UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL STILLING BASIN AND DIFFUSER CHAMBER MISSOURI RIVER BASIN PROJECT, MONTANA

Report No. Hyd-525

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

March 30, 1965

CONTENTS

ABSTRACT

Hydraulic model studies of the spawning channel stilling basin and diffuser chamber at Yellowtail Afterbay Dam in Montana resulted in the use of a slotted baffle near the intake conduit to provide satisfactory stilling action and good flow distribution. Flow enters the spawning channel through a 4-ft-dia intake conduit, passes through a stilling basin, and upward through a diffuser grating into the resting pool at the upstream end. Of the 150-cfs design flow, 30 will be discharged through a 24-in. bypass pipe to lower part of the fish ladder, 20 into the upstream end of the fish ladder, and the rest into the spawning channel. The slotted baffle diffuser was developed for the stilling basin to replace floor block and stepped end sill of the original design. This provided a relatively stable water surface in the basin and good flow distribution from the diffuser chamber into the resting pool, so that flow into and through the pool was quiet. The modified stilling basin and diffuser chamber performed well for any possible operating combination of head and tailwater. To quiet flow from the bypass pipe from main stilling basin before discharging it at right angles into the fish ladder, the bypass diffuser chamber was widened and a seawall-type cover was provided at the downstream end to reduce turbulence.

DESCRIPTORS-- *fish handling facilities/ fish/ fishways/ *diffusers/ water pressures/ flow meters/ *stilling basins/ *hydraulic models/ jets/ erosion/ conduits/ hydraulics/ hydraulic similitude/ laboratory tests/ flow control/ sea walls/ discharges/ research and development/ afterbays/ baffles/ model tests/ discharge measurements/ energy dissipation/ negative pressures
IDENTIFIERS-- resting pools/ spawning channels/ diffuser chambers/ diffuser gratings/ rate-of-flow controllers/ bypass conduits/ Missouri River Basin Proj/ Montana/ hydraulic design/ subatmospheric pressures

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Office of Chief Engineer
Division of Research
Hydraulics Branch
Structures and Equipment Section
Denver, Colorado
March 30, 1965

Report No. Hyd-525
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Subject: Hydraulic model studies of Yellowtail Afterbay Dam spawning channel stilling basin and diffuser chamber, Missouri River Basin Project, Montana

PURPOSE

The studies were conducted to develop the hydraulic design of the stilling basin and diffuser chamber at the upstream end of the spawning channel. Studies were also conducted to develop the hydraulic design of another diffuser chamber at the downstream end of the 24-inch bypass from the stilling basin to the downstream portion of the fish ladder.

RESULTS

1. The preliminary arrangement of the stilling basin and diffuser chamber, which included a large floor block and a stepped end sill, did not provide satisfactory stilling action or flow distribution.

2. A slotted baffle (Figure 9) near the intake conduit was developed for the stilling basin to provide a relatively stable water surface in the basin, and good flow distribution from the diffuser chamber into the resting pool.

3. The diffuser chamber for the discharge from the 24-inch bypass conduit to the lower portion of the fish ladder was widened from 3 feet 9 inches to 4 feet 4 inches, and a sea wall type of cover was provided at the downstream end to reduce the turbulence in the chamber and to improve the distribution of flow into the fish ladder.

ACKNOWLEDGMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the Dams Branch and the Hydraulics Branch during the period September 1964 through November 1964. Laboratory photography was by Mr. W. M. Batts, Office Services Branch.

INTRODUCTION

Yellowtail Dam and Afterbay Dam, parts of the Lower Big Horn Division of the Missouri River Basin Project, are located on the Big Horn River about 60 miles southeast of Billings, Montana (Figure 1). The Afterbay Dam is located about 2-1/2 miles downstream from Yellowtail Dam. The Afterbay Dam is a concrete structure with earth dikes at each abutment rising about 50 feet above the riverbed (Figure 2). The dam includes a sluiceway, radial gate controlled overflow weir, and canal headworks. The total length of the dam, including the earth dikes, is 1,400 feet. The primary function of the Afterbay Dam is to maintain relatively uniform flows in the Big Horn River on a daily basis, in order that existing downstream canals diverting from the river can continue to divert without major overhaul of existing diversion structures.

The spawning channel is located on the downstream side of the dam near the left abutment (Figure 3). Flow enters the spawning channel through a 4-foot-diameter intake conduit, a stilling basin, and a diffuser chamber at the upstream end of the spawning channel. The rate of flow into the stilling basin is controlled by a rate-of-flow controller and meter which contains a small butterfly valve. The flow passes through the stilling basin into the diffuser chamber and then upward through a diffuser grating into the resting pool at the upstream end of the spawning channel. The design flow for the stilling basin is 150 cfs; 30 cfs will be discharged from the stilling basin through a 24-inch bypass conduit to the lower portion of a fish ladder; 20 cfs will be discharged from the resting pool into the upstream end of the fish ladder (Figure 4); and the remaining 100 cfs will flow into the spawning channel. During normal operation the reservoir water surface will fluctuate between elevation 3192 and elevation 3175. The water surface in the spawning channel may fluctuate between elevation 3167.9 and 3169.4. Dimensions of hydraulic features are listed in Table 1 for both English and metric units.

THE MODELS

The first model (Figure 5) was a 1 to 8 scale reproduction of the stilling basin, diffuser chamber, resting pool, and upstream end of the spawning channel. The entrance to the 24-inch bypass conduit from the stilling basin and the entrance to the fish ladder from the resting pool were also simulated in the model. The rate-of-flow controller and meter that discharged the flow from the intake conduit into the stilling basin was simulated by use of a 6-inch butterfly valve in a 6-inch supply line. Flow was supplied to the supply line by means of the laboratory's permanent supply system. The head was measured by piezometers located one pipe diameter upstream from the butterfly valve.

The rate of flow into the spawning channel was controlled by means of a slide gate at the downstream end of the model and was measured with a 90° V-notch weir. The rate of flow through the bypass was controlled by means of a 3-inch gate valve and measured with a 90° V-notch weir. The remainder of the flow discharging into the fish ladder was controlled by a slide gate. The two slide gates also controlled the water surface elevation in the spawning channel. The rate of flow to the fish ladder was determined by subtracting the sum of the spawning channel flow and the bypass flow from the total inflow.

After completion of the model study of the spawning channel stilling basin and diffuser chamber, a 1:4 scale model of the diffuser chamber at the downstream end of the 24-inch bypass conduit was constructed within the existing model (Figure 6). The 6-inch supply line and butterfly valve was used to represent the 24-inch bypass and to control the head. The diffuser chamber was constructed using wooden partitions inserted within the stilling basin of the existing model.

THE INVESTIGATION

The investigation was concerned with flow conditions in the stilling basin, diffuser chamber, resting pool, and spawning channel for the design inflow of 150 cfs discharging from minimum and maximum afterbay reservoir elevations. The investigation was extended at the conclusion of the initial studies to include the flow conditions in the diffuser chamber at the downstream end of the 24-inch bypass conduit.

Preliminary Design

The preliminary design (Figure 7) utilized one large baffle placed on the centerline on the floor of the stilling basin and a stepped end sill at the downstream end of the diffuser chamber under the diffuser grating. The grating was designed so that the average velocity through the open area would be approximately 1/2 foot per second.

