

**CENTRAL
WATERPOWER
IRRIGATION & NAVIGATION
RESEARCH STATION**



**CENTRAL WATERPOWER IRRIGATION AND
NAVIGATION COMMISSION, NEW DELHI**

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HISTORY

~~PROBLEMS~~ On hydrodynamics, river training, navigation, soil mechanics and others of considerable importance and use to the design, construction and rigid economy of river-valley projects in India and of the principal waterways and harbours of this country are carried on at Khadakvasla at the Central Waterpower, Irrigation and Navigation Research Station (CWINRES) near Poona. Within a half-hour's drive from the city the Station is located below an irrigation dam on the Mutha river with a plentiful supply of water for experimentation on reasonably large working models.

CWINRES had its humble beginning as far back as 1916. It started as a Special Irrigation Division of the Bombay Provincial Public Works Department. Research on local problems of land drainage, reclamation and hydrodynamics was assigned to this division. The successful solution of the problems prompted the Bombay Govern-

ment to raise it in 1920 to the status of a Hydrodynamic Research Station.

This Station was opened at Distributary No. 5 of the Mutha Right Bank Cana near Hadapsar (Poona). For the design and construction of the Sukkur Barrage and canals of Sind (which was then a part of the Bombay Province) a considerable volume of useful work was carried out by the Station. By 1925, however, the activities had far outgrown the very limited water supply of eight cusecs. Large working models of syphons were therefore constructed below the Lake Fife at Khadakvasla, where exceptionally good facilities for this class of work were available. By 1934 the entire Station was moved to Khadakvasla. The Station was directed at this stage by Mr. (now Sir) C. C. Inglis.

The Research Station had by now amply established its usefulness. It had been shown that lakhs of rupees could be saved in the construction of engineering projects initially by experimenting on scale models and perfecting the design by repeated trials to suit the requirements.

For without such experimentation it is clear that either the design will not be perfect or alterations on the full scale project will be far too expensive, or the allowances and margins of safety will be unnecessarily large and, therefore, not strictly economical.

The Central Government decided in 1937 to take over the Station so as to be in a position to place its services at the disposal of the entire Indian territory. Irrigation and river-training research were added on to the subjects undertaken by the Station and it was renamed as the Indian Waterways Experiment Station. By 1947 it was evident that the facilities and laboratory equipments of the Station were too meagre to cope with the demands for research of the various problems connected with the post-war projects in India. Accordingly a scheme of expansion and re-organisation was sanctioned by the Central Government.

Under the new scheme the Station would undertake the solution of problems relating to:

i) River and Canal Hydraulics;

- ii) Navigation;
- iii) Soils and Soil Mechanics;
- iv) Concrete and Materials of Construction;
- v) Mathematics;
- vi) Statistics;
- vii) Physics;
- viii) Chemistry;
- ix) Hydraulic Machinery.

Early in 1948 the Research Station was transferred to the administration of the Central Waterpower, Irrigation and Navigation Commission and was renamed the Central Waterpower, Irrigation and Navigation Research Station.

Equipment and Installations

The supply of water for models at the CWINRES is obtained from Lake Fife through nine low-level sluices. This lake has a catchment area of 196 square miles, and impounds 3,000 mill. c.ft. of water. As it is discharged into the canal after use, five hundred cusecs of clear water, free of silt, is available free of charge, in adequate quantities at a head of up to 60 feet in the rainy season, and up to 25 feet in other seasons.

The Station covers an area of 130 acres, of which 100 acres of land have recently been added to cope with the projected expansion to meet the demands of the various new projects of the Central and State Governments. Standard methods for measuring discharges and taking velocities are used for model studies. The discharge-measuring devices include Standing Wave Flumes, Rehbock Weirs and Triangular Notches. Pitot tubes and floats are used for determining velocities. Special devices have been developed for the production and recording of tides and waves. We have not given a detailed description of the apparatus.

Work of CWINRES

Apart from the numerous problems undertaken before 1938, nearly 150 important investigations involving more than 2,000 experiments have been carried out during 1938-48. These include measures for protection against breaches and floods in rivers; prevention of excess sand entering canals; training of tidal and non-tidal waters; evolution of a number of important principles in connection with attracting, deflecting and repell-

ing spurs or pitched islands for controlling and training rivers; factors determining the size and shape of meanders; relation between rainfall and run-off; effect of sand and silt washed into the rivers when hill denudation occurs; the rate of silting of reservoirs; laws governing the movement of sand, and factors affecting accretion and retrogression in rivers; littoral drift; the technique of model experimentation, model limitation and their correct interpretation, etc.

As a result of the experience gained from model studies and inspection of actual works, advice is now given in many cases without the aid of model experiments. Such cases in fact outnumber the problems tackled with models. Models are now used only for the more intricate and essentially new problems.

The cumulative effect of the researches conducted at the CWINRES since its inception more than 30 years ago and the application of the results in the field have led, it may be easily imagined, to the reduction in the expenditure and maintenance of projects by crores of rupees, and

incidentally enhanced their usefulness, efficiency and length of useful life.

Detailed accounts of the investigations conducted at the CWINRES are described in the Annual Reports issued by the Station.

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IRRIGATION AND RIVER TRAINING

MODEL studies on barrages, canal falls, railway and road bridges and river training have revealed the importance of curvature of flow which mainly governs the behaviour of engineering structures. Thus the canals taking off from concave banks draw only sand-free top water. Damage below falls is due to unfavourable rollers with horizontal and vertical axes, which lead to the undermining of pavements and severe side erosion. Scour round bridge piers is due to the water diving at the nose and causing curved flow near the base.

A proper appreciation of the flow conditions and velocity distribution is possible only with the help of models, and has led to better control and greater efficiency of engineering structures.

Rivers can be trained by properly located spurs, guide banks, etc., after due consideration of the river curvature. Some of the specific problems investigated at the Station are described in this chapter.

