UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# HYDRAULIC MODEL STUDIES OF GRASSY LAKE DAM OUTLET WORKS AND SPILLWAY

## UPPER SNAKE RIVER PROJECT, WYOMING

Hydraulic Laboratory Report No. Hyd.-226

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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Branch of Design and Construction
Engineering and Geological Control
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Denver, Colorado
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Laboratory Report No. 226
Hydraulic Laboratory
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Reviewed by: J. N. Bradley

Subject: Hydraulic model studies of Grassy Lake Dam Outlet Works and Spillway--Upper Snake River Project, Wyoming.

## INTRODUCTION

### Description of Structure

The model study on the Grassy Lake Dam Spillway was performed in 1937. This report was prepared in 1946 from the original notes and data.

Grassy Lake Dam is located in Teton County, Wyoming, on the south boundary of Yellowstone National Park (Figure 1). The dam--a combination earth and rockfill structure--intercepts the flow of Grassy Creek, a tributary of Falls River, to form a reservoir with an estimated maximum capacity of 15,549 acre-feet. The total height of the dam is 132 feet from roadway to floor of stilling-pool.

The principal hydraulic features of the structure are a side-channel spillway at the left abutment and the outlet works which pass through the main body of the dam (Figure 2). The outlet works, 718 feet long, consist of a single conduit, terminating at the downstream end in a 30-inch needle valve (Figure 3) with designed capacity of 243 second-feet. The spillway is a concrete-lined open channel, approximately 860 feet in length (Figure 4) and has a designed capacity of 1,200 second-feet at the maximum reservoir elevation.

### Necessity for Investigation

The proposed designs of both the outlet works and spillway presented a strong possibility of scouring action which could be sufficiently excessive to endanger the structures. In the case of the outlet works, the riprap pool, an unconventional type for use in conjunction with needle valves, particularly invited model study. The spillway was subject to erosion both in the approach channel and in the stilling-pool.

## SUMMARY

### Outlet Works

The use of the riprap pool design specified in the initial design would have been conducive to excessive scour and wave action. Substitution of the design developed by model studies (Figure 10) should reduce this scour to desirable limits, so long as care is taken to build up the tailwater elevation to normal before allowing large discharges to pass through the valve. Failure to observe this rule would cause considerable riprap displacement in any of the designs tested.

### Spillway

The original spillway design indicated that improvement could be made in the flow conditions in the spillway approach, chute, and stilling-pool. Model tests showed that the changes as recommended in Figure 16 would make the design adequate for all flows. With these modifications, the spillway will be capable of passing the maximum designed discharge without damage to the structure.

## THE MODELS

### Outlet Works

A 1:12 model was constructed of the pertinent features of the riprap pool of the outlet works (Figure 5). It consisted of a large tailbox containing the excavated and riprapped areas downstream from the needle valve, a model valve, and the necessary piping and measuring devices to supply water to the model. The tailbox was constructed of wood and lined with light sheet metal for watertightness. All pertinent features of the excavated and riprapped areas downstream from the valve were reproduced to scale in this box. The riprap was represented by rock of approximately 1-inch average diameter, and the alluvial deposit by sand except in the trapezoidal channel downstream from the riprapped area. The latter was represented by rough concrete. A hinged wood and canvas gate, installed at the downstream end of the tailbox, was used to regulate the elevation of the tailwater. A water column was used to measure this elevation.

The model needle valve was installed in the upstream wall of the tailbox. Water was supplied through a 6-inch pipe, which terminated in a manifold directly upstream from the valve. Piezometers, located in the base of the valve, were utilized to measure pressure heads. The discharge was measured by a 4-inch Venturi meter located between the supply pump and valve manifold. The valve openings required for each discharge and head combination were determined from curves obtained from a previous calibration.

### Spillway

A 1:20 model, entirely removed from that of the outlet works, was constructed of the spillway (Figure 6). It consisted of a headbox containing the approach topography and side-channel unit, a long wooden chute representing the spillway channel, and a tailbox containing the stilling-pool and downstream topography details. The headbox and tailbox were constructed in the same manner as the tailbox for the outlet works, with the topography reproduced with sand, rock, and concrete. The side-channel unit was made of concrete.

A gate at the downstream end of the tailbox was used to regulate the tailwater elevation. Water columns, attached to piezometer openings in the headbox and tailbox, were used to measure the elevations of the reservoir and tailwater surfaces.

## THE OUTLET WORKS

### Testing Procedure

In designing the outlet works for Grassy Lake Dam, it was planned to substitute a riprap pool (Figure 3) for the more conventional concrete pool commonly used in conjunction with needle-valve outlets. This substitution was desirable because of the decreased cost of such construction. There was no expectation of complete freedom from scour with this pool. It was desirable, of course, to hold the scour within such limits as to prevent the disintegration of the riprap lining and not endanger weakening of the valvehouse foundations. Excessive erosion might also cause deposition of material in a bar downstream from the pool of such magnitude as to interfere with the operation of the outlets.

It was not necessary to insure a minimum of spray during periods when the structure might be operating at maximum capacity, since it was not planned to construct a powerhouse in conjunction with the dam. Therefore, as long as the amount of such spray was not sufficient to cause appreciable erosion of the surrounding finer material, its presence could be tolerated. Based on these premises, it was decided that the following factors, resulting from outlet flow, were the most important ones to observe, evaluate, and reduce by experiment to a desirable minimum:

1. Violent forward currents
2. Reverse currents along the pool walls
3. Splash and severe wave action

To evaluate the extent of each of these manifestations under the most extreme conditions, the following testing procedure for each design was established:

1. Maximum discharge at maximum head, normal tailwater
2. Intermediate discharge at corresponding head, normal tailwater
3. Intermediate discharge with corresponding head, no tailwater (Final design only)

The maximum discharge was established at 243 second-feet (0.488 second-foot model) with a reservoir depth of 104 feet above the centerline of the 30-inch needle valve. With the water surface lowered to 7155.69, (50 feet above the valve centerline), an intermediate discharge of 180 second-feet (0.361 second-foot model) was calculated to be suitable for model tests.

Since the model valve had a 2.8-inch outlet diameter instead of 2.5 inches as dictated by the scale ratio of 1:12, it was essential that special attention be given to its calibration to insure that the mass and velocity of the water striking the stilling-pool would be equivalent to that of the prototype.

For the maximum discharge of 243 second-feet, it was estimated from prototype calculations that the friction losses from the inlet to the valve would be 40 feet. This left an effective head of 64 feet at the upstream end of the valve, which was found to be composed of a velocity head of 18.4 feet and a pressure head of 45.6 feet. Using a corresponding effective model head of 64/12 = 5.33 feet, and substituting the valve inlet diameter of 2.8 inches for the 2.5-inch diameter required by the scale ratio, it was found that the effective head would consist of 1.19 feet of velocity head (14.3 feet prototype) and 4.14 feet of pressure head (49.7 feet prototype).

From Figure 7, obtained from a previous calibration of the model valve, it was established that a valve opening of 8.4 turns would give the required discharge and pressure head combination. It was only necessary then to set the desired head on the piezometer at the base of the valve and to open the valve the required number of turns to assure similitude of mass. Similitude of velocity and trajectory could also be expected because previous tests had shown that the variation of "$C_v$" in the formula $V = C_v\sqrt{2gh}$ (where "V" is the velocity in the vena contracta, and "$C_v$" is the coefficient of velocity) is negligible for needle valve openings greater than 15 percent. Therefore, if the value of "h" (effective head) were made the same, the velocity of flow would be nearly equal.

Using this same procedure, a discharge of 180 second-feet at an intermediate total head of 50 feet was converted to a model discharge of 0.361 second-feet at a pressure head of 2.27 feet with the valve open the same amount as in the previous example.

## Results

In the first series of tests, the performance of the original pool design (Figure 9A), was observed under the condition of maximum discharge and head only. During a run of approximately 20 minutes (model) at normal tailwater, the riprap was badly scoured in some areas. Most of this movement occurred on the side slopes between Stations 12+60 and 13+10, the riprap being moved from its original position and deposited to a maximum depth of 8 feet (prototype) on the bottom of the channel.

Scour on the slopes was deep, exceeding 3 feet on the right side. There was no erosion of consequence between the downstream face of the valve-house and Station 12+60 or beyond Station 13+10. Figure 8A shows the original stilling-pool before the run, Figure 8B shows the valve discharging at 243 second-feet, and Figure 8C illustrates the resulting scour after a 1-hour run. The jet of water from the valve first struck the surface at Station 12+65, creating a maximum splash height of 9 feet at a point 30 feet downstream. In the region upstream from Station 12+65, strong back currents and wave action occurred along the riprap slopes, the waves nearly overtopping the banks. Violent forward and backward currents existed along the bottom of the pool, only the flow beyond Station 13+50 being satisfactory.

It was obvious that this pool was not adequate, so the design shown in Figure 9B (first revision) was substituted. The principal revision was an increase in depth of the stilling-pool by 4 feet. The bottom remained 3 feet in width but this increased the bottom slopes to 2:1 and 4:1. This model was tested for both maximum and intermediate discharges. For the maximum condition, there was practically no movement of the riprap, with the deposit on the bottom of the pool having a maximum depth of about 1 foot. This deposit was located in the same area as that of the original design. The greatest depth of side-slope erosion was less than 1 foot. The former violent back currents and wave action along the sidewalls were decreased in intensity, the waves being approximately 2 feet high in the extreme case. The intensity of the bottom currents was also favorably affected. However, many of the destructive water movements reappeared at the intermediate discharge and head, causing erosion of the bottom in the vicinity of Station 12+60. This scour resulted in a general undermining and collapse of the side slopes near this station, the eroded material being deposited between Stations 12+75 and 12+90.

A comparison of the performance of the two designs showed a revealing trend in the scour patterns. In the original design, the maximum scour occurred in the region where the jet impinged on the water surface in the pool, particularly from Station 12+60 to Station 12+80. For the maximum flow, the side slopes were the principal areas affected, the riprap sliding to the bottom of the slope. When Revision 1 was subjected to the higher discharge, the side-slope erosion was decreased because of the increased area of flow in the channel, but insufficient pool depth at the intermediate discharge did not provide protection for the bottom of the channel, thus it scoured appreciably, contributing to side-slope instability.

In the second revision (Figure 9C) the upstream bottom slope was changed from 2:1 to 3:1 with corresponding changes in the dimensions of the stilling-pool. Little improvement was noticeable in the general performance over that of Revision 1.

In Revision 3 (Figure 9D) the slope of the sides was changed to 1-3/4:1 for increased stability, and a reverse slope of 4:1 was inserted in the region of greatest scour. This design effectively eliminated the bottom and side scour as far out as Station 12+80, but a severe scour of about 3-foot depth occurred on the side slopes from this point to Station 13+10. This was caused by strong back currents and waves 2 feet in height along the side slopes at the maximum discharge and head. These back currents were of such magnitude that a jump was formed on each side of the pool near Station 12+95.

In what proved to be the recommended design (Figure 10) the slope of the sides was maintained at 1-3/4:1, but the reverse slope used in the previous design was eliminated. When this pool was operated under conditions of maximum discharge and head, it was immediately apparent that the strong back currents along the sides had been reduced, both in velocity and area, to harmless proportions. This was also true of the waves. All currents were forwarded downstream from Station 13+25 (Figure 11B). These observations were verified by the scour pattern after a run of 1-hour duration. No erosion occurred on the right bank, but a small area on the left bank at Station 13+10 had been scoured to a maximum depth of 1 foot (prototype). This material had been deposited on the bottom, the amount being negligible. Figures 11A and C show the riprap in the pool before and after the run, respectively. For the intermediate discharge, corresponding to a prototype discharge of 180 second-feet at a total head of 50 feet, there was no disturbance of the riprap. The back currents and waves, referred to previously, were slight in magnitude. The surface appearance of the pool was quite satisfactory.

