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HYDRAULIC LABORATORY REPORT NO. 93

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HYDRAULIC MODEL STUDIES OF THE BALLS FERRY RACK MIGRATORY--FISH CONTROL-- CENTRAL VALLEY PROJECT, CALIFORNIA

By

J. A. LINDSEY, JUNIOR ENGINEER

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Denver, Colorado,
June 23, 1941.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
June 23, 1941

Laboratory Report No. [illegible]
Hydraulic Laboratory
Compiled by: J. A. Lindsey

Reviewed by: J. E. Warnock

Subject: Hydraulic model studies of the Balls Ferry rack--migratory-fish control--Central Valley Project--California.

INTRODUCTION

The prototype. The Balls Ferry rack and trap structure will be built on the Sacramento River, approximately 25 miles below Keswick Dam, as a part of the migratory-fish control on the Central Valley Project in California (Figure 1). The rack will be built on an angle of 60 degrees with the direction of flow in the river, causing the fish swimming upstream to move towards the left bank where they will jump over a small weir to enter the trap structure (Figures 2 and 3). It is planned to trap the entire fish run at the Balls Ferry rack until Keswick Dam is completed. The structure will then serve as an auxiliary to the trapping station at Keswick.

The model. A 1 to 8 scale model of a section of the rack, representing 32 feet of channel width, was built to study the merits of two arrangements of the rack which will be referred to as racks "A" and "B" in this memorandum. For both racks, the angle between the axis of the rack and the direction of the channel was 60 degrees, and the angle between the plane of the rack and the plane of the riverbed was 45 degrees (Figures 4 and 5). The grille members of rack "A" were perpendicular to the base of the rack, while on rack "B", they were inclined at an angle of 67°- 47'. A vertical plane passing through one of the grille members of the latter would be parallel with the direction of flow in the river.

The 1 to 8 scale ratio was adopted to facilitate the measuring of head losses through the racks. Each rack consisted of a grille of 1/8-inch round

brass rod, supported by a 3/4- by 3/4- by 1/8-inch galvanized angle frame (Figure 4). These were placed in a metal-lined box 4 feet wide and 15 feet long (Figure 6). Four inches of sand was placed on the bottom of the box for scour studies.

Summary of the investigation. The hydraulic model studies were initiated to determine which of the two types of rack was the more efficient and to ascertain the loss of head through each. The tests showed that either would work satisfactorily as the head losses for both were small, even under the most adverse conditions.

Model operation. Tests were made at prototype discharges of 1,000 to 15,000 second-feet. The discharge was regulated by valves in the supply line. The water-surface elevation was adjusted to correspond with the prototype by raising and lowering the tailwater gate (Figure 4). The racks were held in place by their own weight and could be quickly interchanged.

Measuring head losses. The head drop at the rack was obtained by measuring the difference in elevation between the upstream water surface and the lowest point in the trough immediately downstream from the structure (Figure 7). These measurements were made with a point gage mounted on an aluminum channel in such a manner that it could be moved freely in the direction parallel with the flow. The net or actual head loss due to the friction of the rack in the river was obtained by measuring the water surface upstream and downstream from the rack with a point gage which could be attached to either of two channels parallel with the rack, one upstream and one downstream from it (Figure 6). Five readings of the water surface were taken upstream and five downstream to obtain average values of the water-surface elevations. The contraction head loss was the difference between the head drop at the rack and the net head loss.

Flow when rack is partially clogged. A maximum head loss through the structure will occur when the discharge in the river is 15,000 second-feet and the rack is partially clogged by trash. To simulate this condition, heavy cloth was laid over the upper two-thirds of the rack, forcing most of the flow through the lower one-third of the grille area.

ANALYSIS OF RESULTS

Changes in flow caused by the rack. Prototype values, converted from model measurements of the net head losses due to friction for a discharge of 15,000 second-feet with debris-free flow, were 0.048 foot for rack "A" and 0.032 foot for rack "B" (Figure 7). The head drops at the rack under the same condition were found to be 0.240 foot for rack "A" and 0.224 foot for rack "B" (Figure 8). The contraction head loss was thus equal to 0.192 foot for both racks.

When the racks were partially clogged and the discharge was 15,000 second-feet, the head loss was approximately 0.70 foot for each rack.

The head drop at the rack was computed to check the measured drop. Using model figures for a flow of 15,000 second-feet prototype:

Q = 4.240 cubic feet per second.

V_1 = 0.912 foot per second.

A_1 = 4.848 square feet.

$A_2 = 2/3 \times 4.848 - \frac{1.5 \times 29.80}{144} = 2.922$ square feet.

$V_2 = \frac{Q}{A_2} = \frac{4.420}{2.922} = 1.513$ feet per second.

The contraction head loss = $h_c = \frac{V_2^2 - V_1^2}{2g}$

$$= \frac{1.513^2 - 0.912^2}{64.32}$$

$$= \frac{2.289169 - 0.831744}{64.32}$$

= 0.023 foot or 0.184 foot prototype.

The average measured net head loss due to the friction of the rack in the stream = h_f = 0.005 foot or 0.040 foot prototype. The head drop at the rack = $h_t = h_v + h_f$

= 0.023 + 0.005

= 0.028 foot or 0.224 foot prototype.

This compares favorably with the average measured head drop for both racks of 0.029 foot. A similar mathematical check of the head drop when the rack was partially clogged with debris could not be made as the percent of flow seeping through the cloth could not be determined.

Scour of the riverbed. No appreciable scour of the riverbed was noted for discharges up to and including 15,000 second-feet when the rack was free of debris. However, when the rack was partially clogged with trash, the high-velocity flow through the lower part scoured the sandbed for a distance of 5 to 10 feet (prototype) downstream from the rack (Figure 6). No scour was apparent upstream from the rack in any of the tests.

Summary. The tests showed that the losses through rack "A" were slightly greater than through rack "B". With debris-free flow, however, the loss through either rack was negligible. The maximum loss amounted to 0.240 foot for rack "A" and 0.224 foot for rack "B" with a discharge of 15,000 second-feet. When the racks were clogged, there was no apparent difference in the losses for the two types. The model studies indicated that the maximum probable head loss on the prototype structure will be 0.70 foot, and this will occur only if the rack should become heavily clogged with debris at a discharge in the river of 15,000 second-feet.

