required before actual recommendations could be made as to the use of Cetyl alcohol.

5.12. Trials already made with Cetyl alcohol and hexadecanol in U.S.A. at Lake Hefner have indicated that monomolecular films have no effect on changing the quality and chemical properties of water.

5.13. Many engineers in U.S.A. were not very optimistic about the results that are being obtained at present. It is, however, too early to arrive at any definite conclusions as to the future possibilities before large scale experiments are conducted.

5.14. The suitability of hexadecanol and other monomolecular films for Indian conditions is yet to be established. Some small-scale experiments are afoot.

5.15. It is of no value to save water from evaporation if the water is left to seep away.

5.16. To meet a critical and prolonged period of water shortage in a highly developed area under the Elephant Butte Reservoir, extensive channelisation has been effectively adopted. This is interesting and valuable for saving water in arid and semi-arid regions.

6.1. Sprinkler irrigation is widely prevalent in U.S.A. and Italy. The cultural practices and high standards

of living have also affected in switching to sprinkler irrigation.

6.2. Though there are many advantages in adopting sprinkler irrigation, the disadvantages are too many for Indian conditions. In India time is not yet ripe to use sprinkler irrigation on large scale because of its high cost. Non-availability of necessary equipment and lack of education of cultivators to adopt new techniques add to the difficulties. However, as and when cheap power is widely distributed, sprinkler irrigation can be adopted by small farms.

6.3. One-ditch for irrigation and drainage is an interesting practice prevalent in U. S. A. This can be adopted with advantage according to site suitability, where water table is near the surface.

7.1. Levees constructed since 1870 have proved to be successful as a flood control measure along the Sacramento River in California.

7.2. There has been no significant rise in river bed due to levees during the 90 years of operation.

There was about 20 ft. rise in the river bed due to a lot of debris thrown into the river from mining operations in the upstream reaches. By the construction of debris dams in the upper reaches the river bed scoured back 10 to 15 ft. There has been no trouble since then.

7.3. The Sacramento River Flood Control Project is an excellent example of carrying flood waters through a comprehensive system of levees and by-pass channels. In some cases the by-pass channels carry a discharge of 500,000 cusec whereas the capacity of the river channel is only 110,000 cusec. These flood control works are of great interest at the present context of flood problems in our country.

Conclusions and Recommendations

7.4. Most of the flood control projects in U. S. A. are undertaken on Federal-State-Local Cooperation. Maintenance of levees is generally the responsibility of Local Government agencies. The policy and techniques employed in the Central Valley of California can be studied with advantage.

7.5. The California Water Plan is a master plan for the overall development of the water resources of California State keeping in view the present and future needs of water.

7.6. This master plan has taken 10 years of intensive study and can be taken as a good and useful guide for the preparation of integrated water plans.

7.7. Brief aspects of study are inventory of data; quality and characteristics of water; present and ultimate requirements; and comprehensive plan for the control, protection, conservation, distribution and utilisation of available water for all beneficial purposes to the maximum feasible extent.

7.8. The most important feature in the plan is the transfer of surplus waters through a network of aqueducts.

7.9. In India, it is necessary to think ahead and formulate long-range integrated plans for water utilisation and transfer of water with engineering and economic analysis keeping in view the present and future needs and national policies of the country.

7.10. Watershed management should be included as a principal objective in planning and development of basin programmes.

7.11. Flood control should be considered as an important part of water resources management.

7.12. Full development of the Nation's underdeveloped power resources should form an integral part of comprehensive basin development.

7.13. Extensive grouting to treat the poor foundations of Shasta Dam (constructed in 1939) proved very effective. There is not much seepage in the foundation and very little grouting has been necessary after completion of the dam. This is significant in view of Bhakra foundation problems.

7.14. Design and construction of Trinity Earth Dam (465 ft.) in U.S.A. can be studied with advantage.

7.15. All pre-construction testing of materials is done at the U.S.B.R. Laboratory at Denver mainly to keep close contact between design and construction engineers. Testing techniques and results are of much value.

7.16. Young engineers from India should be deputed to study and work on the Trinity Dam construction for a few months. At present the construction work is in an interesting stage.

7.17. Future dams in India could be certainly constructed in rolled-fill-zoned earth wherever possible. This will effect enormous saving in the capital cost of the project.

