Hydraulic Model Research for I. B. P.

By
C. VAN BEESTEN*

INTRODUCTION

Following the initial agreements, leading to the Indus Basin Water Treaty of 1960, the need for research facilities to study a large number of hydraulic problems became clear. The Indus Basin Projects would produce many problems in a short space of time as design and construction had to be completed by the year 1970 (1973 for Tarbela Dam).

Facilities for hydraulic research existed in West Pakistan, *i.e.* the Irrigation Research Institute with laboratories in Lahore and a field station at Nandipur, with an area of about 100 acres. Investigations indicated that the capacity of the laboratories would be sufficient for the large programme of studies envisaged. Also, these laboratories have a long experience (since 1924) in hydraulic research on problems similar to those to be expected for the Indus Basin Project. However, the available facilities were not considered to be adequate with respect to instrumentation, number of experienced research workers, and all weather arrangements for the open air field station.

Consideration of the hydraulic research work to be carried out for I.B.P. indicated the need for a large capacity establishment, preferably in West Pakistan as easy access at all times by designers and field engineers is highly desirable. Availability of space in foreign laboratories at any given time for such a large and urgent study programme could not be relied upon.

An agreement was reached between the Irrigation Department, WAPDA, and the World Bank, to employ about 90% of the total I.R.I. capacity for an initial period of 3 years (April 1962—March 1965). A fund was initiated, after an estimate had been made of costs, to cover monthly expenditures of this study programme. Normal delays, due to the usual method of requiring deposit of funds for each separate model study, were in this way avoided. The agreement also included substantial funds for improvements to the facilities of the field station, and the instrumentation section. Two expatriates one for hydraulic models and one for instrumentation, were engaged through Harza Engineering Company International, under this programme, to assist the I.R.I. during the period of intensive research work for I.B.P.

**Principal Research Officer, Indus Basin Project, Wapda, Lahore.*

The initial programme period has been extended by one year and a further extension to March 1968 is under consideration by the World Bank.

INDUS BASIN PROJECTS

The Indus Basin Projects are briefly summarized here, to give an idea of the total programme :—

Mangla Dam Project.

New Barrages, *i.e.* Sidhnai, Mailsi (strictly a syphon crossing the river Sutlej), Rasul, Qadirabad, Marala and Chasma.

Link Canals, *i.e.* Trimmu-Sidhnai-Mailsi-Bahawal ; Rasul-Qadirabad-Balloki-Suleimanke ; Chasma-Jhelum and Taunsa-Panjnad. Tarbela Dam was included for this agreement. Fig. 1 shows the location of these projects.

STUDIES

The majority of studies was carried out at the field station in Nandipur. The sizes of rivers and structures in this country required the use of large models, as the model scales to represent sediment movement should not be less than about 1 : 200 (horizontally). Space requirements make construction of such models indoors impossible. The large river discharges, up to 1 million cusecs or more, combined with the large scales and distortion factors of about 6, also require the availability of a large water supply to the models. The research station at Nandipur filled both space and water supply requirements. Water can be drawn, by gravity, from the Upper Chenab Canal to about 500 cusecs total capacity.

It is not possible to enumerate all specific studies carried out under this programme. Each model served, in many instances, a number of different objects for investigation. A summary is given of all models constructed for I.B.P. in Addendum 'A'.

The variation in the nature of these investigations is marked. Studies covered river diversions, sediment transport and distribution, hydraulic jump structures, pressure tunnel flows, flow-induced vibrations, seepage problems, flow conditions in fish ladders, and performance of the Fabridam.

RESULTS AND RECOMMENDATIONS

In many cases, the studies indicated that changes in the designs would be necessary or desirable. Such changes have usually been incorporated in the final designs, so that the influence of the I.R.I. investigations can be observed throughout the Indus Basin Projects.