No scour of the riverbed was apparent when the rack was free of trash. When it was partially clogged, the resulting high-velocity flow through the lower part of the rack scoured the riverbed for a distance of 5 to 10 feet downstream from the rack.

Recommendations. These tests indicate that the choice between rack "A" and rack "B" is an economic rather than a hydraulic consideration. Ease and economy of construction should govern the design used. To avoid greater head losses and undesirable scour, the rack should be kept reasonably free of trash. It is believed that the prototype structure will be adequate if the design is based on a head loss of one foot at 15,000 second-feet discharge.

FIGURE 1

HYDRAULIC

T32N T31N T30N T29N

R5W R4W R3W R2W R1W

SHASTA
KESWICK DAM
SPRING CREEK DAM
REDDING
PACIFIC GAS & ELECTRIC RR
US 99
US 299
Sacramento River
Middle Creek
Salt Creek
Canyon Creek
Oregon Gulch
Olney Creek
Clear Creek
Cow Creek
French Creek
Stillwater Creek
Dog Run Creek
Clover Creek
Churn Creek
Cottonwood Creek
Bloody Island
Ash Creek
Bowman Creek
Coleman Power House
Red Bluff
PEE BRIDGE
UPPER RACK
PALO CEDRO
MILLVILLE
MIDDLE RACK
ANDERSON
Grant Parkway
Antlers Bridge
BALLS FERRY BRIDGE
BALLS FERRY RACK
COTTONWOOD
ASBURY PUMP
DARRAH HOLDING POND
COLEMAN HATCHERY
TOLO U.S. FISH HATCHERY

INDEX MAP

Delta
SHASTA DAM
Redding
Westwood
Red Bluff
Tehama
Willows
Orland
Chico
Oroville
Ukiah
Yuba City
Marysville
Woodland
Davis
Fulton
Duncan Mills
SACRAMENTO
SAN FRANCISCO
Oakland
TO LOS ANGELES

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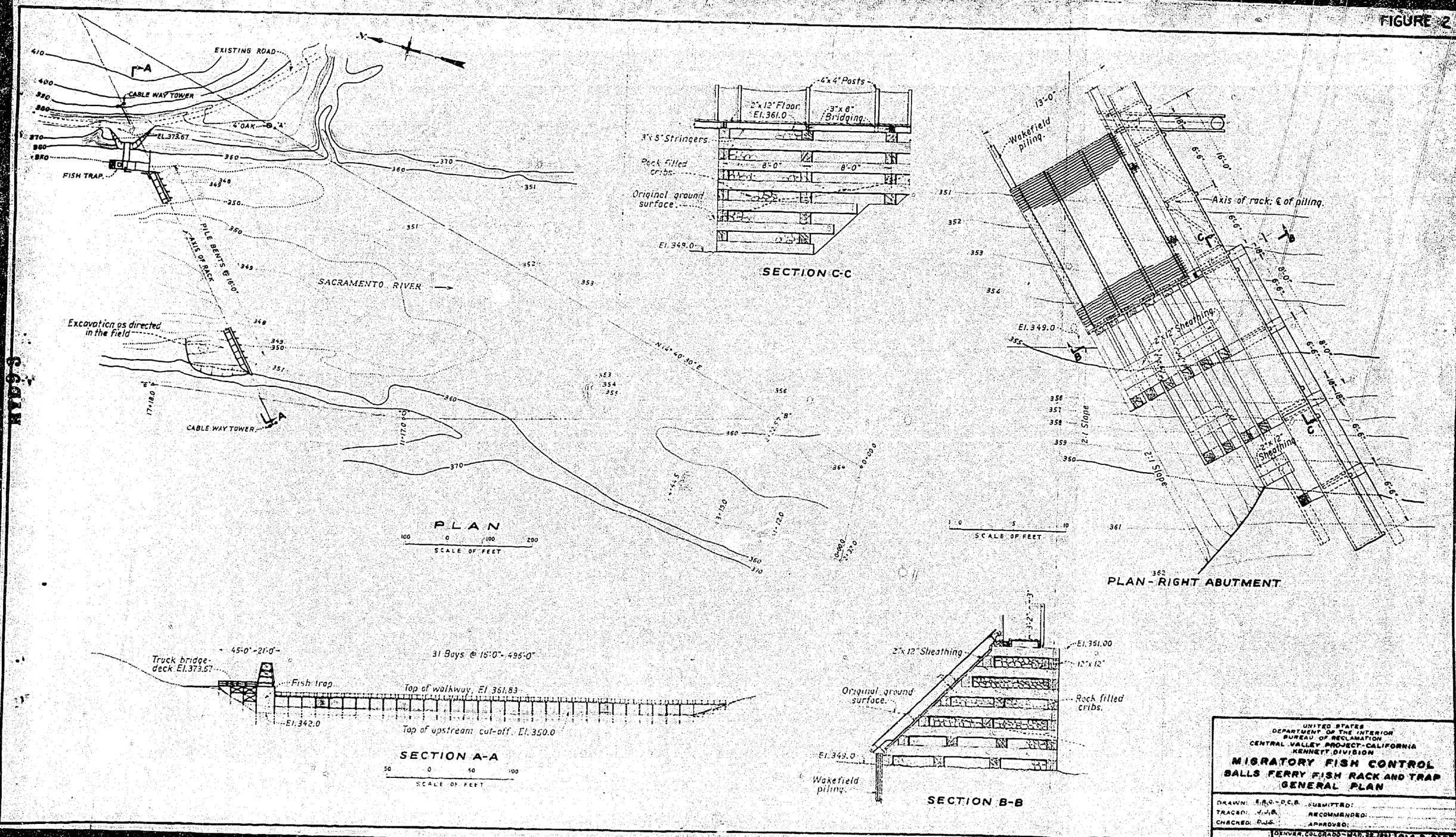
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT-CALIFORNIA
KENNETT DIVISION