7.18. The Cheesman Masonry Dam in U.S.A. constructed in 1908, in the same way as masonry dams in India, is functioning well even today.

7.19. Tests on 3 ft. rubble masonry cubes at U.S.B.R. Laboratory at Denver reveal that by mixing one part of cement with three parts of sand for cementing the stones, masonry develops an average strength of 3,360 lb. per sq. inch in 90 days. These are favourable results.

Conclusions and Recommendations

7.20. If masonry is well done and the joints are taken care of by perfect supervision, it can be expected to take the same stresses as concrete.

7.21. Construction costs of Glen Canyon Dam in 1957 and Hoover Dam in 1931, have revealed that the costs have approximately trippled in the past 26 years. For the construction of the Glen Canyon Dam, a Consulting Board of Engineers and Geologists renders advice.

7.22. The 1,000 million-dollar St. Lawrence Seaway and Power Project is technically an excellent example of 20th century engineering feat in solving diverse problems with a single master plan. It is an excellent example of international cooperation in developing water resources for the benefit of U.S.A. and Canada.

7.23. The navigation channels of this project will negotiate a drop of 602 ft. and will enable ocean-going ships from the Atlantic to go 2,700 miles into the interior, up to the Great Lakes. The power house will have an installed capacity of 1.9 million kW.

8.1. The Experimental Institute for Models and Structures (ISMES) at Bergamo in Italy has done remarkable work in conducting model experiments connected with river valley structures. It has built up a high reputation which has made other countries seek their advice on important structures.

8.2. Effect of earthquakes of various intensities on dams are tested at ISMES, which helps to evolve better designs. Experiments have effected significant saving in construction materials. India can sometimes make use of this laboratory in testing the effect of earthquakes on some of our dams and for other testing.

8.3. In Italy, construction of arch, buttress and dome-shaped dams is becoming more and more common on economic considerations. A better factor of safety is also claimed by the Italian Engineers. There seems to be rapid improvement in design and construction techniques.

8.4. In India it would be preferable in future to adopt arch or buttress type dams according to site conditions and suitability. This will result in big savings in the use of cement as well as in the cost of overall construction.

8.5. There are specialised engineering enterprises in Italy whose advice can be obtained whenever necessary. Mention may be made of the Electro-consult which are closely associated with the design, construction supervision of all types of dams and underground power stations.

9.1. The discussions at the World Power Conference in Yugoslavia on 'Power as a Factor of Development of Underdeveloped Countries' brought out the importance of the subject.

9.2. In the underdeveloped countries there is already an awakening and electricity is no longer considered a luxury but a necessity in every day life of the people. Careful planning to make the full use of water potential for power generation should be ensured.

9.3. Discussions at the conference brought out the fact that though underdeveloped countries have usually abundance of labour it does not remove the need for power required for modern industries and agriculture.

Conclusions and Recommendations

9.4. The most important limiting factor in power development is finance both internal and external.

9.5. The Yugoslav Engineers have advanced much in clay-cement grouting in dams. They have evolved suitable techniques for efficient grouting.

9.6. Clay-cement grouting to treat foundations have been effectively done at the Perricka Dam (190 ft. high). It involved 100 miles of grouting holes which had been completed at the time of the writer's visit. India can take advantage of their experience as and when necessary.

9.7. More importance is attached to coefficient of elasticity of the foundation material rather than to the compressive strength, in Yugoslavia.

9.8. Due to technical and economical reasons, earth and rockfill dams are preferred in Yugoslavia.

9.9. Official engineering enterprises, run on the lines of private venture, in Yugoslavia have contributed greatly to the nation's development. They believe in decentralisation wherever possible so as to have much needed personal contact and also to expedite work with proper coordination.

Itinerary of the tour

Date	Time in hours	
24.4.57	23.50	Leave Delhi.
28.4.57	11.00	Arrive San Francisco.
29.4.57 to 5.5.57		Halt at San Francisco to attend Third Congress of International Commission on Irrigation and Drainage. Discussions with eminent engineers from different parts of the world.
6.5.57 to 9.5.57		Visits to projects in Central and Imperial Valleys of Califor- nia — Sacramento River Flood Control Project, Irrigation and Drain- age Schemes, Trinity Dam, Shasta Dam, etc. Discussions with Water Resource Department Engineers of Califor- nia.
9.5.57	17.00	Leave San Francisco.
	21.00	Arrive Los Angeles.
10.5.57 to 11.5.57		Visit to Boulder Dam and discus- sions.
12.5.57	7.00	Leave Los Vegas.
	11.00	Arrive Denver.
13.5.57 to 17.5.57		Discussions with U.S.B.R. Officers and visits to laboratories. Dis- cussions with Colorado Water Department Engineers. Visit to Cheesman Masonry Dam.
18.5.57	5.00	Leave Denver.
	17.00	Arrive Washington.