As a final test, a discharge of 100 second-feet at a head of 22.7 feet (prototype) was run into the pool for 10 minutes (model time) starting with no tailwater. The purpose of this test was to evaluate the scour to be expected from the impact of the jet on the riprap without the cushioning effect provided by normal tailwater. The jet struck the riprap at approximately Station 12+60, cutting a hole about 14 feet square and 4 feet in maximum depth. The eroded material was deposited in a ridge from one side slope to the other from Station 12+65 to Station 12+75, with a maximum height of 6 feet at Station 12+70. With the exception of the last test, the overall performance of this design was judged to be satisfactory, and was adopted as the recommended design.

## THE SPILLWAY

### Approach Studies

Model tests on the initial spillway design (Figure 6) indicated that both wing-walls of the approach to the side-channel spillway could be improved. Eddies caused by abrupt changes in the direction of flow at these points resulted in scour at the base of both walls and contributed to rough flow in the region of the control sill. Figure 12A shows the original design of the wing-walls, Figure 12B shows the model in operation at 1,200 second-feet, and Figure 12E indicates the scour produced near the walls by the above discharge. Unfortunately, the upstream wall was not included in the photographs.

The flow in the side-channel unit was unusually turbulent. Whether the primary origin of this action was in the approach eddies or in the limits of the structure itself was not immediately apparent.

The shape of the upstream approach wall was then altered to that shown on Figure 4, while that on the upstream side was given a circular flare (Figures 4 and 12D). When the maximum flow of 1,200 second-feet was run through the model for 70 minutes, it was found that this alteration had effectively prevented the erosion inherent in the initial design. Flow conditions in the side-channel unit had also improved, but there was reason to believe that they might be further improved by changing the downstream transitions of the unit and by increasing the height of the control sill.

## Investigation of Side Channel

A supplementary sill 2 feet high (prototype) was tried at various positions in the chute downsteam from the original sill. It was found that if placed in any position upstream from Station 2/40, the capacity of the spillway would be decreased. If the sill were located at the same station as the original sill (Station 2/25), complete submergence of the crest occurred at maximum discharge. It was, therefore, decided that any improvement that might result from such an expedient would not be justified in view of the decreased capacity and the possibility of submerging the crest with a consequent decrease in the coefficient of discharge. It was also decided to abandon any attempt to change the transitions at the downstream end of the side-channel unit because the turbulence remaining was not sufficient in extent or location to be harmful.

Head discharge and coefficient curves for the initial design with altered wing-walls are shown in Figure 13. They demonstrate conclusively that the structure is capable of accommodating 1,200 second-feet at a reservoir elevation of 7212. The coefficient of discharge begins to decrease rapidly at an elevation slightly above 7212 because of submergence of the side-channel crest.

## Chute Studies

It was noted during the first model tests that the flow in the chute could be improved. Flow down the structure was smooth except for a narrow friction fin along each wall, but the transition beginning at Station 8/69.91 was too abrupt for the velocities involved and the jet could not spread sufficiently to follow the walls (Figures 14A and B and Figure 15A).

To remedy this condition, the beginning of the transition was moved upstream to Station 8/00 (Figure 15B). This provided a distance of 115 feet for a 10-foot change in width, but proved inadequate.

The water surface spread satisfactorily down to Station 8+60; but, at this point, left the walls at the maximum discharge, causing oscillating fins on the surface.

As a second revision, the beginning of the transition remained at Station 8+00, but the length was shortened to 69.51 feet, ending approximately 45.5 feet from the stilling-pool (Figure 15C). This change caused a concentration of water along the sides of the chute for the last 20 feet before entering the pool. Considerable splash in the center of the chute was also present.

Revision No. 3 (which proved to be the recommended design) featured a curved transition originating at Station 7+50.02 and ending at Station 9+15.30 (Figures 15D and 16). In addition, it was decided to increase the radius of the vertical curve entering the stilling-pool from 150 to 300 feet to decrease the rate of drop and allow the jet to spread more uniformly. This design accomplished the purpose desired. The center fins and splash action were damped effectively and all other phases of the operation seemed satisfactory.

The value of the sea wall provided in the original design was observed; and, so far as could be determined, was of little or no value in preventing the escape of spray over the walls.

Stilling-pool Studies

The stilling-pool incorporated in the model was provided with a 3-foot Rehbock sill with three teeth and a 3-foot dentated step with the same number of teeth (Figures 6 and 14C). The riprap downstream corresponded to 2-1/2-foot rock on the prototype.

A maximum discharge of 1,200 second-feet was run through the spillway for a period of 50 minutes (model), at normal tailwater (Figure 14D). That the pool was not adequate, was apparent both from the behavior of the jump during the run and from the excessive scour visible after draining the pool.

The front of the jump formed as far upstream as Station 8+95, but excessive boil over the sill was prevalent. This boil, at times, rose above the pool walls, causing considerable splash, the sea wall coping having little effect.

The 1-1/2:1 slopes of the excavated channel were badly deteriorated. The riprap had not been moved by direct water action but the sand beneath it had slumped, carrying appreciable amounts of riprap with it. This reaction resulted in a large deposit, principally of sand, on the channel bottom between Stations 9+90 and 10+30. The deposit had a maximum depth of approximately 3 feet prototype. Starting at the end of the riprap, there were two deeply scoured channels with a central ridge between them, which extended to Station 10+75. The results seemed to be attributable, not only to undesirable flow action developed in the pool, but also to the concentrated jet entering the pool. It was also apparent that the fundamental instability of the excessively steep side slopes was a contributing factor to the channel degeneration.

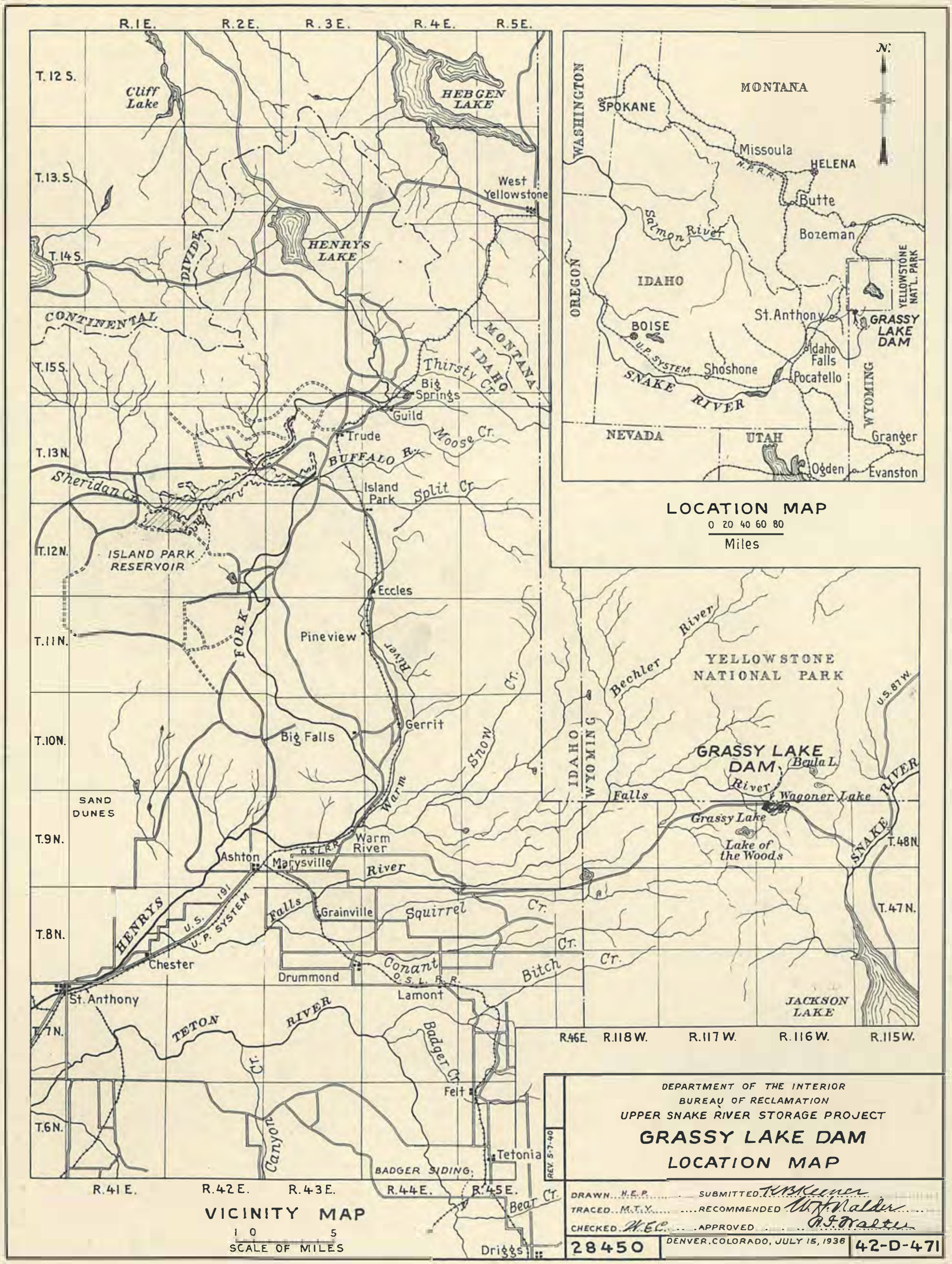
In the first pool change, the number of teeth in the step and sill was increased to five and their positions staggered with respect to each other in an attempt to disperse the concentrated jet more effectively. In addition, it was decided that the rock used for riprap was probably too large to exactly represent that of the prototype. It was, therefore, removed and a graded mixture substituted with maximum and minimum sizes corresponding to prototype dimensions of 10 and 5 inches, respectively. These revisions produced little change in the action of the pool. The boil over the sill was of the same intensity as before, oscillating from side to side, producing a characteristic wave motion that was detrimental to the channel downstream from the pool. After a run of 55 minutes (model) it was noted that the scour pattern was similar to that which had occurred in the original design.

It was more evident than ever that the side slopes were too steep for stability, thus, they were changed to 2:1 for the next design. In addition, it was decided to change the 4:1 transition slope from the end of the pool to elevation 7093 to 2-1/2:1. A step and sill combination with six teeth in the step and five teeth in the sill was used. This pool combination was an improvement over the previous ones, as the oscillating boil over the sill disappeared and the amount of splash decreased. The end of the jump was approximately 1 foot (prototype) upstream from the end of the pool. After a run of 1 hour, it was apparent that the riprap movement was not as great as in the previous tests but the scour below the riprapped section was approximately equivalent to that in the previous tests.

The channel was then further altered by making the floor level (elevation 7086) to the end of the riprapped section (Station 10+10) and inserting a 4:1 transition slope from the end of the riprap to elevation 7093 (Figure 16). This revision seemed to produce little change in the appearance of the pool other than causing the end of the jump to move downstream to the extreme end of the pool. After a run of 1 hour, the riprap did not appear to have moved. The sand erosion downstream from the riprapped section was decreased but not entirely eliminated.