Flow from the butterfly valve simulating the rate-of-flow controller crossed the stilling basin and impinged upon the downstream wall creating a considerable amount of turbulence in the stilling basin (Figure 8). A grid of piezometers installed on the upstream side of this wall showed the pressures to be equal to the rise in water surface along the wall, or about 2 feet of water above the normal water surface elevation.

The flow in the resting pool was relatively quiet; however, the flow entered the pool through the downstream portion of the grating; some of the flow then turned upstream and returned to the diffuser chamber through the upstream portion of the grating. This operation was particularly true at high head and high tailwater. The stepped end sill and baffle block did not provide uniform flow distribution through the grating.

Modifications

The width of the stilling basin was reduced to 17 feet, or the same width as the grating. This modification increased the turbulence in the stilling basin and further concentrated the flow through the downstream end of the diffuser grating. No further tests were made with the narrow basin.

The large baffle and stepped end sill were removed and a slotted baffle was installed between the stilling basin and the diffuser chamber. The baffle extended from the basin floor to the headwall of the resting pool, and blocked off one-half of the flow passage. This change provided much better flow distribution through the grating.

Other minor modifications in size of stilling basin and diffuser chamber and in baffle arrangements, including a large sloping sill on the basin floor beneath the headwall of the resting pool, were investigated, but were not as satisfactory as the slotted baffle.

Recommended Design

The recommended design (Figure 9) consisted of the preliminary basin and diffuser chamber with the large baffle and stepped end sill removed and a slotted baffle placed in the path of the jet near the headwall of the basin. Essentially, the baffle consisted of four walls that provided three slots from which the flow could emerge into the basin. One 16-inch-wide slot on the centerline, 3 feet downstream from the headwall, was flanked by two 32-inch-wide walls. Two additional side-walls extended 3 feet out from the headwall at a point 5 feet 4 inches on either side on the centerline.

This device provided a relatively smooth water surface in the stilling basin (Figure 10) and a fairly uniform flow distribution from the diffuser chamber into the resting pool. The relatively smooth water surface in the stilling basin resulted in a much smoother water surface and a more constant head at the entrance to the bypass than was available with the preliminary design.

The more uniform flow distribution through the diffuser grating reduced the velocities and turbulence and provided a quieter resting pool than was available in the preliminary design. Dye streamers introduced into the flow to trace the flow currents revealed that the flow passed downward from the resting pool into the diffuser chamber only at the extreme upstream edge and corners of the diffuser grating.

The stilling basin and diffuser chamber performed well for any possible operating combination of head and tailwater. The structures also performed well with the fish ladder and bypass closed when the entire 150 cfs discharged into the spawning channel (Figure 11). This discharge at low tailwater elevation created a riffled water surface at the entrance to the spawning channel and a minor amount of erosion in the channel bed. However, the prototype channel will be protected by a gravel lining, and the effects of erosion should be negligible.

Pressures for the design flow of 150 cfs with minimum and maximum heads were recorded at a piezometer located at the upstream corner of one wall of the center slot (Figure 9). At minimum tailwater, the pressures ranged from 1.5 feet below atmospheric at minimum head to 4.8 feet below atmospheric at maximum head. At maximum tailwater elevation, the pressures ranged from 1.7 to 6.4 feet above atmospheric at minimum and maximum heads. Because the maximum flow velocity from the valve is less than 30 feet per second, no adverse pressure conditions are anticipated along the slotted walls.

Bypass Conduit Diffuser Chamber

After the studies of the spawning channel stilling basin and diffuser chamber were completed, the diffuser chamber for the 24-inch bypass (Figure 4) was modeled and tested. The 6-inch model supply line with butterfly valve was used to simulate the 24-inch bypass pipe and to regulate the head. The chamber was constructed at the outlet within the stilling basin of the existing model (Figure 6). Flow from the stilling chamber discharged through a submerged rectangular opening into the right portion of the existing model, which represented one bay of the fish ladder. The area to the left and downstream surrounding the basin represented the stream channel tailwater area. This arrangement provided a model on the opposite hand to the prototype structure.

The diffuser chamber was tested for a flow of 30 cfs assuming no head losses in the approach conduit and for 30 cfs assuming maximum head losses, both for two tailwater conditions. The low tailwater was slightly below the top of the downstream wall of the chamber while the higher tailwater was approximately 1 foot (prototype) above the top of this wall.

The tests indicated that the turbulent flow conditions in the preliminary chamber would be improved if the chamber width of 3 feet 9 inches was increased to 4 feet 4 inches and the bypass line moved to enter at the centerline of the chamber. The tests also showed that wave action would be reduced if a seawall was placed extending 18 inches upstream from the downstream wall (Figure 6).

The enlarged diffuser chamber and seawall helped to contain the flow within the chamber and reduced the turbulence. Although most of the flow discharged through the downstream portion of the submerged opening, flow distribution from the chamber through the submerged rectangular opening into the fish ladder was better distributed than with the preliminary arrangement. The performance was considered to be satisfactory for a discharge of 30 cfs in the range of the operating heads.

Table 1

Dimensions of Hydraulic Features

Feature	English	Metric
Height of dam	50 feet	15.24 meters
Length of dam	1,400 feet	426.72 meters
Discharge to spawning channel	150 cfs	4.25 cms
Discharge in spawning channel	100 cfs	2.83 cms
Discharge from bypass	30 cfs	0.85 cms
Discharge from fish ladder	20 cfs	0.57 cms
Intake conduit diameter	4 feet	1.22 meters
Size of bypass	24 inch	60.96 centimeters