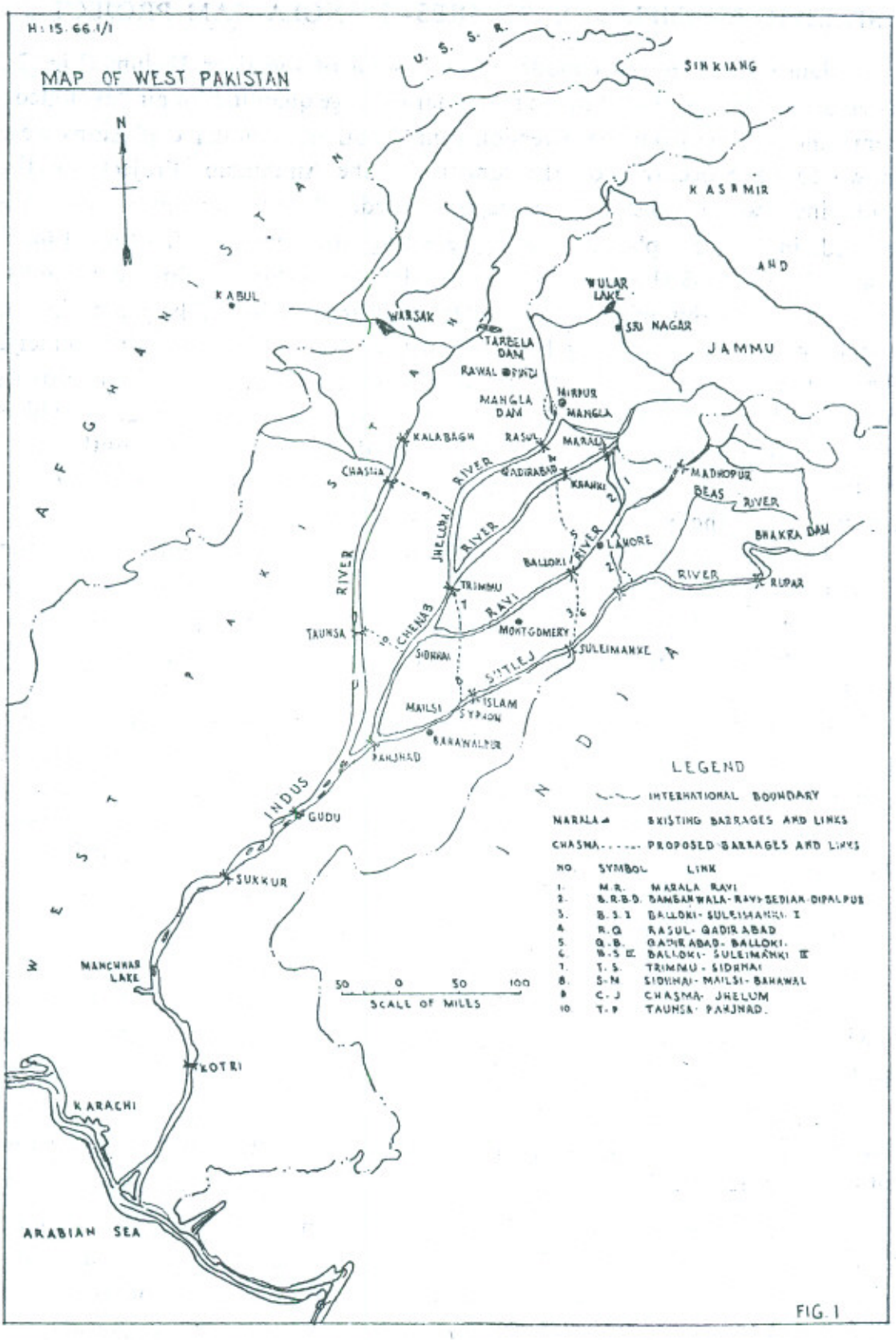

H:15.66.1/1
MAP OF WEST PAKISTAN
U. S. S. R.
SINKIANG
KASHMIR
AND
JAMMU
N
KABUL
WARSAK
TARBELA DAM
WULAR LAKE
SRI NAGAR
RAWAL PINDI
MANGLA DAM
MIRPUR
MANGLA
KALABAGH
RASUL
MARALA
CHASMA
QADIRABAD
KHANKI
MADHOPUR
BEAS RIVER
BHAKRA DAM
LAHORE
BALLOKI
RIVER
JHELUM
RIVER
RIVER
RIVER
RIVER
RUPAR
TRIMMU
RAVI
TAUNSA
CHENAB
MONTGOMERY
SULEIMANKE
SIDHNAI
SUTLEJ
MAILSI
ISLAM
PATTAN
BAHAWALPUR
PAKPATAN
INDUS
GUDU
SUKKUR
MANCHHAR LAKE
KOTRI
KARACHI
ARABIAN SEA
WEST PAKISTAN
INDIA
50 0 50 100
SCALE OF MILES
LEGEND
INTERNATIONAL BOUNDARY
MARALA EXISTING BARRAGES AND LINKS
CHASMA PROPOSED BARRAGES AND LINKS
NO. SYMBOL LINK
1. M.R. MARALA RAVI
2. B.R.B.D. BAMBANWALA-RAVI-BEDIAN-DIPALPUR
3. B.S.I BALLOKI-SULEIMANKI I
4. R.Q. RASUL-QADIRABAD
5. Q.B. QADIRABAD-BALLOKI
6. B.S II. BALLOKI-SULEIMANKI II
7. T.S. TRIMMU-SIDHNAI
8. S-N SIDHNAI-MAILSI-BAHAWAL
9. C-J CHASMA-JHELUM
10. T-P TAUNSA-PANJNAD.