IRRIGATIONAL PROBLEMS

Control of Sand by Curvature—Barrages

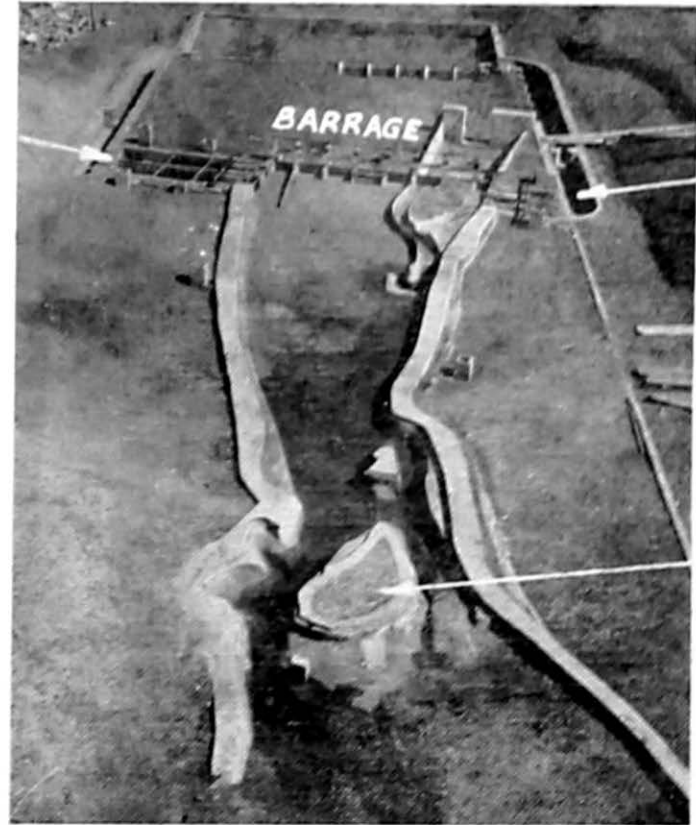
Lloyd Barrage—In 1928 hydrodynamic problems relating to the Lloyd Barrage and Canals at Sukkur were referred to the Poona Station. Basic and specific experiments conducted in this connection were:

- a) 'Still Pond Running' versus 'Open Flow';
- b) Effect of raised sill of a canal regulator on the quantity of sand drawn by the canal;
- c) Design of pockets upstream of barrages

to produce favourable curvature for sand exclusion;

- d) Location of the off-takes for the canals;
- e) 'Diverging Guide Banks' *versus* 'Divide Walls at right angles to the Barrage';
- f) Necessity of maintaining correct velocity ratio inside and outside the pockets for sand control;
- g) Effect of divide walls having a flat-battered and a steep-battered nose on sand exclusion;
- h) Distribution of sand entering a series of canals upstream of a barrage;
- i) Scour at the nose of divide walls and its effect on sand entering the canals.

In Still Pond regulation, the undersluices are kept closed when canals are open, whereas in Open Flow some undersluices are kept open. Though Still Pond running was more successful, either method was suitable for the left bank canals taking off from the concave side; but Still Pond gave markedly better sand exclusion from the right bank canals. Predictions were fully confirmed when the canals were opened.



Model of the Lloyd Barrage at Sukkur

By 1939 large expenditure had to be incurred on sand clearance of the canals and that of the right pocket of the river. The bed of the river on the right bank had by then got badly silted up. The solution recommended consisted in the construction of an approach channel, about 5,000 feet upstream of the barrage, from which the supply for the canals would be drawn off over a raised sill at a point 2,250 feet above the barrage, the rest of the water and most of the bed sand flowing down the tail channel. The success of this suggestion has helped to maintain the discharge capacity of the canal, the reduction of which would have otherwise caused a loss in revenue, as well as in the consequent fall in crop production running into lakhs of rupees.

Lower Sind Barrage—This Station has emphasized that the successful working of a barrage—particularly in respect of sand exclusion from off-takes—depends primarily on its location. It is only when the natural meander length of a river is not taken into consideration and an unnatural distorted curvature is imposed at the very point where for efficient sand

exclusion it is essential to have natural curvature, that sand excluders, ejectors and islands are required for satisfactory exclusion. The design of the Lower-Sind Barrage at Kotri was evolved at the Station on these principles.

Canal Off-takes and Headworks

Mithrao Canal—The most notable example of controlling sand by favourable curvature of flow is that of the Mithrao Canal in Sind. The canal derives its supply from the Eastern Nara above Makhi Regulator. Before the Lloyd Barrage came into operation, the Mithrao Canal off-take was located on the concave side of a bend in the Nara, then a river drawing its supplies from the Indus; with the Lloyd Barrage project, the Eastern Nara was canalised and given a controlled head above the barrage, and the Mithrao Canal was made to take off from a straightened canal. Owing to scour in the Nara, and an unsuitable off-take from a straight reach, coarser sand than previously drawn began to enter the Mithrao in 1932, the previous

drop into the canal of 1 foot 6 inches at full supply discharge gradually disappeared, and the command was lost.

Experiments were therefore carried out to determine how to exclude sand from the Mithrao Canal. On the basis of these, it was recommended that the old river bed should be partly re-opened to carry water to the Makhi Regulator and the Khipro Canal, the existing straight canal after reduction in width should be used as an approach channel to the Mithrao Canal. This lay-out was such that the approach channel took off where the beneficial effect of curvature was at its maximum, so that only the top water containing only fine silt entered the Mithrao Approach Channel and the Khipro Canal, the heavy bed sand being deflected into the river downstream.

The adoption of this recommendation restored the 'command', and the drop into the Mithrao at the Head Regulator gradually increased to a foot and six inches.

'Sand-excluding' heads for the two canals of the

Dehri-on-Sone Anicut (Bihar) were similarly designed with the aid of model experiments by artificially creating a favourable curvature of flow.

Alluvial Channels

It is well known that many alluvial channels diverge from their regime according to the Lacey Theory. A considerable amount of work has been done at the Station, both by analysing the hydraulic data of channels in Northern India and by model investigations on the subject.

Analysis of the data clearly shows that the new silt factor f_m which is connected with the Lacey Silt Factors f_1 and f_s is constant, irrespective of whether the sand load is equal to the regime load or not, and is equal to $\sqrt{f_1 f_s}$.

The shape and slope of a canal depend to a marked extent on the quantity of sand normally passing down the canal. For designing the new proposed canals in the Lower Sind Barrage Project the data on existing canals, *viz.*, Jamrao, Rohri and Dadu Canals were considered, the



SCOUR ROUND BRIDGE PIERS

Dry bed of the Model after a typical run in the series of experiments done in connection with investigations regarding scour round piers of bridges

designs being based on the assumption that excess sand has been excluded at the head of the parent channels.

The formulae worked out to

$$S=0.22'Q^{0.185} \quad B=1.24 Q^{0.30}$$

where B is the bed width of the channel and $Dk=0.90 Q^{0.30}$ where Dk is the depth over the central portion of the channel.

Side slopes of $1\frac{1}{4}/1$ were recommended for discharges exceeding 300 cusecs and $1/1$ for discharges less than 300 cusecs.