MIGRATORY FISH CONTROL
LOCATION MAP

DRAWN S.A.K.	SUBMITTED
TRACED S.A.K.	RECOMMENDED
CHECKED	APPROVED
K1540C	REDDING, CALIF. OCT. 1, 1940

FIGURE 2



EXISTING ROAD
CABLE WAY TOWER
4' OAK
EL. 373.67
FISH TRAP
PILE BENTS @ 16'-0"
AXIS OF RACK
SACRAMENTO RIVER
Excavation as directed in the field
CABLE WAY TOWER
PLAN
SCALE OF FEET
4"x4" Posts
2"x12" Floor El. 361.0
3"x8" Bridging
3"x5" Stringers
Rock filled cribs
Original ground surface
El. 349.0
SECTION C-C
Wakefield piling
Axis of rack; ℄ of piling
El. 349.0
2"x12" Sheathing
2:1 Slope
PLAN - RIGHT ABUTMENT
Truck bridge-deck El. 373.67
45'-0" - 21'-0"
31 Bays @ 15'-0" - 495'-0"
Fish trap
Top of walkway, El. 361.83
El. 342.0
Top of upstream cut-off, El. 350.0
SECTION A-A
SCALE OF FEET
2"x12" Sheathing
El. 361.00
12"x12"
Original ground surface
Rock filled cribs
El. 349.0
Wakefield piling
SECTION B-B
UNITED STATES
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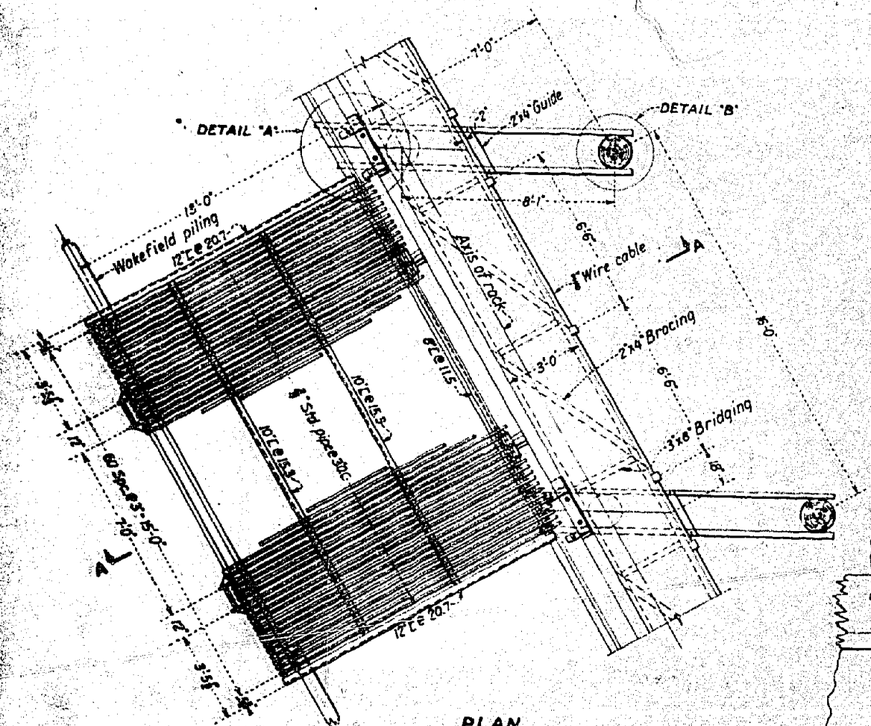
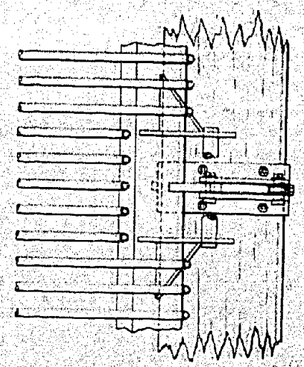
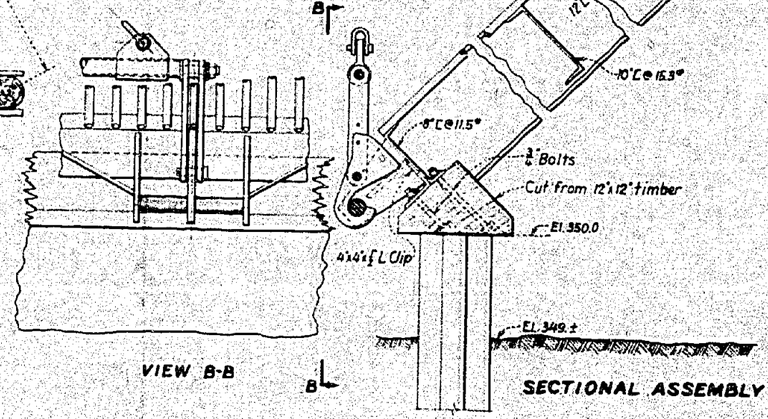
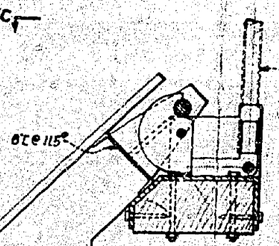
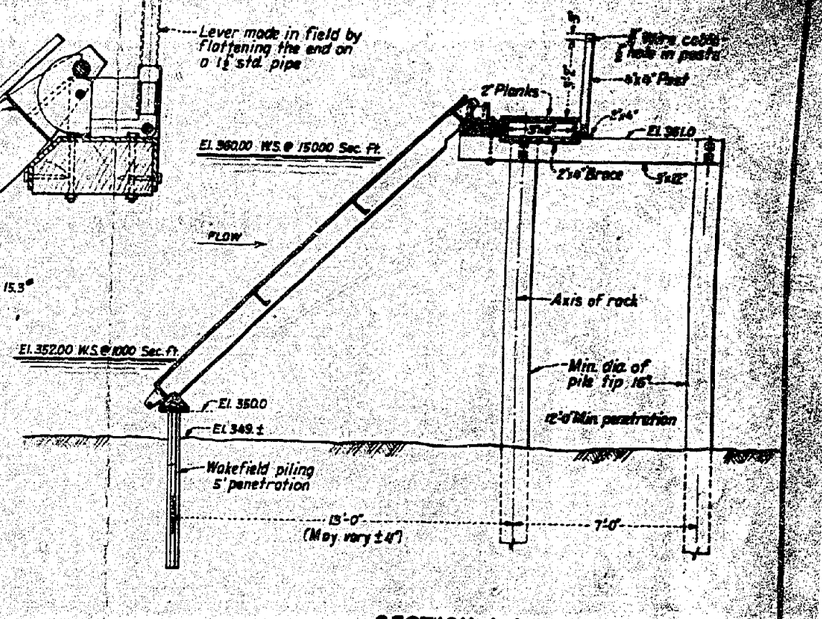
CENTRAL VALLEY PROJECT-CALIFORNIA
KENNETT DIVISION
MIGRATORY FISH CONTROL
BALLS FERRY FISH RACK AND TRAP
GENERAL PLAN
DRAWN: E.R.Q.-D.C.B.
TRACED: J.J.B.
CHECKED: D.J.S.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLORADO
214-D-216