Appendix A

19.5.57		Halt at Washington.
to		Discussions with I.C.A., Army
24.5.57		Corps of Engineers, U.S.B.R. Offi- cials, Soil Conservation Department, Weather Bureau, World Bank Offi- cials, India Supply Mission, etc.
25.5.57	8.30	Leave Washington by car.
26.5.57	2.30	Arrive Massena. Visit to the St. Lawrence Seaway and Power Project.
27.5.57	8.30	Leave Massena by car.
	19.00	Arrive New York.
28.5.57 to		Halt at New York. Visit to U.N.
29.5.57		Offices and Offices of A.S.C.E.
29.5.57	17.00	Leave New York.
30.5.57		Arrive Milano (Italy).
31.5.57		Visits to some arch and buttress
to		dams, underground power houses in
2.6.57		Italy. Discussions with Electro- consult and other engineers.
3.6.57	13.10	Leave Venezia.
4.6.57	18.50	Arrive Belgrade (Yugoslavia) to attend XIth Sectional Meeting of World Power Conference.
5.6.57		Halt at Belgrade. Visits to Perrica
to		Dam and some other river valley
17.6.57		projects in Yugoslavia. Discussions on engineering aspects.
17.6.57	20.00	Arrive Rome.
18.6.57	8.15	Leave Rome.
19.6.57	13.45	Arrive Bombay.
19.6.57	16.00	Leave Bombay.
19.6.57	19.00	Arrive Delhi.

**Extracts from Kanwar Sain's paper on
'canal lining in India' presented at the
third congress of I.C.I.D., San Francisco,
May 1957**

Synopsis

In India today there are about 66,400 miles of canals taking off from rivers and reservoirs, carrying more than 400,000 cusec of water. Of these about 18,800 miles are classified as main canals and branches and the remaining 47,600 as distributaries and minors.

It has been the experience of all irrigation engineers that considerable quantity of water is lost through seepage while the water is stored in tanks and reservoirs and during its transit through canals and conduits. This cannot be viewed with indulgence, when we all realise that water is very precious and the cost of storage and diversion schemes have gone up considerably and they are likely to go up still higher in the future. Engineers are, therefore, called upon to take remedial measures to minimise these losses by constructing improved types of canals and employing better maintenance and operation methods.

Apart from loss of water which could be used for irrigation and for other social and industrial purposes, the huge quantity of water seeping into adjacent lands constitutes a great danger to the terrain. Owing to continuous seepage and the rising sub-soil water table consequent upon it, serious waterlogging may occur which may undermine the productivity of the land, sanitary conditions of the inhabitants dwelling on it and

in the long run convert at once bountiful land into a huge waste and marsh.

Engineers in every country, wherever irrigation system exists, have been aware of these dangers and have, in recent years, taken steps to conserve water from losses either in transmission or in storage.

The object of this paper is to describe the measures taken by Indian Engineers to minimise losses by lining of open earthen channels and to present the results obtained. The author does not deal with the theoretical aspects of the subject in detail as enough information is already available in published literature. Only comparative studies are indicated with similar attempts and achievements in other countries such as U.S.A. in order to appreciate the problem in its proper perspective. A reference to Lower Chenab, Haveli and Thal Canals, now in Pakistan, has been made on account of author's personal association. Experience gained on these canals has played a positive part in subsequent extensive work undertaken in India.

Text of the Paper

Canal losses due to seepage, leakage and evaporation occurring between the headworks and the fields have been estimated to vary within a very wide range from 10 to 50 per cent and sometimes up to 60 per cent of the supplies entering at the head, although canals of moderate length are supposed to have about 20 to 25 per cent. The percentage loss in new and longer canals is proportionately higher than in old and shorter canals. Loss due to evaporation, however, depends on the water spread, prevailing temperature, humidity and wind velocity. This may be appreciable in big reservoirs but not so in canals.