Canal Falls and Flumes

While designing the Lloyd Barrage Canals, it was found that none of the standard canal fall designs was satisfactory. A new type 'the proportional, standing wave flume meter fall, with a baffle and deflector' was evolved. This design, combined with a regulator, is cheaper than any known alternative and works efficiently even where, as a result of scour, heavy retrogression has occurred further downstream. It is also a very accurate meter. Hundreds of these falls

have been constructed and have worked satisfactorily.

Protection of Weirs

Numerous investigations on models have been made and solutions suggested for dissipating energy below ill-designed flat weirs, which had been threatened with disaster by deep adjacent scour holes and undermining.

Protection of Bridge Piers

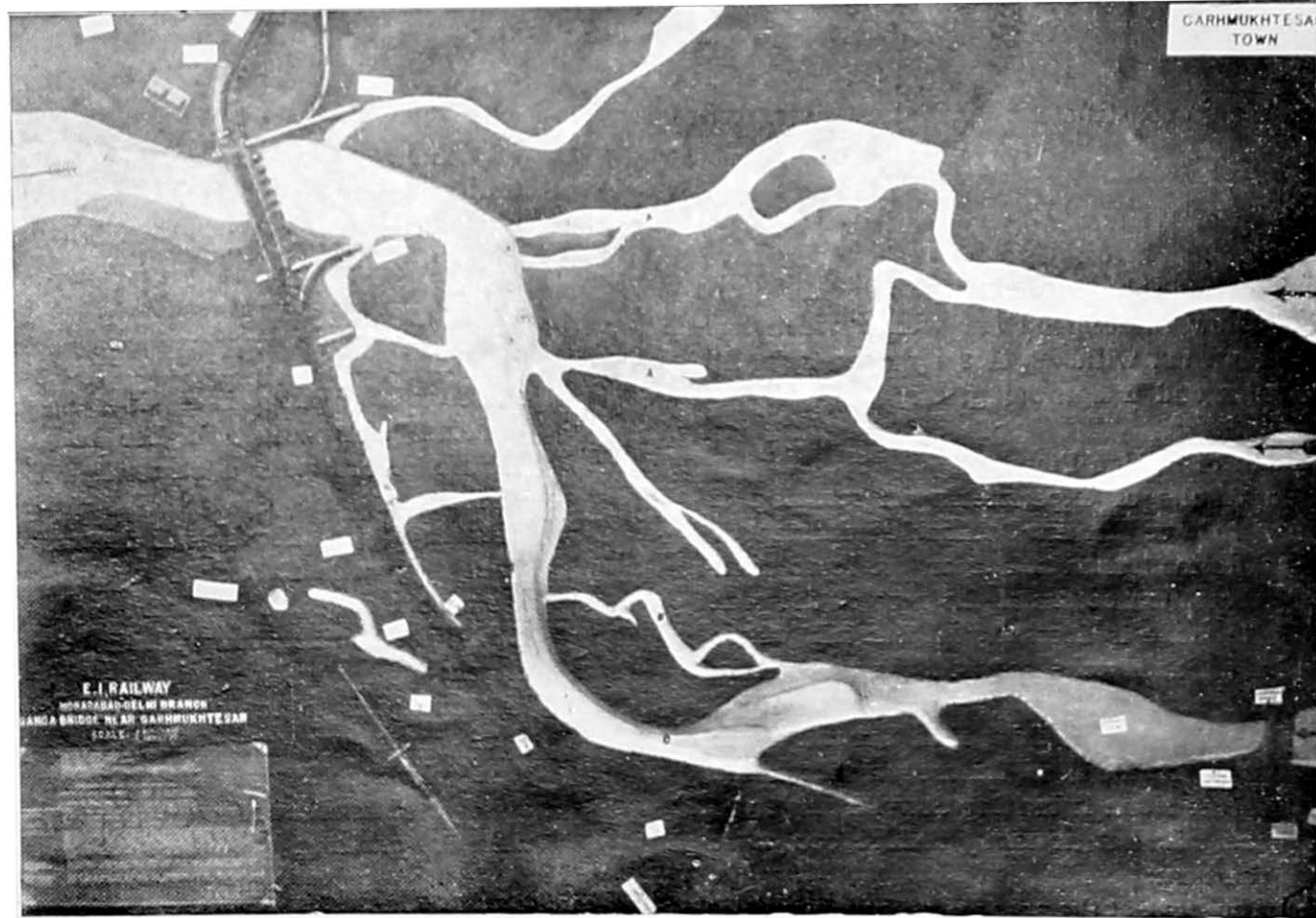
The results of experiments on scouring of bridge piers have furnished valuable information:

- i) The maximum attack on the loose stone protection occurs at the nose of the pier. No stone is necessary at the tail, where sand and stone scoured from upstream are deposited;
- ii) Where stone pitching is laid round a pier at too high a level, failure may occur due to the stone launching downstream from the tail; but normally failure occurs at the nose;
- iii) The stone at the nose remains undisturbed until the attack reaches a critical stage,