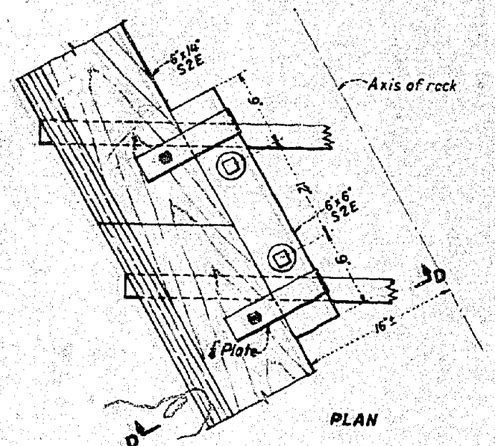


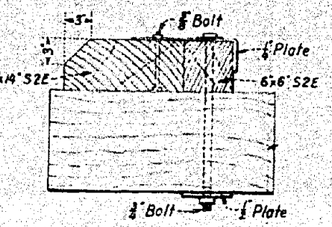


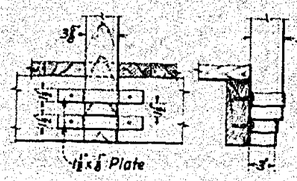


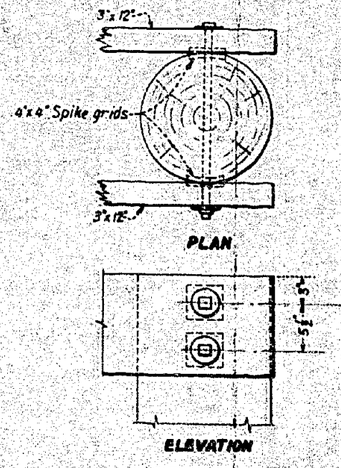












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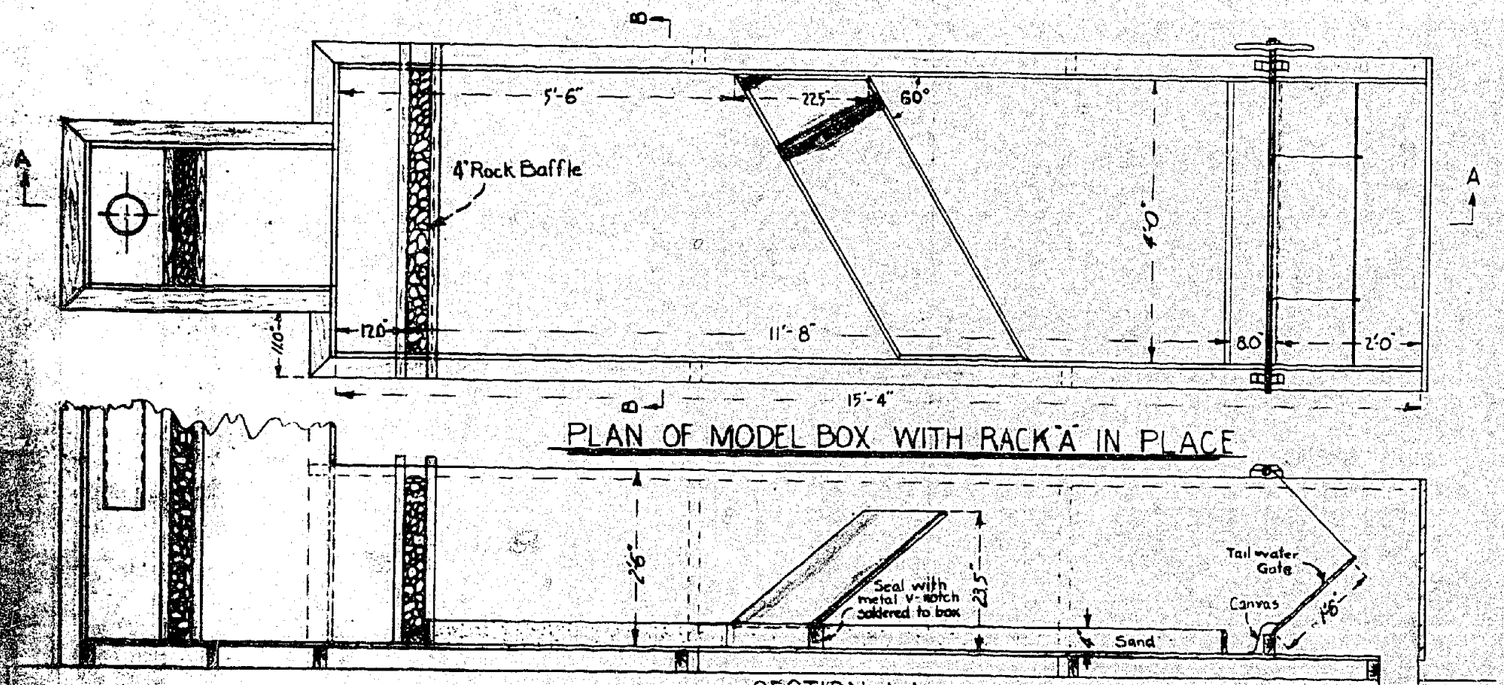
KESWICK DIVISION