FIGURE 1
REPORT HYD-525

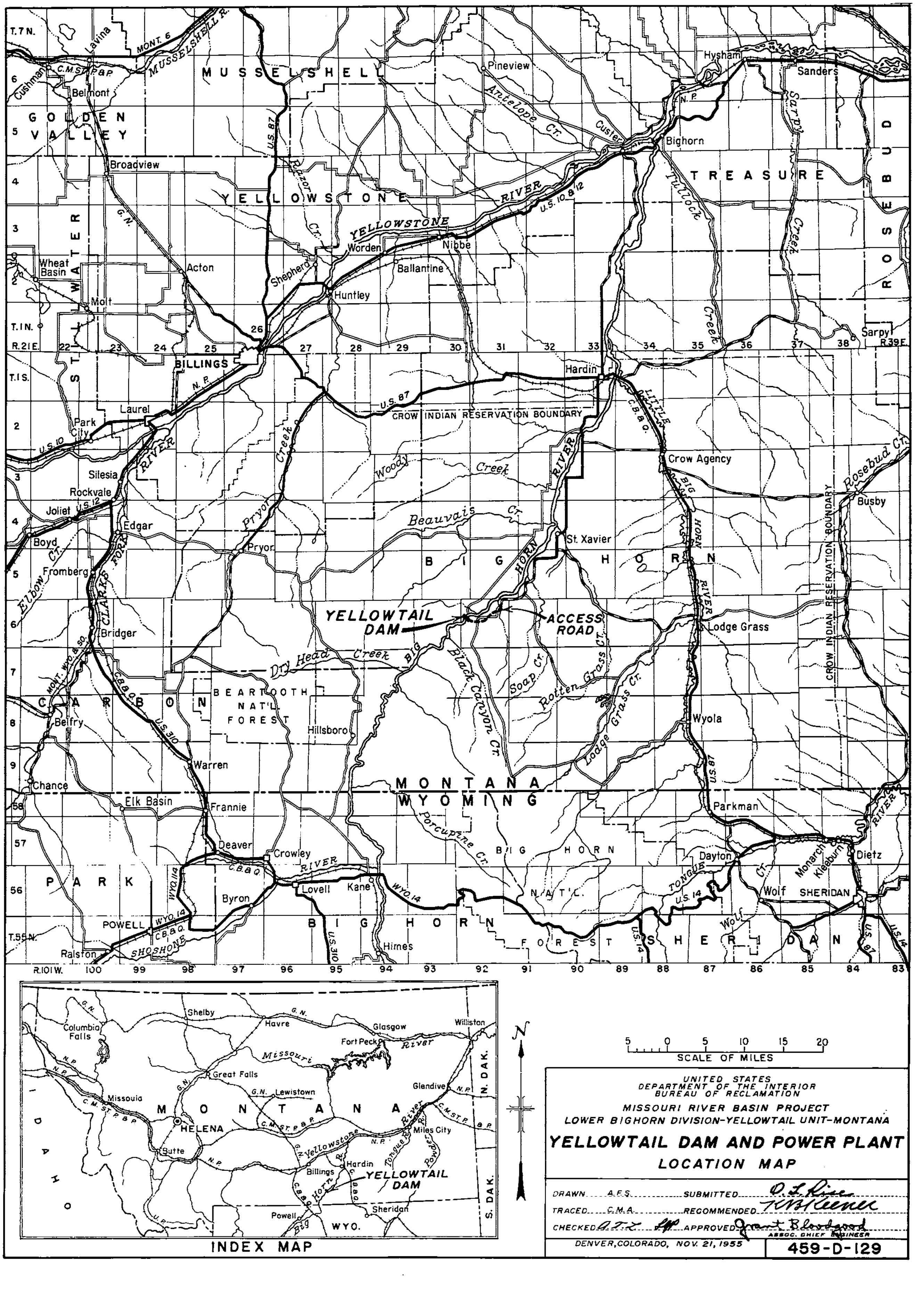


FIGURE 2
REPORT HYD-525

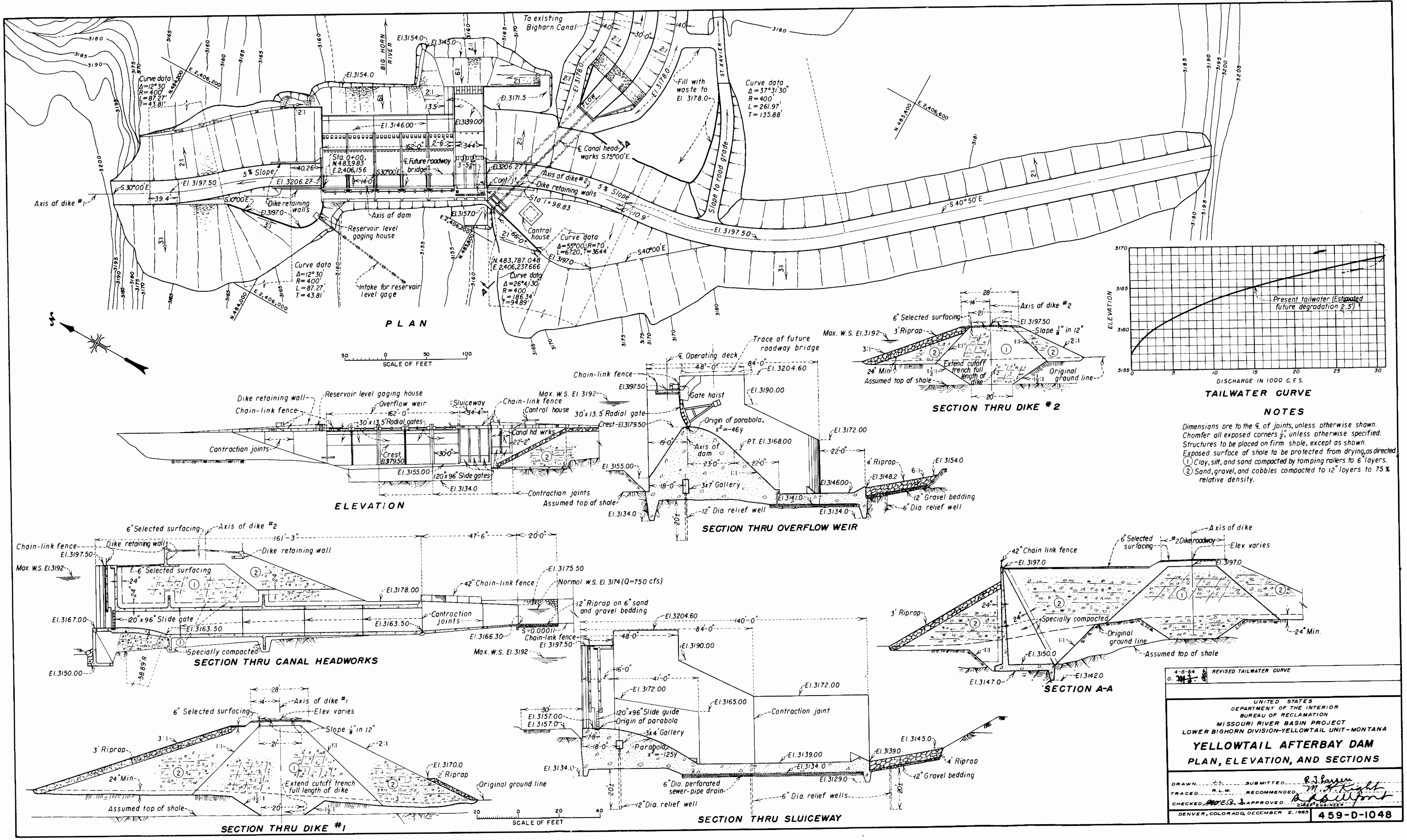