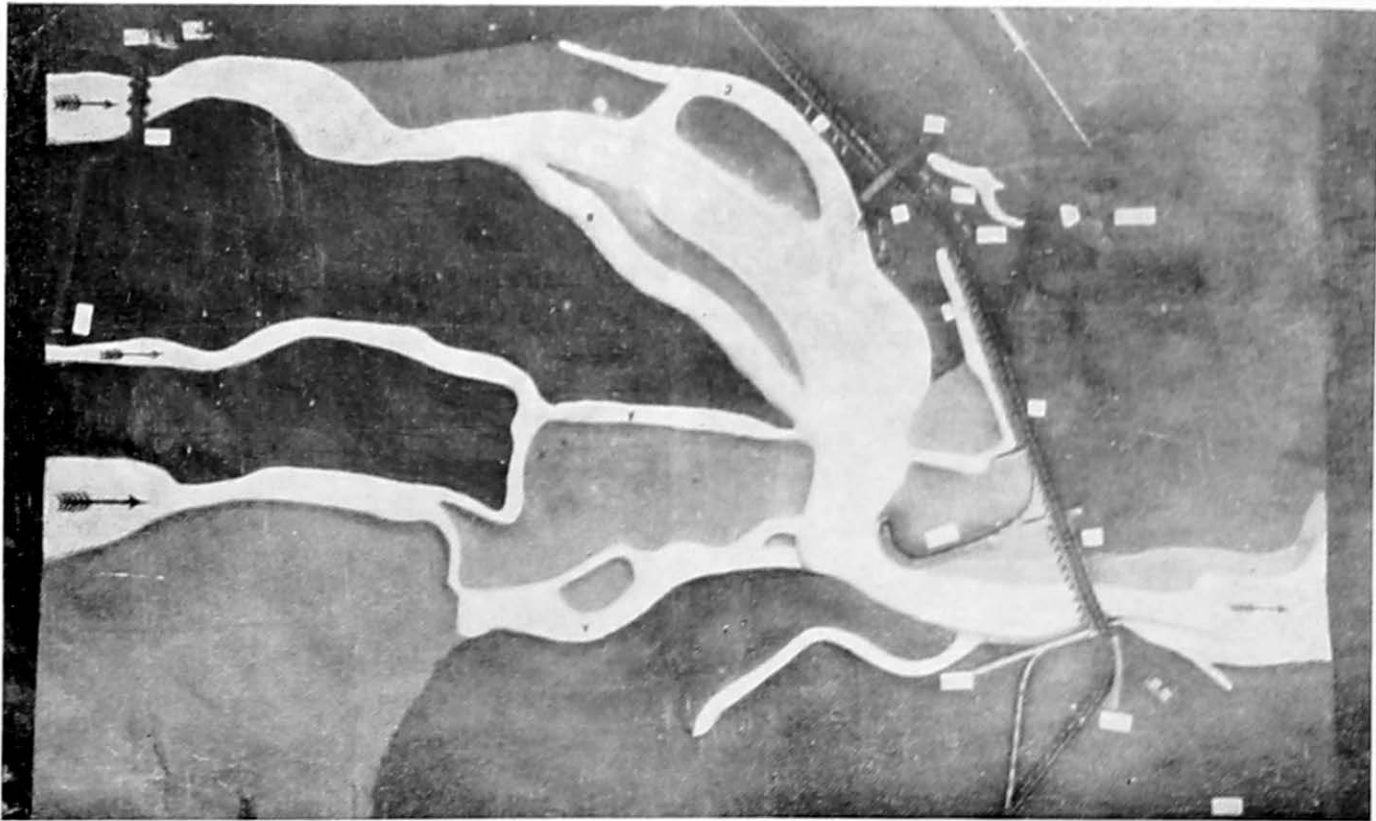
when the stone suddenly begins to be carried away and a deep scour pit rapidly forms, reaching a depth nearly as great as if there had been no protective stone;

- iv) The greater the depth at which the stone is laid, the more stable it is;
- v) The level of the river bed appeared to have little effect on the discharge which causes failure; but such effect as there is, indicates that with a higher bed-level, failure occurs with a somewhat lower discharge;
- vi) Because of (iii) above, it is necessary to place the stone at such a level, and to use a stone of such a size and weight, that it will not be disturbed with the severest attack;
- vii) If a bridge is to be newly built, it is a good practice to take down the pier foundations sufficiently deep below the anticipated maximum scour and do away with the pitching.

All the available data on the depth of scour at heads of guide banks and groynes, pier noses

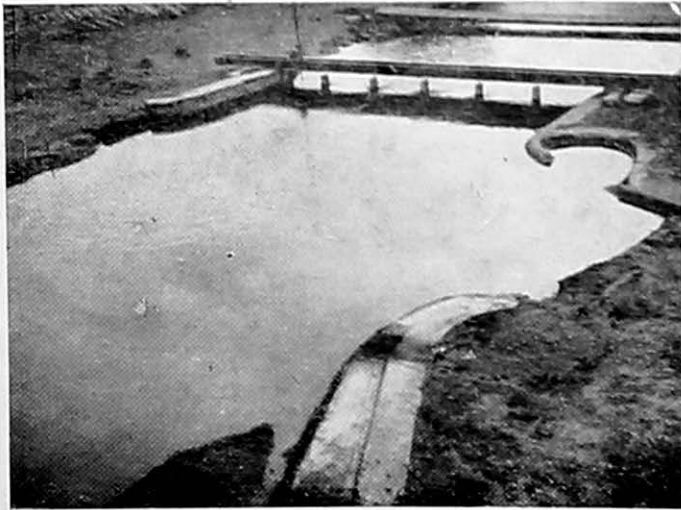


GANGA AT GARHMUKTESWAR BRIDGE
Model before protective works were carried out. River
approached dangerously near the railway track



GANGA AT GARHMUKTESWAR BRIDGE
Model showing the extended left guide bank and conditions after 1949 flood season

and downstream of bridges show that the scour is due to the abnormally high bed velocity of the discharge, so that V^2/d (where V is the velocity and d is the depth), which is related to turbulence, is very high. A definite correlation exists between the scour depth and the Lacey's Regime Depth (defined in terms of discharge and the silt factor).



Model of the Ganga and Hardinge Bridge (1918)

These findings have been applied in designing the prior protection of several bridges. The typical case of the Hardinge Bridge over the river near Calcutta is described here.

The Hardinge Bridge, 200 miles north of Calcutta, is about a mile long, and cost five crores of rupees. Constructed in 1915, it carries the main line of the Bengal and Assam Railway over the Ganga. It was protected upstream and downstream by pitched guide banks. The main current there was along the left bank of the river at the bridge; but gradually it changed its course towards the right bank. In September 1933, the flow along the right bank became so intense that it caused a slip in the bank, thus creating a gap in the guide bank itself. This gap rapidly widened and the river threatened to outflank the bridge. It was temporarily repaired after many train loads of stone had been thrown into the gap, and nearly a crore of rupees was thus spent in two years. On an approach to the Railway authorities a long series of experiments conducted at the Station showed that the conditions which led to the breach were due to severe action caused

by the Sara Protection Bank, 19,000 feet upstream of the bridge on the left bank and accentuated by the Damukdia Guide bank, 11,000 feet upstream of the right bank. These banks turned the high velocity flow into a fiercely eddying, surging flow which undercut the right guide bank and so caused a serious slip, which later developed into a breach.