FIG. 1

SPECIFIC EXAMPLES OF STUDIES—MANGLA DAM PROJECT

During studies on a model for diversion of the river Jhelum (Fig. 2), observations showed that at medium discharges large quantities of air "exploded" from time to time from the diversion tunnel outlets. Similar explosions were known to have occurred on the tunnels for the Ambuklao Project in the Philippines, where substantial damage resulted. A separate model was constructed, in 6" clear plastic pipe, representing one complete diversion tunnel to a scale of 1 : 65 (Fig. 3), for a more detailed study of flow conditions. Observations on this model indicated the existence of hydraulic jumps in the tunnel for discharges ranging between 5000 and 25000 cusecs approximately. These jumps introduce air, in the form of bubbles, in the pressure flow downstream of the jump. The bubbles collect in large air pockets (Fig. 4), which behave in the distinct ways, *i.e.* some move downstream to the outlet and others travel back upstream, after attaining certain critical dimensions, to emerge through the jump.

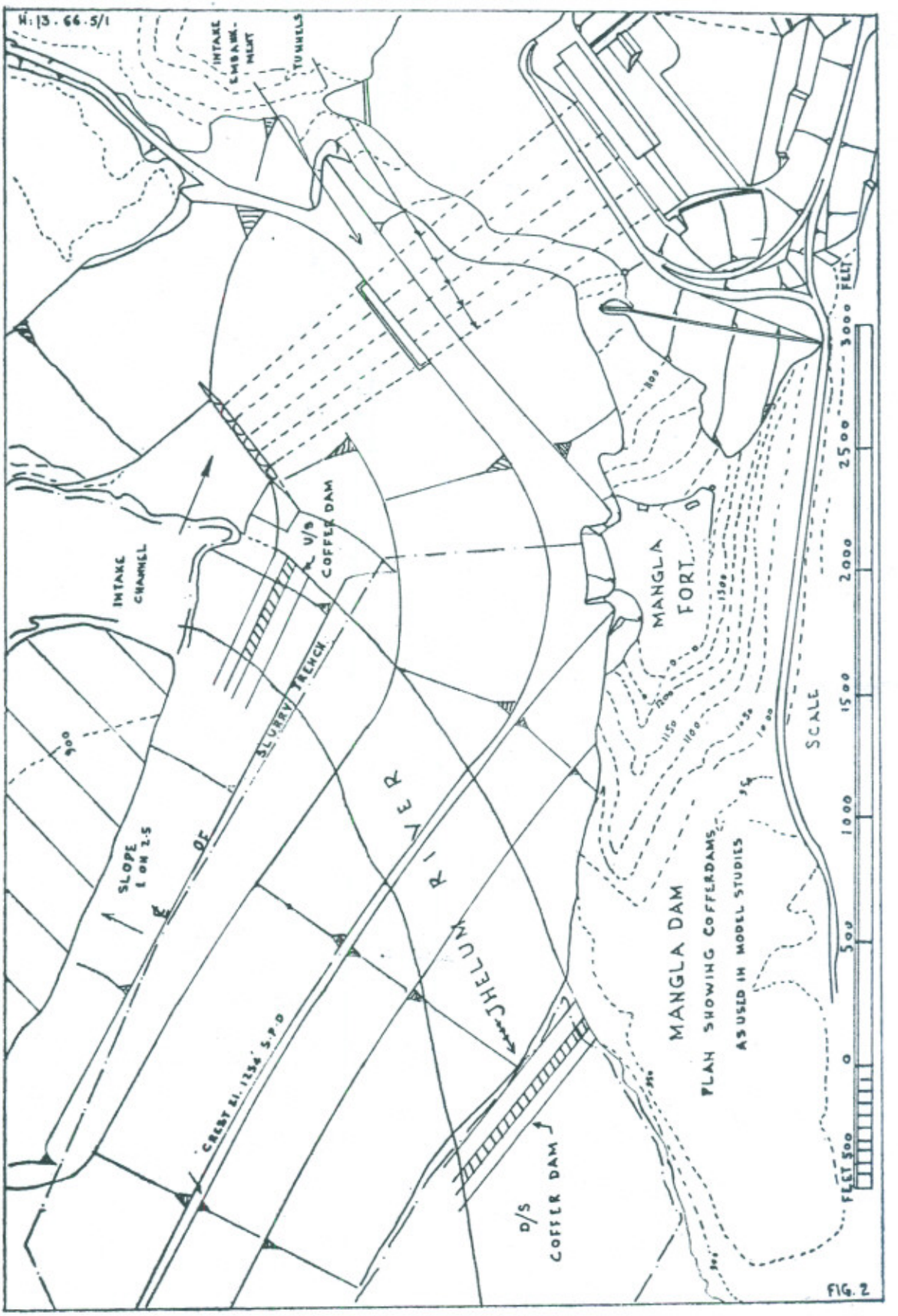
The airpockets travelling downstream collect near the outlet, where the tunnel is turned down (about 10°), until the total volume reaches a stage when the flow can push it through. Emergence of airpockets through the jump appeared to create large extra turbulence and associated vibrations of the model pipe.