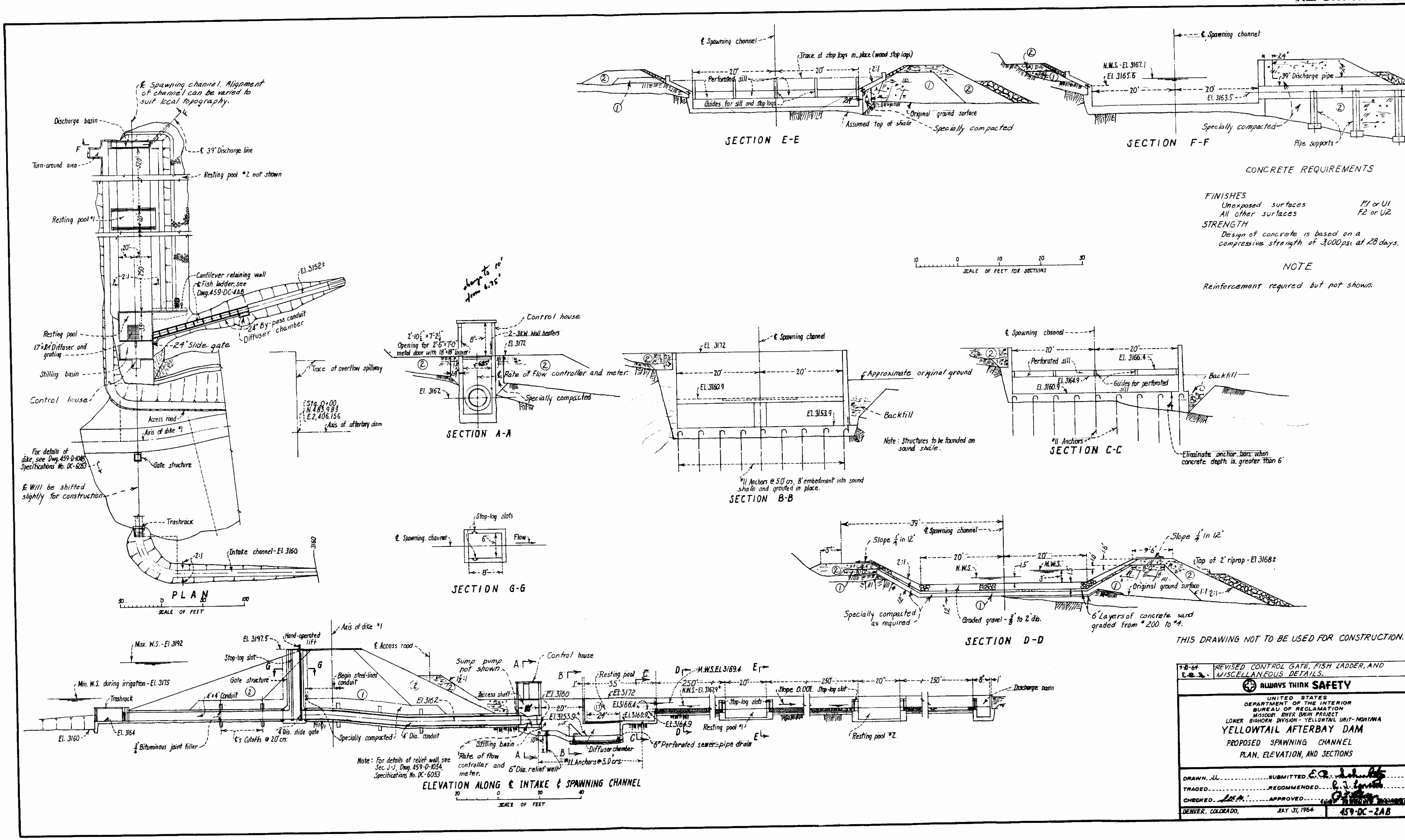
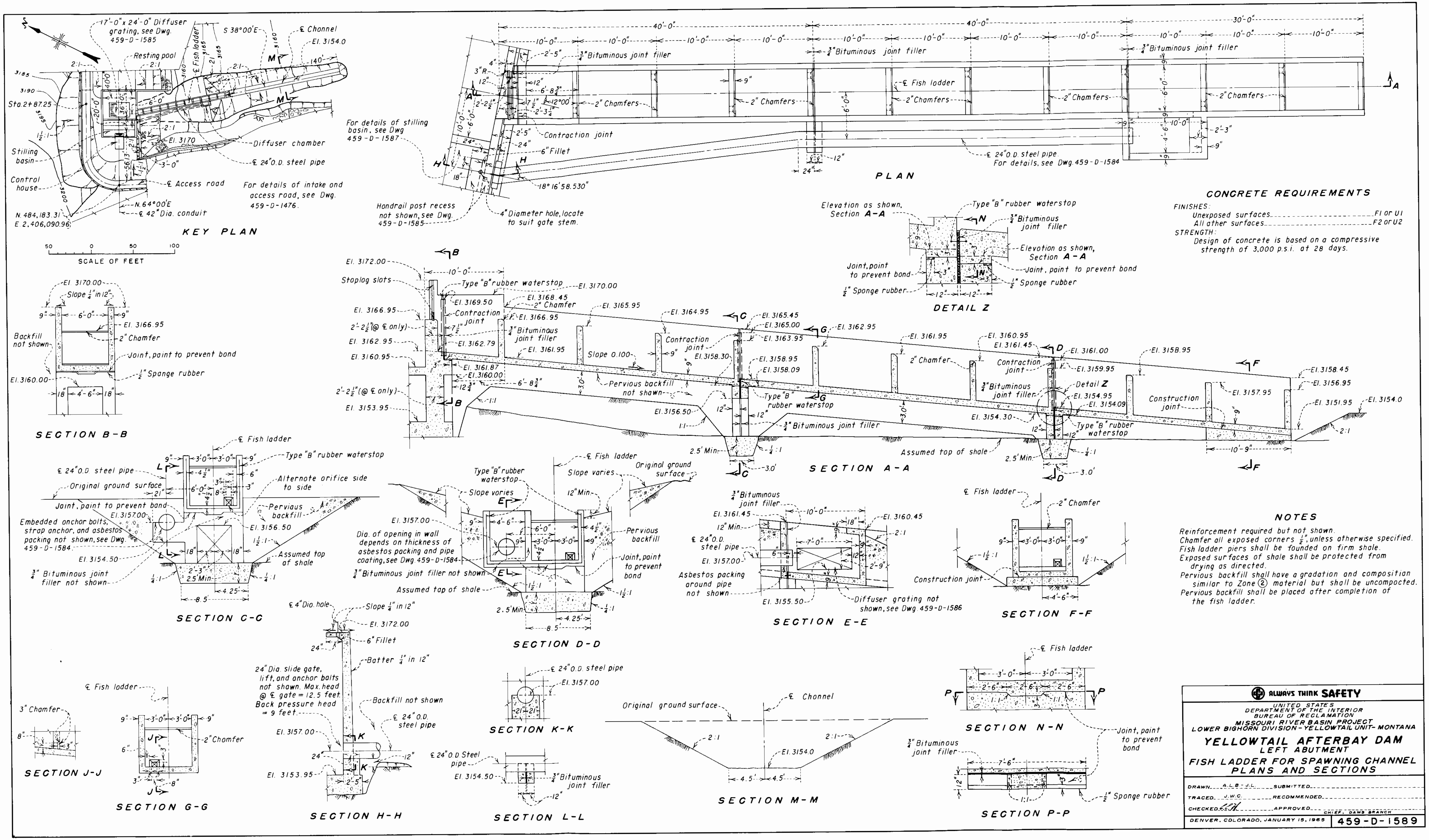
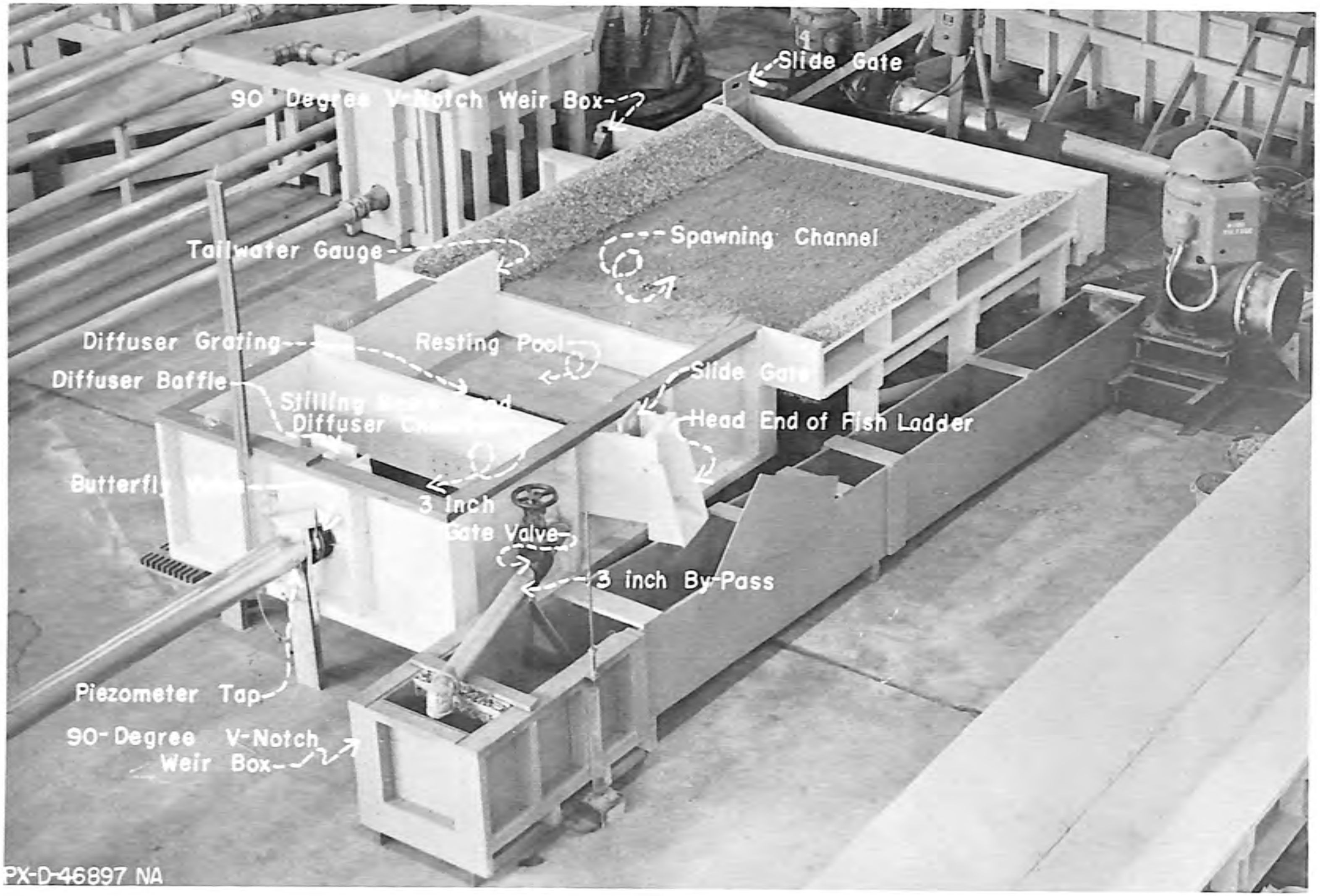