It was decided that the abrupt break in the floor at the intersection of the chute with the stilling-pool floor (Station 9+15.30) should be softened by a 20-foot radius curve. This necessitated the installation of the step shown on Figure 16B. In addition, a new sill, shown in the same figure, was also used. No change was made in the channel. The performance of this design was satisfactory. The jump formed within the limits of the pool with much less boil than had previously occurred, and very little spray escaped over the training-walls. The scour downstream was within satisfactory limits after a run of 1 hour. Photographs of the model before, during, and after a run at 1,200 second-feet are shown on Figure 17. A drawing of the recommended spillway design is included on Figure 16.

FIGURE 1


VICINITY MAP
SCALE OF MILES
R.1E. R.2E. R.3E. R.4E. R.5E.
R.41 E. R.42 E. R.43 E. R.44 E. R.45 E. R.46E.
T.12 S. T.13 S. T.14 S. T.15 S. T.13 N. T.12 N. T.11 N. T.10 N. T.9 N. T.8 N. T.7 N. T.6 N.
Cliff Lake
HEBGEN LAKE
West Yellowstone
HENRYS LAKE
CONTINENTAL DIVIDE
MONTANA IDAHO
Thirsty Cr.
Big Springs
Guild
Moose Cr.
Trude
BUFFALO R.
Sheridan Cr.
Island Park
Split Cr.
ISLAND PARK RESERVOIR
Eccles
FORK
Pineview
Warm River
Snow Cr.
Gerrit
Big Falls
SAND DUNES
Warm River
Ashton
Marysville
O.S.L.R.R.
River
HENRYS
U.S. 191
U.P. SYSTEM
Falls
Grainville
Squirrel Cr.
Chester
Conant Cr.
Bitch Cr.
Drummond
O.S.L.R.R.
Lamont
St. Anthony
TETON RIVER
Badger Cr.
Canyon Cr.
Felt
Tetonia
BADGER SIDING
Bear Cr.
Driggs
LOCATION MAP
0 20 40 60 80
Miles
N.
MONTANA
WASHINGTON
SPOKANE
Missoula
N.P.R.R.
HELENA
Butte
Salmon River
Bozeman
OREGON
IDAHO
YELLOWSTONE NAT'L. PARK
St. Anthony
GRASSY LAKE DAM
BOISE
U.P. SYSTEM
Idaho Falls
Shoshone
Pocatello
SNAKE RIVER
WYOMING
NEVADA
UTAH
Granger
Ogden
Evanston
Bechler River
YELLOWSTONE NATIONAL PARK
U.S. 87 W.
IDAHO WYOMING
GRASSY LAKE DAM
Beula L.
Falls River
Wagoner Lake
Grassy Lake
Lake of the Woods
SNAKE RIVER
T.48 N.
T.47 N.
JACKSON LAKE
R.118 W. R.117 W. R.116 W. R.115 W.
REV. 5-7-40
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BUREAU OF RECLAMATION
UPPER SNAKE RIVER STORAGE PROJECT
GRASSY LAKE DAM
LOCATION MAP
DRAWN H.E.P. SUBMITTED
TRACED M.T.Y. RECOMMENDED
CHECKED W.E.C. APPROVED
28450
DENVER, COLORADO, JULY 15, 1936
42-D-471

FIGURE 2

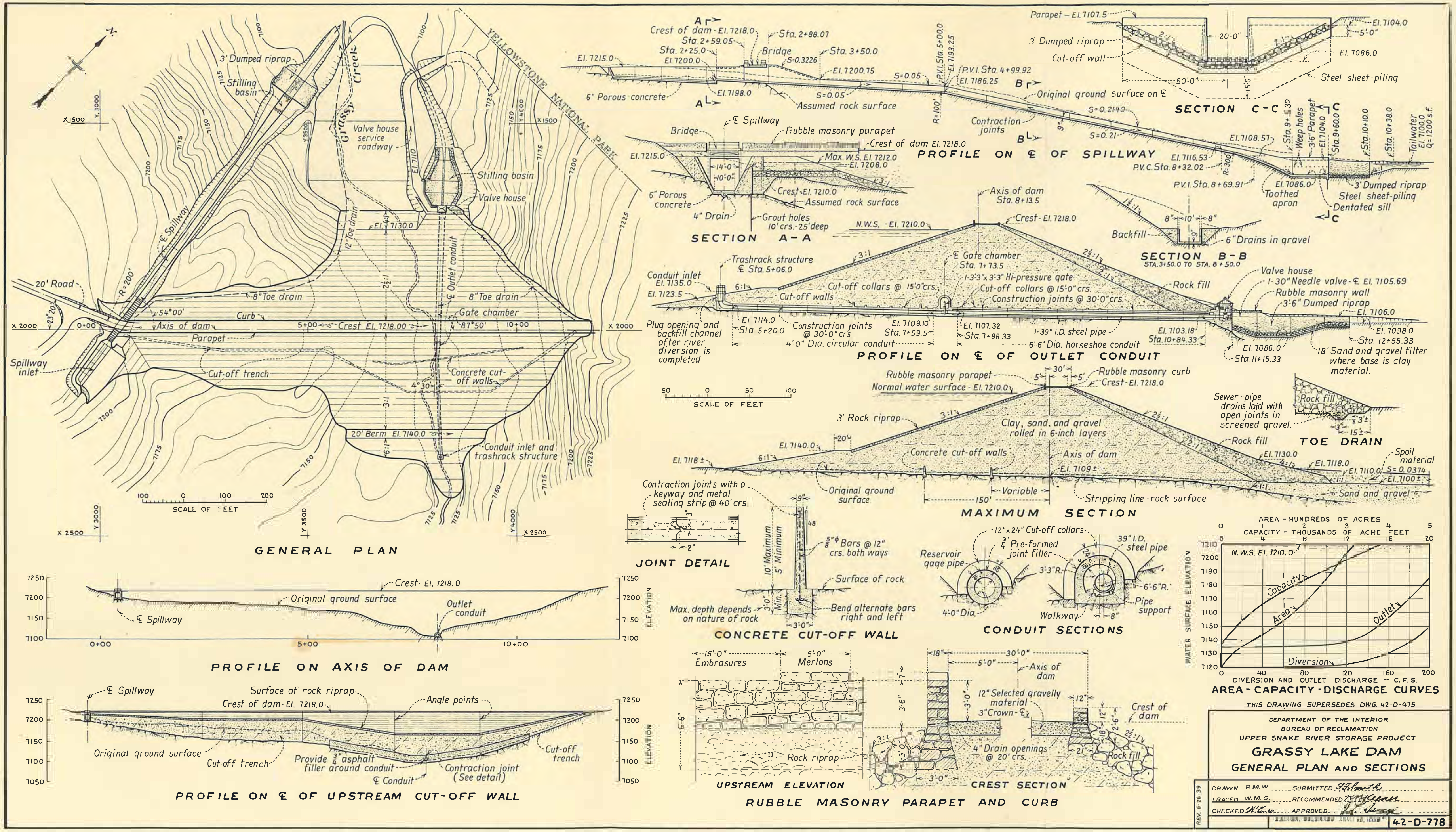
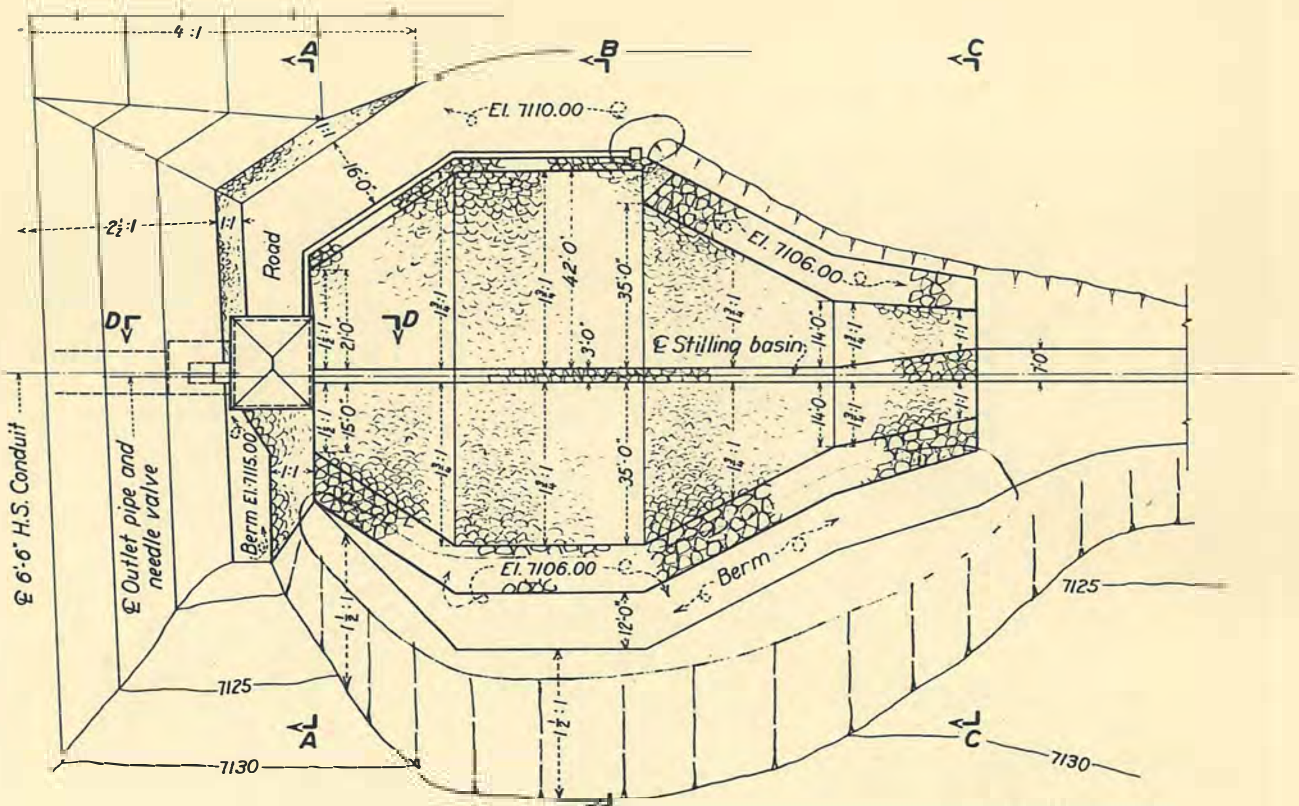
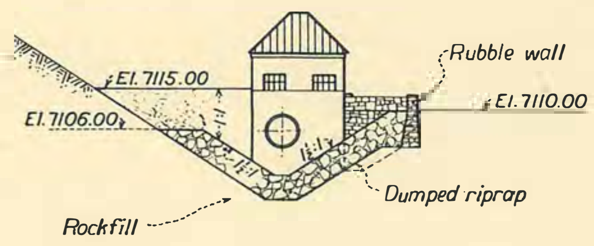