Absorption losses in distributaries, minors and water courses are equal to or often larger than the quantity lost in main and branch canals.

Losses of water from 13·1 to 19·15 per cent of the supply at the head in main and branch canals and 20 to 30 per cent in distributaries were reported as early as 1875 on Bari Doab Canal which was under operation for nearly 16 to 18 years.

Kennedy showed in 1881 that out of every 100 cubic feet of water entering at the head nearly 47 cubic feet were lost as :

- 20 cu. ft. in canal and branches.
- 6 cu. ft. in distributaries.
- 21 cu. ft. in water courses.

This meant about 47 per cent of the supply was lost as losses. Corresponding total loss found in the Ganges Canal was 44 per cent (15 per cent in main and branches, 7 per cent in distributaries and 22 per cent in water courses).

Values very near to these figures were obtained in 1907 in case of canals in Khandesh in Bombay.

It would be interesting to compare the above figures with the canal losses in U.S.A. The following passage is reproduced here from "Lower-Cost Canal Lining" (Bureau of Reclamation—Manual 1948).

"It has been estimated that one-third of all the water diverted from western streams for irrigation is lost in transit to the farm land and it is known that in a few individual cases, this loss in transit is as great as 60 per cent. Of the 14,400,000 acre feet of water diverted for use on 36 Bureau of Reclamation Projects

during 1946, approximately 37 per cent was lost in transit. More than half of the transit loss, or 23 per cent of the total water diverted, was attributed to seepage from canals and laterals. The remaining 14 per cent was lost through waste."

Table I is the result of experiments carried out on Bari Doab Canal by Kennedy which indicates the canal losses in loamy soil in the Punjab area.

TABLE I
Loss by Absorption including Evaporation

Name of channel	Loss of water from 10 ⁶ square feet of water surface (in cusec)
(a) Main line	
Bari Doab Canal where the sub-soil is sandy ...	10.0
(b) All other branches of Bari Doab Canal ...	2.2
(c) On distributaries having constant depths, running steadily...	3.3
(d) On distributaries not running constantly or at constant depth ...	5.9
(e) On village water courses not constant running ...	12.5
(f) Evaporation alone ...	(0.24)
Total loss of items [(a) to (e)] ...	33.9

TABLE II

Nature of soil	Cusec per million square feet of wetted perimeter
(a) Rock	3
(b) Black cotton and loamy soil	5
(c) Alluvial red soil	8
(d) Decayed rock and gravel	10

TABLE III

Table of Absorption Losses in Various Soils

Type of soil	Cubic feet per sq. foot of wetted area in 24 hours	Equivalent cusec per million sq. feet of wetted area
1. Impervious clay loam	0.25—0.35	2.9—3.6
2. Medium clay loam underlaid with hard pan of depth of not over 2 to 3 feet below	0.35—0.50	3.6—5.8
3. Ordinary clay loam, silt soil or lava ash loam	0.50—0.75	5.8—8.7
4. Gravelly clay loam or sandy loam, cemented gravel and sand clay	0.75—1.00	8.7—11.6
5. Sandy loam	1.00—1.50	11.6—17.4
6. Loose sandy soils	1.50—1.75	17.4—20.3
7. Gravelly sandy soils	2.00—2.50	25.2—29.0
8. Porous gravelly soils	2.50—3.00	29.0—34.8
9. Very gravelly soils	3.00—6.00	34.8—69.6

Mr. Hutton's experiments on Ganges Canal losses at various sections are reported to have given values varying from 2 to 11 cusec with an average of 6.3 cusec, while the estimated absorption loss in Indus Valley by P. W. Wood ranged from 3.5 to 10.5 cusec which agreed with the conditions of the Punjab Canals mentioned above. The losses obtained from Sone Canal System also agreed with these.

Seepage losses adopted by engineers in Madras in South India, are as given in Table II for different types of soils normally met with there with the exception of certain tracts in upland areas where the soil is very loose with as high values of seepage as in the Punjab and Uttar Pradesh.

The loss of water by seepage from unlined canals, in general, is enumerated in Table III as per usual soil classification; loss being expressed in terms of cusec per million square feet of wetted area, *i.e.*, area in contact with the water prism.

The values in Table III have been accepted more or less as standard for Indian conditions as the values obtained by actual field experiments have a close agreement with the figures given in the table. Generally a loss of 8 cusec of water per million square feet of wetted area is accepted throughout India.