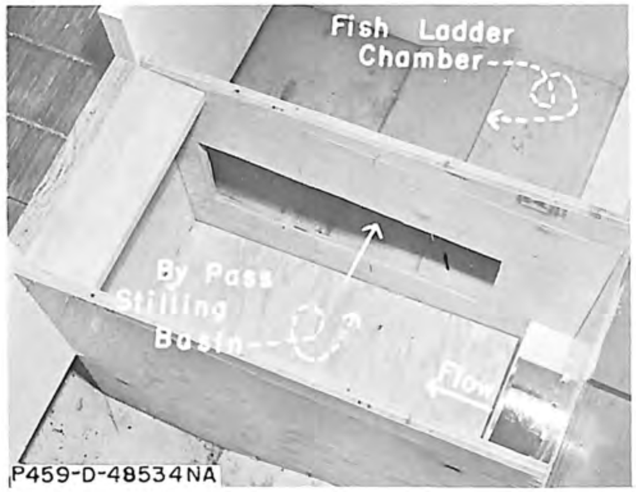
FIGURE 3
REPORT HYD-525




KEY PLAN
SCALE OF FEET
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
SECTION J-J
SECTION K-K
SECTION L-L
SECTION M-M
SECTION N-N
SECTION P-P
DETAIL Z
CONCRETE REQUIREMENTS
FINISHES:
Unexposed surfaces.....F1 or U1
All other surfaces.....F2 or U2
STRENGTH:
Design of concrete is based on a compressive strength of 3,000 p.s.i. at 28 days.
NOTES
Reinforcement required but not shown.
Chamfer all exposed corners 1/2", unless otherwise specified.
Fish ladder piers shall be founded on firm shale.
Exposed surfaces of shale shall be protected from drying as directed.
Pervious backfill shall have a gradation and composition similar to Zone (2) material but shall be uncompacted.
Pervious backfill shall be placed after completion of the fish ladder.
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION - YELLOWTAIL UNIT - MONTANA
YELLOWTAIL AFTERBAY DAM
LEFT ABUTMENT
FISH LADDER FOR SPAWNING CHANNEL
PLANS AND SECTIONS
DENVER, COLORADO, JANUARY 15, 1965
459-D-1589



YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
THE 1:8 SCALE MODEL



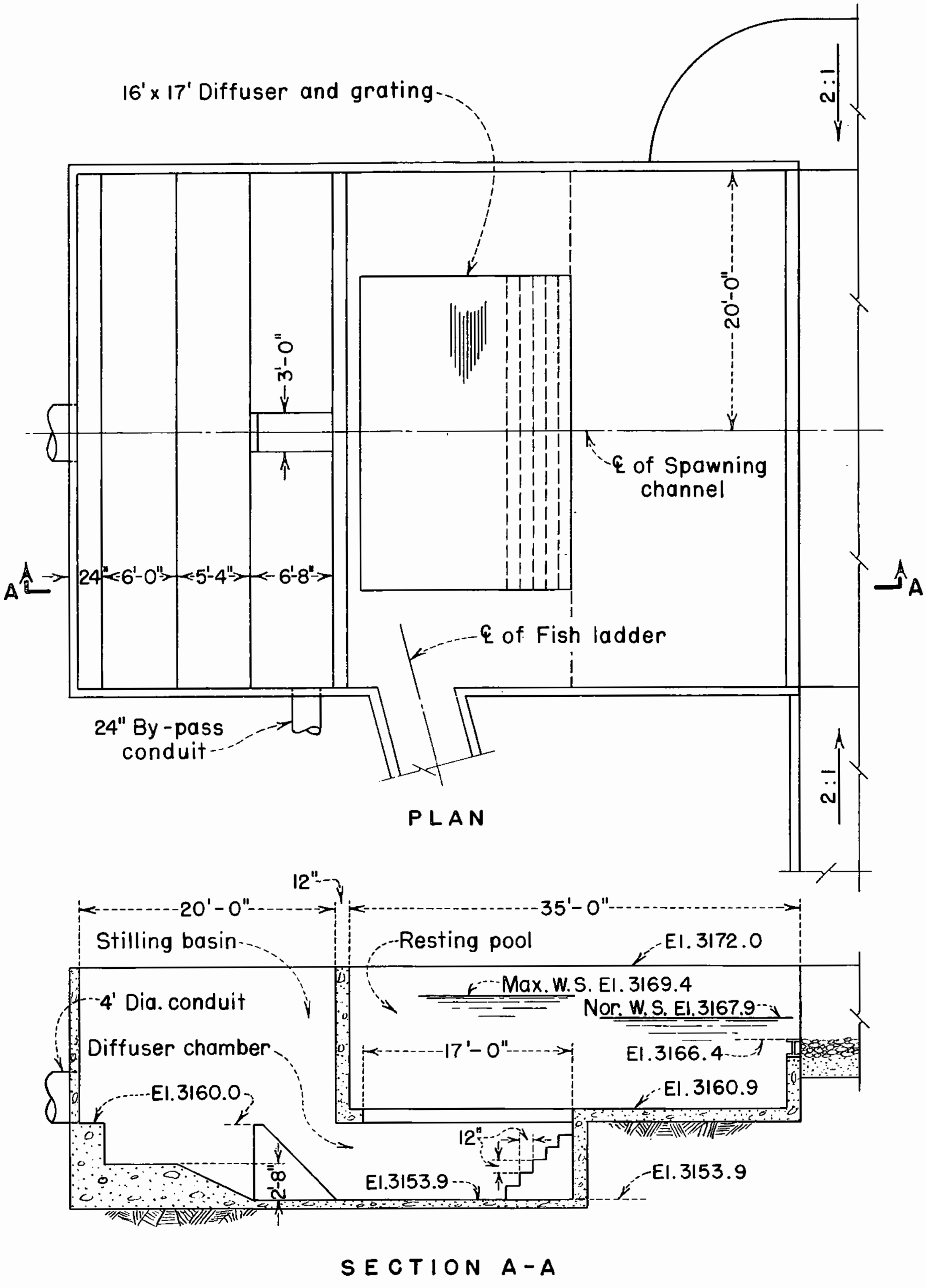
A. Dry Model

B. Headwater elevation 3169.4
Tailwater elevation 3160.0

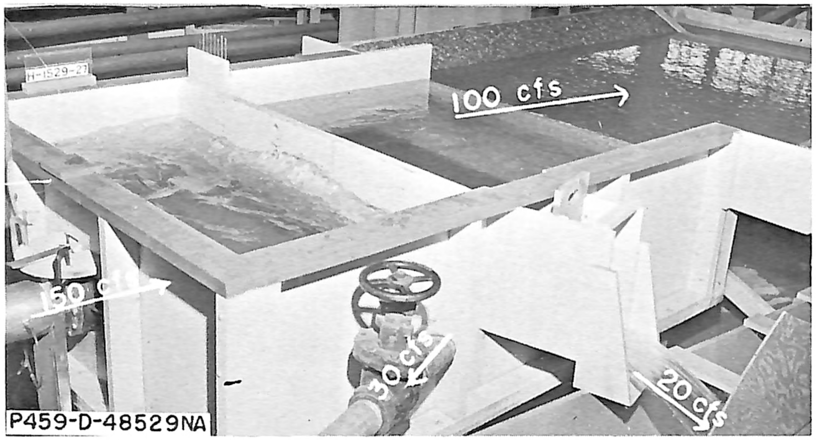
C. Headwater elevation 3169.4
Tailwater elevation 3161.4

NOTE: The model is on opposite hand to the prototype structure.

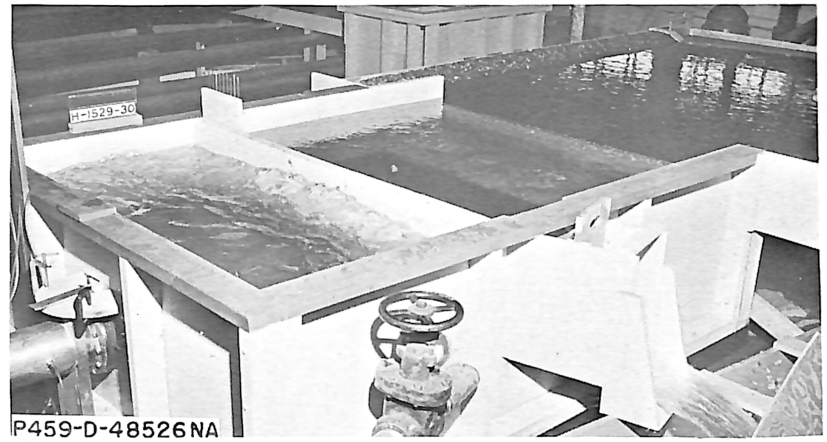
YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
RECOMMENDED BYPASS DIFFUSER CHAMBER
1:4 SCALE MODEL



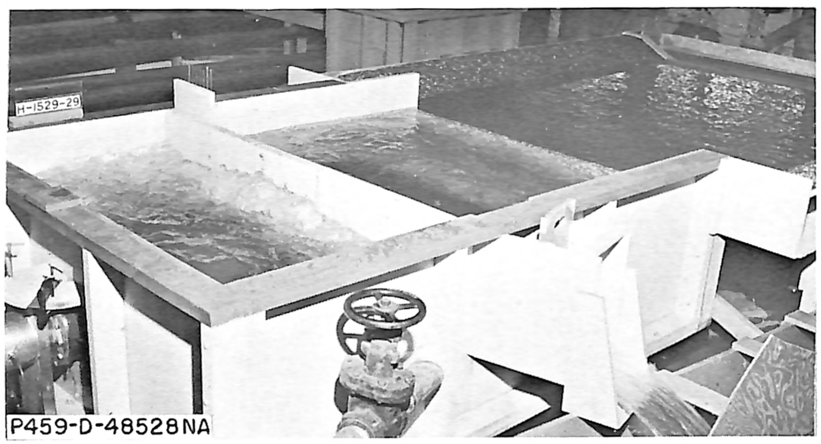
YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
PRELIMINARY STILLING BASIN AND DIFFUSER CHAMBER
1:8 SCALE MODEL



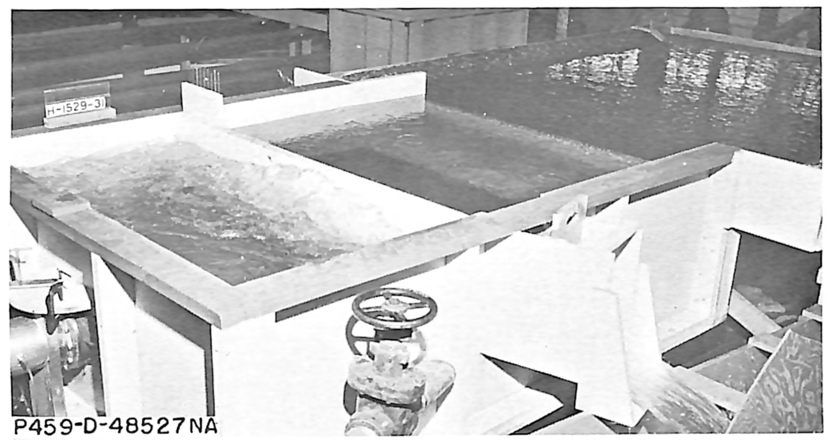
A. Headwater elevation 3175.0
Tailwater elevation 3167.9