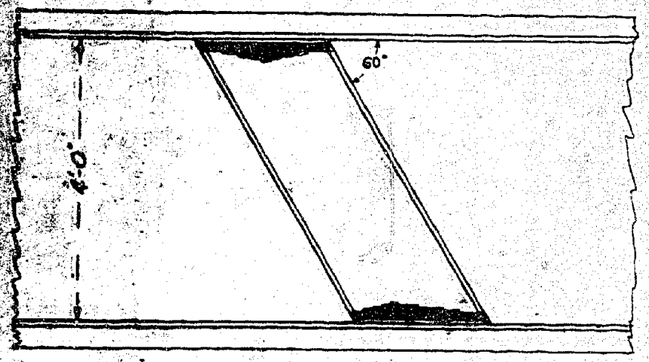
MIGRATORY FISH CONTROL
SALT SPRING FISH TRAP
DETAILS

FIGURE 4

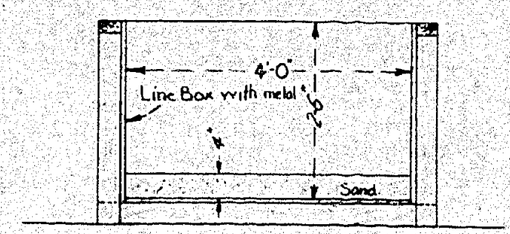


PLAN OF MODEL BOX WITH RACK "A" IN PLACE

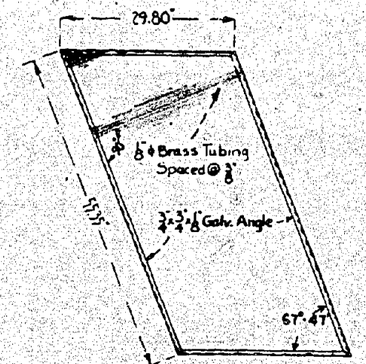
SECTION A-A



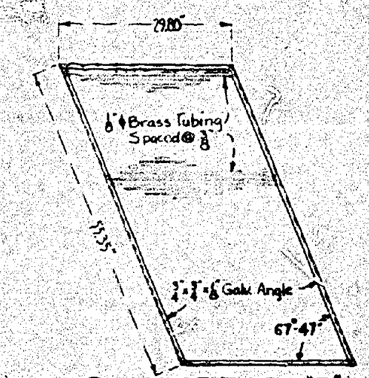
PLAN OF SECTION OF MODEL BOX WITH RACK "B" IN PLACE



SECTION B-B



PLAN OF RACK "A"



PLAN OF RACK "B"