Further information on these vibrations was considered essential. Special pressure transducers were installed on the pipe at various locations, to observe the rapidly fluctuating ("instantaneous") pressures, associated with vibrations. Records obtained through amplifiers and special paper-tape recorders showed appreciable fluctuation, with lowest pressures in the order of—13 ft. head of water. Similar observations, carried out at the Hydraulics Research Station, Wallingford, England, gave low pressures well into the cavitation range.

The Project Consultants decided that the information obtained was sufficient to warrant introduction of measures to suppress or eliminate the occurrence of jump in the diversion tunnels.

Subsequent tests at the I.R.I. showed that this could be achieved by means of a gate at the outlet end of the tunnel, covering a little more than the top half of the outlet opening.

This solution was not considered feasible or advisable for various reasons and the Project Consultants proposed the use of a Fabridam. This fairly new item in engineering consists of inflatable 'bags' made of nylon and rubber. For the problem at Mangla, three bags each about 10 ft. high (inflated) and 200 ft. long, would be installed on a concrete base weir in the tailrace


W:13.66.5/1
INTAKE EMBANKMENT
TUNNELS
INTAKE CHANNEL
U/S COFFER DAM
SLURRY TRENCH
SLOPE 1 ON 2.5
CREST EL. 1234' S.P.D.
JHELUM RIVER
D/S COFFER DAM
MANGLA FORT
MANGLA DAM
PLAN SHOWING COFFERDAMS AS USED IN MODEL STUDIES
SCALE
FEET 500 0 1000 1500 2000 2500 3000 FEET
FIG. 2