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There are a number of types of linings named according to the principal material used in practice as enumerated here :

- (1) Stone and wood linings.
- (2) Mortar linings using either surkhi, lime or cement mortar.

- (3) Concrete lining with or without reinforcement and with contraction joints including concrete precast slab.
- (4) Earth material canal linings including soil cement, bentonite, resin and chemical substances such as sodium chloride etc., used for stabilisation.
- (5) Asphaltic canal linings.
- (6) Brick linings including flat tiles.
- (7) Plastic sheet lining being tried in Australia.

The choice of a particular type of lining for a canal is governed by various factors such as (a) availability of construction material at the site or nearby, (b) the type and strength of labour available for the project at reasonable cost, (c) the degree of water-tightness aimed at, (d) the maximum velocity of flow that is desirable in the canal, (e) the life of canal lining, *i.e.*, durability, and (f) the standards of operational and maintenance charges.

Whatever type of lining is chosen, the guiding principle is one of economics involved in the undertaking. A low-cost type of lining with maximum benefits from the point of water conservation, construction, maintenance and operation would naturally be preferred to those whose cost is high for the same benefits. Experience so far gained in India shows that :

- (i) Cement concrete linings are most reliable and durable but more expensive.
- (ii) Linings constructed out of earth materials are cheap but not durable.

- (iii) Asphalt, brick and stone linings, however, stand somewhere in between the two extremes mentioned above.

Faced with the problem of heavy seepage and consequent water-logging in the rich plains of the Punjab after the advent of large canal systems for irrigation, the Punjab Engineers resorted to lining of canals and developed indigenous techniques for this purpose. Amongst various types of linings described already, cement concrete linings, brick and tile linings with suitable cementing material such as cement and surkhi mortar, sandwiched between them as well as overlying the subgrade, have become popular.

Between the two types of rigid linings namely, (1) cement concrete linings, and (2) the brick or the linings with cement mortar sandwiched between them, preference is shown for the latter type as it is found to have the same degree of impermeability coupled with cheapness in first cost as well as subsequent cost for maintenance. Besides this, the construction methods are very easy and quick and manual labour could be largely employed without any help of machinery. The number of joints found in this work provide for numerous hair cracks which minimise the damage to the lining as against the cracks in cement concrete slabs caused by temperature variations.

Extensive experiments carried out by the Irrigation Research Institute, Punjab, regarding the various types of mortars, indicate that degree of impermeability obtained by the use of (1) kankar lime, a locally available product got by burning kankar, (2) one part of cement and 5 parts of kankar, (3) cement, sand and

surkhi and so on, is quite high as compared with the degree of permeability got when pure cement is used. This knowledge has been fully made use of in case of Bhakra-Nangal, Sirhind Feeder and Sarda Power Canal Systems in order to provide low-cost and efficient canal lining to suit an overall economy.

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The Bhakra Main Line, the Narwana Branch, Bhakra Main Branch and the other two branches are all lined with tiles of size 12 inches × 6 inches × 2 inches. The lining consists of two layers of well-burnt tiles with 5/8 inch thick layer of 1 : 3 cement surkhi and sand mortar, sandwiched between the tiles. The bottom layer of brick tiles is laid over 3/8 inch thick cement, surkhi and sand mortar in proportion 1 : 5, cement and surkhi mixed in 80 : 20 ratio.

Wherever the canal passes through soil impregnated with salts, tiles soaked in coaltar are used with richer mix of mortar of 1 : 2 proportion.

The absorption losses in the lined canals are calculated at 2 cusec per million square feet of wetted area as against 8 cusec for unlined canals thus reducing the losses to 25 per cent which amounts to 1,032 cusec of water saved from the entire main and branch canals. This water saved adds 2,30,000 acres to the total irrigated area at a duty of 255 acres per cusec. The extra food-grains from 2,30,000 acres amount to 80,000 tons and the revenue to the State is Rs. 2.1 millions a year.

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Mahi Canal Lining (Bombay)

The Mahi Canal takes off from a weir across the Mahi River and runs for 46 miles, having a capacity

of 7,000 cusec at the head. 36 miles out of these 46 are proposed to be lined adopting two different types of canal linings. The canal section from 7th to 13th mile, where the sub-soil water is higher than the canal bed level, is lined with cement concrete-cum-sandwiched brick tiles with adequate drainage arrangements, the remaining part is lined with sandwiched brick tiles.