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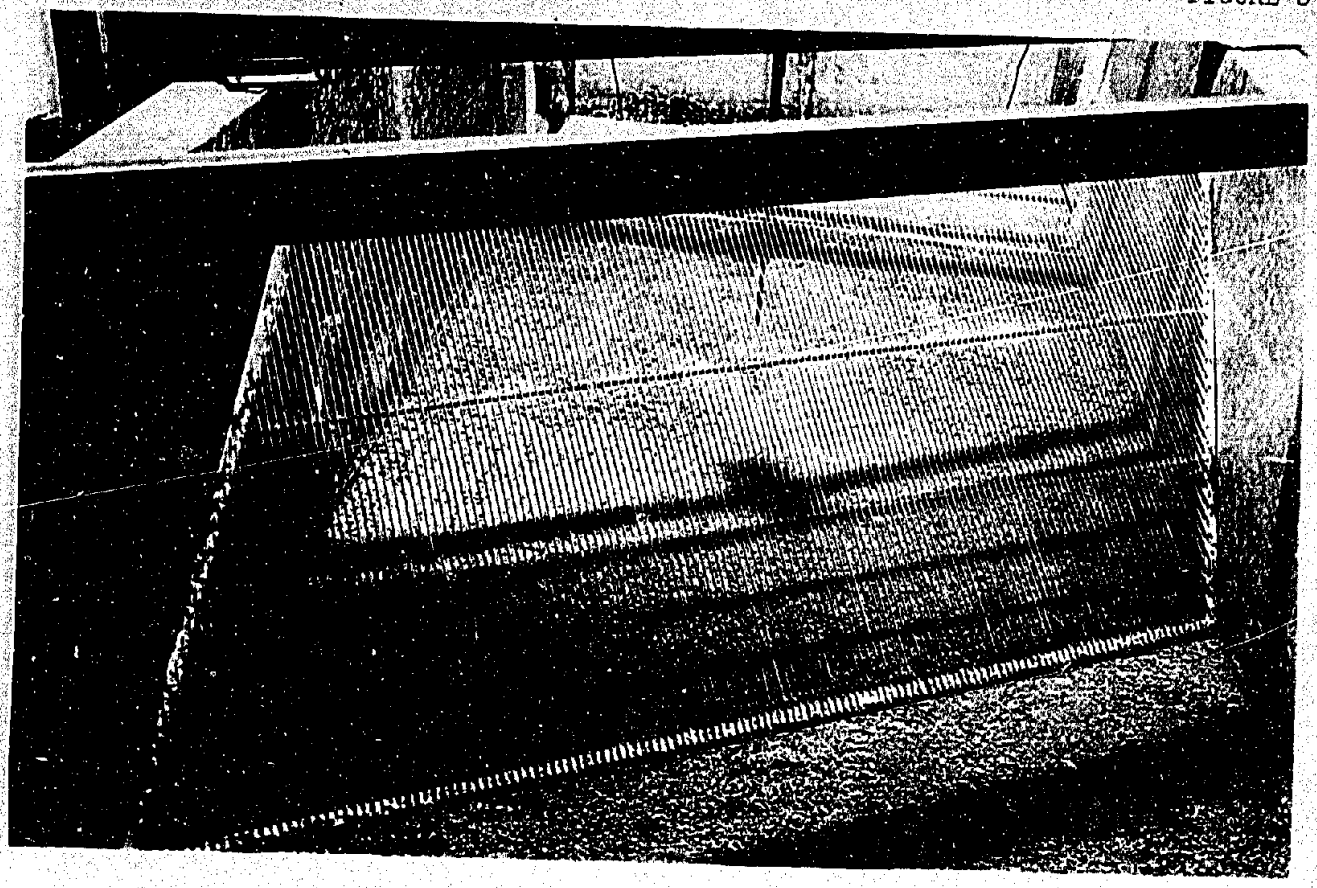
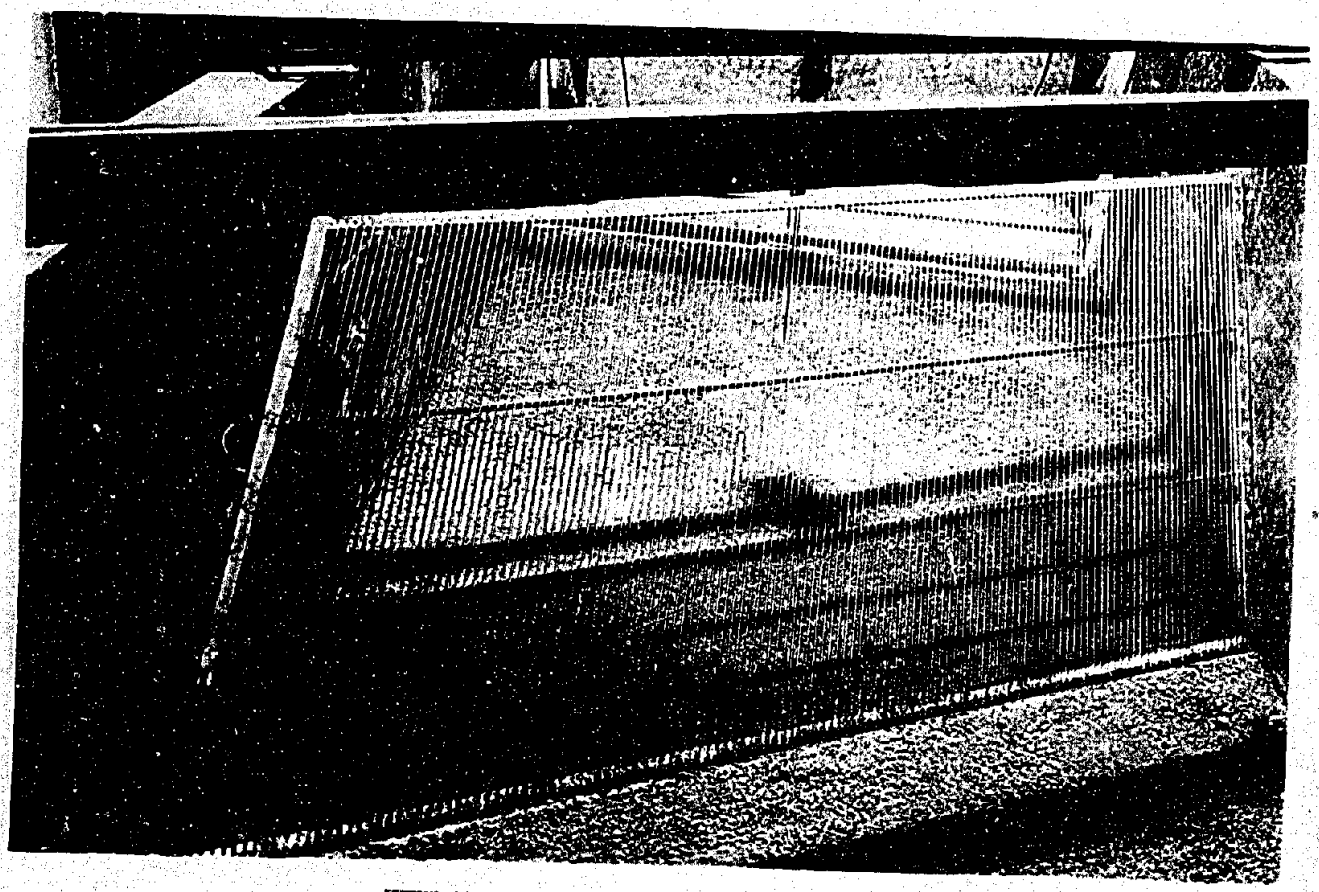
KENNETT DIVISION
MIGRATORY FISH CONTROL
BALLS FERRY RACK
HYDRAULIC MODEL STUDIES
GENERAL PLAN AND [illegible]