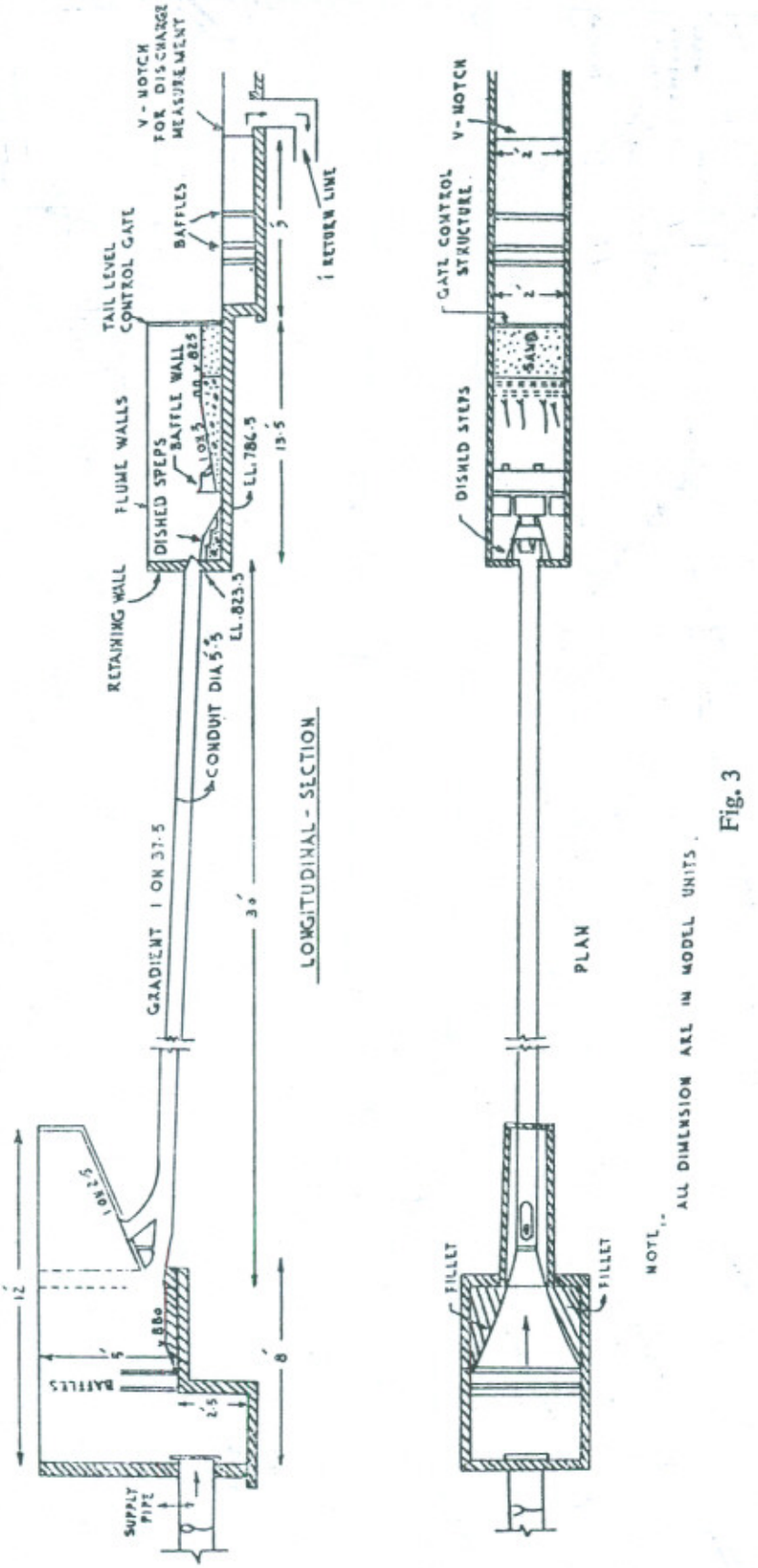

V-NOTCH FOR DISCHARGE MEASUREMENT
BAFFLES
RETURN LINE
TAIL LEVEL CONTROL GATE
FLUME WALLS
DISHED STEPS
BAFFLE WALL
EL. 784·5
EL. 823·5
RETAINING WALL
CONDUIT DIA 5'5
GRADIENT 1 ON 37·5
LONGITUDINAL - SECTION
1 ON 2·5
BAFFLES
SUPPLY PIPE
GATE CONTROL STRUCTURE
V-NOTCH
DISHED STEPS
SAND
PLAN
FILLET
FILLET
NOTE:- ALL DIMENSION ARE IN MODEL UNITS.

Fig. 3

MODEL OF DIVERSION AND POWER TUNNEL
OF
MANGLA DAM
SCALE 1/65.45

H.13.66.5/3

Qn = 15000 CS.
T.W.L. = R.L. 883
POND LEVEL = 907.2

TUNNEL SHOWING POSITION OF HYDRAULIC JUMP AND THE FORMATION OF BUBBLES.