GENERAL PLAN
YELLOWSTONE NATIONAL PARK
Grassy Creek
3' Dumped riprap
Stilling basin
Valve house service roadway
Stilling basin
Valve house
℄ Spillway
20' Road
Axis of dam
Curb
Crest El. 7218.00
Parapet
Gate chamber
8" Toe drain
12" Toe drain
℄ Outlet conduit
Spillway inlet
Cut-off trench
Concrete cut-off walls
20' Berm El. 7140.0
Conduit inlet and trashrack structure
SCALE OF FEET
PROFILE ON ℄ OF SPILLWAY
Crest of dam - El. 7218.0
Bridge
6" Porous concrete
Assumed rock surface
Original ground surface on ℄
Contraction joints
SECTION C-C
Parapet - El. 7107.5
3' Dumped riprap
Cut-off wall
Steel sheet-piling
Toothed apron
Dentated sill
SECTION A-A
Rubble masonry parapet
Max. W.S. El. 7212.0
4" Drain
Grout holes 10' crs.-25' deep
SECTION B-B
STA. 3+50.0 TO STA. 8+50.0
Backfill
6" Drains in gravel
PROFILE ON ℄ OF OUTLET CONDUIT
Axis of dam Sta. 8+13.5
Crest - El. 7218.0
N.W.S. - El. 7210.0
Trashrack structure ℄ Sta. 5+06.0
Conduit inlet El. 7135.0
℄ Gate chamber Sta. 7+13.5
1-3'3" x 3'3" Hi-pressure gate
Cut-off collars @ 15'-0" crs.
Construction joints @ 30'-0" crs.
4'-0" Dia. circular conduit
6'-6" Dia. horseshoe conduit
1-39" I.D. steel pipe
Rock fill
Valve house
1-30" Needle valve - ℄ El. 7105.69
Rubble masonry wall
3'-6" Dumped riprap
Plug opening and backfill channel after river diversion is completed
18" Sand and gravel filter where base is clay material.
MAXIMUM SECTION
Rubble masonry parapet
Normal water surface - El. 7210.0
Rubble masonry curb
Crest - El. 7218.0
3' Rock riprap
Clay, sand, and gravel rolled in 6-inch layers
Concrete cut-off walls
Axis of dam
Original ground surface
Stripping line - rock surface
Sand and gravel
Spoil material
TOE DRAIN
Sewer-pipe drains laid with open joints in screened gravel.
Rock fill
JOINT DETAIL
Contraction joints with a keyway and metal sealing strip @ 40' crs.
CONCRETE CUT-OFF WALL
5/8" ϕ Bars @ 12" crs. both ways
Surface of rock
Max. depth depends on nature of rock
Bend alternate bars right and left
10' Maximum 5' Minimum
CONDUIT SECTIONS
12" x 24" Cut-off collars
3/4" Pre-formed joint filler
Reservoir gage pipe
39" I.D. steel pipe
4'-0" Dia.
Walkway
Pipe support
AREA - CAPACITY - DISCHARGE CURVES
AREA - HUNDREDS OF ACRES
CAPACITY - THOUSANDS OF ACRE FEET
WATER SURFACE ELEVATION
DIVERSION AND OUTLET DISCHARGE — C.F.S.
N.W.S. El. 7210.0
Capacity
Area
Outlet
Diversion
PROFILE ON AXIS OF DAM
Crest - El. 7218.0
Original ground surface
℄ Spillway
Outlet conduit
ELEVATION
PROFILE ON ℄ OF UPSTREAM CUT-OFF WALL
Surface of rock riprap
Crest of dam - El. 7218.0
Angle points
Original ground surface
Cut-off trench
Provide 3/4" asphalt filler around conduit
℄ Conduit
Contraction joint (See detail)
RUBBLE MASONRY PARAPET AND CURB
UPSTREAM ELEVATION
15'-0" Embrasures
5'-0" Merlons
Rock riprap
CREST SECTION
Axis of dam
12" Selected gravelly material
3" Crown - ℄
4" Drain openings @ 20' crs.
Crest of dam
Rock fill
THIS DRAWING SUPERSEDES DWG. 42-D-475
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER SNAKE RIVER STORAGE PROJECT
GRASSY LAKE DAM
GENERAL PLAN AND SECTIONS
DRAWN P.M.W.
TRACED W.M.S.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
REV. 6-26-39
42-D-778

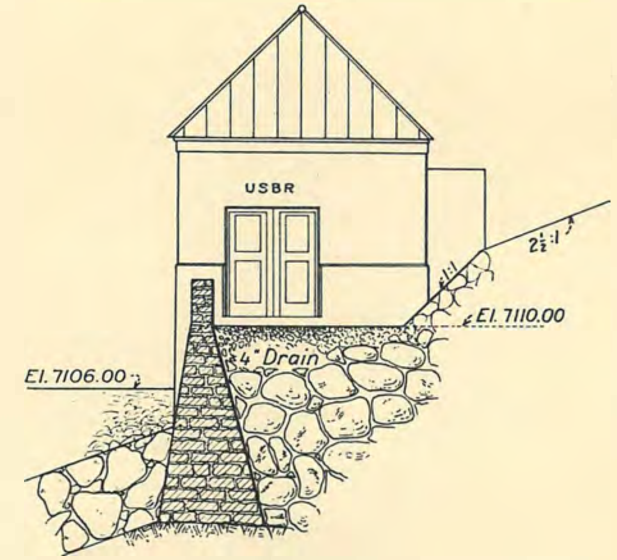
FIGURE 3




PLAN

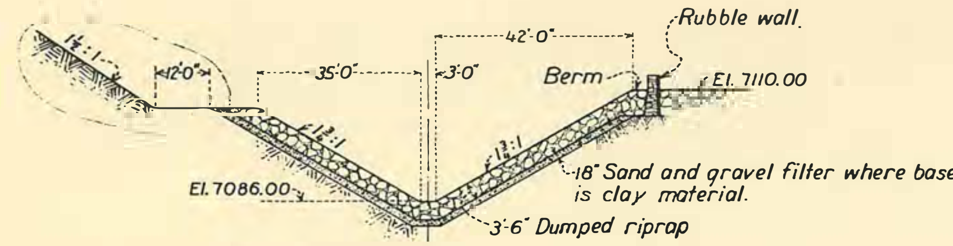



SECTION A-A




SECTION D-D

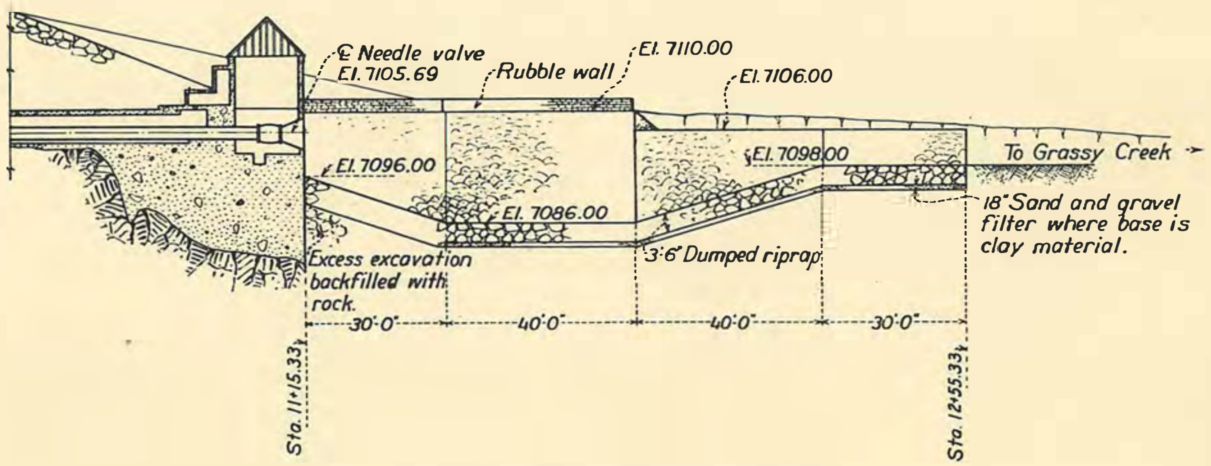
1 0 5 10
SCALE OF FEET




SECTION B-B

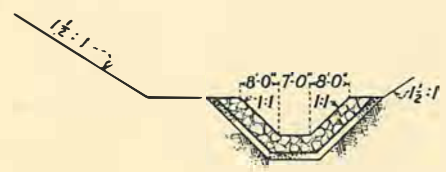
REFERENCE DRAWINGS

GENERAL PLAN AND SECTIONS ................. 42-D-778
CONDUIT ALINEMENT AND PROFILE ............. 42-D-607
VALVE HOUSE SUPERSTRUCTURE ................ 42-D-752
VALVE HOUSE SUBSTRUCTURE .................. 42-D-620




PROFILE ON ℄ OF NEEDLE VALVE

10 0 10 20 30 40 50
SCALE OF FEET




SECTION C-C

RECORD DRAWING

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER SNAKE RIVER STORAGE PROJECT

GRASSY LAKE DAM
OUTLET WORKS
STILLING BASIN - PLAN AND SECTIONS

DRAWN J.C.D. SUBMITTED L.B. Kirkwood
TRACED C.A. RECOMMENDED [illegible]
CHECKED L.B.K. APPROVED W.H. Nalder
REV. 11-22-40
DENVER, COLORADO, MAY 4, 1938
42-D-776