DRAWN J.A.L. SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED

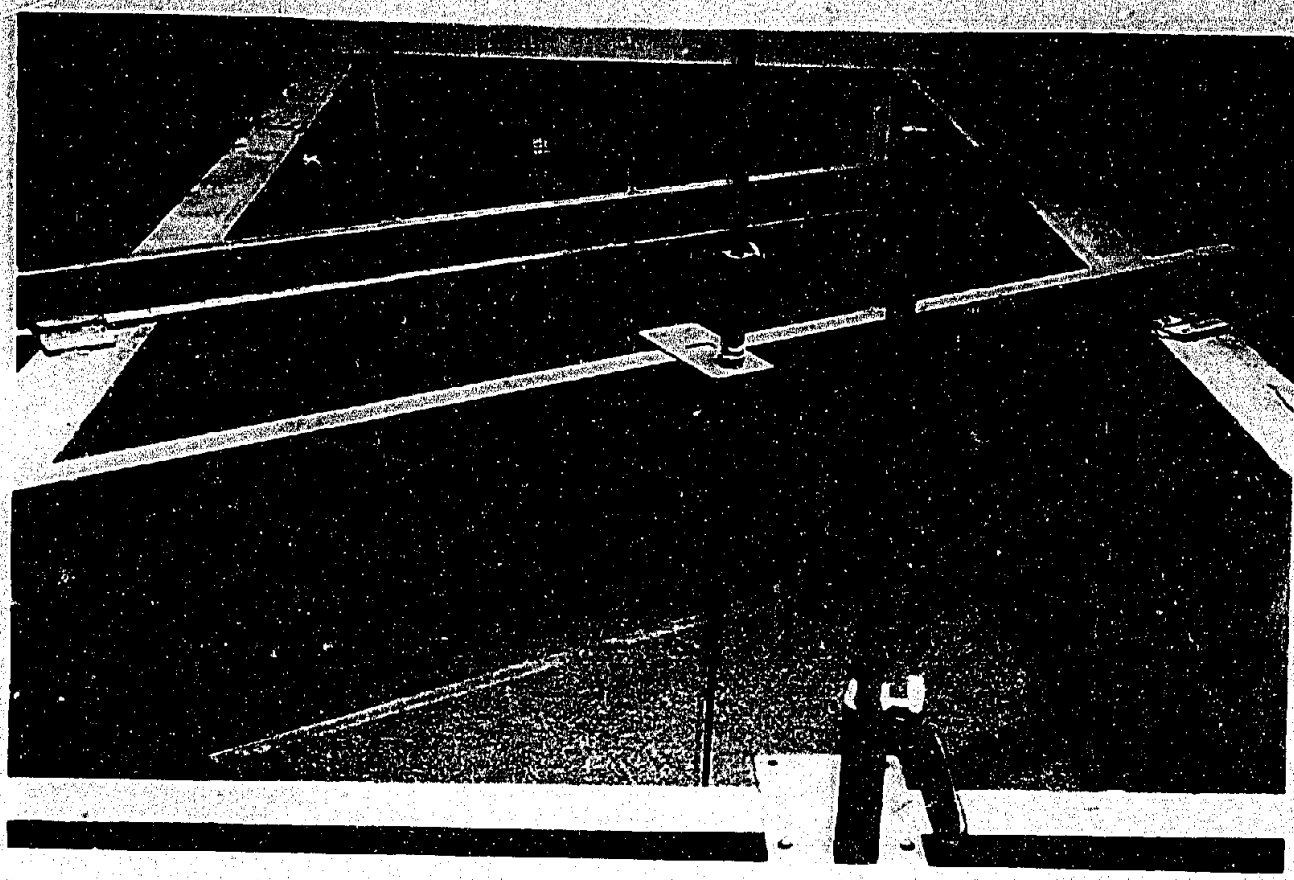


VIEW OF RACK "A" FROM THE UPSTREAM SIDE

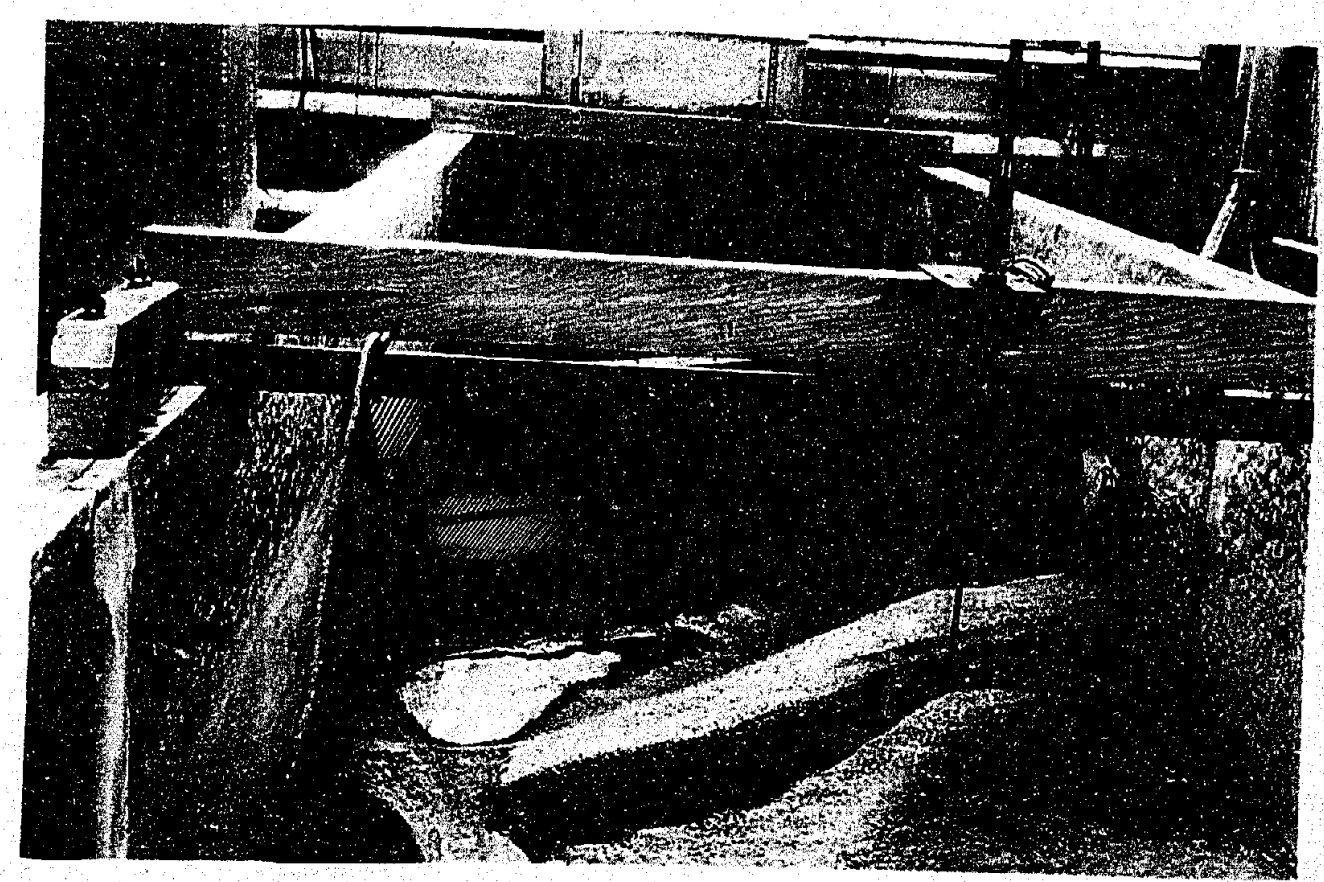


VIEW OF RACK "B" FROM THE UPSTREAM SIDE

BALLS FERRY RACK, 1:8 SCALE MODEL



VIEW OF MODEL SHOWING HOW RACKS WERE HELD IN PLACE



SCOUR CONDITIONS AFTER DISCHARGE OF 15,000 SECOND-FEET THROUGH PARTIALLY CLOGGED RACK

BALLS FERRY RACK, 1:8 SCALE MODEL

Rack "A"