Sandwiched Brick Tile Lining

The lined section of the canal at head is 54 feet \times 17 feet with $1\frac{1}{2} : 1$ side slopes and a bed grade of 1 in 7,000 and has a carrying capacity of 7,000 cusec. Red cement mortar has been used for brick tile masonry in lining. Red cement is obtained by replacing 20 per cent of cement by volume with surkhi. Special size, i.e., 12 inches \times 6 inches \times 2 inches bricks are used for the purpose. The design comprises two layers of tiles 2 inches thick with $\frac{5}{8}$ inch thick impervious layer of 1 : 3 red cement mortar sandwiched in between. The bottom layer is laid on $\frac{3}{8}$ inch thick layer of 1 : 5 red cement mortar. The top layer is laid in $\frac{1}{4}$ inch thick layer of 1 : 3 red cement mortar laid over the $\frac{5}{8}$ inch thick 1 : 3 sandwiched plaster. Lining is taken 2.5 feet above full supply level and keyed well into compacted material. Corners have been curved for easy flow of water.

Cement Concrete-cum-Brick Tile Lining

This type of lining is adopted from Mile No. 7 to 13 where sub-soil water level is higher than the canal bed level, the maximum of which is expected to be about 10 feet. Hence 5-inch thick cement concrete slabs of 1 : 3 : 6 with adequate drainage provisions behind it are provided for the bed and up to 100 feet above bed

level on sides. Beyond this point simple sandwiched brick tile lining has been adopted without any drainage provision. The concrete slabs are supported at joints by bed sleepers of size 6 inches × 3 inches. A sand blanket 4 inches thick in bed and graded filter in three layers each of 4 inches thick on the sides are also provided. The drainage system consists of three longitudinal drains one in centre and two at toes, connected by cross drains at 250 feet centre to centre to relieve water pressures under the lining.

The transit losses in this canal have been estimated to be only 1/10 of the unlined section.

* * *

Prospects of Canal Lining in Future Projects

While the quantity of water available in nature is more or less limited, the demand for the same is increasing day by day.

The total annual runoff of India as a whole is plentiful. But it is distributed unevenly over the various States. Irrigation potential of the country depends upon two factors, the available water and cultivable land. A brief study made in this regard reveals that the States of Punjab, PEPSU, Rajasthan, Uttar Pradesh, Saurashtra, Kutch, Mysore, Andhra, Madras and Hyderabad, have more land than water resources for irrigation development. It will generally pay to conserve water by lining future canals in these States as a long range policy.

Once a canal project is built without lining and put into operation, it becomes uneconomical to line the system subsequently.

LIST OF MAJOR LINED CANALS IN INDIA

Sl. No.	Name of Project or Canal	Full supply discharge (cusec)	Length of lined canal (miles)	Bed width (feet)	Full supply depth (feet)	Side slopes adopted	Bed slope	Type of lining	Quantity of material	Cost of lining (million rupees)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12
1.	Bikaner Canal	2,144	84.00	52.0	8.0	1:1	1.3/10,000	Lime concrete (<i>kankar</i>)	33.5 million square feet	7.5	Size of tiles 12" × 5½" × 2½" reinforced with ¼"
2.	Haveli Canal	6,000	50.00	54.0	12.0	1:1	1/10,500	Brick lining	103,660,000 tiles	6.0	steel 12½" × 12½" mesh in sides and 24½" × 24½" in bed in 1:3 cement mortar.
3.	Thal Canal	10,000	2.00	—	15.0	1:1	1/6,666	Concrete slabs	974,000 square feet	0.287	Slabs of 15" × 15" × 5" size were used.
4.	Nangal Hydel Channel	12,500	40.20	80.0	20.6	1.25:1	1/10,000	Concrete	8.27 million square feet	30.249	Cement concrete 3:6 have been used for Nangal Hydel Channel: Part of the work is done with tiles also.