FIGURE 4

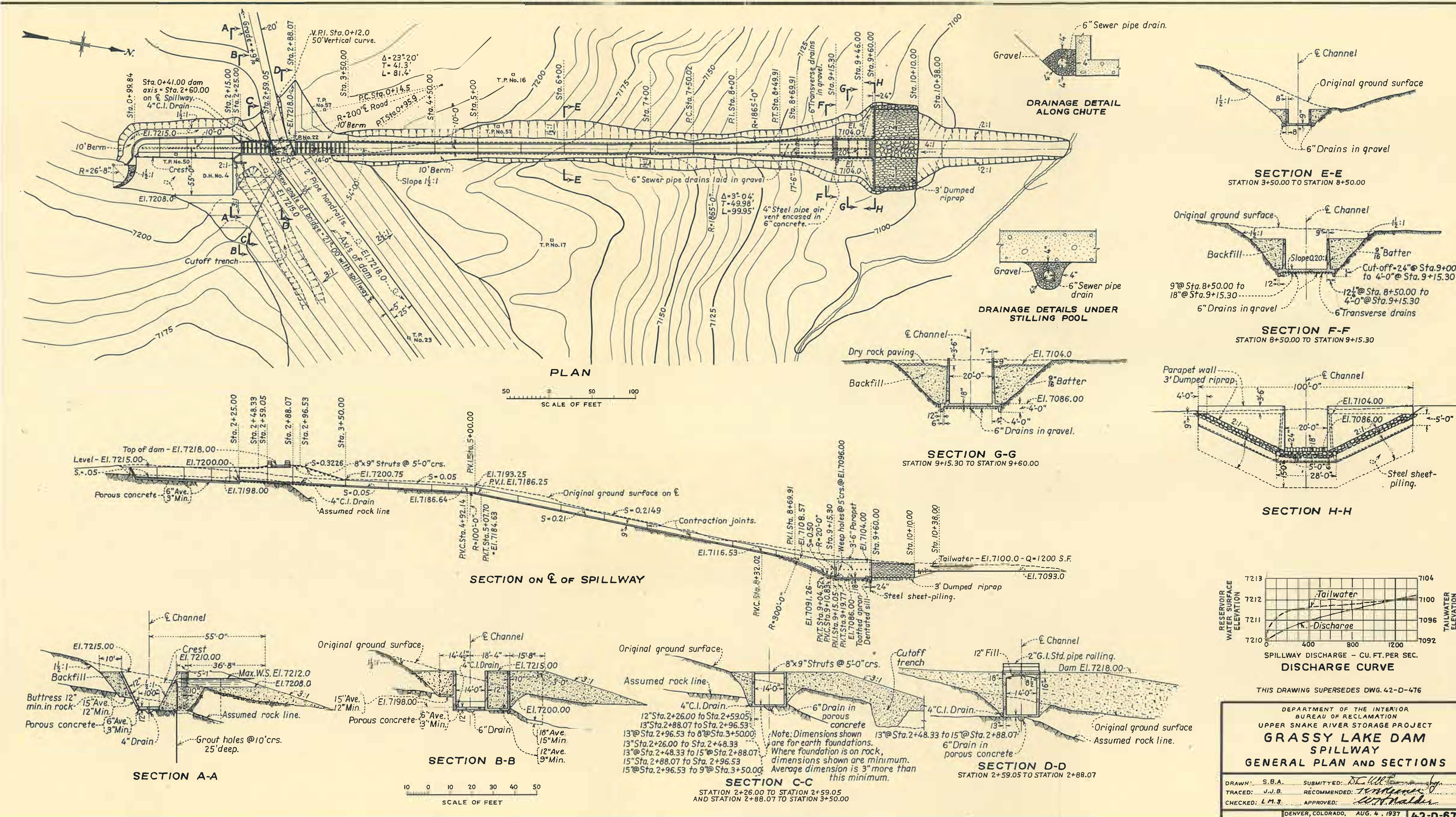
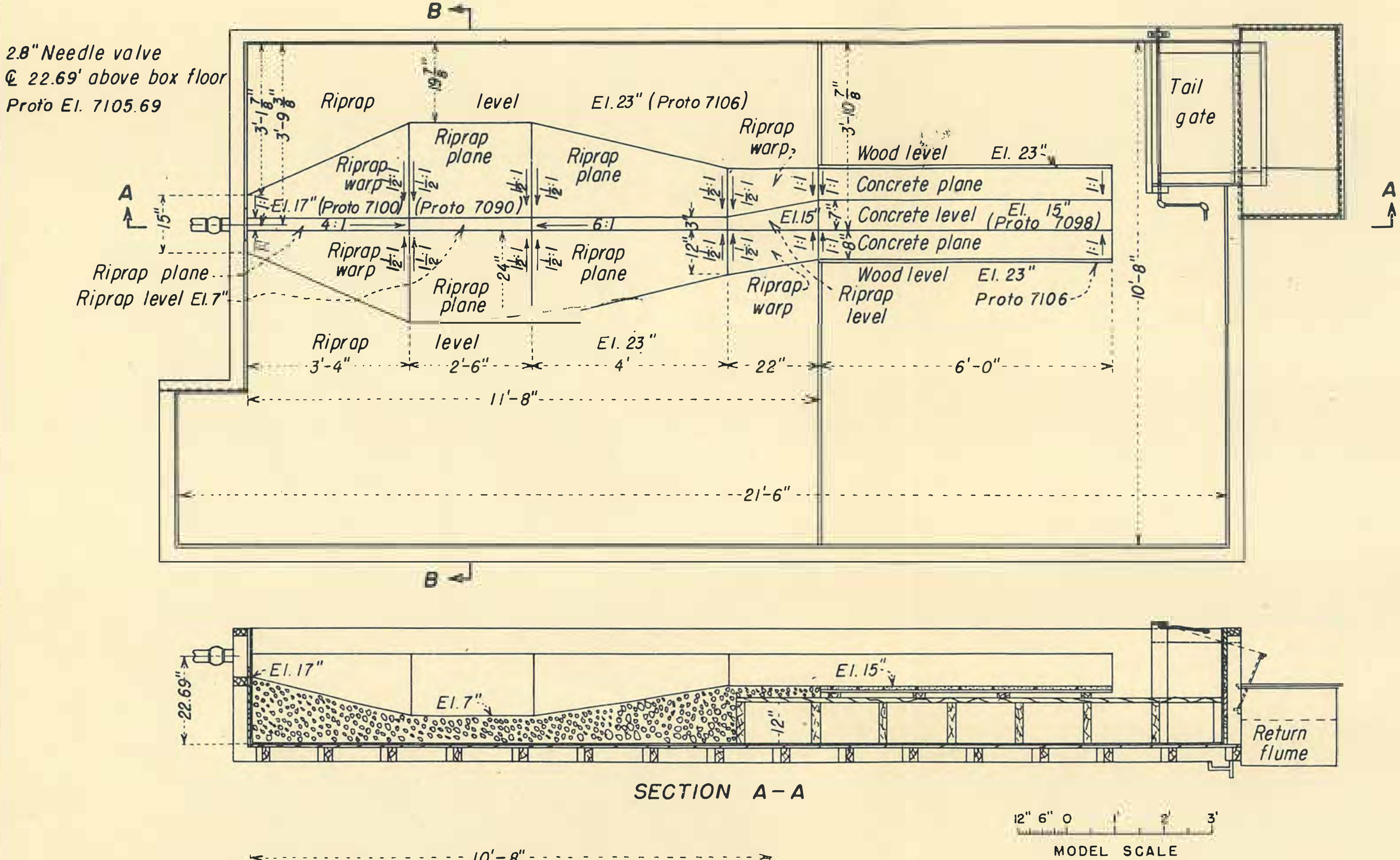
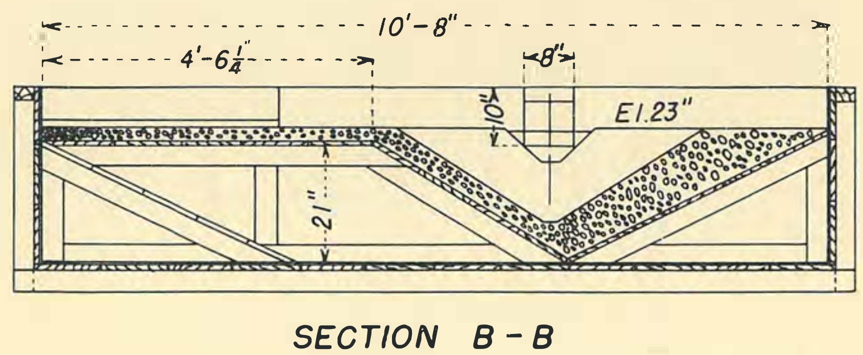

PLAN
SCALE OF FEET
SECTION ON ℄ OF SPILLWAY
SECTION A-A
SECTION B-B
SECTION C-C
STATION 2+26.00 TO STATION 2+59.05 AND STATION 2+88.07 TO STATION 3+50.00
SECTION D-D
STATION 2+59.05 TO STATION 2+88.07
SECTION E-E
STATION 3+50.00 TO STATION 8+50.00
SECTION F-F
STATION 8+50.00 TO STATION 9+15.30
SECTION G-G
STATION 9+15.30 TO STATION 9+60.00
SECTION H-H
DRAINAGE DETAIL ALONG CHUTE
DRAINAGE DETAILS UNDER STILLING POOL
DISCHARGE CURVE
SPILLWAY DISCHARGE - CU. FT. PER SEC.
RESERVOIR WATER SURFACE ELEVATION
TAILWATER ELEVATION
Tailwater
Discharge
Note: Dimensions shown are for earth foundations. Where foundation is on rock, dimensions shown are minimum. Average dimension is 3" more than this minimum.
THIS DRAWING SUPERSEDES DWG. 42-D-476
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER SNAKE RIVER STORAGE PROJECT
GRASSY LAKE DAM
SPILLWAY
GENERAL PLAN AND SECTIONS
DRAWN: S.B.A.
TRACED: J.J.B.
CHECKED: L.M.S.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLORADO, AUG. 4, 1937
42-D-670