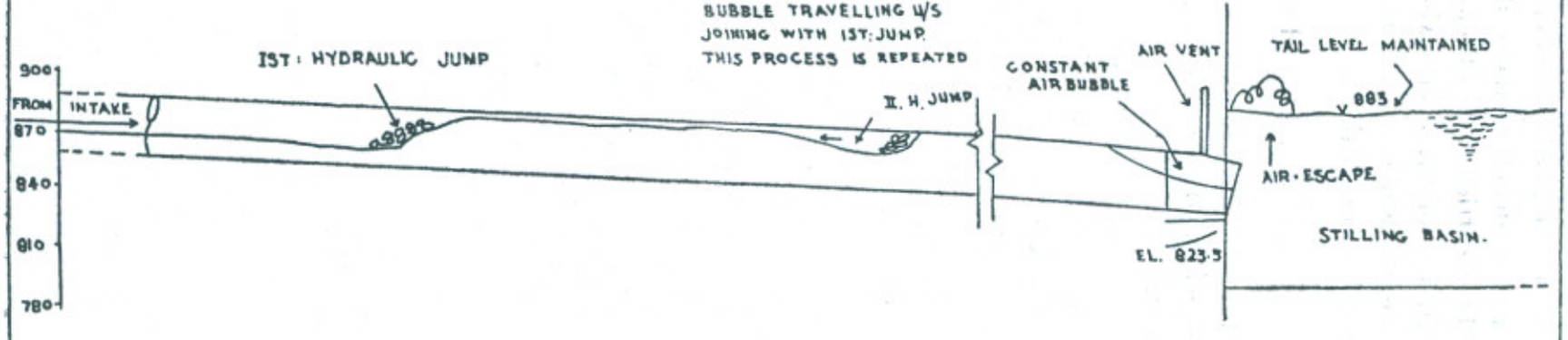


FIG. 4

(Fig. 5). The inflated condition is required up to about 100,000 cusecs discharge and complete deflation above that stage.

Tests carried out with model sized bags (1 : 30 scale) indicated problems with aeration of the overflowing jet, resulting in oscillations of the bags. Increasing the water pressure in the bags was found to be the only method to suppress these oscillations.

CHASMA BARRAGE

Investigations for this new barrage on the river Indus, included the location within the Khadir, training works required, and the elevation of the weir crest.

The size of the Indus at the Chasma site, *i.e.* about 8 miles between natural high banks, necessitated construction of a 'pilot' model'. A pilot, or small scale model is useful to determine quickly the major problems and approximate solutions. The pilot model was in this case made to a distorted scale of 1 : 800 horizontally and 1 : 80 vertically. Tests indicated that the tentative design location should be moved over further to the right hand side of the Khadir, as the two major river channels are on that side.

These studies were later repeated on a larger model, to scales of 1 : 300 horizontally and 1 : 40 vertically. The revised location, determined originally on the pilot model, was confirmed on the larger model.

River training works were determined on both models. These works consisted of one spur on the left side of the new barrage and two spurs on the right hand side. The recommendations by the I.R.I. for location and training works have been incorporated in the final design (Fig. 6).

The crest level of the weir, given in the design, was found to be low. Tests on a sectional model of the weircrest in a glass-sided flume, to a scale of 1 : 53, indicated that for most of the discharge range flow over the weir would be drowned. Further experiments with different crestlevels showed that the level should be raised by 5 ft. to obtain acceptable flow conditions. This recommendation has been adopted for the revised design.