1	2	3	4	5	6	7	8	9	10	11	12
5.	Bhakra Main Line	12,455	108.00	87.0	19.0	1.25:1	1.5/10,000	Brick lining	67.57 million square feet	38.397	
6.	Narwana Branch	4,459	64.00	42.5	16.0	1.25:1	1.5/10,000	Brick tiles in cement mortar	30.57 million square feet	17.744	
7.	Bhakra Main Branch	4,970	90.00	31.1	18.0	1.25:1	1.5/10,000	Brick tiles in cement mortar	36.27 million square feet	24.008	
8.	Sadul Branch	1,244	40.25	—	13.6	1.25:1	1.5/10,000	Brick tiles	10.93 million square feet	6.951	
9.	Tungabhadra Dam Project (Left Bank Hyderabad Canal)	7,000	127.00	84.0	14.0	1:1	1/10,000	Random rubble masonry and precast cement concrete slab	—	28.908	
10.	Tungabhadra Low Level Canal	1,323	4.00	32.0	9.3	1:1	1/10,000	Random rubble	—	—	Portions of the canal are lined.
11.	Sarda Sagar Project	7,500	53.00	93.0	11.5	1:1	1/6,666	Burnt clay tile	—	29.78	Proposed to be lined
12.	Mahi Canal (Right Bank)	7,000	46.00	54.0	17.0	1.5:1	1/7,000	Partly brick and partly cement concrete lining			

**Note on the proposal regarding the inclusion
of the subject of flood problems and
their control in the activities of the
international commission on
irrigation and drainage**

by

KANWAR SAIN, I.S.E.,
Vice-President, International Commission on
Irrigation and Drainage.

The writer of this note put up a suggestion to the Council at its Seventh Meeting held in Madrid in June 1956 that, in view of the increasing importance of the flood problems in our economic and political life all over the world and consequently the urgent need of pooling and disseminating knowledge and experience gained in different countries for tackling these problems properly, the subject of 'Flood Control and their Problems' be included in the activities of the International Commission on Irrigation and Drainage. This suggestion met with a favourable response from the delegates of the different countries who met in Madrid and there was unanimity of view that engineering problems relating to 'Flood Control and River Training' should be included in the scope of the activities of the Commission and it was agreed that there should be a clear definition of the work which the Commission should undertake in order that it did not duplicate the work of other international organizations. A Sub-committee of which the writer is a member was formed to consider the matter

and to report on the subject by 'the end of the year 1956' with proposals for amendment to the Constitution, if necessary.

The Sub-committee appointed by the Council met in Grenoble in July 1956 and the writer was asked to amplify his initial proposal so as to elucidate both the broadening of the activities of the Commission as contemplated and also its limitations.

This note analyses, in brief, the problems of 'Flood Control and River Training' and reviews the work being done on them by other interested international organizations and the matters that have received international cooperation so far and which it is recommended should be included in the activities of the Commission. Lastly proposals regarding the amendment required in the Constitution of the Commission have also been made.

Flood Control Problems

The Flood Control problems can mainly be divided into the following three categories :

- (1) Study of the hydrologic aspects of floods ;
- (2) Flood Control Planning and Design ; and
- (3) Relief and Rehabilitation.

Category (3) relates to the humanitarian aspect such as relief measures to flood victims which are not the responsibility of the engineering profession and will not be discussed here.

(1) *Study of the Hydrologic Aspects of Floods* relates to basic studies of causes (rainfall, snow melt, runoff, physiographic factors etc.), statistics and development of

floods with regard to all the factors and conditions which can effect them.

(2) *Flood Control Planning and Design* aims at protection of cities and towns from flood damage and of agricultural lands from overflows and the utilisation of these seasonal surplus waters for useful purposes. In fact, in arid and semi-arid regions, flood control planning and design often forms an integral part of unified river basin development. Its various aspects include :

(i) *Soil and water conservation measures* — Rational use of forests, correct grazing of pastures, improved cultivation practices, crop rotation, adequate drainages etc., which greatly help in controlling medium and low floods.

(ii) Rationalisation of land use practices in the flood plains.

(iii) Location, design and construction of flood detention reservoirs or storage reservoirs.

(iv) Construction of levees and embankments along the river to prevent the floods from overtopping.

(v) Provision of secondary channels to deal with the excess water such as natural and artificial diversion channels and spillways.

(vi) *Study of river behaviour and its training*— This aspect not only covers flood prevention works such as flood gates, river mouth fixation, cut-offs but also deals with the problem of transportation of sediments in rivers, river works to direct and guide the water flow in a specified direction, training works and channel improvement and related works for navigation purposes.

(vii) Utilisation of flood for recharging underground basins.