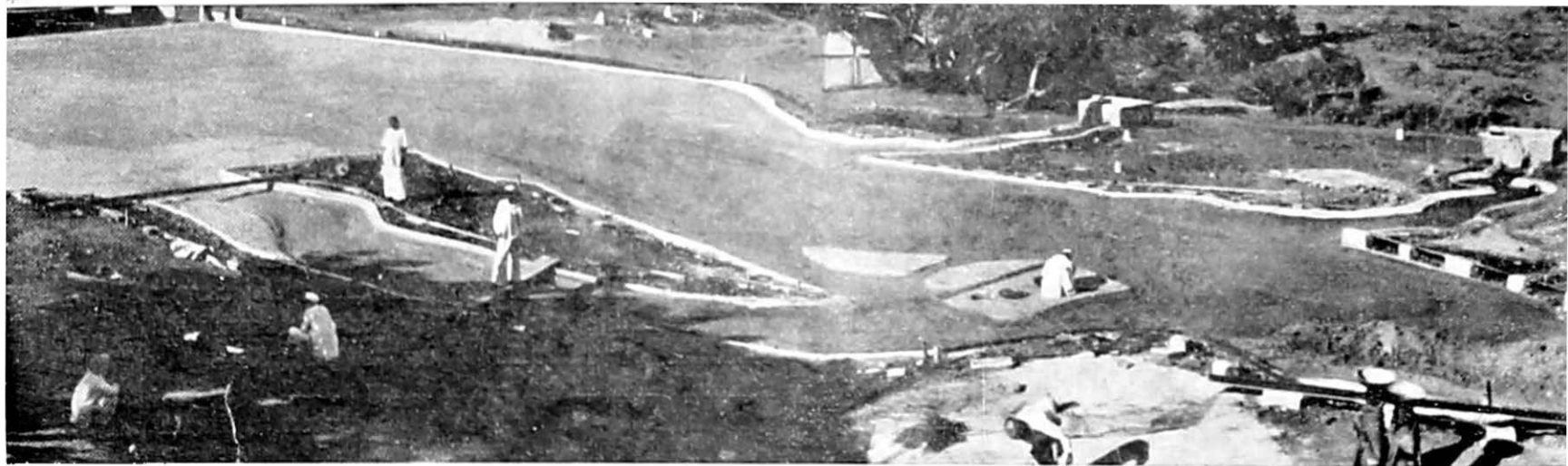
Out of the alternative remedial measures suggested by the Station, the cheapest one, *viz.*, removal of stone from the Sara Protection Bank, was adopted. It had been predicted that by this measure, the attack would cease in eight years. And this actually occurred in nine years.

River training

In most of the major alluvial rivers of India the problem of bank erosion and bed scour have exercised the minds of engineers. Many of India's large towns and cities are situated on the banks of these rivers, obviously because of the water-supply facilities they afford. For the same reason very valuable properties and estates have been developed along them. The land on the banks are

formed due to depositions of water-borne silt and are, therefore, very fertile and cultivated intensively. Arresting the damage caused by the vagaries of rivers has therefore become of prime importance and the Station has achieved a great deal in solving such problems with the aid of models. Mainly the training works recommended consisted of different types of groynes—permeable, impermeable, attracting, repelling, submerged, etc.—vanes, guide banks, and artificial islands. As a typical example of preventing bank erosion, the problem of the Rupnarain River is explained here.

The Rupnarain, a tidal river crosses the B. N. Railway some 85 miles from Calcutta. Since 1938, the river was eroding its left bank, and in 1943 approached dangerously near the railway line to within 1,500 feet. The railway officers suggested a series of small groynes to protect the left bank. But this proposal was objected to by the Station, as the short groynes would have developed a permanent deep channel at their heads along the left bank. Two alternatives were, therefore, suggested by the CWINRES:



- a) A long curved head, upstream of the bridge; or
- b) A repelling groyne, 1,100 feet long on the left bank, pointing 60 degree upstream.

These were tested in tidal models and were found to give satisfactory results. The Railway accepted the second alternative, that was easier of construction. This was completed in 1944, and the safety of the bridge and the railway embankment has been thus ensured. Substantial shoaling has occurred near the left bank (over 12 to 18

feet deep extending to a width of 5,000 feet opposite the groyne) and the main flow is well away from the railway line.

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DAM ENGINEERING RESEARCH

THE CWINRES has carried out numerous model investigations on problems relating to syphon



Model of Hooghly Estuary

spillways, weirs, outlets, etc. A description of the more important ones is briefly given here.

Syphon Spillway

The full scale 520-cusec model, operated during 1924-29, deserves special mention. It was the first large scale syphon study in India. It revealed many interesting facts regarding the action of syphons at a time when the laws of syphon flow formed a very obscure subject. The experiments showed that for the distribution of velocities in a syphon bend, the free vortex law

was a sound working basis to adopt, though the distribution of velocities based on theory is not quite attained in actual practice. The pressures in a syphon bend were found to agree closely with the pressures computed on the basis of the free vortex law for velocity distribution and with the Bernoulli's Theorem, provided the model is sufficiently large. The model clearly demonstrated the harmful effects of excessive negative pressures and indicated the necessity of restricting the negative pressures in a syphon. Smaller scale models were also constructed of the same

syphon to establish the validity of laws of similitude for syphons. Similitude was very well borne out by the investigations, particularly regarding the co-efficient of discharge and pressure distributions. In respect of priming depths, however, the larger models were found to prime at relatively lower depths.

Experience gained on the 520-cusec syphon



Model of 520-cusec Siphon Spillway

was utilised with advantage for the study of the Jamshedpur Syphon Spillway. The syphon units were designed for a discharge of 40,000 cusecs. A novel feature of the design, based on a model study, was a baffle wall downstream of the syphon which acted as a water seal and also aided the formation of a hydraulic jump.

Vaitarna Dam Spillways

In connection with the Vaitarna Dam, proposed to be constructed at Vaitarna to cope with the increased demand for water supply to the city of Bombay, an experimental study was made on (a) the type of waste weir, and (b) the value of the co-efficient of discharge to be adopted in working out the depth of flood for passing the maximum flood discharge.

After considering the various proposals of having syphon spillways, central overflow type and flank spillways with due regard to their feasibility under the geological conditions and hydraulic features, it was concluded that the Ogee type central spillway with a high co-efficient weir was the most economical.

According to the fan catchment formula, developed by the CWINRES, the maximum expected discharge worked out to 92,000 cusecs, and the waste weir was designed to surplus it through a length of 280 feet, clear overflow under a head of 20 feet over the crest. There will be three piers, each 14 feet wide to support the automatic gates which will be installed at a later stage.

The experiments carried out on this problem are:

- a) Development of the shape of the waste weir to give maximum co-efficient of discharge;
- b) To devise effective measures for scour protection downstream of spillway;
- c) Determination of pressures on the spillway profile; and
- d) To evolve a suitable design of downstream guide walls to localise the flow into the narrow bed of the river.