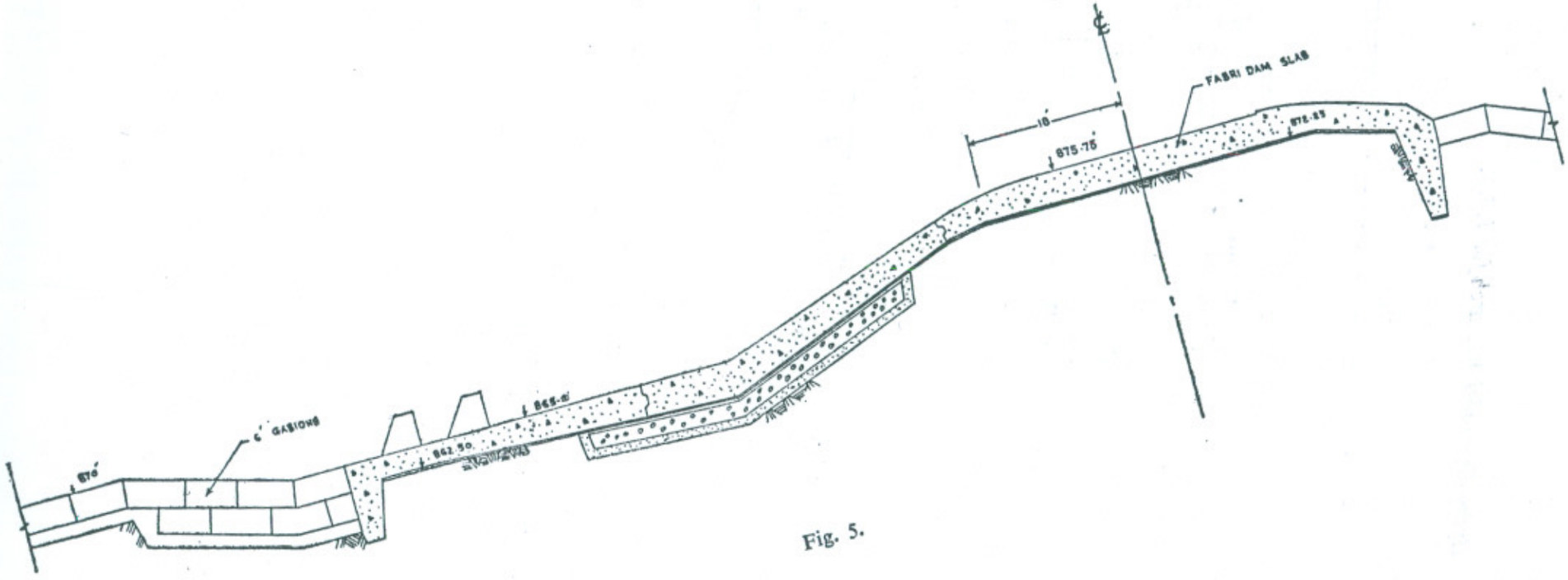
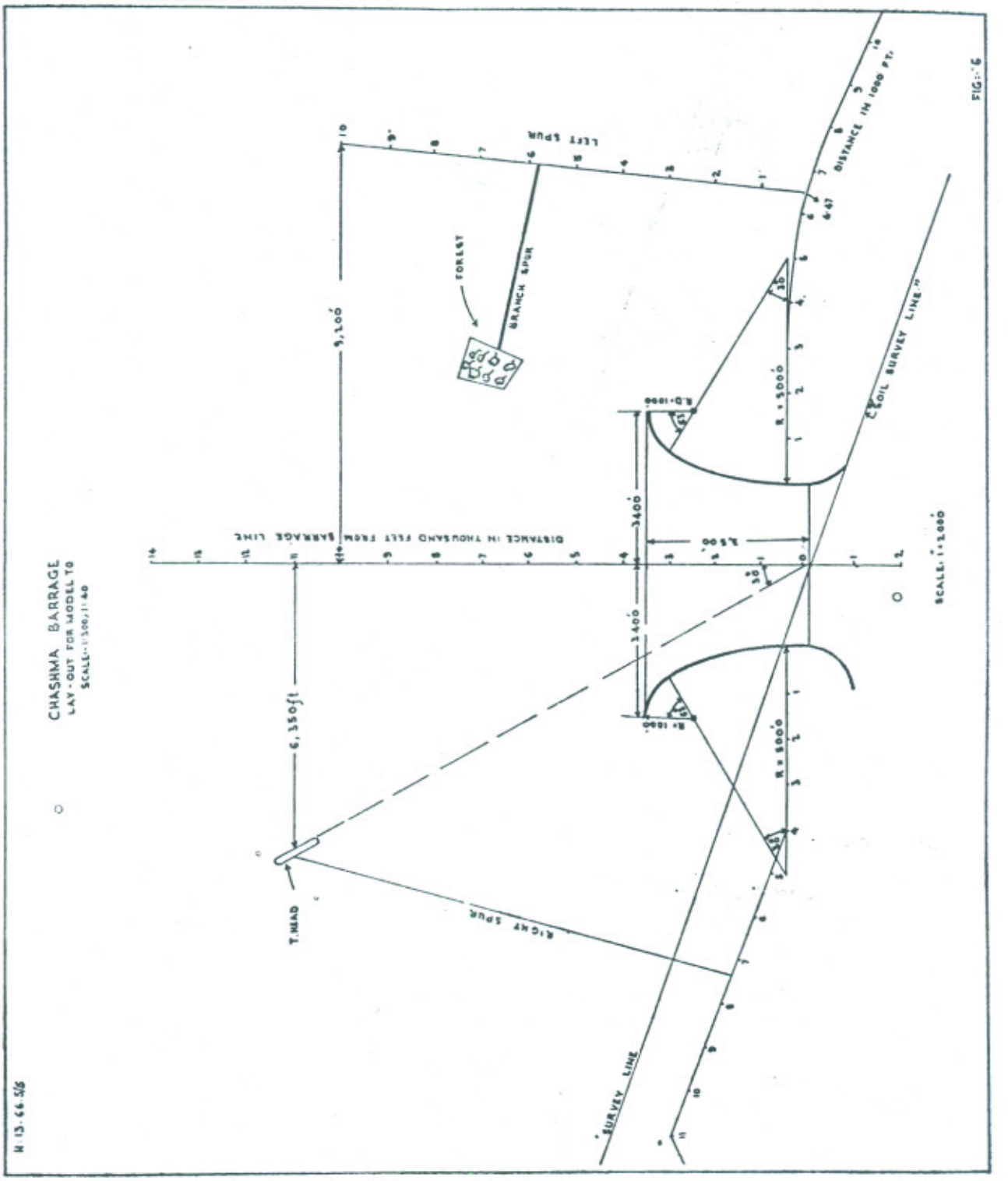