FIGURE 5



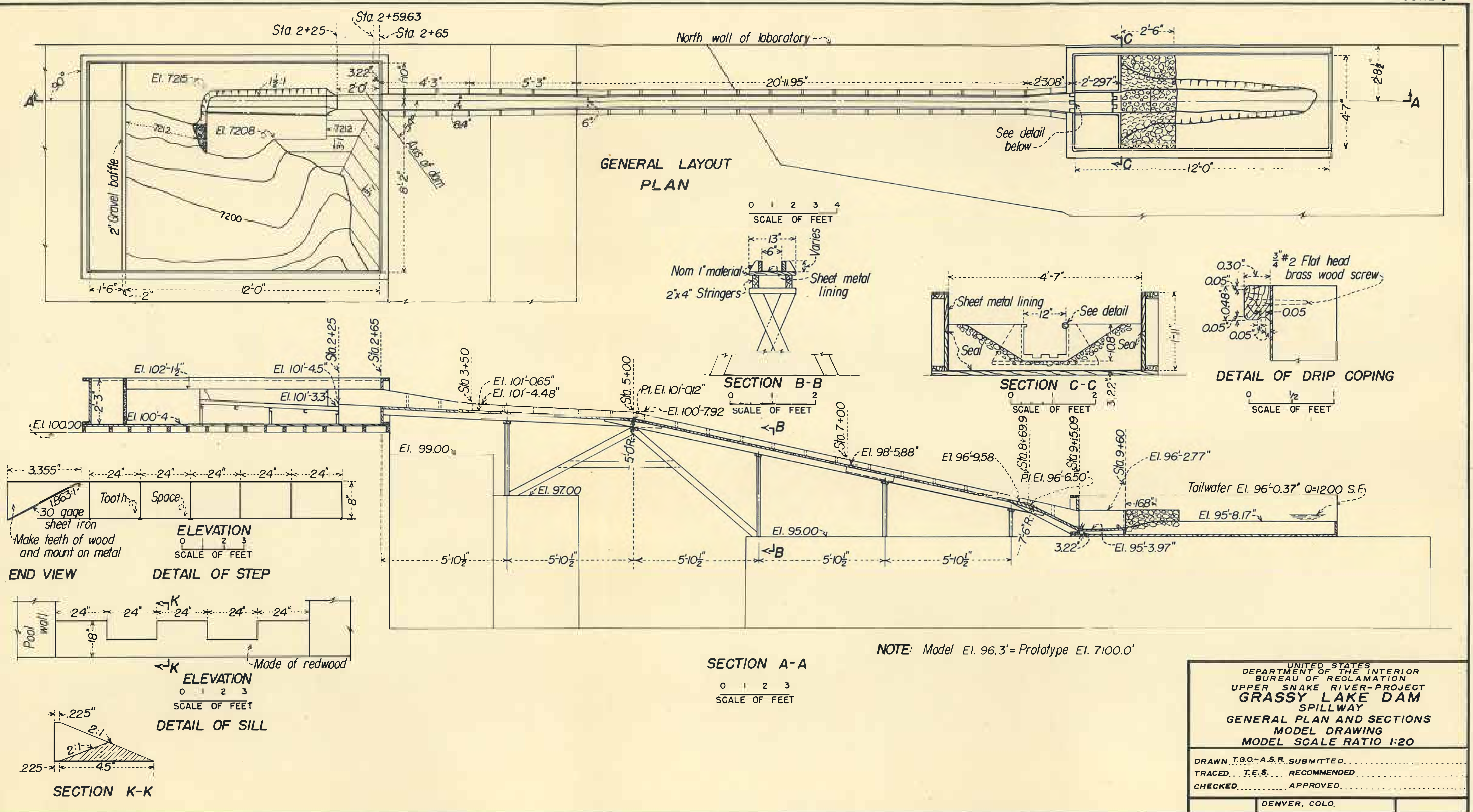



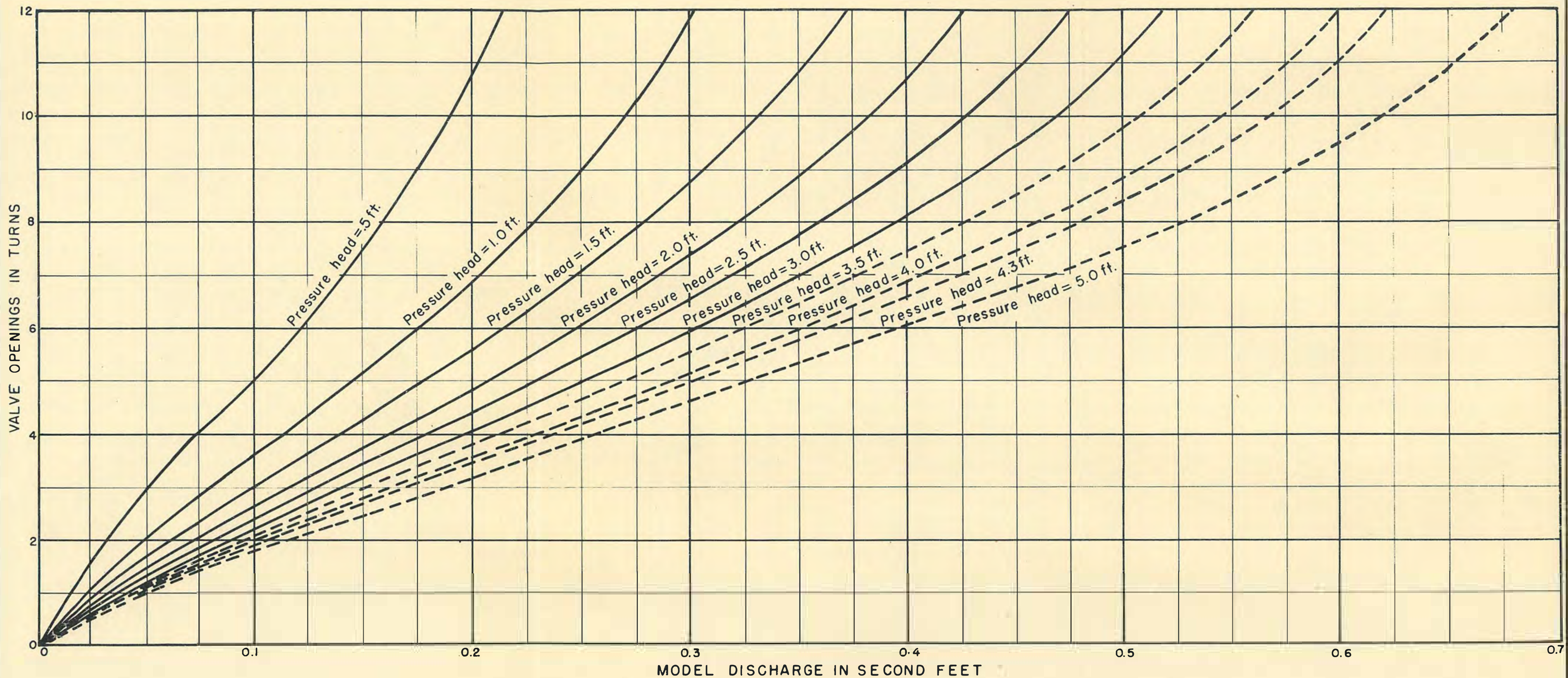

Elevations shown are above bottom of box (Proto 7083). Riprap to be evenly graded from 3/4" to 2" gravel and to have a vertical depth of at least 2".

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER SNAKE RIVER - PROJECT
**GRASSY LAKE DAM**
HYDRAULIC MODEL STUDIES
MODEL SCALE 1:12
ORIGINAL OUTLET WORKS POOL

DRAWN R.C.B. SUBMITTED
TRACED J.H.W. RECOMMENDED
CHECKED APPROVED
DENVER, COLO.

FIGURE 6


GENERAL LAYOUT
PLAN
Sta. 2+25
Sta. 2+59.63
Sta. 2+65
North wall of laboratory
El. 7215
El. 7208
2" Gravel baffle
Axis of dam
See detail below
20'-11.95"
SCALE OF FEET
SECTION B-B
Nom 1" material
2"x4" Stringers
Sheet metal lining
Varies
SECTION C-C
Sheet metal lining
See detail
Seal
DETAIL OF DRIP COPING
3/4" #2 Flat head brass wood screw
END VIEW
Make teeth of wood and mount on metal
30 gage sheet iron
Tooth
Space
ELEVATION
DETAIL OF STEP
Pool wall
Made of redwood
DETAIL OF SILL
SECTION K-K
SECTION A-A
El. 102'-1½"
El. 101'-4.5"
El. 101'-3.3
El. 100'-4
El. 100.00
El. 101'-0.65"
El. 101'-4.48"
P.I. El. 101'-0.12"
El. 100'-7.92
El. 99.00
El. 97.00
El. 98'-5.88"
El. 95.00
El. 96'-9.58
P.I. El. 96'-6.50"
El. 96'-2.77"
Tailwater El. 96'-0.37" Q=1200 S.F.
El. 95'-8.17"
El. 95'-3.97"
NOTE: Model El. 96.3' = Prototype El. 7100.0'
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER SNAKE RIVER-PROJECT
GRASSY LAKE DAM
SPILLWAY
GENERAL PLAN AND SECTIONS
MODEL DRAWING
MODEL SCALE RATIO 1:20
DRAWN T.G.O.-A.S.R. SUBMITTED
TRACED T.E.S. RECOMMENDED
CHECKED APPROVED
DENVER, COLO.



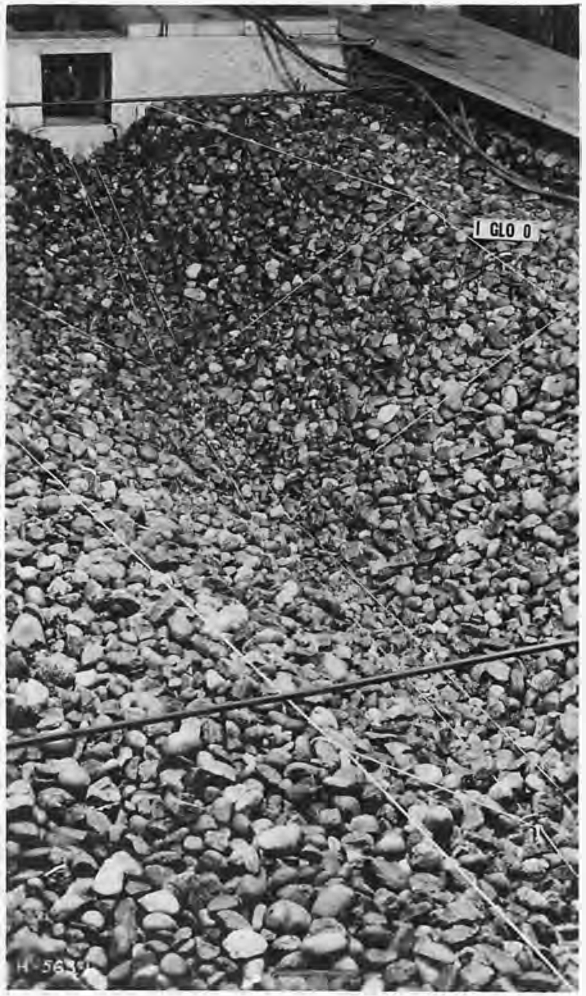

TAKEN FROM TESTS FOR KERN COUNTY CANAL OUTLET WORKS—FRIANT DAM. TESTS SERIES 4—FD TO 9—FD INCLUSIVE.