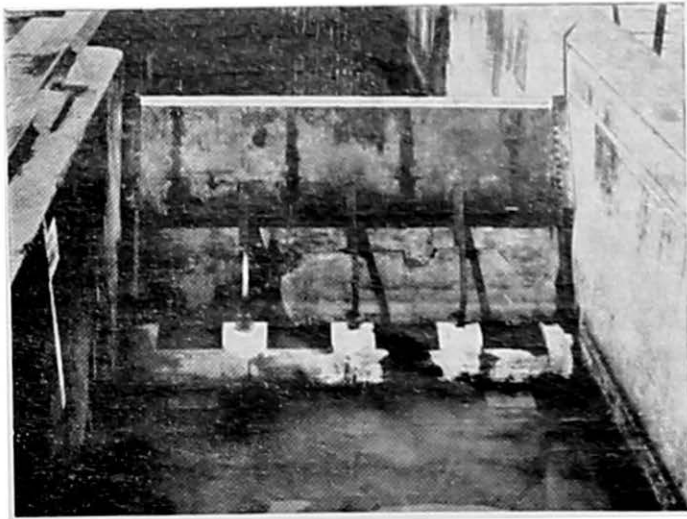
Different scale models, viz., 1/30, 1/40, 1/50, and 1/60, were used for various studies and for

eliminating the scale effect. For dissipating energy below the spillway, various methods were tested, viz., upward curved buckets as well as a hydraulic jump provided by a stilling pool with a subsidiary weir downstream, etc., were tried. Spiltters located on the face of the spillway profile to bring about the desired dissipation were also tried. As a result of basic research conducted on the problem, a new design of bucket-type spiltters with a ledge was evolved which is very efficient in securing bed protection downstream. Side warps and a special design of side-buckets were used on the face of the spillway and the downstream guide-walls were shaped with a hyperbolic contraction curve in order to concentrate the flow in the central parts and converge it to localise within the narrow bed of the river. The downstream flow conditions were quite normal after the energy was dissipated.

Kosi Dam Spillways

Kosi Project is a multi-purpose scheme, its salient features being flood control, hydro-electric generation and irrigation. The dam is proposed

to be constructed on the river Kosi in Nepal; its maximum height above rock will be about 780 feet. The problem of studying experimentally the design of the spillway crest, pressures on spillway profile under a head of 40 feet over the crest and prevention of scour downstream was referred to the Research Station. Experiments have been performed on 1/125 and 1/72 scale



Half-scale Model of Tansa Gate (seen from upside)

models of the central overflow spillway. The area of catchment is 23,808 square miles and a superflood discharge of 956,000 cusecs (1,000 years' flood) was estimated at the proposed dam site as compared to the peak discharge of 705,000 cusecs on record in 1927.

The flood disposal scheme involves the use of three overflow spillways, two on each side and one in the centre (the net length being 945 feet). Besides there are three tiers of 12 sluices each located in the central portion of the spillway and the deep-seated sluices.

Overflow Spillways

In certain instances it is essential that large quantities of water should be discharged with a small depth over the crest, so that the crest may be set at a higher level for increasing the storage capacity without raising the maximum flood level above safe limits.

Basic experiments were carried out, and a weir profile has been evolved which gives a co-efficient of discharge as high as 5.5 in the formula, $Q = C.B.H.^{3/2}$

The capacity of the Lake Arthur Hill which stores water for Pravara Canals in the Western Ghats (Bombay) was in excess of the demand when the dam was constructed in 1926. In 1935 the demand exceeded the supply, and the problem for increasing the storage capacity of the lake was referred to the Station. The existing waste weir consisted simply of a cut, 750 feet wide, through the rocky saddle of the hill which forms the right flank of the gorge. The water was stored only up to the sill level of the cut which was ten feet below the maximum safe level for the dam.

From a study of the conditions prevalent at the dam site, the proposal for installing automatic gates or syphon spillways was not found quite suitable. A design of a high co-efficient weir was, therefore, drawn up on the basis of results of model experiments at the Station.

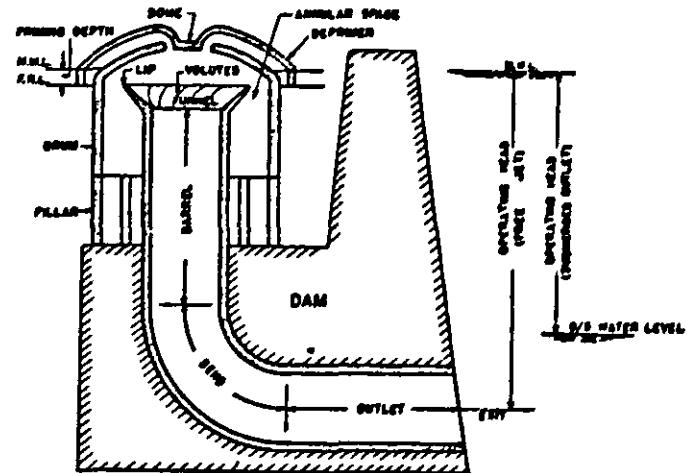
Weir Crest Gates

The data necessary for the design of the tilting type automatic gates were collected and experiments on a half-size, geometrically similar, scale model were carried out. Gates designed on the

basis of these experiments are installed at Tansa Weir and have worked for the first time during the 1949 monsoon to the satisfaction of the authorities.

Volute Syphons

In Mysore an ingenious type of syphon known as the 'Volute Syphon' designed by Shri Ganesh Iyer was developed. The Volute Syphon consists of a shaft terminating in a funnel covered by a



Components of a Volute Syphon

hood consisting of a cylinder and a dome. The hood is generally supported by columns resting on a high masonry platform constructed on the upstream side of a dam forming its integral part. At a suitable distance below the funnel the shaft is turned through an angle of 90 degree by a large bend and carried through the platform and the dam to end as an outlet on the downstream face of the dam. The funnel is provided with a number of low, curved vanes which deflect the water flowing over the periphery of the funnel, during priming, thus producing spiral flow. The Volute Syphon has been found to prime at depths far lower than the corresponding saddle syphon, presumably because of the spiral flow. The hydraulic characteristics are found to be excellent, yielding a co-efficient of 0.80 as against 0.72 in a saddle syphon. In 1945 investigations on the effect of spacing of volute syphons and elevation of the platform floor on the discharge co-efficient of syphons was carried out with the help of 1/24 and 1/10, geometrically similar, scale models. Distribution of pressure in various parts of the syphon was also investigated.

A later study carried out with the help of 1/10; geometrically-similar, scale model showed that erosion below syphons cannot be reduced by impact of jets issuing at an angle from adjoining syphons. Spreading of jets by dispersers and tilting up the jet by a sloping ledge at the outlet, on the other hand, was found to be quite effective in the reduction of scour.