Having listed the various aspects of flood control and river training problems, it is now essential to examine range of activities of international organizations concerned with these subjects. These organizations are :

- (a) Bureau of Flood Control and Water Resources Development of the ECAFE.
- (b) International Association of Hydrology.
- (c) Permanent International Association of Navigation Congresses.
- (d) International Association of Hydraulic Research.
- (e) International Commission on Large Dams.
- (f) Union Internationale de Secours.

In a brief supplied by Prof. Danel regarding the range of their activities the writer has added the list of subjects discussed at the Symposium on Floods held at Dijon in September 1956 under the auspices of the International Association on Hydrology, from which it is clear that this body does not deal with the question of flood control. It will be seen from this note that (a) the Bureau of Flood Control and Water Resources Development of the ECAFE includes in its activities almost all aspects of flood control and river training problems but its limitation is that it is an inter-governmental regional body and does not cover all parts of the globe; (b) International Association of Hydrology mainly deals with hydrologic aspects of floods but its members sometimes in their papers also cover the location of flood control structures and their effects; (c) Permanent

International Association of Navigation Congresses and (d) International Association of Hydraulic Research have studied the flood control problem casually to a limited extent ; (e) International Commission on Large Dams encourages progress in the design, construction, maintenance and operation of large dams and *inter alia* deals with hydrologic aspects of floods in designing the capacities of the spillways ; (f) Union Internationale de Secours aims at collecting scientific data which may be helpful in research and there is no single international body which takes care of all aspects of flood control training problems. As drainage and flood control are closely related subjects and irrigation projects are generally associated with flood control measures it is in the fitness of things that the Council at its Madrid Meeting expressed itself in favour of broadening the scope of the International Commission on Irrigation and Drainage by including in its activities those aspects of flood control and river training problems not dealt with by other international organizations.

It is, therefore, recommended that the following aspects of flood control and river training problems be included in the activities of the Commission :

- (1) Flood control planning and design excluding study of design and construction of large dams, and soil and water conservation measures not connected with irrigation and drainage practices.
- (2) River behaviour, training and control.

The writer would, however, like to record that sometimes it is very difficult to discern between hydrologic aspects of floods and engineering aspects and the

author of a paper may deal with both of them at the same time. With a view to promoting the technique and practice of flood control it is essential that there should be a close cooperation among all the interested bodies and the representatives of one should be invited to the technical sessions of the other and *vice versa*.

Amendments to the Constitution

At the Madrid Meeting some members expressed the opinion that the word "Drainage" already included "Flood Control" but the writer differs from the view as "Flood Control Planning and Design" implies more than that conveyed by the word "Drainage". It is therefore, important that the word "Flood" should be incorporated in the name of the Commission which it is suggested should be changed to "International Commission on Irrigation, Flood Control and Drainage". Further the objects stated in Article 1 of the Constitution should be amplified so as to make them include the subject of flood control, planning and design and river behaviour, training and control. The proposed revised text of Articles 1 & 2 of the Constitution are given below :

Proposed Revised Text of Article 1 of the Constitution

The purpose of the International Commission on Irrigation, Floods and Drainage hereafter called the Commission is to stimulate and promote (a) the development and application of the science and technique of irrigation and drainage in the engineering, economic and social aspects, and (b) progress in the technique of flood control planning and design and the knowledge of river behaviour, training and control. The objects include : (i) all matters relating to planning, financing

and economics of irrigation and drainage undertakings for the reclamation and improvement of lands as well as the design, construction and operation of appurtenant engineering works including canals and other artificial channels for various purposes for irrigation and drainage, (ii) study of the location of all engineering structures for flood control and all matters (except relating to the large dams and soil and water conservation measures not related to irrigation and drainage practices) relating to their planning, financing, economics, design, construction, operation and maintenance, and (iii) study of river behaviour, training and control and all matters relating to planning, financing, economics, design and construction, and operation of appurtenant works.

Proposed Revised Text of Article 2 of the Constitution

The Commission will accomplish its objects by

- (a) interchange of information between its several National Committees ;
- (b) holding periodical meetings ;
- (c) organising studies and experiments ;
- (d) publication of proceedings, reports and documents ; and
- (e) cooperating with other international organisations, whose interests and activities are related and are in harmony with its objectives and for the purpose permanent connections and interchanges shall be established.

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