## GRASSY LAKE DAM

DISCHARGE OF 2.8" NEEDLE VALVES WITH VARIOUS OPENINGS AND UNDER VARIOUS HEADS

F.R.C. 9-14-37

1

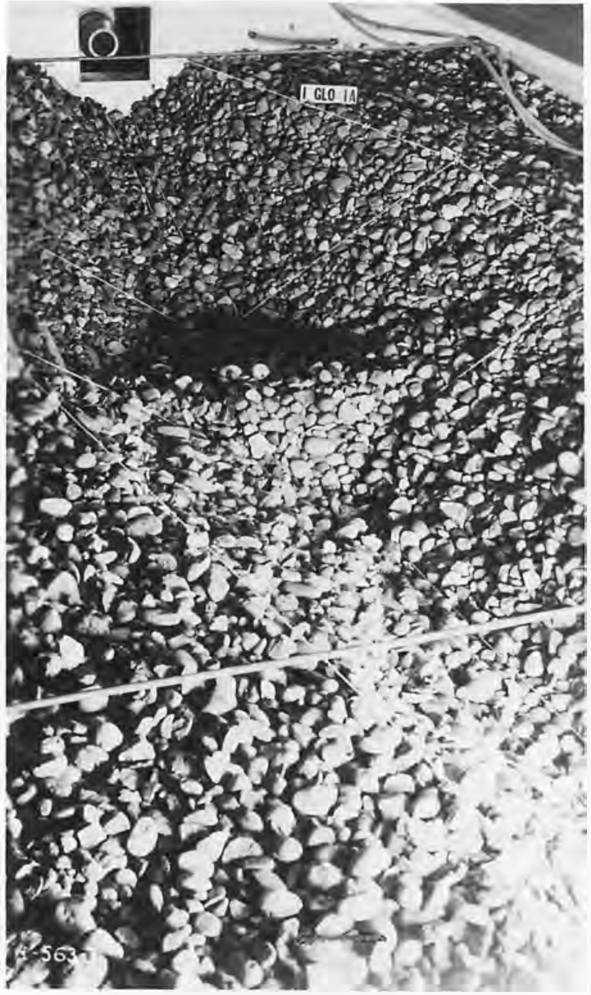



A. Stilling pool before run.

2

B. Flow of 243 second-feet.

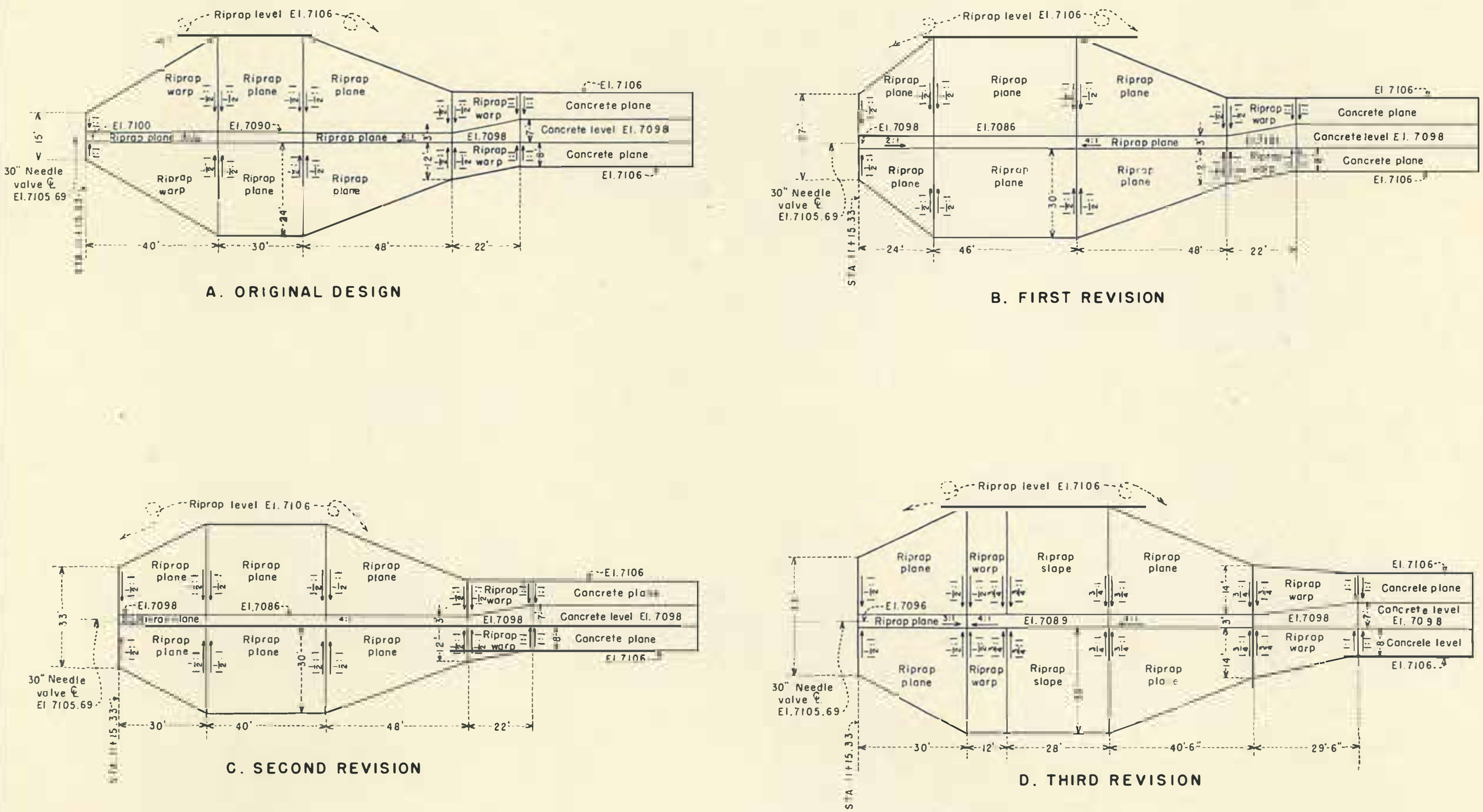
3




C. Riprap scour after 1 hour. (model)

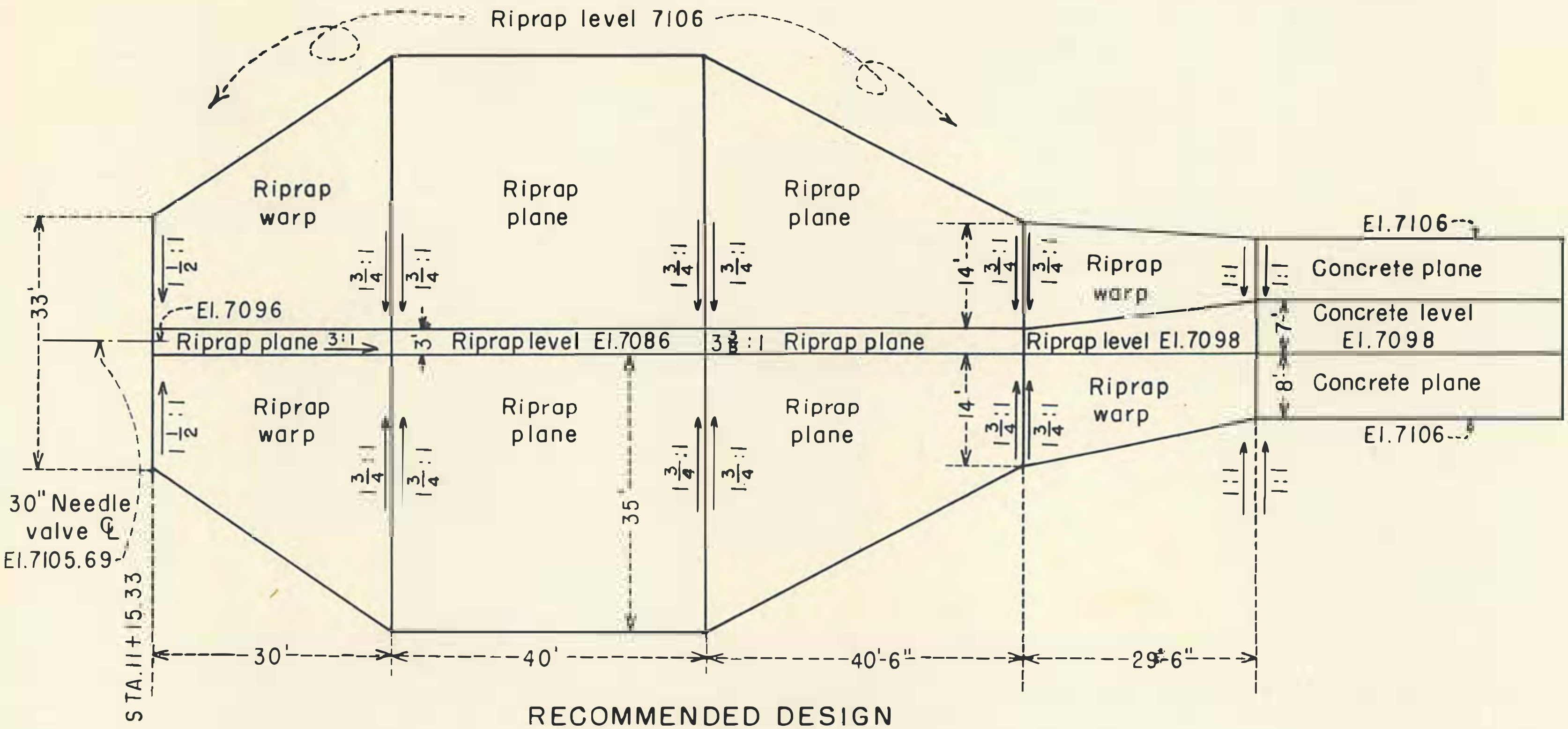
OUTLET STILLING POOL STUDIES 1:12 MODEL
ORIGINAL DESIGN

Figure 8.




GRASSY LAKE
HYDRAULIC MODEL STUDIES
OUTLET WORKS - REVISIONS
MODEL SCALE 1:12

FIGURE 9




RECOMMENDED DESIGN

GRASSY LAKE
HYDRAULIC MODEL STUDIES
MODEL SCALE 1:12
RECOMMENDED DESIGN OUTLET WORKS

FIGURE 10

 4

A. Stilling Pool before run.

 5

B. Flow of 243 second-feet.

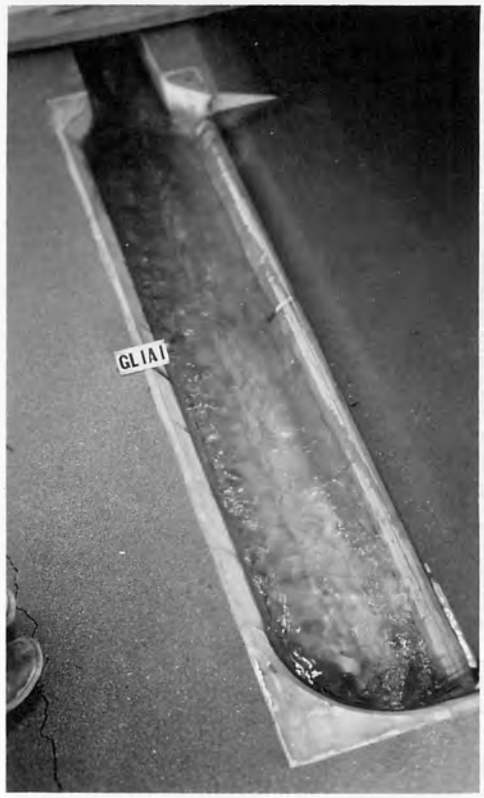
 6

C. Riprap scour after 1 hour run.
(model)

OUTLET STILLING POOL STUDIES 1:12 MODEL
RECOMMENDED DESIGN

Figure 12.