B. Headwater elevation 3175.0
Tailwater elevation 3169.4

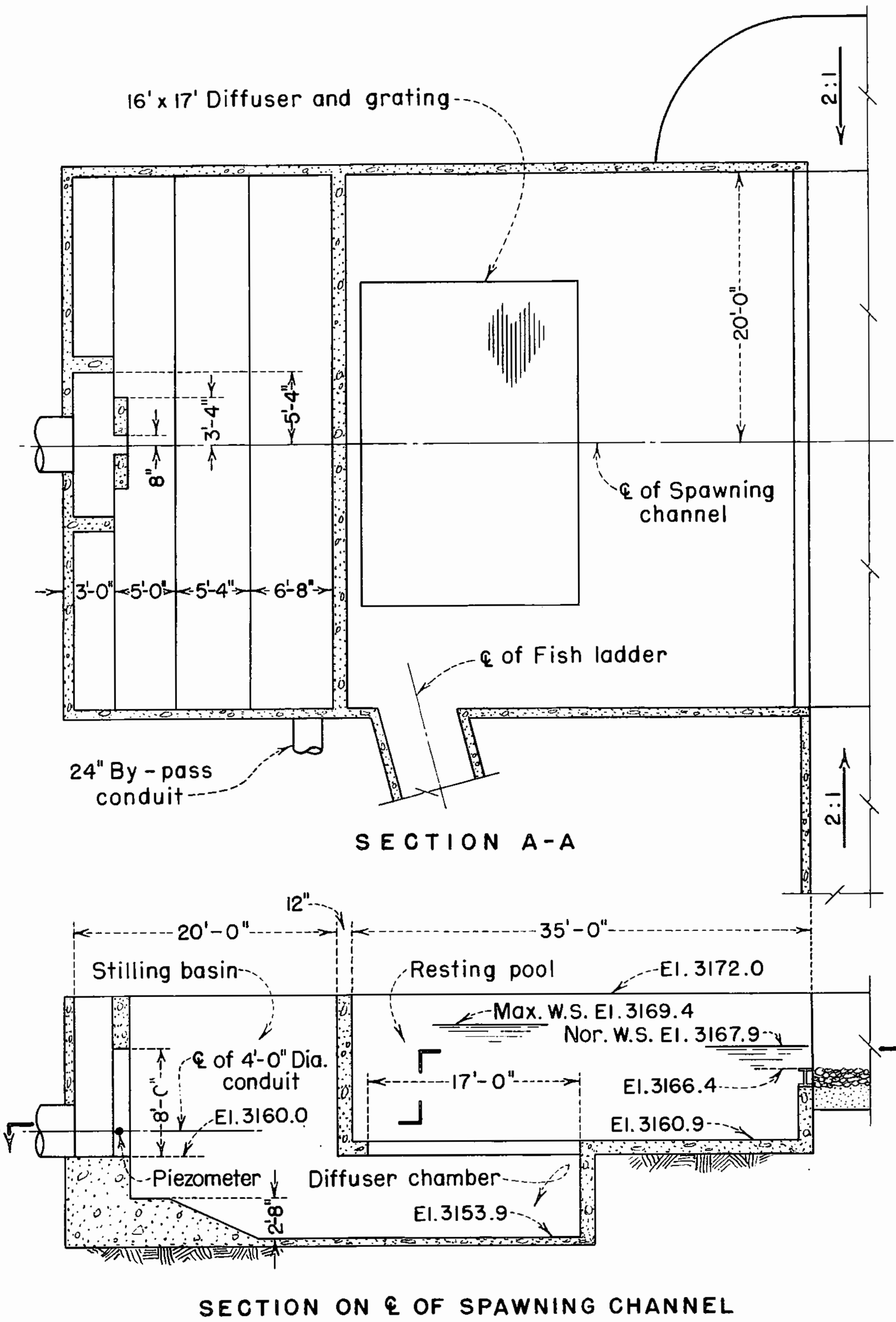


C. Headwater elevation 3192.0
Tailwater elevation 3167.9

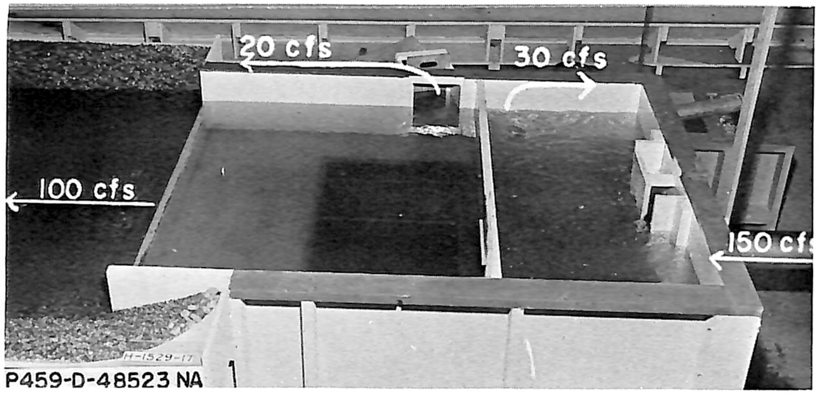


D. Headwater elevation 3192.0
Tailwater elevation 3169.4

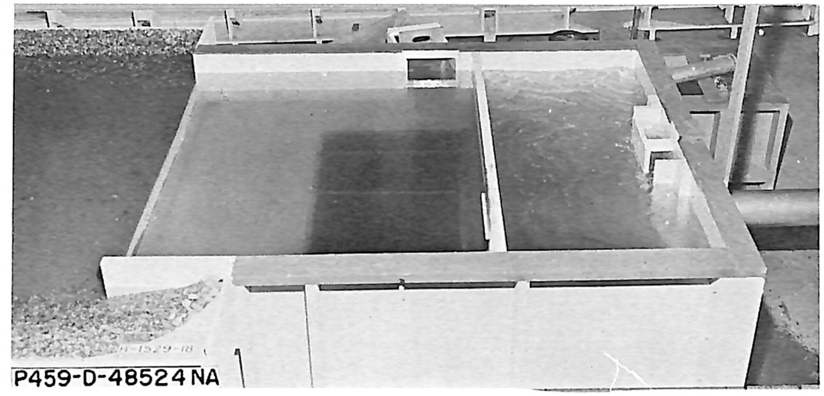
YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
PRELIMINARY DESIGN DISCHARGING 150 CFS
1:8 SCALE MODEL



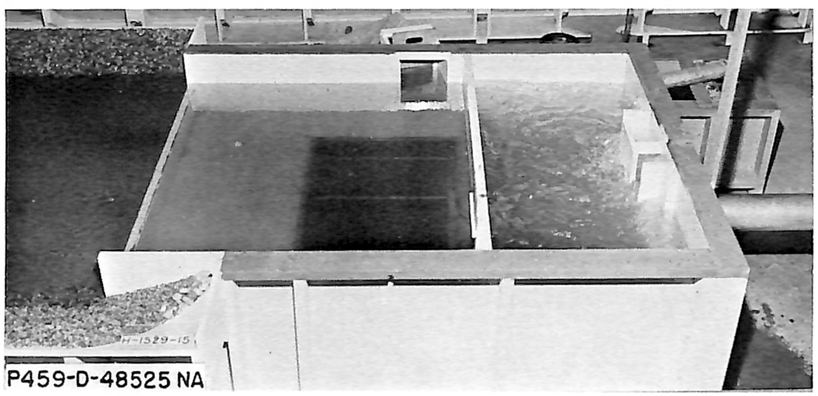
YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
RECOMMENDED STILLING BASIN AND DIFFUSER CHAMBER
1:8 SCALE MODEL