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NAVIGATION

SPECIAL attention is paid by the CWINRES to problems relating to the navigability of rivers and canals, of estuaries and harbours. Model investigations are carried out for the solution of such problems. At present the CWINRES has three models for experimentation :

- 1) Cochin Harbour
- 2) Madras Harbour
- 3) Hooghly Estuary

Cochin Harbour

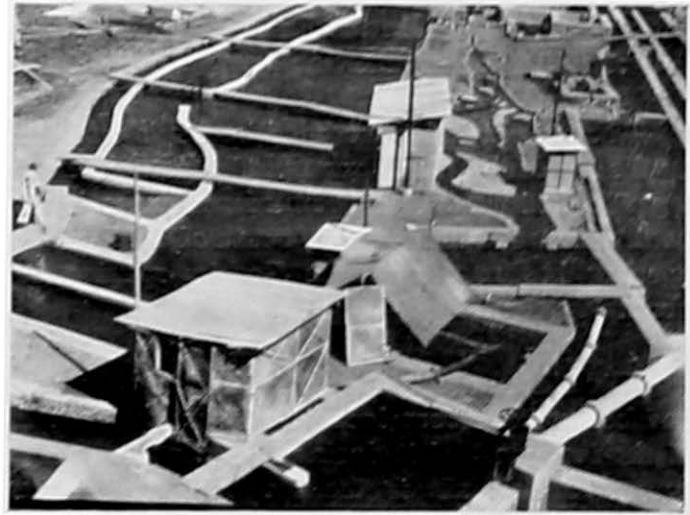
The town of Cochin is situated on the southwest (Malabar) coast of India, about 100 miles north of Cape Comorin.

Behind the Malabar Coast there lies a strip of laterite which has a petrological content unique in geology. On disintegration by weather or flood, it forms an exceedingly fine mud and is carried out to sea through the two main river openings at Cochin and Periyar, about 15 miles apart. Although the silt content of the water forms a very small percentage, yet the catchment area is so great — 3,000 square miles — and the fluvial discharge so high that in the aggregate and over a period of time there is either a rise in the sea bed or an extension of the mud fringe further out at sea.

Regular deposition of mud is effected in three ways, first by the meeting of fluvial discharge with sea water, which accelerates the deposition of silt, second by opposing ground swell which drives the material in the course of deposition, or part of it back shorewards and third what

has been called the encircling arms of the Cochin and Periyar rivers.

The net result of these opposing forces is that, outside the littoral sand brought down by the rivers and deposited more quickly than the mud, there exists a long belt of fine mud with an occasional temporary or permanent bank held in



Model of Cochin Harbour (showing the sea and backwaters)

place by tidal and fluvial currents. The 'toes' of these banks protrude beyond the regular contours of the sea coast. When there is a storm, these toes are immediately attacked by the ground swell in its effort to restore normality of contours. The water over the toes is thrown into a highly viscous state by the stirred up mud. This forms a medium in which the ocean swell is rapidly dissipated. This phenomenon is not observable elsewhere in the world to the same extent, merely because the fineness and composition of the mud are unique.

The stability of these 'mud banks' is affected by the sea currents and waves. The preponderating effect of these is southwards; and the 'mud bank' charted as immediately south of the Periyar opening has moved to the Cochin opening in about 16 years.

The Mattancherry Channel, in which wharves and berths have been located, silts up to a depth of six feet most of it during the monsoon. The source of this silt is the sea bed around the approaches to the port. The sea bed is easily

stirred up in the monsoon, thrown in suspension and carried in with the flood tide and deposited in quantity. The silting hazard has thus necessitated maintenance dredging of the approach channel which costs two lakhs of rupees a year. The amount spent on this operation absorbs an unduly large proportion of the total revenue of the port. It is, therefore, the aim of the model to study the siltation problem and to advise remedial measures to reduce it.

The model has been constructed with a length scale of 1/1,000 and a depth scale of 1/20. An artificial limit to the sea was initially put at 60 feet contour, but later on changed to 42 feet contour, to get the proper tidal curve reproduction. The main features of the model are the recirculation system of alum water which represents sea water in the model, the reproduction of tidal curves by the operation of sliding weirs and the sensitive water-level recorders to check the reproduction of model tidal curves.

Madras Harbour

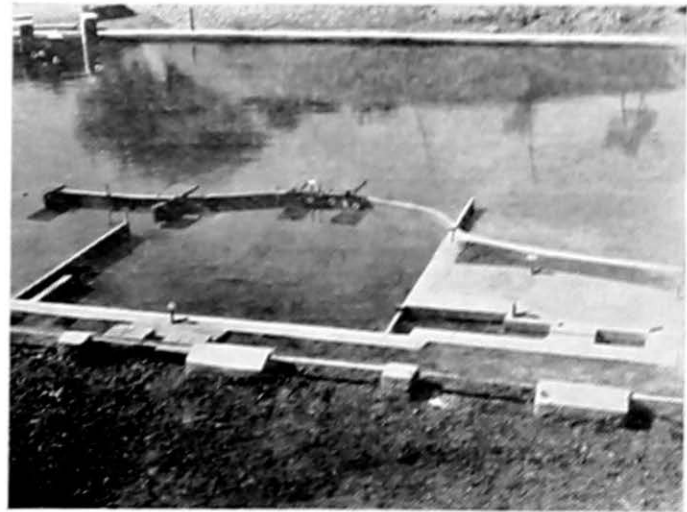
The Madras Harbour is the only port on the

east coast of India which can admit vessels up to 26 feet draft. It is an entirely artificial harbour, enclosing about 200 acres by quay walls extending 3,000 feet into the sea. As originally completed in 1895, it had an entrance from the east quay. This allowed waves into the harbour, practically throughout the year which severely handicapped loading and unloading of cargoes.

The harbour was, therefore, remodelled in 1911. The old entrance was closed, a new entrance opened in the north quay and a sheltering arm constructed. This measure was quite effective in reducing disturbance in the harbour in all weathers except severe storms.

Generally in the months of October and November, cyclonic storms occur in the Bay of Bengal which generate waves as high as 11 feet. The deep sea waves become transitory as they approach the shore and cause a bodily movement of water. Such waves, at the entrance of the harbour, develop a slow periodic surging of the water mass in the harbour. This is called 'range'.

Such undulations of the water level produce a fore and aft motion of ships which goes on increasing till even the strongest ropes snap. One such ship let loose from its moorings can do untold harm to others. Ships are, therefore, instructed to leave port in such weather. This is no happy position, and an all-weather port on the east coast is a necessity.



Model Madras Harbour (inside view)

Measures are being sought to improve conditions in the harbour with the aid of model studies.

A model of Madras Harbour, 120 feet long and 55 feet wide, has been constructed in the open to a scale of 1/250:1/50, which includes a portion of the sea up to 60 feet contour. The prime purpose of this model is to find out the smallest area around the harbour that should be included to reproduce correctly conditions inside the harbour. A large scale, geometrically similar, model which will include the necessary sea portion only will then be constructed and the tentative proposals finalised.