Fig. 5.


CHASHMA BARRAGE
LAY-OUT FOR MODEL TO
SCALE-1:500,1:40
FIG:-6
SCALE: 1"=2000'
DISTANCE IN THOUSAND FEET FROM BARRAGE LINE
DISTANCE IN 1000 FT.
LEFT SPUR
FOREST
BRANCH SPUR
9,100'
6,350ft
T. HEAD
RIGHT SPUR
SURVEY LINE
CIVIL SURVEY LINE
R = 5000'
R = 1000'
3400'
3400'
8,500'
30°
30°
30°
30°
W 13.66 5/6

ADDENDUM A

I.B.P. STUDIES

Mangla Dam Project

1. Diversion tunnel tailrace.
2. River diversion—closure dam and tunnels.
3. Diversion tunnel flow conditions.
4. Diversion tunnel intake and power intake shapes.
5. Main Spillway and conditions in river downstream.
6. Emergency Spillway, including approach and escape channels (4 models).
7. Jari Dam Outlet Tunnel—Howell-Bunger valve and stilling basin.
8. New Bong Escape Structure—location and performance.
9. New Bong Escape—seepage under structure.
10. Fabridam performance.
11. Secondary Power Intake gates.

Tarbela Dam Project

1. River Diversion (pilot model).
2. River Diversion, Access Bridge (1 : 80 scale).
3. Spillways and outlet channel.
4. Diversion Tunnel outfall.
5. Spillway crest, sectional.
6. Service Spillway.

NEW BARRAGES

Sidhnai

1. River approach and downstream channel.
2. Weir, sectional.
3. Silt excluder tunnels.
4. Abdul Hakim Bridge (d/s of new barrage).

Mailsi Syphon

1. Location, river training and diversion.
2. Weir, sectional.

Qadirabad

1. Location, river training and diversion.
2. Weir, sectional.
3. Undersluices, sectional.
4. Silt excluders.
5. Fish ladder (3 models).

Rasul

1. Location, river training and diversion.
2. Weir, sectional.
3. Siltpocket and canal head regulators.

Marala

1. Location, river training and diversion.
2. Weir, sectional.
3. Undersluices, sectional.

Chasma

1. Location and river training (pilot).
2. Location, river training and diversion.
3. Weir, sectional.
4. Undersluices, sectional.
5. Siltpocket and canal head regulators.

LINK CANALS

Trimmu-Sidhnai

1. Siltpocket, silt excluders Trimmu Barrage.
2. Dredge basin, dredge paddock.

Sidhnai-Mailsi

1. Bifurcation with Mailsi Canal.

Qadirabad-Balloki

1. Canal fall, R. D 190, 875.
2. Sediment distribution Sagar Head (L.C.C.)
3. L.C.C. (Upper) realignment.

Balloki-Suleimanki

1. Remodelling Balloki Headworks.
2. B. S. I—B.S. II Bifurcation.
3. Canal Fall (B.S. II), R.D. 34,000.
4. B.S. I—B.S. II outfall structures.

Taunsa-Panjnad

1. Head regulator and bifurcation with Muzaffargarh canal.
2. Outfall regulator.

Chasma-Jhelum

1. Outfall structure (5 models of different alternative designs).

The total number of models given in this list is 59.