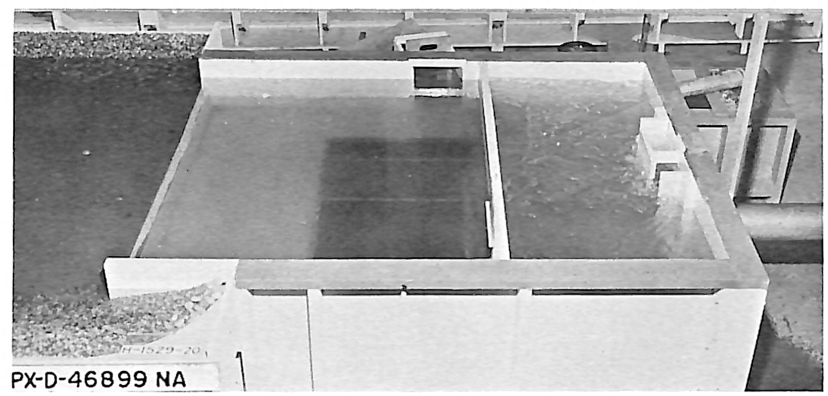
A. Headwater elevation 3175.0
Tailwater elevation 3167.9



B. Headwater elevation 3175.0
Tailwater elevation 3169.4

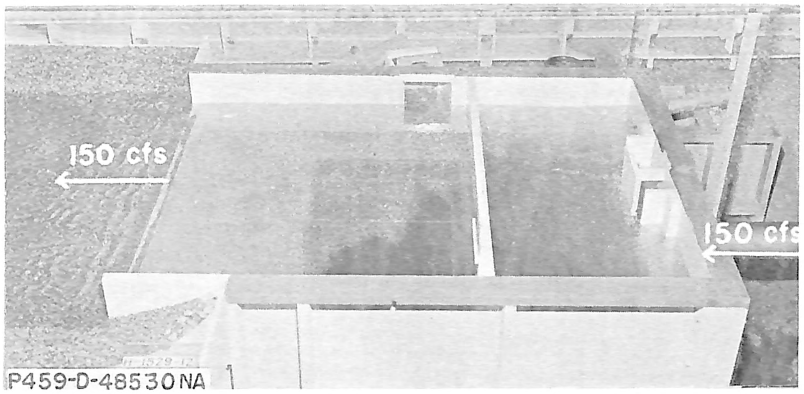


C. Headwater elevation 3192.0
Tailwater elevation 3167.9

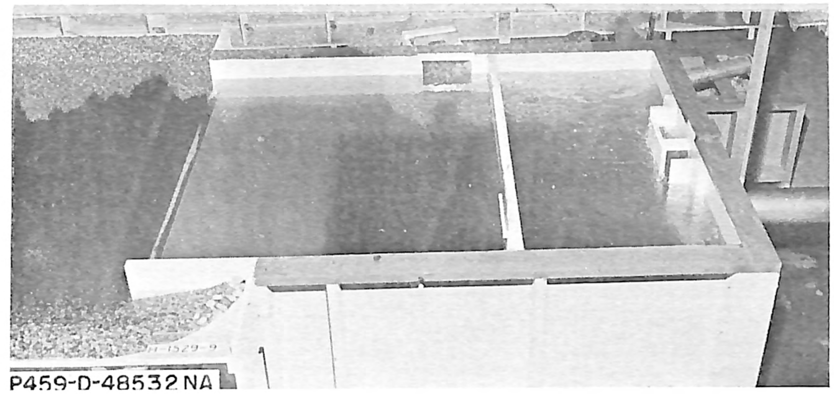


D. Headwater elevation 3192.0
Tailwater elevation 3169.4

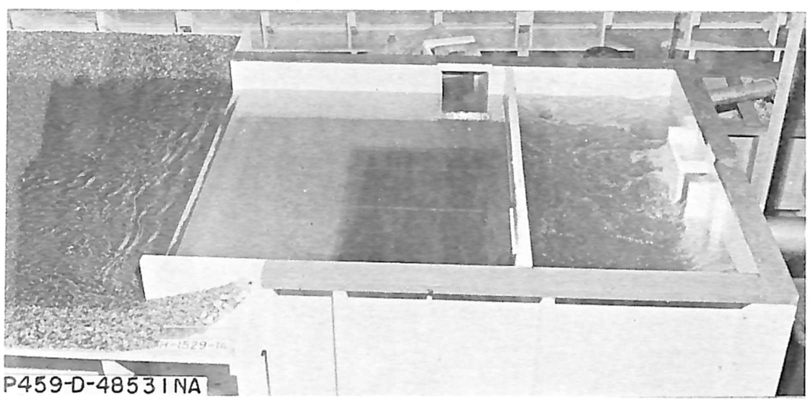
YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
RECOMMENDED DESIGN DISCHARGING 100 CFS
1:8 SCALE MODEL



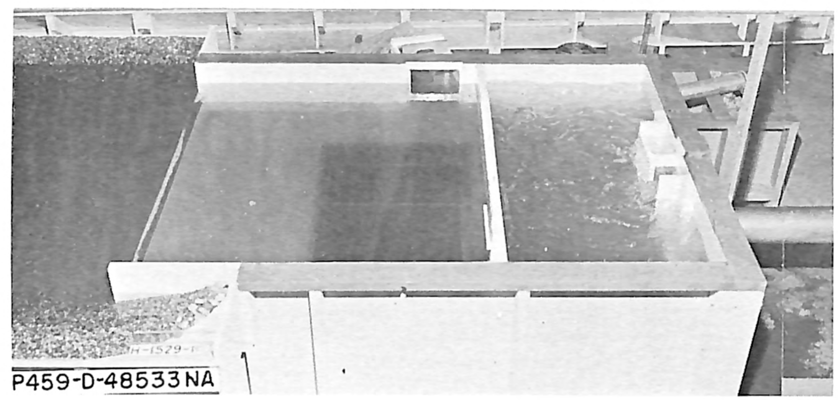
A. Headwater elevation 3175.0
Tailwater elevation 3167.9



B. Headwater elevation 3175.0
Tailwater elevation 3169.4



C. Headwater elevation 3192.0
Tailwater elevation 3167.9



D. Headwater elevation 3192.0
Tailwater elevation 3169.4

YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL
RECOMMENDED DESIGN DISCHARGING 150 CFS
1:8 SCALE MODEL

7-1750
(10-64)

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.02903* (exactly)	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

ABSTRACT

Hydraulic model studies of the spawning channel stilling basin and diffuser chamber at Yellowtail Afterbay Dam in Montana resulted in the use of a slotted baffle near the intake conduit to provide satisfactory stilling action and good flow distribution. Flow enters the spawning channel through a 4-ft-dia intake conduit, passes through a stilling basin, and upward through a diffuser grating into the resting pool at the upstream end. Of the 150-cfs design flow, 30 will be discharged through a 24-in. bypass pipe to lower part of the fish ladder, 20 into the upstream end of the fish ladder, and the rest into the spawning channel. The slotted baffle diffuser was developed for the stilling basin to replace floor block and stepped end sill of the original design. This provided a relatively stable water surface in the basin and good flow distribution from the diffuser chamber into the resting pool, so that flow into and through the pool was quiet. The modified stilling basin and diffuser chamber performed well for any possible operating combination of head and tailwater. To quiet flow from the bypass pipe from main stilling basin before discharging it at right angles into the fish ladder, the bypass diffuser chamber was widened and a seawall-type cover was provided at the downstream end to reduce turbulence.

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IDENTIFIERS-- resting pools/ spawning channels/ diffuser chambers/ diffuser gratings/ rate-of-flow controllers/ bypass conduits/ Missouri River Basin Proj/ Montana/ hydraulic design/ subatmospheric pressures

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