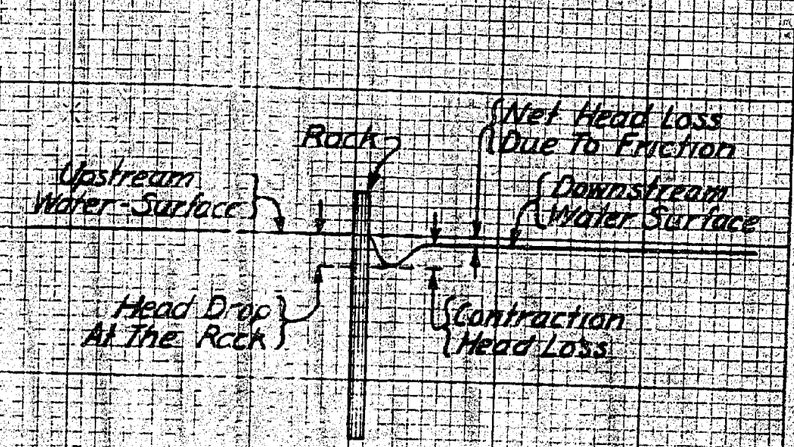
Rack "B"

Head Loss In Feet (Prototype)

0.04
0.03
0.02
0.01
0

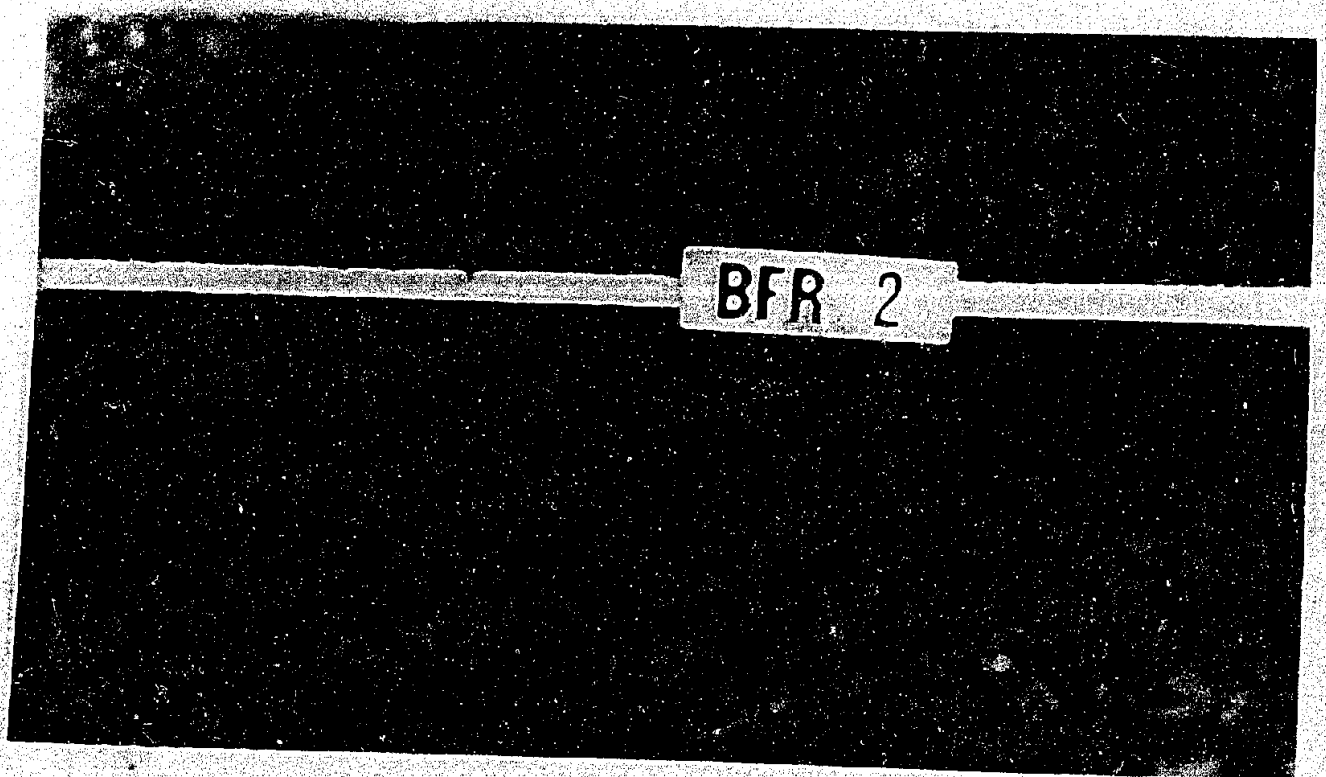
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Discharge In Thousands Of Second-Feet (Prototype)



BALLS FERRY RACK
NET HEAD LOSSES DUE TO FRICTION
FOR UNOBSTRUCTED FLOW
WITH NORMAL TAILWATER
214-2-31 J.E.W.-2
3-6-41 J.A.L.

VIEW OF RACK "A", DISCHARGE 15,000 SECOND-FEET



VIEW OF RACK "B", DISCHARGE 15,000 SECOND-FEET

BALLS FERRY RACK, 1:8 SCALE MODEL