A. Original design.

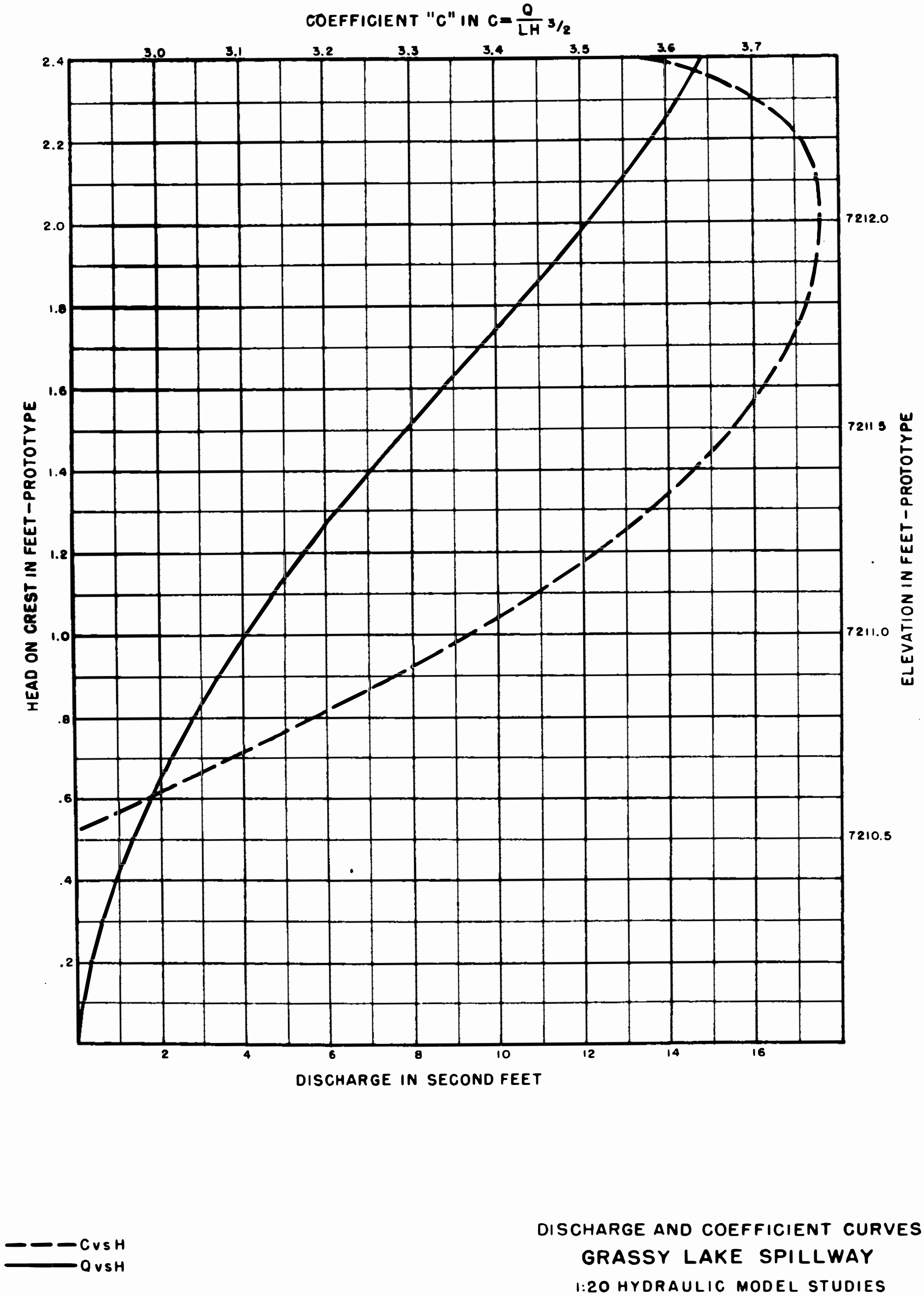



B. Flow of 12,000 second-feet.


C. Erosion caused by flow of 12,000 second-feet.

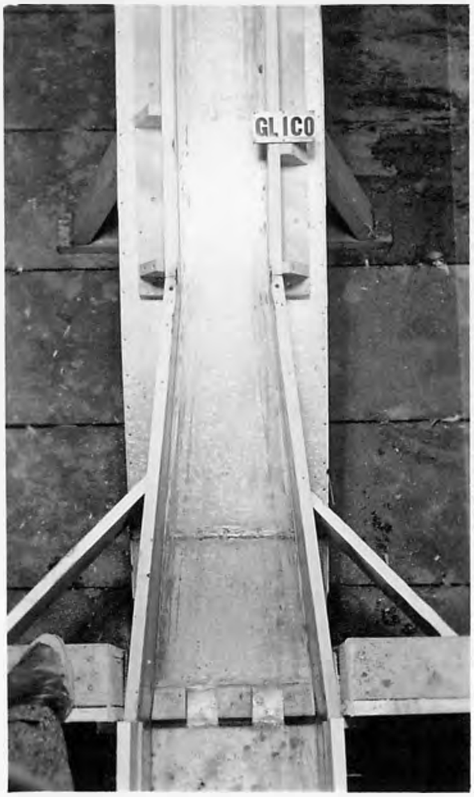

D. Recommended design.

APPROACH CONDITIONS ON 1:20
SCALE MODEL OF GRASSY LAKE SPILLWAY

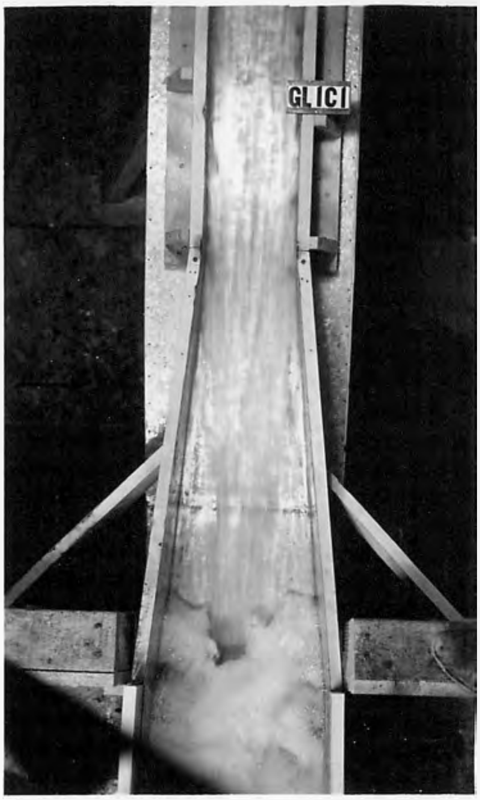



DISCHARGE AND COEFFICIENT CURVES
GRASSY LAKE SPILLWAY
1:20 HYDRAULIC MODEL STUDIES

Figure 14




A. Original design.



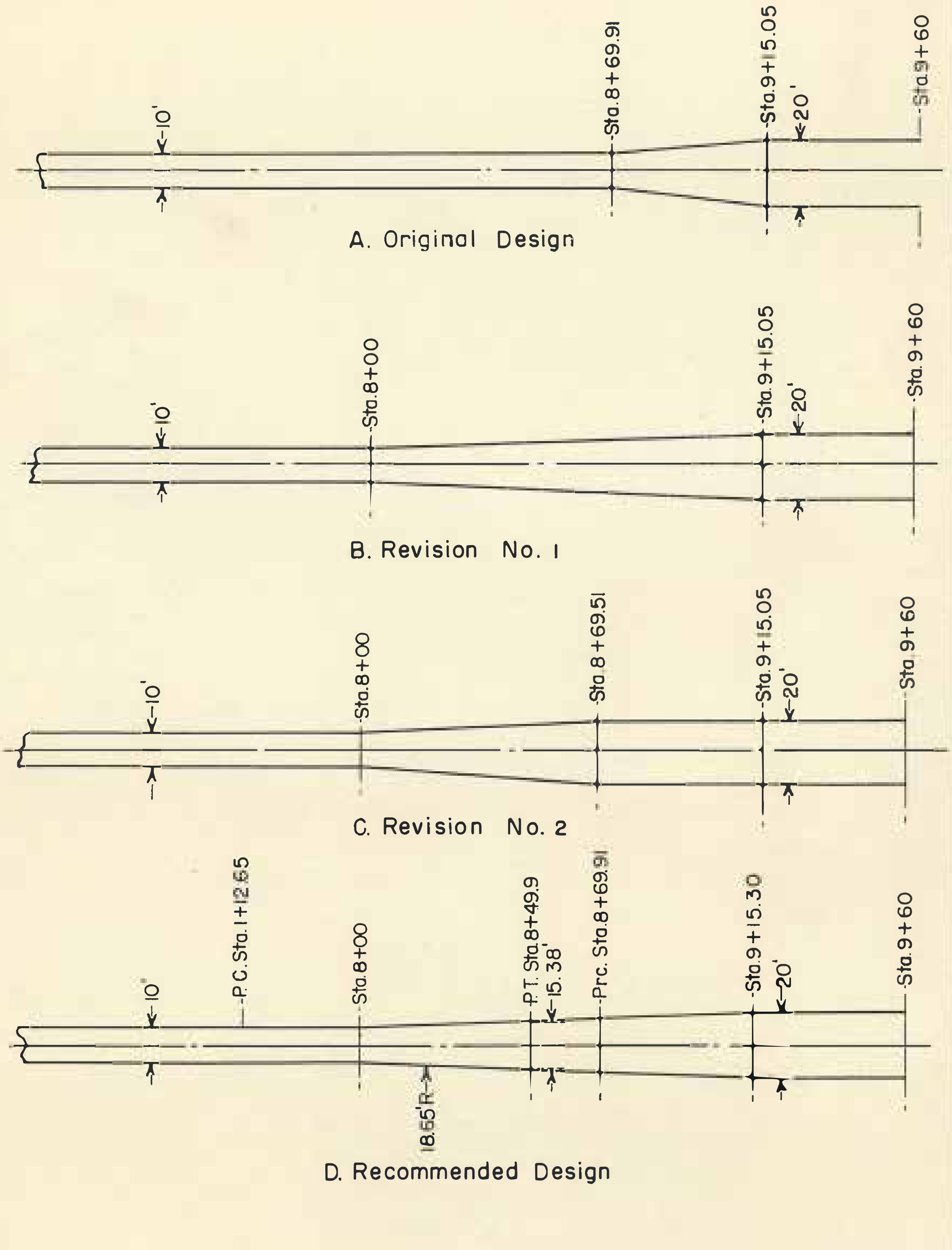

B. Flow of 12,000 second-feet.

CHUTE STUDIES ON 1:20 SCALE MODEL


C. Original design.

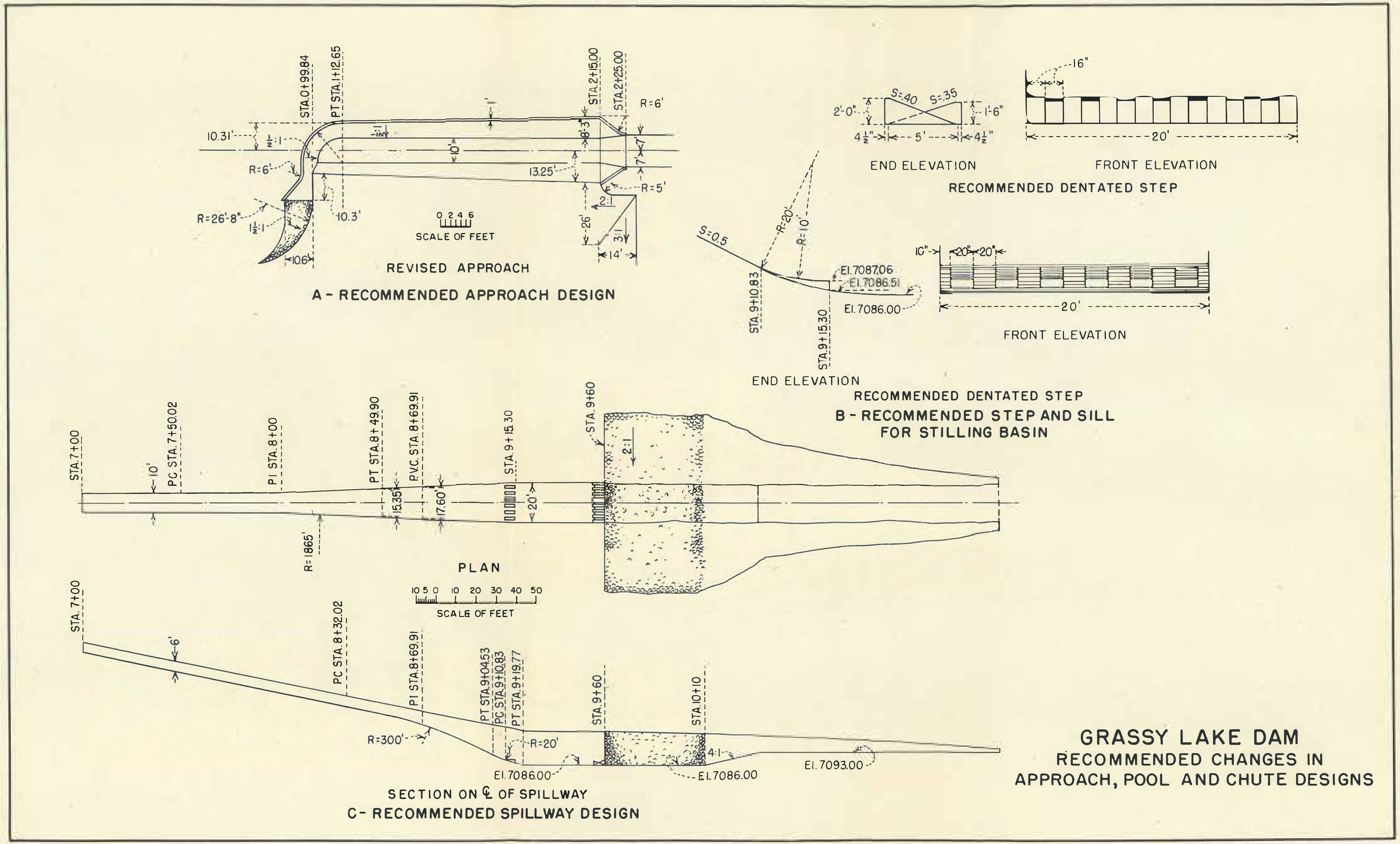

D. Flow of 12,000 second-feet.

STILLING POOL STUDIES ON 1:20 SCALE
MODEL OF GRASSY LAKE SPILLWAY




GRASSY LAKE DAM SPILLWAY
REVISIONS TO SPILLWAY TRANSITION

FIGURE 16




GRASSY LAKE DAM
RECOMMENDED CHANGES IN
APPROACH, POOL AND CHUTE DESIGNS

Figure 17.

A. Recommended design setup.


B. Flow of 1,200 second-feet.


C. Erosion caused by flow of 1,200 second-feet.

STILLING POOL STUDIES ON 1:20 SCALE
MODEL OF GRASSY LAKE SPILLWAY
RECOMMENDED DESIGN