Special Features of the Model

- a) *Wave Generating Apparatus*—Waves will be reproduced in the model on a 50 feet front by a plunger type machine driven by an electric motor. Other types of wave-generating machines will also be used and the results compared.
- b) *Wave-Recording Apparatus*—An apparatus is being developed at the Station for recording

wave characteristics such as shape, period, length and amplitude.

Essentially it consists of two wires of low resistance, closely spaced, immersed in water; the magnitude of current through such a unit will depend on the depth of immersion. A number of such units will be placed in water at right angles to the wave front, and electric currents in each will be recorded for a short duration simultaneously. The depth of immersion of each unit at an instant can be assessed from the strength of current and the wave resulting form.

The apparatus is expected to be very useful for comparison of wave forms produced by different generating machines.

Hooghly Estuary

The development of the Port of Calcutta on the Hooghly river, about 100 miles from the sea, depends on the perennial navigability of the whole reach in all the seasons of the year. Though there is no evidence of progressive

deterioration of the river in general, there are indications that some deterioration has occurred in the region below Calcutta. The fresh water supply of the Hooghly, mainly derived from the Ganga through the three Nadia rivers, has apparently decreased. Again, for about eight months in the year the flood tides predominate. During the remaining four months, owing to the discharge in the rivers, the ebb tides predominate. In accordance with the preponderance of the flood tides or the ebb tides, there are periodical fluctuations, in the navigable channels, more or less regular.

The reach from Calcutta to Diamond Harbour — a distance of 42 miles — has been an impediment towards the upkeep of traffic, owing to a number of difficult shoals and crossings, which are for the present kept dredged. The two major tributaries, the Damodar and the Rupnarain also interfered with the river regime; and the river at the Hooghly Point (the James and Mary sand) has consequently been rendered dangerous.

As a remedy, the Port authorities suggested that a ship canal should be constructed connect-

ing Calcutta and Diamond Harbour at a cost of about Rs. 15 crores, thus avoiding the dangerous reach of the river. It was felt, however, that before embarking on such a project, extensive investigations should be carried out with the help of model experiments.

It is proposed to investigate the problem with the help of two models:

- 1) A 1/2,000, 1/160 model comprising a reach from 25 miles below the mouth of the river to the tidal limit which will indicate the probable changes that are taking place in the few bars below Diamond Harbour;
- 2) A 1/800, 1/80 model comprising the reach between Diamond Harbour and Calcutta for a comprehensive study of this important reach. For the present the first model has been taken in hand. The salient features of the model are outlined below:

Model Design

The model (centre-spread picture) has been

designed to operate by gravity flow or by recirculation with the help of pumps. In the summer months (with alum water for simulation of sedimentation) the recirculation system will be adopted; otherwise gravity supply will be resorted to.

Tide-Generating Apparatus

The system consists of admitting a constant discharge, corresponding to the maximum spring tide over five standing wave flumes into a tide chamber and operating two sets of sliding weirs on the sides so as to reproduce corresponding tides.

The correlation of the tides at the various points in the model with the tides at the lower limit of the model will be done by a Thyatron-controlled motor drive, the weirs being operated by D.C. motors. This will eliminate all the imperfections and difficulties associated with manual operations.

In the proving stage, a photo-elastic system is proposed to be adopted to actuate the driving

mechanism and make the running of the model completely automatic.

Tide Analysis

The choice of representative semi-lunations for various seasons of the year and the statistical correlation of various tides at various places are being investigated and will be used for verifying the model performance.

Scum Formation on Bed

Hooghly sand is used in the model. The trouble resulting from the presence of this fine sand is being satisfactorily overcome by treatment with bleaching powder, copper sulphate, etc.

Investigations carried out with this model, it is hoped, will obviate the necessity for constructing an expensive ship canal. As a result of these trials it may be possible to design a stable, navigable channel in the main river itself to allow the passage of ships all through the year in safety.

OTHER SECTIONS

LABORATORIES on Soil and Soil Mechanics, Materials of Construction, Hydrology, Machinery, Mathematics, Statistics, Physics and Chemistry are under various stages of planning and development. Nearly all the necessary equipments have been received for conducting basic and applied research on Soils, Physics and Chemistry. So far very little is known of the engineering properties of the black cotton soil and red soil, which are widely distributed throughout Southern India, and are economically very important. The soil and chemistry sections will investigate systematically the properties of these soils from the point of view of engineering construction. They will also conduct studies on the stabilization of the soils with cement, bitumen, natural and artificial resins, inorganic salts and with electric charges.

The recent earthquakes in Assam have brought to the forefront the disastrous conse-

quences that may occur to important engineering structures in those areas. Again, seismic shocks are quite common and of frequent occurrence, specially in the north-eastern part of the country, which is situated in the earthquake belt of the world. Protection of dams against such shocks is also receiving attention in the Physics Branch of the Station. Fundamental experiments are being carried out for determining the free periods of dams by exciting vibrations.

Location of faults in the foundations of dams by geophysical, i.e., electrical and seismic methods, will be undertaken shortly. Other important researches relate to the stress analysis of dams and other hydraulic structures by the photo-elastic methods; of arches, by Begg's Deformmeter of three dimensional analysis of pressure below hydraulic structures.

The Statistics Branch has done a considerable amount of work on the analyses of rainfall and run-off data and estimation of tidal gauges at the southern limit of Saugor island from the data observed in the Hooghly Estuary. The latter

analysis is being applied for reproducing tidal curves in the model of the estuary.

CWINRES is also carrying out a number of other investigations with the object of improving the design of hydraulic structures; and problems of structures that are threatened with danger, are also promptly tackled by the Station for imme-

diately remedy.

The application of the results so far obtained in the last three decades at the CWINRES has contributed not only in money—which itself perhaps runs into crores of rupees—but to the total national wealth which naturally accrues from designs and structures that are executed with maximum efficiency and economy.

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PUBLICATIONS OF CWINRES

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Annual Report 1937-38
Annual Report 1938-39
Note on the theory, design and construction of Gibb Modules which, without moving parts, give a constant discharge within working limits irrespective of variations in upstream and downstream water levels by C. C. Inglis and Rao Sahib D. V. Joglekar.
Annual Report 1939-40
Annual Report (Technical) .. 1940-41
Annual Report (Technical) .. 1941-42

Annual Report (Technical) .. 1942-43
Annual Report (Technical) .. 1943
Annual Report (Technical) .. 1944
Annual Report (Technical) .. 1945
Annual Report (Technical) .. 1946
Annual Report (Technical) .. 1947
The Behaviour and Control of Rivers and Canals (with the aid of models), Parts I and II, by C. C. Inglis.
Annual Report (Technical) .. 1948
Annual Report (Technical) .. 1949
(in press)

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